FLOWNEX®
SIMULATION ENVIRONMENT

CASE STUDY

SAVANNAH RIVER REMEDIATION

Savannah River Remediation (SRR) is a consortium of companies led by URS Corporation. It holds the Liquid Waste Operations contract at Savannah River Site in which it is tasked with the processing, removal and storage of nuclear waste. The site is a nuclear reservation built during the 1950s to refine nuclear materials for use in nuclear weapons. Nuclear waste that is being currently processed is from work done in the past. Flownex® is used for the simulation of the PVV system.

NUCLEAR & SMR

CHALLENGE:

The challenge was to simulate the Process Vessel Vent (PVV) system which removes toxic gasses that are released from the processing of nuclear waste and vents the gas out to atmosphere. Therefore it is necessary to develop an engineering simulator for the PVV system.

BENEFITS:

- Develop an engineering simulator for the PVV system and benchmark it against measured data.
- The simulator had a customized Human Machine Interface (HMI).
- Potential location of leakages and blockages on the system were identified.
- Capability of using external calculations/correlations which are user-defined.

SOLUTION:

The simulator developed proved to be a valuable tool to predict the location of leakages and blockages in the PVV system. Flownex® can now be used to predict the system conditions at different inputs, and to evaluate the overall performance of the PVV system.

INTRODUCTION

Savannah River Remediation manages the Liquid Waste Operations at the US Department of Energy's Savannah River Site. These include waste solidification during which by-products of nuclear weapons production are vitrified (glassified) and made ready for permanent disposal. In preparing the nuclear waste for vitrification, its slurry is chemically adjusted, stripped of mercury and concentrated through evaporation. It is then compacted through addition of glass frit. During these preparation processes, toxic and/or radioactive gasses are released. The PVV system maintains vacuum in process equipment, in order to limit and mitigate leakage of highly contaminated vapors into atmosphere.

Figure 1: The Defence Waste Processing Facility (DWPF) at Savannah river site.

SYSTEM DESCRIPTION

The PVV includes the blowers, heater, filter, valves, scrubbers, condensers, piping and other equipment necessary for (1) maintaining negative pressures in the process vessels, (2) filtering particulates and (3) discharging the gas flows.

Nuclear waste slurry is chemically adjusted and concentrated in the SRAT and SME prior to feeding the melter. The process, known as vitrification, produces borosilicate glass canisters. In the SRAT and SME processes toxic gasses, which include hydrogen, carbon dioxide, nitrous oxide as well as other contaminated particles, are generated as a by-product of chemical reactions. The tanks are thus purged with air to keep the levels of gas low. This gas flows through condensers, where the vapor within the gas is condensed and separated. One of the desired reactions is to reduce and strip mercury from the sludge. Ideally the mercury exits the condensers with the condensate while the gas flows to ammonia scrubbers. At the scrubbers, the gas flows through packing material whilst being

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sprayed with water to remove contaminated particles. The gases exiting the SRAT and SME scrubbers are sent to another condenser, the FAVC. The gas is cooled further to 10 °C and filtered to remove finer particles. Blowers drive the circulation of the gas to the exhaust where it is released into the atmosphere.

Due to the radioactive and toxic nature of nuclear waste processing, the PVV system and the equipment it serves are located in a secure and sealed off section within the DWPF building. Thus any maintenance or work on the system has to be performed remotely and knowing the location of leaks and blockages can save valuable downtime.

