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Align PHA Scenarios with PSV Calculation Cases

Views and Perspectives of an Oil Industry Engineer

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Abstract

It is not uncommon to find that Process Hazard Analysis (PHA) scenarios and Process Safety Valve (PSV) calculation cases do not align. The intent of PHA studies, typically performed using the Hazard and Operability (HAZOP) method, is to identify all plausible hazard scenarios and the risk of those events occurring by assessing potential causes, consequences, safeguards, and independent protection layers. The intent of the PSV protection layer is to provide relief capacity for all plausible overpressure scenarios. Therefore, HAZOP scenarios related to overpressure and PSV calculation cases should align. Lack of alignment between the HAZOP and the PSV calculation file creates problems in completeness, quality, and clarity. Lack of alignment also creates engineering rework and "churn" as inconsistencies are discovered and resolution is needed. A simple solution is proposed. Each PSV calculation case that is considered plausible should contain a direct reference to the related HAZOP scenario, preferably in the summary matrix. Likewise, each HAZOP scenario should reference the related PSV case. New or modified PSV calculations and new or modified HAZOP summary sheets associated with plant modifications or engineering document corrections should include this cross-referencing. Where broader changes are introduced, such as changes to engineering assumptions for PSV calculations or changes to HAZOP scenario protocol, the Discipline Subject Matter Experts (SMEs) responsible for approving those changes must consider the impacts to the related documents and define the expectations for updating those documents in order to assure alignment.

1 Background / Problem Statement

It is commonly understood that an integral relationship exists between Process Safety Valve (PSV) calculations and Process Hazard Analyses (PHAs). (Note: PHA studies are commonly conducted using the HAZOP method. The terms PHA and HAZOP may be used interchangeably in this paper.) PSV calculations are considered Process Safety Information (PSI) documents and these calculations are widely understood to be critical reference information for conducting PHAs (29 C.F.R. 1910.119 (d)(3)(i)(D) (1992, as amended); Center for Chemical Process Safety, 2008: 61-62). However, while these documents are consistently used as reference documentation for PHA studies, PHA teams often find that the scenarios considered viable and documented on PSV calculations do not always align with scenarios considered plausible on the PHA. The reverse is true as well. All cases deemed plausible by the PHA team on the HAZOP study are not always recognized or considered plausible by the persons performing and approving the PSV calculations. This situation results in a mismatch between credible scenarios documented on the PHA and cases documented and assessed on the PSV calculations.

The lack of consistency between the two data sources leads to incomplete analysis of the hazards and requires additional engineering work or rework to resolve differences. Additional documents may be created that reference the PHA and the PSV calculations, such as safety system override hazard assessments. These documents also become out-of-date when the source documents do not align. Those additional documents will require rework to assure consistency with all approved process safety information.

When mismatches between reference PSI documentation are found, PSVs generally are not credited in the Layers of Protection Analysis (LOPA) and may not be credited in the HAZOP until resolution is completed. In this situation, the HAZOP and LOPA studies will not properly represent relative risks. Personnel utilizing these studies, including management, operations, and engineering, will be using incomplete information for decision making. Projects involving risk mitigation work may not be properly prioritized until gaps between source data and summary reports are resolved. Hazard assessments utilizing this data may also be compromised.

While revalidation or rework of PSV calculations to current engineering and industry standards may be a necessary task in some instances, PSV calculations are time intensive work and repeated rework is not a value added activity for operating companies. Likewise, the PHA study report is a primary source document for understanding and assessing ongoing risk. This document is expected to fully capture and assess process safety risks within the operation. Gaps and inconsistencies between the PHA report and the data sources expose operating companies to risk, liability, and potential non-compliance findings.

2 Causes of the Problem: Why do these gaps occur?

Reasons that these gaps and discrepancies occur include the following:

1) <u>Multiple owners within one organization</u>:
    a. <u>Different discipline group owners</u>: Typically in larger operating companies, PHAs, in particular 5-year HAZOP revalidation studies, and PSV calculations are managed by different groups. Process Hazard Analysis studies are typically managed by Process Safety or Technical Safety Engineering teams or groups. Relief system studies and PSV calculation completion and approval tasks are

generally owned by Process Engineering. While the groups may be closely related, the technical policies and procedures may have different owners. Those procedures are typically derived from different regulations and standards, such as OSHA for PHA (29 C.F.R. 1910.119 (e), 1992, as amended) and API for PSV calculations (API 521, 2014). The different standards and procedures offer differing methods to identify hazards. Multiple methods may lead to different findings. No expectation is generally given to correlate and reconcile the hazards identified.

    i. Contract Engineering: The same problems occur when contract engineers are given work scope by Process Engineering or Process Safety Engineering groups. Relief system studies and PSV calculations are often outsourced to engineering firms. These firms will meet the requirements set by the client. If there is not an expectation for alignment with PHA scenarios, the PSV calculations will be done in isolation. The PHA study may not be provided as a reference. If alignment of the PHA and PSV calculations is required, that requirement must be stipulated and facilitated.

  b. Regional differences/different protocol: In some companies, different regions within the same company may utilize slightly different standards and protocol which could lead to differing assessment results, such as standards on double jeopardy, etc. Ultimately, the operating company or corporation must come to a single conclusion: Is the scenario viable or not? If the scenario is viable for a PSV calculation, it is also viable as a PHA hazard scenario. The reverse is true, as well. Interpretation will be involved, but a single standard must be accepted and agreed upon by the operating company.

