Distribution:
WM File 109.1
WMEG
NMSS
REBrowning
MJBell
LHBarrett
TCJohnson
EAWick
HJMiller
JOBunting
LBHigginbotham

MAR 7 1985

109.1/EAW/03/0785/

- 1 -

Dr. Thomas O. Hunter, Manager
NNWSI Projects Department 6310
Sandia National Laboratories
Albuquerque, NM 87185

Dear Dr. Hunter:

The paper that I presented at the Workshop on the Source Term for Radionuclide Migration From High-Level Waste or Spent Fuel Under Realistic Repository Conditions in Albuquerque November 13-15, 1984 is enclosed.

Sincerely,

Original signed by

Everett A. Wick
Engineering Branch
Division of Waste Management

Enclosure:
As stated

WM Record File
109.1

WM Project 1
Docket No.
PDR ✓
LPDR

Distribution:

(Return to WM, 623-SS)

8506050757 850507
PDR WASTE
WM-1 PDR

OFC	:WMEG	:WMEG	:	:	:	:	:
NAME	:EAWick:gh	:TCJohnson	:	:	:	:	:
DATE	:03/07/85	:03/07/85	:	:	:	:	:

HOW RELIABLE DOES THE WASTE PACKAGE CONTAINMENT HAVE TO BE?

Everett A. Wick
U.S. Nuclear Regulatory Commission
Washington, DC 20555

ABSTRACT

The final rule (10 CFR Part 60) for Disposal of High-Level Radioactive Wastes in Geologic Repositories specifies that the engineered barrier system shall be designed so that, assuming anticipated processes and events, containment of high-level radioactive wastes (HLW) will be substantially complete during the period when radiation and thermal conditions in the engineered barrier system are dominated by fission product decay. This requirement leads to the Nuclear Regulatory Commission (NRC) being asked the following questions: What is meant by "substantially complete"? How reliable does waste package containment have to be? How many waste packages can fail? Although the NRC has not defined quantitatively the term "substantially complete", a numerical concept for acceptable release during the containment period is discussed. The number of containment failures that could be tolerated under the rule would depend upon the acceptable release, the time at which failure occurs and the rate of release from a failed package.

8504030512 S

1.0 INTRODUCTION

Under the Energy Reorganization Act of 1974 the Nuclear Regulatory Commission (NRC) has responsibility to license the disposal of high-level nuclear waste (HLW) by the Department of Energy (DOE) [1]. In addition, the Nuclear Waste Policy Act of 1982 states that it is federal responsibility to provide for HLW and spent fuel requiring permanent disposal [2]. Thus, DOE has responsibility for disposal of HLW and spent fuel and NRC has responsibility to license the DOE repository or repositories.

The regulation for Disposal of High-Level Radioactive Wastes in Geologic Repositories, 10 CFR Part 60, specifies [3] that the engineered barrier system shall be designed so that, assuming anticipated processes and events, containment of HLW (within the waste packages) will be substantially complete during the period when radiation and thermal conditions in the engineered barrier system are dominated by fission product decay (300 to 1000 years).

The regulation also specifies [3] that the release rate of any radionuclide from the engineered barrier system following the containment period shall not exceed one part in 100,000 per year of the inventory of that radionuclide calculated to be present at 1000 years following permanent closure, or such other fraction of the inventory as may be approved or specified by the Commission.

The requirement for substantially complete containment within the waste packages leads to the NRC being asked the following questions:

1. What is "substantially complete"?

2. How reliable does the waste package containment have to be?

2.0 DISCUSSION

2.1 WHAT IS "SUBSTANTIALLY COMPLETE?"

NRC has not defined quantitatively the term "substantially complete containment". DOE, however, could consider the following or other appropriate approaches:

Limit the release of radionuclides from the waste packages during the containment period to the same number of curies that is permitted annually from the engineered barrier system following the containment period.

2.2 HOW RELIABLE DOES WASTE PACKAGE CONTAINMENT HAVE TO BE?

If the term "substantially complete" were interpreted quantitatively as described above, the level of reliability required for waste package containment could be defined as follows:

Waste package containment should be sufficiently reliable so that radionuclide releases during the containment period do not exceed 1×10^{-5} per year of the radionuclide inventory calculated to be present 1000 years after permanent closure.

The reliability of the waste package that would be required during the containment period would be such that the calculated cumulative number of failures during the containment period and the release calculated to result from them would not exceed the quantity stated above.

