C-65

[redacted] ~~UNDOCUMENTED~~ UNCLASSIFIED

(CLASSIFICATION)

HW--76109

DE93 002084



# GENERAL ELECTRIC

HANFORD ATOMIC PRODUCTS OPERATION – RICHLAND, WASHINGTON

DATE 1-4-63

[redacted]

TITLE

THE CONSEQUENCES OF ACCIDENTAL RELEASES DURING RAIL SHIPMENTS OF RADIOACTIVE STRONTIUM

[X] [redacted]

AUTHOR

E.C. WATSON
R.L. JUNKINS
J.J. FUQUAY
L.L. ZAHN

ISSUING FILE [redacted] JUN 2 1966 [redacted] INC. [redacted] 271-[redacted] Bldg., 200 West

[redacted]

| ROUTE TO: | PAYROLL NO. | LOCATION | FILES ROUTE DATE | SIGNATURE AND DATE |
|---|---|---|---|---|
| ~~R.R. McMurray~~ | | 202-A | | |
| ~~SG Smaler~~ | | | | |
| ~~SG Smaler~~ | | | | |
| ~~W.M. HARTY~~ | | 2... | | 1/19 |
| ~~Smaler~~ | | | | 4/1/66 |
| ~~R.E. Smith~~ | ~~60 76127~~ | ~~271-B~~ | | ~~RES 5-25-66~~ |

REFERENCE COPY

BMW

Received by OSTI

MASTER

54-3000-052 (7-59) A.E.C.-G.E.-RICHLAND, WASH.

[redacted] UNCLASSIFIED

(CLASSIFICATION)

[redacted]
(CLASSIFICATION)

**GENERAL ELECTRIC** UNCLASSIFIED

HANFORD ATOMIC PRODUCTS OPERATION – RICHLAND, WASHINGTON

DOCUMENT NO. HW-76109

DATE 1-4-63 COPY NO. 55

ISSUING FILE

RECEIVED JAN 3 1963 P. R. McMURRAY

TITLE

# THE CONSEQUENCES OF ACCIDENTAL RELEASES DURING RAIL SHIPMENTS OF RADIOACTIVE STRONTIUM


AUTHOR

E. C. Watson, R. L. Junkins,
J. J. Fuquay, and L. L. Zahn


DISTRIBUTION

| NAME | BUILDING | AREA |
|---|---|---|
| 1 - 3. - AEC-ROO Attn: JE Travis | 703 | 700 |
| 4 - 25. - AEC-ROO Attn: JE Goodwin | 703 | 700 |
| 26. - JW Healy-GE/Schenectady | | |
| 27- 29. - RE Richards - GE/APED | | |
| 30. - W. J. Bair | 144-F | 100-F |
| 31. - C. A. Bennett | 325 | 300 |
| 32. - L. K. Bustad | 141-M | 100-F |
| 33. - J. J. Davis | 146-FR | 100-F |
| 34. - J. B. Fecht | 271-T | 200-W |
| 35. - R. F. Foster | 3746 | 300 |
| 36. - W. S. Frank | 2704-E | 200-E |
| 37.-39. - J. J. Fuquay | 2704-W | 200-W |
| 40. - R. K. Hilliard | 325 | 300 |
| 41. - F. P. Hungate | 108-F | 100-F |
| 42. - E. R. Irish | 329 | 300 |
| 43. - J. L. Jaech | 325 | 300 |
| 44. - W. E. Johnson | 703 | 700 |
| 45. - B. F. Judson | 202-A | 200-E |
| 46- 50. - R. L. Junkins | 309 | 300 |
| 51. - A. R. Keene | 3746 | 300 |
| 52. - H. A. Kornberg | 108-F | 100-F |
| 53. - C. E. Linderoth | 325 | 300 |
| 54. - D. W. McLenegan | 761 | 700 |
| 55. - P. R. McMurray | 202-A | 200-E |
| 56. - R. L. Moore | 325 | 300 |
| 57. - R. E. Nakatani | 146-FR | 100-F |
| 58. - J. M. Nielsen | 325 | 300 |
| 59. - H. M. Parker | 3760 | 300 |
| 60. - A. M. Platt | 326 | 300 |
| 61. - E. G. Pierick | 2704-W | 200-W |
| 62. - W. H. Reas | 326 | 300 |
| 63. - D. L. Reid | 325 | 300 |
| 64. - P. H. Reinker | 2704-E | 200-E |
| 65. - H. P. Shaw | 2704-E | 200-E |
| 66. - C. L. Simpson | 622 | |
| 67. - C. W. Smith | 271-T | 200-W |
| 68. - R. E. Smith | 2704-E | 200-E |
| 69. - R. C. Thompson | 108-F | 100-F |
| 70. - R. E. Tomlinson | 2704-W | 200-W |
| 71. - J. H. Warren | 2704-E | 200-E |
| 72. -80. - E. C. Watson | 3701-L | 300 |
| 81. - F. W. Woodfield | 703 | 700 |
| 82. - W. K. Woods | 309 | 300 |
| 83. -85. - L. L. Zahn | 271-T | 200-W |
| 86. - 300 Files | 3760 | 300 |
| 87. - Record Center | | 700 |

