Chapter 610 Vehicle Transfer Span

610.01 General

This chapter provides guidance on the design of new and retrofitted vehicle transfer spans (VTS), aprons and drilled shaft foundations for bridge lift hydraulic cylinders. The vehicle transfer span and apron provide a means for vehicles and pedestrians to load and unload from the fixed trestle to the vehicle deck of the ferry vessel.

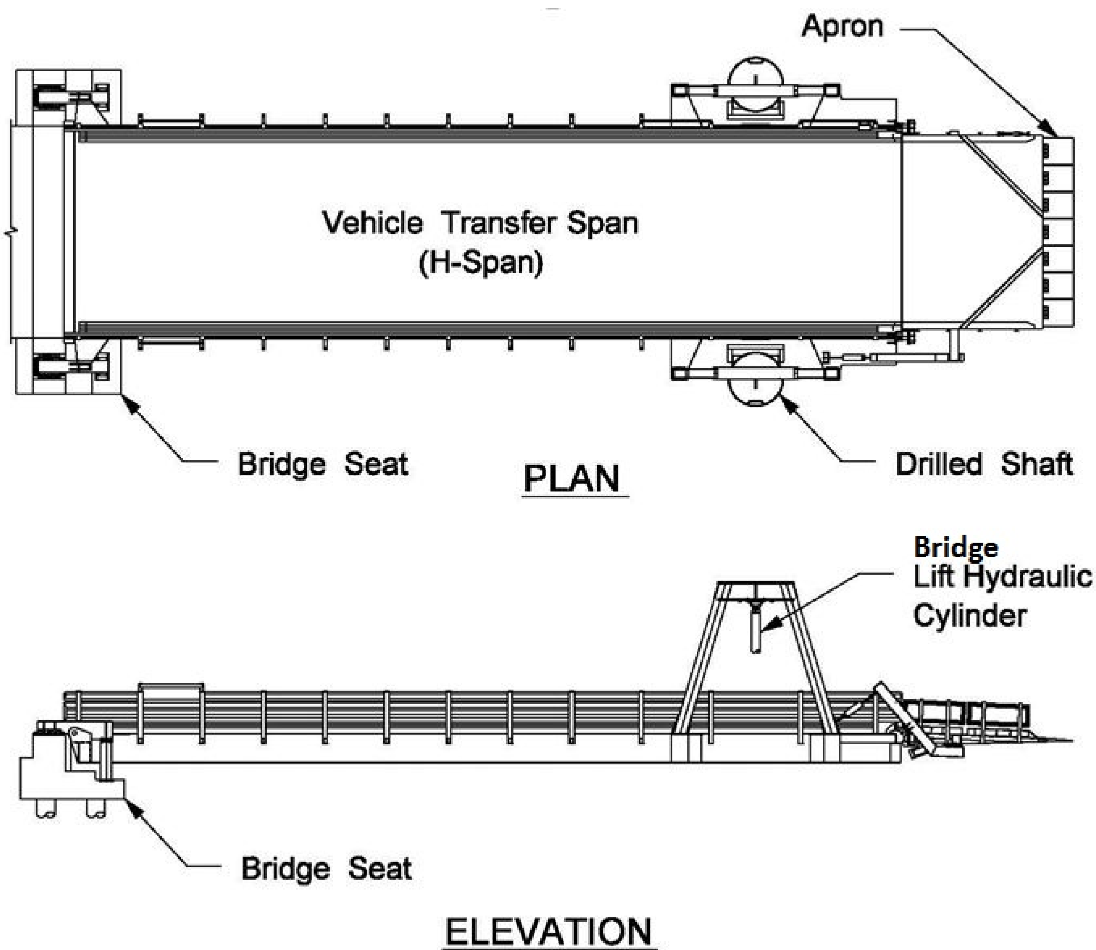
Design the transfer span and apron for the operational and extreme range of motion based on the design tidal range and design vessels identified for a given location. See Chapter 330 for tidal range, design vessels, freeboards, and other related information.

Bainbridge Island Hydraulic Transfer Span (H-Span)
Exhibit 610-1

WSF currently utilizes three distinct VTS system designs − the hydraulically actuated transfer span (H-Span), double cable-operated transfer span (M-Span), and single cable-operated transfer span. Exhibits 610-1 and 610-2 illustrate the H-Span, WSF's preferred design concept for the vehicle transfer span. This concept is discussed in more detail in Section 610.04. The double cable-operated transfer span is no longer being built by WSF due to the high cost of construction and maintenance. The single cable-operated transfer spans are retrofitted when steel structures have projected extended life, but the electrical and mechanical systems are at the end of their life based on the *Life Cycle Cost Model* (LCCM).

For additional information, see the following chapters:

Chapter	Subject
300	Accessibility
310	Security
320	Environmental Considerations
330	Marine
340	Civil
570	Signage and Wayfinding
600	Trestle
620	Passenger Overhead Loading



Hydraulic Transfer Span (H-Span)
Exhibit 610-2

610.02 References

Unless otherwise noted, any code, standard, or other publication referenced herein refers to the latest edition of said document.

(1) Federal/State Laws and Codes

WAC 296-24 *General Safety and Health Standards*

WAC 296-56 *Safety Standards – Longshore, Stevedore and Waterfront Related Operations*

WAC 296-876 *Ladders, Portable and Fixed*

(2) Design Codes and Specifications

AASHTO *LRFD Bridge Design Specifications* (AASHTO LRFD *Specifications*), American Association of State Highway and Transportation Officials, Washington, DC

AASHTO Guide *Specifications for LRFD Seismic Bridge Design* (AASHTO LRFD *Guide Specifications*), American Association of State Highway and Transportation Officials, Washington, DC

AASHTO LRFD *Movable Highway Bridge Design Specifications* (AASHTO LRFD *Movable Specifications*), American Association of State Highway and Transportation Officials, Washington, DC

Bridge Design Manual LRFD M 23-50, WSDOT

Proposed Passenger Vessels Accessibility Guidelines. United States Access Board. Published in the Federal Register on June 25, 2013. This document contains scoping and technical requirements for accessibility to passenger vessels by individuals with disabilities. The requirements are to be applied during the design, construction, additions to, and alteration of facilities and elements on passenger vessels to the extent required by Federal agencies under the Americans with Disabilities Act of 1990 (ADA).

International Building Code (IBC), International Code Council, Inc.

Uniform Plumbing Code (UPC), International Association of Plumbing and Mechanical Officials

Unified Facilities Criteria, "Design: Piers and Wharves", (UFC 4-152-01), Department of Defense, Washington, DC

Specification for Structural Steel Buildings, ANSI/AISC 360 (ANSI/AISC 360), American Institute of Steel Construction, Chicago, IL

General Special Provisions, WSDOT

Reference Drawings, WSF

Regional General Special Provisions, WSF

Standard Specifications for Road, Bridge, and Municipal Construction (*Standard Specifications*) M 41-10, WSDOT

(3) Supporting Information

2010 Port Townsend Ferry Dock Spot Speed Study, WSF

Life Cycle Cost Model (LCCM), WSF

610.03 Design Considerations

(1) Accessibility

Per Section V410 of the *Proposed Passenger Vessels Accessibility Guidelines*, the VTS shall meet all passenger accessibility requirements with the exception of Section V410.2 Slope which states that “Gangway runs shall have a running slope not steeper than 1:12”. Because the VTS may serve both vehicles and pedestrians its slope may exceed 1:12. See Chapter 300 for general accessibility information and Section 300.09 for specific information related to passenger loading.

(2) Security

Chapter 310 includes a general discussion of the United States Coast Guard (USCG) three-tiered system of Maritime Security (MARSEC) levels, vessel security requirements, and additional information pertaining to terminal design. Below are links to relevant sections by topic. Coordinate with the WSF Company Security Officer (CSO) regarding design issues pertaining to security. In addition, coordinate with the USCG and Maritime Security for all terminals, the United States Customs and Border Protection (USCBP) for international terminals, and the Transportation Security Administration (TSA) for Transportation Worker Identification Certification (TWIC) and Sensitive Security Information (SSI).

- MARSEC Levels: 310.04
- Vessel Security: 310.05
- Waterside Structures: 310.09
- Access Control/Restricted Areas/TWIC: 310.10

(3) Environmental Considerations

Refer to Chapter 320 for general environmental requirements and design guidance. Refer to the project NEPA/SEPA documentation for project-specific environmental impacts and mitigation. The design should minimize the risk of hydraulic fluid spills and leaks.

(4) Civil

Refer to Chapter 340 for general civil design criteria pertaining to the VTS. Below are links to relevant sections by topic.

- Design Vehicles: Section 340.07(6)
- Vehicle Turning Analyses: Section 340.07(7)

(5) Marine

Refer to Chapter 330 for marine criteria pertaining to the VTS. Below are links to relevant sections by topic.

- Operations and Maintenance: Section 330.04(4)
- Proprietary Items: Section 330.04(6)
- Long Lead Time Items: Section 330.04(7)
- Corrosion Mitigation: Section 330.04(9)
- Scour and Mudline Elevations: Section 330.04(10)
- Geotechnical Requirements: Section 330.04(11)
- Materials Specification: Section 330.04(12)
- Miscellaneous Considerations: Section 330.04(13)
- Tidal Information: Section 330.06
- Wave, Flood, and Coastal Storm Loading: Section 330.09(1)

(6) Electrical

Refer to Chapter 360 for general electrical design criteria pertaining to vehicle transfer spans. Below are links to relevant sections by topic.

- Wiring and Protection: 360.04
- Wiring Methods and Materials: 360.05
- Equipment: 360.06

(7) Design Life

Design life is based on the current *Life Cycle Cost Model* (LCCM) as required by the Washington State Office of Financial Management (OFM). Refer to Table 1 for the design life of new structures (as of 2007) and Table 2 for design life of structures prior to 2007, in the 2010 *Life Cycle Cost Model* Update (2010 LCCM) for information on when existing marine structures and their systems are due for replacement. Confirm design lives given below are consistent with the current LCCM. Replacement life may be reduced due to functional obsolescence.

