Software Release

Winter 2020 **Version 1.2.1.1**

Coming Soon: iPRSM Version 1.2.1.1

Farris Engineering Services is pleased to announce the 20th Anniversary of the iPRSM® Software with the planned release of Version 1.2.1.1. iPRSM is a patented, web-based software and engineering calculation tool providing a comprehensive approach to the management of pressure relief systems for safety compliance. In the last 20 years, the iPRSM infrastructure has grown to more than 130 production sites with a combined total of 4,000 registered users documenting more than 1,400,000 overpressure contingency scenarios and 100,000 protected relief systems.

Summary

This 1.2.1.1 Release is a significant advancement of iPRSM's capabilities containing hundreds of small bug fixes and improvements that are part of our ongoing commitment to providing industry leading PSM software today and into the future.

Featured Highlights:

- Documentation tool for *Overpressure Protection by System Design* (OPPSD)
- Re-configuration of the Scenario Piping Loss Worksheet
- Enhanced Flare Header computation model includes the following:
  - Multiple exit points to vessels,
  - Multiple exit points to atmosphere,
  - Multiple flow dividing tees,
  - Multiple flow diverting tees,
  - Multiple knockout drums (modelled by phase-splitting tees),
  - Heat transfer tees (adding heat to KO Drum),
  - Verification of maximum mechanical back pressure limits, and
  - Improved Header Reports including DE Zone Preparation, DE Zone Analysis, KO Drums Summary, and Header Exits Summary
- Graphical Reporting for mass flux curves for Numerical Integration
- Improved analysis for validation of Remote-sensing Pilot Valves
- Software support, on request, for data mining or auditing mfg. recalls (i.e. Crosby JBS)

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Farris Engineering Services
10195 Brecksville Road
Brecksville, Ohio 44141 USA
Phone: 281.724.2222
Email: FES@curtisswright.com

Why Update iPRSM Worksheets?

An effective pressure relief management system is a critical component of the OSHA PSM process safety information (PSI) element of the 29 CFR 1910.199 standard. Relief system sizing documentation must reflect *current* process conditions as well as various operating modes and procedures.

A significant role in following this standard is not only the implementation of the management software and the relief sizing calculations, but also the facilities' maintenance and *evergreen* strategy. An evergreen approach to ensure your facilities' relief management tool as well as the relief system calculations are current and up to date plays a significant role in being compliant with regulatory authorities.

Regulatory and standard development bodies (i.e., ASME, API, DIERS, OSHA, NFPA, etc.) are constantly updating codes and standards to reflect the rapid developments in the process safety concerns of today's complex hydrocarbon and chemical process industries. iPRSM reflects this process as it is continually being updated to the latest codes and standards as set out by these bodies as well as changes to current RAGAGEP requirements.

Updating the facilities' relief system calculations not only follows proper PSM practices but also strives for a safe operating environment reflecting current process conditions. These relief evaluations in iPRSM must be manually updated at the discretion and responsibility of the user.

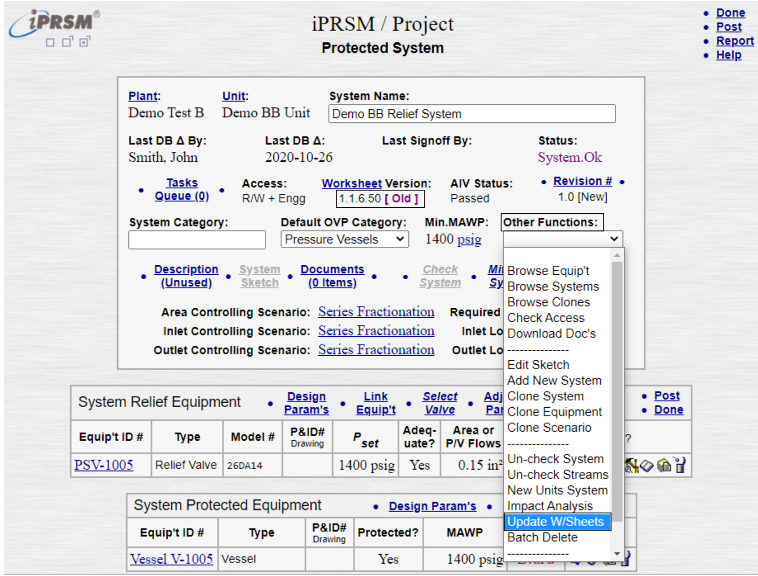
A comprehensive evergreening approach can be broken down into several components:

- A MOC workflow process model developed for the facility. Farris Engineering Services has the resources to implement this strategy to provide the necessary engineering services and effectively manage the relief system calculations.
- The use of the enhanced iPRSM **Impact Analysis** tool which enables facilities and users to directly review the effect of changes on previously calculated relief systems at a fraction of the traditional cost.
- Deficiency mining and risk management procedures developed to provide the facility with a toolset to quickly view, analyze, and manage the various states of relief systems for mitigation efforts.

