SLC-9 Launch Water System

Modifications to the SLC-9 Launch Water System for Adaptation of the Rocket-Tech Heavy Vehicle SRC-13

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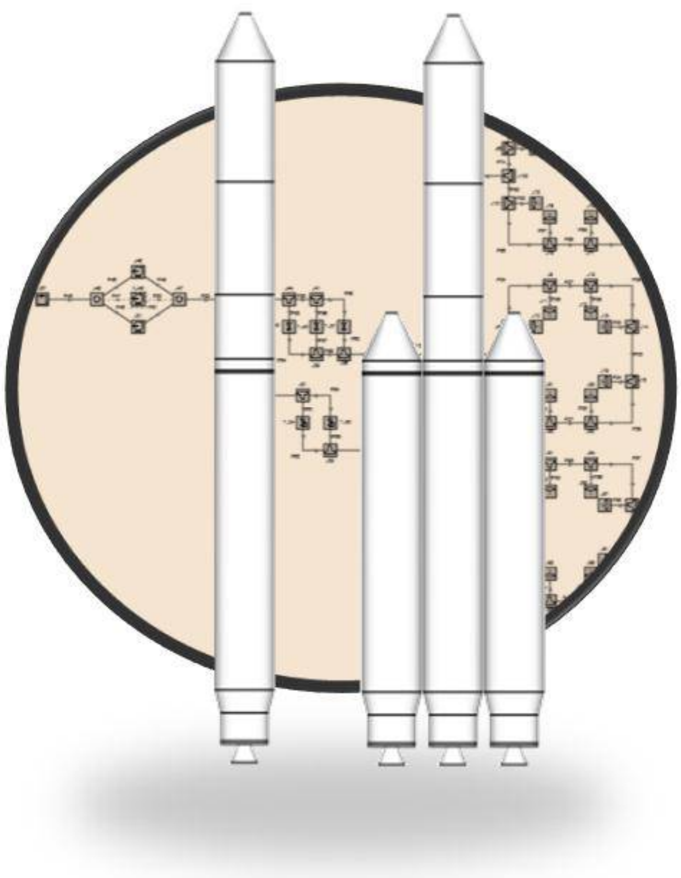

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Abstract/Summary of Results

Rocket-Tech has identified a need to modify the existing Launch Water System (LWS) at Space Launch Complex 9 (SLC-9) to support a larger vehicle's water deluge requirements and to add flexibility to the pad for multiple users. Reynolds, Smith and Hills, Inc. (RS&H) was tasked by Rocket-Tech to analyze the performance of the current LWS and to design the necessary modifications for the improved water system. The modifications include additional below deck sound suppression capability and new above deck cooling and sound suppression capability. These capabilities required an extra 160,000 gpm of water be introduced to supplement the current system.

Rocket-Tech provided RS&H with strict flow and timing requirements for water delivery to the specified subsystems. Through iterative design and analysis using Applied Flow Technology's (AFT) Impulse software, RS&H was able to successfully meet these requirements while adding minimal infrastructure to SLC-9. The required flow rates (provided by Rocket-Tech) along with the predicted flow rates achieved in Impulse are shown in **Table 1** below.

	Current Configuration		Modified Configuration	
System	Flow Rate Required (gpm)	Flow Rate Achieved (gpm)	Flow Rate Required (gpm)	Flow Rate Achieved (gpm)
Cryogenic Abatement Spray	1,400	1,417	1,400	1,490
Sound Suppression Deflectors	30,000	32,480	90,000	90,698
Sound Suppression Rainbirds	-	-	100,000	105,169

Table 1 – Existing (for KW-1) and Modified (for SRC-13) LWS Flow Rates Required and Achieved

Background

Located on Sullivan's Island off the coast of Charleston, SC, Space Launch Complex-9 (SLC-9) has been successfully delivering supplies to the International Space Station (ISS) since September of 2003. The single user of SLC-9 has been the Rocket-Tech KW-1 and has had great success in multiple launches over the past decade. SLC-9 is equipped with a sophisticated Launch Water System that provides cryogenic abatement spray as well as sound suppression and cooling. The system uses a series of pumps to meet the current flow and timing requirements of the KW-1 rocket.

SLC-9 was specifically designed for the KW-1, which is a medium class single core vehicle capable of delivering payloads of 22,000 pounds to Low Earth Orbit (LEO). In early 2013, Rocket-Tech identified a market for delivering payloads up to 54,000 pounds to LEO and has identified the heavy class vehicle, the SRC-13, to fulfill this demand. There was also a desire to provide flexibility to the pad's LWS to support multiple users, once the modifications were complete.

The current medium class KW-1 vehicle has two stages. The first stage is a single liquid core using Liquid Oxygen (LOX) and refined kerosene (RP-1) as propellants. The second (upper) stage is a cryogenic Centaur booster. The proposed heavy vehicle, the SRC-13, will continue using the current Centaur upper stage, but will use three side-by-side liquid cores (each similar to the current single core) for the first stage. Rocket-Tech has tasked Reynolds, Smith and Hills, Inc. (RS&H) with identifying the necessary modifications to the Sound Suppression System to account for the two additional liquid cores. They have requested that RS&H develop a new, economical Launch Water System (LWS) around the existing system that minimizes additional infrastructure due to strict environmental sensitivity at SLC-9. The new requirements set by Rocket-Tech for the modified LWS are shown below in **Table 2**.

