

# VERTICAL PLANAR MOTION MECHANISM (VPMM) SYSTEM

## **Vertical Planar Motion Mechanism (VPMM) System**

Technical Specification

Prepared for:  
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October 20, 2023

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## **VERTICAL PLANAR MOTION MECHANISM (VPMM) SYSTEM**

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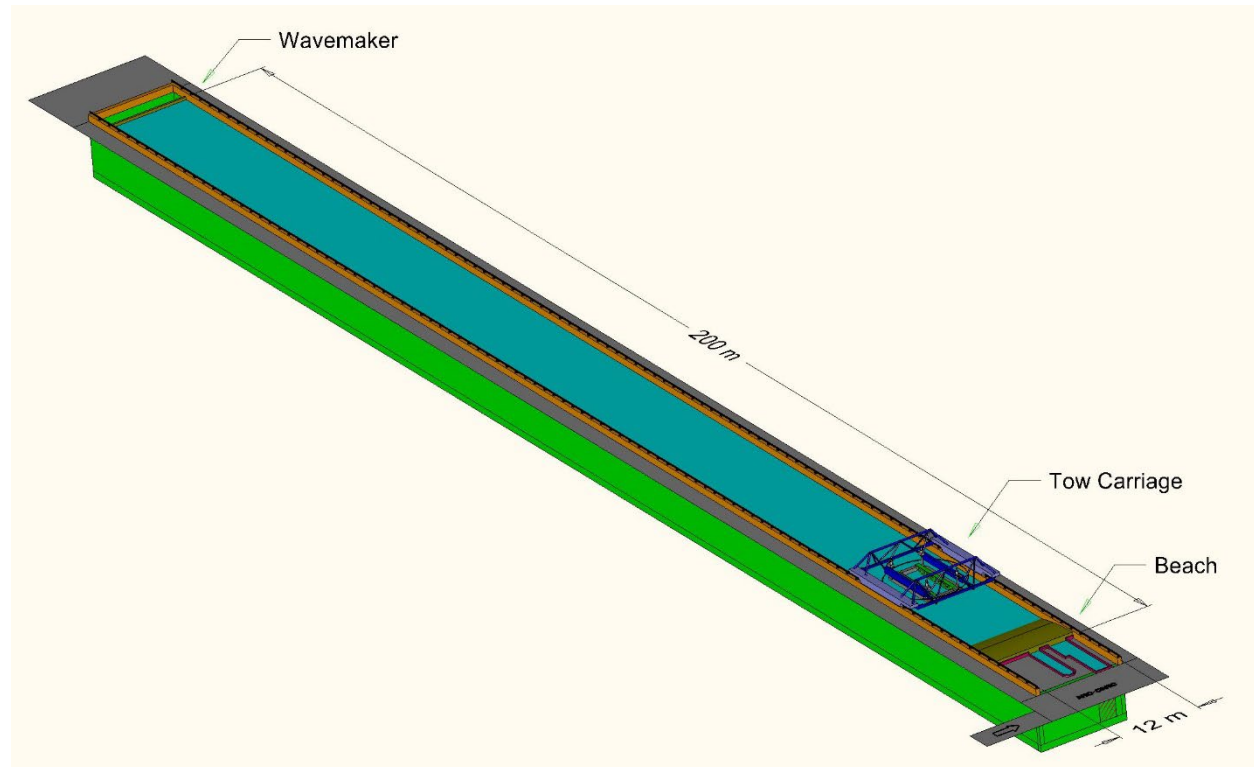
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## 1.0 INTRODUCTION

The National Research Council of Canada's, NRC, Ocean, Coastal, and River Engineering, OCRE, Research Centre in St. John's, NL, Canada requires a Vertical Planar Motion Mechanism (VPMM) for hydrodynamic research in its 200m long Tow Tank. Outline drawings of the tank, for illustration purposes only is shown in Figure 1.



**Figure 1 - Tow Tank**

The VPMM is purposed to move a model of an underwater vehicle in exact, pre-programmed motions of heave, pitch, and surge while forces and moments on the model, as well as the motion of the model, are measured and data recorded. The VPMM will mount to the machined test frame mounting rails of the tank carriage. An elevation view of the carriage, for illustration purposes only, is shown in Figure 2.

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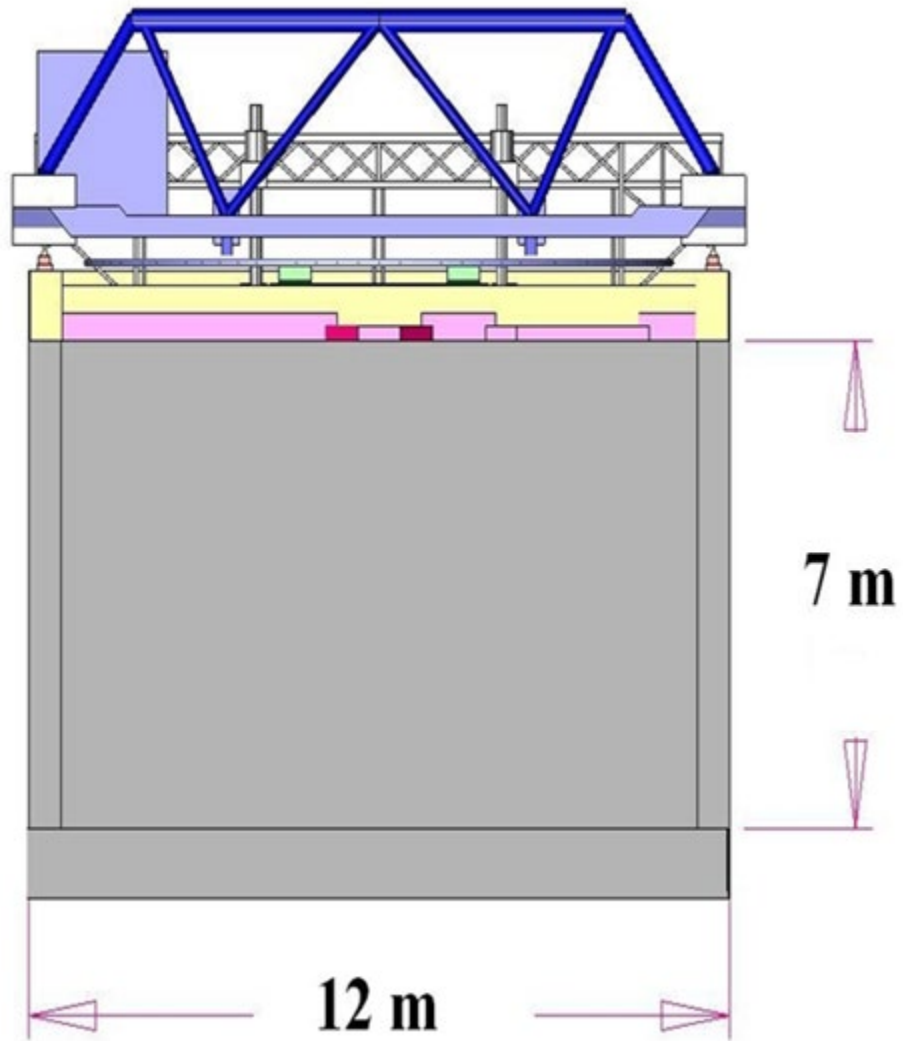


Figure 2 - Tow Tank Carriage Cross Section

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## 1.1 BACKGROUND

The Marine Dynamic Test Facility (MDTF) was developed in Canada in the 1990's, and then used for submarine model tests in the National Research Council (NRC) Clear Water Tank in St. John's, NL until 2010. It was used to force a submarine model through motions in five degrees of freedom at a Reynold's number of around 15 million. As a unique facility, around the world it supported Canadian researchers active in the field of submarine hydrodynamics during its service period. There has been a gap in submarine experimental study capability in Canada since the MDTF decommissioning in the early 2010's.

A concept design of Vertical Planar Motion Mechanism (VPMM) for NRC's towing tank was explored by NRC. The design of VPMM included three main assemblies: a motion mechanism, twin swords, and a dynamometer for the model global load measurement. The motion driving assembly enables the model testbed attached to the swords to perform predefined motion in the vertical plane. The swords rigidly support the model testbed allowing measurement of the forces acting on the model due to these movements.

## 1.2 EXISTING TOW TANK FACILITY

The existing tow tank facility is shown in Figure 3 and the tow carriage is shown in Figure 4. The carriage system was designed by Mitsui Engineering & Shipbuilding Co. Ltd. in 1984. Since it began operation, the testing facility has had modifications. Existing system mechanical, structural, PLC/controls, single line diagrams, and facility drawings are available for reference.

During a test, the carriage accelerates to a defined speed, maintains that speed for the duration of a test, and then decelerates to zero speed at the end of the tow tank. The carriage returns to the start position to run a subsequent test run. Tests are typically completed for approximately 2 months duration. On average, the carriage is run for 10 cycles per run, 4 runs per hour, 12 hours per day, 40 days per experiment, and one experiment per year. Therefore, the carriage duty cycle specification is approximately 19,200 cycles per year. After which, the testing equipment will be removed from the carriage and different equipment will be installed for testing. Each arrangement of testing equipment is typically used by NRC every year.

The model test frame includes 2 mounting rails that can be horizontally and vertical adjusted for different sized test models. The mounting rails are parallel with the tow tank.

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**Figure 3 - Tow Tank Facility**

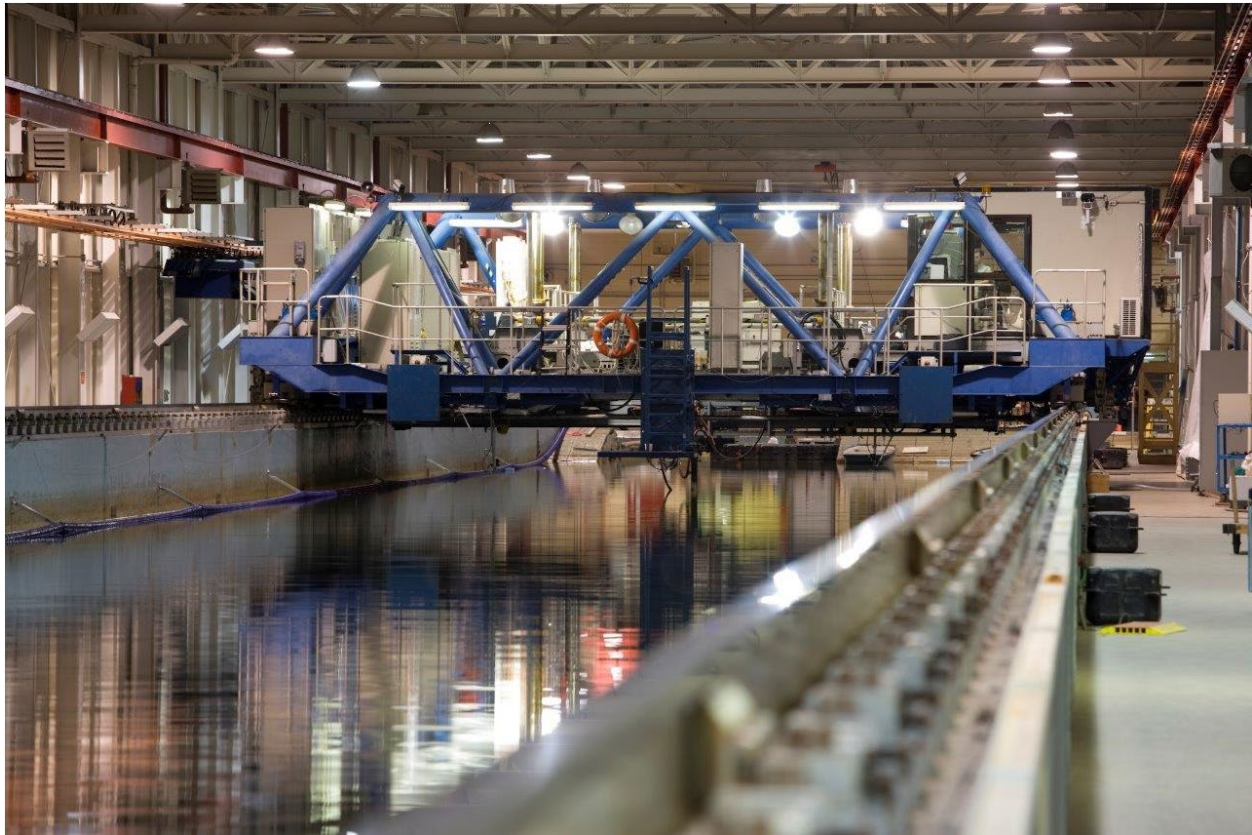
Tow Tank Carriage Operation Limit Parameters are as follows:

Suspended model weight tow tank frame	6000 kg
Test equipment weight tow tank frame	6000 kg
Test frame side thrust	1000 kg
Inertial force on 12000kg model e- stop 0.3g	4000 kg
Model drag torque for test frame	3000 kg-m
Test frame drag force from model	2000 kg
Test frame uplift	8000 kg
Carriage speed	0-10 m/s
Carriage Acceleration	1.0 m/s <sup>2</sup>
Max e-stop	0.3 g

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Electrical power available to the tow carriage is 100A 120/208V/60Hz 3P4W and 1600A 480V/60Hz 3P4W. New motion control panel and PLC is planned to be fed from a 225A 480V/60Hz/3P3W enclosed fused disconnect (400AF, 225AT); laptop in the control room can be fed from a dedicated 120V 15A breaker as required from "Instrument Panel B".



**Figure 4 - Photo of Tow Tank Carriage**

The test facility is serviced by a 5000 kg capacity top running overhead crane. Specifications for this crane are shown in Table 1. The crane can be used to load some equipment (e.g. electrical cabinet) onto the tow carriage. However, clearance between the crane hook and tow carriage is limited. NRC can demonstrate the crane's range of motion on-site.

NRC uses the trim docks (beach) located at the end of the tow tank to allow larger equipment to be installed / removed onto the tow carriage from below. Equipment can be raised onto the tow carriage from an opening in the center. NRC anticipates that the VPMM swords and sub model assemblies will need to be mounted to the tow carriage in this manner.



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Crane capacity	5,000 kg
Crane Classification	CMAA Class 'C'
Crane Span	~ 60'
Main Hoist Capacity	5,000 kg
Main Hoist Height of Lift	5.7 m (6 m available on hoist)
Main Hoist Lift Speed	6/1 m/min 2 Speed
Trolley Travel Speed	2-20 m/min Stepless
Bridge Travel Speed	3.2-32 m/min Stepless
Power Supply	600 V/3 Ph/ 60 Hz
Control Power	120 VAC
Control Type	Radio Remote w/ Back Up Hardwired Pendant
Finish	As Per Spec, Safety Yellow

**Table 1 - 5 Tonne Top Running Single Girder Overhead Crane Specifications**

### 1.3 OBJECTIVE

The concept model, including the NRC-provided supports and sub frame, is shown below in Figures 5 and 6. Appendix A includes an illustration diagram of the components comprising the VPMM concept. Drawings of the VPMM concept are included in Appendix B. The supplier will be provided a copy of NRC's mechanical concept design as a basis for completing the detailed design of the VPMM system. The supplier's scope of services for this contract includes, but is not limited to, the following:

- Project management
- Detailed design, including calculations and analyses
- Procurement and fabrication of materials
- System assembly and testing
- Equipment installation
- Commissioning of equipment
- Operator training

Final deliverable is a fully functional VPMM system installed on the tow carriage at NRC's facility in St. John's, NL.

The VPMM will be installed on the existing tow carriage test frame as a temporary installation. The VPMM will be one of several major test support equipment systems to be used on the tow carriage. As such, there is a design requirement to make the system easy to install and commission, and un-install and decommission. The VPMM cannot be a permanent installation on the test frame. Provisions for frequent removal and storage of the VPMM equipment is a requirement with this contract.

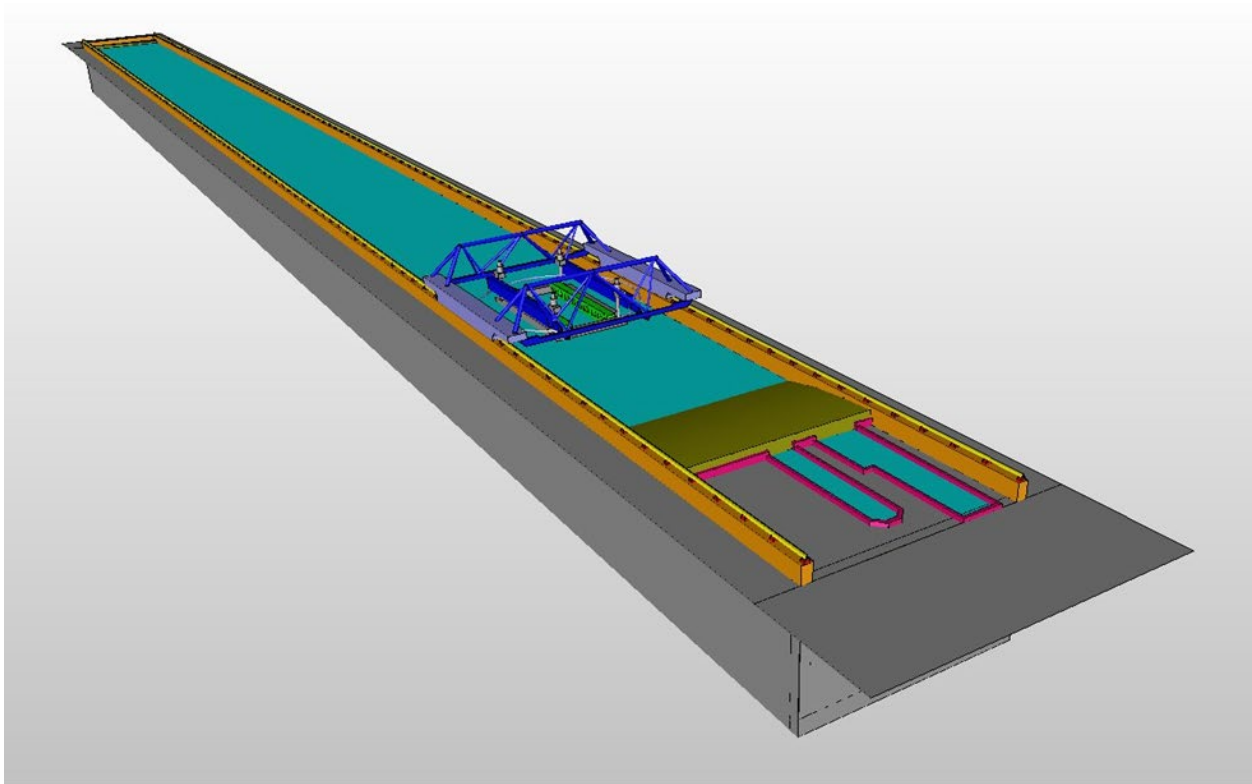
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The intention is for the VPMM to be programmed for various motion profiles of the model testbed, or sub model. Different sub models will be tested over time. The initial sub model is being developed by NRC so currently only a representative central frame is shown for the sub model at the bottom of the VPMM system in Figure 6. A control system panel and laptop will be provided by the supplier to allow the client to operate the system and program the various motion profiles of the VPMM. The control system will be open architecture to allow the client to adapt the system to different motion profiles.

Sub model motion will be limited to 3D freedom on a 2D plane which will be in the same direction of the tow tank carriage. To achieve this, NRC's concept includes three (3) actuators – one (1) horizontal (surge) actuator and two (2) vertical (heave) actuators. VPMM motion will be cyclic (i.e. repeated) during the carriage test run. Motion profiles will include the following:

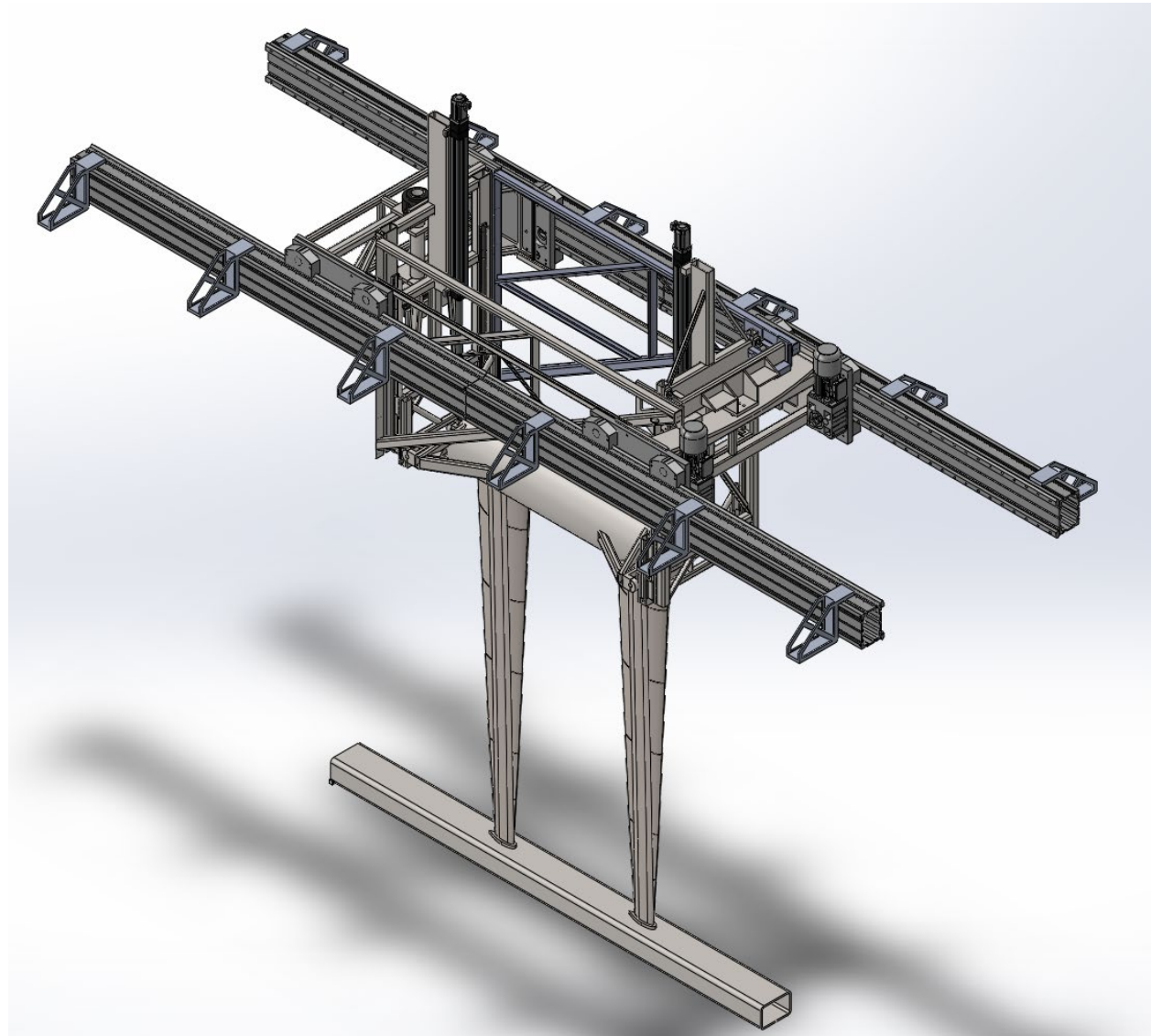
- Horizontal movement only (Pure Surge)
- Vertical movement only (Pure Heave)
- Combined, surge and heave, complex motion (Pitch)



**Figure 5 - Tow Tank with Tow Carriage**

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**Figure 6 - VPMM Mechanical Concept (Tow Carriage Removed)**

The supplier will be required to produce a specific motion profile of the VPMM system, called Pure Pitch, when it is installed on the tow tank carriage. Pure Pitch is defined by the sub model pivoting  $\pm 20^\circ$  about the sub model center point with the sub model centerline 2,500 mm below water level. The sub model will undergo a sinusoidal Pure Pitch motion at a frequency of 0.26 Hz. Pitch period, or one (1) full cycle of motion, is 3.85 seconds. Pure Pitch motion, with respect to the sub model, is achieved via complex motion of the surge and heave actuators comprising the VPMM system. It is imperative that the sub model follow a sinusoidal Pure Pitch motion profile. It is important to note that due to the complex geometry of the VPMM system, each

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actuator will follow a motion profile that is like a combination of one or more sinusoidal profiles of different frequencies and amplitudes, but this motion will not be a true sinusoidal profile.

Following Site Acceptance Testing (SAT) and operator training by the supplier, NRC will assume ownership of the VPMM system. NRC plans to develop different sub model tests that will follow a variety of motion profiles.

### 1.4 DESIGN PARAMETERS

NRC performed calculations to estimate the kinematics and dynamics of the concept VPMM system. Equations were developed to calculate predicted driving speed, force, and power of the individual motion mechanisms – surge carriage and two vertical (heave) actuators. A copy of NRC's estimated capacity calculations of the VPMM system is provided in Appendix C. These calculations account for effects due to the acceleration of the system mass, or Newton's second law ( $F=ma$ ), as well as hydrodynamic and hydrostatic loads imparted on the VPMM system from the sub model and sword assembly movement in the tow tank. Hydrodynamic loads are based on the anticipated maximum tow tank constant carriage testing speed of 3 m/s.

Below is a summary of the design parameters (estimated) for each actuator comprising the VPMM system for the Pure Pitch sinusoidal sub model motion profile:

Surge:  $\pm$  x-direction motion:

Stroke: 2.375 m

Amplitude: 1.188 m

Maximum Velocity: 1.96 m/s

Maximum Acceleration: 3.2 m/s<sup>2</sup>

Heave:  $\pm$  y-direction motion (2 actuators):

Stroke: 0.75 m

Amplitude: 0.375 m

Maximum Velocity: 0.825 m/s

Maximum Acceleration: 1.81 m/s<sup>2</sup>

The drawings of the VPMM concept provided in Appendix B include anticipated displacement limits for each actuator axis. The drawings also show the required  $\pm 20^\circ$  Pure Pitch motion. Below is a summary of actuator limits for clarity:

Surge:  $\pm$  x-direction motion: Total Stroke: 3.8 m

Heave:  $\pm$  y-direction motion (2 actuators): Total Stroke: 1.0 m

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Pitch steady state angular velocity: Minimum of 32.7 degrees/sec

Pitch angular acceleration/deceleration: Minimum of 53.4 deg/sec<sup>2</sup>

Estimated mass (in dry air) of components comprising the concept VPMM system are provided below:

Submarine body including dynamometer	550 kg
Sword mass - 2 swords	600 kg total
Heave pipe including heave bearing bracket	500 kg
Yaw box	406 kg
Heave frame	994 kg
Surge bearing	1200 kg
Total moving mass pitch/heave	1650 kg
Total moving surge mass	4250 kg
Total system mass including surge rails	4950 kg

Items not considered in the mass calculations:

- Electrical cables for sub model data acquisition and power
- Electrical cables for actuator control systems
- Wiring harnesses, cable trays, energy chains, junction boxes
- Fasteners
- Weldment material
- Mass of water. NRC estimates mass of water that will flood the sub model and swords will be 1150 Kg.

The document in Appendix D graphically describes the estimated mass (in dry air) of VPMM components and the calculated design loads on the VPMM concept system. Stated hydrodynamic drag loads are calculated peak values. These forces acting on the VPMM will be cyclical due to the sinusoidal Pure Pitch motion of the VPMM system.

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Information and Equipment Supplied by Owner  
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### 2.0 INFORMATION AND EQUIPMENT SUPPLIED BY OWNER

1. Owner will design and fabricate the sub model and the swords. The scope of this contract is limited to the VPMM motion driving assembly.
2. Owner will provide design reaction loads and deflection limits at the sword connection points to the heave pipe.
3. Owner will provide any other loading criteria important for design considerations of the planned and future operating conditions of the VPMM.
4. Owner will provide available electrical, mechanical, and structural drawings for the existing tow tank carriage system.
5. Owner will provide performance limits (e.g. speed and load ratings) of the tow tank carriage.
6. Owner will provide the VPMM 3D concept models in SolidWorks or STEP format.
7. Electrical documentation to be provided will include the following:
  - a. The Owner will provide the specification for the number and size of conductors to be provided by the Contractor to run through the VPMM Motion mechanism, between the VPMM TOP Junction Box and the FORWARD / AFT SWORD junction boxes. These are expected to be "infinite flex" cables. Components will be designed to endure the specified number of annual cycles with a replacement time frame of 20 years.
  - b. The Owner will supply the specification for the number and type of connectors to be provided by the Supplier in the VPMM TOP junction box. Supplier to provide VPMM TOP junction Box complete with connectors and glands.
  - c. The Owner will supply the specification for the number and type of connectors to be provided by the Contractor in the AFT SWORD and FORWARD SWORD junction boxes, which are both located on the top of the vertical sword assembly. These AFT SWORD and FORWARD SWORD junction boxes are fed from the VPMM TOP junction box. Supplier to provide both AFT and FORWARD SWORD junction boxes complete with required connectors and glands.

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### 3.0 SUPPLIER'S SCOPE OF WORK

The Supplier will provide a completed design meeting or exceeding full functionality and structural stiffness/rigidity of the provided concept model. This will include, but is not limited to, manufacture and delivery to the NRC facility in St. John's, NL, with participation in initial assembly on site, and further participate in, commissioning, and acceptance testing of the VPMM equipment as required. Supplier is also required to deliver a complete set of documentation for the solution, and to train operations personnel in the use of the complete working VPMM System. Supplier is also to provide maintenance training and to provide full O&M manuals for the final solution. Supplier to provide a full functioning system.

### 3.1 MAJOR COMPONENTS

Major VPMM components include but are not limited to:

1. Mechanical
  - a. Heave/Pitch frame, bearings, shafts, bracketing, and heave pipe components.
  - b. Heave cage, linear rails, actuators and bearing components.
  - c. Yaw cage, bearing, clamping, and alignment components.
  - d. Surge cage, bearings, drive unit components.
  - e. Surge drive rails, mounts, alignment components.
  - f. Frame for the VPMM system when not installed on the NRC tow carriage.
  - g. Any required special tools.
2. Electrical/Controls
  - a. Supply of VPMM control panel and control laptop.
  - b. Replacement of 400A fuses with 225A Class J time-delay fuses in existing 400A fused disconnect.
  - c. Supply of new VPMM control panel.
  - d. Cabling from existing fused disconnect to new VPMM control panel.
  - e. Supply of three axis controls. Each axis will consist of the following: single-axis motion drive, servo, absolute encoder / resolver, two (2) hardwired solid-state overtravel switches.
  - f. Supply panel cooling as required to dissipate heat from drives and systems. Supplier to allow for natural conduction from panel surfaces in an environment with maximum continuous ambient temperature of 30°C. Design to provide additional forced ventilation / air conditioning as required per the internal heat rejection of the selected components.
  - g. Cable trays and energy chains and all required components to connect the VPMM panel components to the VPMM Motion Mechanism.
  - h. Interface cabling from VPMM control panel to Model Support Box.

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- i. Supplier to provide emergency stop (6C) and EtherNet (4-pr) cables
  - ii. IP66 quick connects (Amphenol Mil-97 connectors) to be provided by the supplier at both ends of these cables.
  - iii. IP66 mating connectors in the VPMM panel to be provided by the supplier. Mating connector at the Model Support Box to be provided by Owner but with coordination with the Supplier.
- i. Hardware interface from control panel to VPMM motion systems.
  - i. Servo motors, absolute encoders / resolvers, overtravel switches, and cables for a complete motion system.
  - ii. All hardware and components including raceways (cable tray, energy chain, cable channels) for these motion components.
  - iii. Quick connects on the motion cables exiting the control panel. These will be supplied in a watertight (IP66) configuration. Utilize heavy duty connectors from: Harding, Phoenix Contact or Weidmuller.
- j. VPMM TOP junction box and energy chain.
  - i. Junction box to be fixed on the tow carriage for Owner cabling terminations.
  - ii. Energy chain between VPMM TOP junction box and FORWARD / AFT SWORD junction boxes.
  - iii. Junction box to be of stainless steel metallic construction and to allow for termination of box-mounted connectors J27P, J28P, J29P and J30P.
  - iv. Cables to exit the VPMM junction box via cable glands / strain reliefs and to be routed through the energy chain, then to the moving VPMM surge axis platform, and then through cable glands to the FORWARD and AFT SWORD junction boxes.

### 3.2 DETAILED SCOPE OF WORK:

- 1. General
  - a. The design of the VPMM will demonstrate methods, overall approach, and key technologies to be used to meet specifications in this document.
  - b. Supplier must provide milestone dates along with scheduled progress updates for mechanical and electrical/controls system design and integration, procurement, manufacturing, testing, delivery, installation, and commissioning of a completed VPMM system at NRC's facility in St. John's, NL.
  - c. The NMS Specifications provided in Appendix E shall apply to this contract. In the event of a discrepancy between this document and the NMS specifications, this document takes precedent.
  - d. Supplier to manage any sub-contracts in relation to completion of this project. Any planned sub-contractors to be identified in the supplier's bid submission.



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- e. Digital copies of the design documentation including as-built drawings, calculations, specifications, FEA reports, 3D Solidworks or STEP model files, AutoCAD and O&M manuals to be provided by the supplier.
  - f. Supplier must provide Safety Operations reports, evaluating health, safety and environment risks related to machine/human, machine/machine, and machine/building interfaces.
  - g. All equipment signs and labels shall be bilingual.
2. Mechanical
- a. Supplier to use NRC CAD model and drawings of proposed VPMM to produce a design to meet or exceed functionality of the concept model provided.
  - b. Design must adhere (as a minimum) to envelope of motion, velocities and accelerations prescribed in this document and to NRC supplied drawings.
  - c. The supplier is responsible for matching the sword flange interface connection and fasteners that will be supplied by NRC post contract award.
  - d. Supplier to develop a sword flange interface connection for forward and aft sword adjustments. The forward sword adjustment range is +/- 3 cm about nominal center of the flange mounting pattern (along the tank, x-axis). The aft sword adjustment range is +/- 2 cm about nominal center of the flange mounting pattern (across the tank, y-axis).
  - e. Supplier must provide FEA analysis reports of the completed model using applied loading criteria supplied herein, along with required factor of safety for structural integrity of the complete functioning design. Reports to be submitted for review to NRC prior to procurement and manufacture of materials.
  - f. Supplier to complete dynamic and modal analysis to determine natural frequency(s) of the VPMM.
  - g. The VPMM must be able to be broken down (sectioned) into constituent parts for storage.
  - h. A frame must be designed and fabricated for the purpose of storing the VPMM system when not installed on the NRC tow carriage.
  - i. Points ensuring balanced lifts must be integrated into the parts of the final design. Examples include eyebolts, lift rings, mounting pads, or combination of these that are agreeable to NRC.
  - j. Assembly instruction of the equipment must be provided including, but not limited to, bolt torques and alignment procedures that may be necessary for site Installation.
  - k. Supplier is responsible for design and fabrication of a 'mock' sub model and swords assembly that will be used to account for the weight of the actual sub model and swords during Factory Acceptance Testing (FAT) and Site Acceptance Testing (SAT).
    - i. 'Mock' assembly to be constructed using commonly available steel plate and structural shapes.

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- ii. 'Mock' assembly shape does not need to approximate the actual sub model and swords.
    - iii. 'Mock' assembly to be painted the same as other components of the VPMM system.
  - l. The major fabricated components of the VPMM (e.g. frames and weldments) to be constructed from carbon steel.
  - m. All fabricated components of the VPMM to be painted blue, matching existing equipment on the NRC tow carriage.
    - i. Carbon steel to be painted for marine environment.
    - ii. Aluminum to be anodized.
    - iii. Machined surfaces, pins, fasteners, and linear rails are not to be painted. All hardware to be corrosion proof.
- 3. Electrical/Controls
  - a. Systems Overview (Refer to Appendix F for concept electrical sketches)
    - i. Add a new control panel on the tow carriage. This will house a new PLC, three (3) to four (4) new motion drives [design dependent], one (1) door mounted Human Machine Interface (HMI), one (1) door mounted emergency stop mushroom head operator and one (1) emergency stop rearm push button light.
    - ii. New control panel will be provided with 480VAC 3-ph electrical distribution with a maximum short-circuit rating of 25kA. The panel and components must be appropriately rated to support this available short circuit energy.
    - iii. Add a new SCADA laptop computer and display in the control room for entry of motion profiles, diagnostics, trending / logging of information, etc.
    - iv. New motion axes:
      - One (1) horizontal axis for "SURGE". This will consist of one (1) or two (2) (supplier to confirm design) independent motion drives and servo motors operating in unison for a combined motion of this axis.
      - Two (2) Vertical axes:
        - a. Front vertical axis for "HEAVE" motion
        - b. Back vertical axis for "HEAVE" motion
    - v. Each controlled axis will be configured with a single servo motor with multi-turn absolute encoder (or resolver) feedback. Re-homing of each of the axes after electrical power-up / restoration is not permitted.
    - vi. Each axis will be configured with two (2) hardwired normally closed solid state proximity detectors for overtravel, wired directly to the motion drive, immediately stopping motion in that direction. Overtravel switches will be tested for operation and secured to ensure that these do not move without tools.
    - vii. All cable management, power and data cables and runs are correctly sized, and connector terminated (not permanently hard wired) and

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- ensure length so there is no cable strain through the range of motion of the VPMM.
- viii. The VPMM must be able to be broken down (sectioned) into constituent parts for storage. The VPMM electrical cabinet is the only exception and shall be permanently installed on the tow carriage.
  - ix. Test data collection to be the responsibility of Owner with a representative from the supplier to be present on site for initial installation/commissioning.
  - x. Power equipment, actuators and motors suitable to Canadian codes must be used.
- b. Available Electrical Supply
- i. 480V (3P4W) electrical power is supplied to the tow carriage through the following path:
    - 1500kVA 12.47kV/600V  $\Delta$ -Y transformer with solidly grounded secondary connection
    - 1500kVA 600V/480V Y-Y Autotransformer
    - One (1) 3P 1600A circuit breaker
    - Four (4) 1600A fixed busbars
    - Four (4) brushes affixed to the tow carriage
  - ii. 120/208V (3P4W) electrical power is supplied to the tow carriage through the following path:
    - 1500kVA 12.47kV / 600V  $\Delta$ -Y transformer with solidly grounded secondary connection
    - 112.5kVA 600V / 120/208V  $\Delta$ -Y transformer with solidly grounded secondary connection
    - One (1) 3P 100A circuit breaker to the fixed busbars
    - Four (4) brushes affixed to the tow carriage
    - Routing to "Instrumentation Panel B" in the tow-carriage mounted control room. This is a Westinghouse NBA Panelboard, 90A 120/208V 3P4W with 28 spare locations for 1P breakers.
  - iii. VPMM 480V power supply – fused disconnect:
    - Power for the VPMM Motion Mechanism control panel will be obtained from an existing 400A 480V 3P3W fused disconnect switch. There is no neutral feeding this panel.
    - Fused disconnect is Siemens Cat No. ID365. Nameplate rating 600VAC Max, 400A, 3-ph, NEMA 1.
    - This fused disconnect is hp rated for 250hp (max) or 100hp (standard) at 480VAC 3-ph.
    - This fused disconnect is fed with 3 X 300kcmil Teck90 1000V cables, one per phase, terminating in a 600V 400A disconnect switch on

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the tow carriage. Free-air spacing is not maintained for these supply conductors.

- This fused disconnect is also fed with a #3/0 AWG bonding conductor which is terminated inside the enclosure to the frame.
- The Supplier will replace the existing Littlefuse JTD400 (400A Class J time delay fuses) with 225A Class J time delay fuses. These 225A fuse dimensions are the same as the existing 400A fuses and will provide a direct replacement using the existing fuse clips (Supplier to confirm).



- c. Interface with Owner-Supplied Systems
  - i. Owner-supplied systems include the following components:
    - Four (4) dive planes
    - Two (2) rudder servos
    - One (1) propellor servo
    - Submersible vessel
    - NRC MODEL Support enclosure, mounting, cabling and connectors.
    - Sword components downstream of the FORWARD and AFT SWORD junction boxes.
    - Information for required cabling into the VPMM TOP junction box and then to the FORWARD and AFT SWORD junction boxes.
  - ii. Cabling to these systems includes the following:
    - 240V 30A power cable to the propellor
    - Feedback cable from the propellor servo
    - EtherNet cables
    - 120VAC AC distribution cables
    - Systems outside the "red" box as depicted in Appendix G, including the following:
      - a. MODEL support junction box and associated cabling, socket connectors
      - b. Pin connectors and cabling interfacing with FORWARD and AFT SWORD junction boxes (J35p, J36p, J37p and J38p) through the sword and to submersible equipment.
- d. Supplier provided systems / requirements:
  - i. All cables, connectors, supports between the VPMM Motion Mechanism new main control panel and the VPMM Motion Mechanism (servos, encoders, overtravel, etc.)

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- ii. Power feed to the new VPMM Motion Mechanism new main control panel
- iii. Supply VPMM TOP junction box adjacent to the energy chain on the VPMM moving platform. Supplier to provide the following:
  - Stainless steel NEMA 4X enclosure, sized for the four box-mounted pin connectors (J27P, J28P, J29P and J30P)
  - Mounting of the stainless steel enclosure
  - Cable glands / strain reliefs for cables exiting the VPMM Top Junction Box to the energy chain supplying the FWD and AFT SWORD junction boxes.
- iv. Supply and mounting FORWARD and AFT SWORD junction boxes. These will each have the following characteristics:
  - Stainless steel NEMA 4X enclosure, sized for two (2) incoming IP66 watertight box-mounted cable glands and two (2) IP66 box-mounted waterproof connectors (exit to swords).
  - FORWARD SWORD junction box: IP66 fixed cable glands for cables 8 and 9; termination of these cables on box mounted watertight IP66 connector J31S and J32S.
  - AFT SWORD junction box: IP66 fixed cable glands for cables 10 and 11; termination of these cables on box mounted watertight IP66 connectors J33S and J34S.
- v. VPMM TOP junction box → FORWARD SWORD junction box:
  - Cable 8 – Infinite Flex
  - Fixed box-mounted IP66 MIL-97 pin connector J27P (coordination required with Departmental Representative for pin-outs / terminations on Owner-supplied mating connector J23S)
  - Fixed box-mounted IP66 cable gland at exit of VPMM TOP junction box
  - Fixed box-mounted IP66 cable gland at entrance to FORWARD SWORD junction box
  - Fixed box-mounted IP66 MIL-97 socket connector J31S (coordination required with Departmental Representative for pin-outs / terminations on Owner-Supplied mating connector J35P).
  - Cable 9 – Infinite Flex
  - Fixed box-mounted IP66 MIL-97 pin connector J28P (coordination required with Departmental Representative for pin-outs / terminations on Owner-supplied mating connector J24S)
  - Fixed box-mounted IP66 cable gland at exit of VPMM Top Junction Box
  - Fixed box-mounted IP66 cable gland at entrance to forward sword junction box
  - Fixed box-mounted IP66 MIL-97 socket connector J32S (coordination required with Departmental Representative for pin-outs / terminations on Owner-Supplied mating connector J36P).

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- vi. VPMM TOP junction box → AFT SWORD junction box:
  - Cable 10 – Infinite Flex
  - Fixed box-mounted IP66 MIL-97 pin connector J29P (coordination required with Departmental Representative for pin-outs / terminations on Owner-supplied mating connector J25S)
  - Fixed box-mounted IP66 cable gland at exit of VPMM TOP junction box
  - Fixed box-mounted IP66 cable gland at entrance to AFT SWORD junction box
  - Fixed box-mounted MIL-97 socket connector J3SS (coordination required with Departmental Representative for pin-outs / terminations on Owner-Supplied mating connector J37P)
  - Cable 11 – Infinite Flex
  - Fixed box-mounted IP66 MIL-97 pin connector J30P (coordination required with Departmental Representative for pin-outs / terminations on Owner-supplied mating connector J26S)
  - Fixed box-mounted IP66 cable gland at exit of VPMM Top Junction Box
  - Fixed box-mounted IP66 cable gland at entrance to aft sword junction box
  - Fixed box-mounted IP66 MIL-97 socket connector J34S (coordination required with Departmental Representative for pin-outs / terminations on Owner-Supplied mating connector J38P)
- vii. New PLC Control Cabinet – Tow Carriage Platform
  - Supplier to design, build, install and commission a new control panel for housing the new vendor-supplied PLC, three (3) to four (4) motion drives, safety systems, and HMI.
  - This system will interface with the following components:
    - a. One (1) to two (2) surge motors / feedback encoders / resolvers / overtravel positive / overtravel negative
    - b. One (1) Heave motor / feedback encoder / resolver (front) / overtravel positive / overtravel negative
    - c. One (1) Heave motor / feedback encoder / resolver (back) / overtravel positive / overtravel negative
    - d. Emergency stop from VPMM
      - i. VPMM will have an emergency stop operator and reset push button light. The scope of this emergency stop mushroom head operator will be to stop only the VPMM system. This VPMM emergency stop system will not stop the tow carriage but the tow carriage emergency stop relays R49 and R50 will interface to stop the VPMM motion system.

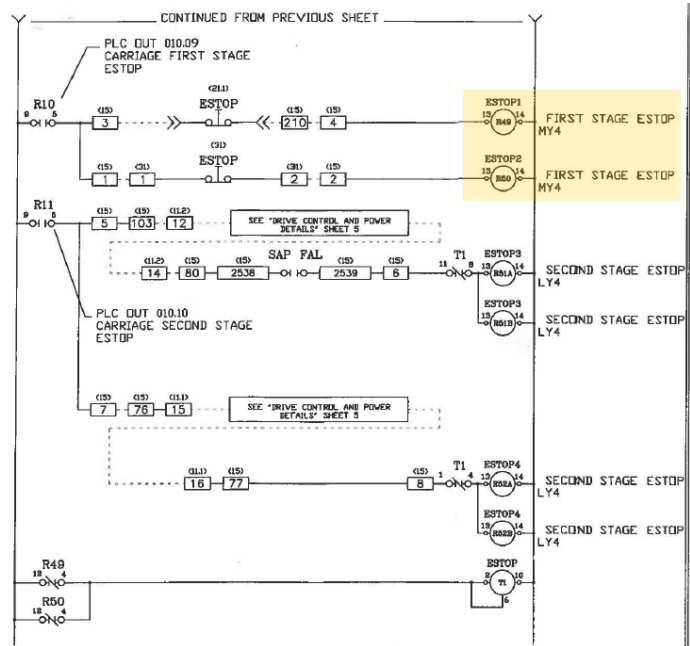
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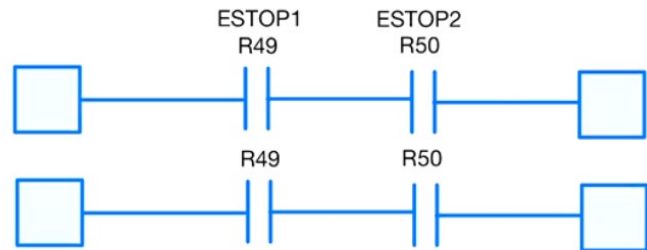
- ii. The VPMM emergency stop will be configured as PLd / Cat 3 (as defined in ISO 13849-1) through a safety-rated safety relay system.
  1. Inputs to the safety relay will be via dual channel N.C. contacts on the emergency stop mushroom head operator and contacts from the existing R49 / R50 relays.
  2. Outputs from the safety relay will be via dual channel outputs to safety contactors with mechanically linked N.C. contacts.
  3. The reset will use a manual push button tied in series with the N.C. status from the safety contactors.
- iii. The tow carriage emergency stop will initiate an emergency stop of the VPMM system. Supplier will interface dual channels (in series) from existing emergency stop control relays R49 and R50 to the VPMM control panel e-stop. Spare capacity for additional N.O. contacts is not confirmed for R49 nor for R50. Supplier to allow for the purchase and installation of two additional safety control relays, wired in parallel with R49 and R50, in the existing panel, for interfacing with the VPMM system. This is understood to be a weak point in the overall safety system architecture.
- iv. While a manual reset push button would normally be required in the tow carriage e-stop circuit, this will not be modified.

