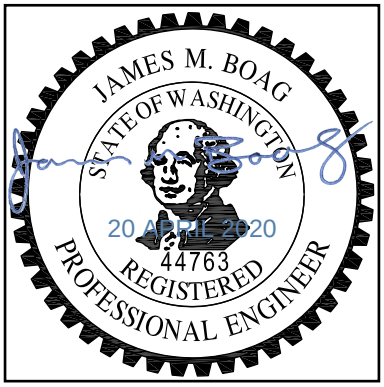
CHELAN COUNTY P.U.D.

Environmentally Acceptable Lubricant Feasibility Report – Rocky Reach Dam

FINAL
Revision No. 2



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0	April 3, 2020	Draft Final Report
1	April 17, 2020	Revised Per District Comments
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1.0 Executive Summary

This report analyzes the feasibility of implementing Environmentally Acceptable Lubricants (EALs) for equipment used at the Rocky Reach Hydro-electric project. To determine feasibility, EALs were defined, candidate EALs were identified, applicable equipment was listed, and a feasibility analysis was performed. This feasibility analysis explored the likelihood of lubricants discharging into the river, the ease to change from current lubricants to EALs, and an estimated long-term cost to implement EALs.

Several important items should be noted:

- The recommendations of the feasibility analysis focus on equipment that is in direct contact with water or that does not have a means of secondary containment.

- For the purposes of this report oils and greases are treated essentially the same. As greases are oils with thickeners and other additives, oils and greases are grouped together as "lubricants" generally.

- During the risk screening process (Appendix B.1), most oil-containing equipment was screened out based on the low risk of discharge into the river. Accordingly, the feasibility analysis in this report concentrates on greased equipment.

- Although adjustable blade turbine hubs contain lubricating oil that may reach the water, no EAL has been identified for use in the hubs. To determine EAL turbine hub compatibility, extensive additional analysis, long term testing, and extensive modifications would be required. For these reasons, turbine hub EAL conversions are not feasible, and the hubs are not recommended for EAL conversion at this time. Chelan PUD, however, is sponsoring a project by CEATI to start studies of using EALs in turbine hubs later this year. Chelan PUD is also evaluating replacing turbine hub oil with water or air

- Wicket gates at Rocky Reach utilize a bushing material that does not require an oil or grease lubricant, termed self-lubricated, and therefore were not evaluated in this report.

Table 1-1 contains a summary of the results of the EAL implementation feasibility analysis as organized into three levels of priority: high, moderate, and low. High ratings indicate in favor of EAL conversion.

Table 1-1. Summary of EAL Implementation Feasibility analysis results

Overall Analysis Priority Rating	Likelihood of Contact Rating	Ease of Implementation Rating	Cost Feasibility Rating	Applicable Equipment
High	Moderate/Low	High	High	Bull gears, chain drives, blocks, sheaves, bearings, couplings
Moderate	Low	High	Moderate	Sheaves, bearings, blocks, chain drives, bull gears, and couplings
	High	High	High	Surface Collector couplings, hooks, blocks and lifting beams
Low	Negligible	High	High	Bearings, couplings, bushing, blocks, chain drive
	High	Moderate	Mod/Low	Gate wire rope

This report identifies several good candidates for EAL implementation. Recommendations discussed in the report include:

- Implement EALs for equipment given a “High” and “Moderate” priority rating.
- Implement EALs for equipment given a “Low” priority rating when the equipment is replaced if technically feasible and not significantly more expensive.
- For wire ropes, investigate replacement of carbon steel wire ropes with stainless steel for ropes at the end of its service life, where applicable. Additionally, for equipment at the end of its design life, investigate replacing carbon steel rope with stainless steel wire rope infused with EAL lubricant.
- For future turbine upgrades, investigate oil-free turbine hub designs.
- Because laboratory testing of the compatibility of in-use lubricants and EALs is still pending, and field trials have not yet been initiated, these recommendations are contingent on the test results and field trials, but it is anticipated that the conclusion of high and moderate ease of implementation for EALs in this equipment will be unchanged.

2.0 Introduction

Chelan Public Utility District (District) operates the Rocky Reach Hydro-electric project (RR Project), located on the Columbia River 5 miles north of Wenatchee, in north-central Washington State. The RR Project includes equipment associated with the dam’s power generation, spillway, and fish passage systems. Much of this equipment requires lubrication to maintain its proper function. Both oil and greases are used at Rocky Reach dam; oil is primarily used in closed-loop systems inside the equipment and

powerhouses, while greases are often used on external surfaces. The District retained McMillen Jacobs Associates (McMillen Jacobs) to study the feasibility of converting currently used mineral oil-based lubricants to environmentally acceptable lubricants (EALs) for equipment that could be directly discharged into river flow. This report presents the findings from this study.

In parallel to this study, the District is also performing an oil accountability study for oil in the closed-loop oil systems. For the reasons stated elsewhere in this report, using EALs in this equipment is not feasible.

3.0 Background to Greases and EALs

Lubricants are used to reduce friction, dissipate heat, and provide separation of the contact surface, all of which reduce wear and increase the life of the equipment. Lubricating oils are typically flowable and greases are typically pastes. Both are composed of a base oil and additives, with greases also containing thickeners, which vary depending on the application. Base oils can stem from vegetable oil or petroleum; thickeners can include clay Bentone, lithium, or calcium soaps; and additives can include rust-inhibitors, anti-wear agents, etc. Each of these can vary in their compositions to enhance different performance qualities.

EALs can have either natural or synthetic base oils, thickeners, or additives; however, per definitions set by the U.S. Environmental Protection Agency (EPA), EALs vary from non-EALs in three fundamental ways: biodegradability, toxicity, and bioaccumulation. Biodegradability refers to the grease's ability to be broken-down by organisms common in the environment. Toxicity refers to magnitude of harmfulness to animals or the environment. Bioaccumulation refers to the grease's tendency to build-up inside of organisms in the river environment. Further discussion of biodegradability, toxicity, and bioaccumulation can be found in Section 4.14.0.

3.1 Requirements for Replacement

Since a turbine oils EAL has not yet been identified, and other lubricating oils were identified to have secondary containment or low risk of water contact, the remainder of this report discusses greases. In this study, EAL replacement for in-use greases must meet the following requirements: (1) the replacement grease must meet the criteria of an EAL grease as defined by the EPA (see Section 4.0); and (2) the replacement grease must meet or exceed the lubricating performance of the in-use grease it is intended to replace.

3.1.1 Compatibility

Compatibility between an in-use grease and an EAL refers to the mixture's ability to maintain individual performance characteristics despite combining two different greases. For example, one common effect of incompatible greases is called drop-out, where the base oil and thickener separate. The impact could include the mixture completely changing its consistency, severely minimizing its ability to lubricate, and causing catastrophic failure. Additionally, this incompatibility can exist between any component of the mixed greases, including its base oils, thickeners, or additives. Consequently, if any two combined

greases are expected to maintain their lubricating functions, it is vital to test the compatibility between the greases.

A grease's consistency is also an important characteristic to determine when testing compatibility. To provide a common standard among greases, the National Lubricating Grease Institute (NLGI) developed a rating system for a grease's consistency, as summarized in Table 3-1.

3.1.2 Performance

Performance characteristics include the grease's ability to resist wear, resist oxidation (deterioration), inhibit corrosion, maintain lubrication in cases of extreme loads, or resist water removal (water washout), etc. The performance characteristics required of a lubricant depend on the equipment and the environment that the equipment is subject to. To determine a suitable replacement for the in-use greases, tests must be performed that demonstrate the EAL's ability to perform in a similar or more effective manner than the grease it is intended to replace. Manufacturer provided performance data for lubricants are included in Appendix A.

Table 3-1. Summary of commonly used NLGI grades. [1]

NLGI Grade	ASTM D-217 Penetration Range	Consistency Description	Food Viscosity Analogy
000	445 – 475	Fluid	Cooking Oil
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
4	175 – 205	Very Firm	Frozen Yogurt
5	130 – 160	Hard	Smooth Pate
6	85 – 115	Very Hard	Cheddar Cheese

4.0 EAL Definition Standards

As mentioned previously, the EPA defined the term "environmentally-acceptable lubricant" (EAL) as a lubricant that meets certain standards for biodegradability, toxicity, and bioaccumulation. While terms like "environmentally-aware" and "environmentally-friendly" refer to lubricants that may be less harmful to the environment, these names generally do not apply to greases that meet the EAL definition set by the EPA.

In addition to the EPA, other organizations and international governments have presented various definitions for an EAL. The following sections describe the EAL standard set by the EPA and international labeling programs that meet or exceed the EAL requirements of the EPA.

4.1 EPA 800-R-11-002 and 2013 Vessel General Permit

The EPA released a document entitled "Environmentally Acceptable Lubricants" EPA 800-R-11-002 (EPA 800) 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". Additionally, in 2013, the EPA re-released the Vessel General Permit (2013 VGP), which further clarifies the EPA's definition for EALs. By themselves, these documents do not detail acceptable test results that define biodegradability, toxicity, and bioaccumulation. Instead, these documents provide background information about EALs, general information and discussion of EAL implementation, and refer to tests and other standards that determine the level of biodegradability, toxicity, and bioaccumulation of greases.

Below is a summary of the EPA 800/2013 VGP definitions and standards for biodegradability, toxicity, and bioaccumulation.

4.1.1 Biodegradability

"Biodegradability is a measure of the breakdown of a chemical (or a chemical mixture) by micro-organisms" (EPA 800). Biodegradability tests measure one of the following parameters: dissolved organic carbon, carbon dioxide, biochemical oxygen demand, or chemical oxygen demand. Per EPA 800/2013 VGP standards for biodegradability, a grease is considered "biodegradable" if a sufficient level of the tested parameter mineralizes or decomposes. While different tests quantify different parameters, these tests tend to require 60% to 70% of the selected parameter to mineralize within 28 days.

4.1.2 Toxicity

While "toxicity" is not defined in the EPA 800 or 2013 VGP, the term "toxicity" in this study refers to a grease's level of poisoning to marine animals. Tests recommended by the EPA 800 measure the lethal dose of grease that could kill 50% of the marine species being tested. While the acceptable limit of the dose can vary between tests, typically this limit is 100 milligrams per liter (mg/L).

4.1.3 Bioaccumulation

"Bioaccumulation is the build-up of chemicals within the tissues of an organism over time" and "is directly related to [a substance's] water solubility" (EPA 800). A substance's bioaccumulation can be slowed when it biodegrades more quickly, or when it dissolves in the fatty tissue of marine animals once ingested. Common testing methods utilize a partition coefficient (referred to as log K_{ow}). Acceptable limits for bioaccumulation include $\log 3 < K_{ow} < 7$.

4.1.4 Summary of EPA 800/2013 VGP

Generally, the EPA 800/2013 VGP reported that greases with a vegetable oil or synthetic ester base oil met the standard for biodegradability, toxicity, and bioaccumulation. Base oils derived from polyalkylen glycols (PAG) tended to perform well for biodegradation and bioaccumulation but demonstrated a propensity to be toxic. Base oils derived from mineral oils, which the majority of lubricants use, scored poorly in all three categories and therefore were not recommended for EAL use.

4.2 European Ecolabel

In 1992, the European Union established the European Ecolabel (EEL), which was designed to set a high environmental standard for "raw material extraction, production, distribution and disposal" [3]. The EEL is based on a variety of other international labeling programs, and consequently became one of the most widely accepted labeling programs for EALs in Europe and abroad. The test requirements and testing methods of the EEL are similar to those of the 2013 VGP, and therefore meet or exceed the requirements set by the 2013 VGP.

4.3 OSPAR

To protect the environment from "dumping" and "land-based sources of marine pollution and the offshore industry" [4], the Oslo/Paris Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) was established. Fifteen governments adopted this standard including Belgium, Denmark, Finland, France, Germany, Iceland, Ireland, Luxembourg, The Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and the United Kingdom. The OSPAR EAL definition is seen as a stricter standard compared to the 2013 VGP, requiring that each individual component of a grease be tested for biodegradability, toxicity, and bioaccumulation as opposed to the lubricant as a whole. The recommended tests provide a depth and breadth similar to that of the tests recommended by the 2013 VGP. Consequently, the testing requirements of OSPAR meet or exceed the requirements set by the 2013 VGP.

4.4 Candidate Grease EAL Criteria

For the purposes of this study, the following criteria were used to select candidate EALs (see Table 4-1):

- Any lubricant that is stated by the manufacturer to be 2013 VGP compliant.
- Any lubricant that is stated by the manufacturer to be EEL compliant.
- Any lubricant that is stated by the manufacturer to be OSPAR compliant.
- Any lubricant listed by the EEL or OSPAR as being compliant.
- Any lubricant that meets or exceeds the specific testing requirements described in the 2013 VGP for biodegradation, toxicity, and bioaccumulation.

Any lubricant approved by a program other than as detailed in this section was not considered for this study.

Table 4-1 - Summary of Environmental Standards.

Standard	Biodegradability	Toxicity	Bioaccumulation	Meets District Environmental Requirements for Implementation
EPA 800/2013 VGP	60%-70% w/in 28 days	100mg/L lethal dose	$\log 3 < K_{ow} < 7$.	Yes
European Ecolabel (EEL)	Meets or exceeds EPA	Meets or exceeds EPA	Meets or exceeds EPA	Yes

Standard	Biodegradability	Toxicity	Bioaccumulation	Meets District Environmental Requirements for Implementation
OSPAR	Meets or exceeds EPA	Meets or exceeds EPA	Meets or exceeds EPA	Yes

5.0 Lubricated Equipment

On November 13, 2019, McMillen Jacobs performed site visits to observe lubricated equipment at Rocky Reach Dam. Prior to the site visit, a list of lubricated equipment was obtained from the Engineering Department of Rocky Reach Dam. This list detailed several hundred pieces of equipment. A spreadsheet was developed that identified the piece of equipment, oil or grease lubricant currently used, equipment location, the system the equipment belongs to, and what kind of EAL may possibly be used. However, not every piece of equipment listed poses a meaningful risk of discharging into the river during operations. Per communications with maintenance personnel, any oil lubricant loss occurring inside the powerhouse (except turbine hub oil) will be captured directly or will be captured by the oil-water separator. Drawings of the powerhouse were reviewed for confirmation.

Consequently, only lubricated equipment outside of the powerhouse where grease seepage poses a risk of reaching the river was included and analyzed in this study, and included the following systems:

- Adult Fish Ladder
- Juvenile Fish Bypass
- Trash Hopper near the upper fishway deck
- Surface Collector near the upper fishway deck
- Forebay Intake Gates
- COH Intake Gantry
- Spillway Tainter Gate Hoisting Equipment
- Moffett Tailrace Crane
- Dewatering and fishway regulating tailrace gates
- Fish Sampling Facility

Upon identifying lubricated equipment that could seep grease into the river, an analysis was performed to determine the possibility of these greases reaching the river and the feasibility for EAL implementation. The following section details this analysis.

5.1 Turbine Lubricants

As noted in Section 5.0, most of the lubricating oil containing equipment in the powerhouses have secondary containment, and oil that escapes the equipment or secondary containment would be captured by oil-water separators. This includes most of the turbine oil from the bearings and the governor. Of notable exception here is the turbine hubs which are filled with oils used to lubricate blade actuation mechanisms in the hub. Hubs are sealed with trunnion seals at the base of the blade to keep the hub oil from entering the river in the turbine passage.

Determining the feasibility of changing turbine hub oils to EALs would require excessive costs to analyze, test, monitor, and very likely require the redesign of much of the turbine components to be compatible with EAL properties and to verify performance of the blade actuating mechanisms, seals, hydraulics, and controls. This is not economically feasible. It is quite likely that the cost of changing to EALs in turbines would approach the cost of a new turbine itself. McMillen Jacobs has no knowledge of existing legacy turbines being changed to EALs and would not recommend it to a client without the approval of the original equipment manufacturer, which in our experience is highly unlikely for an existing turbine.

The current state of the industry is moving towards oil-free hubs (EAL or otherwise) for certain applications for new or rehabilitated machines. McMillen Jacobs recommends that an oil-free design be investigated for future major rehabilitations.

Turbine wicket gate bushings at Rocky Reach have all been replaced with a material that does not need oil or grease lubrication.

6.0 EAL Implementation Analysis

The EAL Implementation Analysis considered: (1) the likelihood of the lubricant to contact river water, (2) the ease of EAL implementation, (3) compatibility of a proposed EAL with the existing lubricant and (4) the cost of EAL implementation.

6.1 Likelihood of Grease/Water Contact Assessment (Appendix B.1)

This section details the process used to determine the likelihood of grease/water contact for the lubricated equipment included in this study.

As discussed in Section 5.0, seepage from lubricated equipment located inside the dam (e.g., powerhouses 1 and 2), excluding turbine hub oil, is routed to and captured by an oil/water separator. Therefore, only lubricated equipment located on the outside of the dam (e.g., intake and tailrace decks, spillway, etc.) was included in the Likelihood of Water Contact assessment and EAL Implementation Analysis.

In Appendix B.1 thru B.4, each piece of lubricated equipment is listed with its primary system, location, and elevation, and the grease in-use for lubrication of that equipment. Some pieces of equipment with identical primary system, location, in-use grease, and Likelihood of Water Contact rating were grouped together (e.g., bearings, bushings, etc.) for organizational convenience. The overall Likelihood of

Grease/Water Contact rating was broken up into three subcategories: proximity to the river, lubrication containment, and frequency of use and lubrication. The inputs used to derive these ratings are described below.

6.1.1 Proximity to Water

The rating associated with the equipment's proximity to the river was categorized as either "Submerged" or "Near Water".

1. If a listed piece of equipment is submerged at any point during operations, the equipment was categorized as "Submerged".
2. If the equipment was not submerged but was above or near the river such that dripping grease posed some meaningful risk of contacting water, the equipment was categorized as "Near Water".

All other equipment was categorized as having a negligible Likelihood of Water Contact and was not included in further assessments.

6.1.2 Containment

The ratings associated with containment fell into four categories: "no containment", "minimal containment", "moderate containment", and "thorough containment".

1. "No containment" refers to lubricated equipment that is neither enclosed nor has secondary containment (see Figure 1 for examples). This rating generally applies to lubricated wire rope, hooks, blocks, or lifting beams that directly overhang or were submerged in the river.
2. "Minimal containment" refers to lubricated equipment that is not enclosed but has a minimal amount of secondary containment (see Figure 2). This rating is generally applied to bearings, or other lubricated equipment that could drip grease with minimal flooring or grated flooring beneath it to prevent the grease from entering the water below.
3. "Moderate containment" refers to lubricated equipment that is either enclosed or has effective secondary containment (see Figure 3). This is applied to open gears with some concrete flooring between the gears and the river, or a partially-enclosed chain drive overhanging a grating or the river, etc.
4. "Fully enclosed" refers to lubricated equipment that is fully enclosed and has effective secondary containment (see Figure 4). This is applied to enclosed motors or gearboxes on the trucks that hang over concrete, or hoisting drum bearings or enclosed gearing in the trolley house, etc. This equipment poses a negligible risk of grease contacting the river or is not expected to leak during typical operations.

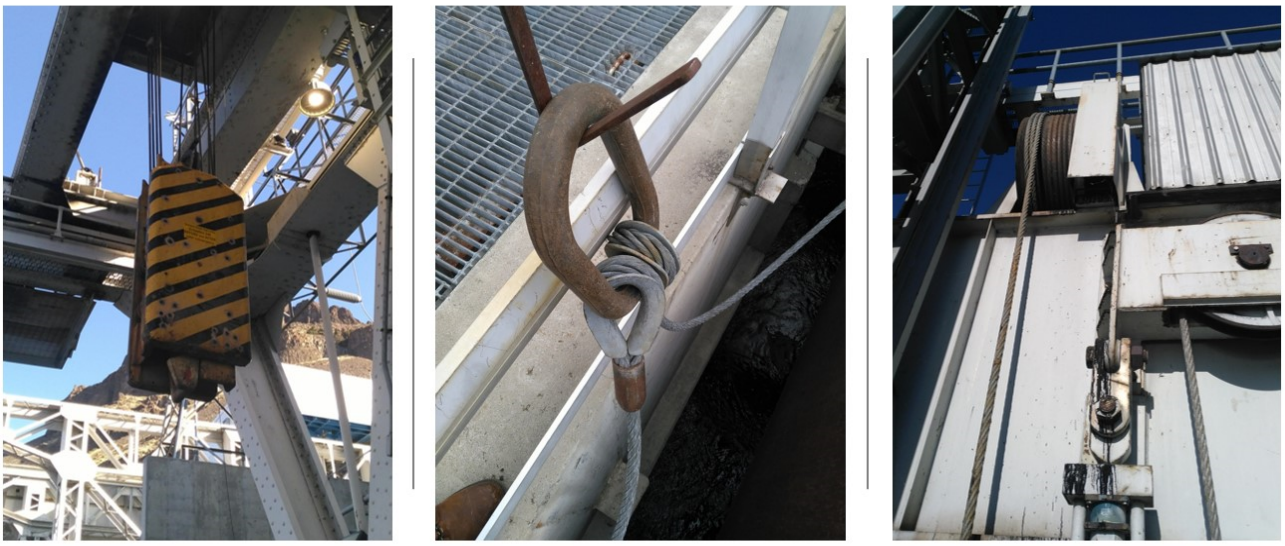

Figure 1. Examples of equipment categorized as "no containment."

