APPENDIX J

Environmentally Acceptable Lubricant Grease for Hydropower Applications

U.S. Army Corps of Engineers,
Portland District
(Contract No.W9128F-09-D-0056)
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Environmentally Acceptable Lubricant Grease for Hydropower Applications

Technical Feasibility Analysis for Eight Hydropower Facilities in Washington and Oregon

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A-E CONTRACTOR STATEMENT OF TECHNICAL REVIEW COMPLETION OF INDEPENDENT TECHNICAL REVIEW

The A-E Contractor, HDR Engineering, has completed the EAL Grease Analysis Report. Notice is hereby given that an independent technical review, that is appropriate to the level of risk and complexity inherent in the project, has been conducted as defined in the Quality Control Plan. During the independent technical review, compliance with established policy principles and procedures, utilizing justified and valid assumptions, was verified. This included review of: assumptions; methods, procedures, and material used in analyses; alternatives evaluated; the appropriateness of data used and level obtained; and reasonableness of the result, including whether the product meets the customer's needs consistent with law and existing USACE policy. The independent technical review was accomplished by an independent HDR team. All comments resulting from independent technical review have been resolved.

Rod Wittinger, Technical Review Team Leader *(Signature)*	24 July 2015 Date
Blaine Graff, Project Manager, A-E Contractor *(Signature)*	24 July 2015 Date

CERTIFICATION OF INDEPENDENT TECHNICAL REVIEW

Significant concerns and the explanation of the resolution are as follows:

There were no significant concerns. All review comments have been fully resolved.

As noted above, all concerns resulting from independent technical review of the project have been fully resolved.

Stephen Spain, Principal, A-E Contractor *(Signature)*	27 July 2015 Date

Contents

EXECUTIVE SUMMARY **1**

Introduction and Feasibility Study Objectives 1

Assessment Methods 1

Findings 1

1.0 INTRODUCTION **3**

2.0 BACKGROUND **3**

2.1 Manufacture and Composition of Greases 3

2.2 In-Water Lubricant Use in Hydropower 4

2.3 Objectives for Replacement Greases 5

2.3.1 Compatibility 5

2.3.2 Performance 6

3.0 EAL DISCUSSION AND CRITERIA **6**

3.1 General 6

3.2 EALs per EPA 800-R-11-002 6

3.3 Vessel General Permit 7

3.4 International Labeling Programs 8

3.4.1 Blue Angel 8

3.4.2 European Ecolabel 8

3.4.3 Nordic Swan (Nordic Ecolabel) 8

3.4.4 OSPAR 8

3.4.5 Swedish Standard 9

3.5 Discussion of EAL Criteria 9

3.6 Candidate Grease EAL Criteria 11

4.0 IN-SERVICE WICKET GATE GREASES **11**

4.1 General 11

4.2 In-Service Grease Sampling 12

4.3 Huskey Hydrolube 12

4.4 Mobil SHC 101 EAL 13

4.5 Chevron Ultra-Duty EP NLGI2 13

4.6 Chevron FM ALC EP2 13

4.7 Summary of In-Service Greases 13

5.0 NEW CANDIDATE EAL GREASES FOR WICKET GATES 14

5.1 General 14

5.2 Panolin BioGrease EP 2 14

5.3 Mobil SHC Aware EP 2 15

5.4 KAJO Longlife Grease LZR 2 16

5.5 Castrol BioTac OG 16

5.6 Industry Survey 16

6.0 ANALYTICAL METHODS 17

6.1 General 17

6.2 Compatibility Testing 17

6.3 Performance Characteristics Testing 18

7.0 ANALYTICAL RESULTS AND DISCUSSION 20

7.1 Compatibility Testing 21

7.1.1 Compatibility Results 21

7.1.2 Discussion of Compatibility Results 22

7.1.3 Summary of Compatibility Results 23

7.2 Performance Testing 24

7.2.1 Performance Testing Results and Discussion 25

7.2.2 Summary of Performance Testing Results 28

8.0 CONCLUSIONS AND RECOMMENDATIONS 29

8.1 Wicket Gate Grease 29

8.2 Wire Rope Grease 31

9.0 IMPLEMENTATION PLAN 33

9.1 Wicket Gate Grease 33

9.2 Wire Rope Grease 35

10.0 REFERENCES 36

Tables

Table 1: Summary of NLGI grades commonly used in hydropower 4
Table 2: EAL Criteria and Definitions per EPA 800 7
Table 3: Summary of in-service greases on the lower Columbia and Snake Rivers 12
Table 4: Summary of in-service grease sampling 12
Table 5: Relevant EAL test results for Panolin BioGrease EP 2. 15
Table 6: Relevant EAL test results for Mobil SHC Aware EP 2. 15
Table 7: Summary of performance testing 19
Table 8: Dropping point compatibility results. 21
Table 9: Shear stability compatibility results. 21
Table 10: High temperature storage compatibility results. 22
Table 11: Summary of grease compatibility results. 22
Table 12: Summary of candidate EAL compatibility across the USACE plants on the Lower Columbia and Snake Rivers. 24
Table 13: Summary of performance testing results. 25
Table 14: Apparent viscosity results per ASTM D1092. 27
Table 15: Summary of compatibility results. 30
Table 16: Summary of grease performance testing results. 31
Table 17: USACE turbines with greased wicket gate bushings on the lower Columbia and lower Snake Rivers. 33

Figures

Figure 1: Relationship of Primary Documents Describing EALs 10
Figure 2: Candidate EAL and reference in-service grease apparent viscosity results. 28

Appendices

Appendix A. EAL Labeling Program Comparison Matrix

Appendix B. In-Service Grease Manufacturer Information

Appendix C. Candidate EAL Grease Tracking Matrix

Appendix D. Candidate EAL Grease Manufacturer Information

Appendix E. Sampling Plan

Appendix F. Sampling Trip Field Notes and Documentation

Appendix G. Industry Survey

Appendix H. Laboratory Testing Results

Appendix I. ASTM D4048 Copper Corrosion Scoring Key

Acronyms

ASTM	American Society for Testing and Materials
BMP	Best Management Practices
cSt	centi-Stoke (1 $mm^2 \cdot s^{-1}$)
CEATI	Centre for Energy Advancement through Technological Innovation
EAL	Environmentally Acceptable Lubricants
EEL	European Eco Label
EP	Extreme Pressure
EPA	United States Environmental Protection Agency
HDC	Hydroelectric Design Center
HDR	HDR Engineering, Inc.
ISO	International Standards Organization
kgf	kilograms force
lbs	pounds
mm	millimeters
MSDS	Material Safety Data Sheet
NLGI	National Lubricating Grease Institute
NPDES	National Pollutant Discharge Elimination System
OECD	Organization for Economic Co-operation and Development
OSPAR	Convention for the Protection of the Marine Environment of the North-East Atlantic
PAG	polyalkylene glycol
PPM	Parts Per Million
psi	pounds per square inch
RPM	Revolutions per Minute
USACE	U.S. Army Corps of Engineers
VGP	Vessel General Permit

Executive Summary

Introduction and Feasibility Study Objectives

The U.S. Army Corps of Engineers (USACE) Hydroelectric Design Center (HDC) contracted with HDR Engineering, Inc. (HDR) to assess the technical feasibility of switching from conventional greases to Environmentally Acceptable Lubricants (EALs) on certain in-water hydroelectric plant equipment.

EALs represent a class of lubricants that have been demonstrated to meet standards for biodegradability, toxicity and bioaccumulation that minimize the potential for adverse consequences in the aquatic environment when compared to conventional lubricants. The feasibility of switching to EALs is being assessed at the following power plants: Bonneville, The Dalles, John Day, McNary, Ice Harbor, Lower Monumental, Little Goose, and Lower Granite. EALs are being evaluated for use on turbine wicket gate bushings and powerhouse balance of plant lifting equipment that may become submerged such as crane hooks, lifting beams and wire rope. The study objective focused on technical feasibility and whether one or more EALs can be used without risk of damage to existing plant equipment.

Assessment Methods

HDR collected representative in-service grease from USACE powerhouses to be used to check compatibility with new candidate EAL greases and serve as a performance target for new products. Candidate EAL greases were selected based on United States Environmental Protection Agency (EPA) and other internationally-accepted criteria defining an EAL. For purposes of this study, only lubricants which meet requirements for the European Eco Label- (EEL), OSPAR- (Convention for the Protection of the Marine Environment of the North-East Atlantic), and Vessel General Permit-specific (VGP) specific testing requirements were considered EALs. Grease already in service at the plants and candidate EAL samples were sent to independent analytical laboratories for testing and analysis.

In-service grease samples were tested for their compatibility with four candidate EAL lubricants to assess whether the greases currently in service can be mixed with the candidate EALs without development of adverse characteristics or degradation in performance. The ability to mix the EAL grease with the in-service grease is very important to prevent clogging of the grease distribution lines or separation of the base oil from the thickener. Either of these scenarios could lead to one or more bearings being starved of lubricant. Additionally, each of the candidate EALs was tested for performance metrics to determine if their performance was equal to or better than a reference in-service grease.

Findings

Based on laboratory data alone, the study concludes that switching to EALs is technically feasible on certain in-water hydroelectric plant equipment. One of the four EAL greases tested (Panolin Biogrease

EP 2[1]) was assessed to be compatible with existing in-service greases and achieved the stated laboratory performance metrics. However, this study was not able to locate wicket gate bushing performance history on the Panolin Biogrease EP 2. For this reason, the question of whether it can be implemented without risk of damage to equipment remains uncertain, and a stepped plan is needed to test performance prior to full implementation.

Based on results of laboratory testing and the absence of wicket gate performance history for Panolin Biogrease EP 2; the implementation of EALs should include a "proof of concept" prior to full implementation. The "proof of concept" can take various forms to fully demonstrate that the new EAL is satisfactory for long-term operation and does not pose a risk to generation assets. This may involve a defined timeline of testing or operation in one or two machines at each site or on each turbine type that is of sufficient duration to determine a successful outcome.

This study also identifies several candidate greases for wire rope applications. Although wire rope greases were not subject to testing because of the reduced sensitivity to compatibility issues in these applications, several greases have been found to qualify as EALs and have promising characteristics for wire rope protection and lubrication.

[1] Reference to any trade names contained in this report does not imply endorsement by the U.S. Army Corps of Engineers.

1.0 Introduction

HDR prepared this report on behalf of the U.S. Army Corps of Engineers Hydroelectric Design Center to assess the feasibility to switch from greases presently used on certain in-water equipment to Environmentally Acceptable Lubricants (EALs). The grease replacement is being considered at each of the following eight power plants: Bonneville, The Dalles, John Day, McNary, Ice Harbor, Lower Monumental, Little Goose, and Lower Granite. The equipment for which EAL greases are to be evaluated includes turbine wicket gate bushings and other power plant lifting equipment that may become submerged (e.g., wire rope, crane hooks, and lifting beams).

This study seeks to identify potential replacement EALs and determine if these candidate replacement lubricants are compatible with existing lubricants and whether their performance is acceptable. The report provides a discussion of the typical grease application for in-water components used at USACE hydropower facilities; an overview of EALs; results of the compatibility and performance testing; identification of potential replacement EAL(s); and consideration of future implementation of EALs.

2.0 Background

This section provides relevant background on grease manufacture and composition, typical uses in hydropower facilities, and performance characteristics and objectives for new greases.

2.1 Manufacture and Composition of Greases

Greases are semi-solid lubricants typically composed of a base oil, thickener, and performance-enhancing additives. Common base oils include mineral or vegetable oils, which have many different compositions and methods of manufacture. Lithium and calcium soaps are the most common thickening agents used to emulsify the base oil and additives and increase the viscosity of the lubricant. Additives are used to modify existing chemical properties or to provide new lubricious benefits. Common additives include PTFE, rust inhibitors, anti-wear agents, and dyes/pigments.

In the United States, the primary means of rating grease consistency is through the National Lubricating Grease Institute (NLGI) standard grade system. Ratings are assigned based on the results of testing per American Society for Testing and Materials (ASTM) D-217, with values ranging from 000 (fluid) to 6 (solid block). NLGI Grade 2 is the most common grade used at USACE facilities due to its resistance to water washout and ease of pumping through grease distribution systems. Table 1 provides a summary of the characteristics of these NLGI grades.

Table 1: Summary of NLGI grades commonly used in hydropower

NLGI Grade	ASTM D-217 Penetration Range (1/10 mm)	Consistency Description	Food Viscosity Analogy
00	400 - 430	Semi-Fluid	Apple Sauce
0	355 - 385	Very Soft/Very Fluid	Brown Mustard
1	310 - 340	Soft	Tomato Paste
2	265 - 295	Normal/Medium	Peanut Butter
3	220 - 250	Firm/Medium Hard	Vegetable Shortening

2.2 In-Water Lubricant Use in Hydropower

Greases are used extensively throughout hydropower facilities to provide lubrication where two moving parts are in contact; however, the focus of this study is limited to in-water components related to the powerhouse such as wicket gate trunnions, lifting beams, and wire ropes. For these components the objective is twofold; to maintain lubrication in extreme pressure/slow speed interfaces and to resist corrosion.

Wicket gate trunnions are considered to be the most critical hydropower-related lubricated component in contact with water. Rotation of the wicket gates about the trunnion bushings provides the regulation of water flowing to the turbine through the scroll case. Each unit has three sets of bushings. The upper bushings and wicket gate linkages are exposed inside the turbine pit. The lower bushings are located inside the water passage and are installed in the head cover (separating the water passage from the turbine pit) and stay ring (on the lower half of the distributor). The upper wicket gate bushings are accessible through removing the wicket gate linkages and control ring; however it still may be difficult to service or inspect the bearing without removing or partially lifting the head cover. The lower bushings in the head cover and bottom ring are only accessible with the wicket gates removed, which requires a significant outage to disassemble the turbine-generator unit.

On larger turbines such as the USACE units, the wicket gate trunnion and linkage bushings are lubricated via grease lines connected to a centrally-located grease supply pump. Wicket gates are lubricated periodically throughout the day or prior to startup.

Lifting beams and other hoisting equipment have a need for lubrication at various sliding interfaces. Since these components are typically only submerged temporarily, the bushings and sliding surfaces could be easily accessed for removal of existing grease and re-application of new grease.

On wire ropes, periodic lubrication is necessary to reduce wear on the ropes as they are spooled onto the drum, and to resist corrosion. Internal lubrication, which is applied to reduce friction on individual wires and strands as the rope is flexed, is provided with most wire ropes as a product of the manufacturing process. In the Pacific Northwest, the USACE typically applies lubricant to the wire ropes above the

waterline by hand. Since pressurized application is not used, it is not expected that compatibility between new lubricant and the manufacturer supplied lubricant would be an issue, especially if the rope has been in service long enough for the existing internal lubrication to be removed.

Unless otherwise noted, the discussion in this report pertains to wicket gate greases. Wire rope greases are discussed in dedicated sections due to their differing application and less frequent lubrication in areas in contact with water.

2.3 Objectives for Replacement Greases

In addition to being an EAL, two primary objectives exist for any replacement lubricant: 1) the new product is compatible with the existing lubricant; and 2) performance is equal to or exceeds that of the existing lubricant. A brief discussion of these criteria is provided below.

2.3.1 Compatibility

The first objective of the replacement EAL grease is that it is compatible with the existing grease. Compatibility of greases is a serious concern in wicket gate bushings due to accessibility issues associated with removing old grease from the wicket gate bushings, and the adverse consequences if greases foul within the bushing itself or within the greasing lines. In order to access the lower wicket gate bushings, the unit would need to be taken off-line and disassembled at significant cost to the owner.

The primary compatibility issue with greases lies with the thickeners. It is well known that when incompatible greases are mixed, the mixture's consistency will change: mixture will either get stiffer (e.g., harder to pump through grease lines) or thinner (e.g., run out of bearings due to separation of base oil from thickener).

With base oils, a subcomponent of the overall grease mixture, incompatibility is generally caused by the undesirable chemical reaction of additives which may cause components of the mixture to dropout. Dropout can result in the development of flocks and precipitation that can lead to the clogging of in-line filters, grease pump lines, and reduction in the clearances between a shaft and bushing. Incompatibility of base oils is seen only in cases when PAG (polyalkylene glycol) is mixed with mineral, vegetable or other synthetic based oils. PAG is not miscible with any other oil but itself.

Additives are used in small quantities in greases to enhance certain properties of the grease mixture to obtain better performance. Additives have extremely poor mobility due to being firmly incorporated in grease. Thus, the majority of the additives are precluded from interacting with each other even if they are incompatible, and incompatibility of grease additives is of low concern.

A common method of checking compatibility of two greases is to mix the two products at several different ratios and observe the effect to the consistency and appearance of the mixture. Testing methodologies are described in more detail in Section 6.2 of this report.

2.3.2 Performance

Performance for any new EAL grease must be equal to or exceed the existing product. Desirable performance characteristics of wicket gate grease include:

- Anti-wear, high lubricity
- High/extreme pressure grease suitable for low speeds
- Low washout/high washout resistance
- Corrosion inhibiting
- Appropriate viscosity for pumping
- Low oxidation

Several widely accepted methods exist to test these performance characteristics. These tests are described in Section 6.3 of this report.

3.0 EAL Discussion and Criteria

3.1 General

The term 'EAL' has been broadly applied to lubricants that have reduced impact to the environment. In the late 1990s and 2000s various groups worked to determine which characteristics of lubricants would be acceptable given their application and geographic location of use, spawning several international standards defining EALs. Presently, the industry is becoming more aligned with their definition of what constitutes an 'Environmentally Acceptable Lubricant,' with several widely accepted labeling and certification programs using similar criteria and definitions for EALs. Industry research has indicated that the term 'EAL' had been used by some manufacturers, such as Mobil in the case of their SHC 101 EAL, to describe their product as an 'Environmentally Aware Lubricant.' In most instances, these do not meet the definition of an EAL as used by the EPA or international labeling programs. The following sections provide a summary of several key documents that define EALs.

3.2 EALs per EPA 800-R-11-002

EPA 800-R-11-002 (EPA 2011), 'Environmentally Acceptable Lubricants' (EPA 800) uses the term EAL to describe lubricants that have been demonstrated to meet standards for biodegradability, toxicity and bioaccumulation potential that minimize the potential for adverse consequences in the aquatic environment when compared to conventional lubricants.

The document provides an overview of lubricant labeling programs and common testing methods used to determine biodegradability, marine toxicity, and bioaccumulation potential of a lubricant or its constituent parts. Testing methods are described in Section 6.0 of the document; however, it should be noted that the listed procedures are not required, and the EPA does not provide labeling or certification of EALs.

Definitions and explanations of biodegradability, toxicity and bioaccumulation per EPA 800 are provided in Table 2.

Table 2: EAL Criteria and Definitions per EPA 800

Term	Definition / Explanation
Biodegradable	Biodegradability is the measure of the breakdown of a chemical (or a chemical mixture) by micro-organisms. *Primary* biodegradation is the loss of one or more active groups in a chemical compound that renders the compound inactive with regard to a particular function. Primary biodegradation may result in the conversion of a toxic compound into a less toxic or non-toxic compound. *Ultimate* biodegradation, also referred to as mineralization, is the process whereby a chemical compound is converted to carbon dioxide, water, and mineral salts.
Minimally Toxic	Minimally toxic means that the product is minimally harmful to aquatic organisms. This is typically measured at three trophic levels; algae, daphnia, and fish.
Non-bioaccumulative	Bioaccumulation is the build-up of chemicals within the tissues of an organism over time.

Appendix A of this report provides a summary of the common testing methods for biodegradability, toxicity, and bioaccumulation potential provided in EPA 800.

3.3 Vessel General Permit

The stated purpose of the EPA 800 document is to "describe the range of environmentally preferable lubricants that may be used as a Best Management Practice (BMP) by operators of vessels covered under the Vessel General Permit for Discharges Incidental to the Normal Operation of Vessels (VGP; EPA 2013)." The VGP was re-released in 2013 and now includes further guidance and definition of EALs.

The VGP provides criteria for the biodegradability, toxicity, and bioaccumulation potential of approved lubricants to be used in ship-to-sea interfaces in the waters of the United States. The permit also stipulates that products labeled by Blue Angel, European Ecolabel (EEL), Nordic Swan, the Swedish Standards SS 155434[2] and 155470, and the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) shall be considered to meet the definition of an EAL for the purposes of the VGP.

Appendix A of the VGP provides a summary of the required testing methods[3] for biodegradability, toxicity, and bioaccumulation potential provided in the VGP (EPA 2013).

[2] SS 155434 applies to hydraulic fluids, and this is not applicable to this study.

[3] These methods are required to qualify a lubricant as an EAL under the VGP if the lubricant has not previously been labeled one or more of the six approved labeling programs; Blue Angel, European Ecolabel, Nordic Swan, the Swedish Standards SS 155434 and 155470, and OSPAR.

3.4 International Labeling Programs

Several international labeling programs have been recognized by EPA 800 and the VGP. While the intent of these programs is similar, the requirements for testing and certification differ widely. A brief summary of the requirements of each program is provided below. Additional detail on required tests for each program is provided in Appendix A .

3.4.1 Blue Angel

The Blue Angel (Der Blaue Engel) is a German labeling program that labels various household consumer items, industrial products, electronic, and other goods, including lubricants (Blue Angel 2014). The basic award criteria for this label contains a series of tests and verification requirements based on the toxicological effects and biodegradability of the components added to the lubricant formula. The testing requirements for biodegradability and toxicity are closely aligned with the EPA's list of common testing methods, and the requirements of the VGP and EEL. The test methods for bioaccumulation do not align with the common testing methods of other EAL labeling programs. See Appendix A for more information.

The Blue Angel labeling program for EALs has been recently active, with updated criteria published in July 2014. The latest publication states that "an attempt should also be made where possible and sensible to harmonise with…" the award criteria for the EEL (Blue Angel 2014), which is described in Section 3.4.2. At the present time, only one grease is labeled by the Blue Angel.

3.4.2 European Ecolabel

The European Union has adopted a single EEL to designate various household, industrial, and other products as being more environmentally friendly. The requirements for EAL labeling under the EEL were derived from existing lubricant labeling programs such as the Blue Angel, the Swedish Standards, the Nordic Swan, and others. For this reason, the EEL is becoming the most widely accepted label for EALs. The testing requirements for biodegradability, toxicity, and bioaccumulation are closely aligned with those of the VGP and the common testing methods as summarized by EPA 800 (European Eco Label 2014). See Appendix A for more information.

3.4.3 Nordic Swan (Nordic Ecolabel)

Nordic Swan (or Nordic Ecolabel) was the first international labeling program for EALs, providing guidelines for lubricants in Norway, Sweden, Finland, Iceland, and Denmark (EPA 2011). Research conducted as part of this study indicates lubricants are no longer certified under this labeling program; the Nordic Swan discontinued certification of lubricants in 2006.

3.4.4 OSPAR

The Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention) was developed to regulate discharges incidental from offshore oil and gas operations in the North Sea. The standards for environmental compliance of industries residing in the waters of the North

Sea are defined within the OSPAR Harmonized Mandatory Control Scheme (EPA 2011). Testing for biodegradation, toxicity, and bioaccumulation under OSPAR is conducted on the individual components of the lubricants rather than the compound as a whole. Research conducted as part of this study indicates the testing requirements align closely with those of the Blue Angel, EEL, and VGP (OSPAR 2015). For more information, see Appendix A.

3.4.5 Swedish Standard

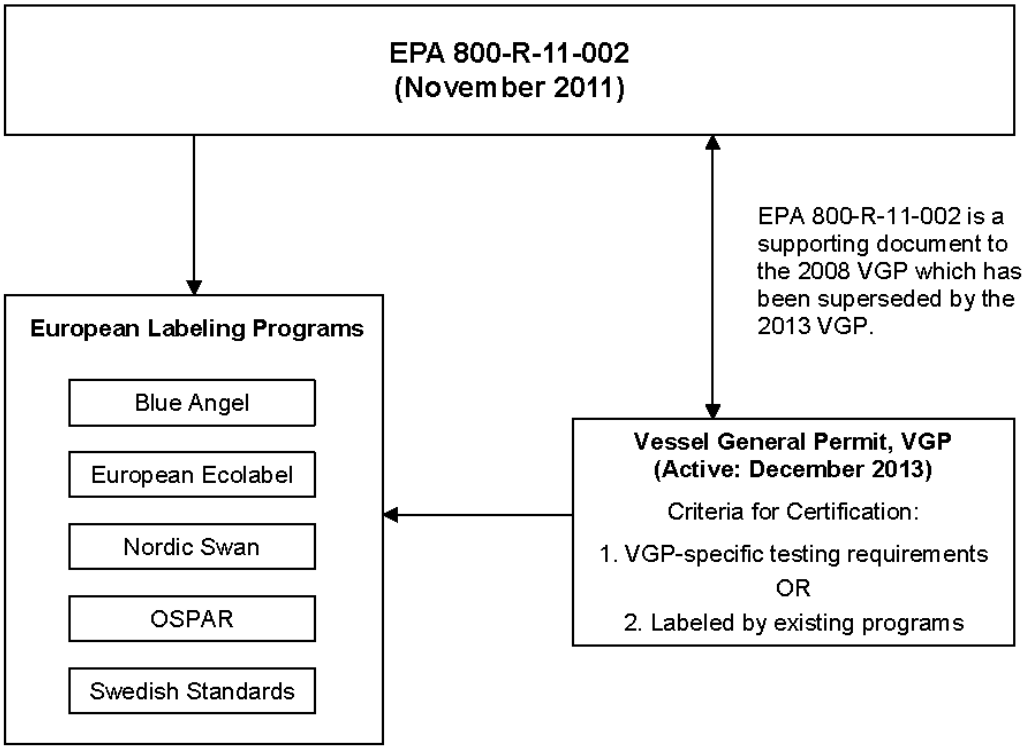
The Swedish Standard SS 15 54 70 was developed collaboratively between the Swedish Government and private industries (EPA 2011). This standard tests lubricants using International Standards Organization (ISO) standards, which do not align with the other existing labeling programs as described by EPA 800 or the VGP. This labeling program appears be active, with the standards still labeled as 'valid' per the Swedish Standards Institute website as of April 2015. Testing requirements summarized in EPA 800 Table 8 could not be verified due to lack of access to the standard. For this reason, it is assumed that the information contained within EPA's Table 8 is accurate and that the Swedish Standards do not account for marine toxicity or bioaccumulation potential.

3.5 Discussion of EAL Criteria

The investigation into the technical feasibility of replacing existing lubricants with EALs for certain in-water equipment began with a review of EPA 800 in an attempt to determine the definition of an EAL. As described above, EPA 800 does not provide requirements for lubricants to be considered EALs, but rather provides a summary of their expected characteristics and common testing methods. Therefore, EPA 800 cannot alone be used to determine if a specific lubricant is an EAL. For this reason, the 2013 VGP and the labeling programs described above to further understand EAL testing standards and establish criteria for the evaluation of suitable candidate lubricants.

Figure 1 below provides a summary of the relationship between the primary documents and programs used to establish EAL selection criteria for this study.

Figure 1: Relationship of Primary Documents Describing EALs



As can be seen from the figure, both the EPA 800 and the VGP refer to five international labeling programs to provide the definition of an EAL. The VGP also references the same labeling programs that may be used to certify a lubricant as an EAL in-lieu of VGP-specific testing for products that are not already labeled by the referenced programs.

A summary of EAL requirements of each of the five labeling programs and the VGP is provided below:

- The Nordic Swan (Nordic Ecolabel) program appears to have been discontinued for lubricants, possibly in favor of a more widespread adoption of the EEL to define EALs. For this reason, this label is no longer valid and lubricants labeled under this program should not be considered EALs for the purposes of this study.
- The Swedish Standard appears to still be active, but the testing requirements summarized in EPA 800 show this program does not require toxicity or bioaccumulation testing. For this reason, this labeling program does not meet the most rigorous definition of an EAL.
- Blue Angel appears to be an active labeling program with strong testing requirements for biodegradation and toxicity; however, the testing methods for bioaccumulation do not align with the common testing methods as provided in EPA 800. At the present time, only one grease is listed under the Blue Angel label.

- The EEL is perhaps the most widely accepted EAL labeling program, and aligns very well with the common testing methods presented in EPA 800 and the requirements of the VGP.
- The OSPAR testing requirements for biodegradability and bioaccumulation align very well with the common testing methods presented in EPA 800 and the requirements of the VGP. OSPAR testing for toxicity differ slightly, but the requirements appear to meet the intent of EPA 800 and the VGP.
- While EPA 800 does not provide criteria for the certification of a lubricant as an EAL, the EPA has subsequently provided the VGP which provides detailed requirements. The VGP is very closely aligned with the suggested methods and requirements of its predecessor document as well as to the EEL. The VGP-specific testing requirements appear to meet the definition of an EAL according to EPA 800. The VGP also allows lubricants labeled by five international labeling programs to qualify as EALs. As discussed previously, several of these programs appear to be discontinued, or do not meet the most stringent definition of an EAL. For this reason, for purposes of this study, only lubricants which meet requirements for the EEL, OSPAR, and the VGP-specific testing requirements will be considered EALs.

3.6 Candidate Grease EAL Criteria

For the purposes of this study, the following criteria were used to select candidate EALs:

- Any lubricant that has been officially represented to be VGP compliant by the manufacturer.
- Any lubricant meeting the specific testing requirements of the VGP for biodegradation, toxicity and bioaccumulation as outlined in Appendix A of the VGP.
- Any lubricant which has been granted EAL certification by the EEL.
- Any lubricant which has officially represented to be OSPAR approved by the manufacturer.

For reasons mentioned above, for the purposes of this study, the following labels *alone* will *not* be considered as meeting the definition of an EAL: Blue Angel, Nordic Swan, and the Swedish Standard(s).

4.0 In-Service Wicket Gate Greases

4.1 General

Table 3, provided by the USACE, lists the greases that are presently used on wicket gates at the facilities in consideration. The general characteristics of these lubricants are discussed in the sections below.

Table 3: Summary of in-service greases on the lower Columbia and Snake Rivers

Project	In-Service Grease(s)
Bonneville Second Powerhouse	Huskey Hydrolube, NLGI 00
The Dalles and John Day	Mobil SHC 101 EAL, NLGI 1
McNary	Chevron Ultra-Duty Grease EP NLGI 0
Ice Harbor	Chevron Ultra-Duty Grease EP NLGI 2
Lower Monumental	Chevron Ultra-Duty Grease EP NLGI 1*
Little Goose	Chevron Ultra-Duty Grease EP NLGI 2
Lower Granite	Chevron FM ALC EP2, NLGI 2
*According to plant staff, Lower Monumental recently switched to NLGI 2	

4.2 In-Service Grease Sampling

In March of 2015, HDR personnel traveled to four USACE dams to collect samples of in-service greases for analysis. Samples were collected in 5-gallon pails (approximately 35 lbs of lubricant) and were shipped to SGS Laboratories in Vallejo, CA for testing. With the exception of John Day Dam where samples were provided in new, unopened containers, lubricant was dispensed directly into the sample container by the transfer pump or by hand scooping. A summary of in-service grease sampling conducted by HDR is provided in Table 4. More details on testing of the in-service lubricants are provided in Section 6.0. Manufacturer literature and cut sheets for each product can be found in Appendix B.

Table 4: Summary of in-service grease sampling

Sample Number	Plant	Grease
1	Bonneville Second Powerhouse	Huskey Hydrolube
2	John Day	Mobil SHC 101 EAL
3	Ice Harbor	Chevron Ultra-Duty Grease EP NLGI2
4	Lower Granite	Chevron FM ALC EP2

4.3 Huskey Hydrolube

Huskey Hydrolube is a fully synthetic lubricant which was originally designed for use in the hydropower industry. Typical hydropower applications include: wicket gates, valves, fish screen equipment, gate linkages, etc. Due to it's registration as a NSF/USDA H-1 product, it is acceptable for use in all areas where incidental food or potable water contact may occur (Huskey Specialty Lubricants 2015a). Although

the manufacturer product literature describes the product as "environmentally responsible," the information available has been insufficient to indicate that this product can be considered an EAL. The manufacturer has indicated that the base oil, Huskey 15A14, which constitutes >93% of the grease formula may meet VGP testing requirements for toxicity (Huskey Specialty Lubricants 2015b). No ecological information is provided in the product MSDS.

The product in use at Bonneville Second Powerhouse is an NLGI 00 grade lubricant with a viscosity of 310 – 340 cSt at 40°C. This viscosity is the lowest NLGI grade which is considered a grease (lower viscosities would be classified as oils), and this grade is considered to be low for use in wicket gates.

4.4 Mobil SHC 101 EAL

Mobile SHC 101 "EAL" grease is a member of the Mobil family of Environmental Awareness Lubricants (not to be confused with Environmentally Acceptable Lubricants). This lubricant is formulated with synthetic ester base oil with lithium soap thickener. According to the manufacturer, common applications for this lubricant include marine equipment, dams, locks, and waterways, and hydroelectric plants. Biodegradability and aquatic toxicity test results were provided by Mobil (Exxon Mobil Corporation, 2015a); however these testing results alone do not meet the definition of an EAL as described in Section 3.0 above.

Due to its history of good performance, this product was identified by the USACE as the reference grease to serve as the performance target for new candidate EALs.

4.5 Chevron Ultra-Duty EP NLGI2

Chevron Ultra-Duty grease is an EP grease designed for a wide variety of automotive and industrial applications. This lubricant is formulated with highly refined mineral oil base oil with lithium-12 hydroxystearate thickener. Per the MSDS, this material is expected to be harmful to aquatic organisms and may cause long-term adverse effects in the aquatic environment. Also per the MSDS, this material is not expected to be readily biodegradable (Chevron U.S.A., Inc. 2014 a,b).

4.6 Chevron FM ALC EP2

Chevron FM ALC grease is a food grade EP grease designed for use in applications where incidental contact with food is possible. The grease is formulated with food grade white oil base and aluminum complex thickener (Chevron U.S.A., Inc. 2010).

4.7 Summary of In-Service Greases

Research completed on the greases presently in service at the eight facilities in consideration has not indicated that any of the existing products meet the definition of an EAL as set forth in Sections 4 and 5 of EPA 800 or as described in Section 3.0 of this report.

5.0 New Candidate EAL Greases for Wicket Gates

5.1 General

To identify new products for testing, products which meet the criteria for an EAL as described in Section 3.6 were identified through market research, responses to the industry survey, internet search, and a review of greases from the available labeling program lubricant lists.

The most effective way of locating candidate EALs was through existing databases offered from the international labeling programs. Of the labeling programs discussed in previous sections of this report, only the EEL and Blue Angel had a published list of certified lubricants. The EEL database was the most extensive, consisting of 134 lubricants, of which 14 were identified as possible candidate EALs for wicket gate greases[4] and 1 identified as a candidate EAL for wire rope grease. Of the 14 grease products, 6 could not be located online, were not available for sale in the USA, or product information was not available in English. The remaining 119 products were hydraulic oils, chain oils, rail flange oils, or other products. The Blue Angel database contained only 1 grease which was already labeled under the EEL.

Several products were identified in the industry surveys as possible greases for consideration; however, research indicated that all products identified in the survey do not meet the criteria for an EAL as presented in Section 3.0. A summary of the responses to the industry survey are provided in Section 5.6.

An internet search also helped identify several possible candidate greases, but more verification of each individual product's credentials was required. The internet search revealed numerous manufacturers that produce 'environmentally friendly' greases, but many of these products meet only a portion of the requirements for biodegradability, toxicity, and bioaccumulation or do not have published testing results indicating that they can be considered an EAL.

Through the methods discussed above, four lubricants were identified as possible EAL candidates to replace in-service wicket gate grease. A tracking matrix for candidate EAL greases under consideration for testing, including those that were rejected for not meeting the definition of an EAL, is provided in Appendix C. Cut sheets and other manufacturer information for the approved candidate EALs utilized for testing are provided in Appendix D. A brief description of each candidate EAL is provided below.

5.2 Panolin BioGrease EP 2

Panolin BioGrease EP 2 is formulated with synthetic base oil with lithium soap thickener. According to the manufacturer, recommended applications for this lubricant include hydroelectric turbine wicket gate bearings, among other applications in sensitive environments (Panolin American Inc. 2013a). The manufacturer has provided a statement that this product meets the requirements of the VGP, and therefore

[4] These figures do not include the Shell Naturelle line of products, which appears to be discontinued.

is considered an acceptable EAL candidate for this work (Panolin American Inc. 2013b). Table 5 provides a summary of VGP testing results provided by the manufacturer.

Table 5: Relevant EAL test results for Panolin BioGrease EP 2.

Characteristics of Test	Method	Units	Specification	Result
Biodegradability	ASTM 5864, OECD 301, 306	%ThOD	> 60	> 60
Toxicity				
Algae	OECD 201	LC_{50}	> 100 mg/l	> 100
Daphnia	OECD 202	EC_{50}	> 100 mg/l	> 100
Fish	OECD 203	LC_{50}	> 100 mg/l	> 100
Bioaccumulation	OECD 107, 117	Log K_{OW}	< 3 or > 7	pass

Source: Panolin American Inc. 2013b

5.3 Mobil SHC Aware EP 2

Mobil SHC Aware EP 2 is formulated with synthetic ester base oil with lithium/calcium soap thickener. According to the manufacturer, the product is typically used on high-pressure interfaces in the maritime industry (Exxon Mobil Corporation 2013). The manufacturer has provided a statement that this product meets the requirements of the VGP. Since the manufacturer has indicated that this product meets the requirements of the VGP it is therefore considered an acceptable EAL candidate for this work . Table 6 provides a summary of testing results provided by the manufacturer.

Table 6: Relevant EAL test results for Mobil SHC Aware EP 2.

Characteristics of Test	Method	Units	Specification	Result
Biodegradability	OECD 301B	%wt	> 60%	> 60%
Toxicity				
Algae	OECD 201	EC_{50}	Not provided	> 1,000 mg/l
Daphnia	Not provided	LC_{50}	Not provided	688 mg/l
Fish	Not provided	LC_{50}	> 100 mg/l	>1,000 mg/l
Bioaccumulation	OECD 117	Log K_{OW}	< 3	< 3

Sources: Exxon Mobil Corporation 2013, 2015b.

5.4 KAJO Longlife Grease LZR 2

KAJO Longlife Grease LZR 2 is formulated with 'high quality basic oils' with lithium soap thickener. According to the manufacturer, the product is typically used in vehicles, industrial machinery of all types, and highly loaded bearings (KAJO Schmierstoffe 2015). This product is labeled as an EEL; however, no specific testing results have been provided.

5.5 Castrol BioTac OG

Castrol BioTac OG is a high performance open gear lubricant developed specifically for the rack and pinion mechanism of the self-elevating mobile drilling rigs used in the offshore oil and gas industry (BP Marine Limited 2009). This product is OSPAR compliant and therefore qualifies as a VGP eligible EAL. No specific testing results have been provided by the manufacturer.

5.6 Industry Survey

A survey was distributed to various hydropower organizations throughout North America and Europe to inquire as to which EALs were in use at hydropower facilities and their performance relative to conventional lubricants. A summary of the responses to the industry survey are provided below, and full responses are provided in Appendix G.

- Many respondents addressed the use of 'food grade' lubricants or other environmentally friendly lubricants that have not been demonstrated to meet the EAL criteria discussed in Section 3.0. It appears that the definition of an 'Environmentally Acceptable Lubricant' is either not well understood in the industry or the respondent chose lubricants prior to the availability of the EPA 800 and VGP guidelines.[5]
- All respondents expressed interest in EALs even if they were not presently in use at their facilities.
- Several respondents are presently using greaseless wicket gate bushings and/or are in the process of converting.
- Two respondents said that their organization has discontinued use of environmentally friendly lubricants due to performance issues.

