**MacGregor© RO-RO Hydraulic Stern Ramp System**

Chief’s Special Project

Cooper Parlee

American RO-RO Carrier: M/V ARC Independence

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**Introduction**

Given the seldom use of the side ramp, the 6.5-meter-tall stern quarter ramp on the M/V ARC Independence is what allows the vessel to deliver on its advertised 8,000 car capacity. This ramp was controlled by a complex system of programmable logic circuits (PLCs) that drive a system of hydraulic actuators on the door. This 9.5-meter-wide vehicle ramp comprises two actuated ramp sections to minimize the inclined gradient for vehicles being loaded and, in total, has a maximum capacity of 240 tons. Given the sheer size and criticality of this piece of machinery, operation is heavily automated and protected by electronic interlocks and permissives. However, the PLCs that govern this logic are centralized and documented, improving the process of regularly troubleshooting the system.

**Equipment**

*Mechanical*

Mechanical operation of the system primarily comprises winches and cylinders of various types. Section one, the upper ramp section, is driven by two W1 winches which are each powered by two hydraulic motors for a total of four hydraulic motors. These can each spin in either direction depending on the direction of fluid admission by the directional control valves. Section two, the lower ramp section, is driven by two W2 winches which only have one hydraulic motor.

Between the two sections is a set of two buttressing cylinders which control the angle between the two sections. These cylinders accept flow in either direction to reduce or increase the angle between the two sections.

A similar set of cylinders exist for the “push-off” or launching cylinders on 8-deck, which are used to break the ramp free when it is stationary and leaning up against the hull instead of being pulled down by gravity. This cylinder only accepts flow in one direction when it is to push out. Fluid is returned once the cylinder is pushed back into its retracted position when the ramp is raised.

Finally, there are a number of locking devices positioned from 5-deck to the upper U-deck. On the lower decks, these are horizontal locking pins which extend into sockets in the ramp and lock it in place at sea. On the upper deck, there are two large cylinders which drive the “kingposts” which are large locking cleats that slide over, pivot, then lock pins on the top of the ramp in place, firmly securing the ramp while at sea.

*Hydraulic*

Control for the stern ramp system begins at the hydraulic pumps for the system. A set of nine electrically driven high pressure hydraulic pumps provide a control media for the ship’s RO-RO systems. Each pump has a running current and voltage of 11.4 A at 220 V and as such the whole system acts as a very significant power draw for the vessel. Two pumps are of particular operating interest for the engineers for the stern ramp system, pumps seven and eight. Each of these two pumps drive two distinct streams of fluid: pilot pressure and cooling circulation for the pumps and are called priming pumps. Each pump was run independently, with the other designed to start as a standby for the running pump. The running pump was changed month to month to share wear and load between the two; the even pump (eight) was run in even months and pump seven in odd months. This set of two pumps allows the deck officer who is operating the stern ramp to actuate the control valves and start the other system pumps.  
PUMPS PICTURE

After the priming pumps have been started, the mate operating the stern ramp is able to flip and hold the “Pumps Start” switch, which activates the start sequence for all of the other pumps in the system. This activates pumps one through six which each have different purposes. Pumps one and two both drive the main hoisting winches for the proximal section of the ramp, W1. Pump three drives all of the cylinders (push out, locking, post cylinders, etc) and can provide extra flow to the W1 winches. Pump four supports W1 and also provides flow to the W2 winches for the distal section of the ramp (called section two or the flap). Pump five drives the buttress cylinder which controls the angle between section one and section two of the ramp. Pump six strictly controls the W2 winches.

*Directional Control Valves*

With all these pumps driving different components of the system, flow needs to be controlled and directed throughout the system. This flow is controlled by a series of directional control valves which are located in the RORO hydraulic room in steering gear, and these are just forward of the hydraulic power pack for the RORO system. There are many control valves with two main distribution valves which can control pressure level to the whole system. These are represented in the pictogram below:

CONTROL VALVE PICTURE

Most of these directional control valves are three-position, spring-centered, meaning that they can allow flow in forward or reverse direction or block flow all-together if the valve is centered. In the case of the pay out and main winch brakes directional control valves, it is only necessary to have flow in one direction and the operation of that machinery in the stopped position is sufficient to clear the internal hydraulic fluid.

The directional control valves are solenoid-controlled by the PLC cabinet. The three-position valves will have two solenoids: one for forward and the other for reverse with the valve being returned to the center closed position by spring force.

*Electrical*

This complex mechanical-hydraulic choreography is controlled by a set of programmable logic circuits (PLCs) designed by MacGregor. These PLCs are fed a set of permissive signals from various indicators throughout the system which allow the system to actuate upon input from the operator. Each input and output of the PLCs could be seen inside the ramp logic control panel CC-1 in the engine room where the inputs and outputs were identified as LED indicator lights on the terminal strips for the PLCs. This significantly helped with troubleshooting.

