SBS Tank 731 Overflow

Executive Summary

On Thursday, August 7, 2008, at approximately 09:50, the Sulfuric Acid Accumulator (Tank 731) on the SBS unit overflowed, eventually releasing approximately 2000 gallons of 30% sulfuric acid into the containment area. Tank 731 contained a 30% sulfuric acid solution which had been drawn off the T-704 quench separator recirculation line. The sulfuric acid was saturated with SO_2 which flashed out of solution into the atmosphere. The SO_2 gas migrated in a southwesterly direction (wind speed approximately 9 mph) setting off fixed SO_2 alarms on the unit. Multiple contract workers immediately downwind of the release area were exposed to SO_2 vapors, eventually resulting in one (1) DAFW [Days Away From Work] case and three (3) first aid cases.

An Incident Report was created following the incident. An investigation team was formed to determine the root/contributing causes of the incident and to suggest proposals for corrective action.

The team consisted of:

Safety Team Lead - Incident Investigation Team Lead
RCA Site Safety Manager, Turnarounds
OCC Root Cause Analyst
SRU Operation Specialist Board (OSB)
Technical Services Engineer, APS Unit
Safety Superintendent

Chronology of Events

<u>Background</u>

In the SBS unit, tail gas is burned at 1200 ^{o}F with excess air and natural gas in the tail gas combustor F-700. This converts the H_2S to SO_2.

Hot gas effluent from F-700 is cooled in the waste heat boiler E-701. Effluent gas from the boiler enters the venturi quench tower V-703 where it is quickly cooled by direct contact with a 30% sulfuric acid solution to approximately 181 ^{o}F. The 30% acid solution comes from the bottom of the T-704 quench separator and is pumped to V-703 via the quench circulating pumps P-704A/B/C in a continuous loop. The acid concentration is maintained at 30% by purging a small (< 2 gpm) slip stream to Tank-731 acid tank and replacing it with water to maintain the process temperature near 181 ^{o}F. The acid from Tank 731 is then removed either by draining to the process sewers (used as Lakefront pH control) or used as a product elsewhere. As the acid enters Tank 731, it is saturated with SO_2. The design of Tank 731 allows for the gas that is entrained in the acid to degas off to another tower, T 707, where it can be further treated. On Thursday August 7th, when tank 731 tank overfilled, there was not sufficient residence time for the SO_2 entrained in the solution to degas properly. As a result, the acid evolved sulfur dioxide to atmosphere as it overfilled to the ground.

Event Chronology (based on interviews and process control data)

The following chronology represents a best estimate of the sequence of key events associated with this incident. The events and associated time frames were pieced together from witness statements, logs, charts, etc. and may be subject to various sources of error such as memory recall limitations, time discrepancies between different sources of information (e.g. there is a difference in the TDC and the PI times), etc.

08:33 - Board Operator attempts to open control valve F-47706, to begin an acid drawdown from the quench recirculation system. The flow meter does not indicate a flow, so the Board Operator calls the Outside Operator to check and see if the manual block valves at the control valve station are closed. Note: The Board Operator stated/believed that the block valves are normally left in the open position to facilitate conducting this operation remotely.

09:11 - Outside Operator finds that the manual block valves are lined up (open) and has the Board Operator open the control valve to different settings in an effort to troubleshoot the situation. Outside Operator also sees no indication of flow on the flow meter and makes an effort to visually verify that there is no flow. He then begins to work (open and close) the manual block valves in an effort to fix the problem. Note: Process control data indicates that the tank level indicator begins to show an increase in the tank liquid level around this time. Acid level in the tank is approximately 7.2 ft. at this time. Per the interviews, neither the Board Operator nor the Outside Operator had any discussion about opening the bypass valve. The Board Operator did not call for the bypass valve to be opened, and the Outside Operator states that he did not open the bypass valve.

