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History Sheet

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Acronyms

AED	aerodynamic equivalent diameter
ARF	airborne release fraction
BC	black cell
CCN	correspondence control umber
D&J	Dombrowski and Johns
DNFSB	Defense Nuclear Facilities Safety Board
DSA	documented safety analysis
DOE	US Department of Energy
FAI	Fauske and Associates
HC	hot cell
HEPA	high-efficiency particulate air (filter)
HLP	high-level waste lag storage and feed blending process
LEF	Lefebvre correlation
M&R	Merrington and Richardson
NRC	Nuclear Regulatory Commission
PDSA	preliminary documented safety analysis
PTF	pretreatment facility
QA	quality assurance
RF	respirable fraction
R&R	Rossin and Rammler
SC	safety class
SLA	severity level assessment
SMD	Sauter mean diameter
SRD	Safety Requirements Document
SS	safety significant
SSC	structures, systems, and components
UFP	ultrafiltration process
ULD	unit liter dose
WTP	Waste Treatment Plant

1 Issue Description

The Waste Treatment Plant (WTP) Preliminary Documented Safety Analysis (PDSA) addresses multiple loss of confinement events. One of the events is a spray leak resulting from corrosion, erosion, jumper misalignment or other initiators which create small openings in the confinement boundary. The consequences of spray leak events have been modeled as an optimized 1/8 in. diameter spray nozzle in a process tank or pipe and then applying the bounding respirable release fraction for sprays from Department of Energy (DOE) Handbook, *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities* (DOE-HDBK-3010-1994 [the Handbook]), to the resultant flow.

During the review of the WTP PDSA addendum and severity level assessment (SLA) calculation, the Defense Nuclear Facilities Safety Board (DNFSB) staff provided comments on the unmitigated spray leak analysis and resultant functional classification. Specifically, the staff commented that the DOE-HDBK-3010-1994 airborne release fraction (ARF) may not adequately represent the droplet size distribution produced by possible leak geometries and for WTP conditions, that evaporation from the droplets as they settle could substantially change the size distribution of the spray increasing the amount of respirable material available for release, and that the breach configuration assumed in the SLA calculation was non-conservative. Subsequent discussion focused on comment resolution has called into question the established values in DOE-HDBK-3010-1994 for the respirable airborne release fraction (ARFxRF) used in spray leak scenarios.

DOE-HDBK-3010-1994 has limited guidance for spray leak scenarios to provide ARF and respirable fraction (RF) to be used in consequence analysis. The Handbook Section 3.2.2.3.1, Venting Below the Liquid Level, provides the following bounding ARFxRF recommendation and additional guidance related to the geometry of the leak and evaporation:

> *For the purposes of airborne suspension, a conservative assumption would be the pressurized release of the liquid via a very fine hole as occurs in a commercial spray nozzle…. It is not anticipated that drops formed from breaches, cracks, leaks would generate finer drop size distribution. Therefore, the respirable fraction of the coarsest distribution generated by commercial spray nozzles shown in Figure 3-4 is selected as the bounding ARF, 1E-4, with a RF of 1.0. For other size fractions, the values can be inferred from the 0.128-inch (3.25-mm) diameter spray nozzle values at 200 psig (1.38 MPA_g) upstream pressure.*
>
> *Other recent investigations … using an analytical model suggest that, under some conditions, the fraction of drops in the finer size fractions (i.e., 10-µm and less) are greater for fine orifices (and possibly slot-type breaches) at high pressures, and that the evaporation of the liquid prior to deposition may reduce the size of the larger diameter drops to some extent. There is considerable uncertainty as to the value to assign the critical factor (Q, a drop size fitting parameter) and the analytical model, though useful in understanding the phenomenon, cannot presently be used to predict the size distribution of sprays.*

The Handbook ARFxRF recommendation is based on limited data from commercial hollow cone spray nozzles with orifice diameters of 0.063 in., 0.086 in., and 0.128 in. at three pressures (i.e., 50, 100, and 200 psig). The Handbook selects the respirable release fraction from the coarsest distribution generated by these commercial spray nozzles (i.e., 0.128 in. and 200 psi) as the bounding ARFxRF. Given this guidance, the WTP project modeled the spray leak as a 0.128 in. diameter hole with an ARFxRF of 1E-4.

WTP contracted one of the principal authors of DOE-HDBK-3010-1994 to support resolution of the open issues and project modeling of potential spray releases, assuming leakage from pipes carrying pumped viscous waste slurries at pressures up to several hundred psig. In December 2009, the contracted author concluded that the Handbook spray release model may not be conservative in establishing an ARFxRF for the WTP application considering the following:

- The Handbook-recommended bounding ARFxRF of 1E-4 of respirable droplets (≤10 µm aerodynamic equivalent diameter [AED]) is based on "the coarsest distribution generated by commercial spray nozzles shown in [Handbook] Figure 3-4." While the 1E-4 value corresponds to discharge from a nozzle of 0.128 in. diameter and 200 psig, no specific recommendations regarding leak size and pressure are made in the Handbook.
- The ARFxRF of 1E-4 of respirable droplets was originally selected for the U.S. Nuclear Regulatory Commission (NRC) evaluation by the Pacific Northwest National Laboratory of a seismic scenario in a specific facility, Babcock and Wilcox mixed oxide fuel fabrication, and was incorrectly labeled as a "spray release". The value is an estimate of the stable (post interaction and deposition) liquid aerosol in a glovebox based on 10 mg/m^3 "fog" limit due to breakage of glass/fragile equipment. Droplet evaporation is limited in such an environment. The selected ARFxRF of 1E-4 was considered conservative by comparing to the commercial spray nozzle data for largest diameter coarse sprays, which showed a 1E-4 respirable value.
- The 1E-4 value was carried over to the guidance for investigators for the DOE Safety Survey in 1992 for engineering analysis of the potential releases from DOE Weapons Complex nonreactor nuclear facilities. The Safety Survey guidance was shortly thereafter formalized into DOE-HDBK-3010-1994 which included the commercial spray data for water (Figure 3-4) and recommended the 1E-4 as a bounding value for spray releases.
- Figure 3-4 of DOE-HDBK-3010-1994 shows that the size distribution of a spray formed by forcing liquid through a pressure nozzle/orifice becomes finer with decreasing size of the orifice and increasing pressure.
- The recommended 1E-4 value in DOE-HDBK-3010-1994 remains valid for the studied glovebox, but is not a bounding value for liquid droplets of respirable size generated by sprays from metal piping and vessels as a function of opening size, configuration, and upstream pressure, with liquid properties that may be significantly different than water.

Based on the review by the Handbook's principal author and the comments from the DNFSB staff, the WTP has concluded that the ARFxRF of 1E-4 of respirable droplets recommended in DOE-HDBK-3010-1994 for pressurized release of liquid through a small breach (hole or crack) cannot be relied upon as sufficiently conservative to meet DOE-STD 3009-94 requirements for analyzing postulated leaks from waste piping in an environment comparatively open (e.g., process cells) relative to the originally evaluated glovebox.

Limited experimental data relevant to liquid waste fluids (e.g., slurries, high-salt content solutions, mixtures, etc.) have been identified upon which a technical basis can be formulated with respect to such parameters as droplet size distributions from a potential leak site, evaporation rate of the small droplets, and the behavior of droplets containing suspended solids. There are experimental data from industry with respect to spray nozzle droplet distributions and there are textbook correlations for some parameters but this information is not directly applicable for the range of fluids of interest for the WTP scenarios. Given this limitation in the relevant data, the analyses for spray leaks must employ judgment regarding the

existing experimental data and textbook correlations to establish a meaningful and conservative approach for use by WTP.

Long-term, for the final documented safety analysis (DSA), additional research work and testing would be beneficial to reduce the evaluated range of uncertainties for spray leaks in WTP facilities. However, the near-term approach is to identify a spray leak methodology for the WTP that provides an adequately conservative model for WTP preliminary design and serves as the basis for conservative control selection. Adequacy of the control selection is to be assured by performing sensitivity studies.

2 Purpose

This report develops near-term methodology that will be used to analyze spray leak scenarios in WTP facilities. Once the unmitigated spray leak consequences have been determined, controls to either prevent or mitigate the event are established. This report describes the regulatory basis and the proposed approach to the selection of the controls for the spray leak scenario at WTP, illustrating that process for the pretreatment facility (PTF).

