Applying ASME Section VIII Ug 140 (Code Case 2211-1) Reasoning to Exclude a Vessel from the Need for a Fire Case Relief Valve

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APPLYING ASME SECTION VIII UG 140 (CODE CASE 2211-1) REASONING TO EXCLUDE A VESSEL FROM THE NEED FOR A FIRE CASE RELIEF VALVE

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Abstract

This paper briefly discusses the history of Code Case 2211 and the resulting UG-140 update to ASME Pressure Vessel Code, Section VIII. This code case was the origin of ASME allowing SIS and other statistical arguments (such as FTA and now LOPA) to help a PHA team and a chief engineer from the involved process determine when there is a better alternative than a fire case relief valve. The first application in 1993 timeframe was a case where an external fire could lead to an explosive reaction of the contents of a reactor if the fire case PSVs vent during external fire and concentrate the higher boiling reactant.

The paper will discuss cases analyzed at AR-RAZI in Jubail, KSA, where the vessels had no fire case relief valves. The step-by-step application of the Code Case 2211-1 approach is shown for each. Examples of the sign-off forms used by the PHA leader & chief engineer are provided to aid others. Of the vessels reviewed (which comprised about 5% of the pressure vessels), 92% of these were exempted from the need for a fire case relief valve.

Introduction

Code Case 2211-1 allows for providing overpressure protection by system design in lieu of pressure relief devices as required in Section VIII, Division 1, paragraph UG- 125(a) and in Section VIII, Division 2, paragraph AR-100. Code Case 2211-1 is applicable to unfired pressure vessels associated with processing systems and requires that the user conduct a detailed, systematic, multidisciplinary analysis to ensure that the MAWP (Maximum Allowable Working Pressure) of the vessel is greater than the highest pressure that can reasonably be expected due to all credible operating and upset conditions. The analyses consider instrumentation and other design features of the system that are provided to limit the pressure as well as other characteristics of the system in which the pressure vessel is installed.

This paper provides guidance in performing the detailed analysis required to implement ASME Section VIII UG-140 (Code Case 2211-1) in justifying that the System Design (inherently safer design) is adequate to protect the pressure vessel for the external fire case, eliminating the need for a fire-case relief valve (UG-140a), along with its application by Process Improvement Institute (PII) at one of the largest Methanol manufacturing facilities in the world, AR-RAZI, located in Jubail, in Saudi Arabia (KSA)

Application of UG-140 for Overpressure Protection

When a pressure vessel is designed per code ASME Section-VIII Division-1 (henceforth referred as code), the requirements of the code are followed for design, fabrication, inspection and testing. One of the basic requirements of the code is to provide overpressure protection for the vessel covered by ASME Section-VIII Division-1, UG-125 through UG-140. The ASME UG-140 requirements and procedures are commonly known as "Code Case 2211". In 2008, ASME incorporated "Code Case 2211" into the body of Section-VIII Division-1 as Section UG- 140. Overpressure protection for a pressure vessel can be achieved by either or combination of the following:

Overpressure protection for pressure vessel

1. Relief Device
Requirements of relief device for pressure vessel are covered by UG-125 through UG-138. When the findings of detailed evaluation of various overpressure scenarios per API Standard-521 state that there are credible cases for overpressure, pressure relief devices are provided and sized per applicable equations given in API Standard-521.

2. System Design (Inherently Safe Design)
This option overcomes the requirement of a relief device to protect pressure vessel. The documentation and other specific requirements of this option are covered by UG-140(a).

3. Safety Instrumented or High Integrity Protection System (HIPS)
This option can overcome the requirement of a relief device in specific cases when a SIS (PII believes SIL 2 or better) are provided to prevent a case that would otherwise be the limiting case for sizing of the relief device. The documentation and other specific requirements of this option are covered by UG-140(b).

All overpressure protection systems addressed by second or third option (figure above) or a combination of second and third require compliance with ASME UG-140 including all approvals, responsibilities, analysis and reviews including documentation and signoffs.

