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Heavy Vehicle Load Simulator for Bridge Deck Testing Application:

Volume II

Final Report

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16. Abstract

This is Volume II of the Heavy Vehicle Load Simulator for Bridge Deck Testing Application, the Operations & Maintenance and Standard Operating Procedures. This document refers to the facility under the name given and branded by CAIT, the Bridge Evaluation and Accelerated Structural Testing Laboratory or BEAST Lab. All references to the laboratory herein will follow the BEAST lab naming convention. The equipment developed under this grant remains the Heavy Vehicle Load Simulator for Bridge Deck Testing Application.

Given the importance of overcoming the challenges associated with aging and deteriorating bridges, and the need for a full scale proving ground for evaluation of new and advanced materials and devices, CAIT has procured a full-scale load testing equipment. The Heavy Vehicle Load Simulator for Bridge Deck Testing Application is a one-of-a-kind testing equipment that will evaluate full scale bridge elements and bridge decks in an accelerated manner. CAIT collaborated with Applied Research Associates (ARA) to prepare, design and fabricate the Heavy Vehicle Load Simulator. The equipment will evaluate the samples by applying realistic traffic and environmental loading conditions in a greatly compressed timeframe, simulating 15 years of deterioration in 6 months (30 fold). This equipment, for the first time, will allow the scientific study of deterioration processes on full-scale bridges. Since deterioration processes operate over long durations and at a glacial time-scale, time compression is highly desirable. The innovative manners, implemented in this laboratory, to accelerate deterioration processes without distorting them will provide bridge owners with critical information in the near-term. The equipment is a large complex system enclosing a 125' long by 75' wide footprint and standing 13'-6" tall. The equipment consists of a load chassis applying a 60,000lb load in an enclosed environmental chamber that weathers the test sample, simulating seasonal temperature fluctuations (0^{o}F to 104^{o}F) and applying deicing salts (as per current practice during the simulated winter months). The physical and environmental loading on the test specimens will simulate actual stress and impact levels exerted by truck traffic on bridge decks and superstructure elements at a greatly accelerated pace.

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Bridge Evaluation and Accelerated Structural Testing Laboratory (BEAST)

OPERATIONS MANUAL
&
STANDARD OPERATING PROCEDURES

Revision 1 9/7/2016

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Table of Contents

List of Figures

Introduction

The Bridge Evaluation and Accelerated Structural Testing (BEAST) Laboratory is a bridge engineering research tool designed to apply a rolling load of up to 60,000 lb to a bridge deck surface, through four sets of dual tires over a traverse distance of 50 ft at a top speed of 20 mi/hr. The equipment is a large complex system enclosing a 125' long by 75' wide footprint and standing 13'-6" tall. The load is applied by pneumatic cylinders reacted against the static weight of the machine. The BEAST can be laterally positioned using two powered railroad carts with built in lifting mechanisms.

The BEAST is constructed around a steel frame consisting of two parallel I-beams, 114 feet long, spanning the length of the test section. The two beams are connected by a steel support frame structure at each end. The wheel load is applied by a pneumatic load system mounted aboard a carriage, which traverses almost the entire length. During loading, the carriage runs on steel rails attached under the center of each main beam. When unloaded, the carriage runs on soft wheels, on the lower flanges of the main beams. The carriage is propelled by an electronically controlled winch mounted at one end of the BEAST through two wire ropes, one of which attach to each end of the load carriage, one of them by way of a tensioning sheave at the opposite end of the winch**.** Loading is applied to the test surface through both of the specified wheel/tire assemblies with an electronically controlled pneumatic loading system.

The loading system and tire pressures are controlled by two electro-pneumatic servo pressure controllers. Operational control of the BEAST can be either manually from a control panel, or by a computer from inside the operator control room. The control software has a user-friendly Windows interface, allowing the operator to quickly and easily set up the desired testing sequence.

The entire test area is environmentally enclosed and includes heating and cooling elements designed to maintain constant temperature within the chamber at temperatures ranging from 0F (-18C) to 104F (40C). A heating, cooling or combined profile can be set using the temperature control functions on the computer located in the control room. In addition, a brine or water spray can be applied to the test section by means of a distribution system mounted to the load carriage. The computer interface also is used to provide the sequence of brine/water spray to the test section.

The following sections describe in more detail specific aspects of the BEAST subsystems.

1. Safety Summary

1.1. Definitions: WARNINGS, CAUTIONS, AND NOTES

WARNING

An operating or maintenance procedure, practice, condition statement, etc., which, if not strictly observed, could result in injury to or death of personnel or long-term health hazard to personnel.

CAUTION

An operating or maintenance *procedure, practice, condition, statement, etc., which, if not strictly observed, could result in damage to, or destruction of, equipment or loss of test effectiveness.*

NOTE

An essential operating or maintenance procedure, condition or statement which must be followed.

1.2. General WARNINGS

WARNING

1. The BEAST is supplied by 1200 Amps at 480 VAC. Work on all high voltage equipment including, but not limited to: distribution panels, high voltage fuses, conduit, winch, HVAC equipment, and rail carts should only be performed by a qualified electrician. See pictures below.

1. Observe all high voltage warning signs.
2. The BEAST is moved laterally by rail carts. When the BEAST is being moved by the rail carts all persons must keep clear.
3. When the BEAST rail carts or drive systems are energized all persons must keep a safe distance from the moving cylinders, carriage, rail carts and cable system.
4. Before performing any maintenance on or around the BEAST ensure that all power disconnects (Winch, Control, Rail Cart) are switched off, locked out and tagged out.
5. A qualified electrician should verify the grounding effectiveness of the power supply periodically. The BEAST structure and end frame must be bonded to an electrical ground that satisfies all applicable code requirements.
6. The environmental enclosure is also mounted on rails to allow test sections to be replaced. While moving the roof trusses, people should stay clear of the wheels and other roof trusses.
7. The Environmental Chamber will remain unoccupied during bridge specimen environmental and mechanical loading. The bridge deck and environmental chamber may be slippery when water spray is in use. Use caution when moving in and around the BEAST after the spray has been activated.
8. Hard hats and gloves are suggested while working inside the environmental chamber.
9. During operation, the braking resistors will get very hot. Do not touch them until they have cooled down.

CAUTION

1. Trained personnel must correct all faults detected by the control systems before BEAST operation can resume. Failure to do so could result in equipment damage.
2. The sheave nitrogen valve must be activated to provide cable tension for high-speed manual operations. Failure to do so could result in equipment damage.
3. The sheave cylinder contains high pressure and may move suddenly. Be aware of pinch points.

Sheave Warning Labels.

4. The electric lift & rail cart system should not be used in conjunction with the test control or drive systems. Failure to operate rail cart system correctly could result in equipment damage.
5. Ethernet cables, camera cables, and water hoses must be unplugged and stowed appropriately before operating the rail cart system. Failure to do so could result in equipment damage.
6. Ethernet cables, camera cables, and water hoses must be installed prior to running the BEAST. Failure to do so could result in equipment damage.
7. The carriage must be securely fastened prior to moving the BEAST. Failure to do so could result in equipment damage.

NOTES

1. An emergency stop button is located near the chamber door on each side of the machine.
2. A push button emergency stop is located on the control panel.
3. There is an emergency stop on each bumper that will trip if the carriage moves too far on the deceleration ramp.
4. There are two emergency stops on the tension cylinder which trigger if the cable is too tight or too slack.
5. The PLC and Computer Emergency stop will disable load control, tire pressure control, and the drive system.
6. The Rail Cart Emergency Stop only disables the Rail Carts.
7. One person should be on each end of the environemental enclosures while pushing the roof trusses.
8. Tires and load air-bags should be properly pressurized with nitrogen prior to use.

2. System Components and Function

2.1. System Components

The BEAST is comprised of several main components. The Subsections below describe the main systems components of the BEAST and give a brief explanation of their function. Proper understanding of each main component's function is necessary to properly operate the BEAST.

2.1.1. Overall Structure

As shown in Figure 1. the BEAST structure consists of two main box beams that run the length of the machine. The box beams are attached together by 7 cross braces and two end frames. A winch end frame houses controls and the winch and a sheave end frame houses the sheave assembly. Both end frames are supported on a leveling frame. Inside of the end frames there are two powered railroad carts that lift and move the machine when needed. In the center of the two box beams the carriage assembly rides on two rails that run the full length on the bottom of the beams.

Figure 1. BEAST Overall Structure and Main Components

2.1.2. Sheave End Frame Assembly

The Sheave End Frame Assembly supports the sheave end of the structure, houses the sheave, and the sheave end rail cart as shown in Figure 2. The sheave assembly itself is comprised of a support frame, a guide beam, a large pneumatic cylinder pressurized with nitrogen and a yolk that holds a large pulley. The winch cable wraps around the pulley and the pressure in the pneumatic cylinder maintains tension on the winch cable attached to both the winch and one end of the load carriage. The sheave guide beam also has two sensors attached on it that provide data to the control system to make sure the sheave does not move to a point where it could not maintain tension on the cable. The sheave provides a means to take up both the dynamic cable movements as the load cart moves, and the static stretch of the cable as it lengthens as it is used.

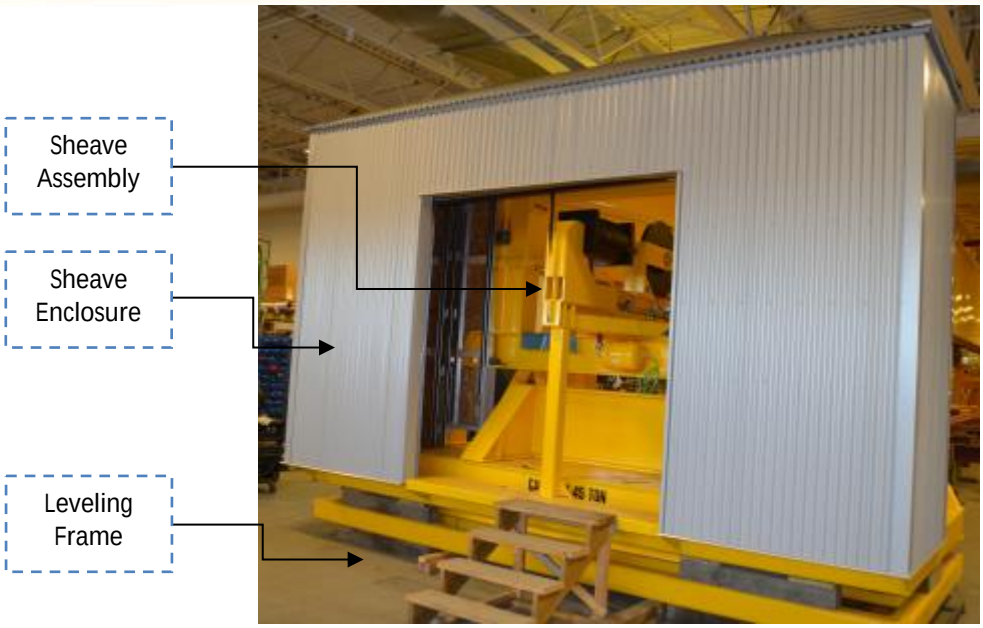

Figure 2. Sheave End Frame Assembly

2.1.3. Winch End Frame Assembly

The winch end frame assembly houses most of the drive and control components of the BEAST. As shown in Figures 3 and 4, the 400 horsepower winch assembly, the winch controller, the electrical main distribution panel (MDP), the programmable logic controller (PLC), and the rail cart controllers are all housed in this enclosure. The winch provides the force to move the load cart. The winch controller interfaces with the PLC, which in turn is controlled by the control computer in the control room. The winch controller interprets the commands from the PLC and provides the proper current to run the motor. It also directs the excess current generated when the load carriage is stopping to the braking resistors located next to the winch. The MDP is the electrical connection to the transformer that provides power to the BEAST. It is wired for 3 phase, 480 volt power. Another transformer in this enclosure provides the 240 and 120 volt power for lights and other uses. The PLC is attached to the sensors located in other portions of the BEAST. Based on the instructions coming from the control computer and the sensor output, it provides the command signals to the winch controller to operate the load cart. The rail cart controllers are commanded with a hand held controller attached directly to the controllers via a special connection. The rail carts can lift the whole BEAST and move it laterally on the rails to allow access, maintenance or replacement of the bridge deck being tested.

Figure 3. Winch End Frame Assembly Showing Winch, MDP, and Winch Controller

Figure 4. Assembly Showing PLC and Rail Cart Controllers in Winch End Frame.

2.1.4. Leveling Frame & Jacks

The leveling frame, shown below, provides a means to make up minor differences in height and slope between the BEAST and the test section. The end frame fits over the leveling frame and the leveling jacks adjust for the differences in height from end to end or side to side. Shear clamps are also provided to allow any impact or side loads to be transferred into the concrete structure from both the end frame and the leveling frame. The multiple views below show how the frames and clamps fit together.

