LABORATORY DREDGE CARRIAGE FOR MODELING DREDGE OPERATIONS

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ABSTRACT

The Haynes Coastal Engineering Laboratory was dedicated in June 2003 on the campus of Texas A&M University in College Station, Texas. The 2,045 m^2 (22,000 ft^2) laboratory houses a 36.6 m long, 22.9 m wide, and 1.22 m deep (120 ft long, 75 ft wide, and 4 ft deep) wave basin with a multidirectional wave maker and a 45.6 m long, 3.7 m wide, and 3 m deep (149.5 ft long, 12 ft wide, by 10 ft deep) dredge/tow flume that has an additional 1.5 m by 7.6 m long (5 ft deep by 24.8 ft long) sediment pit. Four water pumps provide the capability of pumping a total of 2,233 L/s (35,000 GPM) through the flume facilities. The objective is to describe the capabilities and possible uses of the new dredge/tow carriage that is mounted on rails above the dredge/tow flume. The dredge carriage was constructed in Houston, Texas and installed in the laboratory in April 2005. The dredge carriage has a maximum horizontal speed along the flume length of 2 m/s (6.6 ft/s). A 10 cm (4 in) suction by 7.6 cm (3 in) discharge dredge pump is mounted on the carriage, and a moveable upper vertical and lower articulating ladder has a 30 cm (12 in) cutter for dredging sediment from the sediment pit. Other size cutters or hopper dragheads can also be attached to the suction inlet to model performance. The dredged sediment is pumped to a 22.9 m^3 (30 yd^3) hopper in front of the carriage. The hopper is used to monitor the amount of sediment dredged and to place it back into the sediment pit. Wireless technology is used to control the carriage operations and a data acquisition system is used to collect the data. Instrumentation on the carriage monitors cutter torque, forces on the ladder, location of the carriage and ladder, slurry flowrate and density, suction and discharge pressure, and pump rotation speed. Use of the model dredge system for studying slurry inlet flow conditions, cutter forces, sediment resuspension, and hopper draghead performance are described.

Keywords: Dredge carriage, dredge laboratory modeling, cutter performance, draghead modeling, and sediment resuspension modeling.

INTRODUCTION

The Ocean Engineering Program at Texas A&M University received a grant from the National Science Foundation in 1995 that provided partial support for a new Coastal Engineering Laboratory. With additional funding from the Texas Engineering Experiment Station and private donors, the laboratory construction began in August 2001 and the new laboratory was dedicated in June 2003. Funding for a directional wave maker was obtained through another National Science Foundation grant and a private donation from Reta and Bill Haynes and the laboratory was named the Reta and Bill Haynes'46 Coastal Engineering Laboratory in 2003. In September 2003, the Barrett G. Hindes Foundation established the Barrett G. Hindes Dredging Engineering Education Fund, and these funds were dedicated to the construction of the a dredge/tow carriage for the dredge/tow flume.

Randall, Edge and Cox (1998) described the initial laboratory needs for dredging research. Subsequently, Glover (2002) and Glover and Randall (2004) described the conceptual design of a dredge/tow carriage for the new dredge/tow flume in the Haynes Coastal Engineering Laboratory. Cavnar (2004) describes the conceptual design of the hopper for the dredge/tow carriage. In January 2004, Mr. Kevin Williams, President of Oilfield Electric Marine (OEM), Inc and Mr. Peter deJong, President of Digital Automation and Control Systems, Inc. (DACS) agreed to

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complete the final design, construct and install the dredge/tow carriage. Mr. Steve Sonye of DACS and Mr. Nick Krippner with OEM assisted with the electrical, control and data acquisition systems. The carriage was delivered and installed in the laboratory in April 2005. The objective of this paper is to describe the new dredge carriage facility, its capabilities, and proposed uses.

LABORATORY FACILITY

The Haynes Coastal Engineering Laboratory

The Haynes Coastal Engineering Laboratory (Figure 1) at Texas A&M University College Station is equipped with a shallow water wave basin and a dredge/tow flume. The dredge/tow flume can be used for testing of model cutterheads, suction heads, dragheads, modeling of open water disposal, and disposal site monitoring. The dredge/tow flume can also be used for testing of offshore facilities and scour around coastal structures. The wave basin can be used for testing coastal facilities and shallow water mooring systems. Both flume facilities are equipped to pump 2,233 L/s (35,000 GPM) of water through either of the flumes. A multidirectional random wave maker is installed in the wave basin to generate model wave conditions for shallow water coastal applications.

Building Exterior **Wave Basin** **Dredge/Tow Flume**

Figure 1. Haynes Coastal Engineering Laboratory located in the Research Park at Texas A&M University in College Station, Texas.

Dredge/Tow Flume

The dredge/tow flume is 45.6 m (149.5 ft) long with a maximum water depth of 3.05 m (10 ft) and a width of 3.66 m (12 ft). At one end of the flume is a 7.56 m (24.8 ft) long by 1.52 m (5 ft) deep sediment pit. Figure 2 shows the general dimensions and flume layout. The flume walls rise 30.5 cm (1 ft) above the maximum water line and are 91 cm (3 ft) above the laboratory floor. Steel rails are installed on the top of the flume walls for the dredge/tow carriage. The sediment pit can be covered during model towing operations, and it can be uncovered using the overhead crane to lift the cover plates for dredging operations. In the flume wall directly above the sediment pit there are several viewing and instrument windows. The windows are particularly useful in flow visualization studies around the cutter or suction head, or to simply monitor testing operations. Four axial flow pumps driven by variable speed motors are capable of producing a maximum flow rate of 2,233 L/s (35,000 GPM) through the flume, and adjustable height weirs are located at the end of the flume to control flow and water level.