- VTS and Apron: 75 years
- VTS Substructure: 75 years

(8) Operational Classification

WSF vehicle transfer spans are operationally classified per AASHTO LRFD *Specifications* Section 1.3.5 as typical, not critical or essential, unless noted otherwise. The performance objective for "typical" bridges is life safety. See Section 610.06(1)(c) Limit States for use of this classification.

(9) Design Drawing Information

Drawing format and software used shall follow the WSF Terminal Engineering (TE) CADD Standards. See Division 8 – CADD Standards and Procedures

Include or reference the following information on design drawings:

- Principal loads used in design and number of load cycles anticipated over the life of the structure
- Statement of conformity to *Terminal Design Manual* and any other applicable guidelines
- Provide the operational and extreme range of motion (highest and lowest elevations); maximum and minimum slopes of the transfer span and any other specific operating limitations
- Tide or sea level variation considered for design
- Materials specified for structure elements and load-bearing components
- Features of vessels used in design (displacement, freeboard, geometry of gate openings, etc.)
- Design life expectancy
- Description of the sequence of operations as well as any operating limitations
- Weight of major components and structural sections

(10) Proprietary Items

WSF uses competitively acquired products to fulfill the requirements of a contract wherever feasible to help achieve the lowest price, the best quality, and the most efficient use of resources. There are instances in which competitive bidding may not or cannot be provided and a specific proprietary product is allowed. Refer to Section 220.07(2) for limitations on the use of proprietary items.

(11) Signage and Wayfinding

Refer to Chapter 570 for information regarding signage requirements on the vehicle transfer span.

(12) Seismic Design

Perform seismic design of VTS structures in accordance with the AASHTO LRFD *Specifications* and supplemented by the AASHTO LRFD *Guide Specifications* where appropriate. Design VTS structures for a design level earthquake (DLE) corresponding to a 7 percent probability of exceedance in 75 years (~1000 year return period) with a life safety protection/collapse prevention performance objective. VTS structures are expected to support gravity loads after the DLE but may suffer significant damage that may disrupt service.

VTS Structures shall also be checked for an operational level earthquake event (OLE). This is an event in which no damage or only minor structural damage will occur, but a temporary interruption in service may occur.

For the fixed portions of the VTS system, e.g., the bridge seat, the OLE is similar to a 50 percent exceedance in 75 years (~100 year return event). Expansion joint design and locations where the relative displacement of different structures could cause damage shall be checked for this level earthquake event.

For the movable portions of the VTS system, the OLE is based on the AASHTO LRFD *Movable Specifications*. The OLE for movable bridges is defined as half of the demand values associated with the DLE. For the OLE, design and detailing are intended to allow the transfer span and apron to remain operational, i.e., movable.

Minor damage to the movable span is acceptable during the OLE event provided that it is designed to occur at a predetermined location and can be easily identified and quickly repaired.

The designer shall identify in the general structural notes of the contract drawings the anticipated structural failure locations for both the OLE and the DLE.

For seismic design of drilled shaft foundations, plastic hinging is limited to aboveground and near-ground locations. In-ground plastic hinging is not permitted.

For geotechnical requirements, refer to Chapter 330.

(13) Accelerated Bridge Construction

Accelerated bridge construction methods such as precast concrete bridge seat caps in the design are options where the duration of slip closures must be kept to a minimum. Use of these methods minimizes interruptions during construction and can be cost effective at busy terminals.

610.04 VTS Components (H-Span)

Design new VTS systems using an H-Span concept similar to the existing hydraulic vehicle transfer spans installed at Bainbridge Island Ferry Terminal, Eagle Harbor Maintenance Facility, and most recently Port Townsend Ferry Terminal. The H-Span system consists of a vehicle transfer span, bridge seat, apron, and two bridge lift hydraulic cylinders and foundations. WSF uses the most recent project drawings as the basis for design of new H-Spans. Review and incorporate into the design all issues and lessons learned from past projects. In particular, fabrication issues from past projects have included welds and bolted connections, control of distortion due to welding, and steel coating.

(1) Vehicle Transfer Span and Bridge Seat

The vehicle transfer span with apron is a movable bridge which connects the fixed trestle to the vessel. The offshore end is adjusted vertically to account for the tides. The VTS is vertically supported on hydraulic cylinders via an A-Frame on the offshore end and by a bridge seat on the shoreward end. Refer to Chapter 600 for bridge seat requirements. The transfer span is torsionally stiff allowing the bridge and WSF design live load to be safely supported on one cylinder should one of the two lift cylinders on either side fail.

Bainbridge Island Vehicle Transfer Span (H-Span)
Exhibit 610-3

(2) Hydraulic Apron

The hydraulic apron provides a connection between the hydraulic transfer span and the vehicle deck of the ferry vessel for loading and unloading. The hydraulic apron is lowered onto the vessel after the vessel is positioned in the operating slip using a single hydraulic cylinder and lever arm. Exhibit 610-4 shows the hydraulic apron on the Bainbridge Island Ferry Terminal vehicle transfer span. Design the contact plates on the apron underside with rounded edges to minimize damage and excessive wear to the vessel deck.

Provide apron lips to transition between the hydraulic apron and the vessel. Apron lips along the offshore edge of the apron are separated by a 1-inch gap. This gap allows for the lips to move independently of each other and creates a smooth transition for vehicles during loading and unloading. The gaps can pose a potential hazard for bicycles. Mark these gaps with high-visibility paint so that they are noticeable to bicyclists while loading and unloading the vessel. Additionally, consider providing signage in areas such as the bicycle holding area notifying bicyclists of the gaps and the potential hazard. For additional signage information, see Chapter 570.

Bainbridge Island Hydraulic Apron
Exhibit 610-4

(3) Bridge Lift Hydraulic Cylinders and Foundations

The bridge lift hydraulic cylinder foundations provide support and hazardous spill containment for the hydraulic cylinders that raise and lower the vehicle transfer span. The cylinders are housed in a steel casing filled with concrete to the base of the cylinders. The piston ends of the compression cylinders are mounted in cup-shaped bearings to accommodate the operating and seismic motions of the cylinders. The rod ends are connected to the A-Frames using spherical bearings. Because the cylinders are pinned end members, no lateral loads are taken by them. All seismic loads are resisted by the bridge seat assuming no contact between the VTS and seismic bumpers attached to the steel casings. For H-Span design, it is preferred the VTS does not contact the shaft seismic bumpers. The design includes a gap between the VTS and the seismic bumpers to accommodate VTS seismic motions during the design earthquake. However, the design should be bracketed between the entire seismic load being resisted at the bridge seat and the seismic bumpers engaging and lateral load being resisted by the drilled shaft foundations. Exhibit 610-5 shows a bridge lift hydraulic cylinder and maintenance ladder within the lift hydraulic cylinder foundation casing.

Bainbridge Island Bridge Lift Hydraulic Cylinder and Foundation
Exhibit 610-5

(4) Security

(a) Gates

Design security gates at new vehicle transfer spans where vessels tie up overnight to prevent unauthorized personnel from gaining access to the vessel. Security gates consist of either sliding gates or swing gates across the two vehicle lanes fitted with a person-sized, self-closing, and pass-through door with electronic locks. Locate gates in the bridge seat area such that when open they do not impede traffic.

Design gates with an overall gate height of 9 feet above the pavement and a maximum clearance of 6 inches from the bottom of gate to the lowest deck elevation when the gate is closed. Gates are to be non-climbable with a spacing that shall not allow the passage of a 4 inch sphere, measured at any point between the vertical bars.

Provide gates which are lockable in the closed position, utilizing a latch and padlock system.

Fit swing gates across the traveled lanes with drop bolts to prohibit the gates from swinging in the offshore direction beyond the plane in which they will be locked.

Provide gates with a means whereby the gate will remain in the open position during normal operations of the ferry terminal.

Bainbridge Island VTS Security Gates
Exhibit 610-6

(b) Camera and Intrusion Detection

Equip all gates and doors with intrusion detection to detect gate openings.

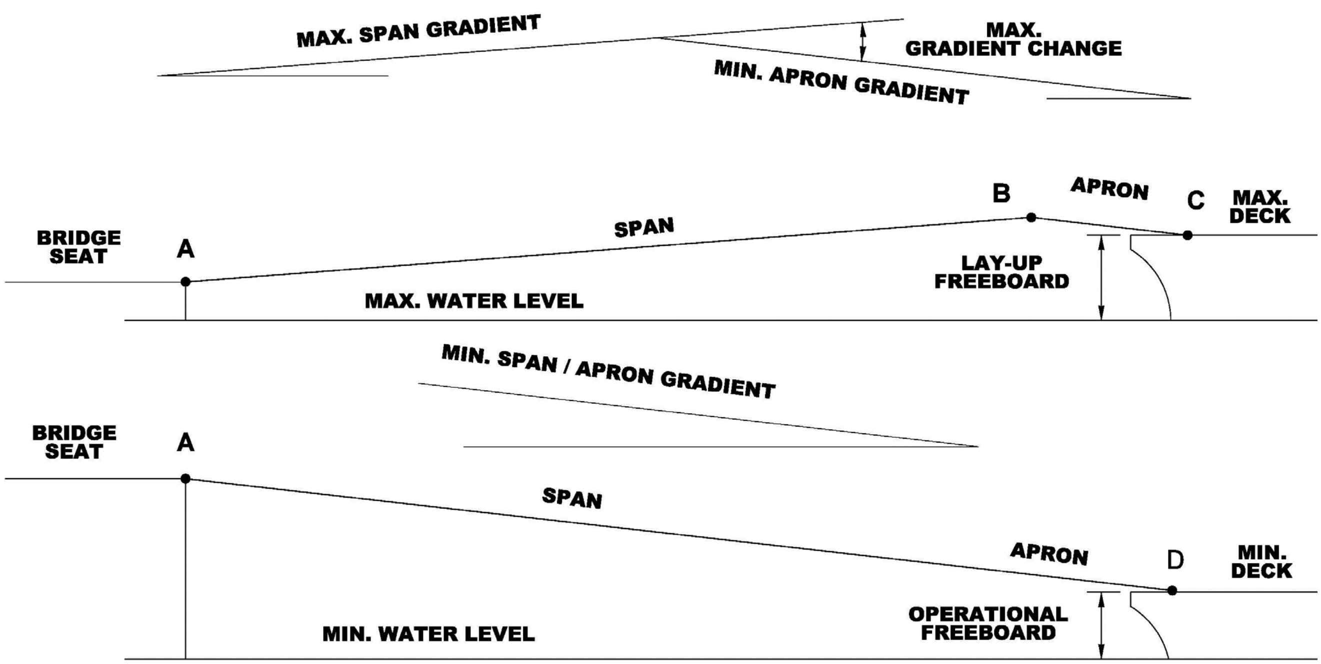
Install cameras that can monitor the pass through doors and the overall operation on the transfer span. Where field of view allows, use pan tilt zoom (PTZ) camera on the structures to monitor gate security. Refer to Chapter 310 for additional information.