CLASSIFICATION CANCELLED
Per Doc May 1973
By B Jones 3-20-74

This m[redacted] contai[redacted]ation [redacted]g the [redacted]nal defe[redacted] the U[redacted]es w[redacted] the me[redacted]e es- pi[redacted]ge law[redacted] 18, U[redacted] 70[redacted] ansmiss[redacted] revela[redacted] which [redacted] to an unauth[redacted]ed perso[redacted]rohi[redacted] law.

SPECIAL RE-REVIEW
FINAL DETERMINATION
DECLASSIFICATION CONFIRMED
BY [signature] DATE 10-19-81
BY A O Baker DATE 11-3-81

| ROUTE TO | PAYROLL NO. | LOCATION | FILES ROUTE DATE | SIGNATURE AND DATE |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |

[redacted]
(CLASSIFICATION)

54-3000-030 (1 -61)
AEC-GE RICHLAND, WASH.

TO BE USED ON UNCLASSIFIED AND OFFICIAL USE ONLY DOCUMENTS.

[redacted]

[redacted] UNCLASSIFIED HW-76109

# THE CONSEQUENCES OF ACCIDENTAL RELEASES DURING RAIL SHIPMENTS OF RADIOACTIVE STRONTIUM

by


E. C. Watson, R. L. Junkins,
J. J. Fuquay, and L. L. Zahn

HANFORD LABORATORIES and
CHEMICAL PROCESSING DEPARTMENT


Classific[redacted] Canc[redacted] (Change t[redacted]
CON[redacted]NDO[redacted] 6-6-[redacted])
By [redacted]thori[redacted]
[redacted]
By [redacted] 12-63

January 4, 1963

HANFORD ATOMIC PRODUCTS OPERATION
RICHLAND, WASHINGTON

## NOTICE!



[redacted]

54-3000-366 (9-59) AEC-GE RICHLAND, WASH.

[redacted]

[redacted]



## INTRODUCTION

Large quantities of radiostrontium in the form of strontium carbonate have been shipped from HAPO in the HAPO-II shipping systems. Modifications have recently been completed to equip the two HAPO-I systems[1] for shipment of strontium. This report updates previous hazards evaluations[2] of such shipments, to account for the greater strontium inventory of the HAPO-I system.

## SUMMARY

The product container, cask and cask container combination, known as HAPO-IB, will withstand severe conditions of impact, fire, and loss of heat dissipation. Nevertheless, it is recognized that the integrity of the system could be breached under even more severe conditions. Recognizing that such conditions could occur, releasing a portion of the contents to the environment, estimates were made of the hazards involved.

Under very probable atmospheric conditions of release of 6000 curies of Sr-90 and associated Sr-89 could lead to a significantly contaminated area of up to 2000 square miles. During periods of greater atmospheric variability, the area affected could be much less; however, changes in quantity released, location, or conditions of the accident could produce changes of comparable magnitude.

## NATURE OF THE SHIPMENT AND CASK

The HAPO-IB casks were designed to ship fission product fractions of various compositions containing Sr-90, or alternately Ce-144, as the principal radioactive constituent. The materials will be shipped as a stabilized cerium or strontium salt. While the casks are capable of shipping either the cerium-rare earth product or the Sr-90 product, it is not planned to use the casks interchangeably.

The specifications of the customer indicate that the Sr-89 to Sr-90 activity ratio should be $<1$, and that other radionuclides should not exceed the following specifications in terms of c/g of Sr-90:Ce-144 0.15, Zr-95:Nb-95, Ru-106 and Cs-137 each $<0.03$. With the exception of Sr-89, the radioactive impurities present in previous shipments were probably an order of magnitude less than this specification. Gamma-emitting radionuclides were below the detection levels using gamma ray spectroscopy, preceded by removal of Sr-89 and Sr-90 to avoid the interference of Bremsstrahlung radiation.

[redacted]

[redacted]

[redacted]



For the purpose of this evaluation, it was assumed that future shipments could contain as much as 600,000 curies of Sr-90 together with associated Sr-89. The Sr-89 to Sr-90 curie ratio has been taken as 2.5 maximum. Larger quantities of Sr-89 could be associated with 600,000 curies Sr-90 depending upon the degree of aging; however, at about 1,500,000 curies Sr-89, the design limit of 34,000 BTU/hr heat dissipation would be approached. The specification covering Sr-89 in the product is met by aging.