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New e-stop interconnections from the tow carriage emergency stop to the new VPMM safety relay (in series with dual mushroom head N.C. contacts – not shown for clarity):

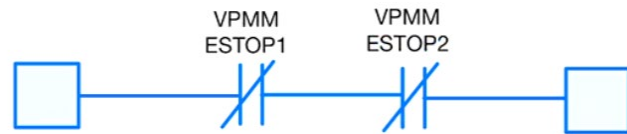


- v. Two sets of mechanically linked N.C. from the VPMM safety contactors will be wired in series as feedback:
  1. One set of N.C. contacts will be wired to the tow carriage emergency stop system. These conductors will be wired and prepared from the VPMM to the tow carriage but will only be used for future configurations.
  2. One set of N.C. contacts will be wired to the VPMM emergency stop system.



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- Panel to be cooled as required (forced ventilation, air conditioner) to dissipate heat from the internal panel components. Maximum ambient air surrounding the panel is 30°C.
  - Panel is to be designed to CSA C22.1-2021, CSA C22.2 No 14, CSA C22.2 No 286 and other applicable codes.
  - Panel interface wiring to be designed to meet CSA C22.1-2021 (Canadian Electrical Code) and other applicable standards.
  - Panel is to be CSA approved as a complete system or reviewed / approved through an approved special inspection body (SPE-1000 or other codes as applicable).
- viii. Outside Panel Details
- Panel to be located adjacent to an existing 400A 480V 3P3W power source. Panel maximum dimensions to be 2000mm (W) x 600mm (D) x 2200mm (H). Appropriate feet / plinth to be added as required to provide proper working area for serviceable parts (400mm – 2000mm)
  - Panel to be light grey in colour: ANSI 61.
  - Supplier to provide a minimum of 1000mm of free footing in front of the enclosure per CEC requirements.
  - Panel to be gasketed stainless steel NEMA 4X. There is the potential of some splashing water near / on the panel.
  - Panel can be locked in the closed position with a standard HASP and padlock.
  - Disconnect switch:
    - a. Door to be supplied with a disconnect switch, with handle operable from the outside of the panel.
    - b. Disconnect handle to be mechanically interlocked with the opening of the panel door and will inhibit this opening if the disconnect is in the ON position.
    - c. Disconnect handle to be fitted with a mechanical defeater to allow this safety feature to be bypassed by authorized personnel.
    - d. Disconnect switch to have an option for padlocking in the OFF position for LOTOTO.
  - Door opening to minimum 90° for full access to panel components.
  - Door to be fitted with the following systems:

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- a. One (1) HMI. Minimum 7" colour touchscreen for local alarms and adjustments / status of the VPMM system.
  - b. One (1) diameter 60mm emergency stop maintained twist-to-release red mushroom head operator. This will be fitted with two (2) with self-monitoring N.C. contacts. Mushroom head operator to have a yellow "EMERGENCY STOP" label behind.
  - c. One (1) "Rearm Emergency Stop" push button light. The push button light will be illuminated RED if the emergency stop is tripped. The push button is to be wired into the rearm for the safety relay circuit.
- ix. Interior Panel Details
- Panel to house three (3) to four (4) motion drives, suitably sized to match the servo motors and required motion profiles.
  - One (1) PLC chassis with power supply and modular I/O cards.  
Minimum configuration:
    - a. Modular Chassis with minimum of 25% (or minimum of 3) spare slots for future expansion.
    - b. One servo controller as required with required CAM Follower programming and communications to the servo drives.
    - c. Digital input card for monitoring the following:
      - i. Emergency stop status
      - ii. VPMM motion permitted (constant signal)
  - While an approved Safe Torque Off (STO) signal can be interfaced to each of the motion drives, there is an additional requirement for dual safety rated upstream contactors to be fitted in series for the motion drive groupings.
    - a. These contactors will be opened in the event of an emergency stop condition to fully isolate the motion drives from the 480V power supply.
    - b. The status of the safety-rated mechanically interlocked normally closed contact will be monitored by the Supplier safety system.
    - c. Allow for a maximum of six (6) operations per hour of this emergency stop system.
    - d. A safety-rated emergency stop safety relay is to be used for the emergency stop system.
    - e. Emergency stop system as described above.
  - All required overcurrent and overload protection devices (Motor protection circuit breakers, fuses, etc.)
  - Wiring to be enclosed in plastic wireway with a cover.
- x. Panel Wiring Interconnections

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- 225A 3P3W power feed (Teck90 or RGS) into the control panel from the existing adjacent fused disconnect.
- The fused disconnect and control panel will always remain in-place.
- New cable tray is to be added between the new control panel and the VPMM system. This will serve as a raceway for the following systems:
  - a. Three (3) to four (4) Servo motor power cables
  - b. Three (3) to four (4) Servo motor feedback cables
  - c. Three (3) to four (4) Positive Overtravel Limit
  - d. Three (3) to four (4) Negative Overtravel Limit
  - e. This cable tray system must be easily removable as it will be removed with the VPMM system (motors and actuators) when not in use.
  - f. Suggested path for removable tray is from the top of the new control panel, through a vertical 90 (up) to a horizontal section past the handrailing, then to another vertical 90 (down) and then horizontal tray to the new energy chain.
- All outgoing cables are to be fitted with weatherproof IP66 quick connects to facilitate future removal of the VPMM. These include quick connects at both the control panel enclosure and at the VPMM end-devices (servo power, servo feedback, overtravel switches, home switches). Cables will be removed from the raceways as required for facility operations. Quick connects to be fitted with IP66 waterproof covers.
- Allowance for two cables between the Model Support Box and the VPMM panel:
  - a. 6C #18 AWG cable for "External E-stop to VPMM" interconnections
  - b. Cat 6 EtherNet cable for communications with PC / operator interface
- Energy chain for Supplier cables.
  - a. Multiple segments will be required to house and protect cables.
  - b. While the relative position between the tow carriage and the VPMM main rails will remain constant, the entire VPMM surge-axis assembly moves relative to the tow carriage.
  - c. The segments must be planned to accommodate minimum cable bending radius as well as adherence to the cable flexibility and electrical requirements for spacing (noise and electrical insulation voltages) with a permanent barrier as required between systems.

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- xi. HMI Display Requirements
  - The HMI on the front of the panel will be used for local control of the motion axes and for diagnostics for the VPMM systems.
    - a. Specifications:
      - i. Touch screen
      - ii. Colour display
      - iii. Minimum 12"
      - iv. EtherNet communications
    - b. Local control requires the following:
      - i. Auto / Manual selection for each axis
      - ii. Enable Auto / Disable Auto control functions
      - iii. Manual controls for each axis include:
        - 1. Jog Positive (away from motor)
        - 2. Jog Negative (towards motor)
        - 3. Jog speed setting
        - 4. Identify current position as home
        - 5. "Go Home" push button
        - 6. Incremental move option from current location.
          - a. Specify distance (mm)
          - b. Start motion momentary push button
          - c. Stop motion momentary push button
    - c. Local display includes, but is not limited to, the following for each axis :
      - i. Graphic of auto / manual selection
      - ii. Graphic of overtravel positive and overtravel negative status
      - iii. Current distance from home position (mm)
      - iv. Ready / faulted status
      - v. Existing axis faults
    - d. Ability to review current and historical system faults, with time stamp. Faults includes, but are not limited to, the following:
      - i. Drive faults (overtemperature, faulted, overvoltage, undervoltage, etc.)
      - ii. Emergency stop
- xii. Interface Computer
  - A new interface computer will be installed in the control room. This will communicate with the PLC for enhanced diagnostics and control of the VPMM system.
  - See specifications for requirements.
  - Interface will allow the user to enter / view the following motion profile information:

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- a. Automatic Control (Axis identified in "green")
  - b. Manual Control (Axis identified in "white")
  - c. Axis Faulted (Axis identified in "red")
- Motion profiles include:
  - a. Surge.
    - i. This is the "x-axis" travel alone.
    - ii. Motion will be purely sinusoidal in nature.
    - iii. Input parameters include the following:
      - 1. Amplitude (mm)
      - 2. Cycle Period (sec)
  - b. Heave.
    - i. This is the "y-axes" travelling aligned. Both heave axes will start at the same vertical point and will travel in unison for perfectly vertical (level) travel.
    - ii. Motion will be purely sinusoidal in nature.
    - iii. Input parameters include the following:
      - 1. Amplitude (mm)
      - 2. Cycle Period (sec)
  - c. Pitch.
    - i. The submarine pitch will vary tangentially along the defined sinusoidal waveform.
    - ii. The submarine middle position will remain in exactly the same position, relative to the heave and surge axes.
    - iii. Motion will be purely sinusoidal in nature.
    - iv. Input parameters include the following:
      - 1. Pitch (degrees)
      - 2. Cycle Period (sec)
- xiii. PLC Programming
  - Ladder logic programming to be used. Function block diagrams, structured text or other programming methods shall be pre-approved by the Departmental Representative.
  - Logical programming to be prepared for the system. Separate subroutines are to be prepared for major systems including the following:
    - a. Surge Axis programming
    - b. Heave Axis (forward) programming
    - c. Heave Axis (aft) programming
    - d. CAM Follower motion programming
    - e. HMI Interface
    - f. PC Interface
    - g. Fault Routine
    - h. Interface with Outside Systems

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- Coordination with Owner for dedicated EtherNet subnet for VPMM automation system topology (drives, PLC, HMI, laptop)
- xiv. Spare Parts
  - The Supplier shall provide the following spare parts with this project to Owner:
    - a. Programmable Logic Controller (PLC), pre-programmed
    - b. PLC power supply
    - c. One spare card for each type used (input, output)
    - d. Three (3) 225A Class J Time Delay fuses

### 3.3 ENGINEERING

#### 3.3.1 Mechanical

Below is a summary of calculations to be completed by the supplier for the VPMM system, in order of priority:

- a. Kinematic calculations for the Pure Pitch sinusoidal motion of the sub model.
  - i. Graph the sub model displacement, velocity, and acceleration vs time.
- b. Kinematic calculations for the three (3) actuators based on the Pure Pitch sinusoidal motion of the sub model. Calculate the resulting motion profiles for the surge and heave actuators.
  - i. For the surge and heave actuators, graph actuator displacement, velocity, and acceleration vs time.
- c. Dynamic calculations (force and power) based on the condition of VPMM in air for the three (3) actuators comprising the Pure Pitch motion.
  - i. For the surge and heave actuators, graph actuator force and power vs time.
- d. Complete dynamic calculations for the three (3) actuators of the VPMM system for the Pure Pitch motion with considerations of hydrodynamic and hydrostatic loads when operating in the tow tank with carriage velocity of 3 m/s. Use equations developed by NRC that are provided in Appendix C.
  - i. For the surge and heave actuators, graph actuator force and power vs time.
- e. Based on Pure Pitch motion, size and select linear actuation solutions for all 3 axes of motion comprising the VPMM system: The sizing of the actuators will be determined by a combination of the kinematic and dynamic calculations. The velocity, acceleration, force, and power requirements to be used to size the system components. Sizing to include an appropriate design factor for the application.
- f. Maximum reaction loads on the tow carriage:
  - i. Calculate overall reaction loads ( $F_x$ ,  $F_y$ ,  $F_z$ ) and moments ( $M_x$ ,  $M_y$ ,  $M_z$ ) transferred by the VPMM system to the tow carriage.
  - ii. Compare calculated reaction loads on the tow carriage with the tow carriage capacities. Confirm loads are within acceptable limits.

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- g. Calculate reaction loads ( $R_x$ ,  $R_y$ ,  $R_z$ ) and moments ( $M_x$ ,  $M_y$ ,  $M_z$ ), where applicable, on each linear actuator system for the purpose of validating sizing of actuators and linear components (ex. guides, rails, bearings).
  - i. Verify capacity of selected linear actuation systems are within calculated reaction loads. Include an appropriate design factor for the application.
- h. Identify worst case loading scenario(s) based on Pure Pitch motion for manufactured components comprising the VPMM system. The worst-case loading scenario(s) will be the basis for FEA studies outlined in the next section.
- i. Conduct FEA studies to size manufactured components of the VPMM system. Studies required include:
  - i. Component size / geometry validation using the worst-case loading conditions. Mass of each component comprising the concept VPMM system is an estimate. During detailed design, effort must be taken to optimize mass of components and stiffness of the system. The mass should be minimized to decrease the overall force and power required for driving the system during operation. Supplier to conduct FEA studies including NRC supplied design reaction loads at the sword connection points to the heave pipe. FEA studies to meet or be lower than NRC supplied deflection limits at the sword connection points to the heave pipe.
  - ii. An FEA study of the VPMM system experiencing a 0.3 g emergency stop deceleration scenario.
  - iii. Modal analysis to determine natural frequency of each sub-frame (i.e. heave pipe, heave bearing brackets, heave frame, yaw box).
  - iv. An FEA study of the VPMM system including side load induced by sword lift.
  - v. FEA studies of all lift point loading scenarios. NRC requires a minimum factor of safety of 3 for all lift points.  
Consider the following: tension, compression, buckling, torsion on the members and connections. Supplier to provide FEA reports summarizing results.
- j. Perform loading and stress calculations for fastener (e.g. bolt, pin, clevis, etc.) connections.
- k. Calculate resulting Dead Load of VPMM system following FEA studies. Confirm load is within capacity of tow carriage.
- l. Update calculations completed in points c. through h. above using mass of VPMM components determined following FEA studies. All these calculations are iterative during the FEA study process.
  - i. Re-run FEA studies if/when loading conditions change based on updated results of calculations completed in points c. through h.
  - ii. Re-run FEA studies if/when there are any design changes/component changes to the VPMM solution (e.g. geometry changes due to form, fit, or function).
  - iii. Update FEA reports for all updated FEA studies.
- m. Conduct a FEA study on the VPMM storage frame.

Detailed drawings and visuals of design to include, but are not limited to:

- a. Geometric tolerance on critical machined faces and relationships.

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- b. Welding requirement details.
- c. Machining process and details.
- d. Overall finish details.
- e. Cable management layout and routing details.
- f. Range of motion details (e.g. stroke limits, stroke distances, etc.).
- g. Bill of Materials
- h. Mass data.
- i. Lift point capacities.
- j. Rigging information.
- k. Installation details for placing, leveling, aligning, and securing the VPMM to the tow carriage.

Manufacturer's specifications to include, but are not limited to:

- a. Material mill certificates.
- b. Hardware/fastener specification data.
- c. Bearing, actuator, linear drive unit and linear rail specification data.
- d. Coating specification data.
- e. Lubrication requirements.
- f. A list of recommended spare parts.

### 3.3.2 Electrical

Supplier is to provide full electrical design for the project. Required schematics include the following documents:

- a. Electrical schematics, complete with unique wire numbers for each node, detailing the wiring interconnections between components. This will include detailed wiring for the PLC, motion drives, emergency stop, required power supplies, etc.
- b. Control panel layout, with dimensions for critical values.
- c. Heat dissipation calculations for the panel.
- d. Plan view of the system detailing cable routing, device locations, etc.
- e. Cabling Systems Overview, detailing the source / destination, cable type, routing, wire numbers assigned to each conductor, etc.
- f. Panel design shall to in compliance with CSA C22.2 No 14 and CSA C22.2 No 286 as required.
- g. External Wiring design shall be in compliance with CSA C22.1-2021.
- h. Complete parts list / nomenclature / Bill of Materials for components used as part of this design.
- i. A list of recommended spare parts.

### 3.3.3 Controls

Supplier is to provide full controls design for the project. Scope includes the following:

- a. PLC programming (unlocked / not password protected)



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- b. HMI programming (unlocked / not password protected)
- c. PC interface programming (unlocked / not password protected)
- d. Drive programming (unlocked / not password protected)
- e. Servo interface CAM-follower programming (unlocked / not password protected)
- f. SCADA logging of commanded position and actual position for each axis
- g. Recipe selection for profile to be run (up to 100 unique profiles)
- h. Historical and active faults
- i. Written operating instructions / controls narrative for the system. This includes details for selecting the required profile, completing adjustments to the profile, etc.
- j. Troubleshooting tools and techniques for the system.

### **3.4 PRELIMINARY DESIGN REVIEW (PDR)**

1. A preliminary (50% complete) mechanical/electrical design package must be provided and approved by NRC prior to completion of final mechanical/electrical design.
2. The PDR will include mechanical detailed shop production drawings, control system layout, electrical layout, wire routing layout, and functional detailed Solidworks or STEP 3D CAD models.
3. Supplier's schedule to include the PDR milestone.

### **3.5 CRITICAL DESIGN REVIEW (CDR)**

1. A critical (100% complete) mechanical/electrical design package must be provided and approved by NRC prior to procurement and manufacture of materials.
2. The CDR will include mechanical detailed shop production drawings, control system layout, electrical layout, wire routing layout, and functional detailed Solidworks, or STEP, 3D CAD models.
3. Supplier's schedule to include the CDR milestone.

### **3.6 PROCUREMENT AND FABRICATION**

1. The supplier is responsible for the procurement, fabrication, and assembly of the VPMM system.
2. Supplier responsible for payment of purchased goods and any sub-contracts in relation to completion of this project.
3. Supplier to provide copies of material mill certificates for manufactured components.
4. Supplier to manufacture the VPMM system with features to allow for repeatable installation and removal on the tow carriage. Drilling and pinning connections following initial setup and alignment is recommended to be able to repeat alignment of parts during future installations.

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### 3.7 FACTORY ACCEPTANCE TESTING (FAT)

The supplier is responsible for the factory acceptance testing of the VPMM system. The supplier must arrange the FAT with NRC to ensure the testing is completed before the system is put in operation. The FAT will validate that the operation of the VPMM equipment meets the design and operation requirements of this contract. The factory acceptance testing must be completed before the VPMM is delivered to site.

At the supplier's facility, with representatives from NRC in attendance, the supplier must:

1. Pre-assemble the VPMM system in air without the 'mock' sub model and swords assembly installed.
2. Rig up a static load test on the VPMM to test structural performance. The reaction loads provided by NRC are to be applied to the sword connections on the heave pipe. Displacement results will be compared with displacement limits provided by NRC.
3. Install the 'mock' sub model and swords assembly onto the VPMM.
4. Test full range of motion, data entry, fault reporting, and operation of each actuator comprising the VPMM system. Tests to be conducted one axis at a time, each at reduced speed/acceleration.
5. Test full range of motion, data entry, fault reporting, and operation of each actuator comprising the VPMM system. Tests to be conducted one axis at a time, each at rated speed/acceleration.
6. Test the Pure Pitch motion. Test to be conducted at reduced speed/acceleration.
7. Test the Pure Pitch motion. Test to be conducted with required sinusoidal motion profile at rated speed/acceleration.  
Perform each test for a minimum of 10 minutes continuous operation. The VPMM to be monitored during each test and following each test to confirm acceptable performance (e.g. no unexpected motions, no unexpected vibrations, all hardware securely fastened, systems do not fault or overhead, etc.)

Prepare and submit FAT report to NRC following FAT testing.

### 3.8 DELIVERY, INSTALLATION, AND CONSTRUCTION

1. Transportation of the VPMM to the National Research Council of Canada, Ocean, Coastal and River Engineering Laboratory in St. Johns Newfoundland, Canada will be the responsibility of the Supplier. Brokerage information will be provided at the time of award.
2. Supplier will unload the package equipment at the specified NRC location. NRC will assign a space, as required by the supplier, to house the components until the time of installation.
3. The Supplier to uncrate components of the VPMM system.
4. The Supplier to provide a lift plan for installation of the VPMM components onto the tow carriage.
5. The Supplier to carry out the assembly/construction of the VPMM system components at the tow tank facility under the supervision of NRC. Supplier to provide labour, mobile equipment,

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and assembly materials to complete installation work. The NRC overhead crane can be used by the supplier.

6. Following the installation work, site acceptance testing of the VPMM will take place. Data acquisition will be performed during this period to verify the performance of the VPMM.

### **3.9 SITE ACCEPTANCE TESTING (SAT)**

The Supplier is responsible for the site acceptance testing of the VPMM system. The Supplier must arrange the SAT with the Owner to ensure the testing is completed before the system is put in operation. The SAT will validate that the operation of the VPMM equipment meets the design and operation requirements of this contract. The site acceptance testing must be completed before the VPMM it is handed over to the Owner.

At the National Research Council of Canada, Ocean, Coastal and River Engineering Laboratory in St. Johns Newfoundland, Canada facility, with representatives from the Owner in attendance, the Supplier must:

1. Repeat FAT steps 3 through 8 with the tow tank carriage stationary.
2. Conduct FAT steps 6 and 7 with the tow tank carriage operating at 3 m/s.
3. Data acquisition will be performed during this period to verify the performance of the VPMM.

Prepare and submit SAT report to Owner following SAT testing.

### **3.10 TRAINING**

Training will take place following the SAT. NRC reserves the right to videotape the training session for future internal training. The Supplier will provide training for Owner staff including, but not limited to, the following:

1. Installation and operation of the VPMM.
2. Mechanical maintenance.
3. Software use.
4. Electrical/controls troubleshooting.
5. Safety procedures during operation and emergency situations.

### **3.11 DOCUMENTATION**

Operation and maintenance manuals will be provided at time of delivery of the VPMM to the Owner. Electronic format in Microsoft Word and PDF is preferable. Contents will include:

1. A general description of the device.
2. Specifications and limitations.
3. Operating instructions.
4. Installation instructions.

## **VERTICAL PLANAR MOTION MECHANISM (VPMM) SYSTEM**

Supplier's Scope of Work  
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5. Mechanical drawings (PDF Preferred) and 3D CAD model in electronic format. Solidworks is preferable for the 3D model.
6. A complete wiring diagram for the electrical/electronic/control systems. Complete data sheets and manuals for all components in these systems to be provided.
7. Documented electronic and unlocked PLC, HMI, Drive programs.
8. As-built drawings for all disciplines.
9. O&M manuals.
10. A complete parts list, including manufacturer and source.
11. A list of recommended spare parts and quantities.
12. A list of consumables, if applicable.
13. A maintenance schedule and maintenance procedures, as applicable.
14. A set of repair procedures and references for the equipment.
15. A detailed description and set of operating procedures for all software.
16. Expected lifetime of the VPMM will be stated in the documentation.
17. Safety procedures and documentation.

### **3.12 WARRANTY AND SERVICE**

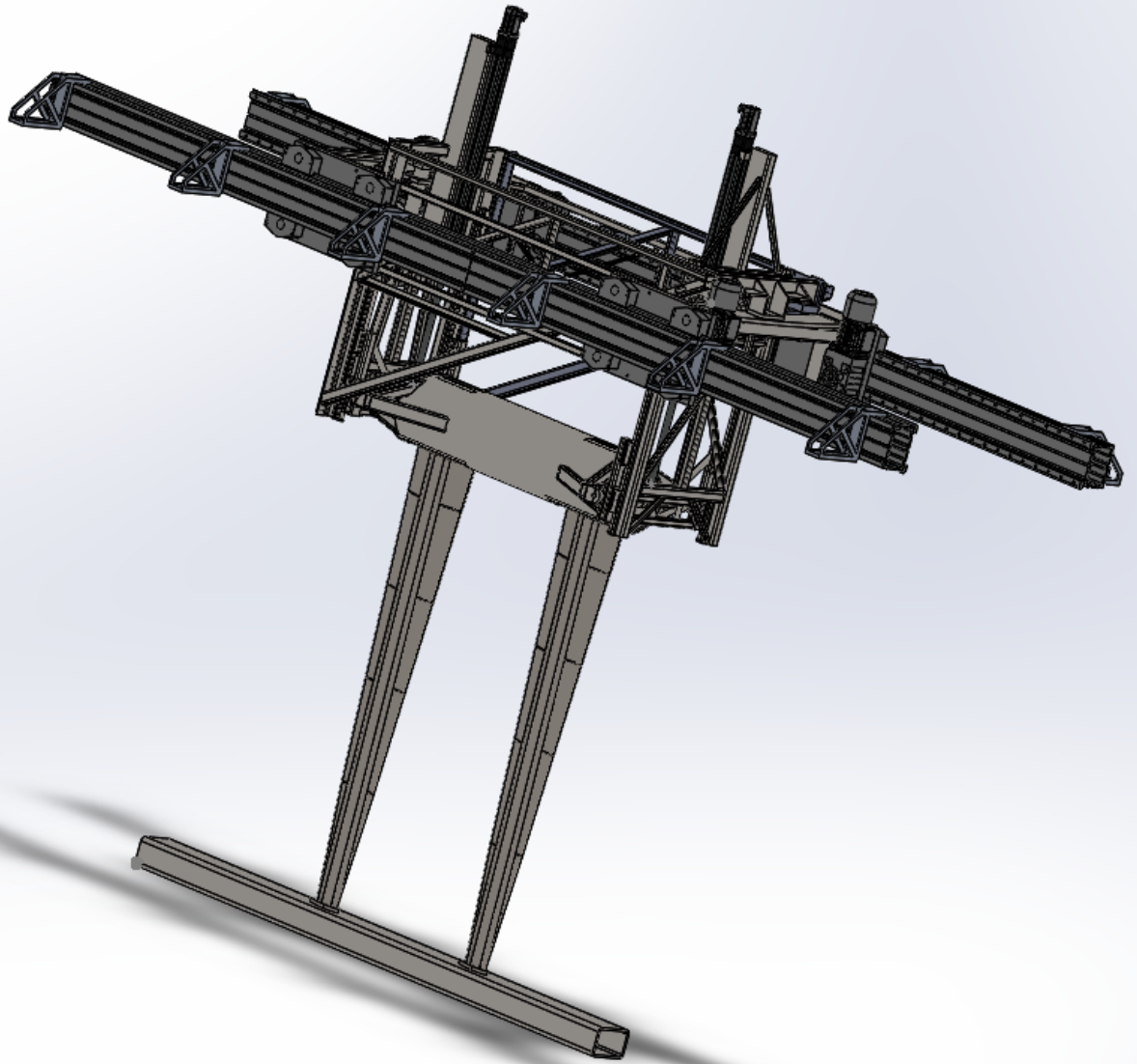
1. The Supplier will warrant that the VPMM shall be free from all defects resulting from faulty design, materials, or workmanship for a period of one (1) year from the SAT completion date.
2. Within the warranty period, the Supplier will respond within two working days of notification of a problem covered by the warranty. This response will include proposed timing of remedial action. As soon as is practical, the Supplier will restore the VPMM to proper working order. The Supplier shall be responsible for all costs associated with any warranty repair.

