Flare Quantitative Risk Analysis (QRA)

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Our Key Message

Flare QRA is a systematic, risk based approach to determine common header system adequacy.

What will you learn?

- Limitations of traditional Flare Studies
- What is Flare QRA
- How QRA differs from traditional approaches
- Benefits of Flare QRA

Traditional Flare Studies

Pressure vessels and associated pressure relief requirements are governed by ASME BPVC Section VIII; however, guidance on the design requirements of common relief headers is lacking.

> The sizing of any section of common-discharge header downstream from each of the two or more pressure relieving devices that may reasonably be expected to discharge simultaneously shall be based on the total of their outlet areas, with due allowance for the pressure drop in all downstream sections.
>
> \- Nonmandatory Appendix M

Traditional Flare Studies

Simultaneous relief scenarios are broadly defined into two categories by API Standard 521, Sixth Edition:

a) External Fire Zones

b) Utility Failures (Section 4.4.15)

API Standard 521, Section 5 provides detailed guidance in the design of common relief header systems.

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Traditional Flare Studies

Guidance on developing the design load for the system is provided in Section 5.3. The resulting traditional workflow for determining can be summarized as:

Identification of Global Scenarios

Calculation of Maximum relieving rates for individual systems

Summation of all the individual relieving rates for each global scenario

Problems with Traditional Flare Studies

Determines adequacy of the system based on the **simultaneous relief of worst-case static loads** for all contributing systems.

Resulting theoretical combined loads, header system pressures, knockout drum and flare tip performance may **contradict actual plant experience**.

Traditional solutions to theoretical inadequacies can get expensive:

- Replace header sections with larger piping
- New knockout drums
- New flare stacks
- High Integrity Pressure Protection Systems (HIPPS)

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Working Towards a Solution

API Standard 521 permits the refinement of the common header design to account for “load reduction credits” including:

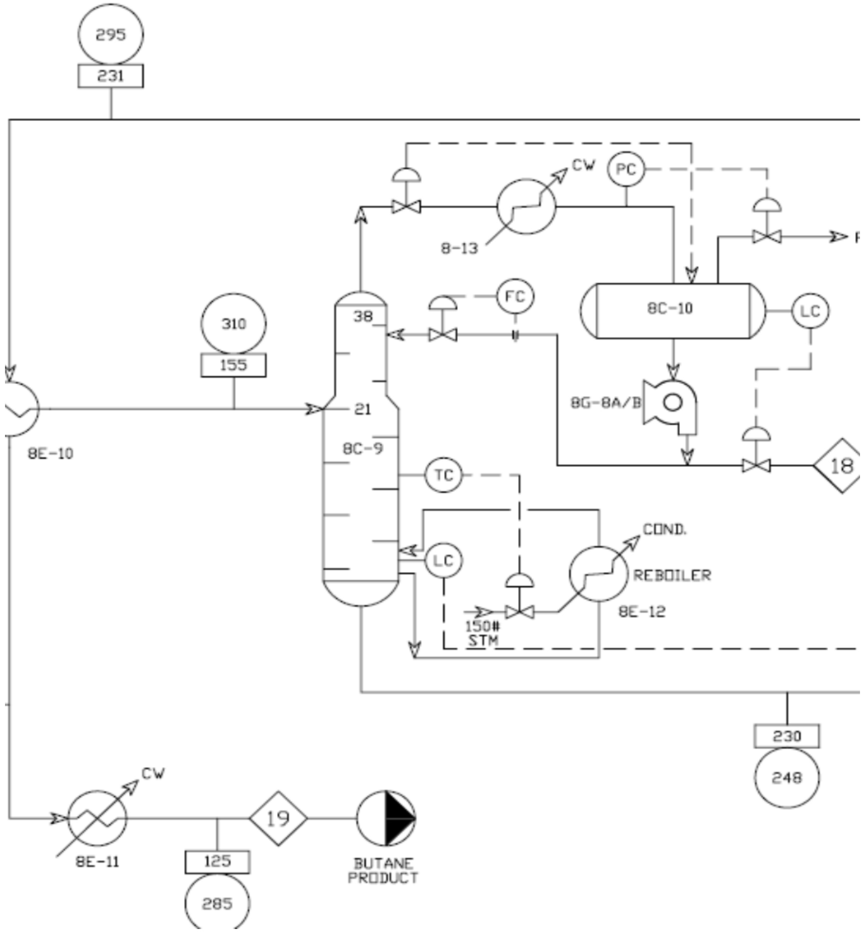
- HIPPS
- Operator intervention
- Basic process control

How can credits be used?