	Current Configuration	Modified Configuration
System	Maximum Flow Rate Required (gpm)	Maximum Flow Rate Required (gpm)
Cryogenic Abatement Spray	1,400	1,400
Sound Suppression Deflectors	30,000	90,000
Sound Suppression Rainbirds	-	100,000

Table 2 – Existing (for KW-1) and Modified (for SRC-13) LWS Flow Requirements

RS&H has previous experience with launch pad water systems. Having designed the Ignition Over Pressure (IOP) and Sound Suppression (SS) systems at Kennedy Space Center's Pad 39A & 39B in Florida, as well as the pad water system at NASA's Wallops Flight Facility in Virginia, RS&H was eager and excited for the opportunity to assist in the modifications to SLC-9's pad water system to support larger vehicles.

RS&H investigated different software packages that are capable of modeling the existing and the modified systems. The software needed to be able to accurately model the entire system including pumps, valves and nozzles, as well as model the transient events in the launch sequence in order to provide the required amount of water during launch. After considering select software options, RS&H chose Applied Flow Technology's (AFT) Impulse software package.

System Description

Current SLC-9 Launch Water System

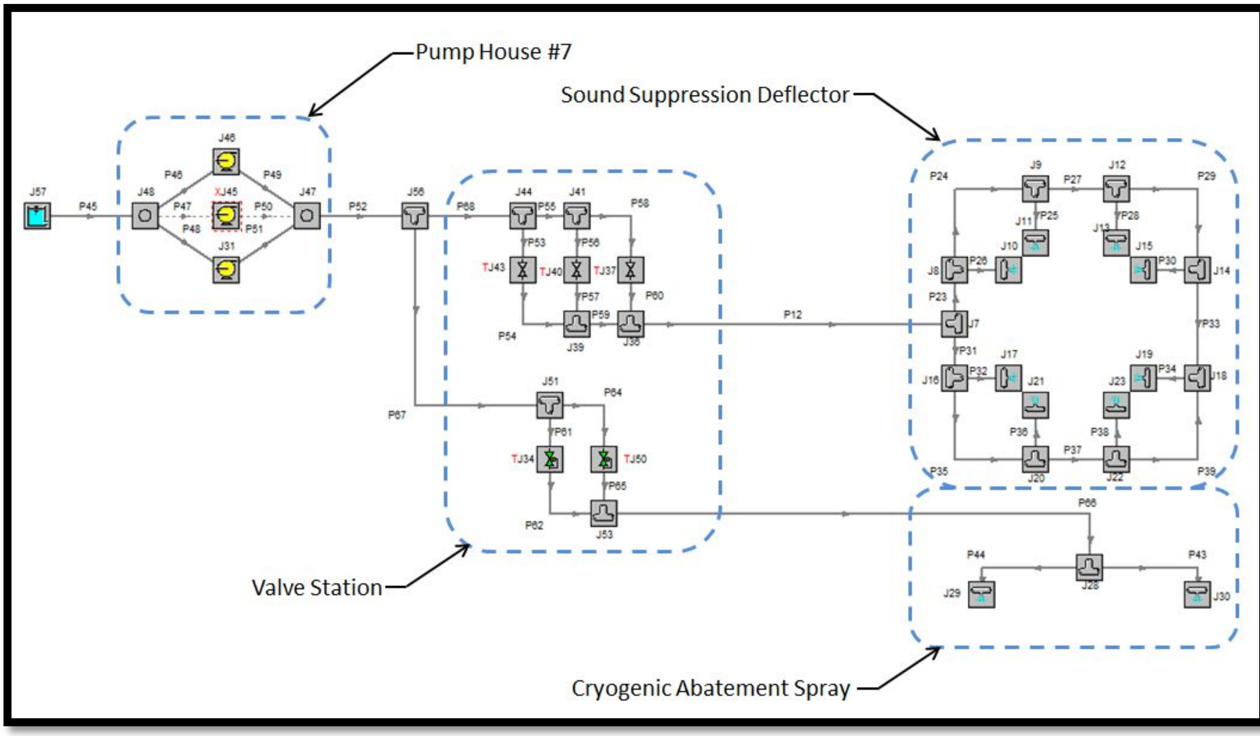

Figure 1 – Current LWS in Impulse

Shown above in **Figure 1** is the existing configuration for the Launch Water System at SLC-9, which provides 30,000 gpm for Sound Suppression and 1,400 gpm (max) for Cryogenic Abatement Spray, required for the Rocket-Tech medium class KW-1 rocket. The combined 34,400 gpm is provided at 30 psi from Pump House #7 located approximately 250 feet from the launch point. The pump house is capable of delivering 100,000 gpm at 150 psi, and consists of three variable frequency drive pumps in parallel. Currently, two pumps are used at 55% rated speed during launch with one additional pump on standby should a failure occur in one of the first two pumps. The sound suppression valve station consists of three 20" butterfly valves in parallel with pneumatic/hydraulic actuators. The valve actuators are capable of opening the valves in 0.5 seconds. These valves are redundant in that if one valve should fail to open, there is enough flow through the other two to meet the flow requirement. **Figure 2** shows the profile used to accurately model the valve opening transient using % of maximum C_V values vs. % open