(Left) A block that attaches to the top of a submerged gate. (Middle) Wire rope attached to a joint hook on the top of a submerged gate. (Right) Wire rope, hoisting drum, and pulley wheels that attach hoisting equipment to the top of a submerged gate. All equipment shown here typically overhangs water.

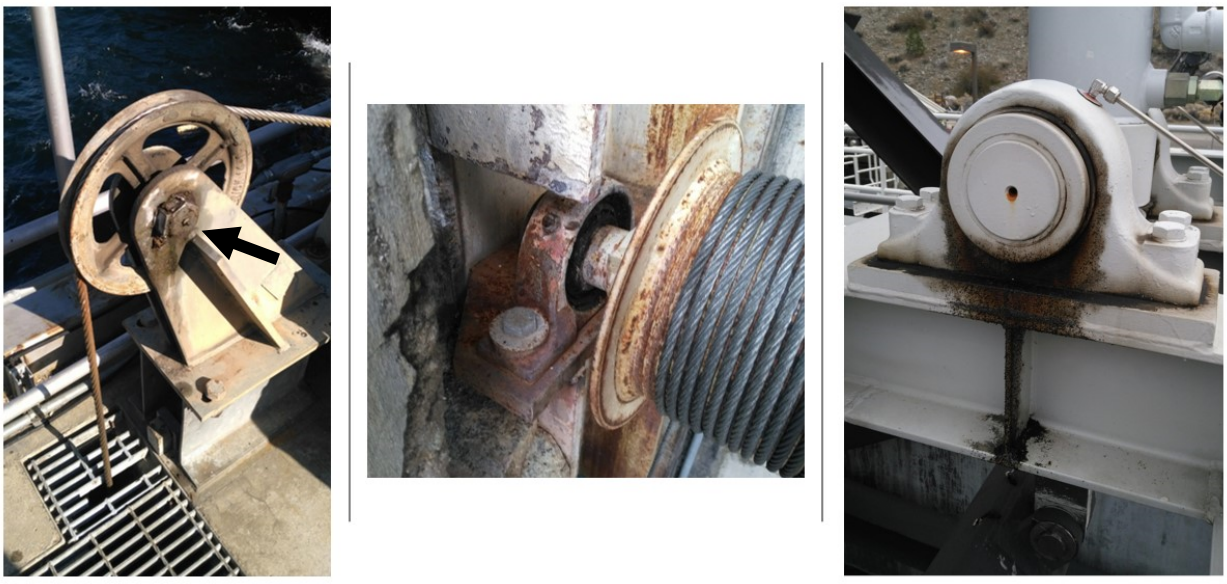

Figure 2. Examples of equipment categorized as "minimal containment".

All the equipment has a minimal amount of material between the grease exit point and the water. (Left) A grease input zerk to a wire rope pulley wheel. Grease can be seen dripping down the side of the equipment. (Middle) Pillow block supporting a wire rope hoisting drum. (Right) Trunnion block supporting a tainter gate. Grease can be seen dripping down the side of the equipment.

Figure 3. Examples of equipment categorized as "moderate containment".

(Left) Pillow block zerk for enclosed gearing. (Middle) Partially enclosed gearing with some concrete flooring immediately beneath the equipment with a hole to river flow nearby. (Right) Crane zerks next to a submerged gate slot.

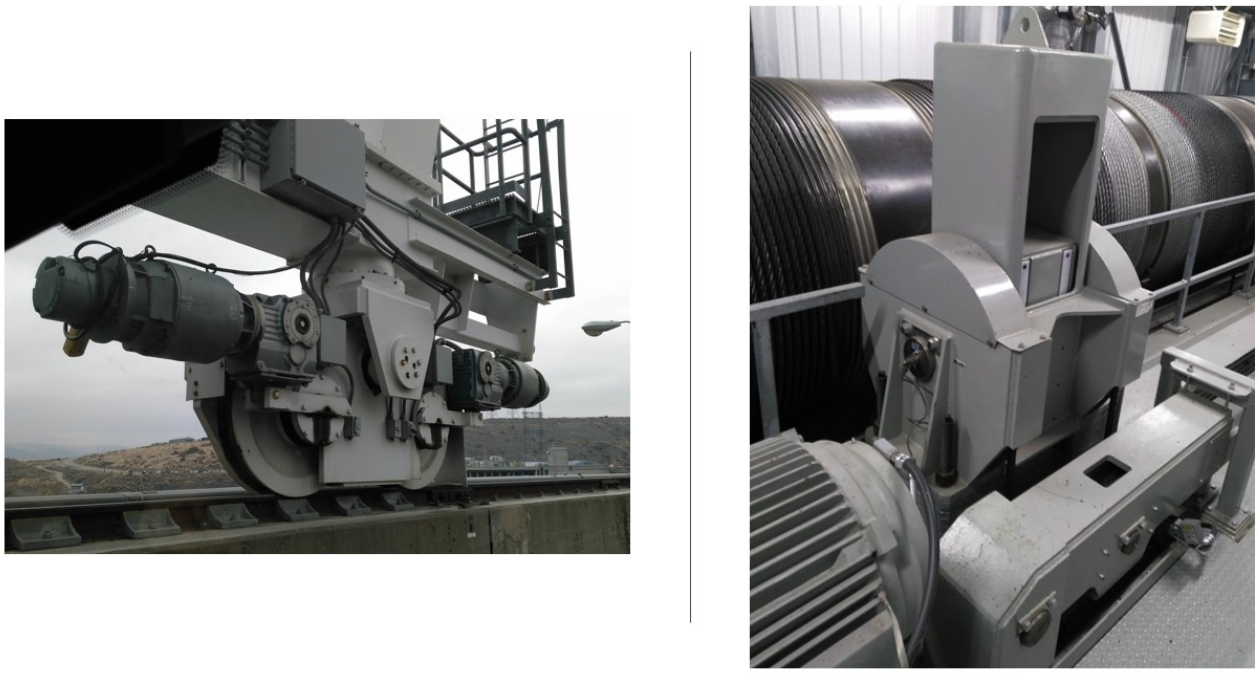

Figure 4. Examples of lubricated equipment categorized as "fully enclosed."

All of the "fully enclosed" equipment has no signs of discharging. (Left) Fully enclosed crane truck motors and gear drives. (Right) Fully enclosed hoisting equipment inside the trolley of a gantry crane.

6.1.3 Frequency

The rating for frequency designated lubricated equipment according to how frequently it was used and lubricated, and was categorized as follows:

1. "Frequently" is the rating for a piece of lubricated equipment that is used frequently and is lubricated at each use.
2. "Annually" is the rating for a piece of lubricated equipment that is used frequently and is lubricated on an annual basis.
3. "Rarely" is the rating for a piece of lubricated equipment that is not used frequently but is also lubricated on an annual basis.

6.1.4 Categorization of Likelihood of Water Contact

Once the proximity to the river, containment, and frequency ratings (as detailed above) were determined, the Likelihood of Water Contact ratings were categorized as "High", "Moderate", "Low", or "Negligible". Generally, all non- "Negligible" items pose some risk of grease contact with water; however, some lubricated equipment is more likely to seep lubricant than others. These ratings are associated with lubricated equipment in the following ways (see Table 6-1):

- A "High" risk rating was given to equipment where grease could contact the river during every use. Any lubricated equipment that submerges during typical operation was automatically assigned a "High" rating, independent of containment or frequency.
- A "Moderate" risk rating was given to equipment that does not have direct contact with the river but is used and lubricated frequently and/or has minimal to no containment, such that when the equipment is used, it is possible that grease drippage could get into the river.
- A "Low" risk rating was given to equipment that has some sort of containment that prevents drippage into the river. Consequently, a significant quantity of grease would need to be dripped in order for grease to enter the river.
- A "Negligible" risk rating was given to lubricated equipment where grease contact with the river is highly improbable.

The complete assessment can be found in Appendix B.1. All "submerged" equipment was automatically given a "High" Likelihood of Water Contact rating. All other equipment (i.e., equipment categorized as "Near Water") was categorized at various intersections of containment and frequency.

Consistent with the ratings given in each assessment below, a higher rating suggests a higher priority for implementation, while a lower rating suggests a lower priority for implementation.

It should be noted that while all lubricating equipment was evaluated, all oil containing equipment (mostly gearboxes) were rated a "Negligible" risk given the history of this type of equipment not to leak significantly. Accordingly, this equipment was screened out based on the low risk profile. On an added note, McMillen Jacobs experience with gearboxes is such that replacing EALs with current gearboxes is

not feasible, and it is very difficult to find a new gearbox original equipment manufacturer who specifies EALs as an option.

Table 6-1. Risk or Likelihood of Water Contact categorization per various levels of containment and frequency.

A higher rating denotes a higher priority for implementation while a lower rating denotes a lower priority for implementation. See Appendix B.1 for the complete assessment.

Risk level at intersection of containment and frequency		Frequency		
		1) Frequently	2) Annually	3) Rarely
Contain-ment	1) No containment	High	High	Moderate
	2) Minimal containment	High	Moderate	Low
	3) Moderate containment	Moderate	Low	Low
	4) Fully enclosed	Negligible	Negligible	Negligible

6.2 Ease of Implementation Assessment (Appendix B.2)

The ease of implementing EALs corresponds to the risks associated with implementation. Implementing or converting in-use greases to EALs can have significant risks depending on the answers to the following questions:

1. Are significant quantities of equipment disassembly required for implementation?
2. Could EAL implementation require generation outages?
3. Could EAL implementation cause equipment malfunction and impose a major personnel safety concern?

For each piece of equipment, points 1 (Equipment Disassembly), 2 (Generation Outages), and 3 (Safety) were rated with either a "Yes" or "No" response (see Appendix B.2). The ratings associated with implementation ease were categorized in the following ways (see Table 6-2):

- A "High" rating was given to equipment that received 0 - "Yes" responses, such that EAL implementation did not require equipment disassembly, generation outage(s), or cause a major safety concern. Therefore, there is a high ease associated with implementing EALs for this piece of equipment.
- A "Moderate" rating was given to equipment that received 1 - "Yes" response from any of the three points listed above and denotes a moderate ease to implementing EALs for this equipment.
- A "Low" rating was given to equipment that received 2 - "Yes" responses from any of the three points listed above and denotes a low ease associated with implementing EALs for this equipment.
- A "Negligible" rating was given to equipment that received 3 - "Yes" responses, such that EAL implementation requires disassembly, power outage(s), and poses major safety concerns. The relative ease of implementing EALs for this situation is "Negligible".

Table 6-2. Ease of EAL implementation categorization*.

*Per a "Yes" or "No" response to whether or not EAL implementation requires equipment disassembly, generation outages, or poses major safety concerns. A higher ease rating denotes a higher priority for implementation while a lower rating denotes a lower priority for implementation.

Cumulative responses to the below Criteria	0 - "Yes"	1 - "Yes"	2 - "Yes"	3 - "Yes"
Ease of Implementation	High	Moderate	Low	Negligible

6.2.1 Assessment Results Summary

The equipment included in this assessment (and listed in Appendix B.2) does not require significant disassembly for implementation, nor will implementation require generation outages. Therefore, the equipment listed as "Low" or "Negligible" above were screened out for further EAL implementation analysis.

Of all the equipment included in this study, effectively lubricating wire rope requires significant access, safety and cost challenges. Effectively pressure lubricating rope is not practical in general as it requires significant fixtures and equipment that dam operations do not possess. Implementing EAL on these ropes requires re-application of the EAL grease every few weeks versus six months or more for mineral oil based lubricant. For this reason, implementation of EALs on wire ropes is not seen as practical due to the extraordinary amount of labor cost in addition to safety concerns.

A more practical solution is to replace ropes with corrosion resistant ropes as part of a rope lifecycle replacements which may have a relatively low incremental cost if it can be done without significantly altering the equipment or reducing equipment capacities or wire rope life. A caveat is that stainless steel ropes are typically readily available in a more limited number of sizes and configurations; usually 1-inch diameter and under. Equipment alteration would be required if existing wire rope drums and sheaves cannot accommodate a larger wire rope size that is often required when changing to stainless steel because it has reduced performance for the same sizes compared to carbon steel ropes. For these circumstances changing wire ropes from carbon steel to stainless steel should be considered when the base equipment is changed as part of an equipment lifecycle change.

Beyond wire rope, there are no major safety concerns from EAL implementation for all other equipment included in this study.

6.3 Cost Feasibility Assessment (Appendix B.3)

Costs for implementing EALs could come from three main sources: (1) the cost of purchasing EAL grease in lieu of the in-use grease, (2) the cost of initial EAL implementation (e.g., cleaning all existing, non-compatible grease on equipment), and (3) the cost of increased lubrication frequency. Other indirect costs associated with implementing EALs include operational losses from water spilled while lubricating, but those costs are not quantified here.

6.3.1 Cost of EAL Grease vs. In-Use Grease

While the purchase price for some EALs included in this study was not provided by the Vendor, enough cost data was acquired such that the relative cost of EALs compared to the in-use greases could be estimated. The relative cost increase for EALs compared with various in-use greases is shown in Table 6-3.

Table 6-3. Approximate cost increase per unit volume of EALs relative to in-use greases.

In-Use Grease	In-Use Grease vs. EAL Approx. Cost Increase
Wire Rope Lubricant	$25/gallon
Open Gear Lubricant	$20/gallon
Multi-Purpose Lubricants	$20/14-oz tube

The quantity of grease used to lubricate the various pieces of equipment was approximated and the cost for purchasing EALs in lieu of in-use greases was calculated (see Appendix B.3).

6.3.2 Initial Cost of EAL Implementation

The initial cost of EAL implementation is the cost of removing the existing grease from the equipment and is only necessary if the greases are not compatible. However, because of the safety risks associated with ill-lubricated wire ropes (as discussed in Section 6.2.1), there are two apparent options: (1) clean the existing grease off wire rope before applying EALs, or (2) replace the wire rope, preferably with stainless steel where lubrication is not required.

The process of cleaning in-service wire rope is expensive and labor intensive, can rarely be contracted out, and cleans off only surface grease and not grease in the wire rope core. Cleaning is typically done by attaching the cleaning device to the wire rope and securing the device such that the device is held stationary. Wire rope is then pulled through the device and the device wipes off the grease from the wire rope surface. To approximate a cost, it was assumed that gantry crane wire rope was 1,000 feet long, other spillway gate hoists 250 feet long, and all other hoisting wire rope was 100 feet long. Due to the labor intensity of cleaning wire rope, it was also assumed that 1,000 feet of rope could be serviced by two technicians in 2 days, for a total of 16 hours. Assuming technicians are paid $100/hour, this yields a cost of approximately $3.20/linear foot of rope. Cost calculations for each equipment line item are shown in Appendix B.3.

6.3.3 Cost of Increased Lubrication Frequency

It is anticipated that for most equipment included in this study, which is not normally submerged, the frequency of lubrication will not change to the extent where cost of implementation would impact overall O&M significantly. However, equipment that is regularly exposed to water (e.g., submerged equipment) requires significantly more maintenance if EALs are implemented. By definition, all EALs that lubricate continuously submerged equipment will lose at least 60% of their mass to biodegradation after 28 days and would lose significant lubricant properties before that. Consequently, an EAL applied to regularly submerged equipment will probably need to be reapplied every two weeks, compared to the typical 6-12

month lubrication maintenance schedule. The costs associated with reapplying biodegraded EALs were estimated and are shown in Appendix B.3. It is not anticipated that non-submerged equipment requires a higher frequency of lubrication; therefore, there is no cost related to increased lubrication frequency. As noted above, submerged equipment requires more frequent lubrication, and this also incurs costs associated with larger quantities of grease used and personnel time in applying the EAL. The calculation for this cost assumes that:

1. The EAL is applied biweekly (26 times annually); and
2. One hour of staff time is required at $100/hour per equipment line item in Appendix B.3.

For various equipment line items, this cost increase ranges from approximately $20 to $12,000 annually with most of the costs being associated with wire rope routine lubrication. How this cost is related to the overall Cost Feasibility Assessment is discussed in the section below.

- Total annual plant-wide incremental cost increase associated with converting to EAL's evaluated (high, medium, and low priorities) is expected to be approximately $80,000 for the first year due to initial implementation labor, higher grease costs, and increase frequency of lubrication.
- Following years would have an incremental cost increase approximately $60,000 per year due to increased labor and grease costs for all EALs evaluated in this report.
- The recommended EAL implementation (high and medium priorities) cost would total approximately $25,000 for the first year and $25,000 for following years primarily due to increased labor due to increased greasing frequency for submerged components.
- This cost increase does not account for the cost of replacing in-use wire rope with stainless steel wire rope, equipment changes, or replacement of turbine hub oil which is not economically feasible (see paragraph 5.1).

6.3.4 Cost Feasibility Assessment Summary

EAL cost feasibility was assessed as the cost of initially implementing EALs, purchasing EALs in lieu of in-use greases, and the cost of increased lubrication frequency. The most significant cost associated with implementing EALs stems from lubricating submerged equipment. Because EALs readily biodegrade, it is recommended that submerged equipment be lubricated every 2 to 4 weeks, 13 to 26 more times than this equipment is currently lubricated, which adds significant costs.

The cost per line item to implement EALs ranged from $20 to over $12,000 annually, depending on the equipment. This range of costs was categorized into three feasibility groups as follows:

- A "High" cost feasibility rating, meaning that implementing an EAL for this equipment line item does not require significant funding, referred to a cost of less than $1,000 annually. This rating typically pertained to unsubmerged equipment.
- A "Moderate" cost feasibility rating, meaning that implementing an EAL for this equipment line item requires a moderate amount of funds, referred to a cost of $1,000 to $4,000 annually. This

typically pertained to submerged hooks, blocks, liftings beams, etc. and hoists with shorter lengths of wire rope.

- A "Low" cost feasibility rating, meaning that implementing an EAL for this equipment line item requires significant funding, referred to a cost greater than $4,000 annually. This typically pertained to spillway gate and gantry crane wire rope that has longer lengths of wire rope.

See Table 6-4 for a summary of feasibility ratings per annual cost of EAL implementation.

Table 6-4. Feasibility categorization for EAL implementation.

A higher rating denotes a higher priority for implementation while a lower rating denotes a lower priority for implementation.

Cost Feasibility level at Intersections			
Approx. Annual Cost to Implement EALs per equipment line item	$0 - $1,000	$1,000 - $4,000	> $4,000
Cost Feasibility	High	Moderate	Low

6.4 EAL Implementation Analysis Summary (Appendix B.4)

The Likelihood of Water Contact, Ease of Implementation, and Cost Feasibility of each piece of equipment included in this study were assessed, and three levels of EAL implementation priority: "High", "Moderate", and "Low" are presented. A "High" priority rating refers to equipment that is considered to have a high priority for EAL implementation, a "Moderate" rating refers to a moderate priority, and a "Low" rating refers to a low priority. Table 6-5 shows how the equipment ratings were organized relative to each priority level. The results from the analysis are discussed below.

Table 6-5. EAL Implementation priority matrix related to the ratings from the Likelihood of Water Contact, Ease of Implementation, and Cost Feasibility assessments.

Priority	Likelihood of Water Contact	Ease of Implementation	Cost Feasibility	Applicable Equipment
High	High	High	High	Bull gear, chain drive, pillow blocks (Not contained)
	Moderate	High	High	Sheaves, bearings, pillow blocks, chain drive, and couplings (minimally containment)
Moderate	Low	High	High	Sheaves, bearings, pillow blocks, chain drive, bull gear, and couplings (moderately containment)
	High	High	Moderate	Surface collector couplings and gate hoist hooks, blocks, lifting beams (submerged)
Low	Negligible	High	High	Bearings, couplings, bushings, pillow blocks, chain drive (Thoroughly contained)
	High	Moderate	Moderate	Tainter gate and orifice gate wire rope, Moffett crane wire rope, fish ladder wire rope, etc. (submerged)
	High	Moderate	Low	COH hoist wire rope (submerged)

6.4.1 Analysis Results Discussion

In this study, the feasibility of converting to EALs is expressed by the Cost Feasibility and Ease of Implementation assessments. Consequently, the results of these two assessments drive the priority of implementation. In general, if EAL conversion for a piece of equipment is financially and operationally feasible and does not pose major safety risks to dam personnel, then EAL conversion for this equipment was given a higher priority.