09:25 - Outside Operator finishes his effort to work (open and close) the manual block valves. He reports having heard a clunking sound and thought something might have “broke loose” so he asks the Board Operator to try opening the control valve again. Outside Operator still sees no flow on the flow meter but does not make another effort to visually verify this condition. Note: the tank level is now at approximately 7.7 ft. at this time. Outside Operator gets a call to perform other unit duties and tells the Board Operator to call him when he wants to try again. Outside Operator leaves the manual block valves at the control valve station in the open position. Board Operator leaves the control valve in the closed position (confirmed by process control data).

09:37 - Tank 731 high level alarm sounds in the control room Tank level is at approximately 8.5 ft. Board Operator acknowledges the alarm. About a minute and a half later the alarm is disabled.

09:49 - Alarm B45002L on the Beavon-Stretford unit sounds, indicating an Emergency RGG-One Fire Eye went out. This event and alarm is associated with on-going unit operations to move Pit Sweep from the SBS to Beavon-Stretford.

09:50 - Tank 731 appears to overflow (i.e., chart flat lines).

10:00 - SO_2 alarm (A47710) sounds at 4 ppm, but quickly climb to 25 ppm (maximum instrument reading). At about the same time, emergency alarm B45002LL at the Beavon-Stretford goes off, indicating both fire eyes on the RGG went off, causing it to trip. Board Operator contacts Outside Operator via radio and asks him to check it out at the Beavon-Stretford unit

~10:25 – Based on interviews, at approximately this time exposed workers make their way to area southeast of affected area and report odor and irritation problems to their Job Rep.

~10:31 – Based on interview with Outside Operator, at approximately this time the manual block valves around the control valve were closed by Outside Operator.

10:48 - BP ambulance requested

10:54 - Unit evacuation alarm sounded by unit asset supervisor

11:33 - SO_2 concentration drops below 4 ppm (alarm set-point) on analyzer (A47710).

13:18 - SO_2 concentration is non-detectable at analyzer (A47710).

Root Cause Analysis

In analyzing this incident, the team developed a detailed timeline of key events to help in the identification of critical events and contributing/critical factors.

Findings:

Immediate Causes

Actions:

1.1 Violation (by individual)
At approximately 09:37 a high level alarm sounded on Tank 731. The Board Operator acknowledged the alarm but took no action in response, reporting that he believed the liquid level was "tickling" the sensor and triggering a false alarm. The Board Operator had previously attempted to fill the tank, but believed that there was no flow into the tank because the flow meter to the tank was not working. However, during the previous 26 minutes, the liquid level in the tank had risen 1.3 ft. (from 7.2 ft. to 8.5 ft.) representing a flow rate of approximately 25 gpm (about what would be expected from a fully open control valve or bypass valve). The available evidence should have been sufficient to give the Board Operator a clear indication that Tank 731 was indeed filling and required immediate attention.

4.1 Distracted by other concerns

The Board Operator reported that he was distracted by other concerns related to transferring the Pit Sweep from the SBS to the Beavon-Stretford which demanded his attention during the time of this incident. An alarm indicating that the Emergency RGG-One Fire Eye went out sounded at approximately the same time as the SO_2 alarm.

4.4 No warning provided to workers downwind

No warning was provided to workers downwind of the immediate release area that there had been a release of SO_2 gas at the SBS until the unit evacuation alarm sounded at 10:54 (approximately 54 minutes after SO_2 was detected by analyzer A47710). While there is not a written unit procedure, interviews indicate that the standard response to an SO_2 alarm on the SBS unit is to have an operator conduct a field assessment of the situation. There is not a specific ppm limit designated as must evacuate the unit. Additionally, the time required to conduct this assessment can vary based on the specific unit circumstances. In this case, 31 minutes transpired from the time the SO_2 alarm sounded until the Outside Operator reached the unit, conducted an assessment, and implemented measures to stop the release. **The response time was inadequate to protect adjacent workers from exposure.** SO_2 continued to evolve off the spilled sulfuric acid for another 23 minutes before the evacuation alarm was sounded. By this time the ambulance had already arrived on scene to transport an exposed employee to the hospital.

