Chapter 6
Installation, Operation & Maintenance, and Inspection

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6.1 Installation.

6.1.1 General. This section discusses some of the factors that affect the quality of construction during the manufacturing and installation of gate operating equipment for new construction, for major rehabilitation, and for major maintenance work. It discusses the gate operating equipment and does not include the gate itself except when the operation of the gate, misalignment of the rollers or maladjustment of the gate seals for example, affects the operation of the gate operating equipment.

6.1.2 Designer Involvement. It is important that the designer be involved with construction activities from shop drawing review, through shop inspection, to final field inspection. ER 1110-2-112 establishes policy that requires field construction participation by design personnel. The designer needs to maintain a good working relationship with the Corps construction office and needs to include engineering's involvement in the Engineering Considerations and Instructions to Field Personnel as provided in ER 1110-2-1150.

6.1.3 Contract Requirements. The contract specifications should require the contractor to perform all testing associated with the manufacturing and installation of equipment. The Contractor Quality Control (CQC) representative should be present and witness the testing. The contract documents should identify the test data that needs to be recorded and the contractor should record all test data required by the contract. The contract documents should hold the contractor responsible for any re-testing required due to the contractor's inability to fulfill the contract requirements.

6.1.3.1 Shop Assembly and Test. Each hoist should be fully assembled in the shop. Alignment of component parts, correctness of fabrication, and tolerances, as shown on the shop drawings, should be checked. Each hoist should be given a no load operational test in the shop. In addition to the proper operation of the hoist assembly, items such as limit switches, motor brake, torque switches, and control panel should be checked for proper settings and operation in accordance with the manufacturer's recommendations.

6.1.3.1 Field Installation and Tests. The contractor should be required to submit a detailed installation procedure. The installation procedure should show items such as storage and handling requirements, installation sequence, alignment techniques and criteria, bolt torque requirements, anchorage requirements, fits and tolerances, lubrication requirements, fluid levels, inspection and testing requirements, operation and maintenance information. The hoist units should be shipped assembled, ready for field installation in accordance with the contractor's installation procedure. All installed equipment should undergo field testing. The field test should include operational tests of the installed equipment with the gate in the dry and if possible at or near design head. The gate should be operated through a number of complete cycles in the dry to check the alignment of gate operating equipment and gate rollers and seals, and operation of the

controls, limit switches, and brake. The gate operating system should also show that it can hold the gate in any position on demand. A dynamometer or load test should then be conducted at or near design head (if possible) with the measurements of the motor current, voltage, temperature, and vibration taken. For hydraulic operating systems, the pressure and leakage tests should be witnessed and the operating pressures should be checked against the design pressures. Relief valve and torque switch settings should be checked.

6.1.4 CQC/QA Responsibilities. In order for the CQC program to be effective it must be enforced. The designer, as a member of the command's QA team, can assist the construction office in program enforcement.

6.1.4.1 The designer should have the opportunity to review the CQC plan to ensure that the plan includes the manufacturing and installation of the gate operating equipment. A Preparatory Inspection should be conducted for this phase of the contract work and the designer should have the opportunity to attend the Preparatory and Initial Inspections. The designer should also have the opportunity to review Follow-up Inspection reports.

6.1.4.2 Also as part of the QA responsibilities, the designer should attend the shop inspection and test. To prepare for this, the designer should review the appropriate technical and non-technical parts of the contract documents. The designer should also review the referenced industry standards and shop drawings and check with the CQC representative to make sure that the contractor is working from the same documents. Both CQC and QA should spot check to confirm that the equipment is being manufactured in accordance with the shop and manufacturing drawings.

6.1.4.3 When multiple hoists are being built, as is common to many of the Corps facilities, the designer should witness the shop and field assembly and testing of at least the first unit. The assembly and testing procedures should be reviewed with the contractor's CQC representative and the calibration of the testing equipment should be checked by the CQC.

6.1.4.4 During installation and prior to operation, the CQC representative should perform the following and the QA representative should spot check for compliance.

- Verify that an approved welding procedure has been submitted and qualified welders are on-site when field welds are required.
- Witness the tensioning of the wire rope for multiple rope hoists.
- Witness dynamometer testing.
- Visually check alignment of shafts, couplings, gears, etc.
- Check operation of electrical components, i.e., motors, controls, limit switches, brakes, etc.

- Verify that all fluid levels and lubrication of components are in accordance with the manufacturer's recommendations.

- Check that the effects of corrosion have been minimized by a properly applied paint or coating system and that there is adequate drainage designed into the hoists to prevent water retention.

- Verify that all reporting requirements have been met.

6.1.5 Acceptance Criteria. The designer should assure that the installation acceptance criteria are provided in the contract documents. When a performance specification is developed for contractor-designed equipment, the specification should also require the contractor to develop the acceptance criteria. The acceptance criteria should be based on Corps standards or applicable industry standards when such standards exist.

6.1.6 As-Built Drawings. The development of as-built drawings is a continuous process and should be a contract requirement. As the contractor is manufacturing and installing the equipment, the as-built drawings should be revised to reflect actual conditions. The CQC and QA representatives should monitor this process. All proposed changes should be coordinated with the designer. The as-built drawings, shop drawings, assembly drawings and installation procedures should be revised as changes occur. The contractor should be required to furnish CADD drawing files on disc or CD compatible with the customer's existing CADD system.