3 WTP Methodology for Spray Leak Scenarios

The methodology for evaluating spray leak scenarios at WTP needs to provide an approach to evaluate the following factors to determine the amount of respirable material released:

- droplet size distribution formed by the passage of the waste through a breach in the primary confinement as a function of fluid properties, flow properties, and breach configuration
- breach configuration to be assumed in the analysis
- the effect of evaporation on the droplets
- the effect of surface tension on droplet distribution
- additional contributions to aerosol formation such as splash/splatter and entrainment (either from a pool or following dry-out)

Each of these considerations is discussed below.

3.1 Droplet Size and Distribution Correlations

For the purposes of estimating the ARFxRF resulting from a spray leak, the two most important factors are the mean spray droplet size and the droplet size distribution. Prediction of droplet size distributions resulting from sprays typically involves predicting the Sauter mean diameter (SMD) of the droplets and then the distribution of drop sizes about the SMD.

There are numerous correlations in the literature for predicting SMD for different types of nozzles. In *Gas Turbine Combustion* (Lefebvre 1999), the author cautions against extending any correlation beyond the conditions from which it is derived (refer to section 6-18-1 of Lefebvre 1999) and also comments on the scarcity of correlations for plain orifices (refer to section 6-16-1 of Lefebvre 1999).

Absent data based on WTP fluid properties and breach configurations, prediction of spray drop size distribution is necessarily based on extending a correlation developed for conditions different from those at WTP. Hanford tank farms apply the correlation reported in *Atomization and Sprays* (Lefebvre 1989)

and attributed by Lefebvre (LEF) to Merrington and Richardson (M&R) in analyzing wastes similar to the feeds to WTP. M&R collected data using plain orifices rather than specifically engineered spray nozzles and included a wide variety of fluids with different viscosities, densities, and surface tensions. Lefebvre (1989) identifies the LEF correlation as the "best available for engineering calculation of mean drop sizes" for the plain-orifice atomizer. WHC-SD-GN-SWD-20007, Revision 0 (*A Model for Predicting Respirable Releases from Pressurized Leaks*, July 29, 1994) provides the following description of the correlation.

> *The disintegration of liquid jets injected into stagnant air was studied empirically in The Break-Up of Liquid Jets (Merrington and Richardson 1947). Drop-size distribution curves were obtained by a stationary nozzle directed vertically downward in an enclosed spray tower. The pressure supply was held constant during each test run by using a pressure-regulated gas cylinder. Liquid injection pressures ranged from 100 psi to 680 psi in the tests. The various liquids used in the tests and the pertinent physical properties of those liquids are provided in Table 2-1.*
>
> *Table 2-1. Test Liquid Parameters (Merrington and Richardson 1947).*

Test Liquid	*Density (gm/cm3)*	*Kinematic Viscosity : (cm2/sec)*
Zinc Chloride	*1.76*	*0.10*
Soap Solution	*1.00*	*0.020*
Titanium Tetrachloride	*1.76*	*0.006*
Carbon Tetrachloride	*1.60*	*0.006*
Methylene Chloride	*1.33*	*0.004*
Methyl Salicylate	*1.33*	*0.030*
Chlorosulphonic Acid	*1.77*	*0.030*
Water	*1.00*	*0.012*
Methyl Salicylate	*1.34*	*7.0*
Glycerine	*1.26*	*10.0*
GIycerine + Water	*1.21*	*1.0*

> *Merrington and Richardson (1947) provide few details on the design parameters of the nozzles used in the tests. The only information provided specifies that two conical nozzles of 0.15 and 0.25 in. diameter and two sharp edged orifices of 0.030 and 0.3125 in. were used in the tests.*
>
> *The spray droplets in the Merrington and Richardson tests (1947) were collected on a filter paper exposed to the spray for a short period to prevent overlapping of drops. The drop stains, made visible by adding a dye to the liquid, were measured. The relationships between the stain diameter and drop size were established by shooting single drops of known diameter from a pipette onto samples of the filter paper. The results of the tests were reduced to provide an empirical correlation for the Sauter Mean Diameter (SMD) of the droplet distribution.*
>
> *In Atomization and Sprays (Lefebvre 1989), a revision of the Merrington and Richardson SMD correlation is presented which includes the effect of orifice diameter on the resulting SMD. The correlation for SMD, in meters, as presented in Atomization and Sprays is provided in Equation 1.*
>
> $SMD = 500\, d^{1.2}\, v^{0.2}/U$ *(Equation 1)*
>
> *where*

d = orifice diameter (m)
v = kinematic viscosity (m^2/s)
U = liquid jet velocity (m/s)

The SMD is a characteristic diameter of the droplet distribution. This diameter is defined as the drop size with a surface-to-volume ratio equal to that of the entire droplet distribution.

The diameter term in the Equation 1 above represents a modification of the original M&R work which did not include any dependence on orifice size. Equation 1 is conservative with respect to the M&R work for diameters less than 2.15 mm.

In addition to the mean spray droplet size, the droplet size distribution must also be determined. According to Lefebvre, the most widely used expression for droplet size distribution is the Rosin and Rammler (R&R) formula. WHC-SD-GN-SWD-20007 provides this description of the R&R expression.

The most widely used equation for expressing drop size distributions is that developed in The Laws Governing the Fineness of Powdered Coal," (Rosin and Rammler 1933). This is provided below as Equation 2.

$$Q = 1 - \exp[-(D/X)^q] \qquad \text{(Equation 2)}$$

where
Q = fraction of the total volume contained in drops of diameter less than D
X = characteristic diameter
q = fitting constant; provides a measure of the spread of the drop sizes in the distribution.

The relationship between the characteristic diameter (X) and the SMD using the Rosin and Rammler (1933) distribution is

$$SMD/X = [\Gamma(1 - 1/q)]^{-1} \qquad \text{(Equation 3)}$$

where Γ denotes the gamma function.

The LEF correlation and R&R formula provide an accepted correlation suitable for a plain-orifice atomizer. Figure 1 shows a comparison of the DOE-HDBK-3010-1994 data to the correlations described above for the same conditions (water, 200 psi, 0.128 in. orifice). For this comparison, the fitting constant *q* has been set to the value of 2.4 recommended in WHC-SD-GN-SWD-20007.

As seen in Figure 1, the DOE-HDBK-3010-1994 data indicate an airborne respirable fraction that is about an order of magnitude larger than what is predicted by the correlation. However, it must be understood that the LEF correlation was developed to predict the behavior of a plain orifice while the DOE-HDBK-3010-1994 data is for a hollow cone nozzle. For a hollow cone nozzle, fluid is passed into a whirl chamber through tangential passages or through a fixed spiral to impart a rapid rotation. The orifice for the hollow cone nozzle is placed on the axis of the whirl chamber, and the fluid exits in the form of a hollow, conical sheet. This sophisticated hollow cone nozzle is not representative of a piping wall failure caused by corrosion, erosion, cracking, or other mechanisms, that could lead to a spray leak event. Thus, even though it has been suggested that both the M&R and R&R correlations could be adjusted to match the particle size data presented in DOE-HDBK-3010-1994 for a pressurized spray leak in DOE accident

analysis, this approach is not recommended given the nozzle geometry is not prototypic of a leak configuration.

