Appendix C
Example Performance Specification for FRP Components

(The following example of a performance specification is loosely based on an actual specification used for procurement of a composite wicket gate for a prototype test for Olmsted Dam. This example is provided to illustrate the types of information which should be included in the specification.)

COMPOSITE WICKET GATE

PART 1 GENERAL

1.1 REFERENCES

MILITARY HANDBOOK

MIL-HDBK-17-1D Polymer Matrix Composites; Volume 1. Guidelines.

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM) PUBLICATION

D 2344-84	Apparent Interlaminar Shear Strength of Parallel Fiber Composites by Short-Beam Method
D 3039-76	Test Method for Tensile Properties of Fiber-Resin Composites
D 3410-75	Standard Test Method for Compressive Properties of Unidirectional Crossply Fiber Resin Composites
D 3518-76	Inplane Shear Stress-Strain Response of Unidirectional Reinforced Plastics

SUPPLIERS OF ADVANCED COMPOSITE MATERIALS ASSOCIATION (SACMA) PUBLICATION

SRM 3	Open Hole Compression

1.2 SYSTEM DESCRIPTION

1.2.1 General Requirements

The wicket gate shall be constructed primarily from fiber reinforced polymeric (FRP) materials. Gate components which may be constructed using steel materials are defined in paragraph 1.2.2. The wicket gate serves as a movable water control device. The main system requirements are to provide long-term performance in the river environment, with minimum maintenance. Strength and stiffness requirements for the gate are defined paragraph 1.2.4. Metal components of the gate should be limited to minimize potential corrosion. Resin and fiber materials should be selected to provide necessary properties after exposure to fresh water, temperature changes, and sunlight over a period of 20 years. Limited gate weight is not a requirement.

1.2.2 Materials

Main gate components shall be constructed using FRP materials except as follows. The following items

shall not be fabricated from FRP materials: hinges; prop; attachment devices for hinges, prop, and actuator; fasteners. Fasteners may be of other materials such as metal. Metal materials shall conform to the requirements of SECTION_____.

1.2.3 Geometry

The exterior dimensions of the wicket shall conform to the dimensions shown on the drawings. This includes all locations and dimensions of attachment devices for gate operating equipment and for gate mounting to the dam sill.

1.2.4 Design

The design calculations, as required in paragraph 1.3.2, must demonstrate the ability of the gate to withstand design loads and provide required stiffness during a service life of 20 years, including up to 10,000 load cycles, and exposure to fresh water, sunlight, and site temperature variations. Strength and stiffness calculations shall be based on appropriate test data from the selected gate material, or from similar materials, as specified in paragraph 1.3.3. Test results shall be adjusted to account for changes in properties due to environmental exposure and load cycles. When used to determine gate strength and stiffness, nominal material properties shall be taken as a value which is exceeded by 95 percent of all test results.

1.2.4.1 Strength

The nominal strengths shall be reduced by a factor of 2.0 to provide an adequate factor of safety to resist the following applied loads.

1.2.4.1.1 Normal Hydrostatic Loading

Pressure applied normal to the gate surface, varying linearly from ____ at the hinge line to ____ at the top of the gate, and uniform across the width of the gate. For this loading the gate is supported at the hinges and by the prop in the raised position.

1.2.4.1.2 Maximum Equipment Loading

Pressure applied normal to the gate surface, varying linearly from ____ at the hinge line to ____ at the top of the gate, and uniform across the width of the gate. For this loading the gate is supported at the hinges and by the actuator cylinder, with the gate raised 23 degrees from horizontal.

1.2.4.1.3 Emergency Lifting

Pressure applied normal to the gate surface, varying linearly from ____ at the hinge line to ____ at the top of the gate, and uniform across the width of the gate. For this loading the gate is supported at the hinges and by a lifting hook at the top of the gate. The gate is raised 23 degrees from horizontal, and the angle of the lifting force acts upstream, 50 degrees up from horizontal.

1.2.4.1.4 Torsional Loading

Pressure applied normal to the gate surface, varying linearly on one edge of the gate from ____ at the hinge line to ____ at the top of the gate, and along the other edge from ____ hinge line to ____ at the top. The pressure varies linearly across the width of the gate. For this loading the gate is supported at the hinges and by the prop in the raised position.

1.2.4.2 Stiffness

1.2.4.2.1 Bending

When subjected to the loading defined in paragraph 1.2.4.1.1, the gate shall have adequate bending stiffness to limit deflection of the gate to _____ as measured at the center of the top edge, when supported rigidly at the hinge and prop locations.

1.2.4.2.2 Torsion

When subjected to the loading defined in paragraph 1.2.4.1.4, the gate shall have adequate bending stiffness to limit twist of the gate to _____ as measured between the hinge line and a line through the outer corners of the top of the gate.

