FINAL REPORT
Crude Oil Storage Tank Vent Snow Damage



Report Prepared for:

PRINCE WILLIAM SOUND RCAC
REGIONAL CITIZENS' ADVISORY COUNCIL

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The opinions expressed in this PWSRCAC commissioned report are not necessarily those of PWSRCAC.

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ACRONYMS & ABBREVIATIONS

AAC – Alaska Administrative Code

ADEC – Alaska Department of Environmental Conservation

AKOSH – Alaska Occupational Safety and Health

APSC – Alyeska Pipeline Service Company

AST – Aboveground Storage Tanks

ETF – East Tank Farm

FLIR – Forward Looking Infrared

LEL – Lower-Explosive Limit

MP – Monitoring Procedure

PWSRCAC – Prince William Sound Regional Citizens' Advisory Council

TAPS – Trans Alaska Pipeline System

TK – Tank

VMT – Valdez Marine Terminal

1.0 EXECUTIVE SUMMARY

Background

In March of 2022, Prince William Sound Regional Citizen's Advisory Council (PWSRCAC) informed Taku Engineering that the snow accumulated on Alyeska Pipeline Service Company's (APSC or Alyeska) crude storage tanks at the Valdez Marine Terminal (VMT) had damaged several of the tank pressure vacuum pallets (or vents). The vent damage caused crude vapor to leak from the headspaces of the tanks. PWSRCAC requested that Taku Engineering (Taku) provide technical support during an investigation of the damage, the associated vapor release, Alyeska's response, and the proposed repair methods. This report presents the findings associated with that effort.

Snowfall for the 2021-2022 winter was not exceptionally high. Utilizing a 5-year benchmark, the accumulated snow depth that led to the tank vent damage was 25-30% lower in 2021 than in 2016. The snow accumulation was within the level that should have been anticipated.

The vent damage ranged from slightly bent tank nozzles to vents or tank nozzles sheared completely off the tanks. During a March 31, 2022, meeting with PWSRCAC, APSC indicated that 12 of the 14 active crude tanks had suffered some vent damage and that 11 of the vent nozzles had been sheared off by the moving snowpack. During that same meeting, APSC indicated that the oxygen (O_2) content in the low-pressure vapor header piping never went above 6.0%. APSC also noted that when headspace quality was checked at a tank thief hatch, the O_2 content was below 5%.

In April of 2022, PWSRCAC submitted a request to Alyeska for documents intended to provide clarification around the level of damage to the tank vents. Additionally, PWSRCAC submitted a request for operational data on the tank vapor system and O_2 concentration measurements. This operational data was intended to support calculations to determine the O_2 content in the headspace of the damaged tanks during the period when peak O_2 concentrations were measured in the low-pressure vapor header. To date, Alyeska has not provided the requested data.

In June of 2022, PWSRCAC provided the same information request to Alaska Occupational Safety and Health (AKOSH) who then passed that request on to Alyeska. APSC provided the requested documentation and data information to AKOSH in a timely fashion. AKOSH subsequently passed the applicable documents on to PWSRCAC in July 2022.

The vapor system has an extremely limited number of O_2 monitoring points. However, Taku was able to use the limited data available to complete a mass balance, which approximated the O_2 content of the tank headspaces during the period of peak O_2 content in the tank farm low-pressure header.

Conclusions

Based on the information provided by APSC during the site visit, and data received through AKOSH and Taku's analysis, the following conclusions can be drawn:

1. During the period of peak O_2 levels in the low-pressure vapor header, there is a very high probability that the headspace in one or more of the crude tanks was above the lower-explosive-limit (LEL). This means that the presence of a spark or flame source could have resulted in a fire or explosion.
2. The VMT has no fixed instrumentation that can readily identify vapor releases, such as those that would be expected as the result of the tank vent damage.
3. The tank headspaces are not homogeneous. Collection of gas readings at a single test point (i.e., the thief hatch) will not provide an accurate composite reading of the gas composition throughout the headspace.