General conditions in UG-140(a) for using System Design as alternative

Per UG-140(a), a pressure relief device is not required to protect a pressure vessel if the System Design (inherently safer design) is adequate to protect the pressure vessel for an overpressure event (or for elimination of a specific overpressure scenario).

The major requirements of UG-140(a) are to perform a detail analysis of various overpressure scenarios; conduct a multidisciplinary team review; perform a risk assessment for the credible scenarios; if a new system, then provide the manufacturer data report to state the system protected by design, otherwise the owner provides the equivalent statement of fitness for duty; and documentations & signoffs. These major requirements are briefly summarized as follows:

- **Detail analysis of various credible scenarios** - API Standard 521, Pressure-Relieving and De-pressuring Systems, describes "Causes of Overpressure". Other standards or recommended practices that are more appropriate to the specific application may also be considered. Typical overpressure scenarios that need to be analyzed are tabulated below:

Table 1. Typical overpressure scenarios

Loss of cooling medium	Loss of instrument air	Individual equipment failure	Unique scenarios from PHA Teams (especially for start-up, shutdown, online maintenance)
Loss of air cooling	Individual control valve failure	Thermal expansion	
Loss of power	Inadvertent valve operation	Heat exchanger tube rupture	
Loss of steam	Blocked outlet	Liquid overfill	
Gas blowby	Reactive hazard/runaway	External fire	

  All the scenarios shall be evaluated with detailed explanation to identify whether the scenario is applicable and if it is applicable how the pressure reached in the scenario is less than MAWP of pressure vessel at co-incident temperature. All the relevant documents such as P&IDs, PFDs, general arrangement drawings, Data Sheets, Plot Plans, Paving and Drainage Plans, SDS of chemicals and inventories involved, etc., shall be used to evaluate credibility of overpressure scenarios and attached as a part of documentation.

  > *Be sure analysis includes detailed analysis for non-normal modes of operations, as those account for about 7% of the limiting cases for relief and these 7% dominate the unmitigated risk (these many times lead to catastrophe).*

- **Multidisciplinary team review** - The documentation shall be reviewed and evaluated by multidisciplinary team of people including Process Safety engineer, Process Technology Leader, Manufacturing representatives, Process Engineers, and Relief Design Subject Matter Experts (SME). A PHA team meets this criterion.

- **Risk assessment in case of credible overpressure scenario** - For a pressure vessel, if a scenario is found to be credible for overpressure, then risk associated with the event shall be judged to decide whether or not the relief device shall be provided. The design shall comply with local regulations and owner's risk tolerance criteria. This approach is scenario specific and if it can be justified that having a relief device is not required to reach tolerable risk then one can go without having a relief device even when the case is credible for overpressure. To illustrate, an example can be as follows:
    - If fire scenario is applicable to a pressure vessel operating in gas service (empty of liquid), pressure relief device is of no help in protecting the vessel as the vessel ruptures due to overheating (exceeds the Maximum Allowable Working Temperature [MAWT]) before the pressure reaches the set pressure of relief device. The pressure vessel is empty, and fire case is applicable, but a relief device is of no help for the reasons stated.

  Analysis procedures (as separate analysis or as part of a PHA) suggested in Code Case 2211-1 are
    - Fault Tree Analysis (FTA)
    - What-If Analysis
    - Hazards and Operability Analysis (HAZOP) and LOPA
- **Documentation and Sign-off** – There shall be a concurrence by the PHA team that the specific overpressure event is not credible as the vessel is protected by system design. This can be a team vote (qualitative), but it is better to achieve a numerical value (order of magnitude) of "low probability of failure of the safe design" that is equivalent to the PFD of a relief valve (PFD ≤ 0.01). The documentation shall include the available System Design features and measures to maintain these features and the design will be Signed Off by the PHA Team leader (as representative of the team) and by the engineer responsible for the Operating system.
- **For New equipment that is about to be installed, the Manufacturer's data report (U-1 or U-1A form) must state the system is protected by System Design for each specific scenario that is protected by System Design instead of by a Relief Device that is sized for that specific scenario** – UG-140 requires that manufacturing data report shall mention that the vessel is protected by system design. Typically, vessel manufacturers provide a data report, and this requirement is mentioned in the notes section of the report. To the data report, a U-1 or U-1A form is included.