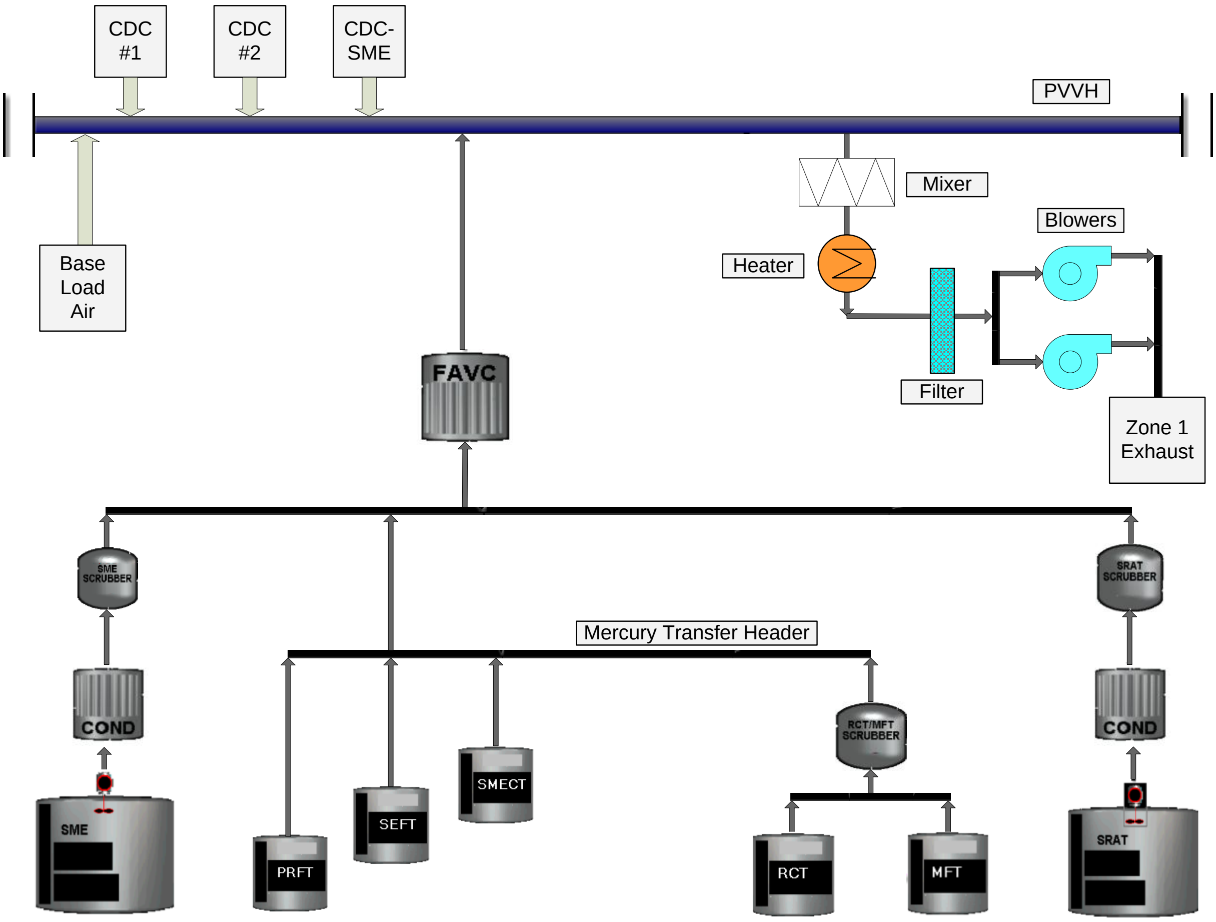

Figure 2: Adiagram of the PVV system.

OBJECTIVE OF SIMULATION

- Develop an engineering simulator of the PVV system.
- Benchmark the simulator against measured data, and
- Locate possible areas on the system where there may be leakages and/or blockages, and any other impediments to the flow through the system.

FLOWNEX MODEL

The Flownex® model of the PVV system is pictured below. One way to improve process efficiency and speed up the SRR process is to decrease concentration times by increasing boiling rates in the SRAT and SME. However, the SRAT and SME must be kept under vacuum so boiling rates are limited by pressure restrictions in the PVV. At increased boiling rates pressure drops across the condenser and scrubber are increased. This is caused by the increased vapor that is boiled off from the tanks at increased boiling rates. To fully account for this phenomenon, a mixture of incondensable air and vapor was used as the working fluid in the network from the boiling tanks to the exit of the condensers.

For the rest of the network, however, the gas composition is similar to that of dry air. Air was used as a working fluid. The yellow boxes in the picture are used for input data (Plant measurements can be added here) and the green boxes display the results. The computer icons are scripts which were used to perform external calculations which were integrated into the model. These included the pressure drop correlation across the scrubbers and display of results in custom units that are familiar to end-users.