610.05 VTS Gradients

Maximum and minimum gradients for the vehicle transfers spans at each terminal have been tabulated in Exhibit 610-7. Normal operation gradients are intended to be used to check existing transfer spans for operational issues and are based on Mean Higher High and Mean Lower Low Water levels and the controlling freeboard of both the Category I and Category II vessels assigned to each route. Design gradients are intended to be used for design of new transfer spans and are based on Minimum and Maximum Design Tidal Ranges and the controlling freeboard of only the Category I vessels assigned to each route.

See Terminal Tidal Datums (Exhibit 330-10), Design Vessels (Exhibit 330-4) and Appendix O: Vessel Data for Terminal Engineer for data used in the calculations of the gradients. For additional data, assumptions and intermediate values used in calculating the gradients see Appendix AA.

Terminal	Slip	Normal Operation Gradient (%) Max Span Gradient	Max Apron Gradient	Max Gradient Change	Min Span/ Apron Gradient	Design Gradient (%) Max Span Gradient	Max Apron Gradient	Max Gradient Change	Min Span/ Apron Gradient
Anacortes	1	1	-4	5	-10	5	-4	8	-14
Anacortes	2	2	-4	5	-9	5	-4	8	-13
Bainbridge Island	1	3	-5	8	-10	7	-5	11	-14
Bainbridge Island	2	3	-6	9	-10	7	-6	13	-14
Bremerton	1	5	-4	8	-9	9	-4	12	-14
Bremerton	2	6	-4	9	-8	9	-4	13	-13
Clinton	1	4	-2	6	-10	7	-2	10	-14
Clinton	2	4	-4	7	-10	7	-4	11	-14
Coupeville	1	4	-3	7	-7	7	-3	10	-11
Edmonds	1	5	-4	8	-9	8	-4	11	-13
Fauntleroy	1	6	-4	10	-8	10	-4	13	-12
Friday Harbor	1	1	-4	4	-10	4	-4	8	-14
Kingston	1	3	-5	8	-10	7	-5	11	-14
Kingston	2	4	-4	8	-9	7	-4	11	-13
Lopez	1	-1	-4	3	-11	2	-4	6	-15
Mukilteo	1	4	-2	6	-9	7	-2	9	-13
Orcas	1	-1	-3	2	-12	2	-3	5	-15
Point Defiance	1	3	-4	7	-11	6	-4	10	-16
Port Townsend	1	1	-3	5	-9	5	-3	8	-13
Port Townsend	2	2	-7	9	-11	6	-7	13	-16
Seattle	1	3	-5	8	-11	7	-5	11	-15
Seattle	2	3	-4	7	-10	7	-4	10	-15
Seattle	3	3	-4	7	-10	7	-4	10	-15
Shaw	1	6	-4	10	-6	10	-4	13	-11
Southworth	1	2	-4	6	-11	6	-4	10	-15
Tahlequah	1	4	-4	8	-10	8	-4	11	-15
Vashon	1	2	-4	6	-11	6	-4	10	-16
Vashon	2	3	-4	6	-11	6	-4	10	-15



Maximum and Minimum VTS Gradients

Exhibit 610-7

610.06 Structural Design Criteria

(1) New Structures

(a) Design Codes

Design the bridge seat foundation, transfer span, apron, and bridge lift hydraulic cylinder shafts in accordance with the AASHTO LRFD *Movable Specifications* and the AASHTO LRFD *Guide Specifications*. Additional owner-specified loads are defined by WSF. Supplement design using the WSDOT *Bridge Design Manual* LRFD.

Design curb and bridge railing in accordance with the AASHTO LRFD *Specifications* and the given design speeds provided in (1)(d)2.

Design hydraulic cylinder shaft access platform and ladder in accordance with WAC 296-24, WAC 296-56, WAC 296-876 and ANSI/AISC 360. WAC 296-56 takes precedence over WAC 296-876.

WSF is to approve any deviation from these design codes not specified below. Include a signed deviation in the Project File (PF)/Design Documentation Package (DDP). Refer to Section 220.05 for details on the PF/DDM.

(b) Design Life

The design life of new vehicle transfer span structures, including the transfer span, apron, and foundations, is based on deterioration from corrosion due to exposure and/or fatigue in accordance with Section 610.03(7).

(c) Limit States

Utilize Limit States as specified in the AASHTO LRFD *Specifications*, Section 1.3.

Factor Relating to Ductility:	$\eta_D = 1.0$	For Conventional Designs and Details Complying with the AASHTO LRFD *Specifications*. Notify WSF if the value of η_D is not 1.0.
Factor Relating to Redundancy:	η_R	Determine During Design
Factor Relating to Operational Importance:	$\eta_I = 1.0$	For Typical Bridges

(d) Design Loads

The permanent and transient loads listed below apply.

1. **Permanent Loads**

DC	Dead Load of Structural Components and Nonstructural Attachments
DW	Dead Load of Wearing Surfaces and Utilities

2. **Transient Loads**

BR **Vehicular Braking Force**

For all AASHTO-specified load combinations, design the transfer span and apron for both one and two lanes of HL-93 load headed in the same direction during loading and unloading of the vessel.

For the Design Level Earthquake (DLE), use a vehicular braking force factor γ_{EQ} of 0.

For the Operational Level Earthquake (OLE), use a vehicular braking force factor γ_{EQ} of 0.5.

CT **Vehicular Collision Force**

Design transfer span railing as equivalent in strength and geometry to bridge railing that has been successfully crash tested to Test Level One (TL-1) or greater in accordance with AASHTO LRFD Specifications. The design speed for the transfer span and curb is 15 mph as established by WSF in the *2010 Port Townsend Ferry Dock Spot Speed Study*. The lowest speed listed in AASHTO LRFD *Specifications* for design and testing of bridge railing is 30 mph, associated with the TL-1 test selection criteria. TL-1 is for work zones with low posted speeds and very low volume, and low speed local streets.

Design speed for the apron is 10 mph. Therefore, it is assumed vehicle wheels will not ride up and over the apron curb. Design apron curb for a lateral load of 500 plf. Design apron railing for pedestrian and bicycle loads in accordance with the AASHTO LRFD *Specifications*.

DAD **Dead Load Dynamic Load Allowance**

As specified in the AASHTO LRFD *Movable Specifications*, Section 2.4.1.2.2, “Structural parts in which the force effect varies with the movement of the span, or in parts which move or support moving parts shall be designed for a load taken as 20 percent of the total dead load to allow for dynamic load allowance or vibratory effect.”

For load combinations involving moving of the transfer span and/or apron with stationary live load, the DAD factor applies to dead load and stationary live load.

DAM Force Effects Due to Operation of Machinery

As specified in the AASHTO LRFD *Movable Specifications*, Section 2.4.1.2.3, “Structural components supporting forces caused by machinery during operation of the span shall be designed for the calculated machinery forces, increased 100 percent as a dynamic load allowance.”

For the transfer span, the DAM factor applies at the following structural components:

- A-Frame
- A-Frame connection to the transfer span
- Apron lever arm
- Apron lever arm connection to the transfer span
- Apron lift hydraulic cylinder shoreward support post
- Apron lift hydraulic cylinder shoreward support post connection to transfer span

The DAM factor does not apply to design of the apron or the transverse lift beam.

Force effects on structural connections to hydraulic cylinders are as specified in the AASHTO LRFD *Movable Specifications*, Section 2.4.1.8, “Hydraulic Cylinder Structural Connections”.

EQ Earthquake Load

Seismic design is based on a two-level approach considering a Design Level Earthquake (DLE) and an Operational Level Earthquake (OLE).

The DLE is the 1000-year event specified in the AASHTO LRFD *Specifications*. For the DLE, design and detailing are intended to prevent collapse of all or part of the transfer span. Transfer span and apron can be in any position.

The OLE as specified in the AASHTO LRFD *Movable Specifications* is defined as having half of the demand values associated with the DLE. For the OLE, design and detailing are intended to allow the transfer span and apron to remain operational, i.e., movable. Minor damage to the H-Span is acceptable during the OLE event provided that it is designed to occur at a predetermined location and can be easily identified and quickly repaired.

The designer shall identify on the contract drawings anticipated structural failure locations for both the OLE and the DLE.

Soil parameters for developing seismic response spectra will be provided by the WSDOT Geotechnical Branch.

FL **Fatigue Load**

Evaluate the fatigue limit state in accordance with the AASHTO LRFD *Specifications*, the AASHTO LRFD *Movable Specifications*, and the WSDOT BDM for 75 year design life. The fatigue load shall be as specified in AASHTO LRFD *Specifications* Section 3.6.1.4.1.

In addition to vehicular traffic, include the number of times the transfer span and apron are raised and lowered (ADO), in the fatigue calculations.

ADT (*average daily traffic*):	20,000
ADTTSL (*average daily truck traffic*):	270
ADO (*average daily openings*):	40

Note: These numbers are based on 2012 traffic data from the Edmonds and Mukilteo Ferry Terminals and include an applied 1.4 future traffic factor. The Edmonds and Mukilteo Ferry Terminals are the busiest single-slip terminals in the system.