Dredge/Tow Carriage

The model dredge consists of a carriage, ladder, and cradle as illustrated in the assembly drawing shown in Figure 4. The cradle is used to move the ladder side-to-side in the flume to simulate the swinging motion of a cutterhead dredge. The cradle can be removed from the carriage using the 2721 kg (3 ton) overhead crane and placed in the work area adjacent to the flume. The model dredge carriage incorporates an upper vertical ladder that provides vertical translation of the model dredge ladder. The articulating ladder at the bottom of the vertical ladder allows an adjustable angle between 0 and 50 degrees with the horizontal. The model cutterhead can be attached at the end of the articulating ladder and the suction inlet is located directly behind the cutter. Table 1 lists the characteristics for the dredge/tow carriage and Figure 4 shows the dredge/tow carriage with the model dredge atop the flume and the articulating ladder in the sediment pit of the dredge/tow flume. To ensure that the carriage remains centered over the flume and is not derailed by strong lateral forces during a dredging operation, the carriage has guide wheels contacting the inner and outer surface of the starboard rail.

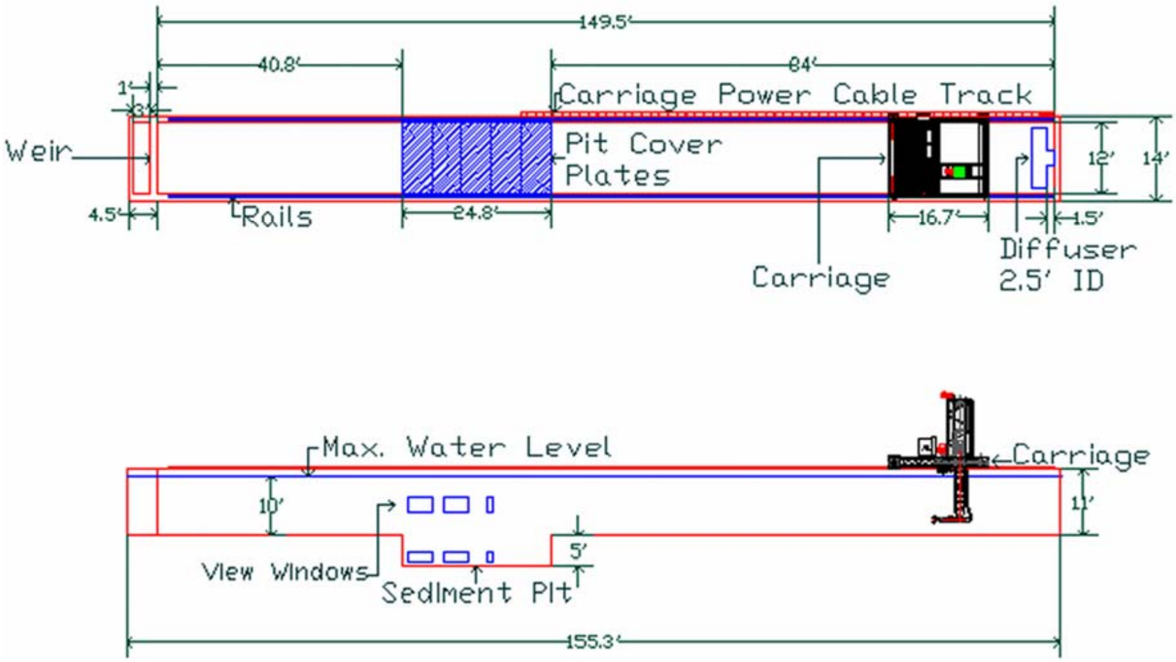

Figure 2. Plan and side view of the dredge/tow flume (dimensions in ft, divide by 3.28 for m).

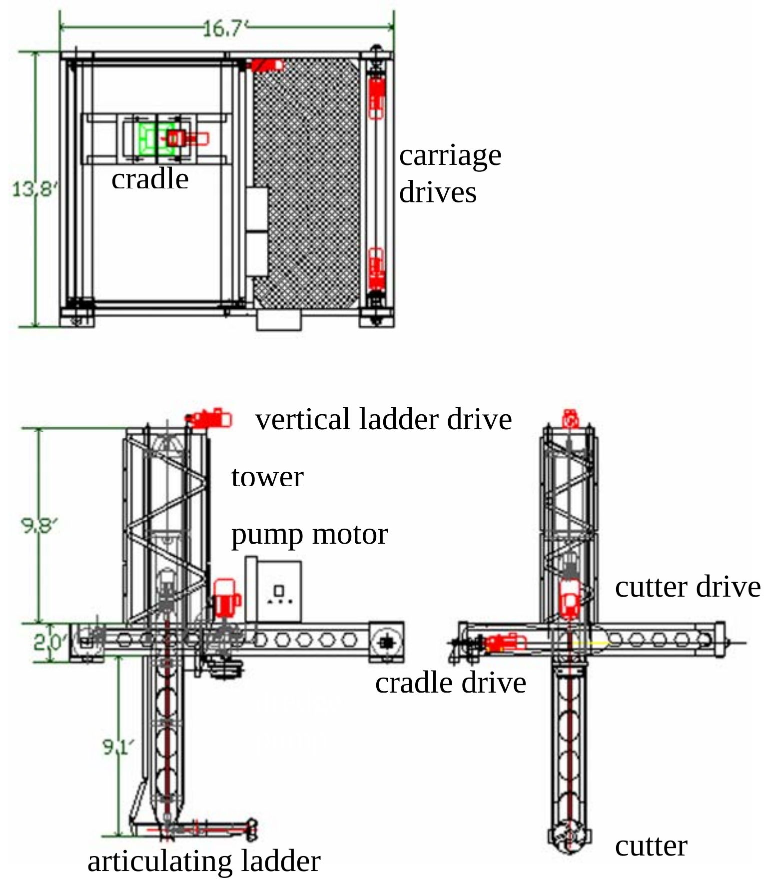

Figure 3. Dredge/tow carriage assembly drawing (dimensions in ft, divide by 3.28 for m).

Table 1. Characteristics of dredge/tow carriage.