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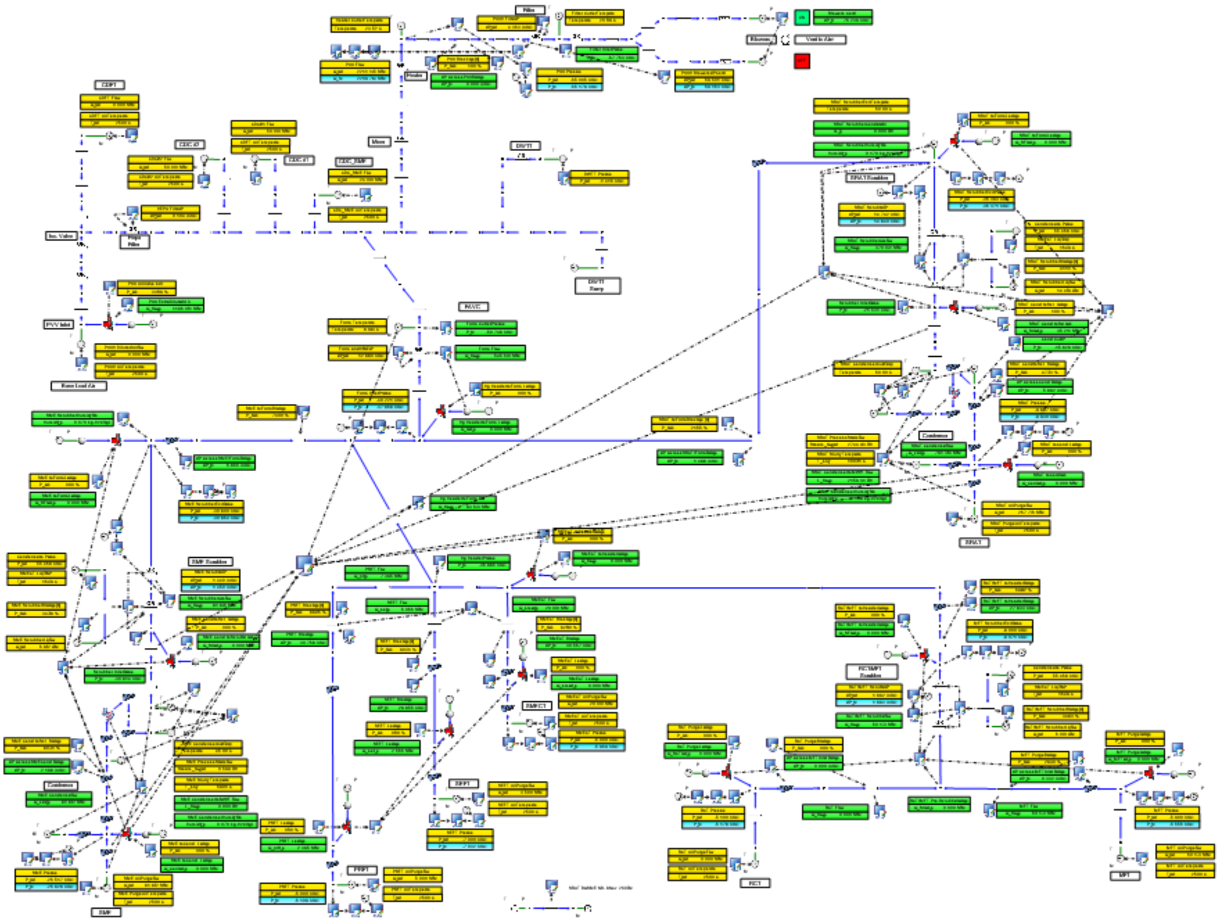


Figure 2: The Flownex® model used for the simulation.