FR **Friction Load**

As the vessel deck supports the apron during loading and unloading operations, friction forces occur between the bottom of the apron and the vessel deck as wind, wave, current, and braking forces cause the vessel to move. The friction load is equal to a friction coefficient multiplied by the maximum normal reaction of the apron bearing on the vessel deck. In practice, the vessel is typically held motionless against a dolphin resulting in little or no movement during loading and unloading operations.

For both the DLE and OLE, the friction force between the bottom of the apron and the vessel deck is not considered because of the low probability of the simultaneous occurrence of the friction force and the earthquake.

Use the following friction coefficients specified in UFC 4-152-01 to calculate friction forces:

Steel to steel:	0.25
Steel to rubber:	0.65

IM **Vehicular Dynamic Load Allowance**

LL **Vehicular Live Load**

For AASHTO-specified load combinations, design the H-Span for both one and two lanes of HL-93 load headed in the same direction during loading and unloading of the vessel.

For the DLE, use a vehicular live load factor γ_{EQ} of 0.

For the OLE, use a vehicular live load factor γ_{EQ} of 0.5. The associated mass of live load need not be included in the dynamic analysis.

MLL1 Apron Maintenance Live Load

WSF personnel occasionally use the H-Span to launch a small boat. A single-axle boat trailer approximately 16 feet long is backed onto the apron and then the transfer span is lowered to the level of the seawater. With boat included, the service level load at each of the two trailer wheels spaced 6 feet apart is 2000 pounds. In addition, consider two personnel having a service level load of 300 pounds each to be on the apron. Consider both the trailer wheels and personnel to be located anywhere on the apron. Neglect wheel loads for the tow vehicle because the distance from the trailer axle to the vehicle hitch is approximately 15 feet, placing the vehicle rear axle wheel loads very close to the apron hinges.

The apron maintenance live load is supported by the apron lifting arm (apron lever arm) and apron hinges. During loading and unloading the vessel, the apron lever arm does not support any load.

Design the apron lever arm to support the apron's dead load and maintenance live load. The strength load factor applied to service level dead load and maintenance live load shall be 1.25.

MLL2 Bridge Lift Hydraulic Cylinder Shaft Access Platform Maintenance Live Load

Design the bridge lift hydraulic cylinder access platform for a uniform live load of 100 psf.

Do not apply the dynamic load allowance (IM) to the access platform live load.

OLL Operational Vehicular Live Load

OLL consists of a single lane of HL-93 load with WSF-defined load factors that are used only with specific WSF-defined load cases.

Geometry constraints, including turning requirements and lane widths, make it impractical to load two large trucks side by side on the H-Span. WSF's normal loading and unloading practice is to send large trucks and RVs single file across the H-Span. Smaller trucks, weighing up to 36 kips, may be loaded side by side. A single lane of OLL with WSF-defined load factors is approximately equivalent to the maximum expected loading on the transfer span for WSF-defined load cases.

Design the H-Span for the additional WSF-defined loads described below.

1. One Transfer Span Lift Hydraulic Cylinder Failure: WSF-defined load to ensure that the H-Span can support one lane of HL-93 load located anywhere on the H-Span in the event one lift hydraulic cylinder fails. The AASHTO LRFD *Specifications* multiple presence factor (m) and vehicular dynamic load allowance factor (IM) apply. The AASHTO LRFD *Movable Specifications* dynamic load allowance factors (DAD) and (DAM) do not apply.

2. Moving Transfer Span with Stationary Vehicular Live Load: WSF-defined load to ensure that the transfer span can be moved with one lane of stationary HL-93 load located anywhere on the transfer span. Consider vehicular live load on the apron only when the apron is supported by the vessel deck. The AASHTO LRFD *Specifications* multiple presence factor (m) applies and the vehicular dynamic load allowance factor (IM) does not apply. The AASHTO LRFD *Movable Specifications* dynamic load allowance factors (DAD) and (DAM) apply to dead load and stationary live load.

PL Pedestrian Live Load

Design the H-Span for a uniform pedestrian live load of 100 psf.

TL Tie-up Line Force

Two tie-up lines between the vessel and apron are used as a backup to vessel propulsion to maintain the vessel position during loading and unloading operations. Each line is a 1.75-inch diameter 3-strand blue steel poly rope with a minimum breaking force of approximately 68 kips. Install a fuse mechanism in the line to limit the service level force (TL) transferred to the apron to 68 kips per line. Design all of the components in the line using a strength limit state load factor of 1.25 to ensure that the fuse mechanism fails before other components in the line.

WA Water Loads – Wave, Flood, and Coastal Storm Loading

Refer to Section 330.09(1) for wave, flood, and coastal storm loading criteria.

WL Wind on Live Load

WS Wind Load on Structure

Design wind load on structure in accordance with the WSDOT *Bridge Design Manual* LRFD and the AASHTO LRFD *Specifications*.

The design water level elevation is 0.00 feet corresponding to Mean Lower Low Water (MLLW).

(e) Unfactored Load Combinations

Provide WSF-defined unfactored load combinations seen at the hinge points and cylinder connections to the mechanical designer for use in designing the mechanical system. Reference Section 610.08 for mechanical load combinations.

Limit State	Description
Strength IA:	Normal vehicular use of the bridge without wind.
Strength IB:	Pedestrian use of the bridge without wind.
Strength II:	Does not apply. Owner-specified special design vehicles are not considered.
Strength III:	Bridge exposed to wind velocity exceeding 55 mph.
Strength IV:	Does not apply. DL to LL ratio effect is not considered.
Strength VA:	Normal vehicular use of the bridge with a 55 mph wind velocity.
Strength VB:	Pedestrian use of the bridge with a 55 mph wind velocity.
Extreme IA:	OLE with vehicular live load.
Extreme IB:	OLE without live load.
Extreme IC:	DLE without live load.
Extreme II:	Collision by vehicles.
Service IA:	Normal operational use of bridge with a 55 mph wind velocity.
Service IB:	One transfer span lift hydraulic cylinder failure with one lane HL-93 load.
Service IC:	Pedestrian use of bridge with a 55 mph wind velocity.
Service IIA:	Control yielding of steel structures due to vehicular live load.
Service IIB:	Control yielding of steel structures due to vehicular live load for one transfer span lift hydraulic cylinder failure with one lane HL-93 load.
Service IIC	Control yielding of steel structures due to pedestrian live load.
Service III:	Does not apply. For longitudinal analysis relating to tension in prestressed concrete superstructures.
Service IV:	For tension in prestressed concrete columns only with the objective of crack control.
Fatigue I:	Does not apply. Infinite load-induced fatigue life is not considered.
Fatigue II:	Finite load-induced fatigue life.
WSF-STR-1:	Vessel tie-up line force on apron.
WSF-STR-2:	One transfer span lift hydraulic cylinder failure with one lane HL-93 load.

Note: Refer to AASHTO Guide Specification for Bridges Vulnerable to Storms for additional load combinations.

Fixed (Non-Moving) Bridge Design Limit States
Exhibit 610-8

Limit State	Description
WSF-STR-3:	Moving bridge with no live load, both cylinders operational. Structural components where the dynamic load allowance factor DAD applies. Bridge not exposed to wind.
WSF-STR-4:	Moving bridge with no live load, both cylinders operational. Structural components where the dynamic load allowance factor DAM applies. Bridge not exposed to wind.
WSF-STR-5:	Moving bridge with no live load, both cylinders operational. Structural components where the dynamic load allowance factor DAD applies. Bridge exposed to wind velocity exceeding 55 mph.
WSF-STR-6:	Moving bridge with no live load, both cylinders operational. Structural components where the dynamic load allowance factor DAM applies. Bridge exposed to wind velocity exceeding 55 mph.
WSF-STR-7:	Moving bridge with one lane of stationary HL-93 load, both cylinders operational. Structural components where the dynamic load allowance factor DAD applies. Bridge not exposed to wind.
WSF-STR-8:	Moving bridge with one lane of stationary HL-93 load, both cylinders operational. Structural components where the dynamic load allowance factor DAM applies. Bridge not exposed to wind.
WSF-STR-9:	Moving bridge with one lane of stationary HL-93 load, both cylinders operational. Structural components where the dynamic load allowance factor DAD applies. Bridge exposed to a 55 mph wind velocity.
WSF-STR-10:	Moving bridge with one lane of stationary HL-93 load, both cylinders operational. Structural components where the dynamic load allowance factor DAM applies. Bridge exposed to a 55 mph wind velocity.

Movable Bridge Design Limit States
Exhibit 610-9

Design Load	Description
Strength IA:	η_i [$\gamma_{p,DC}$ DC + $\gamma_{p,DW}$ DW + 1.75 (LL + IM) + 1.75 BR + (FR + IM)]
Strength IB:	η_i [$\gamma_{p,DC}$ DC + $\gamma_{p,DW}$ DW + 1.75 PL + FR]
Strength III:	η_i [$\gamma_{p,DC}$ DC + $\gamma_{p,DW}$ DW + 1.4 WS + FR]
Strength VA:	η_i [$\gamma_{p,DC}$ DC + $\gamma_{p,DW}$ DW + 1.35 (LL + IM) + 1.35 BR + 0.4 WS + WL + (FR + IM)]
Strength VB:	η_i [$\gamma_{p,DC}$ DC + $\gamma_{p,DW}$ DW + 1.35 PL + 0.4 WS + WL + FR]
Extreme Event IA:	η_i [$\gamma_{p,DC}$ DC + $\gamma_{p,DW}$ DW + □EQ (LL + IM) + □EQ BR + 0.5 EQ]
Extreme Event IB:	η_i [$\gamma_{p,DC}$ DC + $\gamma_{p,DW}$ DW + 0.5 EQ]
Extreme Event IC:	η_i [$\gamma_{p,DC}$ DC + $\gamma_{p,DW}$ DW + EQ]
Extreme Event II:	η_i [$\gamma_{p,DC}$ DC + $\gamma_{p,DW}$ DW + 0.5 (LL + IM) + 0.5 BR + (FR + IM) + CT]
Service IA:	η_i [DC + DW + (LL + IM) + BR + 0.3 WS + WL + (FR + IM)]
Service IB:	η_i [DC + DW + 1.25 (OLL + IM) + 1.25 BR + 1.25 (FR + IM)]
Service IC:	η_i [DC + DW + PL + 0.3 WS + WL + FR]
Service IIA:	η_i [DC + DW + 1.3 (LL + IM) + 1.3 BR + 1.3 (FR + IM)]
Service IIB:	η_i [DC + DW + 1.65 (OLL + IM) + 1.65 BR + 1.65 (FR + IM)]
Service IIC:	η_i [DC + DW + 1.3 PL + FR]
Service IV:	η_i [DC + DW + 0.7 WS + FR]
Fatigue II:	η_i [0.75 (FL + IM) + 0.75 BR]
WSF-STR-1:	η_i [$\gamma_{p,DC}$ DC + $\gamma_{p,DW}$ DW + 1.25 TL]
WSF-STR-2:	η_i [$\gamma_{p,DC}$ DC + $\gamma_{p,DW}$ DW + 1.60 (OLL + IM) + 1.60 BR + 1.25 (FR + IM)]

Load combinations pertaining to the design of the lift hydraulic cylinder shaft access platform are not included.