4. The existing vapor system oxygen monitoring points are inadequate for identifying abnormal operating conditions (high oxygen content) in a single tank headspace.
5. On 3/31/22, APSC met with PWSRCAC to share that there had been a slight increase in O_2 levels in the low-pressure header. They went on to say that the increase was so minor that it didn't require any shutdown or alarm. However, a slight increase in the O_2 levels in the low-pressure vapor header can be indicative of a much higher O_2 level in one or more of the tank headspaces.
6. The lack of accurate information on the gas quality in each tank means that the workers clearing the tank roofs may not have been provided accurate information regarding the actual headspace conditions of the tanks that they were asked to clear.
7. On numerous occasions, APSC has not provided data requested by PWSRCAC in a timely fashion, citing that providing the documentation would entail significant amounts of time. Yet when the same information was requested by a regulator, APSC provided the documentation within days. The delays in providing information to PWSRCAC prevent the Council from effectively overseeing APSC's activities and further, hamper the Council's ability to provide recommendations in an actionable timeframe. These delays add risk to APSC operations by delaying valuable feedback that PWSRCAC could offer if the information had been provided sooner.

Recommendations

Taku offers the following recommendations:

1. APSC should develop a model of their system that predicts the average O_2 content of the headspace of each tank based on vapor valve settings, tank headspace pressures (or vacuum), and data from the limited test points in the system.
2. APSC should install permanent Forward Looking Infrared (FLIR) monitoring systems throughout the East Tank Farm (ETF) to provide accurate, early warning of vapor releases from the crude storage tanks.
3. APSC should consider installing additional thief hatches in closer proximity to the pallets to allow for more accurate headspace monitoring. Using a single test point (such as a thief hatch) is not an effective method to determine if the tank headspace gas quality is outside of the flammable range. The thief hatches are in close proximity to the low- and high-pressure roof nozzles. Gas quality at the thief hatch may be different than the concentrations near the tank pallets (at the tank perimeter).
4. APSC should use improved monitoring instrumentation, an accurate gas model and field testing, to better define the tank headspace. This would allow APSC to provide more accurate information to their workers and to better define the risks associated with tank snow clearing.
5. APSC should prioritize worker safety during abnormal operating conditions by ensuring that they fully define the hazards associated with their response. For instance, it is not apparent that Alyeska understood that the headspaces within some of their tanks were likely above the lower explosive limit. Had that been fully understood, those conditions should have been better defined and communicated to the tank-top workers and the use of potential spark producing equipment should have been curtailed.
6. PWSRCAC should elevate their requests for information to the APSC President. The delays in providing data to PWSRCAC have negatively impacted the Council's ability to provide actionable recommendations in a timely fashion. These delays may increase the risk of operating TAPS by preventing the Council from providing valuable oversite and feedback.
7. PWSRCAC should acquire Alyeska's post-accident report on the incident to determine what, if any, lessons-learned were gleaned from this incident.

2.0 BACKGROUND

In late February of 2022, Alyeska identified vapor leaks from the pressure/vacuum pallets (vents) on one of the tanks in the Valdez Marine Terminal (VMT) East Tank Farm (ETF). Further investigation determined that movement of the snow accumulated on top of the tanks had caused damage to the pressure/vacuum (P/V) pallets on multiple tanks. Workers were mobilized to clear snow from the tank tops to accommodate repair of the damaged pallets.

Subsequent concerns were raised over the operational risks associated with oxygen (O_2) ingress into the tank head space, and/or hydrocarbon vapor egress from the tanks, as well as explicit concerns for the safety of the workers clearing snow off the tank roofs under these conditions.

On March 31, 2022, Donna Schantz, Austin Love (PWSRCAC) and Bill Mott (Taku Engineering) attended a meeting at the VMT with Klint VanWingerden, Weston Branshaw, Brian Huey, and Chris Steves from Alyeska Pipeline Service Company (APSC). The meeting was intended to discuss the damage to the vents and APSC's response. During that meeting, APSC indicated that 12 of the 14 tanks had suffered damage to the P/V pallets (all tanks except Tanks 7 & and 8) and that 11 of the vent nozzles had been sheared off by the snowpack. The group was also told that the O_2 content in the low-pressure vapor header piping never went above 6.0% as Alyeska worked to clear the tanks of snow and secure damaged P/V pallets.