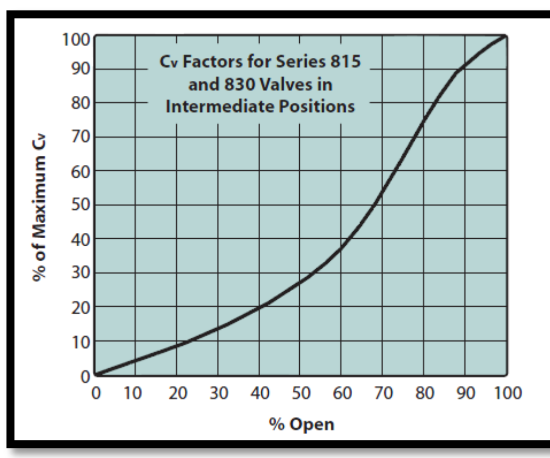

Figure 2 - Jamesbury % C_V vs. % Open

from the Jamesbury catalog. The Sound Suppression Deflector ring, located downstream of the valve complex, consists of an 18” diameter header and (8) 12” diameter branches and nozzles. The ring delivers water directly into the rocket engine exhaust stream to provide sound suppression during lift off.

LOX is supplied to the KW-1 at three different flow rates. A small quantity of LOX is discharged from the engines which would cause damage to the launch pad exhaust hole and flame deflector if not abated. To mitigate this, water is mixed with the discharged LOX to convert it into a gas before it can touch the surfaces of the pad. The cryogenic abatement spray system consists of two flow control valves that produce three flow rates to correspond with the different rates of cryogenic supply. The abatement spray is injected directly under the engines to mix with the LOX streams.   A summary of these flow rates is shown below in **Table 3**. The durations are prior to liftoff (T-0 seconds), and the high flow is held throughout launch.

	Duration (s)	Flow Rate (gpm)
Low Flow	10	450
Medium Flow	10	800
High Flow	10	1,400

Table 3 – Cryogenic Abatement Spray Requirements

Proposed Modifications & Additions to SLC-9 LWS

With the addition of two liquid first stage cores, more water is required for cooling and sound suppression before and during launch. Additional water is needed on the exhaust trench deflector for cooling and there is a new requirement to provide water to the launch pad surface for both cooling and sound suppression. The proposed modifications call for two new sound suppression deflector rings in addition to the existing deflector ring but do not affect the cryogenic abatement spray system. The layout of the proposed modifications to the LWS deflector rings is shown below in **Figure 3**.