# VERTICAL PLANAR MOTION MECHANISM (VPMM) SYSTEM

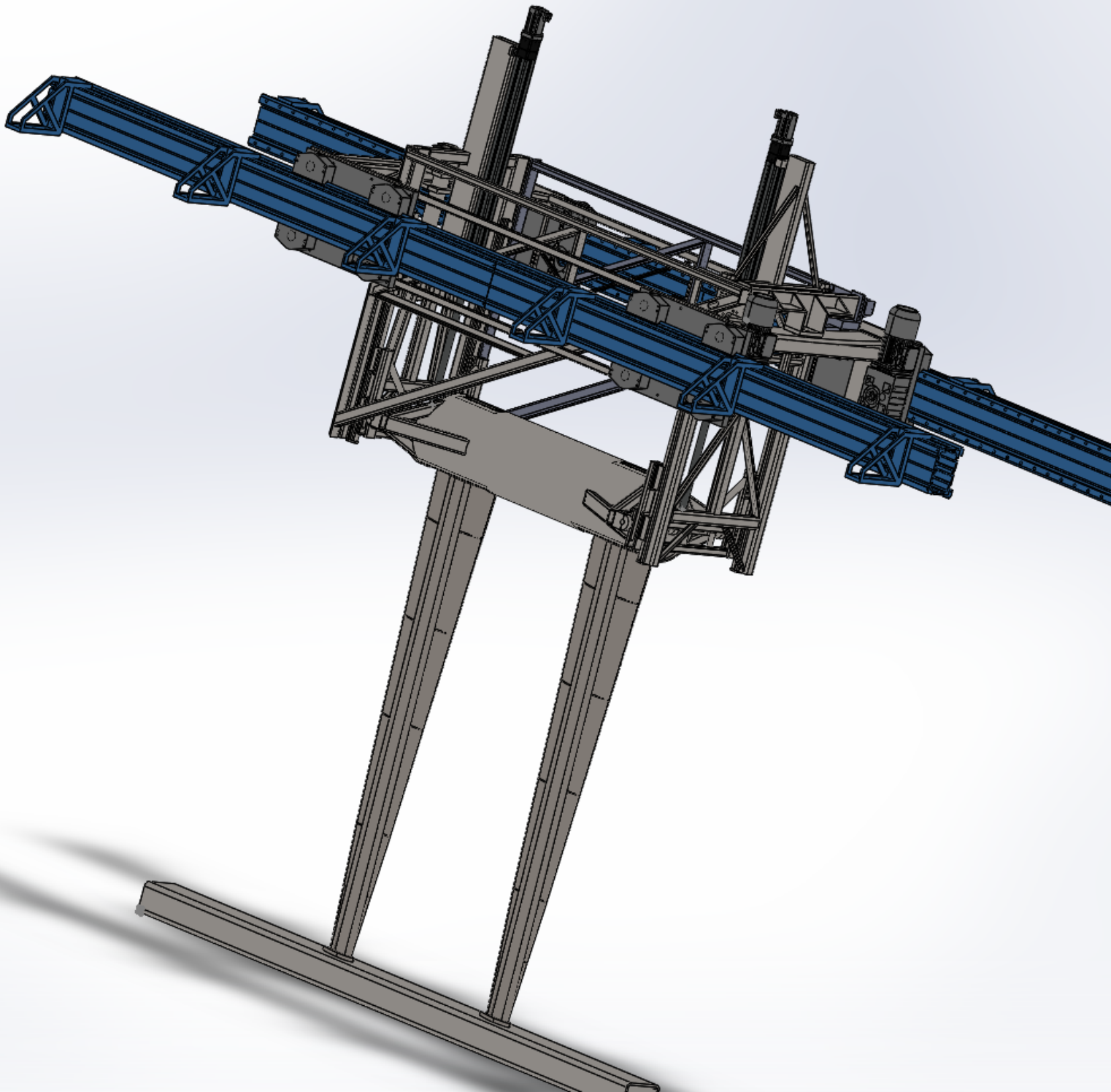
Appendix A  
October 20, 2023

## APPENDIX A

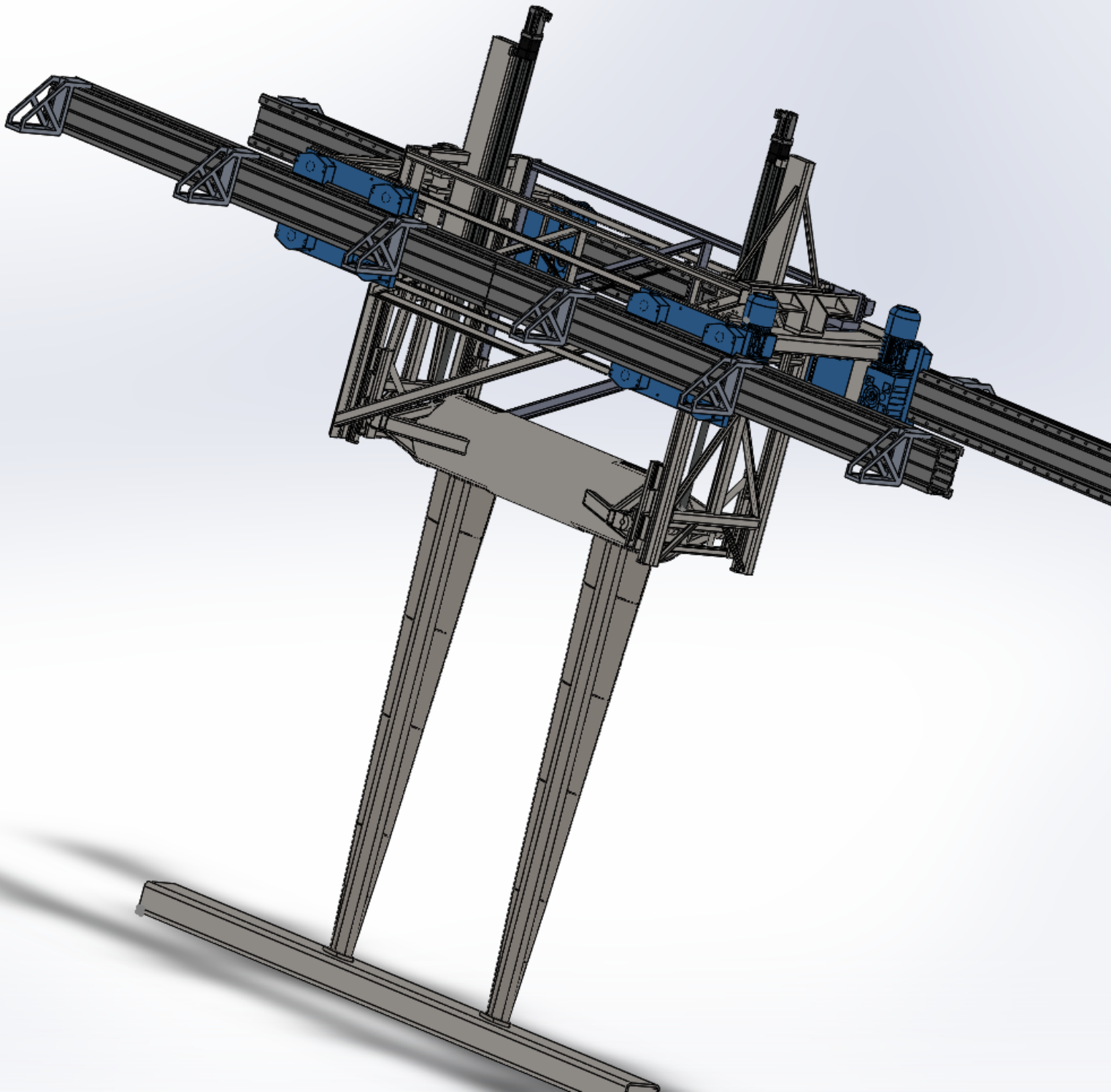
# VPMM System



# Surge Rails

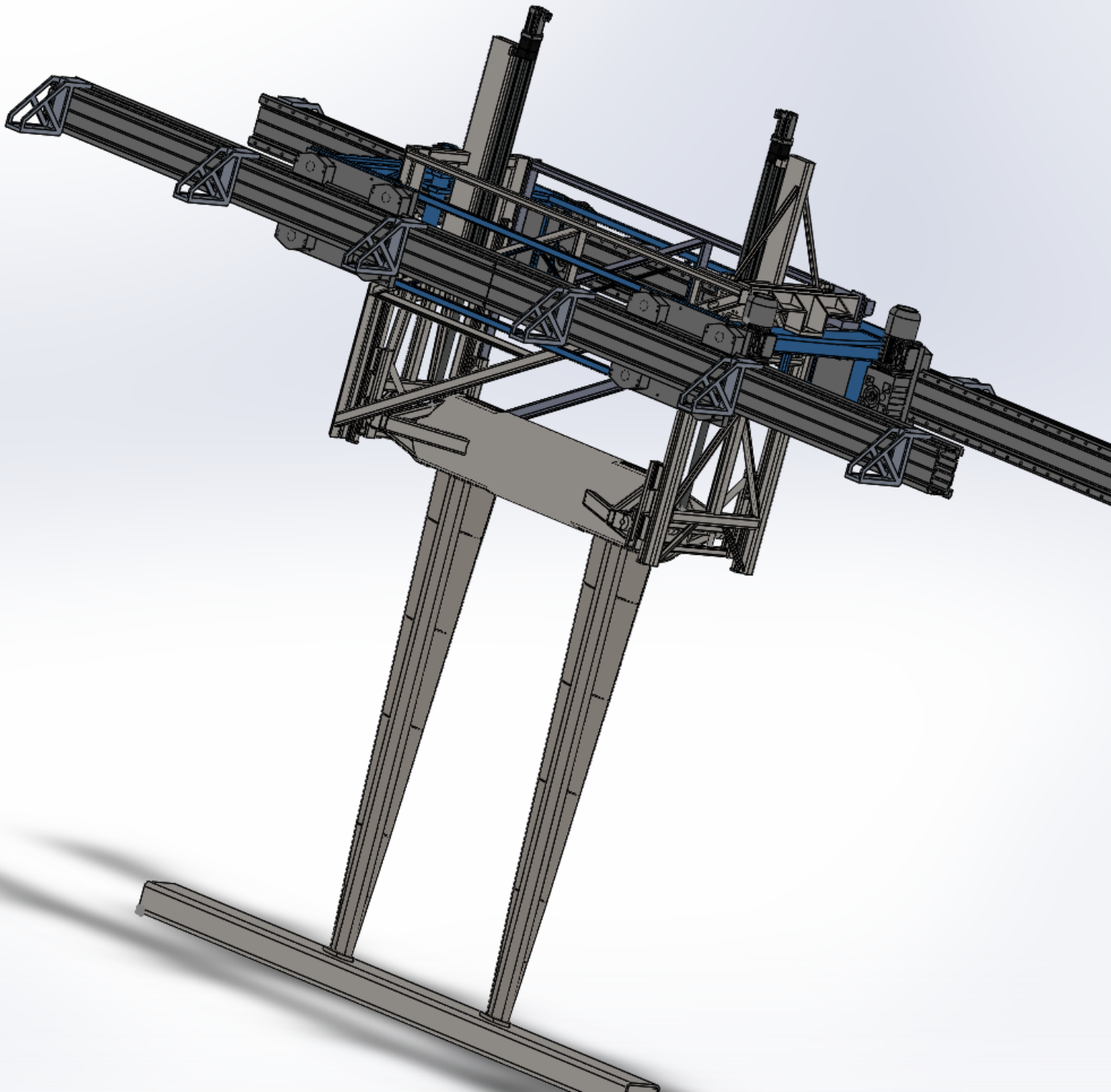


## Surge Bearings

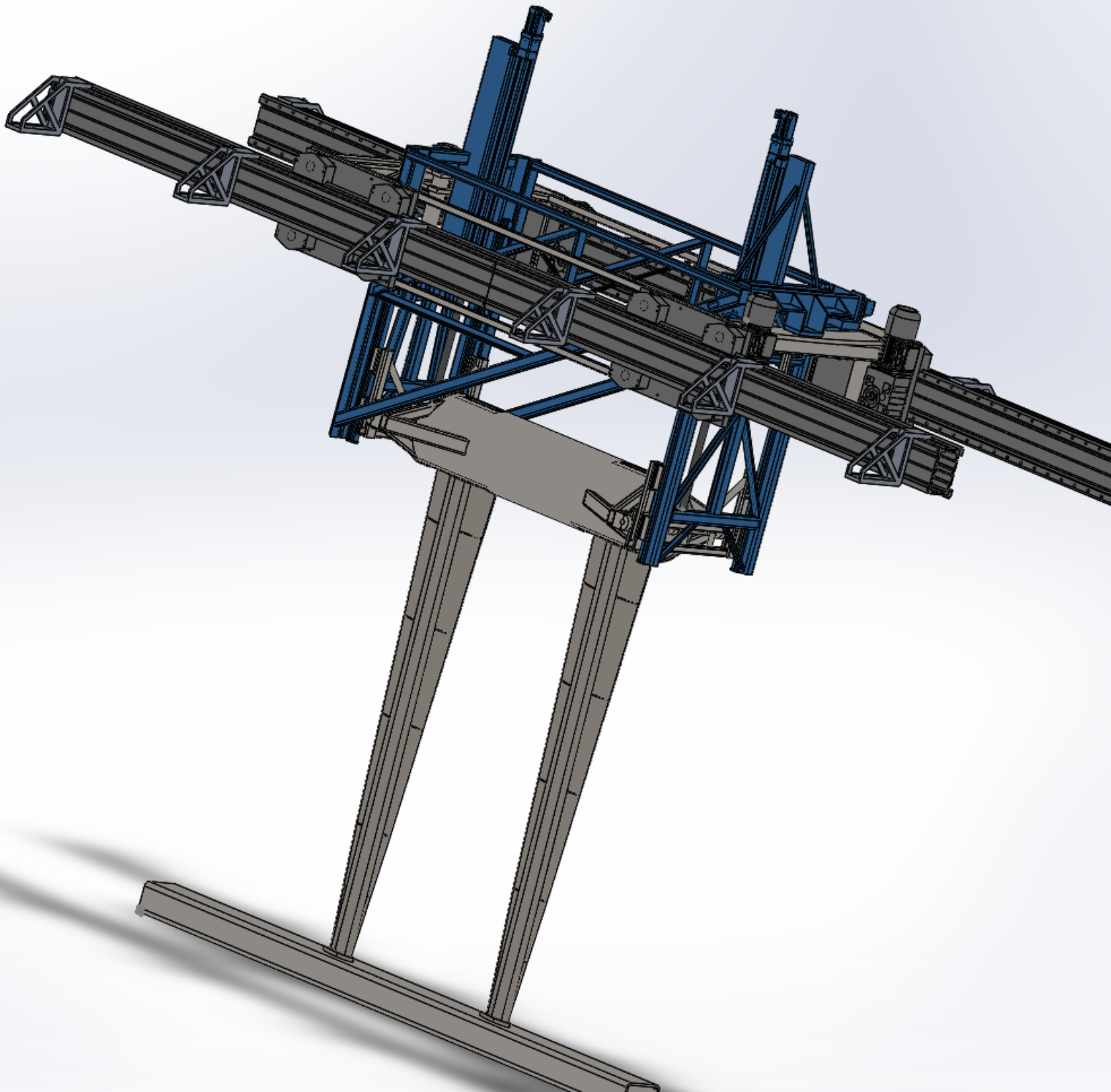




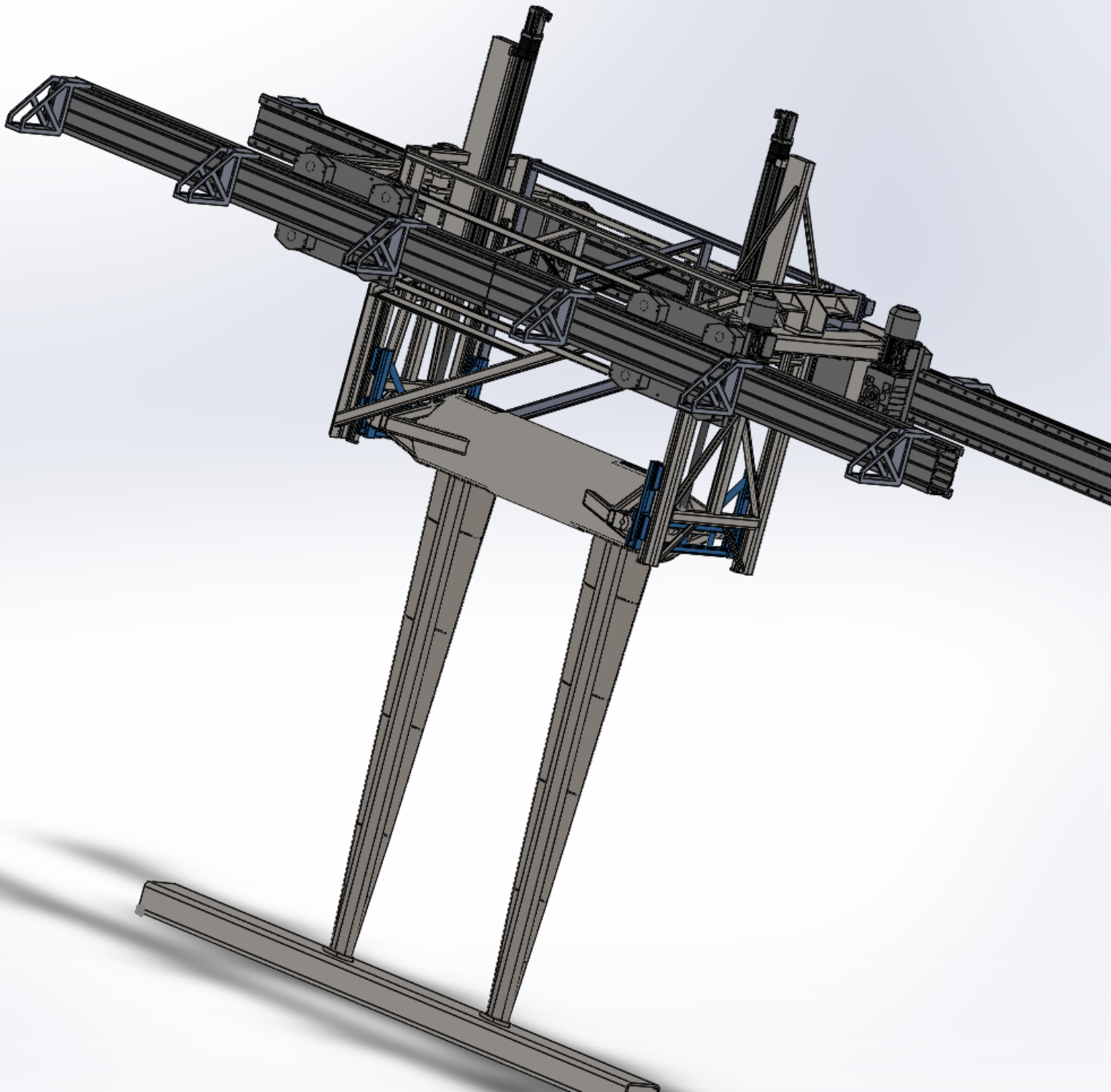
Yaw Box



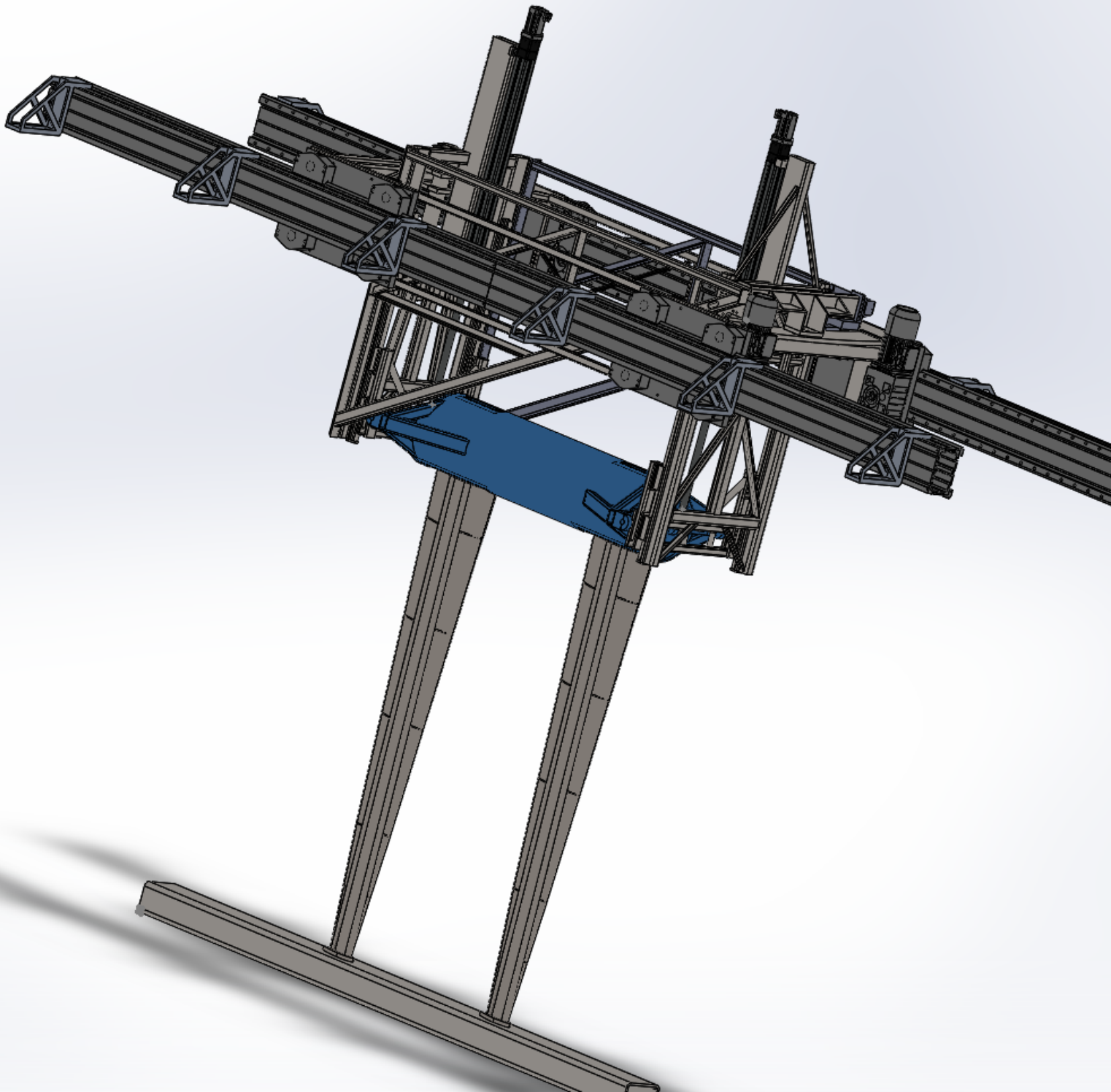
# Heave Frame



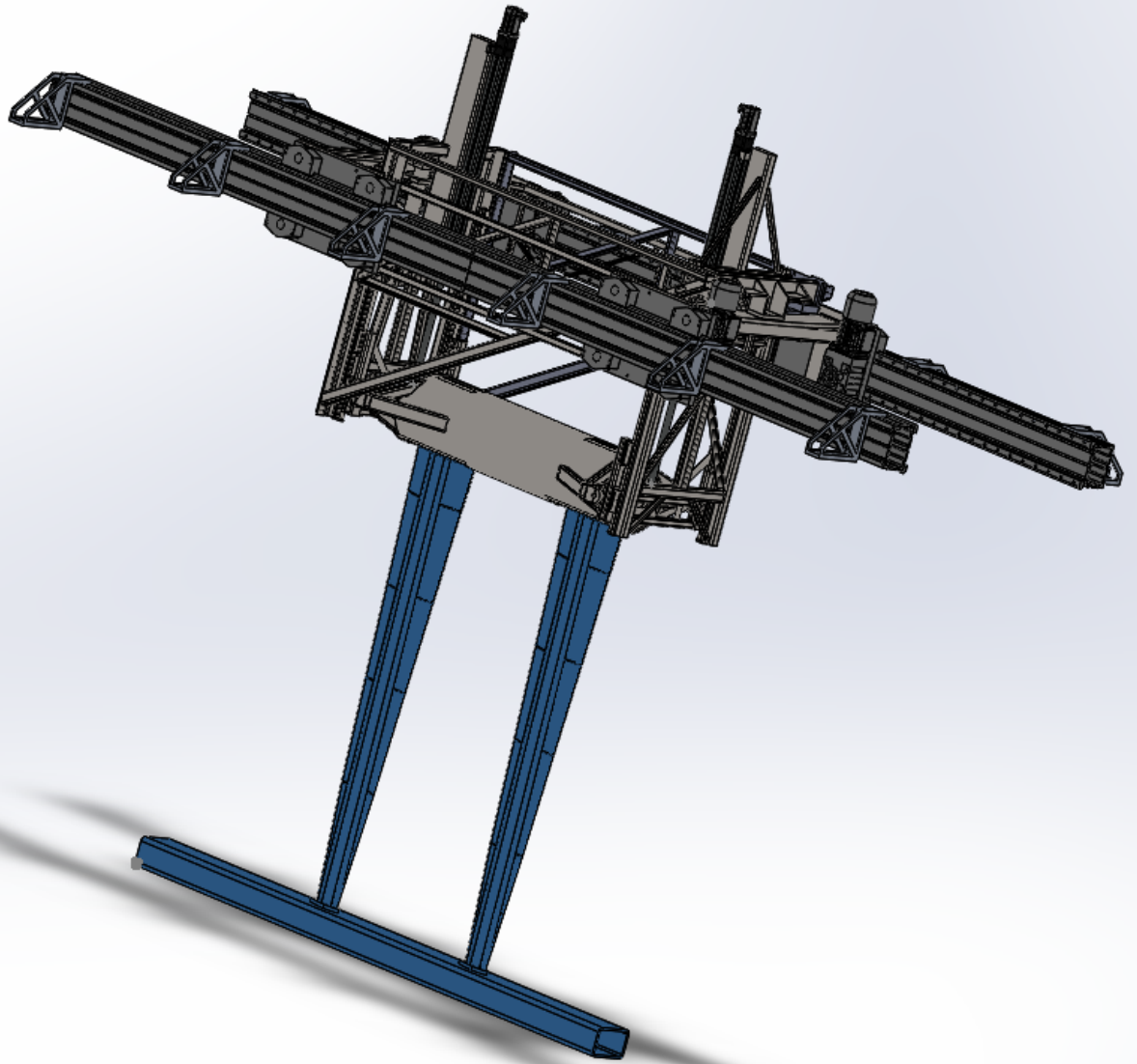
# Heave Bearing Brackets



# Heave Pipe



# Swords and Sub Mockup



# VERTICAL PLANAR MOTION MECHANISM (VPMM) SYSTEM

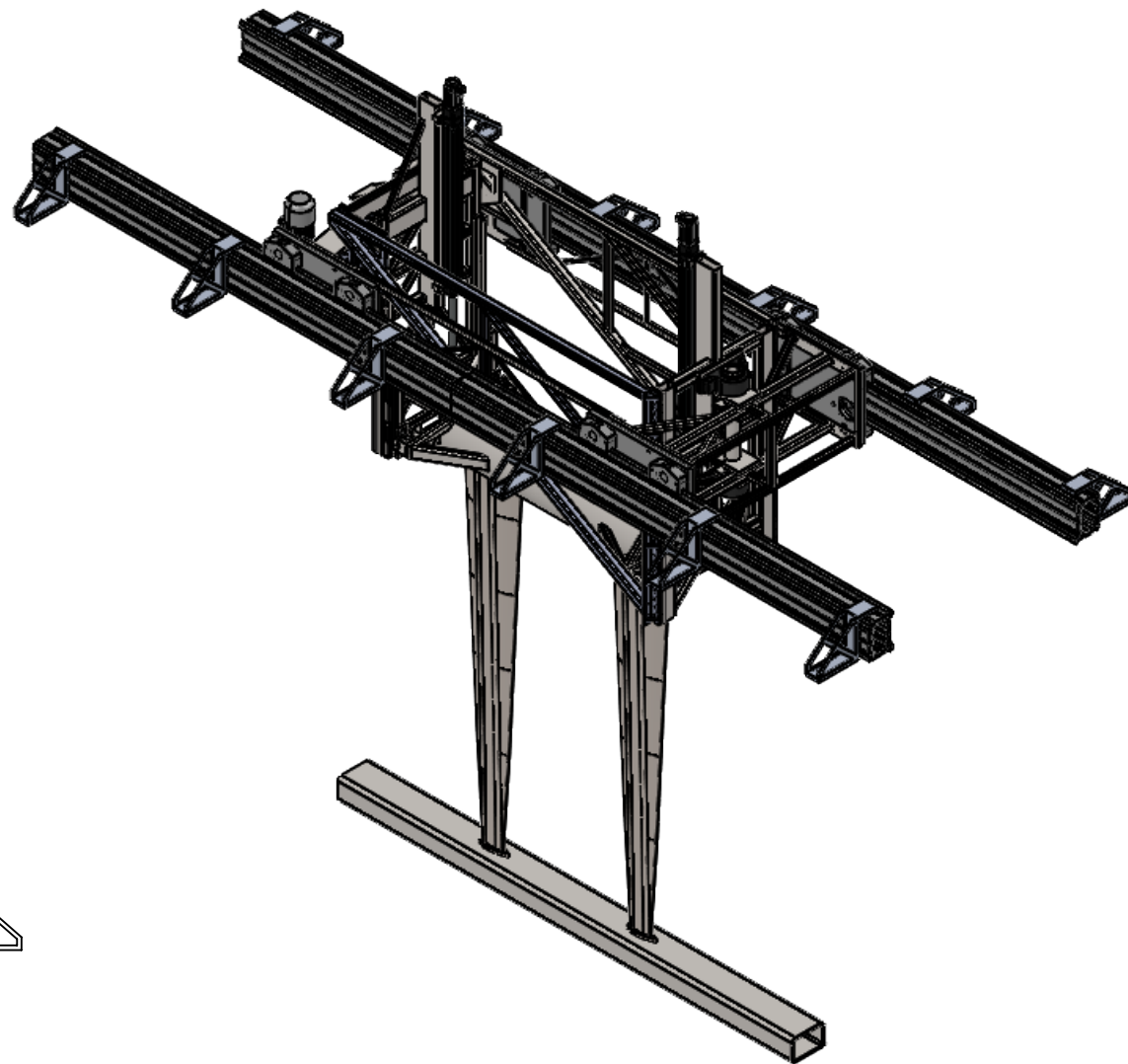
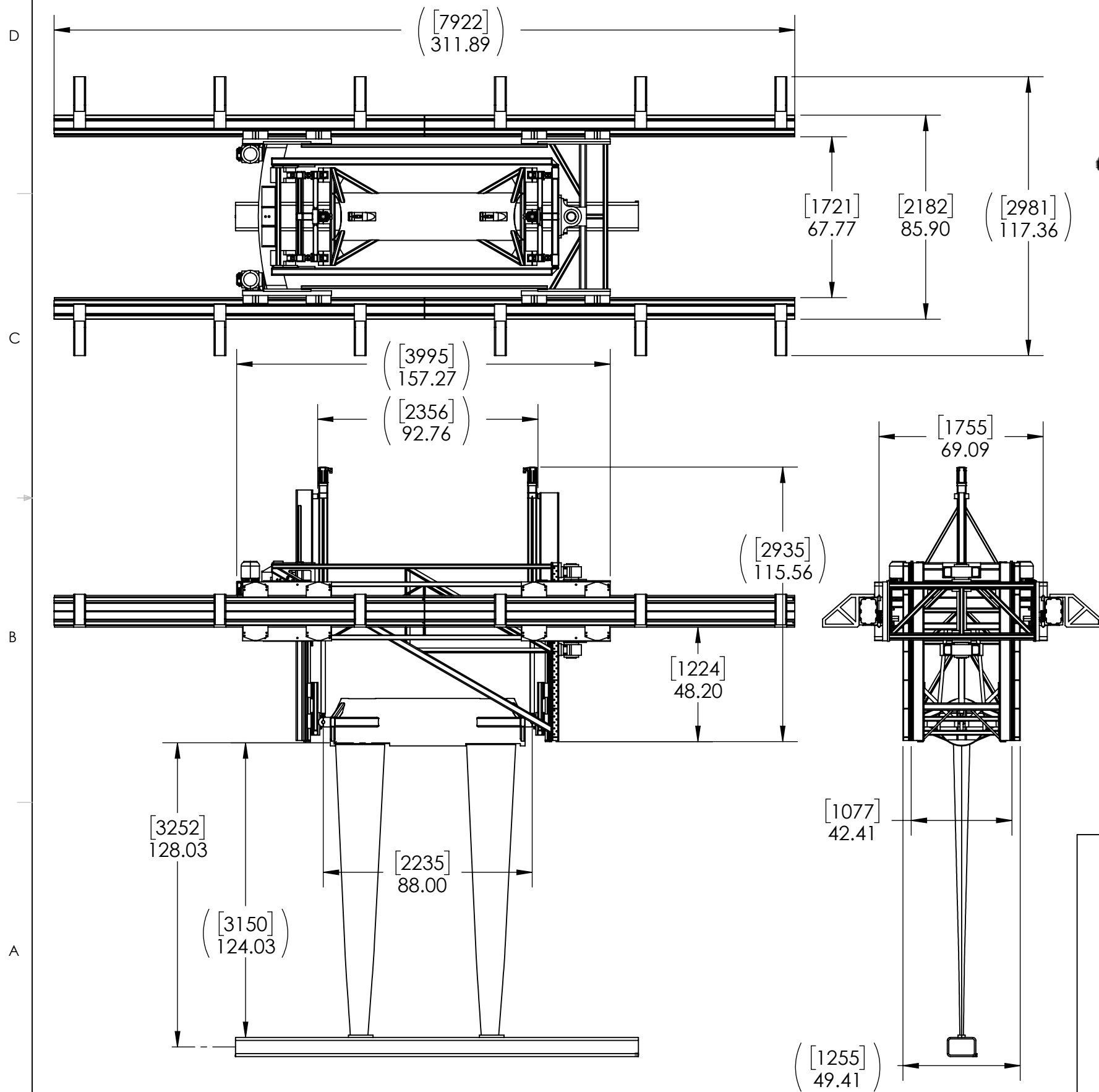
Appendix B  
October 20, 2023

## APPENDIX B

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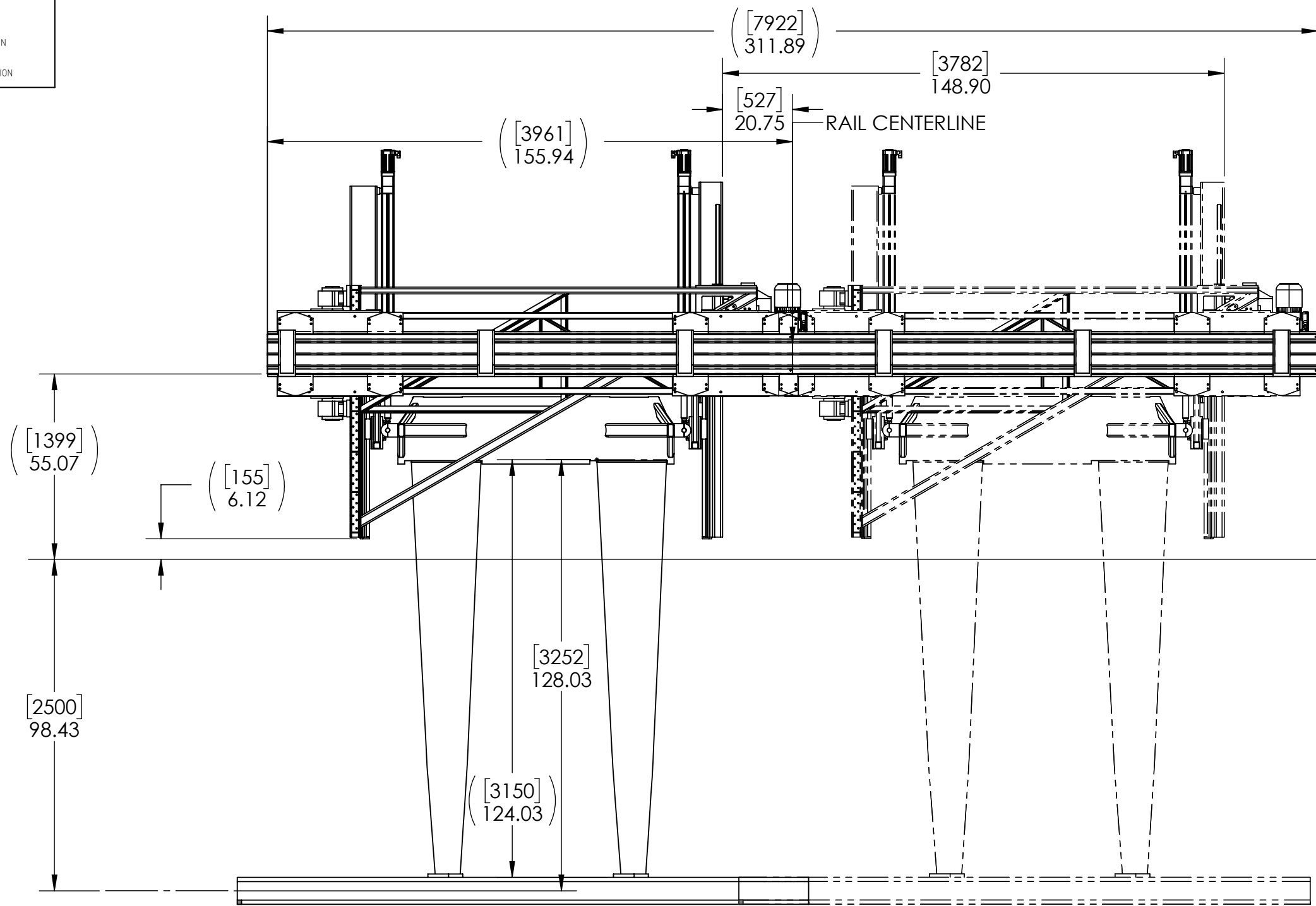


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UNLESS OTHERWISE NOTED SAUF INDICATION CONTRAIRE		HEAT TREAT./TRAITEMENT THERM.		OCEANS, COASTAL, AND RIVER ENGINEERING GENIE OCEANIQUE, COTIER, ET FLUVIAL	
ALL DIMENSIONS IN INCHES DIMENSIONS EN POUÇES		FINISH/FINI		TITLE / TITRE	
X ± .020 XX ± .010 XXX ± .002 ALL FRACTIONS ± 1/32		DFS/SCF FAB No.		HYBRID MOTION R2 MECHANICAL detached	
ANGULAR ± .50° / .010 FIM		DES. /CONCEPT.		INST./CLIENT	
CONFORMS TO/CONFORME A ASME Y14.100 - 2000		DRAWN /DESSINÉ <b>D Sparkes</b>		MODEL NAME / NOME DE MODELE	
BREAK ALL SHARP EDGES CHANFREINER TOUTES ARRÊTES COUPANTS .010 - .020		STRESS / CON.		SHEET/FEUILLE 1 of /de 1	
		CHECKED/VÉRIF.		SCALE/ÉCHELLE NTS	
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STRESS / CON.  CHECKED/VÉRIF.  APP./APP. Created Date: 2022-01-31 Last Saved Date: 2022-02-23	INST./CLIENT  MOD CARD	MODEL NAME / NOME DE MODELE  ASSEMBLY NO./No ASSEMBLAGE	SHEET/FEUILLE 1 of /de 1	SCALE/ÉCHELLE NTS	QTY. NA  REV. 2

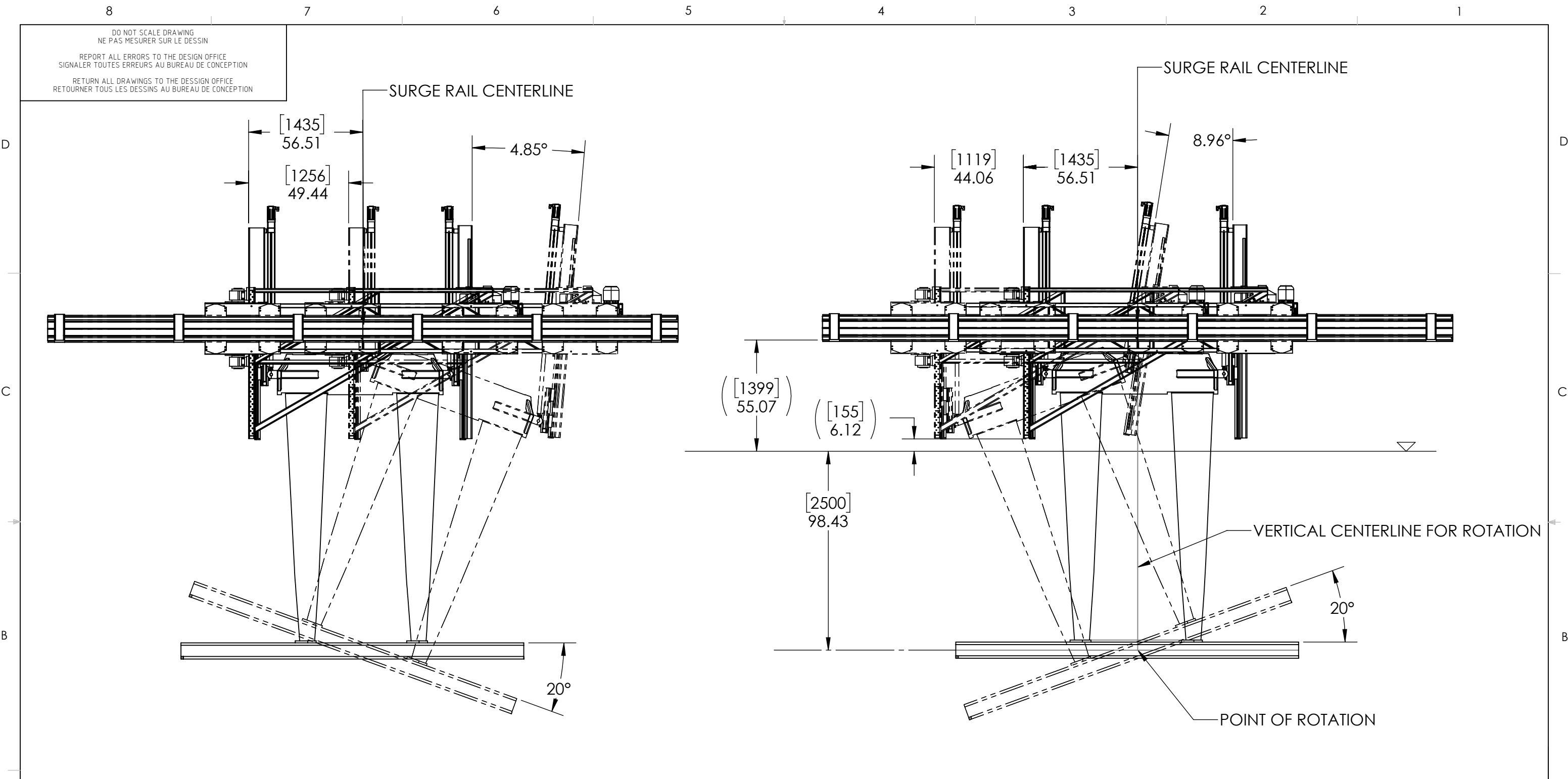
**B**



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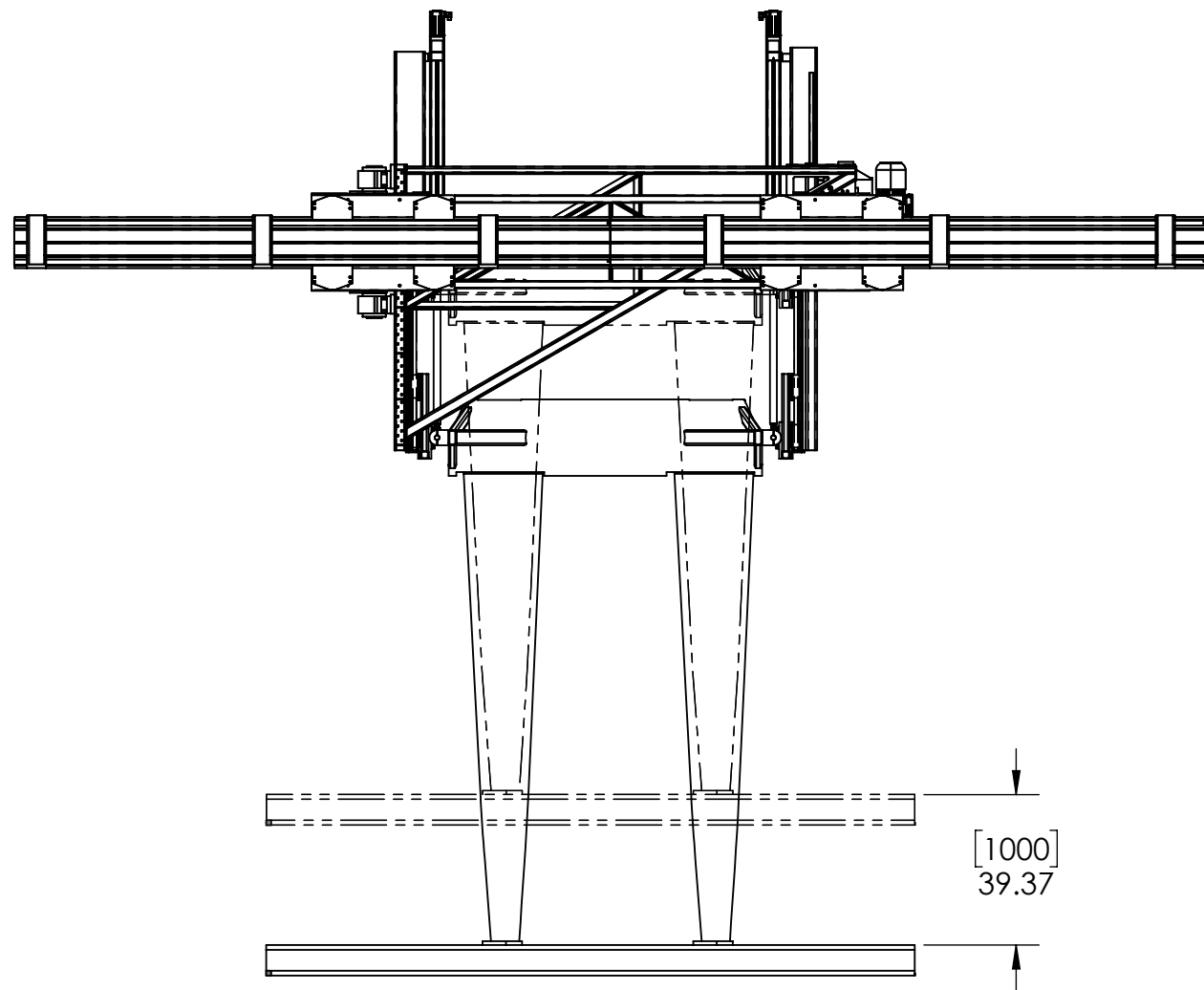
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INST./CLIENT MODEL NAME / NOME DE MODELE SHEET/FEUILLE 1 of /de 1 SCALE/ÉCHELLE NTS QTY. NA	MOD CARD ASSEMBLY NO./No ASSEMBLAGE DRAWING No./No DESSIN	REV. <b>B</b> 2			

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<p>TOLERANCES/TOLÉRANCES</p> <p>UNLESS OTHERWISE NOTED SAUF INDICATION CONTRAIRE</p> <p>ALL DIMENSIONS IN INCHES DIMENSIONS EN POUÇES</p> <p>.X ± .020 .XX ± .010 .XXX ± .002</p> <p>ALL FRACTIONS ± 1/32</p> <p>ANGULAR ± .50° / .010 FIM</p> <p>CONFORMS TO/CONFORME A ASME Y14.100 - 2000</p> <p>BREAK ALL SHARP EDGES CHANFREINER TOUTES ARRÊTES COUPANTS .010 - .020</p>	<p>MATERIAL/MATÉRIEL</p>		<p> National Research Council Canada Conseil national de recherches Canada <b>NRC-CMRC</b></p>					
	<p>HEAT TREAT./TRAITEMENT THERM.</p>		<p><i>OCEANS, COASTAL, AND RIVER ENGINEERING</i> <i>GENIE OCEANIQUE, COTIER, ET FLUVIAL</i></p>					
	<p>FINISH/FINI</p>							
	<p>DFS/SCF FAB No.</p>		<p>TITLE / TITRE</p> <p style="text-align: center;">HYBRID MOTION R2 heave</p>					
<p>DES. /CONCEPT.</p>		<p>DRAWN /DESSINÉ <b>D Sparkes</b></p>		INST./CLIENT	MODEL NAME / NOME DE MODELE	SHEET/FEUILLE 1 of /de 1	SCALE/ÉCHELLE NTS	QTY. NA
<p>STRESS / CON.</p>		<p>CHECKED/VÉRIF.</p>		MOD CARD	ASSEMBLY NO./No ASSEMBLAGE	DRAWING No./No DESSIN		REV. 2
<p>APP./APP.</p>		<p>Created Date: 2022-01-31 Last Saved Date: 2022-02-22</p>						<b>B</b>

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## **VERTICAL PLANAR MOTION MECHANISM (VPMM) SYSTEM**

Appendix C  
October 20, 2023

# **APPENDIX C**

## Appendix C: Estimated Capacity of Motion Mechanism

The motion mechanism of the VPMM has several key components whose capacities dominate the success of the VPMM development. These include the surge carriage, and the two vertical actuators which control the combination of the model heave and pitch.

In order to estimate required driving speed, force and power of these individual motion mechanisms a simplified model was created for dynamic analysis. The model was shown in Figure A-1 with estimated masses and dimensions for all major parts and assemblies. These inputs of masses and dimensions can be updated when necessary during the stage of fabrications.

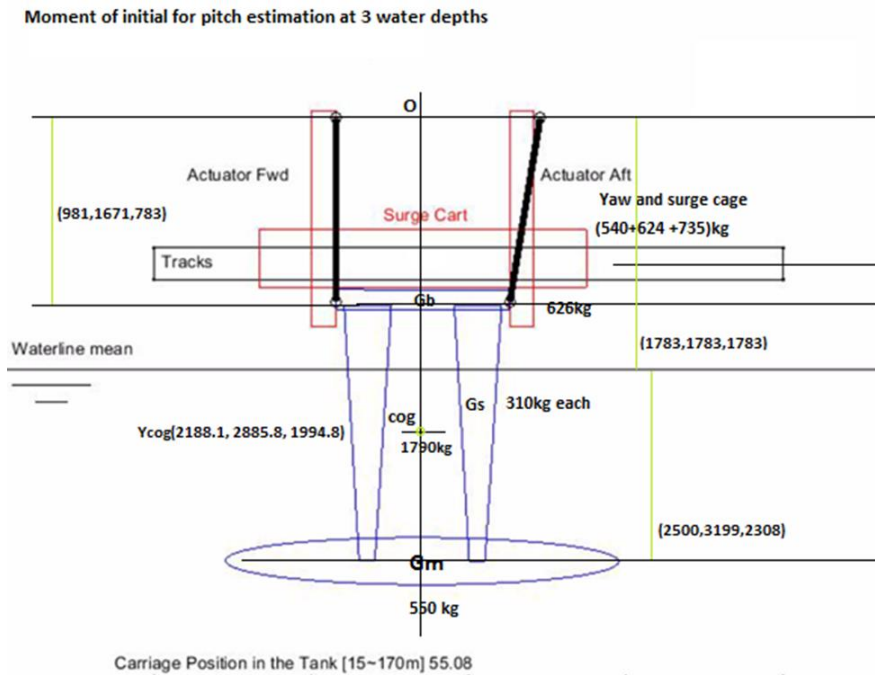


Figure A-1 VPMM Test Setup

Estimations of required driving speed, force and power were carried out through case studies, namely pure surge, pure heave and pure pitch motions at the model gravity centre.

### 1. Pure Surge

The total mass moving with surge cage was assumed about 3775 kg in this estimation. This total mass includes the yaw adjustment frame, surge cage, heave cage, twin swords, and the model of 550kg.

A pure surge motion of the model can be formulated as a constant forward speed, carriage speed, plus a sinusoidal motion in x direction.

$$\dot{x}_m = U + \dot{x}_{vpmm} = U + A_u \sin(2\pi f_{surge} t) \quad (A1.1)$$

where  $A_u$  is the amplitude of VPMM surge speed in m/s,  $f_{surge}$  is the frequency in Hz, and  $t$  is the time,  $U$  is the carriage steady speed in m/s,  $\dot{x}_m$  and  $\dot{x}_{vpmm}$  are speeds for model and VPMM respectively.

The displacement amplitude in surge is,

$$A_x = \frac{-A_u}{2\pi f_{surge}} \text{ in meter, and } A_u = -2\pi f_{surge} A_x \text{ in m/s.} \quad (A1.2)$$

The Hydrostatic and Hydrodynamic load on the surge driving system consists of loads on the twin swords and the model. As a simplified estimation the Hydrodynamic load on the twin sword has been assumed to be a half of the load on the submarine model.

$$X_{hd} = X_{hdm} + X_{hds} = X_{model} + X_{sword} \cong 1.5 X_{model}$$

There is no contribution to the surge from hydrostatic for this case. The only hydrostatic contribution is the buoyancy of the model and twin in the vertical direction affecting the model heave. It will be discussed in heave and pitch test.

Refer to a typical submarine derivatives the steady load on a towed model is presented by its drag coefficient and tow speed.

$$X_U = -\frac{1.65}{1000} * 0.5\rho L_{pp}^2 \dot{x}^2 \cong -18U^2 \quad \text{in Newton when } U \text{ in m/s} \quad (A1.3)$$

where  $L_{pp} = 4.67$  m for case studies in following sessions.

Unsteady Hydrodynamic load due to added mass is estimated using following function.

$$X_{add} = -\frac{0.45}{1000} * 0.5\rho L_{pp}^3 \ddot{x}_m \cong -23 \ddot{x}_m \text{ in Newton meter when } \ddot{x}_m \text{ in m/s/s} \quad (A1.4a)$$

$$X_{hdm} = X_U + X_{add} = -18U^2 - 23 \ddot{x}_m \quad (A1.4b)$$

The total hydrodynamic load of model and sword is then represented as,

$$X_{hd} = 1.5 * (X_U + X_{add}) = 27U^2 + 34.5 \ddot{x}_m \quad (A1.5)$$

The driving force  $D_{surge}$  required to move the model in the pure surge test consists of two major parts, the force to overcome the hydrodynamic load shown as in eq(1.5) and the driving force to overcome the reaction force from VPMM to generate predefined motion.

$$D_{surge} = X_{hd} + (1 + 0.1) * (m_{surge} * \ddot{x}_{vpmm}) \quad (A1.6)$$

The reaction force was a product of the moving mass and its acceleration. A factor of 1.1 is applied tending to include friction and windage effects. Be aware of this estimation applies to the period of the carriage at steady state.

The surge driving force required is then presented as follow,

$$D_{surge} = 27U^2 + 34.5 \ddot{x}_m + 1.1 * m_{surge} * \ddot{x}_{vpmm} \quad (A1.7a)$$

or

$$D_{surge} = 27 * U^2 + (2.2 * m_{surge} + 69.0) * \pi f_{surge} A_u \cos(2\pi f_{surge} t) \quad (A1.7b)$$

$$P_{surge} = D_{surge} * u_{surge} \quad (A1.8)$$

Estimated results from an example case were shown in Figure A-2. The inputs for this example case were  $f_{surge} = 0.26\text{Hz}$ ,  $A_u = 1.882\text{m/s}$ ,  $A_x = 1.152\text{m}$ , and  $U = 3\text{m/s}$ .

The peak force estimated was  $D_{surge} = 13.1\text{ kN}$ ; and the peak power obtained was  $P_{surge} = 12.4\text{ kw}$

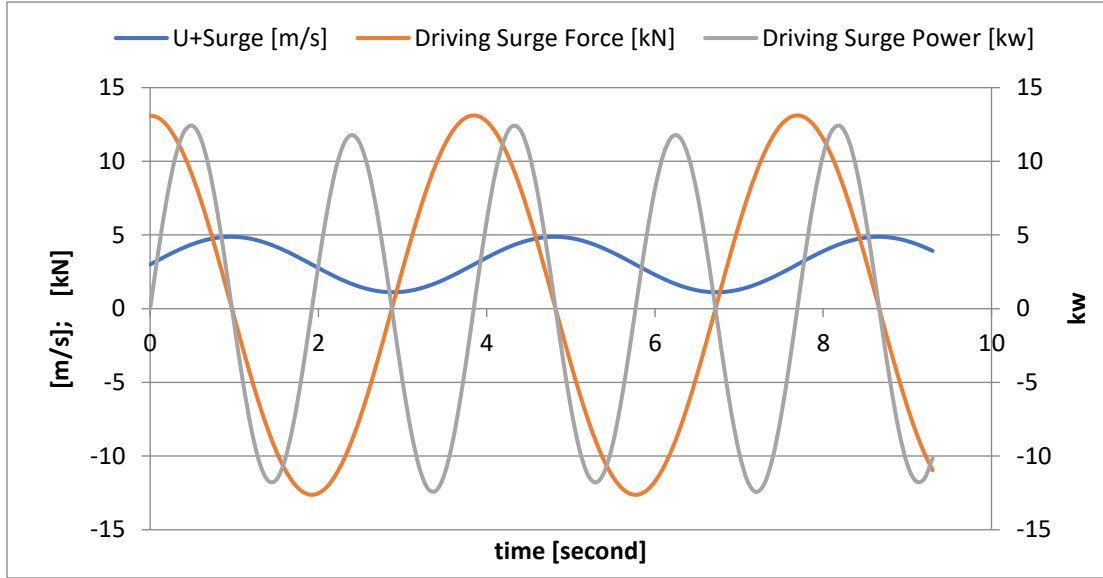


Figure A-2 Required Driving Force and Power for a Pure Surge

## 2. Pure Heave

The total mass moving with heave cage was estimated about 1796kg. This total mass includes heave cage, twin swords, and the model. However, the model added mass will be considered as hydrodynamic load, and its buoyancy will be considered in hydrostatics.

The pure heave motion of the model can be formulated as a sinusoidal motion in vertical direction plus a constant carriage speed in x direction. For pure heave test the model is considered to be zero trim, and the model vertical motion  $\dot{z}_m$  is exactly the same as that of the heave cage of VPMM  $\dot{z}_{vpmm}$ .

$$\dot{z}_m = \dot{z}_{vpmm} = A_w \sin(2\pi f_{heave} t) \quad (A2.1)$$

where  $f_{heave}$  is the heave frequency of VPMM, and  $A_w$  is the amplitude of heave speed. The heave displacement amplitude  $A_z$  is then,

$$A_z = \frac{-A_w}{2\pi f_{heave}} \text{ in meter} \quad (A2.2)$$

The driving force required for heave is majorly affected by three terms, hydrostatic load, hydrodynamic loads from the submerged swords and model, and reaction from all moving bodies with the heave motion.

Usually a submarine model is over ballasted by 10% during deeply submerged tests. For the case considered the buoyancy of the model is assumed to be negative -50kg. The buoyancy of twin swords is estimated around +170kg. The total contribution from gravity and hydrostatic is then expressed as,

$$Z_{ghs} = -g(1796 - 170 + 50) = -1676g \quad \text{in Newton} \quad (A2.3)$$

Hydrodynamic load on the model is estimated using imposed hydrodynamic derivative values.

$$Z_{hdm} = 0.5\rho L_{pp}^2 \left( \frac{0.41}{1000} * U^2 - \frac{30}{1000} * UW - \frac{44}{1000} * w|w| - \frac{16.6}{1000} * L_{pp}W_{dot} \right)$$

$$Z_{hdm} = 4.47U^2 - 327\dot{z}U - 480\dot{z}|z| - 823\ddot{z} \quad (A2.4)$$

Hydrodynamic load in vertical direction is assumed to be 20% of that on the model. The total hydrodynamic load on the model and sword will be,

$$Z_{hd} = 1.2 * Z_{hdm} = 5.36U^2 - 392\dot{z}U - 576\dot{z}|z| - 988\ddot{z} \quad (A2.5)$$

Driving force for heave test consists three terms, gravity and hydrostatic  $Z_{ghs}$ , hydrodynamic  $Z_{hd}$ , and reaction from the heave motion.

$$D_{heave} = -Z_{ghs} - Z_{hd} + (1 + 0.1) * (m_{heave} * \ddot{z}_{vpmm})$$

Mechanical friction and windage effects are considered by adding ten percent to the reaction force term. And  $\ddot{z} = \ddot{z}_{vpmm}$  is applicable to heave test.

$$D_{heave} = 1676g - (5.36U^2 - 392\dot{z}U - 576\dot{z}|z| - 988\ddot{z}) + 1.1(1796 \ddot{z}_{vpmm})$$

$$D_{heave} = 1676g - 5.36U^2 + 392\dot{z}U + 576\dot{z}|z| + 2964\ddot{z} \quad (A2.6)$$

Substitute imposed heave motion into eq(2.6) then,

$$D_{heave} = 1676g - 5.36U^2 + 392UA_w \sin(2\pi f_{heave}t) + 576A_w^2 \sin(2\pi f_{heave}t) |\sin(2\pi f_{heave}t)| + 5928A_w \pi f_{heave} \cos(2\pi f_{heave}t) \quad (A2.7)$$

$$P_{heave} = D_{heave} * \dot{z} \quad (A2.8)$$

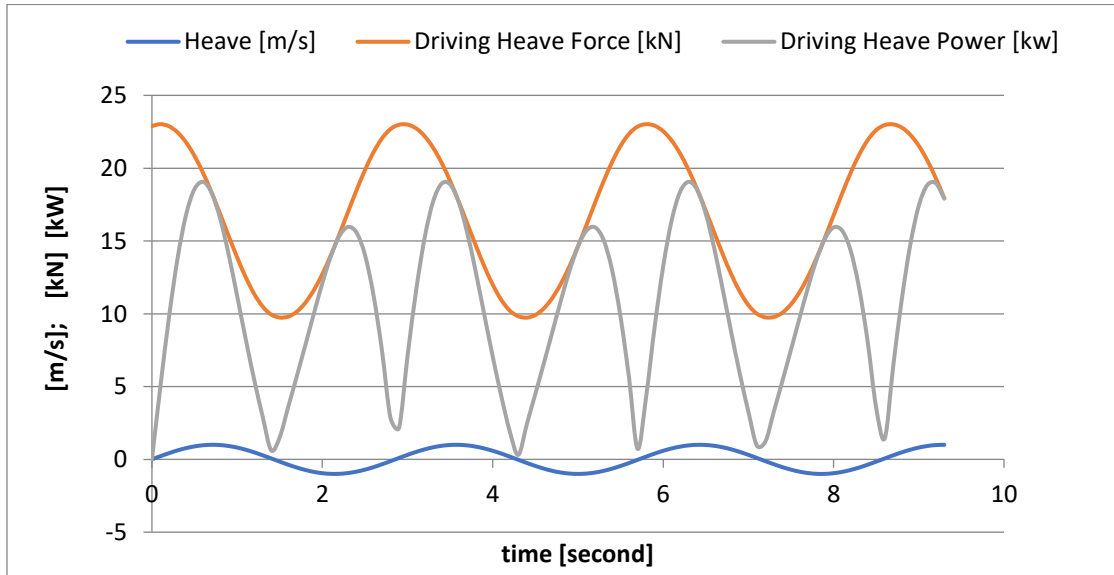


Figure A-3 Required Driving Force and Power for a Pure Heave

$$(f_{heave} = 0.35 \text{ Hz}; \quad A_w = 1.000 \text{ m/s}; \quad U = 3 \text{ m/s})$$

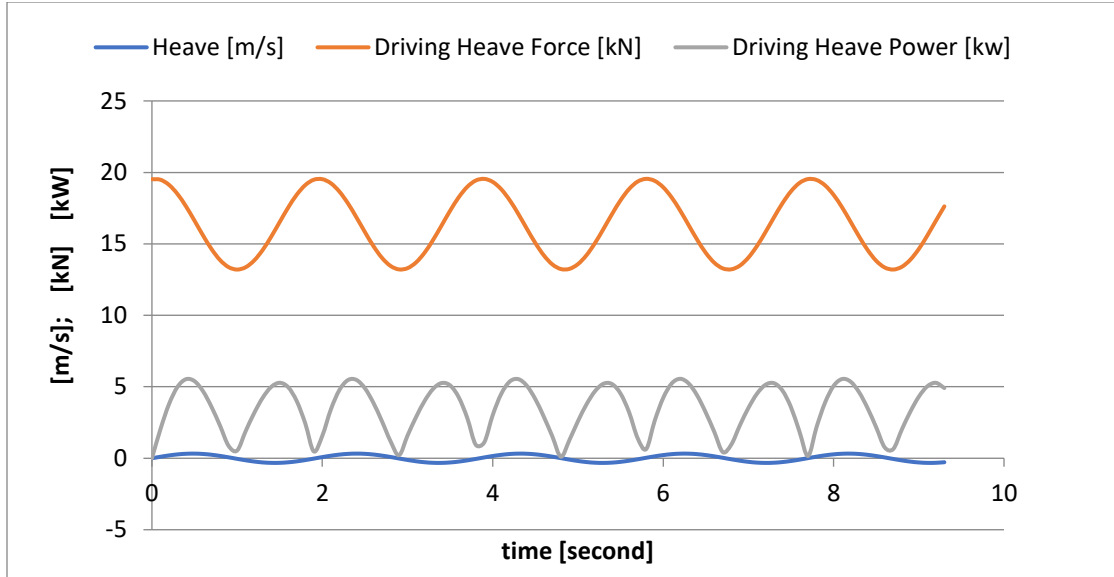


Figure A-4 Required Driving Force and Power for a Pure Heave

$$(f_{heave} = 0.52 \text{ Hz}; A_w = 0.325 \text{ m/s}); U = 3 \text{ m/s})$$

Two cases have been investigated. Their inputs and resulted driving forces and power were illustrated in Figures A-3 and A-4, and their maximum were summarized as follows.

**Case heave:**  $f_{heave} = 0.35 \text{ Hz}; A_w = 1.000 \frac{\text{m}}{\text{s}}; A_z = 0.455 \text{ m}, U = 3 \text{ m/s}$

The peak load  $D_{heave} = 23.0 \text{ kN};$  The peak power  $P_{heave} = D_{heave} * \dot{z} = 19.1 \text{ kw}$

**Case heave2:**  $f_{heave} = 0.35 \text{ Hz}; A_w = 0.325 \frac{\text{m}}{\text{s}}; A_z = 0.100 \text{ m}, U = 3 \text{ m/s}$

The peak load  $D_{heave} = 19.5 \text{ kN};$  The peak power  $P_{heave} = D_{heave} * \dot{z} = 5.6 \text{ kw}$

### Pure Pitch

Pure model pitch test, in fact is realized by a combined VPMM motion of pitch, heave and surge. Model pure pitch generation, load and driving power estimation are described and estimated in this section.