The product cake generates heat at a maximum rate of about 34,000 BTU/hr which will produce the following calculated temperature profile during normal operations:

| | |
|---|---|
| Outside Air (assumed summer conditions) | 100 F |
| Cask Surface | 300 F |
| Fission Product Container Surface | 430 F |
| Maximum Fission Product Cake Temperature | 600 F |

Lower heat generation values would produce lower temperatures throughout.

The HAPO-IB shipping system,[1] consists of three primary components: the product filter container, the cask proper, and the cask container. Figure 1 is a cutaway drawing of the cask showing the filter container in place. The container is designed to withstand a pressure of 200 psig at 1000 F. The precipitate is collected in an annular space 7/16-inch thick, 18 inches in diameter, and about 30 inches high. A fine-mesh, composite stainless steel wire cloth filter, which is capable of 98 percent retention of particles larger than 10 microns, collects the precipitate as the slurry is transferred through the cask during loading. At the receiving site, the fission products are removed from the container by dissolution.

The HAPO-IB cask is an externally finned, lead filled, hollow cylinder with lead shielding confined by a 1-inch thick outer shell and a ½-inch thick inner shell. The assembled cask is about 4 feet in diameter, about 6 feet in over-all height, and weighs about 20 tons. The filter container is supported from the cask lid, and held within the cask cavity. The process connections (for loading and unloading the filter container) project through the cask lid and terminate on top of the cask. Three containment barriers are provided over the process connections: (1) a high-integrity mechanical connector equipped with a Belleville spring-type metallic gasket; (2) a cap with a silver-clad, stainless steel O-ring which fits over the mechanical connectors; and (3) a gasketed cover which bolts over the cupola containing all the secondary caps. The cask cover is permanently welded to the cask body. Both cask cover and body are fabricated from 304 stainless steel. A low-melting indium alloy is used to transfer the heat from the filter container to the cask inner wall. From there the heat flows through the walls of the cask to a free-convecting air stream. The indium alloy melts at 117 F and boils above 1500 F.

[redacted]