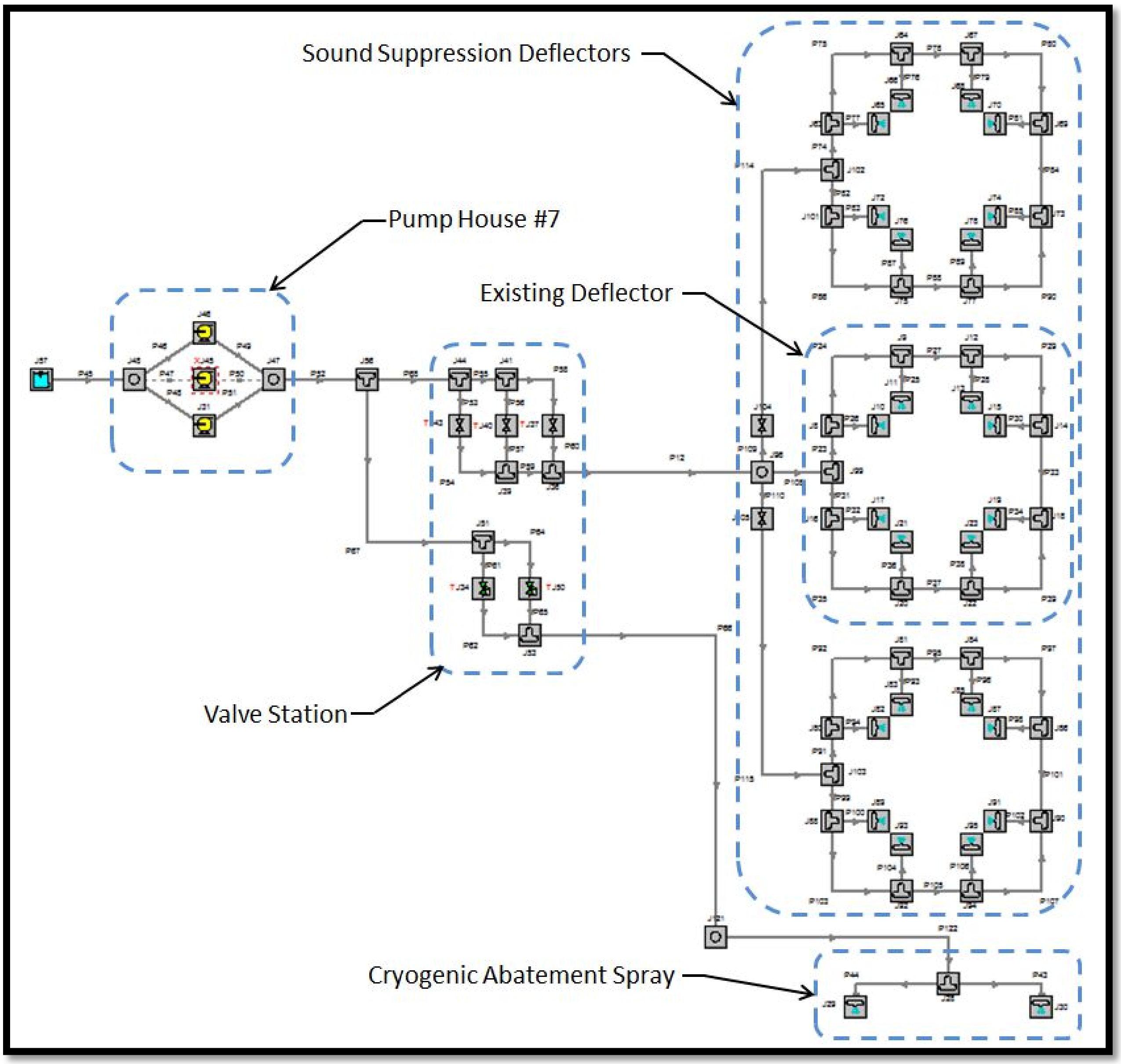

Figure 3 - Proposed Modifications to SLC-9 in Impulse – Additional Sound Suppression Deflector Rings

The existing pumps were capable of providing enough water to satisfy the addition of two deflector rings by increasing the pump speed to 98% of maximum, however, in order to provide enough cooling and sound suppression to the pad surface, a separate system was implemented. Shown in **Figure 4**, four rainbirds (nozzles J55, J25, J26, and J27) spray the pad surface with water just following vehicle liftoff. This water provides additional sound suppression as well as cooling to the pad surface and ground support equipment (GSE). Instead of using pumps, this system is supplied with water from a pressurized tank. This 45,000-gallon tank is pressurized with gaseous nitrogen (GN2) to a pressure of 200 psi. A source of GN2 maintains the pressure nearly constant as the water is withdrawn from the tank. Redundant butterfly valves open just after vehicle liftoff to allow the pressurized tank to supply 100,000 gpm to the four rainbirds.

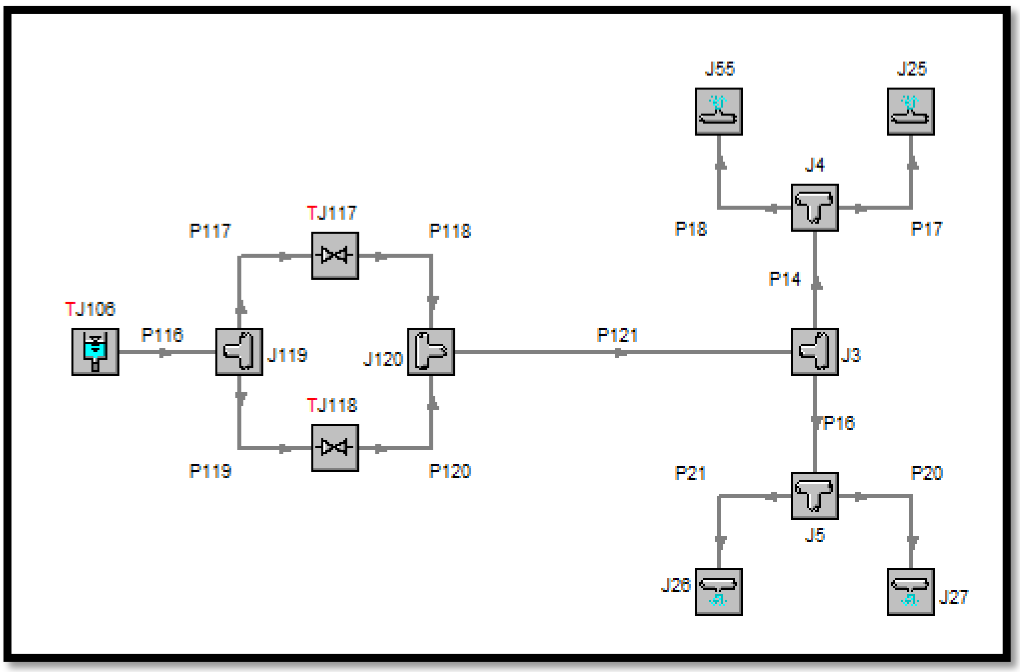

Figure 4 – Proposed Modifications to SLC-9 in Impulse – Additional Tank, Valves, and Rainbirds

The pressurized tank was chosen over using additional pumps because the current pump house would require extensive modifications to create the needed room. The pressurized tank system also has a small footprint that does not greatly impact this environmentally sensitive location. Further, this new system, independent of the current pump system, allows greater flexibility for future modifications of this now multi user pad.

