CONTAINMENT ANALYSIS OF TRUPACT-I*

M. M. Warrant, J. M. Nelsen
Sandia National Laboratories
Albuquerque, NM 87185

S. W. Woolfolk†
Remote Sensing Systems
Albuquerque, NM 87110

ABSTRACT

TRUPACT-I is a packaging which will be used to transport contact-handled transuranic (CH-TRU) wastes generated by defense programs in the U.S. This paper presents the general approach for the containment analysis for TRUPACT-I.

INTRODUCTION

Containment System of TRUPACT-I

The inner door, inner frame, fasteners, filtered vent, inner door seal, and containment liner constitute the containment system of TRUPACT-I. The containment system is continuously vented through four filters in the filtered vent mounted in the inner door frame. This vent prevents the formation of an unacceptable pressure differential (over 5 psig) between the cavity and the package exterior which might develop under operating extremes of altitude variation, environmental temperature range, and contents heat or gas generation. Gas venting from the containment cavity will pass through the filter elements, thereby trapping airborne activity which would be present in the form of fine particulates. No gaseous radionuclides will be shipped in TRUPACT-I.

Waste Contents

TRUPACT-I has been developed for the transport of contact-handled transuranic (CH-TRU) wastes among generating, storage, or repository sites. The CH-TRU wastes contain primarily plutonium isotopes and daughter products and will be packaged in Type A drums or boxes. The waste forms and their packaging significantly limit the dispersibility of the particles attached to or mixed with the wastes.

The allowable activity in a TRUPACT-I shipment is determined by a number of factors including isotopic mixture, dose rate, criticality safety, heat generation, and release of activity from containment. For normal transport,

TRUPACT-I must not release any of its radioactive contents, as demonstrated, to a sensitivity of 10^{-6} A_2 per hour. For hypothetical accident conditions, TRUPACT-I must not release more than an A_2 quantity in one week [1].

*This work supported by the U. S. Department of Energy under Contract No. DE-AC04-76DP00789

†Currently with Science Applications International Corp., Las Vegas, Nevada 89109

SOURCE TERM FOR RELEASE OF ACTIVITY

Aerosolized particles which have radioactive material associated with them are conservatively assumed to be released from 3 percent of the Type A containers into the interior of TRUPACT-I during normal transport and 100 percent during a hypothetical accident. The aerosol may then be released from TRUPACT-I to the environment through the filtered vent or hypothetical leak holes. The analysis is based on a shipment of 36 drums.

The source term is determined by the fraction of activity present in the Type A containers that escapes into the TRUPACT-I cavity and is available for release, the maximum activity in a TRUPACT-I shipment discussed above, and the particle size distribution.

Activity Release Fractions

The assumptions that determine the fraction of activity that is available for release from TRUPACT-I are summarized in Table I. (Explanations of how the values in Table I were chosen are presented in [2]. The total release fraction RF is the product of the three terms:

$$RF = WCF \times LC \times AC.$$

Particle Size Distribution

A conservative particle size distribution for airborne wastes is used as the basis for the release source term. This distribution contains a large activity fraction of particles of size 0.1-0.3 micron or smaller. Particles smaller than 0.1 micron are assumed to have agglomerated to 0.1 micron.

MODEL FOR RELEASE OF ACTIVITY FROM TRUPACT-I

The seals and the filters are the only paths for release of activity because the remaining components of the containment system will be verified to be leaktight following construction and are not susceptible to mechanical or thermal damage during normal transport or the hypothetical accident. The analysis conservatively calculates release from the filtered vent assuming that all air flow occurs through the

TABLE I

Release Fraction Assumptions

Type of Release Fraction	Value for Normal Conditions	Value for Hypothetical Accident Conditions
Fraction of waste containers that fail (WCF)	0.03	1.0
Fraction of contents within the failed containerthat leak to the TRUPACT-I cavity(LC)	0.0001	0.10
Fraction of leaked contents that are aerosolized and available for release (AC)	0.01	0.01

filtered vent, subtracts the activity released from the appropriate regulatory release limit, and estimates the maximum size of an equivalent leak hole and the corresponding leakage rate that would permit the remaining allowable activity to be released.

The driving mechanism for the release is a pressure differential between the interior and exterior of the package. While the filtered vent will prevent a significant pressure differential from occurring, the analysis conservatively assumes a pressure differential of 0.30 atm (4.4 psig), which was established by considering a truck-borne TRUPACT-I traveling up a 4 percent grade at 45 mph to make an elevation change of 9,500 feet starting from sea level in one hour.