To many users, the engineering model pictured above would look daunting at first glance. So to make the model user friendly and to only display the required results, an HMI was developed. The HMI shows the different sub-sections of the PVV system schematically, as well as a summary of system conditions. Users can fully control the model, and investigate phenomena on the system without working on the engineering model. A few pages of the HMI are shown below:

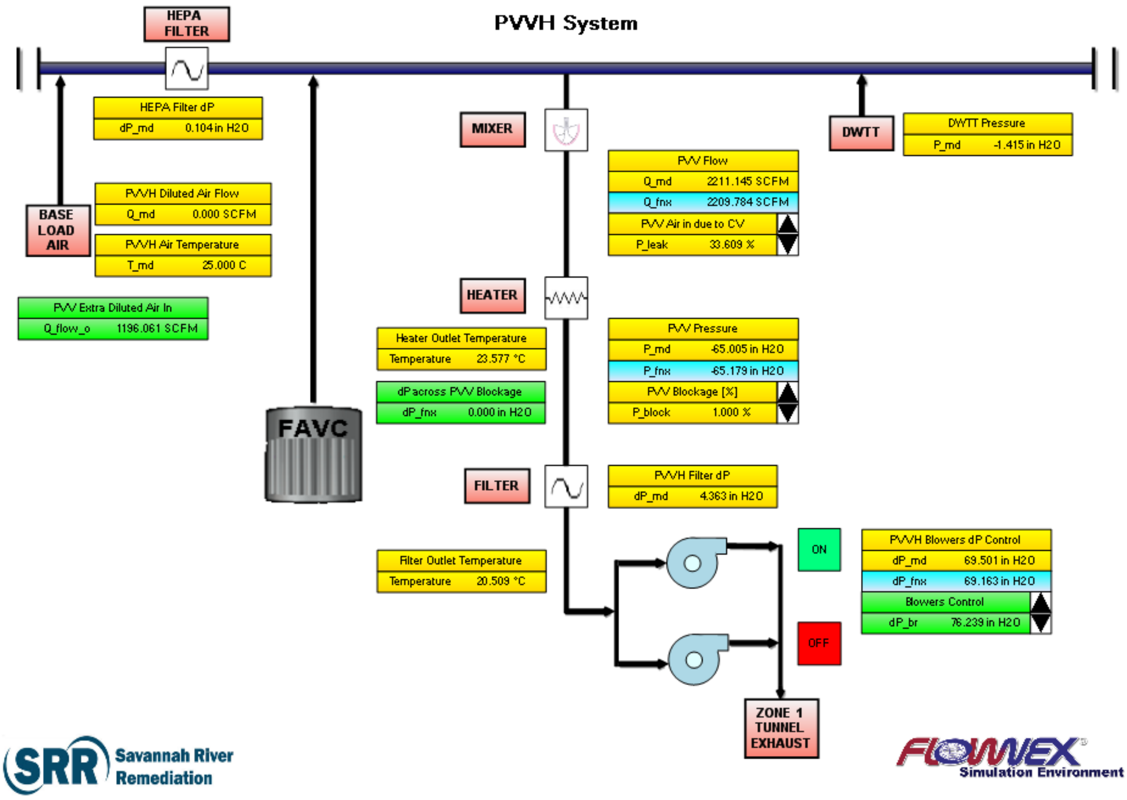


Figure 3: The header and the blowers.

