Title 210 – National Engineering Handbook

PART 645 – Construction Inspection

Subpart S – Water Control Gates and Metal Fabrication

March 2025

645.19 Introduction

A. Water control gates are common in conservation engineering work. Slide gates, also called sluice gates, are gated inlets on principal spillway towers and installed in irrigation and drainage structures. Flap gates are installed in flood walls and at the end of drainage structures. Radial gates are used for dam spillways and flow control in other structures. NRCS Construction Specification 71, "Water Control Gates," covers the installation of these gates. Details for slide gates, flap gates, and radial gates are specified in Material Specifications 571, 572, and 573, respectively. This subpart covers installing water control gates, defines the terminology used to describe their parts, and identifies the inspection items required to ensure correct gate installation and function.

B. In addition to water control gates, items such as trash guards, antivortex hoods and baffles, flashboard guides, grating, catwalks, and similar structures and parts are fabricated for hydraulic structures. This subpart identifies metal fabrication and installation inspection items necessary to verify specification compliance.

645.191 Installation

A. Materials

1. Slide Gates

a. Some slide gates are self-contained with the operating device mounted on a yoke attached to the top of the gate frame (see figure 645S-1). These are installed at shallow depths. Where the lift mechanism is at a greater distance from the gate, non-self-contained slide gates, such as the one shown in figure 645S-2, may be installed. Principal spillway inlet towers typically use non-self-contained slide gates. The gate is framed by a metal frame designed so that the sides of the gate slide up and down in slots in the frame. The frame may be mounted directly to the side of a wall, but those installed in NRCS inlet towers are typically mounted to a wall thimble which is embedded in one wall of the tower.

b. Gates are designed for their application, operating conditions including seating and unseating head pressures, and appropriate safety factors. Seating head is the head on the front of the gate; it causes the seating surfaces to be pressed against each other. Unseating head is head on the

back of the gate that tends to push the gate away from the seat; the unseating head force can be resisted by the wedges. The gate class is expressed in feet of head. For example, a class 55-20 gate has a maximum seating head of 55 feet of water and a maximum unseating head of 20 feet of water.

Figure 645S-1: Self-Contained Slide Gate (Courtesy of McWane Plant and Industrial)

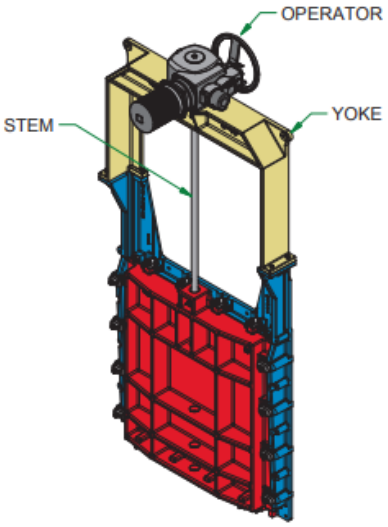
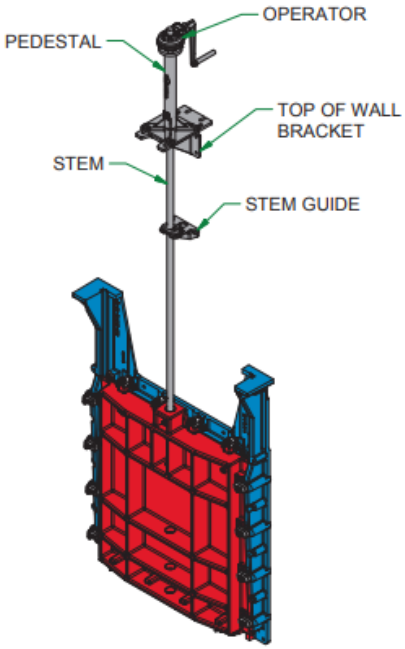


Figure 645S-2: Non-Self-Contained Slide Gate (Courtesy of McWane Plant and Industrial)



2. Flap Gates

    a. Flap gates allow water to flow in one direction only. They are mounted on a concrete wall (see figure 645S-3) or may be mounted directly on the end of a pipe. When mounted on a concrete wall, the gate may be mounted to a thimble embedded in the wall or mounted on bolts embedded in the wall. When mounted to a pipe, the gate frame is attached to a mechanism that is clamped or bolted to the end of the pipe.

