Chapter 7
Operating Equipment

7-1. Introduction

a. General. Traditionally, tainter gates have been operated by lifting with wire rope or chains attached to a hoist located above the gate. More recently, hydraulic hoist systems have also been utilized to operate tainter gates due to economy, reduced maintenance, and advantages concerning operating multiple gates. Chain hoists are not recommended for new designs due to past maintenance problems. The components of the lifting equipment associated with the gate shall be designed to withstand forces including the weight of the gate, silt and ice loads, and friction loads (side seals and trunnion) using the load cases defined in Chapter 3. Component design of the lifting machinery is the responsibility of the mechanical engineer.

b. Coordination. The design process is an iterative procedure where alternate hoist arrangements are evaluated jointly with the structural systems of the tainter gate and pier to arrive at a design that minimizes cost. Throughout this process, the structural engineer requires the technical assistance of a hydraulic engineer and a mechanical engineer. The hydraulic engineer specifies the opening requirements and flow nappes for various flood events. The location and layout of the machinery is dependent on gate opening requirements, and the flow nappe is needed so that the cylinder for hydraulic hoist systems can be located to avoid submergence. The mechanical engineer designs the operating machinery and determines the layout of operating machinery and operating machinery design loads. There are many acceptable solutions for the layout of the machinery and each alternate geometry will result in a different system design. For example, the requirements for a hydraulic cylinder (stroke length, bore, piston rod diameter, and operating pressure) and resulting machinery loads will be affected by the layout of the cylinders. The tainter gate design (and possibly the anchorage and pier design) is affected by the unique machinery loads of each layout. The optimum layout is determined by jointly evaluating overall costs of the hoist system, tainter gate, gate anchorage, and pier.

7-2. Machinery Description

a. Hydraulic hoist. A hydraulic hoist system consists of two synchronized hydraulic cylinders as described in paragraph 3-2.c (Figure 3-7). Each cylinder is mounted on the adjacent pier with a trunnion and is connected to the downstream side of the gate with a pin connection. The connection between the cylinder and gate is generally made near the end of a horizontal girder or at a connection in the end frame. The cylinder location should be selected to provide a practical connection to the gate and to minimize hoist loads while maintaining a relatively constant cylinder load through the required range of motion. The arrangement must accommodate required angular movement necessary to lift the gate through the range of motion. The cylinder position and point of connection of the cylinder to the gate affects the entire structural design and coordination between designers of the cylinder and gate is essential. Layout of the hydraulic cylinder is discussed in Chapter 3.

b. Wire rope hoist. A typical wire rope hoist consists of single or multiple wire ropes attached to each end of the gate, wound on overhead drums (Figures 3-6 and 3-8). The drums can be interconnected with a shaft and powered by a single motor or powered individually with synchronized motors. Although ropes can be attached to the upstream or downstream side of a gate, common practice is to attach ropes to the upstream face of the gate at lifting hitches located near the bottom of the gate. The hoist is typically located so that the wire ropes are in contact with the skin plate for the full height of the gate (in closed position) to prevent floating debris from becoming lodged between the gate face and the wire rope. A detailed discussion on the location of the wire rope and associated hoists is provided in Chapter 3.

7-3. Machinery and Gate Loads

For all of the load cases described in paragraph 3-4.b, the operating machinery may be loaded and include some force. Regarding gate design, the effect of the machinery is considered to be a gate reaction for cases in which the machinery supports the gate, and an applied load when the gate is supported otherwise. For all of the load cases with variable gate position, the machinery force varies in magnitude and direction throughout the range of motion. Therefore, for load cases 2, 3, and 4 of paragraph 3-4.b, all positions through the operating range must be accounted for in design of the gate and operating equipment.

a. Machinery loads. Operating machinery must have the capacity to support the gate during operation. Given the load requirements specified in paragraph 3-4.b, the required capacity is determined from the gate operating load conditions (load cases 2 and 3), in which the machinery loads are treated as gate reaction forces. The machinery load requirements are the reaction forces since these are the forces required to operate the gate. In determining the machinery design loads, coordination between the project structural and mechanical engineer is essential.

b. Gate loads. Due to application of appropriate factors of safety and machinery efficiency requirements, the actual maximum machinery capacity can be much larger than that required to operate the gate. Loads Q, described in paragraph 3-4.b(1) and applied in load cases 1, 4, and 5, are based on the actual machinery force. Determination of the magnitude of Q is discussed in paragraph 7-3.c.