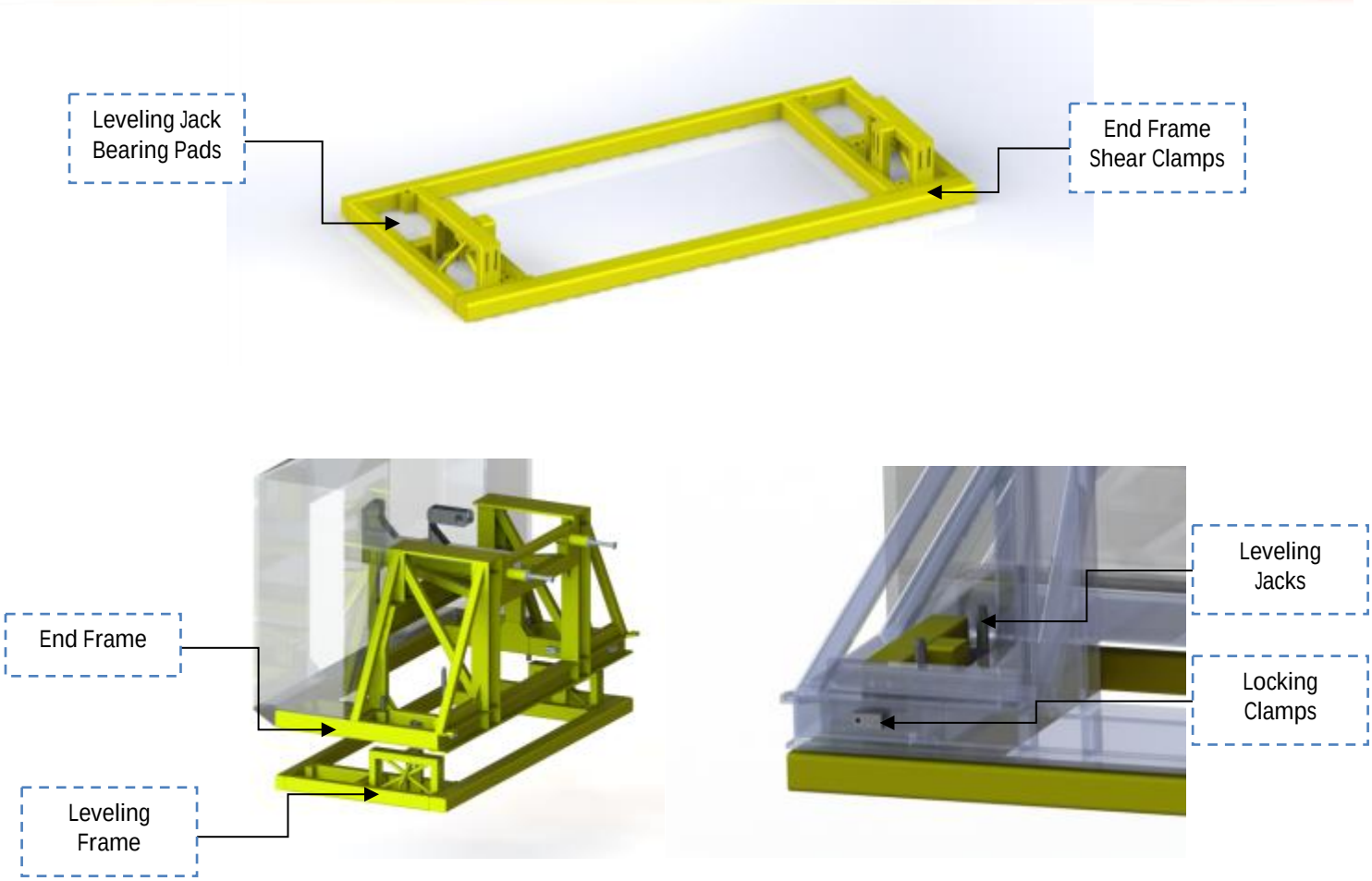

Figure 5. Leveling Frame Assembly

2.1.5. Rail Carts

The rail carts as shown in Figure 6 are constructed of structural steel and plate members welded into a heavy duty unit suitable for lifting and moving the BEAST. The unit is equipped with a 3/4" flat steel deck plate with removable access covers to allow access to the components beneath the deck. A mechanical screw jack arrangement is powered by a 480 Volt AC SEW-Eurodrive Gearmotor providing 6" of vertical lift. A drive axle arrangement consisting of (2) 16" diameter single flange steel wheels, SKF Flange Bearings, C-1045 carbon steel axle and a 480 Volt AC SEW-Eurodrive Gearmotor is mounted on the rear of the unit and (2) Idler Wheel Assemblies mounted on the front. Both of the gearmotors are equipped with a spring applied and electrically released motor brake to prevent movement when the power is off.

Figure 6. Rail Cart Assembly

The rail carts are set up as a "master" and "slave" arrangement whereas each car is controlled by a single Allen-Bradley PLC mounted in the winch end frame, as shown in Figure 7, and each car is equipped with a variable speed drive used to control the drive arrangement. Each cart is equipped with an encoder allowing the PLC to synchronize the lift of each endframe. The drive arrangement provides travel speed of 2-10 feet per minute (FPM).

Figure 7. Rail Cart Control System

The “master” car is equipped with a hand held pendant control equipped with a variable speed control, forward/reverse and lift/lower controls as shown in Figure 8.

Figure 8. Rail Cart Handheld Pendent Control

2.1.6. Winch Assembly

The winch assembly is an electrically powered cable drum used to propel the carriage assembly back and forth. It has a 400 HP 480 Volt 3 phase drive motor with encoder feedback and a gear reducer. The drum rotation speed is reduced by powering the motor in the opposite direction. While the drum is still spinning in the original direction the excess current is redirected through a bank of resistors to dissipate the excess energy. The main components of the winch assembly are shown in Figure 9.

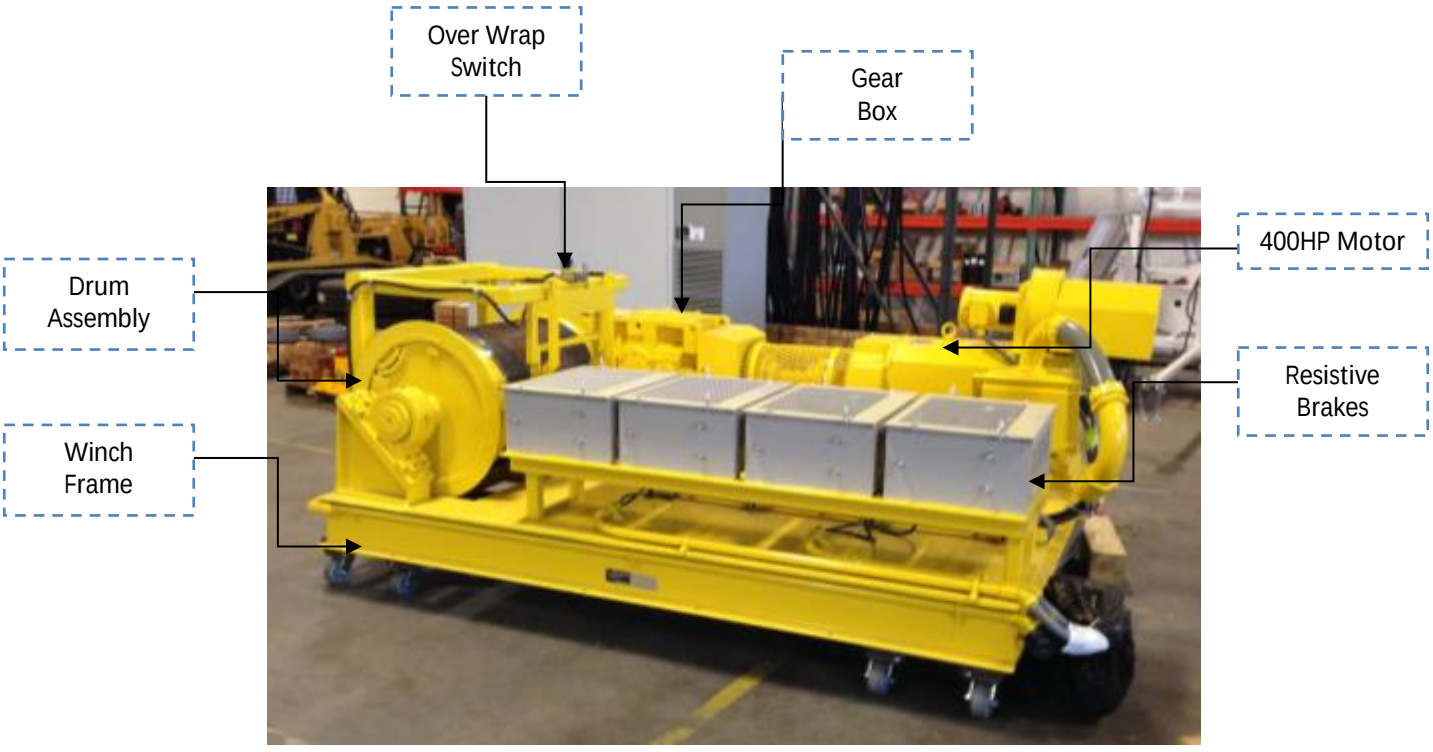

Figure 9. Winch Assembly

2.1.7. Tension Cylinder & Sheave Assembly

The Tension Cylinder and Sheave are located at the opposite end from the winch on the sheave end frame. The Tension Cylinder is pneumatically operated and provides tension to the wire rope. Typical pressure is 80 psi and applies about 12,000 lbs. of pull on the sheave wheel. Two limit switches detect the extents of the cylinder position. These switches are connected to the E-stop circuit and will shut the BEAST control system off when the cable stretches enough to reach the limit of the cylinder stroke. It will also shut down if the cable goes slack and the Sheave fully retracts. The details of the Sheave assembly are shown in Figure 10.

Figure 10. Sheave Assembly

2.1.8. Carriage Assembly

The carriage assembly provides the tire loading to the bridge deck test surface. Figure 11 is a side view of the complete carriage assembly. It is comprised of two parts, the upper and lower sections. The upper section guides the carriage and also provides a load path to react against the load applied to the bridge deck. The lower carriage has the truck wheels and tires and applies the load to the bridge deck. In between the upper and lower portions of the carriage is space for the environmental chamber (not shown in Figure 11) to fit in. Brushes on the inside edge of the environmental chamber will resist the air from flowing out as the carriage movers across the test section.

Figure 11: Side View of the Carriage Assembly

Additional components of the upper frame are shown in Figure 12. In order to move the carriage when there is no bridge deck below it, return rollers support the weight of the carriage on the bottom flange of the beams. Energy absorption cylinders are mounted to both the upper carriage and the end frames to dissipate the energy of the moving carriage if the control system and/or brakes fail on the BEAST.

Figure 12: End View of the Carriage Assembly

As shown in Figure 13, the large gray wheels on the upper section roll on the rails mounted to the beams. These wheels push against the rails and the load put on the bridge deck is reacted against by the weight of the BEAST. Guide rollers are positioned inside and outside the rail on all four corners of the upper carriage. The rollers on one side of the carriage are set to guide the carriage as it travels. The rollers on

the opposite side are set slightly farther out from the rail and act as a safety guide in case the rollers on the primary side fail.

Figure 13: Side View of the Carriage Assembly Highlighting the Rail Wheels and Guide Rollers

The upper carriage supports several of the sub-systems on the carriage. Shown in Figure 14 are the pressure gages used to set and read the pressure in the tires and the airbags used to load the axles.

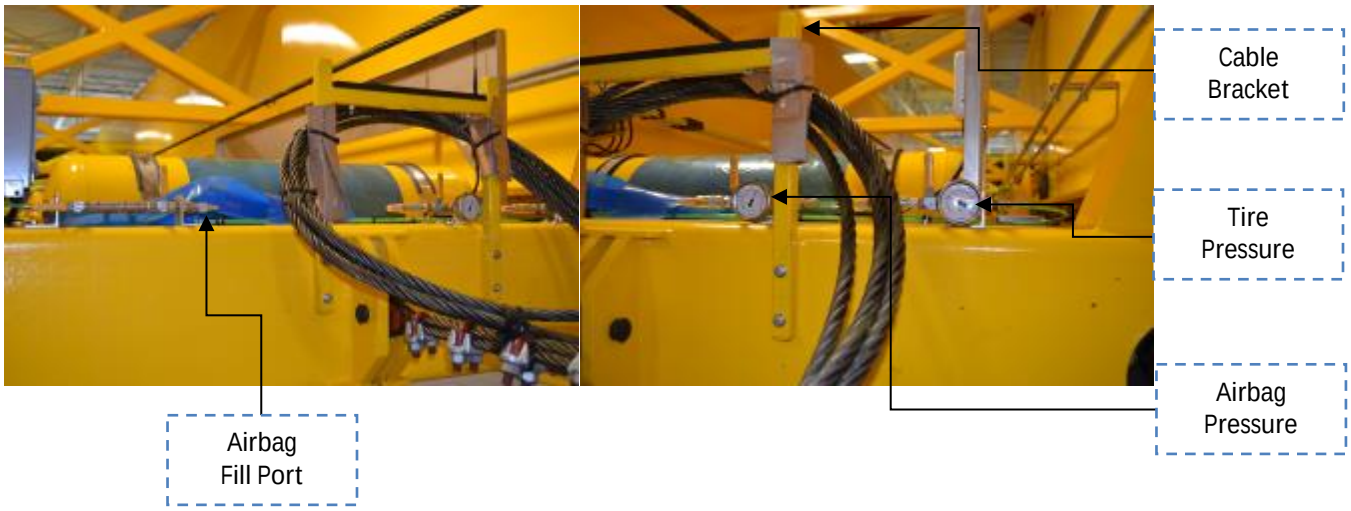

Figure 14: End View of the Upper Carriage Assembly Highlighting Pneumatic items.

