Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, November 2-3, 2006

Control Room Habitability for Accidental Sulfuric Acid Release

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1. Introduction

The 10 CFR 50 Appendix A Criterion 19, "Control Room", requires that a control room be provided from which actions can be taken to operate the nuclear power unit safely under normal conditions and to maintain it in a safe condition under accident conditions. For compliance with the requirement, the control room of a nuclear power plant should be appropriately protected from hazardous chemicals that may be discharged as a result of equipment failures, operator errors, or events and conditions outside the control of the nuclear power plant. We have excluded sulfuric acid from a target of estimation for control room habitability merely because its boiling point is too high; qualitative analysis in this paper shows that we can exclude sulfuric acid from the target of habitability estimation.

2. Methodology

2.1. Chemicals stored or situated at distances greater than five miles(8 km) from the plant need not be considered because, if a release occurs at such a distance, atmospheric dispersion will dilute and disperse the incoming plume to such a degree that there should be sufficient time for the control room operators to take appropriate action.

2.2. Two types of industrial accidents should be considered for each source of hazardous chemicals: maximum concentration chemical accidents and maximum concentration-duration chemical accidents.

- For a maximum concentration accident, the quantity of the hazardous chemical to be considered is the instantaneous release of the total contents of one of the following:

(1) the largest storage container falling within the guidelines of Table C-2 of Reference 1 and located at a nearby stationary facility, (2) the largest shipping container (or for multiple containers of equal size, the failure of only one container unless the failure of that container could lead to successive failures) falling within the guidelines of Table C-2 of Reference 1 and frequently transported near the site, or (3) the largest container stored onsite (normally the total release from this container unless the containers are interconnected in such a manner that a single failure could cause a release from several containers.).

- For a maximum concentration-duration accident, the continuous release of hazardous chemicals from the largest safety relief valve on a stationary, mobile, or onsite source falling within the guidelines of Table C-2 of Reference 1 should be considered.

2.3. The vapor from instantaneous flashing (puff) and from continuous vaporization or evaporation (plume) moves in the direction of the wind and disperses by diffusion into the atmosphere. [2]

2.4. For the worst 5% meteorology observed at the majority of nuclear plant sites, the five percentile meteorological dilution factor between release point and control room for instantaneous and continuous releases is used for this analysis.

2.5. Standard deviations for horizontal distance (σ_h) and for vertical distance (σ_z) described in AZAP program function are applied to this analysis.

2.6. Evaporation Rate [2]

The evaporation of a liquid in an open space with wind or in a confined area with good ventilation can be described as a mass transfer process by forced convection. The evaporation rate may be calculated by the following formulas:

$$\frac{dm_v}{dt} = \frac{h_d M\ A(t)(P_s - P_a)}{R_g(T_a + 273)}$$

Where,

h_d : Mass transfer coefficient (cm/sec)

D : Diffusion coefficient (cm^2/sec)

L : Characteristic length (cm)

M : Molecular Weight of the liquid (g/mole)

P_s : Saturation vapor pressure of the liquid at ambient temperature(℃) (mmHg)

P_a : Actual vapor pressure of the liquid in air (mmHg)

A(t) : Surface area for spilled liquid

R_g : Universal gas constant

u : Wind speed (cm/sec)

ρ : Density of air (g/cm^3)

μ : Viscosity of air (g/cm-sec)

2.7. Vapor Dispersion

The vapor from instantaneous flashing (puff) and from continuous vaporization or evaporation (plume) moves in the direction of the wind and disperses by diffusion into the atmosphere. The dispersion is assumed to follow a Gaussian distribution for short travel times (a few minutes to one hour) [2]. In this case, we assumed sulfuric acid is dispersed in a plume of smoke. The diffusion equation for the continuous release of a plume with a finite initial volume and a receptor at z above the ground level is given by the following equation:

$$\chi(x,y,z,h)=\frac{Q'}{2\pi\mu\sigma_Y\sigma_Z}\exp\left\{-\frac{y^2}{2\sigma_Y^2}\right\}\left[\exp\left\{-\frac{(z-h)^2}{2\sigma_z^2}\right\}+\exp\left\{-\frac{(z+h)^2}{2\sigma_z^2}\right\}\right]$$

Where,

χ : Concentration (g/m^3)

σ_Y , σ_Z : Standard deviations of plume concentration in the Y and Z directions, respectively (m).

Q' : Continuous source strength (g/sec)

3. Calculation

In a postulated accident, it is assumed that the entire container of the toxic substance ruptures and the horizontal distance from control room air intake to sulfuric acid storage tank is 104 meter and the vertical distance is 24 meter. Conservatively, the atmospheric temperature is assumed to be 40℃ because the evaporation of liquid is more rapid at higher temperatures due to the greater number of energetic molecules and stable atmospheric dispersion conditions is assumed to Pasquill Condition F. Diffusion coefficient is $0.2\,cm^2/sec$ [2].

Sensitivity analyses are performed for wind speed of $1.0\times10^{-7} \sim 1.0\times10^{3}$ m/sec and Spilled area of $1.0\times10^{-4} \sim 1.0\times10^{6}$ ft^2, respectively. As shown from these figures, even consider the most severe wind speed or the maximum spilled area, the concentration of sulfuric acid is calculated within the toxicity limit of 2 mg/m^3 [1].

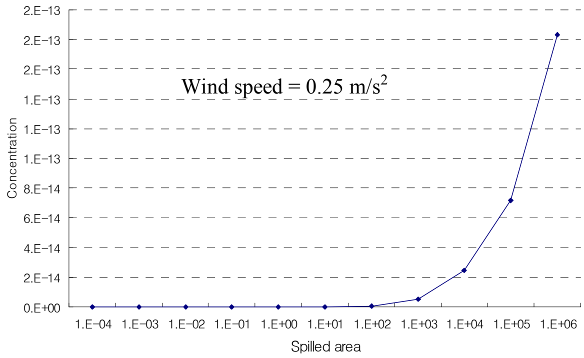

Figure 1 Concentration[g/m^3] Responses for Spilled Area[ft^2]

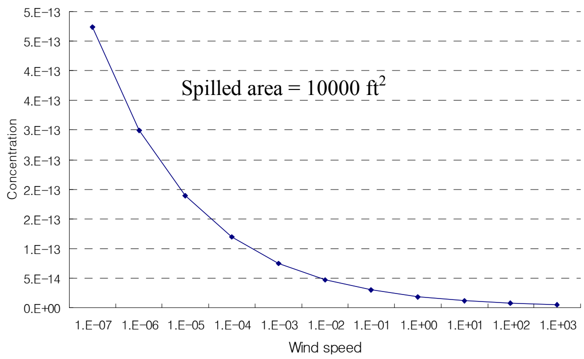

Figure 2 Concentration[g/m^3] Responses for Wind speed[m/s]

4. Conclusion

In case of accidental release of sulfuric acid from stationary source, the concentration at air intakes of Control Room HVAC System reaches about $2.0\times10^{-14} \sim 5.0\times10^{-13}$ g/m^3. Toxicity limit of sulfuric acid is 0.002 g/m^3 at standard temperature and pressure. Therefore, the accidental release of sulfuric acid has no effect on the operator habitability at the main control room.

REFERENCES

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[3] “Perry's Chemical Engineers' Handbook”, 6th Edition, written by Robert H. Perry and Don Green, published by McGraw Hill Book.