Interviews with operations personnel did not produce a clear reason why the response to the SO_2 alarm took 31 minutes. The only explanation was that there was not a sense of urgency since, in their experience, previous SO_2 alarms were attributed to minor releases which did not require a unit evacuation.

Conditions:

5.5 Warning Systems not effective

When the SO_2 analyzers on the SBS alarm, they trigger flashing strobe lights on the unit. However, as there is no audible alarm, these strobe lights are only effective if they are within the workers line of sight. Several of the exposed workers were over 100 yards from the unit and were not able to see the flashing lights. As SO_2 is a gas, it has the potential to travel away from the unit and around objects to reach workers who may not be able to see the flashing strobe lights. The upper detectable limit of the analyzers is 25 ppm. During the incident, analyzer A47710 maxed out at 25 ppm almost instantly, making it impossible to determine the actual SO_2 concentration during the incident. The Field Operator has no mechanism for distinguishing between these conditions. The Board Operator can observe the analyzer reading but does not routinely communicate this information to the Field Operator. Additionally, there is not established criteria in a procedure for what SO_2 levels and/or alarms constitutes an emergency condition which should trigger sounding the evacuation alarm. Unit training information does contain information on the hazards of SO_2, including IDLH (Immediate Danger to Life and Health) information, but this information has not been instituted in standard operating / emergency procedures.

Also, as noted below, one of the Tank 731 high level alarms was not functioning. None of the alarms were designated as critical alarms which may have elicited a higher degree of attention amongst the competing priorities of the Board Operator.

6.1 Plant/Equipment malfunction

Significant attention was focused on the functioning of control valve (F47706). Both the Board Operator and the Field Operator stated that they believed that there was no flow entering Tank 731 because they saw no flow reading on the flow meter. However the data shows that the Tank 731 began filling around 09:11 (around the time that the operator began working the block valves) and continued to fill even when the control valve OP indicated it was closed. At about 09:25 the Board Operator opened control valve F47706 to 44% OP for about two minutes, then closed it. The manual block valves were all left in the open position. Tank 731 continues to fill at the rate of about 25 gpm (which is equivalent to the flow through a fully opened control valve or bypass valve) until it overflows at approximately 09:50. Potential explanations for how the tank continued to fill despite the control valve F47706 appearing to be closed, include: 1) a broken valve stem, 2) the by-pass valve was open, 3) instrument air failure, or 4) the valve simply stuck open. In response to scenario #1, control valve F47706 was inspected post incident and found to be in good operating condition. In response to scenario #2, the Outside Operator stated that the by-pass valve was never opened during this operation. In response to scenario #3, it was verified that the control valve would air fail closed so an instrument air failure was ruled out as a potential cause. In response to scenario #4, the control valve did not stick or hang-up during post incident testing. This left the team to conclude that the most likely explanation for why Tank 731 continued to fill being a temporarily stuck control valve or the bypass valve being inadvertently left open (differing from Field Operator interview statements).

In addition, at the time of the incident, the drain from the containment area to the process sewers was plugged and water had backed up in the containment area flooding the trench that the Tank 731 overflow pipe discharged to. Rather than flow through the trench into the process sewer, the liquid spread out on the ground near the base of the tank. .

7.6 Unanticipated exposure to hazardous chemicals

Unanticipated exposure to hazardous chemicals (SO_2) was the most immediate cause of worker injury associated with this incident. When tank 731 overfilled SO_2 was released to the atmosphere. The design of tank 731 allows for vapor that is entrained in the acid to degas off to another tower, T 707, where it can be further treated. As this tank overfilled there was not sufficient residence time for any SO_2 entrained in the solution to degas properly. As a result of this, the acid evolved sulfur dioxide to atmosphere as it overfilled to the ground. The MSDS describes SO_2 as a colorless gas with a pungent odor. It causes respiratory tract, skin and eye burns at high concentrations. Workers who were exposed to the SO_2 gas during the incident reported feeling a burning sensation in their eyes, nose, throats, and lungs. Figure 1 shows the approximate location of the workers who were exposed to the SO_2 in relation to Tank 731. At the time of the release, the wind was the NNE at about 9 mph.

