# Technical Peer Review Report

## Report of the Review Panel

# AIRBORNE RELEASE FRACTIONS

ASME International

Institute for Regulatory Science

PREPRINT

# EXECUTIVE SUMMARY

## BACKGROUND

The purpose of this Peer Review was to assess the technical basis and the numerical values for a set of Airborne Release Fractions (ARFs) for use in facility Hazard Categorization.

A U.S. Department of Energy (DOE) *Handbook*, DOE-HDBK-3010-94, provides ARFs values for a wide variety of material forms subjected to different energy sources or accident stresses (accident-specific). The DOE standard on Hazard Categorization and accident analysis techniques known as DOE-STD-1027-92 identifies four ARFs that are not accident-specific, but are bounding for use in Hazard Categorization analysis. DOE-Standard-1027-92 does not address several forms of material encountered by the Office of Environmental Management (EM) at the various DOE sites. For facility Hazard Categorization purposes, DOE-STD-1027-92 allows ARFs other than the four provided to be used if they can be shown to be credible for physical and chemical form and dispersive energy sources across the range of accident scenarios.

In early 1996, DOE attempted to establish and standardize ARF values across the EM complex by developing the *EM Facility Hazard Categorization Standard*, known as SAFT-0029, which included specific ARF values. However, SAFT-0029 was never finalized. The ARF numerical values included in SAFT-0029 are recognized and used by some DOE sites, but other DOE sites have chosen to use DOE-STD-1027-92 ARF values or to develop and use their own values based on their analyses of specific situations.

The significance of an ARF is derived from its contribution to the source term, which in turn is a key parameter for estimating the scope of the potential release spectrum from a facility or an activity and potential downwind consequences.

## DOE HAZARD CATEGORIZATION

DOE has thousands of nuclear facilities ranging from inactive buried waste sites; nuclear weapons materials production facilities (active and inactive); and laboratory facilities, to nuclear reactors. A DOE Standard, DOE-STD-1027, was developed in order to sort these facilities and tailor the nuclear safety requirements to corresponding hazard levels. The DOE-STD-1027 Standard provides guidance for sorting nuclear facilities into four categories: Categories 1 through 3, and Below Category 3 (i.e., Radiological Facilities). Category 1 consists of nuclear reactors above 20 MW and other facilities as may be designated by line management. These have the potential for significant off-site consequences from accidents. Category 2 consists of facilities with nuclear criticality hazards and those with the potential of significant on-site consequences. Category 3 is for those with only significant localized consequences. Below Category 3 are those facilities for which the consequences are expected to be less than for Category 3.

Category 1, 2, and 3 nuclear facilities are subject to the provisions of 10 CFR 830 Subpart B, *Safety Basis Requirements*. These requirements include the development of a Documented Safety Analysis and Technical Safety Requirements, as well as the development and implementation of an Unreviewed Safety Question procedure to deal with situations outside the safety basis. The objective of these provisions is to require a systematic identification of hazards; evaluation of normal, abnormal, and accident conditions; the derivation of hazard controls; and operation of the facility within the safety basis in order to provide adequate protection against hazards associated with operations for the public, workers, and the environment.

The focus of this Peer Review was to assess five alternative ARF values that are proposed for adjusting the Hazard Categorization of facilities that have been initially designated as Hazard Category 2 or 3. However, this adjustment must be on an "unmitigated" basis, i.e. the alternative ARFs may not take credit for reductions in source terms that are dependent on safety features. In most cases the Hazard Categorization involves radioactive waste in drums or other containers, and radionuclides mixed with soils. While the preliminary Hazard Categorization is based only on the inventory of radionuclides within a facility, the final Hazard Categorization of facilities that have been preliminarily designated as Hazard Categories 2 or 3 is based on considerations from hazards analysis.

## AIRBORNE RELEASE FRACTIONS

There are several DOE documents that provide definitions of both Release Fractions and ARFs. However, the definitions for ARFs are conflicting, because different documents use different definitions. Faced with the situation created by the different definitions and interpretations for ARFs provided by the DOE documents, the Review Panel (RP) decided to interpret ARFs in the sense used in the DOE-HDBK-3010-94 *Handbook* because of the handbook's widespread use throughout the DOE Complex.

The ARFs values under Peer Review are intended exclusively for use in Hazard Categorization. The quantity of radioactive material (in g or Ci) released to the air is called the Airborne Source Term (AST). The AST is typically estimated as the product of the following five factors:

AST = MAR x DR x ARF x RF x LPF

where MAR is the Material-at-Risk; DR is the Damage Ratio; ARF is the Airborne Release Fraction (or Airborne Release Rate for continuous release); RF is the Respirable Fraction; and LPF is the Leakpath Factor. The ARF is the coefficient used to estimate the amount of a radioactive material suspended in air as an aerosol, and thus available for transport due to physical stresses resulting from a specific accident. For mechanisms that continuously act to suspend radionuclides (e.g., aerodynamic entrainment/resuspension), a release rate is required to estimate the potential airborne release for postulated accident conditions.