Category	Characteristic
Maximum Carriage Speed	2 m/s (6.6 ft/s)
Distance to reach constant speed	3.1 m (10 ft)
Total Dredge/Tow Carriage Weight	4545 kg (10,000 lb)
Cradle Weight	1364 kg (3,000 lb)
Ladder Weight	909 kg (2,000 lb)
Carriage Power	Two 3.8 kW (5 hp) motors
Cutter Power	7.5 kW (10 hp)
Pump Power	14.9 kW (20 hp)
Side to Side Cradle Motor Power	1.1 kW (1.5 hp)
Vertical Ladder Motor Power	1.1 kW (1.5 hp)
Articulating Ladder Position Motor Power	0.5 kW (0.8 hp)
Dredge Pump Flow Rate	Maximum 1893 LPM (500 GPM)
Dredge Pump Size	10.4 cm (4 in), suction; 7.62 cm (3 in), discharge
Control System	Wireless LPC Automated and manual operation
Data Acquisition	Real-time display and data storage (Microsoft Entivity)
Swing Travel	1.6 m (5.3 ft) on either side of flume centerline
Ladder Angle	0 to 50 degrees from horizontal

The towing carriage rides on the steel flume rails using polyurethane rimmed steel wheels. Two 3.8 kW (5 hp) motors, one on each side of the carriage, drives two of the four wheels to provide carriage translation along the flume rails. The large weight of the fully assembled carriage provides the traction necessary to drive the carriage with the wheels. The towing carriage has a length of 5.08 m (200 in) and a width of 4.01 m (158 in) that is equal to the width of the flume plus the 254 mm (10 in) thick walls. The fully assembled dredge/tow carriage with the dredge cradle and ladder weighs up to 4545 kg (10,000 lb). The dredge/tow carriage uses a wireless remote control system that is controlled through a moveable computer station that can be placed along the wall of the dredge/tow flume.

The speed requirements for the dredge/tow carriage are a maximum speed of 2 m/s (6.6 ft/s) for model towing operations. The distance to reach the maximum constant speed is 3.1 m (10 ft). During dredging operations the carriage drive motor advances the model cutter axially through the sediment analogous to the motion created by spud carriage motion on a prototype dredge.

Figure 4. Dredge carriage sitting atop the dredge/tow flume (left) and the dredge ladder just above the sediment pit (right).

Four 76 mm (3 in) diameter chromed steel guide rods span the vertical length of the dredge cradle superstructure and Teflon sleeve bearings in the upper ladder arm assembly provide for smooth vertical motion of the cutterhead. The motor on top of the dredge cradle tower (Figure 4) is capable of positioning the ladder arm assembly, which is estimated to weigh approximately 909 kg (2000 lb). When the cutter head is undercutting, vertical cutting forces may increase the tension in the cable and the load on the winch. The swing movement of the dredge is simulated by the lateral motion of the cradle superstructure. Two chrome-plated 11.4 cm (4.5 in) outside diameter thick walled tubes are the guide rods for the cross flume motion. The cradle superstructure slides on Teflon bushings using a 1 HP servo motor to drive the cradle with a maximum swing speed of approximately 6.1 m/min (20 ft/min).

The ladder arm assembly stands about 5.79 m (19 ft) tall and has 137 cm (54 in) of vertical travel. At the lower end of the ladder arm is the 76.2 cm (30 in) long articulating dredge ladder containing the pump suction inlet and cutterhead. This configuration allows the ladder angle to be adjusted independently of the cutter elevation. The result is that the cutter angle can be adjusted from 0 to 50 degrees from the horizontal and cut at any elevation in the sediment pit from 3.05 to 4.27 m (10 to 14 ft) deep. The cutterhead can be replaced with a suction head or a draghead, depending on the type of equipment being tested. The vertical ladder has a variable speed, variable torque, 7.5 kW (10 hp) motor to drive the model cutter via the 51 mm (2 in) diameter drive shaft and double universal joint. A14.9 kW (20 hp) variable speed, constant power motor to drive 7.62 cm (3 in) by 10.2 cm (4 in) diameter centrifugal pump. A servo motor is used to adjust the ladder angle and maintain the desired position during dredging.

DREDGE/TOW CARRIAGE ELECTRICAL, CONTROL, INSTRUMENTATION AND DATA ACQUISITION SYSTEM

Electrical, Control and Instrumentation Systems

The electrical system provided is designed predominantly around four major design criteria:

1. Control and data acquisition (accuracy and reliability)
2. Mobility of mechanical system (motion in x, y and z planes)
3. Flexibility
4. Safety for personnel and equipment

The electrical system uses the latest state-of-the-art technology available on the market in order to fulfill the design criteria for the dredge/tow carriage. It is also designed to meet the need for accurate control and reliable data acquisition. Every motor on the system is controlled either by digital variable frequency drives (VFDs) operated in vector control or by servo drives (Figure 5). The VFDs and servo drives provide accurate rates of acceleration, constant velocities and speeds (RPM), exact linear movements, and the necessary torque to the motors as needed to maintain the desired operating set points. In conjunction with these control capabilities they also broadcast, via RS485 communication interface, all of this data to the supervisory control and data acquisition (SCADA) system. These data will then be manipulated by the SCADA personal computer (PC) for logging and/or display purposes. In-line dynamometers, tension/load cells, laser range meters, flow, pressure, and vacuum transmitters, and density meters are also employed as part of the data acquisition system. All of these sensors will provide accurate data feedback regarding cutter forces, fluid flow and density details, and pump pressure and vacuum conditions of the dredge/tow carriage system during testing operations (Figure 6). This information will also be displayed and/or stored for future evaluation purposes.