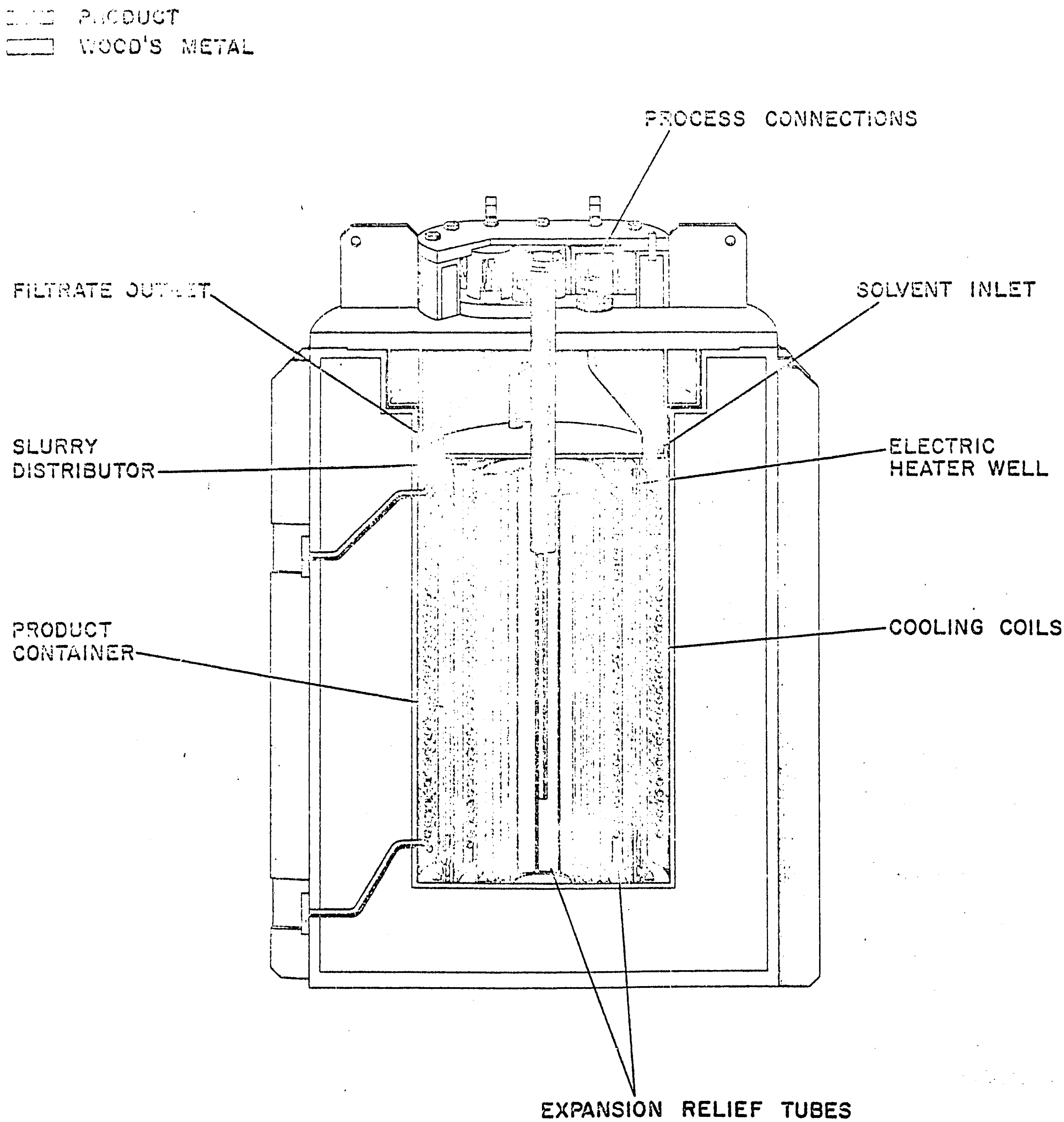


Figure I

[redacted]

[redacted]



The assembled cask, enclosed in the cask container, is shown in Figure 2. The cask container for the HAPO-IB cask is about 10 feet in diameter, 14 feet high, and weighs about 18 tons. The cask container consists of four concentric steel shells separated by rubber buffers. Rubber buffers are also provided in the spaces above and below the cask. Flexibility in cask container heat dissipation ability is provided to suit outside weather conditions. During most severe winter conditions (-35 F) the rubber buffers must be kept above about 30 F to maintain their resiliency; yet under extreme summer temperatures (100 F) the rubber cannot be allowed to exceed 220 F or the product temperature to exceed 600 F. In the wintertime an insulated cover completely seals the cask container and heat transfer to the atmosphere is accomplished by a naturally convecting internal air stream which transfers heat from the cask surface to the outer shell of the cask container. Insulation outside of the outer container shell regulates the air temperature in the outer container annulus. In the summer the cask container cover is removed, and free convection of outside air cools the cask surface directly.

## TYPES OF ACCIDENTS WHICH COULD BE ENCOUNTERED IN RAIL SHIPMENTS

The rail routing planned for the HAPO-IB shipments from Hanford to Oak Ridge, described in Table I, is illustrated in Figure 3.

TABLE I
HAPO-I SHIPMENT ROUTING
HANFORD, WASH. TO OAK RIDGE, TENN.

| From | To | Rail Line | Major River Crossing |
|---|---|---|---|
| Beverly, Wash. | Aberdeen, S.D. | Milwaukee | Columbia (Beverly, Wash.) |
| Aberdeen, S.D. | Mitchell, S.D. | Milwaukee | Missouri (Mobridge, S.D.) |
| Mitchell, S.D. | Canton, S.D. | Milwaukee | |
| Canton, S.D. | Marquette, Iowa | Milwaukee | |
| Marquette, Iowa | Savanna, Ill. | Milwaukee | Mississippi (Savanna, Ill.) |
| Savanna, Ill. | Forreston, Ill. | Milwaukee | |
| Forreston, Ill. | Cairo, Ill. | Illinois Central | Ohio (Cairo, Ill.) |
| Cairo, Ill. | Corinth, Miss. | Illinois Central | |
| Corinth, Miss. | Chattanooga, Tenn. | Southern | Tennessee (Decatur, Ala.)<br>Tennessee (Stevenson, Ala.) |
| Chatanooga, Tenn. | Blaire, Tenn. | Southern | Tennessee (Boyce, Tenn.) |

[redacted]