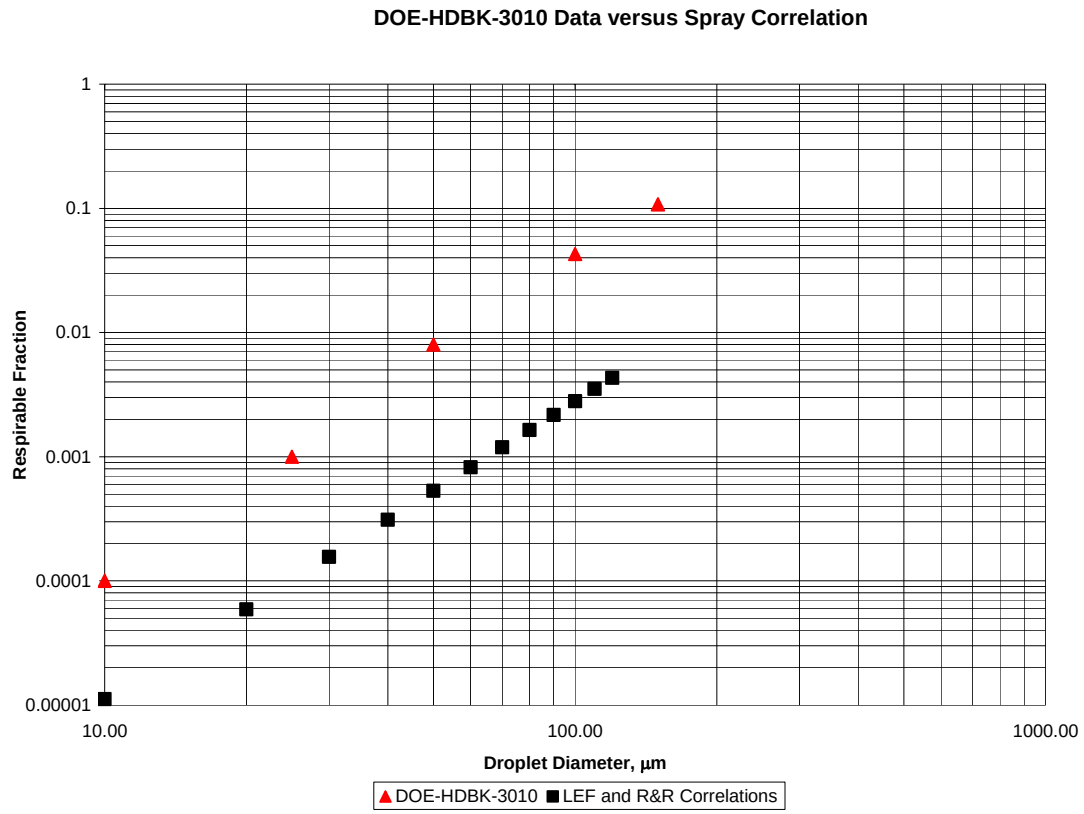

Figure 1 - Comparison of DOE-HDBK-3010-1994 Pressurized Spray Data to Correlation Results

A more appropriate comparison is a comparison of the data obtained by Lee (see WHC-SD-GN-SWD-20007, Revision 0) from a 0.02 in. plain orifice with fuel oil (density of 860 kg/m^3 and kinematic viscosity of 3.46E-6 m^2/s) at 450 psi to results from the LEF and R&R correlations.

Figure 2 shows the predicted results. The correlation agrees well with the fuel oil spray data. The fitting constant in Equation 3 is set equal to 2.4 in this comparison as was done to generate Figure 1. The jet velocity calculation uses a velocity coefficient of 0.82. The SMD determined from the spray data was 68.8 µm while the correlation predicts 65 µm.

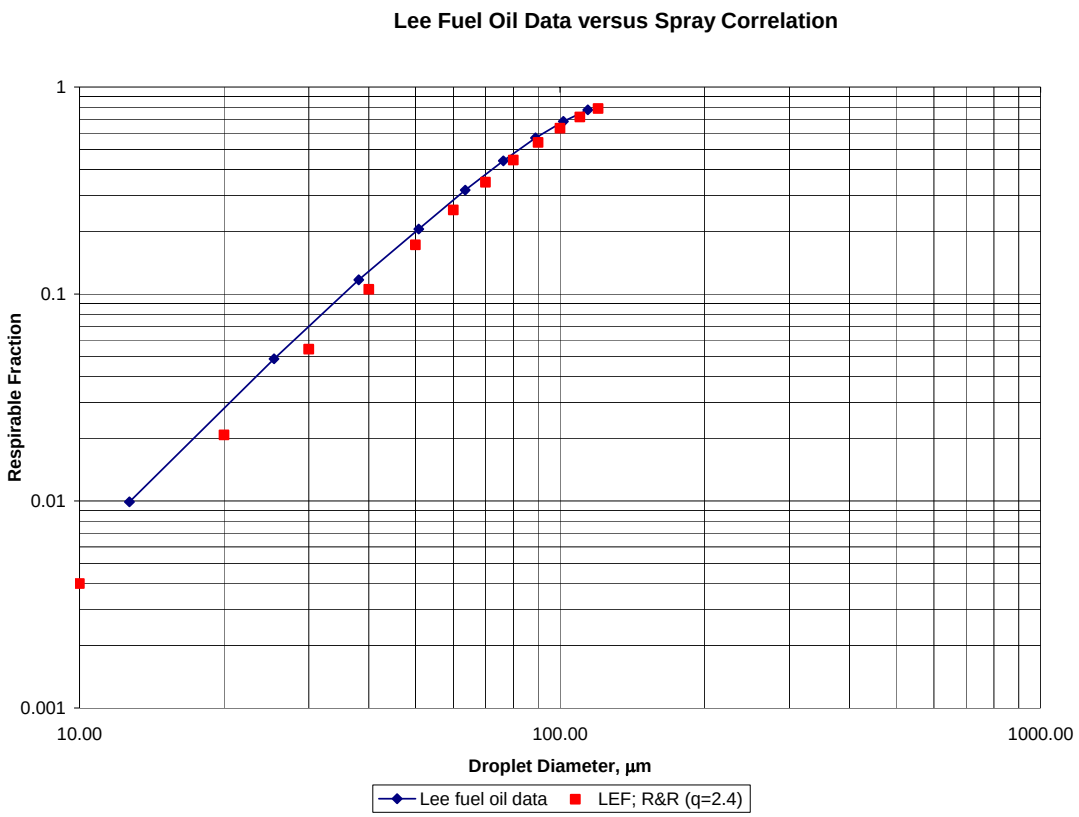

Figure 2 - Comparison of Plain Orifice Pressurized Spray Data to Correlation Results

WHC-SD-GN-SWD-20007 states that the best fit of the spray data is obtained when the Equation 3 fitting constant is set to 2.8. However, WHC-SD-GN-SWD-20007 recommends a lower fitting constant (2.4). This value is used by Hanford tank farms. Figure 3 shows the correlation compared to the fuel oil data for q values of 2.4 and 2.8. The q value of 2.4 predicts more small diameter aerosol than does the q value of 2.8 and is judged to provide an adequate fit.

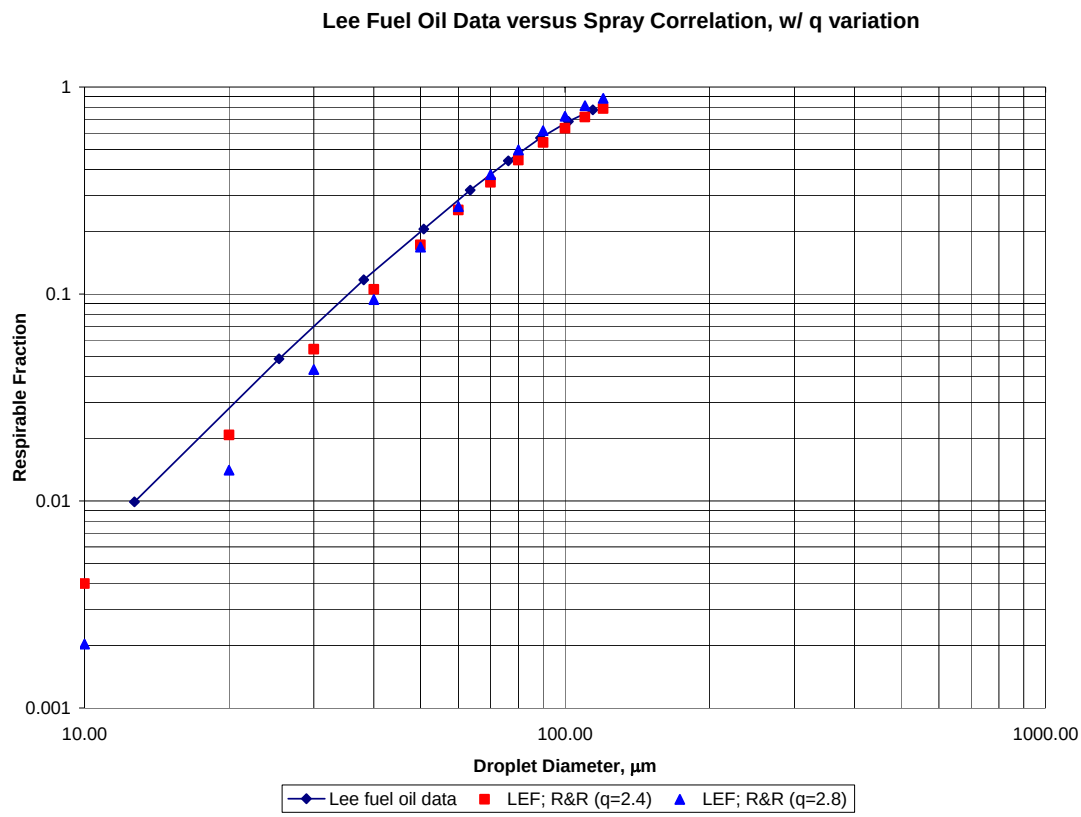

Figure 3 - Comparison of Spray Data to Correlation Results at Different *q* Values

The determination of the SMD for droplets from a crack- or slit-type breach has also been evaluated. Although Lefebvre (1989) does not identify a correlation for this type of spray, he does refer to studies of flat spray nozzles by Dombrowski. RPP-5098, Revision 1, *Analysis of Waste Leak and Toxic Chemical Release Accidents from Waste Feed Delivery (WFD) Diluent System,* identifies two correlations for fan spray, compares these correlations to the M&R plain orifice correlation, and concludes that the Dombrowski & Johns (D&J) correlation does a good job predicting the SMD for fan sprays.