In order for the electrical system to meet the mobility requirements of the dredge/tow carriage the system is broken down into four major components: The carriage, the cradle, the tower and the ladder as shown in the previous Figure 3. The carriage is designed to remain permanently attached to the track and moves east and west along the X-axis. The cradle can be removed, as per the design requirement, and supports the tower which moves north and south along on the Y-axis on guide rails mounted inside the cradle. The tower supports and carries the ladder which moves up and down along the Z-axis on guide rails inside the tower assembly. As the dredge/tow carriage moves in the X, Y and Z axis, the electrical system accommodates for this range of motion not only efficiently but in a manner that would limit the total stress on the power, control, and sensor cables. The electrical design for the carriage motion utilizes a power track system which is a totally enclosed cable carrier that operates in a similar manner to the treads on a military tank (Figure 7). The power track provides the capability to cable the primary 480 VAC, 3-phase power and 120 VAC, 1-phase control power from the local, fixed-mounted disconnect breaker box to the mobile dredge/tow carriage system's carriage VFD cubicle in a safe and efficient manner. The power track system also allows operations of up to 34.5 m (113 ft) of travel, at speeds of over 122 m/min (400 ft/min) and acceleration rates above 0.31 m/s^2 (1 ft/sec^2). To meet the design requirement of a removable cradle all of the components and wiring related to that system are designed in a manner that allows it to be isolated from the permanently mounted carriage. Plugs and receptacles mounted on the side of the carriage VFD cubicle are used to cable the 480 and 120 VAC power to the removable cradle. The cradle PLC and VFD cubicles along with cradle related motors, sensor devices, and wiring are attached to and completely supported by the cradle assembly. By designing the system in this manner the cradle can be removed with a minimum amount of effort. This design also allows the carriage system to remain safe by eliminating exposure to deadly voltage sources through use of receptacle covers as well as functional by means of a local mounted carriage VFD HMI (human-machine interface). For cradle motion, the electrical design utilizes a free floating cable harness that attaches to the carriage and tower using highly flexible cable. The flexible cable harness carries the power, control, and sensor feedback signals to and from the cradle VFD and PLC cubicles and the ladder mounted components. For ladder motion, all the sensor signals are terminated inside a single interface junction box mounted on top of the ladder. This allows the use of more robust multiconductor cables, capable of handling the extensive, repetitive operation, to carry the feedback signals to the cradle PLC cubicle. This design will reduce the stress on the smaller, more delicate sensor wires which remain stationary on the ladder. Finally, the SCADA system (described later in this paper) utilizes two Ethernet radio systems. The radio telemetry setup eliminates all hardwired communication and sensor feedback cables from the carriage mounted PLC to the SCADA PC based remote operating system.

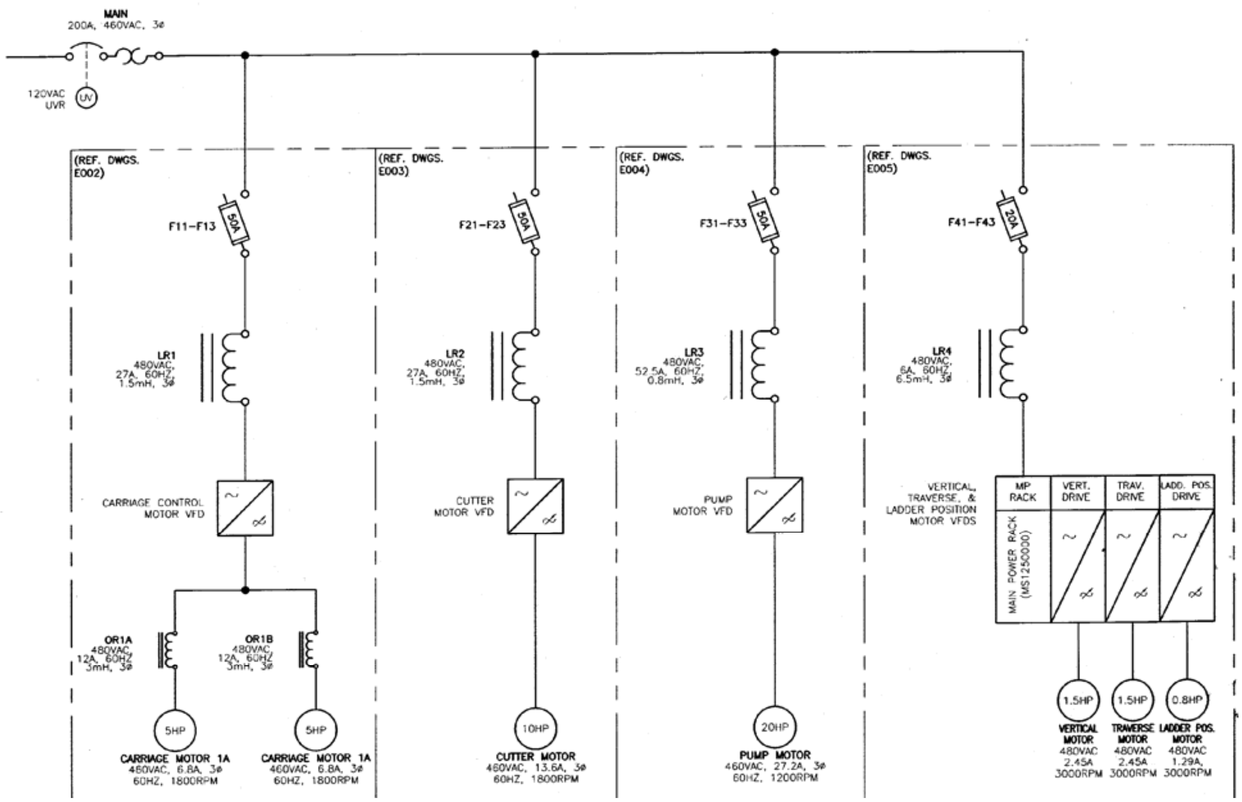

Figure 5. Electrical supply for dredge/tow carriage drive motors.