System Causes

19.1 No work planning or risk assessment performed

The unit could not produce evidence that it had conducted a risk assessment and developed operating procedures that adequately accounted for the risk associated with the acid drawdown and tank filling operation. The design of Tank 731 included controls such as a process vent routed to T-707, the goose neck in the overflow pipe, and RV that adequately controlled the release of SO_2 during normal operations. However, the operators involved in this incident did not demonstrate an awareness of the risks associated with overflowing the tank and potential to generate high concentrations of SO_2 if the sulfuric acid was spilled. Furthermore, during the incident, the both the Outside Operator and Board Operator (who ultimately makes the decision to conduct the acid drawdown) did not appear to have a full awareness of all the work being performed on or near the unit, making decisions concerning the appropriate response more difficult.

21.4 Incorrect adjustment/ repair/ maintenance

At the time of incident, flow meter (FT47706) and level transmitter (L47731A) were not functioning properly. The flow meter (FT47706) appears to have not been working the previous time the tank was filled, however, no work order had been written to fix it. On August 7, neither the Board Operator nor the Outside Operator were aware that the meter was not functioning leading them to believe that the tank was not filling when, in fact, it was.

Level transmitter (L47731A) was a redundant level sensor on the tank. The readings from this transmitter had been erratic since about January 2006. A work order was written to repair the transmitter in July 2008 (D-04304). Work was performed on it on July 25, but it appears that the transmitter still was not functioning properly at the time of the incident leaving only level transmitter (L47731) working properly. Both transmitters had high level alarms. The high level alarm on transmitter (L47731A) was set to alarm at 7.5 ft. The high level alarm on transmitter (L47731) was set to alarm at 8.5 ft. So effectively, one of the high level alarms was not working detracting from the effectiveness of the alarm system.

Concerns were expressed during the interviews about the large backlog of maintenance work orders associated with unit equipment. A review of safety work orders revealed that the average age of a "safety" work order on the unit is about 86 days. The target for completing safety work orders is 4 weeks.

22.1 Lack of SPP for the task

Currently there is no risk assessed operating procedure for drawing down acid and filling Tank 731. The valve configuration on the acid line to Tank 731 includes block valves positioned on the inlet and outlet side of the control valve. The investigation team received conflicting statements about the routine positioning of the block valves at the control valve station. Some employees indicated that it was standard practice to leave the block valves open so that the operator could initiate the acid drawdown process without having to involve the Outside Operator to reposition the valves. Others indicated that it was standard practice to close the block valves when not engaged in filling the tank. The latter practice would have prevented this incident from occurring. There are not specific unit procedures or other protocols which define critical operational parameters such as the sequence of steps required to initiate the drawdown process (e.g., notification of Outside Operator, manual block valve positioning, etc), process control parameters (e.g., drawdown initiation and endpoint, specified flow rate into the tank, etc.), the safe level at which Tank 731 is considered full, the sequence of steps necessary to conclude and secure the tank filling process (e.g., closing block valves), and appropriate response to alarms.

23.1 Communication between work groups not effective

Effective communication is critical to the proper handling of an emergency. The investigation revealed several gaps in communication that occurred during this incident. As noted earlier, there was inadequate communication from BP operations to contractors working in the area that an incident involving the release of sulfuric acid had occurred and that the SO_2 alarms had sounded. There was also a lack of communication back to the Board Operators about worker exposure and the resulting affects. It was not until the Shift Supervisor arrived on-site and received information about both the incident that had occurred and the effect it was having on workers, that a decision was made to sound the unit evacuation alarm.