One common approach is to asses which credits result in the largest load reduction and assume those to fail to provide the desired response.

However, this simple approach becomes far more difficult as the number of credits to be assessed increases.

Working Towards a Solution – An Example



Consider a scenario in which 10 individual systems are expected to contribute to the total load.

Further assume that each of the 10 systems have 2 identified load reduction credits (safeguards).

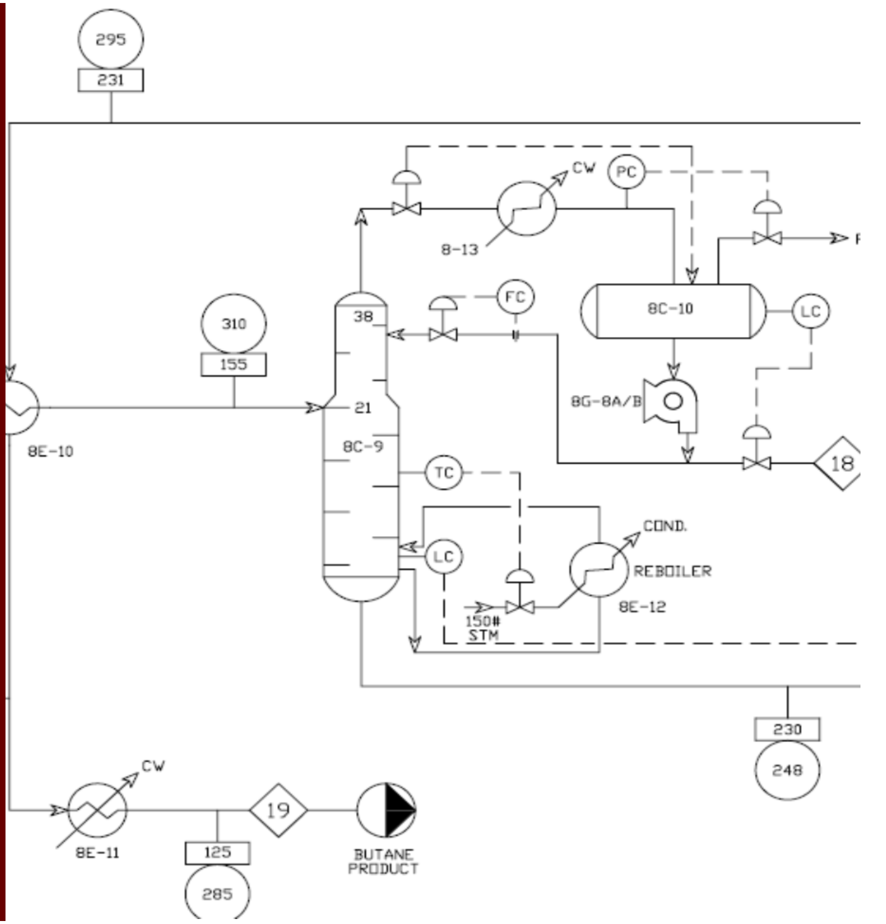
4^{10} = 1,048,576 possible relieving scenarios

Working Towards a Solution – An Example

Now, assume that experience shows each safeguard has a probability of failure on demand (PFOD) of 10%

The probability of every safeguard acting is only 0.920, or about 12%.

However, the likelihood of all 20 safeguards failing at the same time is only once in every 1020 demands.



Quantitative Risk Analysis (QRA)

