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**101-SY DOME PRESSURE ISSUES SURROUNDING MITIGATION PUMP
DECONTAMINATION DURING REMOVAL**

WHC-SD-WM-ES-335

REV 0

January 31, 1995

by

S. W. Shaw

Packaging Programs and Testing

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ABBREVIATIONS AND ACRONYMS

CFM	Cubic Feet per Minute
DAC	Data Acquisition and Control
DP	Difference in Pressure
GPM	Gallons per Minute
HEPA	High Efficiency Particulate Air
L	Liter
SSSF	Steady State Steady Flow

atm	atmosphere
cm	centimeter
in wg	inches water gauge
min	minute
psi	pounds per square inch

101-SY DOME PRESSURE ISSUES SURROUNDING MITIGATION PUMP DECONTAMINATION DURING REMOVAL

1.0 INTRODUCTION

During the July, 1993 water lancing in 101-SY, moisture entrained in the exhaust air stream plugged the High Efficiency Particulate Air (HEPA) filters, and resulted in the unplanned shutdown of the K-1 exhaust system. In May of 1994, it was requested that a recommendation be made with respect to the configuration of the ventilation system during removal and decontamination of the SY mitigation pump.

At that time, decontamination of the pump was to be accomplished using a spray ring attached to the pump's load frame located in the pump pit, and two spraywands located in risers (13A and 23A) adjacent to the pump. Present planning calls for the installation of an additional spraywand in riser 3A, raising the total number of spraywands to three. The spraywands offer the benefit of removing a large portion of the waste from the pump prior to the final rinse in the pump pit.

However, use of the spraywands also incurs the liability of increased moisture in the tank dome. This moisture would lead to plugging of the K-1 system's HEPA filters, similar to the incident with the water lancing. Additionally, contamination in the form of aerosols would cause undesirable contamination of the exhaust header. Finally, rupture of the HEPA's resulting from a high differential pressure incurred as a result of their saturation with water was deemed a possibility.

1.1 SY EXHAUST SYSTEM CONFIGURATION

The exhaust system for the tanks maintains them at a pressure less than atmospheric, ensuring that air flows into the tank, providing a means of contamination control. Air enters the tank through a 30.48 cm (12") diameter HEPA filter inlet, and exits through a 30.48 (12") header, which handles the 28320 L/min (1000 CFM) combined air flow of tanks 101, 2 and 3 SY. Dampers are provided at each tank outlet to throttle their individual flow rates through the system. The exhaust air passes through a moisture separator intended to remove entrained moisture. It then flows through a heater section, intended to lower the relative humidity of the exhaust air stream. Finally, it flows through a HEPA filter to remove any entrained radioactive contaminants, and exhausted to atmosphere.

Historically, the moisture handling capabilities of the system have been found wanting. High differential pressures, the result of moisture loading of the HEPA filters, are observed during periods of inclement weather (ie. when it rains).

1.2 INITIAL RECOMMENDATION

Based on the systems lack of capacity with respect to moisture in the exhaust air stream, the potential for contamination of the exhaust header, the remote yet possible rupture of the exhaust HEPA filter, and the high humidity/aerosol content expected for the tank dome during mitigation pump decon, it was recommended that the ventilation system be shut down for the

approximately 45 minutes that it would take to remove the pump mitigation pump from 101-SY.

2.0 ANALYSIS PERFORMED

To determine the possible consequences of shutting down the exhaust system, the 101-SY dome space, and ventilation system were modeled using the GOTHIC computer code to determine changes in tank dome pressure and temperature during operation of the sprays.

2.1 MODEL DEFINITION

For all cases, the initial tank gas space temperature was 32.2 °C (90 °F), and the relative humidity was 20%. Atmospheric temperature was 25 °C (77 °F), and the relative humidity was 33%. For the cases in which the 101-SY ventilation flow was 11,320 L/min (400 CFM), the initial tank pressure was -498.2 Pa (-2" wg). For the cases with zero ventilation system flow, the initial tank pressure was atmospheric.

Water addition to the tank dome space were modeled as wand sprays, which are located within the gas space, and operate at 227.5 L/min (60 gpm), and the spray ring, located in the pump pit, which operates at 454.2 L/min (120 gpm). Flow from the ring sprays was assumed to leak into the gas space as a solid stream of water at the same rate as it was produced. Flow from the wand sprays was assumed to enter the gas space as droplets. The size of the droplets were calculated from a drop size distribution used by Steve Roblyer in previous 101-SY spray calculations. The value used in the analysis was the mean drop diameter, which was determined to be about 6 microns.

