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Title	COF Sections 4.4-4.7 Clarifications
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Purpose:	COF clarification to clear up confusing discussion of inventory masses and time calculations
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4.4 Estimate the Fluid Inventory Available for Release

4.4.1 Overview

The leaking component's inventory is combined with inventory from other attached components that can contribute fluid mass. Additional background on the development of the inventory group concept is provided in Annex 3.A.

4.4.2 Maximum Mass Available for Release (Available Mass)

The available mass for release is estimated for each release hole size as the lesser of two quantities:

a) Inventory Group Mass – The component being evaluated is part of a larger group of components that can be expected to provide fluid inventory to the release. These equipment items together form an inventory group. Additional guidance for creating logical inventory groups is provided in Annex 3.A. The inventory group calculation ~~as presented here~~ is used as an upper limit on the mass of fluid available for a release and does not indicate that this amount of fluid would be released in all leak scenarios. The inventory group mass ~~can be~~is calculated using Equation (3.9).

$$mass_{inv} = \sum_{i=1}^{N} mass_{comp,i} \tag{3.9}$$

b) Component Mass – It is assumed that for large leaks, operator intervention will occur within three minutes, thereby limiting the amount of released material (see Annex 3.A for additional background). Therefore, the amount of available mass for the release is limited to the mass of the component plus an additional mass, $mass_{add,n}$, that is calculated based on three minutes of leakage from the component's inventory group. This ~~additional mass~~ $mass_{add,n}$ is calculated assuming the same flow rate from the leaking component, but is limited to a 203 mm (8 inch) release hole size. The $mass_{add,n}$ ~~additional mass~~ ~~can be~~is calculated for each release hole size using Equation (3.10).

$$mass_{add,n} = 180 \cdot \min\left[W_n,\ W_{max8}\right] \tag{3.10}$$

In Equation (3.10), the M~~m~~aximum F~~f~~low R~~r~~ate, W_{max8}, to be added to the release from the surrounding components~~, W_{max8},~~ (limited by a 203 mm (8 inch) diameter leak) ~~can be~~is calculated using Equations (3.3), (3.6), or (3.7), as applicable, with the hole area, A_n = 32,450 mm^2 (50.3 inch^2).

The maximum mass available for release, $mass_{avail,n}$, is calculated using Equation (3.11).

$$mass_{avail,n} = \min\left[\left\{mass_{comp} + mass_{add,n}\right\},\ mass_{inv}\right] \tag{3.11}$$

Plant detection, isolation, and mitigation techniques, as described in Section 4.6, will limit the duration of the release such that the actual mass released to atmosphere can be significantly less than the available mass as determined above.

Further guidance on the basis of the above methodology for calculating the available mass and the inventory grouping is provided in Annex 3.A.

4.4.3 Calculation of Inventory Mass

a) STEP 4.1 – Group components and equipment items into inventory groups (see Annex 3.A).

b) STEP 4.2 – Calculate the fluid mass, $mass_{comp}$, in the component being evaluated.

c) STEP 4.3 – Calculate the fluid mass in each of the other components that are included in the inventory group, $mass_{comp,i}$.

d) STEP 4.4 – Calculate the fluid mass in the inventory group, $mass_{inv}$, using Equation (3.9).

e) STEP 4.5 – Calculate the flow rate from a 203 mm (8 inch) diameter hole, W_{max8} , using Equations (3.3), (3.6), or (3.7), as applicable, with $A_n = A_8 = 32,450$ mm^2 (50.3 inch^2). This is the maximum flow rate that can be added to the equipment fluid mass from the surrounding equipment in the inventory group.

f) STEP 4.6 – For each release hole size, calculate the added fluid mass, $mass_{add,n}$, resulting from three minutes of flow from the inventory group using Equation (3.10) where W_n is the leakage rate for the release hole size being evaluated and $W_{\max 8}$ is from STEP 4.5.

g) STEP 4.7 – For each release hole size, calculate the available mass, $mass_{avail,n}$ ~~,~~ for release using Equation (3.11).

4.5 Determine the Release Type (Continuous or Instantaneous)

4.5.1 Release Type – Instantaneous or Continuous

The release is modeled as one of two following types:

a) Instantaneous Release – An instantaneous or puff release is one that occurs so rapidly that the fluid disperses as a single large cloud or pool.

b) Continuous Release – A continuous or plume release is one that occurs over a longer period of time, allowing the fluid to disperse in the shape of an elongated ellipse (depending on weather conditions).