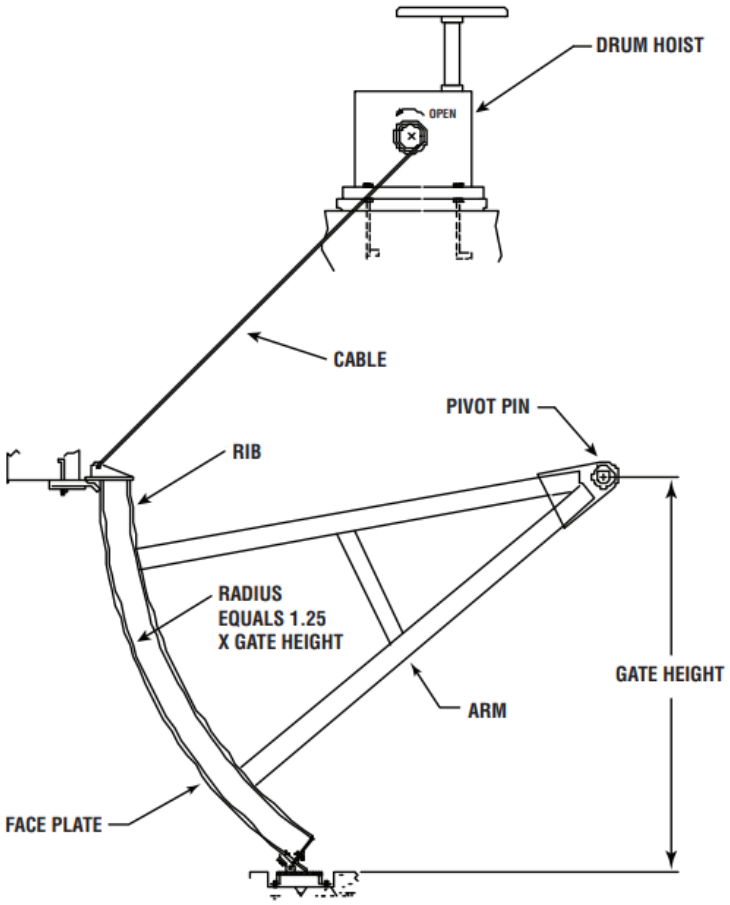
Figure 645S-3: Flap Gate (Courtesy of McWane Plant and Industrial)

3. Radial Gates

    a. Radial gates, or Tainter gates, (see figure 645S-4) have the advantage of passing large flowrates but require a substantial reinforced concrete structure to support the gate, pivot pin, and lift mechanism. They are commonly used for spillways or drainage systems where large flowrates preclude the use of smaller gates. Although radial gates have been used on some NRCS projects, they are not as common in NRCS flood control work as slide gates and flap gates. Figure 645S-5 shows a sectional diagram of a radial gate. Radial gates are different from commercially fabricated gates in standard sizes.

Figure 645S-4: Radial Gates (Courtesy of McWane Plant and Industrial)

Figure 645S-5: Radial Gate (Courtesy of McWane Plant and Industrial)



4. Metal Fabrication

   a. NRCS personnel typically do not inspect manufacturing facilities. Material submittals and certifications are adequate to verify the manufacturer used the specified materials to manufacture the gate, and that all attachment hardware complies with all requirements for the specified type, class, and size of gate. All material mill certificates, weld inspection records, welding procedure records must be submitted. Do not accept material deliveries until the responsible engineer has received and accepted the submittals and certifications. The certification must show that it has been reviewed by the contractor first, to verify that it meets the contract requirements.

   b. The responsible engineer must document in writing to the contractor that the submitted certification is either sufficient or deficient. Once the engineer agrees that the gate and appurtenances comply with specification requirements, the gate and attendant materials can be delivered to the site.

   c. Upon delivery, the contractor's quality control personnel must check to verify that the correct materials have been delivered complete with all

attachment hardware and are represented by the accepted certification. The gate and materials must be inspected for damage with attention paid to seating faces and seals. Any damaged material must be rejected or repaired as applicable. Drawings must indicate which members are considered fracture critical (FCM). Any members designated as FCM will require special certifications for both the metal and weld material.

