Smith & Burgess
Process Safety Consulting

Example Calculations on a Two-Load System

Detailed below is a working example on how a two-load system is presented, with the analysis of the probable flow as a function of frequency. Note that the rates and probabilities are fictitious and specified for illustrative purposes only.

Suppose **System A** uses steam to provide heat to the column and is controlled based on temperature on the bottom tray. In the event of an overpressure, the temperature on the bottom tray will increase and the BPCS would tend to close the steam valve to maintain a constant temperature.

Suppose **System B** uses steam to provide heat to the column and is controlled based on pressure in the tower, which will increase if the overpressure scenario occurs. In the event of an increase in pressure, the BPCS would tend to close the steam valve reducing the relief load to the flare system.

The following table describes these two systems:

System	Initial Rate (lb/hr)	BPCS Response PFD	Mitigated Load (lb/hr)
A	400,000	0.1	40,000
B	300,000	0.1	30,000

Based on the table above...
The probable load can be calculated accounting for the likelihood of the residual (mitigated) load.

System	Initial Load (lb/hr)	Probability of the Initial (Full) Load	Mitigated Load (lb/hr)	Probability of Mitigated Load
A	400,000	0.1	40,000	0.9
B	300,000	0.1	30,000	0.9

For flare loading, the following cases were looked at. Since there are two possible relief loads for each system (mitigated relief or unmitigated relief); and with a combination of two systems, the number of possible cases for this system is $4 = 2^2$. Respectively, for a system with 10 possible releases, each with two possible relief loads, the number of different potential flare system load cases would be 210, or 1,024 cases.

Case	System A	System A Load	System A Load Prob.	System B	System B Load	System B Load Prob.	Event Prob.	Event Load (lb/hr)
1	Mitigated	40,000	0.9	Mitigated	30,000	0.9	0.81 = 0.9 x 0.9	70,000
2	Mitigated	40,000	0.9	Initial	300,000	0.1	0.09 = 0.9 x 0.1	340,000
3	Initial	400,000	0.1	Mitigated	30,000	0.9	0.9 = 0.1 x 0.9	430,000
4	Initial	400,000	0.1	Initial	300,000	0.1	0.01 = 0.1 x 0.1	700,000

The information in the previous table could be expressed as a probability per event that the load will be less than or equal to the maximum expected event load. The addition of a frequency of an initiating event, such as a total power failure, allows for the calculation of the frequency with which the flow is likely to equal or not exceeding the maximum event load. For this example we have the following load frequency, assuming the Initiating Event Frequency [IEF] is 1/10 years:

Case	Load	Frequency of Event Load Equaling or Exceeding Given Value	Required Criteria to Achieve Scenario
1	70,000	0.1 = 0.1 x (0.81 + 0.09 + 0.09 + 0.01) *This is the minimal load for the system given the initiating event occurs.*	All probabilities of load for both columns (sum to 1) and are multiplied by the IEF frequency
2	340,000	0.019 = 0.1 x (0.09 + 0.09 + 0.01)	Cases 2, 3, or 4
3	430,000	0.01 = 0.1 x (0.09 + 0.01)	Only Cases 2, 3, or 4
4	700,000	0.001 = 0.1 x (0.01) *This is the worst case load for the system given the initiating event occurs.*	Only Case 4 - Since this is the worst case the load is not expected to exceed what is listed.

(The probability of a Total Power Failure in any given year can be expressed as 0.1 (or 1/10 years) or no Total Power Failure (0.9) sums to 1.0.)

The maximum possible load expected for this system (due to only two loads being reviewed) will be case 4, 700,000 lb/hr (or the total load). This load represents a maximum bound for the system regardless of frequency. As components are added to the system (e.g. if the system had two columns similar to System A and two columns similar to System B) the probability of the worst case scenario occurring is further reduced. Increasing the number of systems or the reliability of the safeguards reduces the likelihood a worst case scenario would occur.