[5] 'Food grade' does not imply that a lubricant is environmentally friendly. For a product to be considered an H1 food grade lubricant, it is safe for incidental food contact in concentrations no larger than 10 PPM and must not cause physiological harm or change the food's odor or taste. Research conducted during this study has not uncovered any food grade lubricants that can be considered EALs. For more information on food grade lubricant regulations, see NSF International guidelines.

6.0 Analytical Methods

6.1 General

In this study, grease was analyzed for compatibility and performance. Compatibility testing is important to determine whether the in-service greases can be mixed with the candidate EALs without development of adverse characteristics or degradation in performance. When incompatible greases are mixed, the resulting blend can harden or soften, possibly resulting in the translating bearing surfaces being improperly lubricated. In some circumstances, this can lead to catastrophic bearing failure. Compatibility is most important for wetted components that cannot be easily accessed to remove existing grease (e.g., wicket gate trunnions that require the unit be disassembled for service).

Another primary objective of this study was to verify that new candidate EALs provide a level of performance that meets or exceeds the existing in-service greases. The physical characteristics of each of the new candidate EAL greases was analyzed and compared to Mobil SHC 101 which was selected as the reference grease due to its history of performance with the USACE. These tests are described in further detail below.

6.2 Compatibility Testing

Compatibility of replacement grease with existing greases is of paramount importance due to the possibility of flocking or changes in consistency, causing abnormal or insufficient distribution of grease. These conditions may cause pressure changes in the lines resulting in one or more bearings receiving less lubrication while others receive more than desired. Thickening of the grease within the lines or bearing may cause the grease to clog or stagnate, while thinning of the grease may cause washout and less protection of the bearing surfaces. The only means of repairing fouled lines that service the lower wicket gate bushings or replacing the bearings themselves is to disassemble the unit and manually remove the blockage and fouled mixture.

Compatibility tests between the in-service and new EAL greases was completed per ASTM D6185-10, Standard Practice for Evaluating Compatibility of Binary Mixtures of Lubricating Greases by SGS Herguth Laboratories in Vallejo, California. In this test, the properties of binary mixtures of lubricating greases are tested and compared to the neat (individual) properties of the constituent greases. Three properties are evaluated the ASTM D6185-10 testing protocol using standard test methods:

- Dropping point by test method ASTM D566.
    - Dropping point is the temperature at which the base oil starts to separate from the thickener. The base oil may ‘drop out’ due to the thickener melting or the oil becoming so thin that the surface tension and capillary action become insufficient to hold the oil within the thickener matrix. This test is important because a significantly lowered dropping point for a mixture of greases when compared to the neat oils may lead to catastrophic lubrication failure.
- Shear stability by test method ASTM D217; 100,000 stroke worked penetration.

- Shear stability (or mechanical stability) of grease is its ability to withstand repeated working with minimum change in its structure or consistency. For this reason, mixtures and neat greases are subjected to a 100,000-stroke process (the lubricant pushed through a perforated plate with 1/16-inch diameter holes for 100,00 cycles) in a working-vessel before the penetration characteristic (NLGI rating) is measured. No significant change to the consistency of the grease mixtures and neat greases should be observed.

- Storage stability at elevated-temperature by change in 60-stroke penetration by test method ASTM D217

  - The storage stability test measures possible changes in grease consistency when subjected to a thermal stress. Grease samples are heated at 120°C for 70 hours, and the 60-stroke worked penetration test is conducted before and after the heating and compared. Grease is deemed incompatible if the consistency after heating for the mixture changes at a greater rate than the consistency of neat greases (more than 5 percent higher or lower than the maximum and/or minimum value limits set by the test method).

  - The results from this test, if not significantly different from the results of the neat greases, may not alone disqualify the candidate EAL. The grease used in USACE wicket gate lubricating applications would not be subjected to the test temperature (120°C) either in the storage rooms or the intended equipment and the equipment-related environment. This test should be considered a general indicator of grease performance only.

A significant change of the tested characteristics in mixtures when compared to the neat greases would indicate that those greases may be incompatible, as noted in the ASTM D6185 test method guidance. This compatibility rating guidance provides for three outcomes of testing:

- A 'Pass/Compatible' is awarded when the grease mixture is considered compatible; the mixture does not have a significant degradation of properties or performance when compared to the neat greases. A compatible mixture achieves a better test result of that of the poorer of the two constituent greases.
- 'Borderline Compatible' means that the grease mixture(s) showed slight degradation, meaning that the performance of the mixture is poorer than of the two neat greases but by an amount not exceeding the repeatability value of the test method.
- A 'Fail/Incompatible' is awarded when the greases are considered incompatible; the test result is inferior to the poorer of the two constituent greases by an amount exceeding the repeatability of the test method used for the evaluation.

The compatibility tests were conducted at three different mixing ratios between the in-service greases and new candidate EALs at 10%/90%, 50%/50%, and 90%/10%. The same tests were also conducted on the neat greases to serve as a reference for the testing results of the in-service and candidate EAL mixtures.

6.3 Performance Characteristics Testing

Four new candidate EALs and one in-service grease (Mobil SHC 101) were each tested for their performance characteristics. The USACE selected Mobil SHC 101 as the reference in-service grease, as it

is used by the most units (40), has base oil viscosity closest to what turbine manufacturers recommended across the eight plants. Historically, the performance of Mobil SHC 101 has been satisfactory and provides a suitable baseline target for new candidate EALs. The performance tests investigate anti-corrosion properties, water washout resistance, apparent viscosity, oxidation stability, and wear properties. Table 7 provides a summary of the physical characteristics testing program.

Table 7: Summary of performance testing

ASTM Test Method	Description
D4048	Standard Method for Detection of Copper Corrosion from Lubricating Grease
D1264	Standard Test Method for Determining the Water Washout Characteristics of Lubricating Greases
D1092	Standard Test Method for Measuring Apparent Viscosity of Lubricating Greases (at 40°F)
D942	Standard Test Method for Oxidation Stability of Lubricating Greases by the Oxygen Pressure Vessel Method
D2266	Standard Test Method for Wear Preventive Characteristics of Lubricating Grease (Four-Ball Method)

A detailed description of each test is provided below:

- ASTM D942 Oxidation Stability of Grease:
  - In an artificially induced oxidation-accelerated environment, this test evaluates grease's resistance to oxidation by measuring the net pressure change in the oxygen-charged test vessel. The pressure drop indicates the expected rate of grease oxidation. Lower numbers for pressure drop are more desirable as this signifies that less oxygen has been converted into oxidation.
  - Oxidation stability of EAL lubricants are expected to be slightly poorer than of the petroleum based lubricants, because they are formulated with either vegetable based base oils or from synthetic esters produced from vegetable based oils. It is well documented that the vegetable based lubricants are more prone to oxidation than the petroleum based products; however, if such greases are used for an underwater application where the oxygen is not abundantly present, a slightly poorer oxidation stability of vegetable oil based greases are not expected to jeopardize the equipment.
- ASTM D1264 Water Washout at 38°C (100°F), 60 minutes
  - This test estimates the resistance of grease to water washout under the test conditions, by measuring the weight percentage loss of grease washed out of a ball bearing which is rotating at 600 RPM while being indirectly sprayed by water. This characteristic is paramount for selecting greases that would be used for lubricating underwater equipment.

- The acceptable limits for water washout characteristic in general, and especially for an underwater application, is not well defined in the industry. However, a sample grease specification for Grand Coulee Dam was located in which the water washout characteristic was specified to be less than or equal to 5% per ASTM D-1264-96 (U.S. Department of Interior, Bureau of Reclamation 2015). This limit can be used as a reasonable target for evaluation of candidate EAL greases for use in hydropower machinery in this study.

- ASTM D4048 Copper Corrosion at 100°C, 24 hours
  - This test method measures the tendency of lubricating grease to corrode copper under specific static conditions. At the conclusion of the test, the appearance of the test-strips are compared/matched to appearance of the standard copper corrosion strips and consequently rated based on their color changes. The results may be used to predict possible chemical attack from grease on lubricated parts, such as bearings that contain copper or copper alloys. All of the plants in consideration in this study have bronze wicket gate bushings which contain significant amounts of copper.

- ASTM D2266 Four Ball Wear at 75°C, 60 minutes, 40 kgf load
  - This test quantitatively evaluates wear preventive characteristics of grease in sliding steel-on-steel applications. Wear caused by the rotating ball on the stationary three remaining balls is quantified using a microscope to measure and record the average diameter of the wear scar (in millimeters). The test is at 40kgf load at 75°C temp for 1 hour at 1200 rpm.

- ASTM D1092 Apparent Viscosity at 40°C
  - This test measures the force required to force the grease through an orifice under pressure. Apparent viscosity is defined as the ratio of shear stress (pressure) and shear rate (flow). At start-up, grease has a higher resistance to motion, implying a high viscosity. However, as grease is sheared between wearing surfaces and moves faster, its resistance to flow reduces; viscosity decreases as the rate of shear increases. This test helps predict the flow characteristics of grease through pipes, lines, and dispensing equipment.

ASTM D4048 was performed by SGS Herguth Laboratories, while the balance of the performance tests was completed by Savant Inc. laboratory of Midland, Michigan.

7.0 Analytical Results and Discussion

This section presents the results of laboratory testing and a discussion of the performance and compatibility of the lubricants. The results are presented in two sections for compatibility and performance testing, respectively. The discussion provided for each set of tests (each section) is provided on a stand-alone basis; Section 8.0 of this report will provide conclusions and recommendations considering the combined results for compatibility and performance.

7.1 Compatibility Testing

7.1.1 Compatibility Results

Results from compatibility testing of greases are provided in the following two sections for 60 and 100,000 stroke tests per ASTM D6185-10, respectively. A summary of compatibility testing results from the laboratory report is provided in Table 8, Table 9, and Table 10 on a pass/borderline/fail basis. Detailed results from 60 and 100,000 (100K) stroke laboratory compatibility testing per ASTM D6185-10 are provided in Appendix H. Note: Table 8 through Table 10 show the results from the testing laboratory which are based solely on the test method criteria for compatible/borderline/incompatible. These ratings do not necessarily represent the specific operational conditions of wicket gate bearings and other hydropower equipment in consideration. The raw results provided in these tables are consolidated into one summary table with discussion and interpretation for each in-service and EAL mixture in Table 11.

Table 8: Dropping point compatibility results.

In-Service Grease	EAL #1	EAL #2	EAL #3	EAL #4
	Panolin Biogrease EP NLGI 2	Mobil SHC Aware EP NLGI 2	KAJO Longlife LZR NLGI 2	Castrol BioTac OG NLGI 2
Huskey Hydrolube 878 NLGI 00	Pass	Pass	Pass	FAIL
Huskey Hydrolube 878 NLGI 1	Pass	Pass	Pass	Pass
Mobil SHC 101	Pass	Borderline	Pass	Pass
Chevron Ultra-Duty Grease EP NLGI 2	Pass	Pass	Pass	FAIL
Chevron FM ALC EP2	FAIL	Borderline	Pass	Pass

Table 9: Shear stability compatibility results.

In-Service Grease	EAL #1	EAL #2	EAL #3	EAL #4
	Panolin Biogrease EP NLGI 2	Mobil SHC Aware EP NLGI 2	KAJO Longlife LZR NLGI 2	Castrol BioTac OG NLGI 2
Huskey Hydrolube 878 NLGI 00	Pass	Pass	Pass	FAIL
Huskey Hydrolube 878 NLGI 1	Pass	Pass	Pass	FAIL
Mobil SHC 101	Pass	Pass	FAIL	Pass
Chevron Ultra-Duty Grease EP NLGI 2	Pass	Pass	Borderline	Borderline
Chevron FM ALC EP2	Pass	Pass	Pass	Pass

Table 10: High temperature storage compatibility results.

In-Service Grease	EAL #1	EAL #2	EAL #3	EAL #4
	Panolin Biogrease EP NLGI 2	Mobil SHC Aware EP NLGI 2	KAJO Longlife LZR NLGI 2	Castrol BioTac OG NLGI 2
Huskey Hydrolube 878 NLGI 00	Borderline	Pass	Pass	Pass
Huskey Hydrolube 878 NLGI 1	Pass	Pass	FAIL	Pass
Mobil SHC 101	Borderline	Borderline	FAIL	Pass
Chevron Ultra-Duty Grease EP NLGI 2	FAIL	Borderline	Borderline	Borderline
Chevron FM ALC EP2	FAIL	FAIL	FAIL	Pass

7.1.2 Discussion of Compatibility Results

Table 11 contains the evaluation rating of the EAL greases and their compatibility with the in service greases. Notes for selected results from the summary are provided below the table.

Table 11: Summary of grease compatibility results.

In-Service Grease		EAL #1	EAL #2	EAL #3	EAL #4
		Panolin BioGrease EP	Mobil SHC Aware EP	KAJO Longlife LZR	Castrol BioTac OG
Huskey Hydrolube NLGI 00	In-Service Grease #1	Compatible	Compatible	Compatible	Incompatible(8)
Huskey Hydrolube NLGI 1[6]	Proxy for In-service Grease #1	Compatible	Compatible	Acceptable(7)	Incompatible(8)
Mobil SHC 101	In-Service Grease #2	Compatible	Acceptable(3)	Incompatible	Incompatible(8)
Chevron Ultra-Duty EP NLGI 2	In-Service Grease #3	Acceptable(1)	Acceptable(4)	Acceptable(6)	Incompatible(8)
Chevron FM ALC EP2	In-Service Grease #4	Acceptable(2)	Incompatible(5)	Incompatible	Incompatible(8)

1. Test data show that the consistency of 50/50 mixture of Panolin Biogrease EP 2 and Powerhouse #3 grease after 60-strokes failed the test by small margin, and therefore was reported incompatible in the SGS laboratory report. However, the same mixture (50/50) tested after 100,000-strokes showed acceptable shear stability

[6] The low viscosity of the Huskey Hydrolube NLGI 00 made compatibility testing and repeatability unreliable; for this reason, Huskey Hydrolube NLGI 1 was added to the testing program.

(consistency, or mechanical integrity) value[7]. For this reason, the compatibility of these two greases is considered 'Acceptable.'

2. The 50/50 mixture of Panolin Biogrease and Chevron FM ALC narrowly failed the dropping point test, and failed 60-stroke (after heating) consistency test at 10/90 mixing ratio. Consequently, the SGS lab report reported these products to be incompatible, even though this mixture passed the shear stability consistency test at more rigorous test conditions. For this reason, the compatibility of these two greases is considered 'Acceptable.'
3. Test data show that Mobil SHC Aware grease is compatible with Mobil SHC 101, even though borderline compatibility is recorded for the dropping point at 10/90 mixture, and for the consistency at 90/10 mixture before the heating sequence. For this reason, the compatibility of these two greases is considered 'Acceptable.'
4. Test data show that Mobil SHC Aware grease is compatible with Chevron Ultra-Duty, even though borderline compatibility is recorded for grease consistency (storage stability) at 90/10 mixture before the heating sequence. For this reason, the compatibility of these two greases is considered 'Acceptable.'
5. Test data show that Mobil SHC Aware grease is incompatible with Chevron FM ALC grease due to failing the consistency test (storage stability) at the 10/90 mixture. Borderline compatibility of the dropping point characteristic at 90/10 and 50/50 ratios was also observed. For this reason, these two greases are considered 'Incompatible.'
6. Test data show that KAJO Longlife grease is compatible with Chevron Ultra-Duty, even though the shear stability and the consistency (storage stability) for the 50/50 mixture is rated borderline compatible. For this reason, the compatibility of these two greases is considered 'Acceptable.'
7. KAJO Longlife grease failed the consistency test after heating by a small margin for the 50/50 mixture in the 60-stoke tests; however, shear stability of the same mixture measured after 100K-strokes is within the acceptable limits. Since the shear stability test more closely simulates the conditions grease would be subjected to while in the lubricating system, KAJO compatibility with Huskey Hydrolube NLGI 1 is rated 'Acceptable.'
8. Test data show that consistency of neat Castrol BioTac OG grease and its mixtures significantly changed when worked 100K-strokes (in comparison to 60-stroke tests) or when subjected to increased temperature. When worked for extended periods of time, the grease thinned out more than 5 percent above the upper limit of the testing method. In most cases, the grease samples showed dramatic thinning of its consistency that was beyond the test method's recording range. For this reason, Castrol BioTac OG was given an 'Incompatible' rating for all in-service grease mixtures.

7.1.3 Summary of Compatibility Results

The compatibility testing results are summarized below for each candidate EAL.

- Panolin Biogrease: compatible with all wicket gate greases in-service at the powerhouses in consideration. A minor level of flushing should be conducted when replacing Chevron Ultra-Duty and Chevron FM ALC. See Section 8.0 for additional discussion on flushing.
- Mobil SHC Aware: compatible with Huskey Hydrolube products. A minor level of flushing should be conducted when replacing Mobil SHC 101 and Chevron Ultra-Duty. Mobil SHC Aware is not compatible with Chevron FM ALC and should not replace this in-service grease without fully emptying and cleaning the wicket gate bushings and grease lines.
- KAJO Longlife: compatible with Huskey Hydrolube and Chevron Ultra-Duty products although flushing should be conducted when replacing these products due to ratings of 'Acceptable' in several tests. KAJO Longlife is not compatible with Mobil SHC 101 or Chevron FM ALC and

[7] As noted in ASTM D6185, paragraph 5.3: "*A 50/50 mixture simulates a ratio that might be experienced when one grease (Grease A) is installed in a bearing containing a previously installed, different grease (Grease B), and no attempt is made to flush out Grease B with Grease A. The 10/90 and 90/10 ratios are intended to simulate ratios that might occur when attempts are made to flush out Grease B with Grease A.* "

should not replace these in-service greases without fully emptying and cleaning the wicket gate bushings and grease lines.

- Castrol BioTac OG: This product exhibited excessive thinning when worked for extended periods of time during the 100K-stroke compatibility test. This product is not considered compatible with any of the in-service greases and should not replace these products without fully emptying and cleaning the wicket gate bushings and grease lines.

With the results as provided above, Panolin Biogrease and Mobil SHC Aware have 100% unit compatibility across the USACE plants in consideration when a minor level of flushing as described in Section 8.0 is conducted. KAJO Longlife has approximately 50 percent unit compatibility due to incompatibility with Mobil SHC 101 and Chevron FM ALC products. Castrol BioTac OG is considered incompatible with all in-service greases. Table 12 provides a summary of candidate EAL compatibility with in service greases at USACE plants on the lower Columbia and Snake Rivers.

Table 12: Summary of candidate EAL compatibility across the USACE plants on the Lower Columbia and Snake Rivers[8].

			Compatibility			
Powerhouse	In-Service Grease	# Units	Panolin Biogrease EP NLGI 2	Mobil SHC Aware EP NLGI 2	KAJO Longlife LZR NLGI 2	Castrol BioTac OG NLGI 2
Bonneville 2	Huskey Hydrolube	8	X	X	X	
The Dalles	Mobil SHC 101	22	X	X		
John Day	Mobil SHC 101	16	X	X		
McNary	Chevron Ultra-Duty	14	X	X	X	
Ice Harbor	Chevron Ultra-Duty	6	X	X	X	
Lower Monumental	Chevron Ultra-Duty	6	X	X	X	
Little Goose	Chevron Ultra-Duty	6	X	X	X	
Lower Granite	Chevron FM ALC	6	X			
	Total Compatible Units		84	78	40	0
	Compatible Percentage		100%	93%	48%	0%

7.2 Performance Testing

This section summarizes and discusses the results of performance testing. Detailed results from the laboratory report can be found in Appendix H.

[8] Judged compatible when a minor level of flushing of in-service greases is conducted where compatibility is 'Acceptable' as noted in ASTM D6185-10.

7.2.1 Performance Testing Results and Discussion

A summary of performance testing results are summarized below in Table 13. The results for ASTM D942 oxidation stability of grease are in the expected range, with the exception of Castrol BioTac OG. The pressure drop experienced for the Castrol product is extremely high, indicating that the sample experienced approximately 3 to 10 times more oxidation than the other candidate EALs or the in-service reference grease.

Table 13: Summary of performance testing results.

EAL Sample Number	Sample Name	ASTM D942 Oxidation Stability of Grease	ASTM D1264 Water Washout @ 38°C (100°F)	ASTM D4048 Copper Corrosion @ 100°C, 24 hours	ASTM D2266 Four Ball Wear @ 75°C, 60 minutes, 40kgf load
		Mean Pressure Drop after 100 hours (psi)	%wt Washout over 24 hours at 38°C	Visual Score for Corrosion of Polished Copper	Average Wear Scar (mm)
1	Panolin Biogrease EP NLGI 2	8.0	4.19%	1B	0.442
2	Mobil SHC Aware Grease EP NLGI 2	9.2	1.15%	3A	0.817
3	KAJO Longlife LZR NLGI 2	3.5	19.63%	4B	0.452
4	Castrol BioTac OG	31.3	3.85	1A	0.751
REF	Mobil SHC 101 (In-service)	2.0	2.47%	1A	0.730
Assessment Limits		<= 10.0 (1)	<= 5% (2)	Score of 1 or 2 is Acceptable (3)	<= 0.730 (4)

1. This limit was determined to be appropriate on the basis that lubricants formulated with vegetable-based oils or synthetic ester fluids synthesized from vegetable-based oils are more prone to oxidation than lubricants formulated with the petroleum-based oils.
2. Water washout limit is based on the specified value published by Grand Coulee Dam as discussed in Section 6.3 which was determined to be a reasonable target for wicket gate greases.
3. Industry best practice indicates that a result of Class 3 or greater in this test is undesirable and may indicate poor protection against corrosion for bearings (SKF Group 2015).
4. Limit set based on the wear protection characteristic of the in-service reference grease.

All greases except KAJO Longlife produced very good water washout resistance results. Approximately 20% of the KAJO product was removed from the ball bearing during the 1 hour test period. The value

measured in this study is much higher than the manufacturer reported value of 0.2%[9]. The remaining candidate EALs and the reference in-service grease all yielded washout results in the expected range.

High values for copper corrosion were noted for Mobil SHC Aware and KAJO Longlife; however, both of these values conflict with the manufacturer reported scores of 1B for both products. The results for the remaining EALs and in-service reference grease indicate that wicket gate bronze bushings would most likely not suffer corrosion due to use of these greases. A classification guide for the results of ASTM D4048 is provided in Appendix I.

The wear testing results were in the expected range for all products tested. Panolin Biogrease and KAJO Longlife both out-performed the reference in-service grease.

Apparent viscosity testing results per ASTM D1092 are provided below in Table 14. Three tests per grease were conducted at varying shear rates (flow). A comparison of the apparent viscosity of the candidate EALs to the reference in-service grease (Mobil SHC 101) could not be completed in a straight forward manner because of the difference in the NLGI grades. The reference grease is NLGI 1 grade, while all candidate EAL greases are NLGI 2. As previously mentioned, the consistency of the grease is typically similar to 'tomato paste' for NLGI 1, and 'peanut butter' for NLGI 2 greases. Consequently, the resistance to flow through the testing capillary tubes and required pressures are expected to be higher for NLGI 2 greases than NLGI 1 greases at all testing sequences of applied various shear rates (flow).

[9] This value was reported by the manufacturer as shown in Appendix D, and may be in error as this is an extremely low value that is in conflict with laboratory results as measured in this report.

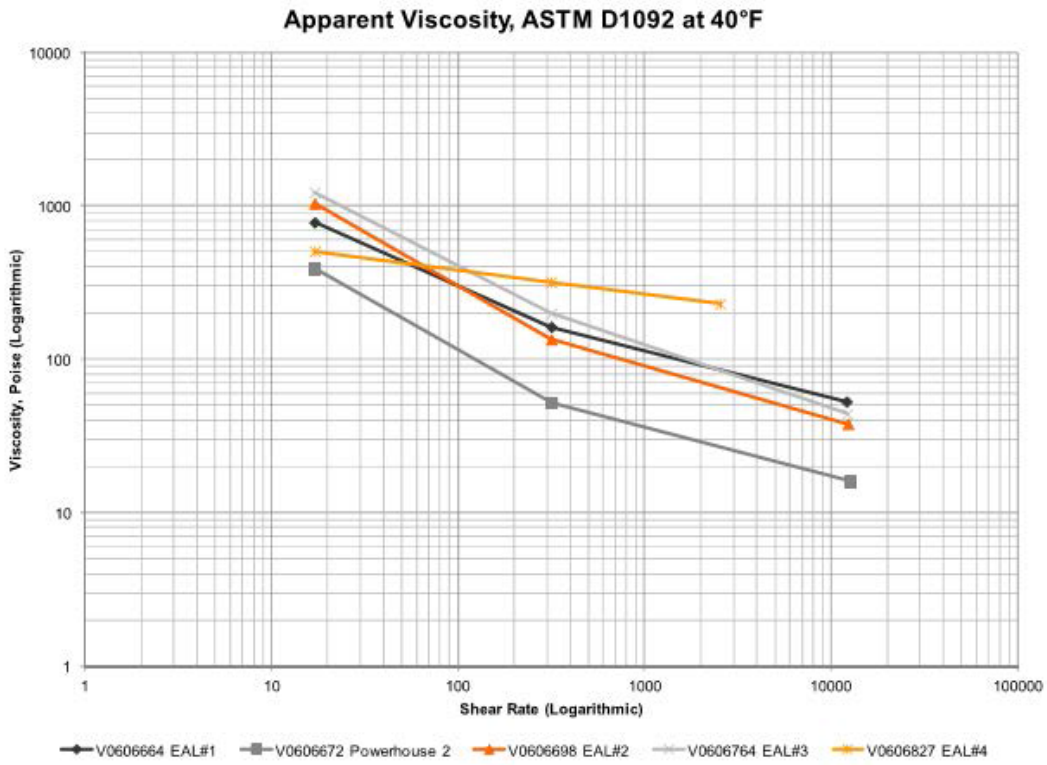
Table 14: Apparent viscosity results per ASTM D1092.

Sample Description	Shear Rate (s^{-1})	Pressure (psi)	Viscosity (P)
EAL #1 – Panolin Biogrease EP NLGI 2	17	30	781
	316	120	163
	12098	1480	53
EAL #2 – Mobil SHC Aware Grease EP NLGI 2	17	40	1041
	316	99	135
	12312	1074	38
EAL #3 – KAJO Longlife LZR NLGI 2	17	47	1224
	316	146	199
	12224	1250	44
EAL #4 – Castrol BioTac OG	17	20	507
	315	233	319
	2546	1360	230
REFERENCE In-Service Grease - Mobil SHC 101	17	15	390
	317	38	52
	12578	456	16

The apparent viscosity of the tested EAL candidate greases showed similar patterns, as seen in the log graph (Figure 2). The values for the pressures and the apparent viscosities are all slightly higher than the reference grease as expected due to the differences in NLGI grades. From these results, it is expected that the automatic centralized grease lubrication systems in place at USACE powerhouses would deliver and dispense NLGI 2 greases with sufficient ease.

It should be noted that the observed shear rate for Castrol BioTac OG was approximately five times lower than the other greases. The target shear rate of approximately 12,250 s^{-1} could not be achieved due to the 2,000 psi pumping limitation on the test equipment. A shear rate of 2,546 s^{-1} was achieved for a pumping pressure of about 1,300 psi (the pressure at which the other greases achieved the target shear rate of 12,250 s^{-1}). This characteristic of the Castrol BioTac OG grease is understandable as a low shear rate is desirable when extreme pressures are experienced on open gears (hence the OG designation). The results for this product are in-line with the other greases at the 17 s^{-1} and 316 s^{-1} target shear rates which require reasonable pumping pressures. The test results for this product are acceptable for use in automatic greasing systems with pressures not exceeding 500 psi.

Figure 2: Candidate EAL and reference in-service grease apparent viscosity results.



7.2.2 Summary of Performance Testing Results

A summary of performance testing results is provided below. For the purposes of this study, laboratory measured data found in Appendix H are given preference when conflicting with manufacturer reported values.

- Oxidation testing values were in the target range with exception of Castrol BioTac OG, which resulted in an approximately 3 to 10 times greater pressure drop when compared to the other greases, indicating high oxidation rates.
- Water washout values were in the target range for all products with exception of KAJO Longlife. Approximately 20% of the KAJO product was observed to be removed from the bearing during the 1 hour test.
- Mobil SHC Aware and KAJO Longlife experienced unacceptable elevated copper corrosion levels.
- Mobil SHC Aware and Castrol BioTac OG exhibited slightly inferior wear protection than the reference in-service grease. Panolin Biogrease and KAJO Longlife out-performed the reference in-service grease.

- The apparent viscosity of the candidate EAL greases is slightly higher than the reference in-service grease. It is expected that these greases can be delivered by the existing lubrication systems with sufficient ease.

8.0 Conclusions and Recommendations

One of the four EAL greases tested (Panolin Biogrease EP 2) was assessed to be both compatible with existing in-service wicket gate bushing greases and achieved the target laboratory performance metrics. Based on laboratory data alone, the study concludes that switching to EALs is technically feasible on certain in-water hydroelectric plant equipment. Although the Panolin Biogrease EP 2 emerged as the top candidate based on the laboratory results, this study did not find wicket gate bushing performance history on the Panolin Biogrease EP 2. For this reason, there remains some unquantified risk of damage to equipment. This risk could be minimized through a phased implementation plan designed to gradually test in-service performance before full implementation.

Additional EAL greases that were not subjected to testing and analysis in this study may also prove to be acceptable replacement greases; however their evaluation was beyond the scope of this study.

Further discussion of the conclusions and recommendations for wicket gate and wire rope greases are provided in their respective sections below.

8.1 Wicket Gate Grease

Table 15 provides a summary of in-service grease compatibility with new candidate EALs. For the purposes of this study, the rating system for ease of implementation for fully compatible, acceptably compatible, and incompatible greases is as follows:

- Fully compatible: the in-service grease and candidate EAL products are fully compatible and flushing of the existing grease may not be required for implementation.
- Acceptably compatible: the in-service grease and candidate EAL were shown to be compatible in the majority of tests conducted in this study. The few instances where borderline or incompatible test results were observed were determined to be unrepresentative of the overall typical performance of the grease mixture. Minor flushing of the greasing equipment is recommended to remove as much of the existing product as possible before introducing the replacement EAL.
    - Minor flushing could most likely be conducted during a short routine maintenance outage. This flushing process may include:
        - Removal of existing grease from the grease pumping system reservoir, reload with replacement EAL.
        - Disconnect grease distribution lines one at a time at the farthest accessible location, then operate the pump until existing grease is purged to the extent possible, as indicated when

the EAL product emerges. Color changes between the existing and replacement lubricants can be used to indicate when flushing is sufficient.

- After flushing of the distribution lines is complete, reconnect and commence operation and performance monitoring of the new grease as described below in Section 9.0.

- Incompatible: the in-service grease and candidate EAL were shown to be incompatible; direct replacement of the in-service grease is not recommended without fully cleaning and flushing the existing greasing and greased equipment. This would most likely require a significant unit outage to implement.

As can be seen from the table, Panolin Biogrease and Mobil SHC Aware have the greatest compatibility with in-service greases. These products can be implemented on 100% and 93% of main generating units at the powerhouses in consideration if minor flushing is completed for greases with 'Acceptable' compatibility, respectively. KAJO Longlife would require major flushing on approximately one-half of main generating units for implementation. Castrol BioTac grease is not compatible with any of the tested in-service greases. Further discussion on the flushing process and replacement grease implementation is provided in Section 9.0.

Table 15: Summary of compatibility results.

Candidate EAL	In-Service Grease Compatibility		
	# Greases Fully Compatible	# Greases with Acceptable Compatibility[10]	# Greases Incompatible
Panolin Biogrease EP NLGI 2	3	2	0
Mobil SHC Aware EP NLGI 2	2	2	1
KAJO Longlife LZR NLGI 2	1	2	2
Castrol BioTac OG NLGI 2	0	0	5

Table 16 contains the performance rating of the candidate EAL greases in comparison to the in-service reference grease. Based on the results above for compatibility and performance, the following EAL products should be removed from consideration for use in wicket gate bushings:

- Mobil SHC Aware: despite high marks for compatibility and three of the four performance tests, this product should be removed from consideration due to poor scoring in the test for copper corrosion. All of the eight hydropower facilities in consideration have bronze wicket gate

[10] Products which were reported to have incompatibilities at specific mixing ratios which were determined to be 'Acceptable' for implementation with existing in-service greases with only minor flushing of greasing equipment. See notes regarding the assignment of an 'Acceptable' rating in Table 11 located in 7.1.2.

bushings. Use of this product could lead to corrosion of the bushings causing increased trunnion friction and possibly seizing or mis-operation of the gates.

- KAJO Longlife: this product should be eliminated from consideration due to difficulty of implementation (major flushing required on approximately one-half of generating units) and very poor scores for water washout and copper corrosion.
- Castrol BioTac OG: this product should be eliminated from consideration due to difficulty of implementation (major flushing required on approximately one-half of generating units), and very poor oxidation stability scoring. Poor oxidation stability indicates that the performance of this product could deteriorate rapidly when in contact with air. Although wicket gates are submerged in water, the product may still be exposed to air entrained in water and also within the greasing system or while in storage. In addition, the consistency of this grease, whether tested as a neat grease or in mixtures, changes dramatically (thins out) to the point where the result is out of the test method's range for the 100K-stroke compatibility test.

Table 16: Summary of grease performance testing results.

Grease Tested	Characteristic Tested and Evaluation Results			
	Oxidation Stability	Water Washout	Copper Corrosion	Wear Prevention
Mobil SHC 101 (In-Service Reference)	Benchmark	Benchmark	Benchmark	Benchmark
Panolin Biogrease EP 2	Good	Good	Very Good	Excellent
Mobil SHC Aware EP2	Good	Very Good	Poor	Slightly Inferior
KAJO Longlife LZR NLGI 2	Very Good	Very Poor	Very Poor	Excellent
Castrol BioTac OG NLGI 2	Very Poor	Good	Excellent	Slightly Inferior

With the elimination of Mobil SHC Aware, KAJO Longlife, and Castrol BioTac OG for the reasons mentioned above, the remaining candidate EAL is Panolin Biogrease EP 2. This product is compatible across all plants with minor flushing at McNary and the four plants on the Snake River (38 main generating units total). Panolin achieved results which were in-line with the reference in-service grease, even exceeding performance for wear prevention. This product is produced in Switzerland but is available in the United States via their distribution center in Ventura, California. One 55-gallon drum of this product costs about $2,500 when purchased in bulk.

8.2 Wire Rope Grease

Although wire rope greases were not specifically tested, the research presented in Section 3.0 of this study has provided direction towards appropriate EAL selection criteria for wire rope greases. Market research has also uncovered several products which may be appropriate wire rope lubricants to replace those

presently in-service. One EAL product which has a favorable service history is Biogen Wireshield from the ROCOL Company. This product is a gel type lubricant which can be applied either via automatic pressurized lubricators or by hand. Due to its pseudoplastic rheology characteristic (lowered viscosity when subjected to shear strain), when shear is applied, the viscosity is reduced, allowing the product to penetrate into the rope core. The penetration of this product would be superior to non-pseudoplastic rheological lubricants. Biogen Wireshield is EEL certified and therefore is VGP compliant.

Although wire rope lubricants can be successfully applied by hand, superior results can be achieved using a pressurized embedment system. This will improve the lubrication of the individual strands and wires as well as the core, helping to reduce internal rope failures. When applying new wire rope lubricant, it is recommended to remove as much of the existing product from the outside of the rope as possible before applying the replacement lubricant. Additional testing should be considered to check for compatibility issues between the new candidate EAL and the manufacturer-supplied lubricant in the rope core which cannot be removed by hand.

Lubricants identified in the scope of work which may be suitable replacements for in-service wire rope greases include:

- Vickers Oil, Bio Grease – manufacturer states compliance with the VGP, but no additional data available. Per the criteria presented in Section 3.0, this should be considered as a viable replacement wire rope grease.
- Renewable Lubricants, Bio-EP Wire Rope Lubricant – manufacturer states compliance the with VGP, but no additional data available. Per the criteria presented in Section 3.0, this should be considered a viable replacement wire rope grease.

Other wire rope lubricants identified in the scope of work:

- TKG Inc., Dynagard Blue – manufacturer states positive aquatic toxicity testing results but no additional information available at the present time. More information is needed to verify this product meets the criteria set forth in Section 3.0 of this report.
- TKG Inc., Dynagard "E" – manufacturer states that the product is non-toxic and 97% biodegradable, but no additional information is available at the present time. More information is needed to verify this product meets the criteria set forth in Section 3.0 of this report.

At the present time, no information is available concerning Nordic Swan or OSPAR labeled lubricant products. Similarly, at the present time there are no wire rope greases listed under the Blue Angel label. For more possible candidate wire rope greases, refer to Appendix C.

It should be noted that the wicket gate lubricants discussed in the preceding sections are not suitable for use in wire ropes. Wicket gate lubricants should, however, be suitable for other lifting equipment applications, such as pins, sheaves, and hook swivels, that may become periodically submerged, provided the loads are within the manufacturer recommended ranges. The manufacturer should always be consulted before a new lubricant is applied to determine if the application is appropriate.

9.0 Implementation Plan

This section provides recommendations on a stepped approach to test the performance of new EALs with hydropower equipment.

9.1 Wicket Gate Grease

After a suitable EAL grease(s) is identified based on the results of laboratory testing, the "proof of concept" must be completed prior to full implementation. This "proof of concept" can take various routes to fully demonstrate that the new EAL is satisfactory for long term operation and does not pose a risk to generation assets. This may involve a defined time line of testing or operation in one or two machines at each site or on each turbine type that is of sufficient duration to determine a successful outcome. This also provides the opportunity to test and refine greasing system flushing procedures and equipment.

"Proof of Concept" steps:

1. Select one or more units from each turbine family for trial implementation of the EAL grease. Select unit(s) that are scheduled for a maintenance outage (six months to a year) to minimize outages and other interruptions. Turbine families at the plants in consideration are shown in Table 17.

Table 17: USACE turbines with greased wicket gate bushings on the lower Columbia and lower Snake Rivers.

Project	Turbine Family	Units	HP
Bonneville Second Powerhouse	Allis Chalmers	11 - 18	105,000
The Dalles	BLH	1 - 14	123,000
	BLH	15 - 22	136,000
John Day	BLH	1 - 16	212,400
McNary	S. Morgan Smith	1 - 14	111,300
Ice Harbor	Allis Chalmers	1 - 3	143,000
	Allis Chalmers	4 - 6	174,000
Lower Monumental	BLH	1 - 3	212,400
	Allis Chalmers	4 - 6	212,400
Little Goose	BLH	1 - 3	212,400
	Allis Chalmers	4 - 6	212,400
Lower Granite	BLH	1 - 3	212,400
	Allis Chalmers	4 - 6	212,400

2. Verify the existing grease dispensing systems are fully operational.
3. Record wicket gate servo motor differential operating pressures for in-service greases. Baseline performance of the system with existing grease should be recorded in at least three separate instances for the operations as described in below:

   a. Servo breakaway pressure when starting at rated head with the governor oil either fully cooled or at a steady state warm temperature.
   b. After operation for a duration of at least 4 hours with governor oil at a steady state warm temperature, record servo pressure time-history from 80% to 20% load.
4. Implement new grease(s) utilizing one of the following procedures:
   a. While in-service, disable automatic grease system empty and clean existing reservoir. Conduct minor flushing as necessary as outlined in Section 8.1. Install EAL grease in the grease system reservoir and return the existing automatic grease system to service. As time progresses, the EAL grease will replace the non-EAL grease during normal operation. No specific outage should be required. Residual waste non-EAL grease can later be removed from turbine pit during a scheduled outage.
   b. During a scheduled watered-up outage, disable automatic grease system empty and clean existing reservoir. Conduct minor flushing as necessary as outlined in Section 8.1. Install EAL grease in the grease system reservoir and return the existing automatic grease system to service. Remove existing accumulated residual non-EAL grease from turbine pit. Remove existing grease metering lines and arrange to collect residual non-EAL grease from metering lines by operating the automatic grease system in manual until EAL grease is being discharged at each metering line end point. Reinstall metering lines and return grease system to automatic operation.
   c. During a scheduled or unscheduled unwatered outage while access to wicket gate bushings is available, disable automatic grease system empty and clean existing reservoir. Conduct minor flushing as necessary as outlined in Section 8.1. Install EAL grease in the grease system reservoir and return the existing automatic grease system to service. In the turbine water passage, at the wicket gate bushings, prepare containers to accept the residual non-EAL grease from all the wicket gate upper and lower bushings. Repair or replace any non-functioning metering lines. Operate the automatic grease system collecting non-EAL grease until the new EAL is discharged at each bushing. Remove existing accumulated residual non-EAL grease from turbine pit. Return the automatic grease system to service.
5. Operate the unit until the next scheduled maintenance outage. Periodically record the wicket gate servo motor operating pressures in the same or similar conditions as described in item 3 above. Allow the new grease to break in through at least 10 wicket gate operations before recording pressures for comparison to values observed for the existing in-service greases.
6. Inspect top wicket gate bushings in the turbine pit. Disassemble bushings or remove caps to the extent possible to inspect bushings, to:
   a. Determine if grease is being satisfactorily distributed among bushings and within individual bushings,
   b. Determine if any grease degradation is occurring by visual inspection.
   c. Determine if abnormal or uneven wear is occurring. Bearing clearances can be observed without disassembly using feeler gages.
7. If preliminary monitoring results of bearing wear, grease consistency, and wicket gate servo motor pressures are satisfactory, schedule the remaining units for grease replacement and full adoption of EAL lubricants in wicket gate bushings. If results are not satisfactory, repeat this

process with a new candidate EAL. Testing of additional candidate EALs may identify other suitable replacement greases.