The total mass moving with pure pitch was estimated about 1796 kg. These include the model, twin swords, and heave cage which bound the two swords together. The middle point between two joints where two vertical actuator joint with the cage is defined as the reference center where heave and pitch motions are combined. The moment of initial around the reference center is estimated  $J=4500 \text{ kg.m.m.}$

A pure pitch motion around the model (aligned to the model GC as close as possible) in fact is a combined motion of the VPMM mechanism. To generate a pure model pitch, for example within +/-20 degrees of 0.26 Hz, surge and heave mechanisms of VPPM move passively to compensate the surge and heave of the model introduced from pitching the model by the VPMM.

$$\dot{\theta} = A_p \sin(2\pi f_{pitch} t) \tag{A3.1}$$



where  $A_p = -A_\theta 2\pi f_{pitch}$  and  $A_\theta$  is the amplitude of pitch angle in rad, for example 0.349 equivalent to 20 degrees.

$$\theta = A_\theta \cos(2\pi f_{pitch} t) \quad (A3.2)$$

The model center is around 3.3m (4283-981mm in pos1.pdf 1 and 4091-783mm in pos3.pdf) below the middle point of the heave cage. It is designated as the sword length  $L_s = 3.3m$ . The surge and heave motion induced are  $x_{ind} = -L_s \sin(\theta)$ , and  $z_{ind} = L_s (1 - \cos(\theta))$ . Flipping the signs get required compensation motions  $x_{comp}$ , and  $z_{comp}$ .

$$x_{comp} = -L_s \sin(\theta) \quad (A3.3)$$

$$z_{comp} = L_s (\cos(\theta) - 1) \quad (A3.4)$$

$$\dot{x}_{comp} = -L_s \cos(\theta) \dot{\theta} = L_s A_\theta 2\pi f_{pitch} \cos[A_\theta \cos(2\pi f_{pitch} t)] \sin(2\pi f_{pitch} t) \quad (A3.5)$$

$$\dot{z}_{comp} = L_s \sin(\theta) \dot{\theta} = -L_s A_\theta 2\pi f_{pitch} \sin[A_\theta \cos(2\pi f_{pitch} t)] \sin(2\pi f_{pitch} t) \quad (A3.6)$$

The surge motion for compensation is dependent to actions of two vertical actuators. However, pitch and heave are coupled motion driven by the two vertical actuators. To implement these predefined motions of pitch and heave actions of the two actuators are derived by following approximations.

$$z_{ActFwd} + z_{ActAft} \cong 2 z_{comp}$$

$$z_{ActFwd} - z_{ActAft} \cong L_h \sin(\theta)$$

where  $L_h = 2.252m$ , the length of heave cage defined as the distance between two joints at the two actuator lower ends.

$$z_{ActFwd} \cong z_{comp} + 0.5L_h \sin\theta = L_s \cos(\theta) - L_s + 0.5L_h \sin\theta \quad (A3.7)$$

$$z_{ActAft} \cong z_{comp} - 0.5L_h \sin\theta = L_s \cos(\theta) - L_s - 0.5L_h \sin\theta \quad (A3.8)$$

Hydrodynamic load on the model is estimated by imposing related hydrodynamic derivatives with selected values.

$$M_{hdm} = 0.5\rho L_{pp}^3 \left( -\frac{0.07}{1000} * U^2 - \frac{0.696}{1000} * L_{pp}^2 \dot{q}_{dot} - \frac{5.73}{1000} * L_{pp} U q - \frac{1.33}{1000} * L_{pp}^2 q |q| \right)$$

$$M_{hdm} = (3.56 * U^2 + 774 \ddot{\theta} + 1362U \dot{\theta} + 1476 \theta |\dot{\theta}|) \quad (A3.9)$$

Hydrodynamic load on the model and swords

$$M_{hd} = 1.5(M_{hdm} + L_s X_{hdm}) = 1.5 M_{hdm} - 1.5L_s (27U^2 + 34.5 \ddot{x}_m)$$

$$M_{hd} = -139 * U^2 - 1161 \ddot{\theta} - 2032U \dot{\theta} - 2216\theta |\dot{\theta}| - 171 \ddot{x}_m$$

Applying  $\ddot{x}_m = L_s \ddot{\theta}$  to above equation

$$M_{hd} = -139 * U^2 - 1725 \ddot{\theta} - 2032U \dot{\theta} - 2216\theta |\dot{\theta}| \quad (A3.10)$$

Pitch moment from wet weight ( $m_{wet} = 1676kg$ )

$$M_{gravity} = -m_{wet} g L_s \sin \theta = -54202 \sin \theta \quad (A3.11)$$

Driving moment for pitch motion needs overcome the load of three terms, initial reaction to the motion, hydrodynamic, and gravity ( $m_{wet} = 1676\text{kg}$ )

$$D_{pitch} = J \ddot{\theta} - M_{hd} - M_{gravity}$$

$$M_{pitch} = 4500\ddot{\theta} + 139 * U^2 + 1725 \dot{\theta} + 2032U \dot{\theta} + 2216\theta|\dot{\theta}| + 54202 \sin \theta$$

$$M_{pitch} = 6225\ddot{\theta} + 139 * U^2 + 2032U \dot{\theta} + 2216\theta|\dot{\theta}| - 54202 \sin \theta$$

$$M_{pitch} = 12450\pi f_{pitch} A_p \cos(2\pi f_{pitch} t) + 139 U^2 + 2032U A_p \sin(2\pi f_{pitch} t) + 2216 A_p^2 \sin(2\pi f_{pitch} t) |\sin(2\pi f_{pitch} t)| + 54202 \sin \theta$$

(A3.12)

Since the pitch moment and heave forces are coupled and they are overcome by the combination of driving forces,  $D_{ActFwd}$  and  $D_{ActAft}$ , generated from the two vertical actuators. They are presented as,

$$D_{ActFwd} + D_{ActAft} = D_{heave}$$

$$D_{ActFwd} - D_{ActAft} = M_{pitch}/L_h$$

Then two actuator forces are calculated by using following equations,

$$D_{ActFwd} = 0.5 D_{heave} + 0.5 M_{pitch}/L_h \quad (A3.13)$$

$$D_{ActAft} = 0.5 D_{heave} - 0.5 M_{pitch}/L_h \quad (A3.14)$$

To assembly the driving forces in the surge cage and two vertical actuators some preparations should be done properly. Firstly matching surge and heave motions to compensation motions required for the pure model pitch. Then driving forces for the surge and heave are estimated by using the equation derived in sections of pure surge and pure heave. Finally driving forces and moment are assembled and transferred to the driving forces on the surge cage, and two actuators.

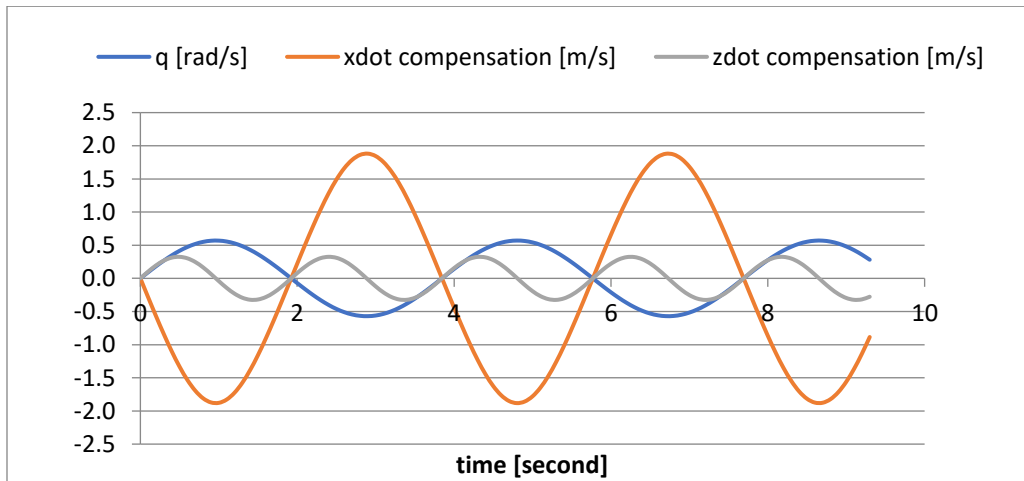


Figure A-5 Model Pure Pitch and Compensation Surge and Heave

Compensation surge and heave are calculated by using equations A3.3 and A3.4. As shown in Figure A-5 that the frequency of compensation surge is the same as the frequency of pitch. However, the frequency of compensation heave is twice of the frequency of the pitch.

$$f_{surge} = f_{pitch} \quad (A3.15)$$

$$f_{heave} = 2f_{pitch} \quad (A3.16)$$

Refer equations A3.5 and A3.6 amplitudes of compensation surge and heave are functions of pitch frequency, sword length, and

$$A_u = 2\pi f_{pitch} L_s A_\theta \quad (A3.17)$$

$$A_w = 2\pi f_{pitch} L_s A_\theta \sin A_\theta \quad (A3.18)$$

Driving force in surge and heave are estimated by using equations A1.7 and A2.7 after matching the frequency and amplitude to that of required compensation motions. Substitute equation A3.15 to A3.18 to equations A1.7 and A2.7 one will have

$$D_{comps} = 27 * U^2 + (4.4 * m_{surge} + 138) * (\pi f_{pitch})^2 L_s A_\theta \cos(2\pi f_{pitch} t) \quad (A3.19)$$

$$D_{comph} = 1676g - 5.36U^2 + 784U\pi f_{pitch} L_s A_\theta \sin A_\theta \sin(4\pi f_{pitch} t) + 2304(\pi f_{pitch} L_s A_\theta \sin A_\theta)^2 \sin(4\pi f_{pitch} t) |\sin(4\pi f_{pitch} t)| + 23712(\pi f_{pitch})^2 L_s A_\theta \sin A_\theta \cos(4\pi f_{pitch} t) \quad (A3.20)$$

Plus

$$M_{pitch} = -24900(\pi f_{pitch})^2 A_\theta \cos(2\pi f_{pitch} t) + 139 U^2 - 4064U A_\theta \pi f_{pitch} \sin(2\pi f_{pitch} t) + 8864 (A_\theta \pi f_{pitch})^2 \sin(2\pi f_{pitch} t) |\sin(2\pi f_{pitch} t)| + 54202 \sin(A_\theta \cos(2\pi f_{pitch} t)) \quad (A3.21)$$

$$P_{surge} = abs(D_{surge} * \dot{x}_v) \quad (A3.21)$$

$$P_{ActFwd} = abs(D_{ActFwd} * \dot{z}_{Fwd}) \quad (A3.22)$$

$$P_{ActAft} = abs(D_{ActAft} * \dot{z}_{Aft}) \quad (A3.23)$$

Selecting  $A_\theta = 20$  degrees,  $f_{pitch} = 0.26$  Hz, and carriage speed of  $U = 3$  m/s, as an study case. The Driving forces required for surge and two actuators are plotted in Figure A-6. Equations used for these calculations are A3.21 - A3.23, and A3.13 - A3.14.

Driving power estimated for the surge and two actuators are plotted Figure A-7. Equations used for these estimations are A3.21 - A3.23.

The maximum driving forces for surge, and two actuators are 13.1, 14.5, and 13.9kN respectively. Corresponding required driving powers are 12.1, 8.8, and 8.4kw.

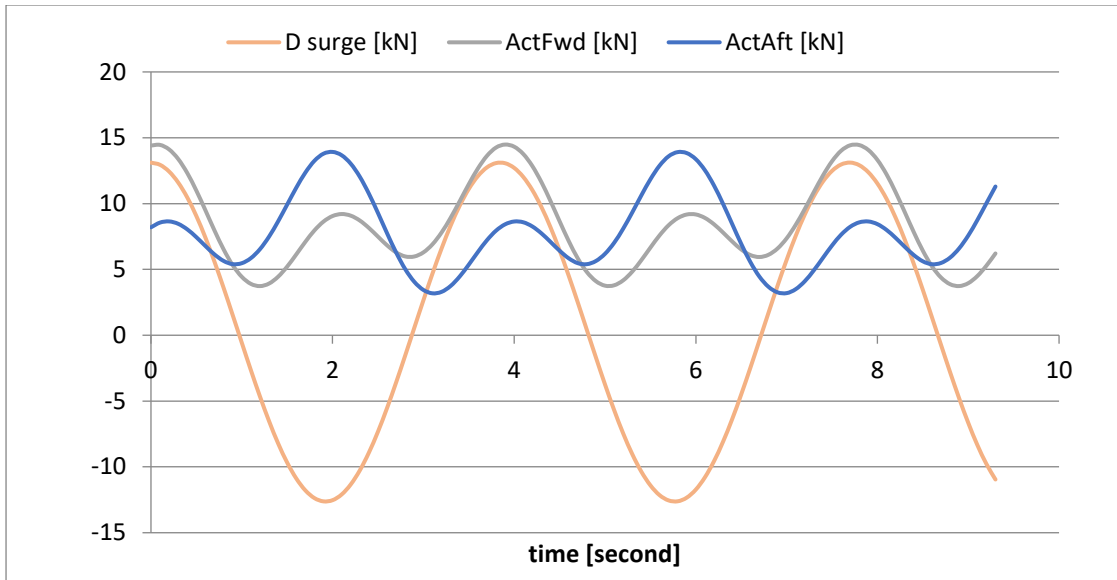


Figure A-6 Driving force estimation for a pure model pitch

$(U = 3 \text{ m/s}, f_{pitch}=0.26 \text{ Hz}, A_{\theta} = 20 \text{ degrees})$

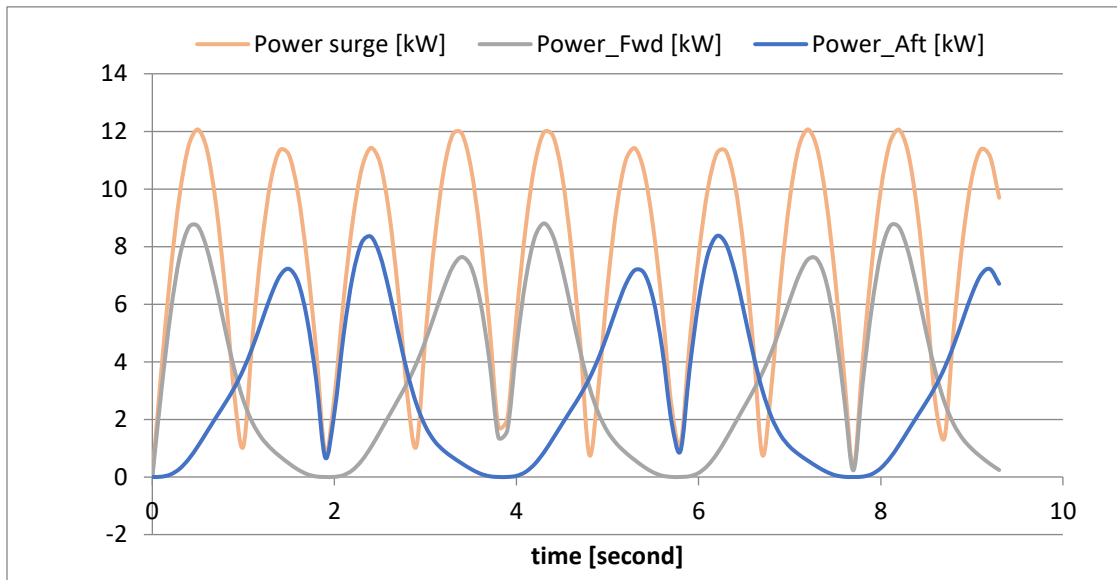


Figure A-7 Driving power estimation for a pure model pitch

$(U = 3 \text{ m/s}, f_{pitch}=0.26 \text{ Hz}, A_{\theta} = 20 \text{ degrees})$

Based on analysis of the 4 cases a summary of required driving forces and power are listed in following table.

Table A1. Summary of Case Studies

Cases	freq	Amp	X_vpm	Z_vpm	M_vpm	Z_Fwd	Z_Aft	Pow_x	Pow_fwd	Pow_aft
	Hz	u/w/p	kN	kN	kNm	kN	kN	kW	kW	kW
surge	0.260	1.882m/s	13.115					12.433		
Heave	0.350	1.000		23.021		11.511	11.511		9.533	9.533
Heave2	0.520	0.325		19.548		9.774	9.774		2.779	2.779
pitch	0.260	0.570	0.013	23.019	14.431	0.014	0.014	0.012	0.009	0.008
MAX			<b>13.115</b>	<b>23.021</b>	<b>14.431</b>	<b>11.511</b>	<b>11.511</b>	<b>12.433</b>	<b>9.533</b>	<b>9.533</b>

Recommendations will be made as follows.

1. Surge carriage Driving force and power for the surge are estimated as 13.1kN and 12.4kW. So the driving force and power for the surge cage are suggested 15kN and 15kw.
2. Driving forces estimated for the two vertical actuators are 14.5kN and 13.9kN respectively. Driving power estimated are 9.5kw, the same for both forward and afterward actuators. The two actuators are suggested to be the same, and its force and power are 15kN and 10kw.

These recommendations lead a brief specification for key components of surge mechanism and vertical actuators as listed in Table A2. These specified motion ranges and power capacities will be used as reference in seeking market parts and assemblies for the VPMM fabrication.

Table A2. Required Capacities of Motion Mechanism

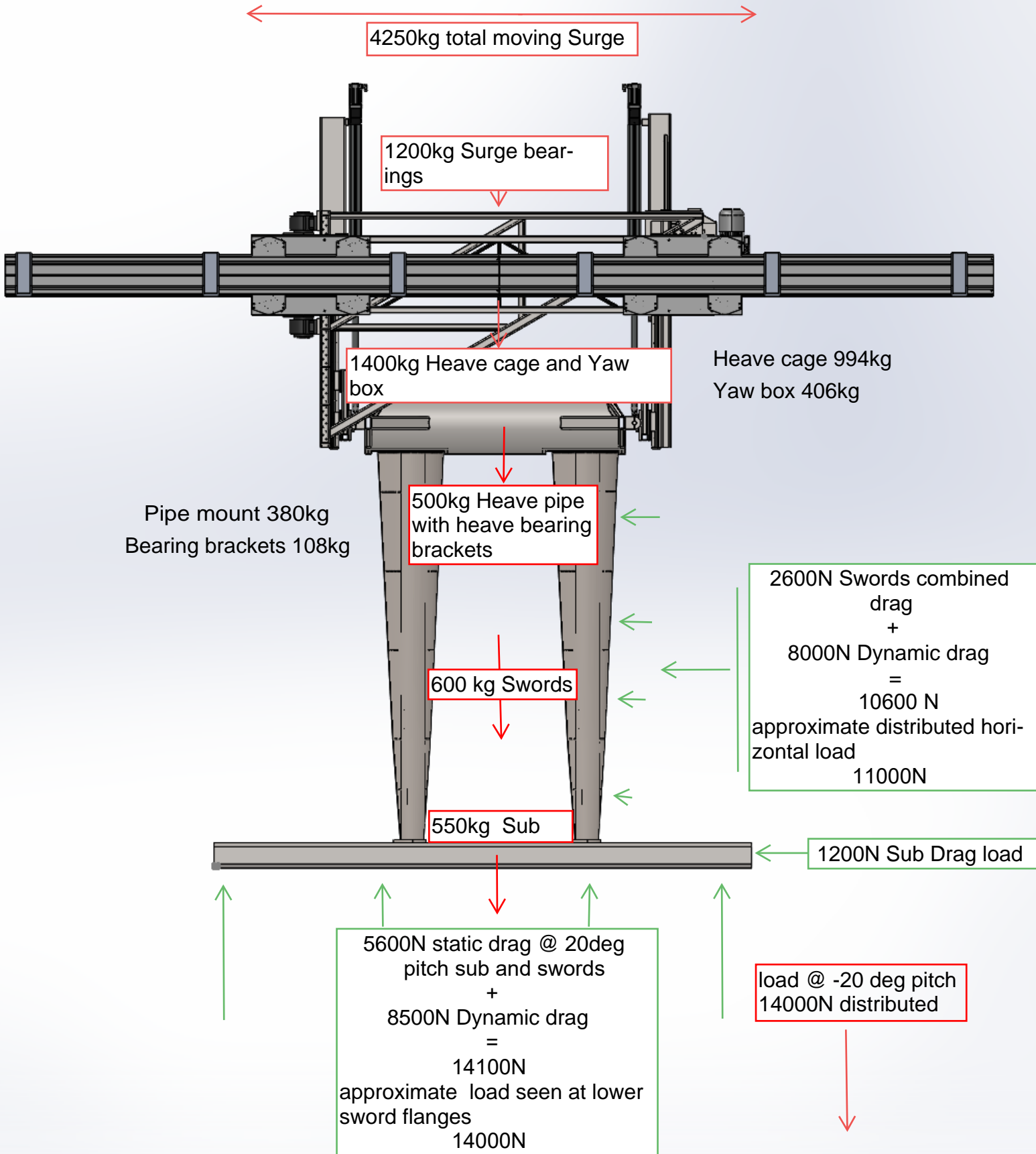
Parameters	unit	Surge Mechanism	Vertical Actuators
Stroke, amplitude	m	1.152	0.455
Max. speed	m/s	1.882	1.000
Max. Frequency	Hz	0.26	0.52
Max. Force	kN	15	15
Max. Power	kW	15	10

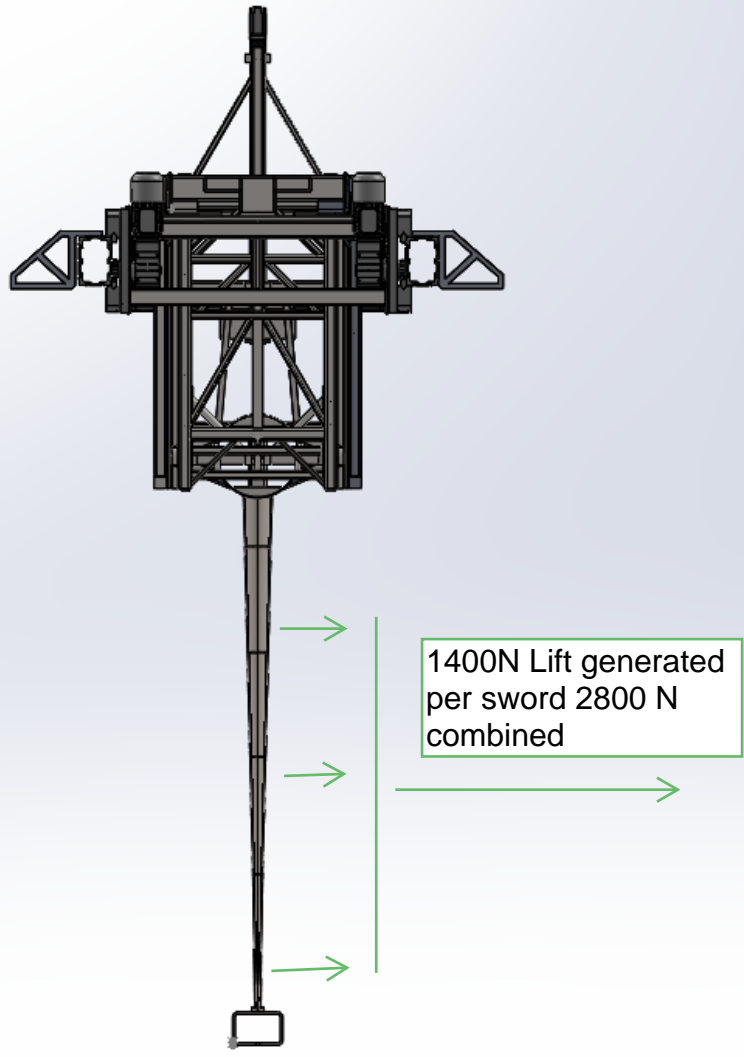
# VERTICAL PLANAR MOTION MECHANISM (VPMM) SYSTEM

Appendix D  
October 20, 2023

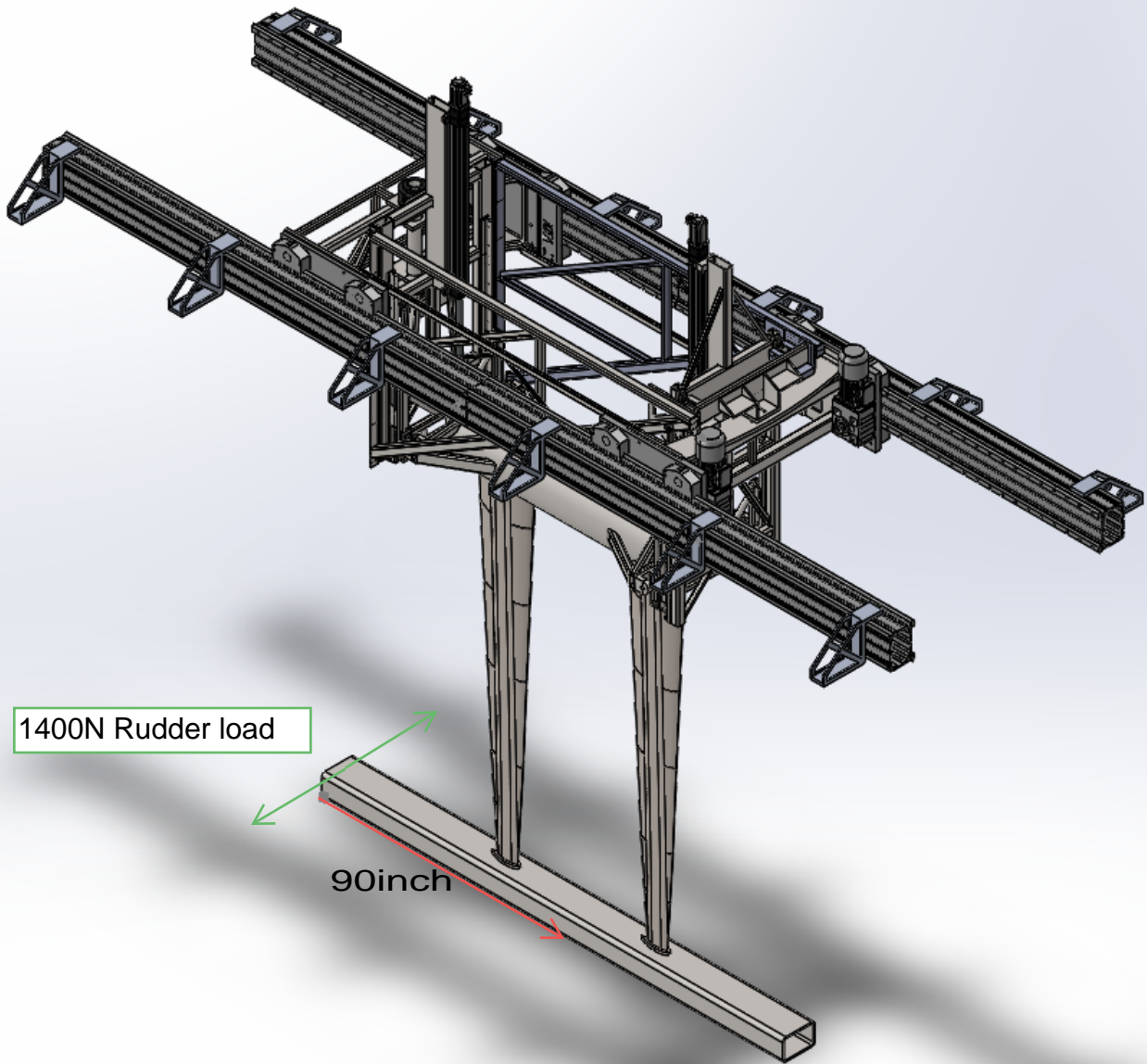
## APPENDIX D

# Concept Estimated Design Loading









1400N Rudder load

90inch

# VERTICAL PLANAR MOTION MECHANISM (VPMM) SYSTEM

Appendix E  
October 20, 2023

## APPENDIX E

# **NATIONAL RESEARCH COUNCIL**

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**Vertical Planar Motion Mechanism (VPMM)**

**St. John's, NL**

**Contract No. 979700**

**SPECIFICATIONS**

**Issued for Tender**

**2023-10-20**

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## **Part 1 General**

### **1.1 WORK COVERED BY CONTRACT DOCUMENTS**

- .1 Work of this Contract comprises general construction of a Vertical Planar Motion Mechanical (VPMM), located at the National Research Council, St. John's, NL; and further identified in the drawings and technical specifications, consisting of the following components:
  - .1 Mechanical system frame to allow the mounting of a pair of support swords which carry the system dynamometer;
  - .2 All necessary hardware to allow the VPMM to be assembled and disassembled to the existing carriage, including any special tools;
  - .3 Electrical system which shall be connected to the existing NRC Tow Tank carriage;
  - .4 Interface cabling to allow the system to be connected to NRC system;
  - .5 Junction boxes and energy chain system;
  - .6 Control panels and other systems to be integrated with NRC Tow Tank controls systems;
  - .7 Storage system to allow the system to be stored when not in use.
  - .8 System shall be shipped, install, tested and commissioned at National Research Council, Ocean, Coastal and River Engineering Research Centre, located at 1 Arctic Avenue, St. John's, NL.

### **1.2 SUBMITTALS**

- .1 Submit in accordance with Section 01 33 00 - Submittal Procedures
- .2 Submit Project construction progress schedule in accordance with Section 01 31 00 - Project Management.
- .3 Sustainable Design Submittals:
  - .1 Construction Waste Management:
    - .1 Submit project Waste Management Plan highlighting recycling and salvage requirements.
- .4 Submit site-specific and Work Plan Health and Safety Plan in accordance with Section 01 35 29.06 - Health and Safety Requirements.

### **1.3 WORK BY OTHERS**

- .1 Owner to supply underwater apparatus and sensors for this project execution.
- .2 Coordinate with Owner for final product selections and cabling in-order to provide a complete operating system.
- .3 Owner will be responsible for final terminations of cables (supplied by this Contract) at end-devices.
- .4 Contract to include all intermediate terminations of cables at noted plug/socket connectors.

### **1.4 WORK SEQUENCE**

- .1 Construct Work in stages to accommodate Owner's continued use of premises during construction.

- .2 Co-ordinate Progress Schedule and co-ordinate with Owner Occupancy during construction.
- .3 Construct Work in stages to provide for continuous user access. Do not close off user access of facilities until use of one stage of Work will provide alternate usage.
- .4 Maintain fire access/control.
- .5 Protect workers and public safety.

#### **1.5 CONTRACTOR USE OF PREMISES**

- .1 Limit use of premises for Work, for storage, and for access, to allow:
  - .1 Owner occupancy.
  - .2 Partial owner occupancy.
  - .3 Work by other contractors.
- .2 Co-ordinate use of premises under direction of Departmental Representative.
- .3 Obtain and pay for use of additional storage or work areas needed for operations under this Contract.
- .4 Remove or alter existing work to prevent injury or damage to portions of existing work which remain.
- .5 Repair or replace portions of existing work which have been altered during construction operations to match existing or adjoining work, as directed by Departmental Representative.
- .6 Ensure that operations conditions of exiting work at completion are still the same, equal to or better than that which existed before new work started.

#### **1.6 OWNER OCCUPANCY**

- .1 Owner will occupy premises during entire construction period for execution of reduced operations.
- .2 Co-operate with Owner in scheduling operations to minimize conflict and to facilitate Owner usage.

#### **1.7 PRE-PURCHASED EQUIPMENT**

- .1 Owner to supply underwater apparatus and sensors for this project execution.

#### **1.8 ALTERATIONS, ADDITIONS OR REPAIRS TO EXISTING BUILDING**

- .1 Execute work with least possible interference or disturbance to building operations and occupants, public and normal use of premises. Arrange with Departmental Representative to facilitate execution of work.
- .2 Use only elevators existing in building for moving workers and material.
  - .1 Investigate the status of existing elevators in building(s), if they are functional and safe for moving workers and materials before the Work starts.
  - .2 Provide the required protection for passenger elevators walls, obtain Departmental Representative approval before using these elevators.
  - .3 Accept liability for damage, safety of equipment and overloading of existing equipment.

#### **1.9 EXISTING SERVICES**

- .1 Notify, Departmental Representative of intended interruption of services and obtain required permission.

- .2 Where Work involves breaking into or connecting to existing services, give Departmental Representative 48 hours notice for necessary interruption of mechanical or electrical service throughout course of work. Minimize duration of interruptions. Carry out work at times as directed by governing authorities with minimum disturbance to building operations.
- .3 Establish location and extent of service lines in area of work before starting Work. Notify Departmental Representative of findings.
- .4 Submit schedule for approval by Departmental Representative for any shut-down or closure of active service or facility including power and communications services. Adhere to approved schedule and provide notice to affected parties.
- .5 Provide temporary services when directed by Departmental Representative to maintain critical building and tenant services.
- .6 Where unknown services are encountered, immediately advise Departmental Representative and confirm findings in writing.
- .7 Protect, relocate or maintain existing active services. When inactive services are encountered, cap off in manner approved by authorities having jurisdiction.
- .8 Record locations of maintained, re-routed and abandoned service lines.
- .9 Construct barriers, as required, to ensure health and safety of workers and building occupants.

**Part 2 Products - Not Used**

**Part 3 Execution - Not Used**

**END OF SECTION**

## **Part 1 General**

### **1.1 GENERAL SITE CONDITIONS AND WORK REQUIREMENTS**

- .1 Prior to start site work, contractor is responsible to obtain security clearance to their team, or work with Departmental Representative to secure the services of an appropriate escort (i.e. Commissionaires). Time to obtain security clearances shall be clear identified in the project schedule.
  - .1 Any supplier personal working on a regular basis on an NRC site location will be required to complete a reliability level security assessment. In case this is not possible supplier is responsible to secure an escort (i.e. Commissionaires) and bear the associated costs of hiring such services.
- .2 Contractor is responsible to set-up all temporary facilities needed for the work to be completed on site. The location of temporary facilities at site is to be discussed and approved by Departmental Representative.
- .3 Contractor is expected to have all materials available and ready for installation prior to start as part of the mobilization scope. Storage location for any material needed for this project to be discussed and approved by Departmental Representative.
- .4 Contractor is responsible to visit the site prior to installation and review with Departmental Representative the minimum work area required.
- .5 Contractor shall verify and list any on site interferences, which shall be listed as part of the testing plan.
- .6 If existing interferences have not been listed in the interference list, the contractor will be responsible to work with Departmental Representative to resolve them, without impacting the installation schedule.
- .7 NRC is responsible to provide a cleaned installation area, to the extent possible, to allow contractor to perform the work in the proposed time frame.
- .8 Any shutdowns shall be properly coordinate with Departmental Representative and the RPPM authority on site. Contractor to provide 72 hrs notice.

### **1.2 ACCESS AND EGRESS**

- .1 Design, construct and maintain temporary "access to" and "egress from" work areas, including stairs, runways, ramps or ladders and scaffolding, independent of finished surfaces and in accordance with relevant municipal, provincial and other regulations.

### **1.3 USE OF SITE AND FACILITIES**

- .1 Execute work with least possible interference or disturbance to normal use of premises. Make arrangements with Departmental Representative to facilitate work as stated.
- .2 Maintain existing services to building and provide for personnel and vehicle access.
- .3 Where security is reduced by work provide temporary means to maintain security.
- .4 Departmental Representative will assign sanitary facilities for use by Contractor's personnel. Keep facilities clean.
- .5 Use only elevators existing in building for moving workers and material.
  - .1 Protect walls of passenger elevators, to approval of Departmental Representative prior to use.
  - .2 Accept liability for damage, safety of equipment and overloading of existing equipment.



- .6 Closures: protect work temporarily until permanent enclosures are completed.

#### **1.4 ALTERATIONS, ADDITIONS OR REPAIRS TO EXISTING BUILDING**

- .1 Execute work with least possible interference or disturbance to building operations and normal use of premises. Arrange with Departmental Representative to facilitate execution of work.

#### **1.5 EXISTING SERVICES**

- .1 Notify, Departmental Representative of intended interruption of services and obtain required permission.
- .2 Where Work involves breaking into or connecting to existing services, give Departmental Representative 48 hours of notice for necessary interruption of mechanical or electrical service throughout course of work. Keep duration of interruptions minimum. Carry out interruptions after normal working hours of occupants, preferably on weekends.
- .3 Construct barriers, as needed, to ensure health and safety of workers and building occupants.

#### **1.6 SPECIAL REQUIREMENTS**

- .1 Submit schedule in accordance with Section 01 31 00.
- .2 Ensure Contractor's personnel employed on site become familiar with and obey regulations including safety, fire, traffic and security regulations.
- .3 Keep within limits of work and avenues of ingress and egress.

#### **1.7 BUILDING SMOKING ENVIRONMENT**

- .1 Comply with smoking restrictions. Smoking is not permitted.

**Part 2 Products - Not Used**

**Part 3 Execution - Not Used**

**END OF SECTION**

## **Part 1 General**

### **1.1 SECTION INCLUDES**

- .1 Coordination Work with other contractors and work by Owner under administration of Departmental Representative.
- .2 Pre-installation and Scheduled progress meetings.

### **1.2 RELATED REQUIREMENTS**

- .1 Section 01 33 00 - Submittal Procedures.
  - .1 This section describes requirements applicable to all Sections within Divisions 02 to 49

### **1.3 COORDINATION**

- .1 Perform coordination of progress schedules, submittals, use of site, temporary utilities, construction facilities and construction Work, with progress of Work of others, under instructions of Departmental Representative.

### **1.4 PROJECT MANAGEMENT REQUIREMENTS**

- .1 After award of the contract, the selected contractor will assign a Project Manager and/or a Project Engineer as a single point(s) of contact for all matters related to the project.
- .2 The contractor Project Representative(s) will be responsible to communicate any project information to the Departmental Representative, including but not limited to: Status Reports, Meeting agendas and minutes, Change Orders, design drawings, design reviews, etc.

### **1.5 PROJECT MEETINGS**

- .1 Eight (8) milestones meetings are expected as part of this contract:
  - .1 Project kick off meeting;
  - .2 Preliminary Design review meeting;
  - .3 Critical Design Review meeting;
  - .4 Pre-FAT meeting;
  - .5 Site pre-installation meeting;
  - .6 Site pre-commissioning meeting;
  - .7 Commissioning completion meeting;
  - .8 Project close-out meeting.
- .2 Contractor is responsible to schedule the meeting dates.
- .3 Contractor is responsible to prepare meeting agenda and minutes for each meeting, with exception of the project kick off meeting that will be prepared and distributed by the Departmental Representative.
- .4 Distribute written notice of each meeting fifteen (15) days in advance of meeting date to Departmental Representative.
- .5 Contractor is expected to secure an online venue to carry the meetings, which shall be accessible to all the participants. When applicable, Departmental Representative will support the contractor to identify a meeting location on site.
- .6 Preside at meetings.

- .7 Record minutes. Include significant proceedings and decisions. Identify action by parties.
- .8 Reproduce and distribute copies of minutes within five (5) days after each meeting and transmit to meeting participants, as well as to affected parties not in attendance.
- .9 The following attendees shall be included in each meeting:
  - .1 Contractor's project authority(ies).
  - .2 Departmental Representative(s).
  - .3 Other attendees as required for the specific meeting.

## 1.6 CONSTRUCTION ORGANIZATION AND START-UP

- .1 Within fifteen (15) days after award of Contract, request a meeting of parties in contract to discuss and resolve administrative procedures and responsibilities.
- .2 Departmental Representative, Contractor, major Subcontractors, field inspectors and supervisors are to be in attendance.
- .3 Establish time and location of meeting and notify parties concerned minimum five (5) days before meeting.
- .4 Incorporate mutually agreed variations to Contract Documents into Agreement, prior to signing.
- .5 Agenda to include following:
  - .1 Appointment of official representative of participants in Work.
  - .2 Schedule of Work, progress scheduling.
  - .3 Schedule of submission of shop drawings as specified in Section 01 33 00.
  - .4 Requirements for temporary facilities, offices, storage sheds, utilities, fences etc.
  - .5 Delivery schedule of specified equipment.
  - .6 Site safety as specified in Section 01 35 29.06.
  - .7 Proposed changes, change orders, procedures, approvals required, mark-up percentages permitted, time extensions, overtime, and administrative requirements.
  - .8 Owner-furnished Products.
  - .9 Record drawings as specified in Section 01 78 00.
  - .10 Maintenance material and data as specified in Section 01 78 00.
  - .11 Take-over procedures, acceptance, and warranties as specified Section 01 78 00.
  - .12 Monthly progress claims, administrative procedures, photographs, and holdbacks.
  - .13 Appointment of inspection and testing agencies or firms as specified in Section 01 45 00.
  - .14 Insurances and transcript of policies.
- .6 Comply with Departmental Representative's allocation of mobilization areas of site; for field offices and sheds, for access, traffic, and parking facilities.
- .7 During construction, coordinate use of site and facilities through Departmental Representative's procedures for intra-project communications: Submittals, reports and records, schedules, coordination of drawings, recommendations, and resolution of ambiguities and conflicts.
- .8 Comply with instructions of Departmental Representative for use of temporary utilities and construction facilities.
- .9 Coordinate field engineering and layout work with Departmental Representative.

## 1.7 CONSTRUCTION PROGRESS MEETINGS

- .1 During course of Work and 2 weeks prior to project completion, schedule progress meetings biweekly or monthly as agreed by the team during the kickoff meeting. Meeting frequency can and will vary through project execution.
- .2 Contractor, major subcontractors involved in Work and Departmental Representative are to be in attendance.
- .3 Notify parties minimum of 15 days prior to meetings.
- .4 Record minutes of meetings, and circulate to attending parties and affected parties not in attendance within 5 days after meeting.
- .5 Agenda to include following:
  - .1 Review, approval of minutes of previous meeting.
  - .2 Review of Work progress since previous meeting.
  - .3 Field observations, problems, conflicts.
  - .4 Problems that impede construction schedule.
  - .5 Review of off-site fabrication delivery schedules.
  - .6 Corrective measures and procedures to regain projected schedule.
  - .7 Revision to construction schedule.
  - .8 Progress schedule, during succeeding work period.
  - .9 Review submittal schedules: expedite as required.
  - .10 Project risk register.
  - .11 Project issues register.
  - .12 Action Items list (when applicable).
  - .13 Maintenance of quality standards.
  - .14 Review proposed changes for effect on construction schedule and on completion date.
  - .15 Review site safety and security issues.
  - .16 Other business.

## 1.8 SPECIAL MEETINGS

- .1 Departmental Representative reserves the right to require special meetings which may be held on short notice and at which attendance by the contractor and representatives of the affected subcontractors is mandatory. Contractor shall keep detailed and accurate meeting notes and distribute copies promptly to all in attendance and those affected by agreements made at such meetings.

## 1.9 SCHEDULES

- .1 Submit preliminary construction progress schedule to Departmental Representative coordinated with Departmental Representative's project schedule.
- .2 Preliminary schedule shall be provided at the kick-off meeting for Departmental Representative review. Schedule shall be reviewed during project status meetings, or prior to any major proposed changes.
- .3 After review, revise and resubmit schedule to comply with revised project schedule.
- .4 During progress of Work revise and resubmit as directed by Departmental Representative.
- .5 Any NRC related task (if needed) shall be clearly identified and highlighted in the schedule.

- .6 Proposed schedule does not supersede the contractual dates, if a change is proposed that will impact the contractual schedule a formal change request needs to be submitted and approved in order to amend the contract.
- .7 The detail schedule shall be developed in MS Project, highlighting the main development milestones associated with the project. The following milestones are proposed:
  - .1 M0 KOM – Kick off meeting
  - .2 M1 PDR – Preliminary Design Review
  - .3 M2 CDR – Critical Design Review
  - .4 M3 Major (Long Lead time) Items procurement completed
  - .5 M4 Completion of Production
  - .6 M5 Testing set-up completed
  - .7 M6 System ready for FAT notice (45 days before FAT)
  - .8 M7 Factory Acceptance Testing
  - .9 M8 Factory Acceptance Testing Report
  - .10 M9 System ready for shipment
  - .11 M10 System shipment
  - .12 M11 System ETA at NRC
  - .13 M12 On site system assembly
  - .14 M13 On site system testing
  - .15 M14 SAT – Site Acceptance Testing
  - .16 M15 System final acceptance
  - .17 M16 Project closed

**1.10 PROJECT DOCUMENTATION**

- .1 The contractor is expected to provide the following project documentation:

Document	Type/format	Due Date	Purpose	Notes
Project schedule with Milestone list	PDF	KOM	Review	Critical Path Method shall be used
Risk/issue Registers	XLS/PDF	5 business days after KOM	Control and review	Template to be issued by Departmental Representative
PDR Design drawings and cut sheets	DWG/PDF	@PDR	Approval	Mechanical and Electrical drawings, P&ID drawings (if applicable), Installation drawings, Cut sheets as needed.
Approved equals/ alternates list	PDF	15 business days after KOM	Approval	List all approved equals for pre approval by Departmental Representative prior to commence fabrication
CDR Design drawings and cut sheets	DWG/PDF	@CDR	Approval	Mechanical and Electrical drawings, P&ID drawings (if applicable), Install drawings, Cut sheets as needed.
Health and safety system design reports	PDF	@CDR	Approval	Provide a detail report addressing the following: Machine-human interface;

				Machine-facility interface; Machine-machine interface.
Health and safety plan	PDF	45 calendar days prior to commence work on site	Review	Departmental Representative will provide comments, but is not responsible for the Health and Safety plan contents
Factory acceptance testing template	PDF	30 calendar days prior to FAT	Review and control	Specify all steps required to complete the test and acceptance criteria / sign-off
Factory acceptance testing report	PDF	10 business days after FAT	Control and documentation	The document used during test shall be signed and sent to Departmental Representative for record purposes
Site acceptance testing template	PDF	30 calendar days prior to SAT	Review and control	Specify all steps required to complete the test and acceptance criteria / sign-off
Site acceptance testing report	PDF	10 business days after SAT	Control and documentation	The document used during test shall be signed and sent to Departmental Representative for record purposes
O&M Manuals	PDF	30 calendar days after SAT	Control and Documentation	One hard copy + soft copy
O&M equipment and component	PDF	30 calendar days after SAT	Control and documentation	Provide a detail list with all O&M related components and equipment identifying their maintenance schedule and expected life
As built finals drawings	DWG/PDF	30 calendar days after SAT	Control and documentation	One hard copy + soft copy

.2 Technical submittal documents and other documents not included in the list above are mandatory as per the information provided within the sections and drawings that compose this tender package.

### 1.11 SUBMITTALS

- .1 Prepare and issue submittals to Departmental Representative for review.
- .2 Submit preliminary Shop Drawings, product data and samples as specified in Section 01 33 00 for review and for compliance with Contract Documents; for field dimensions and clearances, for relation to available space, and for relation to Work of other contracts. After review, revise and resubmit for transmittal to Departmental Representative.
- .3 Submit requests for payment for review, and for transmittal to Departmental Representative.
- .4 Submit requests for interpretation of Contract Documents, and obtain instructions through Departmental Representative.
- .5 Process substitutions requests through Departmental Representative.
- .6 Process change orders through Departmental Representative.
- .7 Deliver closeout submittals for review and preliminary inspections, for transmittal to Departmental Representative.

## 1.12 PROJECT RISK REGISTER

- .1 The contractor is required to provide a detailed risk register identifying project related technical risks and other project risks identified during project development.
- .2 Template will be provided prior or at the KOM by the Departmental Representative.
- .3 Identified risks are expected to receive an appropriate risk response, as well as be monitored and control regularly. The Risk Register document shall be reviewed during project status meeting.
- .4 Obsolete risks are to be retired during the status review meeting, and new risks documented as applicable.