2) Broader organization goals vs. narrower group or individual roles:
  a. Working in silos: PHA Teams may delegate or assign work to Process Engineering groups stemming from PHA Recommendations. The Process Engineering group is tasked with completing the calculations not questioning the origin of the work.
  b. Task goal vs. ultimate business unit goal: In some cases, the Process Engineers performing the PSV calculations may deem their task as a validation or a second-set-of-eyes reviewing the potential overpressure scenarios. As such, these engineers may wish to assess the scenario without having pre-conceived notions of what scenarios were considered viable by others. This method may be a prudent approach for validating scenarios; however, in conjunction with delivering final products, the two sources must ultimately be reconciled and viable overpressure scenarios should align in documentation of record.
  c. Lack of outside of the box thinking: Routinely in PHA studies, the gaps between PSV calculation cases and PHA scenarios are recognized. A standard approach for addressing these gaps may be to create PHA Recommendations or Action Items to follow-up and rework the PSV calculations. While these follow-up actions may close individual gaps at the time that new calculations are completed, these actions items do not systemically address the root cause of the problem.

3) Ineffective Management of Change (MoC):

a. Management of Change (MoC) misses: Theoretically, MoC is intended to pick up discrepancies and errors on projects and modifications. However, reality is not always consistent with theory. New projects may continue to miss discrepancies given the various groups and methods involved in assembling those data and analyses. Without an explicit expectation for the documents to align, some amount of inconsistency may be deemed acceptable.
b. MoC for Engineering Document Updates: Operating companies not only remain in differing states of maturity regarding MoC on physical changes, but also regarding MoC on engineering documentation updates and corrections. In some cases, isolated document updates or corrections may not receive the same rigor that physical changes and modifications receive. Associated documents that may be impacted by the engineering updates and corrections may be missed.
c. Missing applications for Management of Change (MoC): In some instances, MoC may be missed altogether. Companies are getting better at performing MoC on isolated modifications and changes. Managing administrative change is generally understood to be a requirement but may be less evolved. Fewer tools and methods are available to review wider administrative changes. For example, technical guidance and best practices may change over time with regard to engineering evaluations. Technical guidance may become more conservative which may result in larger relief capacity requirements. If new technical guidance is introduced that impacts all PSV calculations of a given type, all PHA scenarios based for the same type of failure are also impacted. The reverse is true as well. Changes in PHA scenario guidance to PHA teams may require additional process engineering work in order to assure those cases are captured in the PSV calculations. Understanding the implications of those guidance changes and the resources required to follow-through must be understood and defined at the time that the guidance is changed.

3 Solutions: How do we prevent the problem?

Now for the solution: Disclaimer . . . this is not rocket science!

First, define and communicate the new expectation and requirements. The requirement may be described in the form of policy or procedural expectations for the PSV calculation cases and PHA scenarios to align one-to-one. These policies and procedures are communicated via administrative management of change training. However, training alone may not reinforce nor instill the practice.

Institutionalizing the change may be as simple as modifying a standard form or template used to document PSV calculations and PHA scenarios. Many companies include a summary matrix within the PSV calculation that includes typical API 521 scenarios, physical properties, and results of the calculations by scenario. Adding a column to this summary matrix for PHA scenario cross-reference would facilitate gathering and easily locating that information. Figure 1 illustrates a sample PSV summary table that cross references the HAZOP Node/Scenario. This table was derived from API Standard 521. Companies that do not currently use this type of summary matrix may adopt the example provided in Figure 1 or create their own summary table. Populating this table completely should be a requirement for approval of new PSV calculations.

The PHA scenarios should reference the appropriate PSV calculation case, as well. There should be correlation between every viable PSV calculation case and every viable PHA scenario involving overpressure. Some PHA scenarios based on non-pressure related deviations will also lead to overpressure and relate to PSV calculation cases as well. The final PHA report should include appropriate cross-referencing.

A more evolved solution would involve assembling all hazard and risk related data, including data associated with independent protection layers and safeguards, into a comprehensive database. Having a single source for the data is preferred since source data should not be maintained in multiple locations. A single database would facilitate easy searching, filtering, extraction, and downloading of data. Discussion of developing such as database is beyond the scope of this paper.

As stated at the outset, the idea of cross-referencing PHA scenarios with PSV calculation cases is a simple concept and should be equally simple to implement. However, recent experience indicates that this straightforward idea is currently not widely implemented. Modifying the forms and templates used for PSV calculations and PHA documentation will provide reminders to the authors of the documents of the need to reconcile scenarios. Concise, standard summary formats will support effective communication of key information. These improvements assume that a mature and rigorous MoC process is in place where changes to process safety information are approved and documents are updated.