9.2 Wire Rope Grease

Several possibilities for replacement wire rope grease are identified above in Section 8.2 and also in Appendix C. The first step in implementation is to verify that each product meets the definition of an EAL as discussed in Section 3.0 of this report. After a suitable replacement product is chosen, it is advisable to perform testing. If possible, the product should be applied to wire rope on hoists that are operated on a regular basis to observe the product's performance during and after the rope is wound onto the drum. The new lubricant should be applied after first removing the existing product to the extent possible from the exterior of the rope.

A performance inspection of the new lubricant on each hoist should be conducted at regular intervals and compared to performance of the in-service grease. Inspection should be carried out by a qualified engineer and include observations of corrosion, grease oxidation, noise during operation, and other parameters.

If a pressurized grease embedment system is used, then additional testing should be considered to check for compatibility issues between the new candidate EAL and the manufacturer-supplied lubricant in the rope core which cannot be removed by hand.

10.0 References

Blue Angel (by Ecolabel Index)

2014 Basic Criteria for Award of the Environmental Label - Biodegradable Lubricants and Hydraulic Fluids, RAL-UZ 178. July 2014.

BP Marine Limited

2009 Castrol BioTac OG Grease - Product & Technical Data. September 14, 2009.

Chevron U.S.A. Inc.

2010 Chevron FM ALC EP Food Machinery Grease - Product Data Sheet. March 1, 2010.

2014a Chevron Ultra-Duty Grease EP - MSDS. Chevron U.S.A. Inc., June 26, 2014.

2014b Chevron Ultra-Duty Grease EP - Product Data Sheet. Chevron U.S.A. Inc., June 3, 2014.

EU Ecolabel

2014 European Union Ecolabel application pack for lubricants, Version 1.1. September 2014.

Exxon Mobil Corporation.

2013 Mobil SCH Aware Grease EP 2 - Product Data Sheet. 2013.

2015a Mobil SHC Grease 100 EAL Series - Manufacturer Website Listing. March 4, 2015.

2015b Mobil SHC AWARE GREASE EP 2 - MSDS. Exxon Mobil Corporation, March 16, 2015.

Huskey Specialty Lubricants.

2015a Huskey Hydrolube Product Description. March 4, 2015.

2015b Environmental Summary of Huskey 15A14 Family of Oils and Greases. March 4, 2015.

KAJO Schmierstoffe

2015 KAJO Longlife Grease LZR 2 - Product Information. January 29, 2015.

OSPAR Commission

2014 OSPAR Guidelines for Completing the Harmonised Offshore Chemical Notification Format (HOCNF). Agreement Update 2014-2012.

Panolin America Inc.

2013a Panolin BioGrease EP 2 - Product Data Sheet. March 27, 2013.

2013b Panolin Biogrease EP2 - Compliance of EPA Vessel General Permit 2013. August 14, 2013.

SKF Group.

2015 Understanding Grease Technical Data. June 29, 2015.

United States Department of the Interior, Bureau of Reclamation

2015 91--Lubricating Turbine Grease, Solicitation Number: 40184833. January 8, 2015.

United States Environmental Protection Agency (EPA)

2011 Environmentally Acceptable Lubricants, EPA 800-R-11-002. November 2011.

2013 Vessel General Permit for Discharges Incidental to the Normal Operation of Vessels. December 19, 2013.

Appendix A. EAL Labeling Program Comparison Matrix

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EAL Labeling & Certification Program Comparison Matrix
Common Testing Methods for Grease Mixtures
HDR Engineering, Inc.
Updated: 7/24/2015

Testing or Labeling Program	Biodegradability Test Method	Toxicity Test Method	Bioaccumulation Potential Test Method	References
Potential Methods per EPA 800-R-11-002, November 2011	Common testing methods include: OECD 301 A through F ASTM D5864 ASTM D7373 CEC L-33-A-94 ISO 19696 EPA 560/6-82-003 (per Table 2, page 11)	Common testing methods include OECD 201, 202, 203, 204 EPA 560/6-82-002, Sections EG-8, EG-1, and EG-9 (Analogous to OECD tests 201-203) OECD 208, 210, 211, 212	Common testing methods include: OECD 117 OECD 107	United States EPA, Environmentally Acceptable Lubricants, EPA 800-R-11-002 November 2011
Blue Angel	Ultimate Biodeg (all 3 tests) 28 day test per Part C.4 of Annex to EC No. 440/2008 or OECD 301 (B,C,D,F) --OECD 306 --OECD 310 Inherent Biodeg (either test 3A or 3B) --Blue Angel (reqm't 3A: Part C.9 of Annex to EC No. 440/2008 or OECD 302 C --Blue Angel (reqm't 3B: 28-days: Part C.4 of Annex to EC No. 440/2008 or OECD 306 or OECD 310	Test required for each trophic level for final grease product (not components): algae, daphnia, fish. One test per level required --Algae. Acute - ISO/DIS 10253 or OECD 201 or Part C.3 of Annex to EC No. 440/2008 --Daphnia. Acute - ISO TC 147/SC5/WG2 or OECD 202 or Part C.2 of Annex to EC No. 440/2008. Chronic - OECD 211 or Part C.20 of Annex to EC No. 440/2008. --Fish. Acute - OECD or Part C.1 of Annex to EC No. 440/2008. Chronic - OECD 204, 210, or 215 or Part C.14 of Annex to EC No. 440/2008	One of the following: - Part A.8 of EC No. 440/2008 - OECD test 123 - Part C.13 of EC No. 440/2008 - OECD 305	Blue Angel, Basic Criteria for Award of the Environmental Label Biodegradable Lubricants and Hydraulic Fluids, RAL UZ 178, July 2014
European Eco Label	--28-day study per to Reg. 440/2008/C.4 (OECD 301 A-F), OECD 306 or OECD 310, and in case they are not available: The BOD5 and COD studies according to Regulation 440/2008/C.5 for the BOD5 and for the COD according to Regulation 440/2008/C.6	The aquatic toxicity assessment is based on chronic toxicity data of the trophic levels: Daphnia and fish. When these chronic toxicity data are not available, acute toxicity data can be used (see doc for more details). --Chronic (daphnia and fish): Regulation 440/2008/C.20 (OECD 211) for Daphnia (crustacean) and Regulation 440/2008 (OECD 215) or OECD 210 for fish --Acute (daphnia and fish): for marine environment ISO/DIS 10253 for algae, ISO TC 147/SC5/WG2 for crustacean and OECD 203 for fish. For freshwater Regulation 440/2008/C.3, (OECD 201) for algae, Regulation 440/2008/C.2, (OECD 202) for daphnia and Regulation 440/2008/C.1, (OECD 203) for fish. CNV (72h) EC50 for algae, (48hr) EC50 for daphnia and (96hr) LC50 for fish are accepted.	Data on bioaccumulation will be submitted if the substance is not ultimately not inherently biodegradable If not meeting biodegradability criteria submit proof of one of the following: --Molecular Mass (MM) or Molecular Diameter (MD): MM> 600 Dalton or MD > 15A are non-bioaccumulative; --Substance is a polymer and the MM > 1000 Dalton is below 1% in the polymer itself; --Test per Reg 440/2008/C.13 (OECD 305) or any other equivalent test method. -- log Kow of the substance according to Reg 440/2008/A.8 (OECD 107 or OECD 117) or OECD 123 or any other equivalent test method --Organic compound, not surfactant: calculation of, CLOGP, LOGKOW, (KOWWIN) and SPARC.	EU Ecolabel, European Union Ecolabel Application Pack for Lubricants, Self-Assessment Methods, Version 1.1, September 2014
Nordic Swan OSPAR	NA --OECD 306 (marine degradation) OR --OSPAR Ring Test OR --OECD 301 A-F and freshwater BODIS tests	OECD 201-202 --Algae: ISO/DIS protocol 10253 --Crustacea: ISO protocol TC-147/SC5/WG2 --Fish: Part B of OSPAR protocols on Method of Testing Chemicals Used in the Offshore Industry (OSPAR, 1995)	None --OECD 117 or 107 (KOW) --OECD 305 or ASTM E1022 --MW >780 --Other internationally recognized methods	NA (OSPAR Guidelines for Complating the Harmonised Offshore Chemical Notification Format (HOCNF), (OSPAR Agreement: 2012/05, Update 2014)
Swedish Standard	ISO 9439	NA	None	NA
Vessel General Permit (US EPA)	OECD 301 A-F, 302C, 306, and 310, ASTM E964, ASTM D-7373, OCSPP Harmonized Guideline SUB 3110 (EG) 16593 1996	Must test either: --Acute: OECD 201, 202, and 203 (all three) --Chronic: OECD 210 and 211 (both) Equivalent toxicity data for marine species, including methods ISO/DIS 10253 for algae, ISO TC147/SC5/WG2 for crustacean, and OSPAR 2005 for fish, may be substituted for OECD 201, 202, and 203	Not Bioaccumulative means: -- log KOW <3 or >7 using test methods OECD 117 and 107, -- molecular mass > 800 Dalton, -- molecular diameter > 1.5 nanometer, --BCF or BAF is <100 L/kg, using OECD 305, OCSPP 850.1710 or OCSPP 850.1730, or a field-measured BAF or --polymer with MW fraction below 1,000 g/mol is < 1%.	US EPA, Vessel General Permit for Discharges Incidental to the Normal Operation of Vessels (VGP), Appendix A, 2013

Note: The testing lists above are a summary only. The information above summarizes common testing methods for grease mixtures for several international EAL labeling programs. Although permissible in several labeling programs, testing / certification of a grease mixture based on a disclosure of its constituent parts is not included in this summary. For complete list of testing requirements, read the referenced documents for each label.

Appendix B. In-Service Grease Manufacturer Information

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HUSKEY SPECIALTY LUBRICANTS

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HUSKEY™ HYDROLUBE

Description

HUSKEY HYDROLUBE GREASE represents the most advanced lubricant technology. It is an Environmentally Responsible, non-toxic, pure synthetic, waterproof lubricant formulated to provide maximum parts protection in adverse conditions of extreme loads, high water washout and chemicals. **HUSKEY HYDROLUBE** is NSF/U.S.D.A. H-1 *Registered which gives it full acceptability for use in all areas where incidental food or potable water contact may occur. **HUSKEY HYDROLUBE** does not contain any lead, chlorine, phosphorous, sulphur, chromates, antimony, benzene, free metallic or other potentially hazardous ingredients that may harm the environment.

Advantages

- ENVIRONMENTALLY RESPONSIBLE
- BIODEGRADABLE
- CHEMICALLY RESISTANT
- NON-MELTING
- WIDE TEMPERATURE RANGE (10°F to 350°F)
- NSF/U.S.D.A. H-1 *REGISTERED
- WATERPROOF
- WITHSTANDS EXTREME LOADS
- SHEEN REDUCING
- PREVENTS RUST & CORROSION

*NSF H-1 Registration No. 0593110

Usage

HUSKEY HYDROLUBE was originally designed as an Environmentally Responsible alternative for greases used in both underwater and extreme pressure applications found in Hydroelectric plants and Dam facilities. However, due to its heavy duty lubrication qualities and NSF/U.S.D.A. H-1 *Registration, it is an excellent choice for all open gears, sliding surfaces and slow to moderate moving bearings found in both FOOD PROCESSING AND WATER INDUSTRIES. **HUSKEY HYDROLUBE** is compatible with most rubbers and plastics which makes it a superior lubricant for "O" rings.

HUSKEY HYDROLUBE is the first choice in grease where maximum equipment protection and environmental impact is a primary concern. Some such applications include;

- TURBINE WICKET GATES
- VALVES
- FISH SCREEN EQUIPMENT
- TRUNNIONS
- OPEN GEARS
- STERILIZER CHAINS
- GATE LINKAGES
- GUIDE RAILS
- GASKETS & O-RINGS
- BUSHINGS

Package Availability

- 5 gal. Pail

- 15 gal. Keg
- 55 gal. Drum

Typical Specifications

Product: HYDROLUBE Grease (grades 00, 0, 1 & 2) **Base Oil:** Synthetic

Thickener: Synthetic **Texture:** Tenacious

Color: White **NSF/U.S.D.A. Rating:** H-1

Test	ASTM Test Method	00 N.L.G.I. GRADE	0 N.L.G.I. GRADE
Worked Penetration, 60 strokes	D-217	400-430	355-385
Base Oils Viscosity,			
cSt @ 40° C	D-445	7800	7800
cSt @ 100° C	D-445	200	200
Dropping Point, °F	D-566	+500	+500
Pour Point, °C. (°F.)	D-97	20	20
Flash Point, °C. (°F.)	D-92	350	350
Corrosion Preventative Test	D-1743	PASS	PASS
Oil Separation, % Loss	D-1742	0.5	0.3
Water Washout, % Loss	D-1264	1.0	0.5
Timken OK Load, Lbs.	D-2509	60	60
Four-Ball EP			
Load Wear Index	D-2596	45	45
Weld Point, Kg	D-2596	160	160

Test	ASTM Test Method	1 N.L.G.I. GRADE	2 N.L.G.I. GRADE
Worked Penetration, 60 strokes	D-217	310-340	265-295
Base Oils Viscosity,			
cSt @ 40° C	D-445	7800	7800
cSt @ 100° C	D-445	200	200
Dropping Point, °F	D-566	+500	+500

Pour Point, °C. (°F.)	D-97	20	20
Flash Point, °C. (°F.)	D-92	350	350
Corrosion Preventative Test	D-1743	PASS	PASS
Oil Separation, % Loss	D-1742	0.0	0.0
Water Washout, % Loss	D-1264	0.0	0.0
Timken OK Load, Lbs.	D-2509	55	55
Four-Ball EP			
Load Wear Index	D-2596	45	45
Weld Point, Kg	D-2596	160	160

MSDS SHEET NSF REGISTRATION Call for a Quote

The name of this product or group of products is for product identification only. HUSK-ITT CORPORATION makes no warranties, representations or conditions of any kind expressed or implied, whether for merchantability or fitness with respect to these products. The final determination of the suitability of the products for the application contemplated by the user is the sole responsibility of the buyer. HUSK-ITT CORPORATION sales personnel are not authorized to amend this warranty limitation.

Return

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HUSKEY Specialty Lubricants

manufactured by HUSK-ITT Corporation / SPECIALTY LUBRICANTS Corporation

Western Region Office:
1580 Industrial Avenue, Norco, California 92860
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(888) 4-HUSKEY · www.huskey.com

Eastern Region Office:
8300 Corporate Park Drive, Macedonia, Ohio 44056
(330) 425-2567 · Fax: (330) 425-9637
(800) 238-LUBE

ENVIRONMENTAL SUMMARY OF
***HUSKEY*™ 15A14 FAMILY**
OF OILS AND GREASES

BACKGROUND: Page 1.

In today's world, all facets of Industry are becoming more aware and increasingly concerned with the environmental impact lubricants can pose.
The Water Industry is a primary example of one Industry that this concern specifically affects.

The *HUSK-ITT Corporation* has been developing lubricants to address these concerns without sacrificing maximum equipment protection for the past 15 years.

In 1982, the *HUSK-ITT Corporation* introduced to the Food and Drug Administration (FDA) and the United States Department of Agriculture (USDA) new synthetic waterproof, biodegradable base fluids for evaluation and approval.

In 1984, The *HUSK-ITT Corporation* was granted full approvals for the new oils and greases, for use in incidental food contact in the food processing industry. From this technical break-through has come a **New Generation** of lubricants that have extreme service qualities and are environmentally benign.

This new family of Oils and Greases is called the *HUSKEY 15A14* Family. This family consists of eight separate viscosities of the 15A14 Series of Oils and six different greases; which include *HUSKEY* LUBE'O'SEAL, LVI-50, LVI-50 NT, HYDROLUBE and LUBE'O'SEAL Valve Lubricant Grade.

As all of these greases share the same common base oil, (in varying viscosities) and the 15A14 oils are 93% to 95% of the grease formula, with the balance being primarily a synthetic thickener, the focus of environmental testing has been done on the oils themselves.

The following information reviews aquatic toxicity information about the *HUSKEY* 15A14 oils, and indicates the German Water Classification (WGK) for these *HUSKEY* oils.

AQUATIC TOXICITY STUDIES:
The *HUSKEY* 15A14 base oil for HYDROLUBE Grease and both LUBE'O'SEAL Grease and LUBE'O'SEAL Valve Lubricant, was tested in an ecotoxicity screening program sponsored by the Chemical Manufacturer's Association. The acute toxicity of the water accommodated fraction (WAF) of this 15A14 Oil to the freshwater invertebrate Daphnia magna, and to the freshwater fish, the fathead minnow (Pimephales promelas) was tested. *HUSKEY* 15A14 Oil was among those materials rated as "non-toxic to daphnids (LC_{50} greater than 1,000 mg/L)" and as "non toxic" to fathead minnows (96 hour LC_{50} greater than 1,000 mg/L).

Page 2 - Aquatic Toxicity Studies (continued)

The tests were designed to establish approximate toxicity ranges as a screening procedure. The WAF was obtained by stirring the material in water for 24 hours, allowing the solution to settle for about 1 hour, and siphoning the water phase off to use for testing. Initial amounts of material were 0, 100, 300 and 1,000 mg/L (before stirring). This procedure provides a way to test the toxicity of materials that are not soluble in water, or have a very low solubility. However, some insoluble fractions may be stirred into suspension or may form emulsions. This seemed to be the case with the *HUSKEY* 15A14 Oil, as a slight oily sheen at the surface of the test containers was observed during the test.

All fish survived in all test concentrations of the 15A14 Oil, and no sublethal effects were observed. (Sublethal effects could include abnormal fish behavior, excitability, gulping air, or lethargy.)

Slightly over half the daphnia survived at the highest concentration tested. The endpoint of the acute test is the LC_{50}, the estimated concentration at which 50% of the exposed organism dies after 48 hours exposure. Consequently, the 48 hour LC_{50} exceeded the highest concentration tested. A large number of daphnia were floating, appearing to be stuck in the layer of material on the surface. This impact appears due to the physical effects of insoluble material, rather than due to toxicity due to the material.

GERMAN WATER ENDANGERMENT CLASSIFICATION:

The German Federal Ministry for the environment has published a method to classify hazard to the aquatic environment that uses data on oral toxicity to rats, acute toxicity to fish, and acute toxicity to bacteria to calculate a score ranging from 0 to over 6, with higher values increasing hazard. Using the calculation method presented in the German regulation, 15A14 Oils have been assigned a water endangerment classification (WGK) OF ZERO (0).

The background information for the WGK calculation is attached. The key data used include the fish study noted above, a rat oral toxicity study, and a bacterial inhibition test. The bacterial test of 15A14 Oils conducted using two grades of *HUSKEY* 15A14 Oils (ISO Grades 22 and 460). No inhibition of bacterial respiration was found with either grade of 15A14 Oils.

Submitted by:

Hugh J. Woodworth
Hugh J. Woodworth,
Technical Coordinator

ATTACHMENT

German Water Classification (WGK) for *HUSKEY* 15A14 Oils

A commission within the German Federal Ministry for the Environment has devised a scheme for classifying substances as "water endangering" based on potential human and environmental health hazards. The scheme provides a classification (WGK) derived from a scoring system using data from three types of studies; acute mammalian oral toxicity (preferably in rats) acute fish toxicity, and bacterial toxicity. Higher scores reflect increasing potential for water endangerment.

Additional considerations must be considered if other relevant test data are available concerning the environmental fate or effects of the substance.

The data from the three test systems are used in the following way:

Acute Mammalian Oral Toxicity

The acute oral toxicity endpoint, LD_{50} in mg/kg is used to determine a score, the BZ_s, from the following table:

LD_{50} mg/kg	BZ_S
< 25	7
25-200	5
200-2000	3
>2000	1

Toxicity tests for *HUSKEY* 15A14 Oils indicate that the rat oral LD_{50} is >2000 mg/kg, so the BZ_s is 1.

Acute Fish Toxicity

The BZ_f is defined by the toxicity threshold (LC_0 value) in mg/L (ppm) following the table on oral mammalian toxicity (above). Ecological toxicology tests conducted with *HUSKEY* 15A14 Oils showed no fish mortality at loadings up to 1000 mg/L. Water accommodated fractions and water-dispersed fractions were tested using the freshwater fish, Pimephales promelas. These data indicate that the LC_0 is in the 200-2000 mg/L range so the BZ_f is 3.

Acute Bacterial Toxicity:

HUSK-ITT Corporation has not conducted the preferred bacterial toxicity test specified in the WGK legislation, namely the Bringmann-Kùhn Cell Multiplication Test. However, data obtained from several tests with microbes indicate that 15A14 Oils have low toxicity to bacteria. Following a modified OECD Method 209, bacterial inhibition using activated sludge microbes was tested with two grades of *HUSKEY* 15A14 Oils. The tests showed no bacterial inhibition at 15A14 Oil loadings of up to 25 mg/L, as determined by measuring oxygen consumption (respiration).

Page 2 - German Water Classification, Acute Bacterial Toxicity (continued)

In separate tests, the biological oxygen demand (BOD) of microorganisms was measured. These tests, done at higher loadings of 15A14 Oils, about 200,000 ppm showed no evidence of bacterial toxicity. The oxygen demand is indicative of degradation of 15A14 by microorganisms. For all grades of 15A14 Oils, BOD was small, and it increased with decreasing 15A14 Oil chain length. The reduced capacity of the microorganisms to decompose higher molecular weight 15A14 Oils is probably due to the increased size of the 15A14 Oil molecules.

The bacterial toxicity threshold in mg/L (ppm) BZ_B is calculated as:

$$BZ_B = -\log(\text{toxicity threshold in ppm})$$

For 15A14 Oils, the microbial inhibition data, showing no inhibition at 25 mg/L, is used as a conservative estimate of the bacterial toxicity threshold. This resulting calculated BZ_s is:

$$BZ_B = -\log(25\text{ ppm}) = 1.4$$

Water Classification Score:

The three test systems, mammalian, bacterial and fish, are considered equally when determining the water endangerment number (WGZ) using the following calculation:

$$WGZ = \frac{BZ_S + BZ_B + BZ_F}{3}$$

For 15A14 Oils, the $WGZ = \frac{1 = (-)\ 1.4 + 3}{3} = 0.87$

The water endangerment class is then determined from the following table:

WGZ	WGK	
0 - 1.9	0	In general, not endangering water
2 - 3.9	1	Slight water endangerment
4 - 5.9	2	Water endangering
≥ 6	3	Severe water endangerment

According to the calculation, the WGK for 15A14 Oils, is 0, which indicates they pose no water endangerment.

ADDITIONAL INFORMATION

Additional information, such as solubility, carcinogenicity, mutagenicity, chronic toxicity, toxicity to daphnia or algae and bioaccumulation and biodegradation, can also be used to influence the classification.

15A14 Oils are poorly soluble in water. This minimizes their bioavailability and is consistent with a classification that 15A14 Oils do not endanger water.

Page 3 - German Water Classification (continued)

Acute toxicity tests of *HUSKEY* 15A14 Oils were conducted with the freshwater invertebrate, Daphnia magna. The 48 hour EC_{50} was greater than 1000 mg/L (expressed as the nominal amount of test substance used to prepare the water-accommodated fraction). This is consistent with the fish data used in the WGZ.

Based on the results of toxicity tests, supporting information and professional judgment, the weight of the evidence indicates that 15A14 Oils are non-hazardous. After performing the self-classification, HUSK-ITT Corporation recommends a WGK of 0, indicating that 15A14 Oils and their grease counterparts pose no water endangerment.

Addendum (July 1, 2006)

As outlined in the attachment above the *HUSKEY* 15A14 Oils have a WGK value of 0 however, the system was changed eliminating this class. The method of evaluating products is the same just the classifications have changed. WGK 1 is now the lowest classification and based on all of the original data the *HUSKEY* 15A14 Oils are now classified as WGK 1.

Submitted by:
James F. Landry
James F. Landry
Technical Coordinator

Lab Reports15A14 Enviro Study

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Mobil

Mobil SHC™ Grease 100 EAL Series

Grease

Product Description

Mobil SHC™ Grease 101 EAL and 102 EAL are superior performance greases designed specifically for applications that require environmentally sensitive lubricants. These high performance greases are biodegradable and virtually non-toxic. They are formulated from a biodegradable synthetic ester base oil, carefully chosen high performance additives and a lithium soap thickener. The wax-free nature of the synthetic base fluid, together with its low traction coefficient, provide excellent low temperature pumpability and very low starting and running torque - a significant benefit considering that many environmentally sensitive applications are outdoors.

The Mobil SHC Grease 100 EAL Series is formulated for applications where grease leakage or run out could contaminate soil, groundwater, surface water systems, or indoor plant water systems. They are recommended for plain and rolling element bearings and couplings that operate at temperatures from -40°C to 120°C, with appropriate adjustments to re-lubrication interval. Mobil SHC Grease 101 EAL and 102 EAL are NLGI grade 1 and 2 respectively.

Features and Potential Benefits

The Mobil™ EAL brand of environmentally sensitive products has gained an exceptional reputation with OEMs and customers for its excellent performance. These greases provide the optimum balance between the need for environmentally friendly lubricants and the requirement for high performance lubricants for mobile and stationary mechanical equipment Mobil SHC Grease 100 EAL Series greases are compatible with the previous generation Mobilgrease EAL 100 Series.

Mobil SHC Grease 101 EAL and 102 EAL offer the following benefits:

Features	Advantages and Potential Benefits
Virtually non-toxic in the OECD 203 Method Aquatic Toxicity Test	Minimal effects of spills on environment
Formulated from biodegradable synthetic ester base oil	Biodegradation of material in sensitive areas with minimal non-biodegradable residue, avoidance of costly clean-up in some jurisdictions
Good adhesion and water resistance	Resists water washout, avoiding need for frequent re-greasing
Excellent rust and corrosion protection	Excellent bearing protection in wet conditions, with long bearing life

Applications

Mobil SHC Grease 101 EAL and 102 EAL are members of the Mobil family of Environmental Awareness Lubricants (EAL) and are specifically designed for applications where contamination of the environment is a risk.

- Marine equipment
- Water treatment plants
- Dams, locks and water ways
- Construction equipment
- Farm machinery
- Hydroelectric generation plants

Specifications and Approvals

Mobil SHC Grease 100 EAL meets or exceeds the requirements of:	101	102
DIN 51825: (2004-06)	KPE1K-40	KPE2K-40

Typical Properties

Mobil SHC 100 Grease EAL Series	101	102
NLGI Grade	1	2
Thickener Type	Lithium	Lithium
Color, Visual	Tan	Tan
ISO Viscosity Grade of Oil	100	100
Dropping Point, ASTM D 2265, ºC	180	180
Worked Penetration, ASTM D 217, mm/10 @ 25°C	325	280
Water Washout @ 79ºC, ASTM D 1264, wt%	8.0	6.5
EMCOR Bearing Corrosion in Distilled Water, ASTM D 6138, Rating	0,0	0,0
Copper Corrosion, ASTM D 4048, Rating	1a	1a
Four Ball Weld, ASTM D 2596, kgf	200	200
Four Ball Load Wear Index, ASTM D 2596, kgf	35	34
US Steel Mobility @ -18°C, g/min	-	50
Low Temperature Torque @ -30°C, Start/Run, ASTM D 1478, gcm	-	800/170
Biodegradability of ester base oil, OECD 301B, wt%	74	74
Aquatic Toxicity, OECD 203, LL50 ppm	>10000	>10000

Health and Safety

Based on available information, this product is not expected to produce adverse effects on health when used for the intended application and the recommendations provided in the Material Safety Data Sheet (MSDS) are followed. MSDS's are available upon request through your sales contract office, or via the Internet. This product should not be used for purposes other than its intended use. If disposing of used product, take care to protect the environment.

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8-2014

Exxon Mobil Corporation
3225 Gallows Road
Fairfax, VA 22037

1-800-ASK MOBIL (275-6624)

Typical Properties are typical of those obtained with normal production tolerance and do not constitute a specification. Variations that do not affect product performance are to be expected during normal manufacture and at different blending locations. The information contained herein is subject to change without notice. All products may not be available locally. For more information, contact your local ExxonMobil contact or visit www.exxonmobil.com
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Material Safety Data Sheet

SECTION 1 PRODUCT AND COMPANY IDENTIFICATION

Chevron Ultra-Duty Grease EP NLGI 0, 1, 2

Product Use: Grease
Product Number(s): 238011, 238012, 238013
Company Identification
Chevron Products Company
a division of Chevron U.S.A. Inc.
6001 Bollinger Canyon Rd.
San Ramon, CA 94583
United States of America
www.chevronlubricants.com

Transportation Emergency Response
CHEMTREC: (800) 424-9300 or (703) 527-3887
Health Emergency
Chevron Emergency Information Center: Located in the USA. International collect calls accepted. (800) 231-0623 or (510) 231-0623
Product Information
email : lubemsds@chevron.com
Product Information: 1 (800) 582-3835, LUBETEK@chevron.com

SECTION 2 COMPOSITION/INFORMATION ON INGREDIENTS

COMPONENTS	CAS NUMBER	AMOUNT
Highly refined mineral oil (C15 - C50)	Mixture	70 - 99 %wt/wt
Zinc dialkyldithiophosphate	68649-42-3	1 - 5 %wt/wt

SECTION 3 HAZARDS IDENTIFICATION

****

EMERGENCY OVERVIEW

- HARMFUL TO AQUATIC ORGANISMS. MAY CAUSE LONG-TERM ADVERSE EFFECTS IN THE AQUATIC ENVIRONMENT

****

IMMEDIATE HEALTH EFFECTS
Eye: Not expected to cause prolonged or significant eye irritation.
Skin: Contact with the skin is not expected to cause prolonged or significant irritation. Contact with the skin is not expected to cause an allergic skin response. Not expected to be harmful to internal organs if absorbed through the skin. High-Pressure Equipment Information: Accidental high-velocity injection under

the skin of materials of this type may result in serious injury. Seek medical attention at once should an accident like this occur. The initial wound at the injection site may not appear to be serious at first; but, if left untreated, could result in disfigurement or amputation of the affected part.

Ingestion: Not expected to be harmful if swallowed.
Inhalation: Not expected to be harmful if inhaled. Contains a petroleum-based mineral oil. May cause respiratory irritation or other pulmonary effects following prolonged or repeated inhalation of oil mist at airborne levels above the recommended mineral oil mist exposure limit. Symptoms of respiratory irritation may include coughing and difficulty breathing.

SECTION 4 FIRST AID MEASURES

Eye: No specific first aid measures are required. As a precaution, remove contact lenses, if worn, and flush eyes with water.
Skin: No specific first aid measures are required. As a precaution, remove clothing and shoes if contaminated. To remove the material from skin, apply a waterless hand cleaner, mineral oil, or petroleum jelly. Then wash with soap and water. Discard contaminated clothing and shoes or thoroughly clean before reuse.
Ingestion: No specific first aid measures are required. Do not induce vomiting. As a precaution, get medical advice.
Inhalation: No specific first aid measures are required. If exposed to excessive levels of material in the air, move the exposed person to fresh air. Get medical attention if coughing or respiratory discomfort occurs.
Note to Physicians: In an accident involving high-pressure equipment, this product may be injected under the skin. Such an accident may result in a small, sometimes bloodless, puncture wound. However, because of its driving force, material injected into a fingertip can be deposited into the palm of the hand. Within 24 hours, there is usually a great deal of swelling, discoloration, and intense throbbing pain. Immediate treatment at a surgical emergency center is recommended.

SECTION 5 FIRE FIGHTING MEASURES

FIRE CLASSIFICATION:
OSHA Classification (29 CFR 1910.1200): Not classified by OSHA as flammable or combustible.

NFPA RATINGS: Health: 0 Flammability: 1 Reactivity: 0

FLAMMABLE PROPERTIES:
Flashpoint: 274 °C (525 °F) Minimum
Autoignition: No data available
Flammability (Explosive) Limits (% by volume in air): Lower: Not Applicable Upper: Not Applicable

EXTINGUISHING MEDIA: Use water fog, foam, dry chemical or carbon dioxide (CO_2) to extinguish flames.

PROTECTION OF FIRE FIGHTERS:
Fire Fighting Instructions: This material will burn although it is not easily ignited. See Section 7 for proper handling and storage. For fires involving this material, do not enter any enclosed or confined fire space without proper protective equipment, including self-contained breathing apparatus.
Combustion Products: Highly dependent on combustion conditions. A complex mixture of airborne solids, liquids, and gases including carbon monoxide, carbon dioxide, and unidentified organic compounds will be evolved when this material undergoes combustion.

SECTION 6 ACCIDENTAL RELEASE MEASURES

Protective Measures: Eliminate all sources of ignition in vicinity of spilled material.
Spill Management: Clean up spills immediately, observing precautions in Exposure Controls/Personal Protection section. Stop the source of the release if you can do it without risk. Contain release to prevent further contamination of soil, surface water or groundwater. Clean up spill as soon as possible, observing precautions in Exposure Controls/Personal Protection. Use appropriate techniques such as applying non-combustible absorbent materials or pumping. Where feasible and appropriate, remove contaminated soil. Place contaminated materials in disposable containers and dispose of in a manner consistent with applicable regulations.
Reporting: Report spills to local authorities and/or the U.S. Coast Guard's National Response Center at (800) 424-8802 as appropriate or required.

SECTION 7 HANDLING AND STORAGE

Precautionary Measures: Keep out of the reach of children.
General Handling Information: Avoid contaminating soil or releasing this material into sewage and drainage systems and bodies of water.
Static Hazard: Electrostatic charge may accumulate and create a hazardous condition when handling this material. To minimize this hazard, bonding and grounding may be necessary but may not, by themselves, be sufficient. Review all operations which have the potential of generating and accumulating an electrostatic charge and/or a flammable atmosphere (including tank and container filling, splash filling, tank cleaning, sampling, gauging, switch loading, filtering, mixing, agitation, and vacuum truck operations) and use appropriate mitigating procedures. For more information, refer to OSHA Standard 29 CFR 1910.106, 'Flammable and Combustible Liquids', National Fire Protection Association (NFPA 77, 'Recommended Practice on Static Electricity', and/or the American Petroleum Institute (API) Recommended Practice 2003, 'Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents'.
Container Warnings: Container is not designed to contain pressure. Do not use pressure to empty container or it may rupture with explosive force. Empty containers retain product residue (solid, liquid, and/or vapor) and can be dangerous. Do not pressurize, cut, weld, braze, solder, drill, grind, or expose such containers to heat, flame, sparks, static electricity, or other sources of ignition. They may explode and cause injury or death. Empty containers should be completely drained, properly closed, and promptly returned to a drum reconditioner or disposed of properly.

SECTION 8 EXPOSURE CONTROLS/PERSONAL PROTECTION

GENERAL CONSIDERATIONS:
Consider the potential hazards of this material (see Section 3), applicable exposure limits, job activities, and other substances in the work place when designing engineering controls and selecting personal protective equipment. If engineering controls or work practices are not adequate to prevent exposure to harmful levels of this material, the personal protective equipment listed below is recommended. The user should read and understand all instructions and limitations supplied with the equipment since protection is usually provided for a limited time or under certain circumstances.

ENGINEERING CONTROLS:
Use in a well-ventilated area.

PERSONAL PROTECTIVE EQUIPMENT
Eye/Face Protection: No special eye protection is normally required. Where splashing is possible, wear safety glasses with side shields as a good safety practice.
Skin Protection: No special protective clothing is normally required. Where splashing is possible, select protective clothing depending on operations conducted, physical requirements and other substances in the workplace. Suggested materials for protective gloves include: Neoprene, Nitrile Rubber, Silver Shield,

Viton.
Respiratory Protection: No respiratory protection is normally required.
If user operations generate an oil mist, determine if airborne concentrations are below the occupational exposure limit for mineral oil mist. If not, wear an approved respirator that provides adequate protection from the measured concentrations of this material. For air-purifying respirators use a particulate cartridge. Use a positive pressure air-supplying respirator in circumstances where air-purifying respirators may not provide adequate protection.

Occupational Exposure Limits:

Component	Agency	TWA	STEL	Ceiling	Notation
Highly refined mineral oil (C15 - C50)	ACGIH	5 mg/m3	10 mg/m3	--	--
Highly refined mineral oil (C15 - C50)	OSHA Z-1	5 mg/m3	--	--	--

Consult local authorities for appropriate values.

SECTION 9 PHYSICAL AND CHEMICAL PROPERTIES

Attention: the data below are typical values and do not constitute a specification.

Color: Red
Physical State: Semi-solid
Odor: Petroleum odor
pH: Not Applicable
Vapor Pressure: <0.01 mmHg Maximum @ 100 °C (212 °F)
Vapor Density (Air = 1): >1 Minimum
Boiling Point: 260°C (500°F) Minimum
Solubility: Soluble in hydrocarbons; insoluble in water
Freezing Point: No data available
Melting Point: 165°C (329°F) (Min)
Specific Gravity: 1.1 @ 15.6°C (15.6°F) / 15.6°C (60.1°F) (Estimated)
Density: No data available
Viscosity: No data available
Evaporation Rate: No data available

SECTION 10 STABILITY AND REACTIVITY

Chemical Stability: This material is considered stable under normal ambient and anticipated storage and handling conditions of temperature and pressure.
Incompatibility With Other Materials: May react with strong acids or strong oxidizing agents, such as chlorates, nitrates, peroxides, etc.
Hazardous Decomposition Products: None known (None expected)
Hazardous Polymerization: Hazardous polymerization will not occur.

SECTION 11 TOXICOLOGICAL INFORMATION

IMMEDIATE HEALTH EFFECTS
Eye Irritation: The eye irritation hazard is based on evaluation of data for similar materials or product components.
Skin Irritation: The skin irritation hazard is based on evaluation of data for similar materials or product components.
Skin Sensitization: The skin sensitization hazard is based on evaluation of data for similar materials or

product components.
Acute Dermal Toxicity: The acute dermal toxicity hazard is based on evaluation of data for similar materials or product components.

Acute Oral Toxicity: The acute oral toxicity hazard is based on evaluation of data for similar materials or product components.

Acute Inhalation Toxicity: The acute inhalation toxicity hazard is based on evaluation of data for similar materials or product components.