2.1.1 Drop Size Issues

The smaller the drop size, the greater the surface area of the injected water, and resulting heat/mass transfer. The nozzles used in the spraywands produce a steady stream of water. What is needed to make the GOTHIC model more closely reflect actual conditions in the tank during mitigation pump decon is a "rebound mean drop diameter," the mean drop size after the solid spray streams have impacted on the pump. The nozzle vendor was contacted in an effort to obtain more accurate data. Not surprisingly, the vendor was unable to supply any meaningful rebound drop size information for sprays impacting a variety of waste coated curved surfaces at an angle. Intuitively, drops on the order of 1500 microns (1/16") were expected however.

A significant amount of energy has been expended in trying to develop a more reasonable approximation of the mean drop diameter. Analysis performed shows that one of the most significant factors effecting the predicted pressure changes in the tank dome is the value used for the drop size. A comparison of Figures 6 (6 micron drop) and 7 (1500 micron drop) demonstrates the significance of drop size on analytical results.

Unable to determine a more realistic value for mean drop diameter, Roblyer's values were used, with the knowledge that this would result in a conservative result.

2.2 CASES OF INTEREST

A number of model cases were run to determine the sensitivity of the tank dome pressure to changes in ventilation flow rates, decon water temperatures, inlet/exhaust riser configuration, the rates at which spraywand flows were increased, and just as a point of interest, one case with the mean drop diameter at 1500 microns (1/16"), as opposed to the 6 microns used in all other cases.

The nine cases summarized in the table below can be used to demonstrate the effects mentioned above. Figures 1 and 2 show the flow rates (instant on) for the spraywands and ring in cases 1 - 6. Figure 9 shows the spraywand flow rates with respect to time for cases 7 - 9, where the wand flow rate was incrementally stepped up to their full 227.5 L/min (60 gpm) flow.

TABLE 1
ANALYSIS CASE SUMMARY

Case Number	Vent Flow L/min(CFM)	Wand Spray Flow L/min(gpm)	Spray Water Temp °C(°F)	Exhaust Damper Setting	Reference Figure #
1	11327(400)	227 (60)	21 (70)	Open	3
2	11327(400)	227 (60)	32 (90)	Open	4
3	11327(400)	227 (60)	43 (110)	Open	5
4	0	227 (60)	32 (90)	Closed	6
5*	0	227 (60)	32 (90)	Closed	7
6	0	227 (60)	32 (90)	Open	8
7	0	227 (60)	21 (70)	Open	10
8	0	227 (60)	32 (90)	Open	11
9	0	227 (60)	43 (110)	Open	12

* 1500 microns (1/16") Used as mean drop diameter.

A comparison of cases 1, 2 and 3 demonstrates the effect of decon water temperature on the dome pressure. Cases 2 and 4 can be compared to determine the impact of turning the ventilation system off, and closing the exhaust damper. Cases 2 and 6 can be compared to see the effect of turning the ventilation system off, with the exhaust damper open. A comparison between cases 4 and 6 demonstrate the effects of opening the exhaust damper, with the ventilation system off. A comparison of cases 4 and 5 demonstrate the sensitivity of the analysis to mean drop diameter. Comparing cases 6 to 8 shows the effect of stepping up the spraywand flow rates, as opposed to the instant on version. And finally, a comparison of cases 7, 8, and 9 demonstrates the effects of water temperature when the spray wands are stepped up to full flow.

Figure 1 Flow Rate vs Time for Spraywands

Figure 2 Flow Rate vs Time for Spray Ring-Instant On

Figure 3 Pressure vs Time for Case 1

Figure 4 Pressure vs Time Plot for Case 2

Figure 5 Pressure vs Time Plot for Case 3.

Figure 6 Pressure vs Time Plot for Case 4.

Figure 7 Pressure vs Time Plot for Case 5.

Figure 8 Pressure vs Time Plot for Case 6.

Wand Flow Rate vs Time

Spray Ring Flow Rate vs Time

Figure 9 Spraywand and Spray Ring Flow Rates used for Cases 7 - 9.

Figure 10 Pressure vs Time Plot for Case 7.

Figure 11 Pressure vs Time Plot for Case 8.

Figure 12 Pressure vs Time Plot for Case 9.