  Note: The original Code Case from ARCO Chemicals in the early 1990s used this alternative with a P ≤ 0.01 for a "kill" injection system to stop a runaway reaction on high temperature due to external fire. This external fire case would lead to concentration and ultimate detonation of the explosive heavies, as the lights boil off via the relief valves. ASME agreed in writing with the removal of the 3 fire case PSVs from the reactor since all relief cases were handled by System Design, with a likelihood of the scenario < 0.0001/year, as validated by experiments with the fire fighting system and FTA for all features.

Applying Code Case 2211-1 (UG-140a) to endorse alternatives to Fire-Case Relief Valves.

The application of the risk-based approach for justifying that the System Design is adequate to protect the pressure vessel for the external fire case (eliminating the need for a fire-case relief valve) was performed by PII staff at one of the largest Methanol manufacturing facilities in the world, AR-RAZI, located in Jubail, in Saudi Arabia. The facility had completed PHAs (led by PII) for all its Methanol plants and Utilities. About 5% of the pressure vessels had no fire case relief valves. These were analyzed to see if they could be exempted by inherently safety design.

Questions concerning vessels identified for an external fire case

The primary approach to analyzing a vessel with respect to external fire case is to obtain answers for the below set of questions.

A. *Is there a PSV available to the vessel when blocked in for maintenance outage? Is it sized for external fire case?*
B. *Is the bottom of the vessel more that 25 ft (7.6 m) above a potential pool of flammable liquid? – the limit of flame height from API 521*
C. *If the vessel is normally empty, will the MAWT be reached before the MAWP?*
D. *Is liquid normally in vessels during a maintenance outage (such as washing out)? And is there an engineering feature to ensure no liquid in the vessel during a maintenance outage?*
E. *Are there engineering features, including slope of pad, dike, trench, and/or distance to nearest flammable liquid source, to ensure no flammable pooling under the vessel?*
F. *Are there engineering features to ensure automatic extinguishing of fire under the vessel, including during a maintenance outage?*
G. *Does the vessels MAWP and MAWT make it inherently safe from external fire when considering the intensity and duration of the fire?*

Project-specific considerations

During the detailed analysis of the scenarios and based on the nature of service of the vessel evaluated, the below justifications were developed for two of the guiding questions.

D. *Is liquid normally in vessels during a maintenance outage (such as washing out)? And is there an engineering feature to ensure no liquid in the vessel during a maintenance outage?*

Example: A vessel is in gas service (empty of liquid) and there is no credible reason to have liquid (including wash water/condensate) within the vessel during a shutdown when the vessel is isolated.

- This is the most difficult to validate to a Probability ≤ 0.01 as the justification is solely human error prevention (which is very difficult to ensure less than 1 in 100 errors)
- For the project (example) shown here, the team decided NOT to use this alternative

F. *Are there engineering features to ensure automatic extinguishing of fire under the vessel, including during a maintenance outage?*

This is expensive to design and difficult to validate to a Probability < 0.01 as the justification

- For the project shown here, the team decided NOT to use this alternative.

Tabulate the answers/results for each identified vessel

PII staff along with the Operational experts, which in this case were the Plant Process Engineer and an experienced Area Operator, surveyed the identified vessels in the plant, measuring the height of the vessels from grade, distance between vessels and the source of hydrocarbon and the layout of the area including the location of the trenches. Detailed review of the drawings was performed for the slope of the concrete pads.