How to Update iPRSM Worksheets?

After the decision is made by the user to update both earlier and active relief system calculations, the worksheets within an *entire* Protected System can be converted by following the recommended practice; **Other Functions** + Update W/Sheets.

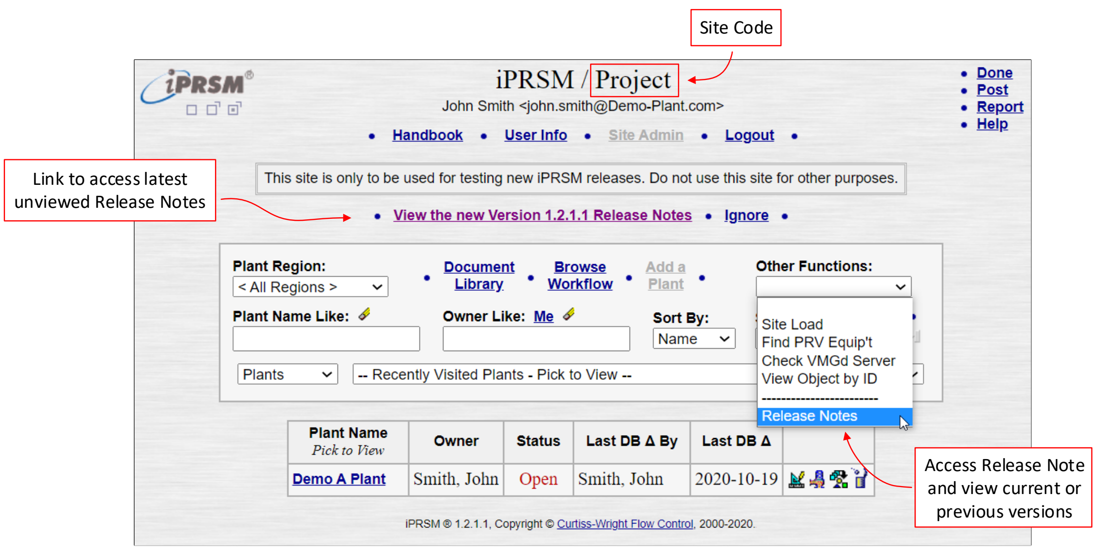
Farris Engineering Services
10195 Brecksville Road
Brecksville, Ohio 44141 USA
Phone: 281.724.2222
Email: FES@curtisswright.com



Check Out What's Changed:

To view the **Release Notes** in its entirety for iPRSM 1.2.1.1, navigate to www.iPRSM.com and enter your **Site Code** and log into your iPRSM site.

From the main iPRSM site page, select Other Functions + *Release Notes*.



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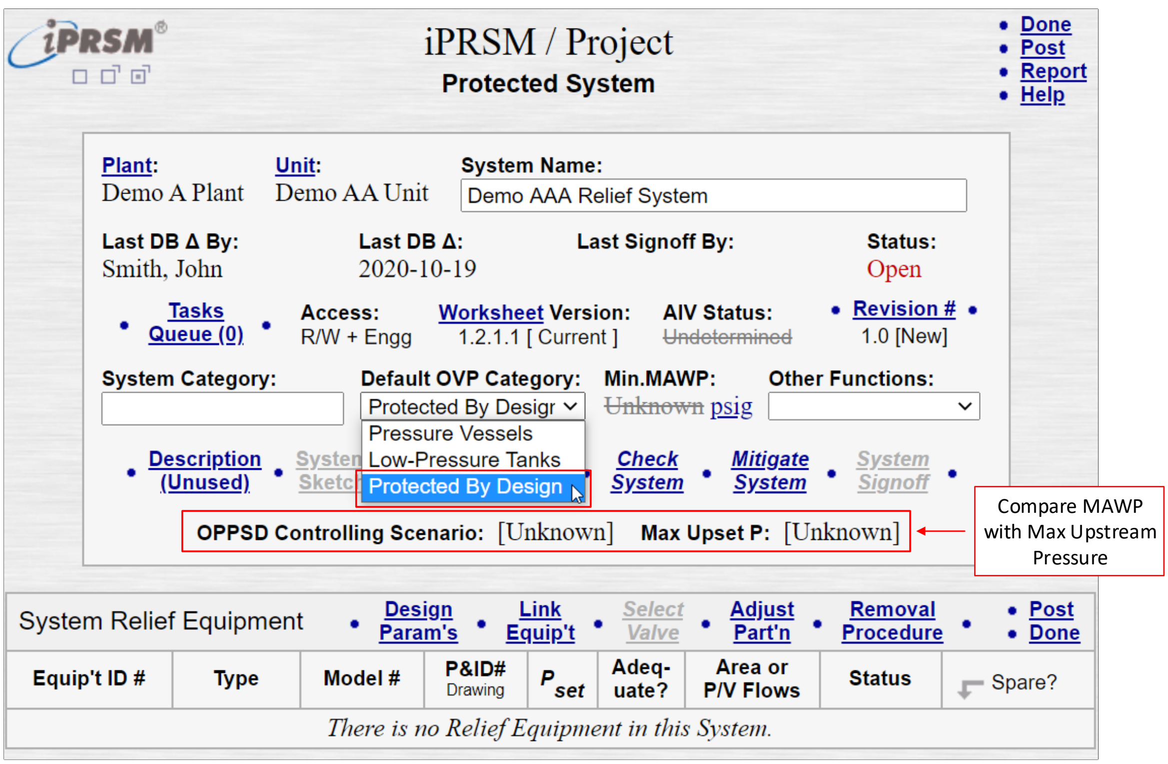
Overpressure Protection by System Design (OPPSD):