Vibration is a primary indicator of a system starting to fail. Vibration sensors have been placed on the upper carriage as shown in Figure 15. These sensors are monitored by the control system and if the signal goes above a pre-selected range, the BEAST will automatically shut down.

Figure 15: Vibration Sensors located on the Upper Carriage Assembly.

A top view of the upper carriage is shown in Figure 16 identifying several key components. The air bags used to load the system are connected to a large tank providing additional volume for the pressurized nitrogen to occupy. This extra volume prevents an overload of the system if a step function in load would occur causing the wheels to rise suddenly. For example, if a block of wood is mistakenly left on the bridge deck and the system is started. The wheels would run over the block and compress the gas in the air backs. This sudden loading could cause the bridge to be loaded at a level not anticipated for the test or may cause damage to the air bags themselves. The additional volume reduces this effect and protects both the test section and the equipment.

The carriage control box houses the electronics used to control the load on the bridge deck, the tire pressure, and monitor the safety systems on the carriage. All this data is provided to the wireless communication system. Also shown in the figure are the locations of the optical sensor target, tire and air bag solenoids, and the nitrogen supply tank.

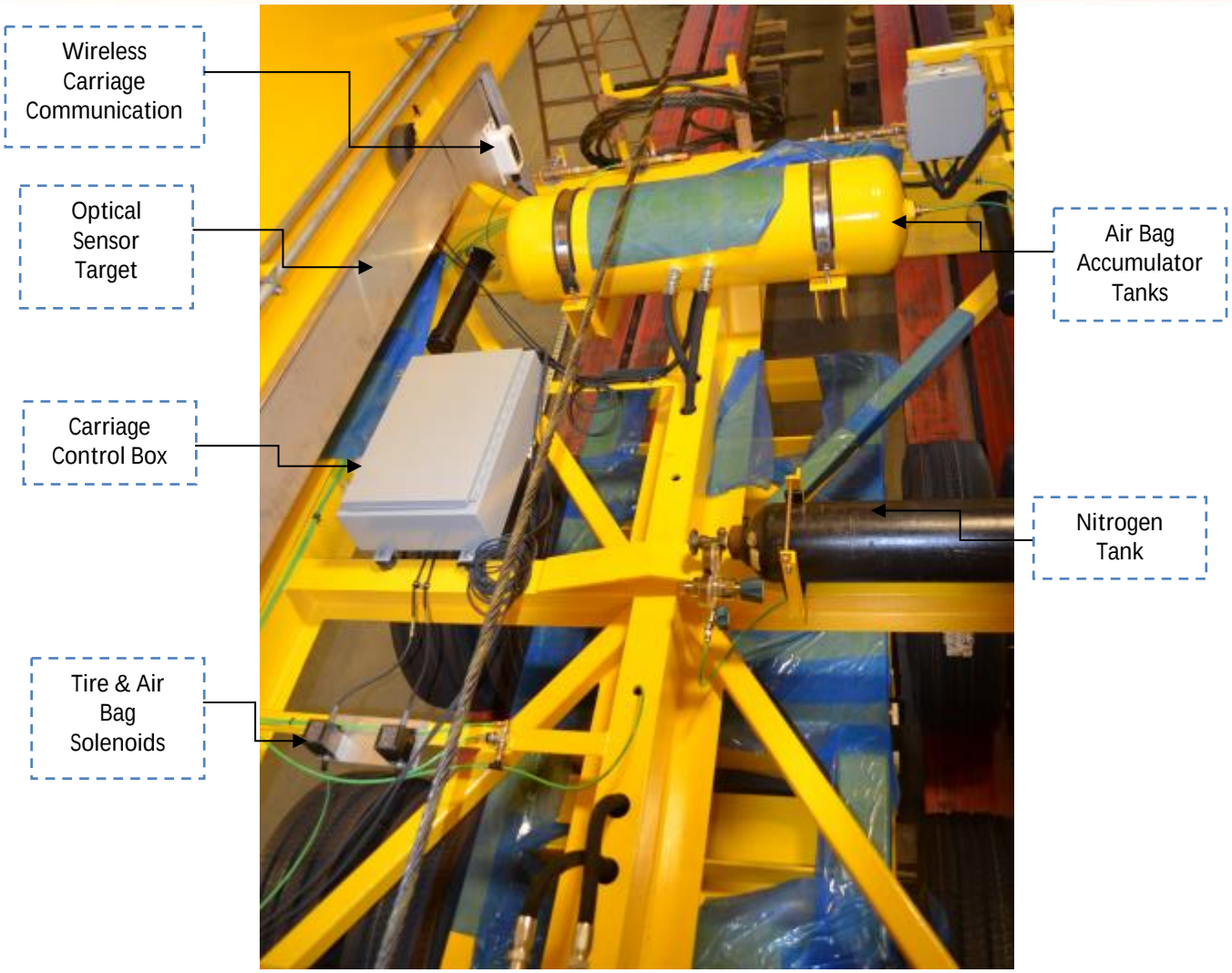

Figure 16: Top View of the Upper Carriage Assembly.

Electrical power is provided to the carriage through an electrical bus bar. Figure 17 shows the location of the bus bar and the trolley that rides along the bus bar as it travels with the carriage. This system provides 120 volt electricity to the carriage.

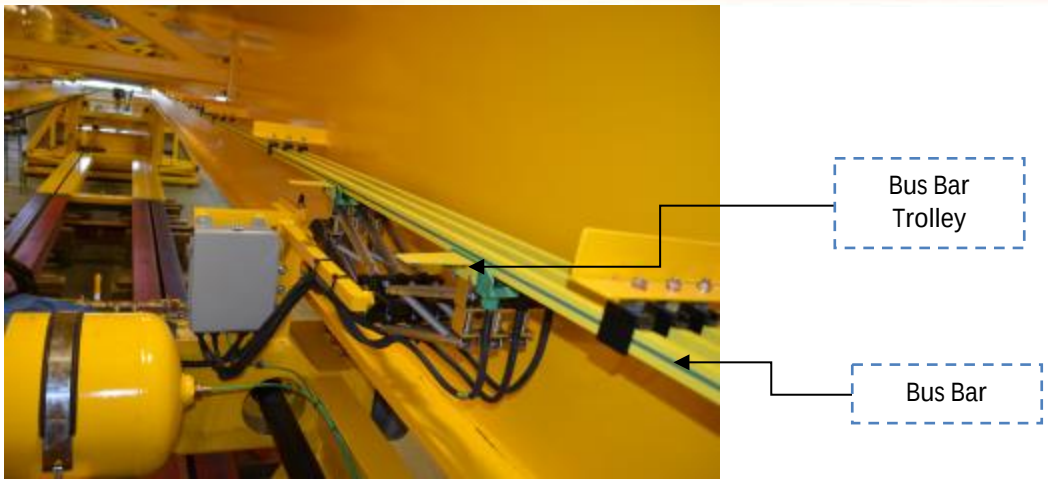

Figure 17: Top View of the Upper Carriage Assembly Highlighting the Bus Bar and Bus Bar Trolley.

The lower frame assembly is shown in Figures 18 and 19. The lower frame is where the tires, axles, air bags and swing arms are attached to the BEAST. Truck tires were selected based on the peak load of 7500 pounds per tire. The axles are rated for 30,000 pounds each. The swing arms and air bags work together to keep the load at the proper level while maintaining constant contact with the bridge deck.

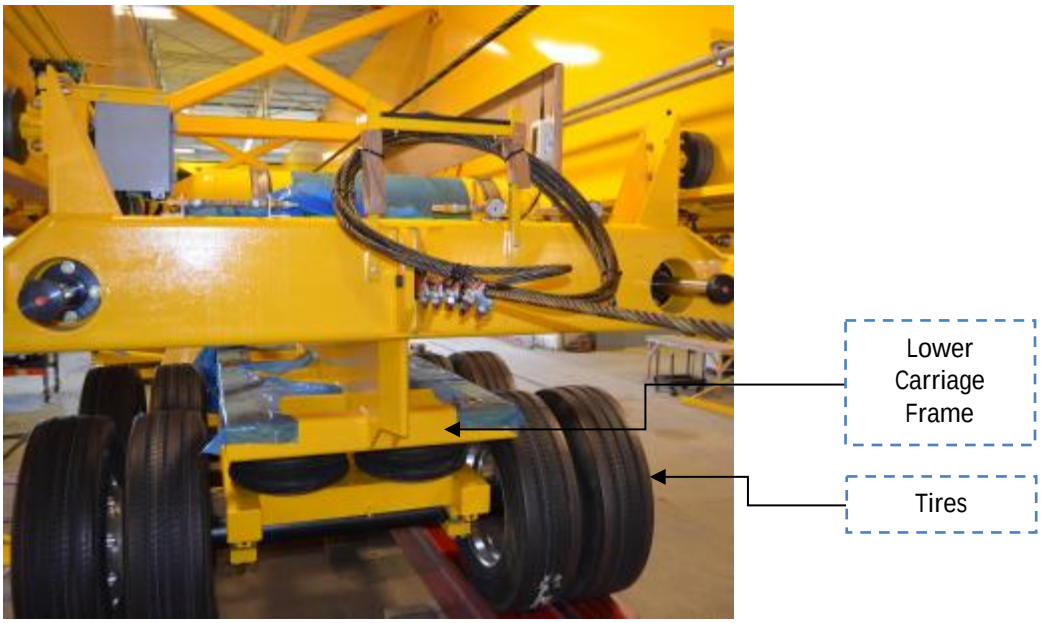

Figure 18: End View of the Lower Carriage Assembly.

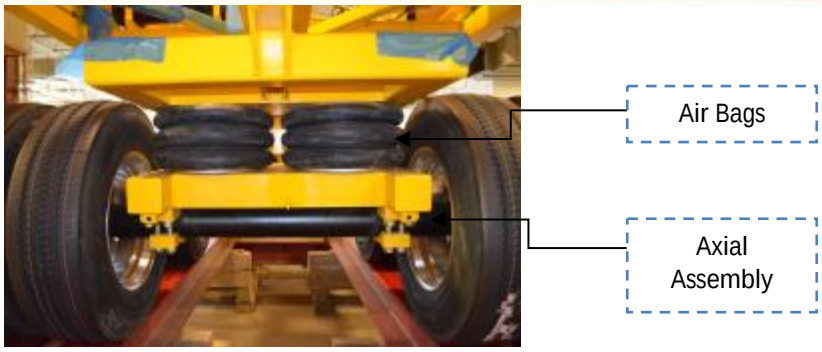

Figure 19: End View of the Lower Carriage Assembly Showing the Axle and Air Bags.

Proper alignment of the tires on the carriage is important for maintaining low side loads on the BEAST and preventing pre-mature wear of the tires. Figures 20 and 21 show the location of the swing arms and the axle alignment system used to adjust the position of the tires relative to the carriage. The axles are properly aligned at delivery and should rarely require adjustment by the operator.

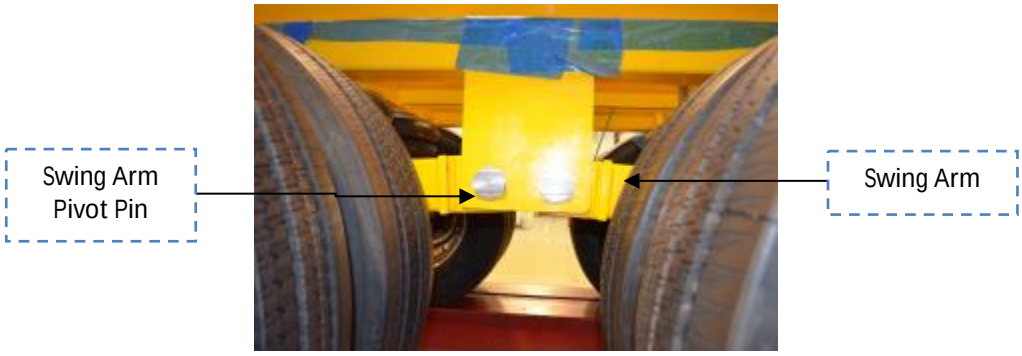

Figure 20: Side View of the Lower Carriage Assembly Showing the Swing Arms and Pivot Pins.

Figure 21: Bottom View of the Lower Carriage Assembly Highlighting the Axle Clamp and Alignment System.

2.1.9. Load ramps

There are two ramps that extend from each end frame to the bridge deck. These ramps are used for acceleration and deceleration of the load carriage. They are normally enclosed in the end frame environmental chamber. Each ramp must be installed, lined up with the carriage and bridge deck, and secured in place before testing begins. After testing, they must be raised and secured prior to using the rail carts.