~~The process for determining the appropriate type of release to model requires determining the time required to release 4,536 kgs (10,000 lbs) of fluid, t_n, through each of the release hole sizes.~~ The~~is has been determined to be the~~ transition point between continuous and instantaneous release types is 28.20 kg/s (55.6 lb/s) or $\frac{10,000\ lbs}{180\ s} = 55.6\ lb/s$. Further guidance on the background and importance of selecting the proper type of release is provided in Annex 3.A.

4.5.2 Calculation of Release Type

~~a) STEP 5.1 – For each release hole size, calculate the time required to release 4,536 kgs (10,000 lbs) of fluid.~~

~~$$t_n = \frac{C_3}{W_n} \qquad (3.12)$$~~

~~b)~~a) STEP 5.~~2~~1 – For each release hole size, determine if the release type is instantaneous or continuous using the following criteria. The release is continuous if any of the following conditions exist, otherwise the release is instantaneous:

1) ~~If t~~The release hole size is ≤6.35 mm (0.25 inch)~~ or less, then the release type is continuous.~~

2) ~~If $t_n \le 180\ sec$ and t~~The release mass, $mass_{avail,n}$ ~~,~~ is ~~greater than~~ ≤ 4,536 kgs (10,000 lbs)~~, then the release is instantaneous; otherwise, the release is continuous.~~

~~2)~~3)The release rate, W_n , is < 25.20 kg/s (55.6 lb/s)

4.6 Estimate the Impact of Detection and Isolation Systems on Release Magnitude

4.6.1 Overview

Petrochemical processing plants typically have a variety of detection, isolation, and mitigation systems that are designed to reduce the effects of a release of hazardous materials. A simplified methodology for assessing the effectiveness of various types of detection, isolation, and mitigation systems is included in API RP 581. These systems affect a release in different ways. Some systems reduce magnitude and duration of the release by detecting and isolating the leak. Other systems reduce the consequence area by minimizing the chances for ignition or limiting the spread of material.

Detection, isolation, and mitigation systems are assumed to affect the release in two ways:

a) Detection and Isolation Systems – These systems are designed to detect and isolate a leak, and tend to reduce the magnitude and duration of the release, (see Section 4.6.2).

b) Mitigation Systems – These systems are designed to mitigate or reduce the consequence of a release (see Section 4.8.3).

4.6.2 Assessing Detection and Isolation Systems

Detection and isolation systems that are present in the unit can have a significant impact on the magnitude and duration of the hazardous fluid release. Guidance for assigning a qualitative letter rating (A, B, or C) to the unit's detection and isolation systems is provided in Table 4.5. Detection System A is usually found in specialty chemical applications and is not often used in refineries.

The information presented in Table 4.5 is used when evaluating the consequence of continuous releases; see Section 4.7.1.

4.6.3 Impact on Release Magnitude

Detection and isolation systems can reduce the magnitude of the release. For the release of both flammable and toxic materials, isolation valves serve to reduce the release rate or mass by a specified amount, depending on the quality of these systems. The recommended reduction values are presented in Table 4.6.

4.6.4 Impact on Release Duration

Detection and isolation systems can reduce the duration of the release. This is extremely important when calculating the consequence of toxic releases because toxic consequences are a function of concentration and exposure duration. The duration is used as direct input to the estimation of flammable and toxic consequences.

The quality ratings of the detection and isolation systems have been translated into an estimate of leak duration. Total leak duration, $ld_{max,n}$, presented in Table 4.7, is the sum of the following:

a) Time to detect the leak.

b) Time to analyze the incident and decide upon corrective action.

c) Time to complete appropriate corrective actions.

Note that there is no total leak duration provided in Table 4.7 for the rupture case (largest release hole size, if greater than 102 mm (4 inch) diameter).

4.6.5 Releases to the Environment

Environmental consequence is mitigated in two ways: physical barriers act to contain leaks on-site, and detection and isolation systems limit the duration of the leak. In API RP 581, the volume contained on-site is accounted for directly in the spill calculation. Detection and isolation systems serve to reduce the duration of the leak and, thus, the final spill volume.

4.6.6 Calculation for Detection and Isolation

a) STEP 6.1 – Determine the detection and isolation systems present in the unit.

b) STEP 6.2 – Using Table 4.5, select the appropriate classification (A, B, C) for the detection system.

c) STEP 6.3 – Using Table 4.5, select the appropriate classification (A, B, C) for the isolation system.

d) STEP 6.4 – Using Table 4.6 and the classifications determined in STEPs 6.2 and 6.3, determine the release reduction factor, $fact_{di}$.

e) STEP 6.5 – Using Table 4.7 and the classifications determined in STEPs 6.2 and 6.3, determine the ~~total~~ maximum leak duration~~s~~ for each of the selected release hole sizes, $ld_{max,n}$.