Fixed (Non-Moving) Bridge Design Load Combinations
Exhibit 610-10

Design Load	Description
WSF-STR-3:	η_i [1.55 (DC + DW + DAD) + (FR + DAD)]
WSF-STR-4:	η_i [1.55 (DC + DW + DAM) + (FR + DAD)]
WSF-STR-5:	η_i [1.25 { (DC + DW + DAD) + WS } + (FR + DAD)]
WSF-STR-6:	η_i [1.25 { (DC + DW + DAM) + WS } + (FR + DAD)]
WSF-STR-7:	η_i [1.55 (DC + DW + DAD) + 1.3 (OLL + DAD) + (FR + DAD)]
WSF-STR-8:	η_i [1.55 (DC + DW + DAM) + 1.3 (OLL + DAM) + (FR + DAD)]
WSF-STR-9:	η_i [1.25 { (DC + DW + DAD) + 0.3 WS + WL } + 1.3 (OLL + DAD) + (FR + DAD)]
WSF-STR-10:	η_i [1.25 { (DC + DW + DAM) + 0.3 WS + WL } + 1.3(OLL + DAM) + (FR + DAD)]

Load combinations pertaining to the design of the apron lever arm are not included.

Movable Bridge Design Load Combinations
Exhibit 610-11

(2) Retrofitted Single Cable-Operated Transfer Span System

Base retrofitting of existing VTS systems on the particular type of structure to be upgraded. The majority of existing single cable-operated transfer spans consist of pile-supported concrete foundations, a steel frame superstructure (headframe and towers), and a cable and counterweight (CW) mechanical system. The WSF inventory also includes a small number of timber pile-supported steel headframes and timber bridge seats. The majority of existing transfer spans consists of a pair of longitudinal plate girders, transverse floor beams, longitudinal stringers and a steel grid deck, which is either unfilled or filled with concrete. The apron is typically operated with hydraulic cylinders or, in some older VTS systems, a hoist cable and counterweight system. The WSF inventory also includes a small number of pre-1964 truss transfer spans which are equipped with hoist cable and counterweight-operated aprons. Several variations of the span cable and counterweight system are utilized at WSF facilities. Exhibit 610-12 shows the Seattle Ferry Terminal single cable-operated vehicle transfer span and apron.

Seattle Single Cable-Operated Transfer Span
Exhibit 610-12

WSF has existing VTS systems that have remaining life in the foundations, bridge seats, towers, vehicle transfer spans, etc., while the electrical and mechanical machinery have reached the end of their service life. Some of these existing VTS systems were retrofitted with an updated electrical and mechanical single wire rope hoist system. Completely new VTS systems were also constructed with this same single wire rope hoist system as recently as 2003.

The main features of these new and retrofitted single wire rope systems are as follows:

- Single wire rope hoist system
- Multi-layering non grooved wire rope drum
- Hoist machinery mounted on girder of bridge
- Hoist motor mounted single brake
- Approximately 30,000 lbs unbalanced, span heavy load on hoist system
- 50” diameter CW sheaves for 1.5” diameter wire rope
- Hydraulic apron, operated by two hydraulic cylinders
- Hydraulic live load pins

- Hydraulic power unit with full fluid containment
- Slotted hanger bars for supporting live load
- Wire rope tension control
- PLC control system

These main features represent the ideal solution; however, vessel slips are evaluated for full or partial retrofits depending on usage, age, impending future projects and available budget.

610.07 VTS Piped Utilities

(1) Water Line Criteria

(a) Design Codes

See Section 610.02(2).

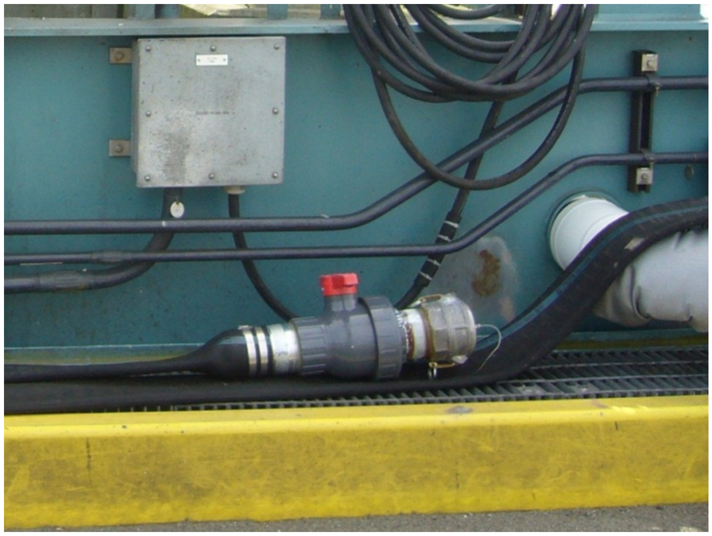
Water Line on VTS
Exhibit 610-13

(b) Water Lines

- Incorporate freeze protection valves in transfer span lines located as close to the vessel connection shutoff valve as possible. Route valve discharge off the span.
- Incorporate a swivel joint and a potable water rated flexible hose in the water line flexible connection from the trestle to the bridge.
- Incorporate a backflow preventer in each transfer span water line. For 4” lines, locate the backflow preventer in a heated enclosure or room on the trestle near the transfer span hinge line. For smaller lines, locate the backflow preventer towards the offshore end of the transfer span and cover with an insulated blanket.
- Design transfer span piping and water line to vessel connections to match the water line size under the trestle.
- Provide an aluminum cam and groove type A adapter with dust cap at the off shore end of the water line.

- Propose the following parts as sole-source components to increase the reliability of the system and to facilitate maintenance:
  - Backflow preventer: Febco Model 860 reduced pressure type
  - Backflow preventer enclosure: Hot Box (for 4" valves)
  - Swivel joint: OPW Model #3930, 3730, 3940 or 3740, as appropriate.
  - Hose: Gates Food and Beverage Master #3132-XXXX.

(2) Sewer Line Criteria



Sewer Line Connection
Exhibit 610-14

(a) Design Codes

See Section 610.02(2).

(b) Sewer Lines

- Design exposed hard sewer lines with heat tape, insulation, and jacketing.
- Design sewer hose connection between the trestle and transfer span with heat tape and insulation.
- Design sewer line to vessel connections to be 4 inches.
- Incorporate a swivel joint and a flexible hose in sewer line connection from the trestle to the bridge.
- Provide an aluminum cam and groove type B coupler with dust plug at the off shore end of the sewer line.
- Propose the following parts as sole-source components to increase the reliability of the system and to facilitate maintenance:
  - Swivel joint: OPW Model #3930-0401.
  - Ball valve:
    - Single entry: Spears # 2431-0409
    - Double entry: Spears # 2321-0400

610.08 Mechanical Design Criteria

(1) Tidal Range of Motion

Design the VTS for a tidal range in accordance with Section 330.06.

(2) Vessel Fit Requirements

Check each installation for fit up for each appropriate vessel class under the following conditions.

- Each appropriate vessel class in light (lay-up) and full (operational) load conditions
- At low tide
- At high tide
- At 0 degree span slope

(3) Maintenance

The mechanical system shall be designed with ease of maintenance in mind. There shall be sufficient access to remove and replace all components without having to remove or disassemble adjacent components.

Safe access to all mechanical system components shall be provided.

There shall be sufficient clearance on all fittings and fasteners that they can be tightened or loosened without requiring the use of special tools. All spot faces and countersinks shall be sized to allow for the use of standard tooling in the removal of the associated components.

Provisions shall be made to support the apron structure while replacing the apron lift system.

(4) New Dual Wire Rope Hoist Operated VTS Structures

The design criteria for this new design/construction can be found in the following reports, criteria documents and project drawings/calculations available in the WSF library.

- Final Design Report for Vehicle Transfer Spans (M-Span), Volume 1 and 2
- Conceptual Design Report - Hydraulically Actuated Transfer Span Systems
- Millennium Vehicle Span - Hoist Machinery Calculations
- Port Townsend Ferry Terminal Standard Transfer Span - Contract #6519 (installed at Friday Harbor under Contract #6737)
- Friday Harbor Ferry Terminal Preservation Project - Contract #6737 (full size span)
- Shaw Island Ferry Terminal Slip Reconstruction - Contract #6576 (reduced size span)

(5) New and Retrofitted Single Wire Rope Hoist Operated VTS Structures

In the late 1990's WSF established design criteria for the mechanical components of a single wire rope hoist system based on available ASME, CFR's, L & I rules, WAC's, and ANSI rules and codes. This was required because no single code or set of rules exactly fit or defined WSF's actual installations or method of operation. WSF's moveable bridge system was not defined by any rules or codes, including AASHTO.

WSF put together a book called *Safety Rules and Regulations*. This document includes 17 codes/rules on which WSF based the single hoist wire rope design/retrofit criteria. At this time none of the designs or existing installations followed any AASHTO design criteria nor did the existing AASHTO criteria seem reasonable for WSF's design or method of operation. The other codes in the safety book also did not entirely address WSF's particular needs. So WSF Engineering took available parts of the listed codes which seemed reasonable and, studying existing designs, using engineering logic, common sense and past experiences, came up with the following design criteria for single wire rope hoist operated vehicle transfer spans.