d. All gate and attendant materials must be stored above ground to remain clean and undamaged.
e. Unless necessary for installation, preassembled materials must not be disassembled. If disassembly is necessary, it must be delayed until immediately prior to installation to limit the potential for lost parts and aid in recalling the order of assembly. All mounting hardware must be inspected to verify specification compliance.
f. All metal members and assemblies must be rejected if they are warped or distorted so much that they cannot be installed or function as intended if installed.
g. The contract drawings and specifications (and shop drawings when required) show the dimensions of the materials and the details necessary for their assembly. If the metal is not fabricated correctly, it must be rejected and replaced. Sharply kinked, warped, or bent metal must be rejected. Only minor straightening is permissible if approved by the engineer or manufacturer.
h. The workmanship and finish must be true and smooth to ensure a correct fit. Bolt holes must be the correct size, in the correct location, normal to the surface, and must not deform the material. Multiple plies must be clamped tightly together so that no cutting or burrs are forced out between the plies. All outside burrs must be removed.
i. Holes must be drilled 1/16 inch larger than the bolt diameter unless otherwise specified. The drilling and reaming of the holes for turned bolts must be truly cylindrical and no larger than the approved tolerances.
j. Shop-installed bolts and nuts must meet the class, finish, form, and size specifications. Temporary bolting used during shipping must be removed and replaced with bolts as specified. The threads must be nicked or upset, if specified, to prevent the nuts from backing off.
k. Gate assemblies and other metal components often require high-strength bolts. If the contract specifications require them, the contractor's quality control personnel must ensure the bolts meet the requirements. See figure 645S-6 for a table of structural bolts, washers, and their acceptable marks. Secure all bolts with a torque wrench to the correct applied tension.
l. Any mismatched holes must be re-reamed, not burned.
m. All surfaces intended for welding must be cleaned of all loose mill scale, slag or flux deposits, rust, spatter, dirt, grease, oil, and other foreign materials. Edges must be gas cut with a mechanically guided torch whenever possible. All welding must be done by qualified welders and only where specified in the drawings.

Figure 645S-6 Typical Marks for Structural Bolts and Nuts (used with permission from American Institute of Steel Construction)

Bolt/Nut/Washer/Matched Bolt Assembly	Type 1	Type 3
ASTM F3125 Grade A325 bolt		
ASTM F3125 Grade F1852 bolt		
ASTM F3125 Grade A490 bolt		
ASTM F3125 Grade F2280 bolt		
ASTM F3148 Grade 144 bolt		
ASTM A563 nut	 Arcs indicate Grade C	 Arcs with "3" indicate Grade C3
ASTM A563 nut	 Grade D	
ASTM A563 nut	 Grade DH	 Grade DH3

n. Fabrication or assembly errors must be corrected before final welding, and preferably before the metal is erected.

o. For painted metal, all foreign material must be thoroughly cleaned from all metal surfaces and joints before a prime coat is applied. The coat must be continuous and uniform on the surfaces and worked into the joints. Metal surfaces or edges to be welded, or those to be embedded in concrete must not be painted. CS 82, Painting Metalwork, is often used to specify painting of metal components and may be a good reference if not included in your contract.

p. When specified, steel metal work is galvanized by the hot-dip process. The required weight in ounces per square foot, if specified in the contract, must be certified by the fabricator or treating plant. The material must be inspected to determine that the zinc coating is continuous, smooth, and uniform. All blisters and other chemical flux or projections must be removed so that the coating bonds to the metal. The bond must be strong enough that, under heavy pressure, paring or whittling with a strong knife will expose only minute areas of the metal base.

q. Galvanized members and assemblies must be transported and handled in a manner that will not cause abrasion or other damage to the zinc coating. The use of hooks, chains, or other metal to hoist assemblies is prohibited. Any damaged surfaces must be thoroughly cleaned, repaired, and coated as specified.

r. The cathodic protection must be checked to ensure that it is correctly attached by bolted connections.

s. The quality assurance (QA) inspector's responsibilities related to metal fabrication materials include verifying:
   (1) Material, certifications, and assembled metal submittals have been accepted by the engineer.
   (2) Preassembled materials are not disassembled unless necessary for installation.
   (3) Templates and installation instructions have been furnished.
   (4) Delivered materials and assemblies are complete with all mounting hardware.
   (5) Delivered materials and assemblies comply with specifications and accepted submittals.
   (6) Workmanship and finish are smooth and true.
   (7) All shop-installed fasteners meet the class, finish, form, and size specifications.
   (8) Coatings are as specified and undamaged.
   (9) Materials are undamaged and correctly stored above ground.