Figure 21: View of Load Ramps with Carriage in Place.

2.1.10. Control System

The BEAST is controlled by a PLC based control system. There are three control boxes on the BEAST: Frame, Chamber, and Carriage. The frame control box has the master PLC. The chamber and carriage modules are wirelessly connected to the master module. The master PLC is located in the winch end frame and provides a Human/Machine interface (HMI), as shown in Figure 22. This master PLC connects to the chamber PLC through a wireless Ethernet connection; it connects to the carriage PLC through a wireless bridge. The winch vector drive, temperature controller, load system, tire pressure, and brine system are all controlled using analog and digital outputs from the various PLCs.

The master PLC sends speed, forward, reverse, and stop commands to the vector drive. All of the structure limit switches and the optical forward and reverse switches are fed in to the master PLC. The master PLC is used locally to perform the following functions

- Toggle power to Vector drive
- Set speed
  - Reduce speed to 1MPH max if load is below 12,000lb
- Jog carriage forward and reverse
- Enable auto run
  - Monitor and adjust speed of the carriage
- Monitor frame emergency stops
  - Disable motion if a stop occurs

Figure 22: Master PLC Control Box with HMI.

The control system provides data acquisition, carriage control and system feedback. The PLC is highly modular which allows for upgrades and addition of future options and sensors. The system utilizes a real time operating system for rapid feedback and control. A master monitors the limit switches and sensors on Bridge Deck Testing System frame. A wireless module handles the precision control and fault monitoring of the carriage. A second wireless module handles fault monitoring around the chamber, temperature control and brine solution spray. The HMI mounted to the winch end frame control panel allows manual control of the machine. A computer with a graphical user interface (GUI) provides the ability to observe and change control aspects of the system from the control station located inside the Rutgers building.

The computer is connected via Ethernet to the end frame control panel. Ethernet cameras will provide the ability to monitor system activity from the provided computer.

2.1.10.1. Control System Fail-Safe

There are multiple fail-safe systems implemented on the main structure of the BEAST. These include: the control panel E-stop, optical limit switches, winch encoder, winch over-wrap switch, bumper-kill switches and tension cylinder switches. These items are shown in Figures 23 through 25. In addition, there are bumpers similar to the ones on the carriage that are mounted to the structure on each end, as shown in Figure 26. If a mechanical stop occurs, the machine will need to be restarted manually. If there is a software stop, the user can restart from the laptop GUI.

Figure 23: Structure bumper kill switch (circled)

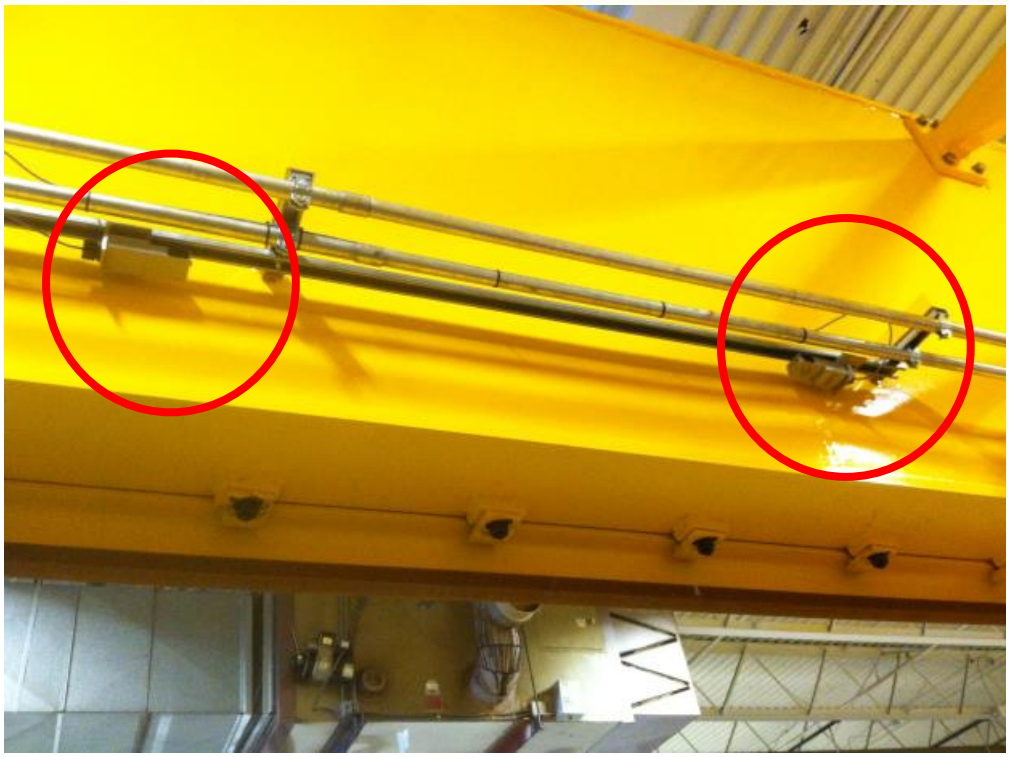

Figure 24: Optical limit switches (circled).

Figure 25: Tension cylinder with cylinder extend and retract switches (circled)

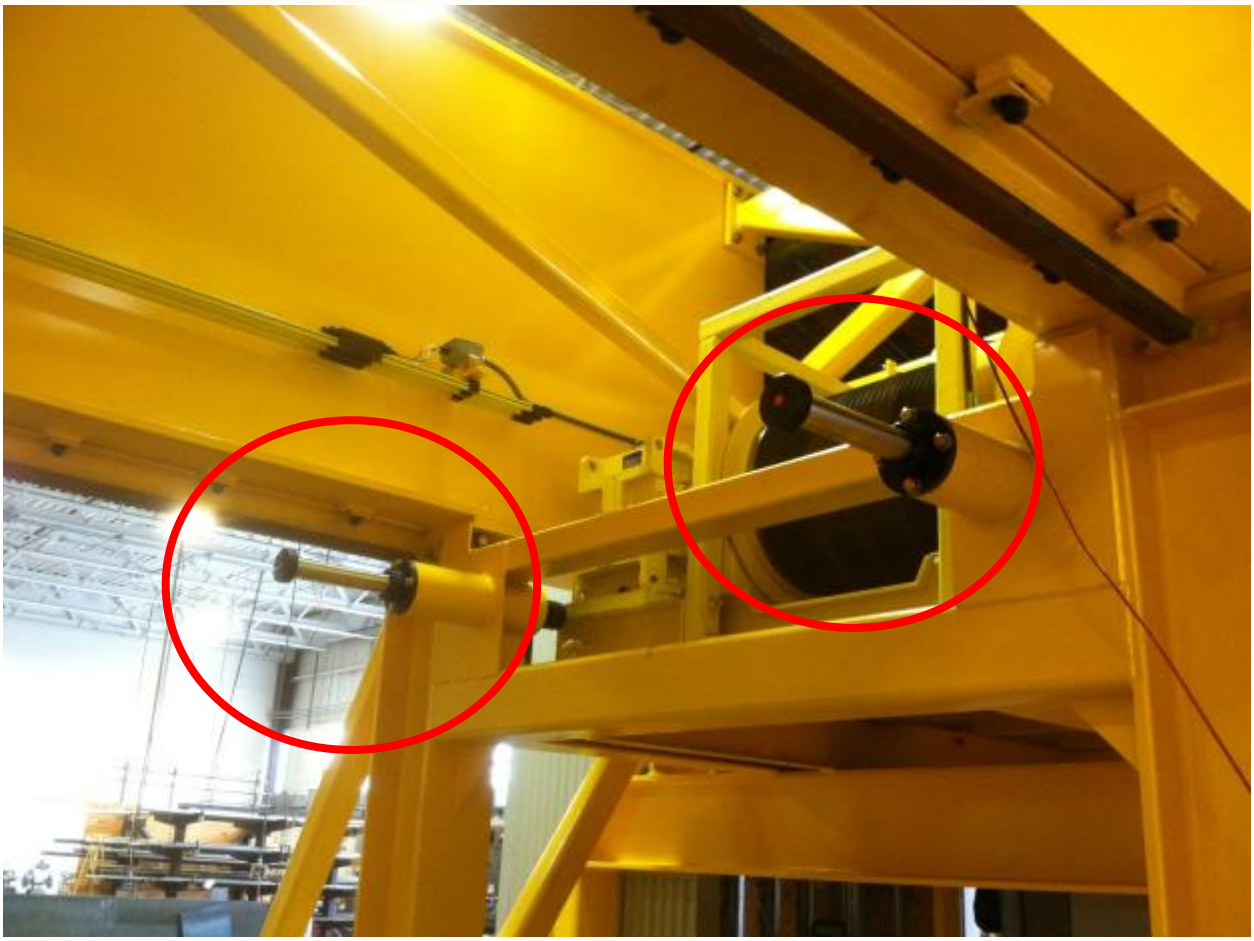

Figure 26: Structure bumpers

2.1.10.2. Carriage Controls

The carriage control box is located on the truck dolly inside the BEAST chamber. It connects wirelessly to the frame PLC. The carriage PLC is used to set and adjust load and tire pressure. It also monitors load, tire pressure, and carriage vibration and reports that data back to main PLC and the control computer. A low load signal reduces maximum speed to 1 MPH.

Vibration sensors are also mounted to the carriage to monitor for bearing failure. If vibration of the carriage exceeds set values, the control system will shut down the carriage to avoid further damage to the system.

2.1.11. Data records

After each completed forward and reverse pass, the following averaged data points are recorded to a file: pass count, carriage speed, deck load, tire pressure, chamber temperature, and sprinkler enable.

A system log will record auto-run start and stop events and any emergency stops.

Video will be available for remote viewing at the control computer.

2.1.12. User interface

The control computer interface is shown in Figure 27 below. Details on the operational aspects of the user interface are described in the Operating Procedures section. In general, all aspect of the operation of the BEAST during testing can be observed, adjusted and implemented from this screen. It also provides a means to assess the progress of the test sequence and monitor the ongoing testing.

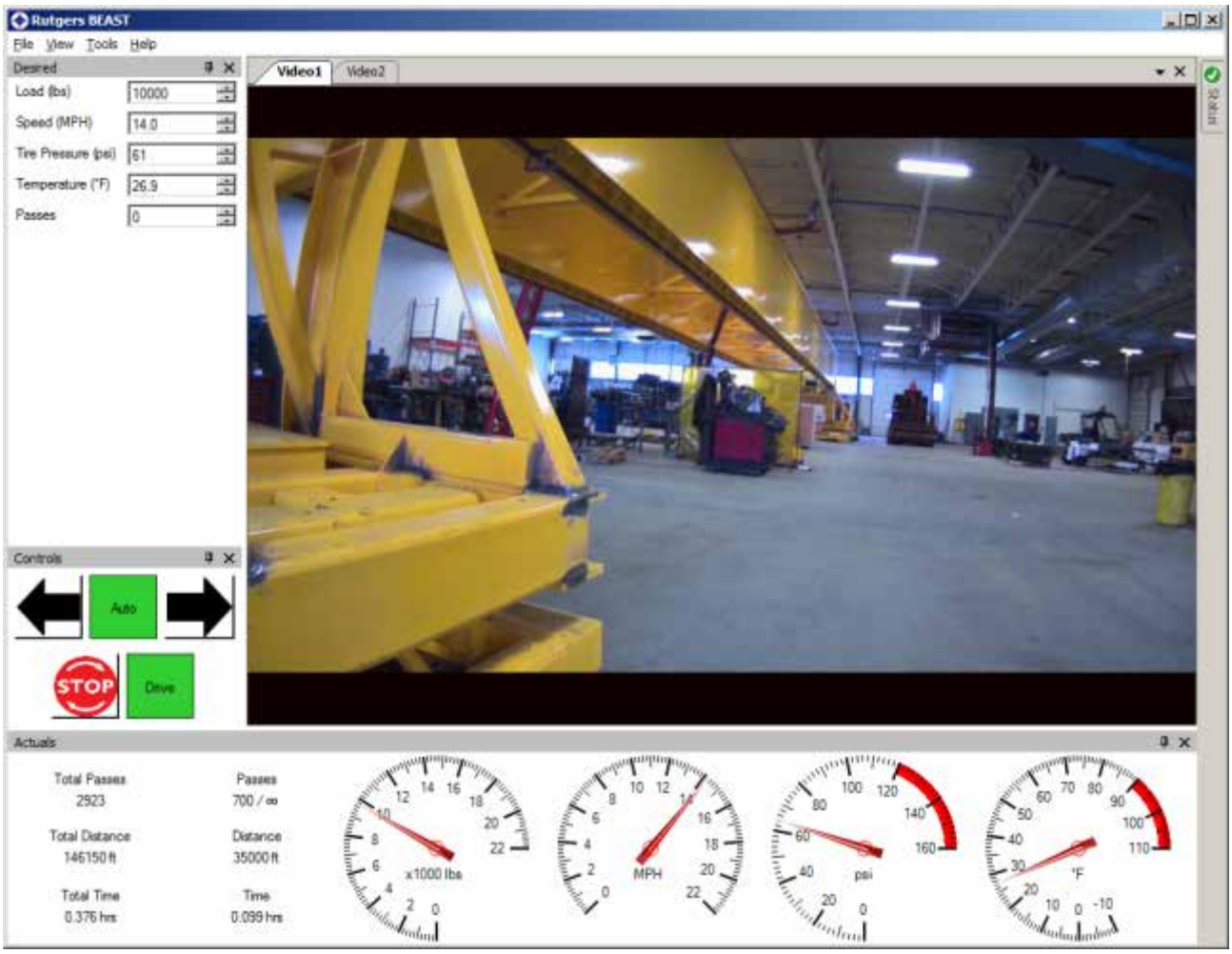

Figure 27. The User Interface.