ARFs are the integrated value of Accident Release Rates over a given time period. Generally, Accident Release Rates are based upon measurements over some extended period that encompass most release situations for a particular mechanism. The rates are average rates for the broad spectrum of situations, and the typically meaningful time unit to reflect average conditions is one hour. The ARFs are based primarily upon experimentally-measured values for the specific material (e.g., plutonium, uranium, mixed fission products) or surrogates subjected to the particular type of stress under controlled conditions.

## REASONABLE BOUNDING VALUE

The RP was not provided with a definition of "reasonable bounding values". The DOE-HDBK-3010-94 *Handbook* states that in most cases, the ARFs and Respirable Fractions for conditions bounded by the experimental parameters can be defined to one significant digit. However, based on the measured ARFs provided to the RP, in many cases it appears that the ARFs and Respirable Fractions cannot be defined with a precision better than a few orders of magnitude. Ideally, the "reasonable bounding value" should be the $95^{th}$ (or $99^{th}$) percentile of the measured ARF values. This approach requires fitting a probability density function to the experimental data. However, the DOE-HDBK-3010-94 *Handbook* specifically warns against assignment of a distribution function to limited sets of data. Any assessment of appropriate ARFs needs to consider the constraints that a limited amount of data place on choosing a reasonably conservative point value for the phenomenon being modeled.

## REVIEW CRITERIA AND SUMMARY OF FINDINGS

The RP was provided review criteria, written documentation, and extensive briefings on the technical basis for the ARFs under review, as well as how the ARFs are used at several major sites in the DOE Complex. Listed below are the Review Criteria and the summary of Findings of the RP. The RP also developed additional findings that are discussed in this report.

### Criterion 1

Is an ARF of $5 \times 10^{-4}$ a reasonable bounding value for contaminated combustibles in closed metal containers or drums (generic metal drums or containers)?

### Finding of the RP

Data provided to the RP do not support a reasonable bounding ARF value of $5 \times 10^{-4}$. Evaluation of the available information suggests that the ARF value may be considerably higher. The limitations of the data provided to the RP make it unrealistic to select a reasonable bounding ARF value as an alternative to the DOE-STD-1027-92 value. In order to estimate such bounding values, it is necessary to identify the bounding conditions for contaminated combustibles in closed metal containers or drums and perform experiments specifically designed for this purpose. Such experiments need to be replicated adequately to fit a statistical distribution to these experimentally-measured bounding values. This way it is possible to select the $95^{th}$ percentile as an alternative ARF that could be used for Hazard Categorization. Until such experiments can be completed, the existing DOE-STD-1027-92 Standard can be used.

### Criterion 2

Is an ARF of $1 \times 10^{-4}$ a reasonable bounding value for contaminated combustibles in closed metal containers or drums (Waste Isolation Pilot Plant-certified metal containers or drums)?

### Finding of the RP

Under fire conditions there is no significant difference between the level of containment of Waste Isolation Pilot Plant-certified metal containers or drums referred to in Criterion 2, and the level of containment of generic metal drums or containers referred to in Criterion 1. The conclusions of the RP regarding a reasonably bounding ARF value for Criterion 1 also apply to Criterion 2.

### Criterion 3

Is an ARF of $5 \times 10^{-5}$ a reasonable bounding value for contaminated noncombustible solids/powders/liquids in closed metal containers or drums?

### Finding of the RP

It is not reasonable to assume a single ARF value bounding "noncombustible solids/liquids/powders." An appropriate bounding ARF value for powders is one order of magnitude larger than a bounding ARF value for liquids and two orders of magnitude larger than a bounding ARF value for solids. In order to obtain a reasonable bounding ARF value for mixtures of these materials the following equation may be used:

$$\text{ARF (for the mixture)} = w_{powders} \times 1 \times 10^{-2} + w_{solids} \times 1 \times 10^{-4} + w_{liquids} \times 1 \times 10^{-3}$$

where $w_{powders}$, $w_{solids}$, and $w_{liquids}$ represent the mass fraction of powders, solids, and liquids, respectively. The fractions of powders, solids, and liquids need to be based upon the best available knowledge of the content of the drums.

### Criterion 4

Is an ARF of $1 \times 10^{-6}$ a reasonable bounding value for fixed matrix forms in closed metal containers or drums (e.g., concrete, vitrified materials)?

