

ioMosaic[®]

Minimizing risk. Maximizing potential.[®]

January 30-31, 2023 | 17th Annual Global Software Users Group Meeting | Virtual

Evaluate Overpressure Scenario Credibility

Neil Prophet
Senior Vice President & Partner
prophet@iomosaic.com

QMS_7.3_7.4.F06 Rev.9

© ioMosaic Corporation

Any information contained in this document is copyrighted, proprietary, and confidential in nature belonging exclusively to ioMosaic Corporation.
Any reproduction, circulation, or redistribution is strictly prohibited without explicit written permission of ioMosaic Corporation.



Neil Prophet – Senior Vice President and Partner



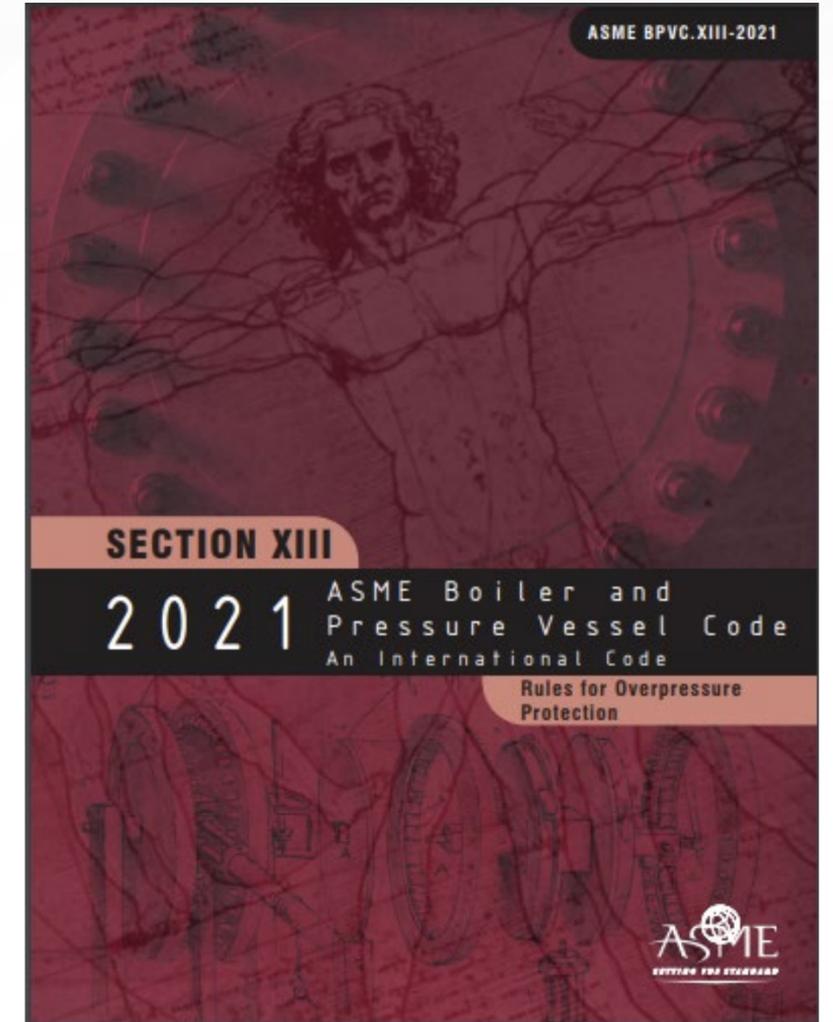
- ▶ B.Eng. (Honors), Chemical Engineering, University of Strathclyde
- ▶ More than 20 years' experience in the field of process safety including consulting, project management, technical support, technical sales, training course development and presentation and operations management, along with authoring many industry publications as well as presenting at various industry related organizations
- ▶ Technical Expertise includes:
 - ▶ Process Safety and Risk Management
 - ▶ Hazard Identification (FMEA, HAZOP, What-if, Checklist, SVA)
 - ▶ Auditing
 - ▶ Pressure Relief and Flare System design
 - ▶ Consequence Analysis, Quantitative Risk Analysis, Facility Siting
 - ▶ LNG
 - ▶ Litigation Support
- ▶ Contact info: prophet.n.tx@ioMosaic.com

Introduction

- ▶ Discuss and demonstrate the application of Overpressure Protection by System Design
- ▶ Reference several guideline documents:
 - ▶ ASME Section VIII
 - ▶ ASME Section XIII
 - ▶ WRC Bulletin 498
- ▶ Overpressure Protection by System Design requires a rigorous methodology
 - ▶ Overpressure scenario credibility
 - ▶ Magnitude of the overpressure
- ▶ It helps to have a rigorous software tool to help you in this process!

What does ASME Section XIII say?

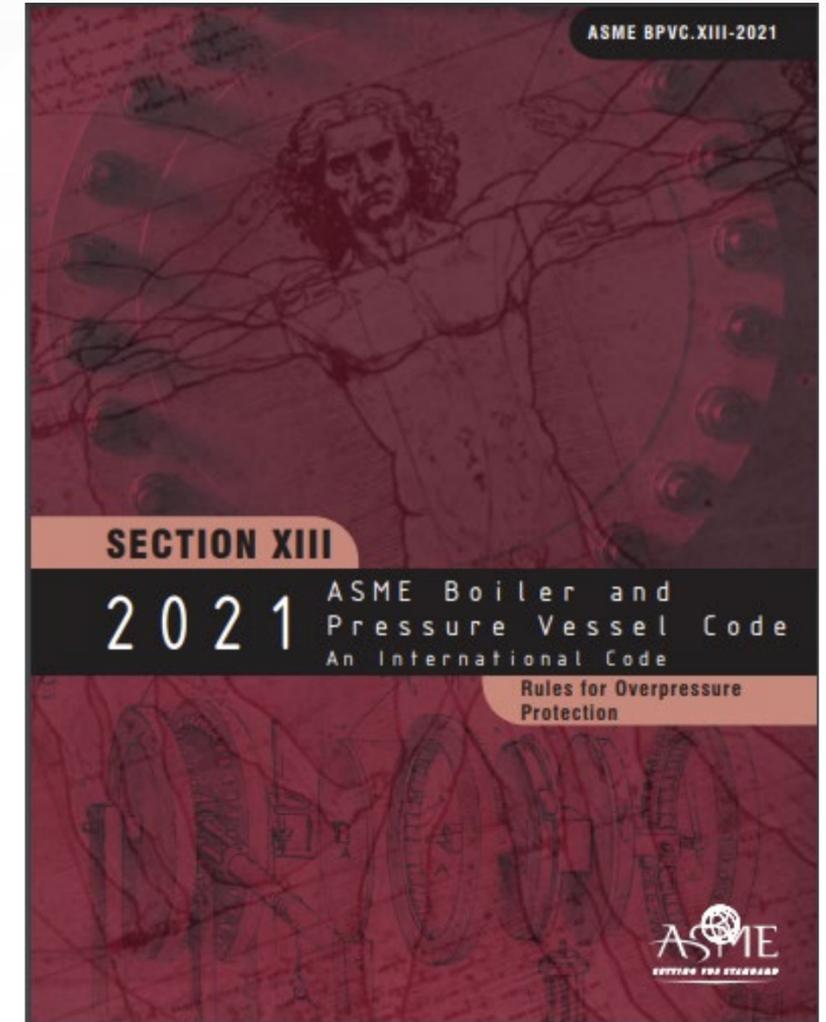
- ▶ ASME Section XIII (released in 2021), Part 13 “Rules for Overpressure Protection by System Design” (replacing UG-140)
- ▶ Pressurized Equipment For Which the Pressure is Self-Limiting
 - ▶ *Process Safety Office (SuperChems™) - determine maximum coincident pressure and temperature for overpressure scenarios*
- ▶ Pressurized Equipment For Which the Pressure is Not Self-Limiting
 - ▶ *Process Safety Office (SuperChems™) - determine maximum coincident pressure and temperature for overpressure scenarios*
 - ▶ *Process Safety Office (ioLogic™) – determine overpressure scenario credibility*



Source: American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code an International Code – Section XIII 2021. Used for educational purposes only. Do not copy, share or distribute.

What does ASME Section XIII say?

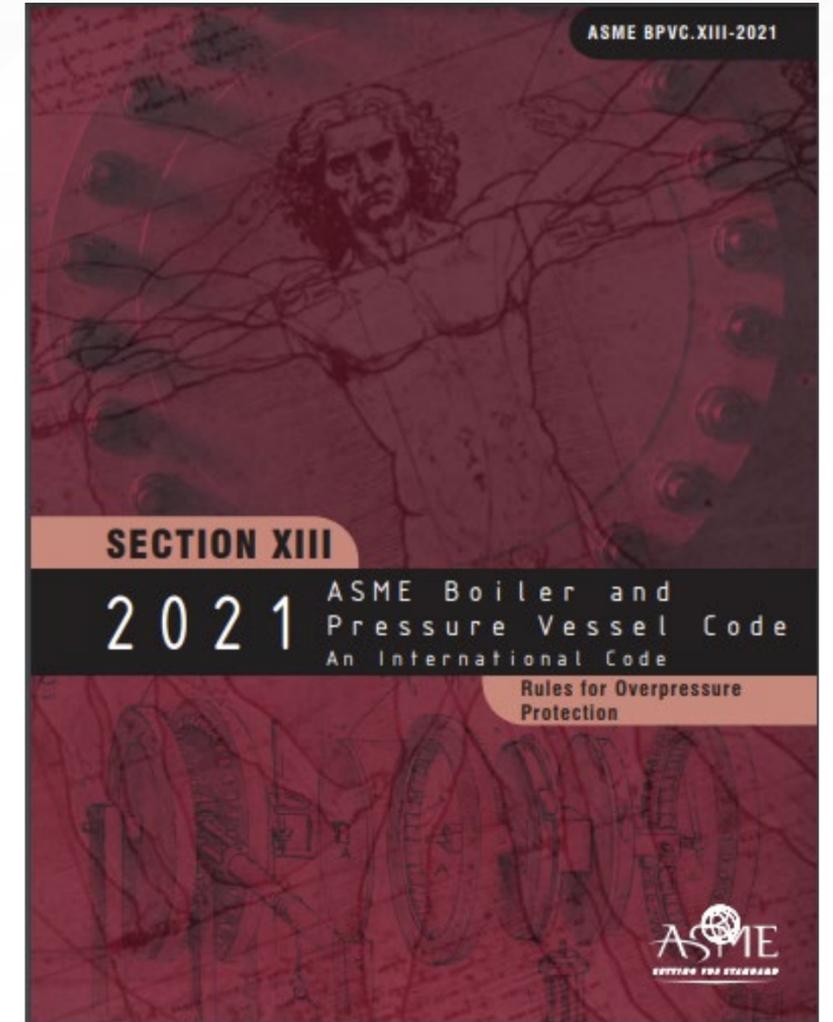
- ▶ Applying Overpressure Protection by System Design, for pressurized equipment for which the pressure is not self-limiting:
 - ▶ System may be protected by a combination of system design and pressure relief devices, if the following conditions are met:
 - (a) pressurized equipment is not exclusively in air, water or steam service, except for:
 - (1) If these services are critical to preventing the release of fluids that may result in safety or environmental concerns
 - (2) Failure or premature opening of the pressure relief device would result in unacceptably high probability of failure or damage to the pressurized equipment or other equipment in the system
 - (3) Failure or premature opening of the pressure relief device would result in significant operational upset(s)



Source: American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code an International Code – Section XIII 2021. Used for educational purposes only. Do not copy, share or distribute.

What does ASME Section XIII say?

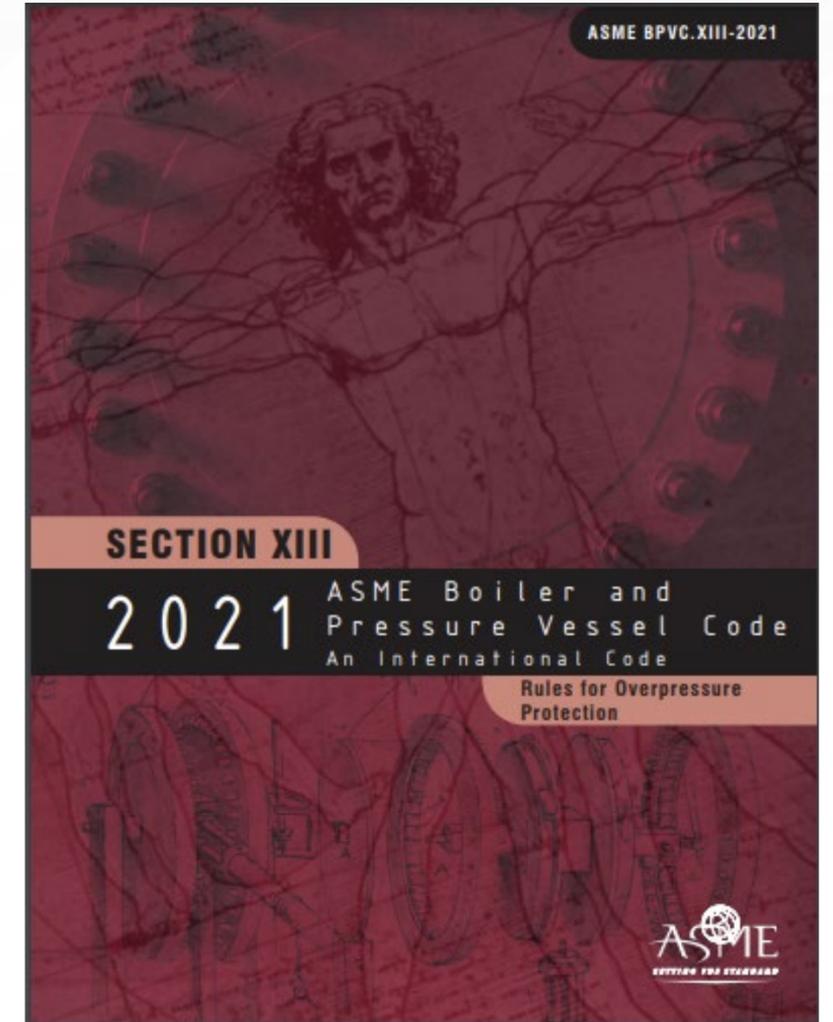
- ▶ Applying Overpressure Protection by System Design, for pressurized equipment for which the pressure is not self-limiting:
 - ▶ System may be protected by a combination of system design and pressure relief devices, if the following conditions are met:
 - (b) The decision is the responsibility of the user
 - (c) The user shall conduct a detailed analysis to identify and examine all scenarios that could result in an overpressure condition, and magnitude of the overpressure. A multidisciplinary team shall conduct the analysis
 - (d) The overpressure scenario shall be readily apparent so that operators or protective instrumentation will take corrective action to prevent operation above the MAWP
 - (e) There shall be no credible overpressure scenario in which the pressure is not self-limiting. Credible events or scenario analysis as described in WRC Bulletin 498 shall be considered



Source: American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code an International Code – Section XIII 2021. Used for educational purposes only. Do not copy, share or distribute.

What does ASME Section XIII say?

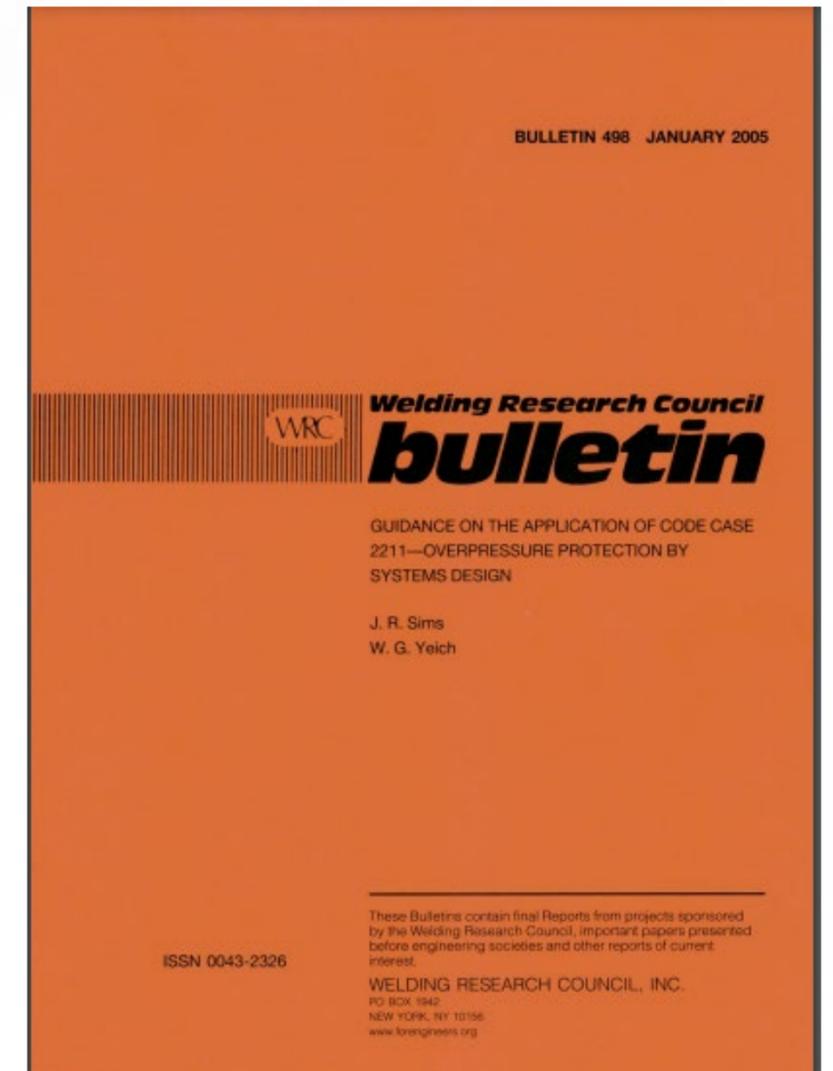
- ▶ Applying Overpressure Protection by System Design, for pressurized equipment for which the pressure is not self-limiting:
 - ▶ System may be protected by a combination of system design and pressure relief devices, if the following conditions are met:
 - (f) The results of the analysis shall be documented and signed by the individual responsible for management of operation of the pressurized equipment
 - ▶ Documentation shall include:
 - ▶ Detailed process flow diagrams and P&IDs
 - ▶ Description of all operating and upset scenarios
 - ▶ Description of any safety critical instrumentation
 - ▶ Analysis showing the maximum pressure that can result from each of the scenarios described



Source: American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code an International Code – Section XIII 2021. Used for educational purposes only. Do not copy, share or distribute.

What is WRC 498? (Referenced by ASME Section XIII)

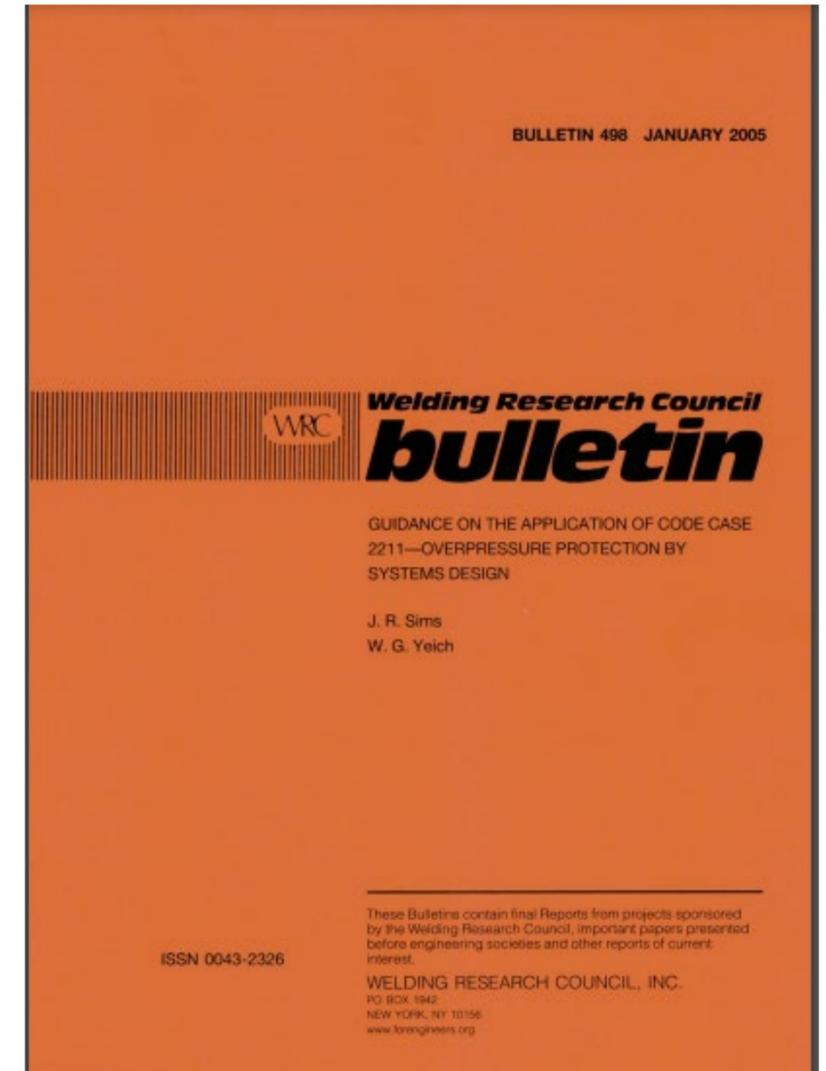
- ▶ Welding Research Council Bulletin 498, published in 2005
- ▶ WRC 498 provides guidance on the application of Code Case 2211 (Overpressure Protection by System Design) which was fully incorporated into ASME VIII UG-140 in 2008
- ▶ WRC 498 was referenced in previous editions of ASME Section VIII
- ▶ Considered RAGAGEP (Recognized and Generally Accepted Good Engineering Practice)



Source: Welding Research Council Bulletin. Used for educational purposes only. Do not copy, share or distribute.

WRC 498 promotes consistency in Overpressure Protection by System Design

- ▶ Recommends a five-step procedure:
 1. Identify and document all initiating events or causes and the resulting overpressure. All scenarios are considered credible until evaluated and specifically designated to be non-credible.
 2. Analyze the actions and consequences of the causes from Step 1 to identify scenarios that are not credible.
 3. For each action and consequence deemed credible, determine a PDP (process design pressure) and MAWP.
 4. Document the design features and the governing scenarios used to establish these design features.
 5. Identify all process equipment that is critical to preventing pressure above the MAWP and document appropriate operating, inspection and maintenance procedures



Source: Welding Research Council Bulletin. Used for educational purposes only. Do not copy, share or distribute.

Presentation Purpose

- ▶ Demonstrate how Process Safety Office[®] can help with this analysis
 - ▶ Determine Overpressure Scenario Credibility
 - ▶ Determine maximum coincident pressure and temperature for overpressure scenarios

Overpressure Scenario Credibility



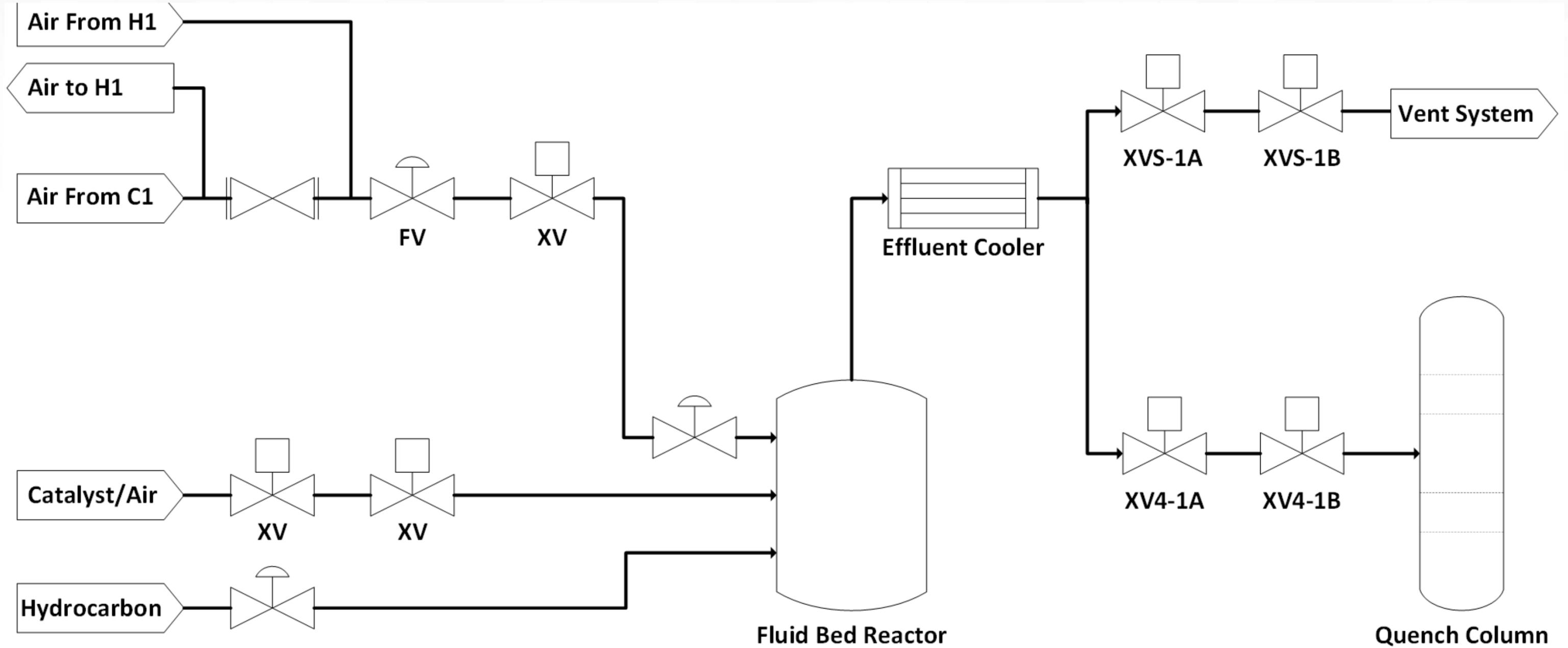
Overpressure Scenario Credibility – Case Study

- ▶ A review of Company X's design indicated that the existing pressure relief systems may be inadequate for possible scenarios of concern:
 - ▶ Loss of the cooling water pumps when only one reactor is operating
 - ▶ Loss of the cooling water pumps when some or all of the reactors are operating
 - ▶ Blocked reactor outlet
- ▶ The reactors are also fitted with Safety Instrumented Systems, which can be taken into account per Annex E (Informative) of API Standard 521