A basis for calculating the number of waste package failures that could be tolerated during the containment period is presented in Section 2.3.

2.3 HOW MANY WASTE PACKAGES CAN FAIL?

The number of waste packages that can fail during the containment period without exceeding the release criterion depends upon:

1. The estimated fractional rate of release from a failed package.

2. When failure occurs.

Although the number of curies that may be released annually during the containment period is constant (1×10^{-5} x 1000 year inventory), the acceptable fractional annual release will increase with time to failure. It may be calculated as follows:

$$\text{Acceptable Fractional Annual Release} = 1 \times 10^{-5} \times \frac{\text{1000 yr. inventory (curies)}}{\text{current inventory (curies)}}$$

For example, the total activity in curies of inventory in one BWR spent fuel rod varies with time after discharge as shown below [4]:

10 years	300 years	1000 years
960	11	4.6

This example is also true on a relative basis of the total inventory of spent fuel waste packages in the repository at 10, 300,

and 1000 years. Therefore, the permissible annual release at 10 years after emplacement (in this example, the time between discharge and permanent closure was taken as zero, although we know this will not be the case) may be calculated as a fraction of the total radionuclide inventory at that time, e.g.,

$$\frac{4.6 \text{ curies}}{960 \text{ curies}} \times 1 \times 10^{-5} \times \text{inventory 10 years after permanent closure}$$

$$= 4.8 \times 10^{-8} \text{ of current (10 yr.) inventory.}$$

Once the acceptable annual fractional release is known and the annual release from a failed waste package is estimated, an acceptable number of waste package failures may be calculated.

Assumptions:

1. The repository will contain 70,000 waste packages.
2. A failed waste package will release 1×10^{-5} per year of the inventory in the package.

Thus, the fractional annual rate of radionuclide release from one failed waste package would be:

$$\frac{1 \times 10^{-5}/\text{yr.} \times \frac{\text{number of curies}}{\text{package}}}{\frac{\text{number of curies}}{\text{package}} \times 70{,}000 \text{ packages}} = 1.43 \times 10^{-10}/\text{yr.}$$

Therefore, the number of waste package failures that could be tolerated 10 years after permanent closure in a repository containing 70,000 wastes packages is:

$$\frac{\text{acceptable fractional release } (4.8 \times 10^{-8}/\text{yr})}{\text{fractional release per package } (1.43 \times 10^{-10}/\text{yr})} = 335 \text{ packages}$$

Therefore, 335 package failures could be tolerated 10 years after permanent closure if annual fractional release of a failed package does not exceed 1×10^{-5} of the inventory in the package. The release rate from a failed package at 10 years, however, may be much higher than 1×10^{-5} per year because the temperature will be relatively high. For example, if the leak rate were a hundred times higher only three failed packages could be tolerated; if it were a thousand times higher, none could be tolerated.

3.0 CONCLUSIONS

1. NRC has not defined quantitatively the term "substantially complete containment." One of the approaches that is being considered, however, is to allow a radionuclide release rate

during the containment period that does not exceed the absolute quantities permitted in the post-containment period, i.e., 1 x 10^{-5} per year of the radionuclide inventory of the repository 1000 years after permanent closure. Since the radionuclide inventory is larger during the containment period, the fractional release at the time of containment failure must be correspondingly smaller.

2. If such an approach were allowed, the reliability of the waste package containment should be such that the calculated cumulative number of failures during the containment period and the releases calculated to result from them would not exceed the quantity stated above.

3. The cumulative number of waste package failures that could be tolerated during the containment period would depend upon when failure occurred and the rate of radionuclide release from a failed package.

REFERENCES

1. Public Law 93-438, Energy Reorganization Act of 1974, Sec. 202, 42 U.S.C. 5842.

2. Public Law 97-425, The Nuclear Waste Policy Act of 1982, 96 stat. 2207, Sec. 111(a).

3. 10 CFR 60, "Disposal of High-Level Radioactive Wastes in Geologic Repositories," Subpart E, Technical Criteria, paragraph 60.113.

4. NUREG/CR-2482, Vol. 7, "Review of DOE Waste Package Program, Subtask 1.1 - National Waste Package Program, Draft Biannual Report", Evelyn Gause, Peter Soo, September 1984, pp. 31 (adapted from ORIGEN-2 calculated values presented in ORNL/TM-6008, 1977).