Users can now declare a system to follow 'overpressure protection by system design' in lieu of a pressure relief device. In this circumstance, pressure within the relief system is self-limiting such that no pressure would exceed the piping and/or equipment's design MAWP and thus does not require the use of a safety device. A well-documented and detailed analysis can then be used to support the justification of this decision.

iPRSM can now serve in this capacity providing a platform to conduct this comparative analysis between the system's MAWP and the 'maximum upstream pressure' (MUP). Like documenting all potential overpressure scenarios detailed in API Standard 521 for a pressure relief device, a full-detailed analysis can easily be conducted, documented, and signed-off for this OPPSD classification.

It is recommended to review the necessary requirements identified in ASME Boiler and Pressure Vessel Code (e.g. Section VIII, Division 1, paragraph UG-140(a)).



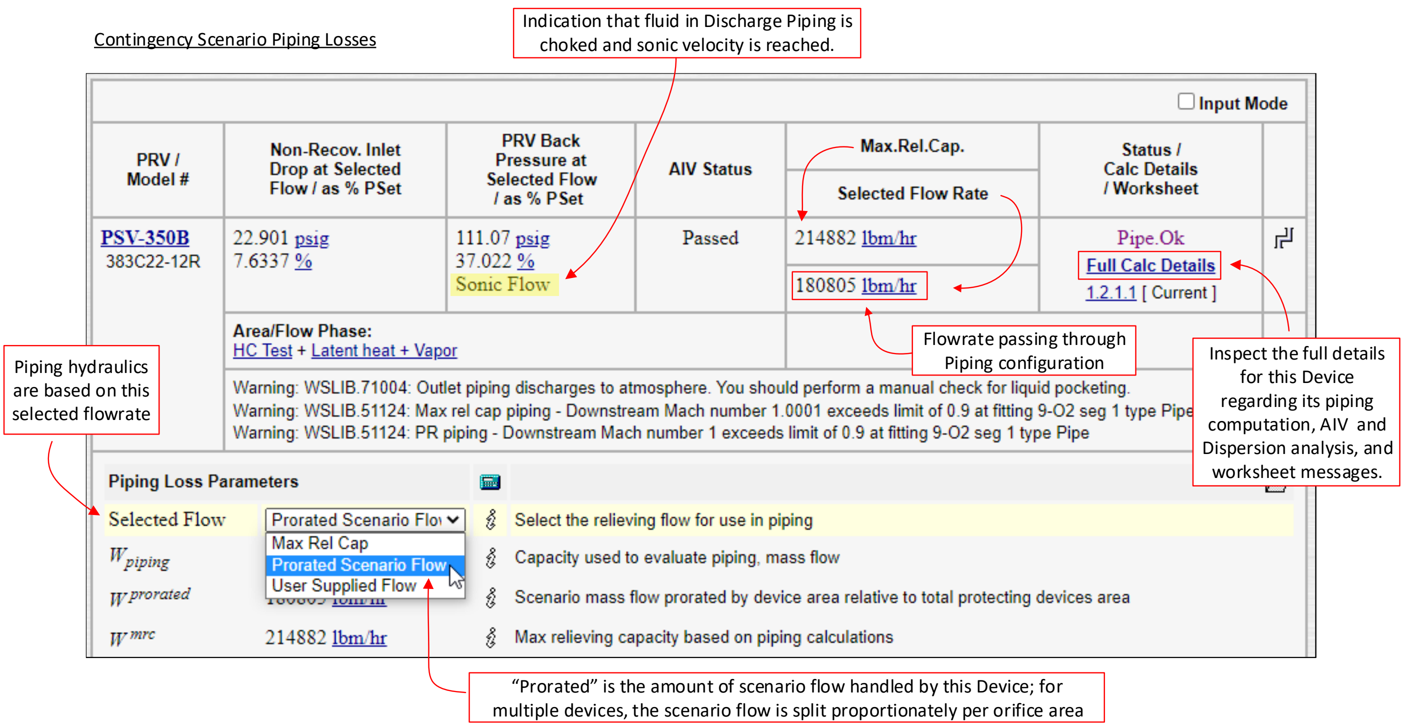
** Contact Farris Engineering Services for a demo of this feature.*