2.1.13. Structure power system

The structure power system is supplied by a 1000A breaker off of the 13kV-480V transformer MDP. The power system includes a 480V MDP, 240V MDP, and a 480-240V transformer. The 480V panel supplies power for the winch and rail carts.

2.2. Environmental Chamber

The environmental chamber encloses the bridge sample under test in an insulated shell. It also includes all components for environmental testing & safety: evaporators, condensers, 480 & 240 power panels, 480-240 transformer, heaters, door E-stops, push button E-stops, roof trusses, cameras, foam, floor drain, lighting, and portable sump pump. Each of these components are described below in more detail.

2.2.1. Upper Enclosure

The upper portion of the environmental chamber, as shown in Figure 28 is composed of 3 distinct items: the end frame environmental enclosures, the beam mounted insulation, and the roof trusses with the foam mounted to them. These three components form the movable portion of the environmental chamber. The end frame enclosures surround the loading ramps and provide space for the carriage to move off the deck and still be enclosed in the chamber. The beam mounted insulation provides the environmental enclosure between the load ramps and the roof trusses. The roof truss portion of the environmental chamber is designed to allow the BEAST to be located at different spots across the bridge deck and still be environmentally contained. Each roof truss section can be separated from the others and then be relocated to the other side of the BEAST. The lateral adjustment is provided by the beam mounted insulation that reaches out to cover and interface with the roof trusses.

Figure 28. The Upper Environmental Chamber, Beam Mounted Wings (top) and Roof Trusses (bottom).

The roof trusses move on the rails that are attached to the abutments. The roof trusses have two wheels on each side that move along these rails as shown in Figure 28. The roof trusses are sealed by clamping them together with a cam lock system using a hex wrench as shown in Figure 29.

Figure 29: Roof truss track rollers

Figure 30: Roof truss sealing mechanism

WARNING

One person should be on either side of the roof truss while moving the trusses from side to side. Make sure all persons are clear of the chamber before moving the trusses.

2.2.2. Evaporators

The evaporators are a part of the HVAC system that provides cooling for the chamber. This component is mounted in the lower chamber as shown in the figure below.

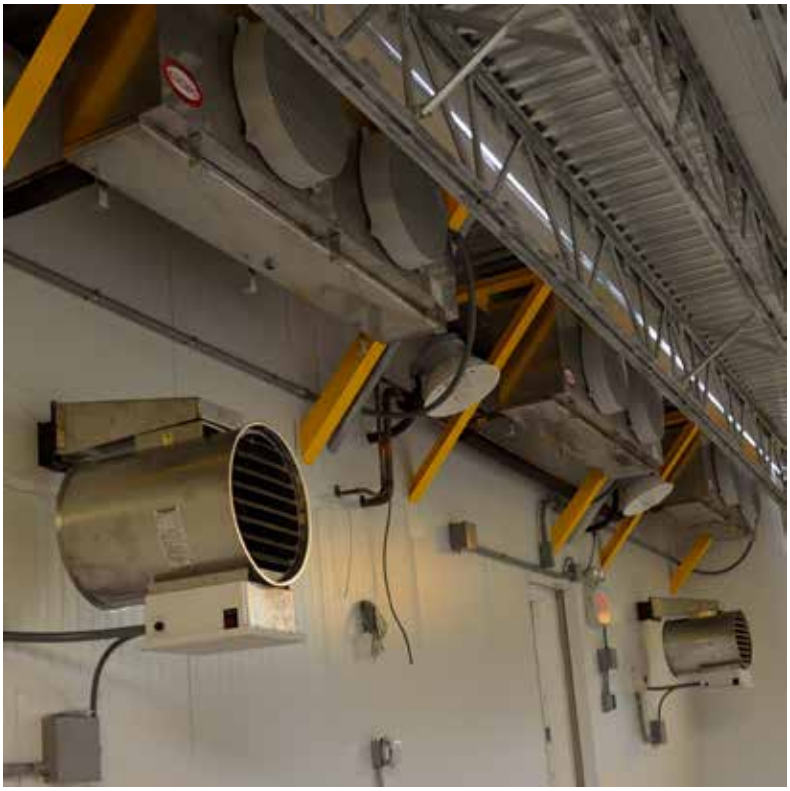

Figure 31. HVAC Evaporators as Mounted in the Lower Environmental Enclosure. Heaters Also Shown.

2.2.3. Condensers

The condensers are part of the HVAC system that removes heat from the chamber. The unit is mounted outside the environmental chamber as shown in Figure 32 between the Main Stair Enclosure and the brine shed.

Figure 32. HVAC Condenser Units

2.2.4. Heaters

Resistance heaters are mounted inside the lower chamber to provide the heating for the chamber. These are shown in Figure 33 below and are also the cylindrical units shown in the lower portion of the picture in Figure 31.

Figure 33. HVAC Heater.

2.2.5. Lower Environmental Chamber

The lower environmental chamber is located in the basin under the bridge sample. The basin has been lined with foam insulation and sealed to prevent air or water leakage. The movable upper chamber interfaces with the lower chamber at the outside of the abutments.

Figure 34. Lower Environmental Chamber Showing Foam Lining.

2.2.6. Floor drain and sump pump

The brine applied to the bridge deck may drip down into this basin and is collected in the floor drain. The sump is used to remove the excess brine from the lower chamber. The used brine is collected in the collection tank in the brine shed.

Figure 34. Sump and Cover.

2.2.7. Chamber power system

The chamber power system is supplied from a 200A breaker off of the 13kV-480V transformer MDP. The power system includes a 480V MDP, 240V MDP, and a 480-240V transformer.

2.2.8. Environmental Chamber Controls

The chamber control box will be located near the entry stairwell. It connects wirelessly to the frame PLC. The chamber PLC communicates with the brine system, temperature system and the chamber emergency stop switches. These chamber E-stop switches include an access door-open and a door-push button to make sure the unit is not running if people enter the pit area. In addition, the brine system and environmental temperature PLC controls interact with the control computer for ease of access and monitoring.

2.3. Brine System Description

The BEAST has the capability to apply a brine solution or water to the bridge deck during testing. The system is composed of several components. The brine mixing tank, shown in Figure 35, the brine distribution system mounted to the carriage (Figure 16), the brine control system and the interconnections between the brine tank and the brine distribution system. The operator can select how often to distribute brine on the bridge deck and the system will automatically provide the brine coverage.

3. Equipment Inspection

3.1. Pre -Operation

1. Cable Tensioning Sheave
    a. Make sure bearing has grease, but do not over grease
    b. Make sure slide has grease
    c. Check for loose bolts on sheave frame
2. Tires
    a. Tread is sufficient for length of test
    b. Air pressure is correct
3. Verify oil at proper level in axle hubs
4. Carriage Load wheels
    a. Check for proper wear
    b. Make sure bearing has grease
5. Return wheels
    a. Check for proper wear
    b. Ensure beam flange is clear of debris
    c. Verify return wheels are ¼ inch above flange while loaded
6. Rail
    a. Make sure it is aligned
    b. Check for abnormal wear
7. Bridge deck
    a. Make sure it is clear of debris
    b. Check end seals for proper placement
8. Rail carts
    a. Wheels aligned with rails
    b. Track is clear of debris
9. Environmental roof sections
    a. Sealed properly
    b. Cam locks secure
10. Cameras
    a. Connected and functional
    b. Pointed at area of interest
11. Cables & connections
    a. Secure in proper position so they don't get crushed during trafficking
    b. Make sure no damage to conductors has taken place
12. Winch bolts
    a. Secure, none loose
    b. Check torque every six months
13. Beam / Endframe bolts
    a. Secure, none loose
    b. Check torque every six months
14. Rail Cart Lift Frame in place
    a. Verify that there is a gap between rail dolly and end frame
15. Winch control cabinet closed and locked
16. Other electronic enclosures closed and locked

17. Load ramp braces in place and tight
18. Inspect winch cable for broken strands or frays
19. Make sure chain binders are tight between load ramps and abutments
20. Wheel lug nuts are tight
21. No leaks on tire pressure system
22. Roller bearings
    a. Bearing vertical against support
    b. Check for signs of abnormal wear
23. Check hoses and fittings for wear and tightness
24. Tires running on center of each load ramp
25. Leveling system lock nuts tight

4. System Operation

This section describes the complete series of activities required to install a new bridge deck and support system, conduct a test sequence, and remove the tested bridge deck and support system. If not all these activities are required, each sub-section can be utilized on its own.

Prior to system operation, be knowledgeable about all key items in this manual and in the Rutgers Health and Safety Plan.

4.1. Move BEAST to Deck Install Position

1. Make sure brine supply line is disconnected
2. Using manual control, move carriage to sheave end loading ramp, until it hits the bumper stop.
3. Reduce load to zero psi.
4. Shut off winch power circuit breaker
5. Loosen clamps and push road side environmental roof sections that are not under the environmental wings toward the road into the storage position.
6. Remove attachment bolts and pins securing the load ramp environmental chambers to the environmental wings
7. Un-Install load ramps off of abutments
   a. Install the Ramp lifting beams on the flanges of the Beasts main beams. Locate these directly above the lifting points on the abutment end of the load ramps.
   b. Remove the abutment end ramp securing hardware (3/4" chain, 7/8 inch shackles and the large binders)
   c. Remove the diagonal bracing pins at the end frame, and rotate brace off of the end frame.
   d. Use the 5/16" chain and the chain pullers to retract the ramps to the point where they will not hit the abutment when the ramp moves sideways. If environmental chambers are going to be switched to the other side of the BEAST for the next test, the ramps must be retracted to the point where the insulating panels do not hit the ramp as they move sideways.
8. Use rail carts to lift Beast and Environmental Chambers attached to the load ramps
9. Keeping Beast in lifted position, use rail carts to move BEAST toward road. The BEAST may be moved over environmental chambers as long as the load ramps have been retracted sufficiently.
10. Lock BEAST in up position using leveling jack screws.
11. Verify all items are clear of the lower environmental chamber and that a deck can be removed / installed.

4.2. Installation of a Bridge Deck and Support Structure

1. If necessary, remove tested bridge deck and support structure from lower environmental chamber.
2. If necessary, remove tested support girders

3. Verify that support structure beam seats are in the correct position and firmly installed
4. Position crane to lift support structure and/or slab from truck
5. If required, use crane to place new steel girders and secure them to beam seats.
6. Move truck with new slab into position
7. Use crane to lift new slab into position
8. Remove truck and crane
9. Hook up bridge deck instrumentation

4.3. Move BEAST into Test Position

1. Determine lateral position of traffic lanes
2. Push appropriate number environmental roof sections back in to position on parking lot side of test pit. Note, if additional roof sections need to be transferred from one side of the BEAST to the other, make sure load ramps are retracted to allow the roof sections to pass by.
3. Retract leveling jack screws and make sure BEAST is lifted sufficiently to move on rails
4. Move BEAST structure laterally into position using rail carts
5. Push remainder of the environmental roof sections back in to position on road side of test pit and secure in position with cam locks between sections.
6. Secure roof chamber sections using rail locks at each end
7. Lower BEAST into position using rail cart controls. Only lower enough to seal insulating wings against the roof trusses.
8. Use leveling screws and carts to level system laterally and end to end with respect to the bridge abutments in all four corners.
9. Re-install ramps
    a. Remove the 5/16” chain and the two chain hoists from the ramps
    b. Use the 5/16” chain and one of the chain hoists between the two ramps to pull them tightly to the abutments.
    c. Re-install the 3/4” chain, 7/8 inch shackles and the large binders to horizontally secure the ramps.
    d. Verify the Telescopic end of the ramps are seated properly on the endframe
    e. Reinstall the diagonal bracing by rotating back into position and inserting pins at the end frame
    f. Before testing, verify that the tires of the carriage are centered on the ramps at all locations.
10. Seat Environmental Chamber and Load Ramp chambers by re-bolting and pining connections
11. Fill brine tank

4.4. BEAST Operation procedure

1. Conduct pre-operation inspection

a. Verify the sheave regulator valve on the nitrogen cylinder is open and the regulator is set to 80 psi
b. Verify the air springs nitrogen cylinder is open and the regulator is set to the appropriate pressure.
c. Verify the turnbuckles are not on the swing arms.
d. Verify the tire pressure is set to the required pressures for testing.
e. Verify the Sheave location is in the operating area of the slide system. If not, the wire rope will need to be tightened
f. Verify load deck free of obstacles
g. Verify end frames are lowered, leveled and secure
h. Verify load ramps are in proper place and secure
i. Verify environmental chamber is in location, sealed and secure
j. Verify Brine tank is full if being used