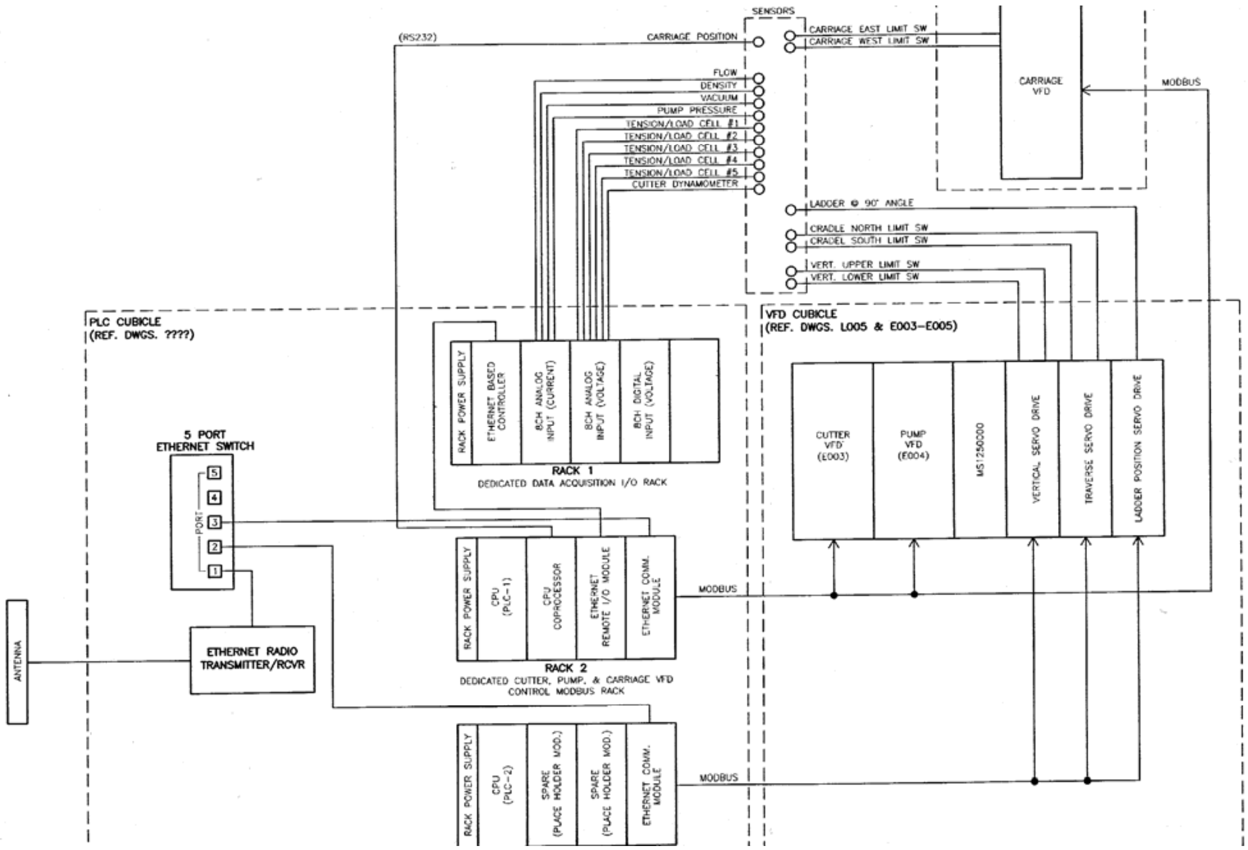

Figure 6. Electrical control and data channels for the dredge/tow carriage.

The flexibility of the electrical system was also taken into account while in the designing stages of the project. All of the VFDs and PLCs provided are digitally operated and controlled, microprocessor based systems. The VFDs supplied to control the carriage, ladder pump, and cutter motors were intentionally oversized so that if future demands should require higher torque and horsepower requirements only the motors will need to be changed. The VFDs supplied for the carriage, ladder pump, and cutter motors are also identical in size as are the Servo Drives supplied for the vertical position, traverse control, and ladder angle motor systems. This allows all of the systems to be interchangeable. This will also reduce the amount of spare parts required as well as aid in trouble shooting. The VFDs supplied for the carriage, ladder pump, and cutter motors can also be operated in over five (5) different modes of control: V/Hz constant and variable torque, sensorless vector (also known as vector control frequency feedback), vector control with speed feedback, or torque (master-slave) control. The remote console is designed to be powered by any standard 120 VAC receptacle which allows it to be setup and operated from almost anywhere within the laboratory facility. The 480 VAC, 3-phase power and the 120 VAC, 1-phase control power are isolated from one another so that the control system can be powered, if desired, by a separate, clean, uninterrupted power source. This assists in preventing dirty power from interrupting or contaminating the data acquired by the data acquisition system. By doing this it also allows the SCADA system and sensor elements to remain energized even if the main 480 VAC power to the building is lost, thereby, preventing loss of communication between the carriage mounted PLC and remote mounted PC. If power is accidentally or unintentionally deenergized to the system a laser range meter is used to recover the position of the carriage once power is reapplied. This eliminates the need to "home" or "re-zero" the carriage as would have to be done if the position of the carriage were calculated by counting pulses from an encoder. This will also allow the system to resume operation with a minimal amount of delay. Even the cabling pulled for the 480 VAC and 120 VAC is over sized by over 200% so that the systems on the dredge/tow carriage can be increased in size, if desired, without having to replace the original cable installed.

Personnel safety, equipment safety, and protection also played a vital role in the design of the electrical system. The main 480 VAC, 3-phase power for the dredge/tow carriage system can be deenergized and locked-out by means of a

480 VAC, 200A panel mounted circuit breaker located on the southwest corner of the dredge/tow flume (Figure 5 and Figure 7). The emergency stop feature for the dredge/tow carriage utilizes a failsafe UVR (Under Voltage Release) on the 200A feeder breaker which will trip the breaker in the event of power loss to the UVR. The power required to energize the UVR is provided by the remote console. If the remote console is removed from the facility the main 480 VAC feeding the dredge/tow carriage system cannot be energized. This should prevent any unauthorized operation of the equipment. The emergency stop can also be activated by either using the hardwired E-stop mounted on the front of the remote console, or will automatically be activated in the event of loss of radio communication between the remote mounted SCADA PC and carriage mounted PLC. The brake systems on the carriage, ladder angle, traverse, and vertical position motors require power to release the brake. In the event of power loss on the 480 VAC system all of the brakes will automatically apply. Each VFD is equipped with its own isolation, fused disconnect switch and, as mentioned in the first paragraph of this section, the 480 VAC and 120 VAC power feeding the cradle electrical system is protected by individual circuit breakers per power source. All of the cabling installed on the dredge/tow carriage that carries 480VAC or 120VAC power is run using offshore rated armored and sheathed cable certified for use in Class 1 Division 1 hazardous regions. Also every cubicle located on the dredge/tow carriage (carriage VFD, cradle VFD, and cradle PLC cubicle) is equipped with a door mounted "480 VAC POWER AVAILABLE" and/or "120 VAC POWER AVAILABLE" LED push-to-test pilot light(s), where applicable.