The pressure differential will result in gases passing through the filtered vent or through leak holes from the TRUPACT-I cavity to the exterior of the package. The activity in the TRUPACT-I cavity that is available for release is assumed to be carried by the cavity gases and may be filtered from the air stream by the filtered vent or by the leak holes.

Model for Release of Activity Through the Filtered Vent

The model for release of activity through the filtered vent conservatively assumes that the pressure differential of 0.30 atm is completely relieved during the one-hour or one-week time period for evaluation thereby allowing 30 percent of the air in the containment cavity to pass through the filters. The release rate through the filtered vent ($R_{F/V}$) is given by

$$R_{F/V} = (0.30/t) * TA * RF * \sum_{i}^{N} [MF(i) * EFF(i)], \quad (1)$$

where TA = total initial activity in TRUPACT-I (Ci),
RF = total release fraction as discussed above,
MF(i) = mass (activity) fraction of particles having size (i),
EFF(i) = filter penetration efficiency of the filtered vent for particles having size (i),
t = time period for evaluation (one hour or one week).

Model for Release of Activity Through Hypothetical Leak Holes

The rate at which activity is released from the cavity is given by

$$\frac{dCAR_i(t)}{dt} = FTMR(t) * TA(t) * RF * \sum_{i=1}^{N} [MF(i) * EFF(i)] \quad (2)$$

$CAR_i(t)$ = cumulative activity released from TRUPACT-I at time t for particle size i (Ci),
FTMR(t) = fraction of the total air mass released in a time increment Δt at time t,
TA(t) = activity in TRUPACT-I at time t (Ci),
EFF(i) = filter penetration efficiency of the leak hole for particles having size (i).

TA(t) is reduced from TA(t=0) by the activity that has already leaked out of the containment cavity and by the activity carried by larger particles that have settled out and are no longer aerosolized (considered only for the hypothetical accident case). Particle settling velocities are calculated using Stokes Law.

The fraction of the total air mass released in a time increment Δt at time t, FTMR(t), is given by

$$FTMR(t) = \frac{P(t-\Delta t) - P(t)}{P(t-\Delta t)} \quad (3)$$

The pressure at time t, P(t), is given by

$$P(t) = \frac{P(t-\Delta t) * V_{TRUPACT}}{(V_{TRUPACT} + Q\Delta t)} \quad (4)$$

where $V_{TRUPACT}$ = internal void volume of TRUPACT-I (cm^3),
Q = volume flow rate from TRUPACT-I between times ($t - \Delta t$) and t (atm - cm^3/s).

The MF(i) are obtained from the particle size distribution and the EFF(i) are obtained from the decontamination factor for the leak hole (DF = 1/EFF), calculated from the following equation[3]:

$$\log_{10} DF_1(t) = 0.0867 + (203.2) * \left(\frac{\mu d_1 L^2}{\Delta P D^4}\right) \quad (5)$$

where μ = absolute viscosity of air (dyne - s/cm^2),
d_i = diffusion coefficient for particle size i (cm^2/s),
L = leak hole length (cm),
P = pressure drop across the leak path (dyne/cm^2),
D = leak hole diameter (cm).

The flow path's filtration efficiency increases with increasing particle size, decreasing leak hole diameter, and increasing number of turns in the flow path.

Gas leakage through small holes for laminar, transitional, and molecular flow modes is estimated by the following equation [4]:

$$Q = 3810 * \frac{D^3}{L} [323 \frac{D}{\mu} * (P^2_{TRUPACT} - P^2_{ambient}) + \sqrt{\frac{T}{M}} (P_{TRUPACT} - P_{ambient})] \quad (6)$$

where T = gas temperature (K),
M = gas molecular weight (amu),
and the other variables are as described above.

Gas leakage through small holes for turbulent flow is estimated using the following equation [5]:

$$Q = P_{TRUPACT} * \left(\frac{P_{ambient}}{P_{TRUPACT}}\right)^{1/\gamma} * \frac{\pi D^2}{4} * \sqrt{\frac{2\gamma RT}{(\gamma-1)M}} * \left[1 - \frac{P_{ambient}}{P_{TRUPACT}}^{(\gamma-1)/\gamma}\right]^{1/2} \quad (7)$$

where R = ideal gas constant,
γ = ratio of specific heats for air,
and all other variables are as defined above.

Rather than analyzing the leakage through many small individual leak paths, the analysis conservatively considers one equivalent-size hole and a straight leakage path.

Figure 1 shows a simplified flowchart for the computer program CONLEAK[2], which calculates the activity released through leak holes of different sizes for normal or hypothetical accident conditions. The program also prints the total air leakage from the hole during the release evaluation period. Figure 2 presents a plot of the calculated activity released versus leak path diameter for hypothetical accident conditions for several different values of TA.