PLC PANEL PICTURE

There are many different types of permissives, but many of the common ones include pressure switches, angle indicators, and proximity sensors.

There were three pressure switches placed throughout the system and they all had to be reading sufficient pressure for anything in the system to activate, including the pumps. In fact, if one of the pressure switches lost pressure or was reading a pressure loss, the system would immediately go into alarm and disengage the distribution valves. These switches were designed to detect a leak in the system by sensing a loss in pressure before that leak was allowed to drain the hydraulic system and its costly oil.

The angle indicator was imbedded under section one of the ramp where it was used to detect the angle of the ramp relative to the horizontal. This angle indicator was likely an absolute encoder and was approximately eight inches in diameter. Logic from this position indicator fed three PLC inputs: ramp 75°, +6.5°, -6.5°.

ANGLE INDICATOR

The ramp 75-degree input tells the ramp that it is two far to the vertical to spool out under its own weight because its angle is greater than 75 degrees. As such, the pay out mode is activated on the hydraulic winches to allow them to free spool, the hydraulic brakes are disengaged, and the push out cylinder is used to start the ramp in its free-fall. That is, until it reaches 75 degrees when the system disengages free spool and the ramp’s decent is instead slowed by the back pressure on the hydraulic pumps.

The 6.5-degree inputs control the end limits of the ramp. The positive 6.5 degree input tells the ramp to start lowering even more slowly since it is approaching the outer range of its control. When the ramp reaches -6.5°, it will prohibit decent because the ramp is at its maximum range of motion.

**Basic Operation**

The stern ramp system is regularly operated by the Chief Mate from the stern ramp shack on the upper deck on the starboard-side stern quarter. Within this shack is a set of controls that the Chief Mate will operate, shown below.

SHACK CONTROLS

In order to lower the ramp, the system must first be in harbor mode to be operated. This is a switch located on the bridge stern ramp control panel. Failure to flip this switch was regularly a cause of issues where the stern ramp would not operate.

BRIDGE CONTROL PANEL

Next, the control key is switched to the on position. The pump switch is turned on and the green pump indicator light is observed and should be illuminated if the pumps are running. It was recommended that the lamp test button be used in order to test the indicator lights before using the system. That way, if a subset of the system was not operational, it would not be missed because the light bulb was burned out or otherwise unusable.

With the system powered up, the locking pins must be removed from the king posts securing the ramp in the raised position for travel. One such pin within the king post is shown below. This is removed by removing the cauter pin which locks the pin for the cleat hook in place.

KING POST WITH PIN

With the lock removed, the system can now begin lowering. The switch for “Winch Section 1” is moved from auto-tension to the manual position with the flap switch set to auto-tension. Now the joystick for section 1 can be pushed into the lowering position. When this happens, several automations occur. These include the unlocking of the wedge cleats, the hooks and the two section locks for the flap are unlocked. Additionally, the pay out control valve in the hydraulic room activates and allows the W1 winch to momentarily free-spool. At this point, however, the ramp is angled vertically and will not begin to open due to the moment created by its own weight. If all permissives are satisfied (as described in the following section), the two launching cylinders located on 8-deck push the ramp off and start its free fall.

The section 1 joystick is continuously held in the lowering position until section 1 reaches 65 degrees on the angle indicator, at which point the “ANGLE, FOLD” light will illuminate and section 2 will be hanging straight down. The “Winch Section 2” (flap) mode switch should be set to manual at this point. Now, section 1 and 2 can be controlled to place the quay (a resting flap at the bottom of the ramp) onto the dock. Section 2 will be hoisted whereas section 1 will be lowered allowing the ramp to approach a horizontal position. Per the manual, it is not recommended that the angle of the flap is not too steep when the quay connects with the dock.

Once the ramp has made contact with the dock, the manual suggests that the section winch selector switches are set to “self-tension,” however, the protocol on the ship was to leave the winches in the manual position in port because the auto-tensioning equipment was inoperative. The pumps are not to be turned off.

To close the ramp, the reverse process can be followed, being sure to secure the locking pins for the cleat hooks on the king post when finished.

**Auto-Tension**

The auto-tension control was a special mode of the system that controlled line tension on either or both W1 and W2 winches. This is done by restricting system pressure using the auto-tension directional control valve, which lowers the pressure that is fed to the relevant system components well below the pressure needed to actuate them, but above the pressure where the components of the system will move freely. For example, if the system pressure was 30 bar, the auto-tension mode might step down pressure to 12 bar. In effect, this means that the winch motors could only deliver 12 bar of pressure to the winch cables. If the cables exceeded this pressure due to a vehicle on the ramp, the motor would rotate under tension because the tensile force would be greater than that of the internal motor force due to pressure.

Given this understanding, the system can not be moved in auto-tension mode and would first need to be controlled in manual then switched to auto-tension when the desired position was reached.

**Troubleshooting**

*Emergency Operation*