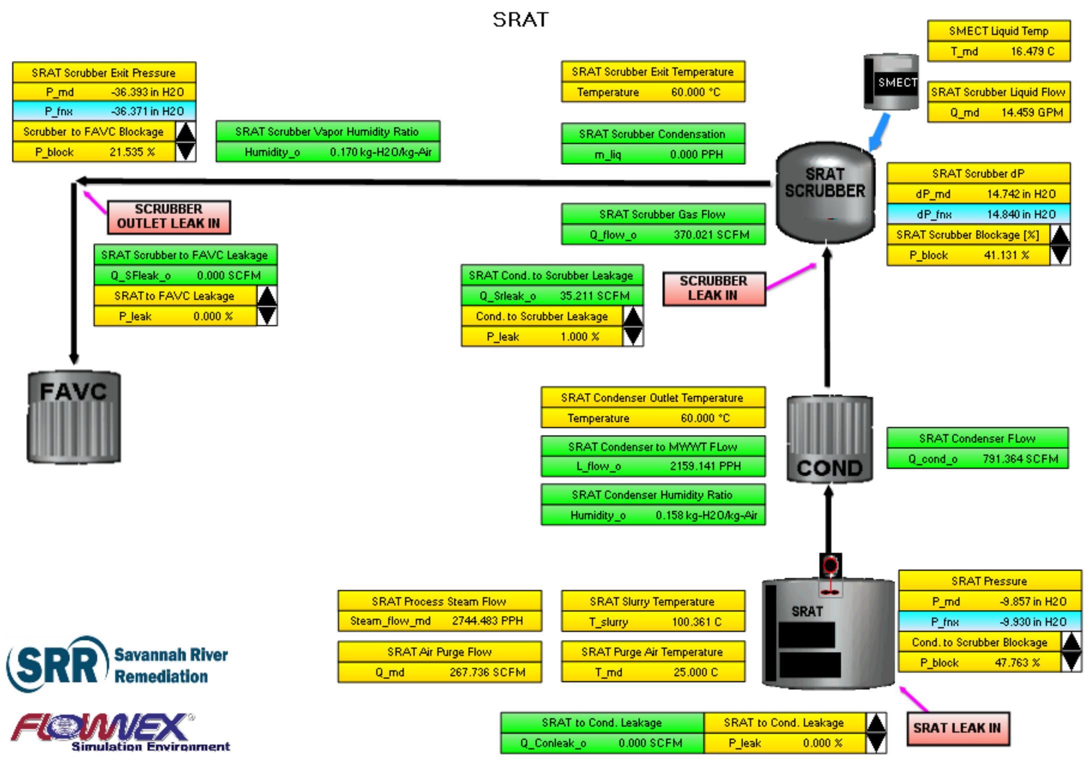
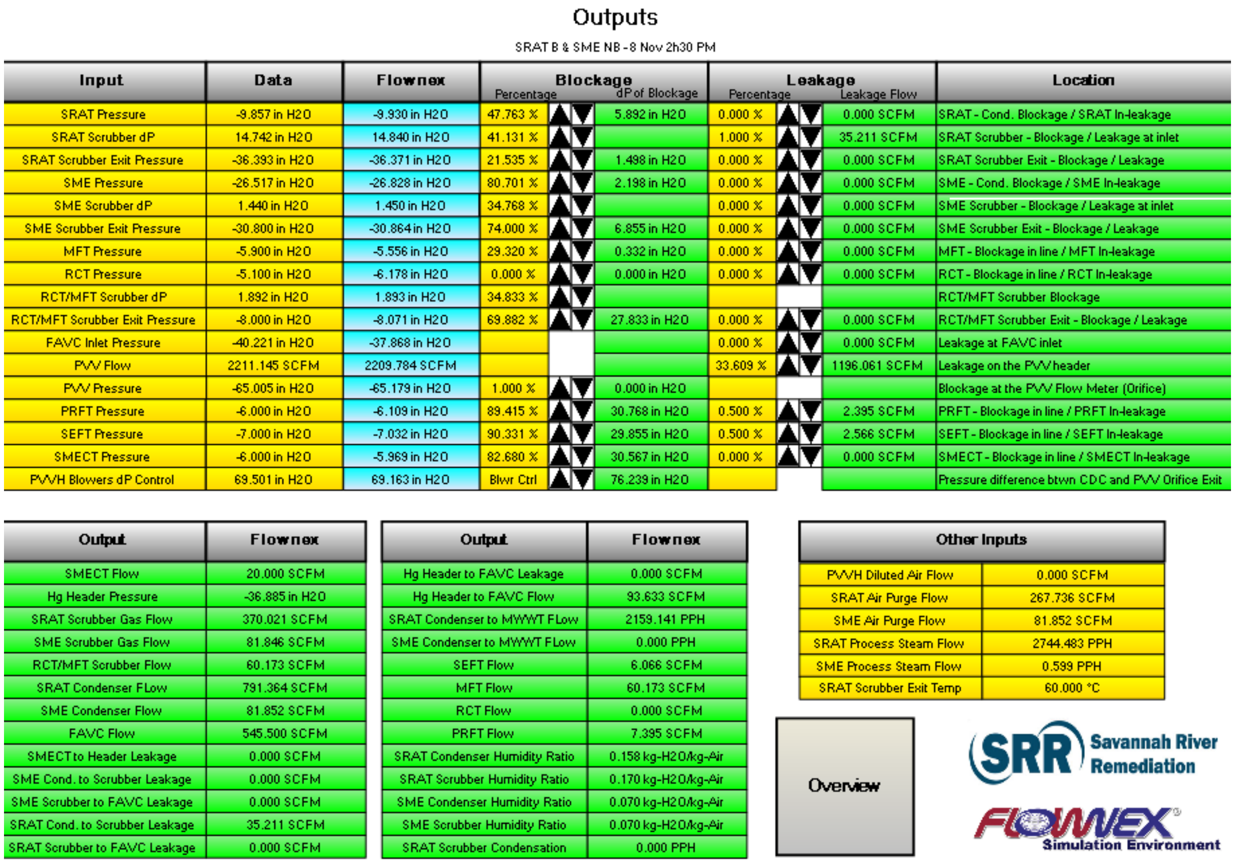