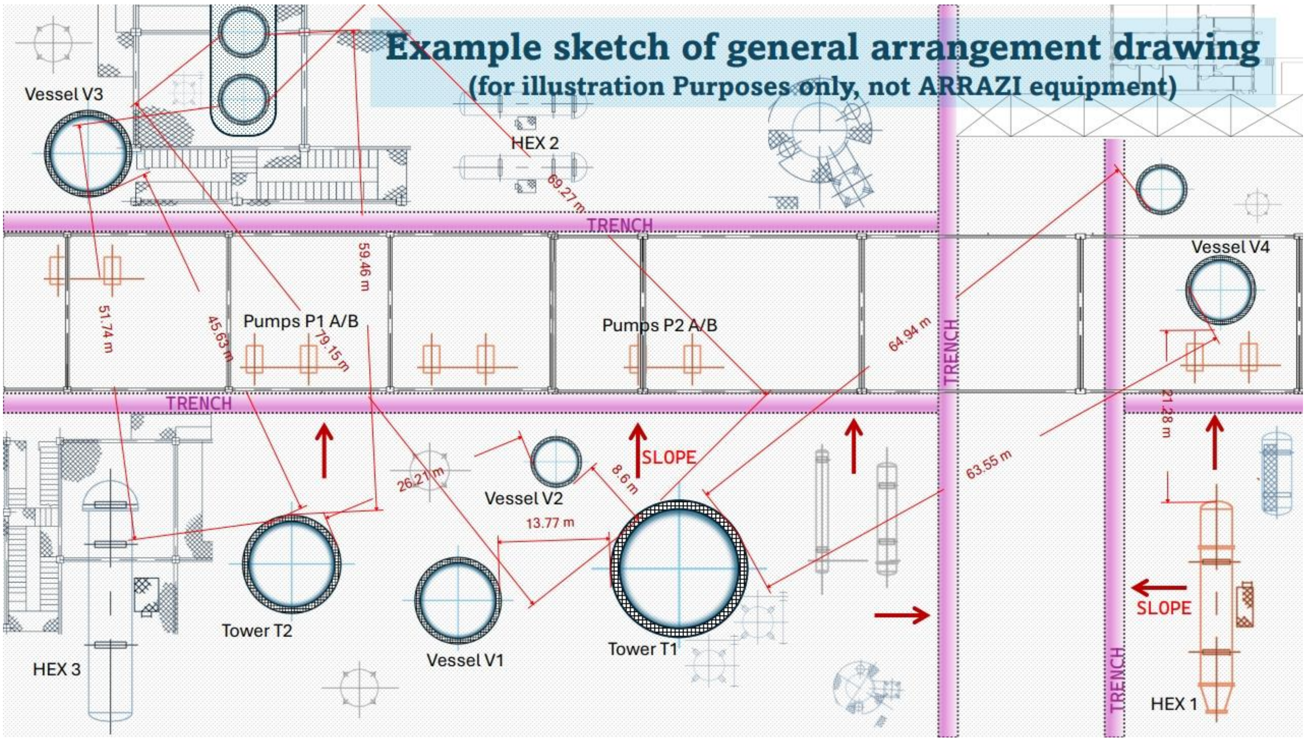

Figure 1. Example sketch of general arrangement drawing

Utilizing this data, a map of the area was prepared on the General Arrangement drawing of the plant (as shown below) that conveys information on the equipment distances from the source of hydrocarbons, the trenches in the plant and the slope of concrete pads on a single drawing.

For a better understanding of the magnitude of the release of MeOH and possible pool fire that could result, PII performed a pool fire model using ALOHA (from US NOAA). This was for the largest inventory in the plant (V-3403).