As shown in Table 6-5 equipment listed with a "High" priority includes non-submerged equipment such as bull gears, chain drives, pillow blocks, sheaves, bearings, pillow blocks, and couplings. This equipment generally has a significant Likelihood of Water Contact, has no significant risk to implement EALs, and is relatively inexpensive to convert to EALs.

Equipment listed with a "Moderate" priority fell into two groups: non-submerged and submerged equipment. The non-submerged equipment includes sheaves, bearings, pillow blocks, chain drives, bull gears, and couplings that have a less significant probability of contacting water, pose no significant safety risk to EAL conversion and are relatively inexpensive to convert to EALs. The submerged equipment with a "Moderate" priority includes surface collector couplings, gate hoist hooks, blocks, and lifting beams. Though these components have "high" Likelihood of Water Contact and ease of implementation ratings, they will require frequent lubrication, which negatively impacts the cost feasibility, reducing its overall rating to "Moderate".

Equipment listed with a "Low" priority either consists of thoroughly contained lubricated equipment (bearings, couplings, bushings, etc.) or submerged wire rope. While the contained equipment was given a "high" cost feasibility rating, this equipment has a "negligible" likelihood of water contact rating, therefore given a "Low" priority for EAL implementation. Regarding the submerged wire rope, these ropes have a "high" Likelihood of Water Contact, but EAL implementation is expected to be expensive and poses some major safety risks if the lubrication is improperly converted to EALs. Safety risks for EAL implementation can be mitigated by replacing the existing wire rope with EAL infused wire rope.

6.4.2 Laboratory Testing Recommendation

Currently performance and compatibility testing of in-service greases and EAL grease candidates is being conducted at SGS laboratories in Vallejo, California. The District is also participating with the Army Corps of Engineers and other utilities to study EAL oils for turbine hubs along with replacement of oil lubricants with water or air. Given the expense of performance and compatibility testing, only the greases used to lubricate equipment given a "High" or "Moderate" rating are being tested. The in-use greases used to lubricate equipment with these ratings include Schaeffer's 248 Moly Syngard, Chevron Ultra Duty EP, Mobil Unirex EP, Huskey LVI-50, and Schaeffer's Silver Streak 200S.

Chevron Coupling grease is also an in-service grease used to lubricate chain drives and couplings given a "High" and "Moderate" priority rating, however, Chevron no longer sells this grease, nor could they locate information or technical data on this grease. Because Schaeffer's 248 Moly Syngard, Huskey LVI-50, and Mobil Unirex EP are also used to lubricate chain drives and couplings, Chevron Coupling grease was not investigated further.

The following sections detail a discussion of these in-service greases and their respective EAL replacement candidates.

7.0 In-Service Greases

With the EAL implementation analysis complete, a study of the in-service greases given a "High" or "Moderate" priority was performed. These greases, each grease's typical purpose, and the equipment that the greases are typically applied to are shown in Table 7-1.

Samples of each grease were provided to Aaron Terry from McMillen Jacobs, in new, unopened containers. Additional quantities of identical greases were purchased and shipped to SGS Laboratories for testing. Cut sheets made available by the grease manufacturers are available in Appendix A.

Table 7-1. Greases used by maintenance staff at Rocky Reach Dam, the grease's relative use, and the equipment the grease is applied to.

Grease	Typical Use	Rocky Reach Equipment Applied to
Schaeffer's 248 Moly Syngard	Multi-purpose, extreme pressure, lubricant	Bearings, bushings, trunnions, couplings, blocks, hooks, sheaves, etc.
Chevron Ultra Duty EP	Multi-purpose, extreme pressure, lubricant	Wheel bearings
Mobil Unirex EP	Multi-purpose, extreme pressure, lubricant	Pillow blocks, wheel bearings, gear reducer, couplings, bushings, seals
Huskey LVI-50	General purpose, water-resistant lubricant	Pillow blocks, sheaves, bearings, chains, couplings
Schaeffer's Silver Streak 200S	Open gear lubricant	Open gears
Lloyd's Laboratory Loobit	Thin, general purpose wire rope lubricant	Wire Rope

7.1 Schaeffer's 248 Moly Syngard NLGI #2

Schaeffer's 248 Moly Syngard is described by the manufacturer as "a multipurpose, extreme pressure, anti-wear grease that is specially formulated for use in all types of heavy-duty construction, mining, farming and industrial equipment that are being used in hot, wet or heavily loaded applications" (Appendix A). The grease is composed of 100% paraffin, derived from petroleum, and with a clay-Bentone thickener. Additives include synthesized moly, which causes the grease to "[plate] itself to metal surfaces".

Because this grease does not meet any of the criteria listed in Section 4.4, Schaeffer's 248 Moly Syngard is not considered to be an EAL.

7.2 Chevron Ultra Duty EP

Chevron describes this grease as a "versatile, high pressure grease with good adhesive properties" with the following characteristics "shock load protection, load-carrying protection, corrosion and rust protection, water resistant, [and] maximum service lubrication" (Appendix A). Chevron states that this oil uses "highly refined base oils" but gives no indication of its environmental "friendliness". Without any verification that this grease meets this present study's criteria for EALs, Chevron Ultra Duty EP is not considered as an EAL.

7.3 Mobil Unirex EP

Mobil describes its Unirex EP as a "versatile grease" that is "premium-quality, lithium-complex product suitable for high-temperature service in rolling-element bearings" with the following features: "Excellent high-temperature performance, outstanding grease life, very good low-temperature characteristics, excellent mechanical stability, excellent water and corrosion resistance, [and] excellent performance in high-speed applications".

Mobil does not indicate that this grease is compliant with any definition of EALs and, therefore, is not considered an EAL in this study.

7.4 Huskey LVI-50

Huskey LVI-50 is advertised as a "multi-service, non-melting, waterproof grease" (see Appendix A). While offering similar performance characteristics to Schaeffer's 248 Moly Syngard, Huskey LVI-50 is more resistant to washing out from water exposure. Additionally, this grease is used to lubricate pump bearings, bushings, valves, conveyors, water filters, universal joints, etc. The manufacturer states that this grease utilizes Polytetrafluorethylene (PTFE) as an additive, which is a synthetic fluoropolymer that has hydrophobic or non-wetting characteristics. However, Huskey has not disclosed the specific base oil or thickener but does describe it as "a pure synthetic based lubricant"; whether this means its base oil is categorized as a synthetic ester is unclear.

While Huskey LVI-50 is a food-grade grease, food-grade greases are not synonymous with EALs, nor do food-grade greases inherently meet the definition of an EAL. Furthermore, Huskey has not indicated that LVI-50 meets EAL criteria as listed in Section 4.4.

7.5 Schaeffer's Silver Streak 200S

Schaeffer's Silver Steak 200S is a "heavy duty, extreme pressure…multi-service lubricant that is recommended for the lubrication of heavily loaded open gears" and "as a surface dressing for slow moving gears open to the atmosphere" (see Appendix A). This grease is thick, "forms an almost indestructible adhesive film with a 'cushioning' effect" and is very "resistant to water washout and water wash-off by immersion or spray". Schaeffer's states that this grease is compounded from paraffin and polyalphaolefin synthetic base oils, both derived from petroleum. While the manufacturer does not state the thickener, it does state that one of the additives is molybdenum disulfide, which contributes to its load bearing performance properties.

Again, the manufacturer does not state that this grease is compliant with any definition of EALs, including the definitions listed in Section 4.4, and is therefore not considered an EAL for this study.

7.6 Lloyd's Laboratory Loobit

Though used to lubricate wire rope given a "Low" priority and is not recommended for compatibility/performance testing, Lloyd's Laboratory Loobit is described here for informational purposes.

Lloyd's Laboratory Loobit is described as a "multiuse, heavy-duty lubricant, formulated for use on rollers, drive chains, wire rope and cables, internal control cables, open gears, exposed bearings, load bearings, load bearing hinges and pivot points" by the manufacturer (see Appendix A). The manufacturer has not disclosed the base oil, thickener, or additives for this grease. However, technical data that details specific performance tests for this grease can be found in Appendix A.

While the manufacturer's cut sheet calls Loobit "environmentally-friendly", the manufacturer does not certify this grease's compliance to any of the criteria listed in Section 4.4. Therefore, for the purposes of this study, Lloyd's Laboratory Loobit was not considered to be an EAL.

7.7 Summary of In-Service Greases

As indicated above, the in-use greases indicated in Table 7-1 do not meet EAL standards or definitions described in Section 4.4. The following section presents several EALs as candidates for replacing the in-use greases listed above.

8.0 EAL Candidate Greases

As discussed previously, Schaeffer's 248 Moly Syngard and Huskey LVI-50 (general purpose lubricants), Schaeffer's Silver Streak 200S (open gear lubricant), and Lloyd's Laboratory Loobit (wire rope lubricant), are used at Rocky Reach Dam. To determine EAL candidates that could replace these greases, general purpose, wire rope, and open gear EALs were explored. The sections below present suitable EAL candidates.

8.1 Multi-Purpose EAL Candidates

The following greases are used as general-purpose lubricants and are potential candidates to replace Schaeffer's 248 Moly Syngard and Huskey LVI-50 grease.

8.1.1 Panolin Margrease EP 2

Panolin Margrease EP 2 is described by the manufacturer as a "readily biodegradable [extreme pressure] multipurpose grease based on synthetic esters and lithium/calcium soap" (Appendix A). This grease is typically used in a marine environment and is rated for "extreme resistance to water wash-out, for exposed lubrication points", per the manufacturer's cut sheet. Typical applications include roller and slide bearings, drive chains, steel ropes, cables, open gears, stabilizers, etc. While the base oil and additives were not disclosed by the manufacturer, Panolin states that the thickener type is a lithium/calcium blend.

The manufacturer states that this grease meets the requirements of the 2013 VGP, and per this study's EAL criteria in Section 4.4, is considered an acceptable EAL. In similar EAL feasibility evaluations, United States Army Corp. of Engineers [5] determined Panolin Margrease had superior performance to other EALs and most mineral oil-based greases.

8.1.2 Renewable Lubricants Bio High Temp 180 EP Grease 2

Renewable Lubricants refers to this grease as a "multipurpose" grease that has "very high load carrying ability, excellent resistance to water, corrosion, and outstanding performance in a wide temperature range" (Appendix A). Typical applications include "industrial and mining machinery, transportation, agricultural, construction and forestry equipment, paper mills, conveyors, journal bearings, electric motors, pumps and marine" environments and industries. While the base oil is not explicitly stated on the grease's cut sheet, all greases made by Renewable Lubricants are made from plant-based sources. Additionally, specific additives for this grease are not stated. The thickener used is a lithium complex.

Renewable Lubricants indicated that this grease was EPA 2013 VGP compliant and is an EAL.

8.2 Open Gear EAL Candidates

The following greases are used to lubricate open gears and are potential candidates to replace Schaeffer's Silver Streak 200S grease.

8.2.1 Grignard 2013 VGP Pro OG

Grignard 2013 VGP Pro OG grease is described by the manufacturer as "open gear grease providing superior corrosion protection, adhesion and lubrication in all atmospheric environments across a wide temperature range" (Appendix A). Grignard also states that this grease "resists water wash-off" while being "readily biodegradable, [and] will not bio-accumulate". Inherent in its name, the main use for this grease is for open gears (OG). This grease "is ideal for a variety of marine, mining or manufacturing applications". Grignard states that the base oil is a fully synthetic, ester-based lubricant with a calcium thickener. No additives were listed.

Grignard states that this grease is compliant with the 2013 VGP definition of EALs and is considered to be an EAL.

8.2.2 Renewable Lubricants Bio SynXtra EP Open Gear

Renewable Lubricants describes this grease as "very tacky and very viscous" and it is "formulated with black graphite and specially designed for lubricating open gear and sliding surface applications which are subject to extreme heavy loading or shock loading" (Appendix A). Typical applications include "large open gears on mills and mixers, semi-enclosed gears and pinions, ring gears, and certain heavy enclosed gears", but it is also applied to "cables, sprockets, chains, wire ropes, flexible couplings, journal bearings, draglines, drives on straddle lift carriers, hoist gears, fifth wheels, etc." As previously discussed, Renewable Lubricants only uses plant-based oils for its greases. While the thickener is not listed, black graphite is added for this specialty open gear grease.

The manufacturer states that this grease is 2013 VGP compliant and is considered an EAL for this study.

8.2.3 Castrol Biotac OG

Castrol describes this grease as "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 must provide protection against corrosion to both the rack and pinion between rig moves" (see Appendix A). Inherent in its name, this grease is designed for open gears (OG) but is also used for "rack and pinion gearing on the legs of jack-up drilling rigs" and "anchor winches or other deck machinery".

The manufacturer indicates that this grease is compliant with both OSPAR and the 2013 VGP.

8.2.4 Kluber AG 39-602

This grease is described as "an adhesive lubricant for open gears and steel cables" that "contributes to long component life and good corrosion and wear protection". The manufacturer stated that this grease can be used in applications "that require lubricants to have good water washout resistance, very good anti-corrosion resistance and/or good load-carrying capacity such as with low-speed plain bearings, guide rails and open winch gears" (see Appendix A).

As for its adherence to EAL standards, Kluber stated that this grease "meets the biodegradability, minimally toxic and non-bioaccumulative standards established by the US EPA for the 2013 Vessel General Permit" and is, therefore, accepted as an EAL for the purposes of this study.

8.3 Wire Rope EAL Candidates

While the in-use wire rope lubricant was given a "Low" priority and, therefore, not recommended for compatibility/performance testing, wire rope EAL candidates are described here for informational purposes.

8.3.1 Renewable Lubricants Bio EP Wire Rope Lubricant 10W-30

Renewable Lubricants describes this grease as "ultimately biodegradable vegetable oils formulated with anti-wear, extreme pressure (EP), anti-rust, oxidation inhibitors, and tackifier" (Appendix A). The low viscosity rating allows the grease to "[penetrate] deep into the inner core of the cable to prevent rust and wear" without the use of a special pressurized applicator. This grease typically protects "cables, pulleys, sliding surfaces, and [wire rope] threads" and is also applied to "chains, slideways, and hinge pins". As stated in 8.1.2, this grease is made from plant-based oils, but the manufacturer provided no further information on its use of specific thickeners or additives.

The manufacturer indicated on the product cut sheet that the Bio EP Wire Rope Lubricant meets the 2013 VGP EAL standards, and therefore is considered an EAL.

8.3.2 Panolin Biotrack E320

Panolin Biotrack is described by the manufacturer as an "environment-considerate oil" (Appendix A) with typical applications of flanged wheels, track switches, gear drive chains, wire ropes and cables, etc. Panolin states that this lubricant is "based on renewable ester[s]", but presents no further information regarding specific base oils, thickeners, or additives used for this grease.

Panolin reported on its website that this grease met the requirements of the 2013 VGP and is therefore considered an EAL.

8.3.3 Panolin Margrease EP 0

Panolin refers to this grease as a "readily biodegradable [extreme pressure] fluid grease based on synthetic esters and lithium soap", has "good water resistance", "good anti-wear and antic corrosion behavior", and "excellent load bearing capacity" (Appendix A). Typical applications include rudders, stabilizers, and pitch propeller gearing where a lighter viscosity is needed. Panolin states that this grease is "based on synthetic esters and lithium soap" but does not state specific additives used.

Panolin Margrease EP 0 meets the requirements for an EAL as set by the 2013 VGP.

8.4 Summary

For each of the four greases shown in Table 7-1, replacement candidates that met at least one of the EAL criteria listed in Section 4.4 were identified. Manufacturer-provided technical data (see Appendix A) was used to select candidate EALs that performed similarly to the in-use grease that it could potentially replace. The in-use greases and their potential replacement EALs are listed in Table 8-1.

As seen in manufacturer-supplied data sheets (see Appendix A), performance test results show that Chevron Ultra Duty EP, Mobil Unirex EP and Huskey LVI-50 grease have many similarities to the performance test results of Schaeffer's 248 Moly Syngard; typically, these greases serve as a multi-purpose, high pressure lubricant. Therefore, the same EAL candidates for Schaeffer's 248 Moly Syngard are also proposed as candidates to replace Chevron Ultra Duty EP, Mobil Unirex EP, and Huskey LVI-50. While these EAL candidates are the same, laboratory testing will still determine the compatibility and performance similarities between Huskey LVI-50 and these EAL candidates. Descriptions of these candidates can be found in Section 8.1.

Table 8-1. EAL candidates per in-use greases.

In-Use Grease	EAL Candidates
Schaeffer's 248 Moly Syngard	Panolin Margrease EP 2
	Renewable Lubricants Bio High Temp 180 Ep Grease 2
Chevron Ultra Duty EP	Panolin Margrease EP 2
	Renewable Lubricants Bio High Temp 180 Ep Grease 2
Mobil Unirex EP	Panolin Margrease EP 2
	Renewable Lubricants Bio High Temp 180 Ep Grease 2

In-Use Grease	EAL Candidates
Huskey LVI-50	Panolin Margrease EP 2
	Renewable Lubricants Bio High Temp 180 Ep Grease 2
Schaeffer's Silver Streak 200S	Grignard 2013 VGP Pro OG
	Renewable Lubricants Bio SynXtra EP Open Gear
	Castrol Biotac OG
	Kluber AG 39-602
Lloyd's Laboratory Loobit	Renewable Lubricant Bio EP Wire Rope 10W-30
	Panolin Biotrack E320
	Panolin Margrease EP 0

9.0 Compatibility and Performance Testing

9.1 General

To provide a thorough understanding of how effectively the EAL candidate greases could substitute for the in-use greases, compatibility and performance tests were included in this study. When adding a new grease to a lubricated piece of equipment, the two greases inevitably mix together. Compatibility testing helps the user determine if two mixed greases can do so without yielding unwanted characteristics. When incompatible greases are mixed together, the blend can change in viscosity, resulting in improperly lubricated bearings. An increase in viscosity could create blockages in grease lines and fail pumps that distribute grease, while a decrease in viscosity can cause bearing lubricant to drip out and cease performing its lubricating function. In some cases, this can lead to catastrophic bearing failure. Compatibility is especially important for equipment that is difficult to clean. Applying a grease that is compatible with an in-use grease can minimize labor and cost impacts.

Some compatibility and performance test results were made available by the greases' manufacturers. These test results provided a reference for McMillen Jacobs to determine candidate EAL substitute greases that likely meet or improve upon the performance of the in-use greases. Further testing was needed to verify and validate compatibility and performance characteristics.

Because EAL implementation for wire rope is expensive and poses a significant safety risk (see Section 6.4.1), wire rope was given a "low" priority for EAL implementation. Consequently, it was determined to not include Lloyd's Laboratory Loobit and its respective EAL candidates in compatibility and performance testing. As discussed in 6.2.1, changing from carbon steel to stainless steel ropes should be examined as equipment is refurbished or replaced.

9.2 Compatibility Testing

Compatibility tests between in-service and EAL greases were completed per ASTM D6185-10 Standard Practice for Evaluating Compatibility of Binary Mixtures of Lubricating Greases by SGS. In these tests, the following grease samples were used:

- 100% (unmixed) In-use Grease
- 90% In-use grease / 10% EAL grease
- 50% In-use grease / 50% EAL grease
- 10% In-use grease / 90% EAL grease
- 100% (unmixed) EAL grease

The two unmixed (100%) grease samples serve as references for the compatibility tests. The 90/10, 50/50, and 10/90 mixtures represent grease mixtures lubricating a piece of equipment after a new grease has been introduced without completely removing the in-use grease from the equipment. These ratios are typical of SGS Laboratories' procedures for grease sampling and are used to understand the behavioral trends of mixed greases relative to the 100% unmixed in-use or EAL grease samples.

Compatibility tests for this study included a measure of two properties of these grease samples:

1. ASTM D566 Dropping point
    a. The grease, or mixture of greases, is placed in an apparatus with a small hole at the bottom and is heated. As the grease is heated, the base oil begins to separate or 'drop out' from the thickener. The base oil melts or thins enough such that surface tension and capillary action no longer hold the oil within the thickener. The temperature at which the oil drops from the apparatus is the dropping point temperature. This measure is important because a significant change in dropping point can lead to catastrophic lubrication failure.
2. ASTM D217 Heated consistency by change in 60-stroke penetration
    a. This test observes the consistency change in a grease sample when subject to thermal stress. Grease samples are heated to 120°C for 70 hours, and 60-stroke worked penetration tests are conducted before and after the sample is heated. If the mixed grease's consistency changes more than the consistency of the un-mixed greases, then the mixed grease is considered not compatible.