Farris Engineering Services
10195 Brecksville Road
Brecksville, Ohio 44141 USA
Phone: 281.724.2222
Email: FES@curtisswright.com

Re-Configuration of Piping Losses

The layout of the ‘Contingency Scenario Piping Losses’ summary box is updated. The User Interface (UI) to select the flow basis for the reported piping hydraulics has been revised to better illustrate essential information.

When the flow through the outlet piping has reached choked or sonic conditions, the term “Sonic Flow” appears underneath the backpressure values within the User Interface. Elevated backpressures may result when the fluid has reached sonic velocity (Mach = 1). Note, hover the mouse pointer over the Sonic Flow label and a tool tip will pop-up stating that sonic flow can lead to higher than expected back pressures.



The term “Relief Flow” is replaced with “Selected Flow” to represent the flowrate that is selected by the user for the determination of the piping losses. These displayed piping losses can be calculated at three different selections; Maximum Relief Capacity (of that device), Prorated Scenario Flow, and a User Supplied Flow.

A device’s prorated flow represents the amount of scenario flow that is proportionately split between other devices based on their orifice area. This is more evident in situations of multiple relief devices relieving for that individual scenario.

CURTISS-WRIGHT
Farris Engineering Services
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Flare Header Model Updates:

iPRSM 1.2.1.1 has a complete rewrite of the flare header flow computation algorithm. It now supports multiple knockout drums, dividing flows, and flare tips. Also, pressure-controlled flow diverters and heat transfer tees were included in the flow model for more advanced flare routing and vaporization within knockout drums.

In previous versions, only a single phase-split tee could be modeled resulting in ad-hoc configurations to account for various installations with several KO drums. This release candidate encompasses multiple KO drums in addition to new Excel export reports assisting in the preparation of header contingencies and post-evaluation analysis for all applicable scenarios.

The new fittings available within the Flare Header model are defined below and are illustrated in the following figure.

Flare Tip
This fitting allows the user to input a pressure delta (< 0 psig means a drop in pressure) associated with the flare tip; this assists with reporting details at this exit fitting.

Phase Split Tee – Vap Through *
Multiple phase-splitting tees (which are intended to model a knockout drum in the flare header model) are available in this release. This tee fitting represents a point within the piping flow model capable of capturing the separation between liquid and vapor phases. The flow into the tee is from the upstream part of the previous fitting with the resulting vapor stream exiting on the through path and the liquid flow on the side branch of the tee.

P delta
This can account for a specific amount of static pressure drop, or delta, across the fitting (note, enter a negative drop, < 0 psig). There is no height, or DeltaH, associated with this fitting. This fitting is like a 'Liquid Seal' available within the Relief Valve Piping and Fittings.

Heat Transfer Tee – Through Flow *
This fitting allows the user to add or remove heat input into the inlet and/or the other side port of the fitting. This is done by combining the enthalpy from the inlet flow with the enthalpy calculated from the heat input to the inlet; thus affecting the enthalpy of the outlet flow. The resulting combined mass flow weighted enthalpy is used to reflash/vaporize the feed stream. In conjunction with phase-splitting tees, this fitting can be used to model a knockout drum where the liquid portion is vaporized such as via a heat exchanger. No frictional losses are computed at this tee.

Flow *Dividing* Tee – Through Flow *
This fitting allows the user to split the mass flow in the header to multiple downstream locations. Normal fitting losses are computed at the tee.

Flow *Diverting* Tee – Through Flow *

This fitting allows the user to divert the flow to another downstream location based on a set pressure (defined as *Pset_out* on the worksheet page). This can be used when there are a main and secondary flare where flow is typically routed to the main flare with flow routed to the secondary flare based on a specific pressure setting.

There are three different modes of operation:

1. Closed – if the pressure at the inlet of this fitting is less than, or equal to the supplied set pressure, the diverting tee will remain in the closed position (meaning the flow is diverted to the outlet/through port of the tee).
2. Regulating – when the pressure in the fitting is above the set pressure, the diverting tee will start to open to maintain the set pressure.
3. Open – when the pressure in the fitting is above the set pressure and the diverting tee is wide open and the tee fitting behaves like a 'flow dividing' tee. No frictional losses are computed at this tee.

