



Fire Hazard Assessment for Valdez Crude Tank Internal Floating Roofs

for



Anchorage, Alaska

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Introduction

During 2003, the Valdez Marine Terminal (VMT) Strategic Reconfiguration study team was tasked by Alyeska's Executive Team and Alyeska's Owners to perform conceptual engineering to identify changes that would lead to a significant increase in the operating efficiency of the Valdez Marine Terminal (VMT). As of January 2004, the study team was in the process of completing the Conceptual Engineering phase.

One basic concept proposed by the study was to eliminate the existing flue gas and vapor handling processes, and replace them with a system that requires fewer and less complex operations, and is a less maintenance-intensive system. An alternative which would eliminate these processes is the installation of internal floating roofs (IFRs) in the tanks. Floating roof tanks are the industry standard for storage of volatile organic liquids with vapor pressures below 11.1psi.

Pursuing this alternative, the Strategic Reconfiguration study team has proposed that the existing crude oil tank storage system be converted to an internal floating roof (IFR) tank system. In order for the alternative to be viable, two essential criteria were established for the Reconfiguration team:

- The new design for the internal floating roof tank must meet or exceed the current level of safety and system integrity.
- The revised VMT system reliability and proration risks must be fully understood.

Project Objective and Scope

This risk assessment was initiated prior to Preliminary Engineering for the internal floating roofs with the following goals:

- Identify whether the change to IFRs would maintain the level of safety and system integrity when compared to the existing cone roof tanks and vapor recovery system.
- Identify design and operational considerations for the tanks, IFRs, and fire systems.

The study was limited to the VMT crude storage system, including the tank flue gas and vapor recovery systems currently in place. Since specific design data are not yet available for the IFR option, the depth of the study was limited to design generalities for IFR tanks.

Study Approach

A study team was assembled that represented a range of expertise in terminal operations, fire-fighting, fire protection, tank design, and risk assessment. A technical representative from a public-interest group also participated on this study. The team was provided with an overview of the proposed Future Case design. The proposed design was a steel IFR with pontoons similar to a CBI Type-5, and removal of the system that provides an oxygen deficient atmosphere in the headspace. Fire protection requirements were to be determined later by the assessment group.

Potential Hazards Assessment

The study team began by exploring ways to compare the hazards of the two options. The two options were defined as follows:

- (1) a Current Case which reflects the design and operation of the crude oil storage system at the VMT and
- (2) a Future Case, which represents the alternative of an internal floating roof tank system for crude oil storage.

The study team reviewed the potential hazards of the following types of operation:

- a. startup
- b. normal operations
- c. maintenance
- d. inspections
- e. emergency situations

Discussions of potential hazards considered the impact to the facility, personnel, and environment with and without safeguards in place. The review focused on the tanks themselves and, to a limited extent, on the vapor recovery system used in the current configuration.

The team studied the potential impacts *assuming all safeguards had failed*. This would be a highly unlikely event in most cases. In order for the postulated effects to occur, multiple safeguards must fail, due to operational errors, hardware failures or acts of nature. The adequacy and reliability of safeguards were not reviewed as part of this study.

Design and Operation Considerations for Internal Floating Roof Tanks

Having assessed the potential hazards for IFR Tanks, the design team conducted a brainstorming session to identify design and operation considerations for the Future Case. The goal of the considerations was to ensure that proposed designs with IFR tanks would be as safe, if not safer, than the current design.

Study Team

The hazards assessment and development of considerations were conducted over a three-day period, January 13-15, 2004 in the Alyeska offices in Anchorage, Alaska. The team composition is provided in Table 1 below.

Table 1. Study Team

Organization	Name	Position/Title
APSC Corporate	Rob Annett Glen Pomeroy, P.E. Andy Postishek Jim Preston Steve Schudel, P.E.	Engineer, Tank Project Reconfiguration Study Lead Fire Quality (clarification briefing) Reconfiguration Study
VMT Operations	Tom Stokes Doug Fleming John Fannin	OM&S and P/V Manager OM&S SPOC P/V Supervisor (via teleconference)
JPO	Chet Weger	Fire Safety Specialist
Valdez Department	Brian Major	Fire Chief
Conoco-Phillips	Mike Miller Bob Steinhart	Owner OM&S Team Rep Tank Coordinator (via teleconference)
Loss Control Associates	Bud Slye, P.E.	RCAC Fire Consultant
Hughes Associates, Inc	Jack Woycheese, P.E. Laura Bradbury, EIT	Senior Engineer Fire Protection Engineer
Capstone Engineering	Bernie Weber, P.E.	Facilitator

Hazard Assessment Results

A brief summary of the findings of the hazards assessment are presented in Appendix A to this report.