2. Turn on power in the main MDP
3. Verify HMI is powered up
4. Hit Config on HMI main page as shown below

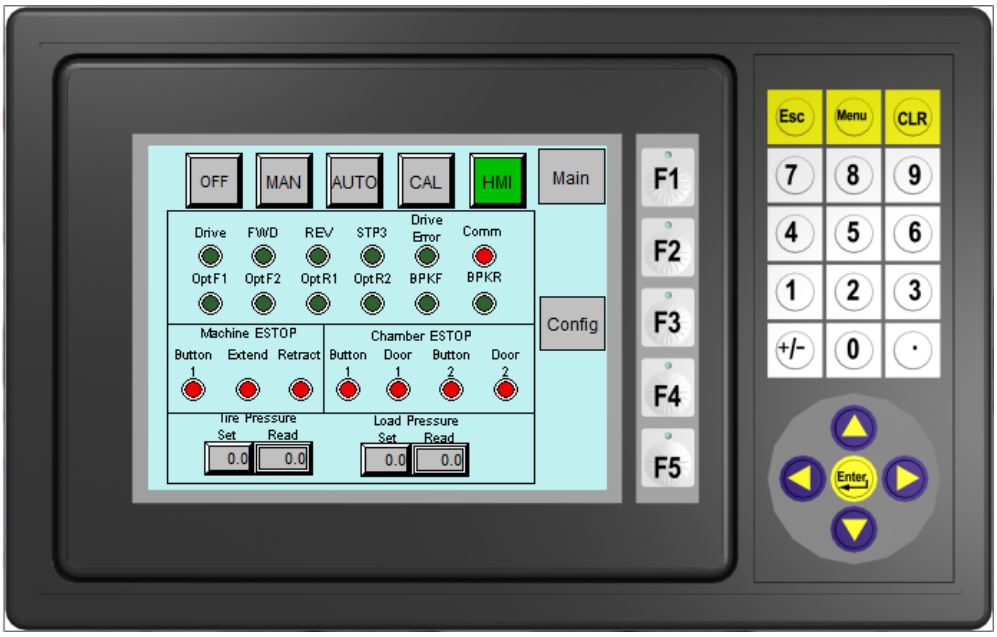

Figure 36. Main Human Machine Interface (HMI) Screen.

5. Enter password, hit enter as shown below

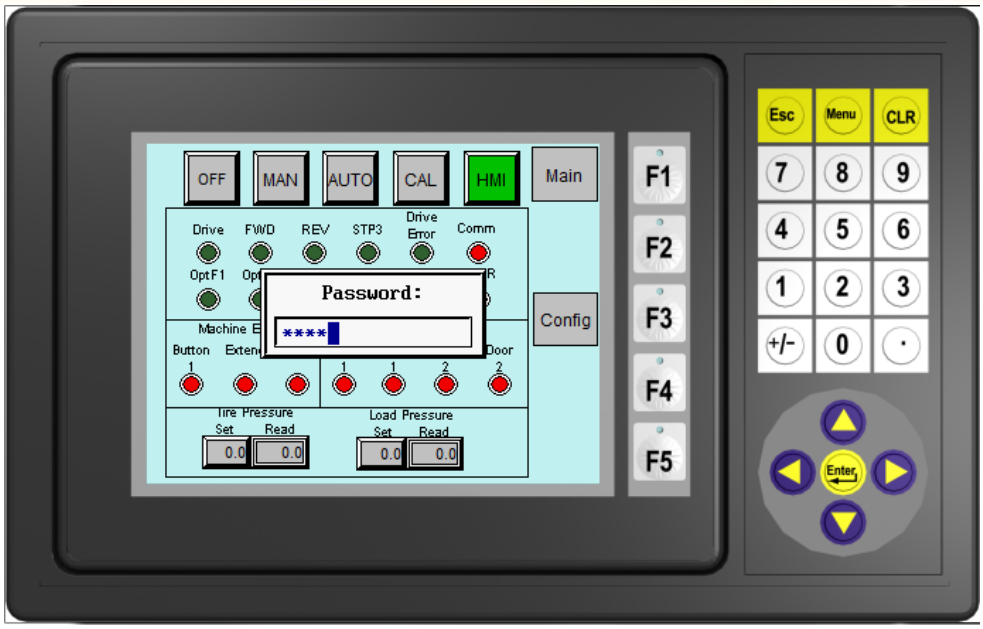

Figure 37. HMI Password Screen.

Screen will change to configuration screen as shown below

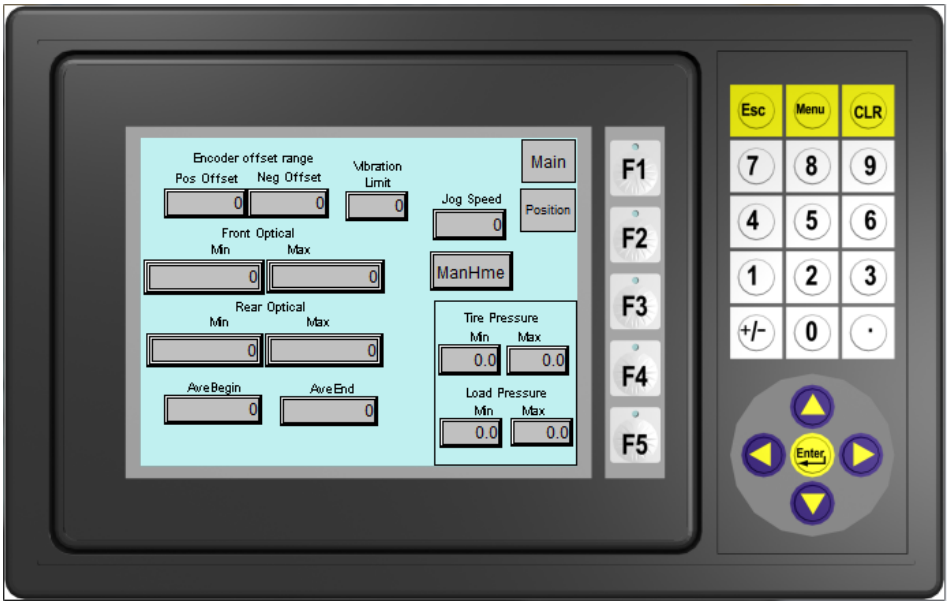

Figure 38. HMI Configuration Screen.

6. Hit Man/Hme and button will turn green and change to Auto/Hme as shown below

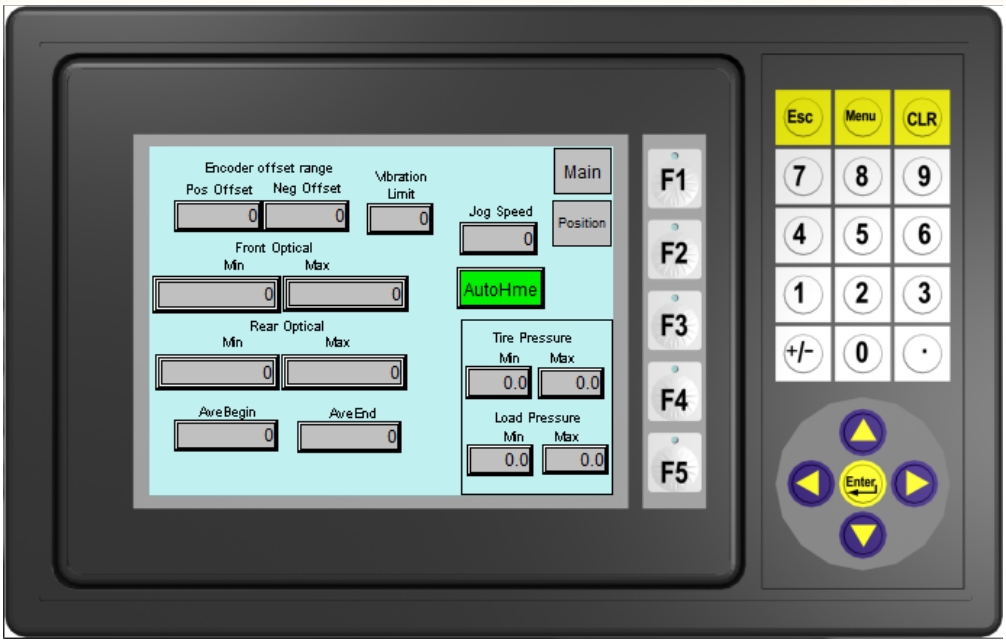

Figure 39. HMI Auto/Home Screen.

7. Hit Main

Screen changes to main screen with HMI button green as shown below

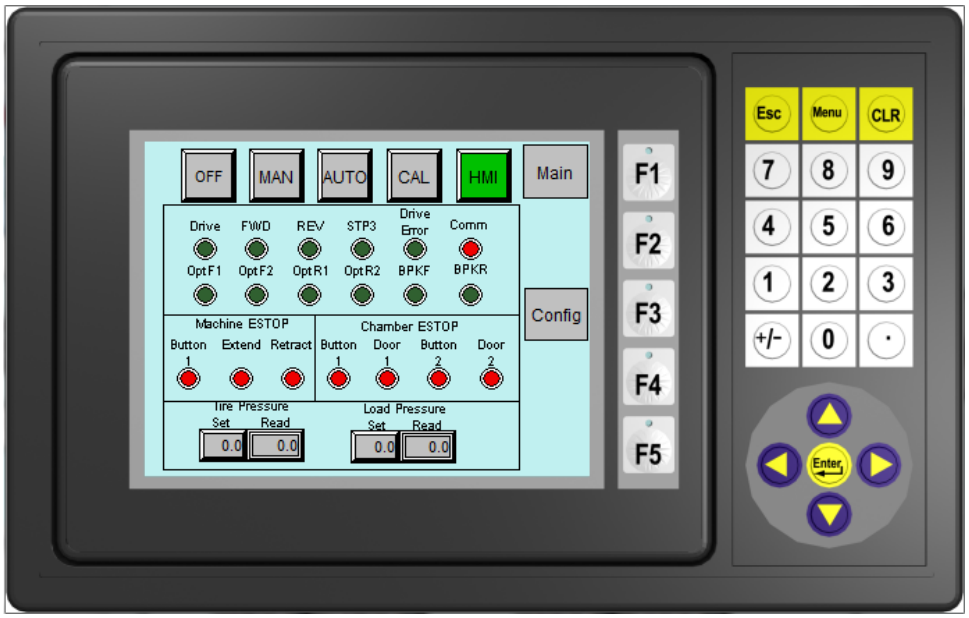

Figure 40. HMI Main Screen.

Verify all lower indicator lights are green, if not, address item causing e-stop. Verify HMI button is green

8. Hit HMI button, should turn red and label changes to PC
9. Launch Rutgers Beast Program from Control Computer
10. Verify both Video Screens are active

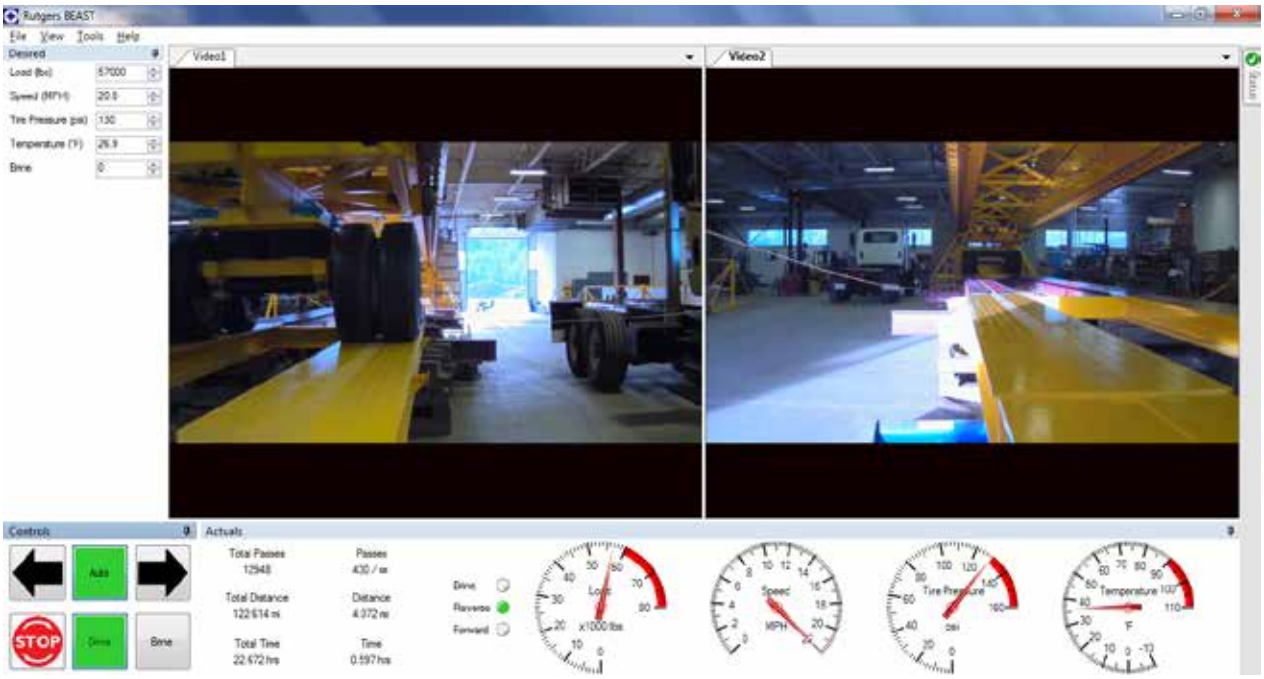

Figure 42. Computer User Interface.