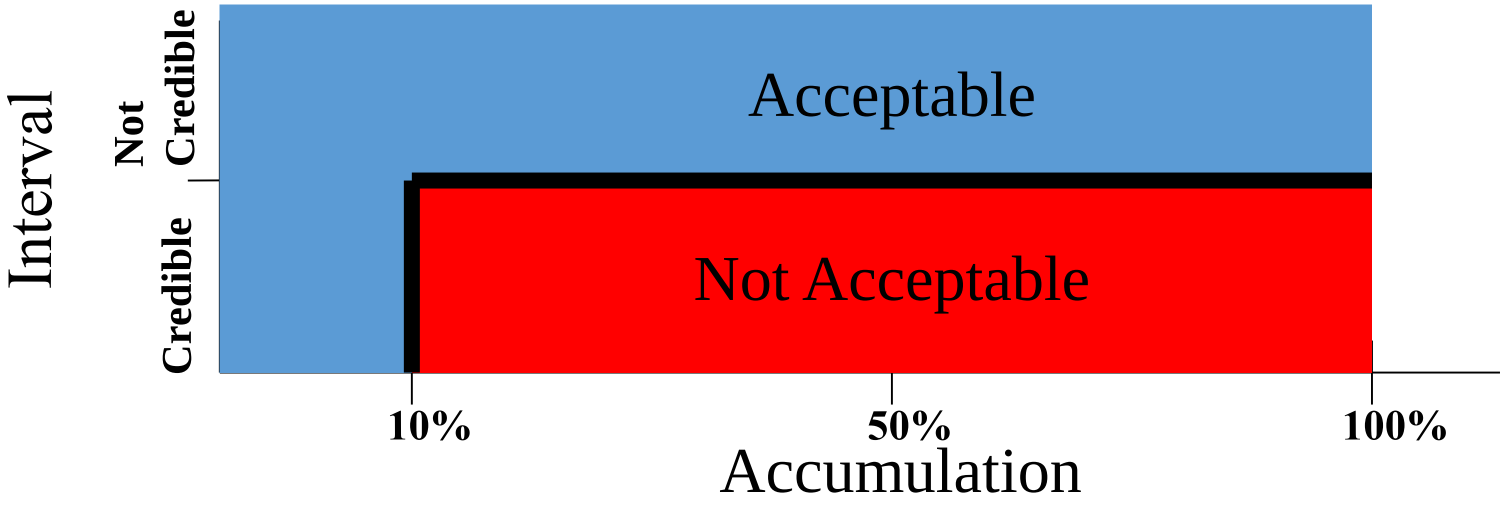
- Systematic approach to determine the adequacy of a flare system based on the operator's risk acceptance criteria
- Comprehensive examination of mitigative factors
- Quantification of the probability for vessel overpressure and the associated consequences
- Accounts for:
  - Load reduction impact of each identified safeguard
  - Reliability of each safeguard (PFOD)
  - Frequency of initiating events (global scenarios)
- System hydraulics are calculated either for all possible relief load permutations, or a subset utilizing a Monte Carlo simulation.
- Calculates accumulation of individual systems

Risk Acceptance Criteria

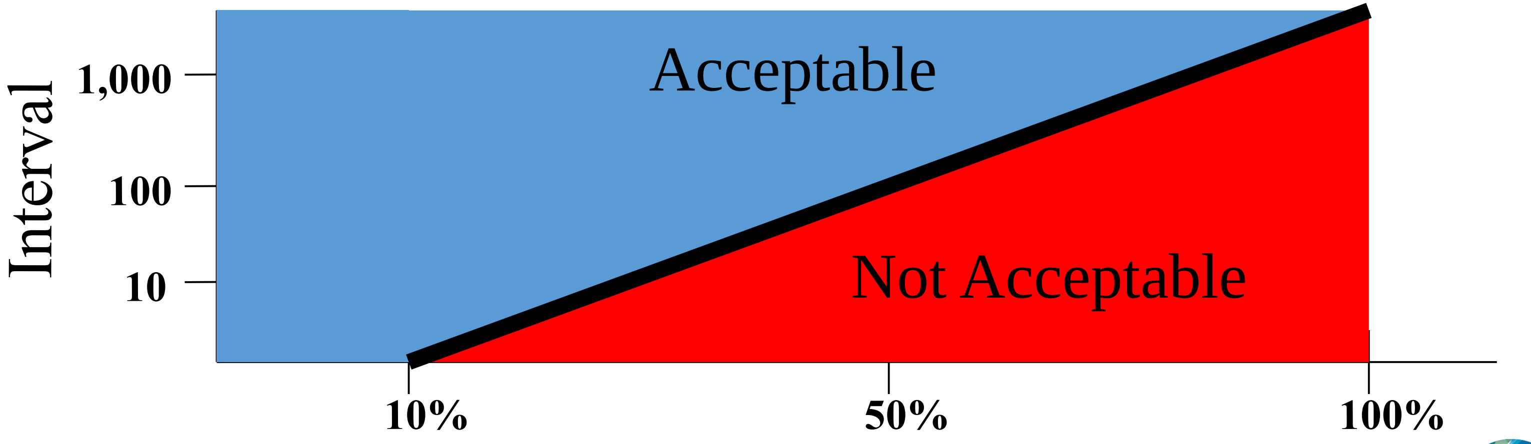
- Define acceptable frequencies for various levels of system accumulation
- Define individual and / or aggregate risk targets
- Individual criteria relates to a specific equipment item
- Aggregate criteria relates to the entire system