ADDITIONAL TOXICOLOGY INFORMATION:
This product contains petroleum base oils which may be refined by various processes including severe solvent extraction, severe hydrocracking, or severe hydrotreating. None of the oils requires a cancer warning under the OSHA Hazard Communication Standard (29 CFR 1910.1200). These oils have not been listed in the National Toxicology Program (NTP) Annual Report nor have they been classified by the International Agency for Research on Cancer (IARC) as; carcinogenic to humans (Group 1), probably carcinogenic to humans (Group 2A), or possibly carcinogenic to humans (Group 2B). These oils have not been classified by the American Conference of Governmental Industrial Hygienists (ACGIH) as: confirmed human carcinogen (A1), suspected human carcinogen (A2), or confirmed animal carcinogen with unknown relevance to humans (A3).

SECTION 12 ECOLOGICAL INFORMATION

ECOTOXICITY
This material is expected to be harmful to aquatic organisms and may cause long-term adverse effects in the aquatic environment. The ecotoxicity hazard is based on an evaluation of data for the components or a similar material.

ENVIRONMENTAL FATE
Ready Biodegradability: This material is not expected to be readily biodegradable. The biodegradability of this material is based on an evaluation of data for the components or a similar material.

SECTION 13 DISPOSAL CONSIDERATIONS

Use material for its intended purpose or recycle if possible. Oil collection services are available for used oil recycling or disposal. Place contaminated materials in containers and dispose of in a manner consistent with applicable regulations. Contact your sales representative or local environmental or health authorities for approved disposal or recycling methods.

SECTION 14 TRANSPORT INFORMATION

The description shown may not apply to all shipping situations. Consult 49CFR, or appropriate Dangerous Goods Regulations, for additional description requirements (e.g., technical name) and mode-specific or quantity-specific shipping requirements.

DOT Shipping Description: PETROLEUM LUBRICATING GREASE; NOT REGULATED AS A HAZARDOUS MATERIAL FOR TRANSPORTATION UNDER 49 CFR

IMO/IMDG Shipping Description: PETROLEUM LUBRICATING GREASE; NOT REGULATED AS

DANGEROUS GOODS FOR TRANSPORT UNDER THE IMDG CODE

ICAO/IATA Shipping Description: PETROLEUM LUBRICATING GREASE; NOT REGULATED AS DANGEROUS GOODS FOR TRANSPORT UNDER ICAO

SECTION 15 REGULATORY INFORMATION

EPCRA 311/312 CATEGORIES:

1.	Immediate (Acute) Health Effects:	NO
2.	Delayed (Chronic) Health Effects:	NO
3.	Fire Hazard:	NO
4.	Sudden Release of Pressure Hazard:	NO
5.	Reactivity Hazard:	NO

REGULATORY LISTS SEARCHED:

01-1=IARC Group 1	03=EPCRA 313
01-2A=IARC Group 2A	04=CA Proposition 65
01-2B=IARC Group 2B	05=MA RTK
02=NTP Carcinogen	06=NJ RTK
	07=PA RTK

The following components of this material are found on the regulatory lists indicated.

Zinc dialkyldithiophosphate	03, 06

CHEMICAL INVENTORIES:
All components comply with the following chemical inventory requirements: AICS (Australia), DSL (Canada), IECSC (China), KECI (Korea), PICCS (Philippines), TSCA (United States).

One or more components does not comply with the following chemical inventory requirements: ENCS (Japan).

NEW JERSEY RTK CLASSIFICATION:
Under the New Jersey Right-to-Know Act L. 1983 Chapter 315 N.J.S.A. 34:5A-1 et. seq., the product is to be identified as follows: PETROLEUM OIL (Grease)

SECTION 16 OTHER INFORMATION

NFPA RATINGS: Health: 0 Flammability: 1 Reactivity: 0

HMIS RATINGS: Health: 1 Flammability: 1 Reactivity: 0
(0-Least, 1-Slight, 2-Moderate, 3-High, 4-Extreme, PPE:- Personal Protection Equipment Index recommendation, *- Chronic Effect Indicator). These values are obtained using the guidelines or published evaluations prepared by the National Fire Protection Association (NFPA) or the National Paint and Coating Association (for HMIS ratings).

LABEL RECOMMENDATION:
Label Category : GREASE 1 - GRS1

REVISION STATEMENT: This revision updates the following sections of this Safety Data Sheet: 1, 15
Revision Date: June 26, 2014

ABBREVIATIONS THAT MAY HAVE BEEN USED IN THIS DOCUMENT:

TLV - Threshold Limit Value	TWA - Time Weighted Average
STEL - Short-term Exposure Limit	PEL - Permissible Exposure Limit
	CAS - Chemical Abstract Service Number
ACGIH - American Conference of Governmental Industrial Hygienists	IMO/IMDG - International Maritime Dangerous Goods Code
API - American Petroleum Institute	MSDS - Material Safety Data Sheet
CVX - Chevron	NFPA - National Fire Protection Association (USA)
DOT - Department of Transportation (USA)	NTP - National Toxicology Program (USA)
IARC - International Agency for Research on Cancer	OSHA - Occupational Safety and Health Administration
NCEL - New Chemical Exposure Limit	EPA - Environmental Protection Agency
SCBA - Self-Contained Breathing Apparatus	

Prepared according to the 29 CFR 1910.1200 (2012) by Chevron Energy Technology Company, 6001 Bollinger Canyon Road San Ramon, CA 94583.

The above information is based on the data of which we are aware and is believed to be correct as of the date hereof. Since this information may be applied under conditions beyond our control and with which we may be unfamiliar and since data made available subsequent to the date hereof may suggest modifications of the information, we do not assume any responsibility for the results of its use. This information is furnished upon condition that the person receiving it shall make his own determination of the suitability of the material for his particular purpose.

CHEVRON ULTRA-DUTY GREASE EP

NLGI 0, 1, 2

PRODUCT DESCRIPTION

Chevron Ultra-Duty Greases EP are versatile, high pressure greases with good adhesive properties designed for a wide variety of automotive and industrial applications.

CUSTOMER BENEFITS

Chevron Ultra-Duty Greases EP deliver value through:

- **Shock load protection**
- **Load-carrying protection**
- **Corrosion and rust protection**
- **Water resistant**
- **Maximum service lubrication**

FEATURES

Chevron Ultra-Duty Greases EP are versatile, high pressure greases with good adhesive properties designed for a wide variety of automotive and industrial applications.

They are manufactured using selected highly refined, high viscosity base oils, a lithium-12 hydroxystearate thickener, rust and oxidation inhibitors, and extreme pressure and tackiness additives. They are red in color and stringy in texture.

Chevron Ultra-Duty Greases EP provide thicker shock-absorbing oil film protection and greater water resistance than conventional multipurpose greases due to their high viscosity components.

The high viscosity components and tackiness additive give Chevron Ultra-Duty Greases EP an excellent adhesive quality which provides a tenacious lubricating film in working parts. The lubricants stay in place under abrasive operating conditions to resist water washout and shock load wear.

The tackiness characteristics of Chevron Ultra-Duty Greases EP make these products somewhat harder to pump than the historical soft, buttery greases. For this reason, we recommend the use of a heavy follower plate with air-driven grease pumps.

Chevron Ultra-Duty Greases EP lubricate well at low temperatures. The ASTM D1478 low temperature torque test shows that they retain their lubricating capacity, as defined by military specification MIL-G-81322, down to about -26°C (-15°F).

APPLICATIONS

Chevron Ultra-Duty Greases EP are recommended for use in automotive and industrial equipment operating under most conditions except where very high operating temperatures are encountered. Typical applications are: mining equipment, construction equipment, material handling equipment, marine deck equipment, marine deck cranes, oil field equipment, offshore drilling equipment, paper machines, dredging equipment, logging equipment, rock quarry equipment, etc., operating in water, mud, or dusty conditions.

Chevron Ultra-Duty Greases EP will help provide the needed shock load and rust protection and, best of all, they stay put which means less frequent regreasing. They are not Chevron's primary recommendation for high temperature wheel bearings. Delo® Greases EP or Black Pearl® Greases EP are preferred for wheel bearing applications.

In industrial service, Chevron Ultra-Duty Greases EP are recommended for use in most types of plain and antifriction bearings from 1-1/2 inch OD to over 16 inch OD, operating at speeds from 50 to 3000 rpm, as well as slides, gears, ways, etc.

Product(s) manufactured in the USA.
Always confirm that the product selected is consistent with the original equipment manufacturer's recommendation for the equipment operating conditions and customer's maintenance practices.

A **Chevron** company product

3 June 2013
GR-150

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12-59

Chevron Ultra-Duty Grease EP — Continued

TYPICAL TEST DATA

NLGI Grade	0	1	2
Product Number	*238013*	*238012*	*238011*
MSDS Number	*6790*	*6790*	*6790*
Operating Temperature, °C(°F) Minimum[a] Maximum[b]	 -26(-15) 132(270)	 -26(-15) 138(280)	 -26(-15) 143(290)
Penetration, at 25°C(77°F) Worked (60 Strokes)	 370	 325	 280
Dropping Point, °C(°F)	172(342)	172(342)	190(374)
Four Ball Weld Point, kg	315	315	315
Four Ball Wear Scar, mm	0.45	0.45	0.45
Timken OK Load, lb	55	70	70
Water Washout, wt %	15	10	7
Water Spray-off, wt %	n/a	40	25
Lincoln Ventmeter, psig at 30 s, at 75°F 30°F 0°F	 100 200 1700	 100 400 1750	 280 600 2500
Thickener, % Type	5.6 Lithium	7.2 Lithium	8.6 Lithium
ISO Viscosity Grade, Base Oil Equivalent	 460	 460	 460
Viscosity, Kinematic* cSt at 40°C cSt at 100°C	 400 24.3	 400 24.3	 400 24.3
Viscosity, Saybolt* SUS at 100°F SUS at 210°F	 2160 121	 2160 121	 2160 121
Viscosity Index*	76	76	76
Flash Point, °C(°F)*	274(525)	274(525)	274(525)
Oil Separation, mass %	5	4	2
Texture	Stringy	Stringy	Stringy
Color	Red	Red	Red

a Minimum operating temperature is the lowest temperature at which a grease, already in place, could be expected to provide lubrication. Most greases cannot be pumped at these minimum temperatures.
b Maximum operating temperature is the highest temperature at which the grease could be used with frequent (daily) relubrication.
* Determined on mineral oil extracted by vacuum filtration.

Minor variations in product typical test data are to be expected in normal manufacturing.

Always confirm that the product selected is consistent with the original equipment manufacturer's recommendation for the equipment operating conditions and customer's maintenance practices.

CHEVRON FM ALC EP
0, 1, 2
Food Machinery Grease

PRODUCT DESCRIPTION

Chevron FM ALC EP food machinery greases are high performance greases that are white in color and water-resistant.

CUSTOMER BENEFITS

Chevron FM ALC EP greases deliver value through:

- **Excellent wear and rust protection**
- **Controlled operating costs** — Minimizes costly inventories while providing one grease that will work in a wide variety of applications. Available in three common NLGI grades to meet specific equipment requirements.
- **Minimal wear and sling out** — Provides good wear protection and is highly water-resistant to help prolong machinery life.
- **Good water tolerance** — Remains grease-like even when subject to gross water contamination or when subjected to direct water spray.
- **Excellent pumpability** — Readily adaptable to centralized greasing systems. Easily handled in conventional grease-pumping equipment.
- **High dropping point** — Helps ensure protection where higher operating temperature properties are required.
- **Slightly tacky and adhesive in nature**
- **Quality control** — Manufactured under closely controlled conditions to help ensure a high degree of purity food manufacturers demand today.
- **Compliance with state and federal regulations** — Composed of materials approved by FDA as incidental or accidental food additives.
- **Corrosion protection** — Provides excellent corrosion protection during food processing and plant cleanup procedures
- **EP properties** — Excellent Timken and Four Ball Weld Point values.

FEATURES

Chevron FM ALC EP food machinery greases are high performance greases that are white in color and water-resistant.

Available in three NLGI grades, Chevron FM ALC EP were developed for the food processing and canning industries.

Chevron FM ALC EP greases are comprised of an aluminum complex thickener and food grade white oils containing a highly effective rust inhibitor package. They are smooth and buttery in texture, and are also slightly tacky.

All grades contain specially-blended additives that impart improved adhesive and stringiness properties to the grease.

APPLICATIONS

Chevron FM ALC EP food machinery greases are multi-purpose lubricants suitable for many grease-lubricated machinery located in canneries, beverage bottlers and canners, potato/corn chip processors, candy manufacturers, meat and poultry packers, frozen food processors, and other food producers and processors. They are specifically recommended for critical applications where there is a possibility of the lubricant becoming an incidental food ingredient.

NLGI 0 is preferred for low temperature operations, particularly in centralized grease systems.

NLGI 1 and **2** are preferred for general plant lubrication including applications such as electric motors and wheeled vehicles where NSF-registered H2 lubricants are often used. This allows for a reduction in the number of greases used in the plant.

Product(s) manufactured in the USA.
Always confirm that the product selected is consistent with the original equipment manufacturer's recommendation for the equipment operating conditions and customer's maintenance practices.

A **Chevron** company product

1 March 2010
FPL-8

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12-11

Chevron FM ALC EP — Continued

NLGI 2 is also recommended for those applications where the grease is exposed to high temperatures, steam, and centrifugal action causing throw-off.

Typical applications for Chevron FM ALC EP greases in processing plants include:

- Electric motor bearings
- Pump shaft bearings
- Conveyor belts
  - Head, tail, and roller bearings
- Food handling machinery - Mechanical linkage
- Automatic lube systems
- Grease gun application
- Grease packed bearings
- Slides and ways
- Mobile equipment
- Wheel bearings
- Grease fittings
- Seamers

Chevron FM ALC EP:

- are formulated in compliance with the **U.S. Food and Drug Administration (FDA)** requirements for lubricants with incidental food contact, 21 CFR 178.3570 and other sections referenced therein. Lubricants with incidental food contact should not contaminate food at levels greater than 10 ppm.
- are registered by **NSF** and are acceptable as a lubricant where incidental food contact may occur (H1) in and around food processing areas. The NSF Nonfood Compounds Registration Program is a continuation of the USDA product approval and listing program, which is based on meeting regulatory requirements of appropriate use, ingredient review and labeling verification.
- are certified **Kosher and Pareve**.
- are accepted by the **Canadian Food Inspection Agency** for use in Registered Plants and for use on food equipment or machinery parts where contact with food is only incidental.

Always confirm that the product selected is consistent with the original equipment manufacturer's recommendation for the equipment operating conditions and customer's maintenance practices.

TYPICAL TEST DATA

NLGI Grade	0	1	2
Product Number	*230202*	*230203*	*230204*
MSDS Number	*14860*	*14860*	*14860*
Operating Temperature, °C(°F) Minimum[1] Maximum[2]	 -20(-4) 163(325)	 -20(-4) 163(325)	 -20(-4) 163(325)
Penetration at 25°C(77°F) Unworked Worked	 340 370	 295 325	 250 280
Dropping Point, °C(°F)	232(450)	260(500)	260(500)
Timken OK load, lb	40	40	40
Four-Ball Weld Point, kg Wear Scar Diameter, mm	 500 0.60	 500 0.60	 500 0.60
Thickener, % type	5.8 Aluminum Complex	6.9 Aluminum Complex	7.7 Aluminum Complex
ISO Viscosity Grade, Base Oil Equivalent	220	220	220
Viscosity, Kinematic* cSt at 40°C cSt at 100°C	 200 20.6	 200 20.6	 200 20.6
Viscosity, Saybolt* SUS at 100°F SUS at 210°F	 1045 104	 1045 104	 1045 104
Viscosity Index*	120	120	120
Flash Point, °C(°F)*	246(475)	246(475)	246(475)
Pour Point, °C(°F)*	-25(-13)	-25(-13)	-25(-13)
Texture	Smooth, Adhesive		
Color	White		

Minor variations in product typical test data are to be expected in normal manufacturing.

[1] Minimum operating temperature is the lowest temperature at which a grease, already in place, could be expected to provide lubrication. Most greases cannot be pumped at these minimum temperatures.

[2] Maximum operating temperature is the highest temperature at which the grease could be used with frequent (daily) relubrication.

* Determined on mineral oil extracted by vacuum filtration.

Always confirm that the product selected is consistent with the original equipment manufacturer's recommendation for the equipment operating conditions and customer's maintenance practices.

1 March 2010
FPL-8

Appendix C. Candidate EAL Grease Tracking Matrix

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USACE Hydroelectric Design Center
Environmentally Acceptable Grease Analysis
Candidate Grease Tracking Matrix

W912EF-09-D-0056, DT04, EAL Grease Analysis
Updated 7/24/2015

				Primary EAL Criteria							
Candidate Grease Name	**VGP Compliant?**	**EPA Recognized Label***	**History of Wicket Gate Use?**	**Biodegradability Test Method**	**Biodeg. Test Doc. Code**	**Toxicity Test Method**	**Tox. Test Doc. Code**	**Bioaccumulation Potential Test Method**	**Bioacc. Test Doc. Code**	**Source of Info**	**Notes**
Greases Procured for Laboratory Testing											
Panolin BioGrease EP 2	Yes	BA, EEL & SS		ASTM D5864, OECD 301 and 306 > 60%	1	OECD 201, 202, 203 >100 mg/l	1	OECD 107 and 117 = pass	3	Data provided by Manufacturer	Documented to meet EPA and VGP standards for EAL
Mobil SHC Aware EP2	Yes			OECD 301B >60%	1	OECD 201, 72h EC50>1000 mg/L	1	OECD 117, log KOW <3	1	Product Data Sheet - Manuf Web Site	Claims to meet EPA and VGP standards for EAL
KAJO Longlife LZR 2	Yes	EEL		Not reported	5	Not reported	5	Not reported	5	Product Data Sheet - Manuf Web Site	This product has achieved the EEL label which meets the EPA requirements for an EAL.
Castrol BioTac OG	Yes	OSPAR		Not reported	5	Not reported	5	Not reported	5	Product Data Sheet - Manuf Web Site	Manufacturer has provided a statement that this product meets the requirements of the VGP since it has been approved by OSPAR.
Greases Under Consideration											
Fuchs Plantogel 2 S (EAL)	Yes	EEL	Yes	Not reported	5	Not reported	5	Not reported	5	Product Data Sheet - Manuf Web Site	This product has achieved the EEL label which meets the EPA requirements for an EAL.
RSC Envirologic 802	Yes			ASTM D 7373	2	OECD 201, 202, 203 >1000 mg/l	2	Test method not reported	4	Safety Data Sheet	Incomplete environmental data. Manufacturer states that this product is compliant with VGP. Similar product available for wire ropes.
Renewable Lubricants Bio-Food Grade Grease EP2	Yes			ASTM D5864 Pw1>60%	2	LC50/EC50 >1000 ppm	2	Not reported	4	Product Data Sheet - Manuf Web Site	Manufacturer provides signed statement they are compliant with VGP. Product is also applicable to wire ropes.
Vickers Biogrease EP2	Yes			OECD 301B >60%	2	OECD 201, 202 & 203 > 1000 mg/L	2	Not reported, grease is biodegradable per the VGP, so bioaccumulation testing is not needed	4	Product Data Sheet - Manuf Web Site	Manufacturer provides signed statement they are compliant with VGP. Product is also applicable to wire ropes.
Greases No Longer Under Consideration											
Husk-ITT LubeOseal	No			None performed	5 (No data available)	Modified OECD 209 (self-certified)	5 (EAL non-compliant)	Not reported	5 (Not evaluated)	2009 era catalog cut	Not conforming to EPA EAL criteria for biodegr., aq. tox. and bioaccumulation
Husk-ITT LVI-50	No			None performed	5 (No data available)	Test method(s) unknown	5 (EAL non-compliant)	Not reported	5 (Not evaluated)	Product Data Sheet	Not conforming to EPA EAL criteria for biodegr., aq. tox. and bioaccumulation
Husk-ITT Huskey Hydrolube	No		Yes	None performed	5 (No data available)	Test method(s) unknown	5 (EAL non-compliant)	Not reported	5 (Not valuated)	Product Data Sheet	Not meeting to EPA EAL criteria for biodegr., aq. tox. and bioaccumulation
Lanopro EP 53	Yes			Not reported	5	Not reported	5	Not reported	5	Product Data Sheet - Manuf Web Site	This product is VGP compliant by association - previous labeling by the Swedish Standard SS 155470, Section 4.2. Manufacturer provides signed statement they are
Mobil SHC 101 EAL			Yes	OECD 301B	2	OECD 203 (missing OECD 201 & 202)	2	Not reported	5 (Not evaluated)	Product Data Sheet - Manuf Web Site	Not meeting EPA EAL criteria due to incomplete aq. tox. and bioaccumulation
Molydal GREEN LIFE	Yes	EEL		OECD 301B >80%	2	Not reported	5	Not reported	5	Product Data Sheet - Manuf Web Site	This product has achieved the EEL label which meets the EPA requirements for an EAL. No US distributor exists, and product information is only available in French.
Shell Naturelle S5	Yes	EEL	Yes	CEC-L-33-A-93	4		4		4	Manufacturer Web Site	Apparently discontinued and unavailable according to distributor Don Thomas Petroleum
VSG Grade 1			Yes	CEC-L-33-T-82	5 (Outdated test method)	Non-toxic to trout & Daphnia	5 (Outdated test method)	Not reported	5 (Not evaluated)	Product Data Sheet - Manuf Web Site	Not conforming to EPA EAL criteria for biodegr., aq. tox. and bioaccumulation
Wire Rope Greases											
ROCOL Biogen Wireshield	Yes	EEL	NA	OECD 306	3	OECD 211 & 215	3	OECD 117	3	Manufacturer statement of VGP compliance	
Castrol BioTac MP	Yes	OSPAR	NA	OECD 306 = 20% to 60% at 28 days	2	ISO 14669:1999 LC50>1000, EPA 821-R-02-14 Method 1007 NOEC<7000	2	Molecular wt. of components >70% are non-bioaccumulative	4	Product Data Sheet - Manuf Web Site	Needs OSPAR conformation sheet from manufacturer. This product can also be used on wire ropes.
Dynaguard E (wire rope grease)			NA	OECD 301B	4	EPA 600/44-90/027	4	Not reported	5 (Not evaluated)	ERDC	
Renewable Lubricants Bio-E.P.	Yes		NA		4		4		4	Product Data Sheet - Manuf Web Site	Manufacturer has stated VGP compliance, but supporting data not available.
Vickers Biogrease EP2	Yes	See above									

*BA (Blue Angel), EEL (European EcoLabel), SS (Swedish Standard)

Testing Documentation Codes
1) Statement of meeting EPA EAL requirements by manufacturer, and/or have provided test results in numerical form, and/or detailed results from a certified testing laboratory
2) Manufacturer cut sheet or website provides references to testing methods and achieved values
3) Manufacturer cut sheet or website provides information on testing completed and results at a Pass/Fail level
4) Manufacturer claims to be an EAL but does not provide specific information
5) Other

HDR Engineering Inc.

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Appendix D. Candidate EAL Grease Manufacturer Information

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SWISS TS
ISO 9001
ISO 14001

PANOLIN
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PANOLIN®
Swiss Oil Technology

Part of the PANOLIN concept
GREENMACHINE®

PANOLIN BIOGREASE EP 2

Bio lubricating EP grease – fully synthetic, readily biodegradable

PANOLIN BIOGREASE EP 2:

- Synthetic multipurpose grease based on lithium soap
- Rapidly biodegradable
- Good mechanical stability
- High oxidation stability
- Good anti-wear and anti-corrosion behavior
- Good water resistance
- Wide temperature range
- Excellent load-bearing capacity thanks to EP additives

Applications (follow manufacturer's instructions)

- Where grease pollution of the environment is possible, e.g. earth moving equipment and vehicles (excl. wheel bearings)
- For water turbine guide-vane pivot bearings
- Bottom bearings of screw pumps used in sewage plants

Performance grade

VKA – Gutlast (OK-load) to DIN 51'350 part 2: > 2'800 N

Norm designation (DIN 51'502)

KPE 2 K–30

Environmental compatibility (average values – biological data subject to natural fluctuations)

PANOLIN BIOGREASE EP 2 is decomposed by microorganisms in water and/or soil almost without any residues.

- Biodegradability acc. to OECD 301 B: > 60 %

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Technical data (mean values, subject to normal tolerances)

PANOLIN BIOGREASE EP	Product No.	Base oil/Viscosity	NLGI-class	Worked penetration in $/_{10}$ mm	Dropping point in °C	Temperature-range in °C	Colour
2	72868	Synthetic oil/100 mm²/s	2	265 – 295	185	–35/120	buff coloured

Safety-relevant notes:
Please refer to the drum label, or for detailed information, to the safety data sheet (available from PANOLIN)

PANOLIN America Inc.
4882 McGrath Street/Suite 220
Ventura, CA 93003-7721
Phone 805-676-1193
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info@panolinamerica.com

Part of the PANOLIN concept

PANOLIN BIOGREASE EP 2

Compliance of EPA Vessel General Permit 2013

PANOLIN BIOGREASE EP 2				
Characteristics of test	Units	Specification	**Result**	Method
Biodegradability [a]	% ThOD	>60	**>60**	ASTM 5864, OECD 301, 306
Toxicity [b]				
Algae	LC_{50}	>100 mg/l	**>100**	OECD 201
Daphnia	EC_{50}	>100 mg/l	**>100**	OECD 202
Fish	LC_{50}	>100 mg/l	**>100**	OECD 203
Bioaccumulation [c]	Log K_{ow}	<3 or >7	**pass**	OECD 107, 117
Visible sheen	Gloss, visual color etc.	– [d]	**no visual color**	58 FR 12507

a VGP accepts result based on formulation and main constituents – see Appendix A, VGP 2013 final version

b VGP accepts testing of formulation – see Appendix A, VGP 2013 final version

c OECD test method valid for single substances testing only; data reported should be seen as a summary of all single > 1 % components in stated formulation

d Report

Assessment in accordance to requirements of Vessel General Permit 2013

United States Environmental Protection Agency

EPA test requirements state, all vessels must use an EAL in all oil to sea interfaces. "Environmentally Acceptable Lubricants" means lubricants that are "biodegradable" and "minimally-toxic" and are "not bioaccumulative" as defined in Appendix A of the Vessel General Permit. PANOLIN has conducted the EPA test requirements for all standards described in the 2013 Vessel General Permit (review above chart for test results)

ABS TYPE APPROVED PRODUCT

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All given information are to the best of our knowledge. Changes without prior notice

ExxonMobil
Marine Fuels & Lubricants

Mobil SHC Aware™ Grease EP 2

Optimal-performance environmentally acceptable* multi-purpose grease

Protect your equipment and the environment.

Our synthetic environmentally acceptable grease is specially formulated to provide maximum protection for shipboard equipment affected by the United States Environmental Protection Agency's (EPA) 2013 Vessel General Permit (VGP).

Mobil SHC Aware Grease EP 2 meets VGP requirements for environmentally acceptable lubricants and is engineered to deliver benefits that customers and original equipment manufacturers (OEM) around the globe expect from Mobil SHC™ synthetic products.

VGP Requirements	Mobil SHC Aware Grease EP 2
Biodegradable	✓
Minimally toxic	✓
Non-Bioaccumulative	✓

Mobil SHC Aware Grease EP 2 provides outstanding performance in applications that include:

- Rudder stock
- Towing notch interface
- General deck grease applications

The potential benefits of using our innovative grease will help today's vessel operators:

- Extend equipment life
- Reduce the need for frequent re-greasing
- Minimise unscheduled downtime and costs
- Keep equipment running reliably and efficiently
- Lower potential remediation and clean-up costs caused by accidental spills or leakage

Reduces potential for environmental impact whilst delivering outstanding protection.

Mobil SHC Aware Grease EP 2 provides an exceptional balance between reducing the potential for environmental impact over conventional products whilst standing up to very demanding performance standards. Mobil SHC Aware Grease EP 2 is formulated using biodegradable synthetic ester base oil and lithium/calcium soap thickener. It performs reliably in temperatures as low as -25°C (-13°F) and as high as 125°C (257°F). The product resists water washout due to rain or salt water, combats rust and corrosion and delivers outstanding protection for bearings working in wet conditions.

* Environmentally acceptable lubricants are defined in the VGP as lubricants that are biodegradable, minimally toxic and non-bioaccumulative.

Download the Mobil SHC Aware Grease EP 2 fact sheet >>

Tech Details

Mobil SHC Aware Grease EP 2	
NLGI Grade	2
Thickener Type	Calcium/Lithium
Color, Visual	Amber
ISO Viscosity Grade of Oil	150
Dropping Point, ASTM D 2265, ºC	>160
Worked Penetration, ASTM D 217, mm/10 @25 °C	280
Water Washout @ 79 ºC, ASTM D 1264, wt%	7
EMCOR Bearing Corrosion in Distilled Water, ASTM D 6138, Rating	0,0
Copper Corrosion, ASTM D 4048, Rating	1b
Four Ball Weld, ASTM D 2596, kgf	400
Four Ball Load Wear Index, ASTM D 2596, kgf	65
Biodegradability of ester base oil, OECD 301B, wt%	>60
Aquatic Toxicity, OECD 201, 72h EC^{50}	>1000
Bioaccumulation, OECD 117, Partition Coefficient, log KOW	<3

Product information

No. 66260000

BIO-Longlife Grease LZR 2

EU Ecolabel Nr. DE/027/039

KAJO-BIO-Longlife grease LZR 2 is a special grease,saponiefied with lithium. Due to the use of efficient and tested additives in synthetic esters it is biodegradable and is awarded with the Ecolabel of the European Community, register-no. DE/027/039.

Practical advantages:
KAJO-Longlife Grease LZR 2 is very suitable for all lubrication areas at mobile and stationary aggregates. As it is easily biodegradable, the product can be used in all sensitive environments. Due to the strong adhesiveness of the basic oils on metal surfaces as well as due to the selected additives, this grease shows an extensive corrosion protection and an excellent water resistance.

KAJO-Longlife Grease LZR 2 can be used universally as long-life lubricating grease. It is especially recommended for lubrication areas, where there may be a discharge into environment, e.g. with nipple lubrication as well as open lubricating areas, where the the used grease or lubricant may discharge.It is always recommended. in forestry machines, construction industry, at lock gates, bridges and the like, where it can be expected, that leaking lubricant can get into water.

Version 3 revised: Pos/T

- All ratings are average values and are subject to production-related variations. -

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email: Schmierstoffe@KAJO.de • Internet: www.KAJO.de**

Product information

No. 66260000

BIO-Longlife Grease LZR 2

Typical ratings:

Characteristics	Value	Unit	DIN / ISO
NLGI class	2		DIN 51 818
Worked penentration (Pw60)	265-285	0,1 mm	ASTM D 217
Dropping point	204	°C	ASTM D 556
Base oil viscosity at 40 °C (synthetic ester)	345	mm²	DIN EN ISO 3104
Water resistance	1-90		DIN 51 807-1
EMCOR dest. water	0-0		DIN 51 802
EMCOR sea water	0 -0		DIN 51 802
Water wash out	0,2	%	ASTM D 1264
Water spray off	18	%	ASTM D 4049
Copper corrosion	1b	corrosion grade	DIM 51 811
VKA O.K.-load	3000	N	DIN 51 350-4
VKA welding load	3200	N	DIN 51 350-4
VKA 150N/1h	0,53	mm	DIN 51 350-5
Operating temperature reange	-30 to +120	°C	DIN 51 825
Viscosity index	185	°C	DIN ISO 2909
Flow pressure Kestemich -30 °C	1200	mbar	DIN 51805
Designation	KPE 2 G-30		DIN 51 502

Version 3 revised: Pos/T.

- All ratings are average values and are subject to production-related variations. -

D-59609 Anröchte • Boschstr. 13 • Telephone: ++49 (0)2947 / 881-0 • FAX: ++49 (0)2947 / 881-50 • email: Schmierstoffe@KAJO.de • Internet: www.KAJO.de

Product information

Nr. 61320000

Longlife Grease LZR 2

KAJO-Longlife Grease LZR 2 is a new grease for roller and friction bearings, which is made from high quality basic oils by using lithium soaps as thickening agents. It shows an extraordinary oxidation resistance.

KAJO-Longlife Grease LZR 2 is water resistant, adhesive, can be loaded with pressure and is protective against corrosion. These characteristics, combined with high work resistance, very good abrasion rating and particularly strong adhesiveness, make this lubricant particularly appropriate for lubrication under difficult operating conditions at highly loaded roller and friction bearings even at low temperatures.

Practical advantages:

KAJO-Longlife Grease LZR 2 can be used universally as long-term grease. It is recommended for lubrication of vehicles, industrial machinery and for all machines and devices in the field of construction, stone and earth.

Ratings:

characteristics	value	unit	DIN / ISO
colour	blue		
nature	smooth, transparent, long-fibrous		
NLGI class	2		DIN 51 818
Working penetration	265 - 295	0,1 mm	ASTM D 217
Working resistance Decrease in penetration after - 10.000 double lifts: - 100.000 double lifts:	 below 15 below 25	 1/10 mm 1/10 mm	ASTM D 217
Dropping point	> 180	°C	ASTM D 556
Behaviour towards water 3 h / +90 °C	1	Evaluation stage	DIN 51 807-1
Copper corrosion 3h/+120°C	1	Evaluation stage	DIN 51 811
Corrosion protection Emcor-Test	0 - 0	Corrosion degree	DIN 51 802
VKA Welding load O.K. load	 2400 2200	 N N	DIN 51 350-4
Flow pressure -30 °C	1050	mbar	DIN 51 805
Working temperature short term	-30 bis +120 bis +140	°C	DIN 51825
Flow pressure	< 100 (22° C)	Mbar	DIN 51 805
Designation	KP 2 k-30		DIN 51 502

All ratings are average values and are subject to production-related variations.

Version 3 date of revison: 28.01.2015 4/3/2 SEK

D-59609 Anröchte • Boschstr. 13 • Telefon: (02947) 881-0 • FAX: (02947) 881-50 •
email: Schmierstoffe@KAJO.de • Internet: www.KAJO.de

PRODUCT & TECHNICAL DATA

CASTROL BIOTAC OG

Environmentally responsible open gear lubricant

2007 OSPAR compliant with no substitutable components

DESCRIPTION

Castrol BioTac OG is a highly tenacious, high performance open gear lubricant developed specifically for the rack and pinion jacking mechanism of self-elevating mobile drilling rigs. This is one of the most arduous environments to which a lubricant can be exposed – not only is it subject to high loads and water washing in the splash zone, it also has to provide protection against corrosion to both the rack and pinion between rig moves. In addition, this is one area of operation where a lubricant is deliberately introduced to the marine environment in the course of normal use. The oceans and seas constitute the major part of our planet, using an environmentally responsible open gear lubricant can minimize environmental impact and help conserve marine biological diversity.

*PLONOR – Pose Little Or No Risk to the Environment (according to the OSPAR definition)

Castrol BioTac OG has been specifically formulated to minimize impact upon the marine environment. All the components of Castrol BioTac OG have been selected for their low environmental impact, either from the PLONOR* list of chemicals or following a thorough assessment of their biodegradability, potential for bioaccumulation and their toxicity towards marine species. As a result, Castrol BioTac OG is OSPAR compliant and contains no substitutable components. However this would count for little if its performance as a lubricant was inferior to those used greases which are currently used on leg racks – any performance deficiencies would prevent its adoption or result in a higher consumption, negating its environmental benefits. We have used the performance characteristics of the best available traditional lubricants as the specification for Castrol BioTac OG and have matched these using new additive technologies. The unique thickener structure is highly resistant to water washing and provides outstanding corrosion protection, ensuring that the volumes of lubricant introduced into the environment are similar to those with traditional products.

APPLICATIONS

Rack and pinion gearing on the legs of jack-up drilling rigs where the lubricant is deliberately placed in contact with the marine environment.

Other open gearing in exposed locations where there is a risk of lubricant egress to the marine environment, such as anchor winches or other deck machinery.

FEATURES/BENEFITS

Castrol BioTac OG environmentally responsible open gear lubricant has been formulated to provide the following key benefits:

- Formulated to minimize environmental impact in service, particularly in comparison with conventional open gear lubricants
- OSPAR compliant with no substitutable components
- All components classified as Green (PLONOR) or Yellow in Norwegian assessments by SFT
- UK OCNS group D
- All components are either PLONOR or are expected to biodegrade completely in the marine environment, a significant improvement in comparison with conventional open gear lubricants
- Reduced potential for bioaccumulation in comparison with conventional open gear lubricants
- Exceeds US EPA toxicity requirements*
  * As specified in NPDES permit GMG29000 for subsea production control fluids
- Passes US EPA static sheen test
- High load carrying performance to minimize wear on pinion teeth and guides
- Highly resistant to water wash-off to give excellent corrosion protection and to maintain lubricant presence between rig moves

CARE AND HANDLING

The wearing of impervious PVC (or other suitable material) apron and gloves, together with eye protection is recommended. Contaminated clothing should be changed immediately and thoroughly cleansed before re-use. This applies especially to under garments.

Castrol Marine

PRODUCT & TECHNICAL DATA

PACKAGING AND STORAGE

All packages should be stored under cover. Where outside storage is unavoidable drums should be laid horizontally to avoid the possible ingress of water and the obliteration of drum markings.

Products should not be stored above 60°C, exposed to hot sun or freezing conditions.

TECHNICAL DATA

TYPICAL CHARACTERISTICS		UNIT	TEST METHOD	VALUE
		-	-	BioTac OG
NLGI Classification		-	ASTM D217	1/0
Appearance			Visual	Beige, tacky grease
Base oil kinematic viscosity @ 40°C		cSt	ASTM D445	650
Base oil kinematic viscosity @ 100°C		cSt	ASTM D445	51
Penetration, Worked (0.1mm)			IP 50 / ISO 2137	340
Relative density		-	ASTM D4052	1.210
Four ball EP test				
Wear scar diameter, 1hr @ 40kg		Mm	ASTM D2596	0.742
Weld load		N	ASTM D2596	>8000
Load Wear Index		-	ASTM D2596	141.1
EMCOR Corrosion Test				
	Demineralised water		IP 220	0.0
	3% NaCl solution		IP 220	0.0
Flow Pressure	@ 0°C	mBar	DIN 51 805	125
	@ -10°C	mBar	DIN 51 805	325
	@ -20°C	mBar	DIN 51 805	425

The above figures are typical of those obtained with normal production tolerance and do not constitute a specification

GENERAL ADVICE

Further information on all Castrol Marine lubricants is available from any Castrol Marine office or from:

Castrol Marine
Technology Centre
Whitchurch Hill
Pangbourne
Reading RG8 7QR
United Kingdom

www.castrolmarine.com

This data sheet and the information it contains is believed to be accurate as of the date of printing. However, no warranty or representation, express or implied, is made as to its accuracy or completeness. Data provided is based on standard tests under laboratory conditions and is given as a guide only. Users are advised to ensure that they refer to the latest version of this data sheet.

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14th Sept 2009
Version 2.0
BioTac OG
Page 2 of 2

Produced by BP Marine Limited.
Registered office: Chertsey Road, Sunbury-on-Thames,
Middlesex. TW16 7BP United Kingdom.
Registered in England & Wales, no 01214291.