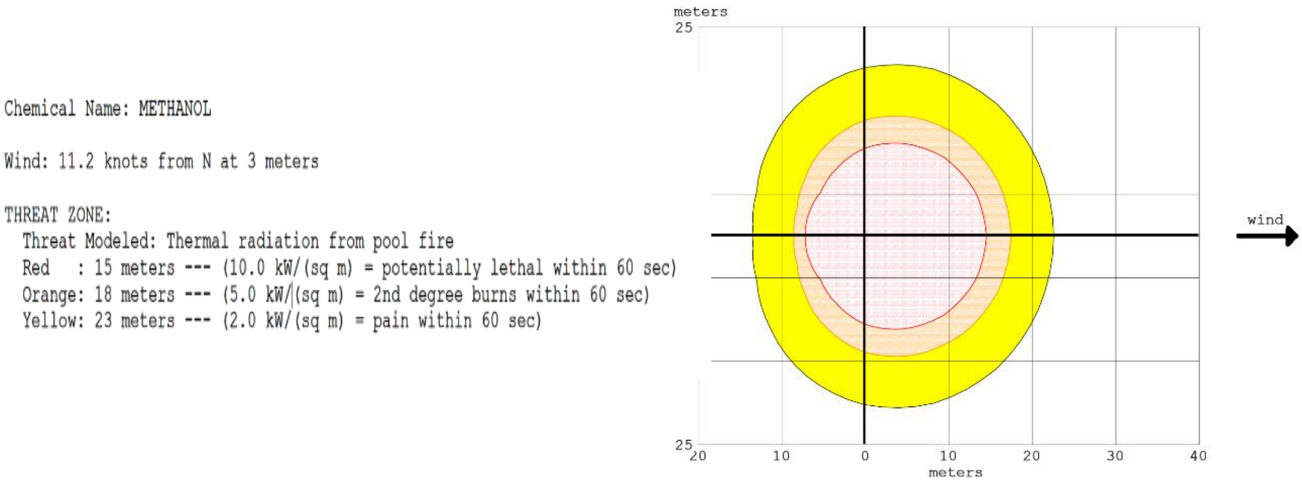

Figure 2. Methanol pool fire model using ALOHA

The results were further tabulated for each identified vessel, compiling all the data collected from the field survey, equipment drawings and the inventory and chemical composition information. A snapshot of the compiled table for 13 of the identified vessels (as examples) is shown below.

Table 2. Data collected from the field survey

Vessel Number	Content	A. Does Vessel have PSV already when isolated	B. If Yes, is the PSV sized for FC?	C. Is the bottom of vessel more than 7.6 m above a potential pool of flammable	G. Is there an engineering feature to ensure no flammable liquid pooling under vessel during TAM? (Such as distance to HC liquid source more than 8.6 m)		Recommended Resolution
V-3101	Gas, water maybe during TAM	No	NA	**0.91 M**	**31 M from V-3403**	**Trench**	Create exemption documentation using distance, slope, and trench. With ITPM requirements to keep trench routine empty, including after releases, draining, or rain
V-3502	Gas, or CP	No	NA	**0.71 M**	**8.18 M from T-3501 (CMA type in column bottom)**	slope uphill from T3501	Dyke/Barrier to prevent reaching Deluge (But difficult to reach 10-2) Or Fire case PSV **or documentation slope and material more rigorously**
V-3509	Gas, or CP	No	NA	**0.81 M**	**7.11 M from T-3501 (CMA type in column bottom)**	slope uphill from T3501	Dyke/Barrier to prevent reaching Deluge (But difficult to reach 10-2) Or Fire case PSV **or documentation slope and material more rigorously**
V-3221	Gas, or CP	No	NA	**0.58 M**	**52 M from T-3501 (CMA type in column bottom)**	**Trench**	Create exemption documentation using distance, slope, and trench. With ITPM requirements to keep trench routine empty, including after releases, draining, or rain
E-3222	Gas and water	No	NA	**4 M**	**51 M from T-3501 (CMA type in column bottom)**	**Trench**	Create exemption documentation using distance, slope, and trench. With ITPM requirements to keep trench routine empty, including after releases, draining, or rain
V-3203	Gas, or CP	No	NA	**0.84 M**	**62 M from T-3501 (CMA type in column bottom)**	**Trench**	Create exemption documentation using distance, slope, and trench. With ITPM requirements to keep trench routine empty, including after releases, draining, or rain
V-3204	Gas, or CP	No	NA	**0.74 M**	**29 M from V-3403**	**Trench**	Create exemption documentation using distance, slope, and trench. With ITPM requirements to keep trench routine empty, including after releases, draining, or rain
V-3402	CMA approx	No	NA	**1.93 M**	**6.1 M from V-3403**	27 cm high raised footer/base, with a full metal skirt, with some openings beginning at 18 cm; largest opening at 25 cm diameter (for looking in)	Deeper evaluation is required for installation of a fire case relief valve since that the vessel would likely fail on high temperature (exceed MAWT) before the fire case PSV opens.
V-3504	Higher alcohol	No	NA	**3.6 M**	**6.5 M from T-3501 (CMA type in column bottom)**	slope uphill from T3501	Dyke/Barrier to prevent reaching Deluge (But difficult to reach 10-2) Or Fire case PSV **or documentation slope and material more rigorously**
R-3101	Gas, and never water	No	NA	**2 M**	**58 from T-3501 (CMA type in column bottom)**	**Trench**	Create exemption documentation using distance, slope, and trench. With ITPM requirements to keep trench routine empty, including after releases, draining, or rain
R-3102 A/B	Gas, and never water	No	NA	**2 M**	**63 M from T-3501 (CMA type in column bottom)**	**Trench**	Create exemption documentation using distance, slope, and trench. With ITPM requirements to keep trench routine empty, including after releases, draining, or rain
V-3202	Gas, water maybe during TAM	Yes	Possible based on sizing	**0.84 M**	**27 M from T-3501 (CMA type in column bottom)**	**Trench**	Create a data sheet for fire case to prove the existing PSV is large enough for that case as well.
V-3650	Gas, water maybe during TAM	Yes	Possible based on sizing	**1.09 M**	**33 M from T-3503**	**Trench**	Create a data sheet for fire case to prove the existing PSV is large enough for that case as well.