Overpressure Scenario Credibility – Case Study

- ▶ Company X operates multiple (four) fluidized bed reactors
 - ▶ Reactor feeds include compressed process air, ammonia and an olefinic hydrocarbon
 - ▶ Chemical reaction is exothermic, and the reactor temperature is maintained by internal cooling coils supplied with cooling water from dedicated pumps
 - ▶ Effluent from each reactor is cooled by heat exchange with a coolant in an Effluent Cooler prior to a Quench Column
 - ▶ The reactors are serviced by two systems that are common to all reactors
 - ▶ Process air (main source for potential overpressure, but requires complete blocked outlet)
 - ▶ Two out of three (2oo3) cooling water pumps are required to handle the total cooling duty of all the reactors

Flow Diagram



Source: ioMosaic Corporation

Overpressure Scenario Credibility – Case Study

WRC 498 provides many techniques for evaluating overpressure scenarios, and determining their credibility

Technique applied is Fault Tree Analysis (FTA) as the most efficient and effective method to assess the relief systems

- Considered RAGAGEP
- Meets the requirements of pressure protection standards (API Standard 521, ISA 84.01, WRC 498)

WRC 498 suggests an annual probability of less than 1 in 10,000 as the maximum probability for an overpressure scenario to be considered non-credible

Overpressure Scenario Credibility – Scenarios Evaluated

Fault Tree	Overpressure Scenario	Details
1	Blocked Reactor Outlet	During reactor heat-up
2 & 3	Blocked Reactor Outlet	During various operating modes (normal operation)
4	Reactor High Temperature (Loss of Cooling)	Heat-up, Start-up and Normal Operation – one reactor operational
5	Reactor High Temperature (Loss of Cooling)	Heat-up, Start-up and Normal Operation – multiple reactors operational

Overpressure Scenario Credibility – Case Study

Initiating Event Modifiers

Time at Risk / Enabling Events:

- Reactor operating phases
- Number of reactors operating

Valve position switch permissives:

- Prevents inadvertent valve position

Independent Protection Layers

Definition:

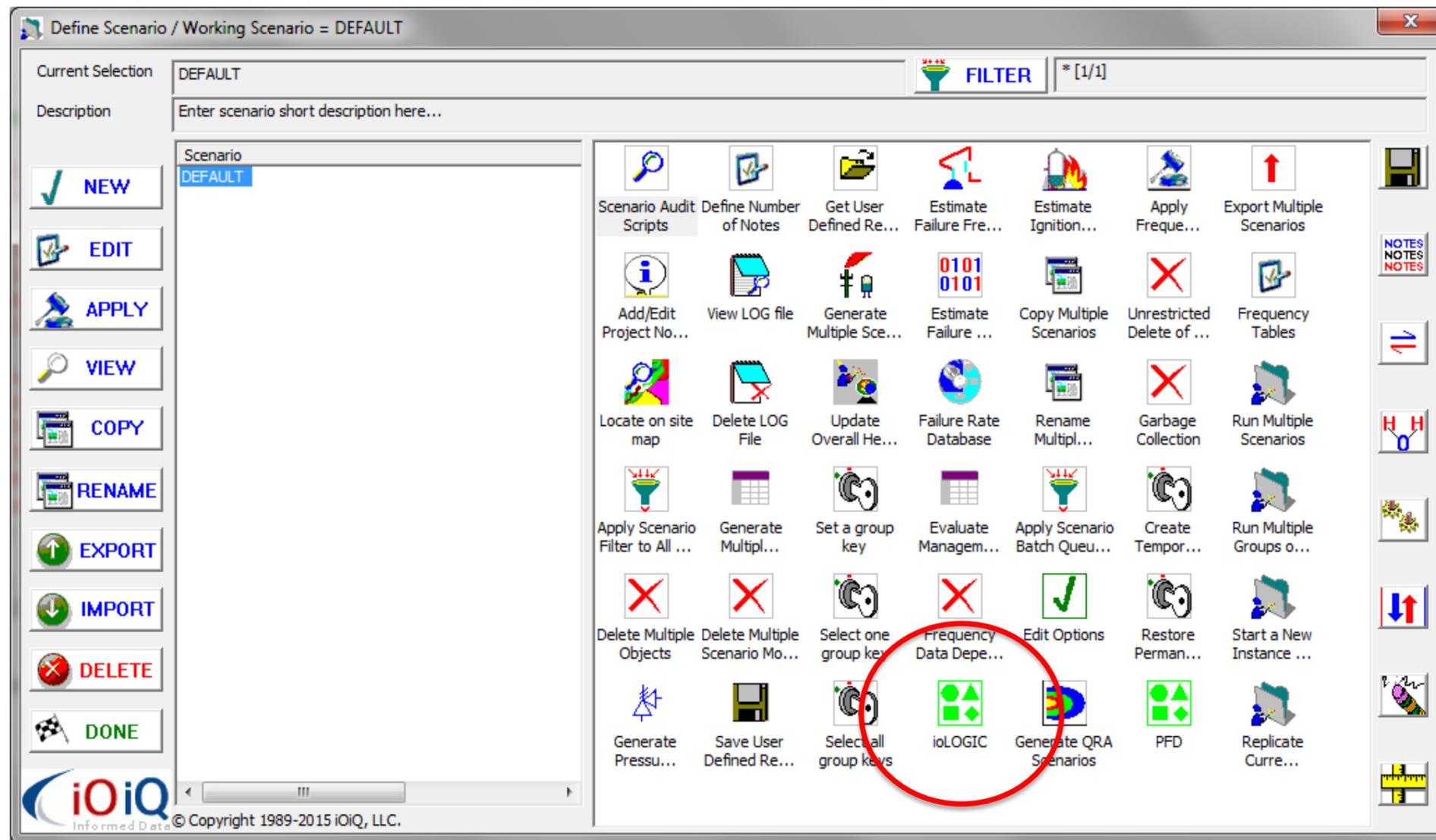
- Active and passive engineered controls
- Interrupts the chain of events leading to an undesirable safety outcome

Examples:

- Safety instrumented systems (e.g., interlocks)
- Safety instrumented functions (dedicated programmable logic controllers (PLCs))
- The basic process control system (BPCS)

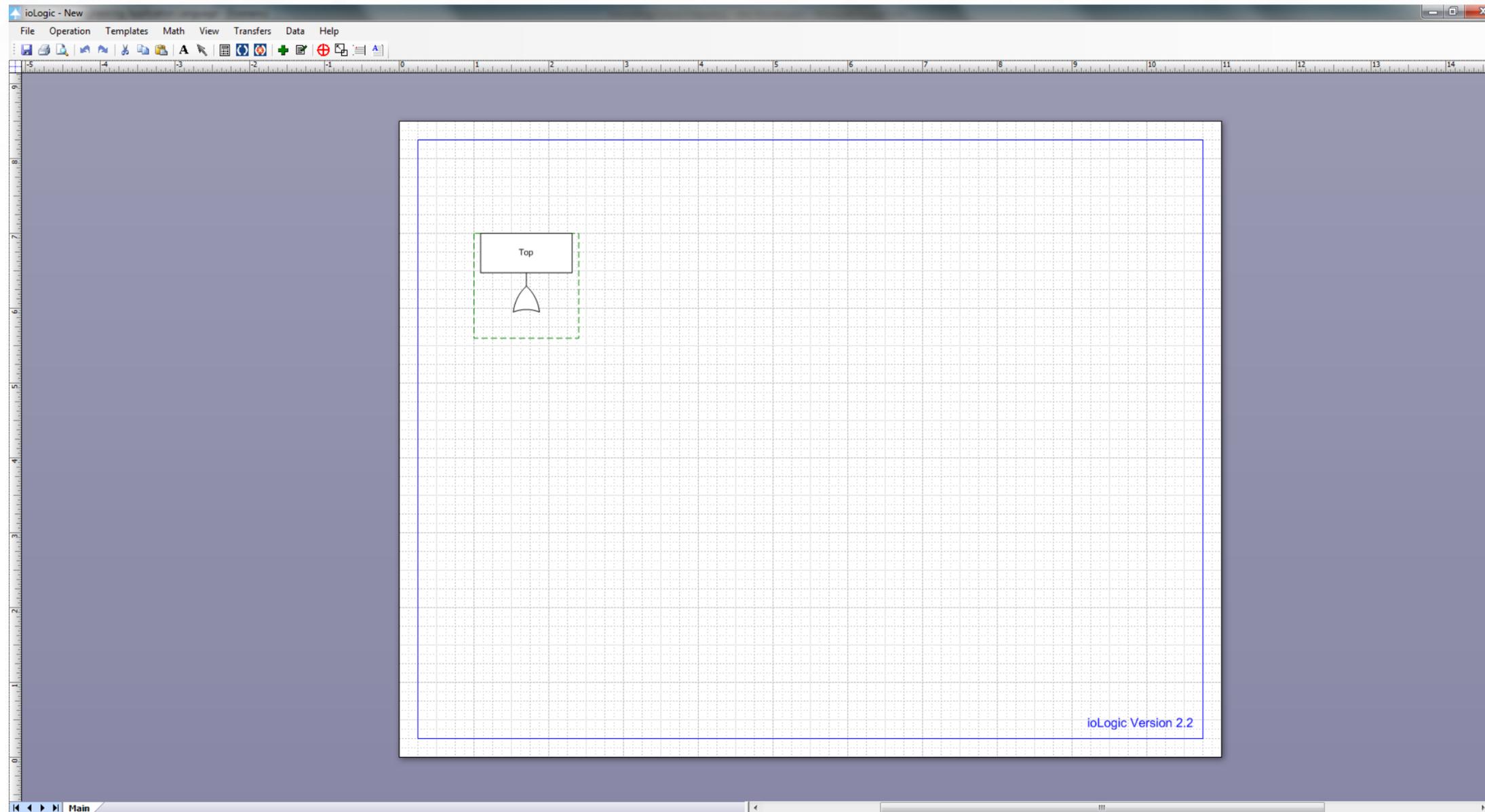
ioLogic™ is provided as either a stand-alone program, or as part of your SuperChems™ installation

- ioLogic™ can be accessed from the Scenario object in SuperChems™

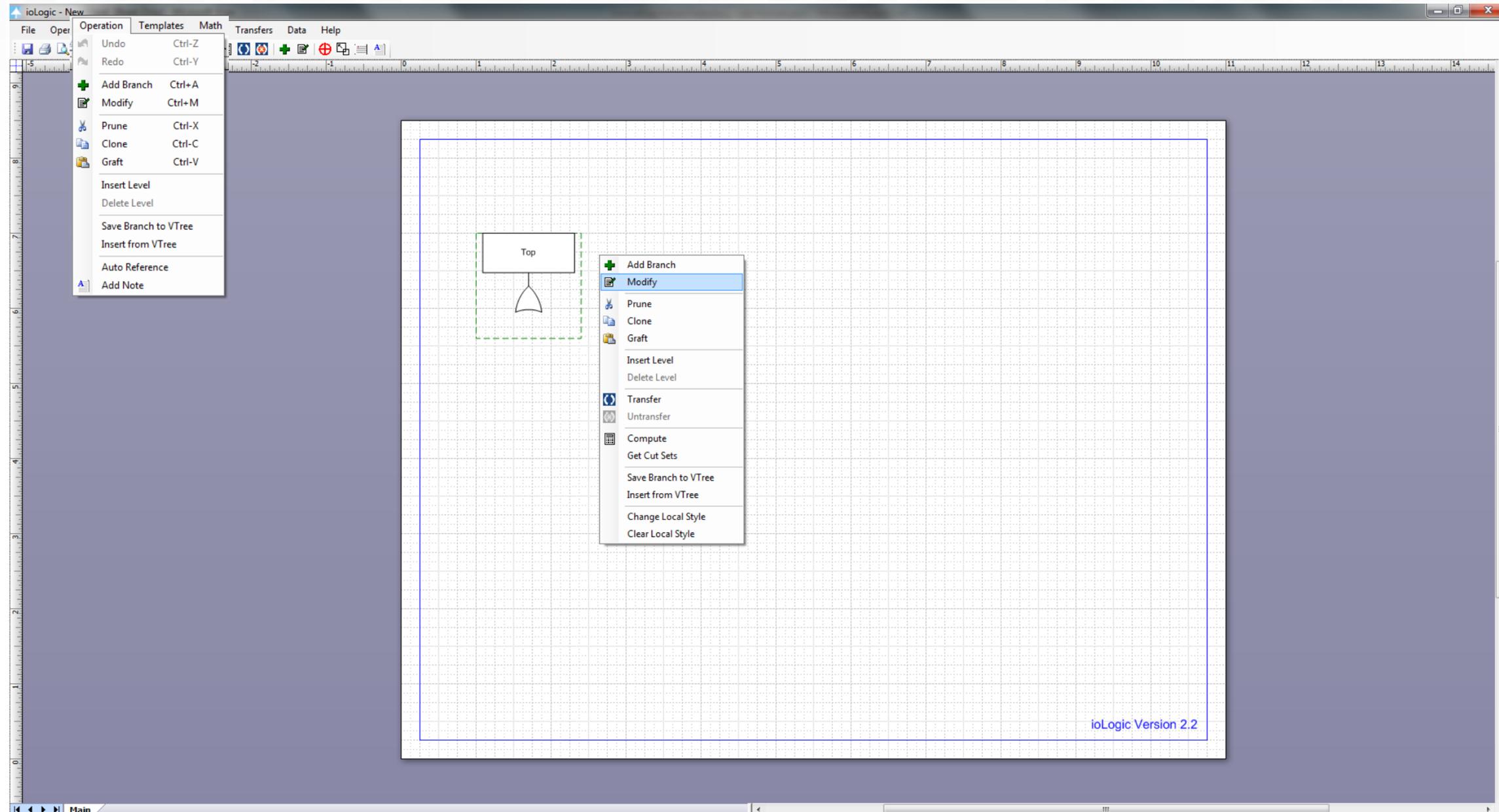


Sources: All screenshot images in this presentation are from Process Safety Office® - SuperChems™, ioLogic™, ioReport™ - ioMosaic Corporation

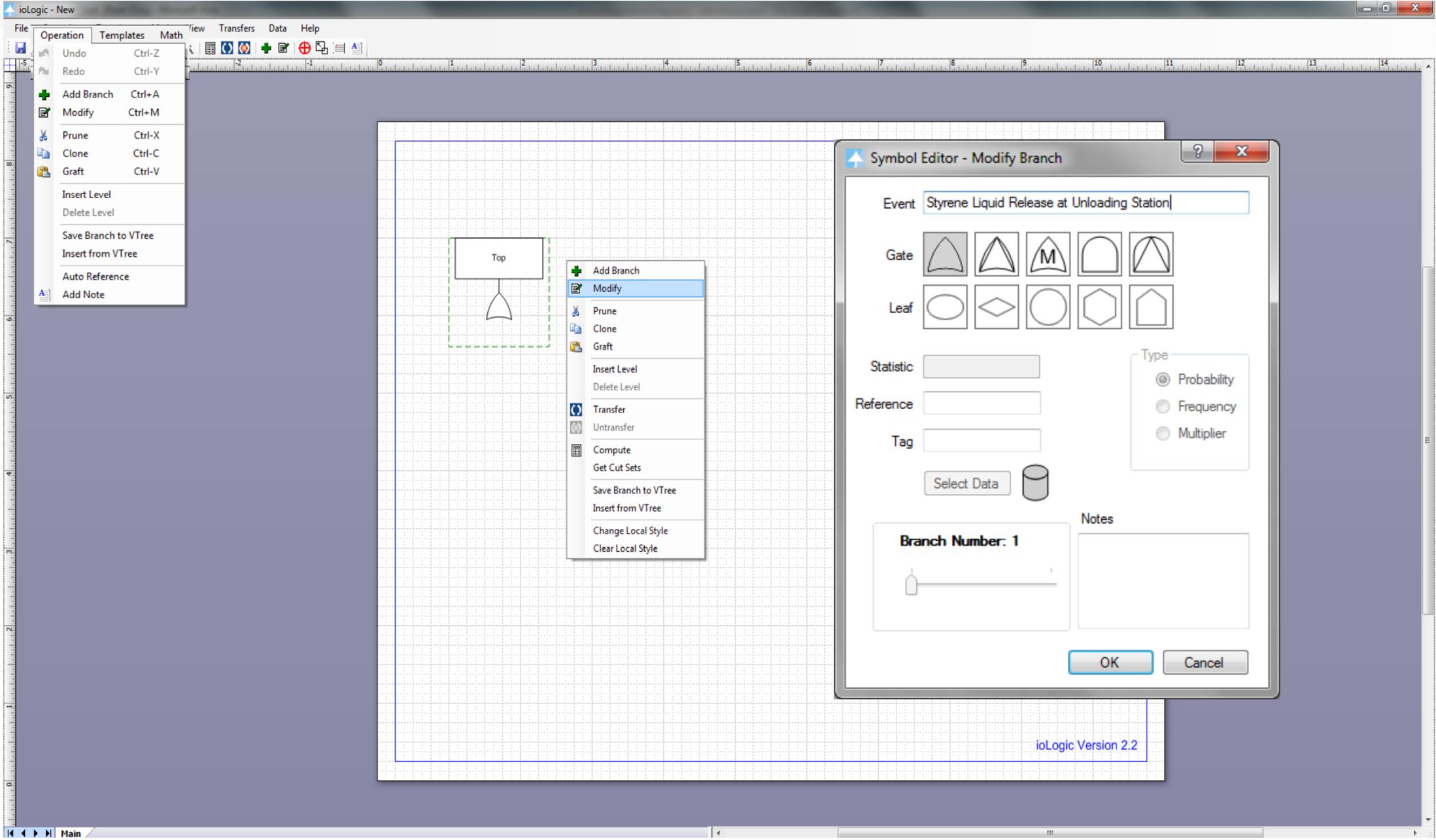
You must have a good understanding of the failure scenario being analyze, prior to constructing the fault tree. Upon opening ioLogic™, only the top event is displayed on a blank worksheet



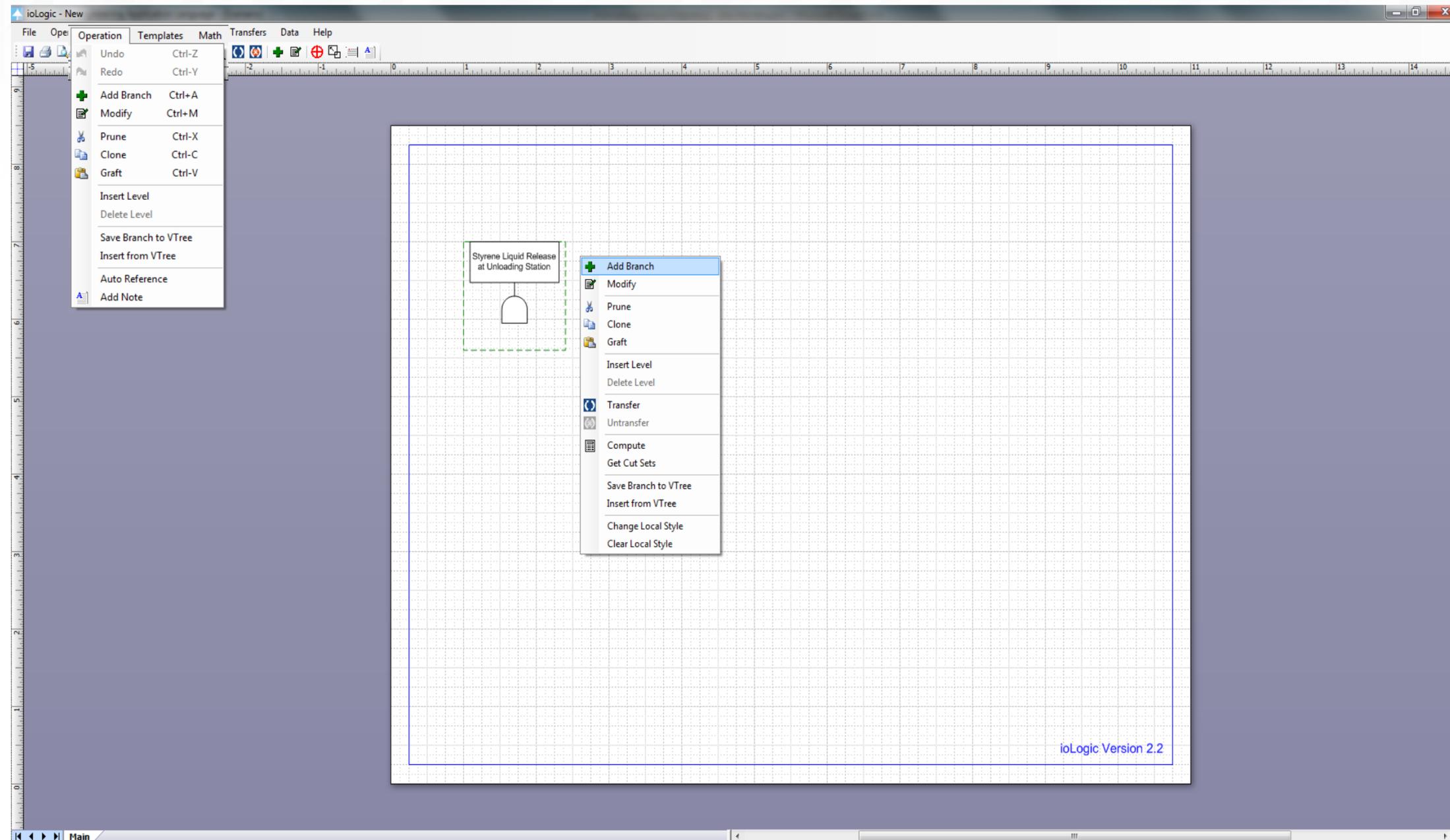
The Top Event can be defined by selecting the “Modify” option from the Operations menu, or by right-clicking



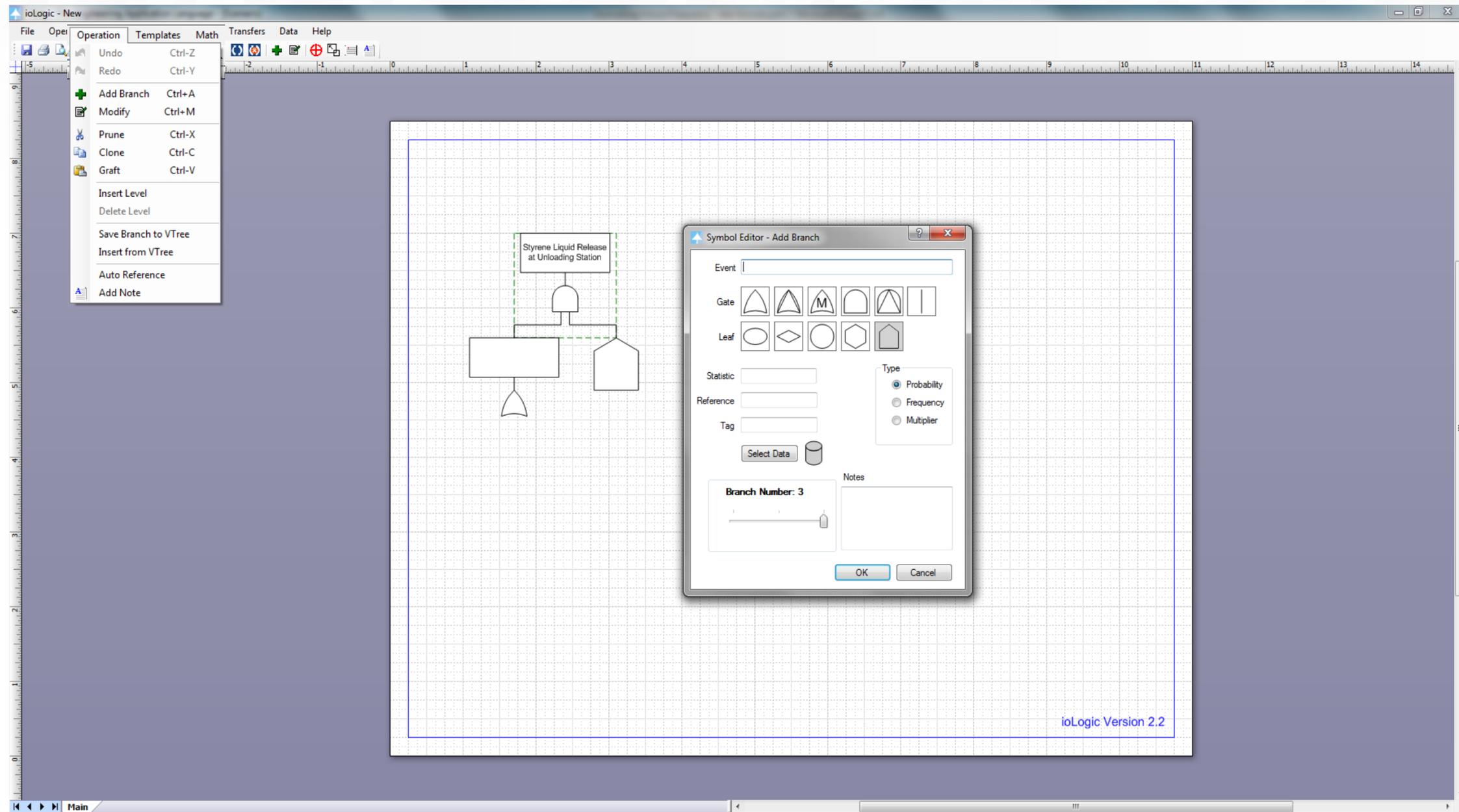
The Top Event is named, and the relevant fault tree symbol assigned to it



The fault tree can then be further developed by selecting “Add Branch” from the Operations menu, or by right-clicking