Risk Acceptance Criteria

Traditional Acceptance Criteria



QRA Acceptance Criteria



Accumulation vs. Consequence

% Over MAWP	Significance	Potential Consequence
16%	ASME code allowable accumulation for process upset cases protected by multiple relief devices	No expected consequences at this accumulation level. Lowest consequence from qualitative risk matrix
30%	ASME standard hydrotest pressure for newer designs	Catastrophic vessel rupture not expected at this accumulation level. Possible leaks in associated instrumentation, etc. Medium consequence for newer ASME vessels
50%	ASME standard hydrotest pressure	Catastrophic vessel rupture not expected at this accumulation level. Possible leaks in associated instrumentation, etc. Medium consequence from qualitative risk matrix
~90%	Minimum yield strength (dependent on the materials of construction)	Catastrophic vessel rupture is a remote possibility. Significant leaks probable. High consequence from qualitative risk matrix
~300%	Ultimate tensile strength (dependent on the materials of construction)	Catastrophic vessel rupture predicted. Highest consequence from qualitative risk matrix

Summary of Typical Risk Targets

Acceptance Criteria Vessel Accumulation Exceeds	Individual Vessel Accumulation Criteria (Years between Occurrences)	Virtual System Accumulation Criteria (Years between Occurrences)	Average Vessel Accumulation Criteria (Years between Occurrences)
30%	20	5	5
50%	50	10	10
70%	100	20	20
90%	500	50	50
150%	1,000	100	100
200%	10,000	1,000	1,000
300%	100,000	10,000	10,000

Common Safeguards

Safeguard	PFOD
Conventional Instrumentation	10-20%
High pressure, temperature over-ride	5%
Spare pump auto-start	10%
Operator field intervention	30-80%
SIL-1	1-10%
SIL-2	0.1-1%
SIL-3	0.01-0.1%
Given/Spare pump in operation	Varies

PFOD associated with SIL are set by ISA 84.01 and IEC 61511

Safeguards

Conventional Instrumentation – Steam control valve to reboiler closes
Operator Intervention – Operator closes steam control valve to reboiler