Considerations for Internal Floating Roof Tanks

The list of considerations developed by the study team is provided in Appendix B to this report.

Fire Protection Considerations

A brief report summarizing the fire protection considerations is supplied in Appendix C to this report.

Conclusions

The study team as a group and individually recognized that the level of safety and system integrity for a tankage system with internal floating roofs, with appropriate safeguards in place, was equal to or greater than a system with cone roof tanks incorporating vapor recovery, even when one does not account for the complex equipment/operation outside of the immediate tank area that is necessary to combust the vapors and provide blanket gas to the tanks.

Due to time constraints a detailed hazard analysis for the Power/Vapor facility portion of the current system was not conducted. Additionally, a Process Hazard Analysis (PHA) for the Vapor Recovery System was not available for the assessment. However, the study team acknowledged that the existing vapor recovery system is a process covered by OSHA 1910.119 (Process Safety Management) and that such facilities have multiple hazards to control (boilers, pumps, compressors, fired equipment, complex control systems, and miles of piping containing hydrocarbon rich vapor). The team therefore concluded that the removal of the vapor recovery system would remove a significant risk and would render the IFR option an inherently safer design.

Although not thoroughly discussed, it should also be noted that incorporating floating roof technology and removing the current tank vapor control system at the Terminal will eliminate the combustion of up to 850 BPD of crude vapors, along with the resultant emissions.

APPENDIX A

Hazards Assessment for Current and Future Cases for Crude Storage at the VMT

Note that for “Effects” to take place, generally multiple safeguards must fail, operational errors, and/or acts of nature have to take place. It is believed that all identified hazards can be satisfactorily mitigated with appropriate design, controls, and/or operating and maintenance procedures.

Internal Floating Roof Tank Hazards

Operating Mode	Potential Hazard	Cause	Effects If No Safeguards in Place
startup	filling the tank with the legs landed	on initial fill, this should normally occur	effects range from no impact to possible fire or environmental release
normal operations	excessive fill rate	operator error	environmental release, potential sunken roof or pool fire
maintenance	release of hydrocarbon vapors from unexpected source in roof seal	maintenance in tank	worker injury
inspection	release of hydrocarbon vapors to the environment during internal inspection	internal inspection as required by regulations	environmental release
startup	flammable environment in head space	on initial fill, this should normally occur	effects range from no impact to possible fire or environmental release
normal operations	if operator is not aware of floating roof level, may inadvertently land the roof, creating vapor in head space	instrument error, operator error	effects range from seal fire to explosion
maintenance	minor fires during maintenance	maintenance in tank, may be more difficult to clean IFR tank prior to maintenance	minor fire during maintenance
normal operations	product on the roof	roof hangs up on columns, earthquake	fire in head space
normal operations	roof hangs up, causing internal fire	hangs up on columns, earthquakes, turbulence during fill, wax build-up	flammable space below floating roof or burning liquid above floating roof
normal operations	high snow loads, with less heat available in IFR design	high snow loads, but less benefit from product heat, area above roof open to the environment	increased snow removal on the cone roof, with commensurate worker injury exposure
normal ops	Static electricity and induced charge differentials	fluid flow, improper grounding, wax buildup, lightning	provides an ignition source which can ignite vapors stemming from a seal leak, leading to seal fire

Internal Floating Roof Tank Hazards

Operating Mode	Potential Hazard	Cause	Effects If No Safeguards in Place
maintenance	mixer motor replacement creates flammable head space	mixer motor failures that require tank entry	possible fire, worker injury
maintenance	worker injury due to reduce working space from floating roof	inherent in IFR Tank design	worker injury
normal operations	Static electricity and induced charge differentials	fluid flow, improper grounding, wax buildup	provides an ignition source which can ignite vapors stemming from a seal leak, leading to seal fire