REFERENCES

1. 10CFR71, "Rule to Achieve Compatibility with the Transport Regulations of the International Atomic Energy Agency (IAEA), Final Rule"; Federal Register 48; August 5, 1983; pp 35600-27; corrected Federal Register 48; August 24, 1983; pp 38449-50.

2. S. W. WOOLFOLK, J. M. NELSEN, and M. M. WARRANT, "Parameter Sensitivity Analysis of the Leakage Calculations for the TRUPACT-I Containment System," SAND83-0326 (1986).

3. L. C. SCHWENDIMAN, "Supporting Information for the Estimation of Plutonium Oxide Leak Rates through Very Small Apertures," Pacific Northwest Laboratory Report PNL-2198 (1977).

4. "American National Standard for Leakage Tests on Packages for Shipment of Radioactive Materials," ANSI N14.5-1977, American National Standards Institute, Inc., New York, New York.

5. B. P. KIRCHNER and P. T. BLUM, "Importance of Leak Flow Mode Assumptions for Interpretation of Package Leaktightness Tests and Influence of Test Conditions on Conclusions," Proc. Sixth International Symposium on Packaging and Transportation of Radioactive Materials (PATRAM 80), Berlin (West), November 10-14, (1980).

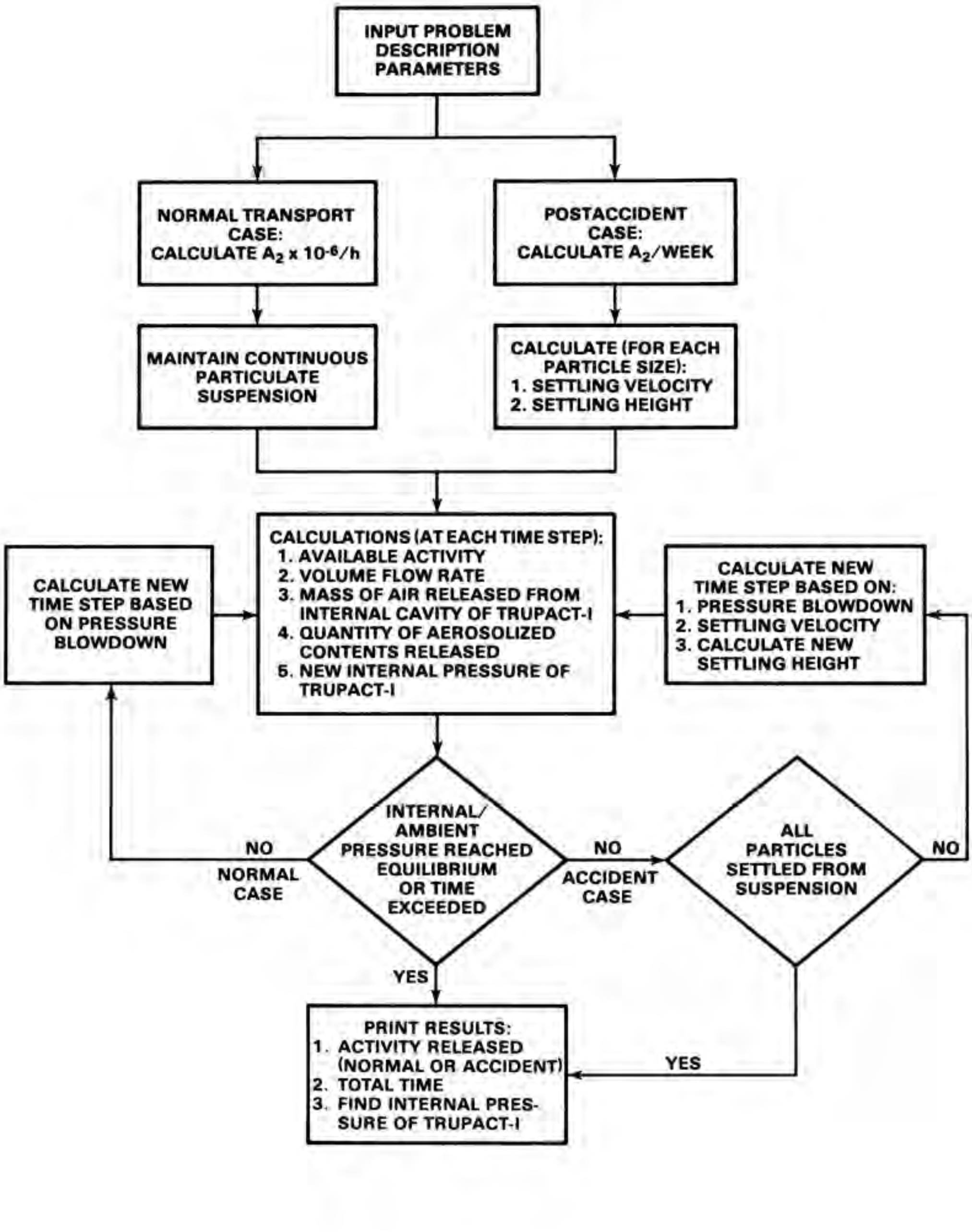

Fig. 1. Simplified Flowchart of Activity Release Calculated for a Specified Leak Hole Size.