Single wire rope hoist system design criteria summary:

- 0.75" diameter hoist wire rope
- Multiple layered non-grooved wire rope drum, 12.75" diameter drum barrel
- 14" diameter hoist wire rope sheaves
- 15 ton single blocks, 4 to 1 minimum safety factor
- 20 ton double blocks, 4 to 1 minimum safety factor
- Minimum factor of safety of 4 for all connection parts and hardware
- 2500 to 2800 lbs dead end wire rope tension
- Up limit travel limit switch
- Hoist wire rope tension control, high, low and low-low tensions settings
- Bridge mounted hoist, with single motor mounted spring applied, electrically released motor brake
- 50" diameter CW weight sheaves
- 1½" diameter CW wire rope, factor of safety of 6 minimum
- CW equalizers attached to counterweights
- Hydraulic apron, with two standard apron cylinders
- Hydraulic live load pins
- Fully contained 30 gallon standard hydraulic power unit as detailed on the Standard Drawings
- PLC control system
- View screen on operators control panel for operational and alarm indicators
- Manual push button for apron control on end of apron
- Remote control capabilities for span and apron
- Email connection to Terminal Engineering of select equipment faults/alarms

(6) Hydraulic Transfer Span (H-Span)

(a) System Description

The hydraulic system operates two hydraulic circuits. A pair of hydraulic cylinders raise and lower the transfer span, and a single cylinder raises and lowers the apron. There is one hydraulic system power unit to serve both span and apron functions. The power unit components such as motors, pumps, tank, filters and valves are located in a dedicated hydraulic power unit (HPU) enclosure incorporating an environmental spill pan. The enclosure also houses electrical power and control cabinets.

The span is powered in the raise direction. Span raise speed is limited by the flow rate of the pumps. The span is lowered by gravity (although a pump must be running to provide pilot pressure to load holding valves). Flow control valves mounted on the lift cylinders control the lowering speed. If, at any time, the operator releases the span pushbutton, span motion will cease.

The apron is powered in both the raise and lower directions. Flow control valves located in the HPU manifold control the apron raise and lower speeds.

For vehicle loading and unloading the apron is lowered onto the vessel deck and the apron cylinder continues to extend until the cylinder has reached full stroke. A pressure transducer connected to the rod end of the cylinder will cause the float light to illuminate indicating to the operator that it is safe to begin loading or off-loading vehicles. When in the float mode, the apron is free to move with the movement of the vessel deck. When raising the apron, the float light is extinguished when the raise apron command is given. If the operator releases the apron pushbutton before the apron weight is supported by the lever arm, the apron cylinder will return to its fully extended position. If the operator releases the apron pushbutton after the apron weight is supported by the lever arm, apron motion will cease.

(b) Emergency Operating Description

In case of electric power loss the transfer span hydraulic system can be operated in a vessel back feed mode. The smaller pump (20 HP) is used in this situation. The span raise operation will be significantly slower and all other operations will occur at normal speeds.

(c) Operating Conditions

1. **Normal Operation**
   - Lifting/lowering bridge + operator + snow load + wind load
   - Span speed minimum 5.75 ft/min at the A-frame (bridge cylinder extend speed)
2. **Live Load Operation**
   - Lifting/lowering bridge + live load as defined in WSF load combinations.
   - HL-93 vehicle is anywhere on the span
   - Reduced span speed is acceptable
   - Full two lane live load

(d) Failure Conditions

1. **Loss of any one component or credible cascade tree**
   - Must not result in harm to persons, vehicles, or structure if the following occur while performing the above operations.
   - Holds design load.
2. **Loss of power**
   - Requires operation on vessel backfeed, limited to 30 amps
   - Lifting/lowering bridge + operator
   - Reduced speed acceptable
   - Ability to provide live load operation at reduced speed a nice to have, but is not required

3. **Jammed Transfer Span**
   - Possible failure scenarios that could result in a jammed span will be investigated and addressed (such as foreign objects inserted into pinch points).
4. **Tie-up**
   - Vessel tied up in slip with incoming tide
   - Systems must allow movement of bridge
   - If an action is required to protect bridge system, an alarm shall signal or some secondary operation will occur automatically
   - Components shall resist tie-up forces as defined in WSF load combinations.

(e) Load Combinations

The mechanical system, including hydraulic cylinders, clevises, cylinder connection pins, and hinge pins, shall be designed per the appropriate sections of the AASHTO LRFD *Movable Specifications* to the maximum extent practical and for the following WSF defined non-factored load combinations. See Exhibits 610-15 and 610-16. Reference Section 610.06 for load combination descriptions. Notify the WSF Mechanical Engineer of instances where deviations to the AASHTO LRFD *Movable Specifications* are recommended.

Limit State	Description
WSF-SER-1:	Control yielding due to vehicular live load.
WSF-SER-2:	Bridge exposed to wind velocity exceeding 55 mph.
WSF-SER-3:	Pedestrian use of bridge with a 55 mph wind velocity.
WSF-SER-4	Control yielding due to pedestrian live load.
WSF-EXT-1:	Design Level Earthquake (DLE) without live load.
WSF-EXT-2:	Operational Level Earthquake (OLE) with vehicular live load.
WSF-EXT-3:	Operational Level Earthquake (OLE) without live load.
WSF-FAT-1	Infinite load induced fatigue live
WSF-FAT-2:	Finite load-induced fatigue life.
WSF-OVL-1:	Collision by vehicles.
WSF-OVL-2:	Vessel tie-up line force on apron.
WSF-OVL-4:	Normal operational use of bridge with a 55 mph wind velocity.
WSF-OVL-6:	One transfer span lift hydraulic cylinder failure with one lane HL-93 load.

Mechanical Load Combination Descriptions
Exhibit 610-15

Design Load	Description
WSF-SER-1:	η_i [DC + DW + (LL + IM) + BR + (FR + IM)]
WSF-SER-2:	η_i [DC + DW + WS + FR]
WSF-SER-3:	η_i [DC + DW + PL + 0.3 WS + FR]
WSF-SER-4:	η_i [DC + DW + PL + FR]
WSF-EXT-1:	η_i [DC + DW + EQ]
WSF-EXT-2:	η_i [DC + DW + γ_{EQ} (LL + IM) + γ_{EQ} BR + 0.5 EQ]
WSF-EXT-3:	η_i [DC + DW + 0.5 EQ]
WSF-FAT-I	$\frac{\sigma'_a}{\sigma_e} + \frac{\sigma'_m}{\sigma_{yt}} \leq 0.80$
WSF-FAT-2:	η_i [(FL + IM) + BR]
WSF-OVL-1:	η_i [DC + DW + 0.5 (LL + IM) + 0.5 BR + (FR + IM) + CT]
WSF-OVL-2:	η_i [DC + DW + TL]
WSF-OVL-4:	η_i [DC + DW + (LL + IM) + BR + 0.3 WS + WL + (FR + IM)]
WSF-OVL-6:	η_i [DC + DW + 1.25 (OLL + IM) + 1.25 BR + 1.25 (FR + IM)]

Mechanical Load Combinations
Exhibit 610-16

For load combinations WSF-EXT-1 and WSF-OVL-6, the pressure in the bridge lift cylinders is allowed to increase to 4500 psi. The safety factors for the cylinder connections and hinge pins is allowed to be as low as 1.7 based on the yield strength of the material. For all other load combinations the hydraulic pressures shall be 3,000 psi or below and the safety factors will be a minimum of 3 or 4 as specified in section 6.6.1 of the AASHTO LRFD *Movable Specifications*.

For the WSF-FAT-1 load combination, the minimum and maximum stresses used in the equation shall be as follows:

- For the bridge lift cylinders, pins and clevises; the bridge hinge pins and clevises; and the apron hinge pins and clevises; use the stress occurring with dead load only for the minimum and the stress occurring from the WSF-SER-1 combination as the maximum.
- For the apron lift cylinder pins and clevises and the apron lever arm pins and clevises, use the stress occurring from the apron lever arm only for the minimum and the stress occurring from the lever arm and apron as the maximum.

(f) Design Criteria

1. **Hydraulic Fluid**

   Hydraulic fluid shall be Mobil DTE 10 Excel 15. The design of span lift/apron hydraulic machinery will utilize all possible means to prevent and contain leaks of hydraulic fluid to the environment.

2. **Component Connections**

   Clevis pins, bearings, clevises, trunnions, and other machinery for support of hydraulic cylinders shall be designed in accordance with the Mechanical and Hydraulic section of the AASHTO LRFD *Movable Specifications* to the maximum extent practical.

3. **Operating Pressure**

   All hydraulic components shall be rated for 3,000 psi minimum working pressure. The hydraulic system shall be designed to operate with pressures ranging from 800-3,000 psi. The maximum working pressure in the system or circuit shall be controlled physically through use of pressure control valves.

   Hydraulic span cylinders shall be sized to achieve pressures below 3,000 psi for all the mechanical load combinations with the exception of : WSF-EXT-1 and WSF-OVL-6. The pressures resulting from these load conditions shall remain below 4,500 psi.

4. **Hydraulic Cylinder Design, General**

   Effort shall be made to utilize hydraulic cylinders of the same dimensions and pressure ratings as those currently in WSF inventory.

   The designer shall specify cylinder bore diameter, rod diameter, stroke, retracted length, mounting pin diameter and manifold mounting configuration.

   All cylinders shall be of welded construction, no tie rod cylinders.

   Provide spacers to prevent cylinders from twisting excessively in the clevis brackets.

   Bearings shall be sized using the bearing manufacturer's published dynamic ratings.

   Pin dimensions and hardness shall be per the bearing manufacturer's recommendation

   Critical dimensions of cylinders shall be identical to those of existing H-Span cylinders. Cylinders shall be interchangeable with existing H-Span cylinders.