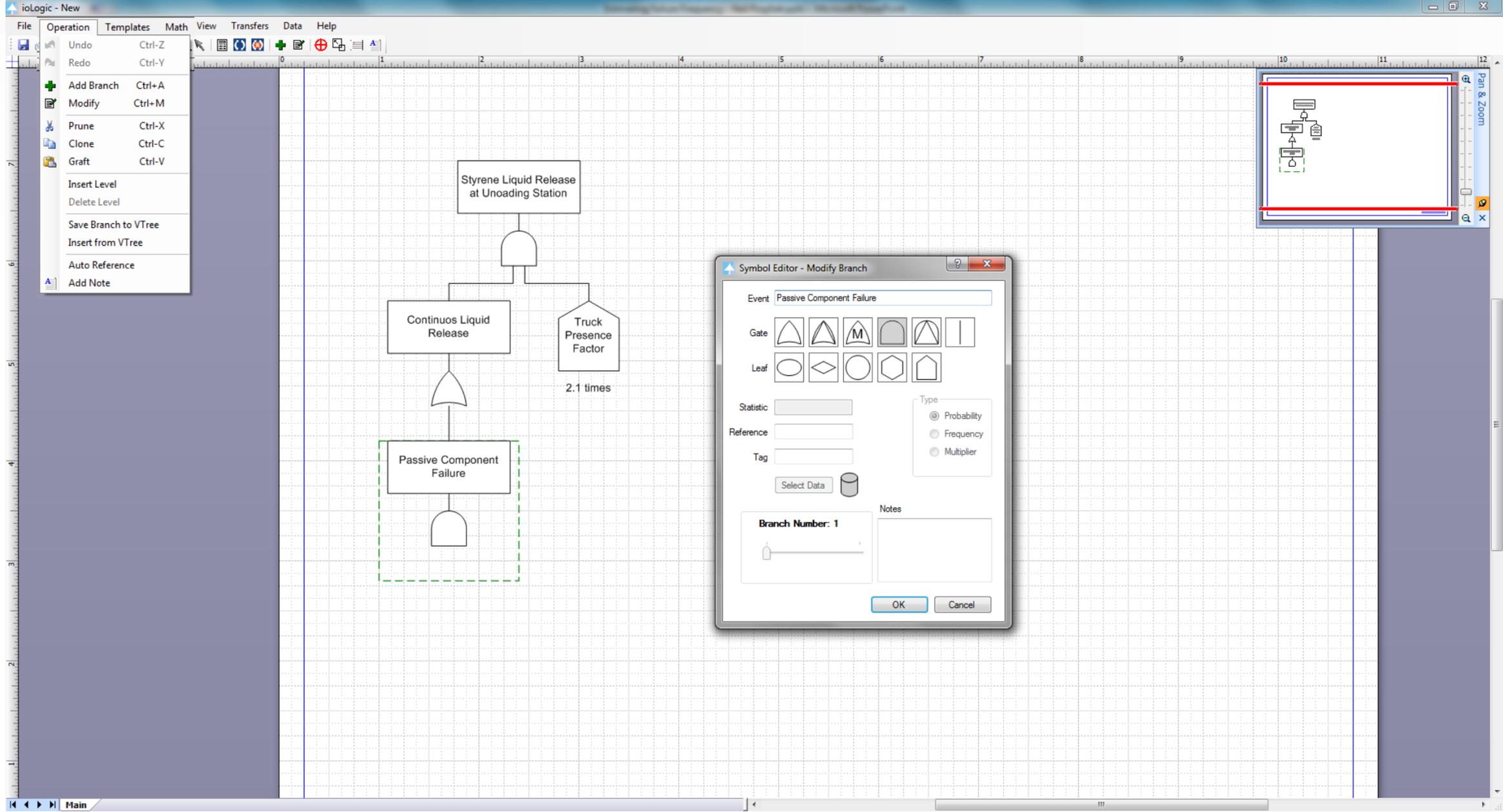
The fault tree can then be further developed by selecting “Add Branch” from the Operations menu, or by right-clicking



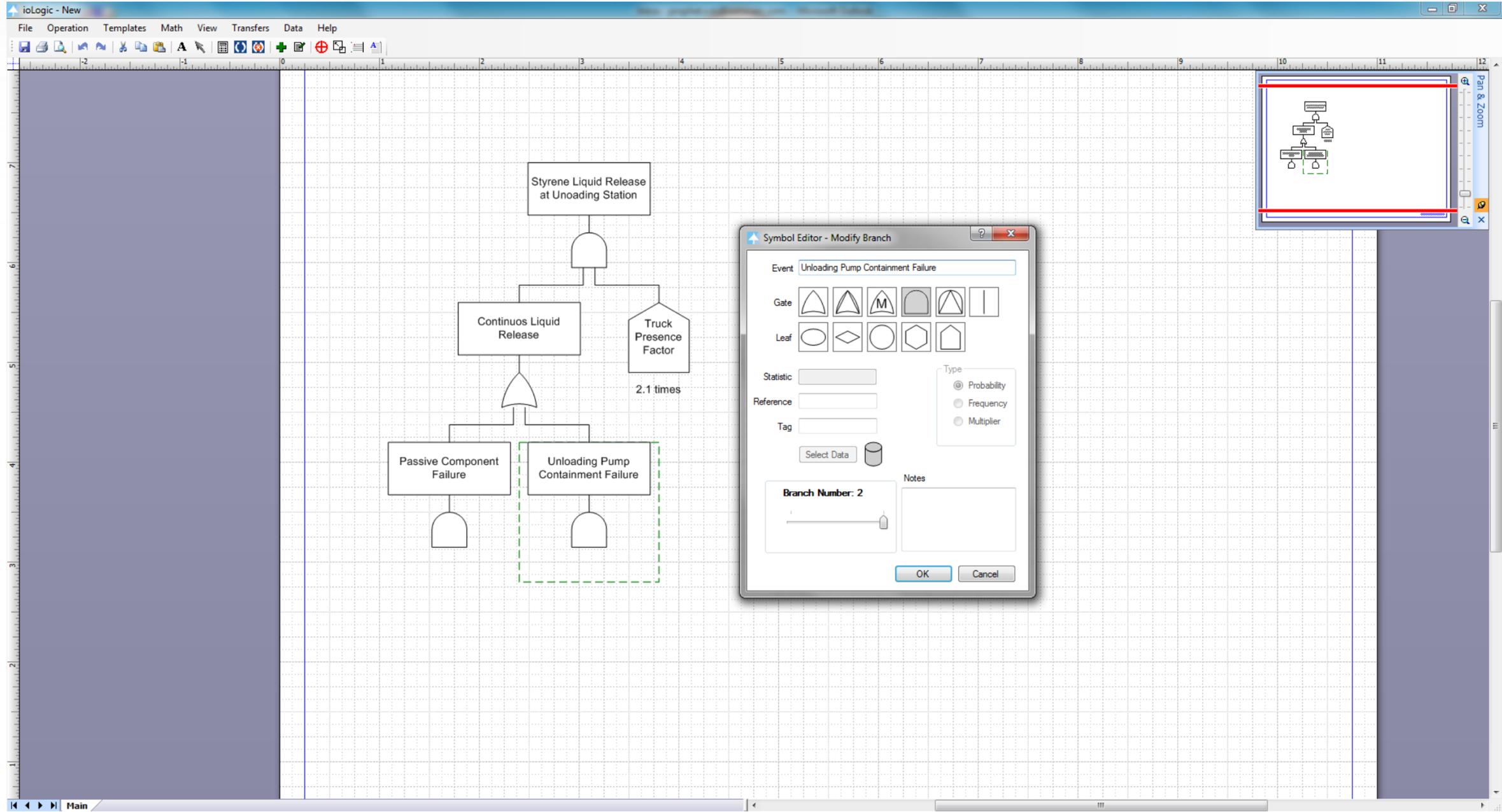
The fault tree can then be further developed by selecting “Add Branch” from the Operations menu, or by right-clicking

The screenshot displays the ioLogic software interface. On the left, a menu is open with the 'Add Branch' option selected. The main workspace shows a fault tree diagram with a top event 'Styrene Liquid Release at Unloading Station' connected to two intermediate events: 'Continuous Liquid Release' and 'Truck Presence Factor'. The 'Truck Presence Factor' event is highlighted with a dashed green box and labeled '2.1 times'. A 'Symbol Editor - Modify Branch' dialog box is open in the foreground, showing the configuration for the selected event. The dialog includes fields for 'Event' (Truck Presence Factor), 'Statistic' (2.1), and 'Type' (Multiplier). It also features a 'Gate' section with various symbols, a 'Leaf' section with symbols, and a 'Notes' section. The 'Branch Number: 2' is displayed at the bottom of the dialog.

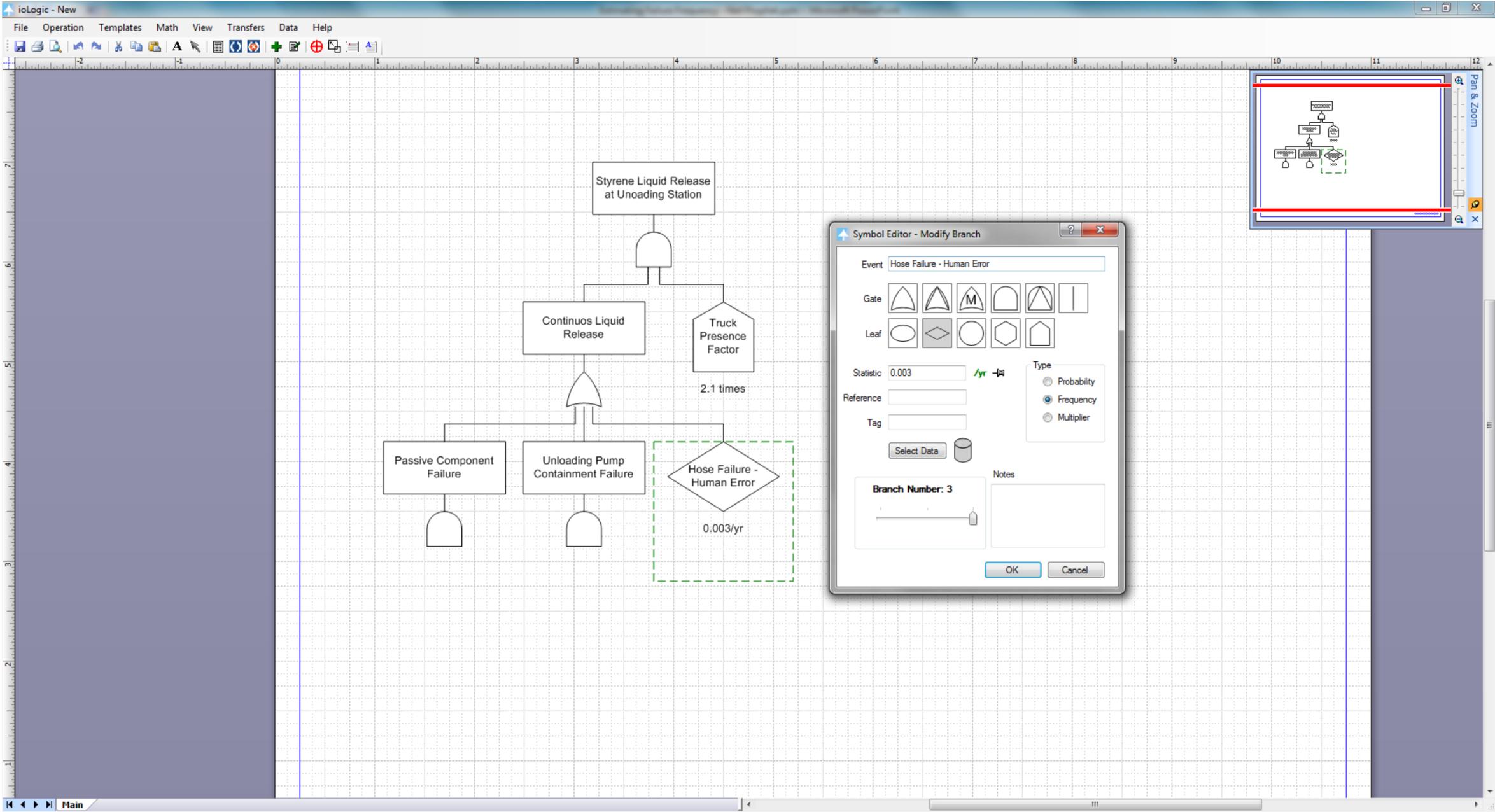
The fault tree can then be further developed by selecting “Add Branch” from the Operations menu, or by right-clicking



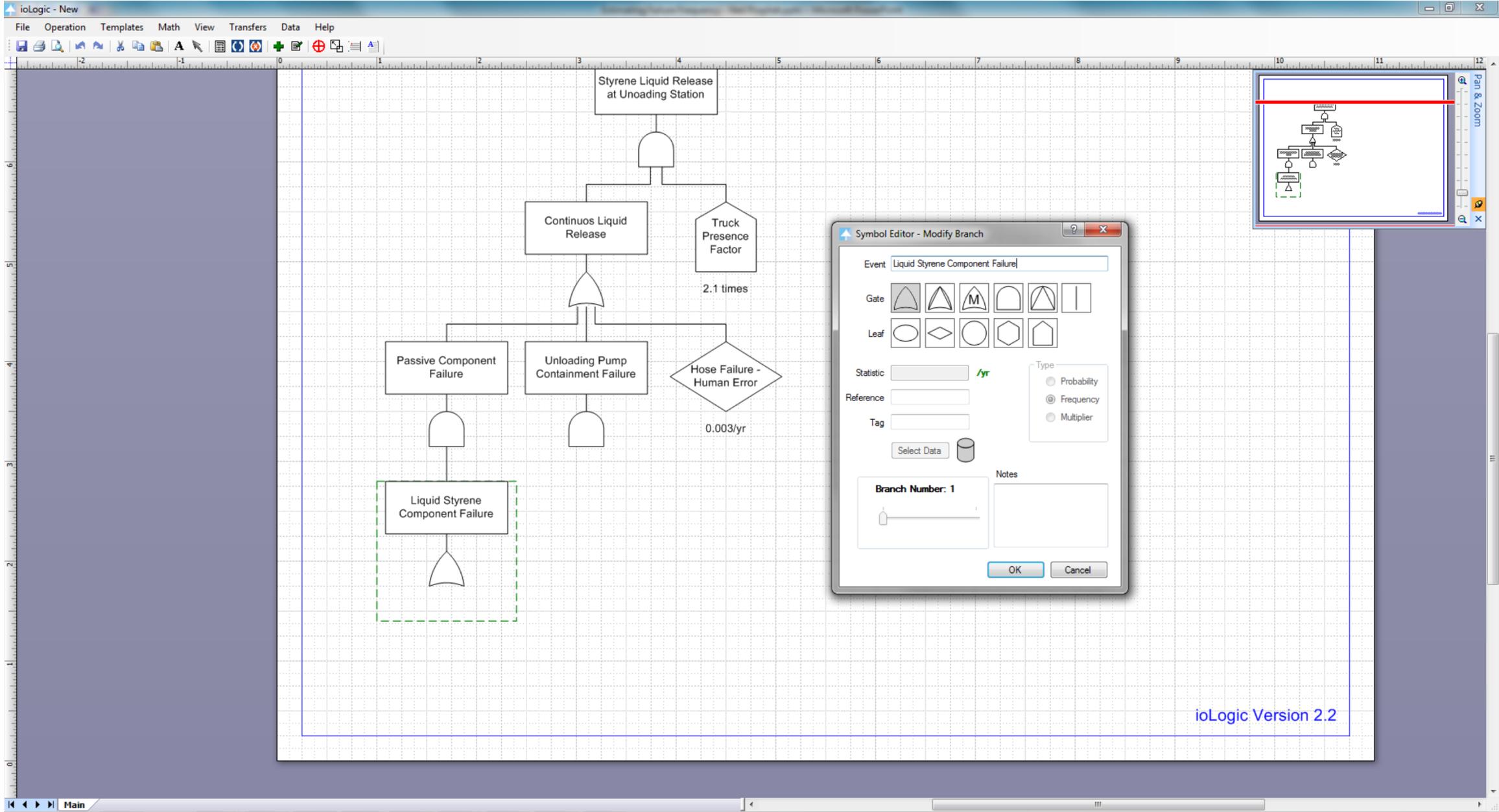
The fault tree can then be further developed by selecting “Add Branch” from the Operations menu, or by right-clicking



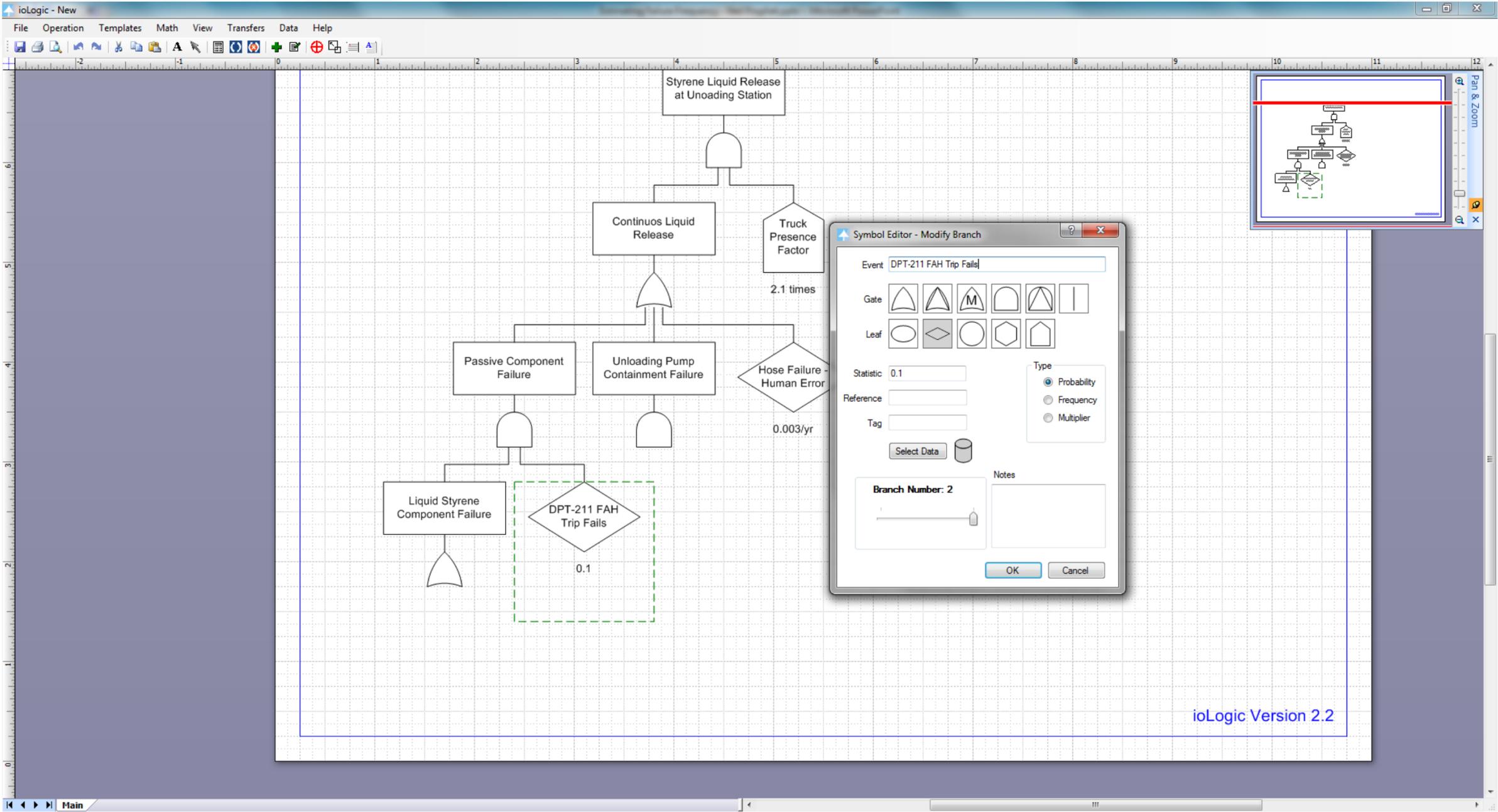
The fault tree can then be further developed by selecting “Add Branch” from the Operations menu, or by right-clicking



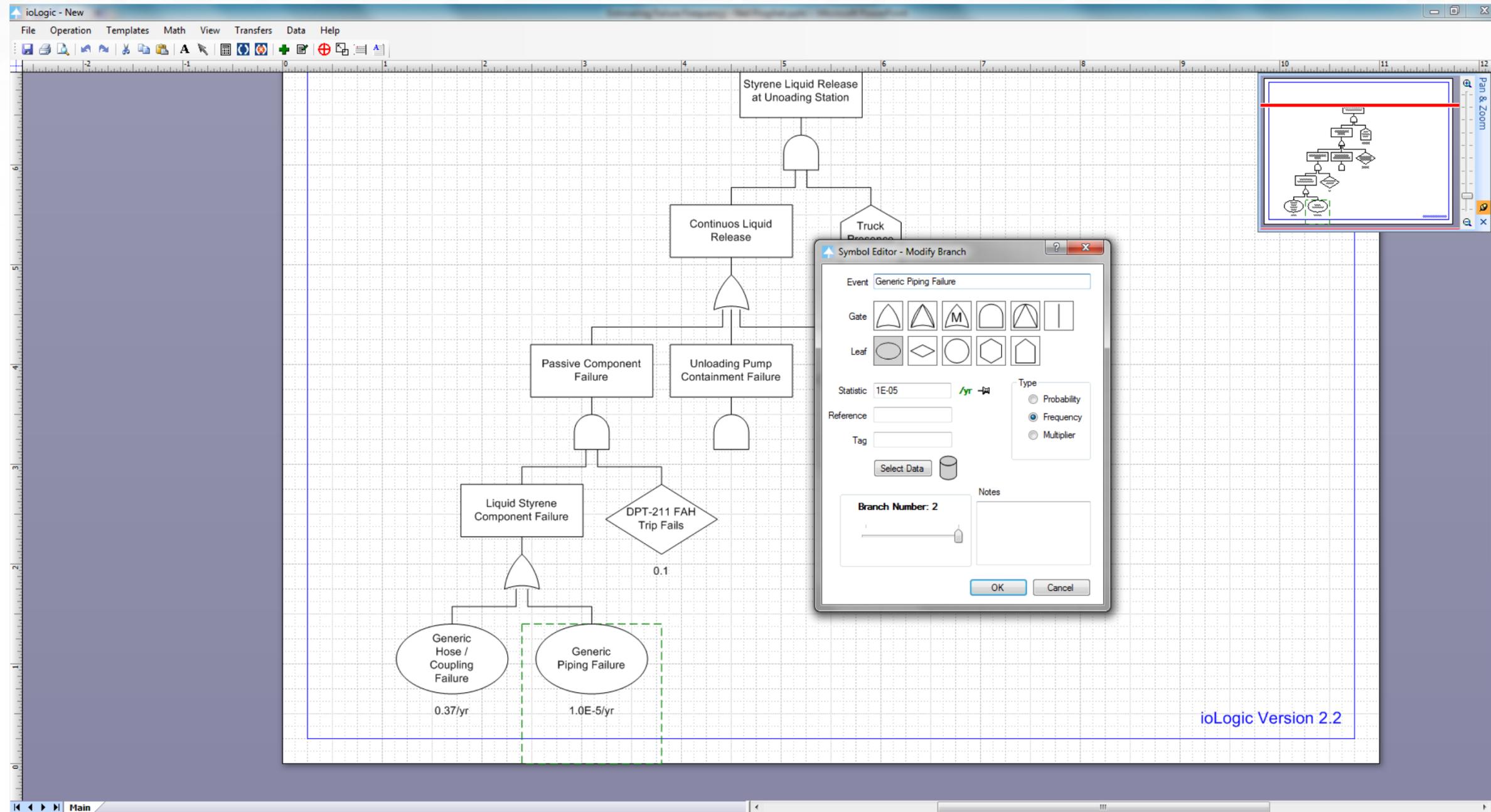
The fault tree can then be further developed by selecting “Add Branch” from the Operations menu, or by right-clicking



The fault tree can then be further developed by selecting “Add Branch” from the Operations menu, or by right-clicking



As the fault tree grows, ioLogic™ will optimize the layout



Failure rate data can be built in to ioLogic™, and accessed during fault tree construction

The screenshot displays the ioLogic software interface. The main workspace shows a fault tree diagram for the event 'Styrene Liquid Release at Unloading Station'. The tree structure is as follows:

- Top Event: Styrene Liquid Release at Unloading Station (AND gate)
- Intermediate Event: Passive Component Failure (AND gate)
- Intermediate Event: DPT-211 FAH Trip Fails (Diamond, 0.1)
- Basic Event: Liquid Styrene Component Failure (OR gate)
- Basic Event: Generic Hose / Coupling Failure (Oval, 0.37/yr)
- Basic Event: Generic Piping Failure (Oval, 1.0E-5/yr)

The 'Select Failure Data - ioLogic.FRD' dialog box is open, showing the following data:

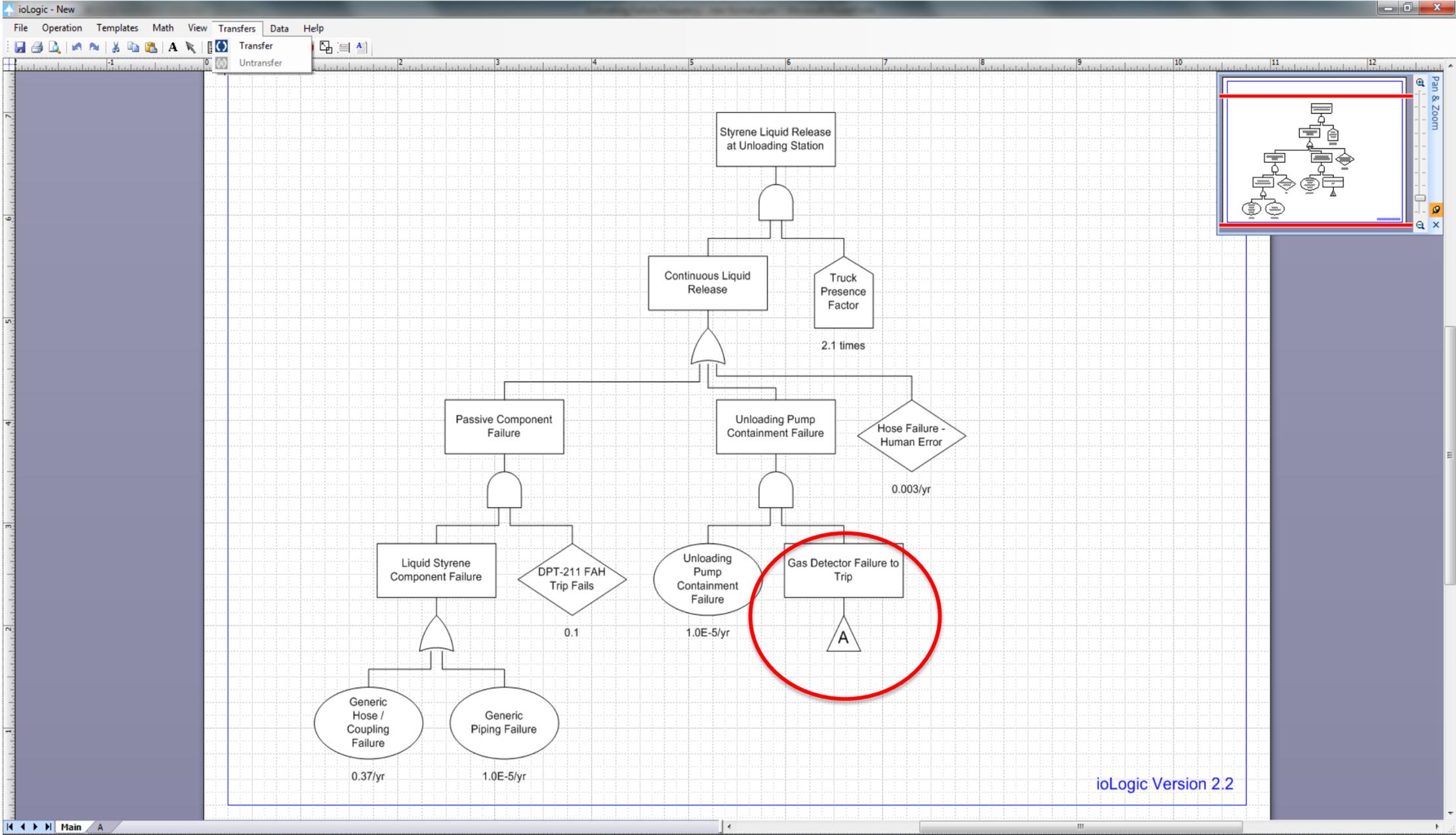
Equipment Description	Failure Mode	Failure Cause	Failure Severity	Equipment Service
Industry > Hydrocarbon > System > Mechanical and Process Equipment > Piping Systems > Equipment Class > Metal > Equipment Type > Steel	Leak	Unknown	Unknown	Hydrocarbon
	Leak	Unknown	Unknown	Hydrocarbon
	Leak	Unknown	Unknown	Hydrocarbon
	Rupture	Unknown	Unknown	Hydrocarbon