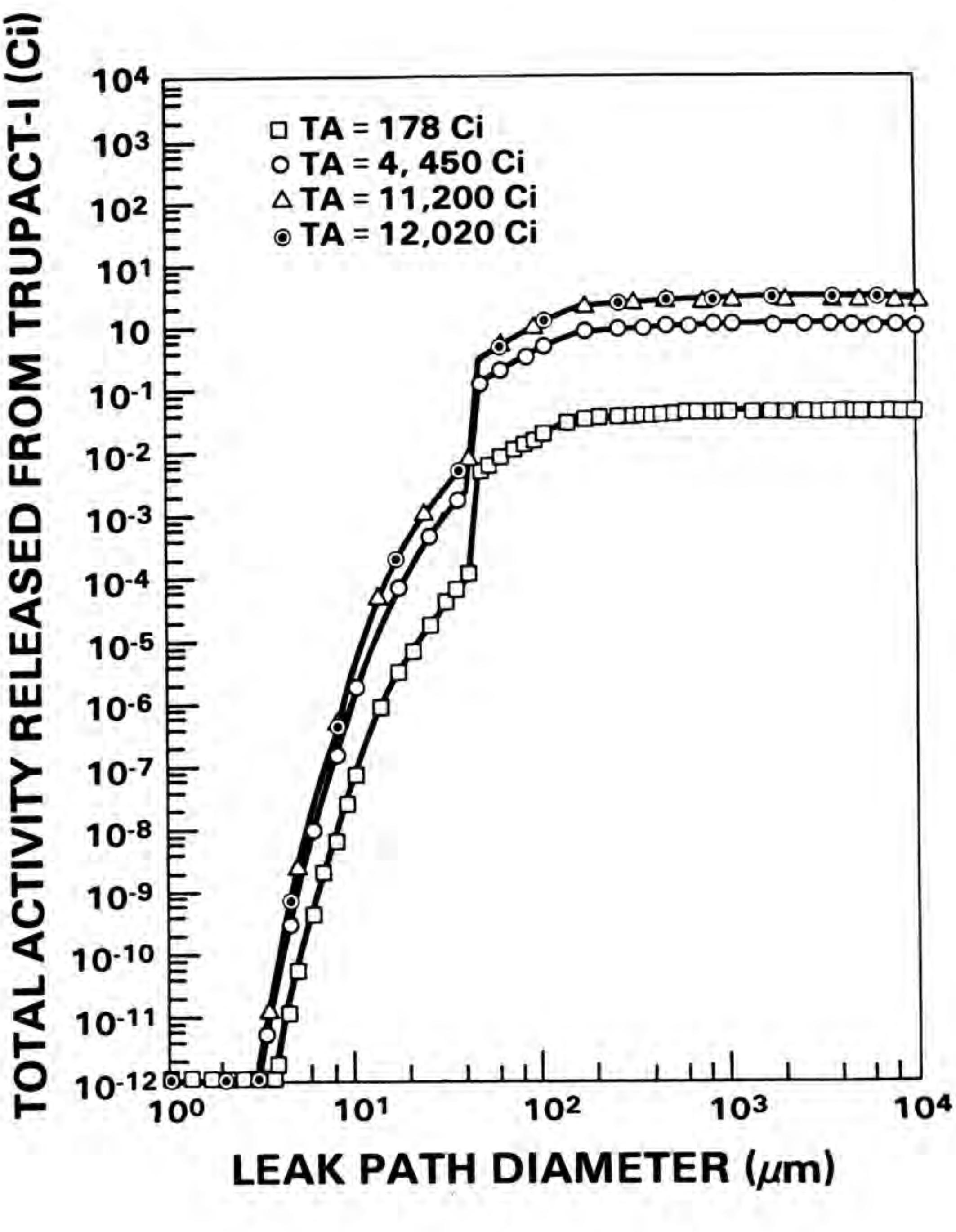

Fig. 2. TRUPACT-I Activity Release During One Week Versus Leak Path Diameters for Hypothetical Accident Conditions.