The summary of alternative System Design considerations for one plant (13 vessels in question) based on the tabulated results (above) were:

- 7 have sufficient distance and slope of pad and have a significant trench between the source vessel and target vessel
- 2 have relief valves between the process isolation valves that need a fire case relief valve datasheet; the relief valves appear to be large enough for the fire case
- 3 need a dike to preclude accumulation under the target vessel and the target vessel does not contain flammable liquid
- 1 needs deeper evaluation.

In the overall study for all the plants at the AR-Razi site in Jubail, of all vessels in question, 92% were exempted from the need for a fire case relief valve.

The Final Sign-off Forms

This study was completed for all the Methanol and Utility plants at AR-RAZI. The concurrence of the PHA team on the results of the evaluation and recognizing that (for scenarios which are not credible owing to System Design) it is likely better to a achieve numerical value (order of magnitude) of "low probability of failure of the safe design" that is equivalent to the PFD of a relief valve (PFD ≤ 0.01) were achieved. This project hence was concluded with the final Sign-off forms for the exemption from the need for Fire Case PSV (per UG-140; Code Case 2211-1) for the identified vessels in the evaluation. A couple of examples of the final Sign-off forms are shown below:

Exemption from need for Fire Case PSV per UG-140 (Case Case 2211-1)	
Plant / Area:	Plant III
FC Item Number:	2 (PHA Recommendation 25)
Vessel Number:	**V-3502**
Vessel Name:	**Refining Column RG Reboiler Condensate Drum**
Vessel Content:	Reformed gas and chemical process water
PSV (if applicable):	N/A
Is the Vessel exempt from Need for FC PSV:	Yes
Explanation of decision on exemption:	Vessel is 14 M from the edge of T-3501 which contains crude methanol (CMA) in the column bottom. There is no trench between V-3502 and T-3501, but the grade slopes upward at 1:40 pitch towards V-3502. Further note that V-3502 is outside of the 2500 sq ft area (>8.6 m radius) and outside of the 5000 sq ft area (> 12 m) from the centerline of T-3501, meeting one of the exclusions allowed in SES: S03-E01, Rev05. This SES references API Std 521 but 4.6.7.2 of API Std 521 does not appear to be an exclusion from requiring a fire case relief valve, but instead states that in such designs, there is no increase in the flare load of a relief header due to external fire (so API std 521 4.6.7.2 does not explicitly remove the requirement for a fire case relief valve for the vessel for protection during a shutdown & blocked-in condition). Nevertheless, the team and responsible engineers concur that the distance is sufficient given the volume of liquid from T-3501 and the opposing slope.
Recommended action to be exempt:	Not applicable
Supporting recommendation to maintain exemption:	
Concurrance on Exemption	
Responsible Area Engineer	Signature: [redacted]
	Name: [redacted]
	Title:Engineer, Process; Process Engineering; AR-RAZI
	ID #: [redacted]
Date	10/20/2024
PHA Team Leader	Signature:
	Name: **William Bridges**
	Title: PHA Leader, Plant III; President of PII
	Company: Process Improvement Institute, Inc.
Date	October 7, 2024