# HAPO I CASK CONTAINER

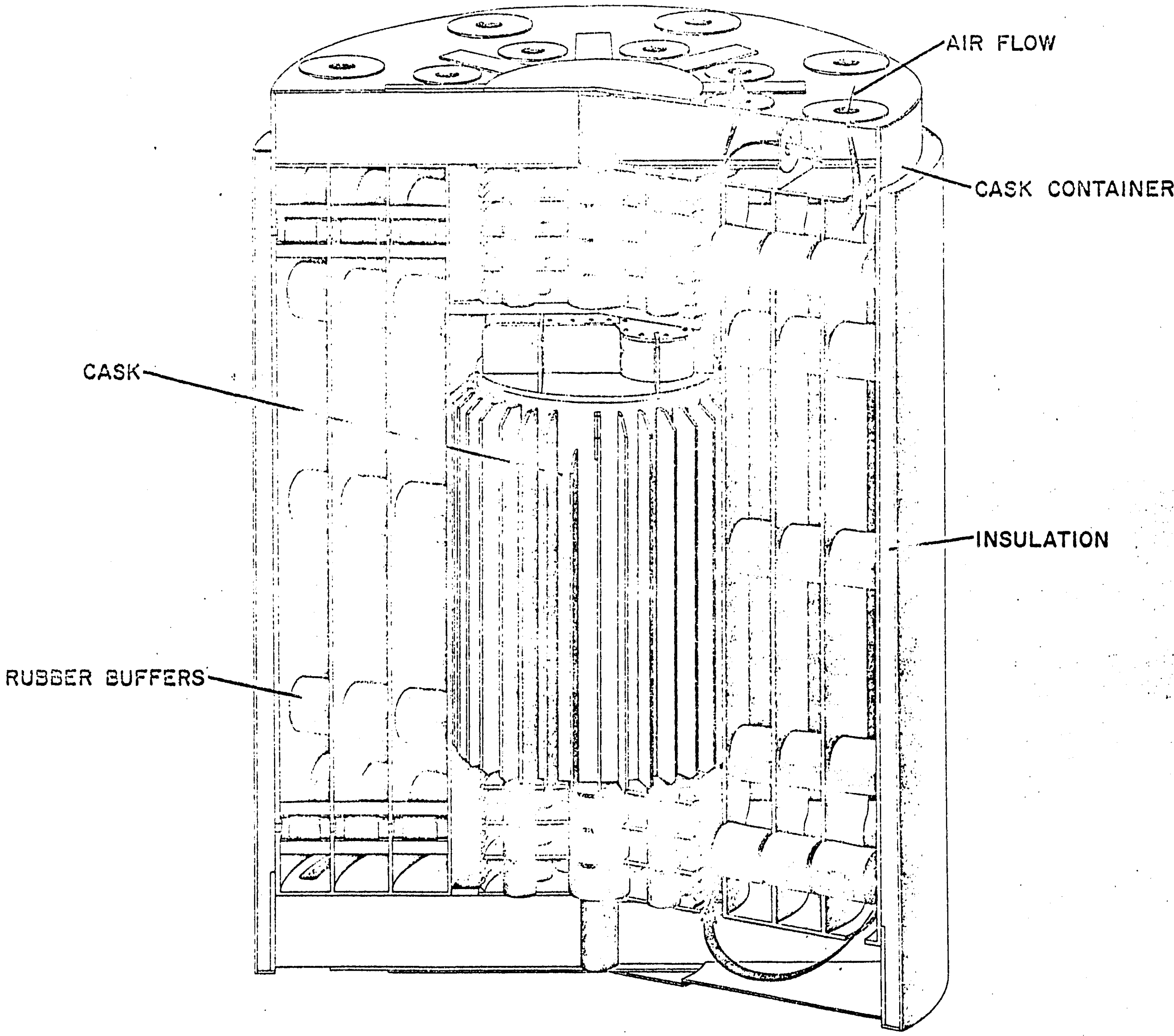


Figure 2

[redacted]