The low-pressure vapor header piping moves vapors from the 14 crude storage tanks and the two Ballast Water Treatment "90's Tanks" to the Power Vapor Facility. The O_2 content of that header is continually monitored downstream of all the storage tanks (Figure 1). The high-pressure header carries inert gases from the Power Plant to the crude and ballast water tanks. During the 3/31/2022 meeting, the group was informed that the continuous O_2 sensors in the vapor system alarm at 6.0%, alarm with actions to eliminate ignition sources at 8.0%, and the system is shut down if O_2 levels are measured at 10%.

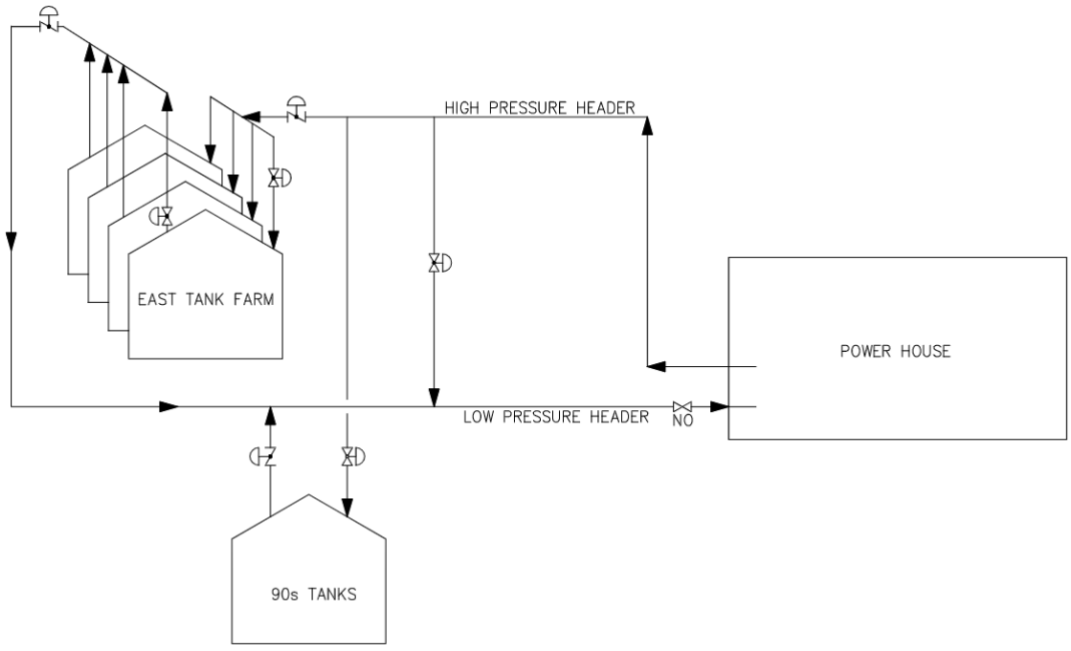

Figure 1 – Tank Vapor Recovery System Simplified Process Flow Diagram

3.0 FINDINGS AND DISCUSSION

3.1 INFORMATION REQUESTS

After the site visit in April of 2022, PWSRCAC submitted a request to Alyeska for documents intended to provide clarification around the level of damage to the tank vents, as well as a request for operational data on the tank vapor system and O_2 concentration measurements. The operational data was intended to support calculations to determine the O_2 content in the headspace of the damaged tanks during the period when peak O_2 concentrations were measured in the low-pressure vapor header. To date, Alyeska has not provided the requested data.

In June of 2022, PWSRCAC provided the same information request to the Alaska Occupational Safety and Health (AKOSH) who then passed that request on to Alyeska. APSC provided the requested documentation and data information to AKOSH in a timely fashion. AKOSH subsequently passed the applicable documents on to PWSRCAC in July 2022.

APSC's failure and delays in providing documents requested have limited PWSRCAC's ability to monitor activities at the VMT. These failures also limit PWSRCAC's ability to provide feedback and recommendations in a timely fashion. This behavior unnecessarily increases the risk of an incident or accident at the VMT.

3.2 TANK HEADSPACE O_2 CONTENTS

The existing O_2 monitoring points in the tank vapor system are extremely limited in number (there is only one location for the East Tank Farm low-pressure header). APSC reported the O_2 concentrations in the low-pressure header peaked at 5.59% at 12:13 pm on March 17, 2022. This represented a relatively minor increase in the O_2 content in the header and fell below the level that APSC sets for a system alarm.