Castrol Marine

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Appendix E. Sampling Plan

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Draft Sampling and Analysis Plan

EAL Grease Analysis

Technical Feasibility Analysis for eight dams in Washington and Oregon

U.S. Army Corps of Engineers
Portland District

USACE Contract: W9128F-09-D-0056
Task Order: DT04

March 4, 2015

Revised March 6, 2015

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Contents

1 Introduction 1
2 Sampling Objectives 1
3 Sample Collection Methods for In-Service Greases 2
3.1 Schedule 2
3.2 Collection Methods 2
3.3 Sample Labels 3
3.4 Chain of Custody 3
3.5 Shipping 3
4 Sample Collection Methods for New Candidate EAL Greases 4
4.1 Candidate EAL Grease Selection 4
4.2 Procurement of New EAL Greases 4
4.3 Shipment of New EAL Greases 4
5 Analytical Methods 4
5.1 Compatibility Testing 5
5.2 Physical Characteristics Testing 5
5.3 Disposal of Grease Samples 6
6 Quality Control 6
6.1 Sample Collection, Requisition, and Shipment 6
6.2 Laboratory Testing 6
6.3 Final Reporting 6

Tables

Table 1: Summary of In-service Greases on the Lower Columbia and Snake Rivers 1
Table 2: Sampling Plan and Greases 2
Table 3: Summary of Physical Characteristics Testing 5

Appendixes

Appendix A. In-Service Grease Sampling Form
Appendix B. In-Service Grease Sample Container
Appendix C. Chain of Custody Form
Appendix D. New Candidate EAL Shipping Form

Acronyms

ASTM	American Society for Testing and Materials
EAL	Environmentally Acceptable Lubricants
HDC	Hydroelectric Design Center
lbs	pounds
NLGI	National Lubricating Grease Institute
QC	quality control
USACE	U.S. Army Corps of Engineers

1 Introduction

HDR has been hired by the U.S. Army Corps of Engineers (USACE) Hydroelectric Design Center (HDC) to assess whether it is technically feasible to switch from conventional greases presently used on certain "in-water" equipment at each of the following eight dams: Bonneville, The Dalles, John Day, McNary, Ice Harbor, Lower Monumental, Little Goose, and Lower Granite to Environmentally Acceptable Lubricants (EALs). The subject equipment for which EAL greases are to be evaluated include the wicket gate bushings and power plant lifting equipment that may become submerged (e.g., wire rope, crane hooks, and lifting beams).

2 Sampling Objectives

The objective of the sampling program is to collect in-service wicket gate bushing greases currently in-service at the eight dams. Table 1, provided by the USACE, lists the greases that are presently used on wicket gates at the facilities in consideration.

Table 1: Summary of In-service Greases on the Lower Columbia and Snake Rivers

Project	In-Service Grease(s)
Bonneville Second Powerhouse	Huskey Hydrolube
The Dalles and John Day	Mobil SHC 101 EAL
McNary	Chevron Ultra-Duty Grease EP NLGI[1] 0
Ice Harbor	Chevron Ultra-Duty Grease EP NLGI 2
Lower Monumental	Chevron Ultra-Duty Grease EP NLGI 1*
Little Goose	Chevron Ultra-Duty Grease EP NLGI 2
Lower Granite	Chevron FM ALC EP2
*According to plant staff, Lower Monumental recently switched to NLGI 2	

Only one of the in-service greases will be subject to physical property testing in order to provide a baseline performance target for the new EALs. During the kickoff meeting for this task order, the USACE provided direction that the Chevron Ultra-Duty Grease EP NLGI 1 would be tested, as this is the median viscosity used by the USACE and this grease family is used at several plants. However, since Lower Monumental has switched to NLGI 2, that NLGI grade 1 is no longer available for sampling. The USACE requested during a meeting on March 5, 2015 that the target in-service grease to be subjected to physical property testing should be the Mobil SHC 101, since it is used by the most units

[1] National Lubricating Grease Institute (NLGI) rating system is a widely used standard which expresses the relative hardness of greases used for lubrication.

(40) and has base oil viscosity closest to what turbine manufacturers recommended across the 8 plants. It is also an NLGI 1, which is the thickest grease recommended for use in the central greasing systems.

3 Sample Collection Methods for In-Service Greases

3.1 Schedule

Table 2 provides a summary of which greases will be collected from each facility. HDR proposes two trips to procure samples. The first trip would be to Bonneville Second Powerhouse and The Dalles Dams via car from Portland. The second trip would be to Lower Granite and Little Goose Dams via plane to Spokane, Washington and car to the projects. It is envisioned that the first trip would be completed in one day and the second trip in two days. USACE staff will escort HDR engineers during collection.

Table 2: Sampling Plan and Greases

Trip	Project	Greases to be Sampled	Minimum Quantity Required (lbs)
1	Bonneville Second Powerhouse	Huskey Hydrolube	21 and 21*
	John Day	Mobil 101 SHC EAL	21 and 25*
2	Ice Harbor	Chevron Ultra-Duty Grease EP NLGI 2	21
	Lower Granite	Chevron FM ALC EP2	21

*Two samples will be procured, one as an in-service grease and one as a potential candidate EAL.

The preliminary dates identified for Trip #1 collection is the week of 9 March 2015. HDR will provide written requests to the projects no later than 5 days before sampling is to occur.

3.2 Collection Methods

HDR plans to collect in-service greases using 5-gallon containers that have been approved by the testing laboratory. Each container will have a removable locking lid. Grease collection from containers at the site will be via grease pumps. If mechanical pumping of the grease is not possible, manual scooping will be necessary. Coordination with the projects to check on the best method of collection will be required.

The weight of each in-service grease will be verified using a hand scale to confirm that enough product has been acquired for testing. The weight of a standard 5-gallon bucket filled with grease varies from about 30 to 35 pounds (lbs), depending on composition. HDR intends fill a full bucket (at least 30 lbs) for each of the greases shown in Table 2.

HDR will ship the samples to the testing laboratory after affixing a sample identifier that does not reveal the grease type or manufacturer. Sample collection procedure is as follows:

1. Discuss sampling methods with plant staff.
2. Confirm grease type and components to which it is applied by witnessing and photographing container labels and equipment.
3. Obtain samples:
    a. Apply labels to the 5-gallon container (see following section for more information).
    b. Photograph sampling in progress.
    c. Weigh sample and container and check that proper amount has been obtained.
    d. Complete the Field Sampling form, provided in Appendix A.
4. Complete the Chain of Custody form.
5. Prepare and ship the sample to the testing laboratory.

More information on the sample container can be found in Appendix B.

3.3 Sample Labels

Sample labels (i.e., samples 1 through 4) will be affixed to each sample container after collection at each project. Labeling should be completed in two locations on the outer walls and once on the bottom of the container. At least one label on the side should be protected with packing tape to reduce the possibility of smudging and/or water causing ink to run.

Labeling will be witnessed by the USACE HDC representative and notes will be kept to indicate which label corresponds to each sample.

3.4 Chain of Custody

A Chain of Custody form will be completed for each sample before shipment to the testing laboratory. A sample Chain of Custody form is provided in Appendix C.

3.5 Shipping

Shipping will be via UPS next day air directly to SGS Herguth's laboratory. Tracking numbers will be recorded in the Field Sampling form.

4 Sample Collection Methods for New Candidate EAL Greases

4.1 Candidate EAL Grease Selection

HDR will submit a recommendation for new candidate EAL greases for analysis before 13 March 2015. Up to five new greases will be selected.

4.2 Procurement of New EAL Greases

New EAL candidate greases will be purchased from local distributors or direct from the manufacturer, if required. During procurement, HDR will not disclose the reason for the purchase so that no bias will be present from the manufacturer or their associates. One, 5-gallon pail of each new candidate EAL will be purchased.

4.3 Shipment of New EAL Greases

The new candidate EAL greases will be shipped to HDR's office for re-labeling and shipment to SGS Herguth's laboratory in Vallejo, California. Each grease will be re-labeled to remove/hide type and manufacturer information. If identifying information is physically imprinted on the container by the manufacturer in a non-removable manner, HDR will make an attempt to obscure this information; however, greases will not be transferred to other containers.

Shipment of new greases shall be made using UPS or FedEx. Tracking numbers will be recorded in the New EAL Sample Form. The Chain of Custody form will be included in the shipment. The New EAL Sample Form will be completed prior to shipping the samples to the laboratory. A Sample form can be found in Appendix D.

Shipment preparations will be independently checked by a second HDR staff member to verify proper labeling and shipping processes have been followed.

5 Analytical Methods

This analysis includes two main types of testing; compatibility and performance testing. Compatibility testing is important to check whether the in-service greases can be mixed with the candidate EALs without degradation in performance. When incompatible greases are mixed, the resulting blend can harden or soften, possibly resulting in the translating bearing surfaces being improperly lubricated. In some circumstances, this can lead to catastrophic bearing failure. Compatibility is most important for wetted components that cannot be easily accessed (e.g., wicket gate trunnions that require the unit be unstacked to remove old grease).

Another objective of this study is to check that new candidate EALs provide a level of performance that meets or exceeds the existing in-service greases. The physical

characteristics of each of the new candidate greases and one in-service grease will be tested in various scenarios.

These tests are described in further detail below.

5.1 Compatibility Testing

Compatibility tests between the in-service and new EAL greases will be completed per American Society for Testing and Materials (ASTM) D6185. This test will be conducted at three different mixing ratios; 10%/90%, 50%/50%, and 90%/10%.

In ASTM D6185, three properties are evaluated in a primary testing protocol using standard test methods:

1. dropping point by Test Method D566;
2. shear stability by Test Methods D217, 100 000 stroke worked penetration; and
3. storage stability at elevated-temperature by change in 60-stroke penetration (Test Method D217).

The dropping point, shear stability test, and 60-stoke penetration test will be performed during the first phase of work and results from this testing included in the draft report. Due to the time needed for testing, the results of the 100,000-stroke penetration test will only be included in the final report.

5.2 Physical Characteristics Testing

Up to five new candidate EALs and one in-service grease (Mobil SHC 101 EAL) will each be tested for their performance characteristics. These include tests to determine anti-corrosion properties, water washout resistance, apparent viscosity, oxidation stability, and wear properties. Table 3 provides a summary of the physical characteristics testing program.

Table 3: Summary of Physical Characteristics Testing

ASTM Test Method	Description
D4048	Standard Method for detection of Copper Corrosion from Lubricating Grease
D1264	Standard Test Method for Determining the Water Washout Characteristics of Lubricating Greases
D1092	Standard Test Method for Measuring Apparent Viscosity of Lubricating Greases (at 40 degrees F)
D942	Standard Test Method for Oxidation Stability of Lubricating Greases by the Oxygen Pressure Vessel Method
D2266	Standard Test Method for Wear Preventive Characteristics of Lubricating Grease (Four-Ball Method)

5.3 Disposal of Grease Samples

Grease samples will be recycled by the testing lab according to local and state regulations.

6 Quality Control

There are three primary quality control (QC) components for the testing program that will occur during the sample collection and shipping, sample analysis, and final reporting phases. The QC program for each phase is outlined below.

6.1 Sample Collection, Requisition, and Shipment

Sample collection, requisition, and shipment will be witnessed independently by HDR or USACE staff to ensure quality and forms will be used to document labeling. Refer to sections 3.5 and 4.3 for more information.

6.2 Laboratory Testing

HDR will request a copy of the testing laboratory's quality plan, which shall meet or exceed HDR's own internal quality requirements. HDR will review the testing results as they become available to check for any results which seem to deviate from the expected values. HDR will also provide oversight on sample shipment, receipt, and chain of custody.

6.3 Final Reporting

HDR will provide a final report that provides a synthesis of the laboratory testing results and recommendations for a replacement EAL if a suitable product is identified through the investigations. QC checks by technical reviewers on the technical and numerical details of the reports are identified in a separate plan "Work and QC Plan, EAL Grease Analysis" dated February 26, 2015.

Appendix A. In-Service Grease Sampling Form

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In-Service Grease Sampling Form
DT04 - Environmentally Acceptable Lubricant (EAL) Grease Analysis
HDR Engineering, Inc.

In-Service Sample 1	
Powerhouse	
Date	
Sample Time	
Witnesses	
Sample Method	
Sample Location	
Sample Name	
Sample Label Number	
Photos (Y/N)	
Other Notes	
Tracking Number	
Note: send copy of Chain of Custody form to SGS before shipping.	

In-Service Sample 2	
Powerhouse	
Date	
Sample Time	
Witnesses	
Sample Method	
Sample Location	
Sample Name	
Sample Label Number	
Photos (Y/N)	
Other Notes	
Tracking Number	
Note: send copy of Chain of Custody form to SGS before shipping.	

In-Service Grease Sampling Form
DT04 - Environmentally Acceptable Lubricant (EAL) Grease Analysis
HDR Engineering, Inc.

In-Service Sample 3	
Powerhouse	
Date	
Sample Time	
Witnesses	
Sample Method	
Sample Location	
Sample Name	
Sample Label Number	
Photos (Y/N)	
Other Notes	
Tracking Number	
Note: send copy of Chain of Custody form to SGS before shipping.	

In-Service Sample 4	
Powerhouse	
Date	
Sample Time	
Witnesses	
Sample Method	
Sample Location	
Sample Name	
Sample Label Number	
Photos (Y/N)	
Other Notes	
Tracking Number	
Note: send copy of Chain of Custody form to SGS before shipping.	

Appendix B. In-Service Grease Sample Container

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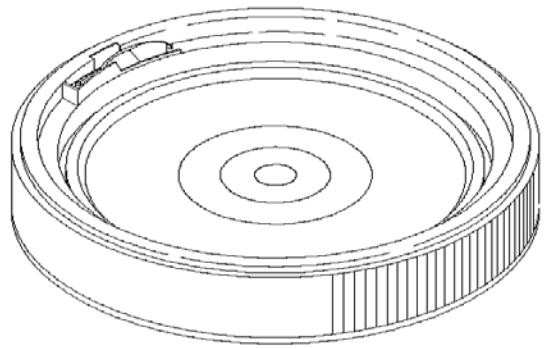
M&M INDUSTRIES, INC.

5.0 Gallon New Generation Pail

Prepared For: Standard Technical Specification
09/06/11

General Specifications for cover:

Material:	High Density Polyethylene (HDPE)
Method of Mfg:	Injection Molding
Weight:	1.02 lbs
Cover Height:	2.50"
Min. Wall Thickness:	.090" (90 mil)
Bottom OD:	12.690"
Gasket:	Neoprene
Qty:	240 per pallet
Standard Color:	White, Red186, Blue300
	Please inquire about custom colors



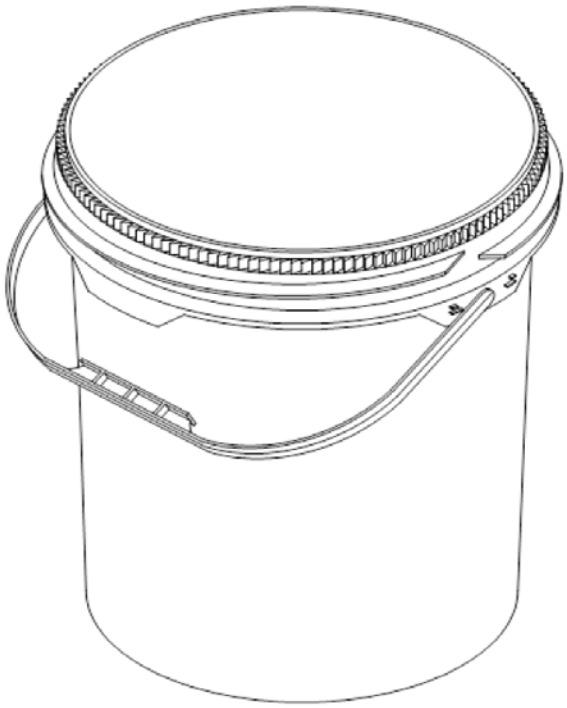
Top ID: 11.25 "

General Specifications for Pail:

Material:	High Density Polyethylene (HDPE)
Method of Mfg:	Injection Molding
Nominal Capactiy:	5.0 Gallons
Weight:	2.40 lbs
Min. Wall Thickness:	.090" (90 mil)
Exterior Height:	15.25"
Top ID:	11.25"
Bottom OD:	10.27 "
Shipping: Case:	4 pails and lids per case
Pallet:	120 units
Truckload:	4,320 units
Handle:	Plastic Handle
Printing Area:	9.5" x 33"
Nesting:	Tapered walls for nesting
Standard Color:	White
	Please inquire about custom colors
UN Certification:	1H2/Y30/S

Height 15.25"

Height w/cover 16.04"



Bottom OD: 10.27"

Manufacturing Plants: Chattanooga, TN (800) 331-5305 / Phoenix, AZ (602) 233-8758

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Appendix C. Chain of Custody Form

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SGS HERGUTH LABORATORIES

CHAIN OF CUSTODY RECORD

Date Initiated _____

Customer Information

Company:	Project or PO#
Address:	Phone Fax e-mail
City, State, Zip	Comments:
Report To:	

Sample Information

Sample ID	Date Sampled	Container Type	Sample Description	Analysis Required (attach specific request if necessary)

Custody Transfer Record

Signature	Print Name	Company	Date / Time	Released? / Received?

Use Reverse Side if Needed or Attach Detail List

HERGUTH LABORATORIES, INC. IS NOW PART OF SGS, THE WORLD'S LEADING INSPECTION, VERIFICATION, TESTING AND CERTIFICATION COMPANY.

SGS Herguth Laboratories, Inc. | 101 Corporate Place Vallejo, CA 94590-6968, USA 1600 Shore Road, Suite H Naperville, IL 60563, USA
t +1 800 645 5227 f +1 707 554 0109 www.sgs.com

Member of the SGS Group (SGS SA)

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Appendix D. New Candidate EAL Shipping Form

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New Candidate Grease Shipping Checklist
DT04 - Environmentally Acceptable Lubricant (EAL) Grease Analysis
HDR Engineering, Inc.

New EAL Sample 5	
Date	
HDR Representative	
HDR Witness	
Grease Manufacturer	
Grease Type	
Sample Label Number	5
Photos (Y/N)	
Other Notes	
Tracking Number	
Note: send copy of Chain of Custody form to SGS before shipping.	

New EAL Sample 6	
Date	
HDR Representative	
HDR Witness	
Grease Manufacturer	
Grease Type	
Sample Label Number	6
Photos (Y/N)	
Other Notes	
Tracking Number	
Note: send copy of Chain of Custody form to SGS before shipping.	

New EAL Sample 7	
Date	
HDR Representative	
HDR Witness	
Grease Manufacturer	
Grease Type	
Sample Label Number	7
Photos (Y/N)	
Other Notes	
Tracking Number	
Note: send copy of Chain of Custody form to SGS before shipping.	

New Candidate Grease Shipping Checklist
DT04 - Environmentally Acceptable Lubricant (EAL) Grease Analysis
HDR Engineering, Inc.

New EAL Sample 8	
Date	
HDR Representative	
HDR Witness	
Grease Manufacturer	
Grease Type	
Sample Label Number	8
Photos (Y/N)	
Other Notes	
Tracking Number	
Note: send copy of Chain of Custody form to SGS before shipping.	

New EAL Sample 9	
Date	
HDR Representative	
HDR Witness	
Grease Manufacturer	
Grease Type	
Sample Label Number	9
Photos (Y/N)	
Other Notes	
Tracking Number	
Note: send copy of Chain of Custody form to SGS before shipping.	

Appendix F. Sampling Trip Field Notes and Documentation

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Trip Report

Date:	March 12, 2015
Project:	DT04 – EAL Grease Analysis
To:	Joshua Sills, HDC
From:	Brian Moentenich, Steve Meicke, Blaine Graff
Subject:	In-Service Grease Sampling Trip Report, March 9 and 10, 2015

Purpose

The purpose of the In-Service Grease Sampling Trip was to collect four different unused in-service grease samples from the wicket gate bushing greasing systems at the power plants listed below, and ship them to SGS Herguth Laboratory in Vallejo California for testing. For more information please reference the Sampling and Analysis Plan submitted March 6, 2015.

Trip Report

General

Table 1 provides a general description of the in-services greases collected on day one and day two of the trip, March 9, 2015 and March 10, 2015, respectively. For each plant, the In-Service Grease Sampling Form was completed, which includes sample names, label numbers, witnesses, tracking numbers, and other information (Appendix A). Chain of Custody Forms were also completed before leaving each plant and were shipped along with the samples to SGS Herguth. Photographs of the sampling and shipping process (including Chain of Custody Forms) are provided in Appendix B.

Table 1: Summary of Sampling Trip Activities

Day	Plant	Grease	Plant Contacts	Sample Number	Sample Amount
1	Bonneville Second Powerhouse	Husky Hydrolube	Megan Fisher, Ken Rochefort	1	2
1	John Day	Mobil SHC 101 EAL	Eric Bretthauer	2	2
1	Ice Harbor	Chevron Ultra-Duty Grease EP NLGI2	Floyd Stredwick	3	1
2	Lower Granite	Chevron FM ALC EP2	Casey Sweeny, John Dammann	4	1

March 9, 2015

Steve Meicke and Brian Moentenich of HDR, and Joshua Sills of the U.S. Army Corps of Engineers Hydroelectric Design Center, drove to Bonneville Dam in two cars arriving at 9:00 AM. Bonneville Dam personnel Garrett Wickham and Meghan Fischer assisted with

collecting two, 5-gallon samples of grease. A mechanic used a transfer pump (normally used to fill Farval pump reservoirs) to fill both containers. These samples were labeled Sample 1, Bucket 1 and Sample 1, Bucket 2 from Powerhouse 1 on the Chain of Custody Forms.

The team then drove to John Day Dam and met with Eric Bretthauer. Eric provided 2 unopened, new 5-gallon pails of grease that were representative of the grease used in the wicket gate bushing lubrication systems. Pumping or manual transfer of the sample was not necessary. The team removed the manufacturer's information (large sticker) from one pail which was then shipped to the lab. Both unopened 5-gallon pails of grease were labelled Grease from Powerhouse 2 on the Chain of Custody Forms.

The final stop of the day was Ice Harbor Lock and Dam. The team met with Floyd Stredwick and proceeded to collect the sample from a transfer pump normally used to fill main unit Faval reservoirs. It was identified as Sample 3, from Powerhouse 3 on the Chain of Custody Form.

After departing Ice Harbor Powerhouse, the samples were taken by car to Pasco, Washington for shipment. One sample from Bonneville Second Powerhouse and one sample from John Day Powerhouse were shipped to the lab, and the extra sample of each was shipped to HDR's Portland, Oregon office for possible future analysis. The sample from Ice Harbor Powerhouse was not shipped at this time, but was held for shipment along with the next day's sample.

The team spent the night in Pasco and planned to visit Lower Granite Powerhouse the next day.

March 10, 2015

We drove to Lower Granite Powerhouse and arrived on the south side of the plant as requested. Casey Sweeney greeted us at the gate. At this plant, the plant staff did not use a transfer pump so the mechanic donned gloves and hand-scooped the grease from the barrel into the sample container. It was identified as Sample 4, from Powerhouse 4 on the Chain of Custody Form.

The team then drove to a UPS store in Moscow, Idaho to ship the containers we had filled at Ice Harbor Powerhouse and Lower Granite Powerhouse to the lab.

Finally, the team drove to the Moscow/Pullman Regional airport for the return flight to Portland.

Appendix A: In-Service Grease Sampling Form

In-Service Grease Sampling Form
DT04 - Environmentally Acceptable Lubricant (EAL) Grease Analysis
HDR Engineering, Inc.

In-Service Sample 1	
Powerhouse	
Date	
Sample Time	
Witnesses	
Sample Method	
Sample Location	
Sample Name	
Sample Label Number	
Photos (Y/N)	
Other Notes	
Tracking Number	
Note: send copy of Chain of Custody form to SGS before shipping.	

In-Service Sample 2	
Powerhouse	
Date	
Sample Time	
Witnesses	
Sample Method	
Sample Location	
Sample Name	
Sample Label Number	
Photos (Y/N)	
Other Notes	
Tracking Number	
Note: send copy of Chain of Custody form to SGS before shipping.	

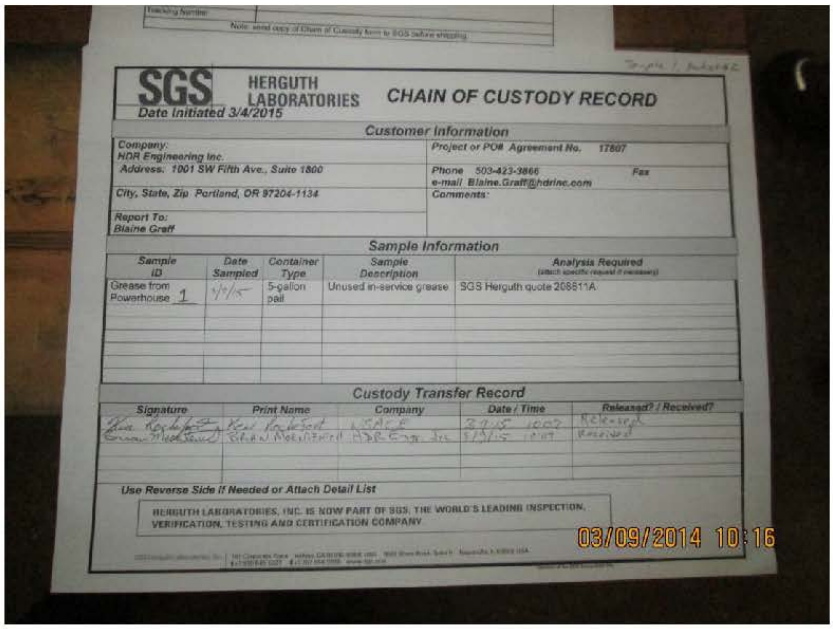
Appendix B: Photos

Bonneville Second Powerhouse

Figure 1: Huskey Hydrolube barrel label at Bonneville Second Powerhouse.

Figure 2: Sampling of Huskey Hydrolube, Sample 1 (1 of 2).

Figure 3: Sampling of Huskey Hydrolube, Sample 1 (2 of 2).



SGS HERGUTH LABORATORIES
Date Initiated 3/4/2015

CHAIN OF CUSTODY RECORD

Customer Information

Company: HDR Engineering Inc.
Address: 1001 SW Fifth Ave., Suite 1800
City, State, Zip Portland, OR 97204-1134
Report To: Blaine Graff
Project or PO# Agreement No. 17807
Phone 503-423-3866 Fax
e-mail Blaine.Graff@hdrinc.com
Comments:

Sample Information

Sample ID	Date Sampled	Container Type	Sample Description	Analysis Required (attach specific request if necessary)
Grease from Powerhouse 1	3/9/15	5-gallon pail	Unused in-service grease	SGS Herguth quote 208811A

Custody Transfer Record

Signature	Print Name	Company	Date / Time	Released? / Received?
[illegible]	[illegible]	USACE	3/9/15 1007	Released
[illegible]	[illegible]	HDR Engineering Inc	3/9/15 1009	Received

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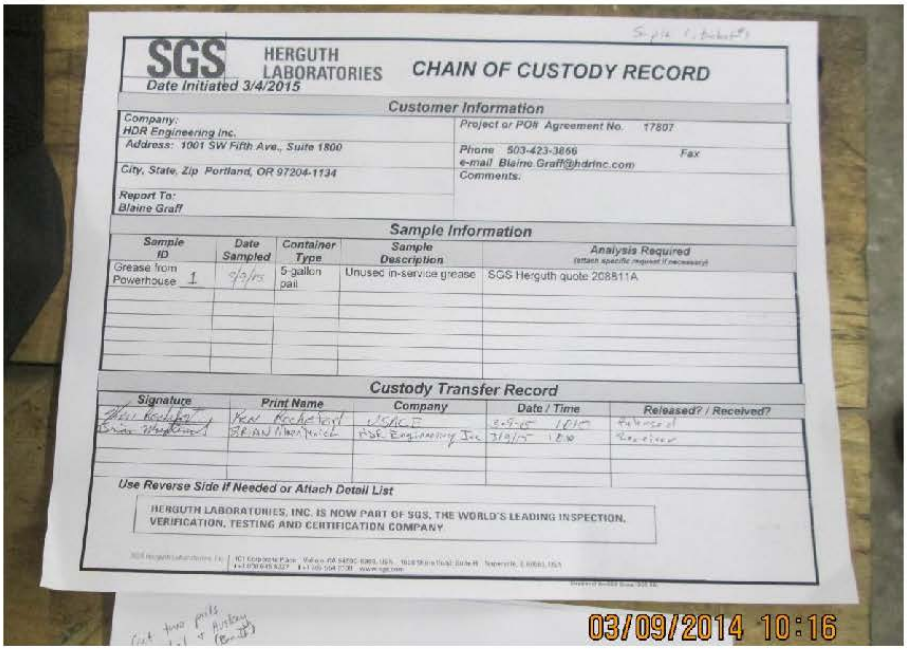
03/09/2014 10:16

Figure 4: Sample 1 Chain of Custody Form (1 of 2).



SGS HERGUTH LABORATORIES — CHAIN OF CUSTODY RECORD

Date Initiated 3/4/2015

Customer Information

Company: HDR Engineering Inc.
Address: 1001 SW Fifth Ave., Suite 1800
City, State, Zip Portland, OR 97204-1134
Report To: Blaine Graff
Project or PO# Agreement No. 17807
Phone 503-423-3866 Fax
e-mail Blaine.Graff@hdrinc.com
Comments:

Sample Information

Sample ID	Date Sampled	Container Type	Sample Description	Analysis Required (attach specific request if necessary)
Grease from Powerhouse 1	3/3/15	5-gallon pail	Unused in-service grease	SGS Herguth quote 208811A

Custody Transfer Record

Signature	Print Name	Company	Date / Time	Released? / Received?
[illegible]	Kent Rockafeyl	USACE	3-9-15 1010	Released
[illegible]	Blaine Graff	HDR Engineering Inc	3/9/15 1030	Received

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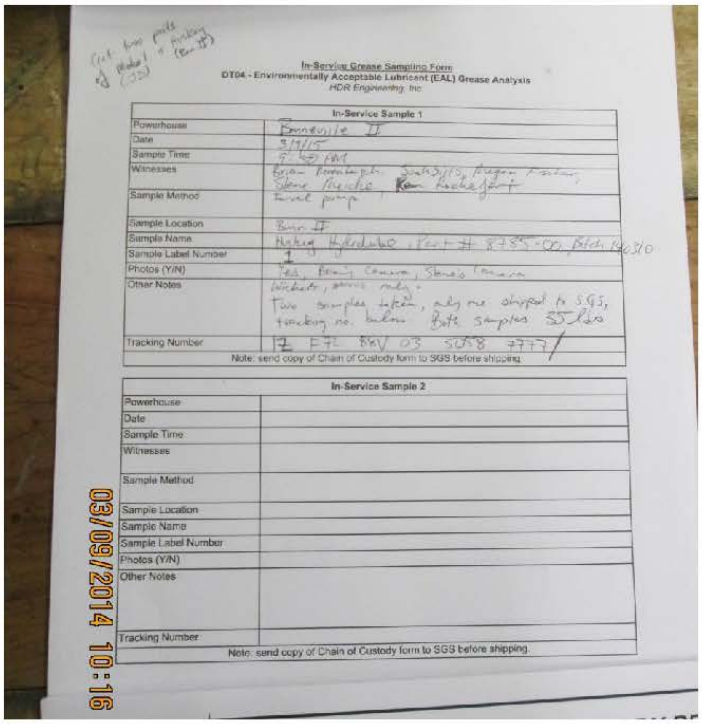
Figure 5: Sample 1 Chain of Custody Form (2 of 2).



In-Service Grease Sampling Form
DT04 - Environmentally Acceptable Lubricant (EAL) Grease Analysis
HDR Engineering, Inc.

In-Service Sample 1

Powerhouse	Bonneville II
Date	3/9/15
Sample Time	9:45 AM
Witnesses	Brian [illegible], [illegible], Steve Meeks, Kent Rockafeyl
Sample Method	Hand pump
Sample Location	Bay II
Sample Name	Mobil Hydrolube, Part # 81855-00, Batch 1462310
Sample Label Number	1
Photos (Y/N)	Yes, Fenny Camera, Steve's Camera
Other Notes	Website, [illegible] only. Two samples taken, only one shipped to SGS, tracking no. below. Bulk samples 55 lbs
Tracking Number	7 EZ RN 03 5058 7777

Note: send copy of Chain of Custody form to SGS before shipping.

In-Service Sample 2

Powerhouse	
Date	
Sample Time	
Witnesses	
Sample Method	
Sample Location	
Sample Name	
Sample Label Number	
Photos (Y/N)	
Other Notes	
Tracking Number	

Note: send copy of Chain of Custody form to SGS before shipping.

03/09/2014 10:16

Figure 6: In-Service Grease Sampling Form - Sample 1.

Figure 7: Sample 1, Buckets 1 and 2, sampling complete.

Figure 8: Fish unit Farval pump, typ.

John Day Powerhouse

Figure 9: Mobil SHC 101 EAL in new containers, Sample 2, Buckets 1 and 2 (stickers shown were removed).

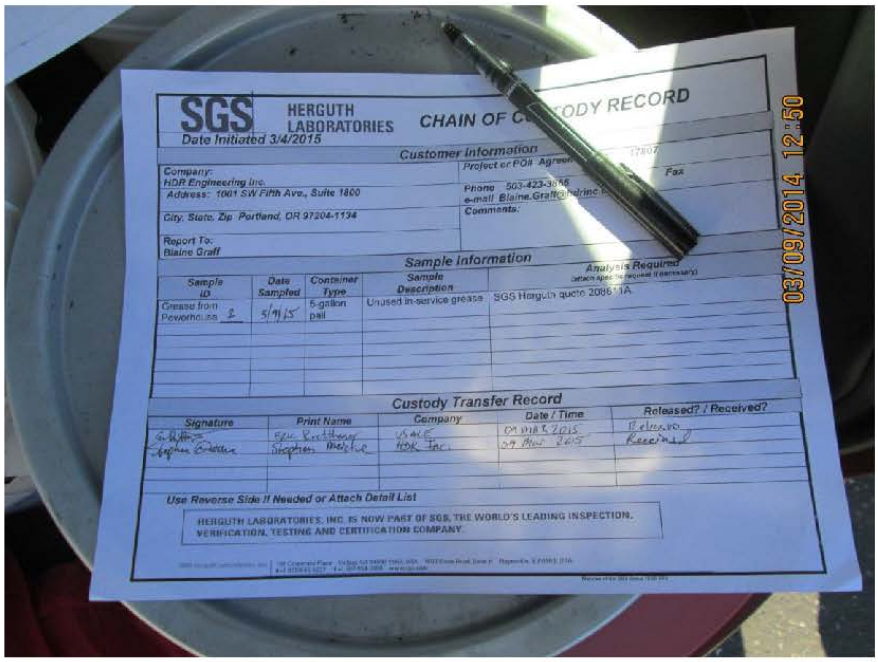
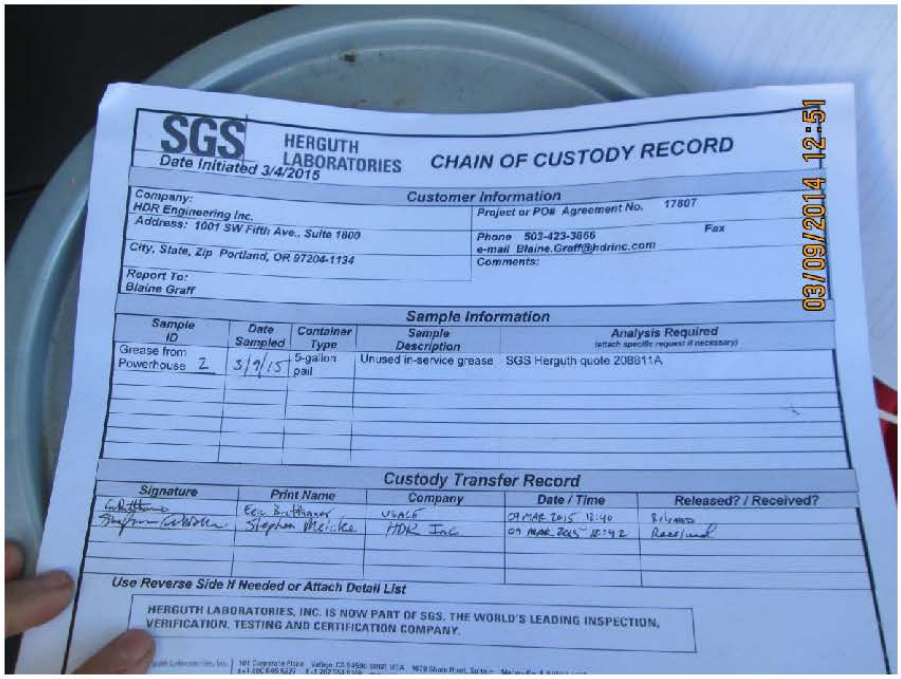


Figure 10: Sample 2, bucket 1 Chain of Custody Form.



SGS HERGUTH LABORATORIES CHAIN OF CUSTODY RECORD
Date Initiated 3/4/2015

Customer Information
Company: HDR Engineering Inc.
Address: 1001 SW Fifth Ave., Suite 1800
City, State, Zip Portland, OR 97204-1134
Report To: Blaine Graff
Project or PO# Agreement No. 17807
Phone 503-423-3866 Fax
e-mail Blaine.Graff@hdrinc.com
Comments:

Sample Information

Sample ID	Date Sampled	Container Type	Sample Description	Analysis Required (attach specific request if necessary)
Grease from Powerhouse 2	3/9/15	5-gallon pail	Unused in-service grease	SGS Herguth quote 208811A

Custody Transfer Record

Signature	Print Name	Company	Date / Time	Released? / Received?
[illegible]	Eric Breitbarger	USACE	09 MAR 2015 12:40	Released
Stephen [illegible]	Stephen Meinke	HDR Inc	09 MAR 2015 12:42	Received

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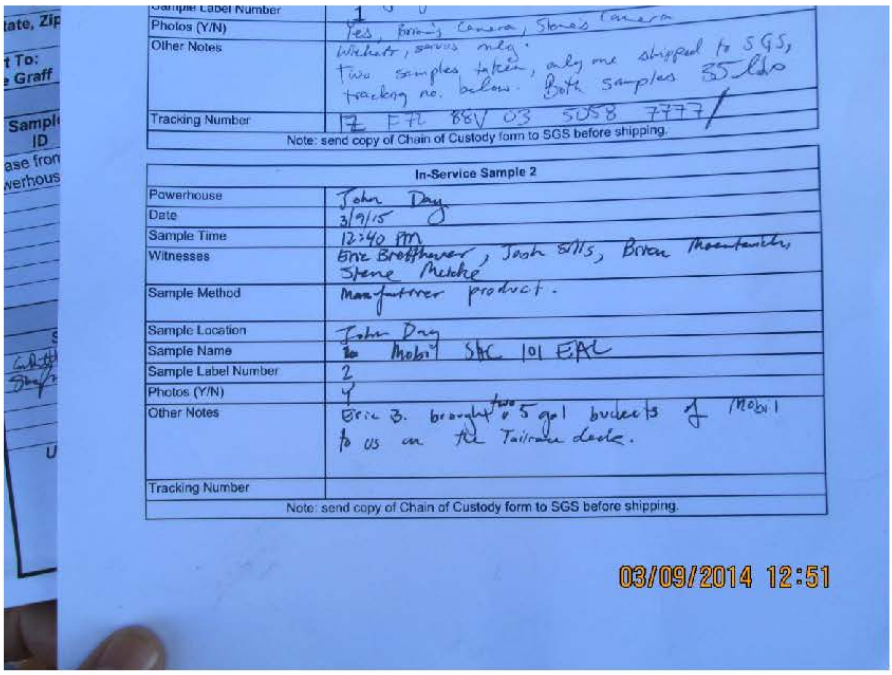
Figure 11: Sample 2, Bucket 2 Chain of Custody Form.



Sample Label Number	1
Photos (Y/N)	Yes, Brian's Camera, Stones Camera
Other Notes	Website, serious only. Two samples taken, only one shipped to SGS, tracking no. below. Both samples 35 lbs
Tracking Number	7 E7 8EV 03 5058 7777

Note: send copy of Chain of Custody form to SGS before shipping.