2.3 COMPARISON OF GOTHIC PREDICTED RESULTS TO HISTORICAL DATA FROM WATER LANCING

GOTHIC was used to model the water lancing which occurred at 6:48 AM on July 3, 1993 in 101-SY. GOTHIC predicted results for tank dome pressure are shown in Figure 13. The pressure actually measured in the tank dome during lancing, as recorded by the DACs, is shown in Figure 14. What is observed in comparing the two figures is that GOTHIC predicts the shape of the curve (ie. pressure becomes more negative, and then increases above the initial 498.2 Pa {2" wg} vacuum), but is off with respect to the magnitude of the change, erring on the side of conservatism. In fairness to the code however, in the GOTHIC model the sprays were oriented horizontally, as opposed to the 45° angle down from horizontal as they are on the actual lance. As such, water sprayed from the lance in the model interacts with the air in the dome to a much greater extent than occurred in actual practice.

3.0 PRESENT CONTROLS FOR WATER WAND OPERATION

The present Safety Assessment, LA-UR-92-3196, Rev 12, provides the following controls for use of the spraywands during mitigation pump removal:

- **WATER TEMPERATURE:** Water temperature must be no less than the dome temperature and no greater than the lesser of 11 °C (20 °F) higher than the dome temperature or 54.4 °C (130 °F) unless authorized by the TRG. (Page 6-49)

Figure 13 GOTHIC Predicted Pressure vs Time Plot For Water Lancing.

Figure 14 Pressure vs Time Plot Data from DACs for Water Lancing .

- MINIMUM DOME PRESSURE: The minimum dome pressure may not be less than -1494.5 Pa (-6" wg). Dome pressure is to be continuously monitored, with an alarm at -996.3 Pa (-4" wg). (Page 6-48)
- MAXIMUM DOME PRESSURE: +373.62 Pa (+1.5" wg). Dome pressure is to be monitored continuously, with an alarm at +373.62 Pa (1.5" wg). (Page 6-48)
- WAND FLOW RATE: The flow rate of the wands must be controlled such that the dome pressure remains within ± 249 Pa (1" wg). The maximum ramp rate in flow for each wand is 2 minutes, from 0 to full flow. The water wand operator will be in continuous contact with the person monitoring dome pressure. The water lines shall be equipped with two valves in series, one for slowly increasing the flow, another for quickly closing the flow. Water flow is to be immediately terminated if the dome pressure gets outside the ± 249 Pa (1" wg) pressure control band. Operations is then to wait for the dome pressure to stabilize before resuming water wand operation.

It should be noted that the controls established for spraywand flow rates tend to make the minimum and maximum dome pressure controls redundant. They are also overly conservative with respect to allowable tank vacuum, and could result in unnecessary exposure to personnel performing the task, and additional expense not technically justified.

Controls identified here are provided for within the work plans for mitigation pump removal, or incorporated into the design of spraywand hardware as appropriate.

4.0 PROPOSED CONTROLS FOR WATER WAND OPERATION

An interest in establishing a procedural control which limits the maximum positive tank dome pressure to 24.91 Pa (0.1" wg) has been expressed. There are a number of factors related to the ability to accurately calculate and measure tank dome pressures so close to atmospheric which should be considered prior to insertion of an administrative control so restrictive. What follows is an attempt to identify some of those factors.

4.1 ISSUES SURROUNDING PRESSURE/FLOW CALCULATIONS

For a water addition of 681 L/min (180 gpm), approximately 681 L/min (24 CFM) of air will be displaced. Once a Steady State, Steady Flow (SSSF) condition has been achieved (ie. tank dome pressure has normalized), there are a number of variables which will affect the accuracy of any pressure/flow calculations for the displaced air, and resultant dome pressure. Recalling that flow is a result of a pressure differential, particular emphasis must be placed on those which could impinge flow, with a corresponding increase in dome pressure. Some of these include:

Moisture Content of Air: Saturated air passing through a HEPA filter will tend to load the filter with water. During sub-freezing temperatures, this may translate to an ice build up on the atmospheric side of the filter. Any of these effects would require an increase in dome pressure to induce flow across the filters.

HEPA Filter Cleanliness: The cleaner the filter, the lower the pressure drop.

Moisture Separator: Similar to the HEPA filter, some unknown differential pressure drop will be required to move air through the separator.

Leak Paths: To make an accurate calculation of dome pressure, it will be necessary to know the flow rates for all of the leak paths (other than through the inlet and exhaust HEPA filters), as a function of the pressure differential between the tank dome and the atmosphere. If we assume these leaks to be zero, an increase in dome pressure should be expected, as a pressure differential sufficient to cause flow across the HEPAs would have to be generated.