B. Installation

1. Slide Gates

a. Where a wall thimble is used, it must be clean so that it bonds to the concrete. The thimble must be oriented so that the front flange (the flange to which the gate frame will be attached) is oriented to the correct side of the wall. The thimble must be firmly held in place in a true vertical plane, square and plumb, with no twist. Grout holes are sometimes provided in

the invert of the thimble on both sides of the water stop to allow air to escape as the concrete flows and consolidates around the thimble. If, like the thimble shown in figure 645S-7, there are no grout holes in the thimble invert, holes must be drilled into the form sheathing to allow air to escape. The drilled and tapped holes in the front flange must be covered or otherwise protected so that they are kept clean and free of mortar during concrete placement.

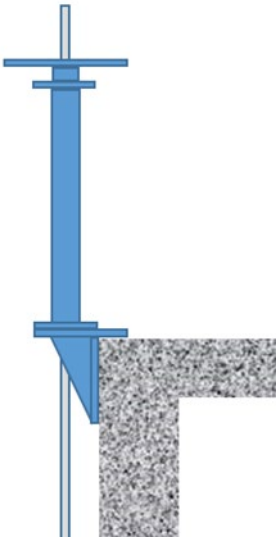
Figure 645S-7: Wall Thimble (NRCS TX)

b. Where gates are mounted on the inside of a wall or in otherwise confined spaces, there must be a minimum clearance between the wall thimble and the walls to either side of the thimble. Concrete on each side and above and below the thimble must be flush with the face of the thimble so that when the gate frame is attached, it fits flush against the thimble with no interference from the concrete. The front flange must be free of mortar and other contaminants at the time the gate frame is attached.
c. Where no thimble is installed and the gate frame is attached directly to the concrete, the concrete must be smooth with a true vertical plane so that the gate frame fits flush against the concrete surface and can be attached without warping the frame. Specifications may require a mortar to be placed between the concrete wall and the gate frame to provide a true planner surface and to avoid warping of the frame. The concrete and mating surface of the gate frame must be clean so that the mortar bonds well to each surface.
d. Stem guides are to be installed as shown on the drawings, or at manufacturer recommended intervals. Stem guide spacing is based on the stem diameter and the amount of thrust anticipated to close the gate. Stem guides must never be spaced farther apart than recommended by the gate manufacturer. J-bolts are usually specified for attaching stem guides and the lift mechanism to the concrete structure. These are set and embedded in the concrete at the time the concrete is placed. Mechanical anchors that

are installed in drilled holes are not allowed as they tend to loosen over time. Epoxy bonded bolts may be allowed, but the engineer must give approval to use any bolts or anchors that differ from those specified. Stem guides, such as that shown in figure 645S-8 must be installed in as close to vertical alignment as possible above the center of the gate. Since stem guides are adjustable, minor misalignment can be tolerated. The operator or lift mechanism (figure 645S-9) must also be installed vertically above the center of the gate and stem guides so that the gate can be opened and closed freely without binding in the gate frame.

Figure 645S-8: Adjustable Stem Guide (Courtesy of McWane Plant and Industrial)

Figure 645S-9: Slide Gate Lift Mechanism



e. When the gate frame is attached to a thimble, a mastic material will be installed between the gate frame and the thimble. The mastic must be evenly distributed around the bonding surface and the bolts securing the gate frame tightened in a sequence that will uniformly draw the frame to the mating surface without warping the frame. After the bolts and nuts are

tightened to the specified torque, any extruded mastic around the inside and outside of the frame must be removed.

f. After the gate is set in the frame, wedges are installed at specific points around the frame. The wedges force the gate up against the seating surface as it closes. These wedges must be adjusted in accordance with manufacturer recommendations to provide the specified amount of thrust against the gate at full gate closure.

g. The stem is inserted in the stem guide and secures to the gate with a thrust nut. The lift mechanism can then be installed. After the lift mechanism is installed, the guides and lift mechanism can be finely adjusted so that the stem is in vertical alignment from side to side and front to back. The gate is then opened and closed, and any adjustments made to ensure its correct function. All bolts and nuts must be tightened to the specified torque. The lift mechanism, stem guide bushings, and wedges must be lubricated as specified by the manufacturer.