In-Service Sample 2

Powerhouse	John Day
Date	3/9/15
Sample Time	12:40 PM
Witnesses	Eric Breitbarger, Josh Sills, Brian Mountenthy, Steve Meinke
Sample Method	Manufacturer product.
Sample Location	John Day
Sample Name	Mobil SHC 101 EAL
Sample Label Number	2
Photos (Y/N)	Y
Other Notes	Eric B. brought two 5 gal buckets of Mobil to us on the Tailrace deck.
Tracking Number	

Note: send copy of Chain of Custody form to SGS before shipping.

03/09/2014 12:51

Figure 12: In-Service Grease Sampling Form - Sample 2.

Ice Harbor Powerhouse

Figure 13: Chevron Ultra-Duty Grease EP NLGI 2 and pump at Ice Harbor Dam, Sample 3.

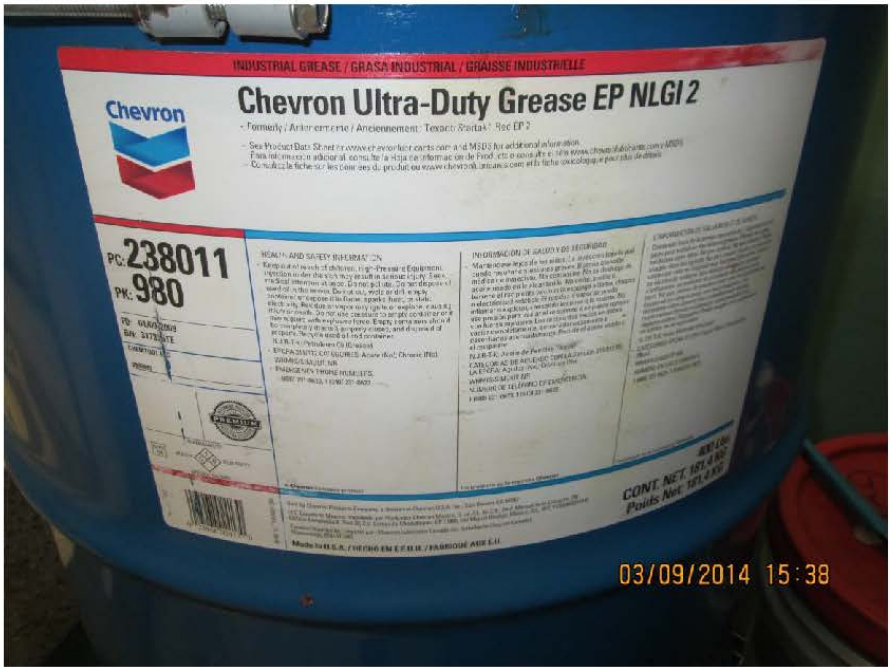
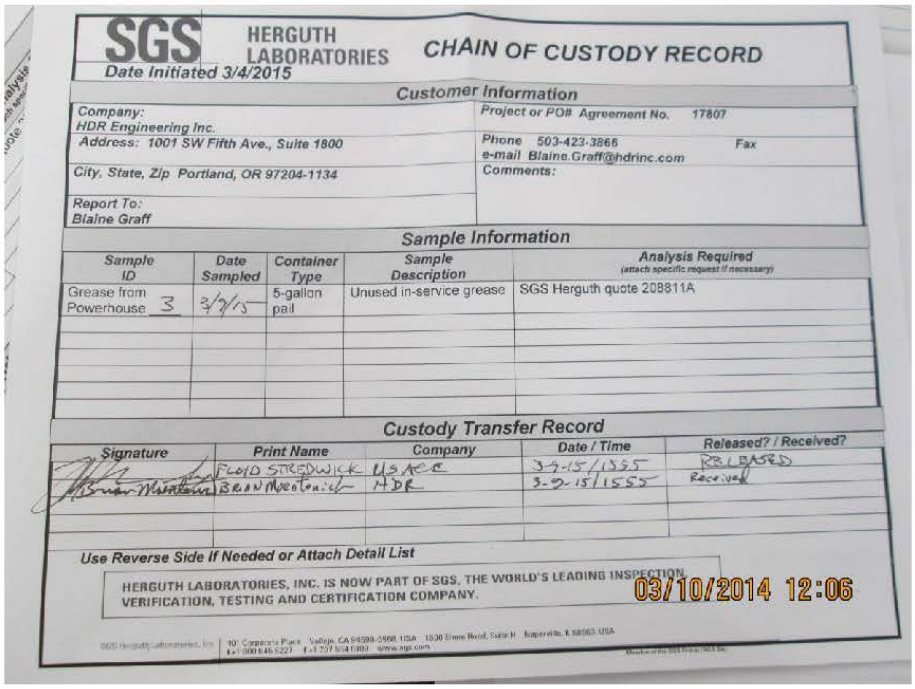


Figure 14: Chevron Ultra-Duty Grease EP NLGI 2 barrel label.

Ice Harbor Powerhouse

Figure 15: Sampling process Sample 3.



SGS HERGUTH LABORATORIES **CHAIN OF CUSTODY RECORD**

Date Initiated 3/4/2015

Customer Information

Company: HDR Engineering Inc.
Address: 1001 SW Fifth Ave., Suite 1800
City, State, Zip Portland, OR 97204-1134
Report To: Blaine Graff

Project or PO# Agreement No. 17807
Phone 503-423-3866 Fax
e-mail Blaine.Graff@hdrinc.com
Comments:

Sample Information

Sample ID	Date Sampled	Container Type	Sample Description	Analysis Required (attach specific request if necessary)
Grease from Powerhouse 3	3/2/15	5-gallon pail	Unused in-service grease	SGS Herguth quote 208811A

Custody Transfer Record

Signature	Print Name	Company	Date / Time	Released? / Received?
	FLOYD STREDWICK	USACE	3-4-15/1555	RELEASED
	BRIAN NORTON	HDR	3-5-15/1555	Received

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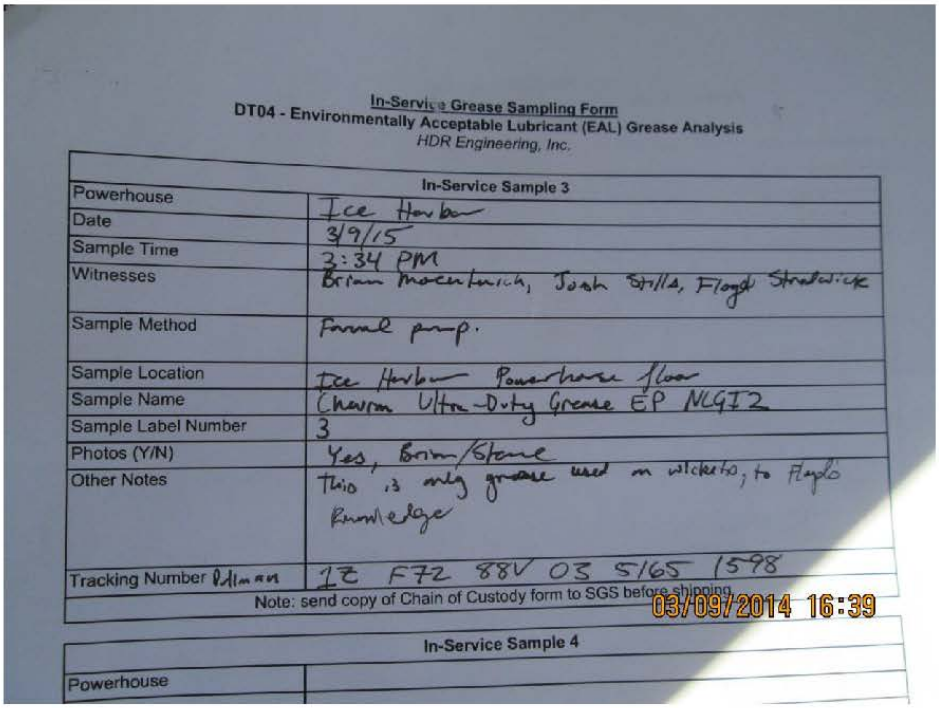
03/10/2014 12:06

Figure 16: Sample 3 Chain of Custody Form.



In-Service Grease Sampling Form
DT04 - Environmentally Acceptable Lubricant (EAL) Grease Analysis
HDR Engineering, Inc.

In-Service Sample 3	
Powerhouse	Ice Harbor
Date	3/9/15
Sample Time	3:34 PM
Witnesses	Brian Moentmich, Josh Stilla, Floyd Stratwick
Sample Method	Farval pump.
Sample Location	Ice Harbor Powerhouse floor
Sample Name	Chevron Ultra-Duty Grease EP NLGI 2
Sample Label Number	3
Photos (Y/N)	Yes, Brian/Steve
Other Notes	This is only grease used on wickets, to Floyd's knowledge
Tracking Number Pelican	1Z F72 88V 03 5165 1598

Note: send copy of Chain of Custody form to SGS before shipping

03/09/2014 16:39

In-Service Sample 4	
Powerhouse	

Figure 17: In-Service Grease Sampling Form - Sample 3.

Figure 18: Main unit Farval pump servicing wicket gate trunnions, typ.

Ice Harbor Powerhouse

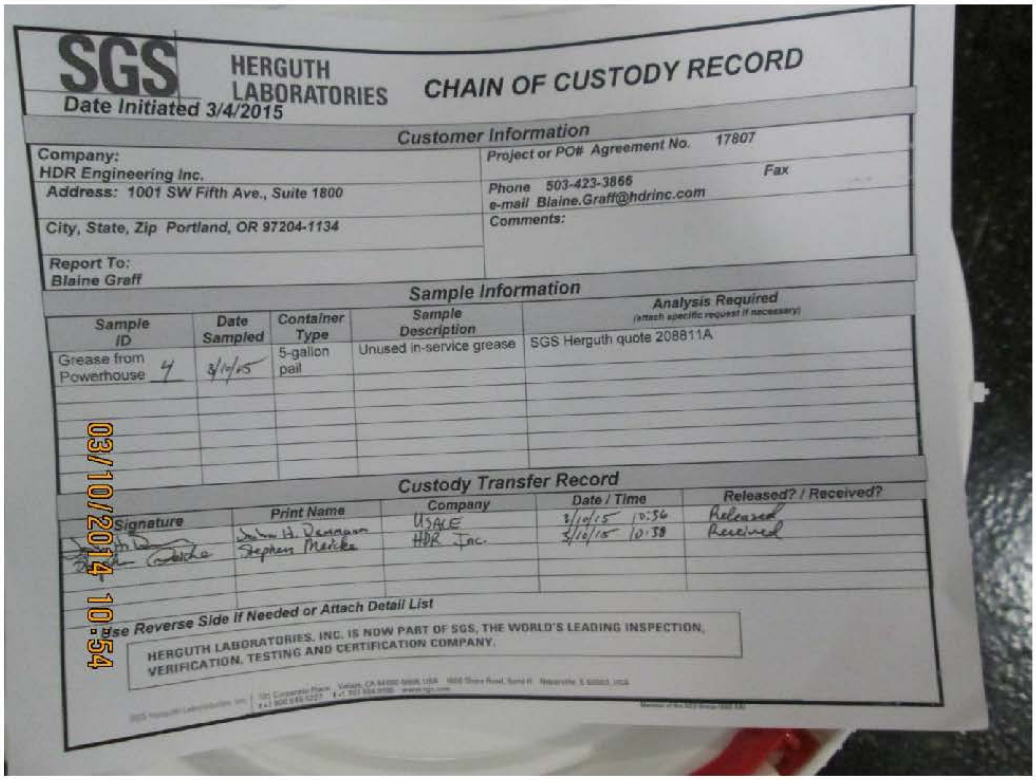
Lower Granite Powerhouse

Figure 19: Chevron FM ALC EP2 in barrel at Lower Granite Dam, Sample 4.

Figure 20: Hand-sampling of Sample 4.

Figure 21: In-service grease 4 barrel label.

Figure 22: Sample 4 container ready for shipment.



SGS HERGUTH LABORATORIES CHAIN OF CUSTODY RECORD

Date Initiated 3/4/2015

Customer Information

Company: HDR Engineering Inc.
Address: 1001 SW Fifth Ave., Suite 1800
City, State, Zip Portland, OR 97204-1134
Report To: Blaine Graff
Project or PO# Agreement No. 17807
Phone 503-423-3866
e-mail Blaine.Graff@hdrinc.com
Fax
Comments:

Sample Information

Sample ID	Date Sampled	Container Type	Sample Description	Analysis Required (attach specific request if necessary)
Grease from Powerhouse 4	3/10/15	5-gallon pail	Unused in-service grease	SGS Herguth quote 208811A

Custody Transfer Record

Signature	Print Name	Company	Date / Time	Released? / Received?
[illegible]	John H. Damgaard	USACE	3/10/15 10:56	Released
[illegible]	Stephen Meiche	HDR Inc.	3/10/15 10:58	Received

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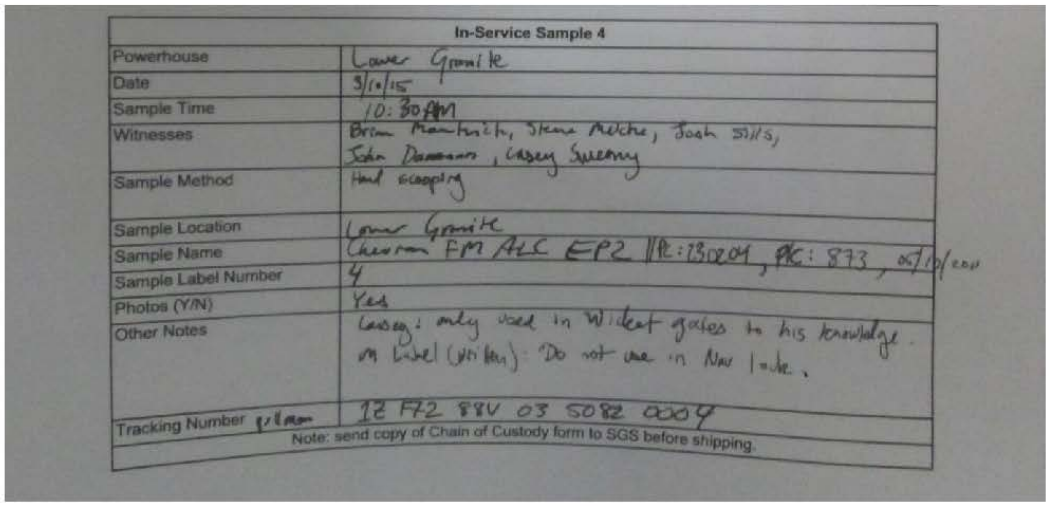
03/10/2014 10:54

Figure 23: Sample 4 Chain of Custody Form.



In-Service Sample 4	
Powerhouse	Lower Granite
Date	3/10/15
Sample Time	10:30AM
Witnesses	Brian Mantzith, Steve Meiche, Josh Sills, John Damgaard, Casey Sweeny
Sample Method	Hand scooping
Sample Location	Lower Granite
Sample Name	Chevron FM AZL EP2 PR: 130204, PK: 873, 03/10/2015
Sample Label Number	4
Photos (Y/N)	Yes
Other Notes	Casey: only used in Wildcat gates to his knowledge. on Label (written): "Do not use in New Lube."
Tracking Number	1Z F72 88V 03 5082 0004

Note: send copy of Chain of Custody form to SGS before shipping.

Figure 24: In-Service Grease Sampling Form for Sample 4.

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Appendix G. Industry Survey

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Industry Survey

Request for Information

The Centre for Energy Advancement through Technological Innovation (CEATI) is a user-driven organization committed to providing technology solutions to its electrical utility participants, who are brought together to collaborate and act jointly to advance the industry through the sharing and developing of practical and applicable knowledge.

CEATI's efforts are driven by over 120 participating organizations (electric & gas utilities, governmental agencies, provincial and state research bodies), represented within 18 focused Interest Groups and specialized Task Forces. Continuously expanding its international reach, CEATI's participants represent 17 countries on 6 continents, a diversity that contributes to the strength of CEATI programs and brings value directly to the participants.

The following two questions were distributed to various contacts throughout the hydropower industry via CEATI:

- Does your facility use EAL greases for in-water components such as wicket gates, fish way equipment, lifting blocks, wire ropes, etc.? If so, what types and where are they used? Please provide brand, name and grade information.
- For each of the EAL greases, is the performance of the lubricant satisfactory? Please elaborate on service history successes and/or performance issues.

HDR also directly approached individuals and hydropower organizations outside of CEATI with the questions above.

Summary of Survey Results

A partial summary of survey responses is provided by organization below. The responses captured here only include those with significant discussion on operational experience with environmentally friendly lubricants and greaseless wicket gate bushings. Other responses are summarized in Section 5.6.3.

Respondent # 1

Respondent # 1 has been using VSG grease manufactured by Eco Fluid Center Ltd for approximately 15 years on one unit. They began using this product following a discovery of some problems with greaseless wicket gate bushings. This specific facility was chosen because it had 3 units that could be used to experiment between various grease/bushing combinations; greaseless bushings, grease from mineral oil on greaseless bushings, and VSG on greaseless bushings. All three units were instrumented with a differential pressure transmitter across the servo motors. The trends over the first 5 years showed the VSG performed better than the mineral oil grease consistently by 10 psi.

The greaseless bushings also performed just as well as the greaseless/VSG combo, but due to greaseless bushing issues at other of Respondent # 1's facilities, a decision was made to continue using the greased bushings.

To date, almost all of Respondent # 1's units have been switched to VSG grease for wicket gate bushings. According to Respondent # 1, VSG grease has what appears to be an infinite shelf life (over 5 years), while the mineral oil grease would separate after 2-3 years.

Editors note: Although VSG was determined to be 'environmentally friendly' at the time of its implementation by Respondent #1, VSG has not been shown to qualify as an EAL under the guidelines discussed in Section 3.0 of this report.

Respondent # 2

Respondent #2 has experimented with some vegetable-based oils and greases, but use has been discontinued because the results were not satisfactory. They have been converting to greaseless bushings, and in several cases have converted from oil-lubricated turbine guide bearings to water-lubricated designs.

Respondent # 3

Respondent # 3 has been using VSG grease since 2003 on three units at one of their facilities. Usage is normally 1 to 2 barrels per unit per year, depending on unit run times. Previously they had used "Mobil EAL 101," but it was too thick and didn't work well with the plant's greasing systems.

Editor's note: Although VSG was determined to be 'environmentally friendly' at the time of its implementation by Respondent #1, VSG has not been shown to qualify as an EAL under the current guidelines. As discussed above, Mobil SHC 101 does not meet the criteria for an EAL.

Respondent # 4

Overall, Respondent # 4's use of EAL is limited as experiments with environmentally friendly products have been marginal. In one area of their system for all greased wicket gate bushings and greased cables, Huskey Hydrolube is used and performance is satisfactory. Respondent # 4 does not use any environmentally friendly greases or oils in other locations. In the past, Shell Naturelle was used on fish screens but was discontinued for the following reasons:

- The product only lasted a year before needing to be changed out;
- It was three times the cost of regular oil and if there was a spill;
- The response required was the same, so the benefits were deemed to be minimal.

Editor's note: Huskey Hydrolube has not been shown to qualify as an EAL under the guidelines discussed in Section 3.0 of this report. Shell Naturelle is labeled under the EEL program; however, recent research has indicated that this product may be discontinued.

Appendix H. Laboratory Testing Results

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SGS HERGUTH LABORATORIES

Certificate of Analysis

Blaine Graff
HDR Engineering, Inc.
1001 SW Fifth Avenue
Suite 1800
Portland, OR 97204
Phone: (503) 423-3866

Lab No. V0606664 (HDREBG)
Report Date: June 23, 2015

Email: blaine.graff@hdrinc.com
Fax: (503) 423-3737

Sample Description:
Environmentally Acceptable Lubricant (EAL) Grease Analysis Project

Dear Blaine:

Thank you for your confidence in SGS Herguth Laboratories, Inc. Please accept this report and attachments as our conclusion to the above numbered project/sample description.

Background: SGS Herguth Laboratories, Inc. was asked to evaluate four (4) unused Powerhouse grease samples to determine their compatibility with four (4) new EAL candidate grease products. One additional grease product was included into the test matrix to review compatibility with the EAL candidate greases. The samples were submitted for grease compatibility testing based on ASTM D6185 (Standard Practice for Evaluating Compatibility of Binary Mixtures of Lubricating Greases), using three different blending ratios of each Powerhouse grease to each EAL candidate grease, respectively.

To determine the dropping point compatibility section of ASTM D6185, the fresh mixtures from each Powerhouse and EAL candidate grease were blended to the following ratios: 90/10, 50/50, and 10/90. The mixtures and constituent greases were then measured for dropping point by ASTM D2265 (Standard Test Method for Dropping Point of Lubricating Grease Over Wide Temperature Range). From these same mixtures, all constituent greases and all 50/50 blends were tested by ASTM D217 (Standard Test Methods for Cone Penetration of Lubricating Grease) to determine the products' shear stability and compatibility under prolonged worked conditions (100,000 strokes).

To determine the high-temperature storage stability and compatibility section of ASTM D6185, 60-stroke cone penetrations of all constituent greases and all blends were determined per ASTM D1403 (Standard Test Methods for Cone Penetration of Lubricating Grease Using One-Quarter and One-Half Scale Cone Equipment), using ½ scale equipment. Portions of the samples were then heated in a laboratory oven for about three days (70 hours) at 120 ± 3°C. After heating, the grease samples were tested again for 60-stroke cone penetration per ASTM D1403 using ½ scale equipment.

Sample aliquots for all EAL candidate greases and Powerhouse #2 grease were obtained to measure additional property data. The grease properties included: ASTM D942 for 100 hours (Standard Test Method for Oxidation Stability of Lubricating Greases by the Oxygen Pressure Vessel Method), ASTM D1264 at 100°F (Standard Test Method for Determining the Water Washout Characteristics of Lubricating Greases), ASTM D4048 at 100°C (Standard Test Method for Detection of Copper Corrosion from Lubricating Grease), ASTM D2266 (Standard Test

These results are submitted pursuant to our current Terms, Conditions and Limitations and Laboratory Pricing Policy. No responsibility or liability is assumed for the manner in which these results are used or interpreted.

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SGS Herguth Laboratories, Inc. | 101 Corporate Place Vallejo, CA 94590-6968, USA 1600 Shore Road, Suite H Naperville, IL 60563, USA
t +1 800 645 5227 f +1 707 554 0109 www.sgs.com

Member of the SGS Group (SGS SA)

SGS HERGUTH LABORATORIES

Certificate of Analysis

Method for Wear Preventive Characteristics of Lubricating Grease (Four-Ball Method)), and ASTM D1092 at 40°F (Standard Test Method for Measuring Apparent Viscosity of Lubricating Greases).

Conclusions: The compatibility ratings of the products tested for dropping point, shear stability, and high-temperature storage stability, as described in ASTM D6185, are shown in Tables 1 through 3. Additional grease property data is shown in Tables 4 & 5, and Figure 1.

All data tables and charts for each compatibility criterion are shown in appendices A through D.

Table 1. Dropping Point Compatibility

Grease Description	*EAL #1*	*EAL #2*	*EAL #3*	*EAL #4*
Powerhouse #1	Compatible	Compatible	Compatible	Incompatible
Powerhouse #2	Compatible	Borderline Compatible	Compatible	Compatible
Powerhouse #3	Compatible	Compatible	Compatible	Incompatible
Powerhouse #4	Incompatible	Borderline Compatible	Compatible	Compatible
Huskey Hydrolube 878 NLGI 1	Compatible	Compatible	Compatible	Compatible

Table 2. Shear Stability

Grease Description	*EAL #1*	*EAL #2*	*EAL #3*	*EAL #4*
Powerhouse #1	Compatible	Compatible	Compatible	Incompatible
Powerhouse #2	Compatible	Compatible	Incompatible	Compatible
Powerhouse #3	Compatible	Compatible	Borderline Compatible	Borderline Compatible
Powerhouse #4	Compatible	Compatible	Compatible	Compatible
Huskey Hydrolube 878 NLGI 1	Compatible	Compatible	Compatible	Incompatible

Table 3. High-Temperature Storage Stability

Grease Description	*EAL #1*	*EAL #2*	*EAL #3*	*EAL #4*
Powerhouse #1	Borderline Compatible	Compatible	Compatible	Compatible
Powerhouse #2	Borderline Compatible	Borderline Compatible	Incompatible	Compatible
Powerhouse #3	Incompatible	Borderline Compatible	Borderline Compatible	Borderline Compatible
Powerhouse #4	Incompatible	Incompatible	Incompatible	Compatible
Huskey Hydrolube 878 NLGI 1	Compatible	Compatible	Incompatible	Compatible

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Table 4. Grease Property Data

Sample ID	Sample Description	ASTM D942 Oxidation Stability of Grease	ASTM D1264 Water Washout @ 38°C (100°F)*	ASTM D4048 Copper Corrosion @ 100°C, 24 hours	ASTM D2266 Four Ball Wear @ 75°C, 60 minutes, 40kgf load
		Mean Pressure Drop after 100 hours (psi)			Average Wear Scar (mm)
V0606664	EAL #1	8.0	4.19%	1B	0.442
V0606672	Powerhouse #2 Grease	2.0	2.47%	1A	0.730
V0606698	EAL #2	9.2	1.15%	3A	0.817
V0606764	EAL #3	3.5	19.63%	4B	0.452
V0606827	EAL #4	31.3	3.85%	1A	0.751

*Bearing dried at 77°C (171°F) for ASTM D1264

Table 5. ASTM D1092 Apparent Viscosity at 40°F Data

Sample ID	Sample Description	Sheaer Rate (s^{-1})	Pressure (psi)	Viscosity (P)
V0606664	EAL #1	17	30	781
		316	120	163
		12098	1480	53
V0606672	Powerhouse #2 Grease	17	15	390
		317	38	52
		12578	456	16
V0606698	EAL #2	17	40	1041
		316	99	135
		12312	1074	38
V0606764	EAL #3	17	47	1224
		316	146	199
		12224	1250	44
V0606827	EAL #4	17	20	507
		315	233	319
		2546	1360	230

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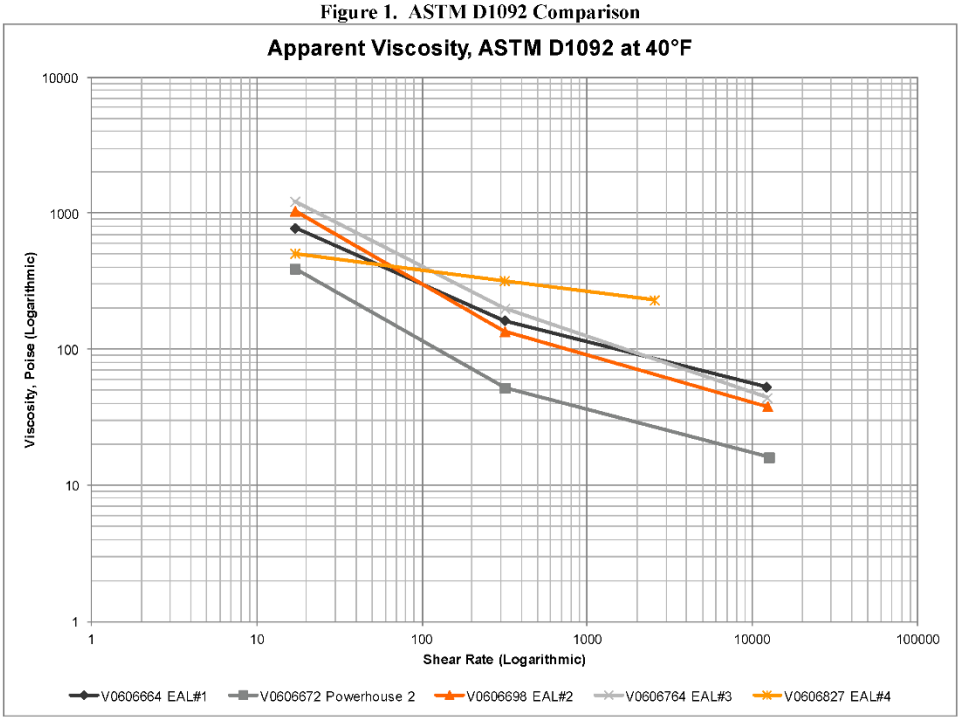
Figure 1. ASTM D1092 Comparison



Respectfully submitted,

Mindy Villalba

Mindy Villalba

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APPENDIX A
DATA TABLES

Table A1: Powerhouse #1 Grease & EAL #1

Grease	Mixture (%)	Lab ID	Dropping Point	High-Temperature Storage Stability		Shear Stability
			D2265 Dropping Point, °C (Before Heating)	D 1403 1/2 Scale Worked Cone Penetration, (Before Heating)	D 1403 1/2 Scale Worked Cone Penetration, (After Heating)	D217 100K Stroke Worked Cone Penetration
EAL #1	100	V0606664	197	275	225	279
A/B	90/10	V0606665	195	299	223	
A/B	50/50	V0606666	189	317	285	347
A/B	10/90	V0606667	173	399	323	
Powerhouse 1	100	V0606668	152	>400 (unworked)	327	>400 (unworked)

Table A2: Powerhouse #1 Grease & EAL #2

Grease	Mixture (%)	Lab ID	Dropping Point	High-Temperature Storage Stability		Shear Stability
			D2265 Dropping Point, °C (Before Heating)	D 1403 1/2 Scale Worked Cone Penetration, (Before Heating)	D 1403 1/2 Scale Worked Cone Penetration, (After Heating)	D217 100K Stroke Worked Cone Penetration
EAL #2	100	V0606698	187	279	241	252
A/B	90/10	V0606699	185	291	271	
A/B	50/50	V0606700	181	315	291	323
A/B	10/90	V0606701	167	>400	301	
Powerhouse 1	100	V0606668	152	>400 (unworked)	327	>400 (unworked)

Table A3: Powerhouse #1 Grease & EAL #3

Grease	Mixture (%)	Lab ID	Dropping Point	High-Temperature Storage Stability		Shear Stability
			D2265 Dropping Point, °C (Before Heating)	D 1403 1/2 Scale Worked Cone Penetration, (Before Heating)	D 1403 1/2 Scale Worked Cone Penetration, (After Heating)	D217 100K Stroke Worked Cone Penetration
EAL #3	100	V0606764	188	293	279	288
A/B	90/10	V0606765	184	305	280	
A/B	50/50	V0606766	194	299	299	334
A/B	10/90	V0606767	161	365	332	
Powerhouse 1	100	V0606668	152	>400 (unworked)	327	>400 (unworked)

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Table A4: Powerhouse #1 Grease & EAL #4

Grease	Mixture (%)	Lab ID	Dropping Point	High-Temperature Storage Stability		Shear Stability
			D2265 Dropping Point, °C (Before Heating)	D 1403 1/2 Scale Worked Cone Penetration, (Before Heating)	D 1403 1/2 Scale Worked Cone Penetration, (After Heating)	D217 100K Stroke Worked Cone Penetration
EAL #4	100	V0606827	107	377	>400 (unworked)	>400
A/B	90/10	V0606828	113	389	>400 (unworked)	
A/B	50/50	V0606829	169	395	397	340
A/B	10/90	V0606830	73	>400 (unworked)	>400 (unworked)	
Powerhouse 1	100	V0606668	152	>400 (unworked)	327	>400 (unworked)

Table A5: Powerhouse #2 Grease & EAL #1

Grease	Mixture (%)	Lab ID	Dropping Point	High-Temperature Storage Stability		Shear Stability
			D2265 Dropping Point, °C (Before Heating)	D 1403 1/2 Scale Worked Cone Penetration, (Before Heating)	D 1403 1/2 Scale Worked Cone Penetration, (After Heating)	D217 100K Stroke Worked Cone Penetration
EAL #1	100	V0606664	197	275	225	279
A/B	90/10	V0606669	198	261	223	
A/B	50/50	V0606670	201	301	257	314
A/B	10/90	V0606671	203	307	307	
Powerhouse 2	100	V0606672	199	325	281	332

Table A6: Powerhouse #2 Grease & EAL #2

Grease	Mixture (%)	Lab ID	Dropping Point	High-Temperature Storage Stability		Shear Stability
			D2265 Dropping Point, °C (Before Heating)	D 1403 1/2 Scale Worked Cone Penetration, (Before Heating)	D 1403 1/2 Scale Worked Cone Penetration, (After Heating)	D217 100K Stroke Worked Cone Penetration
EAL #2	100	V0606698	187	279	241	252
A/B	90/10	V0606702	196	303	305	
A/B	50/50	V0606703	190	305	281	300
A/B	10/90	V0606704	182	295	273	
Powerhouse 2	100	V0606672	199	325	281	332

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Table A7: Powerhouse #2 Grease & EAL #3

Grease	Mixture (%)	Lab ID	Dropping Point	High-Temperature Storage Stability		Shear Stability
			D2265 Dropping Point, °C (Before Heating)	D 1403 1/2 Scale Worked Cone Penetration, (Before Heating)	D 1403 1/2 Scale Worked Cone Penetration, (After Heating)	D217 100K Stroke Worked Cone Penetration
EAL #3	100	V0606764	188	293	279	288
A/B	90/10	V0606768	198	321	283	
A/B	50/50	V0606769	203	343	309	344
A/B	10/90	V0606770	200	341	323	
Powerhouse 2	100	V0606672	199	325	281	332

Table A8: Powerhouse #2 Grease & EAL #4

Grease	Mixture (%)	Lab ID	Dropping Point	High-Temperature Storage Stability		Shear Stability
			D2265 Dropping Point, °C (Before Heating)	D 1403 1/2 Scale Worked Cone Penetration, (Before Heating)	D 1403 1/2 Scale Worked Cone Penetration, (After Heating)	D217 100K Stroke Worked Cone Penetration
EAL #4	100	V0606827	107	377	>400 unworked	>400
A/B	90/10	V0606831	117	361	>400 unworked	
A/B	50/50	V0606832	179	341	>400 unworked	347
A/B	10/90	V0606833	198	341	339	
Powerhouse 2	100	V0606672	199	325	281	332

Table A9: Powerhouse #3 Grease & EAL #1

Grease	Mixture (%)	Lab ID	Dropping Point	High-Temperature Storage Stability		Shear Stability
			D2265 Dropping Point, °C (Before Heating)	D 1403 1/2 Scale Worked Cone Penetration, (Before Heating)	D 1403 1/2 Scale Worked Cone Penetration, (After Heating)	D217 100K Stroke Worked Cone Penetration
EAL #1	100	V0606664	197	275	225	279
A/B	90/10	V0606673	203	283	233	
A/B	50/50	V0606674	203	297	243	298
A/B	10/90	V0606675	202	281	243	
Powerhouse 3	100	V0606676	205	275	241	301

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Table A10: Powerhouse #3 Grease & EAL #2

Grease	Mixture (%)	Lab ID	Dropping Point	High-Temperature Storage Stability		Shear Stability
			D2265 Dropping Point, °C (Before Heating)	D 1403 1/2 Scale Worked Cone Penetration, (Before Heating)	D 1403 1/2 Scale Worked Cone Penetration, (After Heating)	D217 100K Stroke Worked Cone Penetration
EAL #2	100	V0606698	187	279	241	252
A/B	90/10	V0606705	190	267	263	
A/B	50/50	V0606706	191	283	259	281
A/B	10/90	V0606707	196	273	279	
Powerhouse 3	100	V0606676	205	275	241	301

Table A11: Powerhouse #3 Grease & EAL #3

Grease	Mixture (%)	Lab ID	Dropping Point	High-Temperature Storage Stability		Shear Stability
			D2265 Dropping Point, °C (Before Heating)	D 1403 1/2 Scale Worked Cone Penetration, (Before Heating)	D 1403 1/2 Scale Worked Cone Penetration, (After Heating)	D217 100K Stroke Worked Cone Penetration
EAL #3	100	V0606764	188	293	279	288
A/B	90/10	V0606771	193	301	277	
A/B	50/50	V0606772	201	307	279	302
A/B	10/90	V0606773	191	295	277	
Powerhouse 3	100	V0606676	205	275	241	301

Table A12: Powerhouse #3 Grease & EAL #4

Grease	Mixture (%)	Lab ID	Dropping Point	High-Temperature Storage Stability		Shear Stability
			D2265 Dropping Point, °C (Before Heating)	D 1403 1/2 Scale Worked Cone Penetration, (Before Heating)	D 1403 1/2 Scale Worked Cone Penetration, (After Heating)	D217 100K Stroke Worked Cone Penetration
EAL #4	100	V0606827	107	377	>400 unworked	400
A/B	90/10	V0606834	99	>400	>400 unworked	
A/B	50/50	V0606835	174	279	345	293
A/B	10/90	V0606836	190	295	273	
Powerhouse 3	100	V0606676	205	275	241	301

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Table A13: Powerhouse #4 Grease & EAL #1

Grease	Mixture (%)	Lab ID	Dropping Point	High-Temperature Storage Stability		Shear Stability
			D2265 Dropping Point, °C (Before Heating)	D 1403 1/2 Scale Worked Cone Penetration, (Before Heating)	D 217/D 1403 Worked Cone Penetration, (After Heating)	D217 100K Stroke Worked Cone Penetration
EAL #1	100	V0606664	197	275	225	279
A/B	90/10	V0606677	191	287	243	
A/B	50/50	V0606678	186	257	287	292
A/B	10/90	V0606679	241	229	303	
Powerhouse 4	100	V0606680	269	225	281	318

Table A14: Powerhouse #4 Grease & EAL #2

Grease	Mixture (%)	Lab ID	Dropping Point	High-Temperature Storage Stability		Shear Stability
			D2265 Dropping Point, °C (Before Heating)	D 1403 1/2 Scale Worked Cone Penetration, (Before Heating)	D 217/D 1403 Worked Cone Penetration, (After Heating)	D217 100K Stroke Worked Cone Penetration
EAL #2	100	V0606698	187	279	241	252
A/B	90/10	V0606708	184	255	279	
A/B	50/50	V0606709	185	247	241	300
A/B	10/90	V0606710	257	243	345	
Powerhouse 4	100	V0606680	269	225	281	318

Table A15: Powerhouse #4 Grease & EAL #3

Grease	Mixture (%)	Lab ID	Dropping Point	High-Temperature Storage Stability		Shear Stability
			D2265 Dropping Point, °C (Before Heating)	D 1403 1/2 Scale Worked Cone Penetration, (Before Heating)	D 1403 1/2 Scale Worked Cone Penetration, (After Heating)	D217 100K Stroke Worked Cone Penetration
EAL #3	100	V0606764	188	293	279	288
A/B	90/10	V0606774	195	301	283	
A/B	50/50	V0606775	191	297	355	302
A/B	10/90	V0606776	224	261	341	
Powerhouse 4	100	V0606680	269	225	281	318

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Table A16: Powerhouse #4 Grease & EAL #4

Grease	Mixture (%)	Lab ID	Dropping Point	High-Temperature Storage Stability		Shear Stability
			D2265 Dropping Point, °C (Before Heating)	D 1403 1/2 Scale Worked Cone Penetration, (Before Heating)	D 1403 1/2 Scale Worked Cone Penetration, (After Heating)	D217 100K Stroke Worked Cone Penetration
EAL #4	100	V0606827	107	377	>400 unworked	>400
A/B	90/10	V0606837	110	341	>400 unworked	
A/B	50/50	V0606838	196	267	385	336
A/B	10/90	V0606839	250	241	>400 unworked	
Powerhouse 4	100	V0606680	269	225	281	318

Table A17: Huskey Hydrolube 878 NLGI 1 Grease & EAL #1

Grease	Mixture (%)	Lab ID	Dropping Point	High-Temperature Storage Stability		Shear Stability
			D2265 Dropping Point, °C (Before Heating)	D 1403 1/2 Scale Worked Cone Penetration, (Before Heating)	D 1403 1/2 Scale Worked Cone Penetration, (After Heating)	D217 100K Stroke Worked Cone Penetration
EAL #1	100	V0606664	197	275	225	279
A/B	90/10	V0606715	198	257	243	
A/B	50/50	V0606716	221	261	259	309
A/B	10/90	V0606717	>307	269	259	
Huskey Hydrolube 878 NLGI 1	100	V0606718	>307	261	291	331