## 1.13 VPMM HEALTH AND SAFETY INTERFACE REPORT

- .1 Refer to Section 01 35 29.06 - Health and Safety Requirements.
- .2 Contractor shall provide the Departmental Representative a detailed safety report of the VPMM system. This report aims to aid NRC in identifying machine and human safety risks. The following interfaces shall be evaluated:
  - .1 Machine – Human Interface
  - .2 Machine – Machine interface
  - .3 Machine – Facility interface
- .3 The report will be used by NRC to develop their system Operations plan as well our internal Health and Safety assessment so all aspects of the system use and interfaces shall be considered, from removal, to storage and assembly on the carriage, to the use of the system and posterior removal from the carriage and subsequent storage.
- .4 Contractor shall ensure the design of the system takes into consideration risks identified in this report.
- .5 Contractor shall demonstrate how Health, Safety and Environmental risks were eliminated during design and when risk cannot be eliminated, supplier shall demonstrate how they are being mitigated.
- .6 A risk assessment report template will be provided by the Departmental Representative.
- .7 The following tasks are expected to be completed:
  - .1 Complete site visits to observe the carriage layout and operations, in order to identify general operating procedures related to the VPMM system;
  - .2 Review applicable provisions of the Canada Labour Code and comparable provisions of the Regulation for Industrial Establishments under the Newfoundland and Labrador Occupational Health and Safety Act;
  - .3 Review and provide a report of the applicable standards that may be used to demonstrate compliance with the machine guarding provisions of the Canada Labour Code;
  - .4 Review and provide a report of operating sequences and parameters including start-up, shut-down, maintenance, set-up and contingency procedures (as applicable);
  - .5 Review and provide a report of equipment manuals, schematics, operating procedures, and other related documentation for existing equipment;
  - .6 Identify machine mechanical hazards including nip hazards, pinch hazards, abrasion hazards, crush hazards, shear hazards, impact hazards, and cutting hazards;
  - .7 Assess failure modes and complete qualitative risk assessments, as required;
  - .8 Review operations specification to determine the appropriate stop category of the machine;

- .9 Identify locations for fixed guarding modifications, as required;
- .10 Identify automatic safeguarding options, as required;
- .11 Identify options for interlocked guarding, as required;
- .12 Identify options for administrative controls, as required.

#### **1.14 COORDINATION DRAWINGS**

- .1 Provide information required by Departmental Representative for preparation of coordination Drawings.
- .2 Review and approve revised Drawings for submittal to Departmental Representative.

#### **1.15 CLOSEOUT PROCEDURES**

- .1 Notify Departmental Representative when Work is considered ready for Substantial Performance.
- .2 Accompany Departmental Representative on preliminary inspection to determine items listed for completion or correction.
- .3 Comply with Consultant's instructions for correction of items of Work listed in deficiency report.
- .4 Notify Consultant of instructions for completion of items of Work determined in Consultant's final inspection.

#### **1.16 ON-SITE DOCUMENTS**

- .1 Maintain at job site, one copy each of the following:
  - .1 Contract drawings.
  - .2 Specifications.
  - .3 Addenda.
  - .4 Reviewed shop drawings.
  - .5 Change orders.
  - .6 Other modifications to Contract.
  - .7 Field test reports.
  - .8 Copy of approved Work schedule.
  - .9 Manufacturers' installation and application instructions.
  - .10 Labour conditions and wage schedules.
  - .11 Applicable current editions of municipal regulations and by-laws. Current building codes, complete with addenda bulletins applicable to the Place of the Work.

**END OF SECTION**



## **Part 1 General**

### **1.1 ADMINISTRATIVE REQUIREMENTS**

- .1 Submit to Departmental Representative submittals listed for review. Submit promptly and in orderly sequence to not cause delay in Work. Failure to submit in ample time is not considered sufficient reason for extension of Contract Time and no claim for extension by reason of such default will be allowed.
- .2 Do not proceed with Work affected by submittal until review is complete.
- .3 Present shop drawings, product data, samples and mock-ups in SI Metric units.
- .4 Where items or information is not produced in SI Metric units converted values are acceptable.
- .5 Review submittals before submission to Departmental Representative. This review represents that necessary requirements have been determined and verified, or will be, and that each submittal has been checked and coordinated with requirements of Work and Contract Documents. Submittals not stamped, signed, dated and identified as to specific project will be returned without being examined and considered rejected.
- .6 Notify Departmental Representative, in writing at time of submission, identifying deviations from requirements of Contract Documents stating reasons for deviations.
- .7 Verify site measurements and affected adjacent Work are coordinated.
- .8 Contractor's responsibility for errors and omissions in submission is not relieved by Departmental Representative's review of submittals.
- .9 Contractor's responsibility for deviations in submission from requirements of Contract Documents is not relieved by Departmental Representative review.
- .10 Keep one reviewed copy of each submission on site.

### **1.2 SHOP DRAWINGS AND PRODUCT DATA**

- .1 The term "shop drawings" means drawings, diagrams, illustrations, schedules, performance charts, brochures and other data which are to be provided by Contractor to illustrate details of a portion of Work.
- .2 Submit drawings stamped and signed by professional engineer registered or licensed in Province of Newfoundland and Labrador, Canada, as required.
- .3 Indicate materials, methods of construction and attachment or anchorage, erection diagrams, connections, explanatory notes and other information necessary for completion of Work. Where articles or equipment attach or connect to other articles or equipment, indicate that such items have been coordinated, regardless of Section under which adjacent items will be supplied and installed. Indicate cross references to Contract drawings and specifications.
- .4 Allow 10 days for Departmental Representative's review of each submission.
- .5 Adjustments made on shop drawings by Departmental Representative are not intended to change Contract Price. If adjustments affect value of Work, state such in writing to Departmental Representative before to proceeding with Work.
- .6 Make changes in shop drawings as Departmental Representative may require, consistent with Contract Documents. When resubmitting, notify Departmental Representative in writing of revisions other than those requested.
- .7 Accompany submissions with transmittal letter, in duplicate, containing:
  - .1 Date.

- .2 Project title and number.
- .3 Contractor's name and address.
- .4 Identification and quantity of each shop drawing, product data, and sample.
- .5 Other pertinent data.
- .8 Submissions to include:
  - .1 Date and revision dates.
  - .2 Project title and number.
  - .3 Name and address of:
    - .1 Subcontractor.
    - .2 Supplier.
    - .3 Manufacturer.
  - .4 Contractor's stamp, signed by Contractor's authorized representative certifying approval of submissions, verification of site measurements and compliance with Contract Documents.
  - .5 Details of appropriate portions of Work as applicable:
    - .1 Fabrication.
    - .2 Layout, showing dimensions, including identified site dimensions and clearances.
    - .3 Setting or erection details.
    - .4 Capacities.
    - .5 Performance characteristics.
    - .6 Standards.
    - .7 Operating weight.
    - .8 Wiring diagrams.
    - .9 Single line and schematic diagrams.
    - .10 Relationship to adjacent work.
- .9 After Departmental Representative's review, distribute copies.
- .10 Submit electronic copy of shop drawings for each requirement requested in specification Sections and as Departmental Representative may reasonably request.
- .11 Submit electronic copies of product data sheets or brochures for requirements requested in specification Sections and as requested by Departmental Representative where shop drawings will not be prepared due to standardized manufacture of product.
- .12 Submit electronic copies of test reports for requirements requested in specification Sections and as requested by Departmental Representative.
  - .1 Report signed by authorized official of testing laboratory that material, product or system identical to material, product or system to be provided has been tested in accordance with specified requirements.
  - .2 Testing must have been within 3 years of date of Contract award for project.
- .13 Submit electronic copies of certificates for requirements requested in specification Sections and as requested by Departmental Representative.
  - .1 Statements printed on manufacturer's letterhead and signed by responsible officials of manufacturer of product, system or material attesting that product, system or material meets specification requirements.
  - .2 Certificates must be dated after award of Contract complete with project name.
- .14 Submit electronic copies of manufacturers instructions for requirements requested in specification Sections and as requested by Departmental Representative.
  - .1 Pre-printed material describing installation of product, system or material, including special notices and Safety Data Sheets concerning impedances, hazards and safety precautions.

- .15 Submit electronic copies of Manufacturer's Site Reports for requirements requested in specification Sections and as requested by Departmental Representative.
- .16 Documentation of the testing and verification actions taken by manufacturer's representative to confirm compliance with manufacturer's standards or instructions.
- .17 Submit electronic copies of Operation and Maintenance Data for requirements requested in specification Sections and as requested by Departmental Representative.
- .18 Delete information not applicable to project.
- .19 Supplement standard information to provide details applicable to project.
- .20 If upon review by Departmental Representative, no errors or omissions are discovered or if only minor corrections are made, copies will be returned and fabrication and installation of Work may proceed. If shop drawings are rejected, noted copy will be returned and resubmission of corrected shop drawings, through same procedure indicated above, must be performed before fabrication and installation of Work may proceed.
- .21 The review of shop drawings by Departmental Representative is for sole purpose of ascertaining conformance with general concept.
  - .1 This review shall not mean that Departmental Representative approves detail design inherent in shop drawings, responsibility for which shall remain with Contractor submitting same, and such review shall not relieve Contractor of responsibility for errors or omissions in shop drawings or of responsibility for meeting requirements of construction and Contract Documents.
  - .2 Without restricting generality of foregoing, Contractor is responsible for dimensions to be confirmed and correlated at the project site, for information that pertains solely to fabrication processes or to techniques of construction and installation and for coordination of Work of Subcontractors.

### **1.3 MOCK-UPS**

- .1 Erect mock-ups in accordance with section 01 45 00 - Quality Control.

### **1.4 PHOTOGRAPHIC DOCUMENTATION**

- .1 Submit electronic and hard copy of colour digital photography in jpg format, standard resolution monthly with progress statement and as directed by Departmental Representative.
- .2 Project identification: name and number of project and date of exposure indicated.
- .3 Number of viewpoints: 2 locations.
  - .1 Viewpoints and their location as determined by Departmental Representative.
- .4 Frequency of photographic documentation: as directed by Departmental Representative.
  - .1 Upon completion of: Work as directed by Departmental Representative.

### **1.5 CERTIFICATES AND TRANSCRIPTS**

- .1 Immediately after award of Contract, submit Workers' Compensation Board status.
- .2 Submit transcription of insurance immediately after award of Contract.

#### **Part 2 Products - Not Used**

#### **Part 3 Execution - Not Used**

**END OF SECTION**

## **Part 1 General**

### **1.1 RELATED REQUIREMENTS**

- .1 Section 01 31 00 - Project Management and Coordination.

### **1.2 REFERENCE STANDARDS**

- .1 Canada Labour Code, Part 2, Canada Occupational Safety and Health Regulations
- .2 Province of Newfoundland and Labrador
  - .1 Occupational Health and Safety Act, R.S.N. - Updated 2012.

### **1.3 ACTION AND INFORMATIONAL SUBMITTALS**

- .1 Submit in accordance with Section 01 33 00 - Submittal Procedures.
- .2 Submit site-specific Health and Safety Plan: Within 7 days after date of Notice to Proceed and prior to commencement of Work. Health and Safety Plan must include:
  - .1 Results of site specific safety hazard assessment.
  - .2 Results of safety and health risk or hazard analysis for site tasks and operation found in work plan.
- .3 Submit electronic copies of Contractor's authorized representative's work site health and safety inspection reports to Departmental Representative, weekly.
- .4 Submit copies of reports or directions issued by Federal, Provincial and Territorial health and safety inspectors.
- .5 Submit copies of incident and accident reports.
- .6 Submit WHMIS Safety Data Sheets (SDS).
- .7 Departmental Representative will review Contractor's site-specific Health and Safety Plan and provide comments to Contractor within 15 days after receipt of plan. Revise plan as appropriate and resubmit plan to Departmental Representative within 10 days after receipt of comments from Departmental Representative.
- .8 Departmental Representative's review of Contractor's final Health and Safety plan should not be construed as approval and does not reduce the Contractor's overall responsibility for construction Health and Safety.
- .9 Medical Surveillance: where prescribed by legislation, regulation or safety program, submit certification of medical surveillance for site personnel prior to commencement of Work, and submit additional certifications for any new site personnel to Departmental Representative.

### **1.4 FILING OF NOTICE**

- .1 File Notice of Project with Provincial authorities prior to beginning of Work.
- .2 Contractor shall be responsible and assume the Principal Contractor role for each work zone location and not the entire complex. Contractor shall provide a written acknowledgement of this responsibility with 3 weeks of contract award. Contractor to submit written acknowledgement to CSST along with Ouverture de Chantier Notice.
- .3 Work zone locations include:
  - .1 Water tank building at NRC site.
- .4 Contractor shall agree to install proper site separation and identification in order to maintain time and space at all times throughout life of project.

## **1.5 SAFETY ASSESSMENT**

- .1 Perform site specific safety hazard assessment related to project.
- .2 Contractor is advised that conditions at this site can change regularly. The tank can be full of water or drained, each introducing potential hazards to be assessed.

## **1.6 MEETINGS**

- .1 Schedule and administer Health and Safety meeting with Departmental Representative prior to commencement of Work.

## **1.7 REGULATORY REQUIREMENTS**

- .1 Do Work in accordance with federal, provincial and municipal requirements.

## **1.8 GENERAL REQUIREMENTS**

- .1 Develop written site-specific Health and Safety Plan based on hazard assessment prior to beginning site Work and continue to implement, maintain, and enforce plan until final demobilization from site. Health and Safety Plan must address project specifications.
- .2 Departmental Representative may respond in writing, where deficiencies or concerns are noted and may request re-submission with correction of deficiencies or concerns.

## **1.9 RESPONSIBILITY**

- .1 Be responsible for health and safety of persons on site, safety of property on site and for protection of persons adjacent to site and environment to extent that they may be affected by conduct of Work.
- .2 Comply with and enforce compliance by employees with safety requirements of Contract Documents, applicable federal, provincial, territorial and local statutes, regulations, and ordinances, and with site-specific Health and Safety Plan.

## **1.10 COMPLIANCE REQUIREMENTS**

- .1 Comply with Occupational Health and Safety Act, Occupational Health and Safety Regulations, C. Nfld. Reg., latest edition.
- .2 Comply with Canada Labour Code, Canada Occupational Safety and Health Regulations.

## **1.11 UNFORSEEN HAZARDS**

- .1 When unforeseen or peculiar safety-related factor, hazard, or condition occur during performance of Work, follow procedures in place for Employee's Right to Refuse Work in accordance with Acts and Regulations of Province of Newfoundland and Labrador having jurisdiction and advise Departmental Representative verbally and in writing.
- .2 When unforeseen or peculiar safety-related factor, hazard, or condition occur during performance of Work, advise Health and Safety co-ordinator and follow procedures in accordance with Acts and Regulations of Province of Newfoundland and Labrador having jurisdiction and advise Departmental Representative verbally and in writing.

## **1.12 HEALTH AND SAFETY CO-ORDINATOR**

- .1 Employ and assign to Work, competent and authorized representative as Health and Safety Co-ordinator. Health and Safety Co-ordinator must:

- .1 Have site-related working experience specific to activities associated with health and safety.
- .2 Have working knowledge of occupational safety and health regulations.
- .3 Be responsible for completing Contractor's Health and Safety Training Sessions and ensuring that personnel not successfully completing required training are not permitted to enter site to perform Work.
- .4 Be responsible for implementing, enforcing daily and monitoring site-specific Contractor's Health and Safety Plan.
- .5 Be on site during execution of Work and report directly to and be under direction of site supervisor.

### **1.13 POSTING OF DOCUMENTS**

- .1 Ensure applicable items, articles, notices and orders are posted in a conspicuous location on site in accordance with Acts and Regulations of Province of Newfoundland and Labrador having jurisdiction, and in consultation with Departmental Representative.

### **1.14 CORRECTION OF NON-COMPLIANCE**

- .1 Immediately address health and safety non-compliance issues identified by authority having jurisdiction or by Departmental Representative.
- .2 Provide Departmental Representative with written report of action taken to correct non-compliance of health and safety issues identified.
- .3 Departmental Representative may stop Work if non-compliance of health and safety regulations is not corrected.

### **1.15 WORK STOPPAGE**

- .1 Give precedence to safety and health of public and site personnel and protection of environment over cost and schedule considerations for Work.

**Part 2 Products - Not Used**

**Part 3 Execution - Not Used**

**END OF SECTION**

## **Part 1 General**

### **1.1 SUMMARY**

- .1 This Section describes administrative and procedural requirements for reactive activities to verify that completed Work conforms to Contract Documents requirements.
- .2 Having inspection and testing agencies by Contractor or Owner does not relieve the Contractor of their responsibility to perform Work in accordance with Contract Documents.

### **1.2 ADMINISTRATIVE REQUIREMENTS**

- .1 Allow and coordinate access to Work on site, manufacturing off site, and fabrication off site with inspection and testing agencies.
- .2 Retain and pay for inspection and testing that are designated for Contractor's own quality control plan, and when testing and inspection are required by AHJ..
- .3 Give advanced notice to Departmental Representative and to each inspection/testing agency for inspection and testing required by Contract Documents or by AHJ.
- .4 In advance of each test, notify appropriate agency and Departmental Representative in the order that attendance arrangements can be made.

### **1.3 ACTION AND INFORMATIONAL SUBMITTALS**

- .1 Submit in accordance with Section 01 33 00 - Submittal Procedures.
- .2 Submit schedule of testing and inspection activities to Departmental Representative, Owner, applicable Subcontractors, testing agencies, and other affected parties. Include the following:
  - .1 List each testing and inspection agency
  - .2 Identify types of tests and inspections for each agency, and cross reference to applicable specification Section number-title in Contract Documents
  - .3 Description of test and inspection
  - .4 Identify applicable reference standard
  - .5 Identify test and inspection method
  - .6 Indicate number of each test and inspection required
  - .7 Certification records from inspection body
- .3 Submit one digital copy of each quality assurance inspection and test report to Departmental Representative, except where a technical specification Section indicates otherwise.
- .4 Submit reports for inspection and testing required by Contract Documents or by AHJ and performed by Contractor-retained inspection and testing agencies within ten days after inspection or test is completed, except where a technical specification Section indicates a different time period.
- .5 Submit one digital copy of each quality control inspection and test report to Departmental Representative, except where a technical specification Section indicates otherwise.
- .6 Deliver copies of quality control reports to Subcontractor of work being inspected or tested.

#### **1.4 SITE QUALITY CONTROL PROCEDURES**

- .1 Provide labour, Construction Equipment, and temporary facilities to obtain and handle test samples and materials on site. Arrange for sufficient space to store and cure test samples.
- .2 Deliver samples and materials required for testing, as requested in technical specification Sections. Submit with reasonable promptness and in an orderly sequence to avoid delays in Work.

#### **1.5 TESTING AND INSPECTION SERVICES**

- .1 Owner will retain and pay for independent inspection and testing agencies to inspect, test, or perform other quality control reviews of parts of the work, except where indicated otherwise.
- .2 Provide equipment required for executing inspection and testing by appointed agencies.
- .3 Correct defects and deficiencies when they are revealed during inspection or testing as advised by Departmental Representative at no change to Contract Price or Contract Time. Pay costs for retesting and re-inspection. Appointed agency will request additional inspections or tests to ensure full degree of defects or deficiencies are revealed and corrected.
- .4 Quality control testing and inspection reports to include the following:
  - .1 Project name and number
  - .2 Testing/Inspection agency's name, address, telephone number, and website
  - .3 Date of issuing report
  - .4 Dates and locations of tests, inspections, or samples
  - .5 Description of the Work and test and inspection method
  - .6 Numbers and titles of associated specification Sections
  - .7 Test and inspection data and interpretation of test results (e.g., pass or fail)
  - .8 Ambient conditions at time of test, inspection, or sampling
  - .9 Recommendations on re-testing and re-inspecting, if applicable

**Part 2 Products - Not Used**

**Part 3 Execution - Not Used**

**END OF SECTION**



## **Part 1 General**

### **1.1 QUALITY**

- .1 Products, materials, equipment and articles incorporated in Work shall be new, not damaged or defective, and of best quality for purpose intended. If requested, furnish evidence as to type, source and quality of products provided.
- .2 Procurement policy is to acquire, in cost effective manner, items containing highest percentage of recycled and recovered materials practicable consistent with maintaining satisfactory levels of competition. Make reasonable efforts to use recycled and recovered materials and in otherwise utilizing recycled and recovered materials in execution of work.
- .3 Defective products, whenever identified prior to completion of Work, will be rejected, regardless of previous inspections. Inspection does not relieve responsibility, but is precaution against oversight or error. Remove and replace defective products at own expense and be responsible for delays and expenses caused by rejection.
- .4 Should disputes arise as to quality or fitness of products, decision rests strictly with Departmental Representative based upon requirements of Contract Documents.
- .5 Unless otherwise indicated in specifications, maintain uniformity of manufacture for any particular or like item throughout building.
- .6 Permanent labels, trademarks and nameplates on products are not acceptable in prominent locations, except where required for operating instructions, or when located in mechanical or electrical rooms.

### **1.2 AVAILABILITY**

- .1 Immediately upon signing Contract, review product delivery requirements and anticipate foreseeable supply delays for items. If delays in supply of products are foreseeable, notify Departmental Representative of such, in order that substitutions or other remedial action may be authorized in ample time to prevent delay in performance of Work.
- .2 In event of failure to notify Departmental Representative at commencement of Work and should it subsequently appear that Work may be delayed for such reason, Departmental Representative reserves right to request substitution by Contractor to substitute more readily available products of similar character, at no increase in Contract Price or Contract Time.

### **1.3 STORAGE, HANDLING AND PROTECTION**

- .1 Handle and store products in manner to prevent damage, adulteration, deterioration and soiling and in accordance with manufacturer's instructions when applicable.
- .2 Store packaged or bundled products in original and undamaged condition with manufacturer's seal and labels intact. Do not remove from packaging or bundling until required in Work.
- .3 Store products subject to damage from weather in weatherproof enclosures.
- .4 Store cementitious products clear of earth or concrete floors, and away from walls.
- .5 Keep sand, when used for grout or mortar materials, clean and dry. Store sand on wooden platforms and cover with waterproof tarpaulins during inclement weather.
- .6 Store sheet materials, including lumber and metals on flat, solid supports and keep clear of ground. Slope to shed moisture.

- .7 Store and mix paints in heated and ventilated room. Remove oily rags and other combustible debris from site daily. Take every precaution necessary to prevent spontaneous combustion.
- .8 Remove and replace damaged products at own expense and to satisfaction of Departmental Representative.
- .9 Touch-up damaged factory finished surfaces to Departmental Representative's satisfaction. Use touch-up materials to match original. Do not paint over name plates.

#### **1.4 TRANSPORTATION**

- .1 Pay costs of transportation of products required in performance of Work.
- .2 Transportation cost of products supplied by Owner will be paid for by Departmental Representative. Unload, handle and store such products.

#### **1.5 MANUFACTURER'S INSTRUCTIONS**

- .1 Unless otherwise indicated in specifications, install or erect products in accordance with manufacturer's instructions. Do not rely on labels or enclosures provided with products. Obtain written instructions directly from manufacturers.
- .2 Notify Departmental Representative in writing, of conflicts between specifications and manufacturer's instructions, so that Departmental Representative will establish course of action.
- .3 Improper installation or erection of products, due to failure in complying with these requirements, authorizes Departmental Representative to require removal and re-installation at no increase in Contract Price or Contract Time.

#### **1.6 QUALITY OF WORK**

- .1 Ensure Quality of Work is of highest standard, executed by workers experienced and skilled in respective duties for which they are employed. Immediately notify Departmental Representative if required Work is such as to make it impractical to produce required results.
- .2 Do not employ anyone unskilled in their required duties. Departmental Representative reserves right to require dismissal from site, workers deemed incompetent or careless.
- .3 Decisions as to standard or fitness of Quality of Work in cases of dispute rest solely with Departmental Representative, whose decision is final.

#### **1.7 CO-ORDINATION**

- .1 Ensure co-operation of workers in laying out Work. Maintain efficient and continuous supervision.
- .2 Be responsible for coordination and placement of openings, sleeves and accessories.

#### **1.8 CONCEALMENT**

- .1 In finished areas conceal pipes, ducts and wiring in floors, walls and ceilings, except where indicated otherwise.
- .2 Before installation inform Departmental Representative if there is interference. Install as directed by Departmental Representative.

## **1.9 REMEDIAL WORK**

- .1 Perform remedial work required to repair or replace parts or portions of Work identified as defective or unacceptable. Co-ordinate adjacent affected Work as required.
- .2 Perform remedial work by specialists familiar with materials affected. Perform in a manner to neither damage nor put at risk any portion of Work.

## **1.10 LOCATION OF FIXTURES**

- .1 Consider location of fixtures, outlets, and mechanical and electrical items indicated as approximate.
- .2 Inform Departmental Representative of conflicting installation. Install as directed.

## **1.11 FASTENINGS**

- .1 Provide metal fastenings and accessories in same texture, colour and finish as adjacent materials, unless indicated otherwise.
- .2 Prevent electrolytic action between dissimilar metals and materials.
- .3 Use non-corrosive hot dip galvanized steel fasteners and anchors for securing exterior work, unless stainless steel or other material is specifically requested in affected specification Section.
- .4 Space anchors within individual load limit or shear capacity and ensure they provide positive permanent anchorage. Wood, or any other organic material plugs are not acceptable.
- .5 Keep exposed fastenings to a minimum, space evenly and install neatly.
- .6 Fastenings which cause spalling or cracking of material to which anchorage is made are not acceptable.

## **1.12 FASTENINGS - EQUIPMENT**

- .1 Use fastenings of standard commercial sizes and patterns with material and finish suitable for service.
- .2 Use heavy hexagon heads, semi-finished unless otherwise specified. Use No. 304 stainless steel for exterior areas.
- .3 Bolts may not project more than one diameter beyond nuts.
- .4 Use plain type washers on equipment, sheet metal and soft gasket lock type washers where vibrations occur. Use resilient washers with stainless steel.

## **1.13 PROTECTION OF WORK IN PROGRESS**

- .1 Prevent overloading of parts of building. Do not cut, drill or sleeve load bearing structural member, unless specifically indicated without written approval of Departmental Representative.

## **1.14 EXISTING UTILITIES**

- .1 When breaking into or connecting to existing services or utilities, execute Work at times directed by local governing authorities, with minimum of disturbance to Work, and/or building occupants.
- .2 Protect, relocate or maintain existing active services. When services are encountered, cap off in manner approved by authority having jurisdiction. Stake and record location of capped service.

**Part 2 Products - Not Used**

**Part 3 Execution - Not Used**

**END OF SECTION**

## **Part 1 General**

### **1.1 PROJECT CLEANLINESS**

- .1 Maintain Work in tidy condition, free from accumulation of waste products and debris, other than that caused by Owner or other Contractors.
- .2 Remove waste materials from site at daily regularly scheduled times or dispose of as directed by Departmental Representative. Do not burn waste materials on site, unless approved by Departmental Representative.
- .3 Make arrangements with and obtain permits from authorities having jurisdiction for disposal of waste and debris.
- .4 Provide on-site separate containers for collection of waste materials and debris.
- .5 Provide and use marked separate bins for recycling. Refer to Section 01 74 19 - Waste Management and Disposal.
- .6 Dispose of waste materials and debris off site.
- .7 Clean interior areas prior to start of finishing work, and maintain areas free of dust and other contaminants during finishing operations.
- .8 Store volatile waste in covered metal containers, and remove from premises at end of each working day.
- .9 Provide adequate ventilation during use of volatile or noxious substances. Use of building ventilation systems is not permitted for this purpose.
- .10 Use only cleaning materials recommended by manufacturer of surface to be cleaned, and as recommended by cleaning material manufacturer and as approved by Departmental Representative.
- .11 Schedule cleaning operations so that resulting dust, debris and other contaminants will not fall on wet, newly painted surfaces nor contaminate building systems.

### **1.2 FINAL CLEANING**

- .1 When Work is Substantially Performed remove surplus products, tools, construction machinery and equipment not required for performance of remaining Work.
- .2 Remove waste products and debris other than that caused by others, and leave Work clean and suitable for occupancy.
- .3 Prior to final review remove surplus products, tools, construction machinery and equipment.
- .4 Remove waste products and debris other than that caused by Owner or other Contractors.
- .5 Remove waste materials from site at regularly scheduled times or dispose of as directed by Departmental Representative. Do not burn waste materials on site, unless approved by Departmental Representative.
- .6 Make arrangements with and obtain permits from authorities having jurisdiction for disposal of waste and debris.
- .7 Vacuum clean and dust building interiors, behind grilles, louvres and screens.
- .8 Inspect finishes, fitments and equipment and ensure specified workmanship and operation.
- .9 Clean equipment and fixtures to sanitary condition; clean or replace filters of mechanical equipment.
- .10 Remove debris and surplus materials from crawl areas and other accessible concealed spaces.

**1.3 WASTE MANAGEMENT AND DISPOSAL**

- .1 Separate waste materials for reuse and recycling in accordance with Section 01 74 19 - Waste Management and Disposal.

**Part 2 Products - Not Used**

**Part 3 Execution - Not Used**

**END OF SECTION**

## Part 1 General

### 1.1 SUMMARY

- .1 This Section includes requirements for management of construction waste and disposal, which forms the Contractor 's commitment to reduce and divert waste materials from landfill and includes the following:
  - .1 Preparation of a Draft Construction Waste Management Plan that will be used to track the success of the Construction Waste Management Plan against actual waste diversion from landfill.
  - .2 Preparation of a Construction Waste Management Plan that provides guidance on a logical progression of tasks and procedures to be followed in a pollution prevention program to reduce or eliminate the generation of waste, the loss of natural resources, and process emissions through source reduction, reuse, recycling, and reclamation.
  - .3 Preparation of monthly progress reports indicating cumulative totals representing progress towards achieving diversion and reduction goals of waste materials away from landfill and identifying any special programs, landfill options or alternatives to landfill used during construction.
  - .4 Preparation of a Construction Waste Management Report containing detailed information indicating total waste produced by the Project, types of waste material and quantity of each material, and total waste diverted and diversion rates indicated as a percentage of the total waste produced.
- .2 Owner has established that this Project shall generate the least amount of waste possible and that processes that ensure the generation of as little waste as possible due to error, poor planning, breakage, mishandling, contamination, or other factors be employed by the Contractor.

### 1.2 DEFINITIONS

- .1 Clean Waste: Untreated and unpainted; not contaminated with oils, solvents, sealants or similar materials.
- .2 Construction and Demolition Waste: Solid wastes typically including building materials, packaging, trash, debris, and rubble resulting from construction, re-modeling, repair and demolition operations.
- .3 Hazardous: Exhibiting the characteristics of hazardous substances including properties such as ignitability, corrosiveness, toxicity, or reactivity.
- .4 Non-hazardous: Exhibiting none of the characteristics of hazardous substances, including properties such as ignitability, corrosiveness, toxicity, or reactivity.
- .5 Non-toxic: Not poisonous to humans either immediately or after a long period of exposure.
- .6 Recyclable: The ability of a product or material to be recovered at the end of its life cycle and remanufactured into a new product for reuse by others.
- .7 Recycle: To remove a waste material from the Project site to another site for remanufacture into a new product for reuse by others.
- .8 Recycling: The process of sorting, cleansing, treating and reconstituting solid waste and other discarded materials for the purpose of using the altered form; recycling does not include burning, incinerating, or thermally destroying waste.

- .9 Return: To give back reusable items or unused products to vendors for credit.
- .10 Reuse: To reuse a construction waste material in some manner on the Project site.
- .11 Salvage: To remove a waste material from the Project site to another site for resale or reuse by others.
- .12 Sediment: Soil and other debris that has been eroded and transported by storm or well production run off water.
- .13 Source Separation: The act of keeping different types of waste materials separate beginning from the first time they become waste.
- .14 Toxic: Poisonous to humans either immediately or after a long period of exposure.
- .15 Trash: Any product or material unable to be reused, returned, recycled, or salvaged.
- .16 Volatile Organic Compounds (VOC's): Chemical compounds common in and emitted by many building products over time through outgassing:
  - .1 Solvents in paints and other coatings;
  - .2 Wood preservatives; strippers and household cleaners;
  - .3 Adhesives in particleboard, fiberboard, and some plywood; and foam insulation.
  - .4 When released, VOC's can contribute to the formation of smog and can cause respiratory tract problems, headaches, eye irritations, nausea, damage to the liver, kidneys, and central nervous system, and possibly cancer.
- .17 Waste: Extra material or material that has reached the end of its useful life in its intended use. Waste includes salvageable, returnable, recyclable, and reusable material.
- .18 Construction Waste Management Plan: A project related plan for the collection, transportation, and disposal of the waste generated at the construction site; the purpose of the plan is to ultimately reduce the amount of material being landfilled.

### 1.3 REFERENCE STANDARDS

- .1 ASTM International (ASTM)
  - .1 ASTM E1609 01, Standard Guide for Development and Implementation of a Pollution Prevention Program
- .2 Recycling Certification Institute (RCI)
  - .1 RCI Certification Construction and Demolition Materials Recycling

### 1.4 ADMINISTRATIVE REQUIREMENTS

- .1 Coordination: Coordinate waste management requirements with all Divisions of the Work for the Project, and ensure that requirements of the Construction Waste Management Plan are followed.
- .2 Preconstruction Meeting: Arrange a pre-construction meeting in accordance with Section 01 31 00 - Project Management and Coordination before starting any Work of the Contract attended by the Owner, Contractor, affected Subcontractor 's and Departmental Representative to discuss the Contractor 's Construction Waste Management Plan and to develop mutual understanding of the requirements for a consistent policy towards waste reduction and recycling.

### 1.5 ACTION AND INFORMATIONAL SUBMITTALS

- .1 Submit required information in accordance with Section 01 33 00 - Submittal Procedures.
- .2 Action Submittals: Provide the following submittals before starting any work of this Section:
  - .1 Draft Construction Waste Management Plan (Draft CWM Plan): Submit to Departmental Representative a preliminary analysis of anticipated site generated



waste by listing a minimum of five (5) construction or demolition waste streams that have potential to generate the most volume of material indicating methods that will be used to divert construction waste from landfill and source reduction strategies; Departmental Representative will provide commentary before development of Contractor 's Construction Waste Management Plan.

- .2 Construction Waste Management Plan (CWM Plan): Submit a CWM Plan for this Project before any waste removal from site and that includes the following information:
  - .1 Material Streams: Analysis of the proposed jobsite waste being generated, including material types and quantities forming a part of identified material streams in the Draft CWM Plan; materials removed from site destined for alternative daily cover at landfill sites and land clearing debris cannot be considered as contributing to waste diversion and will be included as a component of the total waste generated for the site.
  - .2 Recycling Haulers and Markets: Investigate local haulers and markets for recyclable materials, and incorporate into CWM Plan.
  - .3 Alternative Waste Disposal: Prepare a listing of each material proposed to be salvaged, reused, recycled or composted during the course of the Project, and the proposed local market for each material.
  - .4 Landfill Materials: Identify materials that cannot be recycled, reused or composted and provide explanation or justification; energy will be considered as a viable alternative diversion strategy for these materials where facilities exist and are operated in accordance with Construction and Demolition Waste Management requirements.
  - .5 Landfill Options: The name of the landfill where trash will be disposed of; landfill materials will form a part of the total waste generated by the Project.
  - .6 Materials Handling Procedures: A description of the means by which any recycled waste materials will be protected from contamination, and a description of the means to be employed in recycling the above materials consistent with requirements for acceptance by designated facilities.
  - .7 Transportation: A description of the means of transportation of the recyclable materials, whether materials will be site separated and self hauled to designated centers, or whether mixed materials will be collected by a waste hauler and removed from the site, and destination of materials.

## 1.6 PROJECT CLOSEOUT SUBMITTALS

- .1 Diversion Documentation: Submit as constructed information in accordance with Section 01 78 00 - Closeout Submittals as follows:
  - .1 Construction Waste Management Report (CWM Report): Submit a CWM Report for this Project in a format acceptable to Departmental Representative and submittal requirements and that includes the following information:
    - .1 Accounting: Submit information indicating total waste produced by the Project.
    - .2 Composition: Submit information indicating types of waste material and quantity of each material.

- .3 Diversion Rate: Submit information indicating total waste diverted from landfill as a percentage of the total waste produced by the Project.
- .4 Diversion Documentation: Submit copies of transportation documents or shipping manifests indicating weights of materials, and other evidence of disposal indicating final location of waste diverted from landfill and waste sent to landfill.
- .5 Alternative Daily Cover (ADC): Submit quantities of material that were used as ADC at landfill sites, and that form a part of the total waste generated by the Project.
- .6 Multiple Waste Hauling: Compile all information into a single CWM Report where multiple waste hauling and diversion strategies were used for the project.
- .7 Photographs: Submit photographs of waste diversion facilities documenting location and signage describing usage of waste separation containers.

## 1.7 QUALITY ASSURANCE

- .1 Resources for Development of Construction Waste Management Report (CWM Report): The following sources may be useful in developing the Draft Construction Waste Management Plan:
  - .1 Recycling Haulers and Markets: Investigate local haulers and markets for recyclable materials, and incorporate into CWM Plan.
  - .2 Waste-to-Energy Systems: Investigate local waste-to-energy incentives where systems for diverting materials from landfill for reuse or recycling are not available.
- .2 Certifications: Provide proof of the following during the course of the Work:
  - .1 Compliance Certification: Provide proof that recycling center is third party verified and is listed as a Certified Facility through the registration and certification requirements of the Recycling Certification Institute.

## 1.8 DELIVERY, STORAGE, AND HANDLING

- .1 Storage Requirements: Implement a recycling/reuse program that includes separate collection of waste materials as appropriate to the Project waste and the available recycling and reuse programs in the Project area.
- .2 Handling Requirements: Clean materials that are contaminated before placing in collection containers and ensure that waste destined for landfill does not get mixed in with recycled materials:
  - .1 Deliver materials free of dirt, adhesives, solvents, petroleum contamination, and other substances deleterious to recycling process.
  - .2 Arrange for collection by or delivery to the appropriate recycling or reuse facility.
- .3 Hazardous Waste and Hazardous Materials: Handle in accordance with applicable regulations.

**Part 2 Products - Not Used**

**Part 3 Execution**

**3.1 (CWM PLAN) IMPLEMENTATION**

- .1 Manager: Contractor is responsible for designating an on site party or parties responsible for instructing workers and overseeing and documenting results of the CWM Plan for the Project.
- .2 Distribution: Distribute copies of the CWM Plan to the job site foreman, each Subcontractor, the Owner, the Departmental Representative and other site personnel as required to maintain CWM Plan.
- .3 Instruction: Provide on-site instruction of appropriate separation, handling, and recycling, salvage, reuse, composting and return methods being used for the Project to Subcontractor 's at appropriate stages of the Project.
- .4 Separation Facilities: Lay out and label a specific area to facilitate separation of materials for potential recycling, salvage, reuse, composting and return:
  - .1 Recycling and waste bin areas are to be kept neat and clean and clearly marked in order to avoid contamination of materials.
  - .2 Hazardous wastes shall be separated, stored, and disposed of in accordance with local regulations.
- .5 Progressive Documentation: Submit a monthly summary of waste generated by the Project to ensure that waste diversion goals are on track with Project requirements:
  - .1 Submittal of waste summary can coincide with application for progress payment, or similar milestone event as agreed upon between the Owner, Contractor and Departmental Representative.
  - .2 Monthly waste summary shall contain the following information:
    - .1 The amount in tonnes or m<sup>3</sup> and location of material landfilled,
    - .2 The amount in tonnes or m<sup>3</sup> and location of materials diverted from landfill, and
    - .3 Indication of progress based on total waste generated by the Project with materials diverted from landfill as a percentage.

**3.2 SUBCONTRACTOR'S RESPONSIBILITY**

- .1 Subcontractor 's shall cooperate fully with the Contractor to implement the CWM Plan.
- .2 Failure to cooperate may result in the Owner not achieving their environmental goals, and may result in penalties being assessed by the Contractor to the responsible Subcontractor 's.

**3.3 SAMPLE CONSTRUCTION WASTE MANAGEMENT FORMS**

- .1 Sample waste tracking form below can be used by the Contractor to establish their own forms for recording management of construction waste:
  - .1

Material Stream	Diverted Waste by Report Date					Total	Units
		Sept	Oct	Nov	Dec		
Material Streams Contributing to Credit	Plastic	1.25	2.5	10	5	18.75	m <sup>3</sup>
	Carpet	2.5	2.5	2.5	0	7.5	m <sup>3</sup>
	Paper/Cardboard	5	2.5	2.5	5	15	m <sup>3</sup>

	Clean Wood	0	25	0	1.25	26.25	m <sup>3</sup>
	Metal	1.25	2.5	5.5	7	16.25	m <sup>3</sup>
	Gypsum Board	2.5	2.5	4	5	14	m <sup>3</sup>
	Brick/Concrete	10.5	2.5	5.5	8.75	27.25	m <sup>3</sup>
	Asphalt Shingles	10	0	0	0	10	m <sup>3</sup>
	<b>Total Diverted Waste</b>					<b>135</b>	<b>m<sup>3</sup></b>

.2

Material Streams not Contributing to Credit	Landfill	10.75	7.5	15	10	43.25	m <sup>3</sup>
	Screen Fines (ADC)	5	1.25	0	2.5	8.75	m <sup>3</sup>
	150 mm Minus (ADC)	1.25	1.25	5	5.5	13	m <sup>3</sup>
	<b>Total Landfill/ADC Waste</b>					<b>65</b>	<b>m<sup>3</sup></b>
	<b>Total Waste</b>					<b>200</b>	<b>m<sup>3</sup></b>
	<b>Percent Diverted</b>					<b>67.5</b>	<b>%</b>

**END OF SECTION**

## **Part 1 General**

### **1.1 ADMINISTRATIVE REQUIREMENTS**

- .1 Pre-warranty Meeting:
  - .1 Convene meeting one week before Contract completion with contractor's representative and Departmental Representative, in accordance with Section 01 31 00 to:
    - .1 Verify Project requirements.
    - .2 Review installation instructions and warranty requirements.
  - .2 Departmental Representative to establish communication procedures for:
    - .1 Notifying construction warranty defects.
    - .2 Determine priorities for type of defects.
    - .3 Determine reasonable response time.
  - .3 Contact information for bonded and licensed company for warranty work action: provide name, telephone number and address of company authorized for construction warranty work action.
  - .4 Ensure contact is located within local service area of warranted construction, is continuously available, and is responsive to inquiries for warranty work action.

### **1.2 ACTION AND INFORMATIONAL SUBMITTALS**

- .1 Provide submittals in accordance with Section 01 33 00 - Submittal Procedures.
- .2 Two weeks before Substantial Performance of the Work, submit to the Departmental Representative, four final copies of operating and maintenance manuals in English and French.
- .3 Provide spare parts, maintenance materials and special tools of same quality and manufacture as products provided in Work.
- .4 Provide evidence, if requested, for type, source and quality of products supplied.

### **1.3 FORMAT**

- .1 Organize data as instructional manual.
- .2 Provide documents organized by section in PDF format.
- .3 Arrange content by systems, under Section numbers and sequence of Table of Contents.
- .4 Text: manufacturer's printed data, or typewritten data.
- .5 Provide 1:1 scaled CAD files in dwg format on CD.

### **1.4 CONTENTS - PROJECT RECORD DOCUMENTS**

- .1 Table of Contents for Each Volume: provide title of project;
  - .1 Date of submission; names.
  - .2 Addresses, and telephone numbers of Consultant and Contractor with name of responsible parties.
  - .3 Schedule of products and systems, indexed to content of volume.
- .2 For each product or system:
  - .1 List names, addresses and telephone numbers of subcontractors and suppliers, including local source of supplies and replacement parts.

- .3 Product Data: mark each sheet to identify specific products and component parts, and data applicable to installation; delete inapplicable information.
- .4 Drawings: supplement product data to illustrate relations of component parts of equipment and systems, to show control and flow diagrams.
- .5 Typewritten Text: As required to supplement product data.
  - .1 Provide logical sequence of instructions for each procedure, incorporating manufacturer's instructions specified in Section 01 45 00 - Quality Control.

## **1.5 AS-BUILT DOCUMENTS AND SAMPLES**

- .1 Maintain, in addition to requirements in General Conditions, at site for Departmental Representative one record copy of:
  - .1 Contract Drawings.
  - .2 Specifications.
  - .3 Addenda.
  - .4 Change Orders and other modifications to Contract.
  - .5 Reviewed shop drawings, product data, and samples.
  - .6 Site test records.
  - .7 Inspection certificates.
  - .8 Manufacturer's certificates.
- .2 Store record documents and samples in site office apart from documents used for construction.
  - .1 Provide files, racks, and secure storage.
- .3 Label record documents and file in accordance with Section number listings in List of Contents of this Project Manual.
  - .1 Label each document "PROJECT RECORD" in neat, large, printed letters.
- .4 Maintain record documents in clean, dry and legible condition.
  - .1 Do not use record documents for construction purposes.
- .5 Keep record documents and samples available for inspection by Departmental Representative.

## **1.6 RECORDING INFORMATION ON PROJECT RECORD DOCUMENTS**

- .1 Record information on set of black line opaque drawings, and in copy of Project Manual, provided by Departmental Representative.
- .2 Use felt tip marking pens, maintaining separate colours for each major system, for recording information.
- .3 Record information concurrently with construction progress.
  - .1 Do not conceal Work until required information is recorded.
- .4 Contract Drawings and shop drawings: mark each item to record actual construction, including:
  - .1 Measured depths of elements of foundation in relation to finish first floor datum.
  - .2 Measured horizontal and vertical locations of underground utilities and appurtenances, referenced to permanent surface improvements.
  - .3 Measured locations of internal utilities and appurtenances, referenced to visible and accessible features of construction.
  - .4 Site changes of dimension and detail.
  - .5 Changes made by change orders.
  - .6 Details not on original Contract Drawings.
  - .7 Referenced Standards to related shop drawings and modifications.

- .5 Specifications: mark each item to record actual construction, including:
  - .1 Manufacturer, trade name, and catalogue number of each product actually installed, particularly optional items and substitute items.
  - .2 Changes made by Addenda and change orders.
- .6 Other Documents: Maintain manufacturer's certifications, inspection certifications, site test records, required by individual specifications Sections.
- .7 Provide digital photos, if requested, for site records.

## **1.7 EQUIPMENT AND SYSTEMS**

- .1 For each item of equipment and each system include description of unit or system, and component parts.
  - .1 Give function, normal operation characteristics and limiting conditions.
  - .2 Include performance curves, with engineering data and tests, and complete nomenclature and commercial number of replaceable parts.
- .2 Panel board circuit directories: provide electrical service characteristics, controls, and communications.
- .3 Include installed colour coded wiring diagrams.
- .4 Operating Procedures: include start-up, break-in, and routine normal operating instructions and sequences.
  - .1 Include regulation, control, stopping, shut-down, and emergency instructions.
  - .2 Include summer, winter, and any special operating instructions.
- .5 Maintenance Requirements: include routine procedures and guide for trouble-shooting; disassembly, repair, and reassembly instructions; and alignment, adjusting, balancing, and checking instructions.
- .6 Provide servicing and lubrication schedule, and list of lubricants required.
- .7 Include manufacturer's printed operation and maintenance instructions.
- .8 Include sequence of operation by controls manufacturer.
- .9 Provide original manufacturer's parts list, illustrations, assembly drawings, and diagrams required for maintenance.
- .10 Provide installed control diagrams by controls manufacturer.
- .11 Provide Contractor's coordination drawings, with installed colour coded piping diagrams.
- .12 Provide charts of valve tag numbers, with location and function of each valve, keyed to flow and control diagrams.
- .13 Provide list of original manufacturer's spare parts, current prices, and recommended quantities to be maintained in storage.
- .14 Additional requirements: As specified in individual specification Sections.