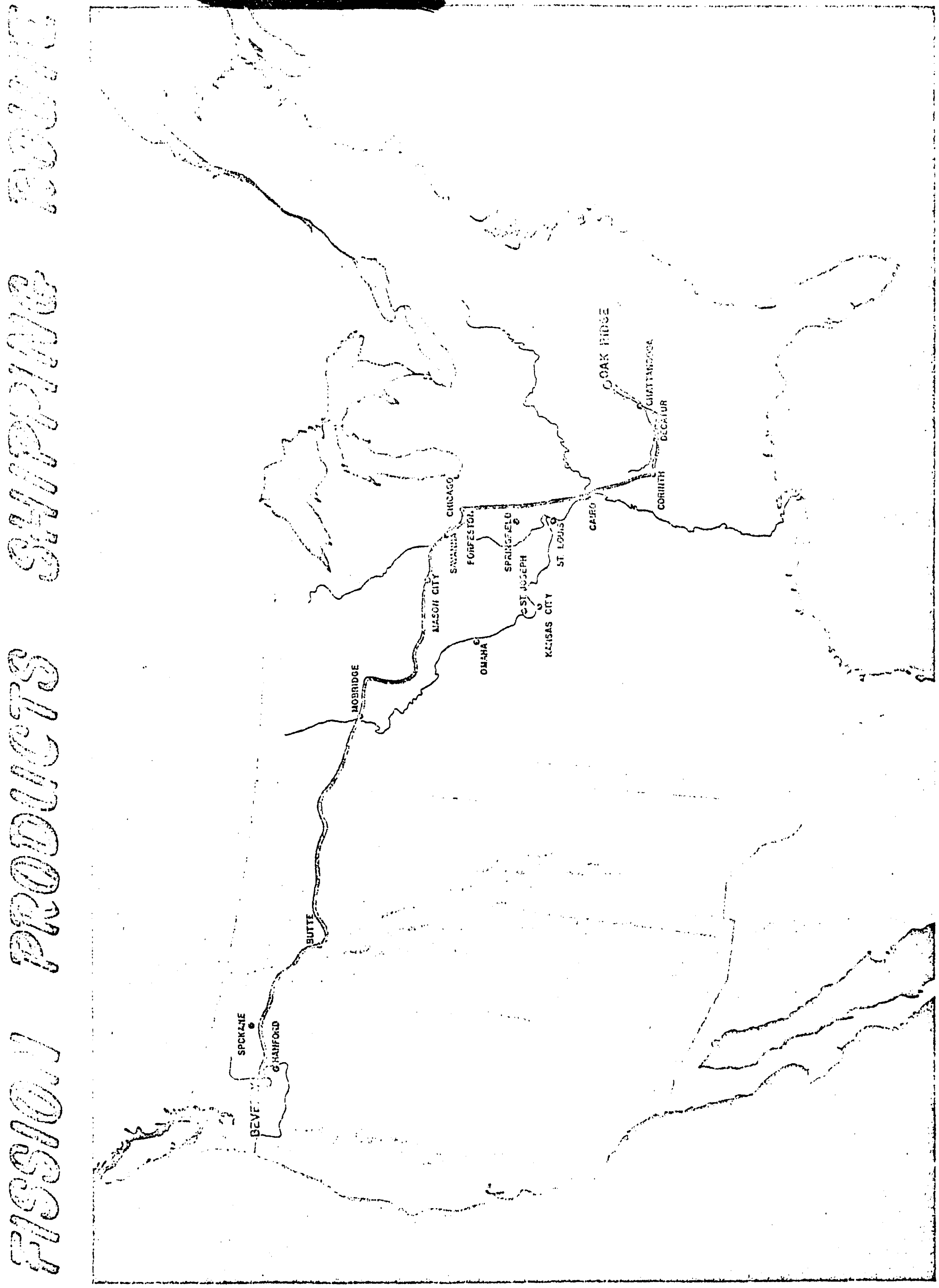


Figure 3

[redacted]

The HAPO-IB system was designed to retain its shipment containment and shielding integrity under extremely adverse conditions corresponding to a severe rail accident coupled with either total insulation for 48 hours or immersion in a fire at 2500 F for two hours. The severe rail accident was defined as equivalent to impact on an unyielding surface at 30 mph. Under accident conditions no more serious than these, no release of the product would be expected. Consequently, assessment of damage potential must necessarily consider more severe accidents which are probably less likely to occur. Administrative controls are intended to reduce the probability and consequences of such events.

Statistically, some relationship must exist between the frequency and severity of rail accidents; the more severe the accident, the lower its probability. Knapp[2] reported an attempt to obtain one point on the severity-frequency curve; that is, to determine the frequency of accidents at and exceeding one degree of severity. The level of severity selected was one which arbitrarily appeared sufficient to seriously damage a typical unprotected shipping cask, and, correspondingly, to demolish a typical freight car. Although the quantitative impact severity (in terms of acceleration)chosen was not stated, it was probably about 100 G at the centers of the cars under consideration. The estimated probability of such rail accidents was one per 80,000,000 miles.

Model tests on the HAPO-IB cask container have demonstrated its capability of translating impact velocities in excess of 30 mph to forces which the cask can sustain without failure. Accordingly, it is concluded that the frequency of HAPO-IB cask failures resulting from rail accidents would be less (probably by at least one order of magnitude) than one per 16,000 round trips to Oak Ridge.

Three modes of possible failure of the HAPO-IB cask exist: (1) damage from external causes either by impact or explosive forces; (2) burial for greater than 48 hours in a total-insulating medium, or correspondingly longer yet for a partial-insulating medium; and (3) exposure to a fire for longer than two hours. The extent of damage resulting from the vast majority of rail accidents would be insufficient to release any of the cask contents.

Cask failures, as considered in this report, are represented by loss of product containment. The mechanism of release of the product to the environment would depend upon the mode of failure. Impact of sufficient magnitude either from rail accident or nearby explosion could damage the cask and disperse the product into the atmosphere by purely mechanical means. The product could be dispersed to a river if the accident occurred along certain segments of the route. Major population areas, rivers, and river crossings along the shipping route are shown in Figure 3.

A fire of sufficient duration and intensity could result in cask failure and product dispersal to the atmosphere. The cask could fail from thermal breakdown of the construction materials, internal pressurization as a result of product decomposition at high temperatures, or a combination of both. Dispersal to the atmosphere could result either from mechanical entrainment of the particles in the ascending thermal draft or from volatilization of the product.