AFT Impulse Results

Current SLC-9 Launch Water System

Shown in **Figure 5** is a graph of the flow requirements of the current sound suppression deflector (blue line) as well as the achieved flow rates modeled in Impulse (red line). The sound suppression valves open at T-5 seconds (5 seconds before liftoff) to allow the system to reach full flow at T-0 (time of launch). Comparison of the required flow versus the achieved flow shows the flow and timing requirements were met for the duration of the launch.

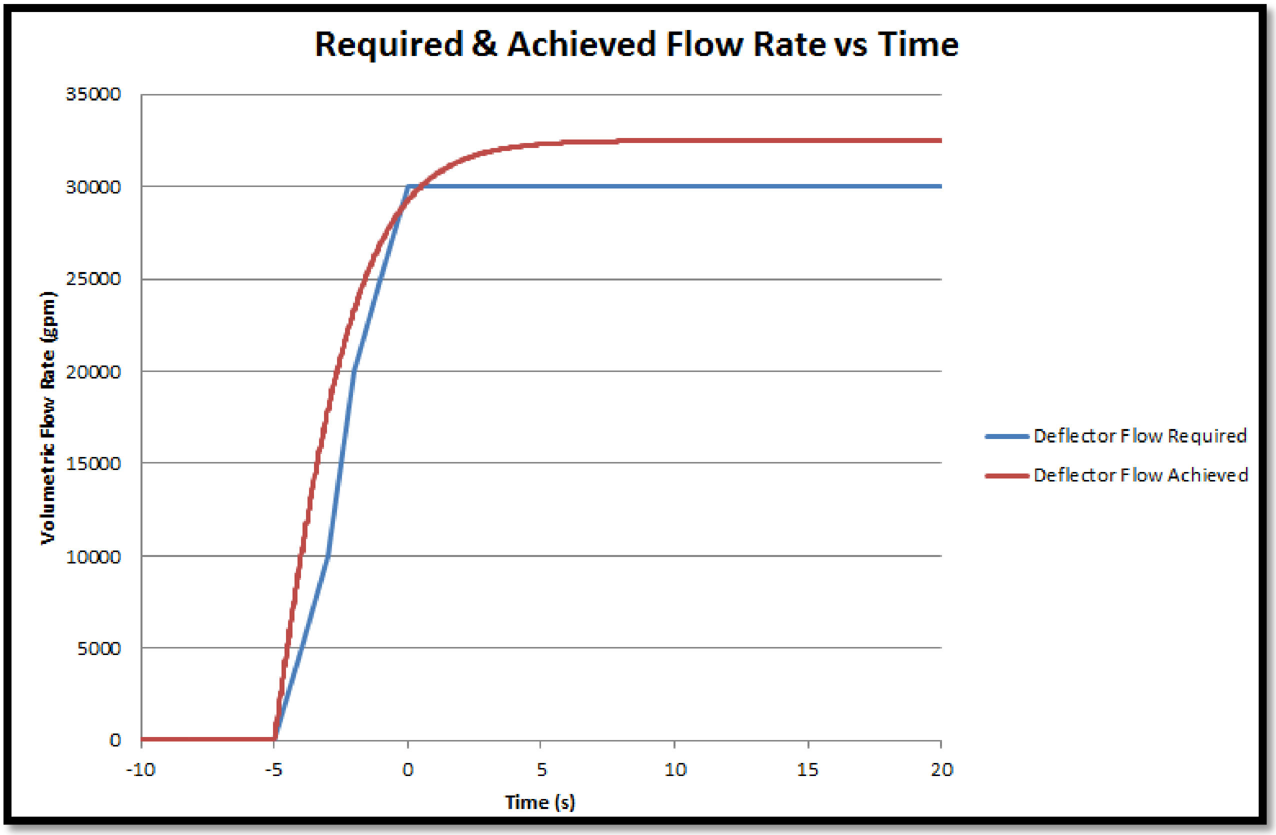

Figure 5 – Sound Suppression Deflector Flow Rate vs. Time – Current Configuration

Figure 6 shows a graph from Impulse of the three flow rates achieved during the Cryogenic Abatement Spray flow. The graph shows that the abatement spray flow requirements (provided in **Table 3**) were met for the full 30 second duration. The disturbance in the graph at time T-5 seconds is due to the Sound Suppression Deflector valves opening.