h. The QA inspector's responsibilities related to slide gate installation include verifying:
   (1) The wall thimble is clean, secured in place in a true vertical plane, square and plumb, with no twist and with front face correctly oriented.
   (2) Grout holes are on the bottom of the thimble or otherwise drilled into both sides of the form sheathing.
   (3) Drilled and tapped holes in the front flange are covered and kept clean.
   (4) The specified minimum clearance is provided between the thimble and frame and the concrete wall to either side of the thimble and frame.
   (5) Concrete around the thimble is flush with the front face to allow the frame to be installed flush with the thimble without interference from the concrete.
   (6) The specified mastic is applied between the gate frame and thimble, the bolts and nuts are tightened in a sequence that avoids warping the frame, and extruded mastic is removed.
   (7) Where the frame is attached to a concrete wall:
      (a) The concrete is smooth with a true vertical plane.
      (b) The concrete and frame are clean and free of contaminants at the time the frame is attached.
      (c) The frame is secured in a true plane utilizing the double-nut system without being warped so that the gate can be seated as specified by the manufacturer.
      (d) The specified grout is installed between the gate frame and wall.
      (e) All bolts and nuts are tightened to the specified torque.
      (f) Stem guides and lift mechanism are installed vertically above the center of the gate at the manufacturer's recommended spacing.
      (g) Lift mechanism, stem guide bushings, and wedges are adjusted and lubricated as recommended by the manufacturer.

(h) The gate is opened and closed, and adjustments made to wedges, stem guides, and lift mechanism to ensure that it operates correctly with the right amount of thrust needed to fully close.

2. Flap Gates

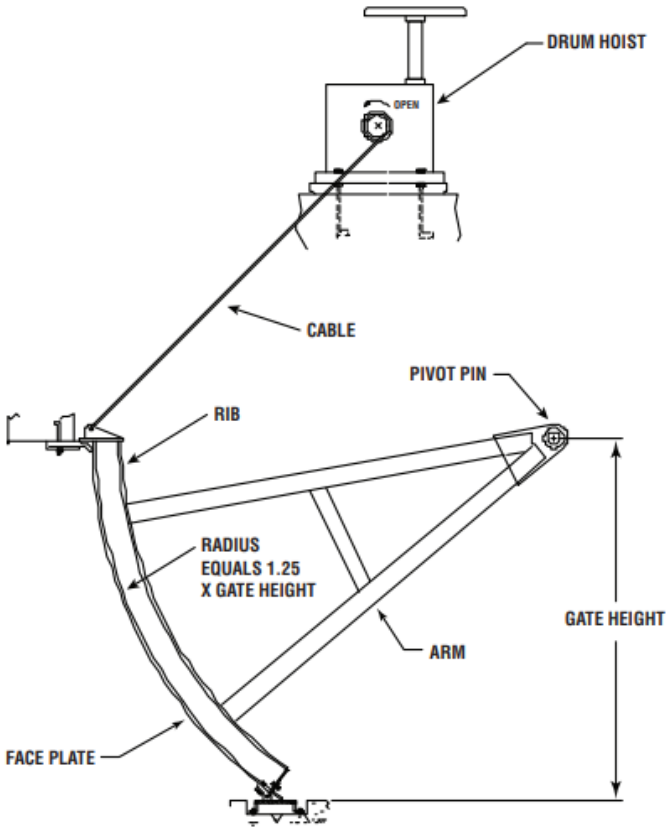
   a. When a wall thimble is installed, it must be clean so that it bonds to the concrete. It must be held firmly in place so that it is in a true vertical plane, square and plumb, with no twist. If there are no grout holes in the thimble invert, holes must be drilled into the concrete form sheathing to allow the air to escape. The drilled and tapped holes in the face of the thimble must be oriented so that when the gate is attached it hangs vertically. For square thimbles, the holes will be oriented correctly if the thimble is plumb, but round thimbles could inadvertently be rotated so that when the gate is attached it does not hang vertically. The drilled and tapped holes in the front face of the thimble must be covered or a bolt inserted in them to avoid getting mortar in them during concrete placement.
   b. When the gate is installed directly onto a concrete wall without a wall thimble, bolts and studs will be embedded in the concrete. The use of a template is recommended when installing these bolts to ensure they are correctly located. The bolts are inserted through the forms with a nut and washer on each side of the forms to secure the bolt at the desired depth of embedment.
   c. After the forms are removed and the concrete gains sufficient strength, a nut is placed on each bolt and positioned within a short distance from the face of the concrete wall. The gate and frame assembly are then carefully slid onto the bolts until it touches the nuts. A second nut is installed against the gate frame. The front and back nuts are adjusted in and out until the frame is plumb and the gate seats correctly. The front bolts are then tightened.
   d. The space between the gate frame and the concrete wall is filled with a non-shrink grout.
   e. Some gates are designed so that they can be adjusted for sensitivity (the ease with which they open and close). For these gates, adjustments are made as necessary to the mechanism that attaches the gate to the gate frame so that the gate will function as intended.
   f. The QA inspector's responsibilities related to flap gate installation include verifying:
      (1) Wall thimble is clean, secured in place in a true vertical plane, square and plumb, with no twist and with front face correctly oriented.
      (2) The drilled and tapped holes in the face of the thimble are oriented correctly.
      (3) The drilled and tapped holes are protected from contamination during concrete placement.
      (4) Where no thimble is installed, and the gate is affixed to a wall:

(a) Embedded bolts are correctly located and secured at the desired depth.
(b) The gate is plumb and seats correctly.
(c) Space between the gate frame and the concrete wall is filled with the specified non-shrink grout.
(d) Adjustable gates are adjusted for sensitivity.

3. Radial Gates

a. There are two types of radial gates: the overflow-type and the breast wall-type (figure 645S-10). The overflow-type is designed for a limited depth of water to flow over the top of the gate when it is closed. The breast wall-type is designed to retain a certain depth of water above the gate; it has a vertical wall (breast wall) above the top of the gate with a seal between the top of the gate and the bottom of the breast wall.

Figure 645S-10: Breastwall-Type Radial Gate (Courtesy of McWane Plant and Industrial)



b. Radial gate installation requires construction of a concrete structure to support and frame the gate. The concrete line and grade must be very

precise with walls that are parallel, plumb, flat, and perpendicular to the invert.

c. The radial arms attach to a pin plate. A pivot pin is inserted through the pin plate into a cast iron pin bearing which is embedded into the concrete. The location of the pin bearing is crucial to the correct function of the gate.

d. Radial gates have side seals and bottom seals. These seals can be flat seals or J-seals. J-seals are generally made of neoprene and held in place by a metal retainer bar. The J-seal rests against an adjustable rubbing plate that is installed in the concrete. A rubbing plate is not required for flat seals, but the wall surface finish against which the seal rests must be more precise if a rubbing plate is not installed.

e. For adjustable side and bottom rubbing plates, a recess is formed into the walls and invert floor with anchor bolts set in the forms to extend into the recess. The plates are attached to the anchor bolts and adjusted so that the gate will seal, open, and close without binding or damaging the J-seal. Once correctly adjusted they are grouted in place.

f. The gate must be opened and closed through its full range of movement to ensure correct plate adjustment before the plates are grouted in place.

g. Hoists are either manual, motorized, or hydraulic. After installation, the gate must be operated by the hoist to ensure correct operation. The hoist mechanism and pin bearings require lubrication for smooth operation.

h. The QA inspector's responsibilities related to radial gate installation includes verifying:
   (1) Concrete walls are parallel, plumb, flat, and perpendicular to the invert.
   (2) The invert is level from side to side.
   (3) The pin bearing is correctly located.
   (4) Where required, rubbing plates are correctly adjusted and grouted in place only after the gate is fully opened and closed to ensure correct adjustment.
   (5) After full assembly, the gate is fully opened and closed by hoist to ensure correct operation.
   (6) The hoist mechanism and pin bearings are lubricated as specified.

4. Metal Works

   a. Metal works on many NRCS projects entail installing premanufactured assemblies such as that shown in figure 645S-11. Metal works could also include building frames or other structures which are erected on site.

   b. Installation of metal assemblies, such as the trash rack or baffle plates shown in figure 645S-11, require bolts and block-outs to be installed as the concrete forms are being assembled. The location and alignment of bolts and block-outs must be inspected to verify that the metal assemblies will be installed at the specified locations.