Note that these tests are performed in a laboratory under controlled conditions, and are not representative of dynamic, in-service conditions.

Per ASTM D6185 test method guidance, three outcomes are possible for compatibility testing:

- A "Pass/Compatible" rating designates a grease mixture as compatible, or when the mixture does not have a significant degradation of properties when compared to the unmixed greases.
- A "Borderline Compatible" rating designates a grease mixture that has some non-compatibility, such that the performance of the mixture was poorer than the two unmixed greases by an amount not exceeding the repeatability value of the test method.
- A "Fail/Incompatible" rating designates a grease mixture as incompatible, or when the grease sample's test result is beyond the test results of the two unmixed greases by an amount exceeding the repeatability of the test method.

9.3 Performance Testing

The primary purpose behind performance testing is to provide data that assists in the determination of which EAL grease could be a suitable replacement, specifically one that meets or exceeds the performance quality of the in-use grease. Because greases vary in their function, a variety of performance tests are available. To determine which tests to perform, the following process was used in this study:

1. Determine the basic functions of the in-use grease.
2. Determine the performance tests that provide indication of these basic functions.
3. Eliminate redundant tests such that the remaining tests sufficiently quantify the basic functions of the grease to be replaced.

9.3.1 In-Use Grease Basic Functions

As described above, Schaeffer's 248 Moly Syngard, Chevron Ultra Duty EP, and Mobil Unirex EP are used as a multi-purpose greases for a variety of mechanical components. Overall, an EAL substitute must be comparable to these greases in the following ways: maintain component lubrication and prevent wear during heavy loads; prevent corrosion on bronze bushings and deterioration from air exposure; and resist removal from precipitation and river flow.

As observed in Appendix B.1, B.2, B.3, or B.4, Chevron Ultra Duty EP, Mobil Unirex EP, and Huskey LVI-50 lubricate components similar to those lubricated by Schaeffer's 248 Moly Syngard, however, Mobil Unirex EP and Huskey LVI-50 are more capable at resisting forced water spray. The performance tests selected were identical for these greases, including quantifying each grease's ability to resist forced water spray.

Schaeffer's Silver Streak 200S is primarily used by maintenance staff to lubricate open gears. This thick, tacky grease must retain lubrication properties and protect equipment under extreme pressure, resist oxidation deterioration, and resist removal from water washout.

9.3.2 ASTM Grease Tests

A detailed description of each performance test included in this study is provided below:

- ASTM D942 Oxidation Stability of Grease
  - This test is a measure of a grease's resistance to oxidation. This is quantified by measuring the net pressure change in an oxygen-charged test vessel. A decrease in pressure is expected and indicates a change due to grease oxidation. A smaller value is ideal because it denotes that less grease molecules have oxidized or chemically combined with oxygen.
- ASTM D1264 Water Washout
  - This test estimates the resistance of grease removal from pressurized water spray. This is done by measuring the percent weight loss of grease washed out of a rotating ball bearing while being indirectly sprayed with water.

- ASTM D4048 Copper Corrosion
  - This test measures the grease's tendency to corrode copper. The sampled grease is applied to a copper strip for a time. Upon removal of the grease, the copper test-strips are compared and matched in appearance to standard copper corrosion strips and rated based on their match to the standards.
- ASTM D2266 Four Ball – Wear Scar
  - This test evaluates the preventative characteristics of greased steel-on-steel sliding applications. Wear caused by a rotating ball on three stationary balls is quantified using a microscope, and the average diameter of the wear scar (in mm) is reported.
- ASTM D2596 Four Ball – Load
  - This test determines the load carrying properties of lubricating greases and is performed by rotating a load-bearing steel ball onto three stationary steel balls. Various loads are applied, and the test is complete when the ball seizes. Several values are generated from this test including the load wear index, the weld point of the four balls, and load at which seizure occurred.
- ASTM D1743 Rust Corrosion Inhibition
  - This test quantifies the corrosion prevention properties of a lubricating grease. The lubricated bearings are run under a thrust pattern which mimics lubrication patterns found in service, exposed to water, then stored for 48 hours at 52°C in 100% humidity. Once completed, the bearings are cleaned and inspected for corrosion.

Table 9-1 lists the performance tests selected to quantify the characteristics of each of the in-use greases and their respective candidate EAL.

Table 9-1. Performance tests performed per in-use grease.

Each EAL grouped with its respective in-use grease had the same tests performed. See Section 9.1 for why Lloyd's Laboratory Loobit is not recommended in this study for performance testing.

In-use Grease	ASTM Test Method	Description
Schaeffer's 248 Moly Syngard	D942	Oxidation stability; measures a grease's resistance to oxidation.
	D1264	Water washout; estimation of a grease's resistance to removal by water.
	D4048	Copper corrosion; visual score for grease corrosion of polished copper.
	D2266	Four ball – Wear scar; wear prevention of grease with steel on steel applications.
	D2596	Four ball – Load; estimates load carrying properties of the grease
Chevron Ultra Duty EP	D942	Oxidation stability; (same as above)
	D1264	Water washout; (same as above)
	D4048	Copper corrosion; (same as above)
	D2266	Four ball – Wear scar; (same as above)

In-use Grease	ASTM Test Method	Description
	D2596	Four ball – Load; (same as above)
Mobil Unirex EP	D942	Oxidation stability; (same as above)
	D1264	Water washout; (same as above)
	D4048	Copper corrosion; (same as above)
	D2266	Four ball – Wear scar; (same as above)
	D2596	Four ball – Load; (same as above)
Huskey LVI-50	D942	Oxidation stability; (same as above)
	D1264	Water washout; (same as above)
	D4048	Copper corrosion; (same as above)
	D2266	Four ball – Wear scar; (same as above)
	D2596	Four ball – Load; (same as above)
Schaeffer's Silver Streak 200S	D942	Oxidation stability; (same as above)
	D1264	Water washout; (same as above)
	D2266	Four ball – Wear scar; (same as above)
	D2596	Four ball – Load; (same as above)

Note that while these tests help determine the impact that grease has on lubricated components, these tests are performed in a laboratory under controlled conditions, and are not representative of dynamic, in-service conditions.

Performance testing was performed on 100% (unmixed) in-use grease samples and 100% (unmixed) EAL grease samples. These tests were performed by SGS Laboratories.

10.0 Laboratory Testing Results and Discussion

Laboratory compatibility and performance testing results are currently underway. As discussed previously, enough manufacturer provided data was available for the multi-purpose greases (Schaeffer's 248 Moly Syngard, Chevron Ultra Duty EP, Mobil Unirex EP, Huskey LVI-50, Panolin Margrease EP 2, and Renewable Lubricants Bio High Temp 180 Ep Grease 2) such that laboratory testing results could be anticipated. A brief discussion of and a recommendation based on these results is found in Section **Error! Reference source not found.**. However, not enough information was provided from the manufacturers of the open gear greases (Schaeffer's Silver Streak 200S, Grignard 2013 VGP Pro OG, Renewable Lubricants Bio SynXtra EP Open Gear, Castrol Biotac OG, and Kluber AG-602). Consequently, laboratory testing results and EAL implementation recommendations will need to be evaluated once laboratory testing has been completed.

11.0 EAL Reliability and Safety

Also important to EAL implementation feasibility is an EAL's ability to be as reliable and safe as the in-use grease it is intended to replace. As discussed previously, poor or deteriorated lubrication can cause catastrophic failure for much of the equipment included in this study. However, the reliability and safety of implementing each of the EAL candidates is adequately expressed through compatibility and performance testing. For example, compatibility test ASTM D217 indicates how stable a grease's consistency is when subject to prolonged heating, performance test ASTM D1264 quantifies a grease's reliability when subject to water spray, and performance test ASTM D942 measures a grease's ability to remain stable by resisting oxidation. These tests, in addition to the other laboratory tests being performed, provide a thorough look at the reliability and safety of EALs. A brief discussion on how these manufacturer-provided test results compare between the candidate EALs and the in-use greases takes place in Section **Error! Reference source not found.**.

12.0 Non-EAL Grease Seepage Mitigation Recommendations

With the primary objective to prevent in-use oil and grease lubricants from entering river water, two options are considered to mitigate this: (1) adding containment, and (2) conversion to EALs.

12.1 Equipment Criteria for Adding Containment

While adding containment to capture seeping lubricant sounds like an obvious solution, at times it is not feasible. For example, capturing grease from lubricated wire rope that connects a hoisting drum to a submerged gate may not be feasible. The following are guidelines to assist in determining ideal use of containment:

- Non-customizable, off-the-shelf containment that does not require welding to, drilling to, or bolting to existing equipment.
- Containment must not encroach on walkways and present a safety hazard for personnel or visitors.
- Containment must not significantly hinder access to equipment.
- Containment must not hinder typical operations.
- Containment must be removable to allow easy collection.

Given these guidelines, ideal candidates for containment include stationary equipment that significantly overhangs flooring or grating. However, after a review of the equipment listed in Appendix B.1, an insufficient quantity of equipment met the above criteria to justify further exploration and recommendation of containment. Most of the equipment listed in Appendix B.1 is either non-stationary or does not overhang significantly enough, making non-customizable containment options ineffective. Significant efforts could be made to customize containers that could effectively capture dripping grease, but the cost to manufacturing and maintaining such containers could be significantly more relative to converting non-EAL greases to EALs.

Therefore, relying on added containment is proposed as secondary to switching to EALs.

12.2 Equipment Criteria for EAL Conversion

Given the guidelines and discussion for containment, ideal candidates for conversion to EAL lubrication include the following:

- Submerged equipment.
- Equipment that overhangs water with minimal to no flooring beneath (i.e., wire rope attached to gates).
- Non-stationary equipment (i.e., crane truck equipment, trolley gearing, etc.).
- Bearings where grease drippage down the sides of the equipment is difficult to contain.

Given that containment is not secondary and that nearly all the equipment listed in Appendix B.1 through B.4 fit the above criteria, EAL conversion is preferred over added containment to mitigate non-EAL grease seepage from lubricated equipment.

13.0 EAL Implementation Procedure

To ensure that the conversion from in-use greases to EALs is successful, it is important for the conversion to be implemented with caution. The general process for implementing EALs is as follows:

1. Apply the EAL in the same manner as the former grease.
2. During operation of equipment, visually observe for any unusual or alarming performance characteristic, including:
    a. Noise, unusual metal-on-metal noise
    b. Jamming or binding of equipment
    c. Rust developing
    d. Unusually quick removal by water

The following sections detail additional implementation information specific to the various equipment included in this study.

13.1 Equipment Lubricated via Remote Mounted Zerks

Equipment lubricated via zerks consists of bushing, bearings, pillow blocks, couplings, etc. that are lubricated such that a reservoir of lubricant is contained in the zerk lines. Because of this reservoir, it is likely that more time will be required before the EAL will completely replace the in-use grease in the grease line equipment. Consequently, more time may be required before the impact of the EAL grease can be observed. It is important to note that the equipment should not be over-lubricated to expedite this process, as this could damage equipment seals.

13.2 Equipment Lubricated via Direct Mounted Zerks

Equipment not lubricated via direct mounted zerks consists of bushings, bearings, pillow blocks, couplings, etc. where lubrication is applied directly to the piece of equipment, not through a zerk grease line. Thus, the impact of the EAL grease can be more readily observed. If the EAL grease is compatible with the in-use grease, then complete removal of the in-use grease is not necessary. However, if a non-compatible EAL grease is to replace the in-use grease, cleaning the in-use grease from the equipment is recommended prior to applying the EAL grease.

13.3 Open Gears

If the EAL and in-use grease are compatible, the EAL grease can be applied directly to the open gear—typically by brush, dipped, or dripped—without cleaning off the existing grease. If the greases are not compatible, performing a full cleaning using a wire brush and solvent is recommended. This can be done by steam cleaning or by using compressed air. Once cleaned, the open gear grease can be applied by brush, dipped, or dripped.

14.0 Conclusion

EAL implementation feasibility priority ratings were prioritized by, first, cost feasibility, second, ease of implementation, and, third, likelihood of water contact. Equipment given a “High” and “Moderate” EAL implementation feasibility priority rating included bull gears, chain drives, pillow blocks, sheaves, bearings, couplings, hooks, and lifting beams that were either submerged or demonstrated some probability of water contact. Equipment given a “Low” EAL implementation feasibility priority rating consisted of turbine hub oil and wire rope and thoroughly contained bearings, couplings, bushings, pillow blocks, and chain drives.

Suitable EAL candidates were identified for the high and moderate priority equipment. Laboratory testing results that compare in-use greases to these EALs are currently pending.

As discussed in Section 10.0, results from laboratory testing are pending. The following recommendations and conclusions are based on anticipated results informed by manufacturer-provided data and McMillen’s experience in Hydro-plant operations and maintenance. This manufacturer-provided data was used to select candidate EALs for laboratory testing.

14.1 Multi-purpose Grease Recommendation

As discussed previously, two EAL options (Panolin Margrease EP 2 and Renewable Lubricant Bio High Temp 180 EP) were presented for laboratory testing and possible replacement of Schaeffer’s 248 Moly Syngard, Chevron Ultra Duty EP, Mobil Unirex EP, and Huskey LVI-50. While both Panolin Margrease EP 2 and Renewable Lubricant Bio High Temp 180 EP are plausible replacements for these in-use greases, they differ in their strengths and weaknesses.

Panolin Margrease EP 2 represents a more comprehensive – and expensive – option. It is anticipated that this grease performs equally to or improves upon the performance of all the multi-purpose in-use greases. Furthermore, data provided by Panolin suggests that Margrease EP 2 is similar to Mobil Unirex EP and

Huskey LVI-50 in its ability to resist forceful water spray and is notably more resistant to water removal than Schaeffer's 248 Moly Syngard and Chevron Ultra Duty EP. However, Margrease EP 2 costs approximately 4 to 5 times more than these multi-purpose in-use greases.

Renewable Lubricant Bio High Temp 180 EP represents a suitable and less expensive option. It is anticipated that this grease performs equally to – and in some ways improves upon – the performance of Schaeffer's 248 Moly Syngard and Chevron Ultra Duty EP. It is also anticipated that Renewable Lubricant Bio High Temp 180 EP performs similarly to Mobil Unirex EP and Huskey LVI-50 except in its ability to resist forceful water spray. Renewable Lubricant Bio High Temp 180 EP costs approx. 2 times more than the multi-purpose in-use greases.

Per the equipment listed in Appendix B.1 through B.4, 20 line items use the less water-resistant multi-purpose greases (Schaeffer's 248 Moly Syngard and Chevron Ultra Duty EP) while 13 line items use the more water resistant multi-purpose greases (Mobil Unirex EP and Huskey LVI-50). To reduce the impact on EAL implementation, McMillen Jacobs anticipates the following recommendation:

- Replace Schaeffer's 248 Moly Syngard and Chevron Ultra Duty EP greases with Renewable Lubricant Bio High Temp 180 EP.
- Replace Mobil Unirex EP and Huskey LVI-50 grease with Panolin Margrease EP 2.

14.2 Open Gear Grease Recommendation

Because little technical data was available from manufacturers on in-use open gear grease and open gear EALs, an EAL implementation recommendation for open gear grease will be provided upon receipt of laboratory test results.

14.3 EAL Implementation Recommendation per Equipment

Regarding which equipment to implement EALs, McMillen Jacobs recommends the following:

- Implement EAL conversion for all equipment given a "High" priority.
- Implement EAL conversion for all equipment given a "Moderate" priority.
- For wire ropes, investigate replacement of carbon steel wire ropes with stainless steel for ropes at the end of its service life, where applicable. Additionally, for equipment at the end of its design life, investigate replacing carbon steel rope with stainless steel wire rope infused with EAL lubricant.
- For future turbine upgrades, investigate oil-free turbine hub designs.
- Because of the negligible likelihood of water contact and the equipment's thorough containment, it is not recommended to implement EALs for the non-submerged "Low" priority equipment. This includes the following equipment:
    - Hoist bearings, gear reducer, couplings, bushing and pillow blocks on the COH intake gantry crane currently lubricated by Mobil Unirex EP.

- Auxiliary hoist chain on the COH intake gantry crane currently lubricated by Fuchs Renolit LZR grease.
- Hoist chain drive and couplings on Tainter gates 1, 11, and 12 currently lubricated by Chevron Coupling grease.
- Dewatering pump zerks on the middle spillway entrance currently lubricated by Huskey LVI-50.

15.0 References

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[2] United States Environmental Protection Agency. Nov 2011. Environmentally Acceptable Lubricants: EPA 800-R-11-002. http://nepis.epa.gov. November 26, 2019.

[3] European Commission. 1992. https://ec.europa.eu/environment/ecolabel/. November 26, 2019.

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

[5] Inland Navigation Design Center (INDC). March 2018. Mechanical Equipment Lubrication: Standardization and Sustainability.

Appendix A – Manufacturer-Provided Cut Sheets

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

TYPICAL TEST DATA

NLGI Grade	0	1	2
Product Number	*238013*	*238012*	*238011*
SDS 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.

RENOLIT LZR 000

Semi-fluid grease.

Classification DIN 51502	GP00-000G-40
Classification ISO 6743-9	-
Thickener	Li/Ca
Base oil	Mineral oil
Solid lubricants	-
NLGI grade	00-000
Base oil viscosity at 40 °C	43 mm²/s
Temperature range	-40/+110 °C
Approvals, recommendations	MB-Sheet 264.0 MAN 283 LI-P 00/000

Ca-X: Calcium complex; CaSX: Calcium sulfonate complex; HDK: Gel thickener; Li/Ca: Lithium/Calcium; Li-X: Lithium complex; PU: Polyurea; Synth. NaX: Synthetic sodium complex; PFPE: Perfluorpolyether

Main application area

Semi-fluid grease for central lubricating systems of commercial vehicles.

Industries

- Agriculture, forestry
- Construction
- Transport
- Automotive

HUSKEY™ LVI-50

Description

HUSKEY LVI-50 is a multi-service, non-melting, waterproof grease fortified with PTFE. It is designed specifically to lubricate, seal out water, and resist chemical attack under the most demanding conditions. **HUSKEY LVI-50** with its excellent film strength and extreme pressure qualities, forms a tough durable film of lubrication that prevents metal to metal contact. **HUSKEY LVI-50** is a pure synthetic based lubricant that is NSF/U.S.D.A. H-1 *Registered and KOSHER approved, which gives it full acceptability for use in ALL areas where incidental food or potable water contact may occur.

Advantages

- NSF/U.S.D.A. H-1 *Registered
- WATERPROOF
- NON-MELTING
- KOSHER APPROVED
- BIODEGRADABLE
- CHEMICAL RESISTANT
- NON STAINING
- WIDE TEMPERATURE RANGE
- REDUCES WEAR
- PREVENTS RUST & CORROSION

*NSF H-1 Registration No. 059323

Usage

HUSKEY LVI-50 with its waterproof and chemical resistant capabilities is an excellent lubricant on all sliding surfaces and slow to high speed bearings, operating in adverse conditions. Because of its pure synthetic base, high load carrying capacity and wear protection characteristics, **HUSKEY LVI-50** is far superior to petroleum, white oil based greases on the market today. This makes **HUSKEY LVI-50** a truly multi-service grease in both food grade and non food grade applications operating in temperatures from -10° F to 325°F. Due to its NSF/U.S.D.A. H-1 *Registration, **HUSKEY LVI-50** is an excellent choice for both Food Processing plants, where equipment wash down is an everyday requirement and Water Industries, where contamination of conventional petroleum lubricants is a primary environmental concern. **HUSKEY LVI-50** is compatible with most rubbers and plastics and is a superior lubricant for "O" rings. Some of its diversified uses include:

- PUMP BEARINGS
- BUSHINGS
- CAN SEAMERS
- VALVES
- GASKETS AND "O" RINGS
- CONVEYORS
- STERILIZER CHAINS
- SLIDES AND WAYS
- POOL EQUIPMENT
- ELECTRIC MOTORS
- WATER FILTERS
- UNIVERSAL JOINTS

Package Availability

- Convenient Disposable Gun Loader 14 oz. Cartridges
- 5 gal. Pail

- 15 gal. Keg
- 55 gal. Drum

Typical Specifications

Product: LVI-50

Base Oil: Synthetic

Thickener: Synthetic

Texture: Smooth & Tenacious

Color: Translucent White

Solid Lubricant: PTFE

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

TEST	ASTM TEST	RESULTS
N.L.G.I. Grade		2
Worked Penetration		
60 Strokes	D-217	280
10,000 Strokes	D-217	290
Base Oil Viscosity,		
cSt @ 40°C	D-445	781
cSt @ 100°C	D-445	42
Pour Point, °F	D-566	-10
Flash Point, °F	D-92	325
Dropping Point, °F	D-566	NONE
Evaporation Loss, % , (10 hours @ 210°F)	D-972	1.5
Corrosion Preventative Test	D-1743	PASS
Water Washout, % Loss	D-1264	1.9
Timken OK Load, lbs	D-2509	35
4-Ball Wear Scar, mm (40 Kg, 1 hr. @ 1200 rpm, 167°F)	D-2266	0.50
Dielectric Strength, KV	D-877	30
WGK (German Water Classification)		0

NSF International Registered

Kosher Certified

SAFETY DATA SHEET NSF REGISTRATION KOSHER LETTER

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Loobit – Multipurpose Lubricant and Wire Rope Dressing

TECHNICAL DATA SHEET

BENEFITS

- User friendly, easy, clean application.
- Health Canada CFIA Listed
- Non flammable as a liquid
- Non solvent, non drying properties for superior lubrication
- WHMIS/OSHA non controlled, environmentally friendly
- Impervious to moisture, salt and most chemicals and gases
- Will not attract dust, dirt and abrasives
- Effective -50ºC to high temperatures
- Dielectric strength 34,000 volts
- Inverted spray valve (360º)
- Withstands extreme pressures.
- Compatible with plastic/nylon, rubber, natural materials and all metal alloys.
- Will not cause static electricity.
- Compatible with I.W.R.C. and fibre core wire rope.