11. Set Parameters on left side of screen
    a. Load
    b. Speed
    c. Tire Pressure 130 psi
    d. Temperature
    e. Brine
12. Hit Drive Button
    a. Verify tire pressure is at set level
    b. Verify axle load is at proper level (at least 20,000 pounds)
13. Open Status window on right side of screen

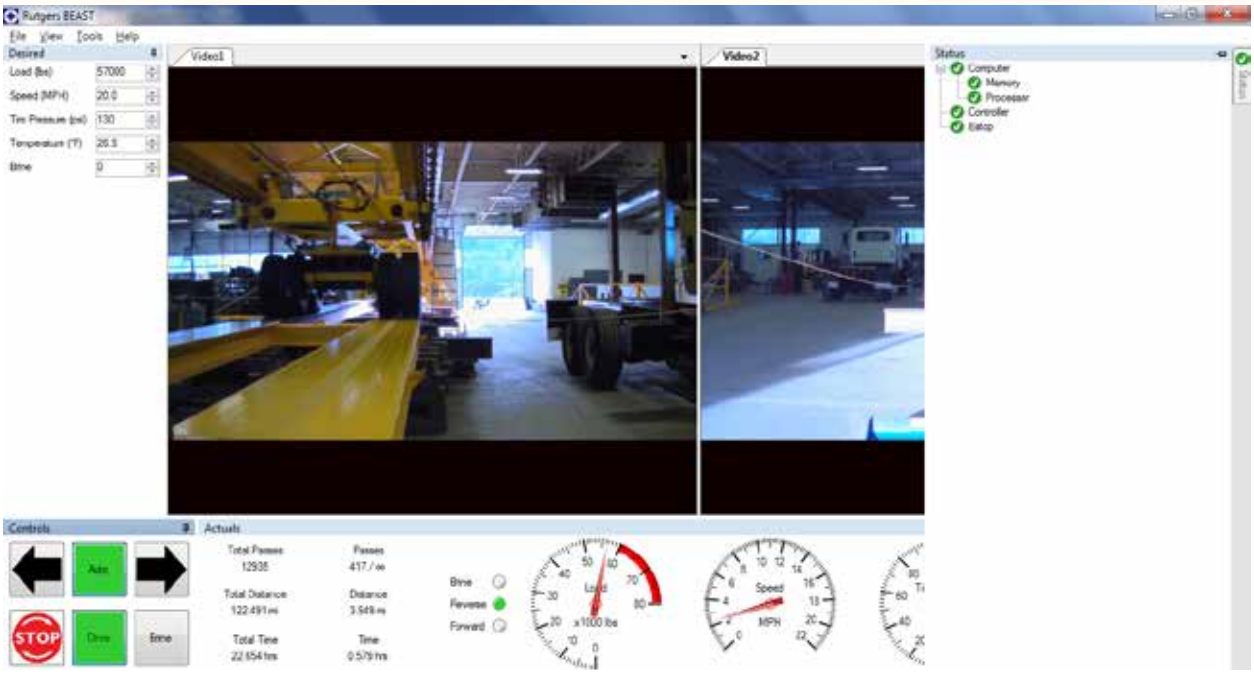

Figure 43. User Interface Showing Status Menu on Right Side of Screen.

a. Verify no errors present
b. Mouse over any errors present to find out more information

14. Hit Auto
    a. Carriage will start to move towards Sheave end and zero encoder count at end switch
    b. Carriage will move to first set of optical switches and read location
    c. Carriage will move to second set of optical switches and read location
    d. Carriage will move to Winch end bumper switch and verify location
    e. Carriage will conduct load for an infinite series of passes

NOTE: If a specific load configuration is desired, the number of passes, load, speed, brine application and tire pressure can be configured in the Test Matrix screen under the Tools tab as shown below.

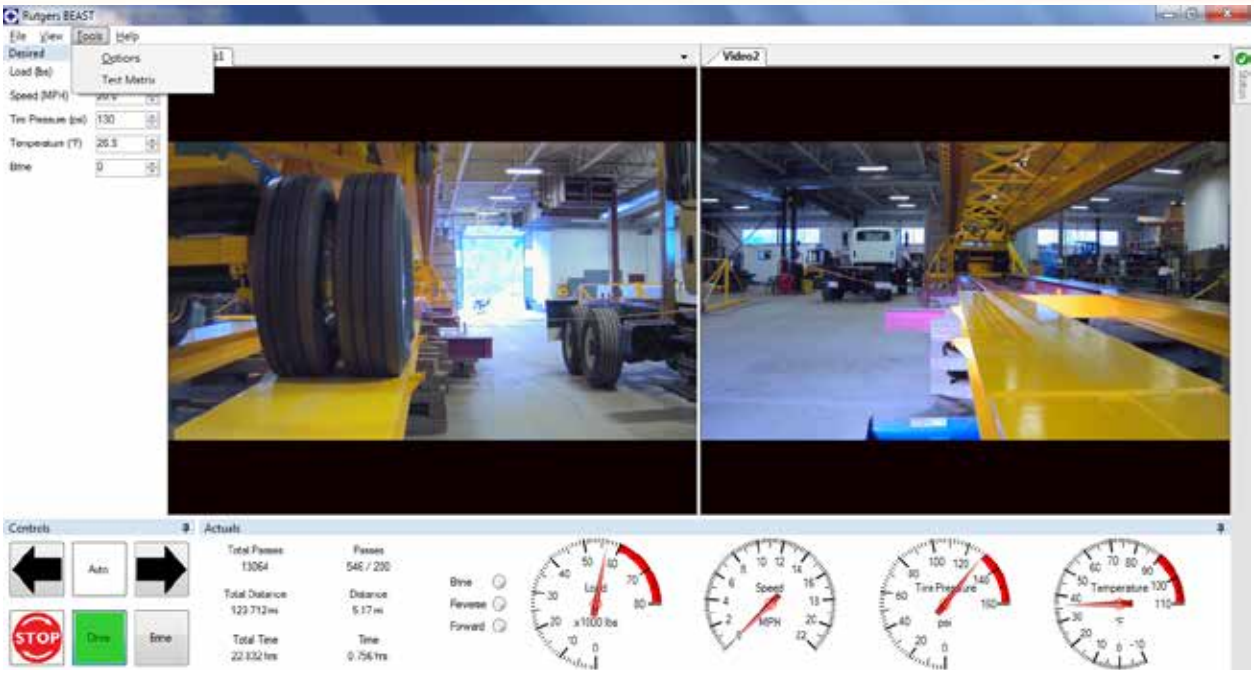

Figure 44. User Interface Showing Tools Menu on Left Side of Screen.

An example test matrix is shown below. Each item can be changed by revising the entry. The total passes setting will override the infinite number of passes identified above and the test will stop at this number of passes.

Test Matrix

File: April09-1.csv Total Passes 200 Total Time 0.0 Use Time

	Pass	Brine	Load (lbs)	Speed (mph)	Tire Pressure (psi)	Temperature (F)
▶	0	0	58000	5	126	26.9
	10	0	58000	6	126	26.9
	20	0	58000	7	126	26.9
	40	0	58000	6	126	26.9
	60	0	58000	6	126	26.9
	90	0	58000	6	126	26.9
*						

Run Save Load New

Figure 45. Example Test Matrix.

15. To stop passes, hit the auto button to revert to manual mode
16. To restart passes, hit Auto button, system will re-run homing procedure and resume passes

NOTE: E-stop switch can be hit at any time, and will shut down power to winch, requiring a repeat of steps from starting computer.

17. Continue testing until end or periodic inspection or maintenance is due. After completion of inspection/maintenance repeat sequence from step 1.

5. Maintenance

5.1. Tires

1. The system is designed to use 305/70R22.5 (Load range L) tires. They should be inflated to 130 psi for testing at maximum load capacity.
2. The tire lug nuts should be tightened to 450-500 ft-lbs
3. The gear lube level in the axles should be checked periodically and topped off if needed with 80W90 gear oil.
4. Alignment of the axles is done with the Bearing adjusting fixtures (**APTM-0714**) . These are uni-directional and care should be taken to make sure the radius on the fixture matches the radius of the axle or pivot axle.
5. Refer to the drawing package and section 5.13 for the torque specs for the axle alignment and mounting hardware .
6. Make sure that the locking screws are tightened on the axle mounting blocks when alignment is complete.
7. Alignment should be checked monthly or when mis-alignment is suspected to verify proper alignment
    a. Use axle alignment fixture (provided) as shown in Figure 46. Note that there are two fixtures to align both sides of one axle at the same time.

Figure 46. Axle Alignment Fixture in Place on One Side of Carriage.

    b. Note that the ends of the alignment fixtures are not symmetrical as the axle and the pivot pin are two different sizes. Therefore it is extremely important to make sure it is oriented properly and verified with a tape measure. If used wrong the axle alignment will be off.

5.2. Winch (motor, drum, fans)

1. Refer to the winch OEM manual: (1) 2.5 Tons – 5,400 lbs. Push/Pull VIRGINIA CRANE® Custom Winch; FMH Serial Number: VC14-2035; Tag: VT-36944 for detailed maintenance procedures.
2. Lubricate winch cable
    a. Wire rope lubricant: CRC- Chain and Wire Rope Lubricant or Jet-Lube WRL in aerosol cans

5.3. Cable Replacement

1. Generally, both wire ropes will be replaced at the same time. In this case, both cables should be removed prior to installing either new one. The long cable is then installed with as much tension as can be applied by hand, and then the short cable is tensioned with a suitable pulling device. If there is a requirement to change just one cable, it should be tensioned with a suitable device before tightening the cable clamps.
    a. Unload the cable tension cylinder by reducing the set pressure on the sheave cylinder pressure regulator. During the below process, the cylinder must be able to extend all the way.
    b. Remove all old cable from the carriage and the winch. With the power off to the winch, it should be able to free spool.
    c. Position carriage close to the winch end. The carriage can be moved manually with 2 or 3 people.
    d. Use a pipe thru the long cable spool to aid in not uncoiling cable without twisting.
    e. Place cable spool mid machine and pull the cable over the top of carriage to the winch drum.
    f. Wrap the cable over the drum so that the cable comes off the TOP of the drum.
    g. Clamp the long cable to the drum using the provided clamps on the motor side of the drum.
    h. Using electrical power, slowly rotate the winch to wrap the cable. Fill almost the entire drum.
    i. Pull the remaining cable off the wooden spool by hand, avoiding twisting and getting it dirty. Wrap the free end around the sheave and pull back toward the carriage
    j. Place the short cable wooden spool between the carriage and the winch. Use the pipe thru the spool to aid in unspooling.
    k. This cable will be threaded under the drum, but first the drum must be rotated to the proper location. This is the point where you can wrap the short cable around the drum and clamp it so there is only a half a wrap open on the drum between the long and short cables
    l. Clamp the short cable to the drum using the provided clamps.
    m. Start to rotate the drum so the short cable fills it. Manually keep tension on the long cable and avoid getting it dirty or twisted. Stop the drum when the lower cable coming off the drum can be attached to the carriage and be very perpendicular to the drum axis. **This is very important!!**
    n. Pull the remaining short cable off the wooden spool and remove the spool. Move the carriage to the point where it is about 1 foot from the winch end kill switch. Verify again that the short cable exiting the drum will be perpendicular when attached to the carriage. **This is very important!!**
    o. Thread the short cable around the thimble on the carriage and attach wire Rope clips as per manufacturers specs. With ¾ inch cable, the dead cable should be 18 inches long and have 4 clamps. Nuts torqued to 130 ft-lbs each.
    p. Seize the ends of all wire ropes to prevent unraveling before cutting. For information on this process see link http://www.assemblyspecialty.com/guide-to-wire-rope/handling-and-installation/seizing-wire-rope/
    q. Cut the excess cable to allow only three inches of free cable beyond the clamps
    r. Next thread the long cable thru the thimble at the other end of the carriage
    s. Pull the cable tight using a suitable tensioning device.

t. Attach wire Rope clips as per manufacturer's specs. With ¾ inch cable, the dead cable should be 18 inches long and have 4 clamps. Nuts torqued to 130 ft-lbs each.
u. Seize the ends of all wire ropes to prevent unraveling before cutting
v. Cut the excess cable to allow only three inches of free cable beyond the clamps

5.4. Rail cart – See Rail cart manual

1. Refer to the rail cart OEM manual for proper maintenance.

5.5. Sheave

1. Clean dirt/debris off sheave slide monthly and re-grease
2. Check torque of sheave frame bolts
3. Grease for sheave and rail wheel bearings: Use NLGI #2 lithium complex grease
4. Sheave bearings - Every four months add about 1 to 1-1/2 ounce of grease. (for best results apply while sheave is turning or as above)

5.6. Load wheels

1. Rail wheels should be greased monthly. Rail Wheels bearings - Every two months add about 1 to 1-1/2 ounce of grease. (If possible, apply half, run machine for few minutes or turn wheels, apply second half)
2. Use NLGI #2 lithium complex grease
3. Check torque on axle supports
4. Verify axles in proper position with fixture quarterly.