## **1.8 MATERIALS AND FINISHES**

- .1 Building products, applied materials, and finishes: Include product data, with catalogue number, size, composition, and colour and texture designations.
  - .1 Provide information for re-ordering custom manufactured products.
- .2 Instructions for cleaning agents and methods, precautions against detrimental agents and methods, and recommended schedule for cleaning and maintenance.
- .3 Moisture-protection and weather-exposed products: Include manufacturer's recommendations for cleaning agents and methods, precautions against detrimental agents and methods, and recommended schedule for cleaning and maintenance.
- .4 Additional requirements: As specified in individual specifications Sections.

## **1.9 MAINTENANCE MATERIALS**

- .1 Spare Parts:
  - .1 Provide spare parts, in quantities specified in individual specification Sections.
  - .2 Provide items of same manufacture and quality as items in Work.
  - .3 Deliver to site; place and store.
  - .4 Receive and catalogue items.
    - .1 Submit inventory listing to Departmental Representative.
    - .2 Include approved listings in Maintenance Manual.
  - .5 Obtain receipt for delivered products and submit before final payment.
- .2 Extra Stock Materials:
  - .1 Provide maintenance and extra materials, in quantities specified in individual specification Sections.
  - .2 Provide items of same manufacture and quality as items in Work.
  - .3 Deliver to site; place and store.
  - .4 Receive and catalogue items.
    - .1 Submit inventory listing to Departmental Representative.
    - .2 Include approved listings in Maintenance Manual.
  - .5 Obtain receipt for delivered products and submit before to final payment.
- .3 Special Tools:
  - .1 Provide special tools, in quantities specified in individual specification Section.
  - .2 Provide items with tags identifying their associated function and equipment.
  - .3 Deliver to site; place and store.
  - .4 Receive and catalogue items.
    - .1 Submit inventory listing to Departmental Representative.
    - .2 Include approved listings in Maintenance Manual.

## **1.10 DELIVERY, STORAGE, AND HANDLING**

- .1 Store spare parts, maintenance materials, and special tools in manner to prevent damage or deterioration.
- .2 Store in original and undamaged condition with manufacturer's seal and labels intact.
- .3 Store components subject to damage from weather in weatherproof enclosures.
- .4 Store paints and freezable materials in a heated and ventilated room.
- .5 Remove and replace damaged products at own expense and for review by Departmental Representative.

## **1.11 WARRANTIES AND BONDS**

- .1 Develop warranty management plan to contain information relevant to Warranties.
- .2 Submit warranty management plan, 30 days before planned pre-warranty conference, to Departmental Representative approval.
- .3 Warranty management plan to include required actions and documents to assure that Departmental Representative receives warranties to which it is entitled.
- .4 Provide plan in narrative form and contain sufficient detail to make it suitable for use by future maintenance and repair personnel.
- .5 Submit, warranty information made available during construction phase, to Departmental Representative for approval before each monthly pay estimate.
- .6 Assemble approved information, submit upon acceptance of work and organize PDF as follows:
  - .1 Separate each warranty or bond.



- .2 List Subcontractor, supplier, and manufacturer, with name, address, and telephone number of responsible principal.
- .3 Obtain warranties and bonds, executed in duplicate by Subcontractors, suppliers, and manufacturers, within ten days after completion of applicable item of work.
- .4 Verify that documents are in proper form, contain full information, and are notarized.
- .5 Co-execute submittals when required.
- .6 Retain warranties and bonds until time specified for submittal.
- .7 Except for items put into use with Owner's permission, leave date of beginning of time of warranty until Date of Substantial Performance is determined.
- .8 Conduct joint 4 month and 12 month warranty inspection, measured from time of acceptance, by Departmental Representative.
- .9 Include information contained in warranty management plan as follows:
  - .1 Roles and responsibilities of personnel associated with warranty process, including points of contact and telephone numbers within the organizations of Contractors, Subcontractors, manufacturers, or suppliers involved.
  - .2 Listing and status of delivery of Certificates of Warranty for extended warranty items, to include mechanical and electrical systems and equipment.
  - .3 Provide list for each warranted equipment, item, feature of construction or system indicating:
    - .1 Name of item.
    - .2 Model and serial numbers.
    - .3 Location where installed.
    - .4 Name and phone numbers of manufacturers or suppliers.
    - .5 Names, addresses and telephone numbers of sources of spare parts.
    - .6 Warranties and terms of warranty: include one-year overall warranty of construction. Indicate items that have extended warranties and show separate warranty expiration dates.
    - .7 Cross-reference to warranty certificates as applicable.
    - .8 Starting point and duration of warranty period.
    - .9 Summary of maintenance procedures required to continue warranty in force.
    - .10 Cross-Reference to specific pertinent Operation and Maintenance manuals.
    - .11 Organization, names and phone numbers of persons to call for warranty service.
    - .12 Typical response time and repair time expected for various warranted equipment.
  - .4 Contractor's plans for attendance at 4 and 12 month post-construction warranty inspections.
  - .5 Procedure and status of tagging of equipment covered by extended warranties.
  - .6 Post copies of instructions near selected pieces of equipment where operation is critical for warranty and/or safety reasons.
- .10 Respond in timely manner to oral or written notification of required construction warranty repair work. Warranty work shall be completed at no additional cost to the Owner.
- .11 Written verification to follow oral instructions.
  - .1 Failure to respond will be cause for the Departmental Representative to proceed with action against Contractor.

## 1.12 WARRANTY TAGS

- .1 Tag, at time of installation, each warranted item. Provide durable, oil- and water-resistant tag approved by Departmental Representative.
- .2 Attach tags with copper wire and spray with waterproof silicone coating.
- .3 Leave date of acceptance until project is accepted for occupancy.
- .4 Indicate the following information on tag:
  - .1 Type of product/material.
  - .2 Model number.
  - .3 Serial number.
  - .4 Contract number.
  - .5 Warranty period.
  - .6 Inspector's signature.
  - .7 Construction Contractor.

**Part 2 Products - Not Used**

**Part 3 Execution - Not Used**

**END OF SECTION**

## Part 1 General

### 1.1 REFERENCE STANDARDS

- .1 ASTM International (ASTM)
  - .1 ASTM A 53/A 53M-12, Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless.
  - .2 ASTM A269M-15a, Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service.
  - .3 ASTM A307-14, Standard Specification for Carbon Steel Bolts and Studs, 60,000 PSI Tensile Strength.
- .2 CSA Group (CSA)
  - .1 CSA G40.20-13/G40.21-, General Requirements for Rolled or Welded Structural Quality Steel/Structural Quality Steel.
  - .2 CAN/CSA G164-M92(R2003), Hot Dip Galvanizing of Irregularly Shaped Articles.
  - .3 CSA S16-14, Design of Steel Structures.
  - .4 CSA W48-14, Filler Metals and Allied Materials for Metal Arc Welding (Developed in co-operation with the Canadian Welding Bureau).
  - .5 CSA W59-13, Welded Steel Construction (Metal Arc Welding) Metric
- .3 The Master Painters Institute (MPI)
  - .1 Architectural Painting Specification Manual - current edition

### 1.2 ACTION AND INFORMATIONAL SUBMITTALS

- .1 Submit in accordance with Section 01 33 00 - Submittal Procedures.
- .2 Product Data:
  - .1 Submit manufacturer's instructions, printed product literature and data sheets for bolts, plates and include product characteristics, performance criteria, physical size, finish and limitations.
  - .2 Submit two copies of WHMIS SDS in accordance with Section 01 35 29.06 - Health and Safety Requirements.
    - .1 For finishes, coatings, primers, and paints applied on site: indicate VOC concentration in g/L.
- .3 Shop Drawings:
  - .1 Submit drawings stamped and signed by professional engineer registered or licensed in Newfoundland, Canada.
  - .2 Indicate materials, core thicknesses, finishes, connections, joints, method of anchorage, number of anchors, supports, reinforcement, details, and accessories.

### 1.3 QUALITY ASSURANCE

- .1 Test Reports: submit certified test reports showing compliance with specified performance characteristics and physical properties.
- .2 Certifications: submit product certificates signed by manufacturer certifying materials comply with specified performance characteristics and criteria and physical requirements.

## **1.4 DELIVERY, STORAGE AND HANDLING**

- .1 Deliver, store and handle materials in accordance with Section 01 61 00 - Common Product Requirements and with manufacturer's written instructions.
- .2 Storage and Handling Requirements:
  - .1 Store materials indoors and in accordance with manufacturer's recommendations in clean, dry, well-ventilated area.
  - .2 Replace defective or damaged materials with new.

## **Part 2 Products**

### **2.1 MATERIALS**

- .1 Steel sections and plates: to CSA G40.20/G40.21, Grade350W.
- .2 Steel pipe: to ASTM A53/A53M extra strong, black finish.
- .3 Welding materials: to CSA W59.
- .4 Welding electrodes: to CSA W48 Series
- .5 Bolts and anchor bolts: to ASTM A307
- .6 Aluminum sheet: plain pattern, 1.0 mm minimum thickness, finish anodized, colour blue.
- .7 Stainless steel tubing: to ASTM A269, Type AISI 304.

### **2.2 FABRICATION**

- .1 Fabricate work square, true, straight and accurate to required size, with joints closely fitted and properly secured.
- .2 Any bolted connections or hardware must be shake-proof.
- .3 Where possible, fit and shop assemble work, ready for erection.
- .4 Exposed welds continuous for length of each joint. File or grind exposed welds smooth and flush.
- .5 Do not paint machined surfaces.

### **2.3 FINISHES**

- .1 Galvanizing: hot dipped galvanizing with zinc coating 600 g/m<sup>2</sup> to CAN/CSA-G164
- .2 Shop coat primer: MPI EXT 5.1A MPI EXT 5.1B.
- .3 Zinc primer: zinc rich, ready mix to MPI-EXT 5.2C GS-11.

### **2.4 SHOP PAINTING**

- .1 Apply one shop coat of primer to metal items, with exception of galvanized or concrete encased items.
- .2 Use primer unadulterated, as prepared by manufacturer. Paint on dry surfaces, free from rust, scale, grease. Paint when temperature minimum 7 degrees C.
- .3 Clean surfaces to be field welded; do not paint.

## **Part 3 Execution**

### **3.1 EXAMINATION**

- .1 Verification of Conditions: verify conditions of substrates previously installed under other Sections or Contracts acceptable for metal fabrications installation in accordance with manufacturer's written instructions.
  - .1 Visually inspect substrate in presence of Departmental Representative.
  - .2 Inform Departmental Representative of unacceptable conditions immediately upon discovery.

- .3 Proceed with installation only after unacceptable conditions remedied and after receipt of written approval to proceed from Departmental Representative.

### **3.2 ERECTION - GENERAL**

- .1 Do welding work in accordance with CSA W59 unless specified otherwise
- .2 Erect metalwork square, plumb, straight, and true, accurately fitted, with tight joints and intersections.
- .3 Provide suitable means of anchorage acceptable to Departmental Representative such as dowels, anchor clips, bar anchors, expansion bolts and shields, and toggles.
- .4 Exposed fastening devices to match finish and be compatible with material through which they pass.
- .5 Supply components for work by other trades in accordance with shop drawings and schedule.
- .6 Touch-up rivets, field welds, bolts and burnt or scratched surfaces with primer after completion of:
  - .1 Primer: maximum VOC limit 250 g/L GS-11.

### **3.3 CLEANING**

- .1 Progress Cleaning: clean in accordance with Section 01 74 00 - Cleaning.
  - .1 Leave Work area clean at end of each day.
- .2 Final Cleaning: upon completion remove surplus materials, rubbish, tools and equipment in accordance with Section 01 74 00 - Cleaning.

### **3.4 PROTECTION**

- .1 Protect installed products and components from damage during construction.
- .2 Repair damage to adjacent materials caused by metal fabrications installation.

**END OF SECTION**

## Part 1 General

### 1.1 REFERENCE STANDARDS

- .1 The Master Painters Institute (MPI)
  - .1 Exterior Structural Steel and Metal Fabrications, 07.
    - .1 EXT 5.1D, Alkyd.
    - .2 EXT 5.1G, Polyurethane, Pigmented (over epoxy zinc rich primer and high build epoxy).
    - .3 EXT 5.4, Aluminum.
- .2 Environmental Choice Program (ECP)
  - .1 CCD-048-98(R2006), Surface Coatings - Recycled Water-borne.
- .3 Federal Standard (FS)
  - .1 FED-STD-595B-89, Colours Used in Government Procurement.
- .4 The Society for Protective Coatings (SSPC)
  - .1 SSPC-SP 1-82(R2004), Solvent Cleaning.
  - .2 SSPC-SP 2-82(R2004), Hand Tool Cleaning.
  - .3 SSPC-SP 3-82(R2004), Power Tool Cleaning.
  - .4 SSPC-SP 6/NACE No. 3-07, Commercial Blast Cleaning.
  - .5 SSPC-SP 7/NACE No. 4-07, Brush-off Blast Cleaning.
  - .6 SSPC-Vis-1-89, Visual Standard for Abrasive Blast Cleaned Steel (Standard Reference Photographs) Editorial Changes September 1, 2000 (Steel Structures Painting Manual, Chapter 2 - Surface Preparation Specs.).
  - .7 SSPC-SP 10/NACE No. 2-07, Near White Blast Cleaning.
  - .8 SSPC-PA 204, Measurement of Dry Coat Thickness with Magnetic Gauges.
  - .9 SSPC Good Painting Practices, Volume 1, 4th Edition.
- .5 NACE International
  - .1 NACE International
    - .1 ANSI/NACE No. 13/SSPC-ACS-1-2016-SG, Industrial Coating and Lining Application Specialist Qualification and Certification.

### 1.2 ACTION AND INFORMATIONAL SUBMITTALS

- .1 Provide in accordance with Section 01 33 00 - Submittal Procedures.
- .2 Product Data:
  - .1 Provide manufacturer's instructions, printed product literature and data sheets for painting exterior metal surfaces and include product characteristics, performance criteria, physical size, finish and limitations.
  - .2 Submit 2 copies of WHMIS SDS in accordance with Section 01 35 29.06 - Health and Safety Requirements.
- .3 Samples:
  - .1 Provide for review and acceptance of each unit.
  - .2 Samples will be returned for inclusion into work.
  - .3 Upon request, Departmental Representative will furnish qualified products list of paints.
  - .4 Paints that do not appear on MPI Approved Products List must be approved by Departmental Representative before use on project. When it is proposed to use non-qualified paint, provide 1 L sample of paint to Departmental Representative

at least 4 weeks prior to commencement of painting for analysis and acceptance. Mark samples with name of project, its location, paint manufacturer's name and address, name of paint, MPI standard number and manufacturer's paint code number.

- .5 Enable Departmental Representative to take 1 L samples of each paint delivered to site, one sample from manufacturer's containers and one sample from painters' pot.
- .4 Certificates:
  - .1 Provide product certificates signed by manufacturer certifying materials comply with specified performance characteristics and criteria and physical requirements.
- .5 Test Reports:
  - .1 Provide test reports showing compliance with specified performance characteristics and physical properties and in accordance with Section 01 45 00 - Quality Control.

### 1.3 QUALITY ASSURANCE

- .1 Certificates: product certificates signed by manufacturer certifying materials comply with specified performance characteristics and criteria and physical requirements.

### 1.4 DELIVERY, STORAGE AND HANDLING

- .1 Deliver, store and handle materials in accordance with Section 01 61 00 - Common Product Requirements and with manufacturer's written instructions.
- .2 Delivery and Acceptance Requirements: deliver materials to site in original factory packaging, labelled with manufacturer's name and address.

## Part 2 Products

### 2.1 MATERIALS

- .1 Paint:
  - .1 Primer MPI #79: MPI EXT 5.1C, primer, marine for steel
    - .1 Primer for second coat: tinted sufficiently off finish colour of first coat to show where second coat is applied.
    - .2 Tinting material: compatible with primer and not detrimental to its service life.
  - .2 Enamel: MPI EXT 5.1G, W.B. light industrial, alkyd, marine, exterior; first coat blue, colour No. 502-202; second coat blue, colour No. 502-101. Colours to match FS-595B. If majority of paint application is to be by brushing, use paint to MPI EXT 5.1D

- .1 Table.
  - .1

Colour	Coat	Colour Number
Grey	First	501-205
Second	501-203	
Grey	First	501-203
Second	501-201	
Green	First	503-209
Second	503-208	
Green	First	503-221

Second	503-201	
Brown	First	504-102 semi-gloss
Second	504-101 semi-gloss	
Blue	First	502-202 semi-gloss
Second	502-101 semi-gloss	
Black	First	501-201
Second	512-201	

- .2 Aluminum paint: to MPI EXT 5.4, paint, aluminum, marine
- .3 Sand for sandblasting: to SSPC (Steel Structures Painting Council)

### Part 3 Execution

#### 3.1 EXAMINATION

- .1 Verification of Conditions: verify conditions of substrates previously installed under other Sections or Contracts are acceptable for painting exterior metal surfaces installation in accordance with manufacturer's written instructions.
  - .1 Visually inspect substrate in presence of Departmental Representative.
  - .2 Carry out tests to determine existence of lead base paint on existing exterior metal surfaces.
  - .3 If lead exists stop work and report findings to Departmental Representative.
  - .4 Inform Departmental Representative of unacceptable conditions immediately upon discovery.
  - .5 Proceed with installation only after unacceptable conditions have been remedied and after receipt of written approval to proceed from Departmental Representative.

#### 3.2 PREPARATION

- .1 New metal surfaces:
  - .1 Clean surfaces of new metal to be painted by removing rust, loose mill scale, welding slag, dirt, oil, grease and foreign substances in accordance with the following:
    - .1 Commercial blast cleaning: to SSPC-SP 6
    - .2 Solvent cleaning: to SSPC-SP 1
    - .3 Hand tool cleaning: to SSPC-SP 2
    - .4 Power tool cleaning: to SSPC-SP 3
    - .5 Brush-off blast cleaning: to SSPC-SP 7
    - .6 Near White Blast Cleaning: to SSPC-SP 10/NACE No. 2
- .2 Metal surfaces to be repainted:
  - .1 Clean surfaces by removing loose, cracked, brittle or non-adherent paint, rust, loose mill scale, welding slag, dirt, oil, grease and other foreign substances in accordance with following.
    - .1 Commercial blast cleaning: to SSPC-SP 6
    - .2 Brush-off blast cleaning: to SSPC-SP 7
    - .3 Solvent cleaning: to SSPC-SP 1
    - .4 Hand tool cleaning: to SSPC-SP 2
    - .5 Power tool cleaning: to SSPC-SP 3
  - .2 Commercial blast clean rusted and bare metal surfaces where existing paint system has failed.
  - .3 Brush-off blast clean remaining metal surfaces to be painted.



- .4 Scrape edges of old paint back to sound material where remaining paint is thick and sound, feather exposed edges.
- .3 Compressed air to be free of water and oil before reaching nozzle.
- .4 Remove traces of blast products from surfaces, pockets and corners to be painted by brushing with clean brushes, by blowing with clean dry compressed air, or by vacuum cleaning.
- .5 Apply paint after prepared surfaces have been accepted by Departmental Representative.
- .6 Prior to starting paint application ensure degree of cleanliness of surfaces is to [SSPC-Vis1](#).
  - .1 Apply primer, paint, or pretreatment after surface has been cleaned and before deterioration of surface occurs.
  - .2 Clean surfaces again if rusting occurs after completion of surface preparation.
- .7 Mixing paint:
  - .1 Do not dilute or thin paint for brush application.
  - .2 Mix ingredients in container before and during use and ensure breaking up of lumps, complete dispersion of settled pigment, and uniform composition.
  - .3 Do not mix or keep paint in suspension by means of air bubbling through paint.
  - .4 Thin paint for spraying according to manufacturer's written instructions. If directions are not on container, obtain instructions in writing from manufacturer and provide copy of instructions to Departmental Representative.
- .8 Number of paint coats: 2.
  - .1 New metal surfaces.
    - .1 Shop: 2 primer coats to minimum dry film thickness of 35 microns per coat.
    - .2 Field: 2 coats to minimum dry film thickness of 25 microns per coat.
  - .2 Repainting existing metal surfaces.
    - .1 One primer coat to minimum dry film thickness of 35 microns to bare and commercial sand blasted areas.
    - .2 Two coats to minimum dry film thickness of 25 microns per coat.

### 3.3 APPLICATION

- .1 Manufacturer's Instructions: comply with manufacturer's written data, including product technical bulletins, product catalogue installation instructions, product carton installation instructions, and data sheets.
- .2 Apply paint by spraying, brushing, or combination of both. Use sheepskins or daubers when no other method is practical in places of difficult access.
- .3 Use dipping or roller coating method of application when specifically authorized by Departmental Representative in writing.
- .4 Caulk open seams at contact surfaces of built up members with material approved by Departmental Representative, before second undercoat of primer is applied.
- .5 Where surface to be painted is not under cover, do not apply paint when:
  - .1 Air temperature is below 5 degrees C or when temperature is expected to drop to 0 degrees C before paint has dried.
  - .2 Temperature of surface is over 50 degrees C unless paint is specifically formulated for application at high temperatures.
  - .3 Fog or mist occur at site; it is raining or snowing; there is danger of rain or snow; relative humidity is above 85%.
  - .4 Surface to be painted is wet, damp or frosted.
  - .5 Previous coat is not dry.

- .6 Supply cover when paint must be applied in damp or cold weather. Supply, shelter, or heat surface and surrounding air to comply with temperature and humidity conditions specified. Protect until paint is dry or until weather conditions are suitable.
- .7 Remove paint from areas which have been exposed to freezing, excess humidity, rain, snow or condensation. Prepare surface again and repaint.
- .8 Apply each coat of paint as continuous film of uniform thickness. Repaint thin spots or bare areas before next coat of paint is applied.
- .9 Brush application:
  - .1 Work paint into cracks, crevices and corners and paint surfaces not accessible to brushes by spray, daubers or sheepskins.
  - .2 Brush out runs and sags.
  - .3 Remove runs, sags and brush marks from finished work and repaint.
- .10 Spray application:
  - .1 Provide and maintain equipment that is suitable for intended purpose, capable of properly atomizing paint to be applied, and equipped with suitable pressure regulators and gauges.
  - .2 Provide traps or separators to remove oil and water from compressed air and drain periodically during operations.
  - .3 Keep paint ingredients properly mixed in spray pots or containers during paint application either by continuous mechanical agitation or by intermittent agitation as frequently as necessary.
  - .4 Apply paint in uniform layer, with overlapping at edges of spray pattern.
  - .5 Brush out immediately runs and sags.
  - .6 Use brushes to work paint into cracks, crevices and places which are not adequately painted by spray. In areas not accessible to spray gun, use brushes, daubers or sheepskins.
  - .7 Remove runs, sags and brush marks from finished work and repaint.
- .11 Shop painting:
  - .1 Do shop painting after fabrication and before damage to surface occurs from weather or other exposure.
  - .2 Spray paint contact surfaces of field assembled, bolted, friction type joints with primer coat only. Do not brush primer after spraying.
  - .3 Remove weld spatter before painting. Remove weld slag and flux by methods as specified in paragraph 3.2.3 Metal Surfaces to be Repainted.
  - .4 Protect machine finished or similar surfaces that are not to be painted but that do require protection, with coating of rust inhibitive petroleum, molybdenum disulphide, or other coating approved by Departmental Representative.
  - .5 Copy previous erection marks and weight marks on areas that have been shop painted.
- .12 Field painting:
  - .1 Paint steel structures as soon as practical after erection.
  - .2 Touch up metal which has been shop coated with same type of paint and to same thickness as shop coat. This touch-up to include cleaning and painting of field connections, welds, rivets, nuts, washers, bolts, and damaged or defective paint and rusted areas.
  - .3 Field paint surfaces (other than joint contact surfaces) which are accessible before erection but which are not to be accessible after erection.

- .4 Where painting does not meet with requirements of specifications, and when so directed by Departmental Representative remove defective paint, thoroughly clean affected surfaces and repaint in accordance with these specifications.
- .13 Handling painted metal:
  - .1 Handle painted metal after paint has dried, or when necessary for handling for painting or stacking for drying.
  - .2 Scrape off and touch up paint which is damaged in handling, with same number of coats and kinds of paint as were previously applied to metal.

### **3.4 FIELD QUALITY CONTROL**

- .1 Site Tests, Inspections:
  - .1 Upon completion of the painting procedures test for dry film reading and evaluate the results as per SSPC-PA 2.
  - .2 Provide a full report/document to demonstrate test results.

### **3.5 CLEANING**

- .1 Progress Cleaning: clean in accordance with Section 01 74 00 - Cleaning.
- .2 Final Cleaning: upon completion remove surplus materials, rubbish, tools and equipment in accordance with Section 01 74 00 - Cleaning.

### **3.6 PROTECTION**

- .1 Protect painted surfaces from damage during construction.
- .2 Protection of surfaces:
  - .1 Protect surfaces not to receive paint.
  - .2 Prevent contamination of cleaned surfaces by salts, acids, alkalis, corrosive chemicals, grease, oil and solvents before prime coat is applied and between applications of remaining coats of paint. Remove contaminants from surface and apply paint immediately.
  - .3 Protect cleaned and freshly painted surfaces from dust to approval of Departmental Representative.
- .3 Repair damage to adjacent materials caused by painting exterior metal surface application installation.

**END OF SECTION**

## **Part 1 General**

### **1.1 RELATED REQUIREMENTS**

- .1 Division 1.
- .2 Section 26 05 32 - Outlet Boxes, Conduit Boxes and Fittings.

### **1.2 REFERENCE STANDARDS**

- .1 CSA Group
  - .1 CSA C22.1-21, Canadian Electrical Code, Part 1 (25th Edition), Safety Standard for Electrical Installations.
  - .2 CAN3-C235-83(R2010), Preferred Voltage Levels for AC Systems, 0 to 50,000 V.

### **1.3 ACTION AND INFORMATIONAL SUBMITTALS**

- .1 Submit in accordance with Section 01 33 00 - Submittal Procedures.
- .2 Product Data:
  - .1 Submit manufacturer's instructions, printed product literature and data sheets for equipment and include product characteristics, performance criteria, physical size, finish and limitations.
- .3 Shop drawings:
  - .1 Submit wiring diagrams and installation details of equipment indicating proposed location, layout and arrangement, control panels, accessories, piping, ductwork, and other items that must be shown to ensure co-ordinated installation.
  - .2 Identify on wiring diagrams circuit terminals and indicate internal wiring for each item of equipment and interconnection between each item of equipment.
  - .3 Indicate of drawings clearances for operation, maintenance, and replacement of operating equipment devices.
  - .4 Submit 600 x 600 mm minimum size drawings and product data to authority having jurisdiction.
  - .5 If changes are required, notify Departmental Representative of these changes before they are made.
- .4 Certificates:
  - .1 Provide CSA certified equipment and material.
  - .2 Where CSA certified equipment or material is not available, submit such equipment or material to authority having jurisdiction for special approval before delivery to site.
  - .3 Submit test results of installed electrical systems and instrumentation.
  - .4 Permits and fees: in accordance with General Conditions of contract.
  - .5 Submit, upon completion of Work, load balance report as described in PART 3 - LOAD BALANCE.
  - .6 Submit certificate of acceptance from authority having jurisdiction upon completion of Work to Departmental Representative.
- .5 Manufacturer's Field Reports: submit to Departmental Representative manufacturer's written report, within 3 days of review, verifying compliance of Work and electrical system and instrumentation testing, as described in PART 3 - FIELD QUALITY CONTROL.

#### **1.4 CLOSEOUT SUBMITTALS**

- .1 Submit in accordance with Section 01 78 00 - Closeout Submittals.
- .2 Operation and Maintenance Data: submit operation and maintenance data for incorporation into manual.
  - .1 Provide for each system and principal item of equipment as specified in technical sections for use by operation and maintenance personnel.
  - .2 Operating instructions to include following:
    - .1 Wiring diagrams, control diagrams, and control sequence for each principal system and item of equipment.
    - .2 Start up, proper adjustment, operating, lubrication, and shutdown procedures.
    - .3 Safety precautions.
    - .4 Procedures to be followed in event of equipment failure.
    - .5 Other items of instruction as recommended by manufacturer of each system or item of equipment.
  - .3 Print or engrave operating instructions and frame under glass or in approved laminated plastic.
  - .4 Post instructions where directed.
  - .5 For operating instructions exposed to weather, provide weather-resistant materials or weatherproof enclosures.
  - .6 Ensure operating instructions will not fade when exposed to sunlight and are secured to prevent easy removal or peeling.

#### **1.5 DELIVERY, STORAGE AND HANDLING**

- .1 Deliver, store and handle materials in accordance with Section 01 61 00 - Common Product Requirements and with manufacturer's written instructions.
- .2 Delivery and Acceptance Requirements: deliver materials to site in original factory packaging, labelled with manufacturer's name and address.
- .3 Storage and Handling Requirements:
  - .1 Store materials indoors and in accordance with manufacturer's recommendations in clean, dry, well-ventilated area.
  - .2 Store and protect equipment and materials from nicks, scratches, and blemishes.
  - .3 Replace defective or damaged materials with new.
- .4 Packaging Waste Management: remove packaging materials in accordance with Section 01 74 19 - Waste Management and Disposal.

### **Part 2 Products**

#### **2.1 DESIGN REQUIREMENTS**

- .1 Operating voltages: to CAN3-C235
- .2 Motors, electric heating, control and distribution devices and equipment to operate satisfactorily at 60 Hz within normal operating limits established by above standard.
  - .1 Equipment to operate in extreme operating conditions established in above standard without damage to equipment.
- .3 Language operating requirements: provide identification nameplates for control items in English.

## 2.2 MATERIALS AND EQUIPMENT

- .1 Provide equipment and materials in accordance with Section 01 61 00 - Common Product Requirements.
- .2 Equipment and materials to be CSA certified. Where CSA certified equipment or material not available, obtain special approval from authority having jurisdiction before delivery to site and submit such approval as described in PART 1 - ACTION AND INFORMATIONAL SUBMITTALS.
- .3 Factory assemble control panels and component assemblies.

## 2.3 ELECTRIC MOTORS, EQUIPMENT AND CONTROLS

- .1 Verify installation and co-ordination responsibilities related to motors, equipment and controls, as indicated.

## 2.4 WARNING SIGNS

- .1 Warning Signs: in accordance with requirements of Departmental Representative.
- .2 Porcelain enamel signs, minimum size 175 x 250 mm.

## 2.5 WIRING TERMINATIONS

- .1 Ensure lugs, terminals, screws used for termination of wiring are suitable for either copper or aluminum conductors.

## 2.6 EQUIPMENT IDENTIFICATION

- .1 Identify electrical equipment with nameplates as follows:
  - .1 Nameplates: lamicoïd 3 mm thick plastic engraving sheet, black face, white core, mechanically attached with self tapping screws.
  - .2 Sizes as follows:

NAMEPLATE SIZES			
Size 1	10 x 50 mm	1 line	3 mm high letters
Size 2	12 x 70 mm	1 line	5 mm high letters
Size 3	12 x 70 mm	2 lines	3 mm high letters
Size 4	20 x 90 mm	1 line	8 mm high letters
Size 5	20 x 90 mm	2 lines	5 mm high letters
Size 6	25 x 100 mm	1 line	12 mm high letters
Size 7	25 x 100 mm	2 lines	6 mm high letters

- .2 Labels: embossed plastic labels with 6 mm high letters unless specified otherwise.
- .3 Wording on nameplates to be approved by Departmental Representative prior to manufacture.
- .4 Allow for minimum of twenty-five (25) letters per nameplate.
- .5 Nameplates for terminal cabinets and junction boxes to indicate system and/or voltage characteristics.
- .6 Disconnects, starters and contactors: indicate equipment being controlled and voltage.
- .7 Terminal cabinets and pull boxes: indicate system and voltage.
- .8 Transformers: indicate capacity, primary and secondary voltages.

## 2.7 WIRING IDENTIFICATION

- .1 Identify wiring with permanent indelible identifying markings, coloured plastic tapes, on both ends of phase conductors of feeders and branch circuit wiring.
- .2 Maintain phase sequence and colour coding throughout.
- .3 Colour coding: to CSA C22.1
- .4 Use colour coded wires in communication cables, matched throughout system.

## 2.8 CONDUIT AND CABLE IDENTIFICATION

- .1 Colour code conduits, boxes and metallic sheathed cables.
- .2 Code with plastic tape or paint at points where conduit or cable enters wall, ceiling, or floor, and at 15 m intervals.
- .3 Colours: 25 mm wide prime colour and 20 mm wide auxiliary colour.

Type	Prime	Auxiliary
up to 250 V	Yellow	
up to 600 V	Yellow	Green
Other Communication Systems	Green	Blue
Fire Alarm	Red	
Other Security Systems	Red	Yellow

## 2.9 FINISHES

- .1 Shop finish metal enclosure surfaces by application of rust resistant primer inside and outside, and at least two coats of finish enamel.
  - .1 Paint indoor switchgear and distribution enclosures light gray.

## Part 3 Execution

### 3.1 EXAMINATION

- .1 Verification of Conditions: verify that conditions of substrate previously installed under other Sections or Contracts are acceptable for installation in accordance with manufacturer's written instructions.
  - .1 Visually inspect substrate in presence of Departmental Representative.
  - .2 Inform Departmental Representative of unacceptable conditions immediately upon discovery.
  - .3 Proceed with installation only after unacceptable conditions have been remedied.

### 3.2 INSTALLATION

- .1 Do complete installation in accordance with CSA C22.1 except where specified otherwise

### 3.3 NAMEPLATES AND LABELS

- .1 Ensure manufacturer's nameplates, CSA labels and identification nameplates are visible and legible after equipment is installed

### 3.4 CONDUIT AND CABLE INSTALLATION

- .1 Install conduit and sleeves prior to pouring of concrete.

- .1 Sleeves through concrete: schedule 40 steel pipe, sized for free passage of conduit, and protruding 50 mm.
- .2 If plastic sleeves are used in fire rated walls or floors, remove before conduit installation.
- .3 Install cables, conduits and fittings embedded or plastered over, close to building structure so furring can be kept to minimum.

### **3.5 LOCATION OF OUTLETS**

- .1 Locate outlets in accordance with Section 26 05 32 - Outlet Boxes, Conduit Boxes and Fittings.
- .2 Do not install outlets back-to-back in wall; allow minimum 150 mm horizontal clearance between boxes.
- .3 Change location of outlets at no extra cost or credit, providing distance does not exceed 3000 mm, and information is given before installation.

### **3.6 MOUNTING HEIGHTS**

- .1 Mounting height of equipment is from finished floor to centreline of equipment unless specified or indicated otherwise.
- .2 If mounting height of equipment is not specified or indicated, verify before proceeding with installation.
- .3 Install electrical equipment at following heights unless indicated otherwise.
  - .1 Local switches: 1400 mm.
  - .2 Panelboards: as required by Code or as indicated.

### **3.7 CO-ORDINATION OF PROTECTIVE DEVICES**

- .1 Ensure circuit protective devices such as overcurrent trips, relays and fuses are installed to required values and settings.

### **3.8 FIELD QUALITY CONTROL**

- .1 Load Balance:
  - .1 Measure phase current to panelboards with normal loads (lighting) operating at time of acceptance; adjust branch circuit connections as required to obtain best balance of current between phases and record changes.
  - .2 Measure phase voltages at loads and adjust transformer taps to within 2% of rated voltage of equipment.
  - .3 Provide upon completion of work, load balance report as directed in PART 1 - ACTION AND INFORMATIONAL SUBMITTALS, phase and neutral currents on panelboards, dry-core transformers and motor control centres, operating under normal load, as well as hour and date on which each load was measured, and voltage at time of test.
- .2 Conduct following tests in accordance with Section 01 45 00 - Quality Control.
  - .1 Power distribution system including phasing, voltage, grounding and load balancing.
  - .2 Circuits originating from branch distribution panels.
  - .3 Lighting and its control.
  - .4 Motors, heaters and associated control equipment including sequenced operation of systems where applicable.
  - .5 Systems: communications.
  - .6 Insulation resistance testing:



- .1 Megger circuits, feeders and equipment up to 350 V with a 500 V instrument.
- .2 Megger 350-600 V circuits, feeders and equipment with a 1000 V instrument.
- .3 Check resistance to ground before energizing.
- .3 Carry out tests in presence of Departmental Representative.
- .4 Provide instruments, meters, equipment and personnel required to conduct tests during and at conclusion of project.
- .5 Manufacturer's Field Services:
  - .1 Obtain written report from manufacturer verifying compliance of Work, in handling, installing, applying, protecting and cleaning of product and submit Manufacturer's Field Reports as described in PART 1 - ACTION AND INFORMATIONAL SUBMITTALS.
  - .2 Provide manufacturer's field services consisting of product use recommendations and periodic site visits for inspection of product installation in accordance with manufacturer's instructions.

### **3.9 SYSTEM STARTUP**

- .1 Instruct Departmental Representative in operation, care and maintenance of systems, system equipment and components.
- .2 Arrange and pay for services of manufacturer's factory service engineer to supervise start-up of installation, check, adjust, balance and calibrate components and instruct operating personnel.
- .3 Provide these services for such period, and for as many visits as necessary to put equipment in operation, and ensure that operating personnel are conversant with aspects of its care and operation.

### **3.10 CLEANING**

- .1 Progress Cleaning: clean in accordance with Section 01 74 00 - Cleaning.
  - .1 Leave Work area clean at end of each day.
- .2 Final Cleaning: upon completion remove surplus materials, rubbish, tools and equipment in accordance with Section 01 74 00 - Cleaning.
- .3 Waste Management: separate waste materials in accordance with Section 01 74 19 - Waste Management and Disposal.
  - .1 Remove recycling containers and bins from site and dispose of materials at appropriate facility.

**END OF SECTION**

## **Part 1 General**

### **1.1 RELATED REQUIREMENTS**

- .1 Section 26 05 00 - Common Work Results for Electrical.

### **1.2 REFERENCE STANDARDS**

- .1 CSA Group (CSA)
  - .1 CAN/CSA-C22.2 No.18-98(R2003), Outlet Boxes, Conduit Boxes and Fittings.
  - .2 CAN/CSA-C22.2 No.65-03(R2008), Wire Connectors (Tri-National Standard with UL 486A-486B and NMX-J-543-ANCE-03).

### **1.3 ACTION AND INFORMATIONAL SUBMITTALS**

- .1 Submit in accordance with Section 01 33 00 - Submittal Procedures.
- .2 Product Data:
  - .1 Submit manufacturer's instructions, printed product literature and data sheets for wire and box connectors and include product characteristics, performance criteria, physical size, finish and limitations.

### **1.4 CLOSEOUT SUBMITTALS**

- .1 Submit in accordance with Section 01 78 00 - Closeout Submittals.
- .2 Operation and Maintenance Data: submit operation and maintenance data for wire and box connectors for incorporation into manual.

### **1.5 DELIVERY, STORAGE AND HANDLING**

- .1 Deliver, store and handle materials in accordance with Section 01 61 00 - Common Product Requirements.
- .2 Delivery and Acceptance Requirements: deliver materials to site in original factory packaging, labelled with manufacturer's name and address.
- .3 Storage and Handling Requirements:
  - .1 Store materials indoors and in accordance with manufacturer's recommendations in clean, dry, well-ventilated area.
  - .2 Store and protect wire and box connectors from nicks, scratches, and blemishes.
  - .3 Replace defective or damaged materials with new.
- .4 Packaging Waste Management: remove packaging materials in accordance with Section 01 74 19 - Waste Management and Disposal.

## **Part 2 Products**

### **2.1 MATERIALS**

- .1 Pressure type wire connectors to: CAN/CSA-C22.2 No.65, with current carrying parts of copper sized to fit copper conductors as required.

### **Part 3 Execution**

#### **3.1 EXAMINATION**

- .1 Verification of Conditions: verify that conditions of substrate previously installed under other Sections or Contracts are acceptable for wire and box connectors installation in accordance with manufacturer's written instructions.
  - .1 Visually inspect substrate in presence of Departmental Representative.
  - .2 Inform Departmental Representative of unacceptable conditions immediately upon discovery.
  - .3 Proceed with installation only after unacceptable conditions have been remedied.

#### **3.2 INSTALLATION**

- .1 Remove insulation carefully from ends of conductors and cables and:
  - .1 Install mechanical pressure type connectors and tighten screws with appropriate compression tool recommended by manufacturer. Installation shall meet secureness tests in accordance with CAN/CSA-C22.2 No.65
  - .2 Install fixture type connectors and tighten to CAN/CSA-C22.2 No.65. Replace insulating cap.

#### **3.3 CLEANING**

- .1 Progress Cleaning: clean in accordance with Section 01 74 00 - Cleaning.
  - .1 Leave Work area clean at end of each day.
- .2 Final Cleaning: upon completion remove surplus materials, rubbish, tools and equipment in accordance with Section 01 74 00 - Cleaning.
- .3 Waste Management: separate waste materials in accordance with Section 01 74 19 - Waste Management and Disposal.
  - .1 Remove recycling containers and bins from site and dispose of materials at appropriate facility.

**END OF SECTION**

## **Part 1 General**

### **1.1 RELATED REQUIREMENTS**

- .1 Section 26 05 00 - Common Work Results for Electrical.
- .2 Section 26 05 20 - Wire and Box Connectors - (0-1000 V).
- .3 Section 26 05 34 - Conduits, Conduit Fastenings and Conduit Fittings.
- .4 Section 26 05 36 - Cable Trays for Electrical Systems.

### **1.2 PRODUCT DATA**

- .1 Provide product data in accordance with Section 01 33 00 - Submittal Procedures.

### **1.3 DELIVERY, STORAGE AND HANDLING**

- .1 Packaging Waste Management: remove packaging materials in accordance with Section 01 74 19 - Waste Management and Disposal.

## **Part 2 Products**

### **2.1 BUILDING WIRES**

- .1 Conductors: stranded for 10 AWG and larger. Minimum size: 12 AWG.
- .2 Copper conductors: size as indicated, with 1000 V insulation of cross-linked thermosetting polyethylene material rated RW90 XLPE, Non Jacketted.

### **2.2 TECK 90 CABLE**

- .1 Cable: in accordance with Section 26 05 00 - Common Work Results for Electrical.
- .2 Conductors:
  - .1 Grounding conductor: copper.
  - .2 Circuit conductors: copper, size as indicated.
- .3 Insulation:
  - .1 Cross-linked polyethylene XLPE.
  - .2 Rating:, 600 V.
- .4 Inner jacket: polyvinyl chloride material.
- .5 Armour: interlocking.
- .6 Overall covering: thermoplastic polyvinyl chloride, compliant to applicable Building Code classification for this project.
- .7 Fastenings:
  - .1 One hole malleable iron straps to secure surface cables 50 mm and smaller. Two hole steel straps for cables larger than 50 mm.
  - .2 Threaded rods: 6 mm diameter to support suspended channels.
- .8 Connectors:
  - .1 Watertight, approved for TECK cable.

### **2.3 CONTROL CABLES**

- .1 Type: LVT: 2 soft annealed copper conductors, sized as indicated:
  - .1 Insulation: thermoplastic.
  - .2 Sheath: thermoplastic jacket, and armour of closely wound aluminum wire.

- .2 Type: low energy 300 V control cable: stranded annealed copper conductors sized as indicated LVT: 2 soft annealed copper conductors, sized as indicated:
  - .1 Insulation: PVC.
  - .2 Shielding: braid over eachover conductors.
  - .3 Overall covering: PVC jackets.

### **Part 3 Execution**

#### **3.1 FIELD QUALITY CONTROL**

- .1 Perform tests in accordance with Section 26 05 00 - Common Work Results for Electrical.
- .2 Perform tests using method appropriate to site conditions and to approval of Departmental Representative and local authority having jurisdiction over installation.
- .3 Perform tests before energizing electrical system.

#### **3.2 GENERAL CABLE INSTALLATION**

- .1 Lay cable in cable trays in accordance with Section 26 05 36 - Cable Trays for Electrical Systems.
- .2 Terminate cables in accordance with Section 26 05 20 - Wire and Box Connectors - (0-1000 V).
- .3 Cable Colour Coding: to Section 26 05 00 - Common Work Results for Electrical.
- .4 Lace or clip groups of feeder cables at distribution centres, pull boxes, and termination points.
- .5 Wiring in walls: typically drop or loop vertically from above to better facilitate future renovations. Generally wiring from below and horizontal wiring in walls to be avoided unless indicated.
- .6 Provide numbered wire collars for control wiring. Numbers to correspond to control shop drawing legend. Obtain wiring diagram for control wiring.

#### **3.3 INSTALLATION OF BUILDING WIRES**

- .1 Install wiring as follows:
  - .1 In conduit systems in accordance with Section 26 05 34 - Conduits, Conduit Fastenings and Conduit Fittings.

#### **3.4 INSTALLATION OF TECK90 CABLE (0 -1000 V)**

- .1 Group cables wherever possible on channels.

#### **3.5 INSTALLATION OF CONTROL CABLES**

- .1 Install control cables as per design drawings and in accordance with Departmental Representative.
- .2 Ground control cable shield.

**END OF SECTION**

## **Part 1 General**

### **1.1 RELATED REQUIREMENTS**

- .1 Section 26 05 00 - Common Work Results for Electrical.

### **1.2 ACTION AND INFORMATIONAL SUBMITTALS**

- .1 Submit in accordance with Section 01 33 00 - Submittal Procedures.
- .2 Product Data:
  - .1 Submit manufacturer's instructions, printed product literature and data sheets for grounding equipment and include product characteristics, performance criteria, physical size, finish and limitations.

### **1.3 CLOSEOUT SUBMITTALS**

- .1 Submit in accordance with Section 01 78 00 - Closeout Submittals.
- .2 Operation and Maintenance Data: submit operation and maintenance data for grounding equipment for incorporation into manual.

### **1.4 DELIVERY, STORAGE AND HANDLING**

- .1 Deliver, store and handle materials in accordance with Section 01 61 00 - Common Product Requirements and with manufacturer's written instructions.
- .2 Delivery and Acceptance Requirements: deliver materials to site in original factory packaging, labelled with manufacturer's name and address.
- .3 Storage and Handling Requirements:
  - .1 Store materials indoors and in accordance with manufacturer's recommendations in clean, dry, well-ventilated area.
  - .2 Store and protect grounding equipment from nicks, scratches, and blemishes.
  - .3 Replace defective or damaged materials with new.
- .4 Packaging Waste Management: remove packaging materials in accordance with Section 01 74 19 - Waste Management and Disposal.

## **Part 2 Products**

### **2.1 EQUIPMENT**

- .1 Insulated grounding conductors: green, copper conductors, size as indicated.

## **Part 3 Execution**

### **3.1 EXAMINATION**

- .1 Verification of Conditions: verify that conditions of substrate previously installed under other Sections or Contracts are acceptable for grounding equipment installation in accordance with manufacturer's written instructions.
  - .1 Visually inspect substrate in presence of Departmental Representative.
  - .2 Inform Departmental Representative of unacceptable conditions immediately upon discovery.
  - .3 Proceed with installation only after unacceptable conditions have been remedied.