GENERAL INFORMATION

Loobit is a multi use, heavy-duty lubricant, formulated for use on rollers, drive chains, wire rope and cables, internal control cables, open gears, exposed bearings, load bearings, load bearing hinges and pivot points, mechanical controls and more. This superior long lasting lubricant leaves a clear protective film that is always active. Loobit has proven itself superior as a medium viscosity, clean, environmentally friendly wire rope dressing since its introduction more than 60 years ago. Loobit works so well because it lubricates and penetrates under high pressures and extreme fluctuations in temperature. The internal strands within wire rope are lubricated to the core where the lubrication and corrosion protection are required. Loobit displaces moisture. After application Loobit is almost invisible. A random cut cross section of a treated wire rope best exemplifies the advantages of Loobit, as it will reveal a wicking effect with penetration to the core. This benefits in corrosion protection and re-lubrication as the cable twists around pulleys and shives. Metal on metal wear is greatly reduced. Loobit works in the cable not on it. Loobit will not accumulate on cable supports and drive mechanisms.

TECHNICAL DATA

Flash Point:	+ 220ºC Close cup ASTM D93
Pour Point:	+90ºC
Cloud Point:	-20ºC
Viscosity:	400 Cts
Dielectric Strength:	34,000 volts

Loobit is available in these sizes:

Part # 31014	12 x 350 g aerosol	Part # 32045	1 x 205 L drum
Part # 32004	4 x 4 L jug	Part # 33010	12 x 284 mL precision pump
Part # 32016	12 x 455 mL w/trigger sprayer	Part # 38888	12 x Empty 16 oz bottle
Part # 32020	1 x 20 L pail		

Proudly Canadian

Lloyds Laboratories Inc., 613 Neal Drive, Peterborough, Ontario K9J 6X7
Tel: 705 876-9997 (800) 361-6766 / Fax: 705 876-6467 (866) 876-6467
email: sales@lloydslaboratories.com

Mobilarma 700 Series

Mobil Industrial , United States

Premium Performance Rust Preventives

Product Description

The Mobilarma 700 Series contains three premium performance rust preventives that cover a range of applications including storage and inter-operational activities. The Mobilarma 777 and 778 are intended for protection cold-rolled sheet and coiled steel in the metal industry. Mobilarma 798 is intended for the lubrication and rust protection of wire rope in industrial, construction, mining and marine applications. The Mobilarma 700 Series products exhibit excellent water displacing properties and form thin tenacious films that protect surfaces even under severe conditions that include high moisture levels and exposure to acid or corrosive fumes.

The Mobilarma 777 and 778 form wet, oily and extremely thin barrier films that are not tacky so that they will not attract dirt or other foreign matter. They will protect sheet and coiled steel for up to twelve months, even under severe conditions that include variations in humidity and exposure to acid fumes that might be found in the vicinity of pickling operations.

Mobilarma 798 forms a grease-like film that protects wire ropes from corrosion tendencies of salt spray and moisture- laden atmospheres. It is effective throughout the extremes of temperature that may be encountered at sea and gives good protection against mild acids. It is pliable at –35°C and will not drip at 60°C. It resists throw-off in high-speed service and adheres without being tacky or stringy. The film is self-healing and does not chip.

Features and Benefits

Mobilarma 777 and 778 provide an effective and cost efficient means of protecting cold-rolled sheet and coiled steel prior to processing and during storage. They provide extended protection, even under severe storage conditions resulting in less reject and scrapped materials.

Mobilarma 798 works well between the strands of wire rope providing excellent lubrication as well as protective films. These characteristics reduce wear and improve life of the wire ropes as well as minimize maintenance costs associated with their use. It is compatible with other wire rope core impregnating materials that may have been applied during manufacture. It is easy to apply and economical to use.

Features	Advantages and Potential Benefits
Effective rust and corrosion protection	Less waste and lower costs
Easy application	Less waste and lower costs
Economical to use	Good coverage and protection with thin films

Applications

Mobilarma 777 and 778 are recommended for use as:

- Protective coatings for cold-rolled sheet and coiled steel
- Coatings for precision machined parts and instruments for storage
- A die lubricant (Mobilarma 778) in some light duty pressing operation

Mobilarma 798 is recommended for use for:

- Lubrication and preservation of strands and running ropes
- Impregnation of steel wire ropes during manufacture

Properties and Specifications

Property	777	778	798
Density @ 15 C, g/cm3, ASTM D4052	0.86	0.88	
Dropping Point, °C, ASTM D2265			63
Flash Point, Cleveland Open Cup, °C, ASTM D92	120	190	238
Kinematic Viscosity @ 100 C, mm2/s, ASTM D445			23.1
Kinematic Viscosity @ 40 C, mm2/s, ASTM D445	18	18	
Pour Point, °C, ASTM D97	-6	-3	

Health and Safety

Health and Safety recommendations for this product can be found on the Material Safety Data Sheet (MSDS) @ http://www.msds.exxonmobil.com/psims/psims.aspx

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12-2019

Exxon Mobil Corporation
22777 Springwoods Village Parkway
Spring TX 77389

1-800-ASK MOBIL (275-6624)

Mobil

UNIREX™ N Series

Mobil Grease, United States

High Temperature Bearing Grease

Product Description

UNIREX™ N greases are premium-quality, lithium-complex products suitable for high-temperature service in rolling-element bearings. These versatile greases can be used in a wide range of industrial applications and are particularly recommended for electric-motor lubrication.

Unirex N 2 in an NLGI No. 2 grade and is preferred in most cases for application by hand packing or by grease gun. UNIREX N 3 is an NLGI No. 3 grade often used for special applications such as sealed-for-life electric motor bearings, vertically mounted bearings, and higher-speed applications. UNIREX N greases are not intended to be used under extreme pressure conditions where extra anti-welding properties are required.

UNIREX N 2 meets the requirements of Lubricating Grease DIN 51825 - K2N - 20L and ISO L-XBDHA 2.

UNIREX N 3 meets the requirements of Lubricating Grease DIN 51825 - K3N - 20L and ISO L-XBDHA 3.

Features and Benefits

Unirex N greases exhibit excellent high and low temperature performance, resistance to water and corrosion, and long service life in a range of bearing applications.

Features	Advantages and Potential Benefits
Excellent high-temperature performance	Lithium-complex thickener resists softening / running out of bearings at temperatures up to 190°C
Outstanding grease life	Laboratory bearing rig tests show outstanding continuous lubrication performance at bearing temperatures of up to 140°C
Very good low-temperature characteristics	Start-up power requirements are low at temperatures down to at least -20°C. Meets DIN 51825 low temperature torque requirements at -20°C
Excellent mechanical stability	Exhibits excellent resistance to softening due to mechanical working
Excellent water and corrosion resistance	Resists water washout and protects bearings against corrosion
Excellent performance in high-speed applications	Channelling characteristics provide excellent performance in high- speed deep-groove ball bearings. Unirex N3 is recommended where DmN (mean bearing diameter X rpm) exceeds 360,000

Applications

UNIREX N 2 is an NLGI No. 2 grade and is preferred in most cases for application by hand-packing or by grease gun. UNIREX N 2 is recommended for the lubrication of electric motors. It is suitable for NEMA (National Electric Manufacturer's Association) Insulation Class A, B, and F motors.

UNIREX N 3 is an NLGI No. 3 grade and is used for special applications such as sealed-for-life bearings, vertically-mounted bearings, and higher-speed bearings.

Most of the uses for UNIREX N involve manual methods of application. Although UNIREX N 2 is suitable for use in automatic centralized systems, equipment served by these systems would normally not require the long-life properties of UNIREX N, since one of the functions of automatic systems is to replenish the lubricant at relatively short time intervals. UNIREX N 3 should not be used in such systems.

Specifications and Approvals

Unirex N Series meets or exceeds the requirements of:	2	3
DIN 51825: (2004-06)	K2N-20L	K3N-20L

Typical Properties

UNIREX N	2	3
Thickener Type	Lithium-complex	Lithium-complex
NLGI Grade	2	3
Color, Visual	Green	Green
Texture	Smooth, Buttery	Smooth, Buttery
Dropping Point, ASTM D 2265, °C	230	230
Base Oil Viscosity, ASTM D 445, cSt @ 40°C	115	115
Base Oil Viscosity Index, ASTM D 2270	95	95
Penetration, worked 60 stokes, ASTM D 217, mm/10	280	235
Penetration change after 100,000 strokes, ASTM D 217, mm/10	25	30
Oil Separation, ASTM D 6184, mass % @ 100°C / 30 hrs	1.5	0.6
EMCOR Corrosion , ASTM D 6138 (Distilled Water), rating	0,1	0,1
Water Washout @ 79°C, ASTM D 1264, mass %	3.7	3.5

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.

03-2019

Exxon Mobil Corporation
22777 Springwoods Village Parkway
Spring TX 77389

1-800-ASK MOBIL (275-6624)

SINCE 1839 Schaeffer MANUFACTURING COMPANY

ISO 9001 CERTIFIED

TECHNICAL DATA

102 Barton Street, St. Louis, Missouri 63104
In-State (314) 865-4100/Out of State 800-325-9962/Fax (314) 865-4107 http://www.schaefferoil.com

#248 MOLY SYNGARD™ 2000 EP

Moly Syngard™ 2000 EP is a multipurpose, extreme pressure, anti-wear grease that is specially formulated for use in all types of heavy duty construction, mining, farming and industrial equipment that are being used in hot, wet or heavily loaded applications especially where operating temperatures are above 350ºF.

Moly Syngard™ 2000 EP is compounded from the finest high viscosity index ,solvent refined severely hydrofinished 100% pure paraffin base stocks available. Blended into these 100% pure paraffin base stocks is an inorganic thickener. This inorganic thickener allows Moly Syngard 2000 EP the ability to lubricate the bearings effectively in temperatures up to 600°F.

Further blended into these 100% paraffin base stocks is synthesized moly. Synthesized moly is an organic type of moly which, like molybdenum, disulfide (MoS_2) plates itself to metal surfaces of the bearings. Once plated to the metal surfaces of the bearings, moly forms a long lasting solid lubricant film. This solid lubricant film will withstand pressures up to 500,000 pounds per square inch, giving the metal surfaces of the bearings the protection they need during periods of high speeds, high shock loads and extreme pressures.

Moly Syngard™ 2000 EP has excellent rust and oxidation inhibiting characteristics, excellent water resistance, shear and thermal stability, and good mechanical and pumpability properties. Moly Syngard™ 2000 EP also has excellent cohesive and adhesive properties. Because of these cohesive and adhesive properties, Moly Syngard™ 2000 EP will not wash out, pound out, splatter or squeeze out even under the heaviest loads or vibrations.

Moly Syngard™ 2000 EP can be applied either manually or by a heavy duty automatic lube system. Moly Syngard™ 2000 EP #1 has an operating temperature of -5ºF to 600ºF. Moly Syngard™ 2000 EP #2 has an operating temperature of 0ºF to 600ºF. Moly Syngard™ 2000 EP #3 has an operating temperature of 30ºF to 600ºF.

TYPICAL PROPERTIES

NLGI	#1	#2	#3
Type Thickener	Bentone	Bentone	Bentone
Dropping Point (ASTM D-2265)	None	None	None
Worked Penetration 77°F/25°C (ASTM D-217)	310-340	285-295	220-250
Roll Stability (ASTM D-1831) % Change in Consistency	20	19.3	19.2
Rust Inhibition Test (ASTM D-1743) Rating	1,1,1	1,1,1	1,1,1
Oxidation Stability (ASTM D-942): Psi Loss @ 100 hrs.	4	4	4
Timken EP Test (ASTM D-2509)	60 lbs.	60 lbs.	60 lbs.
Four Ball EP Test (ASTM D-2596): Load Wear Index, kg	40	45	45
Weld Point, kg	315	315	315
Four Ball Wear Test (ASTM D-2266) Scar Diameter	.68mm	.68mm	.7 mm
Falex Continuous Load (ASTM D-3233) Failure, lbs	1950	2000	2100

TYPICAL PROPERTIES CONTINUED ON REVERSE SIDE

TYPICAL PROPERTIES CONTINUED

NLGI Grade	#1	#2	#3
Wheel Bearing Leakage Tendency Test (ASTM D-1263)			
Leakage, grams*	1	1	1
Deposits	No Deposits	No Deposits	No Deposits
Water Washout (ASTM D-1264)			
% Loss @ 175ºF	7.5	7	7
Water Spray-off Test (ASTM D-4049)			
% Loss	30	30	25
Oil Separation (ASTM D-1742)			
% Wt. of Oil Separation	2	2	2
Evaporation Loss (ASTM D-2595)			
22 hrs. @ 250ºF	0.9	0.9	0.9

Base Oil Properties

Viscosity SUS 100°F (ASTM D-445)	1200	1500	1900
Viscosity cSt 40°C (ASTM D-445)	226.18	282.04	413.11
Viscosity CSt 100°C (ASTM D-445)	18.5	21.95	30.18
Viscosity Index (ASTM D-2270)	105	105	105
Flash Point °F/°C (ASTM D-92)	530°/277°	520°/271°	510°/265°
Fire Point °F/°C (ASTM D-92)	560/293°	590°/310°	540°/282°

SINCE 1839
Schaeffer's
SPECIALIZED LUBRICANTS

TECHNICAL DATA

102 Barton Street, St. Louis MO 63104
Ph: 800-325-9962 / Fax: 314-865-4107
www.schaefferoil.com
ISO 9001 CERTIFIED

200S SILVER STREAK® SPECIAL

Silver Streak® Special is a para-synthetic, heavy duty, extreme pressure non-solvent containing multi service lubricant that is recommended for the lubrication of heavily loaded open gears particularly those found in grinding mills, kilns, shovels, dragline, ship loaders, stackers and reclaimers and excavator applications; as one grease (multipurpose and open gear) for the entire machine on most shovels, excavators and draglines (excluding electric motor bearings); as a surface dressing for slow moving gears open to the atmosphere, plain bearings, pivot pins and bushings and articulations found on earth moving equipment; mooring, static and slow moving wire ropes including those intermittently immersed in salt water and other applications that are common to the mining, marine, railroad, steel mill and power plant industries. Silver Streak® Special also works great on fifth wheels.

Silver Streak® Special is compounded from a unique blend of select solvent refined severely hydro-finished high viscosity index paraffin base oils and polyalphaolefin synthetic base oils. These base oils were selected for their exceptional physical and chemical stability and their exceptional serviceability over a wide range of temperatures. These base fluids are further compounded to provide the Silver Streak® Special with superior adhesive film-forming characteristics. This adhesive film-forming characteristic allows Silver Streak® Special to resist “squeeze out” and “sling out” along with allowing the product to cling tenaciously, even to gears that are in a vertical orientation. Also this compounding allows Silver Streak® Special to have a superior resistance to oil separation due to centrifugal forces that are common in many coupling applications. **This special compounding allows Silver Streak® Special to remain soft and pliable over a long period of time without the use of any kind of solvents, especially non-flammable chlorinated solvents such as 1,1,1 trichloroethane that are being considered undesirable for use due to environmental consideration.**

To fortify the adhesive film strength of Silver Streak® Special, a combination of molybdenum disulfide and various solid lubricants are compounded into Silver Streak® Special. The molybdenum disulfide and various lubricants contribute to the structure of the film, and also improve the anti-wear, extreme pressure characteristics and load-carrying capabilities of Silver Streak® Special beyond those of conventional lubricants. The load carrying ability of Silver Streak® Special is in excess of 500,000 pounds per square inch.
This combination of molybdenum disulfide and various solid lubricants also forms a protective layer between the mating surfaces. This protective layer provides a cushioning effect between the contacting asperities that minimizes pitting of the mating surfaces.

Silver Streak® Special offers the following advantages.

- Forms an almost indestructible adhesive film with a “cushioning” effect even under extreme pressure and at very low speeds.
- Resists film destruction by contaminating oils or greases “migrating” from nearby mechanisms.
- Exceptional physical and mechanical stability.
- Resistant to water washout and water wash-off by immersion or spray.
- Resistant to the adhering of dirt or dust.
- Reduction in contact temperatures.
- Minimizes cold metal welding at the contacting asperities.
- Minimizes the vibration of “stick slip”.
- Excellent anti-wear and extreme pressure characteristics.
- Maximizes a reduction in lubricant consumption rate.
- Excellent corrosion protection to protect metal surfaces from corrosion in hostile environments.

Continued on next page

Only Silver Streak® Special Ultra Light grade can be used in enclosed industrial type gear cases to replace an SAE 250 weight or ISO 1000 viscosity grade lubricant.

Silver Streak® Special can be applied either manually or by heavy duty automatic lube systems. Silver Streak® Special Heavy can be pumped down to 50°F/10°C*. Silver Streak® Special Medium can be pumped down to 45°F/7°C*. Silver Streak® Special Light can be pumped to 32°F/0°C*. Silver Streak® Special Extra Light can be pumped to 14°F-10°C*. Silver Streak® Special Extreme Light can be pumped to -20° to -25°F/-29° to -32°C*. Silver Streak® Special Ultra Light can be pumped to -40°F/-40°C*. When using Silver Streak® Special Ultra Light in summer months or in warm weather conditions, consideration should be given to using a heavier grade of Silver Streak® Special.

***May vary with types of equipment and dispensing system configuration used.**

TYPICAL PROPERTIES

	Ultra	**Extreme**	**Extra**	**Light**	**Medium**	**Heavy**
Specific Gravity 60°F/15.6°C	0.9848	0.9903	1.00	1.00	1.00	1.01
Flash Point °F/°C (ASTM D93), min.	343.4°/173°	334.4°/168°	424.4°/218°	417.2°/214°	415.4°/213°	413.6°/212°
Four Ball E.P. Test (ASTM D2596):						
Weld Point, kg,	800	800	800	800	800	800
Weld Newtons	8000	8000	8000	8000	8000	8000
Four Ball E.P. Test (ASTM D2266):						
Scar Diameter, mm	.59	.56	.57	.59	.60	.61
Falex Continuous Load (ASTM D3233):						
Failure Load, lbs-f	+4500	+4500	+4500	+4500	+4500	+4500
Failure Load, Newtons	+20450	+20450	+20450	+20450	+20450	+20450
FZG DIN 51-354						
Failure Stage	+13th	+13th	----	----	----	----
Rust Inhibition Test (ASTM D1734)	1,1,1	1,1,1	1,1,1	1,1,1	1,1,1	1,1,1
Copper Strip Corrosion (ASTM D4048)	1b	1b	1b	1b	1b	1b
Deleterious Particles (ASTM D404)						
#Scratches	20	15	20	10	14	14
Rating	2	2	2	1	2	2
Base Oil Properties						
Viscosity @ 40°C, cSt	76-90	84-94	608-689	804-926	975-1100	1426-1733
Viscosity @100°C, cSt (ASTM D445)	12.5-17	17-21.5	35-39	45-52	63-76	79-88

Renewable Lubricants, Inc.
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Bio-E.P.™ Wire Rope Lubricants

STABILIZED™ by Renewable Lubricants

"Biobased Lubricants that Perform Like Synthetics"

Bio-E.P.™ Wire Rope Lubricants are ultimately biodegradable[1] vegetable oils formulated with antiwear, extreme pressure (EP), anti-rust, oxidation inhibitors, and a tackifier. They provide a light waxy-tacky coating, and are recommended for lubricating multi-strand cables and wire rope wound around central cores of steel or fiber, which are subject to heavy loading and/or shock loading. These biobased products provide improved fire resistance over equal viscosity petroleum products and contain no chlorine, zinc, or heavy metals. Performance is enhanced by use of the Stabilized HOBS's natural vegetable oil composition, which provides an oily boundary film. In addition, this oily film has a natural polarity to metal surfaces and helps clean and then penetrates deep into the inner core of the cable preventing rust and wear. The super high viscosity index of the Stabilized HOBS adds additional lubrication qualities to this high performance lubricant. Laboratory and field tests have shown that the products provide exceptional protection with excellent low temperature pumpability.