Fauske and Associates reviewed Appendix B of RPP-5098 in CCN 193544. The following summarizes the main points made in that review:

- The RPP-5098 approach estimates the SMD based on the hydraulic diameter of the slit. For high aspect ratio slits this approach effectively equates the slit SMD to the SMD for an orifice with diameter equal to the width of the slit. Section 3 of the FAI review considers this approach to be overly conservative because treating the slit as an orifice leads to results that contradict the trend in the M&R data and other observations - namely, the total aerosol produced increases with decreasing width/diameter. The FAI review suggests, instead, that the D&J correlation be evaluated based on the length and width of the slit.
- Section 3 of the FAI review also questions the LEF correlation and its heavy dependence on orifice size.
- Section 4 of the FAI review noted that special nozzle designs are required to produce fan sprays. The communication observes that the Dombrowski studies used a stream impingement design to generate

their fan sprays. This special configuration is not representative of the liquid release through a slit-type breach in process piping.

- The FAI review also notes that there is some recent experimental data that does not support the assumption that liquid released through a slit release will form a fan spray.

Figure 4 compares the SMD results from the D&J correlation to the LEF correlation for water at 200 psi for various plain orifice sizes. In Figure 4, the breach is treated two different ways: (1) as a plain orifice using the LEF correlation, and (2) as a plain orifice using the D&J correlation.

Optimum orifice diameters or slit widths between 0.5 and 2 mm are expected for WTP conditions. The LEF correlation shows reasonable agreement with the D&J correlation for orifices in this range. For smaller orifice or slit widths, the LEF correlation predicts lower (i.e., more conservative) SMDs than the D&J correlation while the D&J correlation is more conservative for larger openings.

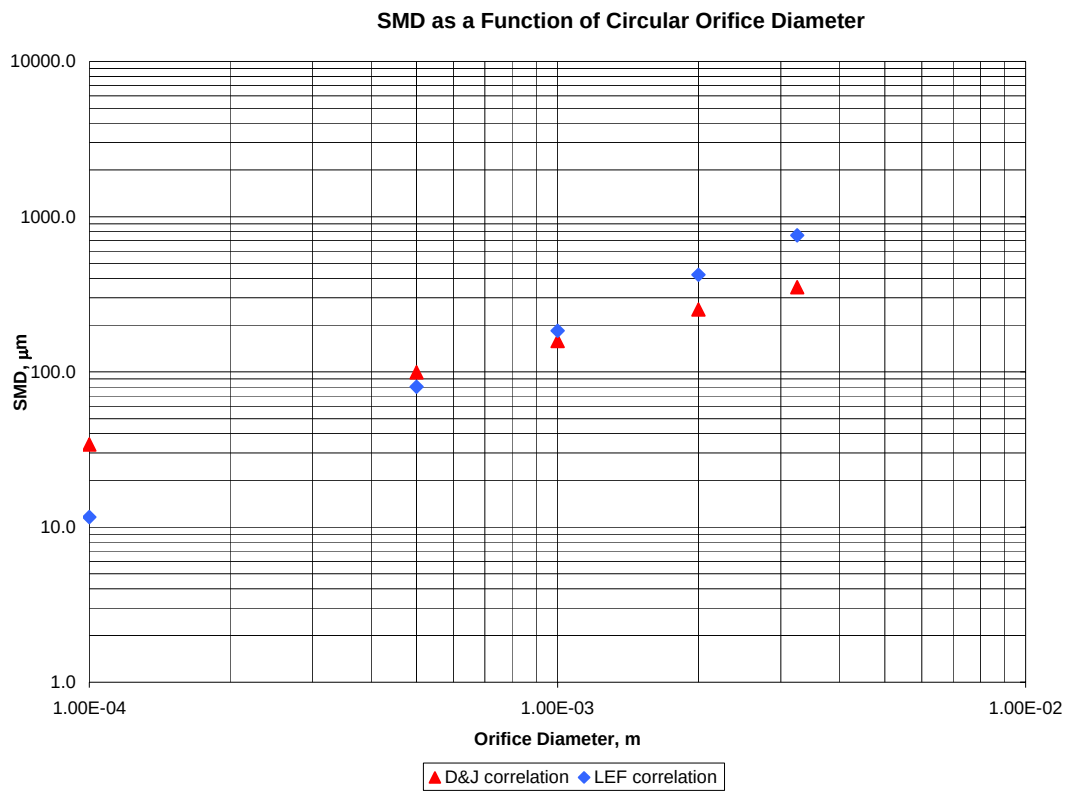

Figure 4 - Comparison of SMD from D&J and LEF Correlations

Figure 5 shows a similar comparison for a 3-in. long breach as a function of breach width. The SMD is predicted in three different ways: (1) using the LEF correlation and the hydraulic diameter of the breach; (2) using the D&J correlation and the approach in RPP-5098 for long, narrow slits; and (3) using the D&J and the area of the breach as suggested by Fauske and Associates (FAI) in CCN 193544. As seen in Figure 5, the predicted SMD is quite sensitive to the correlation and model selected. The SMD predicted by using the approach in RPP-5098 produces the most conservative SMDs. The LEF approach is more conservative than the proposed FAI approach for narrow slits and less conservative than the FAI approach for wider slits.