Below the table, the 'Data Details' section shows failure rate options:

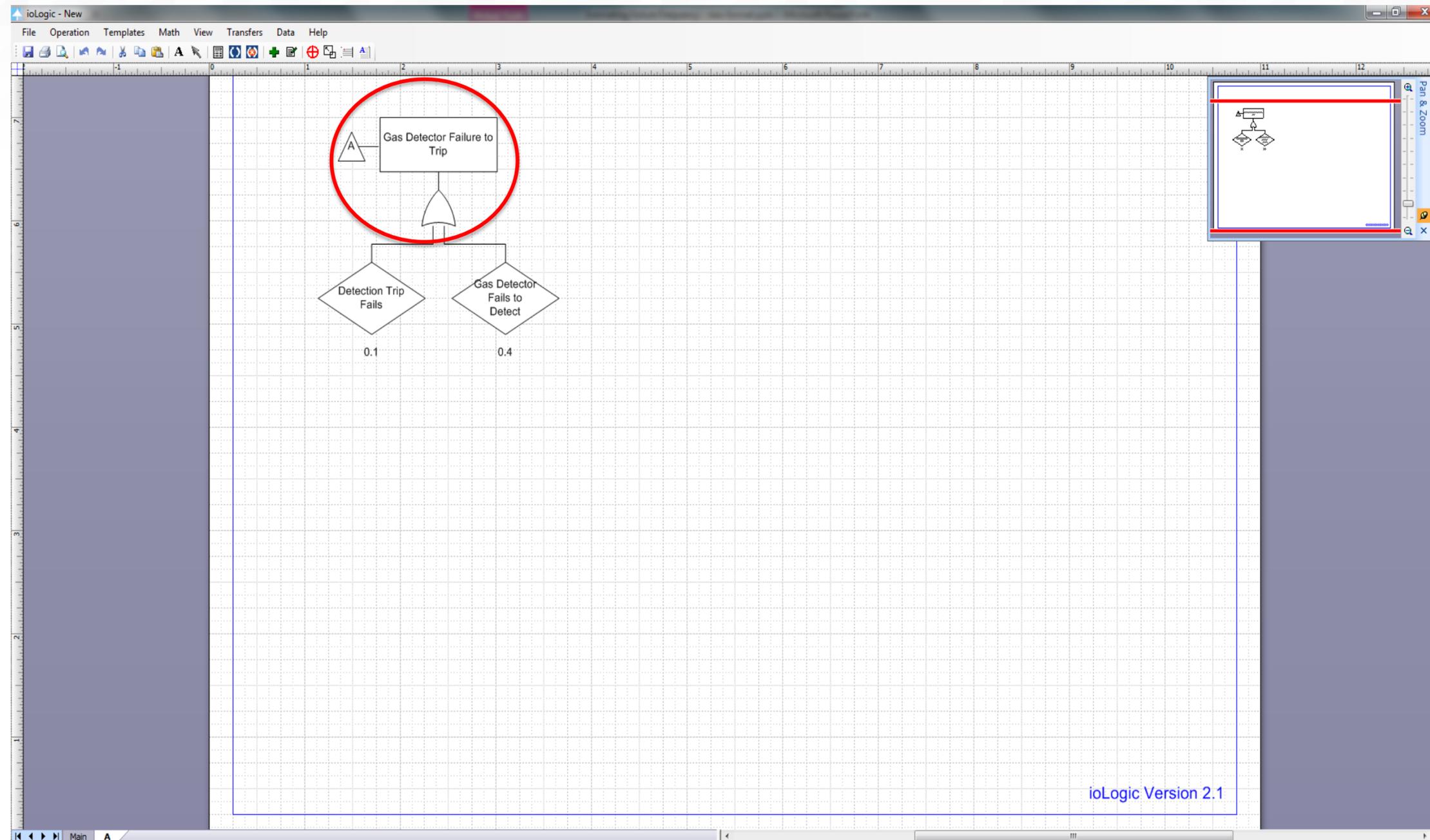
- Failure Rate (in freq.) /h: Lower (7.4E-11), Mean (7.4E-11), Upper (7.4E-11)
- Failure Rate (in prob.): Lower, Mean, Upper
- MTTR yr
- MTTF yr

At the bottom of the dialog, it states '21 out of 21 records enabled' and has 'OK' and 'Cancel' buttons.

The fault tree can be as large or small as desired, and can span multiple pages using the Transfer function



The fault tree can be as large or small as desired, and can span multiple pages using the Transfer function



ioLogic™ will check to ensure that the correct logic is applied when defining frequency or probability inputs

OR GATE

- Inputs to OR gates should be same statistic type
- Inputs are added

AND GATE

- Inputs to AND gates should be different statistic type
- Inputs are multiplied

ioLogic™ will check the logic for you

Symbol Editor - Modify Branch

Event: DPT-211 FAH Trip Fails

Gate: [OR Gate]

Leaf: [Diamond]

Statistic: 1.1

Reference:

Tag:

Type: Probability, Frequency, Multiplier

Select Data

Branch Number: 2

Notes

OK Cancel

Invalid Inputs

Please check units for all input nodes

OK

Once the fault tree is defined, there are a number of results that can be calculated from the Math menu, or by right-clicking

► Compute

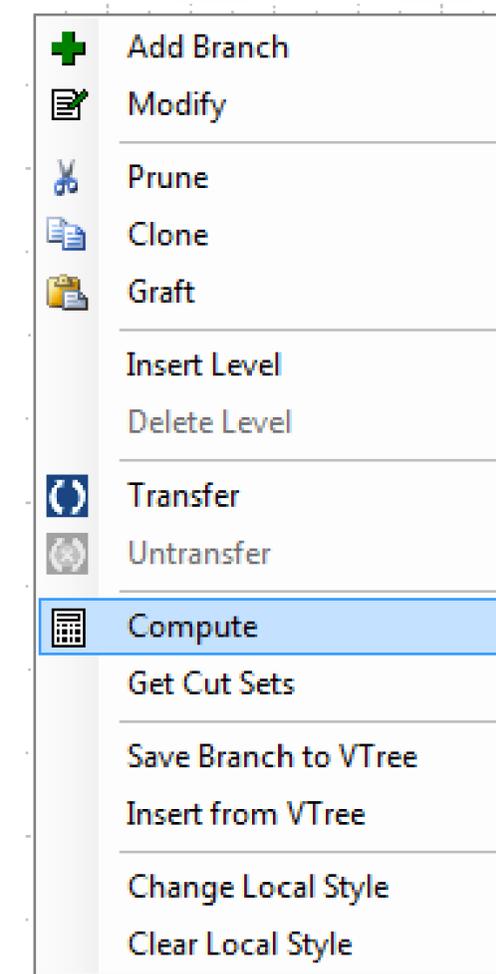
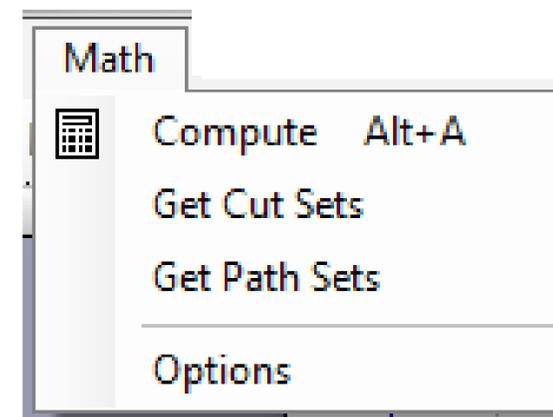
- This will compute the probability/frequency for the selected node.

► Get Cut Sets

- This will get the minimal cut sets for the whole fault tree.

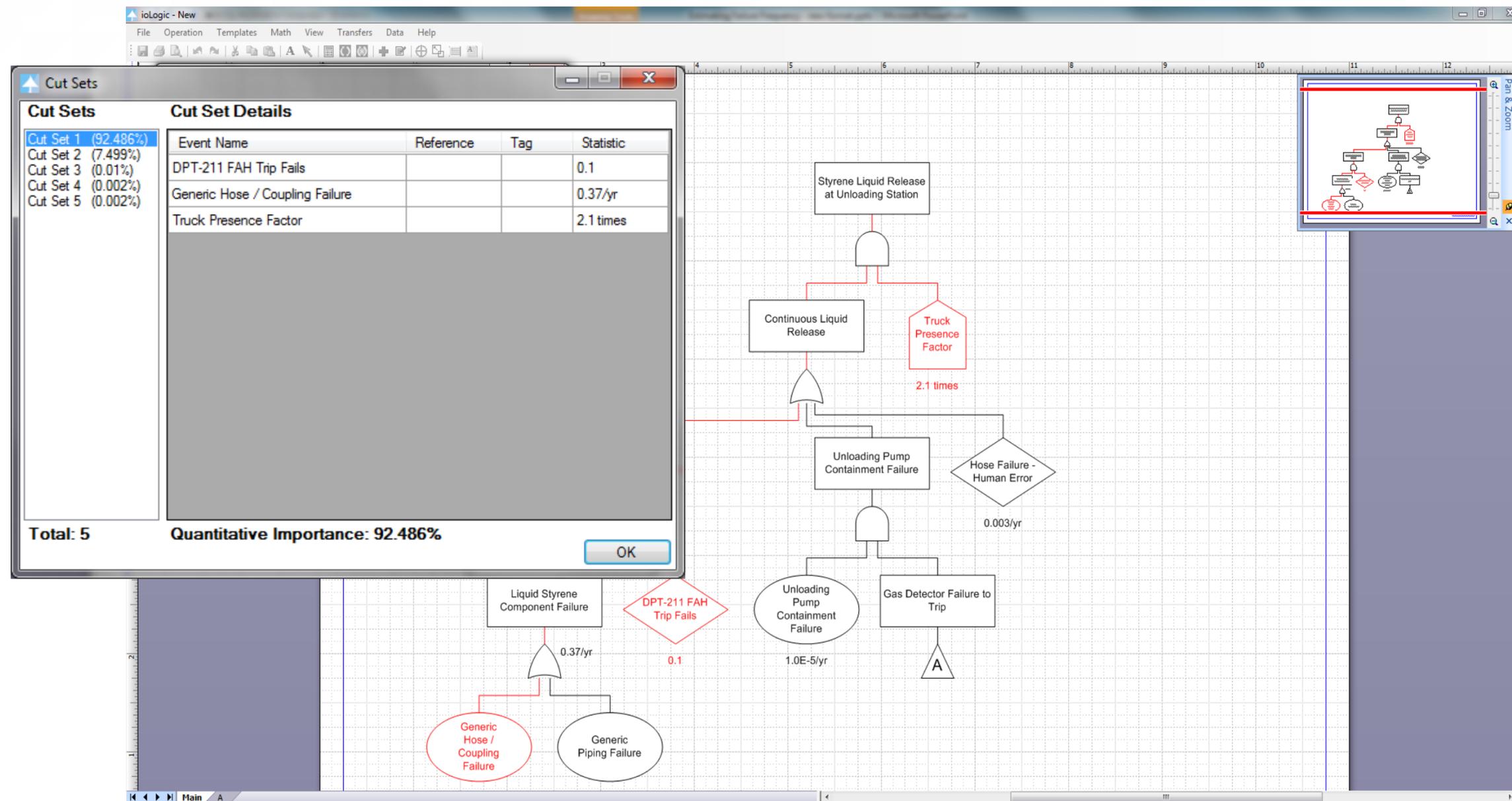
► Get Path Sets

- This will get the minimal path sets for the whole fault tree



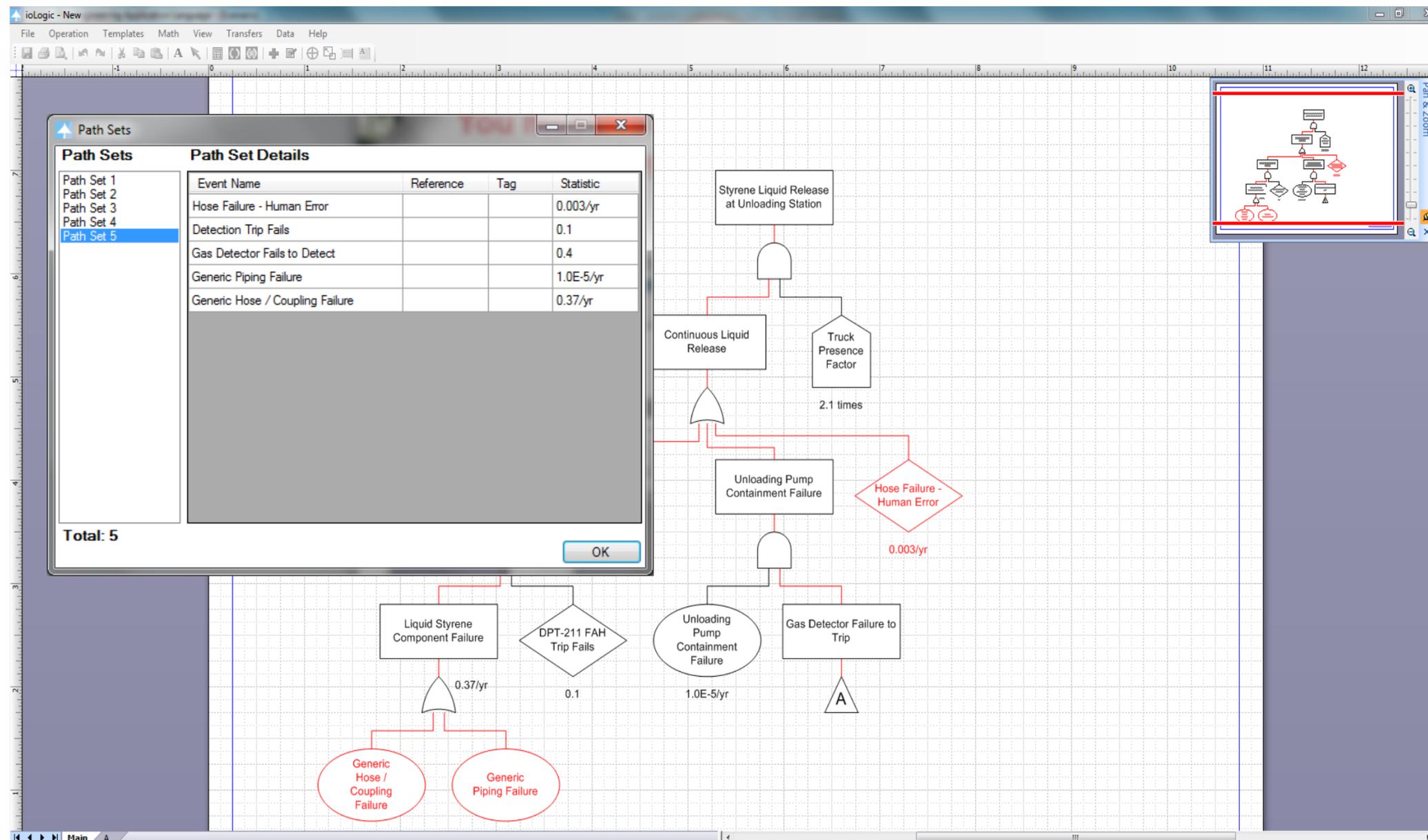
A Cut Set is a route through a tree between an initiator and the top event. The shortest credible way through the tree is called a Minimal Cut Set

- ▶ Cut Sets are shown graphically in red, and in tabular format

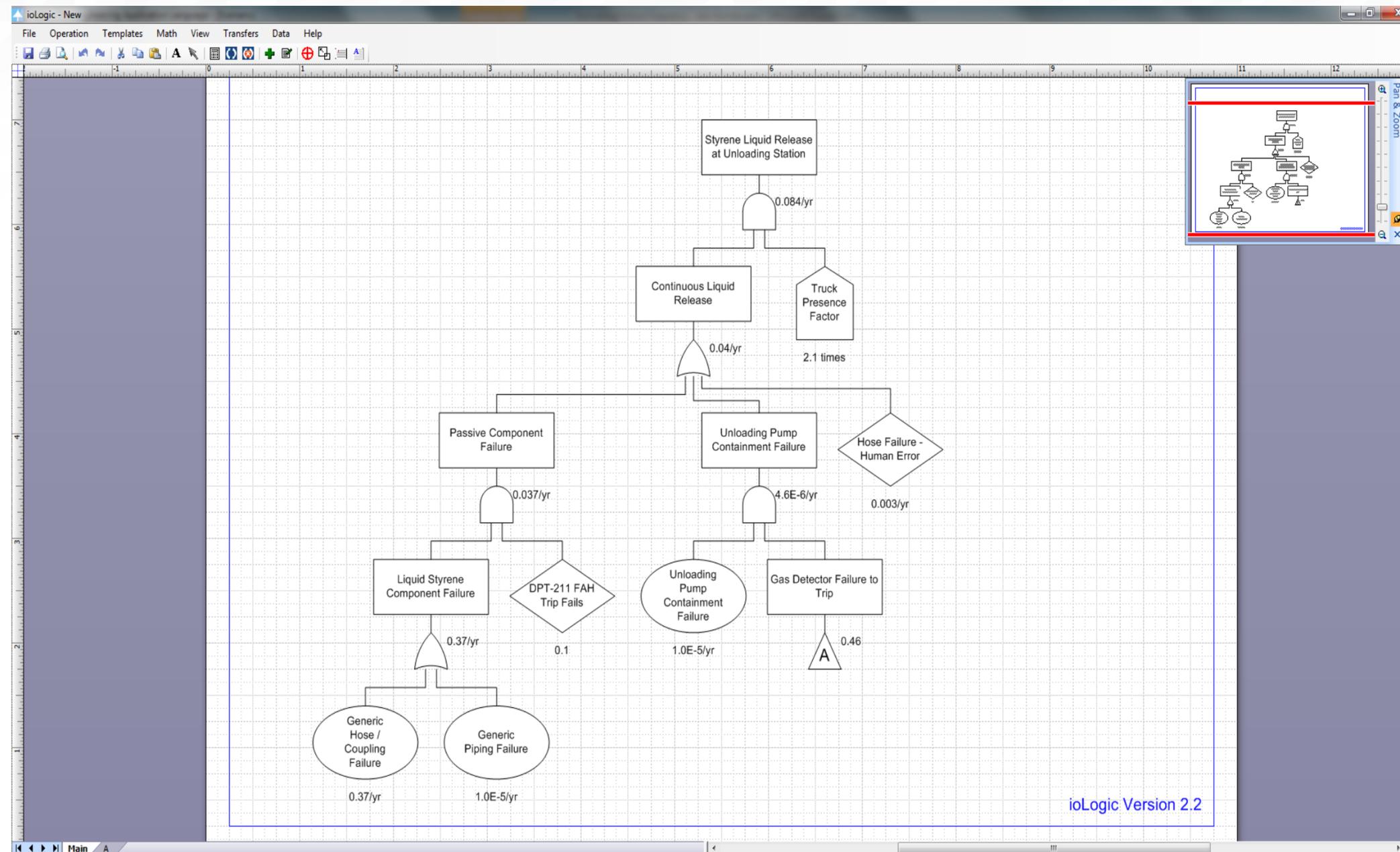


Path sets are the opposite of the cut sets. If none of the events in a path set occur, the top event will not occur

- Path Sets are shown graphically in red, and in tabular format



The 'Compute' option will calculate the probability or frequency for the selected node – whether this is for part of the fault tree, or the top event



In addition to the visual fault tree, several reports can be generated to support the fault tree itself

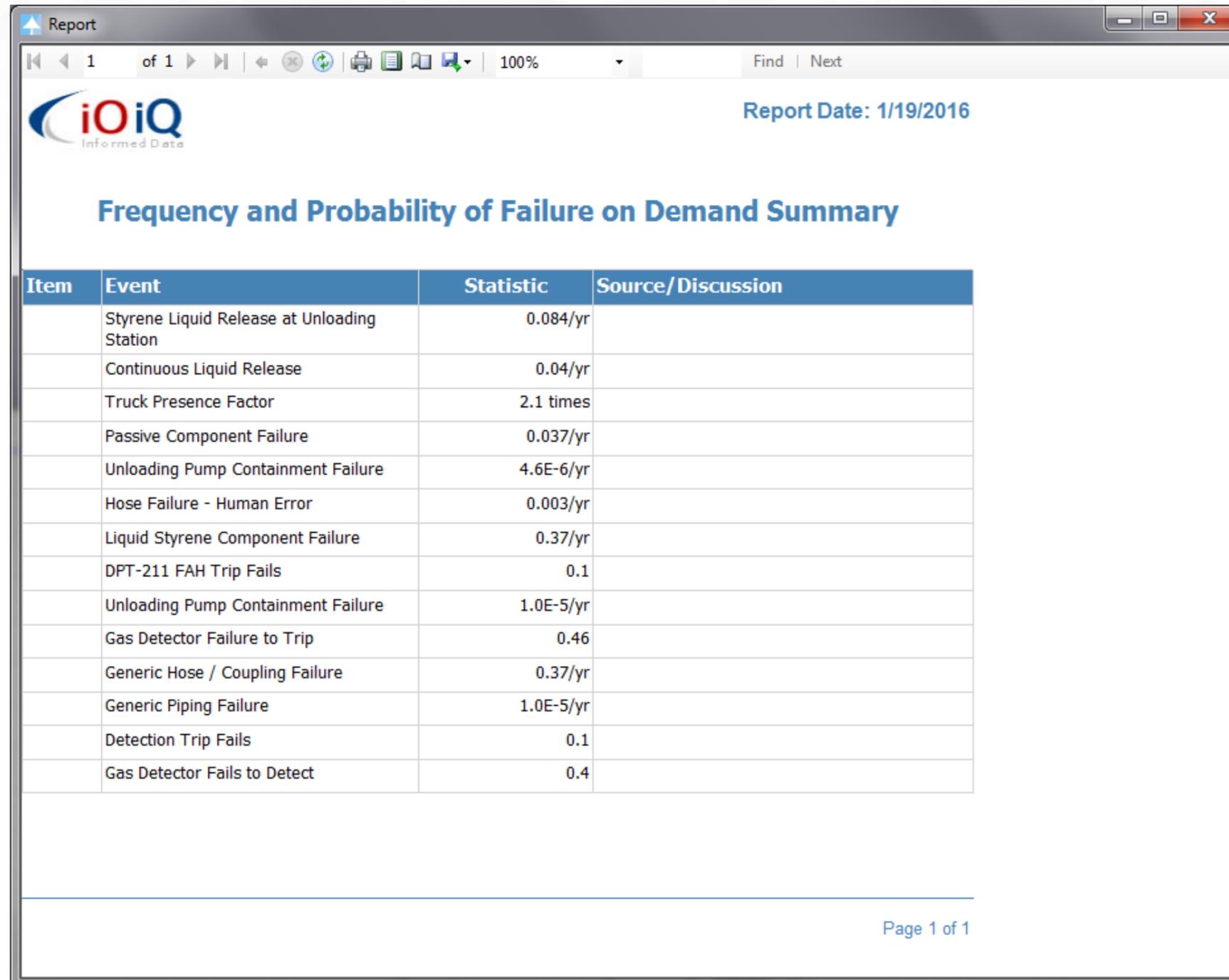
▀ Reports

- ▀ Fault Tree Report
- ▀ Detailed Fault Tree Report
- ▀ Failure Data Report
- ▀ Filtered Failure Data Report



Source: ioMosaic Image

The Fault Tree Report provides a summary of frequency and probability data used in the analysis



The screenshot shows a web browser window with the following details:

- Browser title: Report
- Page number: 1 of 1
- Zoom: 100%
- Report Date: 1/19/2016
- Logo: iOIQ Informed Data
- Section Title: Frequency and Probability of Failure on Demand Summary

Item	Event	Statistic	Source/Discussion
	Styrene Liquid Release at Unloading Station	0.084/yr	
	Continuous Liquid Release	0.04/yr	
	Truck Presence Factor	2.1 times	
	Passive Component Failure	0.037/yr	
	Unloading Pump Containment Failure	4.6E-6/yr	
	Hose Failure - Human Error	0.003/yr	
	Liquid Styrene Component Failure	0.37/yr	
	DPT-211 FAH Trip Fails	0.1	
	Unloading Pump Containment Failure	1.0E-5/yr	
	Gas Detector Failure to Trip	0.46	
	Generic Hose / Coupling Failure	0.37/yr	
	Generic Piping Failure	1.0E-5/yr	
	Detection Trip Fails	0.1	
	Gas Detector Fails to Detect	0.4	

Page 1 of 1

The Detailed Fault Tree Report provides a summary of frequency and probability data used in the analysis, as well as equipment and data details

Detailed Report

1 of 1 | 100% | Find | Next

Report Date: 1/19/2016

Frequency and Probability of Failure on Demand Summary

Item	Event	Statistic	Source/Discussion	Equipment	Data Details
	Styrene Liquid Release at Unloading Station	0.084/yr			
	Continuous Liquid Release	0.04/yr			
	Truck Presence Factor	2.1 times			
	Passive Component Failure	0.037/yr			
	Unloading Pump Containment Failure	4.6E-6/yr			
	Hose Failure - Human Error	0.003/yr			
	Liquid Styrene Component Failure	0.37/yr			
	DPT-211 FAH Trip Fails	0.1			
	Unloading Pump Containment Failure	1.0E-5/yr			
	Gas Detector Failure to Trip	0.46			
	Generic Hose / Coupling Failure	0.37/yr			
	Generic Piping Failure	1.0E-5/yr			
	Detection Trip Fails	0.1			
	Gas Detector Fails to Detect	0.4			