Safety Policy C-13 “Evacuation / Sheltering Plans for Buildings and Units” states

> *At units, any employee shall assess the situation and determine what level of evacuation and what equipment shutdown is necessary to ensure the safety of all personnel, mitigate the environmental impact and potential for equipment/property damage. When in doubt, evacuate.*

The Outside Operator stated that he felt he had the authority to call for a unit evacuation but was not sure that conditions were bad enough to make that call during this incident. The Outside Operator had no knowledge of the fact that the SO_2 analyzer had maxed out at 25 ppm or even that the IDLH (Immediate Dangerous to Life and Health) concentration for SO_2 was 100 ppm, but he clearly understood there was a significant release ongoing. In his interview, he stated that he smelled the release and saw a considerable amount of material on the ground venting/bubbling. The Outside Operator may have put himself at risk by entering the immediate release area to close the manual block valves. The appropriate course of action would have been to declare an emergency and allow the emergency response team (wearing proper PPE) to handle the situation. Critical time was lost in the assessment of the conditions associated with this incident and the improper communications that entailed.

Finally, the Board Operator failed to communicate the high level tank alarm to the Outside Operator who could have taken steps to close the manual block valves and stop the flow of acid to the tank.

13.4 Incorrect behavior not confronted
Investigation interviews and the team's own recollections concerning previous emergency incidents across the site indicate past examples of where units were not properly evacuated in situations where workers may have been at risk. The team discussed previous examples of where units were not evacuated by blowing the evacuation horn, but rather by operations personnel walking through the unit and stopping work. These past examples have set a incorrect precedent on how to address situations where unit evacuation may be required and are contrary to the C-13 policy statement, "When in doubt, evacuate." Additionally, since these past examples were not confronted and/or corrected at the time, an underlying reluctance to "hit the evacuation horn" is apparent among some operations personnel. In this incident, the Outside Operator stated that he was "not sure that conditions were bad enough to make that call".

Recommended Corrective Actions

1. Operator duty to respond appropriately to alarms needs to be reinforced with the work force.
2. Two alarm points (high and high/high) should be established for each of the redundant level sensors on Tank 731. The high alarm should be designated as a critical alarm given the risks associated with overflowing this tank.
3. Consideration should be given to establishing two alarm set-points for the SO_2 analyzers. The current alarm set-point at 4 ppm provides an important warning of the release of SO_2 gas that should be investigated. Consideration should be given to establishing a second alarm set-point at a level that triggers an immediate evacuation alarm (e.g., when the instrument maximum reading is reached).
4. Implement new control of work procedures to achieve to achieve better operational awareness and control of work being performed on the unit. Process hazards and potential risks associated with operational activities should identified by the AA and communicated to the PA for inclusion in risk assessments and crew reviews to improve the awareness of all work groups about the area hazards. Utilize process risk assessment to make more informed decisions about when to best schedule potentially hazardous operations to minimize potential risk to work crews.
5. Develop a risk assessed procedure for the acid drawdown process in accordance with Policy D-22 which defines critical operational parameters such as the sequence of steps required to initiate the drawdown process (e.g., notification of Outside Operator, manual block valve positioning, etc), process control parameters (e.g., drawdown initiation and endpoint, specified flow rate into the tank, etc.), the safe level at which Tank 731 is considered full, the sequence of steps necessary to conclude and secure the tank filling process (e.g., closing block valves), and appropriate response to alarms.
6. Consideration should be given to conducting a gun drill on the unit (last one conducted in 2005) with a focus on how to recognize and report emergency response conditions, proper communications, and the circumstances under which a unit evacuation should be conducted.
7. Unit evacuation procedure should be revised and emphasize that employee shall assess the situation and determine what level of evacuation is necessary to ensure the safety

of all personnel as stated in Safety Policy C-13. Consideration must include ongoing SIMOPs (as posted on CoW boards) in determining evacuation requirements.

8. Convene a cross function team of refinery and OCC personnel to examine "protection of workforce" issues. Areas of focus should include:
   - Evacuation – understanding and awareness of workforce
   - Evacuation – when to activate

   Specific issues to consider include:
   - Identification of potential conditions that could lead to loss of containment by the process unit.
   - Identification and planning to evac during unit upsets and transients, loss of instruments / view, exceeding safe operating limits / critical alarms, loss of level or filling a drum / tower, etc.

     Team recommendations should apply site-wide