5.7. Roller bearings

1. Properly torqued
2. Bearing housing vertical against support
3. Check for signs of abnormal wear
4. If rollers are adjusted or need to be replaced, refer to drawing SYS-0053 to see size and placement of original alignment shims.

5.8. Return wheels

1. Check torque on axle supports
2. Verify axle in proper position (1/4 inch vertical clearance) quarterly.

5.9. Carriage Maintenance

1. If no load is applied to the axles, turnbuckles to hold up the swingarms must be installed. This is **very important when lifting the carriage**. See picture below. The turnbuckles are used to avoid pulling on the air springs with the weight of the axles and swingarms.

Figure 47. Turnbuckle Supporting Axle and Swingarm.

5.10. Overhead Door – see OEM manual

5.11. Verify Load ramp braces lock nuts are tight weekly

5.12. Remove dirt and debris from slides on load ramps and re-grease each move

5.13. Check bolt torque on items listed below.

1. Rail Clips 190 ft-lbs , Loctite 262, Every six months
2. Frame cross braces 350 ft-lbs, Loctite 277 Every six months
3. Frame to end frame 600 ft-lbs Loctite 277 Every six months
4. Track Rollers 300 ft-lbs, no Loctite Every six months
5. Truck wheel Lug nuts 450 ft-lbs, no Loctite Every six months
6. Axle saddle bolts 300 ft-lbs, Loctite 277 Quarterly
7. Axle pinch bolts 200 ft-lbs, loctite277 Quarterly
8. Rail Wheel bolts 400 ft-lbs, Loctite 277 Every six months
9. Sheave frame bolts 275 ft-lbs Quarterly
10. Tire lug nuts 450-500 ft-lbs Monthly

WARNING – Disconnect Power Before Work on Bus Bar items 5.13 through 5.15

5.14. Verify bus bar bolts are tight quarterly

5.15. Bus bar alignment quarterly

5.16. Check Bus bar wear shoes monthly

1. See Bus Bar Manual (Conductix)

5.17. Bumper kill switch bolts tighten quarterly

5.18. Optical switch mounts tighten quarterly

5.19. Conduit mounts tighten quarterly

5.20. Check for loose foam panels on end frame enclosures weekly

5.21. Verify end frame foam enclosures are bolted tightly to wings and load ramps weekly

5.22. Log tank pressure on both nitrogen tanks weekly (carriage and sheave end) and replace when below 400 psi

5.23. Frame Structure

1. Washing
    a. Frame and Environmental chamber can be pressure washed as needed to maintain appearance
    b. End frames should be swept clean of dust and debris after each time opening the overhead doors
2. Touch Up Painting
    a. Scuff up area to be repainted with plastic scouting pad
    b. Clean wax and grease off of area using standard auto wax and grease remover
    c. Apply one coat of Americoat 399 Epoxy Primer to all cut edges and welds
    d. Apply two coats of PPG PSX 700 Signal Yellow #8557 Per Manufacturer Specifications
3. Life Expectancy of components
    a. Structure should last the life of the unit with proper maintenance
    b. Environmental enclosure should last over ten years
    c. Bearings are designed for over 35,000 hours of life under normal loads with proper maintenance
    d. Copper shoe terminals connecting to bus bar – 35,000 hours of life under normal loads with proper maintenance

6. Troubleshooting

6.1. System will not turn on

1. Check for power
    a. Main transformer is not shut off
    b. Beast MDP breakers are in the on position
    c. Check for tripped breakers in the subpanels
2. Check for E-stop conditions
    a. Brine Empty:
        i. This indicates that the brine tank is empty. Refill brine tank.
    b. Brine Full
        i. This indicates that the brine tank is full. To maximize brine passes, brine tank should be full.
    c. Bumper Kill Front Maximum
        i. Carriage traveled past bumper kill switch. Check bumper kill switch and repair if necessary.
    d. Bumper Kill Front Minimum
        i. Carriage traveled past bumper kill switch. Check bumper kill switch and repair if necessary.
    e. Calibration
        i. Calibration procedure failed. Check winch encoder, optical switches and bumper kill switches.
    f. Door1 Chamber
        i. Chamber door is open. Check chamber door and chamber door switch.
    g. Door2 Chamber
        i. Chamber door is open. Check chamber door and chamber door switch.
    h. Ethernet IO
        i. Ethernet cable is unplugged. Check main control panel, chamber control panel and carriage control panel to ensure all Ethernet cables are connected and not damaged.
    i. Extend
        i. Tension cylinder reached extend limit. Check winch cable to make sure there is no damage. Check tension cylinder pressure. If cable and cylinder are in working order, adjust extend limit switch 1".
    j. Front Encoder Too High
        i. Carriage traveled past front optical switch without triggering. Check optical switch.
    k. Front Encoder Too Low
        i. Carriage traveled past front optical switch without triggering. Check optical switch.
    l. Overwrap

i. Winch cable hit the overwrap limit switch. Check winch cable and look for slipping on the drum.

m. Panel Push Button Control
   i. Control panel Estop push button is pressed. Reset control panel push button.

n. Push Button 1 Chamber
   i. Chamber Estop push button is pressed. Reset chamber push button.

o. Push Button 2 Chamber
   i. Chamber Estop push button is pressed. Reset chamber push button.

p. Pressure
   i. Carriage load pressure is too high. Check load servo valve and air lines.

q. Rear Encoder Too High
   i. Carriage traveled past rear optical switch without triggering. Check optical switch.

r. Rear Encoder Too Low
   i. Carriage traveled past rear optical switch without triggering. Check optical switch.

s. Retract
   i. Tension cylinder retracted and hit limit switch. Check tension cylinder pressure.

t. Tensioner
   i. Retract or Extend limit switch tripped. Check winch cable to make sure there is no damage. Check tension cylinder pressure. If cable and cylinder are in working order, adjust extend limit switch 1".

u. Too Fast for Optical Position
   i. Desired speed is too high for optical switch locations. Move optical switches or reduce desired speed.

v. Vector Drive

   Winch drive error. Check drive keypad for error, and refer to manual.

w. Vibration
   i. Carriage vibration is too high. Check bearings on load wheels, return wheels, and guide rollers. Check carriage alignment. Check tires and wheels. Make sure all bolts are properly torqued.

6.2. System making unusual noise

1. Locate Source
   a. Check bearings
      i. load wheels
      ii. return wheels
      iii. sheave bearings
   b. Check swing arm alignment
   c. Check if wire rope rubbing
   d. Check winch components
2. Resolve Issue

a. If bearings, lubricate or replace as necessary
b. If swing arm is out of line, re-align using fixtures
c. If wire rope is rubbing, determine cause and remedy
d. Refer to winch manual to troubleshoot winch components

6.3. Tires not loading concrete

1. Make sure turnbuckles were not left in place
2. Make sure machine is fully seated on end-frames
3. Make sure machine is properly leveled

7. Schematics

7.1. Electrical

Provided in separate binder

7.2. Mechanical Drawings

Provided in separate binder

8. Specification

Specification	Value
Chassis Style	Bridge style
Test Bed Elevation	Up to 60 inches above floor
Length at Speed (ft)	50 ft
Total Travel (ft)	50 ft plus deceleration travel plus axle spacing
Overall Length (ft)	128 feet
Overall Weight (lb)	180,000 lb*
Carriage Weight (lb)	10,000 *
Max Normal Load (lb) Normal	60,000
Min Normal Load (lb) Normal	12,000
Load Stability (% target)	+/-5%
Load Accuracy (% fso)	+/-5%
Trafficking Speed (mph)	up to 20
Loaded Return Speed (mph)	Same as trafficking speed
Unloaded Return Speed (mph)	1 mph (used only when moving BEAST)
Primary Drive System	Electric winch
Drive System Power (hp)	400 HP or less
Axle Size	Two Full 30,000 lb capacity each
Tires	4 pairs of Dual
Computer Controlled	Yes
Variable start/stop position	Yes

Computer Test Matrix	Yes
Computer Fault Monitoring	Yes
Tire Pressure Monitoring	Yes
Tire Pressure Control	Yes
Environmental Control	Yes
Load Method	Pneumatic
Wander Method	None
Bridge Deck Size Capability	1- 28ft x 50ft x 1ft Bridge Deck
Portability	With Electric Rail Carts
Skewed Slab Capability	Per structure constructed at Rutgers
Lateral Test Position	Variable between edges of bridge deck
Bi-directional Loading	Yes
Unidirectional Loading	No
Electrical Power	3 Phase 480 Volt
Warranty/Phone Support/Service Agreement	2 Years from completion of training

9. Reference Documents

The following documents are provided in other binders. The winch manual is contained in its own binder. The others are all included in another binder.

9.1. Winch Manual – Virginia Crane 2.5 Tons – 5,400 lbs. Push/Pull Virginia Crane Custom Winch

9.2. Air Gas Regulator Manual

9.3. Reznor EWHB Unit Heaters Owner's Manual

9.4. HaloGuard II Multi-gas Multi-Sensor Monitor Instruction Manual

9.5. Overhead Door Installation Instructions

9.6. Conductix Wampfler Conductor Bar Manual Series 812

9.7. Trenton Condensing Unit Installation and Maintenance Instructions

9.8. Trenton Evaporators Product Data and Installation Manual

9.9. Emerson Climate Technologies Compressor Application Engineering Bulletin

9.10. Vibration Monitor Calibration Sheets

Applied Research Associates, Inc.

Warranty and Limitation of Remedy and Liability

Applied Research Associates, Inc. (ARA) warrants this equipment to conform to the contract specifications and to be free from manufacturing defects for a period of one year from completion of training.

This warranty is limited to the original purchaser of the equipment.

ARA reserves the right to inspect the equipment prior to any decisions involving a warranty claim.

ARA may either repair the item, provide a serviceable replacement unit, or refund the purchase price at its sole option. In no case shall ARA grant a remedy that either exceeds the purchase price of the product or the cost to ARA of the component or part. These are the only remedies available to the Buyer under this warranty.

ARA also reserves the right to make warranted repairs or replacements either at the site or at ARA's factory. If repair at ARA's factory is the decision, the Buyer is responsible for shipping the item, up to 100 lbs. to the factory at the Buyer's expense.

All claims for failure to conform to specifications or defect in material or workmanship under this warranty must be made promptly after discovery and, in any event, must be received by ARA within one year after delivery of the item. Defective items must be held for inspection by ARA or its authorized distributor and, if requested, returned to ARA, transportation prepaid by the Buyer.

The Buyer is responsible for performing regular maintenance services as specified in the operator's manual applicable to the equipment. Failure to do so shall void this warranty.

ARA's obligation under the warranty shall not apply to:

- Any equipment which has been damaged by negligence, misuse, abuse, neglect, improper adjustment, accident, improper application, over-speeding or modification with parts not manufactured or approved by ARA.
- Any equipment that has been repaired or altered without authorization from ARA or in a manner inconsistent with such authorization.
- Any equipment that has not been maintained in accordance with the operator's manual.
- Normal wear on any item or piece of equipment.
- Lost items.
- Loss of operating time to the Buyer while the equipment is out of operation.

Equipment items or components not manufactured by ARA are only warranted insofar as warranted by the manufacturer of such parts. ARA will act as the warranty manager for these components for the duration of the warranty period.

ARA reserves the right to make design changes without incurring any obligation to make such changes to previously manufactured equipment.

The foregoing is Seller's only obligation and Buyer's exclusive remedy for breach of warranty. Buyer's failure to submit a claim as provided above shall specifically waive all claims for damages or other relief, including but not limited to claims based on latent defects. In no event shall Buyer be entitled to special, incidental, indirect or consequential damages for injury, loss of business profits, business interruption, loss of business information, or any other pecuniary loss arising out of the use of or inability to use the equipment. In any case, ARA's entire liability shall be limited to the amount Buyer actually paid for the item.

Except as modified in writing signed by both parties, this warranty is and shall remain the complete and exclusive agreement between the parties with respect to warranties, superseding all prior agreements, oral or written, and all other communications between the parties relating to the subject matter of this agreement.

11. Appendix

11.1. Appendix A – MSDS Information

Sheave Oil

http://www.bioblend.com/templates/rt_panacea/pdf/biodegradable_msds/BiofloAWS46_msds.pdf

Yellow Paint

https://buyat.ppg.com/EHSDocumentManagerPublic/pdf_main.aspx?StreamId=54105e694c3f32810000&id=54105e694c4032fe0001

Gray Primer

https://buyat.ppg.com/EHSDocumentManagerPublic/pdf_main.aspx?StreamId=556e5030dd301b6a0000&id=556e5031dd311f500001