4.7 Determine the Release Rate and Mass for Consequence of Failure

4.7.1 Continuous Release Rate

For continuous releases, the release is modeled as a steady state plume; therefore, the release rate (units are lb/s) is used as the input to the consequence analysis. The release rate that is used in the analysis is the theoretical release as discussed in Section 4.3, adjusted for the presence of unit detection and isolations as discussed in Section 4.6 (see Equation (3.13)).

$$rate_n = W_n \left(1 - fact_{di}\right) \tag{3.13}$$

4.7.2 Instantaneous Release Mass

For transient instantaneous puff releases, the release mass is required to perform the analysis. The A~~a~~vailable R~~r~~elease M~~m~~ass, $mass_{avail,n}$, as determined in Section 4.4.2 for each release hole size~~,~~ $mass_{avail,n}$ ~~,~~ is used ~~as~~ to determine an U~~u~~pper B~~b~~ound ~~for the~~ R~~r~~elease M~~m~~ass, $mass_n$ as shown in Equation (3.14).

$$mass_n = \min\left[\{rate_n \cdot ld_n\},\ mass_{avail,n}\right] \tag{3.14}$$

In this equation, the leak duration, ld_n, cannot exceed the maximum duration $ld_{max,n}$, established in Section 4.6.4 based on the detection and isolation systems present. Equation (3.15) can be used to calculate the actual duration of the release, ld_n.

$$ld_n = \min\left[\left\{\frac{mass_{avail,n}}{rate_n}\right\},\ \left\{60 \cdot ld_{max,n}\right\}\right] \tag{3.15}$$

4.7.3 Calculation of Release Rate and Mass

a) STEP 7.1 – For each release hole size, calculate the adjusted release rate, $rate_n$, using Equation (3.13) where the ~~theoretical~~ release rate, W_n, is from STEP 3.2. Note that the release reduction factor, $fact_{di}$, determined in STEP 6.4 accounts for any detection and isolation systems that are present.

b) STEP 7.2 – For each release hole size, calculate the leak duration, ld_n, of the release using Equation (3.15), based on the available mass, $mass_{avail,n}$, from STEP 4.6 and the adjusted release rate, $rate_n$, from STEP 7.1. Note that the leak duration cannot exceed the maximum duration, $ld_{max,n}$, determined in STEP 6.5.

c) STEP 7.3 – For each release hole size, calculate the upper bound release mass, $mass_n$, using Equation (3.14) based on the release rate, $rate_n$, from STEP 3.2, the leak duration, ld_n , from STEP 7.2, and the available mass, $mass_{avail,n}$, from STEP 4.7.

$fact_{di}$ is the release magnitude ~~reduction~~ adjustment factor, based on the detection and isolations systems present in the unit.

$fact_{mit}$ is the consequence area ~~reduction~~ adjustment factor, based on the mitigation systems present in the unit.

ld_n is the leak duration of the flammable release based on the available mass and the calculated release rate, associated with the n^{th} release hole size, seconds

$ld_{max,n}$ is the maximum leak duration based on isolation and detection systems associated with the n^{th} release hole size, minutes

$mass_{comp}$ is the ~~inventory fluid~~component mass for the component or piece of equipment being evaluated, kgs (lbs)

$mass_{comp,i}$ is the ~~inventory fluid~~component mass for each of the i components or pieces or equipment that are included in the inventory group, kgs (lbs)

$mass_{add,n}$ is the ~~additional~~ mass ~~that can be added to the release as~~ contributed by~~from~~ the surrounding equipment in the inventory group (limited by W_{max8}), associated 3 minutes release of~~with~~ the n^{th} release hole size, kgs (lbs)

$mass_{avail,n}$ is the available mass for release ~~for each~~ of each of the release hole sizes~~ selected,~~and is the sum of the component release mass, $mass_{comp}$, and added 3 minutes release, $mass_{add,n}$, through the associated with the n^{th} release hole size, kgs (lbs)

$mass_{inv}$ is the inventory group ~~fluid~~ mass, kgs (lbs)

$mass_n$ is the ~~adjusted or mitigated discharge~~upper bound release mass ~~used in the consequence calculation~~ associated with the n^{th} release hole size, kgs (lbs)

$rate_n$ is the adjusted release rate for detection and isolation systems~~or mitigated discharge rate used in the consequence calculation~~ associated with the n^{th} release hole size, kg/s (lb/s)

W_n is the ~~theoretical~~ release rate associated with the n^{th} release hole size, kg/s (lb/s)