Table A18: Huskey Hydrolube 878 NLGI 1 Grease & EAL #2

Grease	Mixture (%)	Lab ID	Dropping Point	High-Temperature Storage Stability		Shear Stability
			D2265 Dropping Point, °C (Before Heating)	D 1403 1/2 Scale Worked Cone Penetration, (Before Heating)	D 1403 1/2 Scale Worked Cone Penetration, (After Heating)	D217 100K Stroke Worked Cone Penetration
EAL #2	100	V0606698	187	279	241	252
A/B	90/10	V0606719	204	277	269	
A/B	50/50	V0606720	198	247	257	304
A/B	10/90	V0606721	>307	247	257	
Huskey Hydrolube 878 NLGI 1	100	V0606718	>307	261	291	331

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Table A19: Huskey Hydrolube 878 NLGI 1 Grease & EAL #3

Grease	Mixture (%)	Lab ID	Dropping Point	High-Temperature Storage Stability		Shear Stability
			D2265 Dropping Point, °C (Before Heating)	D 1403 1/2 Scale Worked Cone Penetration, (Before Heating)	D 1403 1/2 Scale Worked Cone Penetration, (After Heating)	D217 100K Stroke Worked Cone Penetration
EAL #3	100	V0606764	188	293	279	288
A/B	90/10	V0606777	225	297	245	
A/B	50/50	V0606778	225	315	259	323
A/B	10/90	V0606779	>307	297	265	
Huskey Hydrolube 878 NLGI Grade 1	100	V0606718	>307	261	291	331

Table A20: Huskey Hydrolube 878 NLGI 1 Grease & EAL #4

Grease	Mixture (%)	Lab ID	Dropping Point	High-Temperature Storage Stability		Shear Stability
			D2265 Dropping Point, °C (Before Heating)	D 1403 1/2 Scale Worked Cone Penetration, (Before Heating)	D 1403 1/2 Scale Worked Cone Penetration, (After Heating)	D217 100K Stroke Worked Cone Penetration
EAL #4	100	V0606827	107	377	>400 unworked	>400
A/B	90/10	V0606840	115	379	>400 unworked	
A/B	50/50	V0606841	282	323	347	320
A/B	10/90	V0606842	>307	301	305	
Huskey Hydrolube 878 NLGI Grade 1	100	V0606718	>307	261	291	331

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APPENDIX B
DROPPING POINT CHARTS

Figure B1: Powerhouse #1 Grease & EAL #1

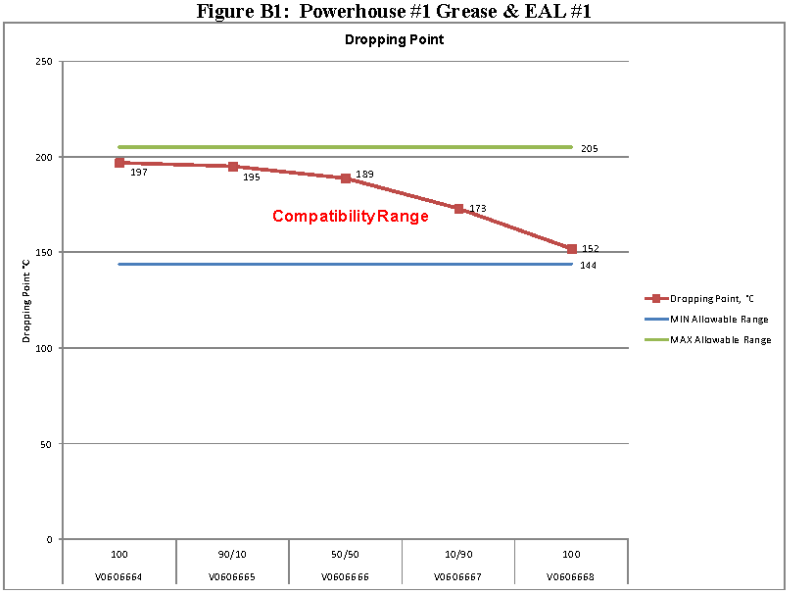

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Figure B2: Powerhouse #1 Grease & EAL #2

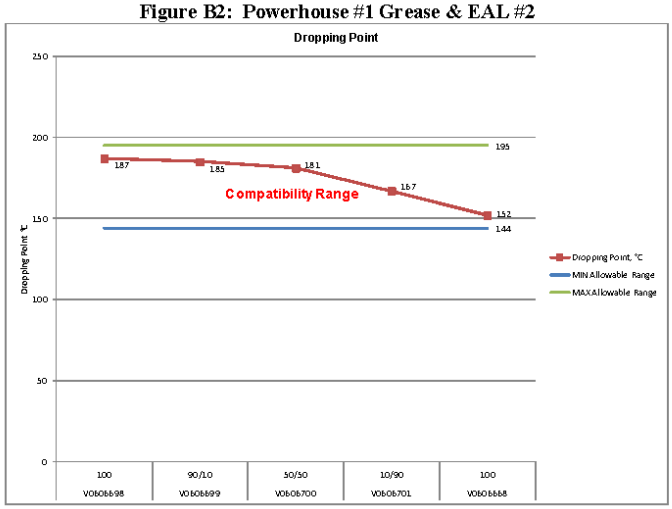

Figure B3: Powerhouse #1 Grease & EAL #3

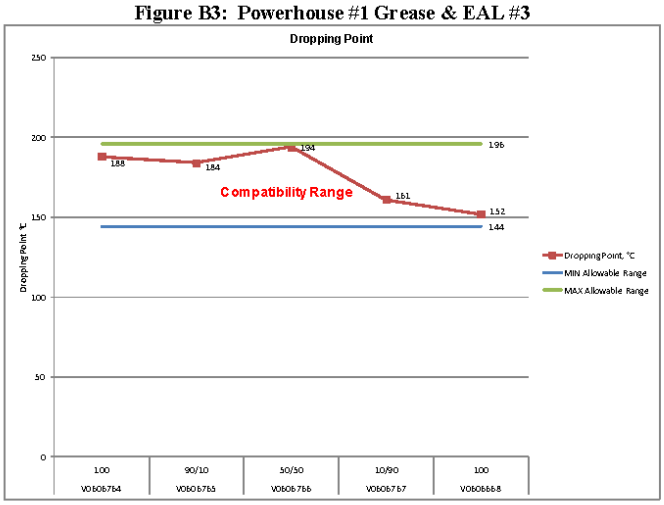

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Figure B4: Powerhouse #1 Grease & EAL #4

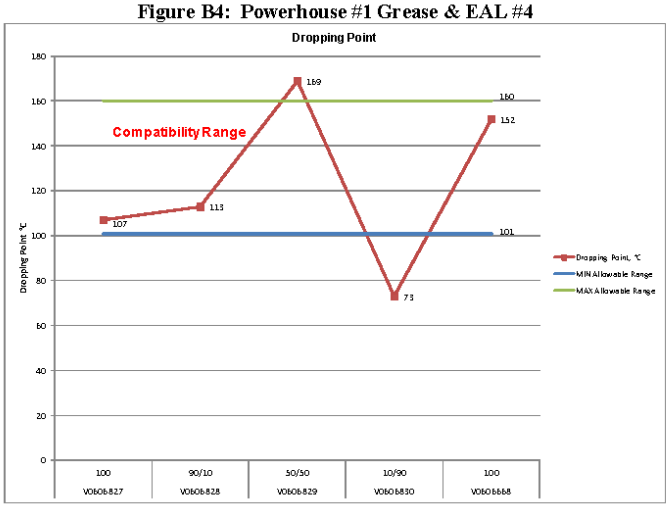
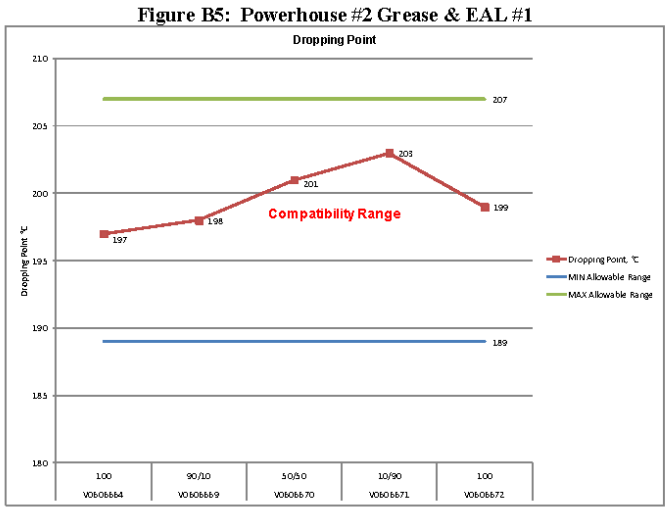


Figure B5: Powerhouse #2 Grease & EAL #1



Page 14 of 44

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Figure B6: Powerhouse #2 Grease & EAL #2

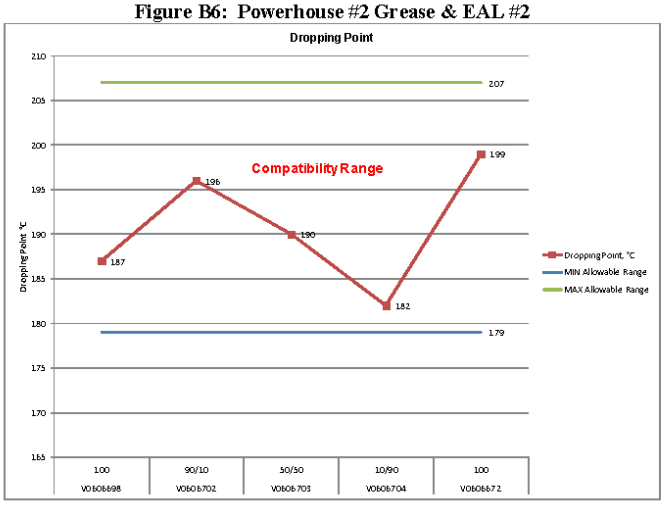

Figure B7: Powerhouse #2 Grease & EAL #3

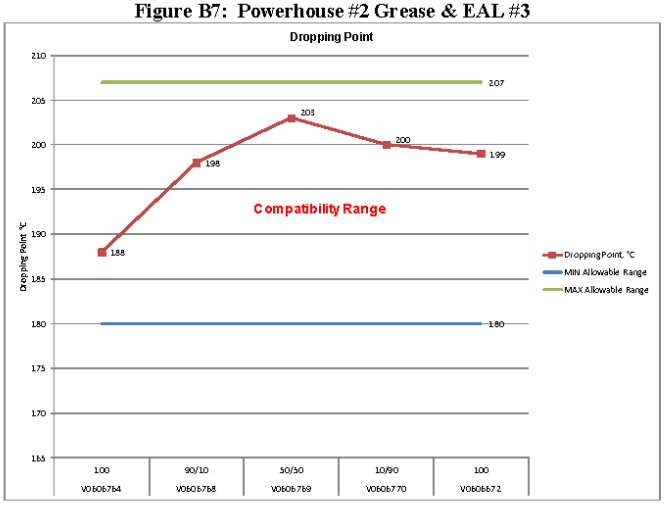

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Figure B8: Powerhouse #2 Grease & EAL #4

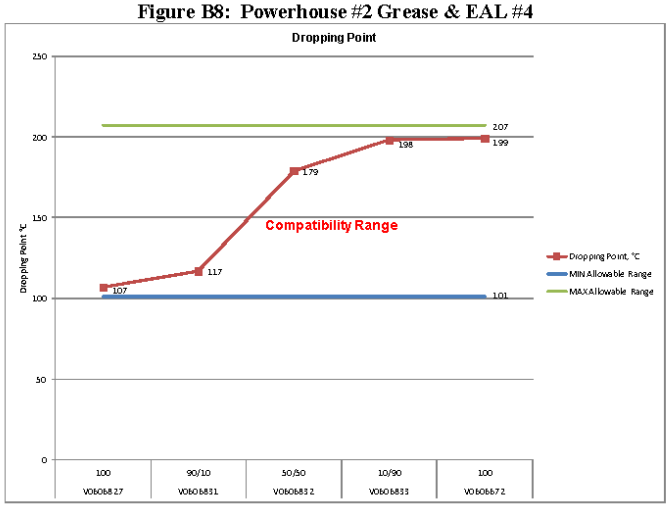

Figure B9: Powerhouse #3 Grease & EAL #1

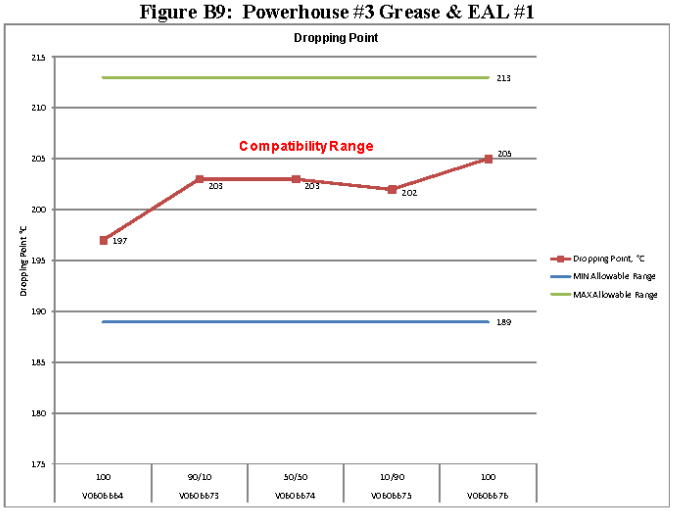

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Figure B10: Powerhouse #3 Grease & EAL #2

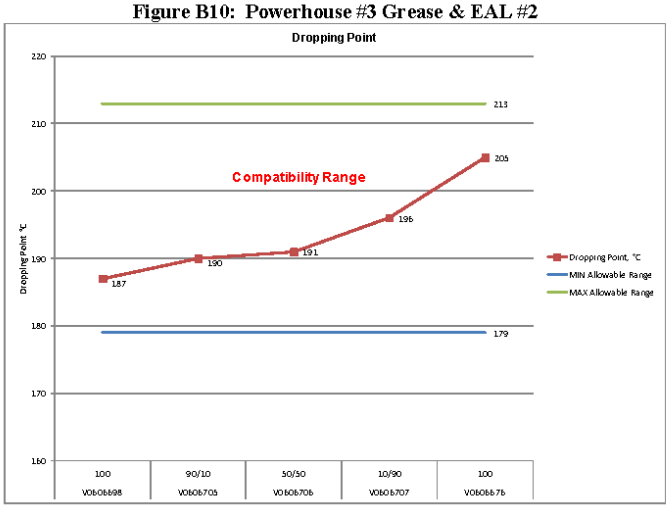

Figure B11: Powerhouse #3 Grease & EAL #3

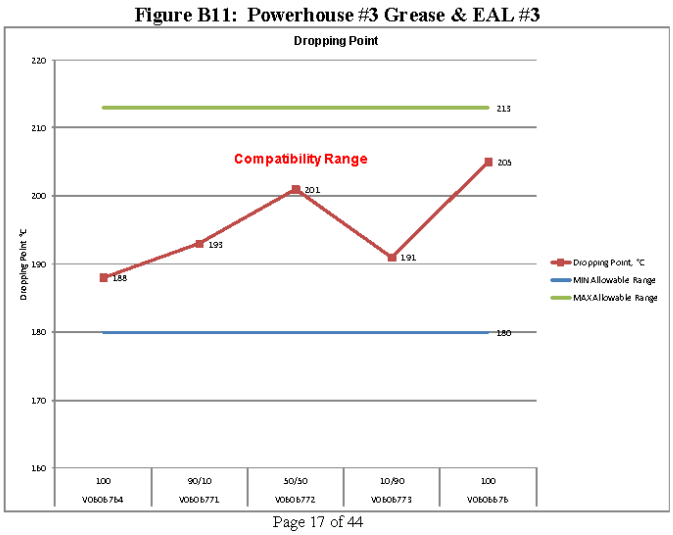

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Figure B12: Powerhouse #3 Grease & EAL #4

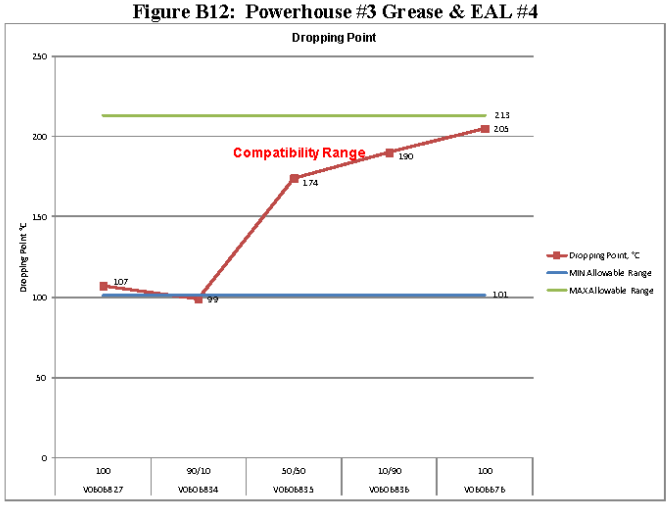

Figure B13: Powerhouse #4 Grease & EAL #1

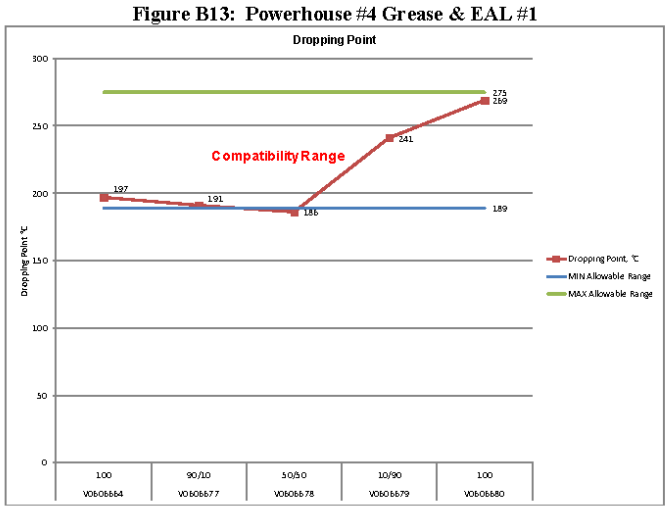

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Figure B14: Powerhouse #4 Grease & EAL #2

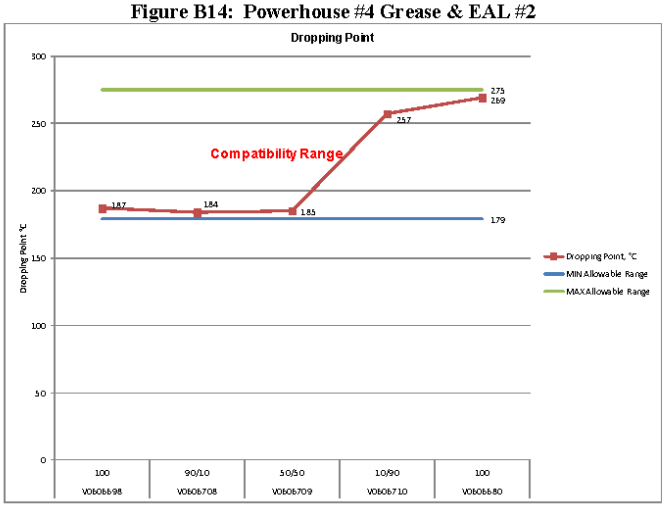

Figure B15: Powerhouse #4 Grease & EAL #3

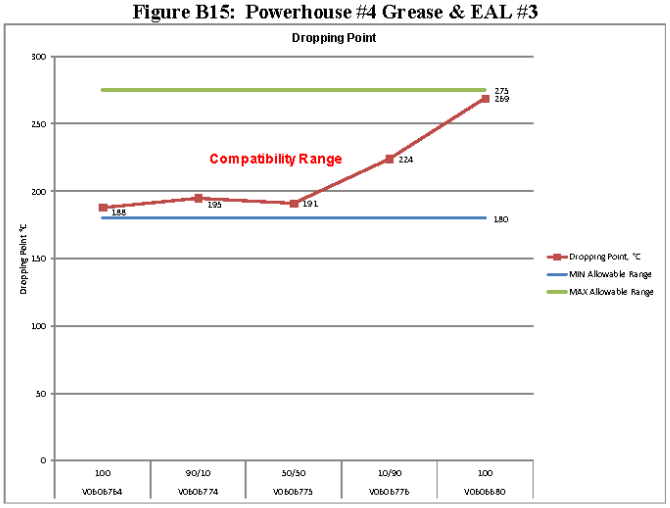

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Figure B16: Powerhouse #4 Grease & EAL #4

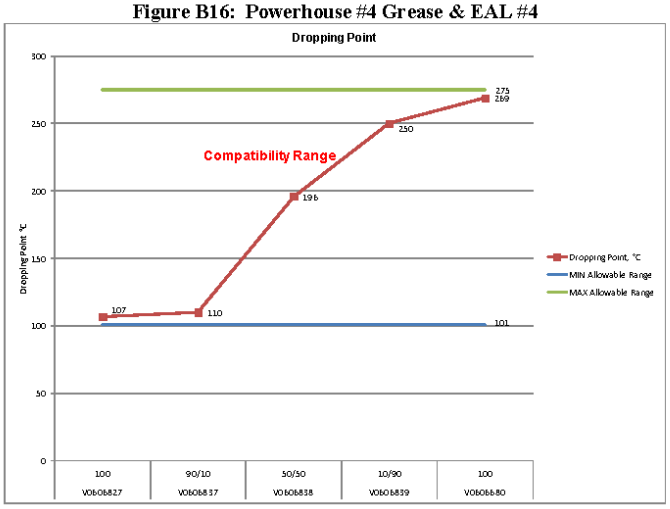

Figure B17: Huskey Hydrolube 878 NLGI 1 Grease & EAL #1

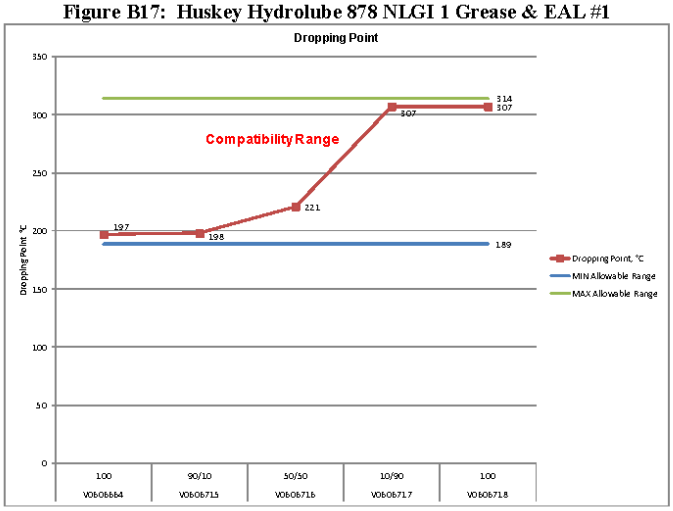

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Figure B18: Huskey Hydrolube 878 NLGI 1 Grease & EAL #2

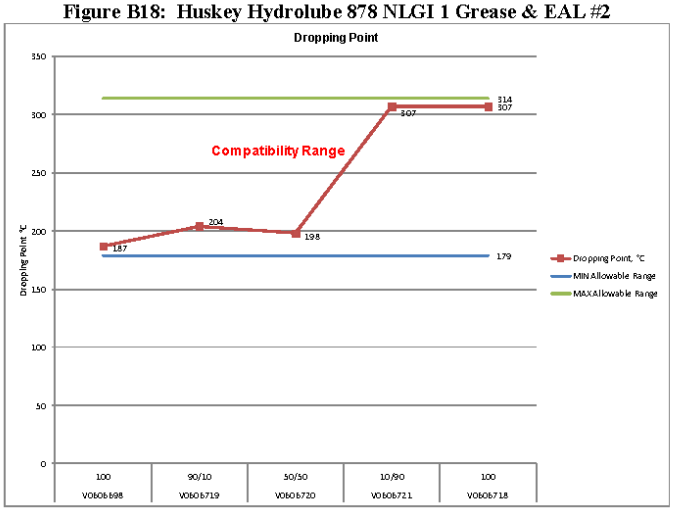

Figure B19: Huskey Hydrolube 878 NLGI 1 Grease & EAL #3

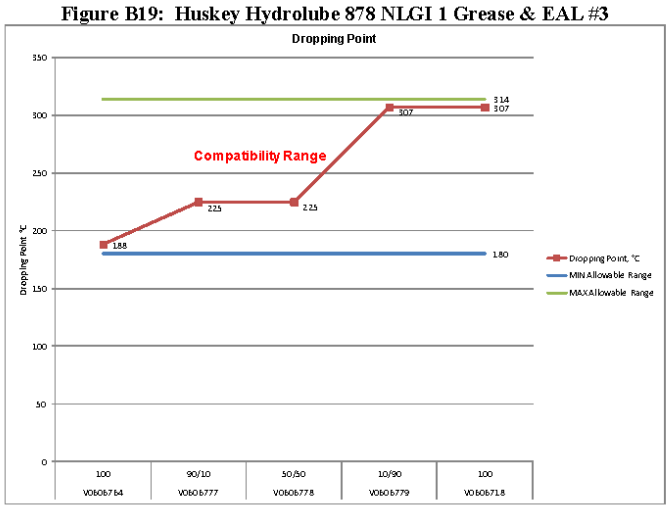

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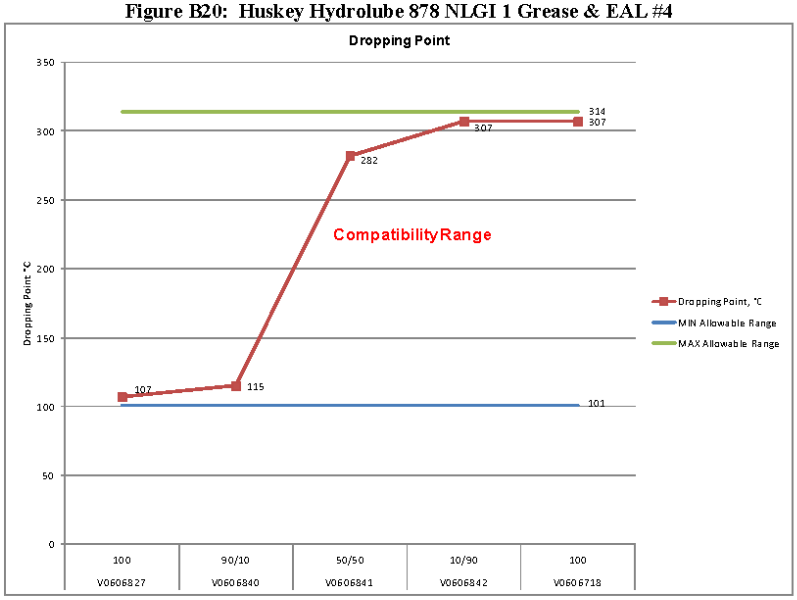
Figure B20: Huskey Hydrolube 878 NLGI 1 Grease & EAL #4



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APPENDIX C
SHEAR STABILITY CONE PENETRATION CHARTS

Figure C1: Powerhouse #1 Grease & EAL #1

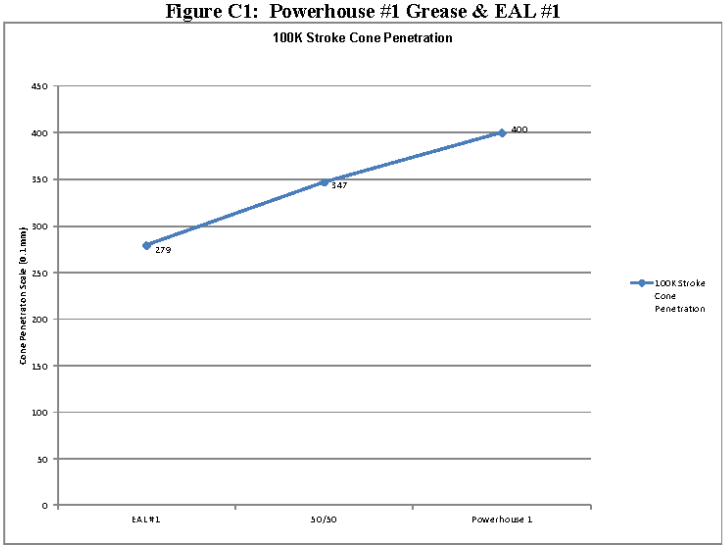

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Figure C2: Powerhouse #1 Grease & EAL #2

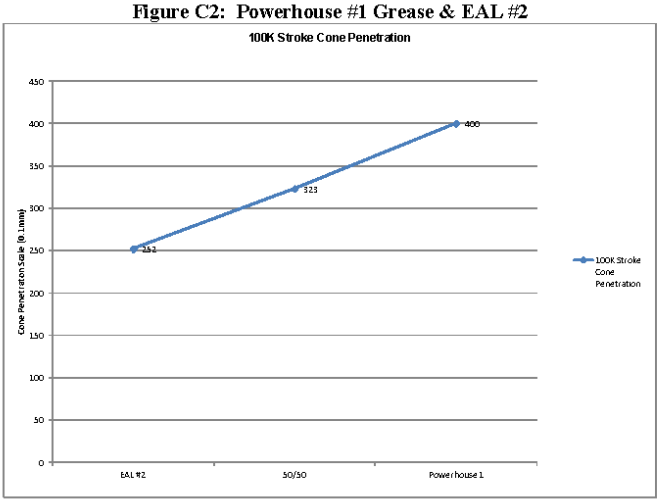

Figure C3: Powerhouse #1 Grease & EAL #3

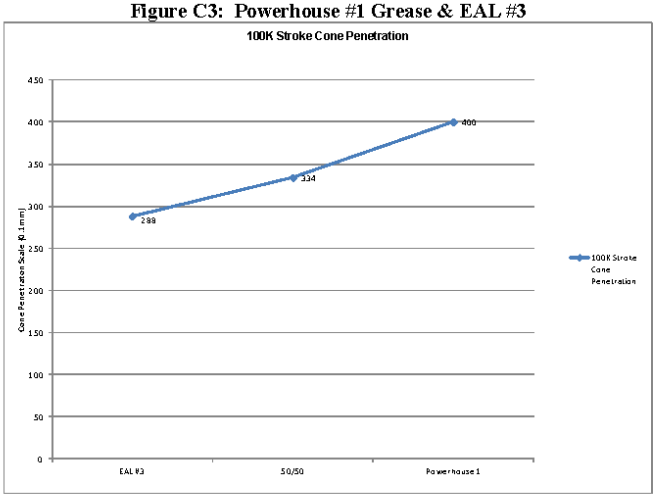

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Figure C4: Powerhouse #1 Grease & EAL #4

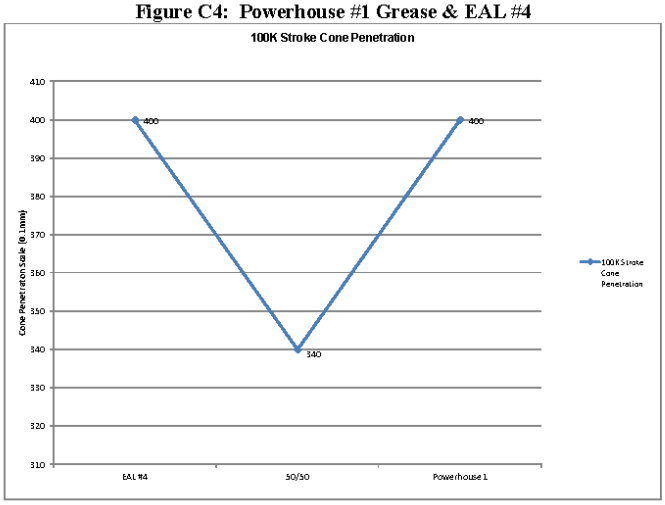

Figure C5: Powerhouse #2 Grease & EAL #1

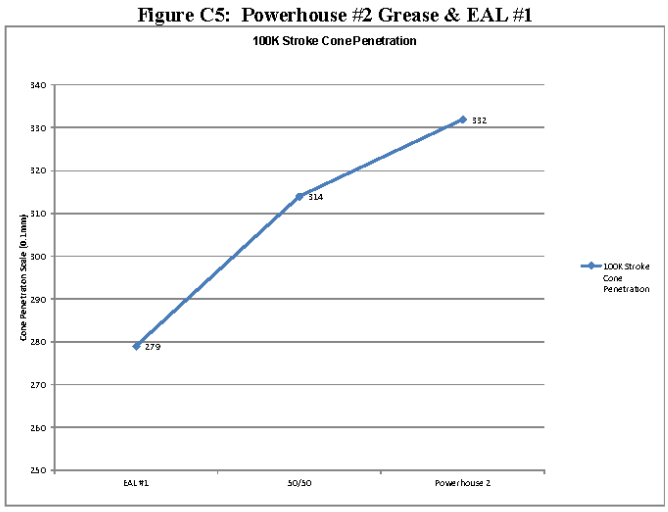

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Figure C6: Powerhouse #2 Grease & EAL #2

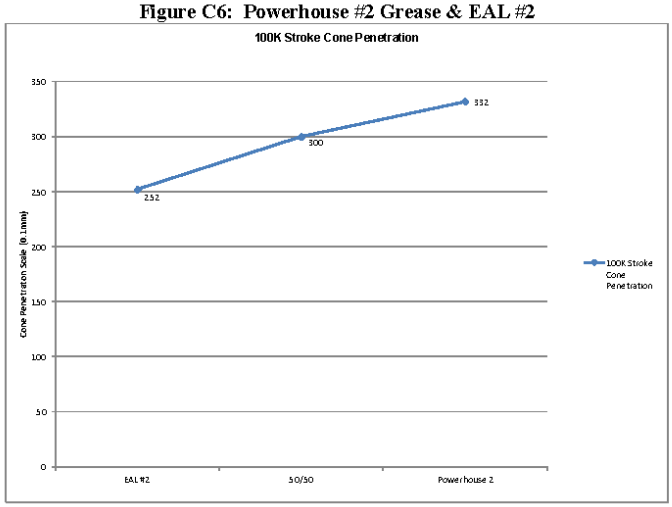

Figure C7: Powerhouse #2 Grease & EAL #3

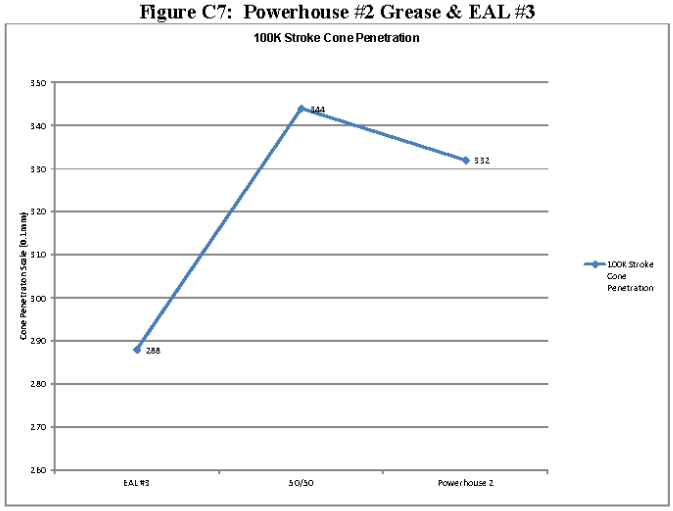

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Figure C8: Powerhouse #2 Grease & EAL #4

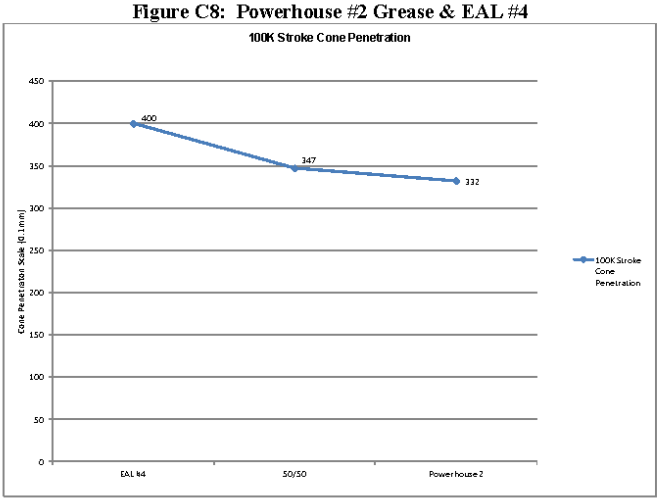

Figure C9: Powerhouse #3 Grease & EAL #1

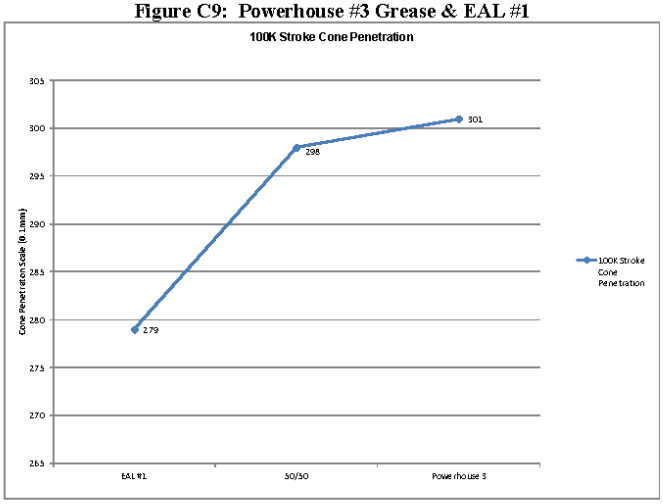

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Figure C10: Powerhouse #3 Grease & EAL #2

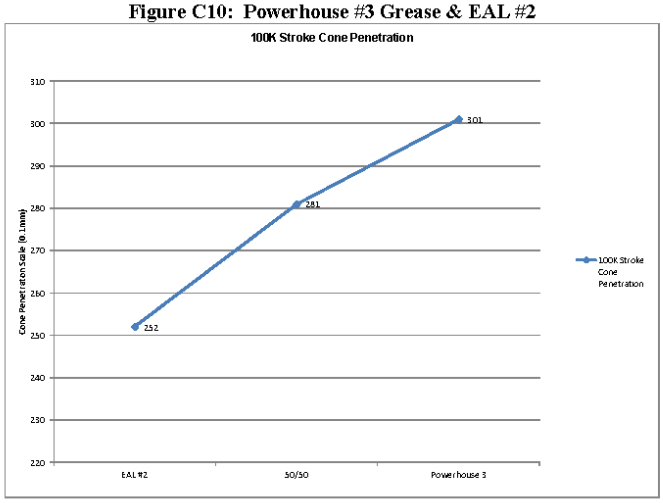

Figure C11: Powerhouse #3 Grease & EAL #3

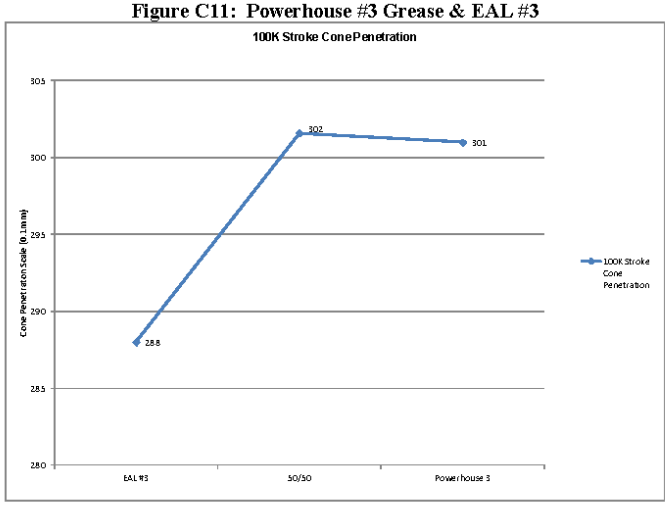

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Figure C12: Powerhouse #3 Grease & EAL #4