   All cylinders shall include a valve manifold mounted directly to the cylinder. Manifolds shall contain a load holding valve to hold fluid in the cylinder and thereby support the load when the cylinder is not in motion.

5. **Seals**

   Specify seals that are compatible with the hydraulic oil specified and which have proven prior usage with the hydraulic oil in similar applications.

6. **Bridge Lift Cylinders**

   Factor of safety for all parts – 5:1 based on material ultimate strength and 4:1 based on material yield strength with 3000 psi pressure

   Buckling safety factor – 3:1 based on 3000 psi

   Buckling calculations based on the AASHTO LRFD *Movable Specifications*, NFPA (Fluid) T3.6.37 or other method approved by the WSF Mechanical Engineer.

   Manifold Ports – to accommodate SAE code 61 4-bolt flange fittings, 1" for the blind side port and ¾" for the rod side port.

   Rod material – rod end stainless steel, rod chrome plated stainless steel

Stop tubes or other design features shall be incorporated to ensure sufficient separation between the piston bearing and rod bearing at full cylinder stroke

Bleed and gage ports shall be provided

The design shall allow for the cylinder to be thoroughly bled in the vertical position

The manifold shall be mounted on the cylinder rod end.

7. **Apron Cylinder**

   The apron cylinder shall have a factor of safety of 3:1 based on material yield strength and 3000 psi working pressure.

   Manifold Ports – to accommodate ¾” SAE code 61 4-bolt flange fittings

   Rod material – chrome plated stainless steel

   Air bleed and gage ports shall be provided on both ends of the cylinders. The bleed ports shall be oriented such that air can be completely bled with the cylinder in the installed position.

8. **Cylinder Testing**

   Each cylinder shall be shop tested with the specified hydraulic fluid and witnessed by a WSF Mechanical Engineer. Hydraulic pressure shall be recorded for no load extension and retraction. Cylinders shall demonstrate the ability to hold pressure on both sides of the piston seal. Tests shall demonstrate that no leakage occurs across piston seal, from either side and that no leakage occurs from the rod seal.

   Cylinders shall be stroke tested to demonstrate that no vibration occurs during operation. Large cylinders shall be tested in the vertical position.

   If manifolds are supplied with the cylinder, the manifold shall be tested for leaks, for pressure holding and valve function independent of the cylinder. The manifold shall also be attached to the cylinder and pressure tested to verify no leakage at the manifold to cylinder connection.

9. **Apron Operational Requirements**

   The apron hinge design will include locating the apron bearing centerlines at the deck level to improve accessibility for maintenance. An apron stop shall be incorporated to facilitate changing the apron cylinder.

10. **Hydraulic Pumps**

    Hydraulic pumps intended for fluid power generation are to be selected based upon maximum flow and pressure. Span operation will be accomplished utilizing a minimum of two pumps selected such that in the event one pump fails the remaining pump can operate the span at a reduced speed. Span operation using vessel power will use one pump and a reduced span speed. Pump power is to be selected to produce a span lift speed of 5.75 ft/min. as measured at the lift cylinders. Span will be gravity lowered, but under the control of pilot operated check valves so that in the event of a fault in the hydraulic system or a power failure, the cylinders will lock.

    Pumps and control valves shall be selected so that electric motors are not started under load.

11. **Control Valves**

Control operating movement of hydraulic lifting systems electronically through solenoid-activated valves or valve stacks. Specify valves that are marine service rated if exposed to weather. Large cylinders shall be controlled through proportional directional control valves to control speed and acceleration/deceleration. The speed and acceleration/deceleration control ranges of the control units shall be sufficient to alter or limit the effects of operating vibrations and frequencies detrimental to component operation.

Include holding valves at all cylinder ports pressurized by carried loads. Provide valves which allow fluid release only for the following conditions:

a. Overpressure from impact or thermal pressure rise

b. Pilot signal descend command

Pilot signal ratios are to be such that the valves do not open at excessive rates and do not require excessive pilot pressure.

Require holding valves that allow free flow in reverse direction.

Solenoid valves protected from the weather shall have lighted plugs. Solenoid valves exposed to the weather shall have conduit connections. Plug connections shall not be allowed.

Cartridge valves shall be made of stainless steel.

12. **Pump Motors**

All motors shall comply to NEMA dimensional standards. Motors to be three phase, squirrel cage induction type. Pump motor power is to be determined by the design.

13. **Hydraulic Fluid Reservoir**

Design fluid reservoirs in compliance with ISO 4413:2010, Hydraulic fluid power – General rules and safety requirements for systems and their components and the following additional requirements:

- **Baffle** – Baffle the reservoir between the suction and return lines.
- **Cleanout access** – Reservoir is to have a cleanout access opening for cleaning and inspection purposes that allows access to both sides of the baffle(s). Locate a drain at the lowest point on the reservoir sloping bottom. Equip drain with a ball valve that is plugged.
- **Material** – Specify reservoirs be fabricated from 316/316L stainless steel and welded with corresponding materials. Covers are to be fabricated with not less than 3/8 inch thickness.
- **Capacities** – Unless heat loss calculations dictate otherwise, size reservoirs to hold the equivalent of 2 minutes of maximum combined pump capacity in addition to the combined swept volumes of all cylinders rods plus 10 percent and, if applicable, to include provisions for any local conditions such as installation at a non-horizontal angle or installation on a moving ramp that results in a fluctuating angle.

- **Intake lines** – Design intake lines for the minimum velocity possible, less than 4 feet per minute (FPM). Ensure the intake line opening is submerged 1.75 to 2 times the intake line inside diameter. Use bell mouth openings on suction pipes to reduce intake velocity, ensure that the intake pipe is 5 to 6 times the pipe ID away from the nearest wall on at least one side and ensure that the intake pipe is no closer to the reservoir bottom than the pipe ID/2.
- **Calculations** – Heat loss calculations are to be supplied with the calculation package.
- The hydraulic fluid reservoir shall be a heavy duty design and constructed of stainless steel conforming to ASTM A276, Type 316L. Volumetric capacity of the reservoir will be determined by the design. The reservoir shall feature a desiccant type breather system to prevent water contamination due to the ingress of moist air.
- The hydraulic reservoir tank shall be fitted with a 10 micron return line filter placed in a location allowing ready access for replacement. Filters shall be fixed for a 5 psi pressure drop at 70 degrees F and shall be fitted with visual element condition indicators.
- Provision of a small continuously running filter circulation pump is desirable.

14. **HPU Enclosure**

The HPU enclosure will be constructed with an oil sump capable of containing oil spillage up to the volume of the hydraulic tank. The enclosure will be mounted on the trestle, preferably on the right hand side of the transfer span adjacent to the bridge seat.

The hydraulic power unit will be located as appropriate for the site but in each case to minimize environmental risks to the cabinet and piping.

15. **Tubing, Pipe, and Fittings**

Hydraulic tube inside the HPU shall be seamless, annealed, 316L SST tube per ASTM A269. Sizes shall be (OD x min. wall): 1 x .109, 1.25 x .120, 1.5 x .156, 2 x .188.

Hydraulic pipe shall be 316L SST SCH 80 pipe per ASTM A312 passivated per Alaskan Copper and Brass “Procedure for Passivation” No. N706. After passivation, the pipe shall be protected from contact with carbon steel at all times. This includes contact with airborne particles produced by machining and blasting operations, carbon steel tools, and other tools, rags, grinding wheels, abrasives, etc. that may have been contaminated with carbon steel particles.

After passivation, the stainless steel pipe that is to run transversely under the transfer span shall be solvent cleaned, blast cleaned and painted with a marine grade protective coating. For the purposes of this requirement, references to pipe include the end flanges. The mating surfaces of the end flanges shall not be coated.

- Follow the surface preparation and product application procedures recommended by the paint manufacturer for stainless steel.
- The pipe shall be solvent cleaned per SSPC-SP 1 using a non-chlorine and non-salts containing solvent. The solvent used shall be compatible with the coating and approved by the coating manufacturer.

- The pipe shall be brush-off blast cleaned per SSPC-SP 16 using virgin garnet abrasive to obtain the surface profile recommended by the coating manufacturer.
- Apply protective coating as soon as possible after blasting.
- The pipe shall be coated with a minimum of two coats high build, high solids, marine grade, epoxy coating acceptable for immersion use in salt water. Final dry film thickness (dft) shall be as listed below.
- Acceptable coatings include: Macropoxy 646 Fast Cure Epoxy manufactured by Sherwin Williams, final dft 8-12 mils; Interzone 954 Epoxy manufactured by International, final dft 20-24 mils; Amerlock 2 Epoxy manufactured by PPG, final dft 8-12 mils; and other coatings as approved by the Engineer.
- Any damage incurred by the coating during the course of the project shall be repaired immediately.

Pipe and tube fittings shall be stainless steel. Fittings up to and including 3/4 inch in diameter shall be Parker Ferulok three piece bite type fittings or SAE Code 61 four bolt flange fittings welded directly to tube/pipe ends. Fittings 1 inch in diameter or greater shall be of the 4 bolt flange type (code 61). Welding of fittings to pipe or tube ends shall be per ASME B31.3 Chapter IX, High Pressure Piping.

Hose fittings shall be of the o-ring face seal type or SAE Code 61 four bolt flange fittings constructed of carbon steel.

16. **Hydraulic Hose and Fittings**

All hydraulic hose except for suction hoses shall be rated for a minimum of 3,000 psi working pressure. All hoses are to be the no skive type.

Except for the ¾” hose connected to the apron lift cylinder, all high pressure hose shall be Parker 782TC. The ¾” hoses connected to the apron cylinder shall be Parker 451TC.

All hose assemblies (hose with attached end fittings) shall be pressure tested to 1.5 times their rated working pressure before installation into the system.

Hose fittings shall have the same pressure rating as that of the hose used, as a minimum. Hose fittings shall be the o-ring face seal type or SAE Code 61 four bolt flange fittings. All hose fittings shall be plated carbon steel and crimped onto the hose.

All hose fitting or attachment bolts are to be tightened to the manufactured specified torque for the particular size and style of fitting used.

All hydraulic hose and hose fittings used in an installation are to be the same model number when possible.