Expander – No Kinetic Gain

This expander does not account for a velocity decrease induced by the recovery of kinetic effects on entry into the downstream volume/space. This fitting allows for the expansion of pipe size and considers only frictional losses and possible static head effects. If these losses are to be ignored, the user must define K = 0 (for DI and non-DI) which gives no frictional effect, and delta H = 0 gives no static effect.

Reducer – No Kinetic Gain

This reducer does not account for a velocity increase induced by the recovery of kinetic effects on exit into the downstream volume/space. This fitting allows for the reduction of pipe size and considers only frictional losses and possible static head effects.

* *Nota Bene:* The phase split, heat transfer, and flow diverting/dividing tees are not actually pipe fitting dependent on diameters and flow/kinetic resistance. These simply add input values (heat, subtracting flow, phase separation, etc.) into the piping flow model.

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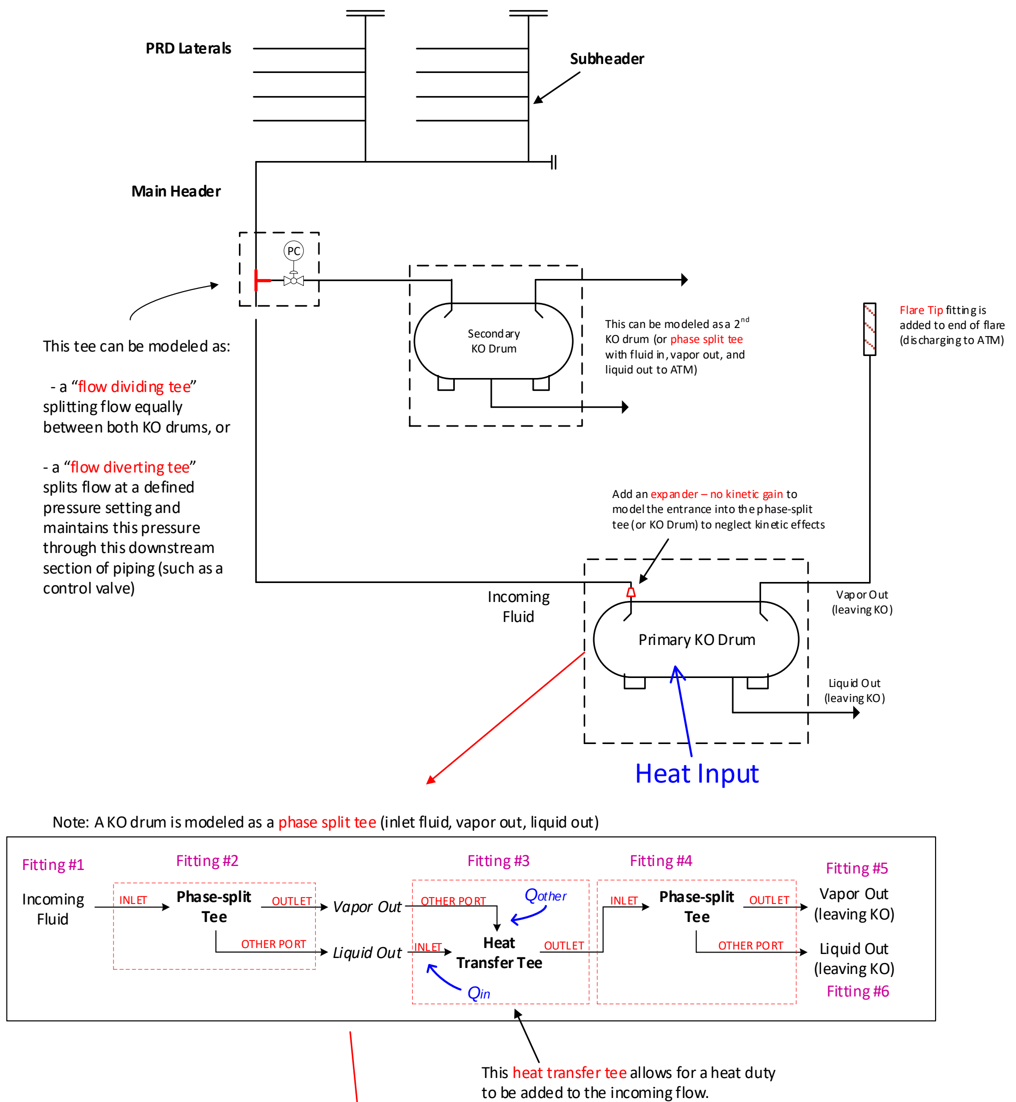
Below is a mock-up of a Flare configuration illustrating new fittings discussed above:



From Relief Devices to Discharge Equipment ☆ Plant Level Header ε = 0.0018 in (New Steel Pipe)