More difficult to address are systemic problems associated with larger policy or procedural changes where higher level guidance changes may widely impact the operating company's ability to maintain accurate and current PSI. These issues must be addressed by management and technical authorities through rigorous application of administrative management of change at the time that changes to policy, procedure, or protocol are proposed.

4 Examples

Below are several examples that demonstrate how to put these simple ideas into practice.

1) Modes of operation, process configuration: Hazards should be considered for all typical or likely modes of operation. If a piece of equipment may be operated in more than one process configuration, the PSV calculations and the PHA should reflect each of those modes of operation. (Refer to Figure 2 for an example where a 2nd Stage Separator may be lined up with either a 1st Stage Low Pressure Separator or a 1st Stage High Pressure Separator. Note: there may be instances where HAZOP/LOPA methodology is applied which dictates that the consequences will be negligible; however, relief systems must be available and properly sized. Those scenarios should be identified in both reference documents.)
2) Differing assumptions:

a. Configuration during hazard scenario: Hazards associated with operating configuration should be considered in the PHA and in the PSV calculations in a manner consistent with company protocol. One example: assumptions regarding bypass valve position may vary over time or from company to company. For configurations involving a bypass valve, the assumption may be: 1) bypass valve is open; 2) bypass valve is closed; or 3) consider both cases, bypass valve is open and bypass valve closed. If both cases are considered, the likelihood of the event may differ between scenarios depending on frequency of operation of the bypass, administrative controls in place such as carseals, and company protocol and direction. Most importantly, each scenario deemed viable based on company guidance should be identified in the PHA scenarios and the PSV calculation cases. (Figure 3 illustrates an example of a scenario involving a bypass valve.)
b. Technical assumptions in calculations: Identifying hazard scenarios requires the team and/or individual to make various technical assumptions. PSV calculations require numerous engineering assumptions in order to determine both required and available relief capacity. One example: A key assumption which drives both the hazard scenario and the PSV calculation is the potential pressure which may be introduced into a system. The highest pressure which a system may see relative to the design pressure rating for that system drives the consequence for a given hazard scenario. Depending on company protocol, the potential pressure seen by a downstream system may be limited by various upstream parameters such as: an upstream mechanical protection device (consider upstream PSV setpoint); an upstream safety instrumented system (consider high-high pressure shut-down set-point); or even a normal operating pressure (least conservative assumption). Generally, PSVs will be in place which protect downstream systems. The relief capacity for those PSVs is calculated based various parameters including an assumed upstream or inlet pressure at the time that the PSV relieves, the PSV setpoint. The required capacity will typically be defined by a maximum potential pressure further upstream (possibly an upstream node) flowing through a limiting device. Whatever the assumption is for potential pressure in the hazard scenario, the PSV calculation should assume the same inlet pressure, or P_1, when calculating the required capacity based on the upstream limiting device. (Figure 4 provides an example of a system which could be overpressured up to 400 psig. The upstream source of the 400 psig pressure is shown. The same value is used in the calculation of the required relief capacity.)

5 Conclusions

This paper focuses on the need for alignment of PHA scenarios with PSV calculation work. Both efforts have historically attempted to identify potential overpressure hazards using different approaches that have, in many cases, yielded different scenarios for consideration. All credible overpressure scenarios should be considered from a risk and risk mitigation standpoint.

A simple solution is proposed, cross-referencing HAZOP scenarios in PSV calculation summary information, and vice versa. A sample template for a PSV calculation summary sheet containing this type of cross-reference is provided. Similar cross-referencing should be shown in HAZOP report summary information.

This paper assumes that traditional methods for calculating relief capacities of PSVs relative to relief requirements will remain an ongoing need. This data is required in order to associate the relief device with HAZOP and LOPA credit. Another related paper tackles the problem by considering risk based relief requirements which focus on dynamic analysis of worst case pressure achieved during potential relieving events. Refer to "Practical Risk Based Approach to Pressure Relief and Effluent Handling System Design," Casey Houston and Neil Prophet, GCPS 2016, for more ideas on that approach.