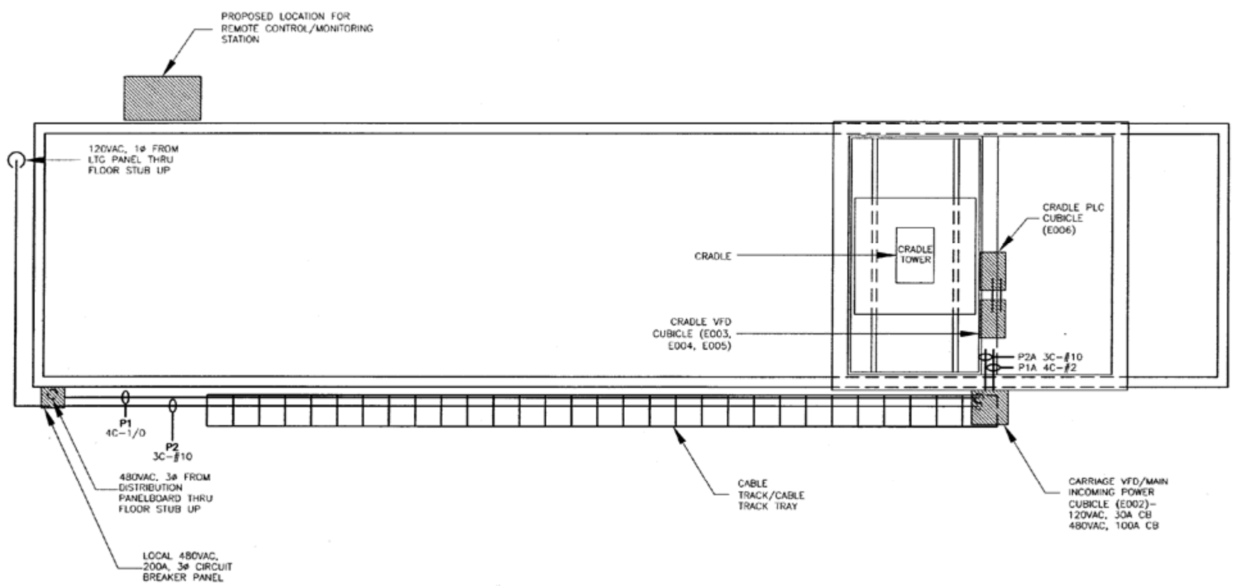

Figure 7. Electrical power cable track for dredge/tow carriage.

In conjunction with the personnel safety features mentioned the dredge/tow carriage is also designed with components that will aid in protection of the system's equipment. Physical end-stop barriers are mounted on the carriage rails to keep the carriage from running off the flume. Proximity switches are installed to prevent over-travel on the carriage, cradle, ladder, and ladder cutter angle systems. If any of these limits are reached the system is programmed to halt all motion in those directions. Each VFD and Servo Drive is also equipped with their own built-in safety features such as over-speed, over-current, over-voltage, speed/position deviation limits exceeded, and 480 VAC supply power loss faults. These built-in features will prevent erroneous operations of the motors that could result in bodily harm or damage to the mechanical systems.

Data Acquisition System

The Supervisory Control and Data Acquisition (SCADA) system consists of a PC/joystick console located at the user/operator desk and a PLC system located on the dredge/tow carriage as shown in previous Figure 8. Communication between the dredge/tow PLC and the user/operator station is completed by an advanced industrial wireless Ethernet link that is immune to interference from normal "Wi Fi" systems. Hardwire emergency stops are in place to override PLC control.

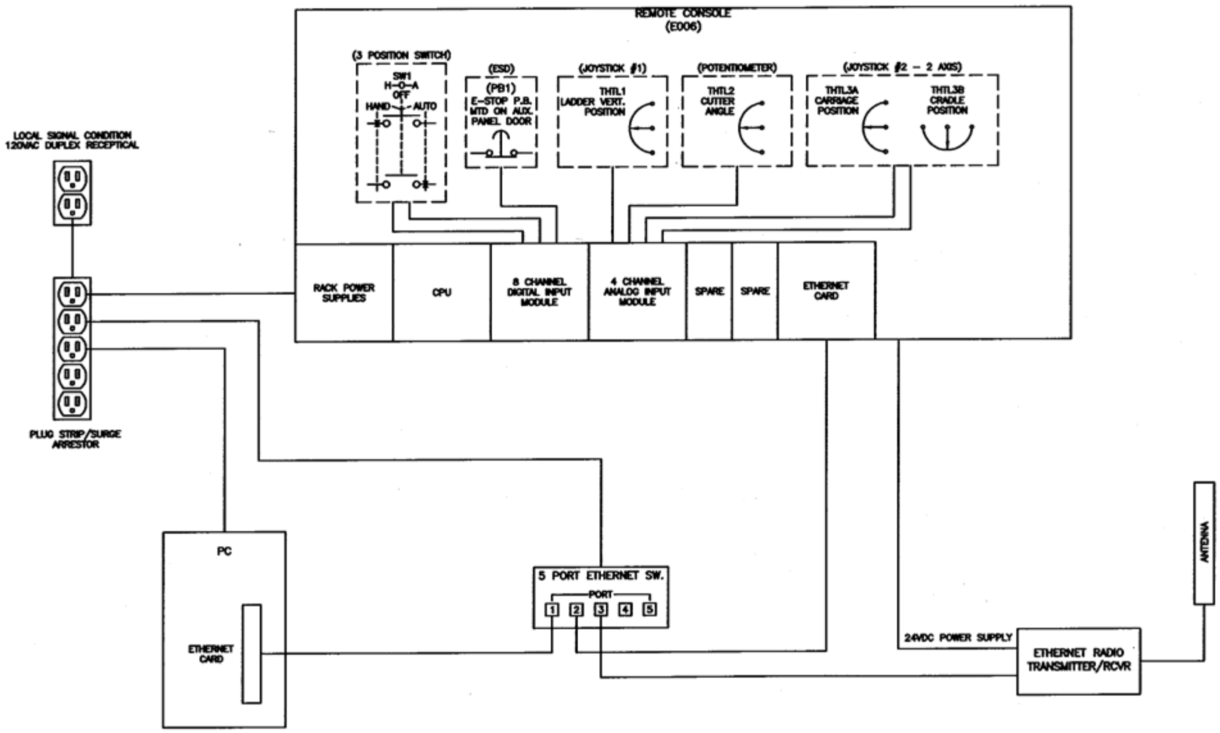

Figure 8. Schematic of SCADA and remote control console.