1.3 SUBMITTALS

1.3.1 Fabrication Drawings

The contractor shall submit shop drawings which fully detail fabrication, assembly, and installation of the gate. Shop drawings shall indicate material thicknesses, dimensions, interface surfaces, connection details, and fit up criteria. The fabrication drawings must show the fiber orientation used in the FRP materials from which the gate is fabricated. Drawings shall include erection details and installation instructions. Shop drawings shall be dimensioned in accordance with SPECIAL CONTRACT REQUIREMENTS.

1.3.2 Design Calculations

The contractor shall submit design calculations which document the capability of the gate to provide the required strength and stiffness during the required 20-year service life of the gate. Calculations shall demonstrate the adequacy of all structural components of the wicket, all joints within the wicket, and all attachments between the wicket and appurtenances. Prior to performing design calculations the contractor shall submit a preliminary design concept, including a list of design calculations to be performed for approval by the Contracting Officer.

1.3.3 Test Results

The contractor shall submit test results to document the FRP basic strength and stiffness values used in the design calculations. As a minimum, results of the following tests shall be provided for each type of laminate or pultruded shape used in gate fabrication. These tests shall be performed on batches of material used for actual gate fabrication. Each test shall be repeated ____ times on different samples of the material.

Tension test, 0 degree, ASTM D 3039

Tension test, 90 degree, ASTM D 3039

Compression test, 0 degree, ASTM D 3410

Compression test, 90 degree, ASTM D 3410

In-plane shear test, ASTM D 3518

Short beam shear test, 0 degree, ASTM D 2344

Open hole compression test, SACMA SRM 3

Test results shall also be submitted to document the variation in material properties expected over the 20-year service life due to environmental exposure and loading cycles, and to document the structural

capacity of all connection types used in fabrication and installation of the gate. These results may be based on tests of similar materials, rather than actual materials used for gate fabrication.

1.3.4 Certificates

1.3.4.1 Manufacturer's experience

The contractor shall certify that the gate manufacturer has been engaged in fabrication of fiber-reinforced polymeric composite structures for a minimum of five years, and has performed work of a size and load resistance of a magnitude comparable to that of the wicket gate.

1.3.4.2 Materials

The contractor shall certify the chemical composition of all fiber, resin, and other material used in fabrication of the completed gate. Where onsite repairs are made to a delivered gate, the contractor shall supply Material Safety Data Sheets (MSDS), toxicity reports, manufacturing lot numbers, and the shelf-life history of the material used in repair of the gate.

1.3.5 Fabrication Records.

The contractor shall submit a preliminary process specification describing how the components will be fabricated, machined, assembled, and inspected for approval by the Contracting Officer prior to beginning the fabrication. Nondestructive evaluation methods such as ultrasonic and/or x-ray shall be used to inspect the integrity of the gate to ensure that delaminations, severe porosity, voids, resin depletions, and foreign objects are minimal in the FRP material. Identification of porosity above ____ percent, a void larger than ____, or a delamination longer than ____ shall be cause for rejection of the gate. Upon delivery of the gate, the contractor shall submit complete fabrication records, including: fiber architecture; matrix placement and curing; component joining operations; storage; and test handling.

PART 2 PRODUCTS

2.1 MATERIALS

2.1.1 FRP Composites

The gate shall be fabricated using a fiber-reinforced polymeric composite material. The fibers shall be glass and/or carbon. The matrix shall be polymeric resins commonly used in the fabrication of composite structural elements. The chemistry, configuration, and coatings for the composite material shall be capable of ensuring the composite maintains its required strength and stiffness during 20 years of environmental exposure to loading cycles, sunlight, seasonal temperatures, and immersion in fresh water. Any joining systems, such as adhesives, used for gate assembly must also be capable of maintaining required strengths under the same exposure conditions.

2.1.2 Metals

Metals used for appurtenances and fasteners shall conform to (reference the Miscellaneous Metals specification). Painting of metal components shall conform to (reference the Painting specification).

PART 3 EXECUTION

3.1 FABRICATION

Fabrication of the gate shall conform to common practice for structural applications of FRP materials. This shall include the following quality control items:

- Ply orientation tolerance of _____
- Clean fabrication environment
- Material control system and traceability of the material lot
- Curing cycle
- Process control procedures
- Nondestructive inspection techniques, such as ultrasonic and x-ray
- Quality control inspections of fiber volume, void content, glass transition temperature, percent cure, and hardness

3.2 REPAIRS

Minor damage to any FRP component of the gate shall be repaired, subject to approval of the Contracting Officer, by addition of resin and reinforcing fibers sufficient to restore the component to its undamaged strength. Damage to any FRP material which is greater than 10 percent of the cross section of any component will be cause for rejection of the wicket.

3.3 INSTALLATION

The FRP gates shall be installed on the dam by attaching the hinges and prop. Each gate shall then be operated through one full cycle of raising and lowering. This operation shall be performed in the dry.

3.4 PAYMENT

Payment for the FRP gates will be made per gate, and shall include the gate and connections, delivery, installation, and required technical assistance during installation.