Figure 5: The SRAT, one of the boiling tanks.



Outputs

SRAT B & SME NB - 8 Nov 2h30 PM

Input	Data	Flownex	Blockage Percentage	Blockage dP of Blockage	Leakage Percentage	Leakage Flow	Location
SRAT Pressure	-9.857 in H2O	-9.930 in H2O	47.763 %	5.892 in H2O	0.000 %	0.000 SCFM	SRAT - Cond. Blockage / SRAT In-leakage
SRAT Scrubber dP	14.742 in H2O	14.840 in H2O	41.131 %		1.000 %	35.211 SCFM	SRAT Scrubber - Blockage / Leakage at inlet
SRAT Scrubber Exit Pressure	-36.393 in H2O	-36.371 in H2O	21.535 %	1.498 in H2O	0.000 %	0.000 SCFM	SRAT Scrubber Exit - Blockage / Leakage
SME Pressure	-26.517 in H2O	-26.828 in H2O	80.701 %	2.198 in H2O	0.000 %	0.000 SCFM	SME - Cond. Blockage / SME In-leakage
SME Scrubber dP	1.440 in H2O	1.450 in H2O	34.768 %		0.000 %	0.000 SCFM	SME Scrubber - Blockage / Leakage at inlet
SME Scrubber Exit Pressure	-30.800 in H2O	-30.864 in H2O	74.000 %	6.855 in H2O	0.000 %	0.000 SCFM	SME Scrubber Exit - Blockage / Leakage
MFT Pressure	-5.900 in H2O	-5.556 in H2O	29.320 %	0.332 in H2O	0.000 %	0.000 SCFM	MFT - Blockage in line / MFT In-leakage
RCT Pressure	-5.100 in H2O	-6.178 in H2O	0.000 %	0.000 in H2O	0.000 %	0.000 SCFM	RCT - Blockage in line / RCT In-leakage
RCT/MFT Scrubber dP	1.892 in H2O	1.893 in H2O	34.833 %				RCT/MFT Scrubber Blockage
RCT/MFT Scrubber Exit Pressure	-8.000 in H2O	-8.071 in H2O	69.882 %	27.833 in H2O	0.000 %	0.000 SCFM	RCT/MFT Scrubber Exit - Blockage / Leakage
FAVC Inlet Pressure	-40.221 in H2O	-37.868 in H2O			0.000 %	0.000 SCFM	Leakage at FAVC inlet
PVV Flow	2211.145 SCFM	2209.784 SCFM			33.609 %	1196.061 SCFM	Leakage on the PVV header
PVV Pressure	-65.005 in H2O	-65.179 in H2O	1.000 %	0.000 in H2O			Blockage at the PVV Flow Meter (Orifice)
PRFT Pressure	-6.000 in H2O	-6.109 in H2O	89.415 %	30.768 in H2O	0.500 %	2.395 SCFM	PRFT - Blockage in line / PRFT In-leakage
SEFT Pressure	-7.000 in H2O	-7.032 in H2O	90.331 %	29.855 in H2O	0.500 %	2.566 SCFM	SEFT - Blockage in line / SEFT In-leakage
SMECT Pressure	-6.000 in H2O	-5.969 in H2O	82.680 %	30.567 in H2O	0.000 %	0.000 SCFM	SMECT - Blockage in line / SMECT In-leakage
PVVH Blowers dP Control	69.501 in H2O	69.163 in H2O	Blwr Ctrl	76.239 in H2O			Pressure difference btwn CDC and PVV Orifice Exit