Seq #	Fitting Type	Schedule In & Out	d_i^{in} & ^{out}	H_Δ	ε	f_{Moody}	K_{Crane}	L/D	L	Version		
		Inlet Port: Capped or Plugged										
#1	Pipe	4.00" S.40 I	4.026 in	0 ft	Plant Level				1 ft	1.2.1.1 [Ok]		
#2	Phase Split Tee - Vap Through	4.00" S.40 I	4.026 in	0 ft 0 ft	Plant Level					1.2.1.1 [Ok]		
		Other Port to Fitting Other Port: #3 - Heat Transfer Tee - Through Flow										
		Other Port from Fitting Other Port: #2 - Phase Split Tee - Vap Through										
#3	Heat Transfer Tee - Through Flow	4.00" S.40 I	4.026 in	0 ft 0 ft	Plant Level					1.2.1.1 [Ok]		
#4	Phase Split Tee - Vap Through	4.00" S.40 I	4.026 in	0 ft 0 ft	Plant Level					1.2.1.1 [Ok]		
		Other Port to Pipe Fitting Inlet: #6 - Pipe										
#5	Flare Tip	4.00" S.40 I	4.026 in	0 ft	Plant Level					1.2.1.1 [Ok]		
		Outlet Discharge to Atmosphere										
		Inlet from Fitting Other Port: #4 - Phase Split Tee - Vap Through										
#6	Pipe	4.00" S.40 I	4.026 in	0 ft	Plant Level				1 ft	1.2.1.1 [Ok]		
		Outlet Discharge to Atmosphere										

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Numerical Integration – Mass Flux Curves

Scenario calculations using Direct Integration in iPRSM 1.2.1.1 now have graphical reporting on the mass flux curves (as well as specific volume and vapor mass fraction) so that entropy vs. enthalpy decisions can be compared. Selection of the mass flux directly affects the required area of the overpressure scenario.

<u>Direct Numerical Integration:</u>

The Direct Integration method in iPRSM is the integration of the isentropic (ideal) nozzle flow equation (or the expansion expression) which originates from the Bernoulli equation (it can also be derived from the 1st Law of Thermodynamics by assuming steady state isentropic flow).

The simple API equations for critical/sub-critical vapor and liquids focus on ideal flow conditions for single phase fluids. Whereas, the homogeneous direct integration method referenced in Annex C of the 10th Edition of API 520 Part I is more rigorous as it stepwise integrates the variation in specific volume across a pressure profile/gradient and thus handles phase changes at the nozzle.

The mass flux equation is applied by introducing a relationship between pressure and specific volume along an *<u>isentropic</u>* path and then integrating between the defined pressure limits. The results of this integration provide the theoretical/ideal mass flux which is the rate of mass per unit area (G = W / Area); or its US units are (lb_m / (sec · ft^2)).

According to industry resources (API 520 Part I, 10th Edition and the DIERS Greenbook, 2nd Edition), the relationship between a fluid's specific volume and pressure through an ideal nozzle can also be modeled along an isenthalpic path (constant enthalpy). iPRSM can perform both methods with the use of its internal physical property database estimated from the selected equations of state (EOS).

> *<u>Note:</u>* The default analysis in iPRSM determines the mass flux, G_{max}, by using the property tables at constant entropy; however, the user can opt to override this selection within each overpressure scenario to constant enthalpy.

As with most equations of state or activity coefficient models, the behavior of the selected model (i.e. Advanced PR, NRTL, APR NG2, etc.) for an individual fluid across a wide range leading to anomalies or outliers within the data set. To assist the user in understanding these anomalies, a new graphical section has been developed within each direct integration scenario calculation reporting on the mass flux curves so that entropy vs. enthalpy decisions can be compared. This is especially useful when encountering streams that approach their thermodynamic critical points where phases are ill-defined.

> *<u>Note:</u>* There are additional functions (such statistical analysis and data comparisons) for power iPRSM users to compare between enthalpy and entropy property tables and mass flux in the dual case.