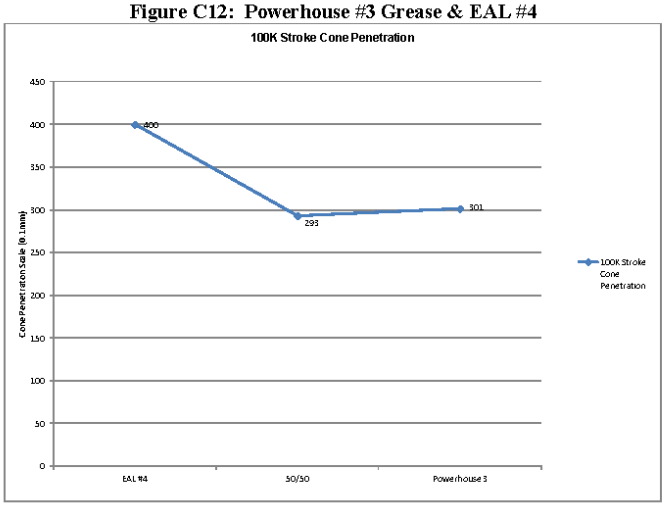

Figure C13: Powerhouse #4 Grease & EAL #1

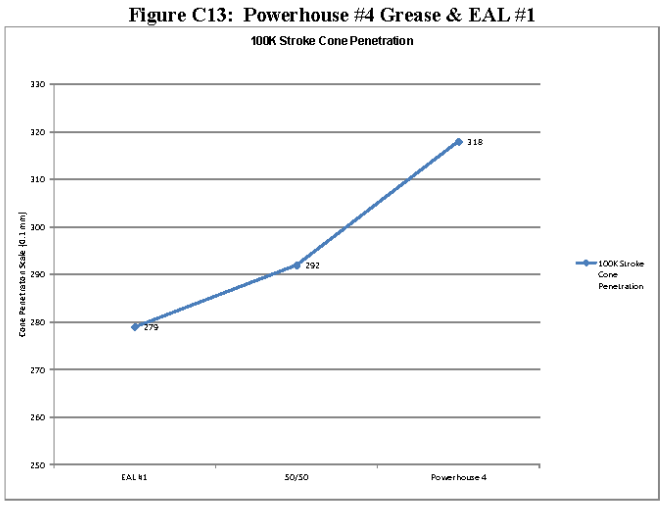

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Figure C14: Powerhouse #4 Grease & EAL #2

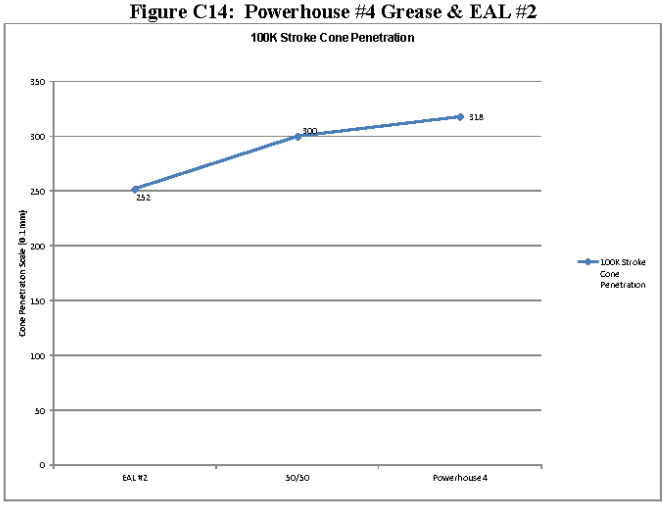

Figure C15: Powerhouse #4 Grease & EAL #3

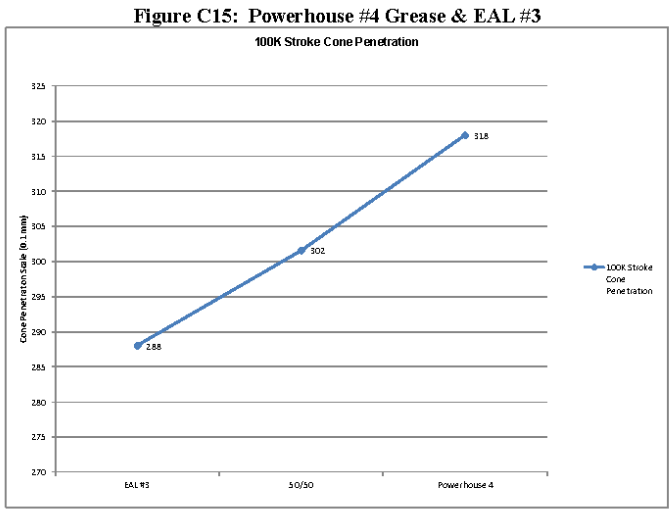

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Figure C16: Powerhouse #4 Grease & EAL #4

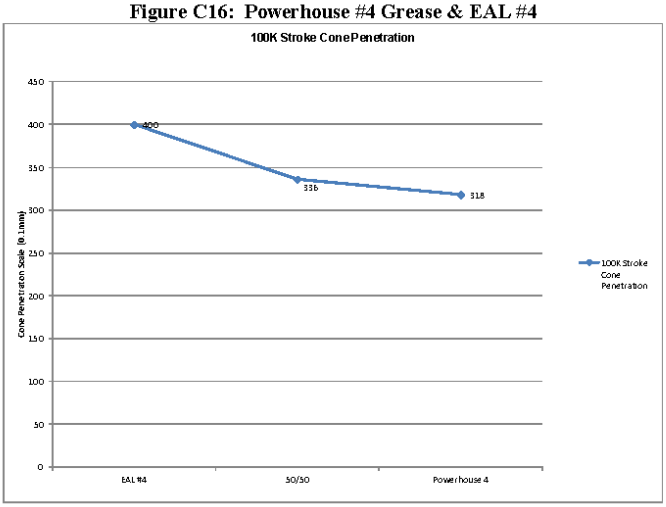

Figure C17: Huskey Hydrolube 878 NLGI 1 Grease & EAL #1

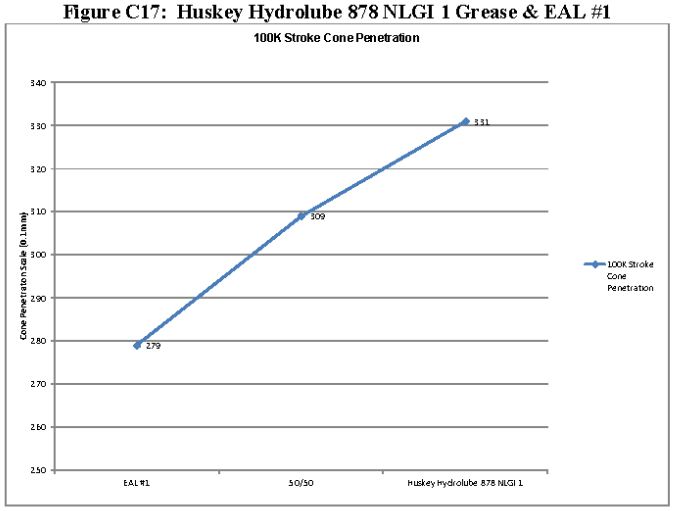

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Figure C18: Huskey Hydrolube 878 NLGI 1 Grease & EAL #2

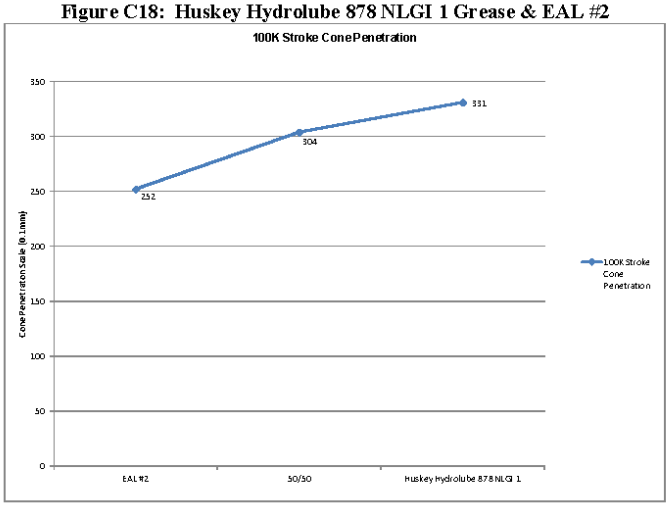

Figure C19: Huskey Hydrolube 878 NLGI 1 Grease & EAL #3

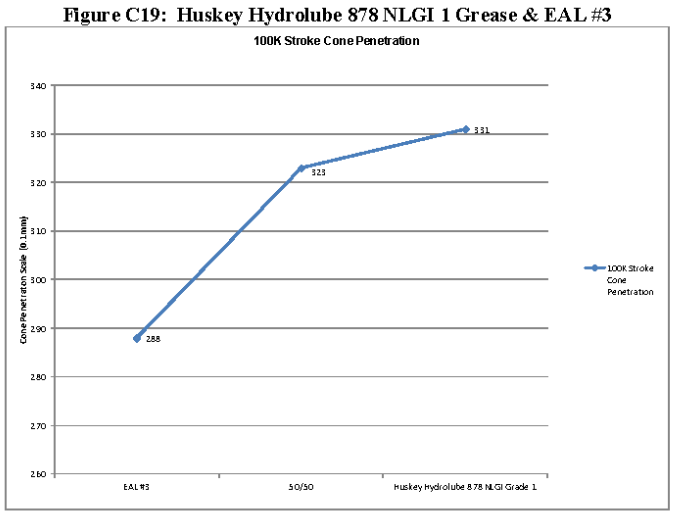

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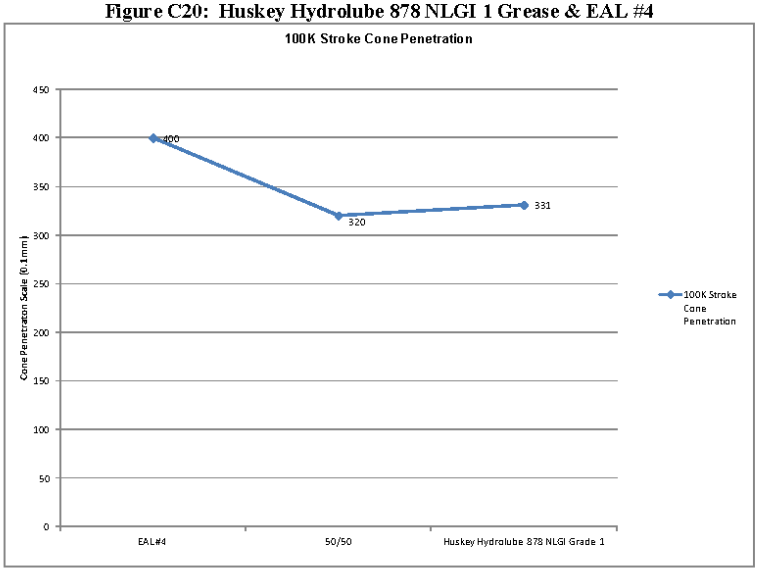
Figure C20: Huskey Hydrolube 878 NLGI 1 Grease & EAL #4



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APPENDIX D
STORAGE STABILITY CONE PENETRATION CHARTS

Figure D1: Powerhouse #1 Grease & EAL #1

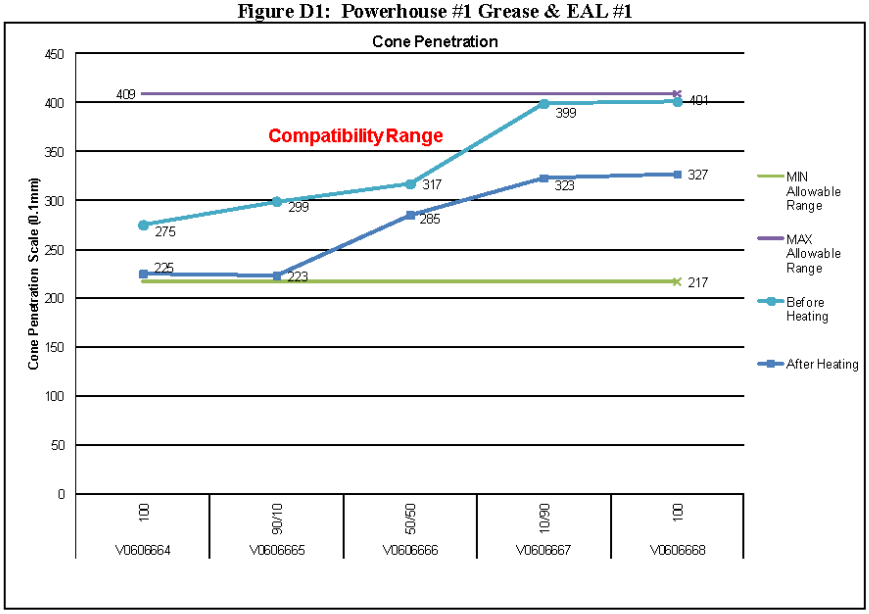

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Figure D2: Powerhouse #1 Grease & EAL #2

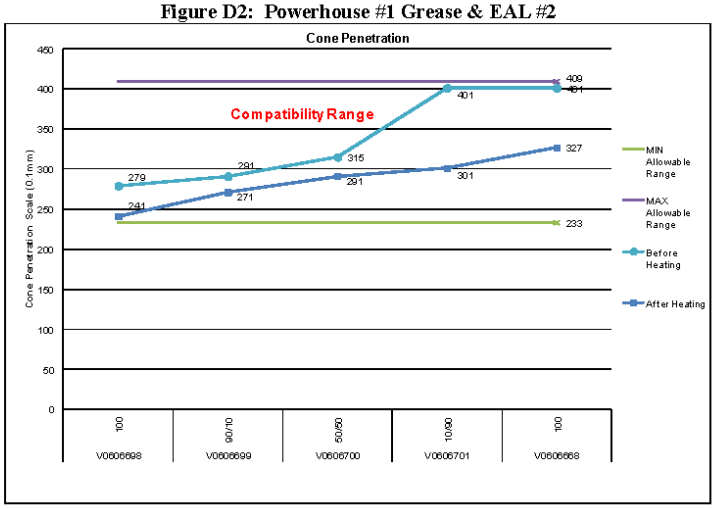

Figure D3: Powerhouse #1 Grease & EAL #3

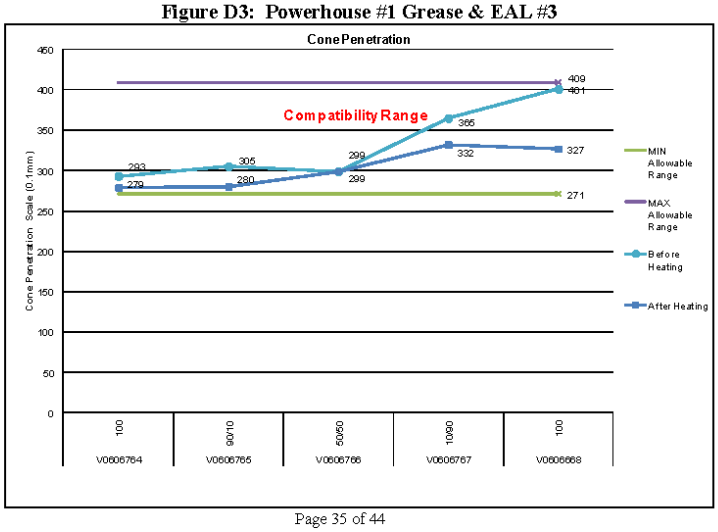

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Figure D4: Powerhouse #1 Grease & EAL #4

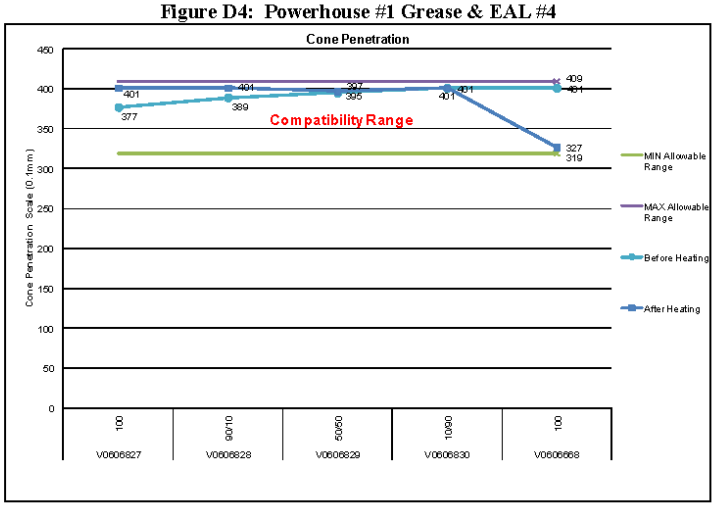

Figure D5: Powerhouse #2 Grease & EAL #1

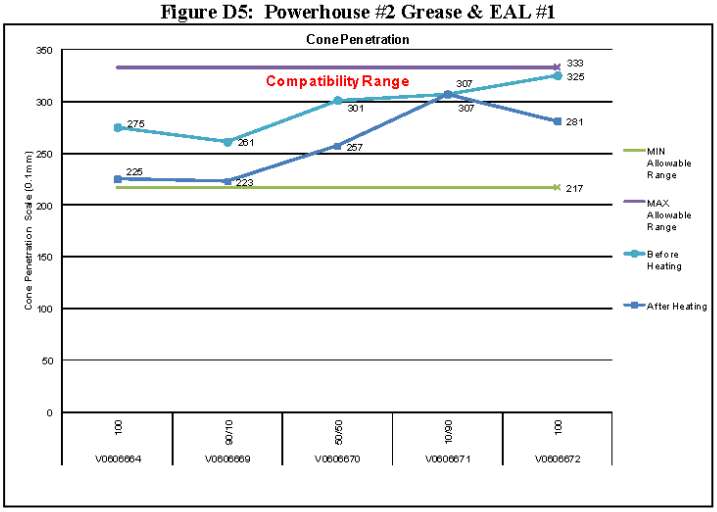

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Figure D6: Powerhouse #2 Grease & EAL #2

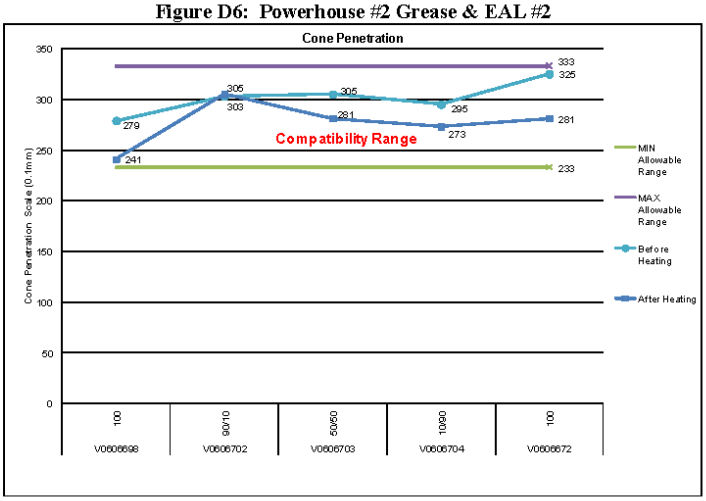

Figure D7: Powerhouse #2 Grease & EAL #3

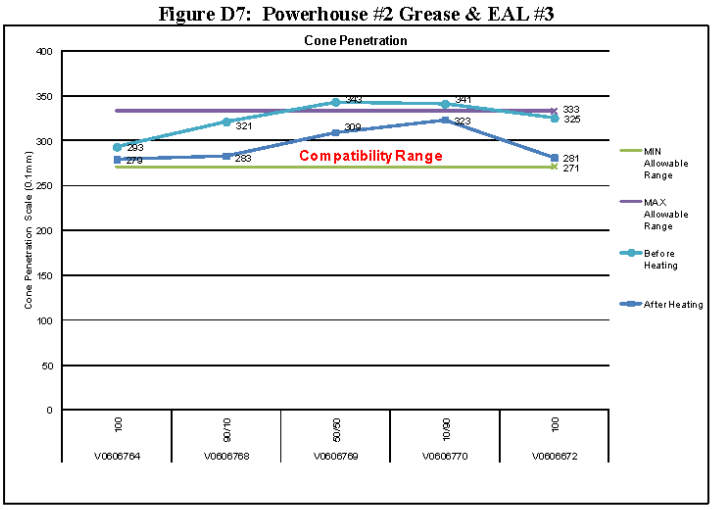

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Figure D8: Powerhouse #2 Grease & EAL #4

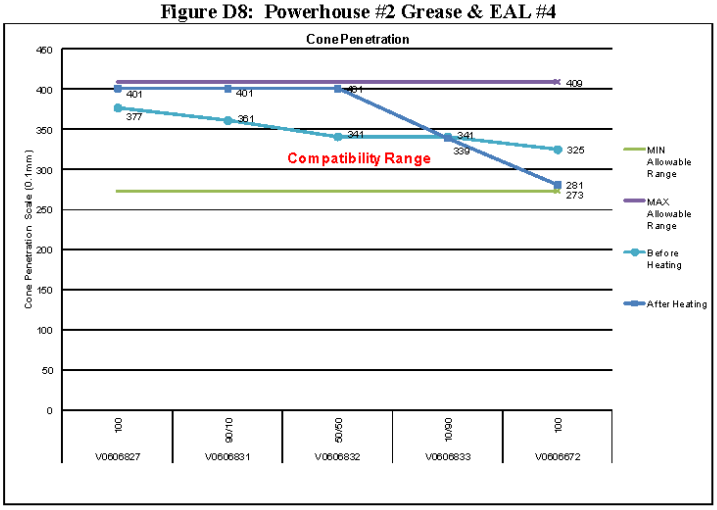

Figure D9: Powerhouse #3 Grease & EAL #1

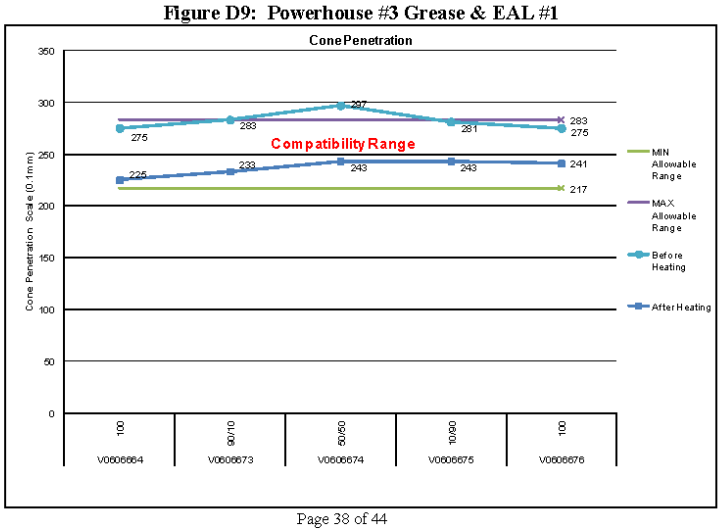

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Figure D10: Powerhouse #3 Grease & EAL #2

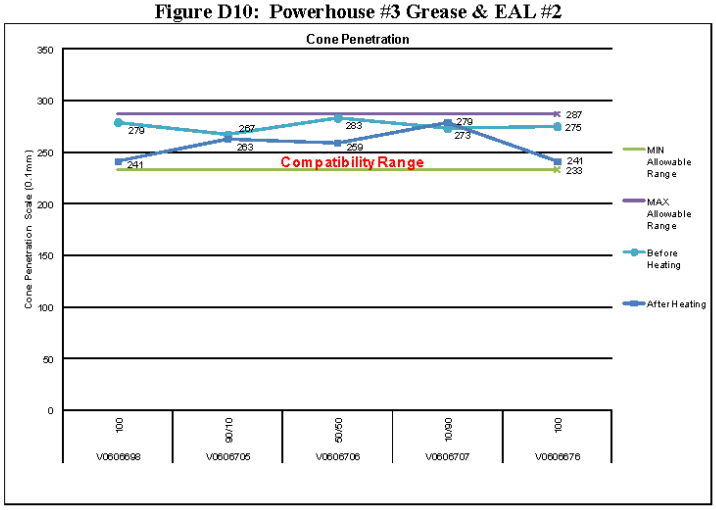

Figure D11: Powerhouse #3 Grease & EAL #3

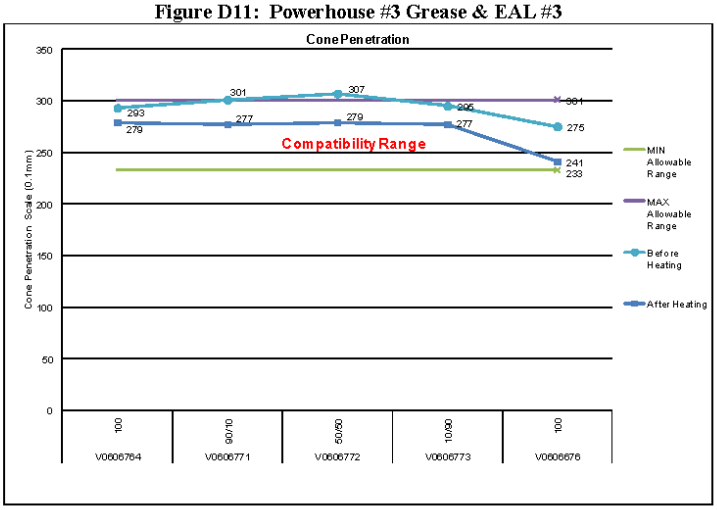

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Figure D12: Powerhouse #3 Grease & EAL #4

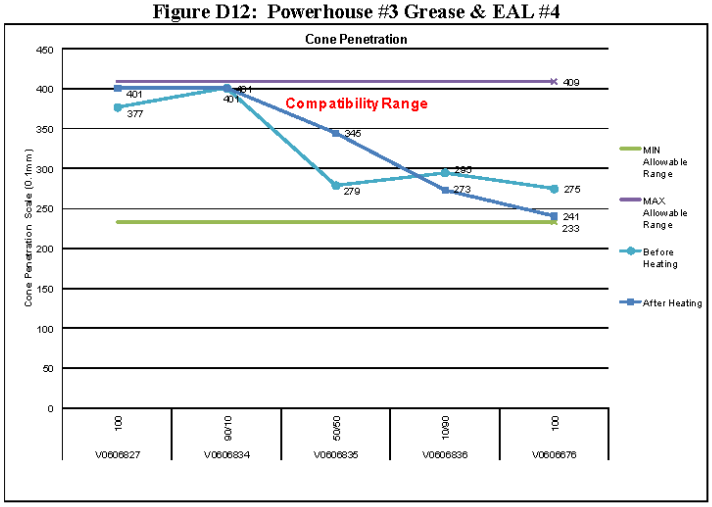

Figure D13: Powerhouse #4 Grease & EAL #1

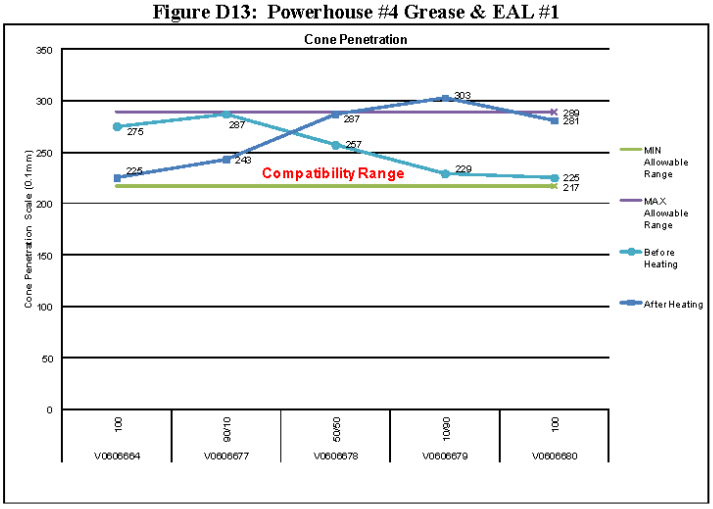

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Figure D14: Powerhouse #4 Grease & EAL #2

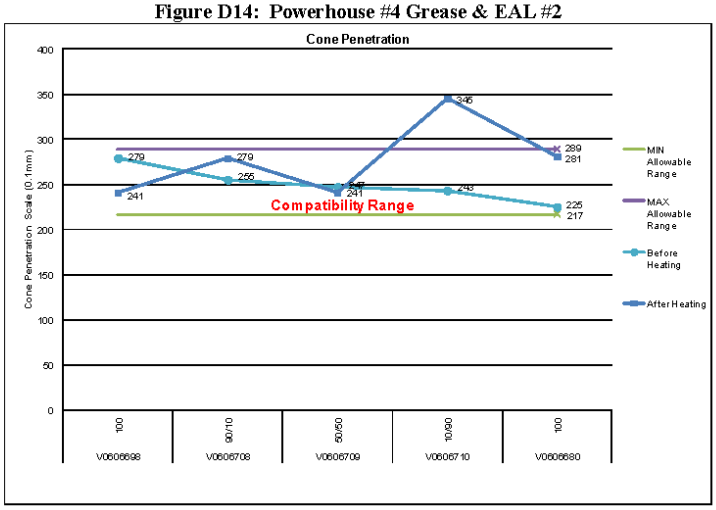

Figure D15: Powerhouse #4 Grease & EAL #3

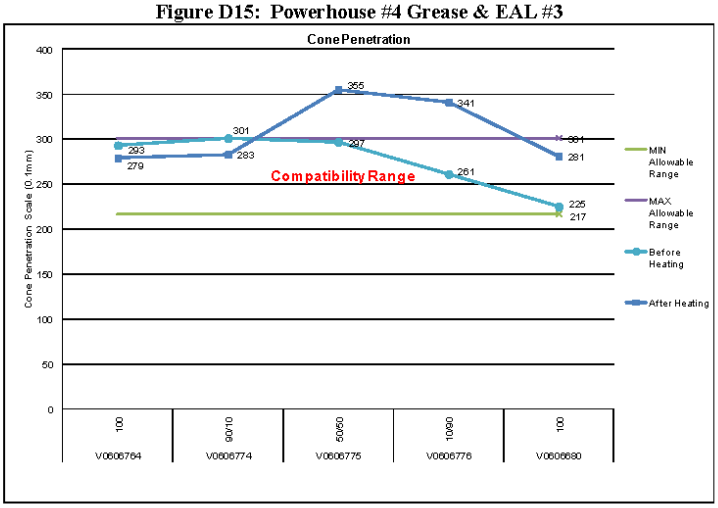

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Figure D16: Powerhouse #4 Grease & EAL #4

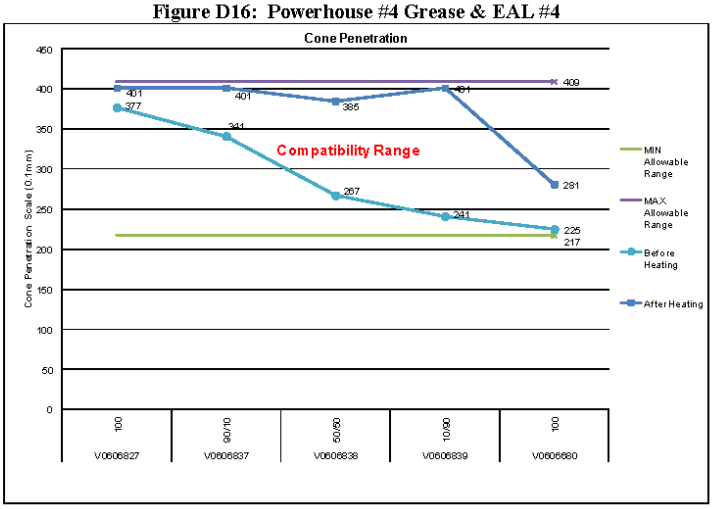

Figure D17: Huskey Hydrolube 878 NLGI 1 Grease & EAL #1

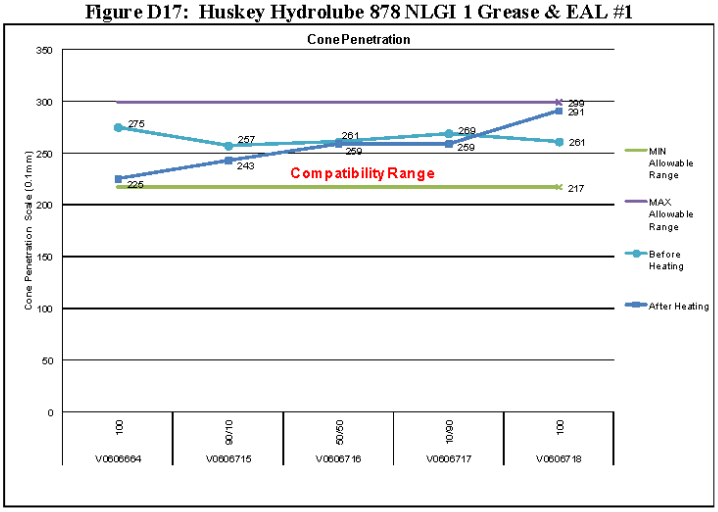

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Figure D18: Huskey Hydrolube 878 NLGI 1 Grease & EAL #2

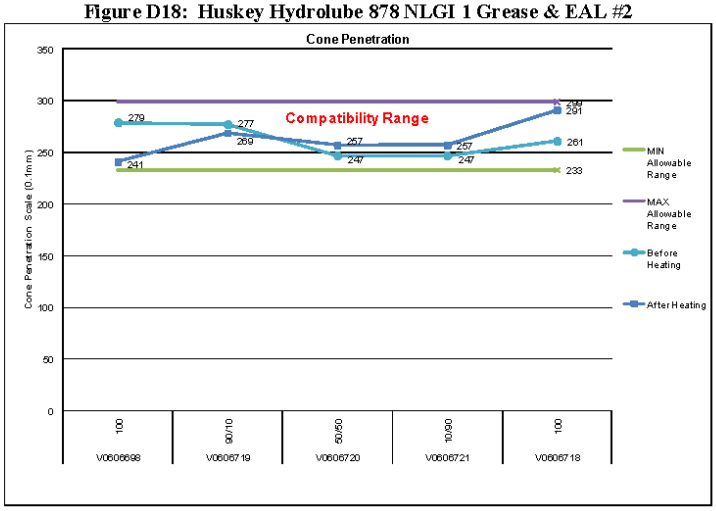

Figure D19: Huskey Hydrolube 878 NLGI 1 Grease & EAL #3

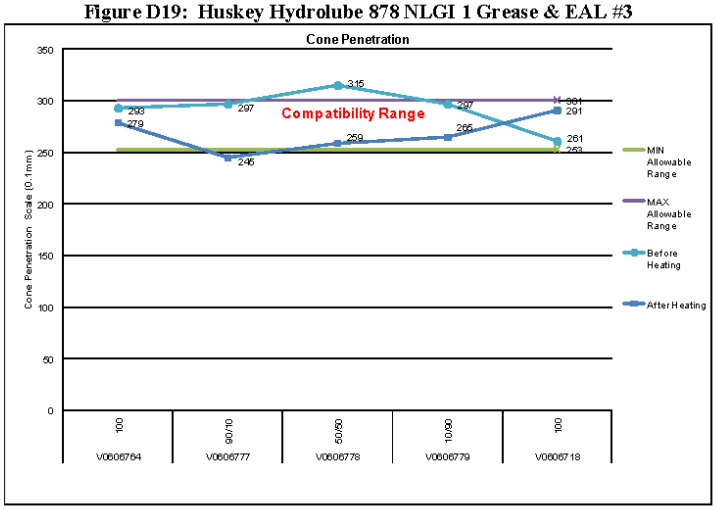

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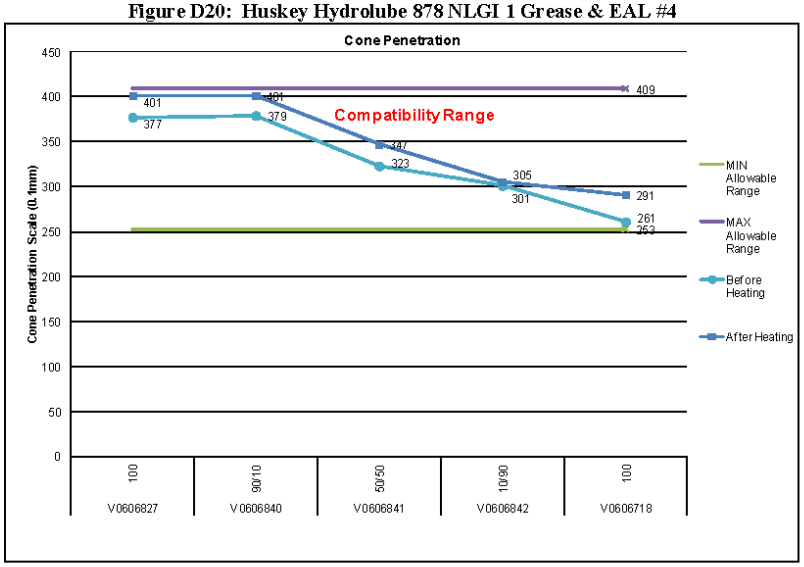
Figure D20: Huskey Hydrolube 878 NLGI 1 Grease & EAL #4



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Appendix I. ASTM D4048 Copper Corrosion Scoring Key

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ASTM D4048 Copper Corrosion Scoring Key		
Classification	**Designation**	**Description**
Freshly Polished Strip	-	-
1	Slight Tarnish	a. Light orange, almost the same as a freshly polished strip
		b. Dark orange
2	Moderate Tarnish	a. Claret red
		b. Lavender
		c. Multicolored with lavender, blue, or silver, or both, overlaid on claret red
		d. Silvery
		e. Brass or gold
3	Dark Tarnish	a. Magenta overcase on brassy strip
		b. Multicolored with red and green showing (peacock) but no gray
4	Corrosion	a. Transparent black, dark grey, or brown with peacock green barely showing
		b. Graphite or lusterless black
		c. Glossy or jet black

SFS	Saybolt Furol Viscometer
SPCC	Spill Prevention, Control and Countermeasure
SR	Special Report
SRV	Schwingung Reibung Verschleiß, i.e”., Reciprocating Friction and Wear”
SSU	Saybolt Seconds, Universal (unit of viscosity)
SUS	Saybolt Universal Seconds
TBN	Total Base Number
TCP	Tricresyl phosphate
TGA	Thermal Gravimetric Analysis
TMP	Trimethylolpropane
TOST	Turbine Oil Stability Test
TR	Technical Report
UFC	Unified Facilities Criteria
UFGS	Unified Facilities Guide Specification
UNS	Unified Numbering System
U.S.	United States
USACE	U.S. Army Corps of Engineers
USACERL	U.S. Army Construction Engineering Research Laboratory (now knows as the Engineer Research and Development Center, Construction Engineering Research Laboratory [ERDC-CERL])
USC	U.S. Code
USDA	U.S. Department of Agriculture
USEPA	U.S Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USP	U.S. Pharmacopeia
UV	Ultraviolet
VCI	Vapor Phase Inhibitor
VG	Viscosity Grade
VGP	Vessel General Permit
VI	Viscosity Index
VM	Viscosity Modifier

VOC	Volatile Organic Compound
VPI	Vapor Phase Inhibitor
WEN	Water Endangering Number
WGK	Wassergefährdungsklasse
WRTB	Wire Rope Technical Board
ZDDP	Zinc Diaryl Dithiophosphate
ZDTP	Zinc Dithiophosphate
ZN/P	Hersey-Stribeck (curve)

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