Although this was a relatively minor O_2 excursion in the header, it was indicative of a substantially higher increase in O_2 concentrations in the tank headspace of tanks with significant vent damage. The lack of any tank-specific headspace O_2 monitoring equipment prevented APSC from recognizing this excursion during the incident.

At the time of the 5.59% O_2 excursion in the low-pressure header (12:13 pm on 3/17/2022), seven of the 14 ETF tanks were operating under a vacuum. Based on Alyeska's comment that tanks were shifted to a slight vacuum when vent damage was discovered, seven of the 14 tanks can be assumed to have had known damaged PV pallets on March 17th, 2022.

Elevated levels of O_2 in the low-pressure header were caused by air entering tanks with damaged PV pallets. Alyeska reported that tanks with noted damage to the vents were operated at a slight vacuum (versus a slight pressure) to reduce vapor emissions. However, operating the tanks at a slight vacuum increases the ingress of O_2 into the tank headspace. This becomes a cause for concern if the ingress of O_2 increases the concentration of O_2 above the lower-explosive-limit (LEL), which is the lowest concentration of gas capable of resulting in a fire when exposed to an ignition source.

Eight of the tanks had "significantly" damaged vents (circled in red in Figure 2). A significantly damaged vent allows much higher ingress of O_2 than a bent or cracked nozzle. Tanks 2 and 4 had three and four significantly damaged vents, respectively. This suggests that a significant fraction or the errant O_2 in the low-pressure-header entered the closed system through the damaged vents on Tanks 2 and 4. **A simple mass balance executed on the O_2 in the vapor recovery system at the time of peak O_2 concentrations in the low-pressure header, indicates that the estimated concentration of O_2 in the headspaces of Tanks 2 and 4 was above the lower-**

explosive-limit (LEL)[1], meaning that the presence of an ignition source could have resulted in a tank fire or explosion at the VMT.

3.3 Vapor System Model

APSC should develop a model of the tank vapor system that calculates the O_2 concentrations in each tank headspace based on the O_2 concentrations measured elsewhere in the system, vapor valve settings, tank pressure (or vacuum) and the areas of known nozzle or vent damage. This would allow them to better define the headspace gas quality and more accurately define the risk associated with tank-related work.