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10195 Brecksville Road
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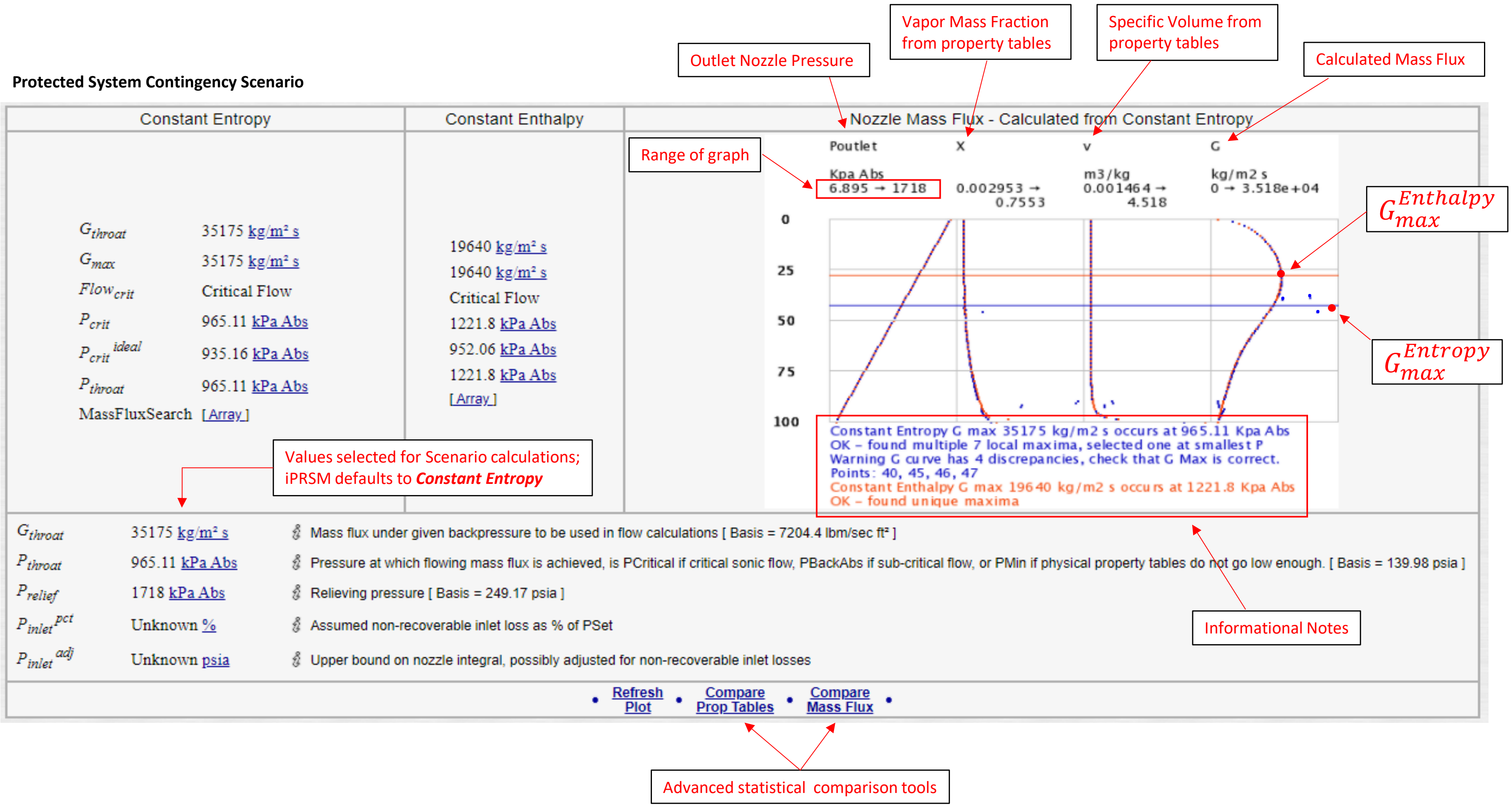
Protected System Contingency Scenario



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Inlet Pressure Adjustment (Remote-Sensing Pilots)

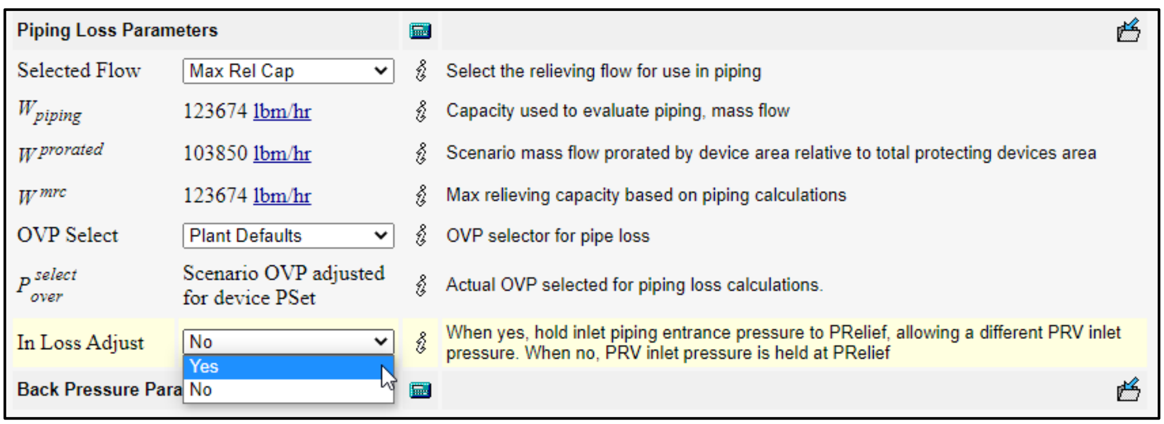
iPRSM 1.2.1.1 modifies the method of adjusting the nozzle pressure at the relief device to account for pressure drop through the inlet piping. This methodology is more prevalent in situations of remote-sensing pilot valves when the inlet pressure drop exceeds 3%. Within a Direct Integration scenario, the piping hydraulics and the required area calculation must be reevaluated at the lower adjusted relieving pressure to ensure adequate valve sizing.