### Findings of the RP

An ARF of $1 \times 10^{-6}$ cannot be justified as a reasonable bounding value for fixed matrix forms in closed metal containers or drums (e.g., concrete, vitrified materials). Data for the impact of these matrix forms on hard surfaces suggest the appropriate ARF for this stressor is on the order of $2 \times 10^{-5}$. Therefore, an ARF value of $2 \times 10^{-5}$ is a reasonable bounding value for vitrified materials in closed metal containers.

Although the effect of thermal stress on matrix forms of glass is likely to be small, the effect of thermal stress on concrete or cement housed within drums can be important. An ARF based on thermal stress to cement or concrete can reasonably be taken to be the same as the ARF for dispersion of powders from drums. However, this ARF value needs to be used in conjunction with a Material-at-Risk equal to the quantity of material converted from cement to powder. Assuming that: 1) the main stressor is fire; and 2) approximately 1% of the cement is converted to powder, for cement in closed metal containers the resulting ARF for Hazard Categorization is $1 \times 10^{-4}$.

### Criterion 5

Is an ARF of $5 \times 10^{-6}$ a reasonable bounding value for widely-dispersed, low-level contamination attached to an inert material (e.g., contaminated soil, surface contamination)?

### Finding of the RP

This segment includes contaminated soil, surface contamination, and related materials. The RP concludes that the technical judgement provided in the May 1996 version of the *EM Facility Hazard Categorization Standard SAFT-0029* is reasonable. It appears that the respirable ARF (i.e., ARF x RF value) of $5 \times 10^{-6}$ is a reasonable bounding value for widely-dispersed, low-level contamination attached to an inert material.

### Additional Findings of the RP

DOE standards and implementing orders regarding ARFs are not sufficiently specific to result in consistent interpretation (and therefore implementation) among the various elements of the DOE.

A major concern is that some of these criteria combine various materials and container configurations for which a single bounding ARF value is not appropriate.

It may be useful to perform a sensitivity analysis along the following lines: A small set of representative sites could be subjected to Hazard Categorization using the methods of DOE-STD-1027-92. To determine the fraction of these sites that could be recategorized from Hazard Category 3 to "radiological facilities", these same sites could then be subjected to Hazard Categorization using anticipated "reasonable bounding ARF values".

The RP was made aware of an effort initiated by the EM program to demonstrate by analysis that such inactive waste sites are properly categorized as Radiological Sites below Hazard Category 3. The RP understands that this analysis has not been completed.

## RECOMMENDATIONS OF THE RP

Based on a careful assessment of the information presented to the RP and the findings developed in response to the review criteria, the RP provides the following recommendations:

1. The DOE should perform experiments specifically designed to determine a reasonable bounding ARF value for contaminated combustibles stored in closed metal containers or drums. Until such experiments can be completed, the existing DOE-STD-1027-92 Standard should be used.
2. Identical reasonable bounding ARF values should be used for: 1) contaminated combustibles stored in generic closed metal containers or drums; and 2) contaminated combustibles stored in Waste Isolation Pilot Plant-certified metal containers or drums.
3. The following equation should be used to determine a reasonable bounding ARF value for contaminated noncombustible solids/powders/liquids in closed metal containers or drums:

   $$\text{ARF (for mixture)} = w_{powders} \times 1 \times 10^{-2} + w_{solids} \times 1 \times 10^{-4} + w_{liquids} \times 1 \times 10^{-3}$$

   where $w_{powders}$, $w_{solids}$, and $w_{liquids}$ represent the mass fraction of powders, solids, and liquids, respectively. The fractions of powders, solids, and liquids should be based upon the best available knowledge of the content of the drums.
4. For vitrified materials in closed metal containers or drums, an ARF value of $2 \times 10^{-5}$ should be used as a reasonable bounding value.
5. For cement waste forms in closed metal containers or drums, for Hazard Categorization, an ARF of $1 \times 10^{-4}$ should be used as a reasonable bounding value.
6. A respirable ARF (i.e., ARF x RF value) of $5 \times 10^{-6}$ should be used as a reasonable bounding value for widely-dispersed, low-level contamination attached to an inert material.
7. The DOE should complete the effort initiated by the EM program to demonstrate by analysis that many, if not all, inactive waste sites are properly categorized as Radiological Sites below Hazard Category 3.
8. The DOE should perform a cost-benefit analysis comparing the estimated savings that may be realized from an investment in research to develop better "reasonable bounding ARF values". If there is a substantial cost benefit, the DOE should proceed with the implementation of this research program.
9. The U.S. Department of Energy should consolidate all data relating to ARFs into one standard that is internally consistent and is routinely updated, then withdraw all superseded documents.