6.1.7 Operation and Maintenance (O&M) Manual. Similar to the as-built drawings, the development of the O&M manual is a continuous process and its development should be a contract responsibility. The O&M manual is developed based on the equipment manufacturer's recommendations. The O&M manual gives basic operating and maintenance procedures, guidelines for troubleshooting and repair procedures, and assembly/disassembly details. It should also include the procedure and frequency of the testing and inspection of components or systems. The O&M manual should be considered a living document. This means that as the project ages and equipment is changed, the O&M manual should be continuously updated to reflect those changes. The O&M manual produced by the contractor will eventually become a part of the project O&M manual developed by the designers.

6.1.8 Submittal Review. The designer should review the shop drawings, assembly drawings, installation drawings, installation procedure, O&M manual and as-built drawings. The assembly drawings, installation drawings, and installation procedure can be submitted for information purposes only. Shop drawings that detail components specifically fabricated for the project should be submitted for approval. Shop drawings for purchased components should be submitted for approval. They should include catalog cuts and sufficient information to determine compliance with the specifications.

6.2 Operation and Maintenance. The operation of a Corps of Engineer lock and dam falls directly under the responsibility of the on-site lockmaster. However, in executing its mission, everyone

connected with the project has a responsibility to improve safety and increase efficiency. All projects should be operated within the guidelines provided in the project O&M manual. The O&M manual should be continually updated to reflect all changes in operating procedures at the project. The manual should contain provisions to record equipment failures and to post maintenance records to enable operators to identify developing trends to avoid an unexpected failure.

As discussed in Chapter 4, automation of a lock and dam project can range from the simple manual start-auto stop of a single gate to the complete lockage and recording of a vessel without operator intervention. The appropriate level of automation for a project is a judgment made by all those involved with the project. As a minimum, new and electrically rehabbed projects should be operated with a Programmable Logic Controller (PLC) control system and Human Machine Interface (HMI) computer interface. In order to improve the effectiveness of the project, the process of locking a boat and operating a dam must be examined for inherent inefficiencies. The PLC is an excellent tool for monitoring such parameters. The PLC never forgets to log movement of equipment, or accurately record gate operating times and other parameters. Inefficiencies will become evident when such data is closely monitored. The time it takes for a vessel to approach the lock may seem to be based entirely upon the vessel operator, but the truth may be that the operation of the lock and dam has a lot to do with the length of time required for this process. Circumstances such as traffic light signaling, traffic queuing, outdraft, operation of the dam, inefficiencies in direction change, operation of adjacent locks, pleasure craft, and visibility may all cause a potential delay to traffic. Only careful monitoring of the process, along with these and other circumstances surrounding it, will present useful data to operations management. This data can be used to improve the operation of the project. Amount of improvement will vary by project but the information gathered will be useful knowledge to have and much of it will come for a one-time set up cost of programming the PLC to monitor particular portions of the project.

6.3 Inspection and Testing

6.3.1 General. Project specific inspection requirements, i.e., items to be inspected, inspection procedure and inspection frequency should be included in the O&M manual. These inspections are also included as part of the Periodic Inspection program as defined in ER 1110-2-100. Typical items include motors, brakes, gears, shafts, couplings, bearings, controls, limit and torque switches, hydraulic systems, wire rope, chain, structural base frames, emergency generators and any other integral parts that transmits the necessary power to operate a gate. Machinery should be inspected not only for its current condition, but also for its condition relative to the last inspection. The operation and maintenance procedures should be reviewed for their adequacy. Operational tests should be performed on a regular basis.

6.3.2 System Condition. The general condition and operation of the gate operating equipment should be observed. Operation should be smooth; any abnormal performance should be noted. Noise and vibration should also be noted and the source determined. The inspector

should report any unsafe or detrimental procedures followed by the operator that could cause injury to personnel or damage to the equipment. The condition of the paint system should also be recorded. Maintenance procedures should be in accordance with the O&M manual. Maintenance records should be reviewed with maintenance personnel. Maintenance procedures should include the periodic operation of equipment that sits idle for long periods of time.

6.3.3 Inspection Guidelines. The following are meant to be condensed guidelines for the major components of gate operating equipment.

6.3.3.1 Open Gearing. Open gearing should be inspected for alignment, including under/ over-engagement, and wear patterns away from the gear pitch line. Alignment problem indicators can predict bent shafting, misaligned bearings, loose mounting bolts, improperly fitted keys or eccentric loading. Excessive or abnormal wear of the tooth mating surfaces should be noted, including pitting, scoring, spalling, and plastic flow. Most tooth wear problems are related to improper fabrication or improper lubrication. Inspect the teeth, spokes, and hub for cracks, which may be the result of fabrication, heat treatment or mishandling during installation. Cracks are often obscured by a coating of paint. Examine lubrication quality and quantity. Meshing gear surfaces that are scarred in the areas from slightly below the pitch line to the tooth tips is an indication of lubrication failure. Check gear teeth for excessive backlash, pitch line mesh, dirt, and corrosion. Inspect all keys, keyways, retainer caps, and bolting materials for proper fit, alignment and tension.