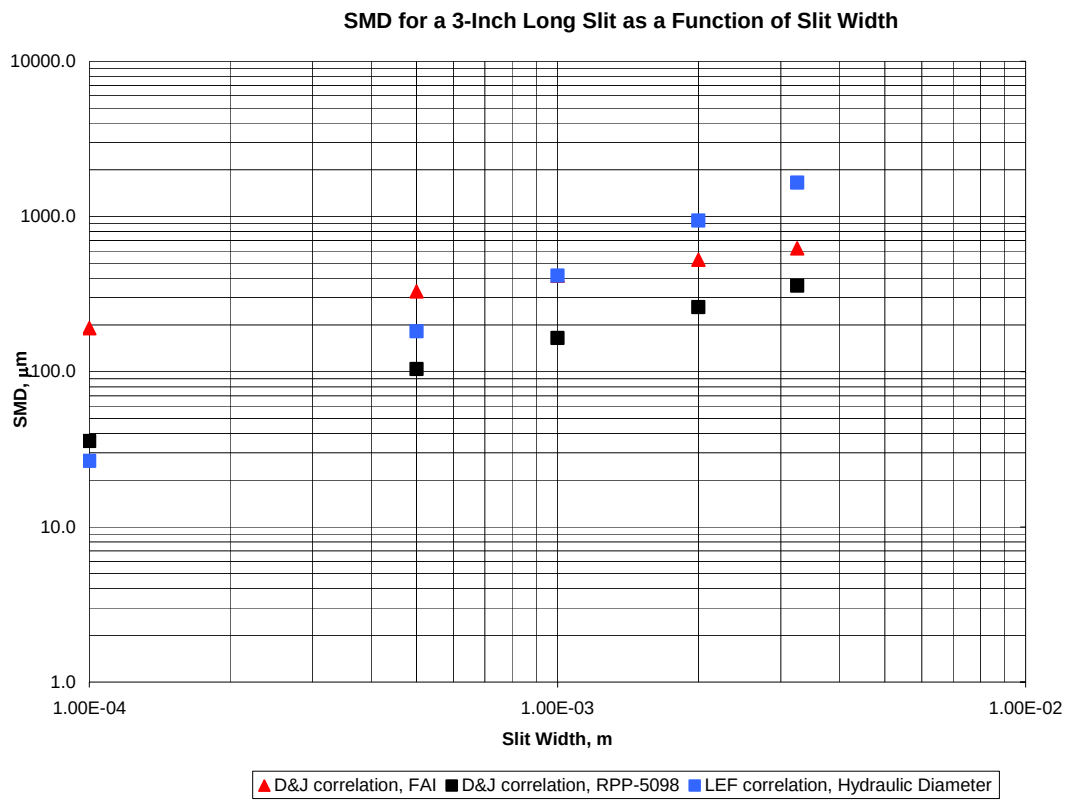

Figure 5 - Comparison of D&J and M&R Correlations using Hydraulic Diameter

Considering the merits of the available correlation, the WTP spray analysis will use the D&J implementation suggested by FAI. The RPP-5098 approach is more conservative than the proposed WTP approach, but as discussed above the RPP-5098 approach is judged to be overly conservative because of its artificial treatment of the slit geometry. The proposed WTP approach is less conservative than the LEF correlation at small breach widths, but this is due to the treatment of orifice diameter in the LEF correlation that is not supported by the M&R data. Also, such small breaches are almost certain to plug for WTP waste types as discussed below.

3.2 Breach Configuration

The maximum dose consequence for a leak or spill would normally result from a scenario that releases the largest inventory of radioactive material. The maximum dose from a spray leak as modeled in RPP-37897 or RPP-5098, however, results from maximizing the efficiency of producing respirable size spray droplets. Two potential shapes are considered for the breach that produces a spray.

One approach to model the spray leak is to consider the leak site as an idealized orifice. The orifice diameter can then be varied over a credible range and the amount of radioactive material in respirable droplets can be maximized (the maximum may occur at either end of the range, or at some intermediate point depending on the nature of the correlation and the diameter range considered.) A second approach is to assume a slit-type breach. As with the idealized orifice leak, the slit width can be optimized in order to maximize the radioactive mass in respirable size droplets for a range of widths. For a given characteristic dimension in the correlations, the ability to produce respirable size droplets is similar whether that dimension is for an idealized orifice diameter or an idealized slit width. However, the slit-

type breach produces higher consequences because the total mass flow is greater. Similarly, a slit-type breach is more conservative than a circular orifice for correlations that predict increasing flow with increasing flow area, as is the case for the FAI treatment of the D&J correlation, For this reason, the WTP analyses will presume a slit-type breach occurs in the pipe being evaluated.

The total mass flow for a slit-type leak depends on the slit length. The NRC specifies a length of one half the pipe diameter and a width equal to one-half of the pipe wall thickness for evaluating the impacts of medium energy line breaks on adjacent equipment. It has also been postulated that a leak could occur at a jumper or connection with a length equal to the circumference of the pipe. This would require the realization of leakage along the entire circumference combined with a width being equal to the optimized width. RPP-37897, Revision 1 (*Waste Transfer Leak Analysis Methodology Description Document*, September 2009) reviewed historic information concerning waste transfer system pipes and jumpers and concluded that it was appropriate to assume a length equal to the pipe diameter with a 3 in. upper limit on length. This assumption was also considered appropriate for a jumper or flange connection leak such as from misalignment or sagging. A spray leak characterized based on a combination of the RPP-37897 and NRC approaches is proposed by WTP, that is:

- one pipe diameter for pipes less than 3 in. in diameter
- 3 in. for pipes from 3 in. to 6 in. in diameter
- one half of the pipe diameter for pipes greater than 6 in. diameter

The optimized width of the breach must also be selected, and must consider physically meaningful constraints and the nature of the SMD correlation to avoid excessive conservatism.

Several approaches have been used on the Hanford site. Simply maximizing the production of fine aerosol without regard to these constraints, as done in RPP-5098 and earlier Hanford spray modeling, can result in very narrow (or small diameter) breaches that are well outside the range of nozzle sizes in the M&R experiments. The increase in total aerosol production with smaller orifice diameters is a result of the formulation of the correlations being used and contradicts the trends observed in the M&R experiments and other spray experiments. Also, continuing to reduce the width of the breach has been judged to produce non-physical results by FAI-01-87 (*Source Term, Downwind Transport and Dispersion of Caustic Solution Aerosol*) because it can result in a leak flow regime that would not produce a significant amount of respirable droplets. The significant solids content in some of the WTP liquid waste being evaluated also creates the difficulty in maintaining good flow through very small breaches. This potential for full or partial plugging is significant and should be considered. It is known that plugging of small orifices will occur independent of the initial particle size distribution. The likely plugging of small openings by WTP wastes is considered in defining the range of widths of interest, but is not otherwise modeled.

RPP-37897 determines the width of the breach by selecting a width such that the value of the Weber Number calculated using the breach width is 60. That is:

$$d = 60 \times \sigma / (\rho_g \times u^2)$$

where σ is the liquid surface tension
ρ_g is the density of air
u is the jet velocity
d is the breadth width
60 is the assumed value of the Weber Number

The Weber Number constraint is based on recommendations in FAI/01-87, *Source Term, Downwind Transport and Dispersion of Caustic Solution Aerosol*. This Weber Number was chosen because it represents the transition to a jet breakup regime where full atomization can occur. This value is consistent with estimates of the critical Weber Number reported in *Fuel Atomization for Spray Modeling*, M. M. Elktob, 1982. Note that the Weber Number definition in RPP-37897 is conservative with respect to the Weber Number definition used by FAI. The FAI definition is based on the hydraulic equivalent diameter which is approximately two times the slit width. It should also be noted that the conditions under which the Lee data were collected produce a Weber Number greater than 60; and that the range of fluids, pressure, and nozzle diameters used to generate the M&R data also support Weber Numbers greater than 60. FAI notes in CCN 193544 that jet break up may occur with the Weber Number as low as 10. Under WTP conditions, such low Weber Numbers require very small breaches (typically less than 0.3 mm). Such small openings are very likely to plug. The K Basins Final Safety Analysis Report (HNF-SD-WM-SAR-062, Revision 10D, A1.3.4.2.1.2) uses a gap width of 0.7 mm based on plugging arguments.

The width criteria used with the LEF correlation are non-conservative when used with the D&J implementation proposed by FAI. For that correlation it would be appropriate to use a slit configuration consistent with the NRC criteria for medium energy line breaks. It is recognized that in a limited number of cases the WTP pump pressures exceed the criteria for medium energy lines (pressures above 200 psi). However, the criteria for high energy line breaks address a double-ended guillotine break or a longitudinal break with surface area equal to the cross-section of the pipe. Such large breaks are judged to be more appropriately treated as line breaks than spray generating scenarios.

WTP will conservatively model the breach configuration as an idealized breach, with a width equal to one half of the pipe wall thickness and length as characterized above. Based on the discussion in section 3.2, the SMD will be determined with the D&J correlation using the FAI implementation. The flow of material through the breach will be determined based on the flow area of the breach, the discharge coefficient, and the maximum differential pressure. Sensitivity studies will be conducted using different correlations and breach widths covering the range of widths used in other Hanford analyses.

3.3 Evaporation Effects

WTP has not identified any general guidance on the effects of evaporation on sprays. Because of this, WTP contracted with BakerRisk to evaluate these effects for the case of a spray at 200 psi through a 0.128 in. diameter hole. The evaluation is documented in the BakerRisk Project 01-02660-002-08 report *Consequences of Sprays from Pipe or Vessel Breaks*. This evaluation considered three different fluids: water, waste with high suspended solids and no sodium hydroxide, and waste with suspended solids and small amounts of sodium hydroxide. The analysis considered a cell with the dimensions and ventilation flow rate of the WTP hot cell (HC). Assumed initial conditions in the cell were 45° C and 5% relative humidity consistent with the project basis of design. The report concludes that, ignoring the hygroscopic nature of NaOH, droplets with initial diameters 100 μm or smaller will evaporate to near dryness while larger drops will retain a substantial fraction of this initial volume. The report also notes that the droplets will not in fact dry completely and that the suspended solids are not expected to become a “truly dry dust”. Finally, the report shows that the evaporation rate will decrease rapidly from an initial peak to roughly two thirds of the peak rate in less than one hour. Evaporation is further reduced as the relative humidity increases to roughly 90% after three hours.