Page 1 of 1

The Fault Data Report provides a summary of frequency and probability data available within ioLogic™

ioIQ Informed Data

Report Date: 1/19/2016

Failure Data Report

Industry	System	Equipment Class	Equipment Type	Failure Mode	Failure Cause	Failure Severity	Failure Data Year	Equipment Service	Diameter (m)	Hole Size (m)	Low Frequency	Mean Frequency	Upper Frequency	Low Probability	Mean Probability	Upper Probability
All																
Protection Systems																
Fire Protection																
Fire Suppression - Dry Powder																
				All	Unknown	Catastrophic					2.5E-8/h	1.4E-6/h	5.5E-6/h			
Fire Suppression - Water																
				All	Unknown	Catastrophic		Water Fire Fighting			1.7E-7/h	9.7E-6/h	3.7E-5/h			
Water Pump - Diesel																
				Fail to Start on Demand	Unknown	Catastrophic		Water Fire Fighting; Standby						0.00077	0.019	0.07
Water Pump - Electric																
				Fail to Start on Demand	Unknown	Catastrophic		Water Fire Fighting						0.0036	0.043	0.14
Pressure Protection																
PRV - Conventional																
				Opens Prematurely	Unknown	Catastrophic		Spring Loaded			2.8E-7/h	1.7E-6/h	4.8E-6/h			
				Failure to Open on Demand	Unknown	Catastrophic		Spring Loaded						7.9E-6	0.00021	0.0008
				Failed to Reclose Once Opened	Unknown	Catastrophic		Spring Loaded						0.00013	0.0052	0.023
PRV - Pilot Operated																
				Failed to Reclose Once Opened	Unknown	Catastrophic								0.00019	0.005	0.019
				Failure to Open on Demand	Unknown	Catastrophic								9.3E-6	0.0042	0.018
Hydrocarbon																
Mechanical and Process Equipment																
Vessels																
Pressurized																
				Rupture	Unknown	Unknown		Hydrocarbon			6.8E-10/h	6.8E-10/h	6.8E-10/h			
				Leak	Unknown	Unknown		Hydrocarbon	0.1		1.1E-9/h	1.1E-9/h	1.1E-9/h			
				Leak	Unknown	Unknown		Hydrocarbon	0.025		1.1E-8/h	1.1E-8/h	1.1E-8/h			
				Leak	Unknown	Unknown		Hydrocarbon	0.0063		4.6E-9/h	4.6E-9/h	4.6E-9/h			
Reactor																

The Filtered Fault Data Report provides a filtered summary of frequency and probability data available within ioLogic™

Data Report

Show

1 of 1 | 100% | Find | Next

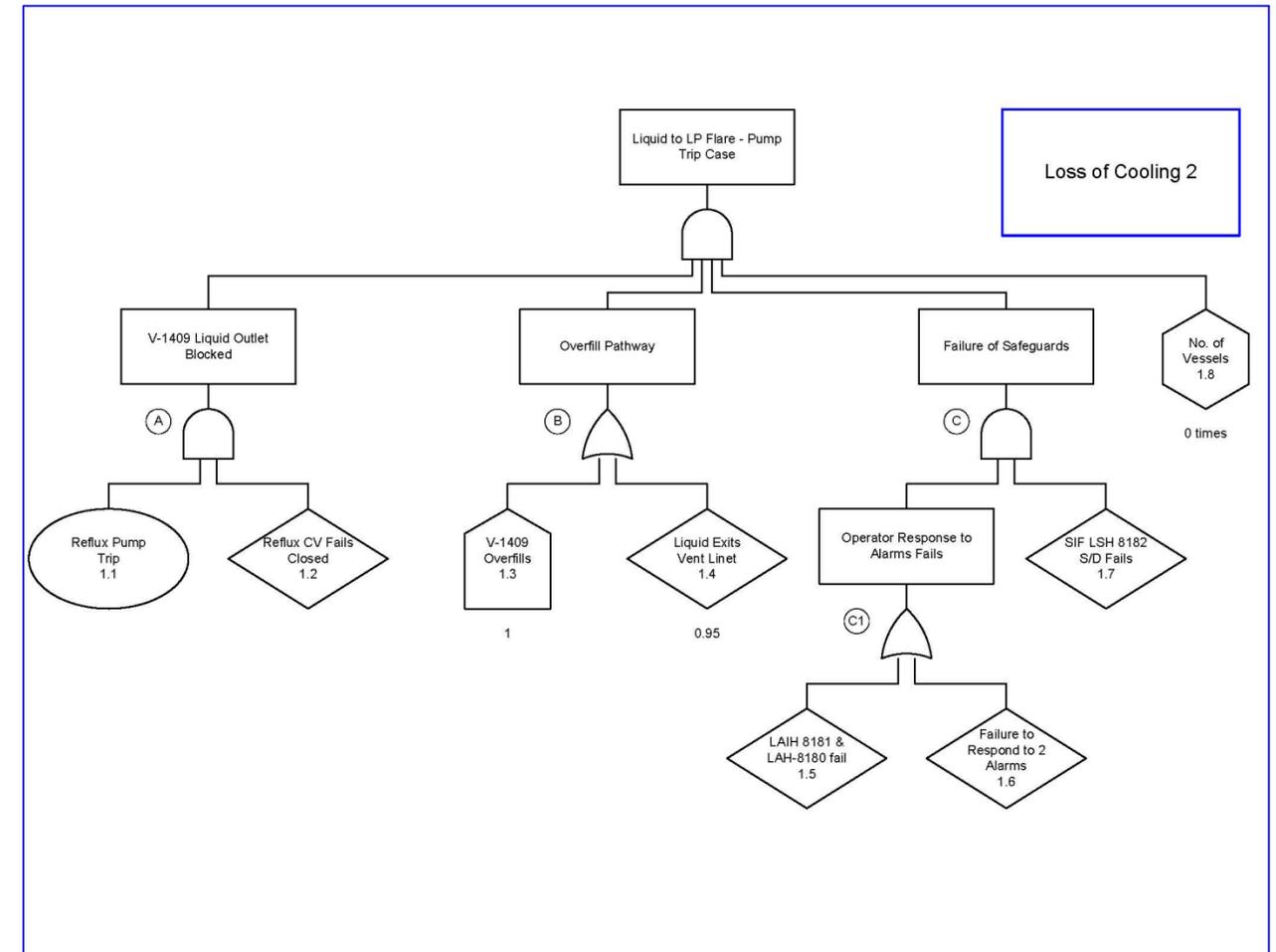
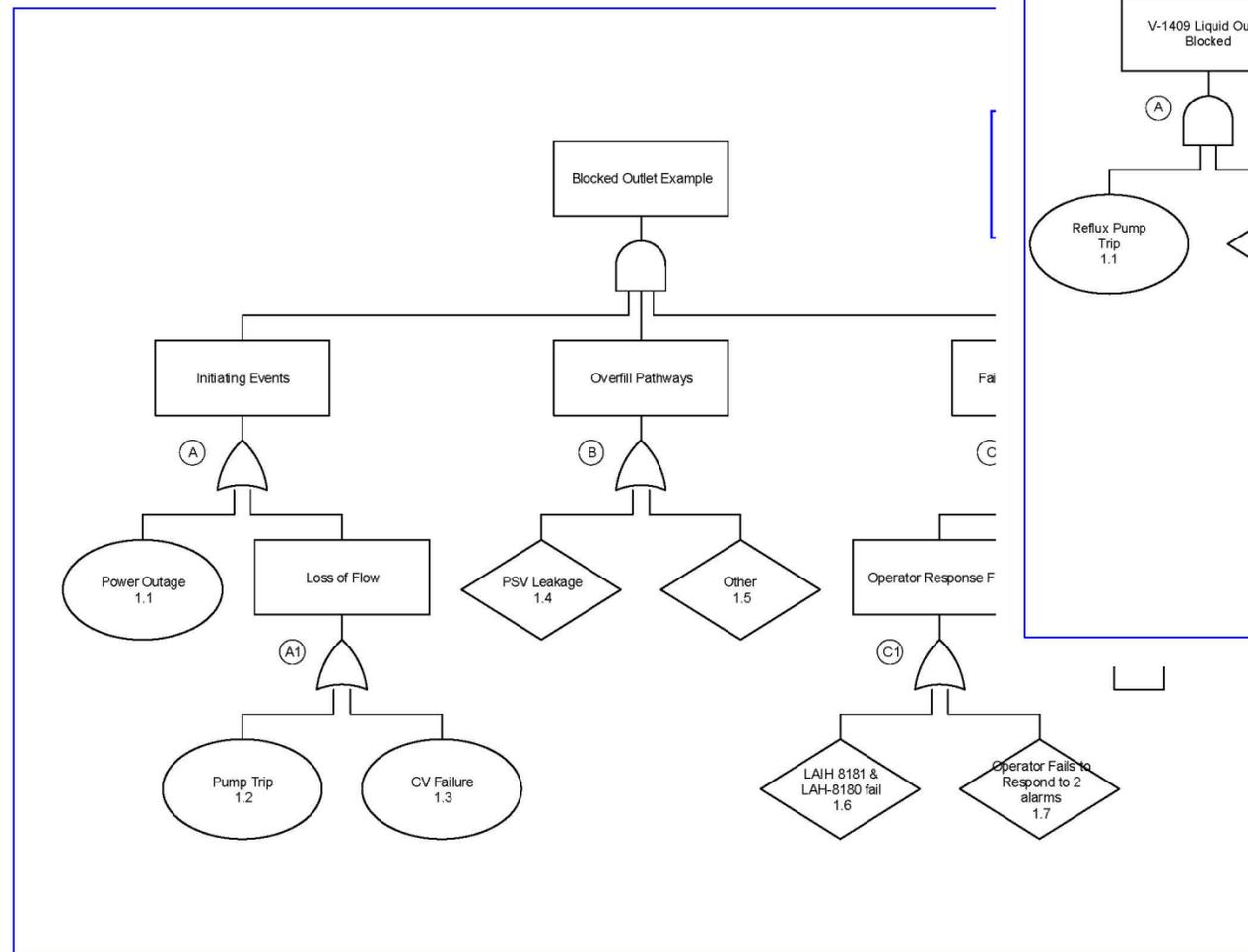
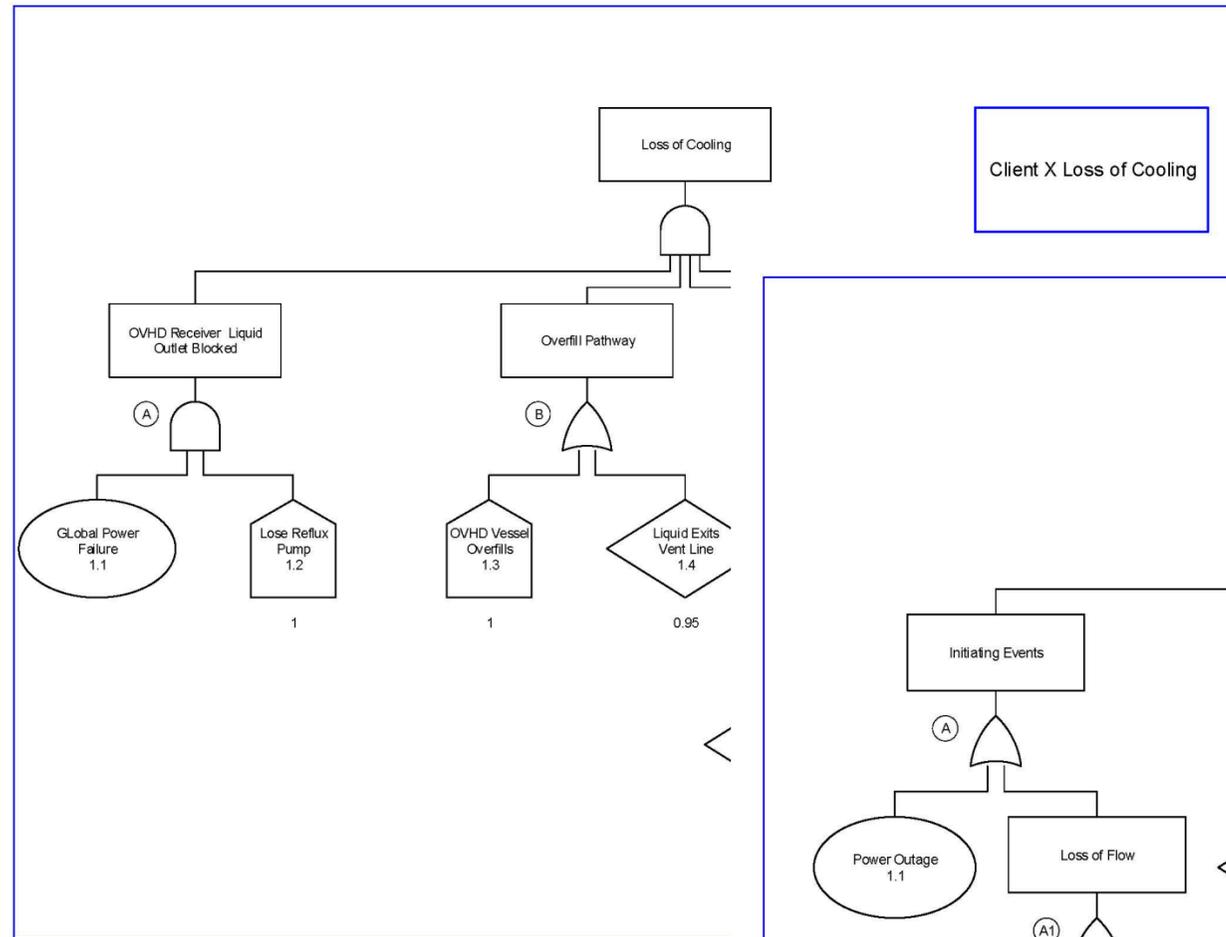
Report Date: 1/19/2016

Failure Data Report

Industry	System	Equipment Class	Equipment Type	Failure Mode	Failure Cause	Failure Severity	Failure Data Year	Equipment Service	Diameter (m)	Hole Size (m)	Low Frequency	Mean Frequency	Upper Frequency	Low Probability	Mean Probability	Upper Probability
All																
Protection Systems																
Fire Protection																
Fire Suppression - Dry Powder																
				All	Unknown	Catastrophic					2.5E-8/h	1.4E-6/h	5.5E-6/h			
Fire Suppression - Water																
				All	Unknown	Catastrophic		Water Fire Fighting			1.7E-7/h	9.7E-6/h	3.7E-5/h			
Water Pump - Diesel																
				Fail to Start on Demand	Unknown	Catastrophic		Water Fire Fighting; Standby						0.00077	0.019	0.07
Water Pump - Electric																
				Fail to Start on Demand	Unknown	Catastrophic		Water Fire Fighting						0.0036	0.043	0.14
Pressure Protection																
PRV - Conventional																
				Opens Prematurely	Unknown	Catastrophic		Spring Loaded			2.8E-7/h	1.7E-6/h	4.8E-6/h			
				Failure to Open on Demand	Unknown	Catastrophic		Spring Loaded						7.9E-6	0.00021	0.0008
				Failed to Reclose Once Opened	Unknown	Catastrophic		Spring Loaded						0.00013	0.0052	0.023
PRV - Pilot Operated																
				Failed to Reclose Once Opened	Unknown	Catastrophic								0.00019	0.005	0.019
				Failure to Open on Demand	Unknown	Catastrophic								9.3E-6	0.0042	0.018
Hydrocarbon																
Mechanical and Process Equipment																
Vessels																
Pressurized																
				Rupture	Unknown	Unknown		Hydrocarbon			6.8E-10/h	6.8E-10/h	6.8E-10/h			
				Leak	Unknown	Unknown		Hydrocarbon	0.1		1.1E-9/h	1.1E-9/h	1.1E-9/h			
				Leak	Unknown	Unknown		Hydrocarbon	0.025		1.1E-8/h	1.1E-8/h	1.1E-8/h			
				Leak	Unknown	Unknown		Hydrocarbon	0.0063		4.6E-9/h	4.6E-9/h	4.6E-9/h			
Reactor																

Overpressure Scenario Credibility - Results

- Multiple Fault Trees were developed to represent each scenario



Overpressure Scenario Credibility - Results

- Calculated frequencies of the potential overpressure scenarios are summarized below indicating scenarios are not credible

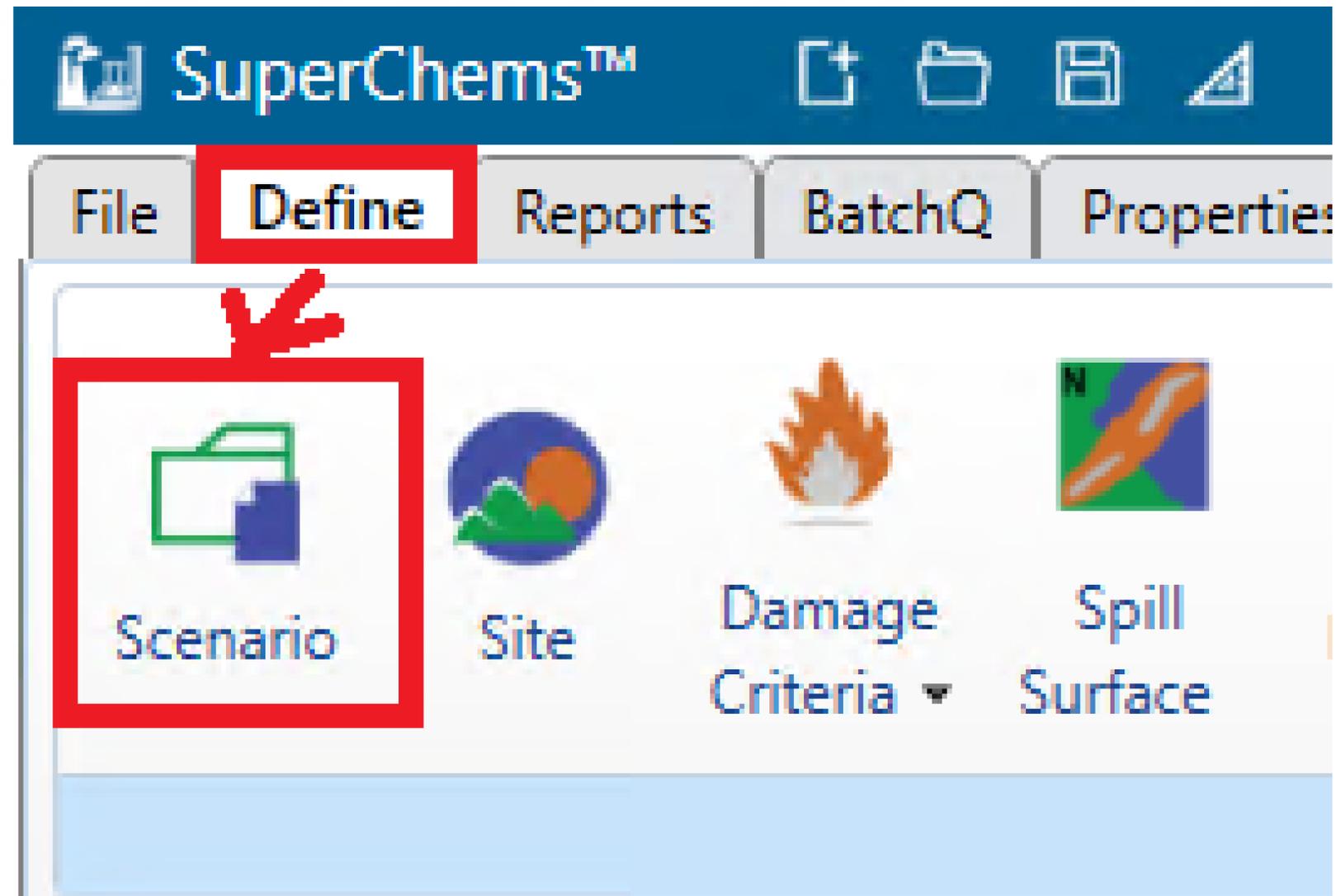
Reactor Tag #	PSV Tag #	Frequency of Excessive Accumulation (Occurrences/ yr)			
		Normal Ops Blocked Outlet	Heat Up Blocked Outlet	One RX CW Loss	Multi Rx CW Loss
Reactor 1	PSV-1	4.40E-07	3.10E-08	7.40E-07	5.20E-05
Reactor 2	PSV-2	4.40E-07	3.10E-08	7.40E-07	
Reactor 3	PSV-3	4.40E-07	3.10E-08	7.40E-07	
Reactor 4	PSV-4	4.40E-07	3.10E-08	7.40E-07	

Maximum Coincident Pressure and Temperature for Overpressure Scenarios



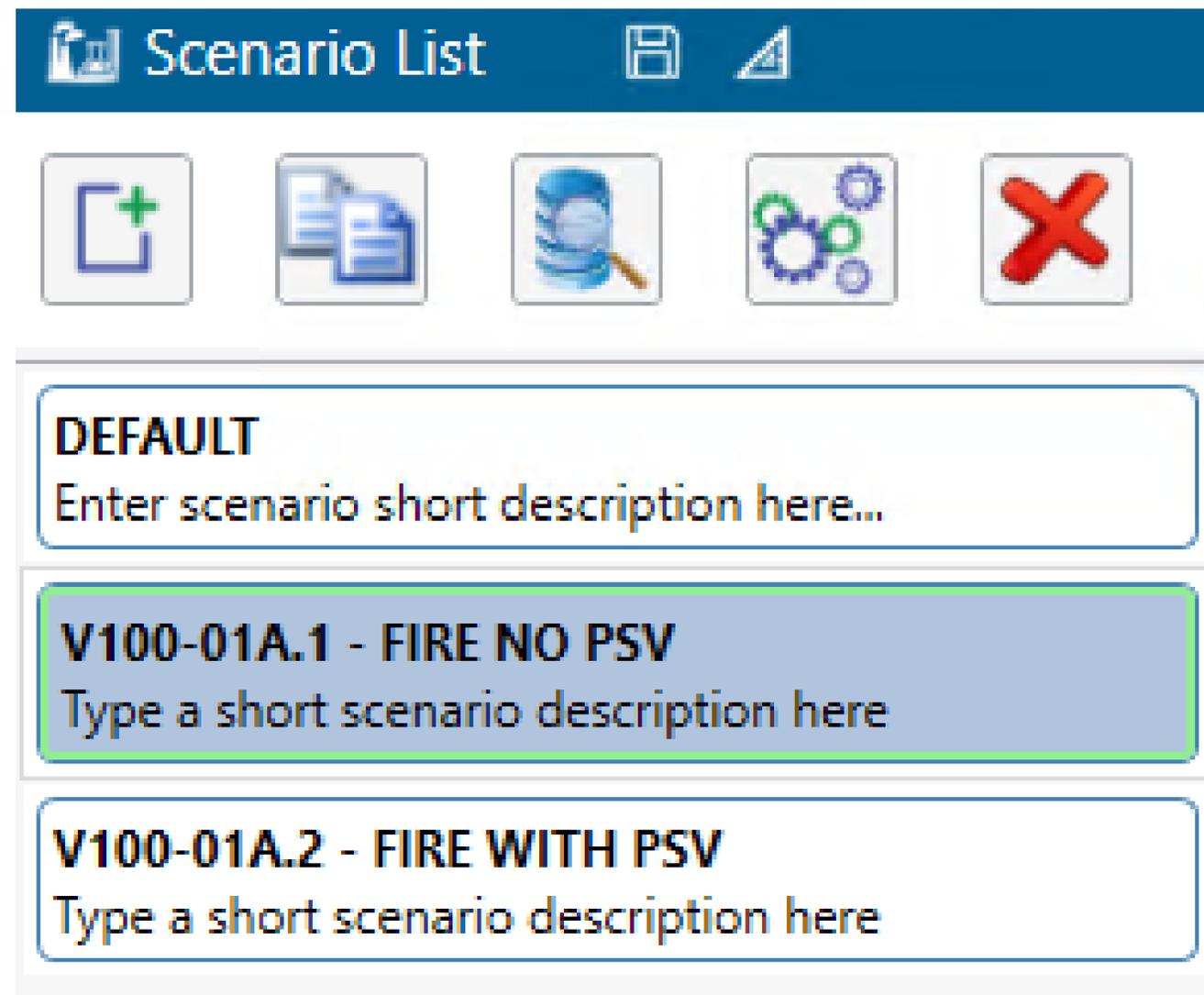
Setting up the dynamic calculation - scenarios

- First, create the scenarios by going to Define → Scenario



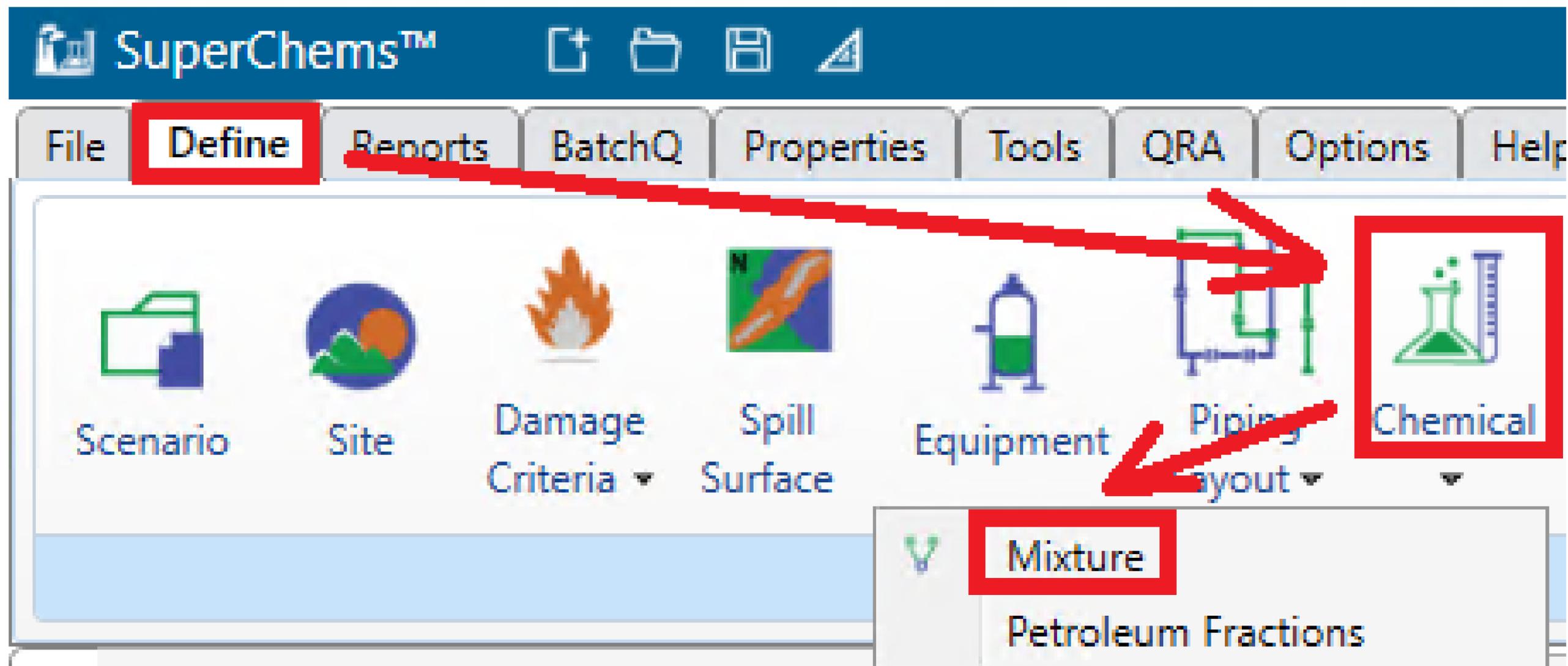
Setting up the dynamic calculation - scenarios