Applications: Bio-E.P.™ Wire Rope Lubricants are specifically designed to provide high anti-wear, EP, and anti-rust protection. They provide a corrosion inhibiting waxy film that is especially effective in protecting ferrous metals in salt and acid fume (hydrochloric acid) environments and against high humidity. They are non-staining to nonferrous metals, water displacing, and also effective in protecting galvanized steel. They protect cables, pulleys, sliding surfaces, and threads against damage from corrosion, galling or seizure. Other applications including: chains, slideways, and hinge pins. Field applications can be applied by spray, brush, dip, drip or pressure boot. (**Can be applied without heating, but warming to 30 to 40°C prior to use will provide faster penetration into strands. Because of the waxes, slight agitation may be needed after months in storage).**

Bio-E.P.™ Wire Rope Lubricants meet the Environmental Protection Agency (EPA) 2013 Vessel General Permit (VGP) guidelines for Environmentally Acceptable Lubricants (EALs), and should be used where **LOW TOXICITY**, **BIODEGRADABILITY** and **NON-BIOACUMMULATION** properties are required. They exceed the acute toxicity (LC-50 / EC-50 >1000 ppm) criteria adopted by the US Fish and Wildlife Service and the US EPA. Bio-E.P.™ Wire Rope Lubricants are ENVIRONMENTALLY RESPONSIBLE lubricants that are formulated from renewable agricultural biobased resources. We believe Earth's environmental future rests in the use of renewable materials.

[1]Ultimate Biodegradation (Pw1) within 28 days in ASTM D-5864 Aerobic Aquatic Biodegradation of Lubricants

Typical Specifications

	ASTM	Light	Medium	Heavy Medium	Heavy	Extreme Heavy
SAE Viscosity Grade Replacement		**10W20**	**10W30**	**15W40**	**15W50**	**20W60**
ISO Viscosity Grade		**32**	**46**	**68**	**100**	**150**
VISCOSITIES:	D-445					
@100°C., cSt.		7.5	10.3	13.4	17.9	24.5
@40°C., cSt.		31.8	45.8	67.2	94.2	137.3
Viscosity Index	D-2270	216	222	206	210	212
Flash Point, COC,°C	D-92	224	230	272	278	282
Pour Point,°C	D-97	-32	-32	-30	-28	-23
Copper Corrosion (3hr @ 100C)	D-130	1B	1B	1B	1B	1B
4-Ball Wear (mm)	D-4172	0.40	0.35	0.35	0.35	0.35
4-Ball EP	D-2783					
Weld Point (kg)		400	400	450	450	450
Load Wear Index		47	55	58	58	58
Timken Load, OK Load (lbs)	D-2782	65	70	70	70	70
Rust Prevention						
A-Distilled water	D-665A	Pass	Pass	Pass	Pass	Pass
B-Syn. Sea water	D-665B	Pass	Pass	Pass	Pass	Pass
Cabinet Humidity	D-1748	>60 days	>60 days	>60 days	>60 days	>60 days
Salt Fog Corrosion	B-117	>60 hrs.	>60 hrs.	>60 hrs.	>60 hrs.	>60 hrs.
RLI Product Item #		**82610**	**82620**	**82650**	**82630**	**82640**

STABILIZED by Renewable Lubricants™* is RLI's trademark on their proprietary and patented anti-oxidant, anti-wear, and cold flow technology. High Oleic Base Stock (HOBS) are agricultural vegetable oils. This Stabilized technology allows the HOBS to perform as a high performance formula in high and low temperature applications, reducing oil thickening and deposits. Patented Product: US Patent 6,383,992, US Patent 6,534,454 with additional Pending and Foreign Patents

Availability F.O.B. :Hartville, Ohio, USA 1 Gallon 5 Gallon Pail Drum Totes

Renewable Lubricants, Inc.
476 Griggy Rd., P.O. Box 474
Hartville, Ohio 44632-0474
Voice: 330.877.9982 Fax 330.877.2266
Web: www.renewablelube.com

Bio-High Temp™ 180 E.P. Grease

STABILIZED™ by Renewable Lubricants

NLGI #2 (Multipurpose Lithium Complex)

"Biobased Lubricants that Perform Like Synthetics"

This High Temperature Biobased grease is a state-of-the-art product, which is characterized by its super high viscosity index base oil and lithium complex thicker. The super high viscosity index of the Stabilized* HOBS naturally improves the thermal shear stability and load capacity. This very high load carrying ability, excellent resistance to water, corrosion, and outstanding performance in a wide temperature range, make it high performance premium grease. It contains no heavy metals or other harmful or environmentally undesirable additives, such as chlorine, barium or lead. The Extreme Pressure performance is supported by an environmentally friendly E.P. additive and the total formulation is Ultimately Biodegradable[1]. The data below shows that this product is truly outstanding multipurpose lithium complex grease with excellent high temperature properties and good cold temperature mobility. This BioBased High Temperature Grease meets and exceeds the performance requirements of ASTM D-4950 (NLGI CG/LB)

Applications: Industrial and mining machinery, transportation, agricultural, construction and forestry equipment, paper mills, conveyors, journal bearings, electric motors, pumps and marine applications can all benefit from its long lasting protection.

- Unique high performance multipurpose automotive and industrial grease
- Provides significant protection in automotive, industrial and agricultural wheel bearing applications where temperatures can be high due to heat from disc brakes
- Excellent for chassis lubrication because of superior low temperature properties, shear stability, and water resistance
- Preferred grease for lubrication of antifriction bearings
- Biodegradable-Environmentally friendly

Typical Specifications:

Base Oil- Viscosity @ 40°C cSt	179
Viscosity @ 100°C cSt	26
Viscosity Index	180
Pour Point	-36°C
Color	Green
Texture	Smooth, Tacky
Drop Point F (C) D-566	>590°F (>310°C)
Bomb Oxidation, 100 h. D-942	5.0 psi
4-Ball Wear D-2266	0.428 mm
4-Ball EP D-2596	Weld 315
	LWI 44
Low Temp Performance, Torque at -40 C D-4693	10.04 Max, 6.39 at 60 sec
High Temperature Life D-3527	100 hrs.
Leakage Tendencies D-4290	7.4 g
Timken OK Load D-2509	60 lbs
Pen, @ 25°C Unwkd D-217	274 mm/10
Pen, Wkd 60 strokes	284 mm/10
Pen, Wkd 10,000 strokes change from 60 strokes	280 mm/10 (-4)
Pen, Wkd 100,000 strokes change from 60 strokes	293 mm/10
Roll Stability D-1831	-4.00%
Cone Bleed D-6184	4.94% Loss
Water Washout D-1264 (Avg.)	5.00% Loss
Evaporation D-6184	0.52% Loss
Oil Separation D-1742	1.1% Loss
Rust Test D-1743	Pass
Copper Corrosion D-130	1A

NATIONAL LUBRICATING GREASE INSTITUTE
NLGI
AUTOMOTIVE WHEEL BEARING & CHASSIS LUBRICANT
GC-LB

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[1] Ultimate Biodegradation (Pw1) within 28 days in ASTM D-5864 Aerobic Aquatic Biodegradation of Lubricants

Patented Product: US Patent 6,383,992, US Patent 6,534,454 with additional Pending and Foreign Patents

* Trademark of Renewable Lubricants, Inc.

Availability	F.O.B. :Manufacturer	14 oz. Tubes	35 lb Pails	120 lb Kegs	400 lb Drums
RLI Product Item #		87611			

Renewable Lubricants, Inc.
476 Griggy Rd., P.O. Box 474
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Web: www.renewablelube.com

Bio-SynXtra™ EP Open Gear Compounds

STABILIZED™ by Renewable Lubricants

"Biobased Lubricants that Perform Like Synthetics"

Bio-SynXtra™ EP Open Gear Compounds are very tacky and very viscous biosynthetic, biodegradable formulas. They are formulated with black graphite and specially designed for lubricating open gear and sliding surface applications which are subject to extreme heavy loading or shock loading. These water resistant formulas have combined energy conserving *Stabilized biosynthetic technology with extreme pressure (EP) antiwear, and anti-corrosion additives. The result is a more environmentally safe product which has the long life heat stability, but additionally offers the protection advantages of increased gear life through extremely high film strength during a wide range of operating temperatures. Performance is enhanced by use of their natural oily and polar composition, which provides excellent boundary film protection under thin film conditions. In addition, these biobased products provide improved fire resistance and biodegradability over equal viscosity asphaltic petroleum products. They contain no petroleum solvents, chlorine, zinc, lead, or other heavy metals. Bio-SynXtra™ EP Open Gear Compounds are EPA-VGP EAL compliant lubricants that are formulated with renewable agricultural plant resources. We believe Earth's environmental future rest in the use of renewable material.

Applications: Mining, Drilling, Marine, Forestry, Agriculture, Heavy Industry, Rail and Shipping: large open gears on mills and mixers, semi-enclosed gears and pinions, ring gears, and certain heavy enclosed gears where they meet the required specifications. Other applications include cables, sprockets, chains, wire ropes, flexible couplings, journal bearings, draglines, drives on straddle lift carriers, hoist gears, fifth wheels, etc. Field applications can be applied by brush, drip, pour, pumping, or automatic lubrication systems.

Typical Specifications

Bio-SynXtra EP Open Gear Compounds	**X1500 9EP**	**X3000 10EP**	**X4500 11EP**
Appearance	Black Viscous Semi-Fluid	Black Viscous Semi-Fluid	Black Viscous Semi-Fluid
Texture	Tacky	Tacky	Tacky
Solids	Black Graphite	Black Graphite	Black Graphite
VISCOSITIES:			
@100^{O}C., cSt. (D-445)	135	195	251
@40^{O}C., cSt. (D-445)	1586	2930	4468
Viscosity Index (D-2270)	190	184	182
Flash Point, COC, ^{O}C (D-92)	298	295	295
Copper Corrosion 3hr @ 100^{O}C (D-130)	1B	1B	1B
4-Ball Wear (US Steel S-205)	.30	.30	.30
4-Ball EP Weld Point (kg)	400	400	400
4-Ball EP Load Wear Index	57	57	57
Rust Prevention (D-665 A&B)	Pass	Pass	Pass
Timken Load, OK Load (lbs) (D-2782)	70	70	70
Biodegradation Classification	Ultimate PW1	Ultimate PW1	Ultimate PW1
Ecotoxicity LC-50 / EC-50 (Fish, Daphnia, Algae)	exceeds 100 mg/l	exceeds 100 mg/l	exceeds 100 mg/l
Non Bioaccumulation	Yes	Yes	Yes
RLI Product Item #	**88960**	**88970**	**88980**

Features (1) Easier to Apply-Energy Conserving Formulas, (Because of the super high viscosity index (VI) the products are easier to apply at lower temperatures therefore more energy efficient at lower temperatures, but at higher operating temperatures do not thin back as fast and provide a more protective heavier viscosity between the gear teeth and sliding surfaces, compared to lower VI petroleum based formulas).
(2) Super high viscosity index provides wider temperature performance
(3) Fortified with additives to resist wear, oxidation, rust and foam
(4) Will not harden, chip, or flake off in cold weather like asphaltic based products
(5) Environmentally Acceptable Lubricant (EAL) according to the definitions and requirements of the US EPA 2013 Vessel General Permit. More Eco-safe, more fire resistant, and does not contain volatile petroleum solvent diluent

*STABILIZED by Renewable Lubricants™ is RLI's trademark on their proprietary and patented anti-oxidant, anti-wear, and cold flow technology. This Stabilized technology allows the biosynthetic oils to perform as high performance formula in high and low temperature applications, reducing oil thickening and deposits. Patented Product: US Patent 6,383,992, US Patent 6,534,454 with additional Pending and Foreign Patents

Availability F.O.B.: Hartville, Ohio, USA **7 lb Pail** **35 lb Pail**

Product Data

Castrol BioTac OG

Environmentally responsible open gear lubricant

Description

OSPAR compliant with no substitutable components. US Vessel General Permit 2013 compliant.
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 minimise environmental impact and help conserve marine biological diversity.
Castrol BioTac OG has been specifically formulated to minimise impact upon the marine environment. All the components of Castrol BioTac OG have been selected for their reduced* 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. It is key that the lubricant performance of BioTac OG is not inferior to those greases currently used on leg racks - any performance deficiencies would prevent its adoption or result in 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 by using new additive technologies. The thickener structure is highly resistant to water washing and provides outstanding corrosion protection, ensuring that the volume of lubricant introduced into the environment is similar to when traditional products are used.

*In comparison with conventional components used in mineral oil based open gear lubricants

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

Application

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 minimise 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 Norway and registered on NEMS.
- 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.
- Meets the requirements for being an Environmentally Acceptable Lubricant under the US 2013 Vessel General Permit.
- Contains significantly reduced levels of components with the potential to bioaccumulate in comparison to a conventional open gear lubricant.
- 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 minimise 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.

Technical Data

Name	Method	Units	BioTac OG
NLGI Classification	ASTM D217	-	1/0
Appearance	Visual	-	Soft, beige tacky grease
Base oil kinematic viscosity @ 40°C	ASTM D445	cSt	650
Base oil kinematic viscosity @ 100°C	ASTM D445	cSt	51
Penetration, Worked (0.1mm)	IP 50 / ISO 2137	-	340
Relative Density	ASTM D4052	-	1.210
Wear Scar Diameter, 1hr @ 40Kg	ASTM D2596	mm	0.742
Weld Load	ASTM D2596	N	>8000
Load Wear Index	ASTM D2596	-	141.1
EMCOR Corrosion Test - Demineralised Water	IP 220	-	0.0
EMCOR Corrosion Test - 3% NaCl Solution	IP 220	-	0.0
Flow Pressure @ 0°C	DIN 51 805	mBar	125
Flow Pressure @ -10°C	DIN 51 805	mBar	325
Flow Pressure @ -20°C	DIN 51 805	mBar	425

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

Additional Information

Tested and registered according to OSPAR (Oslo and Paris Convention for the Protection of the Marine Environment of the North-East Atlantic) requirements and therefore meets the definition of an Environmentally Acceptable Lubricant under the US Vessel General Permit for Discharges Incidental to the Normal Operation of Vessels (VGP) 2013.

Care and Handling

Avoid prolonged or repeated contact with skin. Wash thoroughly after handling.

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 60C, exposed to hot sun or freezing conditions.

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

www.castrolmarine.com

VGP Pro Eco OG #2

Typical Specifications

Test Method	Description	Results
Visual	**Color**	Custom Colors Available Off-White (standard)
	Thickener Type	Calcium
ASTM D217	**NLGI Classification**	2
ASTM D217	**Worked Penetration @ 25°C**	265-295
ASTM D2596	**Load Wear Index**	62.36 kgf
	Last Non-Seizure Load (scar) (psi)	63 kg (0.35mm) (380,22psi)
	Last Seizure Load (scar) (psi)	315 kg (1.95mm) (61,245psi)
	Weld Load	400 kg
ASTM D-93	**Flash Point, ºC**	> 260
ASTM D2265	**Dropping Point**	300°C
ISO 2811	**Density at 25°C**	.98 ± 0.01
ASTM D972	**Evaporation Loss, 22 hrs @105°C**	< 1.50%
ASTM B117	**Salt Spray @ 40°C**	Pass
ASTM D2247	**Humidity Test @ 50°C**	Pass
ASTM D1264	**Water Washout @ 38ºC**	< 2.0%

Grignard Company LLC, 505 Capobianco Plaza, Rahway, NJ Ph 732.340.1111 Fx 732.340.0111
www.grignard.com

VGP Pro Eco #2

Typical Specifications (cont'd)

Test Method	Description	Results
ASTM D4049	**Water Spray Off; % Removed**	< 45%
ASTM D1743	**Pressure Vessel Oxidation Test @ 100 hours**	< 3.5 psi
ASTM D2509	**Timken Load Carrying Test at 80lbs**	Pass
ASTM D1478	**Low Temperature Torque, -20°C, g-cm**	Pass
EPA Static Sheen Test	**Sheen**	No Sheen

Klüberbio AG 39-602

Environmentally acceptable adhesive lubricant for open gears and steel cables

Benefits for your application

- **Complies with the requirements for Environmentally Acceptable Lubricants as defined in Appendix A of the 2013 Vessel General Permit**
- **Reduced environmental impact in the event of discharge into water. The base oil is derived from renewable resources**
- **Good adhesion and water resistance for long relubrication intervals**
- **Selected additives ensure longer component life and reduced wear**
- **Corrosion protection under seawater influence due to especially selected anti-corrosion additives**

Description

Klüberbio AG 39-602 is an adhesive lubricant for open gears and steel cables based on ester oil and selected additives. Klüberbio AG 39-602 contains > 60 % of renewable raw materials.

Their biodegradability acc. to OECD 301 F is ≥ 60 % after 28 days. Klüberbio AG 39-602 contributes to long component life and good corrosion and wear protection. The finished product meets the biodegradability, minimally toxic and non-bioaccumulative standards established by the US EPA for the 2013 Vessel General Permit. With its good adhesion to surfaces, Klüberbio AG 39-602 leads to reduced lubricant consumption and reduced labour costs.

Application

Klüberbio AG 39-602 was developed for the lubrication of open pinion gears on winches and jack-up platforms, as well as steel cables in contact with water.

The product can also be used in other maritime applications that require lubricants to have good water washout resistance, very good anti-corrosion resistance and/or good load-carrying capacity such as with low-speed plain bearings, guide rails and open winch gears.

Application notes

Klüberbio AG 39-602 can be applied continuously through transfer lubrication with pinion or by brush. Compressed-air lubrication equipment can be used for the lubrication of steel cables. The required lubricant quantity depends on the operating conditions in each individual case.

Our Sales Engineers will be glad to assist you in determining the correct quantity for your application.

Please note that the colour of Klüberbio AG 39-602 changes to red under the influence of UV radiation. This does not impair the lubricating grease's effectiveness.

Material safety data sheets

Material safety data sheets can be requested via our website www.klueber.com. You may also obtain them through your contact person at Klüber Lubrication.

Pack sizes	Klüberbio AG 39-602
Cartridge 400 g	+
Can 1 kg	+
Bucket 25 kg	+
Drum 200 kg	+

Klüberbio AG 39-602

Environmentally acceptable adhesive lubricant for open gears and steel cables

Product data	Klüberbio AG 39-602
Article number	009042
Chemical composition, type of oil	ester oil
Chemical composition, thickener	calcium soap
Lower service temperature	-20 °C / -4 °F
Upper service temperature	100 °C / 212 °F
Colour space	yellow
Texture	homogeneous
Texture	fibrous
Density at 20 °C	approx. 0.97 g/cm³
Worked penetration, DIN ISO 2137, 25 °C, lower limit value	290 x 0.1 mm
Worked penetration, DIN ISO 2137, 25 °C, upper limit value	330 x 0.1 mm
Kinematic viscosity of the base oil, DIN 51562 pt. 01/ASTM D-445/ASTM D 7042, 40 °C	approx. 600 mm²/s
Kinematic viscosity of the base oil, DIN 51562 pt. 01/ASTM D-445/ASTM D 7042, 100 °C	approx. 85 mm²/s
Copper corrosion, DIN 51811, (lubricating grease), 24h/100°C	1 - 100 corrosion degree
Corrosion inhibiting properties of lubricating greases, DIN 51802, (SKF-EMCOR), test duration: 1 week, distilled water	<= 1 corrosion degree
Oil separation, DIN 51817 N, after 7 d/40 °C	<= 5 % by weight
Flow pressure of lubricating greases, DIN 51805, test temperature: -20 °C	<= 1 400 mbar
Drop point, DIN ISO 2176, IP 396	>= 120 °C
Four-ball tester, welding load, DIN 51350 pt. 04	>= 4 000 N
Biodegradability according to OECD 301 F, (within 28 days)	>= 60 %
Water resistance, DIN 51807 pt. 01, 3 h/90 °C, rating	0 - 90
FZG scuffing test, based on DIN ISO 14635, A/2,76/50, scuffing load stage	
Minimum shelf life from the date of manufacture - in a dry, frost-free place and in the unopened original container, approx.	24 months

Klüber Lubrication – your global specialist

Innovative tribological solutions are our passion. Through personal contact and consultation, we help our customers to be successful worldwide, in all industries and markets. With our ambitious technical concepts and experienced, competent staff we have been fulfilling increasingly demanding requirements by manufacturing efficient high-performance lubricants for more than 80 years.