RELEASE TO THE ATMOSPHERE

Exposing the cask contents to the atmosphere would lead to entrainment of particles of $SrCO_3$. The particle size range of $SrCO_3$ prepared under simulated process conditions was found to be 1 to 25 μ with most of the particles in the 4 to 12 μ increment. These particles were found to be agglomerates which could easily be broken down into particles of 1 to 4 μ.[3]

The indicated release by volatilization would be of the order of 0.1 percent. Preliminary studies on volatilization of strontium from $SrCO_3$[3] indicated a release of 0.05 percent on gradual increase of temperature for two hours to 2670 F. Isothermal conditions at 2465 F for two hours released 0.14 percent of the strontium. About 65 percent of the volatilized strontium penetrated an 0.8 μ pore size Millipore filter. Control runs at ambient temperature and the same air sweep (about 0.22 ft/sec) entrained 0.05 percent in a two hour period, and increasing the linear velocity to 1.7 ft/sec for two hours increased the entrainment to 0.7 percent.

Both volatilization and entrainment may be significant mechanisms of dispersal of Sr-90. High velocity air flow, if unimpeded, could entrain most of the available strontium carbonate fines. The multiple barriers provided by the product container, the cask and the cask container are assumed, however, to limit the fraction of $SrCO_3$ lost to the atmosphere by entrainment. Although these barriers would be damaged by severe impact and/or fire, some degree of product containment is envisioned. For purposes of this report, it was assumed that one percent of the radiostrontium is released as aerosol particles which would diffuse in accordance with the prevailing atmospheric conditions.

The primary radiological hazards resulting from the passage of the Sr-90 aerosol cloud result from inhalation of material in the air, and deposition on field crops which lead to ingestion of radioactive material by man directly or through various food chains. For a given quantity of aerosol released, the total inhalation of Sr-90 depends on the position of the individual with respect to the accident and to the centerline of cloud passage. Contamination of field crops and ground deposition also decreases with distance from the centerline as well as with distance from the accident site. Areas over which the contamination level or inhalation exposure exceed specified exposure criteria[4] provide a direct measure of environmental consequences of release. The selected levels of importance are shown in Tables II and III with their associated area zone classification. The indicated bone deposition assumes no corrective action is taken.

TABLE II

INHALATION EXPOSURE CRITERIA

| Zone | Quantity Inhaled μc | Deposition of Sr-90 in Bone* μc | Deposition of Sr-89 in Bone* μc |
|---|---|---|---|
| A | $\geq 1.5 \times 10^4$ | $\geq 1800$ | $\geq 4500$ |
| B | $\geq 2.5 \times 10^3$ | $\geq 300$ | $\geq 750$ |
| C | $\geq 17$ | $\geq 2$ | $\geq 5$ |

* Based on intake for standard man. Ratio Sr-89/Sr-90 inhaled = 2.5.

TABLE III

PROPERTY CONTAMINATION CRITERIA

| Zone | | Bone Deposition After 1st Year μc |
|---|---|---|
| D | $\geq 20$ μc Sr-90/$m^2$ | $\geq 670$ |
| E | $\geq 3$ μc Sr-90/$m^2$ | $\geq 100$ |
| F | $\geq 0.15$ μc Sr-90/$m^2$ | $\geq 5$ |

Radiological consequences of release of 6000 curies of Sr-90 (one percent of the shipment) to the atmosphere were estimated on the same basis as in the earlier study.[4] Areas contained within the zones identified in Tables II and III were calculated from atmospheric dispersion equations used at Hanford[4] for three wind speeds and four atmospheric stability classifications. These are summarized in Table IV. The area contaminated in excess of a given level depends not only on the meteorological conditions existent at the time and following the accident, but also in a nonlinear fashion on the total amount of material released, the physical and chemical form of the released material, and the mechanism of deposition on vegetation and other surfaces. The deposition process is dependent on particle characteristics, wind speed, and atmospheric stability. In addition, the diffusion and deposition process interact in such a way as to make the area of a given zone exceedingly sensitive to the level of the exposure criteria

TABLE IV

AREAS OF EXPOSURE LEVELS BY ZONES FOR SEVERAL ATMOSPHERIC CONDITIONS AND SELECTED WIND SPEEDS (Based on a Release of 6000 Curies of Sr-90)

| Zone | Atmospheric Condition | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Very Stable | | | Moderately Stable | | | Neutral | | | Unstable | | |
| | Wind Speed (in meters per second) | | | Wind Speed (in meters per second) | | | Wind Speed (in meters per second) | | | Wind Speed (in meters per second) | | |
| | 1 | 5 | 10 | 1 | 5 | 10 | 1 | 5 | 10 | 1 | 5 | 10 |
| A* | - | - | - | - | - | - | - | - | - | - | - | - |
| B* | - | - | - | - | - | - | - | - | - | - | - | - |
| C | 11 | 3.1 | 1.5 | 2.6 | 0.7 | 0.4 | 0.1 | < 0.1 | < 0.1 | < 0.1 | << 0.1 | - |
| D | 5.1 | 11 | 14 | 1.9 | 4.8 | 7.2 | 0.2 | 0.2 | 0.2 | < 0.1 | < 0.1 | 0.1 |
| E | 60 | 100 | 100 | 25 | 57 | 71 | 1.2 | 1.5 | 1.6 | 0.4 | 0.6 | 0.6 |
| F | 1600 | 1400 | 1100 | 1100 | 1800 | 1700 | 29 | 35 | 41 | 9.5 | 13 | 17 |