Cone Roof Tank Hazards

Operating Mode	Potential Hazard	Cause	Effects If No Safeguards in Place
startup	flammable environment in head space	on initial fill, this should normally occur	possible fire or explosion
maintenance	minor fire during maintenance	maintenance in tank	minor fire during maintenance
normal operations	high snow load	high snow loads, but less benefit from product heat, vents and open manways open to the environment	snow removal on the cone roof, potential for worker injury exposure
normal operations	overflow	operator error, level indication and alarm failure	spill crude to the environment, potential for pool fire
normal operations	static electricity and induced charge differentials	lightning	provides an ignition source which can ignite vapors through an opening in the tank
maintenance	mixer motor replacement leads to flammable environment in tank	mixer motor failure	possible tank fire
normal operations	process safety hazards from vapor recovery system	typical causes of leaks in rotating equipment, piping, and vessels	effects range from seal fire to explosion
inspection	release of hydrocarbon vapors to the environment during internal inspection	internal inspection as required by regulations	environmental release

APPENDIX B

Specific Issues for Consideration if Converting Crude Tanks at VMT to Internal Floating Roof Tanks

The following issues are based on the conceptual design of an internal floating roof tank at VMT.

- 1) Filling under a landed roof will cause vapor to be released to the head space. Depending upon circumstances, there may be safety and environmental consequences. The safety consequence is a function of whether or not personnel are in the dike area during the filling of a landed roof.
- 2) The VMT Emergency Response Plan should be reviewed to assure that responses involving personnel, equipment and procedures are appropriate for hazards created with the IFRTs including the transition period.
- 3) The Project Team should strongly consider a schedule that allows for two tanks in a diked area to be taken out simultaneously. This would minimize ignition sources, exposure of personnel to hazards.
- 4) For relief tanks 1 and 3, the design team needs to determine the appropriate minimal level and/or relief piping configurations required to protect the floating roof and to maintain acceptable back pressure for the relief system.
- 5) Maintenance risks for IFRs are different and need to be considered. Certain seals (log-type seals) have the potential to retain hydrocarbons which may create a hazard during maintenance. The specific design for the seals has not been established, so the team could not fully address this issue. An additional concern for seals is the accumulation of paraffin on the roof and seal and how it would affect maintenance risks.
- 6) Visual inspections of the seals will be required annually. Consider means for carrying out visual inspections without entering the head space.
- 7) The design needs to consider the requirements for maintenance and means of entry into the head space to accomplish inspections and maintenance.
- 8) Pre-fire plans should be modified for IFRTs versus existing cone roof tanks and during transition.
- 9) The team recommends that independent liquid level and floating roof level indication be provided in the design of the IFRT. The concerns are that (1) fill may continue when floating roof is stuck (2) floating roof remains stationary while level drops.
- 10) The amount of head space for work will be reduced from current space with IFRs and may make maintenance more difficult and could increase the chance for injuries.
- 11) Design the IFR so that product is not likely to accumulate on the roof or install a design that provides methods for safe removal of product on the floating roof.
- 12) Consider developing procedures or practices for restoring the roof to its normal operating position in the unlikely event that the floating roof becomes stuck.
- 13) Consider design features to minimize the chances of sinking the roof; for example, sealed pontoon covers, or design of partitions between pontoons, and pontoon drains.
- 14) Consider means for snow control considering that the heat of the crude will not be available to melt snow in the IFRT design. Also review column deflection due to increased snow