Pump Removal Rate: Obviously, as the pump is removed from the tank, the tank realizes a corresponding increase in volume, reducing the amount of air which must be removed to allow for water addition.

Heat Transfer Effects: Speaks to water vapor, thermal expansion effects at the waste surface/decon water interface. Heating of the air at this interface would result in an increase in the specific volume of the air.

Most of the factors identified above speak to flow restrictions which would effect the ability of the displaced air to flow from the tank, with a resulting increase in dome pressure. In a phone conversation held on November 14 with an engineering representative of Flanders (manufacturers of HEPA filters), it was stated that a minimum 24.91 Pa (0.1" wg) pressure differential would be required to cause flow across the SY HEPA filters. This value was extrapolated from a performance database, which contains data obtained during performance testing of the filters between 20 - 100% of rated flow. There is a general measure of skepticism regarding this number however, as (681 L/min) 24 CFM is approximately an order of magnitude below the lowest bound of filter testing.

To this minimum value of 24.91 Pa (0.1"), pressure losses across the demisters and friction losses in the duct must also be accounted for. Unfortunately, pressure drop across the demister is unknown, and I have been unable to locate anything which would even begin to suggest what the pressure losses would be for a 681 L/min (24 CFM) flow rate in a 30.48 cm (12" duct) would be, although certainly very small.

4.2 PRESSURE MEASUREMENT RELATED ISSUES

Instrumentation used to measure dome pressure in risers 11-B and 17-B have a resolution of 2.49 Pa (0.01" wg), with an accuracy of ± 12.45 Pa (0.05" wg) at GMS-1. This translates to a measurement error of $\pm 50\%$ with respect to the 24.9 Pa (0.0036 psi) pressure differential we would hope to measure. The error would increase on the way to the DACs, a result of the analog to digital conversion.

Another factor to be considered would be how to handle the discrepancy between the values reported by the two instruments. Past data indicate pressure readings approximately 49.8 Pa (0.2" wg) higher in riser 11-B than those recorded in 17-B, representing a 200% difference in agreement between the instruments at the proposed delta P.

Due to the near zero measurement we would be attempting to make, additional considerations would include the effect of humidity on instrument accuracy, and where the atmospheric pressure is sensed. The dependence on sensing location can best be demonstrated by example. If atmospheric pressure sensors are located in a "shack," DP measurements could be significantly impacted by the operation of an air conditioner, fans, heater operation, etc..

5.0 SUMMARY

Water addition to 101-SY during mitigation pump decon is estimated at 681 L/min (180 GPM), and will displace 681 L/min (24 CFM). If all the displaced air is assumed to flow through a single 30.4 cm (12" riser) ($A=0.07297 \text{ m}^2$ [0.7854 ft^2]), the resultant velocity is 0.1552 m/sec (30.56 ft/min), regardless of pressure. If both inlet and outlet HEPA filters are considered, air velocities drop to approximately .0762 m/sec (15 feet/min). Either of these velocities should be considered well below the capture velocity required to remove any particulate from the tank.

Pressure will continue to build in the dome until sufficient to overcome any impediment to flow. The difficulties associated with quantifying those impediments, and developing any meaningful approximation of tank dome pressure without error bars larger than the proposed allowable differential pressure, if not insurmountable, would at least be impractical to solve. It is important to understand that regardless of differential pressure, air flows will not exceed 681 L/min (24 CFM).

The difficulties associated with the measurement of near zero differential pressures are difficult to overcome. As the difference approaches zero, the percentage error goes to infinity, and the significance of normally trivial factors become large, regardless of how good your instrument is.

As such, the GOTHIC code which was used to model tank dome behavior indicates a SSSF dome pressure of 124.54 Pa (0.5" wg). To set an administrative control less than this value seems excessive. Even at this pressure, instrumentation error would be 10%.

6.0 CONCLUSIONS AND RECOMMENDATIONS

Controls for operation of the spraywands during mitigation pump removal are clearly defined by the Safety Assessment. It could be argued that with respect to limiting dome pressure to $\pm 249 \text{ Pa}$ (1" wg) is excessive, and will result in unnecessary expense, and exposure to personnel. To further reduce the pressure band allowed for wand operation to $\pm 24.9 \text{ Pa}$ (0.1" wg) could very well prevent the use of the spraywands, and would require an upgrade to the instrumentation used to monitor dome pressures. These upgrades would be expensive, as measuring zero costs money.

Westinghouse must verify that the hardware designed for the spraywands and the work plan which defines their use incorporate the controls identified by the safety assessment.