(1) Hydraulic hoist. The hydraulic cylinders apply a concentrated load to the gate where the cylinder is attached to the gate. Hydraulic hoists may exert upward as well as downward forces when the gate is closed (load case 1) or jammed (load case 4). The cylinder and associated connections at the pier and gate must be designed to withstand the cylinder force. The force over the operational range must be considered, since the cylinder force and its affect on the tainter gate changes with changing gate position.

(2) Wire rope hoist. As opposed to hydraulic hoists, wire rope hoists can exert only upward forces. The wire rope includes a tension force, and where the rope bears on the skin plate, radial contact pressure is applied. The rope always exerts a concentrated force at the lifting hitch, and when the wire rope is not tangent to the top of the gate, a concentrated reaction force occurs at the change in rope profile (paragraph 3-2.c(5)). The lifting hitch and supporting members must be designed to withstand the concentrated rope force, and the skin plate and supporting members must be sized to withstand the contact pressure and any reaction due to change in rope profile. For design, the entire operational range must be considered, since the cable force and its affect on the tainter gate changes with changing gate position.

c. Gate load magnitude.

(1) Hydraulic hoist. Machinery loads applied to the gate (Q) are defined in paragraph 3-4.b(1), and the specific magnitude shall be determined in consultation with the mechanical engineer. The maximum downward load Q_1 is a function of the relief valve setting, the operational range of the relief valve, and dynamic effects of fluid pressure surges when gate movement stops upon impact with the sill. A back-pressure valve controls lowering of the gate. It is set to the minimum value required to hold the gate in any open position. A lowering control relief valve (with a backup) set at 330 Kpa (50 psi) above the back-pressure valve should be provided to relieve the pressure side of the cylinder and protect the system if the gate jams while closing and when the gate impacts the sill. This relief valve setting and the resultant downward load that the cylinder exerts establish the Q_1 load. If a relief valve fails, extreme loading may be possible. Use of relief valves in parallel limits the possibility of valve failure and is more economical than constructing a structural system capable of resisting this condition. As shown by Figure 7-1, the at-rest downward load Q_2 is a function of the dead weight of the piston and rod W_{ROD} and a hydraulic cylinder force P. The force P is that which