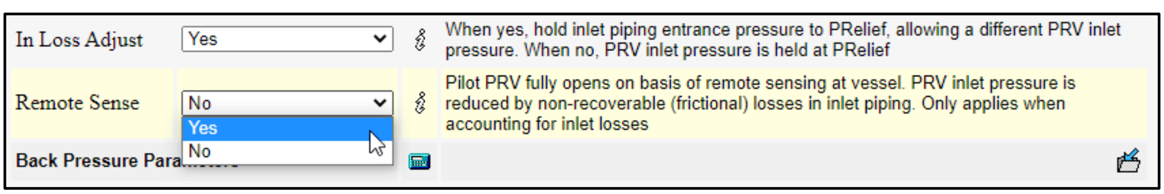
<u>Adjust Nozzle Pressure for Piping Losses:</u>

By default, iPRSM defines the relieving pressure to be the pressure at the inlet nozzle of the valve and is based on set pressure from device's equipment page and overpressure from the scenario. However, the new enhancements to the software will allow the user to hold the stagnation pressure at the protected equipment (i.e. entrance to the inlet piping) as the relieving pressure. As a result, the piping hydraulics would be recalculated at a reduced capacity of the valve due to a lower adjusted relieving pressure. This is an iterative calculation within the software to determine the pressure drops (kinetic, static, and frictional) and the adjusted valve capacity.

On the 'Contingency Scenario Piping Losses' page, select "Yes" from the **In Loss Adjust** toggle (to hold the pressure at the entrance as the relieving pressure) and then "Yes" from the **Remote Sense** toggle to reduce the inlet nozzle pressure by the non-recoverable losses.

Contingency Scenario Piping Losses





Adjust Inlet Pressure for Required Area:

With a lower adjusted relieving pressure, the required area calculated should be reevaluated for the contingency scenario.

Contingency Scenario Piping Losses

SetPInlet Parameters		
P_{inlet}^{select}	No Loss	Choice of PInlet loss adjust for nozzle integration bounds
P_{inlet}^{pct}	0 %	Assumed non-recoverable inlet loss as % of PSet
P_{inlet}^{loss}	0 lbf/in²	Assumed non-recoverable inlet loss
P_{inlet}^{adj}	344.7 psia	Upper bound on nozzle integral, possibly adjusted for non-recoverable inlet losses

On the 'Protected System Contingency Scenario' page, a drop-down bar allows the user to select the desired adjusted relieving pressure (instead of using the relieving pressure based on the valve's set pressure) for the nozzle integration analysis. The available selections are the following:

- **No Loss**
  - No reduction to the upper bound of the mass flux calculation; $P_{inlet} = P_{relief}$
- **3% of Set Pressure**
  - Inlet pressure is adjusted by 3% of the device's set pressure; $P_{inlet} = P_{relief} – (0.03 * P_{Set})$
- **Given Percent of Set Pressure**
  - A user-supplied percent set pressure drop between 0 and 100; $P_{inlet} = P_{relief} – (P_{Set} * Pct/100)$
- **Given Pressure Loss**
  - A user-supplied loss value in psid (i.e. non-recoverable frictional loss); $P_{inlet} = P_{relief} - Delta$
- **Max PRV of Equipment**
  - The 'max allowable inlet pressure drop' identified on the relief valve equipment page for all PRV protecting equipment; $P_{inlet} = P_{relief} - P_{Set} * max \{3, equipPDropInMaxAllowPct\} / 100$

Based on this selection for the adjusted inlet pressure, the software will recalculate the theoretical mass flux table due to the changes to the pressure differential term inside the integral to obtain the maximum mass flux. Changes to the physical properties at the stagnation pressure compared to the adjusted inlet pressure are neglected. The selection of this adjusted inlet pressure has no effect on the calculation of the piping hydraulics.

For the evaluation of remote-sensing pilot valves, this method is recommended to be performed for every applicable contingency scenario which have inlet piping losses greater than 3%.

While the inlet nozzle pressure can be adjusted at the Piping Losses individually for each valve within a multi-valve application, the adjustment of the required area calculation however cannot be done (as the adjusted inlet pressure will be based on the set pressure of the lowest set valve).