The model used by BakerRisk describes the behavior of essentially aqueous slurries. The results suggest that a very conservative model for such solutions would be to assume that drops with diameters less than 100 μm generated in the first three hours become respirable. Following that period, the atmosphere

approaches saturation and only drops with initial diameters less than 10 μm would be considered respirable. This model could be applicable to aqueous slurries. On WTP such a model would apply to concentrated washed and leached solids being transferred from UFP-VSL-00002A/B, HLP-VSL-00027A/B, or HLP-VSL-00028. These slurries have low concentrations of Na (less than 0.5 molar), large concentrations of solids (about 20% by weight), and exhibit non-Newtonian behavior. It would also apply to piping that carries waste from the PWD vessels. These are essentially aqueous streams with low solids concentrations.

The evaporation model is conservative because the flow rates through the proposed rectangular breaches will be at approximately a factor of 6 larger than the flow through the 0.128 in. diameter orifice modeled by BakerRisk assuring that saturated conditions would be reached in less than three hours. It also neglects changes in the evaporation rate over the initial three hour period. Finally, this model is contrary to the expectations of the external review team as described in section 3.7.1 of this report. The review team was unanimous in expecting that solids suspended in the spray drops would agglomerate and would not disperse as the drop loses moisture. Therefore, the assumption that 100 μm drops become respirable is not recommended.

The BakerRisk model does not account for the hygroscopic nature of NaOH. NaOH solutions do not dry out completely. In fact, solid NaOH in anything other than perfectly dry air absorbs moisture and becomes liquid. NaOH solutions that contain equal masses of water and NaOH do not evaporate additional water. RPP-37897 accounts for evaporation using a model that treats the suspended solids and solution residue as a single drop. The RPP-37897 model assumes that the minimum drop size that could become respirable, D_r, is given by:

$$D_r = 10\ \mu m / [F + 0.1]^{1/3}$$

where F is the volume fraction of suspended solids. The added value of 0.1 presumes that the droplet will lose no more than 90% of its initial volume to evaporation (radius reduce to 46.4% of the initial radius.) This is consistent with the evaluation provided in FAI/01-87.

The RPP-37897 model is based on the physical diameter of the drop rather than the AED because it does not account for drop density. The AED is equivalent to the diameter of a sphere of 1 g/cm^3 that exhibits the same terminal velocity as the drop in question. The terminal velocity is proportional to the density and the square of the diameter and inversely proportional to a shape factor. Accordingly, WTP will define D_r as:

$$D_r = 10\ \mu m / [F + V_{sol}]^{1/3} / [\ \rho_d / \kappa\ ]^{1/2}$$

where ρ_d is the density of the drop (g/cm^3)
V_{sol} is the fraction of the initial volume of solution remaining when the concentration of NaOH reaches 19 M.
κ is the dynamic shape factor. A shape factor of 1.5 will be used consistent with the shape factor used for the human lung model in International Commission on Radiological Protection (ICRP) Publication 66 (p. 49).

3.4 Surface Tension Effects

There is limited information available on the surface tension of liquid waste in WTP. It is known that surface tension increases with increasing NaOH and sodium nitrate concentration in water (Weast, R.C.,

1969). Because most WTP waste contains significant amounts of sodium compounds, it is expected that the actual surface tension for liquid waste will be higher that that of water.

As liquid waste is processed through WTP, the constituents change. There will be waste streams closely resembling water containing suspended solids. More important is the planned use of anti-foam which would generally reduce surface tension by a factor of approximately 2 as discussed below.

In PNNL-17170 (WTP-RPT-156, Revision 0, *Results of Large Scale Testing on Effects of AntiFoam Agent on Gas Retention and Release*, December 2007), the measured surface tension of the liquid fraction of AZ-101 simulant ranged from 54 to 73 dynes/cm compared to a value of 72.8 for pure water at 20ºC. With the addition of anti-foam, the measured surface tension values dropped to a range of 27 to 33 dynes/cm. Based on this information, the minimum surface tension value for the liquid waste in WTP is estimated to be approximately 30 dynes/cm.

There is a general divergence of findings on the dependence of spray droplet size on liquid properties. This is perhaps most evident in the findings related to surface tension. Lower surface tension values are commonly thought to produce smaller droplets. This is illustrated by the Weber Number,

$$We = \rho_g u^2 d/\sigma$$

where ρ_g is the air density
u is the flow velocity of liquid jet exiting an orifice
d is the orifice diameter
σ is the liquid surface tension.

The Weber Number represents a ratio of the disruptive aerodynamic force ($\rho_g u^2 d^2$) to the restoring surface tension force ($d\sigma$), and indicates an increased disruption or breakup as the surface tension decreases.

However, the spray droplet size correlations, based on experimental results, do not consistently reflect this behavior. The correlations for plain-orifice atomizers presented in Lefebvre 1989 range from including a dependence on surface tension that reduces the droplet size as surface tension is reduced, to having no dependence on surface tension, to including a dependence on surface tension that *increases* the droplet size as surface tension is reduced. The 6th Edition of Perry's Handbook suggests accounting for deviation from pure water by correcting the estimated mean droplet size by the factor $(\sigma/\sigma_{water})^{0.5}$. Later editions of Perry's have revised this correction factor to $(\sigma/\sigma_{water})^{0.25}$. This correction factor simply represents averages of values reported by a number of studies, which as discussed can be quite variable.

The widely recognized LEF correlation, developed using a wide range of liquids as discussed earlier, does not include a dependence on surface tension. It is important to note that the correlation does a very good job predicting fuel oil data (from Lee, see WHC-SD-GN-SWD-20007) with a surface tension value of 28 dynes/cm (see Figure 3). This surface tension value is consistent with the minimum expected liquid waste surface tension value of 30 to be used in the WTP evaluations.

The LEF correlation, including its lack of dependence on surface tension, is well documented and discussed in spray droplet literature. With the current information, adjustments to this correlation for surface tension would be speculative. Given the good correlation results for a liquid with low surface tension comparable to WTP waste with anti-foam agents added, no adjustment for surface tension is proposed to the M&R correlation. However, a reduced surface tension of 30 dyne/cm will be used in determining the breach width. Using this reduced surface tension will reduce the breach width. The

reduced breach width will reduce the flow thorough the breach, but it will also reduce the predicted SMD and increase the amount of respirable aerosol produced.

3.5 Parameter Selection

The following table documents the parameters that will be used in the evaluation of spray leaks at WTP.

Parameter	Selection
Solids Content (g/L)	Consistent with applicable stream in 24590-WTP-Z0C-W14T-00020, *Unit Dose Factors for Use in Updated MAR Accident Analyses* (Unit Liter Dose [ULD] calculation)
Na Molarity	Consistent with applicable vessel waste from the ULD calculation, but not to exceed 6 M. A reduced Na concentration is consistent with process expectations and is conservative as higher Na molarity increases viscosity and reduces the potential for evaporation.
Solids Volume Fraction	Derived from solids content using 3 g/cc of solids
Slurry Density	Derived using correlation in 24590-WTP-RPT-ENG-07-007, Rev. 0, *Process Stream Properties*
Viscosity	Derived using correlation in 24590-WTP-RPT-ENG-07-007, Rev. 0, *Process Stream Properties*. This report estimates a minimum viscosity of 10 cP is assumed for the non-Newtonian wastes UFP-VSL-00002A/B, HLP-VSL-00027A/B, and HLP-VSL-00028.
Surface Tension	0.03 N/m if anti-foam agent may be present; 0.0728 N/m otherwise (this is the surface tension of water.)
Pressure	Pump shutoff pressure or maximum allowable pressure.
Jet velocity	Calculated using a discharge coefficient of 0.62 for pipe breaches. Discharge coefficients above 0.6 can only be achieved with specially designed well-contoured long nozzles (see section 5.3.20 of the Civil Engineer's Reference Book, 4th Edition, for example). These special nozzles must have a smooth, properly rounded entrance, sufficient in size so that the contraction from the opposite orifice edges do not interfere with each other, and absence of other structures near the nozzle entrance so that flow entering the nozzle is uniform over the cross section. Such conditions are not available for flow through breaches in pipe walls because of several reasons including short length (pipe wall thickness), non-smooth edges and small size of width, and closeness of pipe walls to the orifice.
Breach Configuration	Length as characterized in section 3.2 Width chosen to produce a Weber Number of 60 as discussed in section 3.2
Diameter used in SMD determination	Breach hydraulic diameter as discussed in section 3.1
Maximum initial drop size of interest	As discussed in section 3.3
Release Duration	8 hours (unless the vessel sending the waste is emptied sooner)

3.6 Other Aerosol Generation

The contributions from splashing and entrainment will also be accounted for. The splashing contribution will be evaluated using equation 3-13 from DOE-HDBK-3010-1994, fluid properties as outlined in section 3.5, and a bounding spill height. The contribution from liquid pool entrainment will be evaluated assuming that the entire spill volume is subject to entrainment for 8 hours.