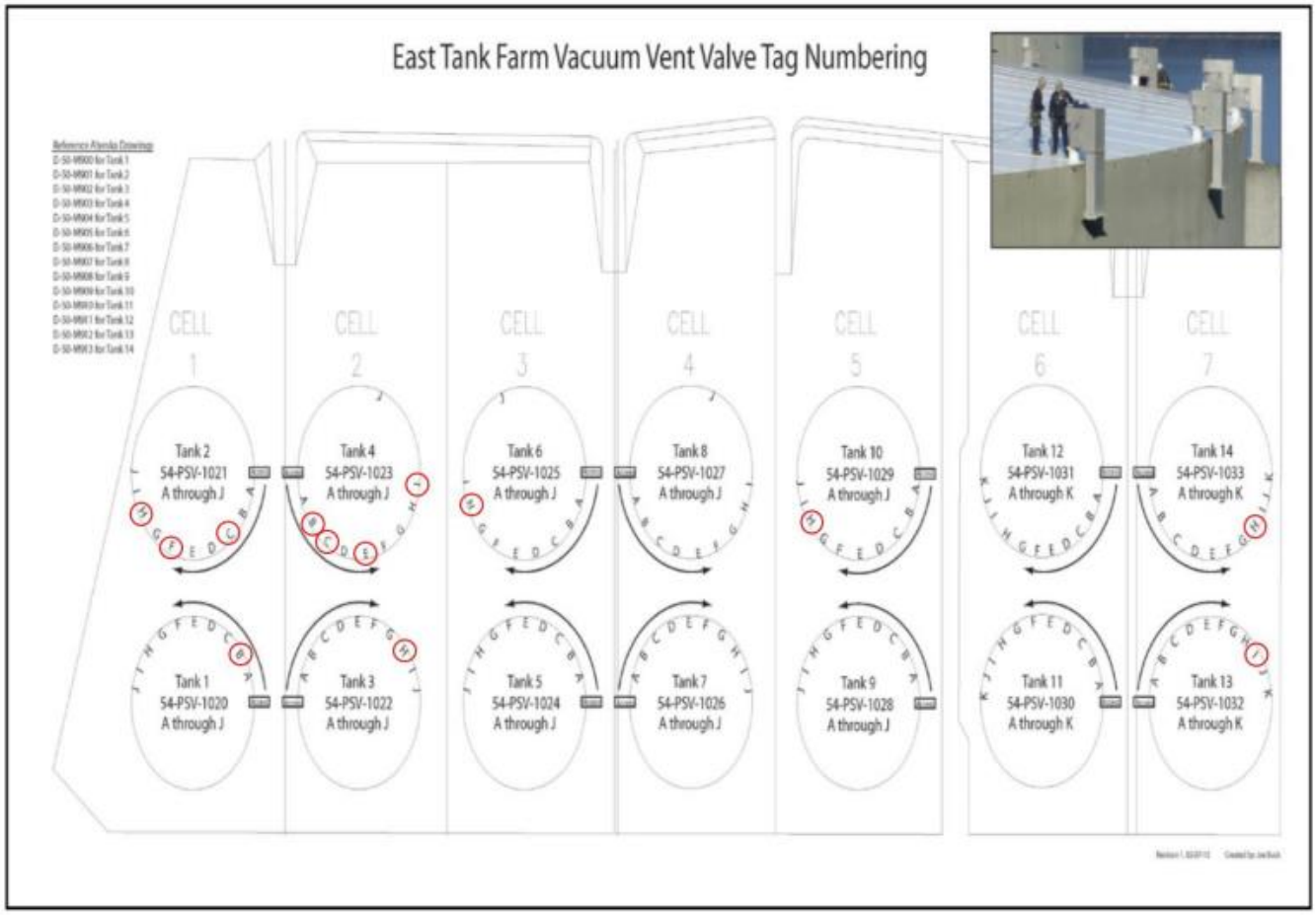

Figure 2 – Significantly Damaged Vents (not comprehensive - does not include lesser damage).

3.4 Vapor System Monitoring Points

The existing vapor system for the VMT includes only a single fixed O_2 monitoring point for the entire East Tank Farm (ETF). That point provides the average bulk O_2 concentration for all the vapor from the ETF tanks. A significant O_2 excursion in a single tank would be non-detectable with the existing fixed monitoring equipment.

[1] The lower explosive limit defines the minimum fuel/oxygen mixture required to support combustion. That number varies with fuel type and temperature. For North Slope crude oil, the LEL oxygen content is around 12-13% O_2.

Further, the tank headspaces are normally operated at a slight pressure. With that in mind, severe damage to a tank roof or tank nozzle would result in vapor egress from the headspace rather than air ingress. The existing fixed vapor system monitoring instrumentation would not detect that. Currently, the VMT relies on operator "olfactory" or smell tests to identify vapor leaks, which means that vapor leaks are not identified until a flammable mix of vapors exists outside of the tank and workers are exposed to the vapors, which carries significant health and safety concerns.

APSC should consider the installation of fixed FLIR vapor detectors around the tank farm to allow them to remotely and rapidly identify tank vapor releases without putting personnel at risk. Additionally, APSC should consider the installation of additional O_2 monitoring points so that headspace gas concentration excursions can be readily identified.

3.5 Tank Headspace Testing

During the March 2022 meeting between PWSRCAC and Alyeska, Alyeska noted that they had defined the O_2 concentrations of the tank headspaces through measurements at the tank thief hatches. There are a couple of issues with that practice. First, as shown in Figure 4, the tank vapor inlet and outlet are adjacent to each other. This has historically caused poor headspace mixing and a non-homogeneous mix of gases in the headspace. Alyeska installed flow diverters in some of the tanks which may offer limited mixing, but the headspace is still non-homogeneous, and no single point should be considered as representative of the entire headspace.