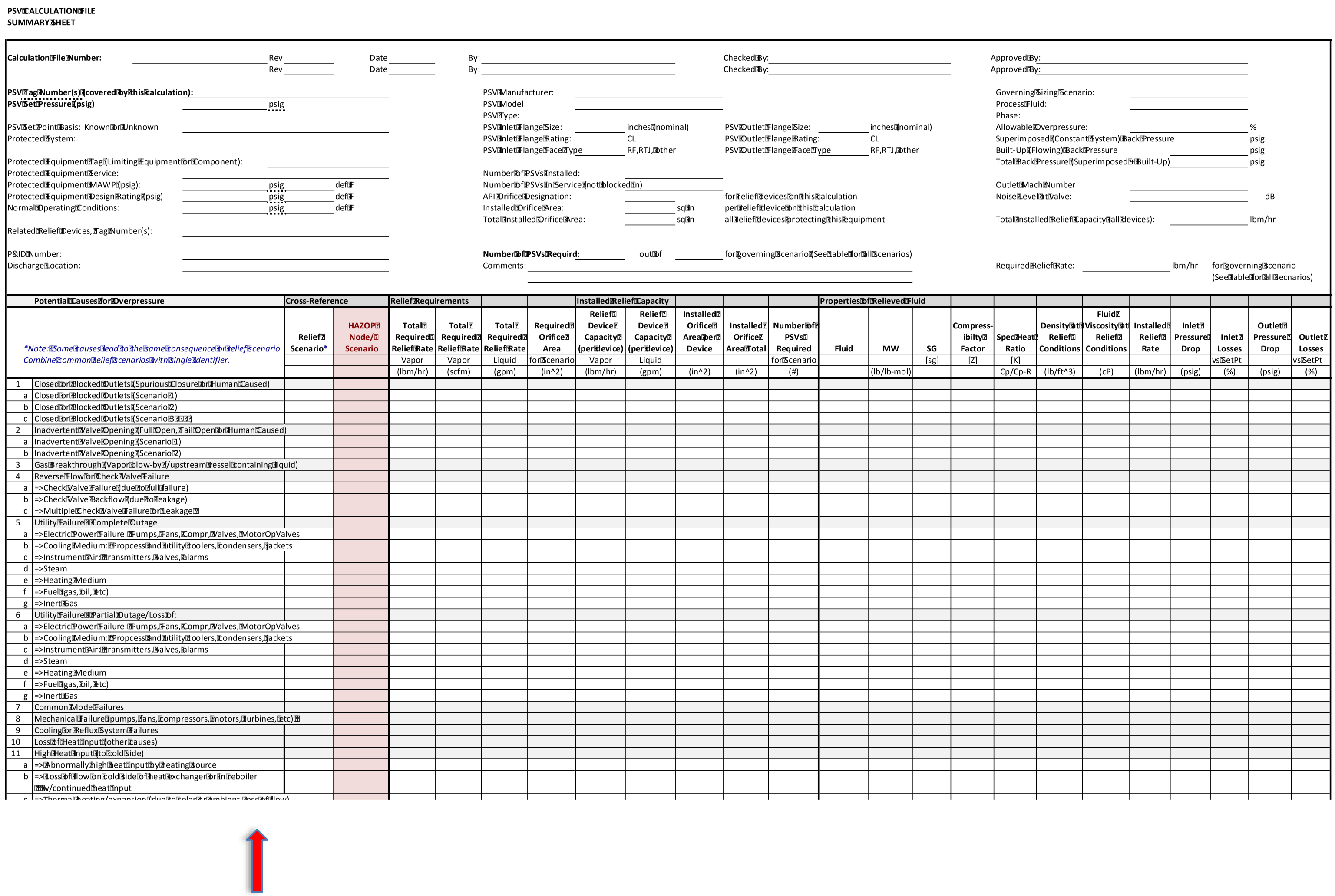
Although the concepts presented in this paper are relatively simple and straightforward, potential benefits to operating companies are significant if these ideas are implemented. Benefits include more efficient use of resources and mitigation of risk and liability. Contract engineering firms also benefit by increasing the likelihood that their work is well received by client users and that the work remains relevant for a longer period of time.

Operating company management and technical authorities are key audience members for these ideas. Managers and technical authorities are best positioned to implement new expectations for aligning these source documents and are responsible for considering unintended implications of wider protocol changes. Where separate groups are responsible for related but distinct deliverables, higher level management must ensure alignment.

6 References / Resources:

1) 29 C.F.R. 1910.119 Process safety management of highly hazardous chemicals. 1992, as amended.
2) American Petroleum Institute (API). *ANSI/API Standard 520: Sizing, Selection, and Installation of Pressure-relieving Devices in Refineries, Part 1 – Sizing and Selection.* 9th Edition. Washington, D.C.: API Publishing. 2014.
3) American Petroleum Institute (API). *ANSI/API Standard 521: Pressure-relieving and Depressuring Systems.* 6th Edition. Washington, D.C.: API Publishing. 2014.
4) Center for Chemical Process Safety (CCPS). *Guidelines for Hazard Evaluation Procedures*. 3rd Edition. New York, NY: CCPS, American Institute of Chemical Engineers, John Wiley and Sons Inc. 2008.
5) Emerson Process Management. "Valve Sizing Calculations (Traditional Method)." Emerson Process Management Documentation, Fisher Valves and Regulators. Web 30 Aug 2016. http://www.documentation.emersonprocess.com/groups/public/documents/reference/d351798x012_11.pdf
6) Houston, Casey and Prophet, Neil. "Practical Risk Based Approach to Pressure Relief and Effluent Handling System Design*,"* presented at 12th Global Congress on Process Safety, Houston, TX, 2016.