6.3.3.2 Speed Reducers. Speed reducer housings and mounting base should be inspected for cracks. All seals and gaskets should be inspected for lubricant leaks. All fasteners should be inspected for corrosion and proper tension. After removing the inspection cover, the interior should be examined for signs of condensation, corrosion, general condition of the gears (see open gearing) excessive shaft movement, and excessive backlash. The lubricant level should be checked daily, while oil samples should be laboratory tested quarterly.

6.3.3.3 Shafts and Couplings. Shafting should be inspected for cracks, twist, bending, strain, and misalignment. Any suspicion of cracking or excessive strain should be verified by dye-penetrant testing. Bending can be estimated by the use of dial indicators. Coupling components should be examined for adequate lubrication, proper fastener tension, damaged keys, and improper alignment.

6.3.3.4 Bearings. Bearing housings, pedestals, and supports should be inspected for cracks and misalignment. Fasteners should be checked for tightness and corrosion. All bearings should be checked for condition and quantity of lubricant. Plain bearings (bushings) should be examined for excessive wear, using feeler gauges, as well as the condition of any seals, as applicable.

6.3.3.5 Brakes. All braking devices should be inspected for proper braking torque setting, and complete release at actuation. On shoe brakes, check brake wheels and shoes for wear, corrosion, misalignment and proper clearance at release. Linkages should be free but not loose. Check that there is no leakage at connections or seals on enclosed hydraulic disc brakes. All limit

switches should be tested for proper setting and actuation.

6.3.3.6 Hoist Motor. Motors should be inspected to insure that nothing is interfering with the motor ventilation. Any unusual noise or odor, such as from scorched insulation varnish, should be cause for more detailed inspection. Bearings should be examined for adequate lubrication, indications of wear (free movement), vibration, and seal leakage. The motor should be started several times to insure that it comes up to proper operating speed. Operation of winding heaters should be verified. Fasteners should be tight and in good condition.

6.3.3.7 Hydraulic System. All hydraulic components should be inspected for signs of leakage. All flexible hoses should be examined for deterioration, flaking, cracking, kinks, and wear. Hydraulic pumps should be checked for noise and vibration. Hydraulic fluid should be tested for viscosity, moisture content and other contamination. Hydraulic fluid should be sampled and analyzed at least quarterly. Filters, tank trappers, breathers and other devices should be examined for contaminants or replacement indication. Personnel should review maintenance records for filter and fluid changes at least quarterly. Hydraulic cylinders should be regularly inspected for misalignment, seal leakage, piston rod coating deterioration and proper function of associated valves. All valves should be inspected for loose locknuts, damaged handles, stems, or wiring connections. All limit switches, speed change switches and pressure switches should be tested for proper function. All pressure relief valve settings should be verified annually by an independent, properly calibrated pressure gauge. All flow rate settings should be verified. Seasonal changes to pump, valve or other equipment adjustable settings should be recorded in the maintenance records.

6.3.3.8 Machinery Supports. Machinery support frames should be inspected for cracking in the steel, grout pad and concrete. All welds should be examined for cracking. Any corrosion should be noted and scheduled for repair. Deformation of any steel members, or anchor bolts, should be cause for immediate analysis of the safety of continued operation. All drain holes should be clear such that there is no standing water.

6.3.3.9 Wire Rope, Drums and Sheaves. Wire rope, drums and sheaves should be inspected in accordance with the guidance provided in Corps of Engineers manual EM 1110-2-3200.

6.3.4 Test Operation of Equipment. ER 1110-2-100 requires at least annual operation of components that are vital to the safe operation of major Civil Works projects under emergency conditions. These components should be test operated using emergency power. The emergency power generator should be full load tested at more frequent intervals such as every other month to maintain its integrity. To satisfy these requirements, the standard operating procedure at most projects is to annually operate one third of the spillway gates through a full open and close cycle. Bulkheads or stop logs may need to be installed at the times when reservoir levels prohibit the full opening of the gates. This establishes a maximum interval between full travel tests of 3 years for each gate. Partial opening of the gates does provide some test benefits, but it is essential that full travel tests be performed to verify non-binding operation at all gate positions. A partial opening test of each gate should be conducted at least every year, except for the year that a full

travel test is scheduled. The gate should be raised as high as reservoir conditions allow without the use of bulkheads or stop logs. Additionally, gates and gate operating equipment should be test operated prior to a flood event.

6.4. Access for Inspection and Maintenance Activities. Designers and those responsible to review completed designs should ensure that access has been provided to inspect and maintain equipment and components. Planning this access should happen early in the design phase of the project and needs to be coordinated with the structural engineer and others responsible for the design and layout of the structure. The designer also needs to develop an inspection and maintenance plan and include that plan in the O&M manual.. The details of the plan needs to be coordinated with those responsible to operate and maintain the project. Details should include locations of removable inspection covers, permanent or portable access platforms, etc. Provide proper lighting and a safe working environment to perform the inspection and maintenance procedures.