### **3.2 EQUIPMENT GROUNDING**

- .1 Install grounding connections to typical equipment included in, but not necessarily limited to following list. Service equipment, transformers, switchgear, duct systems, frames of motors, motor control centres, starters, control panels, building steel work, distribution panels and cable trays.

### **3.3 COMMUNICATION SYSTEMS**

- .1 Install grounding connections for telephone, sound, fire alarm, security systems, intercommunication systems as follows:
  - .1 Sound, fire alarm, security systems, intercommunication systems as indicated.

### **3.4 FIELD QUALITY CONTROL**

- .1 Perform tests in accordance with Section 26 05 00 - Common Work Results for Electrical.
- .2 Perform ground continuity and resistance tests using method appropriate to site conditions and to approval of Departmental Representative and local authority having jurisdiction over installation.
- .3 Perform tests before energizing electrical system.
- .4 Disconnect ground fault indicator during tests.

### **3.5 CLEANING**

- .1 Progress Cleaning: clean in accordance with Section 01 74 00 - Cleaning.
  - .1 Leave Work area clean at end of each day.
- .2 Final Cleaning: upon completion remove surplus materials, rubbish, tools and equipment in accordance with Section 01 74 00 - Cleaning.
- .3 Waste Management: separate waste materials in accordance with Section 01 74 19 - Waste Management and Disposal.
  - .1 Remove recycling containers and bins from site and dispose of materials at appropriate facility.

**END OF SECTION**

## **Part 1 General**

### **1.1 RELATED REQUIREMENTS**

- .1 Section 26 05 00 - Common Work Results for Electrical.

### **1.2 ACTION AND INFORMATIONAL SUBMITTALS**

- .1 Submit in accordance with Section 01 33 00 - Submittal Procedures.
- .2 Product Data:
  - .1 Submit manufacturer's instructions, printed product literature and data sheets for hangers and supports and include product characteristics, performance criteria, physical size, finish and limitations.

### **1.3 DELIVERY, STORAGE AND HANDLING**

- .1 Deliver, store and handle materials in accordance with Section 01 61 00 - Common Product Requirements.
- .2 Delivery and Acceptance Requirements: deliver materials to site in original factory packaging, labelled with manufacturer's name and address.
- .3 Storage and Handling Requirements:
  - .1 Store materials indoors and in accordance with manufacturer's recommendations in clean, dry, well-ventilated area.
  - .2 Store and protect hangers and supports from nicks, scratches, and blemishes.
  - .3 Replace defective or damaged materials with new.
- .4 Packaging Waste Management: remove packaging materials in accordance with Section 01 74 19 - Waste Management and Disposal.

## **Part 2 Products**

### **2.1 SUPPORT CHANNELS**

- .1 U shape, size 41 x 41 mm, 2.5 mm thick.

## **Part 3 Execution**

### **3.1 EXAMINATION**

- .1 Verification of Conditions: verify that conditions of substrate previously installed under other Sections or Contracts are acceptable for hangers and supports installation in accordance with manufacturer's written instructions.
  - .1 Visually inspect substrate in presence of Departmental Representative.
  - .2 Inform Departmental Representative of unacceptable conditions immediately upon discovery.
  - .3 Proceed with installation only after unacceptable conditions have been remedied.

### **3.2 INSTALLATION**

- .1 Fasten exposed conduit or cables to building construction or support system using straps.
  - .1 One-hole malleable iron straps to secure surface conduits and cables 50 mm and smaller.
  - .2 Two-hole steel straps for conduits and cables larger than 50 mm.



- .3 Beam clamps to secure conduit to exposed steel work.
- .2 Suspended support systems.
  - .1 Support individual cable or conduit runs with 6 mm diameter threaded rods and spring clips.
  - .2 Support 2 or more cables or conduits on channels supported by 6 mm diameter threaded rod hangers where direct fastening to building construction is impractical.
- .3 Provide metal brackets, frames, hangers, clamps and related types of support structures where indicated or as required to support conduit and cable runs.
- .4 Ensure adequate support for raceways and cables dropped vertically to equipment where there is no wall support.
- .5 Do not use wire lashing or perforated strap to support or secure raceways or cables.
- .6 Do not use supports or equipment installed for other trades for conduit or cable support except with permission of other trade and approval of Departmental Representative.
- .7 Install fastenings and supports as required for each type of equipment cables and conduits, and in accordance with manufacturer's installation recommendations.

### 3.3 CLEANING

- .1 Progress Cleaning: clean in accordance with Section 01 74 00 - Cleaning.
  - .1 Leave Work area clean at end of each day.
- .2 Final Cleaning: upon completion remove surplus materials, rubbish, tools and equipment in accordance with Section 01 74 00 - Cleaning.
- .3 Waste Management: separate waste materials in accordance with Section 01 74 19 - Waste Management and Disposal.
  - .1 Remove recycling containers and bins from site and dispose of materials at appropriate facility.

**END OF SECTION**

## **Part 1 General**

### **1.1 RELATED REQUIREMENTS**

- .1 Section 26 05 00 - Common Work Results for Electrical.

### **1.2 REFERENCE STANDARDS**

- .1 CSA Group (CSA)
  - .1 CSA C22.1-21, Canadian Electrical Code, Part 1, 25th Edition.

### **1.3 ACTION AND INFORMATIONAL SUBMITTALS**

- .1 Provide submittals in accordance with Section 01 33 00 - Submittal Procedures.
- .2 Product Data:
  - .1 Provide manufacturer's printed product literature, specifications and datasheet and include product characteristics, performance criteria, physical size, finish and limitations.
- .3 Provide shop drawings: in accordance with Section 01 33 00 - Submittal Procedures.
  - .1 Submit drawings stamped and signed by professional engineer registered or licensed in Newfoundland and Labrador, Canada.

### **1.4 DELIVERY, STORAGE AND HANDLING**

- .1 Waste Management and Disposal:
  - .1 Separate waste materials for reuse and recycling in accordance with Section 01 74 19 - Waste Management and Disposal.

## **Part 2 Products**

### **2.1 CABINETS**

- .1 Construction: welded sheet steel hinged door, handle, latch and catch

## **Part 3 Execution**

### **3.1 JUNCTION, PULL BOXES AND CABINETS INSTALLATION**

- .1 Install pull boxes in inconspicuous but accessible locations.
- .2 Mount cabinets with top not higher than 2 m above finished floor except where indicated otherwise.
- .3 Only main junction and pull boxes are indicated. Install additional pull boxes as required by CSA C22.1

### **3.2 IDENTIFICATION**

- .1 Equipment Identification: to Section 26 05 00 - Common Work Results for Electrical.
- .2 Identification Labels: size 2 indicating system name, voltage and phase or as indicated.

**END OF SECTION**

## **Part 1 General**

### **1.1 RELATED REQUIREMENTS**

- .1 Section 26 05 00 - Common Work Results for Electrical.

### **1.2 REFERENCE STANDARDS**

- .1 CSA Group (CSA)
  - .1 CSA C22.1-21, Canadian Electrical Code, Part 1, 25th Edition.

### **1.3 ACTION AND INFORMATIONAL SUBMITTALS**

- .1 Provide submittals in accordance with Section 01 33 00 - Submittal Procedures.
- .2 Submit samples for floor box in accordance with Section 01 33 00 - Submittal Procedures.

### **1.4 DELIVERY, STORAGE AND HANDLING**

- .1 Deliver, store and handle materials in accordance with Section 01 61 00 - Common Product Requirements.
- .2 Waste Management and Disposal:
  - .1 Separate waste materials for reuse and recycling in accordance with Section 01 74 19 - Waste Management and Disposal.

## **Part 2 Products**

### **2.1 OUTLET AND CONDUIT BOXES GENERAL**

- .1 Size boxes in accordance with CSA C22.1
- .2 102 mm square or larger outlet boxes as required.
- .3 Gang boxes where wiring devices are grouped.
- .4 Blank cover plates for boxes without wiring devices.
- .5 347 V outlet boxes for 347 V switching devices.
- .6 Combination boxes with barriers where outlets for more than one system are grouped.

### **2.2 GALVANIZED STEEL OUTLET BOXES**

- .1 One-piece electro-galvanized construction.
- .2 Single and multi gang flush device boxes for flush installation, minimum size 76 x 50 x 38 mm or as indicated. 102 mm square outlet boxes when more than one conduit enters one side with extension and plaster rings as required.
- .3 Utility boxes for outlets connected to surface-mounted EMT conduit, minimum size 102 x 54 x 48 mm.
- .4 102 mm square or octagonal outlet boxes for lighting fixture outlets.

### **2.3 CONDUIT BOXES**

- .1 Cast boxes with factory-threaded hubs and mounting feet for surface wiring of devices.

## **2.4 OUTLET BOXES FOR NON-METALLIC SHEATHED CABLE**

- .1 Electro-galvanized, sectional, screw ganging steel boxes, minimum size 76 x 50 x 63 mm with two double clamps to take non-metallic sheathed cables.

## **2.5 FITTINGS - GENERAL**

- .1 Bushing and connectors with nylon insulated throats.
- .2 Knock-out fillers to prevent entry of debris.
- .3 Conduit outlet bodies for conduit up to 35mm and pull boxes for larger conduits.
- .4 Double locknuts and insulated bushings on sheet metal boxes.

## **Part 3 Execution**

### **3.1 INSTALLATION**

- .1 Support boxes independently of connecting conduits.
- .2 Fill boxes with paper, sponges or foam or similar approved material to prevent entry of debris during construction. Remove upon completion of work.
- .3 For flush installations mount outlets flush with finished wall using plaster rings to permit wall finish to come within 6 mm of opening.
- .4 Provide correct size of openings in boxes for conduit, mineral insulated and armoured cable connections. Do not install reducing washers.
- .5 Vacuum clean interior of outlet boxes before installation of wiring devices.
- .6 Identify systems for outlet boxes as required.

**END OF SECTION**

## **Part 1 General**

### **1.1 RELATED REQUIREMENTS**

- .1 Section 26 05 00 - Common Work Results for Electrical.

### **1.2 REFERENCE STANDARDS**

- .1 CSA Group (CSA)
  - .1 CAN/CSA C22.2 No. 18-98(R2003), Outlet Boxes, Conduit Boxes, Fittings and Associated Hardware, A National Standard of Canada.
  - .2 CSA C22.2 No. 56-17, Flexible Metal Conduit and Liquid-Tight Flexible Metal Conduit.
  - .3 CSA C22.2 No. 83-M1985(R2017), Electrical Metallic Tubing.

### **1.3 ACTION AND INFORMATIONAL SUBMITTALS**

- .1 Provide submittals in accordance with Section 01 33 00 - Submittal Procedures.
- .2 Product data: submit manufacturer's printed product literature, specifications and datasheets.
  - .1 Submit cable manufacturing data.
- .3 Quality assurance submittals:
  - .1 Test reports: submit certified test reports.
  - .2 Certificates: submit certificates signed by manufacturer certifying that materials comply with specified performance characteristics and physical properties.
  - .3 Instructions: submit manufacturer's installation instructions.

### **1.4 WASTE MANAGEMENT AND DISPOSAL**

- .1 Separate waste materials in accordance with Section 01 74 19 - Waste Management and Disposal.
- .2 Place materials defined as hazardous or toxic waste in designated containers.
- .3 Ensure emptied containers are sealed and stored safely for disposal away from children.

## **Part 2 Products**

### **2.1 CONDUITS**

- .1 Electrical metallic tubing (EMT): to CSA C22.2 No. 83, with couplings.
- .2 Flexible metal conduit: to CSA C22.2 No. 56, liquid-tight flexible metal.

### **2.2 CONDUIT FASTENINGS**

- .1 One hole malleable iron straps to secure surface conduits 50 mm and smaller.
  - .1 Two hole steel straps for conduits larger than 50 mm.
- .2 Beam clamps to secure conduits to exposed steel work.
- .3 Threaded rods, 6 mm diameter, to support suspended channels.

## 2.3 CONDUIT FITTINGS

- .1 Fittings: CAN/CSA C22.2 No. 18 manufactured for use with conduit specified. Coating: same as conduit.
- .2 Ensure factory "ells" where 90 degrees bends for 25 mm and larger conduits.
- .3 Watertight connectors and couplings for EMT.
  - .1 Set-screws are not acceptable.

## 2.4 FISH CORD

- .1 Polypropylene.

### Part 3 Execution

## 3.1 MANUFACTURER'S INSTRUCTIONS

- .1 Compliance: comply with manufacturer's written recommendations or specifications, including product technical bulletins, handling, storage and installation instructions, and datasheets.

## 3.2 INSTALLATION

- .1 Install conduits to conserve headroom in exposed locations and cause minimum interference in spaces through which they pass.
- .2 Conceal conduits except in mechanical and electrical service rooms.
- .3 Use electrical metallic tubing (EMT) unless indicated otherwise.
- .4 Use liquid tight flexible metal conduit for connection to motors or vibrating equipment in damp, wet or corrosive locations.
- .5 Minimum conduit size for lighting and power circuits: 21mm.
- .6 Bend conduit cold:
  - .1 Replace conduit if kinked or flattened more than 1/10th of its original diameter.
- .7 Mechanically bend steel conduit over 19 mm diameter.
- .8 Install fish cord in empty conduits.
- .9 Remove and replace blocked conduit sections.
  - .1 Do not use liquids to clean out conduits.
- .10 Dry conduits out before installing wire.

## 3.3 SURFACE CONDUITS

- .1 Run parallel or perpendicular to building lines.
- .2 Locate conduits behind infrared or gas fired heaters with 1.5 m clearance.
- .3 Run conduits in flanged portion of structural steel.
- .4 Group conduits wherever possible on channels.
- .5 Do not pass conduits through structural members except as indicated.
- .6 Do not locate conduits less than 75 mm parallel to steam or hot water lines with minimum of 25 mm at crossovers.

## 3.4 CONCEALED CONDUITS

- .1 Run parallel or perpendicular to building lines.
- .2 Do not install horizontal runs in masonry walls.
- .3 Do not install conduits in terrazzo or concrete toppings.

### **3.5 CLEANING**

- .1 Proceed in accordance with Section 01 74 00 - Cleaning.
- .2 On completion and verification of performance of installation, remove surplus materials, excess materials, rubbish, tools and equipment.

**END OF SECTION**

## **Part 1 General**

### **1.1 RELATED REQUIREMENTS**

- .1 Section 26 05 00 - Common Work Results for Electrical.

### **1.2 REFERENCE STANDARDS**

- .1 CSA Group (CSA)
  - .1 CAN/CSA C22.1 No.126.1-02, Metal Cable Tray Systems.
- .2 National Electrical Manufacturers Association (NEMA)
  - .1 NEMA VE 1-2002, Metal Cable Tray Systems.
  - .2 NEMA VE 2-2001, Cable Tray Installation Guidelines.

### **1.3 ACTION AND INFORMATIONAL SUBMITTALS**

- .1 Provide submittals in accordance with Section 01 33 00 - Submittal Procedures.
- .2 Product Data: submit manufacturer's product data sheets for cable tray indicating dimensions, materials, and finishes, including classifications and certifications.
- .3 Shop Drawings: submit shop drawings showing materials, finish, dimensions, accessories, layout, and installation details.
- .4 Identify types of cabletroughs used.
- .5 Show actual cabletrough installation details and suspension system.

### **1.4 WASTE MANAGEMENT AND DISPOSAL**

- .1 Separate waste materials in accordance with Section 01 74 19 - Waste Management and Disposal.

## **Part 2 Products**

### **2.1 CABLETROUGH**

- .1 Cabletroughs and fittings: to NEMA VE-1.
- .2 Trays: hot-dipped galvanized steel, 305 mm wide with depth of 75 mm.
- .3 Fittings: horizontal elbows, end plates, drop outs, vertical risers and drops, tees, wyes, expansion joints and reducers where required, manufactured accessories for cabletrough supplied.
- .4 Barriers where different voltage systems are in same cabletrough.
- .5 Ground cable trays with #2 AWG bare copper conductor attached to each tray section in accordance with CEC requirements.
- .6 Fire stop system at penetrations of fire separations.

### **2.2 SUPPORTS**

- .1 Provide splices, supports for a continuously grounded system as required.

## **Part 3 Execution**

### **3.1 INSTALLATION**

- .1 Install complete cabletrough system in accordance with NEMA VE 2.
- .2 Support cabletrough on one sides.



- .3 Remove sharp burrs or projections to prevent damage to cables or injury to personnel.

### **3.2 CABLES IN CABLETROUGH**

- .1 Install cables individually.
- .2 Lay cables into cabletrough. Use rollers when necessary to pull cables.
- .3 Secure cables in cabletrough at 6 m centres, with nylon ties.
- .4 Identify cables every 30 m with size 2 nameplates in accordance with Section 26 05 00 -  
Common Work Results for Electrical.

**END OF SECTION**

## **Part 1 General**

### **1.1 RELATED REQUIREMENTS**

- .1 Section 26 05 00 - Common Work Results for Electrical.

### **1.2 REFERENCE STANDARDS**

- .1 CSA Group (CSA)
  - .1 CSA C22.2 No.42-10, General Use Receptacles, Attachment Plugs and Similar Devices.
  - .2 CAN/CSA C22.2 No.42.1-00(R2009), Cover Plates for Flush-Mounted Wiring Devices (Bi-national standard, with UL 514D).

### **1.3 ACTION AND INFORMATIONAL SUBMITTALS**

- .1 Submit in accordance with Section 01 33 00 - Submittal Procedures.
- .2 Product Data:
  - .1 Submit manufacturer's instructions, printed product literature and data sheets for wiring devices and include product characteristics, performance criteria, physical size, finish and limitations.

### **1.4 CLOSEOUT SUBMITTALS**

- .1 Submit in accordance with Section 01 78 00 - Closeout Submittals.
- .2 Operation and Maintenance Data: submit operation and maintenance data for wiring devices for incorporation into manual.

### **1.5 DELIVERY, STORAGE AND HANDLING**

- .1 Deliver, store and handle materials in accordance with Section 01 61 00 - Common Product Requirements and with manufacturer's written instructions.
- .2 Delivery and Acceptance Requirements: deliver materials to site in original factory packaging, labelled with manufacturer's name and address.
- .3 Storage and Handling Requirements:
  - .1 Store materials indoors and in accordance with manufacturer's recommendations in clean, dry, well-ventilated area.
  - .2 Store and protect wiring devices from nicks, scratches, and blemishes.
  - .3 Replace defective or damaged materials with new.
- .4 Packaging Waste Management: remove packaging materials in accordance with Section 01 74 19 - Waste Management and Disposal.

## **Part 2 Products**

### **2.1 RECEPTACLES**

- .1 Duplex receptacles, CSA type 5-15 R, 125 V, 15 A, U ground, to: CSA C22.2 No.42 with following features:
  - .1 Ivory urea moulded housing.
  - .2 Suitable for No. 10 AWG for back and side wiring.
  - .3 Break-off links for use as split receptacles.
  - .4 Eight back wired entrances, four side wiring screws.

- .5 Triple wipe contacts and rivetted grounding contacts.
- .2 Receptacles of one manufacturer throughout project.

## **2.2 COVER PLATES**

- .1 Cover plates for wiring devices to: CSA C22.2 No.42.
- .2 Sheet steel utility box cover for wiring devices installed in surface-mounted utility boxes.
- .3 Stainless steel, for wiring devices mounted in flush-mounted outlet box.

## **2.3 SOURCE QUALITY CONTROL**

- .1 Cover plates from one manufacturer throughout project.

### **Part 3 Execution**

#### **3.1 EXAMINATION**

- .1 Verification of Conditions: verify that conditions of substrate previously installed under other Sections or Contracts are acceptable for wiring devices installation in accordance with manufacturer's written instructions.
  - .1 Visually inspect substrate in presence of Departmental Representative.
  - .2 Inform Departmental Representative of unacceptable conditions immediately upon discovery.
  - .3 Proceed with installation only after unacceptable conditions have been remedied.

#### **3.2 INSTALLATION**

- .1 Receptacles:
  - .1 Install receptacles in gang type outlet box when more than one receptacle is required in one location.
  - .2 Mount receptacles at height in accordance with Section 26 05 00 - Common Work Results for Electrical.
- .2 Cover plates:
  - .1 Install suitable common cover plates where wiring devices are grouped.
  - .2 Do not use cover plates meant for flush outlet boxes on surface-mounted boxes.

#### **3.3 CLEANING**

- .1 Progress Cleaning: clean in accordance with Section 01 74 00 - Cleaning.
  - .1 Leave Work area clean at end of each day.
- .2 Final Cleaning: upon completion remove surplus materials, rubbish, tools and equipment in accordance with Section 01 74 00 - Cleaning.
- .3 Waste Management: separate waste materials in accordance with Section 01 74 19 - Waste Management and Disposal.
  - .1 Remove recycling containers and bins from site and dispose of materials at appropriate facility.

#### **3.4 PROTECTION**

- .1 Protect installed products and components from damage during construction.
- .2 Protect stainless steel cover plate finish with paper or plastic film until painting and other work is finished.
- .3 Repair damage to adjacent materials caused by wiring device installation.

**END OF SECTION**

## **Part 1 General**

### **1.1 RELATED REQUIREMENTS**

- .1 Section 26 05 00 - Common Work Results for Electrical.

### **1.2 ACTION AND INFORMATIONAL SUBMITTALS**

- .1 Submit in accordance with Section 01 33 00 - Submittal Procedures.
- .2 Product Data:
  - .1 Submit manufacturer's instructions, printed product literature and data sheets for circuit breakers and include product characteristics, performance criteria, physical size, finish and limitations.
- .3 Certificates:
  - .1 Prior to installation of circuit breakers in either new or existing installation, Contractor must submit 3 copies of a production certificate of origin from the manufacturer. Production certificate of origin must be duly signed by factory and local manufacturer's representative certifying that circuit breakers come from this manufacturer and are new and meet standards and regulations.
    - .1 Production certificate of origin must be submitted to Departmental Representative for approval.
    - .2 Delay in submitting production of certificate of origin will not justify any extension of contract and additional compensation.
    - .3 Any work of manufacturing, assembly or installation to begin only after acceptance of production certificate of origin by Departmental Representative. Unless complying with this requirement, Departmental Representative reserves the right to mandate manufacturer listed on circuit breakers to authenticate new circuit breakers under the contract, and to Contractor's expense.
  - .4 Production certificate of origin must contain:
    - .1 Manufacturer's name and address and person responsible for authentication. Person responsible must sign and date certificate.
    - .2 Licensed dealer's name and address and person of distributor responsible for Contractor's account.
    - .3 Contractor's name and address and person responsible for project.
    - .4 Local manufacturer's representative name and address. Local manufacturer's representative must sign and date certificate.
    - .5 Name and address of building where circuit breakers will be installed:

### **1.3 DELIVERY, STORAGE AND HANDLING**

- .1 Deliver, store and handle materials in accordance with Section 01 61 00 - Common Product Requirements.
- .2 Delivery and Acceptance Requirements: deliver materials to site in original factory packaging, labelled with manufacturer's name and address.
- .3 Storage and Handling Requirements:
  - .1 Store circuit breakers indoors and in accordance with manufacturer's recommendations in clean, dry, well-ventilated area.
  - .2 Store and protect circuit breakers from nicks, scratches, and blemishes.
  - .3 Replace defective or damaged materials with new.

- .4 Packaging Waste Management: remove packaging materials in accordance with Section 01 74 19 - Waste Management and Disposal.

## **Part 2 Products**

### **2.1 BREAKERS GENERAL**

- .1 Moulded-case circuit breakers,; to CSA C22.2 No. 5
- .2 Bolt-on moulded case circuit breaker: quick- make, quick-break type, for manual and automatic operation with temperature compensation for 40 degrees C ambient.
- .3 Common-trip breakers: with single handle for multi-pole applications.
- .4 Circuit breakers to have minimum symmetrical rms interrupting capacity rating equal or greater that the panelboard in which they are installed.

### **2.2 THERMAL MAGNETIC BREAKERS**

- .1 Moulded case circuit breaker to operate automatically by means of thermal and magnetic tripping devices to provide inverse time current tripping and instantaneous tripping for short circuit protection.

## **Part 3 Execution**

### **3.1 EXAMINATION**

- .1 Verification of Conditions: verify that conditions of substrate previously installed under other Sections or Contracts are acceptable for installation in accordance with manufacturer's written instructions.
  - .1 Visually inspect substrate in presence of Departmental Representative.
  - .2 Inform Departmental Representative of unacceptable conditions immediately upon discovery.
  - .3 Proceed with installation only after unacceptable conditions have been remedied.

### **3.2 INSTALLATION**

- .1 Install circuit breakers as indicated.

### **3.3 CLEANING**

- .1 Progress Cleaning: clean in accordance with Section 01 74 00 - Cleaning.
  - .1 Leave Work area clean at end of each day.
- .2 Final Cleaning: upon completion remove surplus materials, rubbish, tools and equipment in accordance with Section 01 74 00 - Cleaning.
- .3 Waste Management: separate waste materials in accordance with Section 01 74 19 - Waste Management and Disposal.
  - .1 Remove recycling containers and bins from site and dispose of materials at appropriate facility.

**END OF SECTION**

## **Part 1 General**

### **1.1 RELATED REQUIREMENTS**

- .1 Section 26 05 00 - Common Work Results for Electrical.

### **1.2 REFERENCE STANDARDS**

- .1 CSA Group
  - .1 CAN/CSA-C22.2 No.4-04(R2009 ), Enclosed and Dead-Front Switches (Tri-National Standard, with ANCE NMX-J-162-2004 and UL 98).

### **1.3 ACTION AND INFORMATIONAL SUBMITTALS**

- .1 Submit in accordance with Section 01 33 00 - Submittal Procedures.
- .2 Product Data:
  - .1 Submit manufacturer's instructions, printed product literature and data sheets for disconnect switches - fused and non-fused and include product characteristics, performance criteria, physical size, finish and limitations.

### **1.4 DELIVERY, STORAGE AND HANDLING**

- .1 Deliver, store and handle materials in accordance with Section 01 61 00 - Common Product Requirements.
- .2 Delivery and Acceptance Requirements: deliver materials to site in original factory packaging, labelled with manufacturer's name and address.
- .3 Storage and Handling Requirements:
  - .1 Store materials indoors and in accordance with manufacturer's recommendations in clean, dry, well-ventilated area.
  - .2 Store and protect disconnect switches - fused and non-fused from nicks, scratches, and blemishes.
  - .3 Replace defective or damaged materials with new.
- .4 Packaging Waste Management: remove packaging materials in accordance with Section 01 74 19 - Waste Management and Disposal.

## **Part 2 Products**

### **2.1 DISCONNECT SWITCHES**

- .1 Non-fusible, disconnect switch in CSA enclosure Type 1, CAN/CSA-C22.2 No.4 size as indicated.
- .2 Provision for padlocking in on-off switch position by 3 locks.
- .3 Mechanically interlocked door to prevent opening when handle in ON position.
- .4 Quick-make, quick-break action.
- .5 ON-OFF switch position indication on switch enclosure cover.

### **2.2 EQUIPMENT IDENTIFICATION**

- .1 Provide equipment identification in accordance with Section 26 05 00 - Common Work Results for Electrical.
- .2 Indicate name of load controlled on size 4 nameplate.

---

### **Part 3 Execution**

#### **3.1 EXAMINATION**

- .1 Verification of Conditions: verify that conditions of substrate previously installed under other Sections or Contracts are acceptable for disconnect switches - fused and non-fused installation in accordance with manufacturer's written instructions.
  - .1 Visually inspect substrate in presence of Departmental Representative.
  - .2 Inform Departmental Representative of unacceptable conditions immediately upon discovery.
  - .3 Proceed with installation only after unacceptable conditions have been remedied.

#### **3.2 INSTALLATION**

- .1 Install disconnect switches complete with fuses if applicable.

#### **3.3 CLEANING**

- .1 Progress Cleaning: clean in accordance with Section 01 74 00 - Cleaning.
  - .1 Leave Work area clean at end of each day.
- .2 Final Cleaning: upon completion remove surplus materials, rubbish, tools and equipment in accordance with Section 01 74 00 - Cleaning.
- .3 Waste Management: separate waste materials in accordance with Section 01 74 19 - Waste Management and Disposal.
  - .1 Remove recycling containers and bins from site and dispose of materials at appropriate facility.

**END OF SECTION**

## **Part 1 General**

### **1.1 RELATED REQUIREMENTS**

- .1 Section 26 05 00 - Common Work Results for Electrical.
- .2 Section 26 29 03 - Control Devices.

### **1.2 REFERENCE STANDARDS**

- .1 CSA Group (CSA)
  - .1 CSA C22.2 No.14-18, Industrial Control Equipment.
- .2 National Electrical Manufacturers Association (NEMA)
  - .1 NEMA ICS 2-2000 (R2005), Controllers, Contactors and Overload Relays Rated 600 V.

### **1.3 ACTION AND INFORMATIONAL SUBMITTALS**

- .1 Submit in accordance with Section 01 33 00 - Submittal Procedures.
- .2 Product Data:
  - .1 Submit manufacturer's instructions, printed product literature and data sheets for contactors and include product characteristics, performance criteria, physical size, finish and limitations.

### **1.4 CLOSEOUT SUBMITTALS**

- .1 Submit in accordance with Section 01 78 00 - Closeout Submittals.
- .2 Operation and Maintenance Data: submit operation and maintenance data for contactors for incorporation into manual.
- .3 Include operating information required for start-up, synchronizing and shut-down of generating units.

### **1.5 DELIVERY, STORAGE AND HANDLING**

- .1 Deliver, store and handle materials in accordance with manufacturer's recommendations.
- .2 Delivery and Acceptance Requirements: deliver materials to site in original factory packaging, labelled with manufacturer's name and address.
- .3 Storage and Handling Requirements:
  - .1 Store materials indoors and in accordance with manufacturer's recommendations in clean, dry, well-ventilated area.
  - .2 Store and protect contactors from nicks, scratches, and blemishes.
  - .3 Replace defective or damaged materials with new.
- .4 Packaging Waste Management: remove packaging materials in accordance with Section 01 74 19 - Waste Management and Disposal.

## **Part 2 Products**

### **2.1 CONTACTORS**

- .1 Contactors: to CSA C22.2 No.14.
- .2 Electrically held controlled by pilot devices as indicated and rated for type of load controlled. Half size contactors not accepted.



- .3 Complete with 2 normally open and 2 normally closed auxiliary contacts unless indicated otherwise.
- .4 Mount in CSA Enclosure unless otherwise indicated.

## **2.2 EQUIPMENT IDENTIFICATION**

- .1 Identify equipment in accordance with Section 26 05 00 - Common Work Results for Electrical.

## **Part 3 Execution**

### **3.1 INSTALLATION**

- .1 Install contactors and connect power wires and auxiliary control devices.
- .2 Identify contactors with nameplates or labels indicating panel and circuit number.
- .3 Test contactors in accordance with 26 05 00 - Common Work Results for Electrical.

### **3.2 CLEANING**

- .1 Progress Cleaning: clean in accordance with Section 01 74 00 - Cleaning.
  - .1 Leave Work area clean at end of each day.
- .2 Final Cleaning: upon completion remove surplus materials, rubbish, tools and equipment in accordance with Section 01 74 00 - Cleaning.
- .3 Waste Management: separate waste materials for in accordance with Section 01 74 19 - Waste Management and Disposal.
  - .1 Remove recycling containers and bins from site and dispose of materials at appropriate facility.

### **3.3 PROTECTION**

- .1 Protect installed products and components from damage during construction.
- .2 Repair damage to adjacent materials caused by contactor installation.

**END OF SECTION**

## **Part 1 General**

### **1.1 RELATED REQUIREMENTS**

- .1 Section 26 05 00 - Common Work Results for Electrical.

### **1.2 REFERENCE STANDARDS**

- .1 CSA Group (CSA)
  - .1 CSA C22.2 No.14-18, Industrial Control Equipment.
- .2 National Electrical Manufacturers Association (NEMA)
  - .1 NEMA ICS 1-2000(R2008), Industrial Control and Systems: General Requirements.

### **1.3 ACTION AND INFORMATIONAL SUBMITTALS**

- .1 Submit in accordance with Section 01 33 00 - Submittal Procedures.
- .2 Product Data:
  - .1 Submit manufacturer's instructions, printed product literature and data sheets for control devices and include product characteristics, performance criteria, physical size, finish and limitations.
- .3 Shop Drawings:
  - .1 Submit drawings stamped and signed by professional engineer registered or licensed in Newfoundland and Labrador, Canada.
  - .2 Include schematic, wiring, interconnection diagrams.

### **1.4 QUALITY ASSURANCE**

- .1 Conduct tests in accordance with Section 26 05 00 - Common Work Results for Electrical.

### **1.5 CLOSEOUT SUBMITTALS**

- .1 Submit in accordance with Section 01 78 00 - Closeout Submittals.
- .2 Operation and Maintenance Data: submit operation and maintenance data for control devices for incorporation into manual.

### **1.6 DELIVERY, STORAGE AND HANDLING**

- .1 Deliver, store and handle materials in accordance with Section 01 61 00 - Common Product Requirements.
- .2 Delivery and Acceptance Requirements: deliver materials to site in original factory packaging, labelled with manufacturer's name and address.
- .3 Storage and Handling Requirements:
  - .1 Store materials off ground indoors in dry location and in accordance with manufacturer's recommendations in clean, dry, well-ventilated area.
  - .2 Store and protect control devices from nicks, scratches, and blemishes.
  - .3 Replace defective or damaged materials with new.
- .4 Develop Waste Reduction Workplan related to Work of this Section and in accordance with Section 01 74 19 - Waste Management and Disposal.

- .5 Packaging Waste Management: remove for reuse and return by manufacturer of pallets, crates, padding, and packaging materials as specified in Waste Reduction Workplan in accordance with Section 01 74 19 - Waste Management and Disposal.

## **Part 2 Products**

### **2.1 AC CONTROL RELAYS**

- .1 Control Relays: to CSA C22.2 No.14 and NEMA ICS 1.
- .2 Fixed contact plug-in type: heavy duty low coil current with 4 poles. Coil rating: 120 V, 10 VA. Contact rating: 120V, 10 A.

### **2.2 RELAY ACCESSORIES**

- .1 Standard contact cartridges: normally-open - convertible to normally-closed in field.

### **2.3 OPERATOR CONTROL STATIONS**

- .1 Enclosure: CSA Type 4, flush mounting as per design schematics

### **2.4 PUSHBUTTONS**

- .1 Illuminated, Heavy duty Oil tight. Operator recessed flush mushroom type, as indicated. Black, with 1-NO and 1-NC momentary contacts rated at 120 V, 6 A, AC, labels as indicated. Emergency stop pushbuttons coloured red, with dual self-monitoring N.C. contacts and labelled "emergency stop" with yellow background.

### **2.5 INDICATING LIGHTS**

- .1 Heavy duty, full voltage, LED type, lens colour: as indicated, supply voltage: 120 V AC, lamp voltage: 120 V AC, labels as indicated.

### **2.6 CONTROL AND RELAY PANELS**

- .1 CSA Type 1 sheet steel enclosure with hinged padlockable access door, accommodating relays timers, labels, as indicated, factory installed and wired to identified terminals.

### **2.7 CONTROL CIRCUIT TRANSFORMERS**

- .1 Single phase, dry type.
- .2 Primary: 480 V, 60 Hz ac.
- .3 Secondary: 120 V, AC.
- .4 Rating: 1000 VA, or as required from design schematics.
- .5 Secondary fuse: As required to meet C22.2 No. 14.

## **Part 3 Execution**

### **3.1 EXAMINATION**

- .1 Verification of Conditions: verify that conditions of substrate previously installed under other Sections or Contracts are acceptable for control devices installation in accordance with manufacturer's written instructions.
  - .1 Visually inspect substrate in presence of Departmental Representative.
  - .2 Inform Departmental Representative of unacceptable conditions immediately upon discovery.

- .3 Proceed with installation only after unacceptable conditions have been remedied and after receipt of written approval to proceed from Departmental Representative.

### **3.2 INSTALLATION**

- .1 Install pushbutton stations, control and relay panels, control devices and interconnect wiring per schematics.

### **3.3 FIELD QUALITY CONTROL**

- .1 Perform tests in accordance with Section 26 05 00 - Common Work Results for Electrical.
- .2 Depending upon magnitude and complexity, divide control system into convenient sections, energize one section at time and check out operation of section.
- .3 Upon completion of sectional test, undertake group testing.
- .4 Check out complete system for operational sequencing.

### **3.4 CLEANING**

- .1 Progress Cleaning: clean in accordance with Section 01 74 00 - Cleaning.
  - .1 Leave Work area clean at end of each day.
- .2 Final Cleaning: upon completion remove surplus materials, rubbish, tools and equipment in accordance with Section 01 74 00 - Cleaning.
- .3 Waste Management: separate waste materials for reuse and recycling in accordance with Section 01 74 19 - Waste Management and Disposal.
  - .1 Remove recycling containers and bins from site and dispose of materials at appropriate facility.

**END OF SECTION**

## **Part 1 General**

### **1.1 RELATED REQUIREMENTS**

- .1 Section 26 05 00 - Common Work Results for Electrical.
- .2 Section 26 05 31 - Splitters, Junction, Pull Boxes and Cabinets.
- .3 Section 26 05 34 - Conduits, Conduit Fastenings and Conduit Fittings.
- .4 Section 26 05 36 - Cable Trays for Electrical Systems.

### **1.2 REFERENCE STANDARDS**

### **1.3 ACTION AND INFORMATIONAL SUBMITTALS**

- .1 Submit in accordance with Section 01 33 00 - Submittal Procedures.
- .2 Product Data:
  - .1 Submit manufacturer's instructions, printed product literature and data sheets for communication raceway systems and include product characteristics, performance criteria, physical size, finish and limitations.

### **1.4 DELIVERY, STORAGE AND HANDLING**

- .1 Deliver, store and handle materials in accordance with Section 01 61 00 - Common Product Requirements.
- .2 Delivery and Acceptance Requirements: deliver materials to site in original factory packaging, labelled with manufacturer's name and address.
- .3 Storage and Handling Requirements:
  - .1 Store materials indoors and in accordance with manufacturer's recommendations in clean, dry, well-ventilated area.
  - .2 Store and protect communication raceway systems from nicks, scratches, and blemishes.
  - .3 Replace defective or damaged materials with new.
- .4 Packaging Waste Management: remove packaging materials in accordance with Section 01 74 19 - Waste Management and Disposal.

## **Part 2 Products**

### **2.1 MATERIAL**

- .1 Cable trays: hot dipped galvanized ladder type, in accordance with Section 26 05 36 - Cable Trays for Electrical Systems.
- .2 Junction boxes: in accordance with Section 26 05 31 - Splitters, Junction, Pull Boxes and Cabinets.

## **Part 3 Execution**

### **3.1 EXAMINATION**

- .1 Verification of Conditions: verify that conditions of substrate previously installed under other Sections or Contracts are acceptable for communication raceway systems installation in accordance with manufacturer's written instructions.
  - .1 Visually inspect substrate in presence of Departmental Representative.

- .2 Inform Departmental Representative of unacceptable conditions immediately upon discovery.
- .3 Proceed with installation only after unacceptable conditions have been remedied.

### **3.2 INSTALLATION**

- .1 Install empty raceway system, including fish wire, terminal cabinets, outlet boxes, pull boxes, cover plates, conduit, sleeves and caps, cable tray, miscellaneous and positioning material to constitute complete system.

### **3.3 CLEANING**

- .1 Progress Cleaning: clean in accordance with Section 01 74 00 - Cleaning.
  - .1 Leave Work area clean at end of each day.
- .2 Final Cleaning: upon completion remove surplus materials, rubbish, tools and equipment in accordance with Section 01 74 00 - Cleaning.
- .3 Waste Management: separate waste materials in accordance with Section 01 74 19 - Waste Management and Disposal.
  - .1 Remove recycling containers and bins from site and dispose of materials at appropriate facility.

### **3.4 PROTECTION**

- .1 Protect installed products and components from damage during construction.
- .2 Repair damage to adjacent materials caused by pathways for communications systems installation.

**END OF SECTION**

## **Part 1 General**

### **1.1 RELATED REQUIREMENTS**

- .1 Section 26 05 00 - Common Work Results for Electrical.

### **1.2 REFERENCE STANDARDS**

- .1 CSA Group (CSA)
  - .1 CSA-C22.2 No. 214-17 (R2021), Communications Cables (Bi-National standard with UL 444).
- .2 Telecommunications Industry Association (TIA)/Electronic Industries Alliance (EIA)
  - .1 TIA/EIA-568-B.1-(2001), Commercial Building Telecommunications Cabling Standard, Part 1: General Requirements.
  - .2 TIA/EIA-568-B.2-(2001), Commercial Building Telecommunications Cabling Standard, Part 2: Balanced Twisted-Pair Cabling Components.
  - .3 TIA/EIA-606-A-(2002), Administration Standard for the Commercial Telecommunications Infrastructure.

### **1.3 ACTION AND INFORMATIONAL SUBMITTALS**

- .1 Provide submittals in accordance with Section 01 33 00 - Submittal Procedures.
- .2 As-built Records and Drawings:
  - .1 Provide Microsoft Access database reflecting cable installation and cross-connections.
  - .2 Provide electronic drawings in AutoCAD 2000 format depicting all construction.

### **1.4 DELIVERY, STORAGE AND HANDLING**

- .1 Waste Management and Disposal: separate waste materials for reuse and recycling in accordance with Section 01 74 19 - Waste Management and Disposal.

## **Part 2 Products**

### **2.1 FOUR-PAIR BALANCED TWISTED PAIR CABLE**

- .1 Four-pair, unshielded-twisted-pair (UTP) cable, flame test classification FT4 or MPG or CMG to: CSA-C22.2 No. 214, Category 6 (Cat 6) to: TIA/EIA-568-B.2.

## **Part 3 Execution**

### **3.1 INSTALLATION OF HORIZONTAL DISTRIBUTION CABLES**

- .1 Install horizontal cables as indicated from telecommunication rooms to equipment. Identify and label as indicated to: TIA/EIA-606-A.
- .2 Support horizontal cables at intervals not exceeding 2 metres.
  - .1 Where raceways are used to distribute cables to each zone, provide supplementary "J" hooks to support cables at intervals not exceeding 2 metres.
- .3 Install horizontal cables from consolidation point to individual work-area jacks.
  - .1 Provide supplementary "J" hooks to support cables at intervals not exceeding 2metres.
  - .2 Identify and label as indicated to: TIA/EIA-606-A.

- .4 Coil spare cables and store in ceiling space in zone.
- .5 Harness slack cable in cabinets, racks, and wall-mounted termination and cross-connection hardware.

### **3.2 INSTALLATION OF EQUIPMENT CABLES**

- .1 Install equipment cables from equipment patch panel as indicated.
  - .1 Identify and label as indicated to: TIA/EIA-606-A.

### **3.3 FIELD QUALITY CONTROL**

- .1 Test horizontal UTP cables as specified below and correct deficiencies provide record of results as electronic record on CD.
  - .1 Perform tests for Permanent Link on installed cables, including spares:
    - .1 Category 6 using certified level III tester to: TIA/EIA-568-B.2.
  - .2 Perform tests for Channel on 20% of cross-connected data horizontal cabling installed from each telecommunications room, including shortest and longest drops from each telecommunications room: should more than 5% of tested cables fail, test remaining cross-connected data cables.
    - .1 Category 6 using certified level III tester to: TIA/EIA-568-B.2.
- .2 Test backbone UTP cables as specified below and correct deficiencies: provide record of results as electronic record on CD.
  - .1 Perform tests for Permanent Link on 4-pair cables:
    - .1 Category 6 using certified level III tester to: TIA/EIA-568-B.2.
  - .2 Perform Wire Map tests on multi-pair UTP cables to: TIA/EIA-568-B.1.

**END OF SECTION**

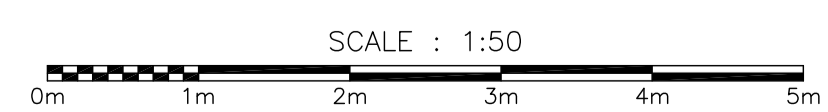
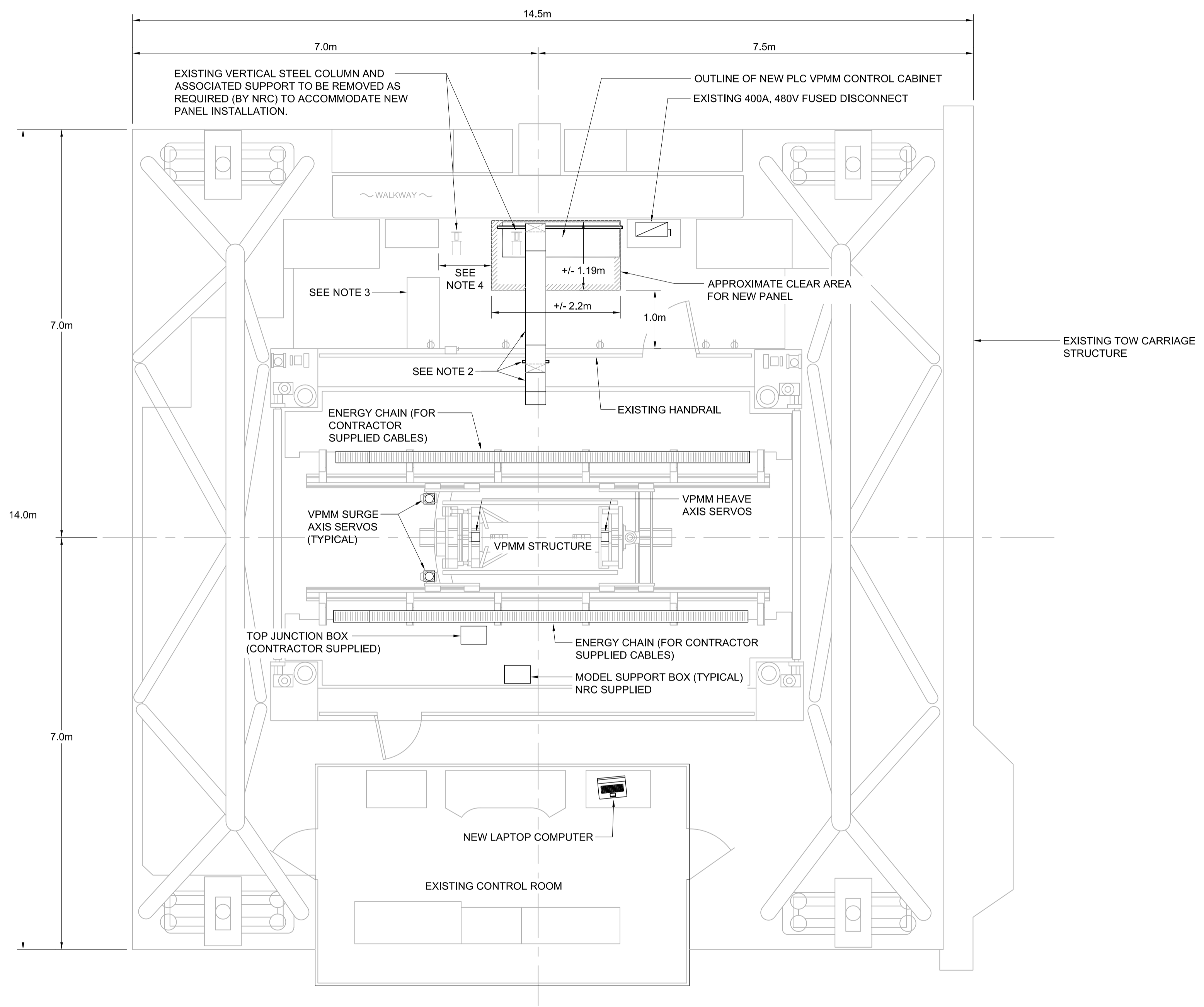


## **VERTICAL PLANAR MOTION MECHANISM (VPMM) SYSTEM**

Appendix F  
October 20, 2023

# **APPENDIX F**

- NOTES:**
- DIMENSIONS ARE APPROXIMATE, CONTRACTOR TO VERIFY ALL DIMENSIONS ON SITE.
  - 300mm WIDE HOT DIPPED GALVANIZED LADDER STYLE CABLE TRAY AND VERTICAL OUTSIDE BENDS. CABLE TRAY TO BE C/W DIVIDING BARRIER AS REQUIRED. MINIMUM HEIGHT OF CABLE TRAY TO BE 2.5m ABOVE FINISHED FLOOR.
  - RAISED PORTION OF FLOOR (MECHANICAL PROTECTION FOR SURFACE MOUNTED CONDUITS).
  - MINIMUM 0.8m CLEAR PATHWAY TO BE MAINTAINED AFTER NEW PLC VPMM CONTROL CABINET INSTALLED FOR ACCESS TO WALKWAY.