Require all hydraulic hose assemblies to have metal tags attached defining pressure rating, length and installation date.

All hydraulic hose will be replaced five years after the date of installation unless inspections determine that replacement of the hose is required earlier.

Provide Partek abrasion sleeves on all hoses connected to moving components.

All hose fittings shall be wrapped with petrolatum impregnated tape after final inspection.

(g) Hydraulic Maintenance Requirements

The incorporation of the standard design features will allow the existing maintenance procedures and schedules to be used on the new installation.

Isolation valves shall be incorporated into the design to allow removal of major components without draining excessive amounts of hydraulic fluid. Lifting lugs shall be provided on the structure above all components weighing over 75 lbs.

The following parts are proposed as sole-source components.

- Tube fittings: Parker Ferulok type up to and including 3/4 inch in diameter.
- Hose fittings: Parker Seal-Lok o-ring face seal type
- Hydraulic components: as shown on the plans.
- High pressure hoses: Parker 782TC and Parker 451TC.

(h) Hydraulic Testing

1. **General**

   All components and sub-assemblies shall be tested by the contractor and inspected by WSF Terminal Engineering before being installed in the field.

2. **Component Testing**

   Key critical components or long lead items that are not easily replaced or substituted shall be tested by the manufacturer and inspected by WSF Terminal Engineering before the component is shipped to WSF or a WSF Contractor.

3. **Shop Testing**

   All Contractor manufactured hydraulic components shall be shop tested. Sub-assemblies, tanks, manifolds and valves shall be tested before final assembly in the HPU or in the OHL structure. Valve settings and flow controls shall be tested and set in the shop prior to installing in the HPU or in the OHL structure. In addition, the completed HPU shall be shop tested before being installed or sent to the terminal site.

5. **Yard Testing**

   The system shall be tested to the maximum extent possible in the Contractor's yard before being moved on site.

6. **Field Testing**

   Once the structure is installed at the terminal site, and the HPU field connections are completed, the hydraulic system shall be tested again following the requirements in the contract specifications.

(i) Alarms and Monitoring

The mechanical designer shall work with the electrical designer in identifying required controls and indication and providing necessary hardware to achieve them.

Alarm Conditions shall be displayed on the message screen on the HPU Operator Control Station and illuminate the alarm light on the span control panel.

Shutdown Conditions shall stop all movement by de-energizing all equipment and valves. Shutdown Conditions shall be displayed in the message screens on the Operator Control Stations and illuminate the shutdown light on the span control panel.

In addition to displaying Alarm and Shutdown messages, the message screens will also display System Status messages.

610.09 Electrical Design Criteria

(1) General

This section provides a description of the electrical systems used in connection with vehicle hydraulic transfer span (H-Span) design. The H-Span electrical design will be provided by WSF Terminal Engineering. Refer to Chapter 360 for additional information including VTS lighting requirements.

Refer to Chapter 360 for non-H-Span transfer span electrical criteria.

(2) Power System Overview

The key components of the transfer span power system are listed and described below.

(a) Junction Box JB-T1 (For Electrical Service from Left Side)

The on-shore electrical service power feed comes onto the transfer span at junction box JB-T1. The power feed is 480V, 3-phase. JB-T1 is located on the outside of the left guardrail near the bridge seat.

(b) Junction Box JB-T2 (For Electrical Service from Right Side)

For electrical service coming from the right side, the power feed comes onto the transfer span at junction box JB-T2. JB-T2 is located on the outside of the right guardrail near the bridge seat.

(c) Vessel Backfeed Cord and Plug

A 480V, 3-phase plug on the end of a 100 foot cord is located on a rack on the left guardrail near the apron. The plug connects to a receptacle on the car deck of ferries and is used to connect vessel power to the transfer span power system.

(d) Manual Transfer Switch (MTS-1)

The onshore electrical service power feed and the vessel backfeed are each routed to a manual transfer switch, MTS-1, located on the inside of the left guardrail. MTS-1 is used to transfer from the onshore service power to vessel power if the onshore service is not available. MTS-1 will normally be connected to the onshore electrical service feed. Moving the handle on MTS-1 to the center position disconnects the transfer span power system from both services.

(e) Motor Control Panel (MCP)

The power feed is 480V, 3-phase from MTS-1. The panel contains the breakers and controls for the HPU motor starters (M1), (M2) and (M3), as well as the breaker for transformer 41T-HPU which serves panelboard 1P-HPU.

The MCP panel is located in the HPU enclosure. See below for a description of the HPU enclosure.

1. **HPU Motor Starter (M1) Section**

   HPU Motor Starter (M1) is an IEC type motor starter rated 480V, 3-phase. It is fed from MTS-1 through the MCP main breaker. M1 is connected to a 30 HP HPU pump motor in the HPU enclosure. The control contact that operates the contactor comes from the PLC cabinet. Control power for the contactor also comes thru the PLC cabinet from panelboard 1P-HPU.

2. **HPU Motor Starter (M2) Section**

   HPU Motor Starter (M2) is an IEC type motor starter rated 480V, 3-phase. It is fed from MTS-1 through the MCP main breaker. M2 is connected to a 30 HP HPU pump motor in the HPU enclosure. The control contact that operates the contactor comes from the PLC cabinet. Control power for the contactor also comes thru the PLC cabinet from panelboard 1P-HPU.

3. **HPU Motor Starter (M2) Section**

   HPU Motor Starter (M3) is an IEC type motor starter rated 480V, 3-phase. It is fed from MTS-1 through the MCP main breaker. M3 is connected to the 20 HP HPU pump motor in the HPU enclosure. The control contact that operates the contactor comes from the PLC cabinet. Control power for the contactor also comes thru the PLC cabinet from panelboard 1P-HPU.

(f) Panel 1P-HPU

Panel 1P-HPU is a 120/240V panelboard fed from an adjacent 10 kVA single phase transformer. The transformer is fed from the motor control panel (MCP). Branch circuits from the panelboard provide 120V power for the PLC cabinet, range lights, cargo lights and control station light, fog light, gate motor, foghorn, duplex receptacles, and HPU enclosure lighting and duplex receptacles. Panel 1P-HPU and the transformer are located in the HPU enclosure.

(3) Vehicle Transfer Span Control System

The transfer span is normally operated from the bridge control station (1PBS) located on the left side of the bridge. There are individual pushbuttons on the front of 1PBS for BRIDGE UP, BRIDGE DOWN, APRON UP, and APRON DOWN. The pushbuttons connect as inputs to the PLC. The PLC is programmed to start the HPU pump(s) and open and close valves in the hydraulic system as required to move the bridge and apron. Exhibit 610-17 summarizes the control system.

Control System Component	Notes
Programmable Logic Controller (PLC)	Allen Bradley CompactLogix Control System
Panel View	On Bridge Control Station 4PBS Allen Bradley PanelView Plus 6 600
Bridge Control Station (1PBS and 4PBS) (Continued Below)	There are two bridge controls stations, 1PBS on the transfer span and 4PBS in the HPU Enclosure. On Bridge Control Station 1PBS, there are pushbuttons for: • BRIDGE UP • BRIDGE DOWN • APRON UP • APRON DOWN • ALARM SILENCE/RESET • GATE UP • GATE DOWN • GATE STOP There is a lighted pushbutton for: • EMERGENCY STOP There are indicating lights for: • MAINTENANCE REQUIRED • SHUTDOWN • APRON FLOAT On Bridge Control Station 4PBS, there are pushbuttons for: • BRIDGE UP • BRIDGE DOWN • APRON UP • APRON DOWN • ALARM SILENCE/RESET There is a lighted pushbutton for: • EMERGENCY STOP There is a selector switch for: • CONTROL POWER 1PBS ON – 4PBS ON
Attendant's Control Station (2PBS and 3PBS)	There are two attendant's controls stations, 2PBS on the transfer span and 3PBS by the traffic gate. On Attendant's Control Station 2PBS there are lighted pushbuttons for: • TRAFFIC STOP • TRAFFIC GO There is a selector switch for: • FOG LIGHT ON - OFF On Attendant's Control Station 3PBS, there are pushbuttons for: • GATE UP • GATE DOWN • GATE STOP There are lighted pushbuttons for: • TRAFFIC STOP • TRAFFIC GO There is a selector switch for: • FOG LIGHT ON - OFF

Summary of Transfer Span Control System
Exhibit 610-17

(a) PLC Cabinet

The PLC Cabinet contains the PLC, remote radio receiver, terminal boards, and counters required to control the bridge and apron.

(b) Bridge Control Station (1PBS)

The bridge control station contains the required pushbuttons and indicating lights for the control of the bridge, apron, traffic gate and trouble indicating light and audible devices associated with the transfer span. Refer to Exhibit 610-18.

(c) Attendant Control Station (2PBS)

The attendant control station contains the required pushbuttons and indicating lights for control of the transfer span miscellaneous systems (traffic signals, foghorn, and fog light). Refer to Exhibit 610-18.

Bridge Control Station and Attendant Control Station
Exhibit 610-18

(d) Attendant Control Station (3PBS)

The attendant control station contains the required pushbuttons and indicating lights for control of the transfer span miscellaneous systems (traffic signals, foghorn, and fog light).

(e) Bridge Control Station (4PBS)

The bridge control station contains the required pushbuttons and indicating lights for control of the bridge, apron, HPU and trouble indicating light and audible devices associated with the transfer span. Control station 4PBS is located in the HPU enclosure.

(f) Motor Control Panel (MCP)

The motor control panel contains the contractors, motor starters and terminal boards required for the operation of the motors associated with the operation of the transfer span.

(4) HPU Enclosure

The HPU enclosure is a freestanding self-contained enclosure containing the hydraulic manifold, valves, tank, filters, pumps, motors, tubing and hoses and the electrical panelboard, transformer, MCP cabinet, PLC cabinet, control station 4PBS and all associated junction boxes, devices, conduit, and wire. Mount the HPU enclosure on the trestle, preferably on the right hand side of the transfer span adjacent to the bridge seat.

(5) Remote Control

The H-Span is designed to allow the personnel on the ferry to adjust the transfer span via wireless radio remote control.