

## APPENDIX C

### PROJECT MAINTENANCE HYDROPOWER

C-1. General. Equipment maintenance is divided into two or three categories: routine operational checks, inspections and periodic maintenance. Each project shall develop a written maintenance plan for each piece of equipment. The plan should outline both the routine checks and periodic maintenance. The frequency of these checks and maintenance activities should be determined by the criticality of the equipment, the past experience with this and similar equipment and scheduling options available to that particular project. A periodic review of these plans should evaluate the effectiveness of the maintenance both from a cost and reliability standpoint. The following establishes some minimum requirements related to the types of maintenance tests and the frequency of these activities.

a. Hydropower Unit Maintenance. Each project must have a maintenance plan that includes regularly scheduled maintenance outages and optional inspection outages.

(1) Maintenance (Overhaul) Outages. These outages should be scheduled with sufficient frequency and duration as to guarantee the continued satisfactory operation of the equipment. Depending on the power and water regimes, it may be necessary to schedule more frequent short outages versus less frequent longer more extensive overhauls.

(2) Inspection Outages. When necessary short inspection outages may be required in order to monitor turbine cavitation or other continuing problems.

b. Hydropower Controls, Instrumentation and Protective Relaying.

(1) Protective Relaying. All protective devices shall be tested on a periodic basis. Bench testing (calibration) shall be performed at least every 2 years. Generator, main station service, main transformers and switchyard protective relay schemes shall be functional tested at least every four years.

(2) Controls and Instrumentation. All unit controls shall be functional tested as part of the unit maintenance outages.

(3) Circuit Breakers. In addition to the insulation test requirement found elsewhere in this EP, all molded case and other types of low and medium voltage circuit breakers shall be tested every 4 -6 years. These tests shall include high current test sets and any other appropriate tests for the particular breaker type.

c. Hydropower Electrical Testing.

(1) Insulation Testing -All electrical equipment shall be included in an insulation testing program. This includes tests at the time of installation of new equipment and periodic maintenance tests.

(a) Low and Medium Voltage Equipment -At a minimum, resistance tests commonly referred to as "meager" testing.

(b) High Voltage -All main unit, station service and switchyard equipment rated at a nominal voltage of 13.8 kV or more shall be in an insulation testing program. This includes tests at the time of installation of new equipment and periodic maintenance tests. Power factor testing (Doble) tests procedures shall be utilized.

- Insulating Oil Testing
  - Field Screening
  - Gas Chromatography
  - Dissolved Gas Analysis
- Gas Insulated Equipment (SF)

(2) Timing Tests. All breakers must be tested to insure proper operation. In addition to the above insulation tests, tests for proper timing is necessary. Test equipment such as the "Cincinnati" timer are used on most all medium and high voltage switchgear.

d. Hydropower Mechanical Equipment.

(1) Governor Tests. In addition to the regular maintenance checks that are incorporated into a unit maintenance or inspection outage, the performance of the governor must be periodically monitored. The manufacturers instructions should list test options.

(2) Other Mechanical Features. While there a many standard tests of electrical equipment in a modern hydropower plant, there are few for mechanical equipment. However, each piece of equipment must have a maintenance plan that includes the required operational checks, inspections and maintenance schedules.

e. Project Lubrication.

(1) Engine Lubricants. See ER 750-1-1 and the Army Oil Testing Program.

(2) Hydro Power Plant Lubricants.

f. Large Transformers. The primary maintenance items for a large transformer is the insulating fluid and the high voltage bushings (discussed elsewhere). Heat exchanges, fans, gaskets and other auxiliary equipment need to be included in the maintenance plan. Many of these items are cover in the routine operational checks and inspections.

g. Hydro Power Plant Cranes and Hoist. The Safety Manual, ER 385-1-1 covers most of the current inspection and licensing requirements for all types of cranes. For the large powerhouse bridge cranes, load testing should be scheduled on a ten-year cycle. Load testing shall be preformed after any major maintenance, repair or replacement. Load testing and an intense inspection should be scheduled prior to any planned unit disassembly (rewind, etc.) Full load testing is not required prior to emergency work.

h. Penstocks, Gates and Other Water Control Features. All water conduits, gates and bulkheads are to be regularly inspected and maintained. Each of these features must have written maintenance plans.

i. Predictive Maintenance. Major hydropower equipment such as turbines, generators and transformers must have maintenance scheduled around seasonal water and power demand

schedules. Traditional practice has been to schedule periodic maintenance around the aforementioned needs. To the greatest extent practical this is to be avoided and a predictive maintenance approach should be used. The full and complete installation of expensive equipment and systems to adopt this approach should be evaluated against the benefits accrued for their installation.