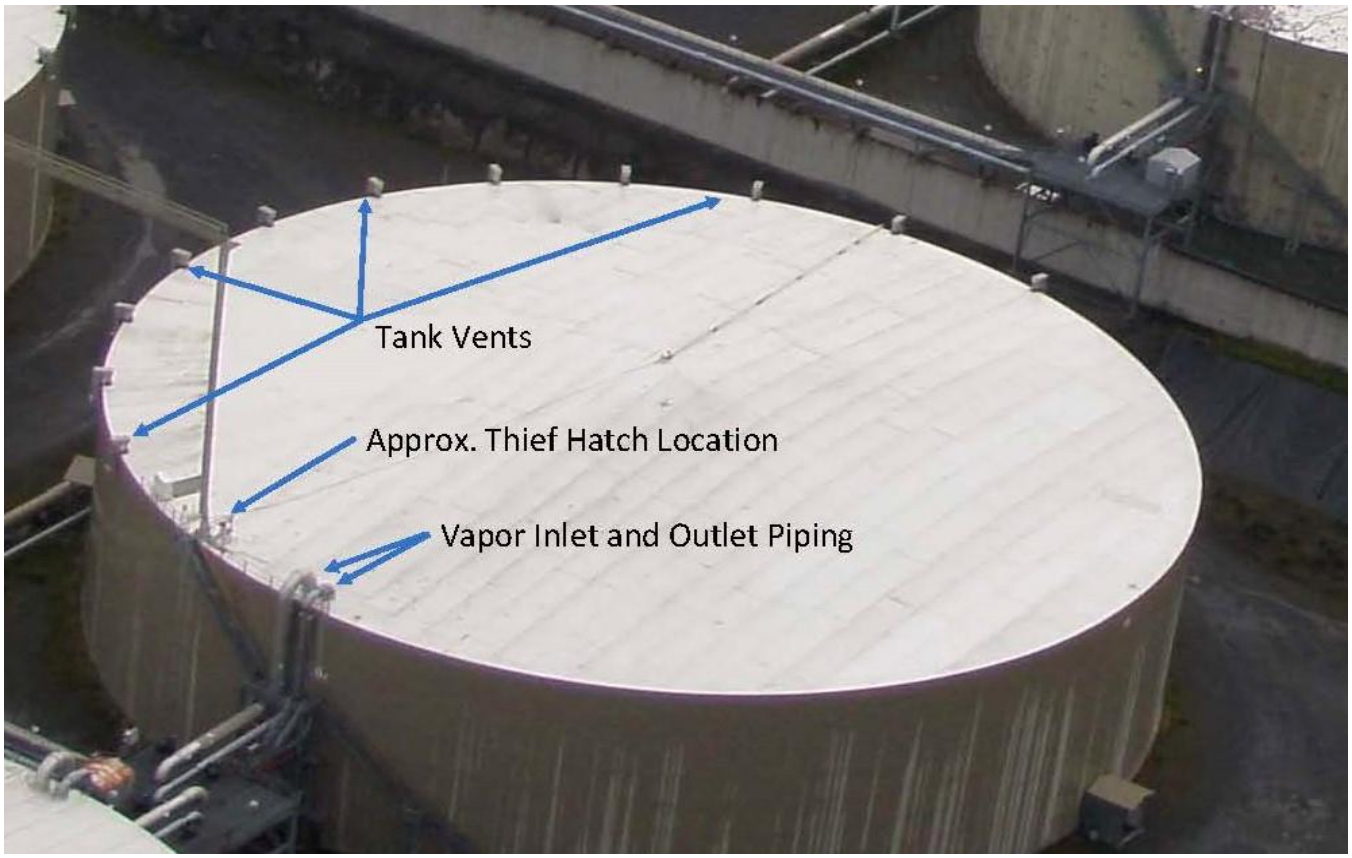

Figure 4 – Tank Roof Appurtenance Locations

Secondly, as shown in Figure 4, the thief hatch is located very close to the inlet and outlet nozzles and a considerable distance from most of the tank vents. Gas testing at the thief hatch will not have the same make-up as gases nearer to a significantly damaged vent.

Alyeska should develop procedures and equipment to better measure and define the headspace gas quality before putting workers on top of the tanks. Workers have the right to know the risks and conditions to which they are being exposed. In this case, workers may not have been provided accurate information upon which to base their decisions. For instance, it is not apparent that Alyeska understood that the headspaces within some of their tanks were likely above the LEL. Had that been fully understood, those conditions should have been better defined and communicated to the tank-top workers and the use of potential spark producing equipment should have been curtailed to prevent a fire or explosion at the VMT.