Figure 1: Sample PSV calculation summary sheet with HAZOP scenario cross-reference



PSV CALCULATION FILE
SUMMARY SHEET

Calculation File Number: ____ Rev ____ Date ____ By: ____ Checked By: ____ Approved By: ____
Rev ____ Date ____ By: ____ Checked By: ____ Approved By: ____

PSV Tag Number(s) (covered by this calculation): ____
PSV Set Pressure (psig) ____ psig

PSV Set Point Basis: Known or Unknown ____
Protected System: ____

Protected Equipment Tag (Limiting Equipment or Component): ____
Protected Equipment Service: ____
Protected Equipment MAWP (psig): ____ psig ____ deg F
Protected Equipment Design Rating (psig) ____ psig ____ deg F
Normal Operating Conditions: ____ psig ____ deg F

Related Relief Devices, Tag Number(s): ____

P&ID Number: ____
Discharge Location: ____

PSV Manufacturer: ____
PSV Model: ____
PSV Type: ____
PSV Inlet Flange Size: ____ inches (nominal) PSV Outlet Flange Size: ____ inches (nominal)
PSV Inlet Flange Rating: ____ CL PSV Outlet Flange Rating: ____ CL
PSV Inlet Flange Face Type ____ RF, RTJ, other PSV Outlet Flange Face Type ____ RF, RTJ, other

Number of PSVs Installed: ____
Number of PSVs In Service (not blocked in): ____
API Orifice Designation: ____ for relief devices on this calculation
Installed Orifice Area: ____ sq in per relief device on this calculation
Total Installed Orifice Area: ____ sq in all relief devices protecting this equipment

Number of PSVs Requird: ____ out of ____ for governing scenario (See table for all scenarios)
Comments: ____

Governing Sizing Scenario: ____
Process Fluid: ____
Phase: ____
Allowable Overpressure: ____ %
Superimposed (Constant System) Back Pressure ____ psig
Built-Up (Flowing) Back Pressure ____ psig
Total Back Pressure (Superimposed + Built-Up) ____ psig

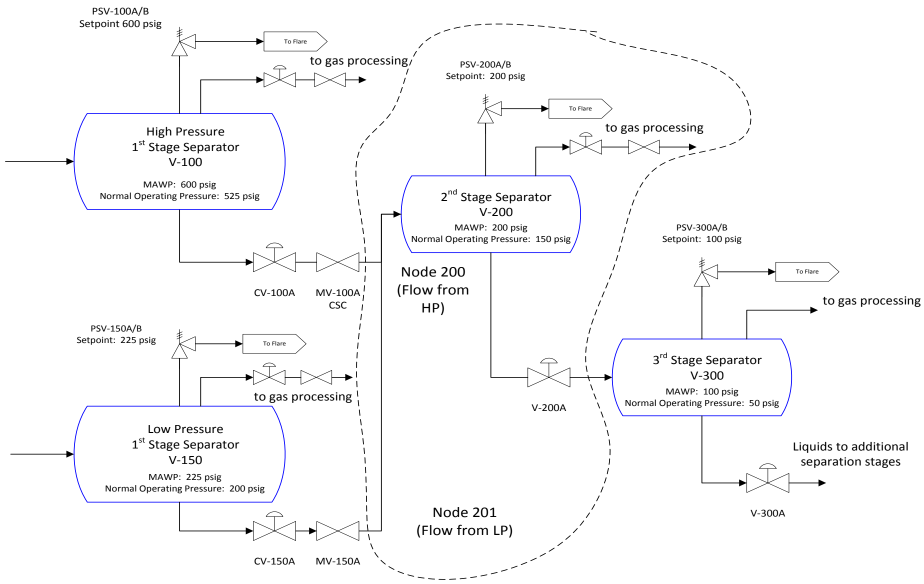
Outlet Mach Number: ____
Noise Level at Valve: ____ dB

Total Installed Relief Capacity (all devices): ____ lbm/hr

Required Relief Rate: ____ lbm/hr for governing scenario (See table for all scenarios)