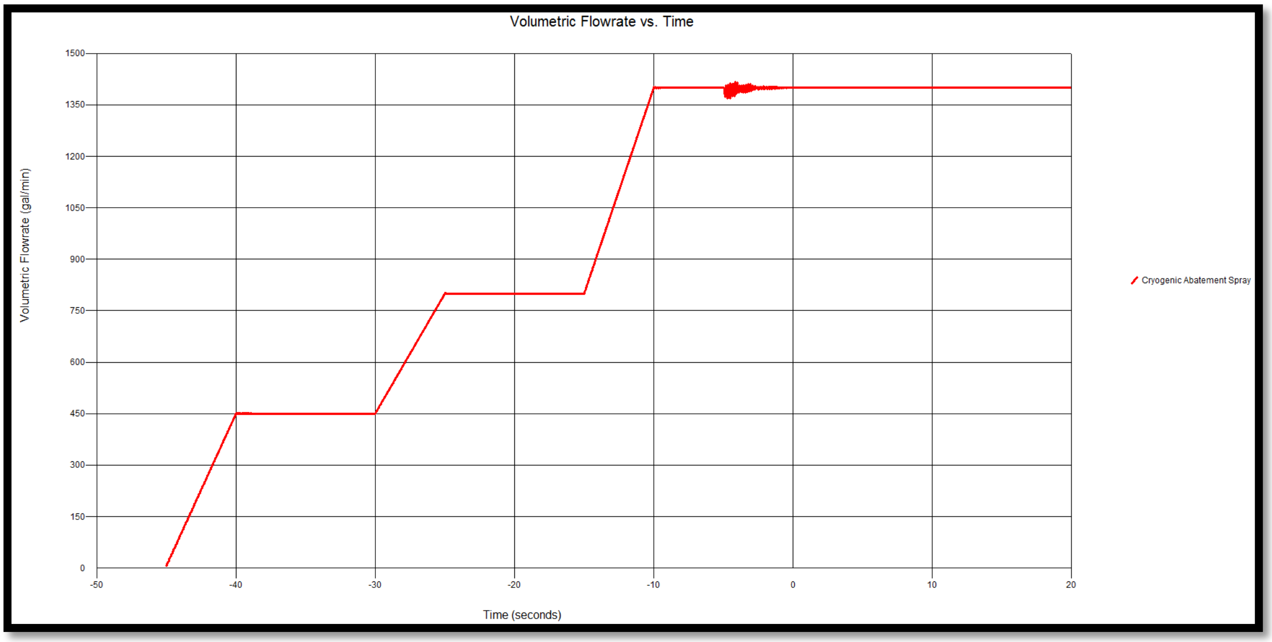

Figure 6 – Cryogenic Abatement Spray – Current Configuration

Proposed Modifications & Additions to SLC-9 LWS

Figure 7 shows the flow rate requirements set by Rocket-Tech (blue line) as well as what was achieved in Impulse (red line). It can be seen that the flow requirements were met with the addition of the new sound suppression deflector rings.