- loading. The design needs to consider the safety of personnel if they are removing snow from the roof.
- 15) The design of the external wind girder should consider the impact of falling snow, ice accumulation, snow accumulation, and protection of tank appurtenances from falling snow (including shell buckling considerations).
 - 16) An evaluation should be made of the tank roof current condition to match the roof life with the API-653 inspection schedule.
 - 17) The columns may currently be open at the bottom and the top. If this is the case, the team recommends that the hazards of the open columns be addressed for the floating roof design.
 - 18) The design of the IFRT should consider multiple layers of protection against static charge accumulation and discharge. The increased waxiness of the crude may limit the effectiveness of grounding via a grounding strap. For example, consider both shunts and grounding cables to mitigate the hazards of wax buildup for the straps and snagged/destroyed cables.
 - 19) Mixer motor seal or shaft replacement was considered to be a high-risk operation, due to the high frequency of repairs of the mixer motors. The team recommends new or rebuilt motors, or a new type of mixer, during IFR installation.
 - 20) Review best practices and then establish prudent design and procedures to perform maintenance below the landed roof.
 - 21) The team identified a few of the Major Hazards to consider for transition planning from current to floating roof design. This list is not considered to be complete.
 - a) Multiple sets of operating/maintenance procedures in place at the same time, could lead to confusion and erroneous operations. For example you would have different high levels for tanks, if you have an IFR and vapor-controlled tank in the same cell.
 - b) A lot of contractors will be on site who must be properly coordinated.
 - c) Training for the operators before transition takes place. Also, new procedures have to be developed.
 - d) May have 2 different fire systems in place at the same time, introduces chance for errors.
 - e) Considering the magnitude of work that will be occurring at any time, be sure to follow construction practices to control the hot work risk.
 - f) This transition work will be carried out year-round. There has not been a lot of construction work during the winter at Valdez.
 - g) Work permit system needs to be carefully controlled to minimize the risk of hot work.
 - h) Energy Isolation Procedures need to be rigorously followed during transition.
 - i) Shear volume of people involved increases the chance for less-qualified personnel on site. Focus on training and safety would help reduce construction risks.
 - j) Velocity Maintenance system needs to be reviewed and analyzed for the interim period due to greater fluctuations in gas management.
 - k) Review timing of installation of vapor combusters, consider this as an aid to resolve Item (j) (above).
 - l) Consider early deployment of alternate power source, to help manage consequences of power loss during the transition.
 - 22) Consider the use of a high-high level automatic shutdown of the inlet to the tanks. Current practice including OCC controls would still be followed; however, considering the risk of overfilling the tank, the installation of the automatic shutdown may be prudent.

- 23) Ensure that the design of the legs and the roof will accommodate the buildup of sludge and impact the chances of a level-landing of the roof.
- 24) Review the current design of the diffuser to ensure that it is appropriate for the internal floating roof design.

APPENDIX C

FIRE PROTECTION CONSIDERATIONS

The study team considered the appropriate level of protection required for the crude tanks if they are converted to internal floating roof tanks (IFRTs). The existing cone roof tanks currently have fixed subsurface foam protection distributed from manually activated foam pumps through piping to each tank to a spider distribution discharge device. The existing foam application system is considered appropriate for cone roof tanks in crude service, particularly when the tank diameters are 250 feet. Fires which occur in cone roof tanks are full surface fires.

The crude tanks are being evaluated to determine what level of fixed fire protection is appropriate if the tanks are converted to internal floating roof tanks. The study team agreed that:

1. It would be unacceptable to convert the crude tanks without providing fixed foam fire protection. The crude tanks have a high level of criticality to the company and to JPO. A VMT internal floating roof crude tank without fixed foam protection is not considered to be equivalent to existing protection.
2. Manual firefighting at VMT is not considered to be a viable option for either IFRTs or cone roof crude tank fires. Manual application of foam is not supported due to concerns about personnel safety, limitations to the application of foam from within the dike to tall tanks, weather conditions, dike configurations and other factors.
3. Seal rim protection is recommended. While not required by current state code, industry practice is to provide such systems for protection against the most common fire in floating roof design tanks when tanks are located in a large municipal area or when a tank is considered critical to the business. Designs for seal rim protection are well established and proven. A fire in an unprotected seal rim in an internal floating roof tank is difficult to fight manually, particularly in a 250 foot diameter IFRT, as access to that portion of the seal fire is limited by multiple roof support columns and access hatches.
4. Column seal protection should also be provided. The fire hazards of column penetrations of floating roofs are not well known. However, the same ignition sources which could cause a seal rim fire can cause a column seal fire. Manual firefighting of a column seal fire in the proposed VMT IFRTs is further limited by the number of columns within the tank and access hatch locations.
 - a. Preliminary calculations indicate that a fully involved column seal fire can create a 2.5 MW fire which may damage a column in five to fifteen minutes. This potential to damage the columns should be reviewed in more detail to confirm the effect of actual column materials and design, and structural effects of a fire.
 - b. Calculations also indicate that smoky gas from a fully involved column fire, 2.5 MW will be noticed at the vents in 3 to 23 minutes depending on the roof position. A smaller fire, 100 kW, will produce sufficient smoke at the vents to be noticed in 6 minutes to 2 hours depending on tank roof location.
5. Use of subsurface foam systems is not common in IFRTs. There is no history of a subsurface system extinguishing a sunken roof fire in a 250 ft diameter IFRT. Success has been reported involving a 150 ft diameter tank. IFRT fires are complicated by the position of the roof, the possibility of pockets of fire above or below the roof which would not be reached by the existing subsurface system, or other foam application. In addition, inadvertent activation of a subsurface foam system could lead to sinking or partially sinking the roof, leading to a much more serious fire situation.