	Potential Causes for Overpressure	Cross-Reference		Relief Requirements				Installed Relief Capacity					Properties of Relieved Fluid											
	Note: Some causes lead to the same consequence or relief scenario. Combine common relief scenarios with single identifier.	Relief Scenario*	HAZOP Node/ Scenario	Total Required Relief Rate	Total Required Relief Rate	Total Required Relief Rate	Required Orifice Area	Relief Device Capacity (per device)	Relief Device Capacity (per device)	Installed Orifice Area per Device	Installed Orifice Area Total	Number of PSVs Required	Fluid	MW	SG	Compress-ibilty Factor	Spec Heat Ratio	Density at Relief Conditions	Fluid Viscosity at Relief Conditions	Installed Relief Rate	Inlet Pressure Drop	Inlet Losses	Outlet Pressure Drop	Outlet Losses
				Vapor	Vapor	Liquid	for Scenario	Vapor	Liquid			for Scenario			[sg]	[Z]	[K]					vs SetPt		vs SetPt
				(lbm/hr)	(scfm)	(gpm)	(in^2)	(lbm/hr)	(gpm)	(in^2)	(in^2)	(#)		(lb/lb-mol)			Cp/Cp-R	(lb/ft^3)	(cP)	(lbm/hr)	(psig)	(%)	(psig)	(%)
1	Closed or Blocked Outlets (Spurious Closure or Human Caused)																							
a	Closed or Blocked Outlets (Scenario 1)																							
b	Closed or Blocked Outlets (Scenario 2)																							
c	Closed or Blocked Outlets (Scenario 3 ...)																							
2	Inadvertent Valve Opening (Full Open, Fail Open or Human Caused)																							
a	Inadvertent Valve Opening (Scenario 1)																							
b	Inadvertent Valve Opening (Scenario 2)																							
3	Gas Breakthrough (Vapor blow-by f/upstream vessel containing liquid)																							
4	Reverse Flow or Check Valve Failure																							
a	=>Check Valve Failure (due to full failure)																							
b	=>Check Valve Backflow (due to leakage)																							
c	=>Multiple Check Valve Failure or Leakage																							
5	Utility Failure - Complete Outage																							
a	=>Electric Power Failure: Pumps, Fans, Compr, Valves, MotorOpValves																							
b	=>Cooling Medium: Propcess and utility coolers, condensers, jackets																							
c	=>Instrument Air: transmitters, valves, alarms																							
d	=>Steam																							
e	=>Heating Medium																							
f	=>Fuel (gas, oil, etc)																							
g	=>Inert Gas																							
6	Utility Failure - Partial Outage/Loss of:																							
a	=>Electric Power Failure: Pumps, Fans, Compr, Valves, MotorOpValves																							
b	=>Cooling Medium: Propcess and utility coolers, condensers, jackets																							
c	=>Instrument Air: transmitters, valves, alarms																							
d	=>Steam																							
e	=>Heating Medium																							
f	=>Fuel (gas, oil, etc)																							
g	=>Inert Gas																							
7	Common Mode Failures																							
8	Mechanical Failure (pumps, fans, compressors, motors, turbines, etc)																							
9	Cooling or Reflux System Failures																							
10	Loss of Heat Input (other causes)																							
11	High Heat Input (to cold side)																							
a	=>Abnormally high heat input by heating source																							
b	=>Loss of flow on cold side of heat exchanger or in reboiler w/continued heat input																							
c	=>Thermal heating (expansion due to solar & ambient, loss of flow)																							

Figure 2: Example showing multiple modes of operation (process configuration)



PHA Log Sheets
Top Gun Energy

PHA Node /Scenario Identifier	Deviation	Causes	Consequence Description	Safety Conse-quence	Safety Likeli-hood Mitigated	Safety Risk Rank	Indepen-dent Protection Layers	Safeguards
Node 200	**2nd Stage Separation (Inlet Fluids from High Pressure 1st Stage Separator, V-100)**							
200.1.1	High Pressure	V-200 Manual Gas Outlet Valve Closed	Blocked flow gas outlet. Potential to overpressure V-200 rated for 200 psig up to 600 psig (based on setpoint of PSV-100A/B). Potential for 2.7x MAWP of V-200 resulting in potential vessel rupture, VCE,	B	5	5	PSV-200A/B	Operator response to alarm
	High Pressure	*Other Causes*						
			Other Scenarios					
Node 201	**2nd Stage Separation (Inlet Fluids from Low Pressure 1st Stage Separator, V-150)**							
201.1.1	High Pressure	V-200 Manual Gas Outlet Valve Closed	Blocked flow gas outlet. Potential to overpressure V-200 rated for 200 psig up to 225 psig (based on setpoint of PSV-100A/B). Potential for 1.13x MAWP of V-200 resulting in slight exceedance of vessel MAWP. No likely leakage or other consequences. **NSCI.**				PSV-200A/B (No IPLs required)	Operator response to alarm
	High Pressure	*Other Causes*						
			Other Scenarios					

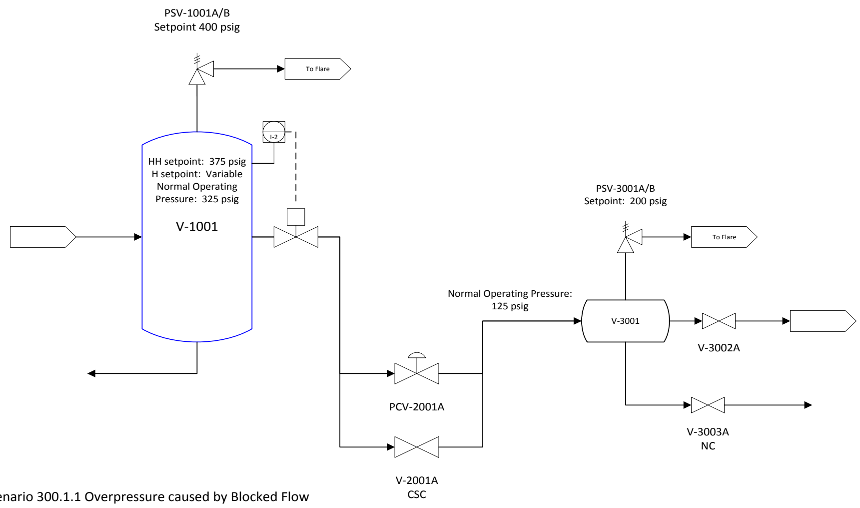
PSV CALCULATION FILE
SUMMARY SHEET

Calculation File Number: PSVCALC-001-002-01 Rev ____ Date ________ By: ____________ Checked By: ____________