**REVISED ELECTRICAL RISER DIAGRAM**  
SCALE: N.T.S.

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E101

0	ISSUED FOR TENDER	MAY 10 2023
revisions		date

project

VPMM TECHNICAL SPECIFICATIONS  
MARINE DYNAMIC TESTING FACILITY  
St. John's, NL, Canada

drawing

TOW CARRIAGE  
GENERAL LAYOUT

designed B. GRAY

date 2022.01.26

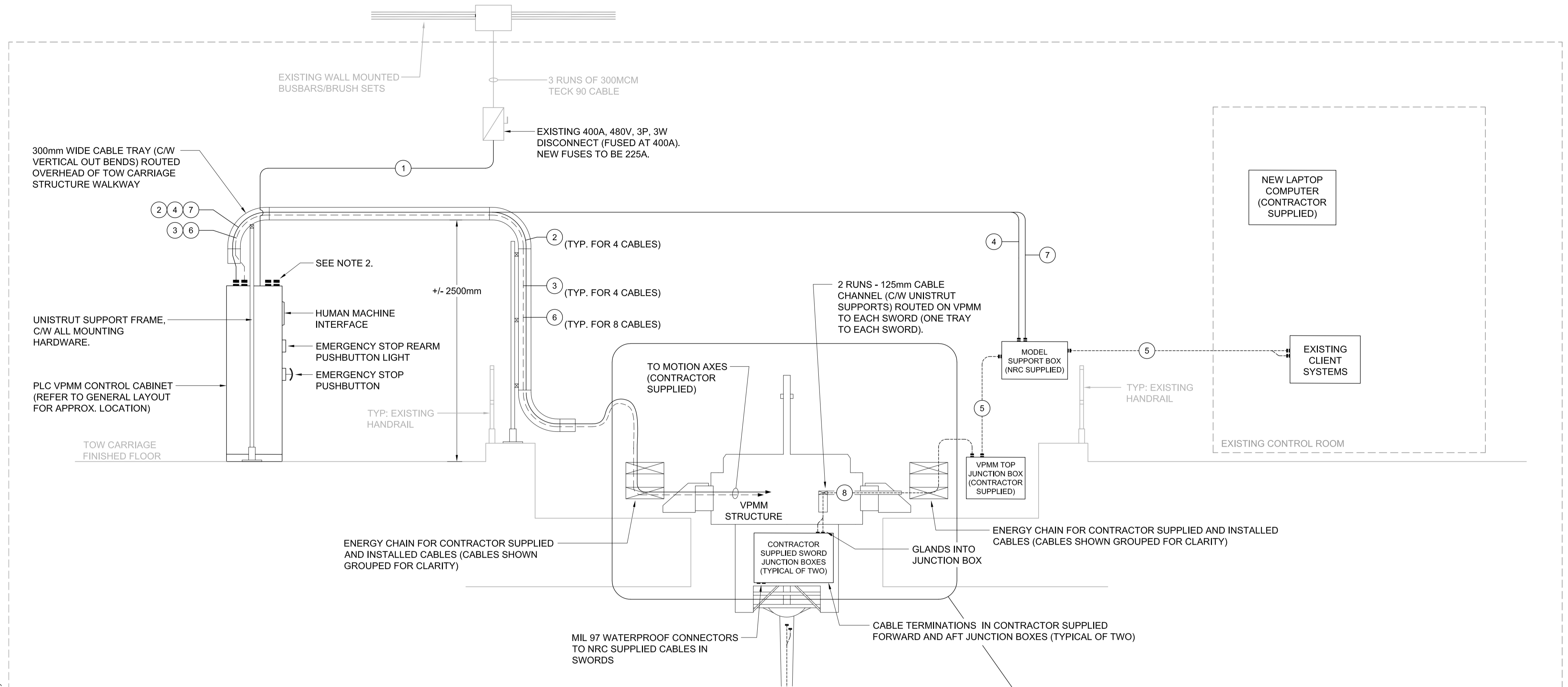
drawn J. DILLON

date 2022.01.26

approved

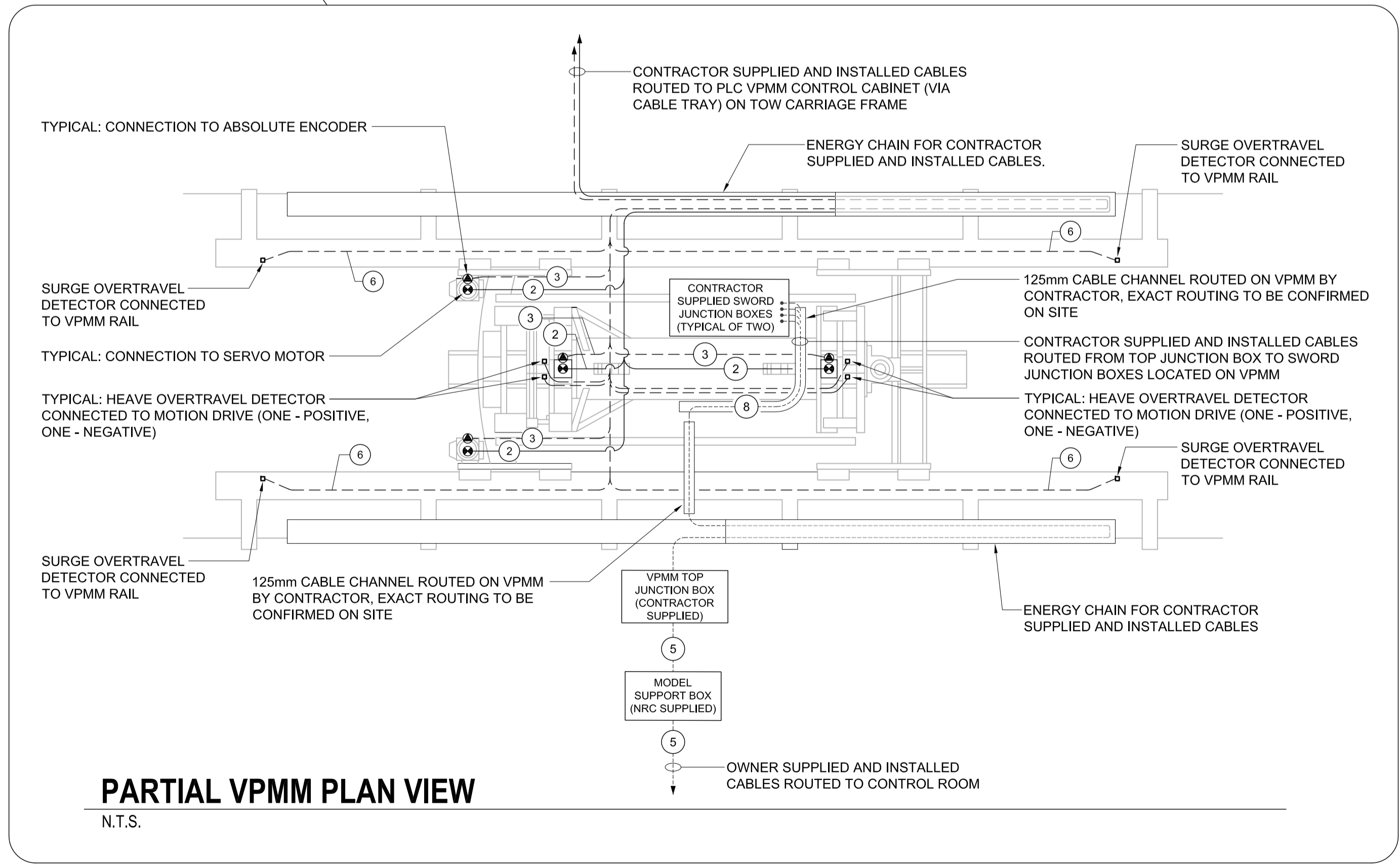
133432238

E101



- NOTES:**
- DRAWING NOT TO SCALE, CABLE ROUTINGS ARE SHOWN DIAGRAMMATIC ONLY.
  - TYPICAL: ALL CONNECTORS TO PANEL TO BE WEATHERPROOF QUICK CONNECTOR TYPE.
  - NOT ALL ENERGY CHAINS SHOWN ON PLANS FOR CLARITY, REFER TO PROCESS CONTROL NARRATIVE FOR COMPLETE LIST.

FEEDER SCHEDULE		
No.	DESCRIPTION	AMPS
1	3C #4/0, 480V POWER CABLE TO VPMM CONTROL CABINET	225
2	3C CABLE (SERVO MOTOR POWER CABLE)	---
3	4pr CABLE (SERVO MOTOR FEEDBACK CABLE)	---
4	CAT 6 CABLE (COMMUNICATION CABLE)	---
5	CABLES SUPPLIED AND INSTALLED BY CLIENT	---
6	2C #18 CABLE FOR OVERTRAVEL LIMIT	---
7	6 - 1C #14 CONTROL CABLE FOR E-STOP	---
8	VPMM CABLES SUPPLIED AND INSTALLED BY CONTRACTOR	---



**PARTIAL VPMM PLAN VIEW**  
N.T.S.

**REVISED ELECTRICAL RISER DIAGRAM**  
SCALE: N.T.S.

0	ISSUED FOR TENDER	MAY 10 2023
revisions		date

project  
**VPMM TECHNICAL SPECIFICATION**  
**MARINE DYNAMIC TESTING FACILITY**  
 St. John's, NL, Canada

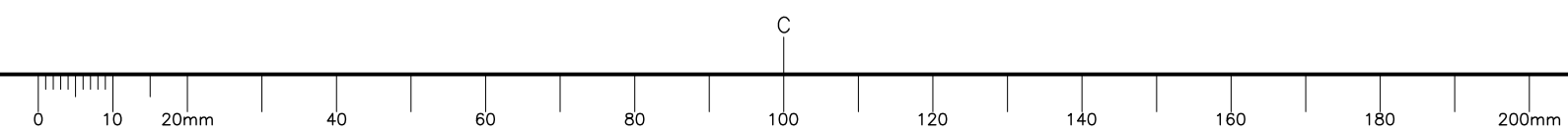
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**VPMM GENERAL SCHEMATIC**

designed	B. GRAY	conçu
date	2022.01.26	
drawn	J. DILLON	dessiné
date	2022.01.26	
approved		approuvé
date		
Tender		Soumission

PWGSC Project Manager / Administrateur de projets TPSC  
 project number / no. du projet  
**133432238**

drawing no. / no. du dessin  
**E102**



## **VERTICAL PLANAR MOTION MECHANISM (VPMM) SYSTEM**

Appendix G  
October 20, 2023

# **APPENDIX G**

### **ARCHITECTURE, Electrical Components, cables and connectors Overview/Introduction**

The Vertical Planer Motion Machine, VPMM, System is meant to be installed for a test program, then un-installed and stored until the next test program. This requires the ability to physically connect and disconnect, mechanically and electrically, the various components that make up the integrated system.

The integrated system consists of:

- The VPMM System, to be designed and supplied by the contractor, which consists of the motion mechanism and support components.
- The NRC Tow Tank Facility, providing the mounting point and electrical resources for the VPMM System,
- The Sword Sub System, providing a mounting method to connect the Model to the VPMM,
- The Model to be tested,
- And the miscellaneous support components to integrate the above.

This document deals primarily with the electrical, electronic and network topology.

Figures 1. – 3. provide an overview of cable and connector configuration for the integrated VPMM - NRC Carriage System.

Figure 4. is provided as context, the purpose of the VPMM is to support this model during testing.

Table 1. is a tabular summary of cables and connectors.

The number and size of conductors indicated for each cable is a nominal count and gauge. Selection of connectors and cable types may require the proposal of a different arrangement. For example, two 16 conductor cables instead of one 32 conductor cable or a different gauge of conductor, as long as it is larger.

If a cable must be split to get the conductor count, the designation would be proposed as cable #a, b..., etc. Cable 2 is an example.

### **Installation/Removal**

Cable breaks at **A – F and G** indicated;

Top Junction Box and Forward Sword Junction Box and Aft Sword Junction Box plus Internal High flex cables to be supplied by contractor, built as integral parts of VPMM System.

### **Components**

Cables and connector series TBD. Deck cables tough and abrasion/crush resistant; connectors Mil 97 series or commercial. VPMM NRC internal cables high flex/continuous flex. Sword mating and sword cables waterproof and water blocked; connectors waterproof/underwater connectors.

Exact wiring to be determined. Final Model design is the driver, design TBD.

### **Parts and Connections**

Parts:

1. Resource points for Model: Power (High power, AC standard), Ethernet. **Carriage Supplied.**
2. Cables: Resource point to model box cables; 1, 2a, 2b, 2c, 2d and 3.

3. Model Support Box: Motor Controllers, Ethernet Distribution, other support components for power conditioning and distribution; connectors to allow connection/dis-connection and removal of Model Support Box. Model Support Box Connects to NRC VPMM Top Junction Box; VPMM System Rack; and Carriage Resource points.
4. Cables: Model Support Box to NRC VPMM Top Junction Box cables; Cables 4, 5, 6 and 7.
5. NRC VPMM Top Junction Box; Junction Box mounted on/to VPMM. Provides mating point from Model Support Box to Internal NRC VPMM high flex cable set. Shown as permanently attached termination device. **This Component is mounted to the non-moving side of the VPMM Motion Mechanism.**
6. Cables: Internal VPMM Cable Set; Cables 8, 9, 10 and 11
7. NRC VPMM Forward Sword Junction Box; Termination and connection point for Cables 8 and 9. Motor Controller power and sensor/control cables for BM3400 propulsion motor.
8. NRC VPMM Aft Sword Junction Box; Termination and connection point for Cables 10 and 11. Ethernet control/telemetry cable and general-purpose AC power.
9. Forward Sword
10. Cables: Forward Sword internal cables; Cables 12 and 13
11. Aft Sword
12. Cables: Aft Sword internal cables; Cables 14 and 15

### **Connections / Dis-connects:**

The system cables and connectors have different design requirements for different parts of the integrated system. The 'deck cables', those running between devices at the working deck levels of the carriage need to have tough/robust cables jackets and be terminated in tough/robust connectors. Mil 97 Series connectors or similar are suggested.

The cables within the VPMM motion mechanism are required to be high flex, as they will be undergoing continuous mechanical bending cycles during operation. The connectors on the 'top-side' of the VPMM motion mechanism can be Mil 97 Series connectors, to mate with corresponding 'deck cables'. The bottom connectors need to be underwater rated to mate with the underwater cables/connectors of the forward and aft swords.

1. **Carriage Resource connections;** Connection Point **A** dis/connection point for installing / removing VPMM system.
  - a. J1 cable end socket to Cable 1, J4 cable end pin, general purpose 120VAC. Maybe multiple feeds. Mil style connectors, 97 series
  - b. J2a Ethernet socket to Cable 2a, J5 Ethernet pin.
  - c. J2b
  - d. J2c
  - e. J2d
  - f. J3 cable end socket to Cable 3, J6 cable end pin. High power AC for motor controller.
2. **Model support cables;** Cables 1 through 3, Carriage resource point(s) to Model Support Box(s):
  - a. Cable 1: J4 cable end pin to J7 cable end socket; Mil style connectors, 97 series; Multiple 15-amp, 120 VAC sources required for various other components. (Possibly two+)
  - b. Cable 2a: J5a Ethernet pin to J8a Ethernet pin; An Ethernet connection is required for control and telemetry.

- c. Cable 2b: J5b cable end pin to J8b cable end pin Mil style connectors, 97 series;
  - d. Cable 2c J5c cable end pin to J8c cable end pin Mil style connectors, 97 series;
  - e. Cable 2d J5d cable end pin to J8d cable end pin Mil style connectors, 97 series;
  - f. Cable 3: J6 cable end pin to J9 cable end socket; Mil style connectors, 97 series; A single 30-amp, 240 VAC supply is required for the BM3400 Motor Controller.
3. **Model Support Box** connections; Connection Point **B** dis/connection point for installing / removing VPMM system plus NRC components.
    - a. J10 pin to Cable 1 J7 socket; Mil style connectors, 97 series GP 120VAC feed(s)
    - b. J11a socket to Cable 2 J8 pin; Ethernet
    - c. J11b
    - d. J11c
    - e. J11d
    - f. J12 pin to Cable 3 J9 socket; Mil style connectors, 97 series High Power AC.
  4. **Model Support Box**; Interface between Carriage Resource Point and Model umbilical support components;
    - a. Aerotech BM3400 Motor Controller and support components, filters, terminal blocks, etc...
    - b. Data Acquisition System; if needed
    - c. Network interface components, if required,
    - d. DC supplies and support components if required
    - e. 120 VAC supply to model motor controllers and components;
    - f. Interface components, if required between VPMM System, Carriage Control System and Carriage Control Room Components
  5. **Model Support Box** connections; Connection Point **C**, dis/connection point for installing / removing VPMM system
    - a. J13 97 series socket to Cable 16 J18 97 series pin; Ethernet, E-Stop Chain and Discreet Signals from VPMM System to Carriage Control System and User Interface in Carriage Control Room.
    - b. J14 97 series bulkhead socket to Cable 4 J19 97 series cable end pin; Ethernet to model DAS, instruments and control.
    - c. J15 97 series pin to Cable 5 J20 socket; ; Mil style connectors, 97 series GP AC distribution
    - d. J16 97 series socket to Cable 6 J21 pin; Mil style connectors, 97 series, BM3400 motor drive cable; direct cable from Motor Controller.
    - e. J17 97 series socket to Cable 7 J22 pin; Mil style connectors, 97 series, BM3400 motor sensor cable; direct cable from Motor Controller.
  6. Model Support Box to **NRC VPMM TOP Junction Box** Cables
    - a. Cable 4; J19 pin to J23 pin; Mil style connectors, 97 series; Ethernet + to model DAS, instruments and control.
    - b. Cable 5; J20 pin to J24 socket; Mil style connectors, 97 series; GP AC distribution
    - c. Cable 6; J21 pin to J25 socket; Mil style connectors, 97 series, BM3400 motor drive cable; direct cable from Motor Controller.
    - d. Cable 7; J22 pin J26 socket; Mil style connectors, 97 series, BM3400 motor sensor cable; direct cable from Motor Controller.

7. **NRC VPMM Top Junction Box**; Connection Point **D**, dis/connection point for installing / removing VPMM system and cable transition point from normal surface cable to internal VPMM high flex cable. The box is mounted to the non-moving portion of the VPMM Motion Mechanism.
  - a. J27 socket to Cable 8 J31 pin; Ethernet to model DAS, instruments and control to **Forward Sword Junction Box**.
  - b. J28 pin to Cable 9 J32 socket; GP AC distribution to **Forward Sword Junction Box**.
  - c. J29 socket to Cable 10 J33 socket, BM3400 motor drive cable; direct cable from Motor Controller to **Aft Sword Junction Box**.
  - d. J30 socket to Cable 11 J34 socket, BM3400 motor sensor cable; direct cable from Motor Controller to **Aft Sword Junction Box**
8. **Internal VPMM NRC cable set**; see above, cables 8, 9, 10 and 11. Cables 8 and 9 are high flex cables designed for continuous bending cycles and run from the **Top Junction Box** to the **Forward Sword Junction Box**. Cables 10 and 11 are high flex cables designed for continuous bending cycles and run from the **Top Junction Box** to the **Aft Sword Junction Box**.
9. **Forward Sword Junction Box**; Connection Point **E**, dis/connection point for installing / removing Forward Sword and cable transition point from VPMM high flex cable to underwater cables. **J39 and J40 are underwater connectors**.
  - a. J35 pin to Cable 12 J39 pin; Ethernet to model DAS, instruments and control, **Forward Sword Junction Box**.
  - b. J36 pin to Cable 13 J40 pin; GP AC distribution; **Forward Sword Junction Box**.
10. **Aft Sword Junction Box** Connection Point **E**, dis/connection point for installing / removing Aft Sword system and cable transition point from internal VPMM high flex cable to underwater cable. **J41 and J42 are underwater connectors**.
  - a. J37 socket to Cable 14 J41 pin, BM3400 motor drive cable; direct cable from Motor Controller.
  - b. J38 socket to Cable 15 J42 pin, BM3400 motor sensor cable; direct cable from Motor Controller.
11. Model Connection Point, Forward Sword, Connection Point **F** dis/connection point for installing / removing Aft Sword system
12. Model Connection Point Aft Sword, Connection Point **F** dis/connection point for installing / removing Aft Sword system.
13. Model Source Cables
  - a. Forward Can
  - b. Aft Can
14. Model Internal Cables
  - a. Forward to Aft Can
  - b. Internal Cables Forward Can
  - c. Internal Cables Aft Can
  - d. Dynamometer Cables



**Cables for VPMM – NRC support**

**Cable 5 – 9 – 13: Communications, E-Stop Chain:** See Figure 2.

**32 conductor (6 x # 14, 8 x #16, 16 x #26); Double shielded;**

**Cable 5; NRC Deck Cable.** Model support box to NRC – VPMM Top Junction Box

NRC supplied; Cable TBD

J24 97 series 32 contact cable end socket – J20 97 series 32 contact cable end pins

Connector Models TBD; Connector / Back Shell / Strain Relief / boot

**NRC VPMM Top Junction Box; Contractor supplied;** Hammond Style utility box. Sized to mount mating 97 series bulkhead connectors:

J27

**J28**

J29 and,

J30

Cables Terminated at bulkhead connector; Cables strain relieved; Cables exit box through glands?

**Cable 9; Contractor supplied** cable; Robotic/Automation – Infinite Flex cable

Cable TBD, terminated to,

J28 97 series 32 contact bulkhead mount pins.

Connector Model TBD, matched to J24 Cable 5;

Cable exits Junction box via gland

Cable path from top junction box to forward sword junction box via energy chains, **contractor supplied.**

**NRC VPMM Forward Sword Junction Box; Contractor supplied;** Hammond Style utility box. Sized to mount underwater bulkhead connectors:

J31

**J32**

J33 and,

J34

Cable 9 terminated at bulkhead connector J32; Cables strain relieved; Cables enter box through glands?

**Cable 13; NRC Sword Cable.** VPMM Forward Sword Junction Box to Lower Forward Sword Junction Box

NRC supplied; Cable TBD

J36 Underwater series 32 contact cable end pin – J39 Underwater series 32 contact bulkhead socket.

J36 Mates to J32

Connector Models TBD;

**Cable 4 – 8– 12: Model Power Supply Chain:** See Figure 2.

**10 conductor (6 x # 12, 4 x #16); Double shielded;**

**Cable 4; NRC Deck Cable.** Model support box to NRC – VPMM Top Junction Box

**NRC supplied**; Cable TBD

J23 97 series 10 contact cable end socket – J19 97 series 10 contact cable end pins  
Connector Models TBD; Connector / Back Shell / Strain Relief / boot

**NRC VPMM Top Junction Box; Contractor supplied**; Hammond Style utility box. Sized to mount mating 97 series bulkhead connectors:

**J27**

J28

J29 and,

J30

Cables Terminated at bulkhead connector; Cables strain relieved; Cables exit box through glands?

**Cable 8; Contractor supplied** cable; Robotic/Automation – Infinite Flex cable

Cable TBD, terminated to,

J27 97 series 10 contact bulkhead mount pins.

Connector Model TBD, matched to J23 Cable 4;

Cable exits Junction box via gland

Cable path from top junction box to forward sword junction box via energy chains, contractor supplied.

**NRC VPMM Forward Sword Junction Box; Contractor supplied**; Hammond Style utility box. Sized to mount underwater bulkhead connectors:

**J31**

J32

J33 and,

J34

Cables 8 terminated at bulkhead connector J31; Cables strain relieved; Cables enter box through glands?

**Cable 12; NRC Sword Cable.** VPMM Forward Sword Junction Box to Lower Forward Sword Junction Box

**NRC supplied**; Cable TBD

J35 Underwater series 10 contact cable end pin – J39 Underwater series 10 contact bulkhead socket.

J35 Mates to J31

Connector Models TBD;

**Cable 6 – 10– 14: HPe Motor Drive Cable Chain:** See Figure 3.

**4 conductor (4x # 10); Double shielded;**

**Cable 6; NRC Deck Cable.** Model support box to NRC – VPMM Top Junction Box

**NRC supplied**; Cable TBD

J21 97 series 4 contact cable end pins – J25 97 series 4 contact cable end socket

Connector Models TBD; Connector / Back Shell / Strain Relief / boot

**NRC VPMM Top Junction Box; Contractor supplied**; Hammond Style utility box. Sized to mount mating 97 series bulkhead connectors:

## Appendix G

J27  
J28  
**J29** and,  
J30

Cables Terminated at bulkhead connector; Cables strain relieved; Cables exit box through glands?

**Cable 10; Contractor supplied** cable; Robotic/Automation – Infinite Flex cable

Cable TBD, terminated to,  
J29 97 series 4 contact bulkhead mount pins.  
Connector Model TBD, matched to J25 Cable 6;  
Cable exits Junction box via gland  
Cable path from top junction box to forward sword junction box via energy chains, contractor supplied.

**NRC VPMM Forward Sword Junction Box; Contractor supplied**; Hammond Style utility box. Sized to mount underwater bulkhead connectors:

J31  
J32  
**J33** and,  
J34

Cable 10 terminated at bulkhead connector J33; Cables strain relieved; Cables enter box through glands?

**Cable 14; NRC Sword Cable.** VPMM Forward Sword Junction Box to Lower Forward Sword Junction Box

**NRC supplied**; Cable TBD  
J37 Underwater series 4 contact cable end pin – J41 Underwater series 4 contact bulkhead socket.  
J37 Mates to J33  
Connector Models TBD

**Cable 7 – 11 – 15: Motor Aux Cable:** See Figure 3.  
**32 conductor (32 x #20); Double shielded;**

**Cable 7; NRC Deck Cable.** Model support box to NRC – VPMM Top Junction Box

**NRC supplied**; Cable TBD  
J22 97 series 32 contact cable end socket – J26 97 series 32 contact cable end pins  
Connector Models TBD; Connector / Back Shell / Strain Relief / boot

**NRC VPMM Top Junction Box; Contractor supplied**; Hammond Style utility box. Sized to mount mating 97 series bulkhead connectors:

J27  
J28  
J29 and,  
**J30**

Cables Terminated at bulkhead connector; Cables strain relieved; Cables exit box through glands?

**Cable 11; Contractor supplied** cable; Robotic/Automation – Infinite Flex cable

Cable TBD, terminated to,

J30 97 series 32 contact bulkhead mount pins.

Connector Model TBD, matched to J26 Cable 7;

Cable exits Junction box via gland

Cable path from top junction box to forward sword junction box via energy chains, **contractor supplied**.

**NRC VPMM Forward Sword Junction Box; Contractor supplied**; Hammond Style utility box. Sized to mount underwater bulkhead connectors:

J31

J32

J33 and,

**J34**

Cable 11 terminated at bulkhead connector J34; Cables strain relieved; Cables enter box through Contractor supplied method.

**Cable 15; NRC Sword Cable.** VPMM Forward Sword Junction Box to Lower Forward Sword Junction Box

**NRC supplied**; Cable TBD

J38 Underwater series 32 contact cable end pin – J42 Underwater series 32 contact bulkhead socket.

J38 Mates to J34

Connector Models TBD;

**Cable 16: VPMM System to Model Box; VPMM to Carriage interface cable. Contractor Supplied, in consultation with NRC.**

**Cable TBD, 24 Conductor (24 x #20); Double shielded;**

**Ethernet:** 8 Conductor

**E-Stop Chain; In/Out:** # conductors TBD

**Status flags:** # conductors TBD

**Analog outputs:** # conductors TBD

J61 97 series 24 contact cable end socket – J18 97 Series 24 contact cable end pins

J18 Mates to J13 on Model Support Box.

Functions:

- E-Stop Chain
- Motion Configuration download?
- VPMM System Status to NRC DAS, User Interface
- Motion Stop / Start
- VPMM Data to NRC DAS
  - Position/Velocity of all axis
  - Load monitoring, current

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Cable #	Function	Nominal Format	Bulkhead 1			Cable end 1			Cable end 2			Bulkhead 2			Supplied by	
1	AC Power	6 x #12	J1	S		J4	P		J7	S		J10	P		Resource to Model Box	NRC
2a	Ethernet 1	8 x #26	J2a	S		J5a	P		J8a	P		J11a	S		Resource to Model Box	NRC
2b	VPMM E-Stop Chain	10 x #20	J2b	S		J5b	P		J8b	S		J11b	P		Resource to Model Box	NRC
2c	PLC/Discreet/TBD	14 x #20	J2c	S		J5c	P		J8c	S		J11c	p		Resource to Model Box	NRC
2d	Ethernet 2	8 x #26	J2d	S		J5d	P		J8d	S		J11d	P		Resource to Model Box	NRC
3	AC Power for MC	4 x #10	J3	S		J6	P		J9	S		J12	P		Resource to Model Box	NRC
4	AC Power to Model	6 x # 12, 4 x #16	J14	S		J19	P		J23	S		J27	P		Model Box to NRC VPMM Top Junction Box	NRC
5	Model Comm's/ E-Stop Chain	6 x # 14, 8 x #16, 16 x #26	J15	S		J20	P		J24	S		J28	P		Model Box to NRC VPMM Top Junction Box	NRC
6	Motor Drive	4 x #10	J16	S		J21	P		J25	S		J29	P		Model Box to NRC VPMM Top Junction Box	NRC
7	Motor Auxiliary	32 x #20	J17	S		J22	P		J26	S		J30	P		Model Box to NRC VPMM Top Junction Box	NRC
8	AC Power to Model	6 x # 12, 4 x #16	J23, cable end	S		J27	P		J31	S		J35, cable end	P		Internal VPMM System cables, NRC VPMM Top Junction Box to Forward Sword Junction Box	Contractor
9	Model Comm's/ E-Stop Chain: #26 conductors are Ethernet	6 x # 14, 8 x #16, 16 x #26	J24, cable end	S		J28	P		J32	S		J36, cable end	P		Internal VPMM System cables, NRC VPMM Top Junction Box to Forward Sword Junction Box	Contractor
10	Motor Drive	4x # 10	J25, cable end	S		J29	P		J33	S		J37, cable end	P		Internal VPMM System cables, NRC VPMM Top Junction Box to Aft Sword Junction Box	Contractor
11	Motor Auxiliary	32 x #20	J26, cable end	S		J30	P		J34	S		J38, cable end	P		Internal VPMM System cables, NRC VPMM Top Junction Box to Aft Sword Junction Box	Contractor
12	AC Power to Model	6 x # 12, 4 x #16	J31	S		J35	P		J39	S		J43, cable end	P		Forward Sword Cable	NRC
13	Model Comm's/ E-Stop Chain	6 x # 14, 8 x #16, 16 x #26	J32	S		J36	P		J40	S		J44, cable end	P		Forward Sword Cable	NRC
14	Motor Drive	4x # 10	J33	S		J37	P		J41	S		J45, cable end	P		Aft Sword Cable	NRC
15	Motor Auxiliary	32 x #20	J34	S		J38	P		J42	S		J46, cable end	P		Aft Sword Cable	NRC
16	VPMM to Carriage I/O Cable	24 x #20													VPMM System to Model Box	Contractor

Table 1. Cable and Connector Tabulation

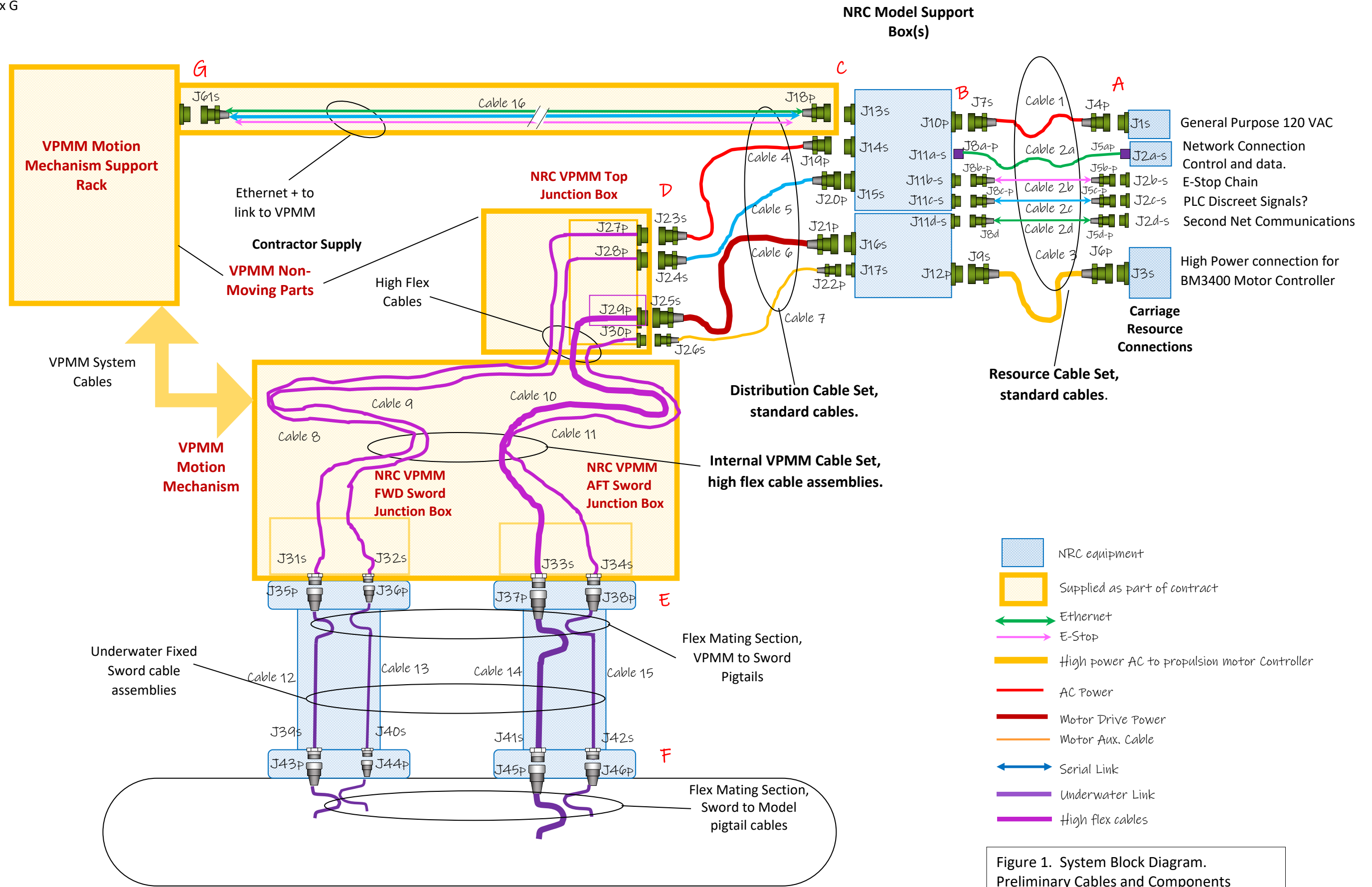


Figure 1. System Block Diagram. Preliminary Cables and Components

DAS and Control Cabling:

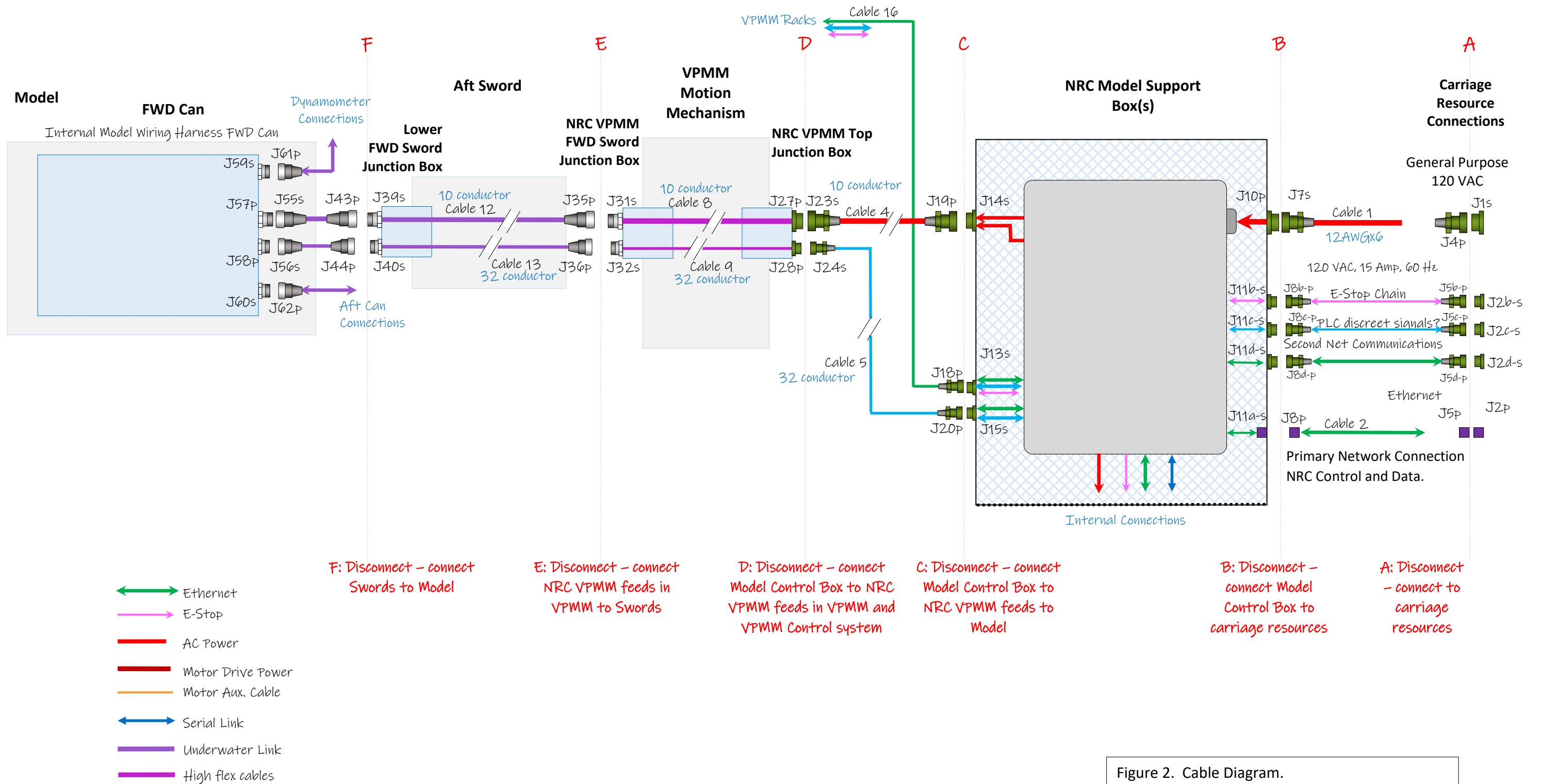


Figure 2. Cable Diagram.  
DAS and System Power Cables and Components



Propulsion Motor Control Cabling:

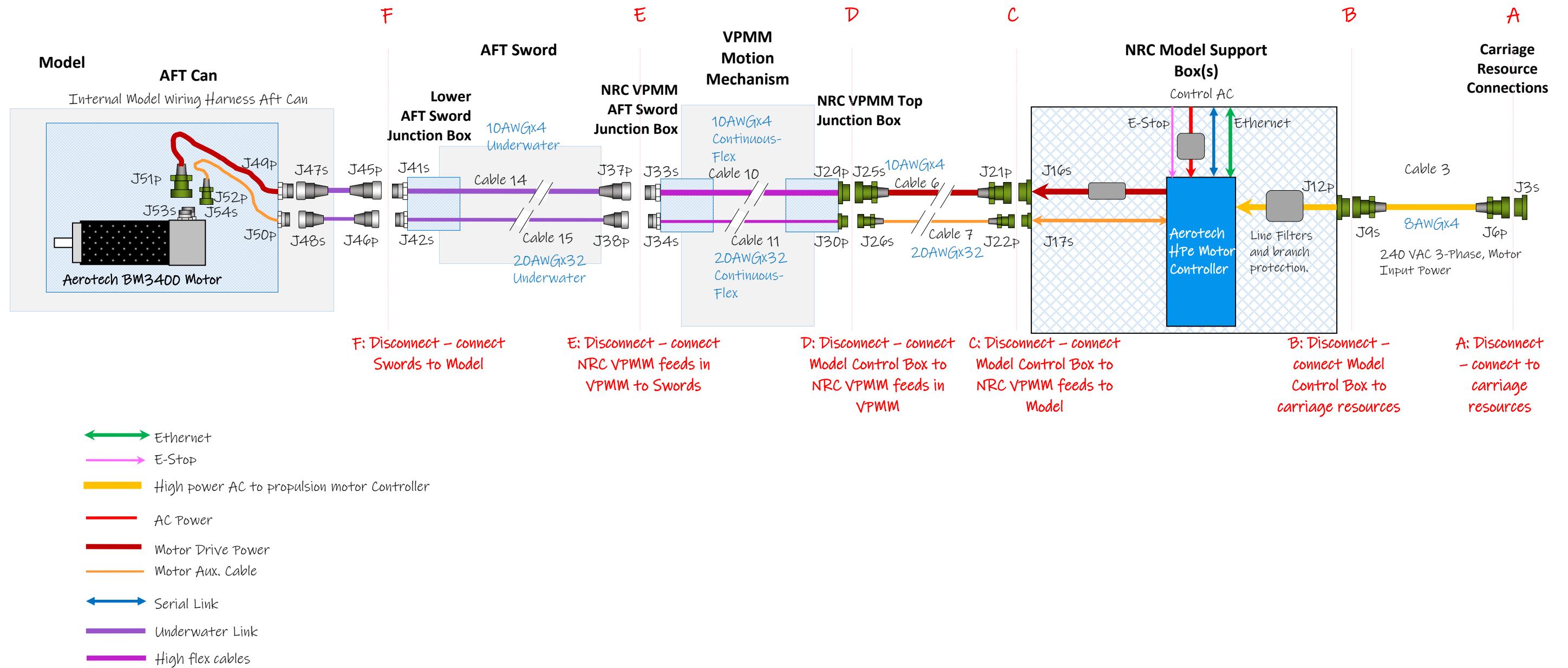


Figure 3. Cable Diagram.  
BM3400 Support Cables and Components

Model System:

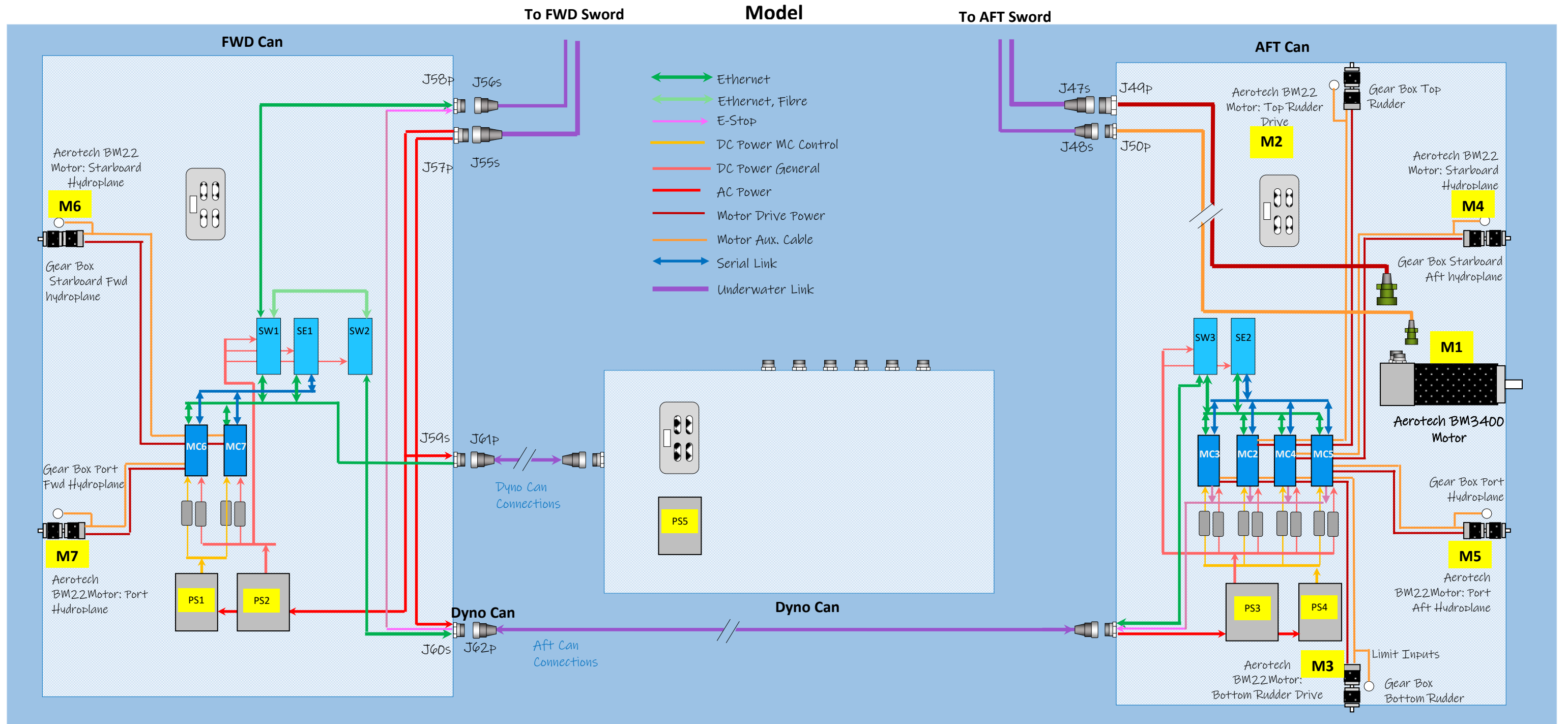


Figure 4. Model Block Diagram. Cables and Components