Output	Flownex
SMECT Flow	20.000 SCFM
Hg Header Pressure	-36.885 in H2O
SRAT Scrubber Gas Flow	370.021 SCFM
SME Scrubber Gas Flow	81.846 SCFM
RCT/MFT Scrubber Flow	60.173 SCFM
SRAT Condenser FLow	791.364 SCFM
SME Condenser Flow	81.852 SCFM
FAVC Flow	545.500 SCFM
SMECT to Header Leakage	0.000 SCFM
SME Cond. to Scrubber Leakage	0.000 SCFM
SME Scrubber to FAVC Leakage	0.000 SCFM
SRAT Cond. to Scrubber Leakage	35.211 SCFM
SRAT Scrubber to FAVC Leakage	0.000 SCFM

Output	Flownex
Hg Header to FAVC Leakage	0.000 SCFM
Hg Header to FAVC Flow	93.633 SCFM
SRAT Condenser to MWWT FLow	2159.141 PPH
SME Condenser to MWWT FLow	0.000 PPH
SEFT Flow	6.066 SCFM
MFT Flow	60.173 SCFM
RCT Flow	0.000 SCFM
PRFT Flow	7.395 SCFM
SRAT Condenser Humidity Ratio	0.158 kg-H2O/kg-Air
SRAT Scrubber Humidity Ratio	0.170 kg-H2O/kg-Air
SME Condenser Humidity Ratio	0.070 kg-H2O/kg-Air
SME Scrubber Humidity Ratio	0.070 kg-H2O/kg-Air
SRAT Scrubber Condensation	0.000 PPH

Other Inputs	
PVVH Diluted Air Flow	0.000 SCFM
SRAT Air Purge Flow	267.736 SCFM
SME Air Purge Flow	81.852 SCFM
SRAT Process Steam Flow	2744.483 PPH
SME Process Steam Flow	0.599 PPH
SRAT Scrubber Exit Temp	60.000 °C

Figure 6: A summary of system conditions.

RESULTS

The flow conditions and state of PVV system equipment were benchmarked against measured data. Particles that are boiled off from the boiling tanks were suspected of cooling and settling along the inside of piping and equipment. SRR engineers had found mercury and other deposits inside the system pipes. Another observation was that when the blower speed was increased, there was no corresponding decrease in pressure at one of the boiling tanks, the Sludge Receipt and Adjustment Tank (SRAT). Thus a leak into the system was suspected along the SRAT's flow path.

Through use of the designer feature in Flownex®, a number of leakages and blockages were introduced to the model. The results of the simulator compared very closely to measured data from several tests. Areas that were found to have significant blockages were the scrubbers and the condensers. Thus there may be significant deposits of particles on the inside of the condenser tubes and on the scrubber packing material. Another possibility, which cannot be confirmed due to limited data, is that the scrubbers are flooded, which leads to an increase in the pressure drop.

A sizable leakage into the system was introduced at the SRAT scrubber inlet. With inclusion of the leakage, the pressure drop across the scrubber was matched with measured data from several tests. The engineering simulator was able to replicate the observation that an increase in the blower's speed did not lead to a decrease in the SRAT tank's pressure, but rather resulted in an increase of the leakage introduced. The simulator also showed an increase in the condenser pressure drop when the rate of boiling at the tank was increased.

CONCLUSION

As the engineering simulator was successfully benchmarked against measured data, it could now be used to predict the system conditions at different inputs. SRR is now able to evaluate the performance of the different components of the system on the engineering simulator. Suggestions to improve the overall efficiency of the PVV system may also be tested on the simulator.

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