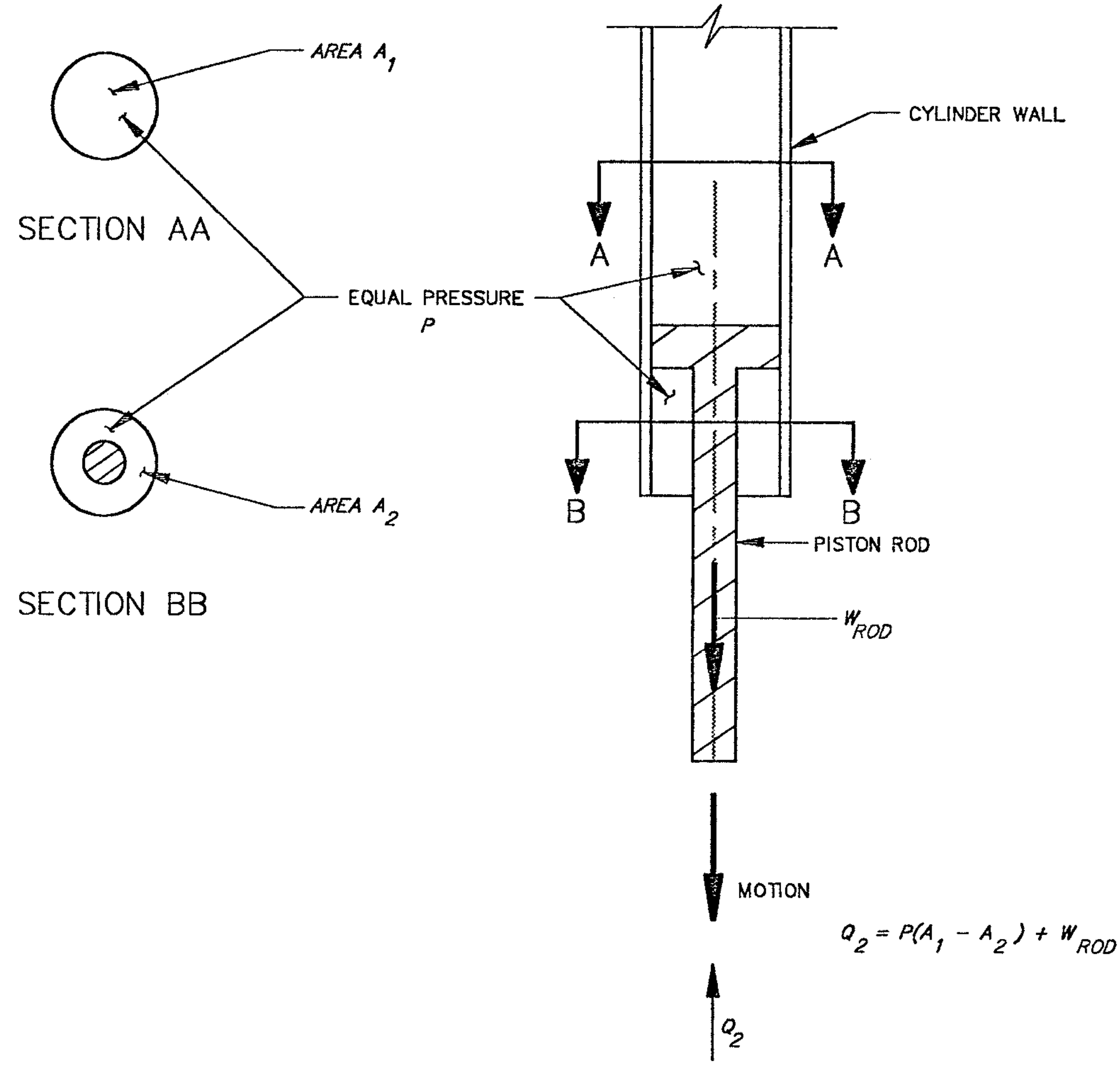

Figure 7-1. Definition of at rest downward operating machinery load Q_2

exists when the pressure across the piston equalizes when the gate is at rest on the sill. The maximum upward load Q_3 is the hoist lifting capacity based on the system pressure relief valve setting and is generally 10 to 30 percent more than that required for one hoist to raise the gate. A second (backup) pressure relief valve should be provided to protect the system if the first valve fails.

(2) Wire rope hoist. The maximum applied machinery load Q_3 is generally two to five times the required lifting load; however, the specific magnitude is generally dependent on some load limit device and shall be determined in consultation with the mechanical engineer. For efficiency, operating machinery is typically oversized. To avoid extreme loading and possible damage to the gate, load limit devices are often utilized. The

overall reliability of the structure is influenced and possibly controlled by the reliability of these load limiting devices. Certain devices have had low reliability (i.e., mechanical switches) and should be avoided. A load limit system with a high degree of reliability should be used and the load limit should be well defined.

7-4. Machinery Selection

The type of operating machinery can include either the wire rope hoist or hydraulic hoist and the selection of type should be based on project specific conditions. For a new design, the primary advantages of the wire rope hoist are that the connection is easily made on the upstream face of the gate (increases moment arm for lifting force) and that there are no environmental concerns of oil spillage. For repair or rehabilitation of existing projects, wire rope hoists may be the only practical alternative. Advantages of hydraulic hoists include the following: a) they are generally more economical especially for relatively large lifting capacities; b) they can apply force in opening and closing; c) several gates can be operated with the same power unit; d) they require low maintenance compared to wire rope systems; and e) they generally require shorter piers for support compared to wire rope systems.