Some study team members have suggested that the seal rim protection system design, or some other mechanism be arranged to allow for the possibility of fighting a fire condition involving a cocked roof. The most compelling argument in favor of such a system is that application of foam

to a partially sunken roof fire in an IFRT is difficult, and the suggested design may help control the fire in the event that time is needed to decrease tank contents, set up exposure protection and prepare for other methods of extinguishment. On the other hand, fire fighting in large diameter tanks with sunken roof fires requires large flows of foam, perhaps in quantities up to 5,000 gpm, for 50 minutes or more using the currently installed fixed system. Inadvertent foam application through the suggested system may waste precious onsite quantities of foam concentrate which may be needed for an appropriate fire fighting effort, and raises the potential of a sunken roof.

6. For informational purposes, fire data for external floating roof tanks, IFRTs and cone roof tanks is provided in the table below, taken from API RP 2021A.

Excerpted from API RP 2021A

Cause of ignition	Floating roof tanks			Cone roof	Roof unknown	Totals
	External	Internal	Unknown			
Debris from external explosion	0	1	0	2	0	3
Flare dropout/bad roof	1	0	0	0	0	1
Ground fire	0	3	1	0	0	4
High vapor pressure product	1	0	0	0	0	1
Hot work	1	0	0	2	0	3
Internal frothing/overpressure	0	0	0	1	0	1
Lightning	36	2	25	2	3	68
Overfill	2	2	0	0	0	4
Pyrophoric deposits	0	1	0	0	0	1
Sabotage	2	0	0	3	1	6
Static	0	0	0	2	1	3
Sunken roof	2	0	0	0	0	2
Unknown	6	2	2	4	2	16
Total	51	11	28	16	7	113

Note: 1 reported incident involved lightning ignition of both a cone roof and external floating roof tank and was counted for both.

7. Several design approaches were discussed, including
- Removing the spider system and connecting a Coflexip hose from the existing foam inlet through a hole in the center of the roof to a distribution piping to feed foam to seal rim foam chambers and column seal nozzles.
 - Installation of a standard seal rim foam chamber design, modified to distribute foam through piping and nozzles to direct foam to the column seals.
 - Over-design of the seal rim foam chambers to provide sufficient foam for a sunken roof fire. This approach is limited by the inability of foam to travel more than 100 ft from the points of application. This may leave the center of the tank unprotected. The IFR's should be designed to support a large volume of fluid above the roof without sinking. Any such over-design of the seal-rim foam chambers would need to take this maximum allowable fluid above the roof into account.
 - Similarly, use of product nozzles to provide subsurface foam protection has limitations, in the number of nozzles available at the tank, travel limitations for foam injected into tanks of this size. Although the installation of four nozzle entry points, each designed to allow fire department connection was discussed. There is again a low probability of effectiveness but a potential use for foam application to the undersurface of a partially

sunken or cocked roof. There are however limitations in the ability to apply foam in such a case to the area above the sunken or cocked roof. Current practice would be to apply foam to the top of a partially sunken roof through the eyebrow vents at the side of the tank.

8. It is recommended that Alyeska study the existing foam pump and storage system for integration into the proposed foam system for the IFRTs. Foam supply rates will need review and flow regulators may be needed as required flow is less for seal rim protection than for a full surface fire. Continued availability of the existing foam pumps and storage will facilitate any fire response and improve the likelihood that fires will be quickly controlled or extinguished.