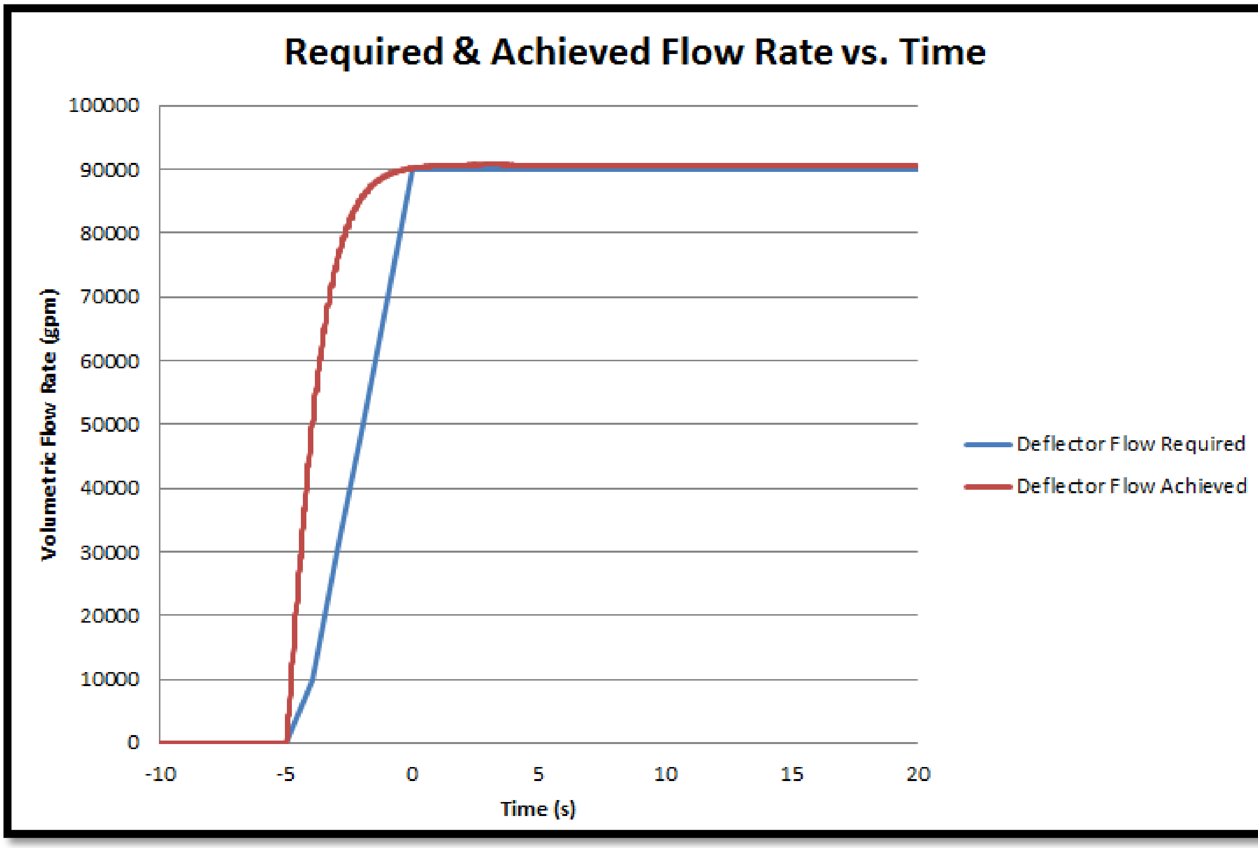

Figure 7 – Sound Suppression Deflector Flow Rate vs. Time – Proposed Modifications

Figure 8 shows the additional rainbird sound suppression system provides sufficient water to the pad surface just after T-0. The achieved flow rate (red line) then drops just below the required flow rate (blue line) due to the supply tank pressure starting at 200 psi and falling to 150 psi. This occurrence was discussed with Rocket-Tech and found to be acceptable due to the rocket having a lesser impact on the pad as it gains altitude. The achieved flow rate falls under the required flow rate at T+5 seconds at which time the vehicle will be an estimated 200' above the pad surface. In the case that this was not acceptable to Rocket-Tech, a larger GN2 accumulator would have been required to sustain the initial pressure for the duration of the launch. The accumulator would require additional infrastructure at the launch facility which Rocket-Tech chose to avoid.

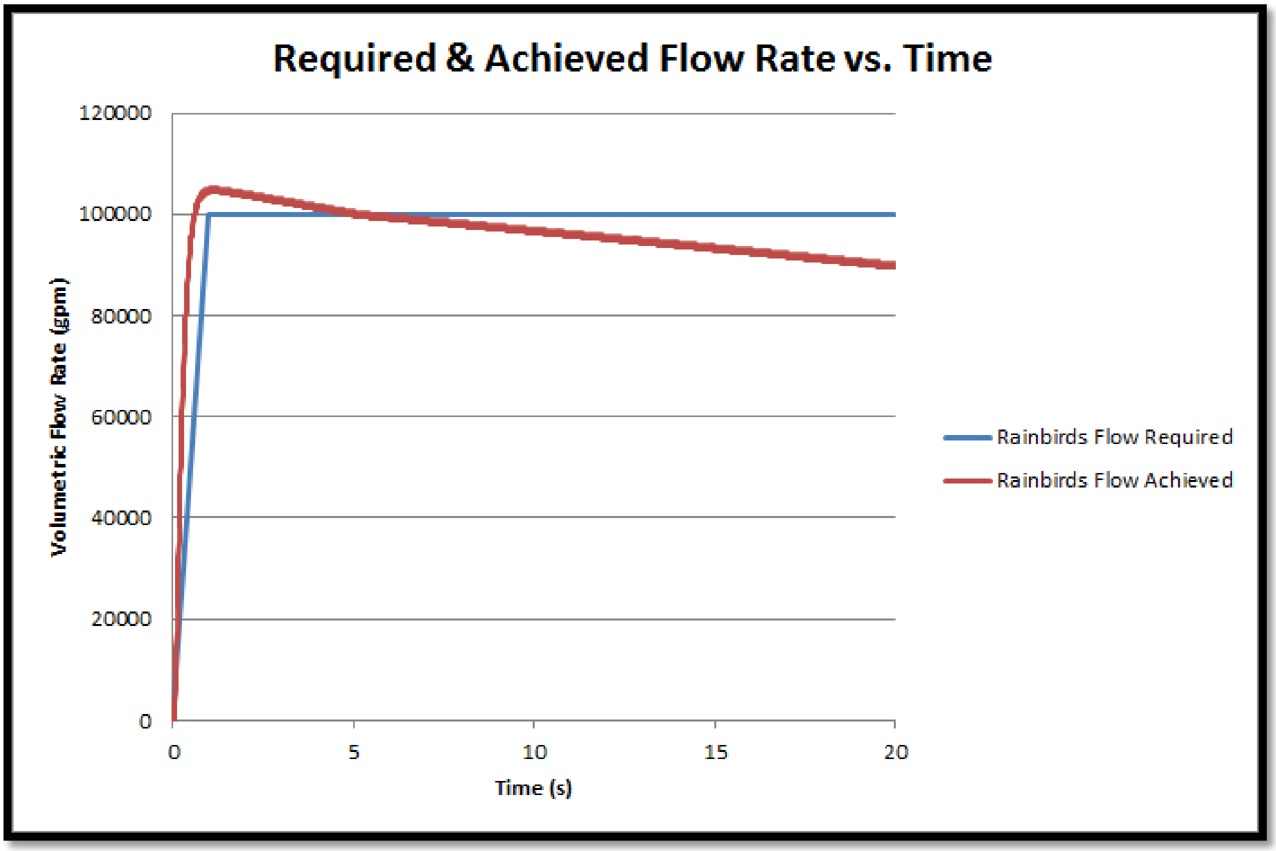

Figure 8 – Sound Suppression Rainbirds Flow Rate vs. Time – Proposed Modifications

Figure 9 shows the modified LWS and also portrays the flexibility that the system now has. Manual isolation valves were included so the LWS can be used for a variety of vehicles (including the single core KW-1). The application shown below, depicts the scenario when the the user has a single core vehicle. For this case, the isolation valves are closed and the pump speed is reduced to provide the appropriate flow rates of sound suppression water. The variable speed pumps are capable of serving both vehicles and are set to 98% for the SRC-13 and to 55% for the KW-1. Additional pump speeds could be used for additional vehicles with different flow requirements.