**Klüber Lubrication München SE & Co. KG /
Geisenhausenerstraße 7 / 81379 München / Germany /
phone +49 89 7876-0 / fax +49 89 7876-333.**

Appendix B.1 – Likelihood of Water Contact Assessment

EAL Implementation - Likelihood of Water Contact Assessment

Risk level at intersection of quantity and frequency		Frequency			
		1) Frequently	2) Annually	3) Rarely	*If submerged, lubed equipment is classified as having a high likelihood of grease getting in the water.
Containment	1) No containment	High	High	Moderate	
	2) Minimal containment	High	Moderate	Low	
	3) Moderate Containment	Moderate	Low	Low	
	4) Thorough Containment	Negligible	Negligible	Negligible	

Proximity to Water		
S	Submerged	Part or all of lubricated equipment is submered under water during regular operations.*
NW	Next to Water	Lubricated equipment is not submerged, but close enough to river flow to be included in this study.
Containment		
1	No containment	Grease is applied to non-enclosed equipment and secondary containment is nonexistent.
2	Minimal containment	Grease is applied to non-enclosed equipment and secondary containment is minimal.
3	Moderate Containment	Grease is applied to enclosed equipment or secondary containment is effective.
4	Thorough Containment	Grease is applied to enclosed equipment and secondary containment is effective.
Frequency		
1	Frequently	Equipment is used frequently, and lubricant is applied at each use.
2	Annually	Equipment is used frequently, but lubricant is only applied annually during equipment maintenance.
3	Rarely	Equipment is not used frequently, but lubricant is applied annually during equipment maintenance.

ID	Primary System	Equip. Description	Floor	EL.	Grease Used	Proximity to Water*	Containment	Frequency	Likelyhood of Water Contact
1	Adult Fish Ladder (RRFW) - Pickett Barrier Hoist	Fish screening gates - Sheaves	Upper Fishway Deck	717	248 Moly Syngard	NW	3	2	Low
2	Adult Fish Ladder (RRFW) - Pickett Barrier Hoist	Fish screening gates - zerks	Upper Fishway Deck	717	248 Moly Syngard	NW	2	2	Moderate
3	Adult Fish Ladder (RRFW) - Pickett Barrier Hoist	Fish screening gates - Wire rope	Upper Fishway Deck	717	Not lubricated	S	1	2	High
4	RRFW CS-S1 Operator	Limit torques actuator - zerks	Upper Fishway Deck	717	248 Moly Syngard	NW	2	2	Moderate
5	Adult Fish Ladder	Adjustable weir - pillow blocks	Upper Fishway Deck	710	248 Moly Syngard	NW	2	2	Moderate
6	Adult Fish Ladder	Adjustable weir - wire rope	Upper Fishway Deck	710	Not lubricated	S	1	3	High
7	Juvenile Fish Ladder (BC-G1, -G6, -G7)	Radial gate - pillow blocks, zerks	Upper Fishway Deck	707	Huskey LVI-50	NW	2	2	Moderate
8	Trash Hopper	Sheaves, roller bearings, zerks	Upper Fishway Deck	713	Huskey LVI-50	NW	3	2	Low
9	Surface Collector	Traveling screens - Motor coupling	Upper Fishway Deck	717	248 Moly Syngard	S	1	2	High
10	Surface Collector	Traveling screens - Chains and sprocket	Upper Fishway Deck	717	Huskey LVI-50	NW	2	2	Moderate
11	Forebay Intake Gate (ISFTP-S1, -S2)	Limit Torques - Zerks	Upper Fishway Deck	717	248 Moly Syngard	NW	2	2	Moderate
12	Juvenile Fish Ladder	Fish screen gates - Pillow blocks, zerks	Upper Fishway Deck	707	Mobil Unirex EP	NW	2	2	Moderate
13	VBS Screen Cleaner	Couplers, motor bearings, and pillow blocks	Transformer Deck	717	Huskey LVI-50	NW	2	3	Low
14	Intake Gantry - COH	Trolley - Wheel bearings, zerks	Transformer Deck	717	Mobil Unirex EP	NW	3	2	Low
15	Intake Gantry - COH	Hoist - Bearings, gear reducer, couplings, bushings, pillow block	Transformer Deck	717	Mobil Unirex EP	NW	4	2	Negligible
16	Intake Gantry - COH	Hoist - Wire rope	Transformer Deck	717	Mobilarma 798	S	1	2	High
17	Intake Gantry - COH	Truck - Zerks, bearings, couplings, seals	Transformer Deck	717	Mobil Unirex EP	NW	3	2	Low
18	Intake Gantry - COH	Aux. Hoist - Hoist chain	Transformer Deck	717	Fuchs Renolit LZR	NW	4	3	Negligible
19	Tainter Gates 2-10	Hoist - Shaft pillow blocks, end bearing, zerks	Spillway	721	248 Moly Syngard	NW	3	2	Low
20	Tainter Gates 2-10	Hoist - Wire rope	Spillway	721	Loob-it	S	1	1	High
21	Tainter Gates 2-10	Hoist - Bull gear	Spillway	721	Silver Streak	NW	1	2	High
22	Tainter Gates 2-10	Hoist - chain drive, couplings	Spillway	721	Chevron Coupling Grease	NW	3	2	Low
23	Tainter Gates 1, 11, 12	Hoist - Shaft pillow blocks, end bearing, zerks	Spillway	721	248 Moly Syngard	NW	2	3	Low
24	Tainter Gates 1, 11, 12	Hoist - Wire rope	Spillway	721	Loob-it	S	1	3	High
25	Tainter Gates 1, 11, 12	Hoist - Bull gear	Spillway	721	Silver Streak	NW	1	3	Moderate

26	Tainter Gates 1, 11, 12	Hoist - chain drive, couplings	Spillway	721	Chevron Coupling Grease	NW	4	3	Negligible
27	Middle Spillway Entrance (HS-1)	Actuator - zerks	Spillway	717	248 Moly Syngard	NW	2	2	Moderate
28	Middle Spillway Entrance (MSE)	Dewater pump - Zerk	Spillway	640	Huskey LVI-50	NW	4	2	Negligible
29	Middle Spillway Entrance (MSE, RG-1 Operator)	Fish Intake Gate - Wire rope	Spillway	640	Not lubricated	S	1	2	High
30	Middle Spillway Entrance (MSE, RG-1 Operator)	Fish Intake Gate - Zerks, pillow blocks, couplings	Spillway	640	248 Moly Syngard	NW	2	2	Moderate
31	Right Powerhouse Entrance (RPE, RG-1 and -3 hoists)	Wire rope	Tailrace Deck	650	Not lubricated	S	1	2	High
32	Fish Unwatering Pump	Zerk	Tailrace Deck	650	248 Moly Syngard	NW	2	2	Moderate
33	Fishway Regulating Gates	Pillow blocks, couplings, chain drive	Tailrace Deck	650	248 Moly Syngard	NW	2	2	Moderate
34	Fishway Regulating Gates	Wire rope	Tailrace Deck	650	Not lubricated	S	1	2	High
35	Tailrace Crane - Moffett	Truck - Wheel bearings, zerks	Tailrace Deck	650	Chevron Ultra Duty EP	NW	2	2	Moderate
36	Tailrace Crane - Moffett	Main hoist - wire rope	Tailrace Deck	650	Not lubricated	S	1	2	High
37	Tailrace Crane - Moffett	Main hoist - Hooks, lifting beam, block zerks	Tailrace Deck	650	248 Moly Syngard	S	1	2	High
38	Tailrace Crane - Moffett	Hoist trolley - Pulley/shaft bearing, pillow/ sheave block	Tailrace Deck	650	Chevron Ultra Duty EP	NW	3	2	Low
39	Tailrace Crane - Moffett	Orifice gate hoist - bearings	Tailrace Deck	650	Chevron Ultra Duty EP	NW	2	2	Moderate
40	Tailrace Crane - Moffett	Orifice gate hoist - wire rope	Tailrace Deck	650	Not lubricated	S	1	2	High
41	Tailrace Crane - Moffett	Orifice gate hoist - zerks, hooks, lifting beam	Tailrace Deck	650	248 Moly Syngard	S	1	2	High
42	Wing Gates	Zerks	Tailrace Deck	650	248 Moly Syngard	NW	2	2	Moderate
43	Wing Gates	Zerks	Lower Fishway Walkway	635	248 Moly Syngard	NW	2	2	Moderate
44	Orifice Gate Hoist	Wire rope	Lower Fishway Walkway	635	Loob-it	S	1	2	High
45	Orifice Gate Hoist	Zerks, pillow blocks, sheave block	Lower Fishway Walkway	635	248 Moly Syngard	NW	2	2	Moderate
46	Orifice Gate Hoist	Couplers	Lower Fishway Walkway	635	Chevron Coupling	NW	2	2	Moderate
47	Fish Sampling Facility	Crowder - Pillow blocks	West Bank	675	Huskey LVI-50	NW	2	2	Moderate
48	Fish Sampling Facility	Process Water Pumps - Zerks	West Bank	675	Huskey LVI-50	NW	3	2	Low
49	Fish Sampling Facility	Sampling Screen - Trucks, chain drive	West Bank	675	Huskey LVI-50	NW	1	2	High
50	Fish Sampling Facility	Tainter Gate - Pillow blocks, zerks	West Bank	675	Huskey LVI-50	NW	1	2	High

Negligible Likelihood of Water Contact

ID	Primary System	Equip. Description	Floor	EL.	Likelihood of Water Contact Rating	Reason for why EAL conversion is not recommended.
51	Intake Gantry COH	Aux. Hoist	Intake Deck	717	Negligible	Fully enclosed. No leakage/spillage during regular operations.
52	Adult Fish Ladder	Fish screening gates - Motor	Upper Fishway Deck	717	Negligible	Fully enclosed. No leakage/spillage during regular operations.
53	Adult Fish Ladder	Adjustable weir - gearbox, motor	Upper Fishway Deck	710	Negligible	Fully enclosed. No leakage/spillage during regular operations.
54	Surface Collector	Drives, motor	Upper Fishway Deck	717	Negligible	Fully enclosed. No leakage/spillage during regular operations.
55	Forebay Intake Gate	Limit Torques - Motor, gearbox	Upper Fishway Deck	717	Negligible	Fully enclosed. No leakage/spillage during regular operations.
56	Intake Gantry COH	Trolley - Motor, drive, input/output shaft bearings	Transformer Deck	717	Negligible	Fully enclosed. No leakage/spillage during regular operations.
57	Intake Gantry COH	Hoist - Motor, gearbox	Transformer Deck	717	Negligible	Fully enclosed. No leakage/spillage during regular operations.
58	Intake Gantry COH	Truck - Motor, drive	Transformer Deck	717	Negligible	Fully enclosed. No leakage/spillage during regular operations.
59	Tainter Gates 2-10	Hoist - motor	Spillway	721	Negligible	Fully enclosed. No leakage/spillage during regular operations.

60	Tainter Gates 1, 11, 12	Hoist - motor	Spillway	721	Negligible	Fully enclosed. No leakage/spillage during regular operations.
61	Middle Spillway	HSC Actuator - Motor, gearbox	Spillway	717	Negligible	Fully enclosed. No leakage/spillage during regular operations.
62	Middle Spillway	Fish Intake Gate - Motor, gear drive	Spillway	640	Negligible	Fully enclosed. No leakage/spillage during regular operations.
63	Sluice Gates - Groups A thru C	Motor	Lower Fishway Walkway	635	Negligible	Fully enclosed. No leakage/spillage during regular operations.
64	Sluice Gates - Groups D thru G	Motor	Lower Fishway Walkway	635	Negligible	Fully enclosed. No leakage/spillage during regular operations.
65	Dewatering Fish Ladder Gates	Motor, gearbox	Tailrace Deck	650	Negligible	Fully enclosed. No leakage/spillage during regular operations.
66	Fishway Regulating Gates	Motor, gearbox	Tailrace Deck	650	Negligible	Fully enclosed. No leakage/spillage during regular operations.
67	Tailrace Crane Moffett	Truck - Motor, drive	Tailrace Deck	650	Negligible	Fully enclosed. No leakage/spillage during regular operations.
68	Tailrace Crane Moffett	Orifice gate hoist - Motor, drive	Tailrace Deck	650	Negligible	Fully enclosed. No leakage/spillage during regular operations.
69	Wing Gates	Motor, gear drives	Tailrace Deck	650	Negligible	Fully enclosed. No leakage/spillage during regular operations.
70	Wing Gates	Motor, gear drives	Lower Fishway Walkway	635	Negligible	Fully enclosed. No leakage/spillage during regular operations.
71	Orifice Gate Hoist	Motor, gearbox	Lower Fishway Walkway	635	Negligible	Fully enclosed. No leakage/spillage during regular operations.
72	Fish Sampling Facility	Crowder - Motors, gearboxes	West Bank	675	Negligible	Fully enclosed. No leakage/spillage during regular operations.
73	Fish Sampling Facility	Process Water Pumps	West Bank	675	Negligible	Fully enclosed. No leakage/spillage during regular operations.

Appendix B.2 – Ease of Implementation Assessment

EAL Implementation Analysis - Ease of Implementation Assessment

	Cumulative responses to the below Criteria	0 - "Yes"	1 - "Yes"	2 - "Yes"	3 - "Yes"
	Ease of Implementation	High	Moderate	Low	Negligible
	Equipment Disassmebly				
Y	Yes	Equipment requires dissembly to implement EAL conversion.			
N	No	Equipment does not requires dissembly to implement EAL conversion.			
	Generation Outages				
Y	Yes	EAL implementation require generation outage(s).			
N	No	EAL implementation does not require generation outage(s).			
	Safety				
Y	Yes	Equipment malfunction from converting to EALs could cause a major personnel safety concern.			
N	No	Equipment malfunction from converting to EALs would not cause a major personnel safety concern.			

ID	Primary System	Equip. Description	Floor	EL.	Grease Used	Equipment Disassembly	Generation Outages	Safety	Ease of Implementation
1	Adult Fish Ladder (RRFW) - Pickett Barrier Hoist	Fish screening gates - Sheaves	Upper Fishway Deck	717	248 Moly Syngard	N	N	N	High
2	Adult Fish Ladder (RRFW) - Pickett Barrier Hoist	Fish screening gates - zerks	Upper Fishway Deck	717	248 Moly Syngard	N	N	N	High
3	Adult Fish Ladder (RRFW) - Pickett Barrier Hoist	Fish screening gates - Wire rope	Upper Fishway Deck	717	Not lubricated	N	N	Y	Moderate
4	RRFW CS-S1 Operator	Limit torques actuator - zerks	Upper Fishway Deck	717	248 Moly Syngard	N	N	N	High
5	Adult Fish Ladder	Adjustable weir - pillow blocks	Upper Fishway Deck	710	248 Moly Syngard	N	N	N	High
6	Adult Fish Ladder	Adjustable weir - wire rope	Upper Fishway Deck	710	Not lubricated	N	N	Y	Moderate
7	Juvenile Fish Ladder (BC-G1, -G6, -G7)	Radial gate - pillow blocks, zerks	Upper Fishway Deck	707	Huskey LVI-50	N	N	N	High
8	Trash Hopper	Sheaves, roller bearings, zerks	Upper Fishway Deck	713	Huskey LVI-50	N	N	N	High
9	Surface Collector	Traveling screens - Motor coupling	Upper Fishway Deck	717	248 Moly Syngard	N	N	N	High
10	Surface Collector	Traveling screens - Chains and sprocket	Upper Fishway Deck	717	Huskey LVI-50	N	N	N	High
11	Forebay Intake Gate (ISFTP-S1, -S2)	Limit Torques - Zerks	Upper Fishway Deck	717	248 Moly Syngard	N	N	N	High
12	Juvenile Fish Ladder	Fish screen gates - Pillow blocks, zerks	Upper Fishway Deck	707	Mobil Unirex EP	N	N	N	High
13	VBS Screen Cleaner	Couplers, motor bearings, and pillow	Transformer Deck	717	Huskey LVI-50	N	N	N	High
14	Intake Gantry - COH	Trolley - Wheel bearings, zerks	Transformer Deck	717	Mobil Unirex EP	N	N	N	High
15	Intake Gantry - COH	Hoist - Bearings, gear reducer, couplings, bushings, pillow block	Transformer Deck	717	Mobil Unirex EP	N	N	N	High
16	Intake Gantry - COH	Hoist - Wire rope	Transformer Deck	717	Mobilarma 798	N	N	Y	Moderate
17	Intake Gantry - COH	Truck - Zerks, bearings, couplings, seals	Transformer Deck	717	Mobil Unirex EP	N	N	N	High
18	Intake Gantry - COH	Aux. Hoist - Hoist chain	Transformer Deck	717	Fuchs Renolit LZR	N	N	N	High
19	Tainter Gates 2-10	Hoist - Shaft pillow blocks, end bearing, zerks	Spillway	721	248 Moly Syngard	N	N	N	High
20	Tainter Gates 2-10	Hoist - Wire rope	Spillway	721	Loob-it	N	N	Y	Moderate
21	Tainter Gates 2-10	Hoist - Bull gear	Spillway	721	Silver Streak	N	N	N	High
22	Tainter Gates 2-10	Hoist - chain drive, couplings	Spillway	721	Chevron Coupling Grease	N	N	N	High
23	Tainter Gates 1, 11, 12	Hoist - Shaft pillow blocks, end bearing, zerks	Spillway	721	248 Moly Syngard	N	N	N	High
24	Tainter Gates 1, 11, 12	Hoist - Wire rope	Spillway	721	Loob-it	N	N	Y	Moderate
25	Tainter Gates 1, 11, 12	Hoist - Bull gear	Spillway	721	Silver Streak	N	N	N	High
26	Tainter Gates 1, 11, 12	Hoist - chain drive, couplings	Spillway	721	Chevron Coupling Grease	N	N	N	High
27	Middle Spillway Entrance (HS-1)	Actuator - zerks	Spillway	717	248 Moly Syngard	N	N	N	High
28	Middle Spillway Entrance (MSE)	Dewater pump - Zerk	Spillway	640	Huskey LVI-50	N	N	N	High
29	Middle Spillway Entrance (MSE, RG-1 Operator)	Fish Intake Gate - Wire rope	Spillway	640	Not lubricated	N	N	Y	Moderate
30	Middle Spillway Entrance (MSE, RG-1 Operator)	Fish Intake Gate - Zerks, pillow blocks, couplings	Spillway	640	248 Moly Syngard	N	N	N	High
31	Right Powerhouse Entrance (RPE, RG-1 and -3 hoists)	Wire rope	Tailrace Deck	650	Not lubricated	N	N	Y	Moderate
32	Fish Unwatering Pump	Zerk	Tailrace Deck	650	248 Moly Syngard	N	N	N	High

33	Fishway Regulating Gates	Pillow blocks, couplings, chain drive	Tailrace Deck	650	248 Moly Syngard	N	N	N	High
34	Fishway Regulating Gates	Wire rope	Tailrace Deck	650	Not lubricated	N	N	Y	Moderate
35	Tailrace Crane - Moffett	Truck - Wheel bearings, zerks	Tailrace Deck	650	Chevron Ultra Duty EP	N	N	N	High
36	Tailrace Crane - Moffett	Main hoist - wire rope	Tailrace Deck	650	Not lubricated	N	N	Y	Moderate
37	Tailrace Crane - Moffett	Main hoist - Hooks, lifting beam, block zerks	Tailrace Deck	650	248 Moly Syngard	N	N	N	High
38	Tailrace Crane - Moffett	Hoist trolley - Pulley/shaft bearing, pillow/ sheave block	Tailrace Deck	650	Chevron Ultra Duty EP	N	N	N	High
39	Tailrace Crane - Moffett	Orifice gate hoist - bearings	Tailrace Deck	650	Chevron Ultra Duty EP	N	N	N	High
40	Tailrace Crane - Moffett	Orifice gate hoist - wire rope	Tailrace Deck	650	Not lubricated	N	N	Y	Moderate
41	Tailrace Crane - Moffett	Orifice gate hoist - zerks, hooks, lifting beam	Tailrace Deck	650	248 Moly Syngard	N	N	N	High
42	Wing Gates	Zerks	Tailrace Deck	650	248 Moly Syngard	N	N	N	High
43	Wing Gates	Zerks	Lower Fishway Walkway	635	248 Moly Syngard	N	N	N	High
44	Orifice Gate Hoist	Wire rope	Lower Fishway Walkway	635	Loob-it	N	N	Y	Moderate
45	Orifice Gate Hoist	Zerks, pillow blocks, sheave block	Lower Fishway Walkway	635	248 Moly Syngard	N	N	N	High
46	Orifice Gate Hoist	Couplers	Lower Fishway Walkway	635	Chevron Coupling Grease	N	N	N	High
47	Fish Sampling Facility	Crowder - Pillow blocks	West Bank	675	Huskey LVI-50	N	N	N	High
48	Fish Sampling Facility	Process Water Pumps - Zerks	West Bank	675	Huskey LVI-50	N	N	N	High
49	Fish Sampling Facility	Sampling Screen - Trucks, chain drive	West Bank	675	Huskey LVI-50	N	N	N	High
50	Fish Sampling Facility	Tainter Gate - Pillow blocks, zerks	West Bank	675	Huskey LVI-50	N	N	N	High

Appendix B.3 – Cost Feasibility Assessment

EAL Implementation Analysis - Cost Feasibility Assessment

Feasibility level at Intersections			
Approx. Annual Cost to Implement EALs per piece of equipment	$0 - $1,000	$1,000 - $4,000	> $4,000
Feasibility	High	Moderate	Low

Initial Cost

Equipment	Explanation
Wire Rope	Approximate COH and Moffett crane main hoist wire rope length to be 1500 ft, Moffett orifice gates hoists to be 800 ft, and all other wire ropes to be 100 ft. Assume $3.20/ft to clean.
All other equipment	No initial costs. Compatiability is recommended, which inherently infers that former grease does not need to be removed.