- Use a meaningful name (Vessel tag, Scenario Key, Descriptor)



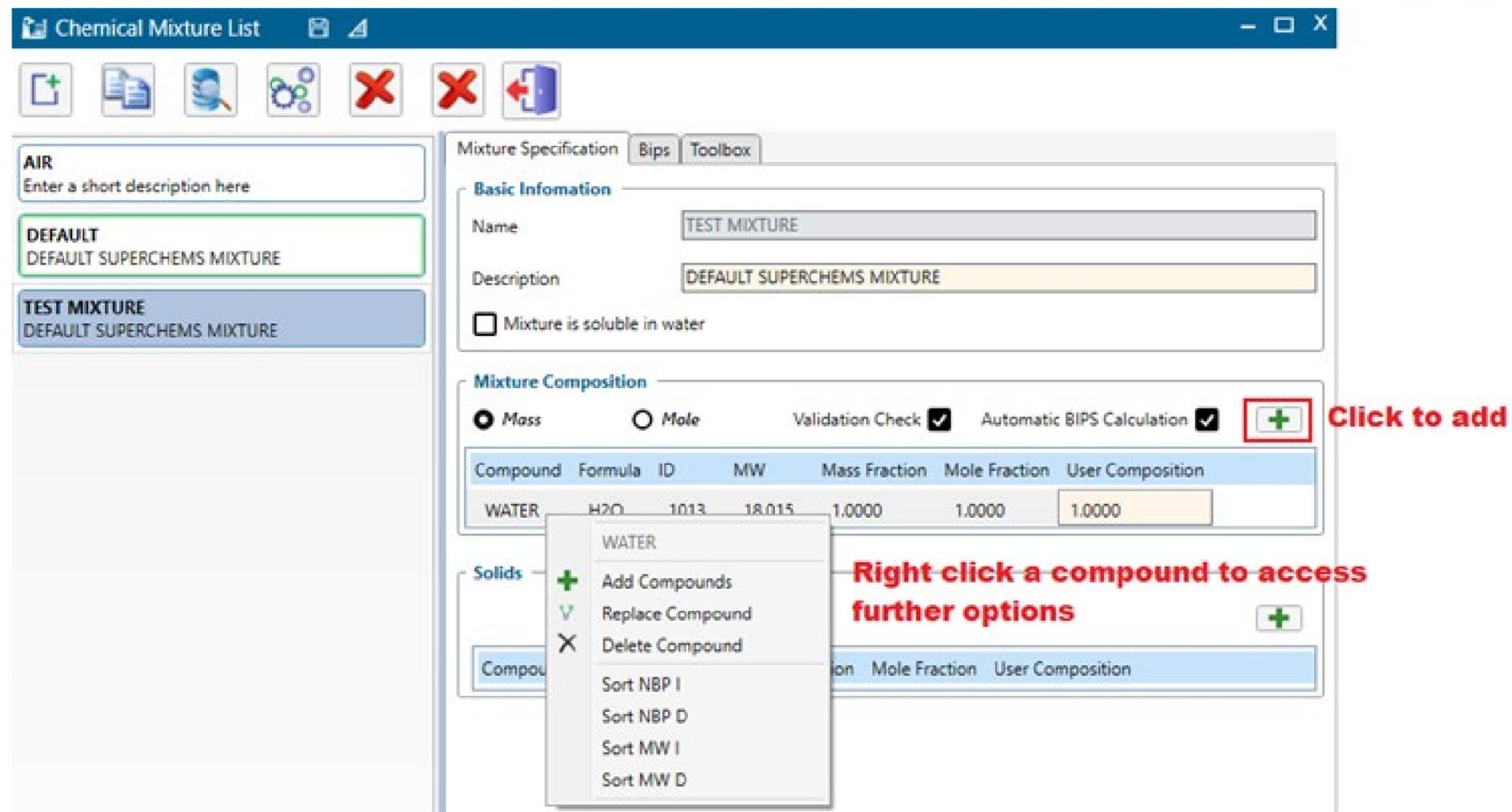
Setting up the dynamic calculation - mixture

- ▶ Create the mixture by going to Define → Chemical → Mixture



Setting up the dynamic calculation - mixture

- Compounds can be added to the mixture by clicking the  icon or right clicking in the mixture window

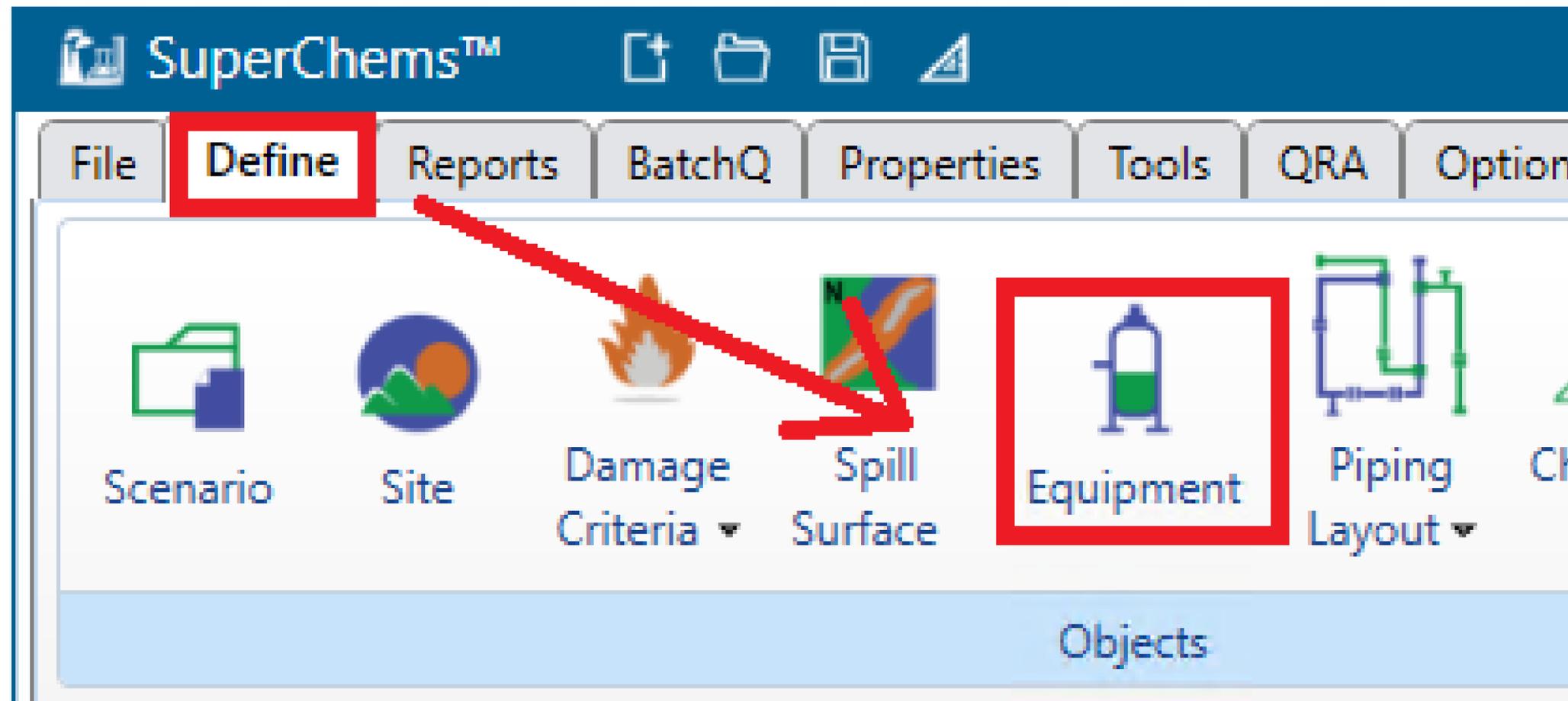


The screenshot displays the 'Chemical Mixture List' application window. On the left, a list of mixtures is shown, with 'TEST MIXTURE' selected. The main panel is divided into 'Mixture Specification' and 'Mixture Composition' sections. The 'Mixture Composition' section includes a table with columns for Compound, Formula, ID, MW, Mass Fraction, Mole Fraction, and User Composition. A red box highlights a green plus icon in the top right of this section, with the text 'Click to add' next to it. A context menu is open over the 'WATER' row, showing options like 'Add Compounds', 'Replace Compound', 'Delete Compound', and sorting options. A red text annotation 'Right click a compound to access further options' points to the context menu. A second green plus icon is visible at the bottom right of the table area.

Compound	Formula	ID	MW	Mass Fraction	Mole Fraction	User Composition
WATER	H2O	1013	18.015	1.0000	1.0000	1.0000

Setting up the dynamic calculation - vessel

- ▶ Create the vessel by going to Define → Equipment



Required for calculation

Useful documentation

Miscellaneous notes

Setting up the dynamic calculation - vessel

- Click the  icon to create a new vessel

Specification Options Report Comments Geometry and Stress Toolbox

Basic
Notes
Profile
External Fire

V100

Description	Process Vessels and Equipment	P&IDs	NA
Location	NA	Equipment type	Blower
Manufacturer	NA	Vessel built per	ASME Section VIII
Serial number	NA	Applicable relief code	OSHA 1910

Pressure		Temperature	
Design pressure	100 psig	Design temperature	450.6296 °F
Vacuum pressure	-14.7 psig	Minimum temperature	-20 °F
Normal operating pressure	50 psig	Normal operating temperature	60 °F
Maximum pressure	50 psig	Maximum temperature	60 °F

Setting up the dynamic calculation - vessel

Physical Dimensions

Vessel type	<input type="text" value="Vertical Cylindrical"/>	Material of construction	<input type="text" value="STEEL"/>
Length	<input type="text" value="10"/>	Actual material	<input type="text" value="STEEL"/>
Inside diameter	<input type="text" value="6"/>	Internals/User defined mass	<input type="text" value="0"/> lb
Shell thickness	<input type="text" value="0.0417"/>	Liquid pool bottom elevation	<input type="text" value="0"/> ft
		Grade bottom elevation	<input type="text" value="0"/> ft

Calculated Area/Volume/Mass

Head	Top	Bottom
Type	<input type="text" value="Elliptical 2:1"/>	<input type="text" value="Elliptical 2:1"/>
Wall thickness	<input type="text" value="0.0417"/> ft	<input type="text" value="0.0417"/> ft

Setting up the dynamic calculation - vessel

Defining fire loading within vessel object

Specification Options Report Comments Geometry and Stress Toolbox

Basic
Notes
Profile
External Fire
1

2 Enable Fire Loading

Fire flux 65.6885 BTU/hr/in²

Fire start time 0 h

Fire duration 4 h

Fraction exposed to fire 0.2878

Wetted area 11048.0522 in²

Fire Loading Methodology

API-521 Fire Flux

Wetted area fraction confined or indoors 0

Adequate drainage and fire fighting equipment are present

Adjust wetted area for liquid level

Maximum liquid level 25 %

Mitigation factor 1

API-2000 Fire Flux

NFPA-30/OSHA 1910

User-defined fire loading

Options

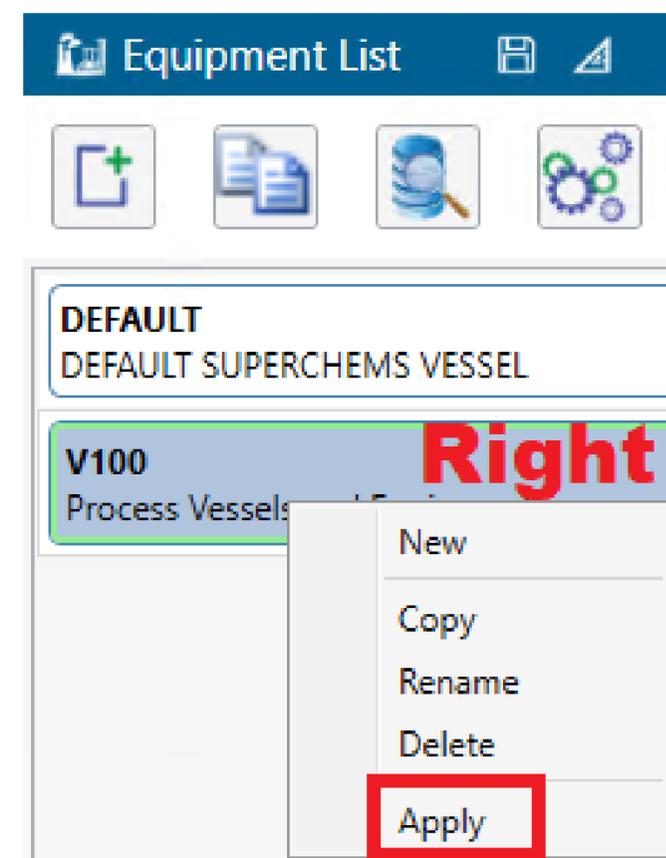
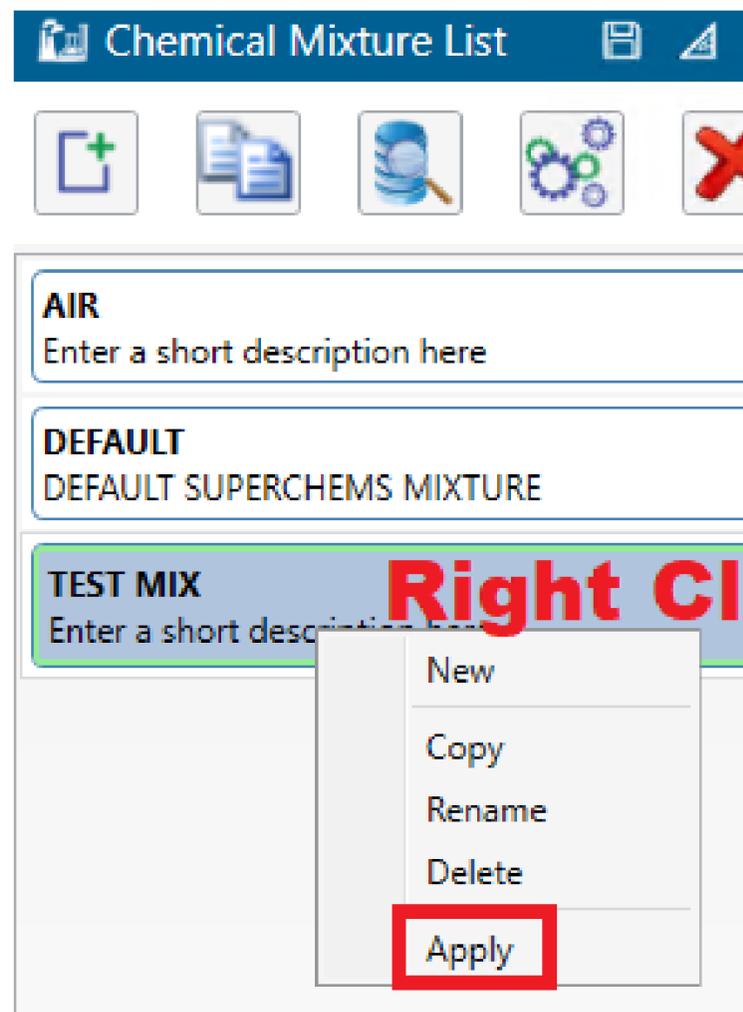
Remove bottom head from estimate of wetted area

Remove top head from estimate of wetted area

Description	Area in ²
Relief and process piping allowance	1105

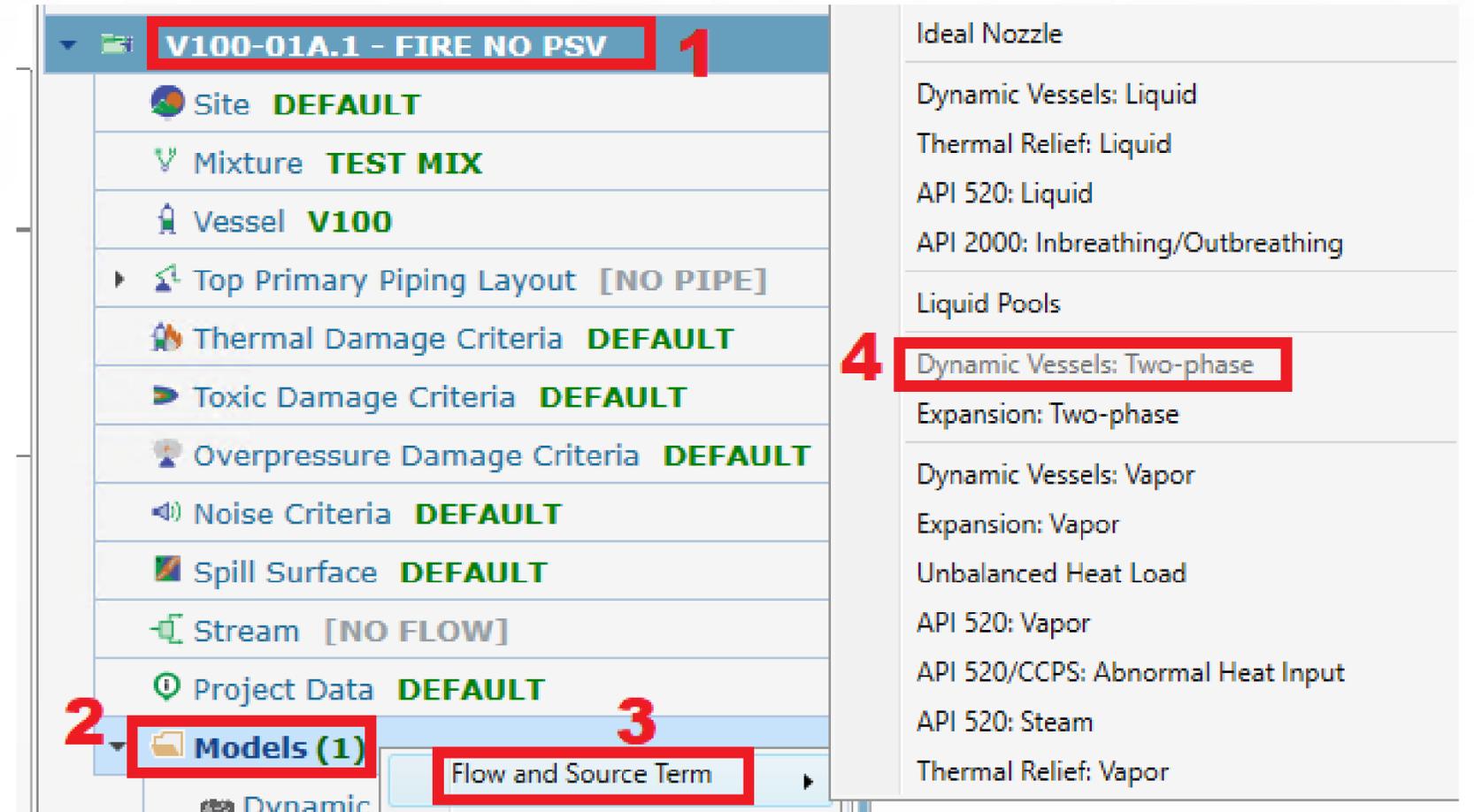
Setting up the dynamic calculation – applying

- Apply the mixture and vessel to the scenario



Choosing Vessels Containing Two Phases (Dynamic)

- All sizing models are located under the Flow and Source Term context menu by right clicking on Models within the scenario of interest. Since the vessel is 25 vol% full, choose the Vessels Containing Two Phases (Dynamic) model



Vessels Containing Two Phases (Dynamic) - Initialize

- ▶ This model needs to be initialized before using. This means the pressure, temperature, vol fill %, and mass of contents need to agree

Dynamic Vessels: Two-phase

Inputs | Toolbox | Notes | Data Sets

Cancel | Update | Run

Model output data is not available, please run the model first

Specifications | Connectivity | Run Parameters | Stop Conditions | Accuracy

Vessel Initial Conditions

Total volume: 2538.0804 gal

Available volume: 2538.0804 gal

Contents mass: 3216.5332 lb

Fluid Phase

- Saturated liquid
- Liquid full
- Vapor full

	Contents	Normal operating	Maximum operating	Minimum design	Maximum design
Temperature, °F	58.2581	60	60	-20	450.63
Pressure, psig	50	50	50	-14.7	100

Relief Piping Path

No piping layouts defined

Time Analysis

Starting time: 0 h

Final time: 4 h

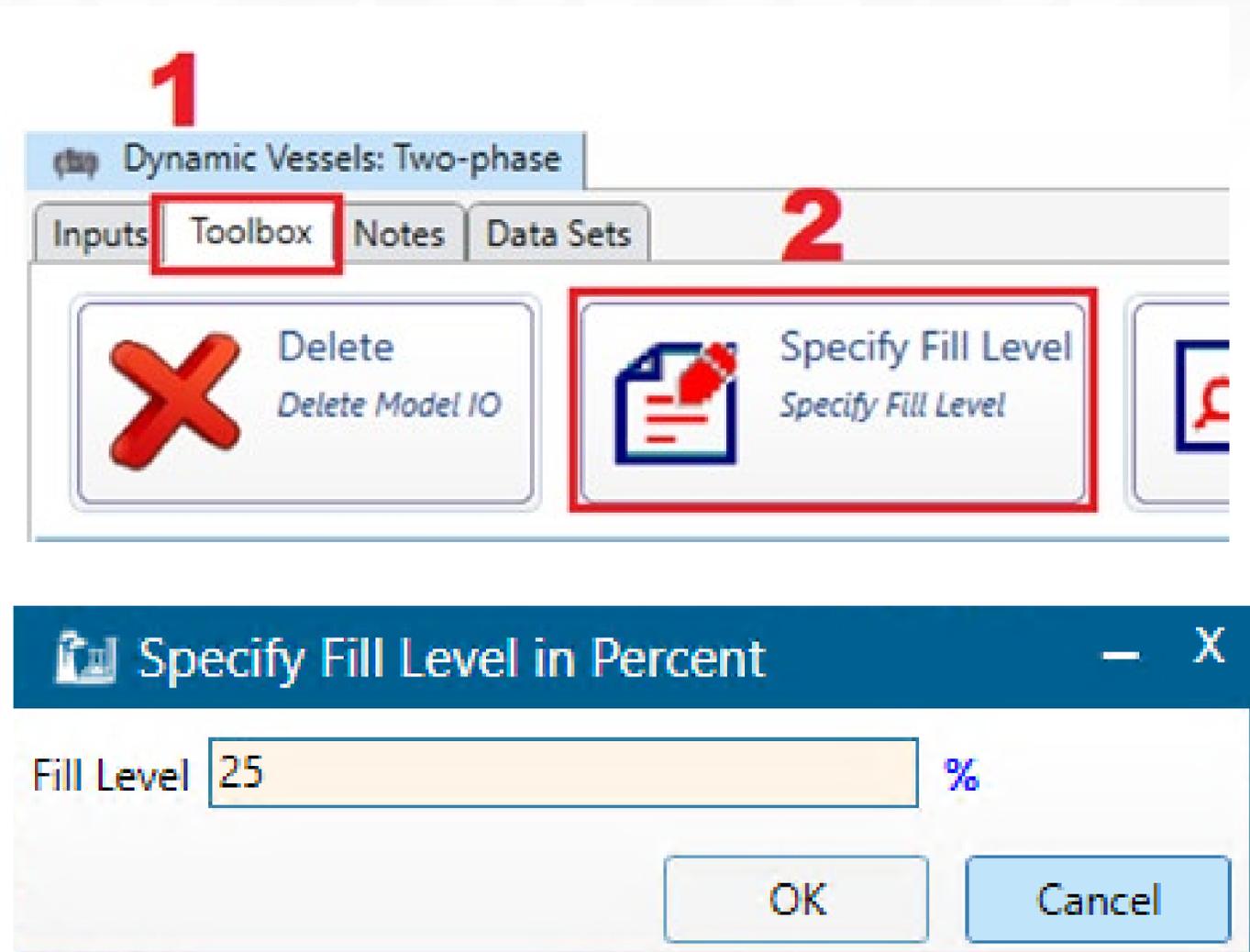
Continue from previous simulation

Simulation Options

- Check starting conditions only
- External fire exposure

Vessels Containing Two Phases (Dynamic) - Initialize

- Start the initialization process by entering the value for Pressure. Then, click Update
- Go to the Toolbox tab. Use the “Specify Fill Fraction” to get the mass and temperature corresponding to a particular volume fill%, pressure, and composition