Figure 645S-11: Metal Baffles and Trash Rack Assembly (source: NRCS OK)

c. Metal fabrications must be anchored during erection to keep them stable. Where anchors are not shown on the drawings, the Contractor must coordinate with the Engineer the design of the type, size, location and spacing to resist the loads and hold the structure firmly in place during erection. There must be no deformation of the metal fabrication or assembly, and all anchors must be located to suit the sequence of installation.
d. As the metal components are erected, it must be adequately held and supported to guard against movement or collapse resulting from any abnormal wind or erection loads. Sufficient bracing and secondary components must be erected and bolted to maintain the stability of the work. Enough bracing must be erected before the final alignment is started so that aligned parts will not be displaced when adjacent parts are added. The final alignment must be started as early as possible during erection so that errors do not accumulate and magnify.
e. Rough handling of the material during erection is avoided if the fabrication is correct. Hard pounding with sledgehammers and excessive drifting must not be allowed. Holes must not be recut with a torch.
f. If welding is required, contractor quality control personnel must ensure that qualified individuals only do welding.
g. To avoid distortion of the members, welds must be performed in a predetermined pattern for the best heat distribution.
h. All dimensions and locations of welds must be checked. Over-welding in length or size must not be permitted. The placing of welds in the wrong location may be as detrimental as omitting them.

i. Before welding, the joints must be inspected to see that they are clean and correctly aligned. Welding rods or other miscellaneous metal must not be used to fill large voids and spaces. Electrodes with damaged or wet coatings must not be used.
j. Welds must be inspected for throat dimension, uniformity, absence of cracking, and specified penetration. This can be done by checking the weld as it is being done and checking the completed weld for surface appearance and for surface defects, craters, undercutting, cracks, and other defects. When specified, welds must be inspected by X-ray, magnetic flux, or ultrasonic testing. The minimum percentage of welds judged acceptable with such testing must meet the specifications.
k. If welding is required or metal assemblies are damaged during handling or installation, the galvanized coating or painted surface must be repaired. Specification requirements for repairing protective coatings include requirements for preparing the surface as well as the application of the coating. Coating means and methods must strictly adhere to the coating manufacturer's directions for surface preparation, surface and ambient temperature, drying time between coats, etc.
l. All bolts, nuts, and washers called for on the drawings, shop drawings, and in the specifications must be installed and tightened as shown and specified.
m. The QA inspector's responsibilities related to metal installation includes verifying:
    (1) Anchor bolts and block-outs are correctly located and secured as concrete forms are being constructed.
    (2) Metal fabrications are adequately anchored.
    (3) Metal is adequately held, braced, and supported.
    (4) Final alignment is started as early as possible.
    (5) Rough handling, pounding with sledgehammers, and excessive drifting is avoided.
    (6) Welding is only done by qualified welders.
    (7) All dimensions and locations of welds comply with specifications and drawings.
    (8) Welding rods and other miscellaneous metal is not used to fill voids.
    (9) Electrodes that are damaged or have wet coatings are not used.
    (10) Welds are inspected for throat dimension, uniformity, absence of cracking, and specified penetration.
    (11) When specified, welds are inspected by X-ray, magnetic flux, or ultrasonic testing.
    (12) The minimum percentage of welds tested and judged acceptable meets job specifications.
    (13) All damaged coatings and surface protection is repaired as specified.
    (14) All bolts, nuts, and washers called for on the drawings, shop drawings, and in the specifications are installed and tightened as specified.

645.192 Sampling and Testing

A. Water control gates are tested by the manufacturer to verify compliance with industry standard specifications, so onsite sampling and testing are not generally required. The designer may specify that a representative from the manufacturer must inspect, adjust, and operate the installed gate to verify functionality.

B. Samples of welded joints are sometimes tested to document weld quality, but NRCS does not sample welded joints or perform these tests. If the project requires x-ray, magnetic flux, or ultrasonic testing, the contractor or owner must retain the services of a qualified individual to assess weld quality.

645.193 Records and Reports

A. Job Diary Entries

1. Record when the gates and materials were delivered. Obtain all shipping tickets and take photos (if applicable) as documentation for payments. Note any omitted items. Document all items delivered in accordance with the contractor's certifications and accepted by the engineer. Document all items the engineer rejected and the reasons for rejection.
2. Record when the contractor installed the items. List any installation problems and their resolution. Where applicable, document that the contractor correctly adjusted and lubricated the gates.

645.194 References

U.S. Department of Agriculture, Natural Resources Conservation Service. 2024. Specifications for Construction Contracts. National Engineering Handbook, Part 642. Washington, DC.

McWane Plant and Industrial. www.mcwanepi.com Birmingham, AL

Henry Pratt Company, LLC. Form 13764 – Hydro Gate Radial Gates (2017). Denver, CO