PSV Tag Number(s) (covered by this calculation): **PSV-200A / PSV-200B** PSV Manufacturer: ____________
PSV Set Pressure (psig) **200** psig PSV Model: ____________
PSV Type: ____________
PSV Set Point Basis: Known or Unknown Design Rating of V-200 PSV Inlet Flange Size: ________ inches (nomina PSV Outlet Flange Size: _

	Potential Causes for Overpressure	**HAZOP Node/ Scenario**	**Relief Requirements** Total Required Relief Rate Vapor (lbm/hr)	Total Required Relief Rate Vapor (scfm)	Required Orifice Area for Scenario (in^2)	**Installed Relief Capacity** Relief Device Capacity (per device) Vapor (lbm/hr)	Installed Orifice Area per Device (in^2)	Installed Orifice Area Total (in^2)	Number of PSVs Required for Scenario (#)
	**Note: Some causes lead to the same consequence or relief scenario. Combine common relief scenarios with single identifier.*								
1	Closed or Blocked Outlets/Discharge (Spurious Closure or Human Caused)								
a	Closed or Blocked Outlets (Fluids from HP Separator)	**200.1.1**	4890	1237	0.322	4660	0.307	0.614	**2**
b	Closed or Blocked Outlets (Fluids from LP Separator)	**201.1.1**	1315	332	0.057	4660	0.307	0.614	**1**
c	Closed or Blocked Outlets (Scenario 3)								
2	Inadvertent Valve Opening (Full Open, Fail Open or Human Caused)								

Figure 3: Assumptions on valve position affect hazard scenario development



Scenario 300.1.1 Overpressure caused by Blocked Flow
Scenario 300.1.2 Overpressure caused by Control Valve Failure

Case a: Assumes Bypass Valve V-2001A is closed during relief scenario
Case b: Assumes Bypass Valve V-2001A is open during relief scenario

Case(s) shown in PHA should match assumptions used in PSV calculations and align with company guidelines and procedures.

PHA Log Sheets
Top Gun Energy
Node 300 Process X Fuel Gas Supply to Process Y

PHA Node / Scenario Identifier	Deviation	Causes	Consequence Description	Safety Conse-quence	Safety Likeli-hood Mitigated	Safety Risk Rank	Indepen-dent Protection Layers	Safeguards
300.1.1a	High Pressure	Manual Valve V-3002A is closed (Assumes Bypass Valve V-2001A (CSC) is Closed)	Blocked flow gas outlet. Potential to overpressure V-3001 rated for 200 psig up to 400 psig (based on setpoint of PSV-1001A/B). Potential for 2.0x MAWP of V-3001 resulting in	B	5	5	PSV-3001A/PSV-3001B	Operator response to alarm
300.1.1b	High Pressure	Manual Valve V-3002A is closed (Assumes Bypass Valve V-2001A (CSC) is Open)	Blocked flow gas outlet. Potential to overpressure V-3001 rated for 200 psig up to 400 psig (based on setpoint of PSV-1001A/B). Potential for 2.0x MAWP of V-3001 resulting in	B	4	6		PSV-3001A/PSV-3001B; Operator response to alarm
300.1.2a	High Pressure	PCV-2001A Fails Open (AND Bypass Valve V-2001A (CSC) is Closed)	Potential to introduce 400 psig gas (based on setpoint of PSV-1000A/B) into V-3001 rated for 200 psig. Potential for 2x MAWP of V-3001 resulting in	B	5	5	PSV-3001A/PSV-3001B	Operator response to alarm
300.1.2b	High Pressure	PCV-2001A Fails Open (AND Bypass Valve V-2001A (CSC) is Open)	Potential to introduce 400 psig gas (based on setpoint of PSV-1000A/B) into V-3001 rated for 200 psig. Potential for 2x MAWP of V-3001 resulting in	B	4	6		PSV-3001A/PSV-3001B; Operator response to alarm

PSV CALCULATION FILE
SUMMARY SHEET

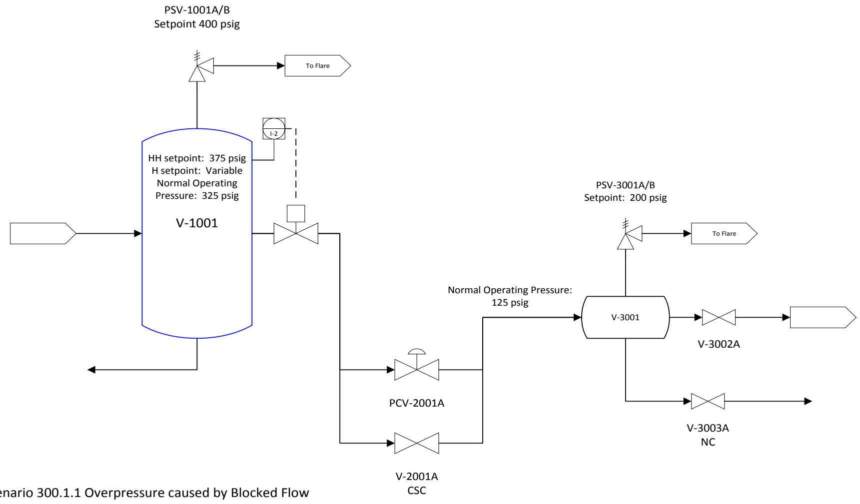
Calculation File Number: PSVCALC-001-001-01 Rev Date Checked By:

PSV Tag Number(s) (covered by this calculation): **PSV-3001A / PSV-3001B**
200 psig

PSV Set Point Basis: Known or Unknown Design Rating of V-3001 PSV Outlet Flange Size:

	Potential Causes for Overpressure		Relief Requirements		Installed Relief Capacity			
	**Note: Some causes lead to the same consequence or relief scenario. Combine common relief scenarios with single identifier.*	**HAZOP Node/ Scenario**	**Total Required Relief Rate**	**Required Orifice Area**	**Relief Device Capacity (per device)**	**Installed Orifice Area per Device**	**Installed Orifice Area Total**	**Number of PSVs Required**
			Vapor	for Scenario	Vapor			for Scenario
			(lbm/hr)	(in^2)	(lbm/hr)	(in^2)	(in^2)	(#)
1	Closed or Blocked Outlets/Discharge (Spurious Closure or Human Caused)							
a	Closed Outlet V-3002A (Assumes Bypass Valve V-3001A closed during relief)	300.1.1a	950	0.063	1652	0.110	0.220	**1**
b	Closed Outlet V-3002A (Assumes Bypass Valve V-3001A open during relief)	300.1.1b	6950	0.463	1652	0.110	0.220	**Not Adequate**
c	Closed or Blocked Outlets (Scenario 3							
2	Inadvertent Valve Opening (Full Open, Fail Open or Human Caused)							
a	Inadvertent Valve Opening (Failure of Automatic Controls) w/Bypass Closed	300.1.2a	1460	0.097	1652	0.110	0.220	**1**
b	Inadvertent Valve Opening (Failure of Automatic Controls) w/Bypass Open	300.1.2b	6950	0.463	1652	0.110	0.220	**Not Adequate**
c	Inadvertent Valve Opening (Human Error, Inadvertently opened)							
3	Gas Breakthrough (Blow-by of vapor from upstream vessel containing liquid)							
4	Reverse Flow or Check Valve Failure							

Figure 4: Apply assumptions on upstream conditions uniformly in PHA & PSV calculation



Scenario 300.1.1 Overpressure caused by Blocked Flow
Scenario 300.1.2 Overpressure caused by Control Valve Failure

Case a: Assumes Bypass Valve V-2001A is closed during relief scenario
Case b: Assumes Bypass Valve V-2001A is open during relief scenario

Case(s) shown in PHA should match assumptions used in PSV calculations and align with company guidelines and procedures.

PHA Log Sheets
Top Gun Energy
Node 300 Process X Fuel Gas Supply to Process Y

PHA Node / Scenario Identifier	Deviation	Causes	Consequence Description	Safety Consequence	Safety Likelihood Mitigated	Safety Risk Rank	Independent Protection Layers	Safeguards
300.1.1a	High Pressure	Manual Valve V-3002A is closed (Assumes Bypass Valve V-2001A (CSC) is Closed)	Blocked flow gas outlet. Potential to overpressure V-3001 rated for 200 psig up to 400 psig (based on setpoint of PSV-1001A/B). Potential for 2.0x MAWP of V-3001 resulting in	B	5	5	PSV-3001A/PSV-3001B	Operator response to alarm

Required relief capacity of the PSVs is be based on maximum calculated potential flowrate through the upstream valves. Control valve flowrate may be calculated using Fisher Valve Sizing equations:

$$Q_{SCFH} = \sqrt{\frac{520}{GT}}\; C_g\, P_1\, \mathrm{SIN}\left[\left(\frac{3417}{C_1}\right)\left(\sqrt{\frac{\Delta P}{P_1}}\right)\right] \mathrm{Deg}$$

C_1 = C_g/C_v
C_g = gas sizing coefficient
C_s = steam sizing coefficient, $C_g/20$
C_v = liquid sizing coefficient
d_1 = density of steam or vapor at inlet, pounds/cu. foot
G = gas specific gravity (air = 1.0)
P_1 = valve inlet pressure, psia
ΔP = pressure drop across valve, psi
$Q_{critical}$ = critical flow rate, SCFH
Q_{SCFH} = gas flow rate, SCFH
$Q_{lb/hr}$ = steam or vapor flow rate, pounds per hour
T = absolute temperature of gas at inlet, degrees Rankine
T_{sh} = degrees of superheat, °F

The upstream pressure P_1, valve inlet pressure, should be the same value assumed in the hazard scenario for maximum potential pressure. In this example, the maximum potential pressure is based on the upstream pressure safety valve setpoint of 400 psig.