The volumes of waste involved in the spray scenarios is expected to be quite large - in the range of 10,000 to 30,000 gallons or more; however, no credit is taken for operator or automatic actions that would shut down pumps and terminate the spray release. Such large spills will be detectable either directly by sump indication or indirectly by level instrumentation. These large volumes will not evaporate quickly in the environment created by the accident. Smaller spills that might dry out are not expected to carry enough activity to have larger consequences than the sprays.

3.7 Perspective

Spray leaks at most DOE sites are treated using the ARFxRF recommended in DOE-HDBK-3010-1994 and are assessed to produce consequences that are bounded by the consequences of a large pipe rupture. The methodology outlined above for WTP is somewhat more conservative in its choice of correlation than current practice on the Hanford site. The proposed WTP methodology does not adopt the most conservative choice possible for every parameter. However, it is judged that, on balance, it is appropriately conservative.

The methodology has been reviewed by an independent panel consisting of Office of River Protection consultants Jofu Mishima and Terry Foppe, Dr. Michael Epstein of FAI, and Dr. John Menna of URS. The reviewers provided informal written comments and held a roundtable discussion by telephone. These comments and conversations are summarized below. The sensitivity of the results produced by the proposed methodology to changes in correlation and evaporation modeling is assessed in section 3.7.2.

3.7.1 Review Team Comments

The proposed methodology initially submitted to the review team proposed was to use the LEF correlation as implemented in RPP-37897 (that is defining the width to produce a Weber Number of 60 and using the hydraulic diameter of the slit as the orifice diameter). Evaporation effects for high Na wastes would be treated as in RPP-37897 while the low Na non-Newtonian waste would be treated assuming the drops smaller than 100 μm would become respirable. The review team observations are summarized below. The methodology outlined above addresses the review team observations concerning the initial proposal.

Correlation

- The available correlations are derived from experiments using pure liquids and engineered nozzles. The reviewers noted that extending these correlations to apply to the WTP wastes and postulated breaches is questionable. The consensus of opinion was that the WTP conditions would produce coarser drop distributions than those predicted using one of the available correlations. This judgment is based on the properties of the WTP slurries and their effects on spray breakup. However, a series of experiments designed to reflect the WTP conditions (and conditions at other DOE facilities) would be necessary to fill this gap in the data.

- Dr. Epstein called into question the LEF correlation. The correlation published by Lefebvre 1989 implies that the SMD is a strong function of the orifice diameter. This dependence on orifice diameter is not evident from the M&R data. Also, the strong dependence on orifice diameter is not consistent with the results of FAI experiments with filtered water reported in FAI/06-55*, Measured Drop Size Distributions Within Cold Sprays Emanating from Small Leak Openings* (FAI 2006). These results indicate that the SMD independent of orifice diameter for diameters between 0.3 mm and 2.8 mm and imply that the LEF correlation would over predict the SMD for water sprays at larger orifice diameters. Dr. Epstein suggested using the D&J correlation because its dependence on diameter is more consistent with his observations than the LEF correlation. As noted above, the D&J correlation was derived for flow conditions and fluid types that are not expected at WTP, but is judged to be conservative for the WTP conditions.

Breach Configuration

- The reviewers noted that the literature discussing jet and sheet breakup cites a wide range of Weber Numbers. The Weber Number constraint selected by WTP is consistent with full atomization, but incipient jet/sheet breakup may be possible at a Weber Number as low as 10.
- At the same time, the reviewers noted that the breaches with the very narrow dimensions consistent with the lower Weber Numbers would rapidly plug in the presence of solids.

Evaporation Effects

- All of the reviewers considered the assumption that suspended solids in low sodium slurries do not agglomerate to be extremely conservative. The consensus of opinion was that any suspended solids in the droplet would tend to form clumps and would be unlikely to disintegrate. The assumption implicitly treats the suspended solids as if they were in solution, that is, the mass of solids per unit volume is independent of drop size. It was observed that smaller drops would likely carry less suspended solids than the base fluid and that the presence of large amounts of suspended solids would tend to result in formation of larger drops.
- The conditions used in the BakerRisk evaporation report (e.g., 5% relative humidity) were felt to be overly conservative. The expectation was that more realistic assumptions would reduce the overall amount of evaporation, thus reducing the potential consequence of the spray leak.
- The reviewers observed that the methodology in RPP-37897 equates the physical diameter of a drop to the aerodynamic equivalent diameter and thus overestimates the respirable fraction of the distribution.

Pump Pressure

- The reviewers noted that assuming that the pump runs at shutoff pressure for eight hours is very conservative. The reviewers suggested limiting this condition to two hours and to also consider a condition in which the pump runs at normal pressure for eight hours.

3.7.2 Assessment

This section assesses the sensitivity of spray leak consequences to factors discussed by the independent panel reviewers. The assessment is based on evaluating the consequences from what is believed to be the bounding scenario for WTP. This is a spray leak in a 10 in. diameter UFP loop pipe. These large diameter pipes operate at relatively high pressure (in excess of 200 psi at the pump discharge with a

shutoff pressure of 280 psi). These lines can carry concentrated washed and leached solids from UFP-VSL-00002A/B. The consequences are evaluated as a function of critical drop size for several cases. The critical drop size is the initial drop size that is assumed to become respirable.

Four different correlation options were used:

- The correlation to be used in WTP analyses, that is, the D&J correlation evaluated using the full area of the breach as suggested in CCN 193544 (D&J A).
- The correlation observed by Merrington and Richardson using the hydraulic diameter of the breach as the diameter of the orifice (M&R).
- The correlation reported in Lefebvre 1989 consistent with RPP-37897 - that is using the hydraulic diameter of the breach as the diameter of the orifice (LEF H).
- The D&J correlation evaluated using the hydraulic diameter of the breach as proposed in RPP-5098 (D&J H).

Three different breach widths were evaluated using each correlation:

- The width to be used in WTP analyses, that is, one half of the pipe wall thickness.
- The breach width that produces a Weber Number of 60 consistent with RPP-37897.
- A breach width of 0.5 mm which is more conservative than the 0.7 mm in the K Basins Final Safety Analysis Report (HNF-SD-WM-SAR-062, Revision 10D, A1.3.4.2.1.2) based on plugging considerations.

Each case was treated using two different evaporation models:

- The modified tank farm evaporation to be used in WTP analyses, that is, the initial drop diameter that could become respirable is evaluated considering the Na molarity of the waste, the mass of suspended solids, and the AED of the final drop.
- A more conservative model that assumes that 100 μm droplets of low Na, non-Newtonian waste become respirable during the first three hours of the release.

The input to the assessment is summarized in the table below. These inputs reflect conditions in the UFP loop.