Vessels Containing Two Phases (Dynamic) - Initialize

- Confirm the starting temperature agrees with the normal operating temperature

Dynamic Vessels: Two-phase

Inputs | Toolbox | Notes | Data Sets

Cancel | Update | Run

Model output data is not available, please run the model first

Specifications | Connectivity | Run Parameters | Stop Conditions | Accuracy

Vessel Initial Conditions

Total volume 2538.0804 gal

Available volume 2538.0804 gal

Contents mass 3216.5332 lb

Fairly close

	Contents	Normal operating
Temperature, °F	58.2581	60
Pressure, psig	50	50

Vessels Containing Two Phases (Dynamic) - Initialize

- Very important for printing. Notes → Check Required

Dynamic Vessels: Two-phase

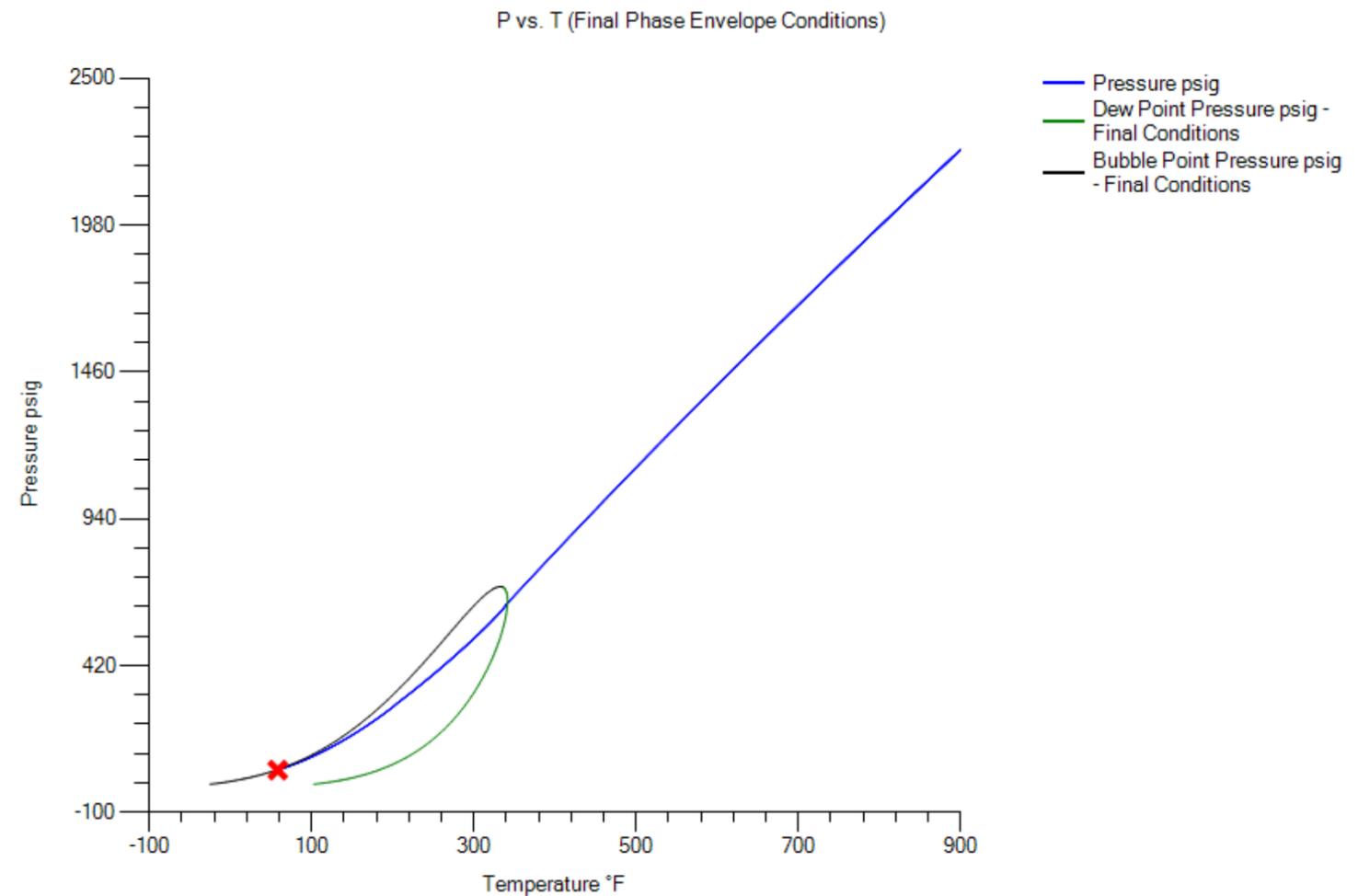
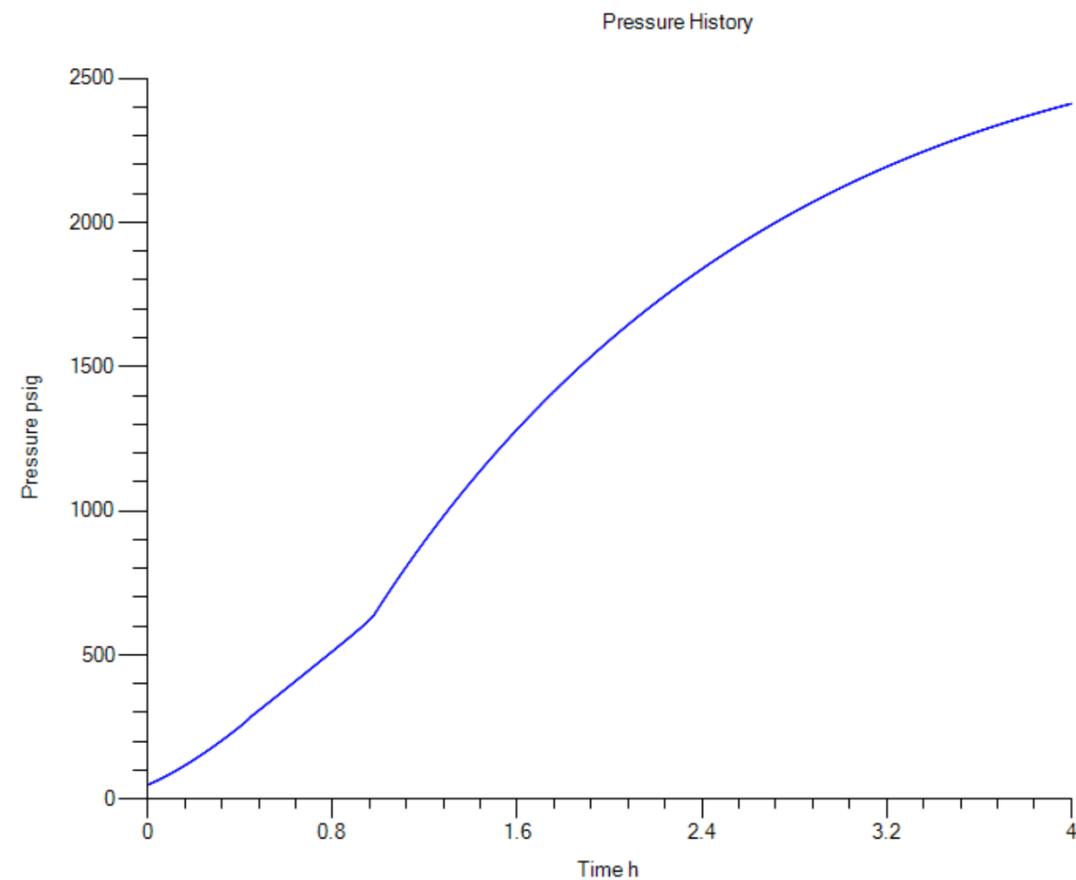
Inputs Results Charts Toolbox Notes Data Sets

Model Attributes

- Not Used. For Information only
- Required
- Rated or Capacity
- Stability
- Supporting
- Consequence and/or Risk Assessment

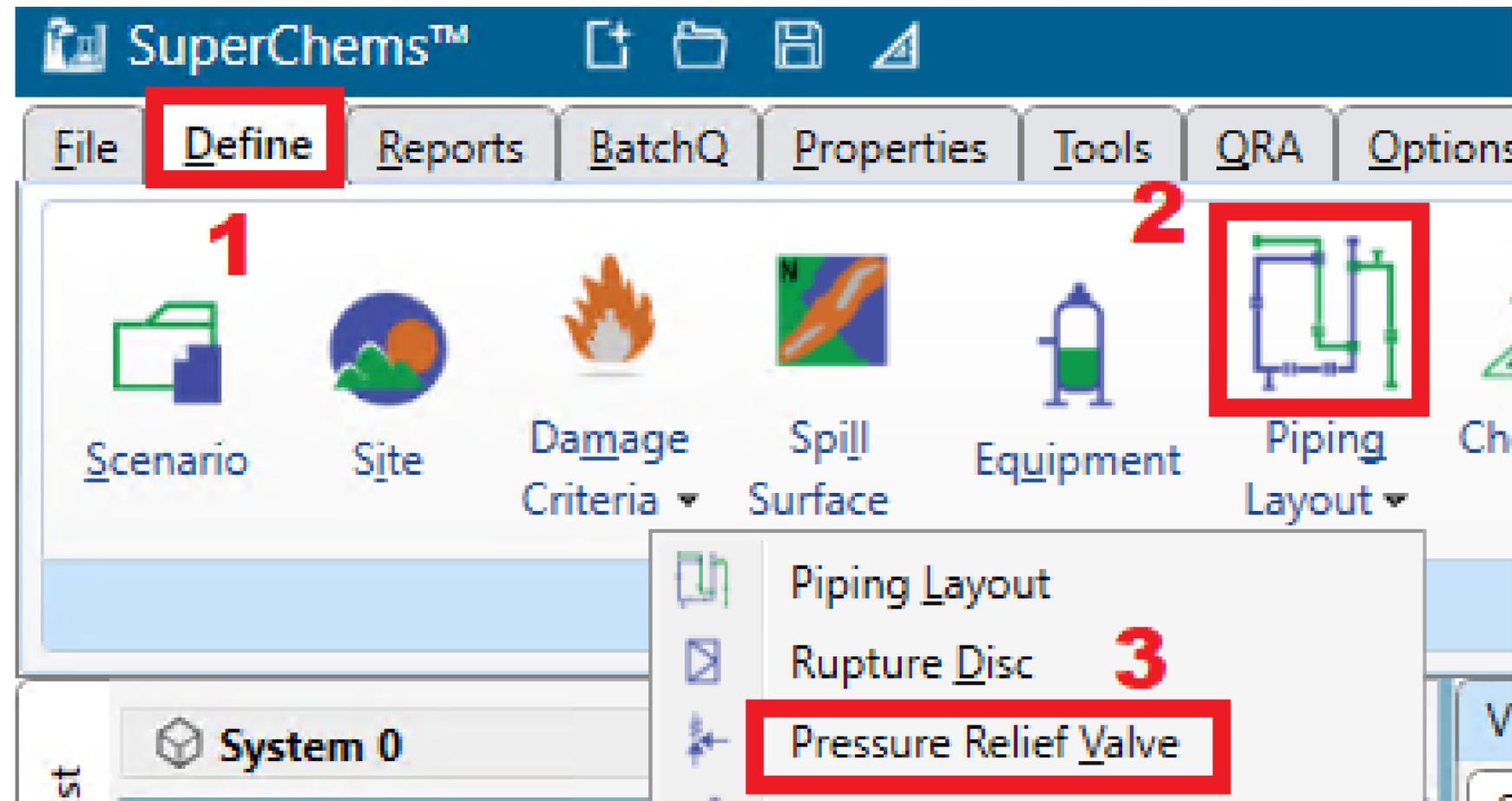
Vessels Containing Two Phases (Dynamic) – Run Results

- ▶ Now the calculation is ready to run
- ▶ Running with no relief device



Vessels Containing Two Phases (Dynamic) – with PSV

- ▶ Create a PSV object by going to Define → Piping Layout → Pressure Relief Valve



Creating PSV object

- Inlet/outlet size
- Discharge coefficient
- Area
- Set pressure

PRV Specifications | Low Pressure | Lift vs. Overpressure | Lift vs. Backpressure | SDOF Parameters | Data Sheet | Cd Calculator

PSV100

Description: Enter Description ... PRV numeric ID: 0 Model number: BY CLIENT
 Equipment protected: Enter protected equipment. Press F12 for list Service: Gas Serial number: BY CLIENT
 Manufacturer: BY CLIENT Design type: Conventional Spring number: BY CLIENT
 Location: P & ID: Use IOGP Datasheet
 Associated RD: Discharge Location:

Inlet Flange Pressure rating: 599.9977 psig Class: Enter Flange Class.. **Outlet Flange** Pressure rating: 599.9977 psig Class: Enter Flange Class..

Inlet Schedule

Name	Value	Unit
Nominal pipe size	2	
Piping schedule	40	
Outside Diameter	0.19792	ft
Inside Diameter	0.17225	ft
Wall Thickness	0.01283	ft
Flow Area	3.35561	in ²

Pipe Info

Outlet Schedule

Name	Value	Unit
Nominal pipe size	3	
Piping schedule	40	
Outside Diameter	0.29167	ft
Inside Diameter	0.25567	ft
Wall Thickness	0.018	ft
Flow Area	7.39266	in ²

Pipe Info

Device Certification

Certified for gas flow ASME-SECTION I certified
 Certified for liquid flow ASME-SECTION IV certified
 Certified for steam flow ASME-SECTION VIII certified
 Modulating valve Designated as spare

Lifting Characteristics

Minimum lift: 0 ft Maximum lift: 0 ft
 Device has a restricted lift
 Restricted lift: 0 ft Critical lift: 0.6919 ft
 Available flow area: 0 %

Use K-Based pipe solver (Advanced users only)

Flow

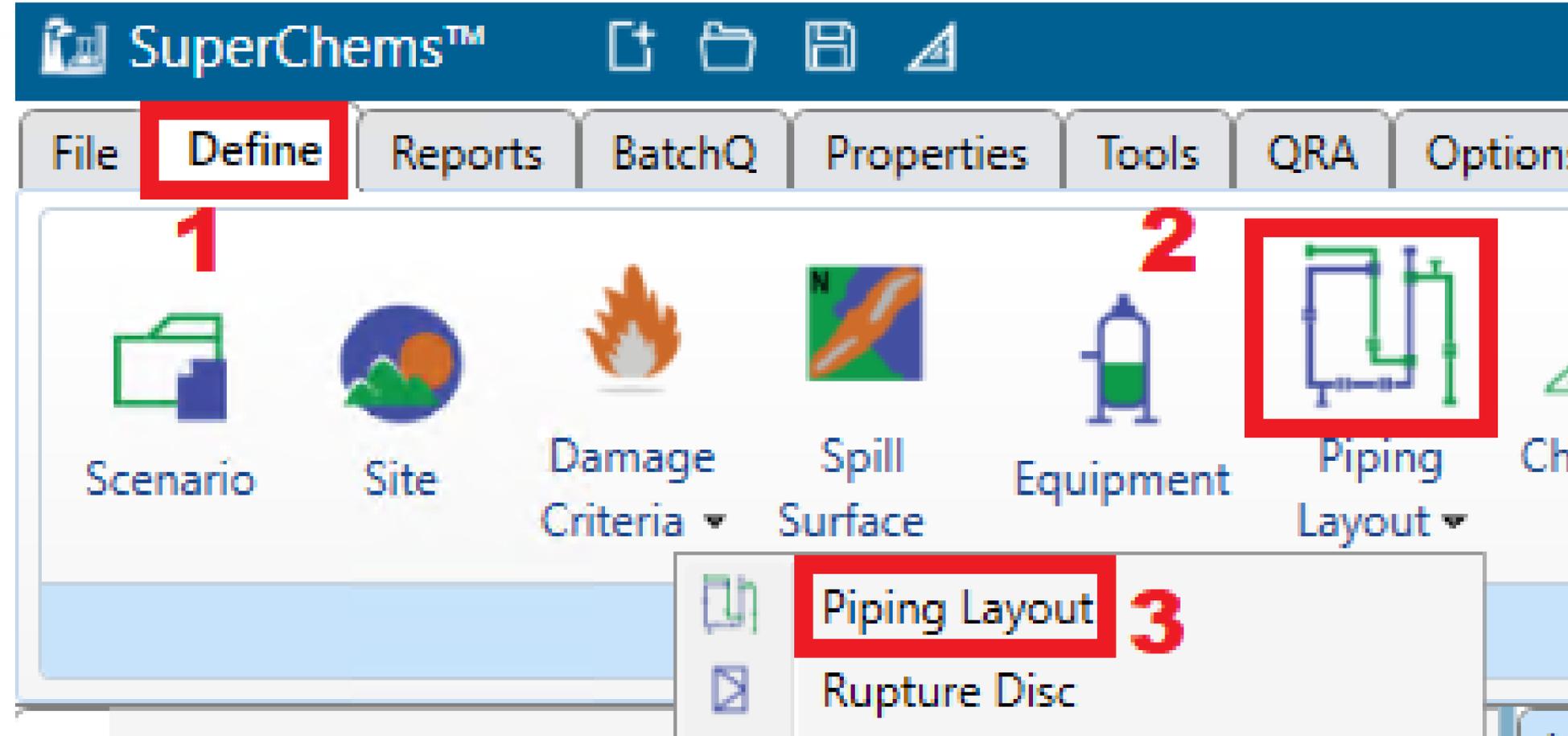
Flow type	Gas/Vapor	Liquid	Two phase
Discharge coefficient	0.975	0.71	0.975
Overpressure curve	OP-1	OP-1	OP-1
Backpressure curve	BP-1	BP-1	BP-1
Slip ratio multiplier			1
Slip ratio exponent			0.0001

Settings

Actual orifice flow area: 0.5589 in² Letter: G
 Design orifice flow area: 0.503 in² Set pressure: 100 psig
 Flow area basis: API Reset pressure: 93 psig
 Maximum blowdown: 10 % Actual blowdown: 7 %
 Cold differential test pressure: -14.6959 psig

Creating piping layout

- Go to Define → Piping Layout → Piping Layout



Creating piping layout

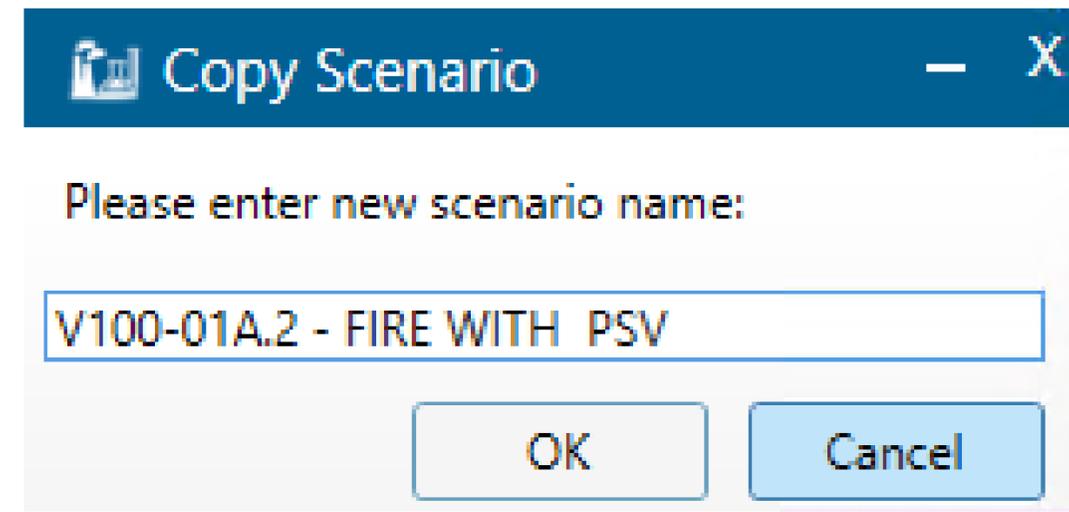
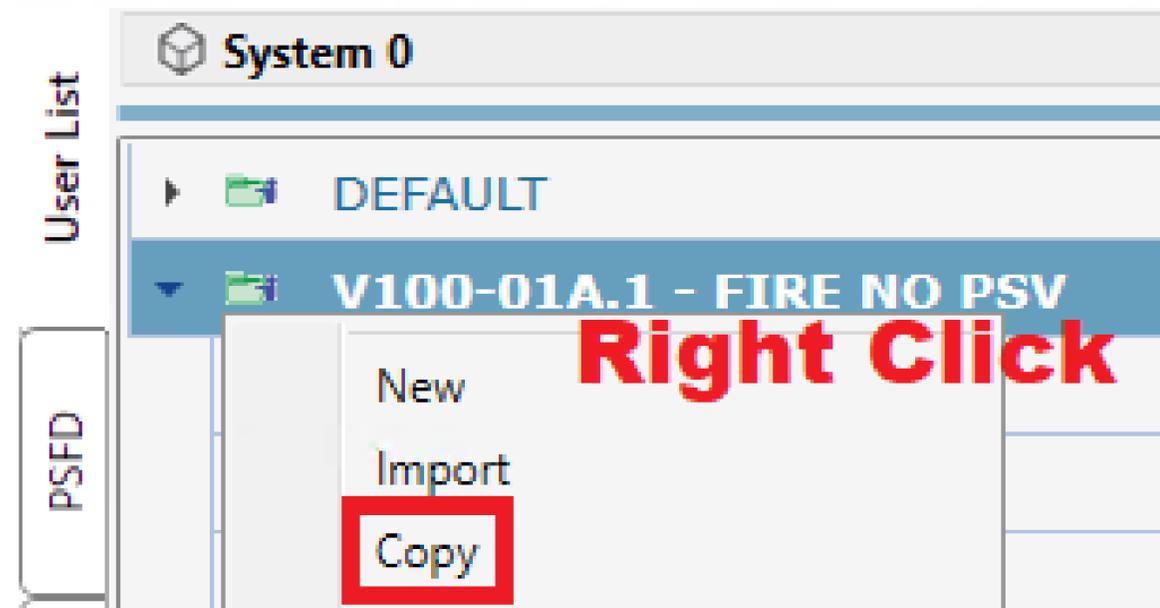
- ▶ The layout includes only the relief device for this example

The screenshot displays the 'Piping Isometric List' software interface. The window title is 'Piping Isometric List'. The interface is divided into several sections:

- Left Panel:** Shows a list of piping units. The 'PSV100' unit is selected and highlighted with a red box and the number '1'. Below it, the 'Available Units' section (labeled '2') lists 'Compressor', 'Control Valve', 'Expander', and 'Orifice', all with 'DEFAULT' status. A red box highlights this list, and a red box with the number '3' highlights the right arrow button next to it.
- Properties Panel:** Contains fields for 'Short description', 'PID/PFD reference', 'Overall mass flow multiplier for flow dynamics' (set to NaN), and '1st segment elevation relative to vessel bottom' (set to 0 ft). There are also checkboxes for 'Layout is an open relief path', 'Layout is a header/network', 'Use CCF', and 'Use design/derated flow area for PRV'.
- Right Panel:** Shows discharge coefficients for the PSV100: 'Gas/vapor discharge coefficient' (0.975), 'Liquid discharge coefficient' (0.62, with a red '5' next to it), and '2phase discharge coefficient' (0.975). These values are enclosed in a red box. Below this are sections for 'Thermodynamic Flow Path' (with 'Isentropic' selected) and 'Nozzle Flow Method' (with 'Use dH' selected).
- Bottom Right Panel:** Shows 'Selected Units' with 'PRV PSV100' listed. A red box with the number '4' highlights the up and down arrow buttons next to the list.

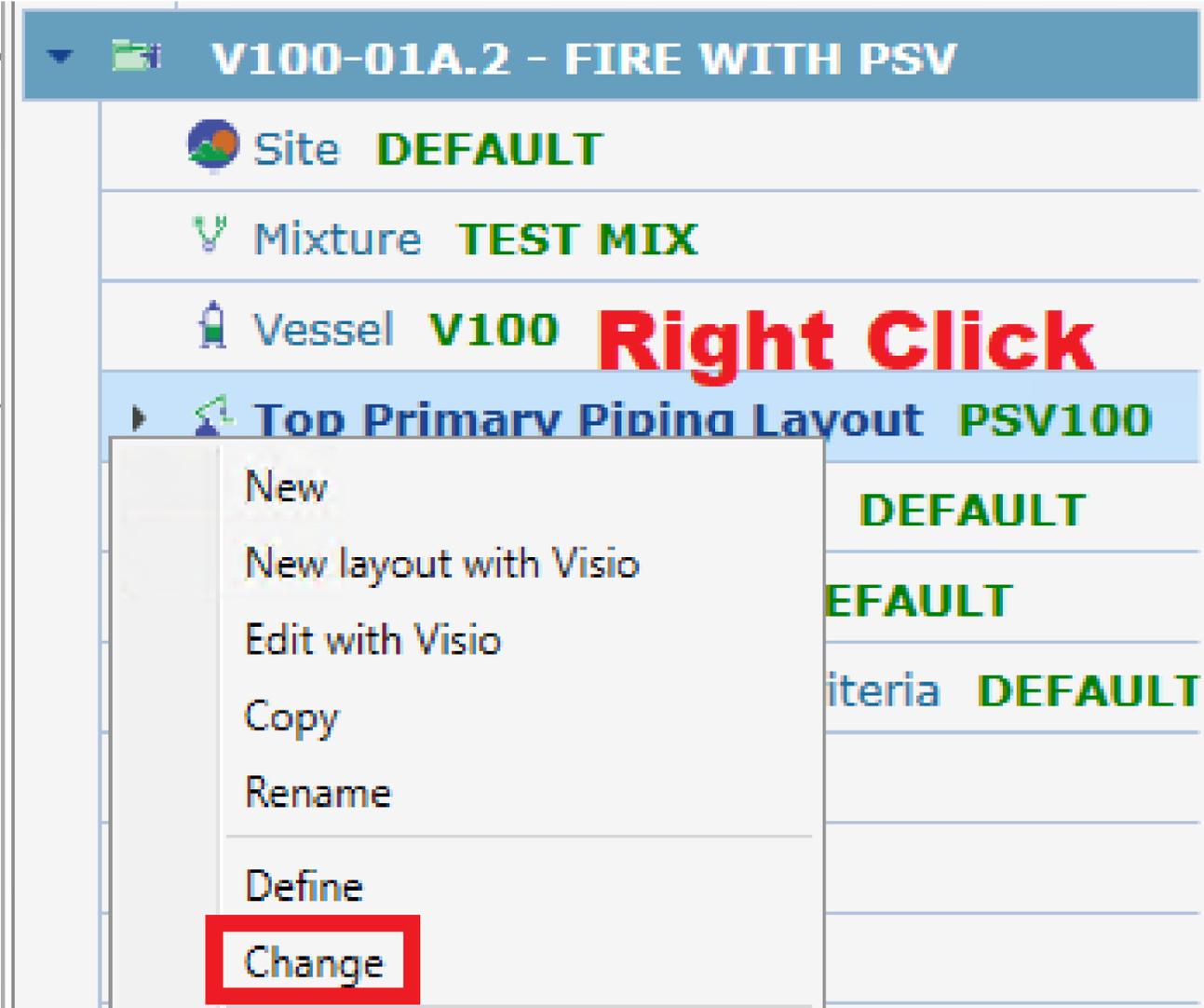
Vessels Containing Two Phases (Dynamic) – with PSV