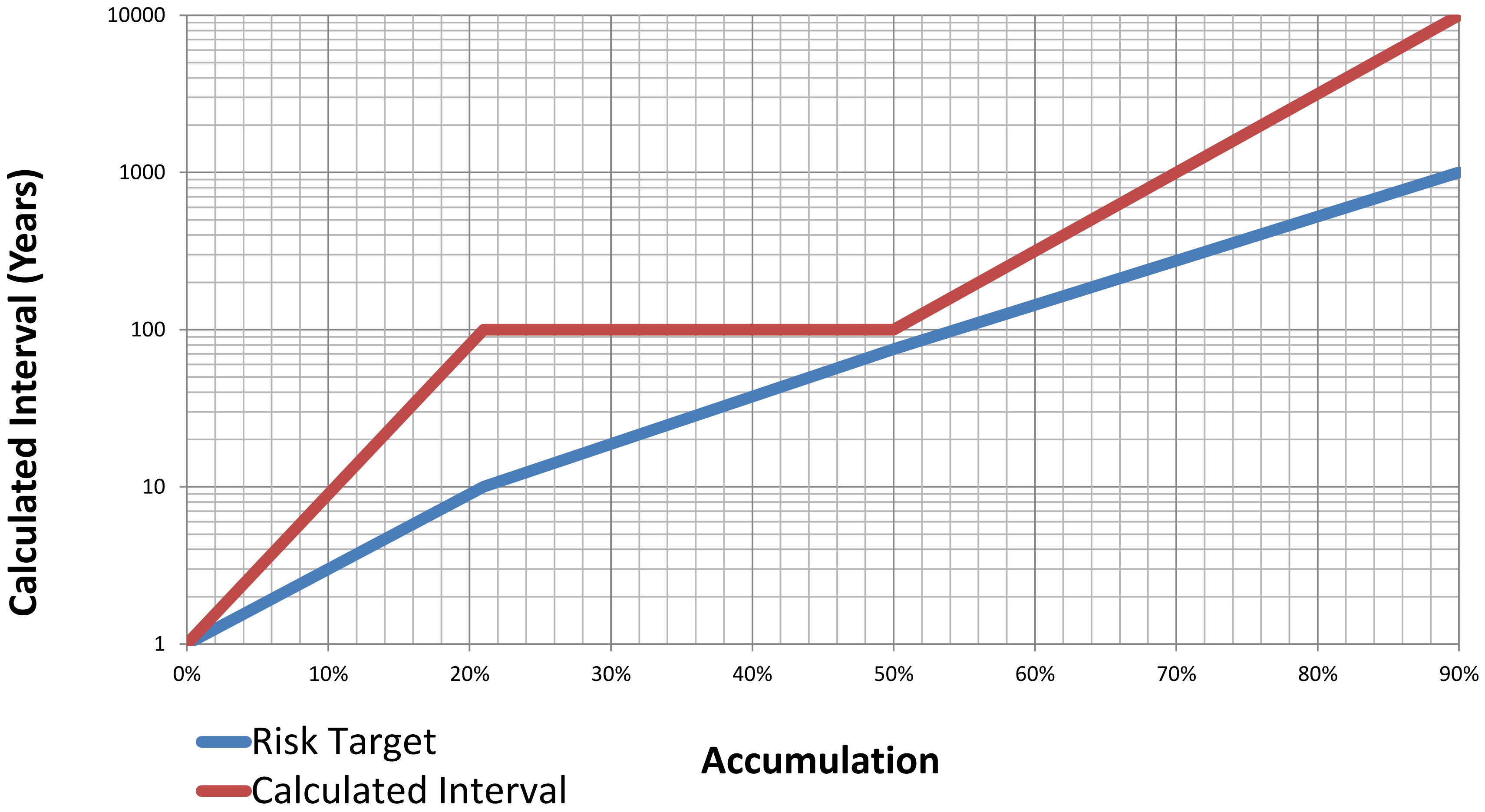
Case	FCI PFOD 10%	FOI PFOD 50%	Load (lb/hr)	Probability
1	N	N	750,000	0.05 = (.10 x .50)
2	Y	N	0	0.45 = (.90 x .50)
3	N	Y	0	0.05 = (.50 x .10)
4	Y	Y	0	0.45 = (.90 x .50)
			Sum of probabilities	1.00

Case	Description	Load (lb/hr)	Probability
1	Both safeguards fail.	750,000	0.05
2	At least one safeguard works.	0	0.95
		Sum of Probabilities	1.00

Initiating Event Frequency

- What scenario is being considered and how often can it occur.
- Differentiate between low and high frequency events
- Published electrical system reliability data
- Electrical system reliability models
- Published equipment failure on demand data (e.g., cooling water pump)
- Plant and industry experience

QRA Results



Calculated Interval (Years)
10000
1000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
Risk Target
Calculated Interval
Accumulation

Interpretation of Results

- Compare simulation results to risk acceptance criteria
- Identify problem areas
- Evaluate most effective modifications
- Upgrade instrumentation reliability
- Add instrumentation
- Increase operator reliability (procedures)
- Physical modifications to flare system

API Standard 521

The Flare QRA methodology has been specifically included as part of API 521 since the 2007 5th Edition.

The basis for taking system-relief load-reduction credits should be evaluated carefully to assure an adequate design. One method of assessing the acceptability of system-relief load-reduction credits is to quantitatively assess the disposal system performance as a whole. This method considers the likelihood of the overpressure contingencies and the reliability of the safeguards that reduce or eliminate individual relief loads. This quantitative approach calculates the probabilistic disposal-system loads, probabilistic hydraulics and probabilistic equipment overpressures. The system performance is compared to the user's acceptance criteria.

API 521 Section 5.3.4.3

Conclusion

A risk based evaluation of the relief headers and flare system

Method for a more realistic statistical evaluation of network equipment

Identification of most cost-effective flare system fixes (if required)

A tool to manage risk in the future (revamps, upgrades, flare maintenance)

Significant cost savings (millions) as compared with upgrades required to meet non-risk based evaluations

Useful QRA References

1. ASME Boiler and Pressure Vessel Code Section VIII, Division I (2017)
2. API Standard 521, 9th edition (2014), “Pressure-relieving and Depressuring Systems”
3. “Quantitative Risk Analysis – A Realistic Approach to Relief Header and Flare System Design”, Siemens (2015)

Contact us for more information!

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