Exemption from need for Fire Case PSV per UG-140 (Case Case 2211-1)	
Plant / Area:	Plant III
FC Item Number:	4 (PHA Recommendation 25)
Vessel Number:	**V-3221**
Vessel Name:	**No. 1 RG Drain Separator**
Vessel Content:	Reformed gas and chemical process water
PSV (if applicable):	N/A
Is the Vessel exempt from Need for FC PSV:	Yes
Explanation of decision on exemption:	Vessel is 52 M from nearest flammable liquid source, T-3501, and there is a trench between the source and target vessel, and the slope of the concrete pad is 1:40 minimum. Therefore, it is not credible (P less than 0.01) for flammable liquid to be under this vessel.
Recommended action to be exempt:	Not applicable
Supporting recommendation to maintain exemption:	Add a critical action for operations or maintenance to keep trench empty, including after releases, after draining, or after rain
Concurrance on Exemption	
Responsible Area Engineer	Signature: [redacted]
	Name: [redacted]
	Title:Engineer, Process; Process Engineering; AR-RAZI
	ID #: [redacted]
Date	10/20/2024
PHA Team Leader	Signature:
	Name: **William Bridges**
	Title: PHA Leader, Plant III; President of PII
	Company: Process Improvement Institute, Inc.
Date	October 7, 2024

Figure 3. Example sign-off forms

Business Case

The business case for this approach to addressing external fire risk with alternatives to fire case relief valves is very significant. For a study of less than $100,000 (counting all labor), the company saved approximately $10,000,000 on the installed cost of otherwise adding fire case relief valves to the vessels that are normally empty. For the pressure vessels that had no fire case relief valves (which were about 5% of the total number of pressure vessels), 92% of the vessels were instead protected by inherently safer designs at much lower cost option for protection against external fire. This same approach can benefit existing plants that were not fully compliant in the past with the ASME Code but the approach can also save significant costs as an alternative to designing and installing fire case relief systems in new plants.

Closing

Code Case 2211-1 incorporated in UG-140 (a) can be used for evaluating Safety Design options as an alternative for an External Fire Case relief valve for a pressure vessel; in addition to using an SIF (of SIL 2 or greater) to eliminate one or more other relief scenarios, UG-140(b). Though the rules for applying Safety Design as an alternative to a fire case relief valve are straightforward, the assessment takes several hours of team effort per scenario once the team is acquainted with the approach.

Acronyms

CCPS: Center for Chemical Process Safety
CM: Continuous Mode
COI: Consequence Of Interest
CSB: US Chemical Safety Board
EPA: U.S. Environmental Protection Agency
HAZOP: Hazard and Operability study
L+S: PHA Leader and PHA Scribe
MAWP: Maximum Allowable Working Pressure
MAWT: Maximum Allowable Working Temperature
NRM: Non-Routine Modes
OSHA: US Occupational Safety and Health Administration
PHA: Process Hazard Analysis
PSM: Process Safety Management
RBPS: Risk Based Process Safety
SOP: Standard Operating Procedure

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[7] Paper on "Application of UG-140 for Overpressure Protection" – Sushant C. Labhasetwar (Daelim, SK)

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