The SCADA PC serves two basic functions. First is the collection and recording of data gathered by the dredge/tow carriage PLC. The data are stored in files that are available for analysis. Real time data are displayed on the PC monitor and are available for use by the operator. Also, the SCADA PC can perform real time calculations on the incoming data. The second function of the SCADA PC is to provide a method of developing 'recipes' of instructions for the dredge/tow carriage. These 'recipes' of instructions are developed using a Microsoft ® Viso flowchart format. A library of 'recipes' can be stored on the SCADA PC.

The SCADA joystick console provides a means to manually control the dredge/tow carriage system. Data from instrumentation can be recorded in either 'Auto Mode' (controlled by the SCADA PC) or 'Manual Mode' (controlled by the SCADA joystick console.) The SCADA joystick console is also used for maintenance functions that require the movement of the dredge/tow carriage.

The SCADA PLC system is located on the dredge/tow carriage and is responsible for controlling the motor/servo drives and collecting the instrumentation data for transmission to SCADA PC. The SCADA PLC system contains its own program to insure the motor drives are still in control in the event of a radio link loss.

The SCADA communication link is provided by two Ethernet radio modems each located at the dredge/tow carriage and the user/operator station. This link uses spread spectrum technology to prevent interference or intervention from typical commercial "Wi Fi" systems. In the event of radio or other failure, a hardwired emergency stop is provided to disconnect power from the dredge/tow carriage.

HOPPER BARGE FOR SEDIMENT TRANSPORT, STORAGE, AND DISPOSAL

During a model run, slurry is discharged through the 7.62 cm (3 in) discharge line into a floating hopper barge in front of the dredge/tow carriage as shown in Figure 9. Most importantly, keeping the sediment contained prevents the discharge from interfering with turbidity produced by the model cutterhead or suction head. In the cases where model cutters are being evaluated on the basis of turbidity generation, this is an absolute necessity. Even in nonturbidity related studies, clouding the water by immediately discharging the slurry into the flume may interfere with any qualitative data being taken by persons looking through the observation windows.

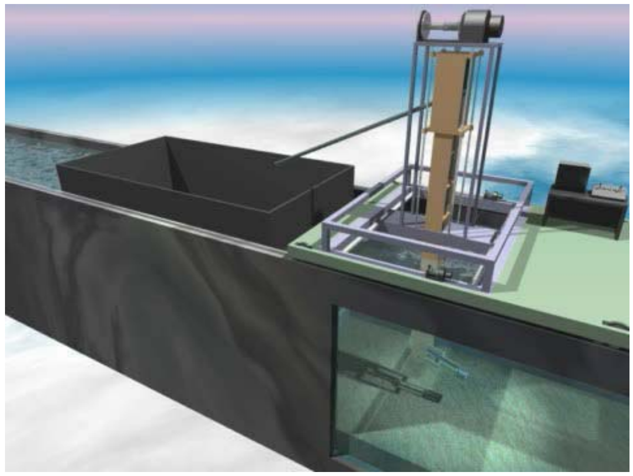

Figure 9. Hopper for dredge carriage (Glover 2002).

The size of the hopper is planned to be 22.9 m^3 (30 cy), and it is a floating rather than hanging type hopper. Weight of the dredge slurry is the single dominant parameter with regard to balancing an adequately sized (volume) hopper with its required buoyancy and then fitting such into the tow flume. The dominant parameter with respect to what type of materials should be used for construction of the hopper and how the buoyancy material might be attached is the capacity of the overhead crane. Obviously, the unit must be removable in whole or easily segment-able parts by the crane. A bottom valve(s) system offers the best chance at achieving a water tight seal for the hopper and it potentially provides the simplest system to maintain. The hopper will be equipped with instrumentation to conduct draft – displacement production calculations. Four pressure sensors on the hopper hull for determining hopper draft and four acoustic sensors above the hopper for measurement of the water level and estimation of the location of the sand-water interface level are planned. Galvanized steel surfaces are used for corrosion protection of the hopper. The hopper should be attached to the tow carriage via a single rigid member with *Lunette* eye and pintle hook connections to provide a range of motion large enough to make the connection yet rigid enough to allow both pushing and pulling of the hopper.

The floating hopper concept displaces a volume of water equal to the discharge volume. The water level in the flume remains constant during a dredging operation. The draft of a floating hopper gives a quick and accurate estimate of total discharge volume. It also allows the modeling of open water disposal while at the same time directly returning the sediment to the sediment pit. With a fixed hopper volume the model flow rate is a critical factor in determining how long a model test can run before the hopper is filled to capacity. Given the dimensions afforded by the flume and sediment pit geometry, the volume of the hopper barge needs to be approximately 25.6 m^3 (30 cy). This means model run time using fine sand could be anywhere from 16 minutes to several hours depending on the prototype sand and conditions being modeled.