- Copy previous scenario and give it a meaningful name



Vessels Containing Two Phases (Dynamic) – with PSV

- Apply the piping layout to the copied scenario



Vessels Containing Two Phases (Dynamic) – with PSV

- Change flow type, Update, and Run

Dynamic Vessels: Two-phase

Inputs | Toolbox | Notes | Data Sets

Cancel | Update | Run

Model output data is not available, please run the model first

Specifications | Connectivity | Run Parameters | Stop Conditions | Accuracy

Vessel Initial Conditions

Total volume: 2538.0804 gal

Available volume: 2538.0804 gal

Contents mass: 3216.5332 lb

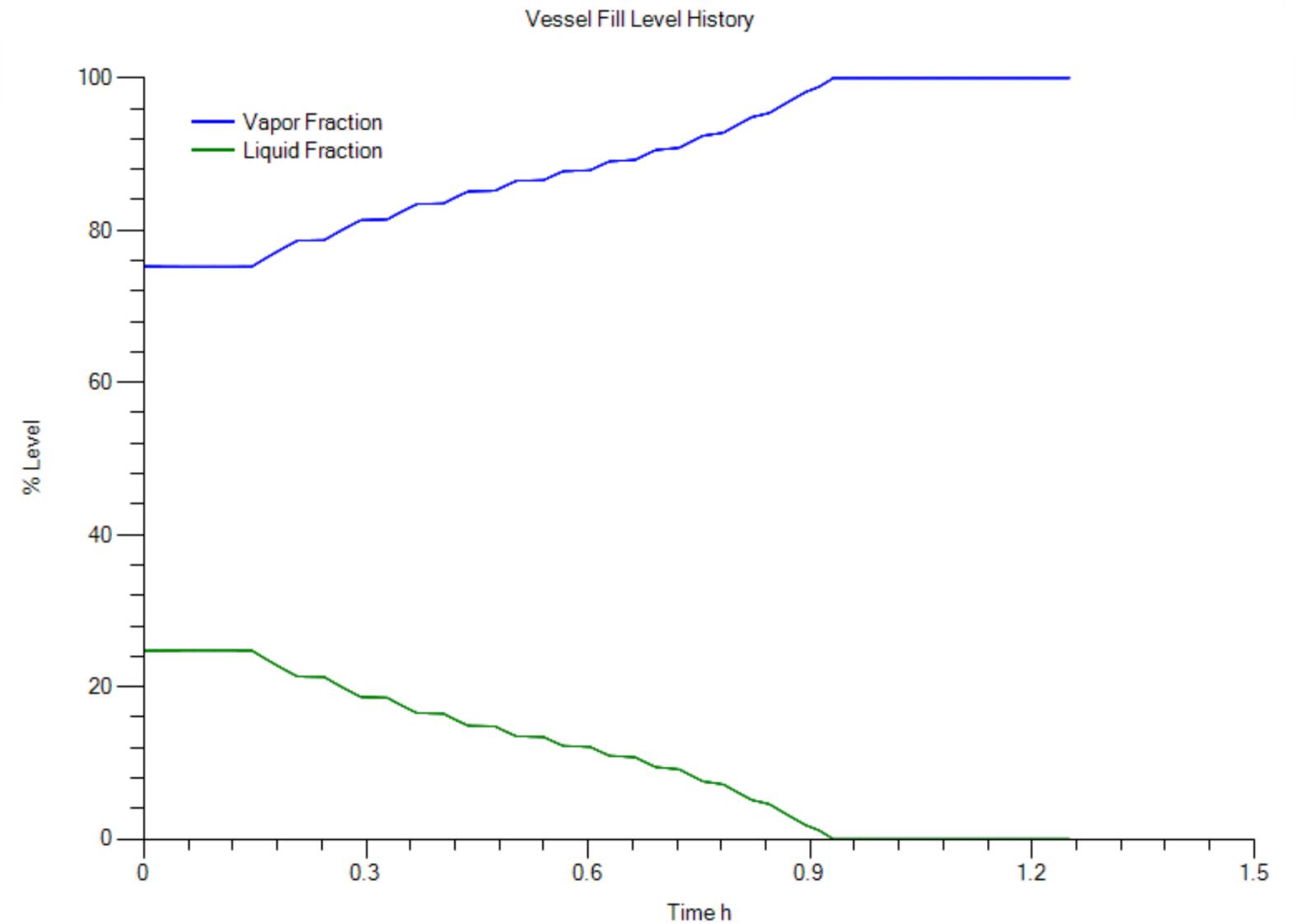
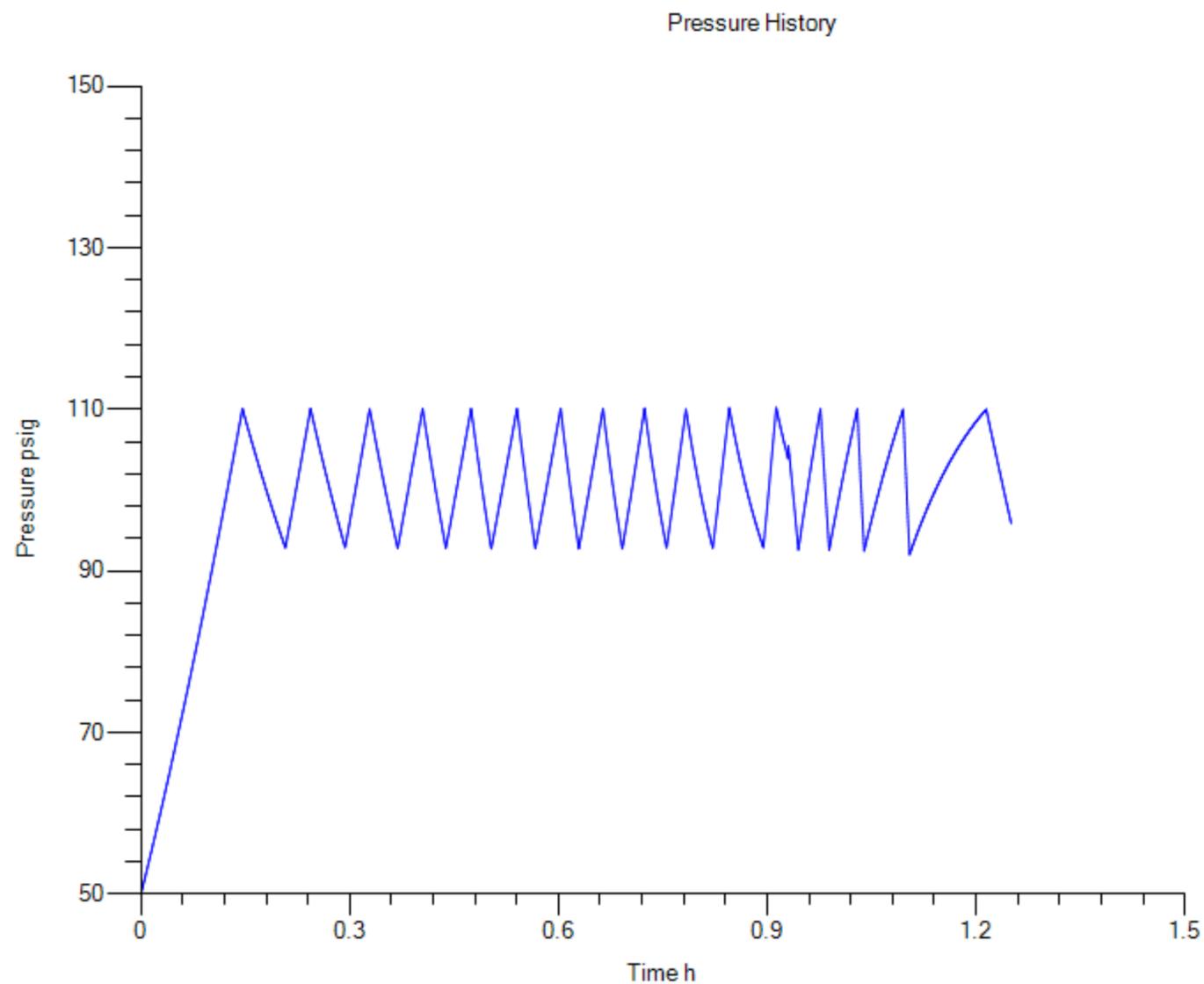
	Contents	Normal operating	Maximum operating	Minimum
Temperature, °F	58.2581	60	60	-20
Pressure, psig	50	50	50	-14.7

Relief Piping Path

Flow path	Backpressure, psig	Piping connection	Flow type
Top: primary	0	PSV100	Vapor

Vessels Containing Two Phases (Dynamic) – with PSV results

- Note the applied relief device keeps the accumulation below vessel test pressure



Overpressure Scenario Credibility - Conclusions

For overpressure scenarios evaluated

- The expected frequency of an event causing accumulation above 116% of the MAWP is less than the tolerability target frequency (e.g. 1.0E-04)

The existing pressure relief systems pressure build-up is within acceptable limits

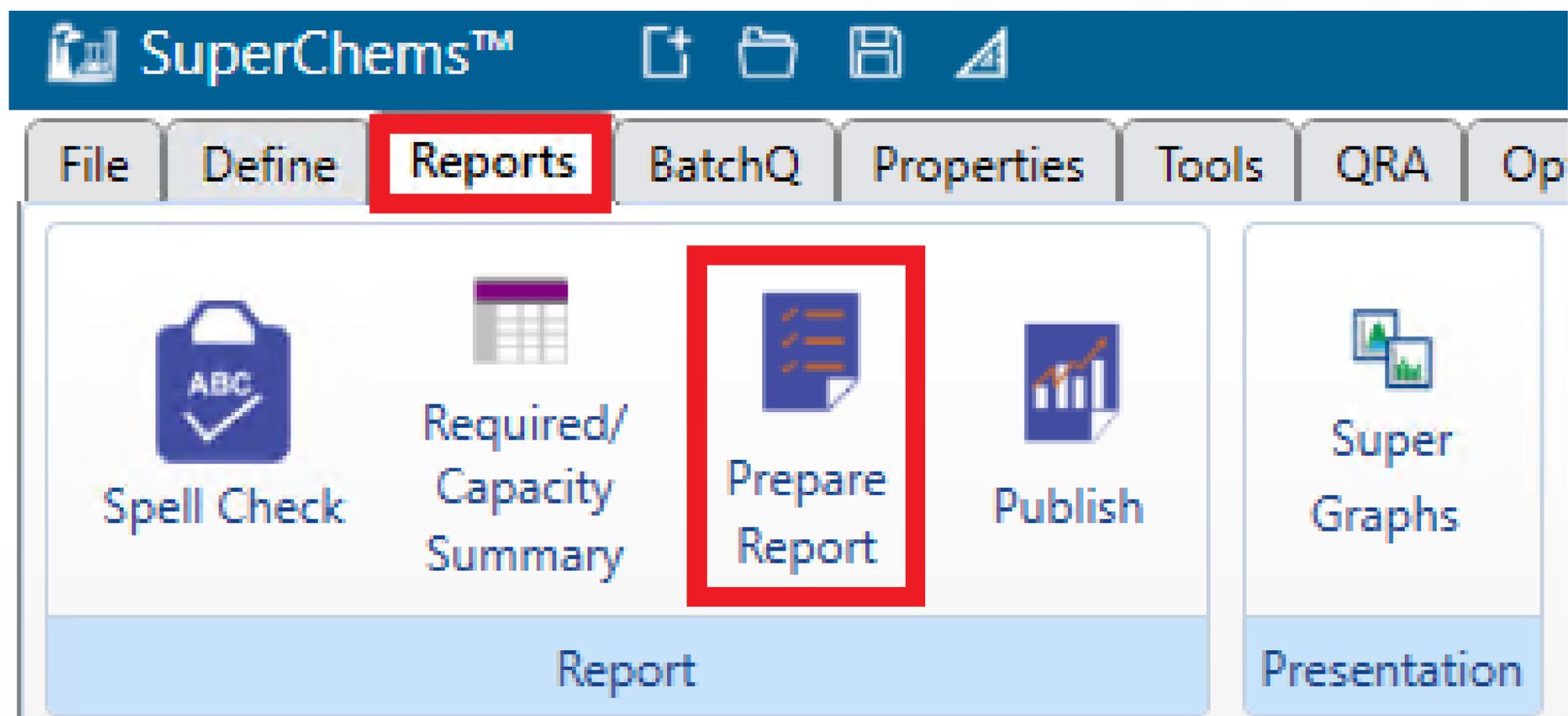
- Capable of mitigating the overpressure risk to a tolerable level

Report Generation



Printing ioReport™

- Report → Prepare Report



Printing ioReport™

- ▶ Select vessel from dropdown

Prepare Report

Select Vessel | Piping & Vessels | Additional Vessels | Final Step

Select equipment & options

Primary equipment **V100** **1**

Modify report comments

Modify PRV Datasheet

Modify Cover Page

Select all options

Cancel **2** Next

Printing ioReport™

- ▶ Select piping layout

Prepare Report

Select Vessel Piping & Vessels Additional Vessels Final Step

Confirm All Independent Piping Isometrics used for Parallel Relief

<input checked="" type="checkbox"/> PSV100
--

1

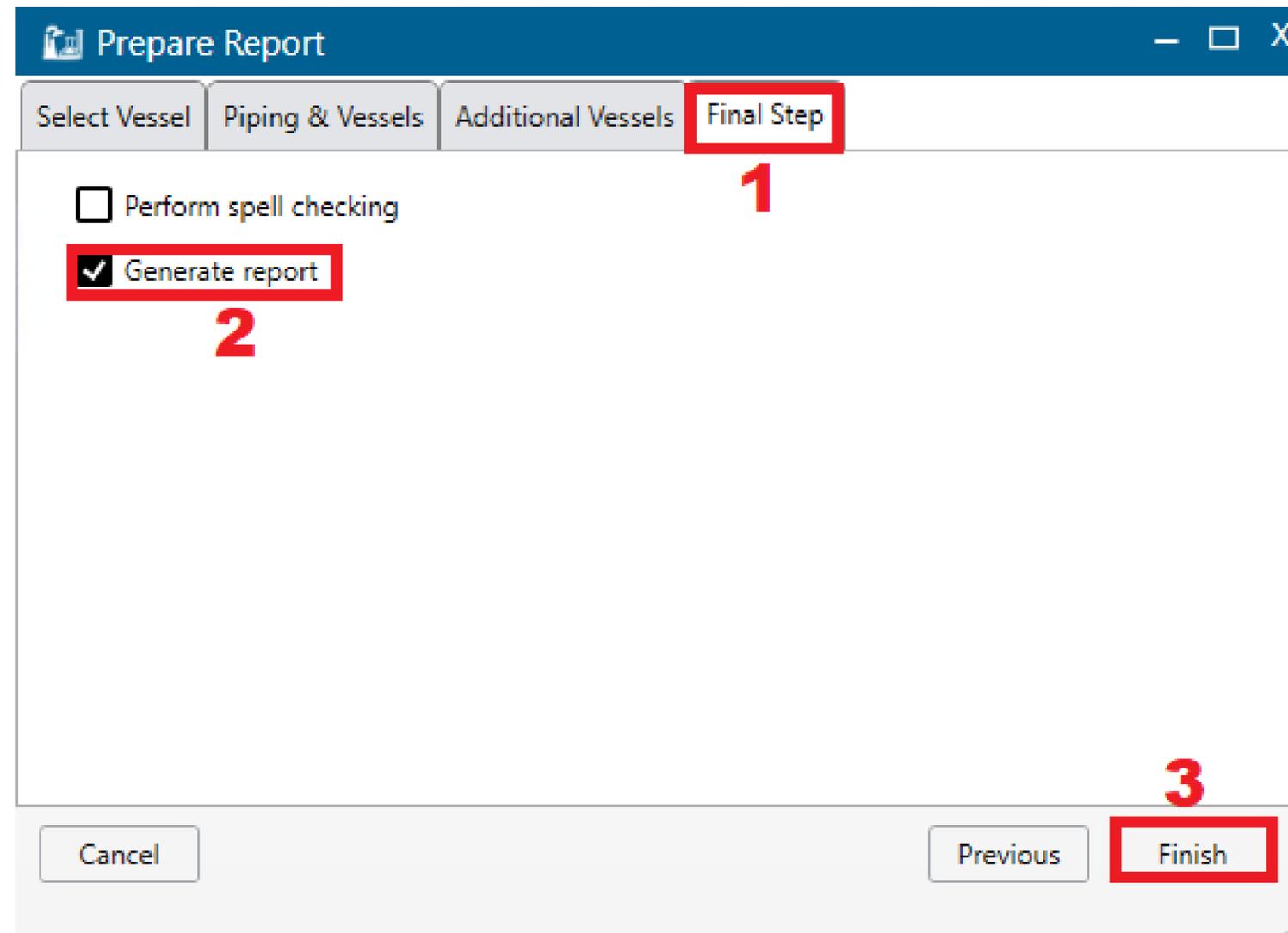
Select all

2

Cancel Previous Next

Printing ioReport™

- ▶ Select Generate Report



Printing ioReport™

Report Writer

Report Graphic Settings User-Defined Sections Output

Report Options Generate Reports Close

Report Method

- Scenario Key Based
- Scenario Based
- Equipment Based
- Model Based

Report Logo

- Logo in Project File
- User Selected

Scenario Key Based Options

- Full Report
 - Add Visio Piping
 - Include Spec Sheet
 - Include PS Flow Diagram
- Overpressure Scenario Report
- Relief Device Spec Sheet
 - Spec Sheet Excel
- Generate Visio Piping Only
- Generate PS Flow Diagram Only

Report Adjustments

- Exclude pressure drop 5% tolerance
- Include 0.9 factor (RD and Open Vents only)
- Don't Show System Adequacy Statement

Print Format

- 0.
- 0.0
- 0.00

Process Safety Office®

Process Safety Office® is a suite of application tools to guide users through the risk reduction process. It includes components to conduct consequence analysis, risk analysis, facility siting study, pressure relief and flare systems design, PHAs, DHAs, compliance audits, and more.

ioMosaic Corporation is an exclusive distributor of Process Safety Office®



Printing ioReport™

► Select Pressure History

The screenshot shows the 'Report Writer' application window with the 'Graphic Settings' tab selected. The interface includes several sections for configuring report output:

- Report Writer** window title bar.
- Navigation tabs: Report, **Graphic Settings** (highlighted with a red box and '1'), User-Defined Sections, Output.
- Buttons: **Select All Models**, **Clear All Models**.
- Category tabs: Flow, Netflow, Dispersion, Fire, Explosions.
- Liquid Pools**: Liquid Pools.
- Vessel Flow**:
 - Vessel Containing Vapor: (Dynamic)**: Results, Mass Flow.
 - Vessel Containing 2 Phase: (Dynamic)**: **2** Results (highlighted with a red box), Mass Flow.
- Graphs**:
 - Buttons: **Select All Graphs**, **Clear All Graphs**.
 - Pressure History** (highlighted with a red box and '3').
 - Pressure History at Vessel Bottom
 - Temperature History
 - Vessel and Flow Overall Vapor Mole Fract
 - Temperature Rate History
 - Pressure Rate History
 - Temperature Rate vs. Temperature
 - Pressure Rate vs. Temperature
 - Vessel Energy of Vaporization History
 - Vessel Energy of Vaporization vs. Temperz
 - Pressure vs. Temperature
 - Heat Input into Vessel Wall and Contents

Printing ioReport™

► Select Vessel Fill Level History

Report Writer

Report **Graphic Settings** 1 User-Defined Sections Output

Select All Models Clear All Models

Flow Netflow Dispersion Fire Explosions

Liquid Pools

- Liquid Pools

Vessel Flow

Vessel Containing Vapor: (Dynamic)

- Results
- Mass Flow

Vessel Containing 2 Phase: (Dynamic)

- Results
- Mass Flow 2

Graphs

Select All Graphs Clear All Graphs

- Venting History
- Vessel Liquid Height
- Vessel Contents Mass Vs Temperature
- Flow Impulse History
- Pressure Backpressure On First And Secor
- Flow Reduction Factor History
- Vessel Contents Mass Vs Time
- Top Flow Critical Pressure Ratio History
- Piping Discharge Velocity History
- Vessel Fill Level History 3
- Vessel Contents Vapor Volume ChangeAt
- Top Flow Critical Temperature Ratio Histo
- Pressure History At Inlet Of First And Seco

Printing ioReport™

- Finally, generate reports

Report Writer

Report **1** Graphic Settings User-Defined Sections **2** Output

Report Options **Generate Reports** Close

Report Method

- Scenario Key Based
- Scenario Based
- Equipment Based
- Model Based

Report Logo

- Logo in Project File

Scenario Key Based Options

- Full Report
 - Add Visio Piping
 - Include Spec Sheet
 - Include PS Flow Diagram
- Overpressure Scenario Report
- Relief Device Spec Sheet

Report Adjust

- Exclude pre
- Include 0.9 only)
- Don't Show

Print Format

- n

Printing ioReport™ - Output

- Report outputs to same folder as cor file

Relief System Summary (System 1 of 1) Part 2



RELIEF SYSTEM COMMENTS	
Relief device: PSV100, vessel: V100	

RELIEF SYSTEM CALCULATIONS SUMMARY					
Overpressure Scenario	PRD Tag	Vapor Quality	Required Relief Rate (lb/h)	Device Capacity (lb/h)	Required Ar (in)
V100-01A.1 - FIRE NO PSV			0.00		
V100-01A.2 - FIRE WITH PSV			6,591.94		0

SCENARIOS AND CALCULATIONS

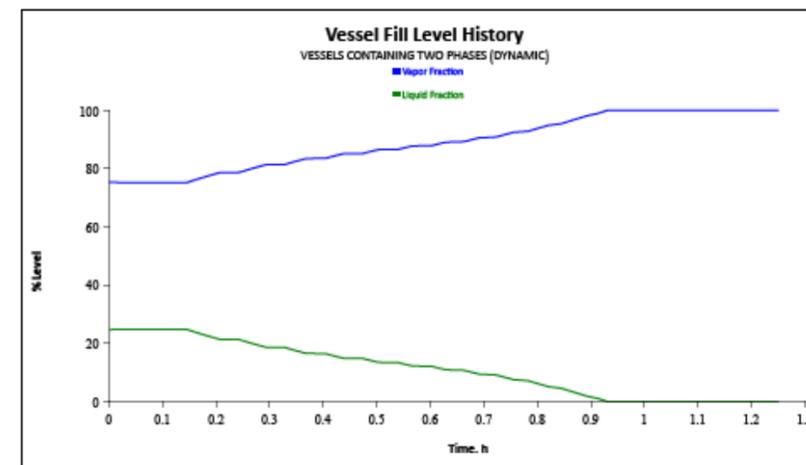
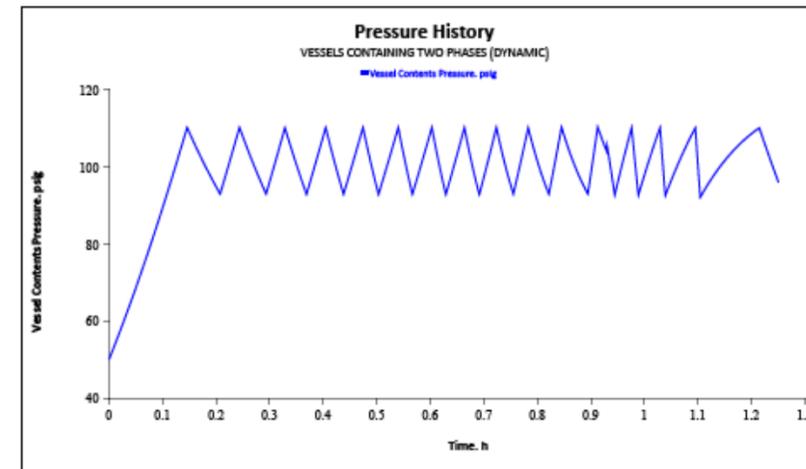
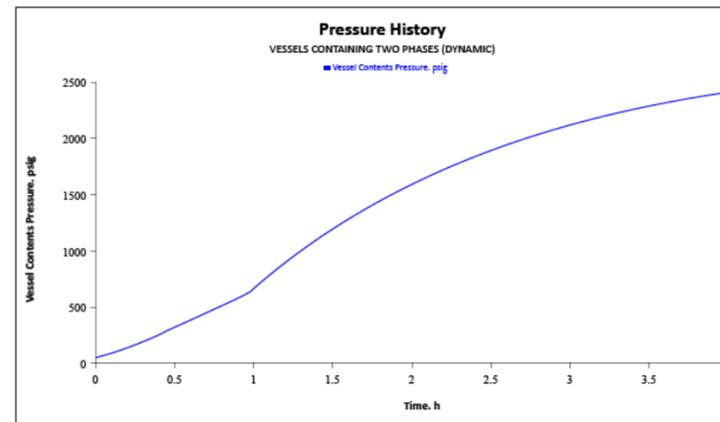
PSV100
 Overpressure Scenario: V100-01A.1 - FIRE NO PSV
 Calculation Method(s): VESSELS CONTAINING TWO PHASES (DYNAMIC)

SCENARIO APPLICABILITY

VESSELS CONTAINING TWO PHASES (DYNAMIC) COMMENTS

VESSELS CONTAINING TWO PHASES (DYNAMIC) INFORMATION

Inputs	
Initial total mass	3,216.52 lb
Volume full of liquid	24.98 %
Temperature	58.26 °F
Pressure	50.00 psig
User defined top flow type	No flow
Top flow user specified backpressure	0.00 psig
User defined bottom flow type	No flow
Bottom flow user specified backpressure	-14.70 psig
Consider external fire exposure	YES
Set pressure	NaN psig
Discharge coefficient	NA
Outputs	
Maximum Pressure Reached	2,412.03 psig
Maximum Temperature Reached	962.03 °F



Conclusions

- ▶ Overpressure Protection by System Design requires a rigorous approach
- ▶ Process Safety Office can help you with Overpressure Protection by System Design, especially with the following activities
 - ▶ Determine Overpressure Scenario Credibility
 - ▶ Determine maximum coincident pressure and temperature for overpressure scenarios

Contact

Neil Prophet, Senior Vice President & Partner

prophet.n.tx@ioMosaic.com

713.490.5220

1.844.ioMosaic

Sales@ioMosaic.com

www.ioMosaic.com



About ioMosaic Corporation

Through innovation and dedication to continual improvement, ioMosaic has become a leading provider of integrated process safety and risk management solutions. ioMosaic has expertise in a wide variety of areas, including pressure relief systems design, process safety management, expert litigation support, laboratory services, training, and software development.

ioMosaic offers integrated process safety and risk management services to help you manage and reduce episodic risk. Because when safety, efficiency, and compliance are improved, you can sleep better at night. Our extensive expertise allows us the flexibility, resources, and capabilities to determine what you need to reduce and manage episodic risk, maintain compliance, and prevent injuries and catastrophic incidents.

Our mission is to help you protect your people, plant, stakeholder value, and our planet.

For more information on ioMosaic, please visit: www.ioMosaic.com