APPENDIX C

ECB 2006-11 Tainter Gate Trunnion Lubrication

US Army Corps of Engineers

ENGINEERING AND CONSTRUCTION BULLETIN

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Subject: Tainter Gate Trunnion Lubrication

Applicability: Information

Reference:

- Forensic Report on Spillway Gate 3 Failure Folsom Dam, U.S. Bureau of Reclamation, Mid-Pacific Regional Office, 18 November 1996
- Improving Reliability of Spillway Gates, United States Society on Dams, December 2002
- EM 1110-2-1424, Lubricants and Hydraulic Fluids, 28 Feb 1999, Table 11-3

1. The referenced documents make a number of recommendations concerning trunnion lubrication. This ECB presents recommendations specific to grease lubricated bronze bushings installed in tainter gate trunnions.

2. The forensic report, the USSD document, and EM 1110-2-1424 recommend that the lubricant used for tainter gate trunnion bushings contain the properties summarized and updated in Essential Lubricant Properties (Encl 1).

Designers or operating personnel should contact lubrication manufacturers for the latest product information and for improved lubricant products. The USSD document recommends that a lubrication specialist or tribologist be consulted for additive selection and chemical reactions as actual field performance will depend on actual trunnion design and material selection. The Corps resident lubrication expert is Mr. John Micetic at the Hydroelectric Design Center. Mr. Micetic provided the information pertaining to the lubricant properties in the enclosure.

3. In addition to recommendations on the type of lubricant to be used, the forensic report and the USSD document recommend that the tainter gates should be exercised and lubricated as they move through their full range of travel at least once a year. Exercising and lubricating the gates without a hydrostatic load would be best as it helps ensure that the lubricant gets between the contact surfaces. It further recommends (for actual gate operations) that the trunnions be lubricated prior to initiation of gate travel and continued throughout full gate travel. This would typically require an automated lubricating system that would be energized during the gate operating sequence. The USSD document explains that recent applied lubricant or lubricant applied during gate movement is beneficial to avoid trunnion chatter (stick/slip action between static and dynamic friction), and to provide smooth (non-jerky) movement.

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4. This ECB only provides excerpts from the referenced documents. It is recommended that Appendix C – Trunnion Lubrication of the referenced USSD document be reviewed in its entirety.

5. Point of contact for this ECB is Dan Casapulla, 202-761-4227

1 Encl

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Essential Lubricant Properties

- Rust prevention – ASTM D-1743 Pass
- Resist water washout – ASTM D-1264 Max 1.9%

1.9% is not too restrictive, and many types of grease would be able to qualify. However, there are greases that are more resistant to water washout (zero or up to 0.5%). This characteristic is very important in trunnion application, especially when re-greasing periods, at high load and low speed conditions, are extended quite a bit and with bearings that are not adequately protected from environmental impact (rain, water splash, dust, dirt, etc). There are products available with the limit set to "up to 1.0%" or even to "up to 0.5%.

- Ease to pump and distribute – ASTM D-217 Worked Penetration NLG 1

Pumpability characteristic is more pronounced and more precisely measured by ASTM D 217, Cone Penetration of Lubricating Grease, than by ASTM D 1403, which uses scaled-down (one half and one quarter) cone equipment instead of regular cone equipment, as in D 217. They both are expressed as NLGI rating, but D 1403 uses back-calculation to get there, while D 217 directly establish NLGI rating (because it is the base for NLGI rating).

- High viscosity mineral and/or synthetic oil base – ASTM D 445 Minimum 700 cSt at 40°C

Oil/grease companies are in a constant race with their competitors to find better chemistry and formulation of grease. There are synthetic oil based greases that perform better than mineral oil based, and are more environmentally friendly. We would not be able to take advantage of best products out there if we limit ourselves only to grease formulated with mineral oils as indicated in the Folsom Forensic Report. By adding this, we don't have to separately refer to viscosity of base oil. Viscosity of base oil does not have an overly significant effect in boundary lubrication regime, especially in high-load/slow-speed application. It does, however, affect the formulation of grease. Greases with higher base oil viscosity require less amount of thickener to meet certain NLGI rating. This is significant because thickeners don't lubricate, only oil and additives do. In the process of grease usage, thickeners from the grease accumulate in the bearing over time, and in fighting for the limited place in a bearing it may impede the performance by limiting the effect of additives (which in fact provide lubrication). Therefore, less thickener is better, but how less is determined by the viscosity of base oil (more viscous base oil – less the amount of thickener).

- Anti wear and anti scuffing – ASTM D-2596

Measurement of Extreme-Pressure Properties of Lubricating Grease (Four-Ball Method); recommend that the criteria be set as follows: minimum Wear Load Index of 40 kgf, and minimum Weld Point of 140 kgf. Trunnion application is typical boundary condition, and it is appropriate to set these parameters to make sure excessive wear and/or welding does not occur at the exhibited loads and speeds.

- Good adhesion to bearing surfaces – No test

Adhesion of grease to metal surfaces is closely related to Water Washout characteristics. Greater the tackiness (which is not measured) of a grease the better is the resistance of grease to water washout. Viscosity of base oil (higher the better) and the type of tackifier or a combination of thickener-tackifier chosen in formulation of grease will determine how strong the grease will cling to a bearing and resist being washed away. Recommend that the selection of tackifier types used be left to the formulators, but would set minimum criteria for the water washout characteristic.

- Corrosion of bronze prevention – ASTM D-4048 Classification 1b

The classification identifies the level of acceptable corrosiveness.

- Non-separation in storage – ASTM D-1742

Maximum separation allowed should be limited to 0.5% or 1.0%. This characteristic is not only important during storage of grease, but to grease in lube lines (where an automatic greasing system is in place and used), because of long pauses between actual greasing. It's important that oil not separate from thickeners and additives while in the grease lines.

Encl. 1