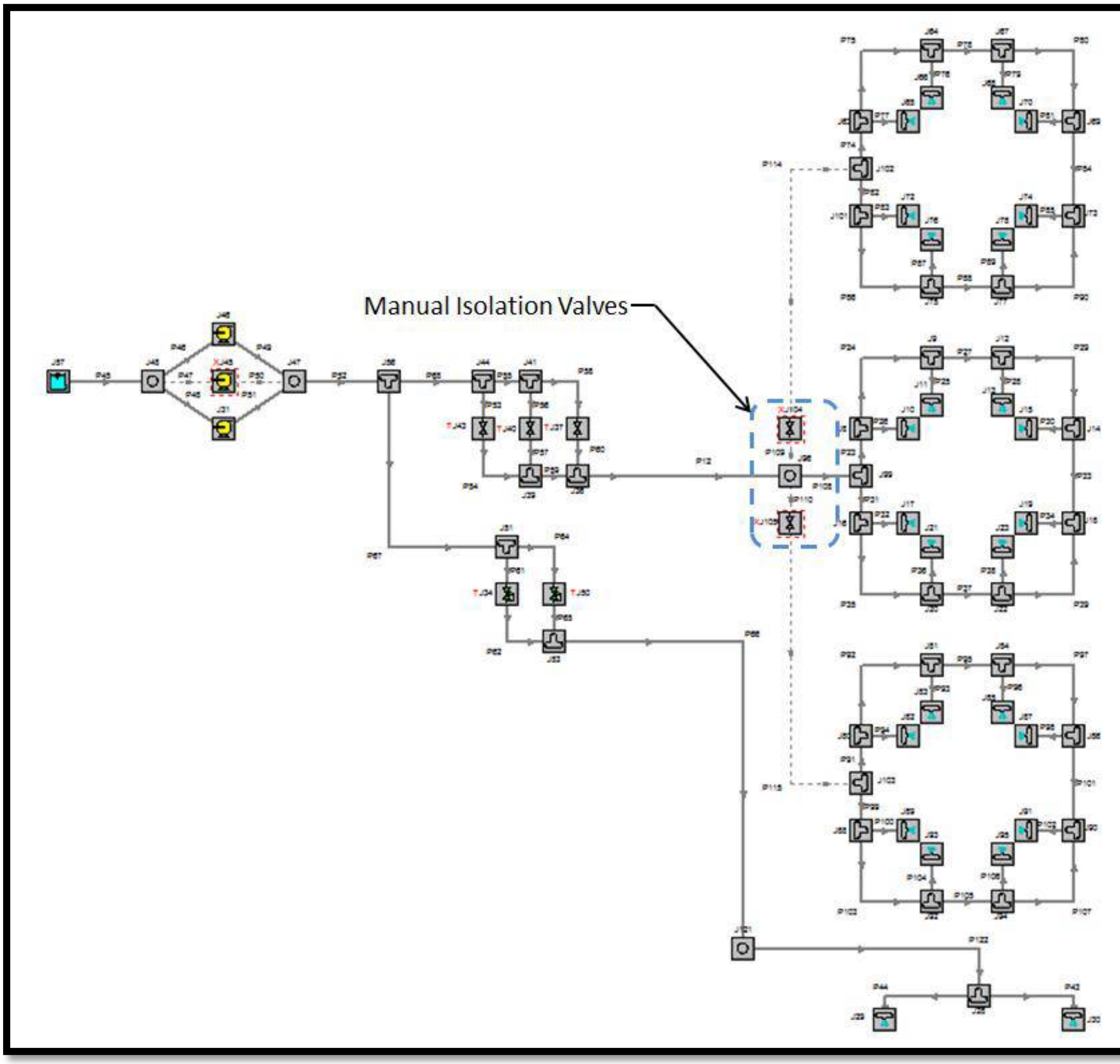

Figure 9 - Proposed Modifications to SLC-9 in Impulse – Sound Suppression Deflectors for Single Core User

Conclusion

The proposed modifications to SLC-9 in support of the SRC-13 rocket meet the requirements set by Rocket-Tech. These modifications also meet Rocket-Tech's intent of minimizing additional infrastructure. The Impulse model used in this analysis is included as part of this submittal. The model provides pipe and component sizes and configurations for both the current and modified systems. The model can easily be updated with any changes in geometry that may occur during the design and construction phases. Once these modifications are complete, the model can be validated using actual flow test results to act as a baseline for future modifications.