Annual EAL vs. In-Grease Cost

Equipment	Explanation
Wire Rope	Approx. 2.5 gal/crane of lubricant, 1 gal/gate hoist, and 0.5 gal for all other equipment, approximately $25 more/gal for EAL.
Open Gears	An estimated 1 gallon of grease is used to lubricate each equipment line item, approximately $20 more/gal for EAL.
All other equipment	Estimated two-14 oz tubes of lubricant is assumed to be used for each equipment line item, approx. $20 more/tube for EAL.

Annual cost of Maintaining Lubrication of EALs

Approximated the material and labor cost of lubricating equipment biweekly. Material is the cost of EAL x 26 (biweekly application). Labor was assumed to be $100, 1 hour at $100/hr

ID	Primary System	Equip. Description	Floor	EL.	Grease Used	Initial	EAL Increase vs. In-Use	EAL Maintanence	Approx. Annual EAL Implementation	Cost Feasibility
1	Adult Fish Ladder (RRFW) - Pickett Barrier Hoist	Fish screening gates - Sheaves	Upper Fishway Deck	717	248 Moly Syngard	$ -	$ 40.00	$ -	$ 40.00	High
2	Adult Fish Ladder (RRFW) - Pickett Barrier Hoist	Fish screening gates - zerks	Upper Fishway Deck	717	248 Moly Syngard	$ -	$ 40.00	$ -	$ 40.00	High
3	Adult Fish Ladder (RRFW) - Pickett Barrier Hoist	Fish screening gates - Wire rope	Upper Fishway Deck	717	Not lubricated	$ 320.00	$ 12.50	$ 2,925.00	$ 3,257.50	Moderate
4	RRFW CS-S1 Operator	Limit torques actuator - zerks	Upper Fishway Deck	717	248 Moly Syngard	$ -	$ 40.00	$ -	$ 40.00	High
5	Adult Fish Ladder	Adjustable weir - pillow blocks	Upper Fishway Deck	710	248 Moly Syngard	$ -	$ 40.00	$ -	$ 40.00	High
6	Adult Fish Ladder	Adjustable weir - wire rope	Upper Fishway Deck	710	Not lubricated	$ 320.00	$ 40.00	$ 3,640.00	$ 4,000.00	Low
7	Juvenile Fish Ladder (BC-G1, -G6, -G7)	Radial gate - pillow blocks, zerks	Upper Fishway Deck	707	Huskey LVI-50	$ -	$ 40.00	$ -	$ 40.00	High
8	Trash Hopper	Sheaves, roller bearings, zerks	Upper Fishway Deck	713	Huskey LVI-50	$ -	$ 40.00	$ -	$ 40.00	High
9	Surface Collector	Traveling screens - Motor coupling	Upper Fishway Deck	717	248 Moly Syngard	$ -	$ 40.00	$ 3,250.00	$ 3,290.00	Moderate
10	Surface Collector	Traveling screens - Chains and sprocket	Upper Fishway Deck	717	Huskey LVI-50	$ -	$ 40.00	$ -	$ 40.00	High
11	Forebay Intake Gate (ISFTP-S1, -S2)	Limit Torques - Zerks	Upper Fishway Deck	717	248 Moly Syngard	$ -	$ 40.00	$ -	$ 40.00	High
12	Juvenile Fish Ladder	Fish screen gates - Pillow blocks, zerks	Upper Fishway Deck	707	Mobil Unirex EP	$ -	$ 40.00	$ -	$ 40.00	High
13	VBS Screen Cleaner	Couplers, motor bearings, and pillow	Transformer Deck	717	Huskey LVI-50	$ -	$ 40.00	$ -	$ 40.00	High
14	Intake Gantry - COH	Trolley - Wheel bearings, zerks	Transformer Deck	717	Mobil Unirex EP	$ -	$ 40.00	$ -	$ 40.00	High
15	Intake Gantry - COH	Hoist - Bearings, gear reducer, couplings, bushings, pillow block	Transformer Deck	717	Mobil Unirex EP	$ -	$ 40.00	$ -	$ 40.00	High
16	Intake Gantry - COH	Hoist - Wire rope	Transformer Deck	717	Mobilarma 798	$ 4,800.00	$ 62.50	$ 7,150.00	$ 12,012.50	Low
17	Intake Gantry - COH	Truck - Zerks, bearings, couplings, seals	Transformer Deck	717	Mobil Unirex EP	$ -	$ 40.00	$ -	$ 40.00	High
18	Intake Gantry - COH	Aux. Hoist - Hoist chain	Transformer Deck	717	Fuchs Renolit LZR	$ -	$ 12.50	$ -	$ 12.50	High
19	Tainter Gates 2-10	Hoist - Shaft pillow blocks, end bearing, zerks	Spillway	721	248 Moly Syngard	$ -	$ 40.00	$ -	$ 40.00	High
20	Tainter Gates 2-10	Hoist - Wire rope	Spillway	721	Loob-it	$ 320.00	$ 12.50	$ 3,510.00	$ 3,842.50	Moderate
21	Tainter Gates 2-10	Hoist - Bull gear	Spillway	721	Silver Streak	$ -	$ 20.00	$ -	$ 20.00	High
22	Tainter Gates 2-10	Hoist - chain drive, couplings	Spillway	721	Chevron Coupling	$ -	$ 12.50	$ -	$ 12.50	High
23	Tainter Gates 1, 11, 12	Hoist - Shaft pillow blocks, end bearing,	Spillway	721	248 Moly Syngard	$ -	$ 40.00	$ -	$ 40.00	High
24	Tainter Gates 1, 11, 12	Hoist - Wire rope	Spillway	721	Loob-it	$ 320.00	$ 12.50	$ 3,510.00	$ 3,842.50	Moderate
25	Tainter Gates 1, 11, 12	Hoist - Bull gear	Spillway	721	Silver Streak	$ -	$ 20.00	$ -	$ 20.00	High
26	Tainter Gates 1, 11, 12	Hoist - chain drive, couplings	Spillway	721	Chevron Coupling	$ -	$ 12.50	$ -	$ 12.50	High
27	Middle Spillway Entrance (HS-1)	Actuator - zerks	Spillway	717	248 Moly Syngard	$ -	$ 40.00	$ -	$ 40.00	High
28	Middle Spillway Entrance (MSE)	Dewater pump - Zerk	Spillway	640	Huskey LVI-50	$ -	$ 40.00	$ -	$ 40.00	High
29	Middle Spillway Entrance (MSE, RG-1 Operator)	Fish Intake Gate - Wire rope	Spillway	640	Not lubricated	$ 320.00	$ 40.00	$ 5,512.00	$ 5,872.00	Low
30	Middle Spillway Entrance (MSE, RG-1 Operator)	Fish Intake Gate - Zerks, pillow blocks, couplings	Spillway	640	248 Moly Syngard	$ -	$ 40.00	$ -	$ 40.00	High
31	Right Powerhouse Entrance (RPE, RG-1 and -3 hoists)	Wire rope	Tailrace Deck	650	Not lubricated	$ 320.00	$ 40.00	$ 5,512.00	$ 5,872.00	Low
32	Fish Unwatering Pump	Zerk	Tailrace Deck	650	248 Moly Syngard	$ -	$ 40.00	$ -	$ 40.00	High
33	Fishway Regulating Gates	Pillow blocks, couplings, chain drive	Tailrace Deck	650	248 Moly Syngard	$ -	$ 40.00	$ -	$ 40.00	High
34	Fishway Regulating Gates	Wire rope	Tailrace Deck	650	Not lubricated	$ 320.00	$ 40.00	$ 5,512.00	$ 5,872.00	Low
35	Tailrace Crane - Moffett	Truck - Wheel bearings, zerks	Tailrace Deck	650	Chevron Ultra Duty EP	$ -	$ 40.00	$ -	$ 40.00	High
36	Tailrace Crane - Moffett	Main hoist - wire rope	Tailrace Deck	650	Not lubricated	$ 4,800.00	$ 62.50	$ 7,150.00	$ 12,012.50	Low

37	Tailrace Crane - Moffett	Main hoist - Hooks, lifting beam, block zerks	Tailrace Deck	650	248 Moly Syngard	$ -	$ 40.00	$ 3,250.00	$ 3,290.00	Moderate
38	Tailrace Crane - Moffett	Hoist trolley - Pulley/shaft bearing, pillow/ sheave	Tailrace Deck	650	Chevron Ultra Duty EP	$ -	$ 40.00	$ -	$ 40.00	High
39	Tailrace Crane - Moffett	Orifice gate hoist - bearings	Tailrace Deck	650	Chevron Ultra Duty EP	$ -	$ 40.00	$ -	$ 40.00	High
40	Tailrace Crane - Moffett	Orifice gate hoist - wire rope	Tailrace Deck	650	Not lubricated	$ 2,560.00	$ 25.00	$ 3,250.00	$ 5,835.00	Low
41	Tailrace Crane - Moffett	Orifice gate hoist - zerks, hooks, lifting beam	Tailrace Deck	650	248 Moly Syngard	$ -	$ 40.00	$ 3,250.00	$ 3,290.00	Moderate
42	Wing Gates	Zerks	Tailrace Deck	650	248 Moly Syngard	$ -	$ 40.00	$ -	$ 40.00	High
43	Wing Gates	Zerks	Lower Fishway Walkway	635	248 Moly Syngard	$ -	$ 40.00	$ -	$ 40.00	High
44	Orifice Gate Hoist	Wire rope	Lower Fishway Walkway	635	Loob-it	$ 320.00	$ 12.50	$ 3,510.00	$ 3,842.50	Moderate
45	Orifice Gate Hoist	Zerks, pillow blocks, sheave block	Lower Fishway Walkway	635	248 Moly Syngard	$ -	$ 40.00	$ -	$ 40.00	High
46	Orifice Gate Hoist	Couplers	Lower Fishway Walkway	635	Chevron Coupling	$ -	$ 12.50	$ -	$ -	High
47	Fish Sampling Facility	Crowder - Pillow blocks	West Bank	675	Huskey LVI-50	$ -	$ 40.00	$ -	$ 40.00	High
48	Fish Sampling Facility	Process Water Pumps - Zerks	West Bank	675	Huskey LVI-50	$ -	$ 40.00	$ -	$ 40.00	High
49	Fish Sampling Facility	Sampling Screen - Trucks, chain drive	West Bank	675	Huskey LVI-50	$ -	$ 40.00	$ -	$ 40.00	High
50	Fish Sampling Facility	Tainter Gate - Pillow blocks, zerks	West Bank	675	Huskey LVI-50	$ -	$ 40.00	$ -	$ 40.00	High

Appendix B.4 – EAL Implementation Analysis Summary

EAL Implementation Analysis - Summary

	Priority	Likelihood of Water Contact	Ease of Implementation	Cost Feasibility	Applicable Equipment
	High	High	High	High	Bull gear, chain drive, pillow blocks (Not contained)
		Moderate	High	High	Sheaves, bearings, pillow blocks, chain drive, and couplings (minimally containment)
	Moderate	Low	High	High	Sheaves, bearings, pillow blocks, chain drive, bull gear, and couplings (moderately containment)
		High	High	Moderate	Surface collector couplings and gate hoist hooks, blocks, lifting beams (submerged)
	Low	Negligible	High	High	Bearings, couplings, bushings, pillow blocks, chain drive (Thoroughly contained)
		High	Moderate	Moderate	Tainter gate and orifice gate wire rope, Moffett crane wire rope, fish ladder wire rope, etc.
		High	Moderate	Low	COH hoist wire rope (submerged)

ID	Primary System	Equip. Description	Floor	EL.	Grease Used	Likelihood of Water Contact	Ease of Implementation	Cost Feasibility	Priority
1	Adult Fish Ladder (RRFW) - Pickett Barrier Hoist	Fish screening gates - Sheaves	Upper Fishway Deck	717	248 Moly Syngard	Low	High	High	Moderate
2	Adult Fish Ladder (RRFW) - Pickett Barrier Hoist	Fish screening gates - zerks	Upper Fishway Deck	717	248 Moly Syngard	Moderate	High	High	High
3	Adult Fish Ladder (RRFW) - Pickett Barrier Hoist	Fish screening gates - Wire rope	Upper Fishway Deck	717	Not lubricated	High	Moderate	Moderate	Low
4	RRFW CS-S1 Operator	Limit torques actuator - zerks	Upper Fishway Deck	717	248 Moly Syngard	Moderate	High	High	High
5	Adult Fish Ladder	Adjustable weir - pillow blocks	Upper Fishway Deck	710	248 Moly Syngard	Moderate	High	High	High
6	Adult Fish Ladder	Adjustable weir - wire rope	Upper Fishway Deck	710	Not lubricated	High	Moderate	Low	Low
7	Juvenile Fish Ladder (BC-G1, -G6, -G7)	Radial gate - pillow blocks, zerks	Upper Fishway Deck	707	Huskey LVI-50	Moderate	High	High	High
8	Trash Hopper	Sheaves, roller bearings, zerks	Upper Fishway Deck	713	Huskey LVI-50	Low	High	High	Moderate
9	Surface Collector	Traveling screens - Motor coupling	Upper Fishway Deck	717	248 Moly Syngard	High	High	Moderate	Moderate
10	Surface Collector	Traveling screens - Chains and sprocket	Upper Fishway Deck	717	Huskey LVI-50	Moderate	High	High	High
11	Forebay Intake Gate (ISFTP-S1, -S2)	Limit Torques - Zerks	Upper Fishway Deck	717	248 Moly Syngard	Moderate	High	High	High
12	Juvenile Fish Ladder	Fish screen gates - Pillow blocks, zerks	Upper Fishway Deck	707	Mobil Unirex EP	Moderate	High	High	High
13	VBS Screen Cleaner	Couplers, motor bearings, and pillow	Transformer Deck	717	Huskey LVI-50	Low	High	High	Moderate
14	Intake Gantry - COH	Trolley - Wheel bearings, zerks	Transformer Deck	717	Mobil Unirex EP	Low	High	High	Moderate
15	Intake Gantry - COH	Hoist - Bearings, gear reducer, couplings, bushings, pillow block	Transformer Deck	717	Mobil Unirex EP	Negligible	High	High	Low
16	Intake Gantry - COH	Hoist - Wire rope	Transformer Deck	717	Mobilarma 798	High	Moderate	Low	Low
17	Intake Gantry - COH	Truck - Zerks, bearings, couplings, seals	Transformer Deck	717	Mobil Unirex EP	Low	High	High	Moderate
18	Intake Gantry - COH	Aux. Hoist - Hoist chain	Transformer Deck	717	Fuchs Renolit LZR	Negligible	High	High	Low
19	Tainter Gates 2-10	Hoist - Shaft pillow blocks, end bearing, zerks	Spillway	721	248 Moly Syngard	Low	High	High	Moderate
20	Tainter Gates 2-10	Hoist - Wire rope	Spillway	721	Loob-it	High	Moderate	Moderate	Low
21	Tainter Gates 2-10	Hoist - Bull gear	Spillway	721	Silver Streak	High	High	High	High
22	Tainter Gates 2-10	Hoist - chain drive, couplings	Spillway	721	Chevron Coupling	Low	High	High	Moderate
23	Tainter Gates 1, 11, 12	Hoist - Shaft pillow blocks, end bearing,	Spillway	721	248 Moly Syngard	Low	High	High	Moderate
24	Tainter Gates 1, 11, 12	Hoist - Wire rope	Spillway	721	Loob-it	High	Moderate	Moderate	Low
25	Tainter Gates 1, 11, 12	Hoist - Bull gear	Spillway	721	Silver Streak	Moderate	High	High	High
26	Tainter Gates 1, 11, 12	Hoist - chain drive, couplings	Spillway	721	Chevron Coupling	Negligible	High	High	Low
27	Middle Spillway Entrance (HS-1)	Actuator - zerks	Spillway	717	248 Moly Syngard	Moderate	High	High	High
28	Middle Spillway Entrance (MSE)	Dewater pump - Zerk	Spillway	640	Huskey LVI-50	Negligible	High	High	Low
29	Middle Spillway Entrance (MSE, RG-1 Operator)	Fish Intake Gate - Wire rope	Spillway	640	Not lubricated	High	Moderate	Low	Low
30	Middle Spillway Entrance (MSE, RG-1 Operator)	Fish Intake Gate - Zerks, pillow blocks, couplings	Spillway	640	248 Moly Syngard	Moderate	High	High	High
31	Right Powerhouse Entrance (RPE, RG-1 and -3 hoists)	Wire rope	Tailrace Deck	650	Not lubricated	High	Moderate	Low	Low

32	Fish Unwatering Pump	Zerk	Tailrace Deck	650	248 Moly Syngard	Moderate	High	High	High
33	Fishway Regulating Gates	Pillow blocks, couplings, chain drive	Tailrace Deck	650	248 Moly Syngard	Moderate	High	High	High
34	Fishway Regulating Gates	Wire rope	Tailrace Deck	650	Not lubricated	High	Moderate	Low	Low
35	Tailrace Crane - Moffett	Truck - Wheel bearings, zerks	Tailrace Deck	650	Chevron Ultra Duty EP	Moderate	High	High	High
36	Tailrace Crane - Moffett	Main hoist - wire rope	Tailrace Deck	650	Not lubricated	High	Moderate	Low	Low
37	Tailrace Crane - Moffett	Main hoist - Hooks, lifting beam, block zerks	Tailrace Deck	650	248 Moly Syngard	High	High	Moderate	Moderate
38	Tailrace Crane - Moffett	Hoist trolley - Pulley/shaft bearing,	Tailrace Deck	650	Chevron Ultra Duty EP	Low	High	High	Moderate
39	Tailrace Crane - Moffett	Orifice gate hoist - bearings	Tailrace Deck	650	Chevron Ultra Duty EP	Moderate	High	High	High
40	Tailrace Crane - Moffett	Orifice gate hoist - wire rope	Tailrace Deck	650	Not lubricated	High	Moderate	Low	Low
41	Tailrace Crane - Moffett	Orifice gate hoist - zerks, hooks, lifting beam	Tailrace Deck	650	248 Moly Syngard	High	High	Moderate	Moderate
42	Wing Gates	Zerks	Tailrace Deck	650	248 Moly Syngard	Moderate	High	High	High
43	Wing Gates	Zerks	Lower Fishway Walkway	635	248 Moly Syngard	Moderate	High	High	High
44	Orifice Gate Hoist	Wire rope	Lower Fishway Walkway	635	Loob-it	High	Moderate	Moderate	Low
45	Orifice Gate Hoist	Zerks, pillow blocks, sheave block	Lower Fishway Walkway	635	248 Moly Syngard	Moderate	High	High	High
46	Orifice Gate Hoist	Couplers	Lower Fishway Walkway	635	Chevron Coupling	Moderate	High	High	High
47	Fish Sampling Facility	Crowder - Pillow blocks	West Bank	675	Huskey LVI-50	Moderate	High	High	High
48	Fish Sampling Facility	Process Water Pumps - Zerks	West Bank	675	Huskey LVI-50	Low	High	High	Moderate
49	Fish Sampling Facility	Sampling Screen - Trucks, chain drive	West Bank	675	Huskey LVI-50	High	High	High	High
50	Fish Sampling Facility	Tainter Gate - Pillow blocks, zerks	West Bank	675	Huskey LVI-50	High	High	High	High

Appendix C – Laboratory Compatibility and Performance Results, Discussion, and Recommendation

APPENDIX TO BE ADDED FOLLOWING
PERFORMANCE TESTING RESULTS