Input Parameters for Consequence Evaluations

Shutoff Pressure (psi)	283
Discharge Pressure (psi)	240
Air Density (kg/m^3)	1.2
Liquid Density (kg/m^3)	1.20E+03
Surface Tension (N/m)	0.03
Viscosity (N-sec/m^2)	1.43E-03
Kinematic Viscosity (m^2/s)	1.19E-06
Pipe Diameter (in)	10.00
Discharge Coefficient	0.62

Breach Width (m)	Varies
Breach Length (m)	1.27E-01
Critical Drop Size (μm)	Per section 3.3
q	2.40
SMD/X	0.65
Release Duration (hr)	8
Public χ/Q (sec/m^3)	2.50E-06
Breathing Rate (m^3/sec)	3.33E-04
Public ULD (rem/L)	1.40E+07

The following summarizes and discusses the results:

Public Consequence (rem) - Modified Tank Farm Evaporation Model				
Width	Correlation			
	D&J A	M&R H	LEF H	D&J H
1/2 Pipe Wall (4.6 mm)	0.1	0.06	0.003	0.4
Weber = 60	0.1	0.06	0.04	1.4
Plugging (0.5 mm)	0.09	0.03	0.2	3

Model selected for WTP analyses

Public Consequence (rem) - 100 μm Evaporation Model				
Width	Correlation			
	D&J A	M&R H	LEF H	D&J H
1/2 Pipe Wall (4.6 mm)	3	5	0.07	11
Weber = 60	3	2	1	50
Plugging (0.5 mm)	3	1	5	80

Correlation

The consequences predicted using the D&J A correlation proposed for WTP or the M&R H correlation increase with increasing breach diameter; the consequences predicted using the LEF H correlation from RPP-37897 or the D&J H implementation from RPP-5098 increase with decreasing breach width. Coincidentally, the maximum predicted consequences using the D&J A correlation, the M&R H correlation, or D&J H correlation are in relatively good agreement - within a factor of 2 - for the range of widths considered. The D&J H predicts significantly larger consequences, but these results have been judged to be artificially high. Note that no case using the proposed WTP evaporation model approaches the DOE-STD-3009-94 public consequence evaluation guideline of 25 rem.

Breach Configuration

The assessment results show that the D&J A and M&R H correlations are not very sensitive to breach width in the range considered. The consequences predicted using the D&J H correlation vary about an order of magnitude over the range considered. The consequences predicted using the LEF H correlation vary about two orders of magnitude over the range of widths considered. As discussed above, the

behavior of the D&J A and M&R H correlations is more consistent with observation than the behavior of the LEF H and D&J H correlations.

Evaporation Effects

The assessment results illustrate the sensitivity of the consequence evaluation to evaporation assumptions. Increasing the critical drop diameter to 100 μm increases the predicted consequences by approximately a factor of 30. However, the predicted consequences do not approach the DOE-STD-3009-94 evaluation guideline except in the case of the D&J H correlation.

Pump Pressure Effects

The results are not very sensitive to pressure. If the pump discharge pressure were used instead of the shutoff pressure, the consequences would be reduced by a factor of 2 or less (the effect depends on the correlation).

Viscosity Effects

Reducing the viscosity of the non-Newtonian wastes from 10 cP to 1 cP to match the viscosity of water increases the predicted consequence by a factor of 2. The consequences predicted using the proposed WTP methodology remain well below 1 rem.

Surface Tension Effects

The results are not very sensitive to surface tension. Increasing the surface tension from 0.03 to 0.072 (which is the surface tension of water) would reduce the predicted consequences by about 20%.

Summary

The WTP methodology predicts a maximum spray consequence of 0.1 rem to the public. The consensus of the technical reviewers is that this result will prove to be very conservative if experiments can be performed using appropriate simulants for the WTP waste rather than the liquids used in the experimental work that forms the basis for published correlations. However, the available correlations do not encompass the WTP conditions so there are uncertainties in the modeling of aerosol production and evaporation effects. The predicted consequences exceed the evaluation guideline of 25 rem only if the initial drop diameter that can become respirable is greater than 100 μm and if the implementation of the D&J correlation in RPP-5098 accurately predicts aerosol production from random pipe breaches. This is very unlikely to be the case in the judgment of the independent review team.

4 Control Strategy

The consequences of the unmitigated accident analyses are compared with a public Evaluation Guideline and worker protection criteria to guide safety-related control selection. 10 CFR 830, Subpart B, and the applicable safe harbor methodology, including DOE-STD-3009-94, establish the framework for the unmitigated analysis and selection of controls. The preferred approach established in DOE-STD-3009-94 is to select controls that prevent accidents over those that mitigate consequences. Engineered features are preferred over administrative controls and passive features are preferred over active controls. The selected control must be able to perform its credited safety function for normal and upset (e.g., accident) conditions. Implementation of preferred control strategies is not always possible or practical and

selection of a strategy that is not the preferred strategy is required to be justified in the safety basis document. The control selection process requires demonstration that each selected control will perform its intended safety function for the accident sequences of concern.

Control selection for the WTP is performed in accordance with 10 CFR 830 Subpart B and the safe harbor methodology in DOE-STD-3009-94 as implemented by Appendices A and B of the Safety Requirements Document (SRD) (24590-WTP-SRD-ESH-01-001-02). The SRD contains requirements for defense-in-depth (e.g., multiple physical barriers) and for selection and functional classification of the controls. Depending on the unmitigated consequences of the spray leak, either safety class (SC) or safety significant (SS) controls could be required. The suite of potential control strategy elements is defined and then the preferred control strategy is selected. The effectiveness of the final control strategy is then demonstrated through the accident analysis which shows that adequate mitigative and/or preventive measures have been selected. In instances where prevention of an event is not practical, the control strategy focuses on a mitigative approach.

As noted in section 3.7.2 above, the expected consequences to the public receptor, when analyzed with the suggested methodology, would be less than 0.1 rem for spray events in PTF. However, uncertainties exist within the methodology that could cause the predicted consequences to approach the 5 rem threshold for challenging the public evaluation guideline, or, in the most conservative bounding case (judged not to be physically plausible), to be greater than 25 rem to the public. Nevertheless, the spray leak uncertainty is not expected to affect the project's primary control selection. In part, the project has chosen an SC mitigation control (C5 boundary and filtered ventilation) that is effective in protecting workers and co-located workers at any of these dose levels (the cells are not occupied during operations that could result in spray leaks). No practical preventive controls were identified that would suffice to preclude spray leak events, particularly leakage at jumper connections, for example. Selection of a mitigating SC control under these circumstances is consistent with applicable DOE guidance.

The primary boundary for high activity process piping subject to possible spray leaks will be designated SS as a major contributor to defense-in-depth in both black cell (BC) and HC areas for those lines with unmitigated doses to the public potentially in the rem range. This commitment will be included in the update of the SLA and PDSA Addendum to incorporate the new spray leak model. This is but one of numerous actions being taken to limit the potential for boundary failure and results in procurement as safety components where appropriate, full penetration welds and 100% volumetric weld inspections in BC areas, and seismic evaluation of piping using seismic category-I methods in BC areas. Hot cells contain all of the jumpers, valves, pumps, and other components judged more vulnerable to leakage. Hot cells can be viewed with cameras to confirm indications of leakage. Should leakage be detected, operating pumps would be secured and systems would be placed in a safe configuration. Ventilation would not be changed from high-efficiency particulate air (HEPA) filters with increasing pressure drop (high loading) to the redundant units without first checking the cells for airborne material to limit loading on the redundant units. Based on these considerations assured early detection is identified as a fallback option that can be installed if necessary in HC duct work, for example, should it prove necessary at the time of DSA submittal. Detection is also an effective means of ensuring environmental qualification of the HEPA filters, should that prove necessary based on the quantity of predicted airborne material. Thus, the sensitivity evaluation of the remaining uncertainties in the chosen spray leak model results in a conclusion that the selected control strategy for PTF remains appropriate.

5 Conclusions

The WTP Project has developed an appropriately conservative approach for evaluating spray releases in response to DNFSB staff concerns and DOE's determination that the spray leak methodology contained in DOE-HDBK-3010-1994 is not appropriate for spray leaks at WTP. Based on the conclusions of the expert review panel, the chosen model meets the standard established in DOE-STD-3009-94, namely that "The intent is that the calculations be based on reasonable conservative estimates of the various input parameters." This approach will be applied to all WTP facilities to determine the unmitigated consequences of spray leaks and guide control selection. For PTF, a control strategy approach for addressing spray leaks where the sprays will be mitigated has been adopted. This control strategy meets the applicable DOE regulations.

Upon DOE acceptance of the spray leak methodology, severity level calculations will be revised to update the consequences of spray leaks and validate the chosen control strategy. Burdens placed on the HEPA filters by the spray leak aerosols will be evaluated to ensure their environmental qualification, adopting any necessary controls for their protection. Changes in PTF consequences will be evaluated through the Integrated Safety Management process to determine if changes to the controls - particularly for defense in depth - are required. Those piping systems that are major contributors to defense in depth considering the range of possible spray leak consequences will be specifically identified as SS in a corresponding update of the PDSA Addendum. Similar evaluations will be performed for High-Level Waste, Low-Activity Waste, and Analytical Laboratory facilities. If necessary, change to the authorization basis will then be made following the established authorization basis change process.

6 References

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