DREDGE MODELING AND USES OF DREDGE/TOW FACILITY

Modeling of hydraulic dredging is complicated as a result of trying to model fluid flow, cutter rotation, and sediment pick-up. Typically, the most important phenomena must be identified and modeled using the appropriate similarity parameters. Glover (2002) and Glover and Randall (2004) discuss the modeling of hydraulic dredging and the various important similarity parameters. For example, the volumetric flow rate of the slurry depends on the geometric scale ratio and the ratio of prototype to model settling velocities. The following example assumes a geometric scale of 1:10 and a prototype flow rate of 189,270 LPM (50,000 GPM) through a 76.2 cm (30 in) diameter discharge line as used previously. Modeling fine sand (d_{50} = 0.1 mm) with fine sand as a bed material requires a model flow rate of 189 LPM (500 GPM) to maintain a properly scaled velocity profile around the suction inlet. On the other end of the spectrum, modeling coarse gravel (d_{50} = 1 mm) with a fine sand bed material (d_{50} = 0.1 mm) requires a model flow rate of 129 LPM (34 GPM) to maintain a properly scaled velocity profile. Consequently, the volume of the discharge hopper and the volumetric flow rate of the discharge limit the time allowed for a model run.

The possible uses of the dredge/tow flume and carriage are many, and it is hoped that the dredging industry, Corps of Engineers, and other organizations will find the facility useful for dredging research, development, and testing. Proprietary and non-proprietary arrangements are available. Examples of research and testing projects for the dredge/tow flume facility are tabulated in Table 2 that includes modeling cutter suction dredging, cutter cutting forces, flow studies at cutter and draghead inlet, towing of offshore models (e.g. semisubmersible sections), vortex induced vibrations of cylindrical sections, dredged material placement, sediment resuspension during dredging, and others.

Table 2. Example dredging research and testing topics for the dredge/tow flume facility.

Excavating & Pumping	Placement	Other
New draghead and cutterhead design	Erosion of dredged material mounds and islands	Vortex induced vibration of offshore platform components
Flow around dragheads and cutterheads	Capping of contaminated sediments	Scour around coastal and riverine structures
Turbidity or resuspended sediment generated by dragheads, cutterheads, and clamshell buckets.	Turbidity or resuspended sediment generation due to dredged material disposal in open water	Forces on towed bodies for offshore applications
Reverse slurry flow through draghead for capping	Pore water pressure variation in sediment caps	Modeling oil spill movement and trajectory in currents
Effect of water jet assisted cutting for cutterheads and dragheads	Modeling dredged material disposal in open water from hopper, barge or pipeline	Modeling coastal erosion
Hoppers used for capping with pump-out through draghead	Physics of dredged material behavior as it falls through the water column	
Model floating dredge dynamics in ocean waves (need new wavemaker)		
Modification of dragheads and cutterheads for minimizing effects on marine life		
Bank height effects on sediment flow to cutterhead		
Dredge cutter cutting of sediments		
New dredge instrumentation related to monitoring hopper contents and overflow		
Measuring production of model dredge		
Modeling mechanical dredging using clamshell, backhoe, and others		

INSTALLATION OF MODEL DREDGE CARRIAGE IN DREDGE/TOW FLUME

On April 8, 2005, the dredge/tow carriage was delivered for installation in the Haynes Coastal Engineering Laboratory. Figure 10 shows a sequence of the installation process. First, the carriage was transferred from the hauling truck to a crane truck, and the crane truck brought the carriage to the loading dock at the back of the laboratory. The weight of the carriage dictated that a combined use of the truck crane, a fork lift, and the laboratory crane was necessary to lift the approximately 4545 kg (10,000 lb) carriage. The ladder for the carriage was delivered separately and placed in the laboratory using the fork lift. The second picture shows the truck crane booming in the carriage where the fork lift could support one side of the carriage and the truck crane could hold the opposite side and lower its crane such that it could boom in the carriage into the laboratory. Once the carriage was inside, the laboratory crane was attached to one side of the carriage and the fork lift was moved to the opposite side after the carriage was set on blocks. The third picture shows the carriage being moved over the rails with the laboratory crane and the fork lift. The carriage is shown in the fourth picture resting on top of the rails with the tower erected that will receive the dredge ladder. The dredge ladder was placed in the flume sediment pit using the laboratory crane and shown in the fifth picture. Next, the carriage was moved over the pit and the laboratory crane hook was lowered through the top of the tower and attached to the top of the ladder. A come along was attached to the front of the carriage and the cutter end of the ladder. Finally the ladder was inserted and connected to the top of the tower.

a b c

d e f

Figure 10. Dredge/tow carriage installation sequence.

SUMMARY

The dredge/tow carriage for Haynes Coastal Engineering Laboratory at Texas A&M University was installed in April 2005 and is expected to be operational by the end of August 2005. The carriage is capable of modeling dredge operations of cutterhead and hopper dredges using a model scale of 1:10 or larger. The dredge pump has a 10.2 cm (4 in) suction and 7.6 cm (3 in) discharge with a maximum flowrate of 600 GPM. A 30.5 cm (12 in) cutter is available and various size and type of cutters and dragheads can be mounted on the bottom articulating ladder. The vertical ladder has a vertical range of motion of 1.5 m (5 ft) to reach into the 7.6 m, 3.7m wide, and 1.5 m deep (24.8 ft long, 12 ft wide, and 5 ft deep) sediment pit that is located approximately 2/3 of the distance down the dredge/tow flume that is 45.6 m (149.5 ft) long. The vertical ladder has load cells installed at the top of the ladder for measuring forces in the three axes of movement. Instrumentation is installed to measure cutter torque, pump suction and discharge pressure, pump rpm and torque, slurry flowrate and density, carriage and ladder position. The vertical dredge ladder is hung from the top of the tower mounted on the cradle that moves across the flume using electrical motors. The control of the carriage uses programmable logic control (PLC) that is controlled by a computer using wireless technology. The data acquisition system captures the data from the carriage instrumentation using wireless technology and stores it on the computer. The dredge carriage is powered by variable speed electrical drives that power the wheels in contact with the rails atop the walls of the dredge/tow flume. The electrical power for the carriage is provided through a cable track system that pays in and out as the carriage moves up and down the flume. The maximum carriage speed is approximately 2 m/s (6.6 ft/s). Initial operation of the carriage during the summer 2005 will establish the actual operating characteristics of the carriage and dredge system. It is anticipated that research and proprietary testing of dredge systems will be conducted for a variety of dredging interests.

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