*The areas contained in Zones A and B are all less than 0.01 square miles. The number of people exposed to the exposure criteria defining these zones depends upon the population density in the near vicinity of the accident.

relative to the amount released. Within the atmospheric classifications of Table IV (which are essentially steady state conditions), the 6000 curie release results in a maximum area of zone F during a moderately stable atmosphere and a five meter per second wind speed. However, approximately the same area would be affected at moderately stable high wind speeds or during strong stability at lower wind speeds. The area of zone E has a somewhat different relationship to the atmospheric conditions, with a maximum area occurring at moderate wind speeds during very stable conditions. The neutral and unstable conditions result in smaller areas in each case in the calculation, however, under certain conditions of wind variability and total release, the areas in the lower exposure zones could be much larger.

The shipment routing shown in Table I traverses a variety of terrain and climatological regimes, which could alter conclusions reached from Table IV. In a previous study[4] the accident was assumed to occur in a large mid-western city. Atmospheric conditions over large urban areas do not exhibit the diurnal or seasonal extremes of stability observed in rural areas.[5] However, from the viewpoint of population density and property value concentration, a low wind speed during moderate atmospheric stability emphasizes the inhalation hazard in terms of exposure and number of persons exposed. In general, the stability of the atmosphere changes through a diurnal cycle, being unstable during daylight hours and stable during night-time hours in continental climates. The areas shown in Table V factor a diurnal course of atmospheric stability and wind speed into the calculation to illustrate the reduction in zone area possible from meteorological variability.

## RELEASE TO A RIVER

An accident which would disperse the carbonate into a river could occur on a bridge or along portions of a railroad closely paralleling a river. For purposes of this evaluation, the accident is assumed to take place along a river comparable to the Missouri River in flow rate, and other characteristics as in the previous study.[4] Channeling of the released Sr-90 could minimize the dilution obtained during the first few miles downstream from the accident. Assuming that channeling reduces the effective dilution to 0.1 of that ultimately obtained in the average flow of the river, and that the cask and buffer are ineffective in impeding the elution rate, the initial concentration entering a water treatment plant would be about 6 μc Sr-90/cc.

Removal of about 99 percent of the particles would be expected in the flocculation, sedimentation, and filtration steps of the water treatment process. Individuals who consumed a liter of water during the peak period of contamination under these conditions would be expected to receive about five times the maximum permissible body burden of Sr-90 and Sr-89 for occupational exposure.

TABLE V

EFFECT OF DIURNAL ATMOSPHERIC CHANGES ON ESTIMATED AREAS IN SQUARE MILES
(Based on a release of 6000 curies Sr-90)

| Zone | Case I | | Case II |
|---|---|---|---|
| | HW-69561 REV* | Present Shipment | (Present Shipment Only) |
| A | $10^{-5}$ | $1.8 \times 10^{-4}$ | $2.4 \times 10^{-5}$ |
| B | $1.4 \times 10^{-4}$ | $2.2 \times 10^{-3}$ | $3.3 \times 10^{-4}$ |
| C | 0.5 | 2.6 | 0.7 |
| D | 0.5 | 1.9 | 4.8 |
| E | 6.4 | 15 | 57 |
| F | 69 | 180 | 830 |

*Areas corrected in accordance with the results of numerical integration.

Case I assumes a wind speed of 1 m/sec and, starting with the time of emission, a moderately stable atmosphere for one-third of a day alternating to a neutral atmosphere for remainder of the day.

Case II assumes, starting with the time of emission, a wind speed of 5 m/sec in a moderately stable atmosphere for one-half of a day alternating to a wind speed of 10 m/sec in a neutral atmosphere for the remainder of the day.

In both cases, the atmospheric conditions are assumed to continue the stated alternations throughout the time of the cloud's downwind travel.

Consumption of another liter of water a few hours later would add only slightly to the bone deposition. Consumption of drinking water near these contamination levels for longer periods is not contemplated because of downstream dilution and rapid passage of the contaminated water. By selection of the shipment routing and consideration of the numbers of people served by various municipal water plants taking water from rivers, it is considered unlikely that more than 25,000 persons would consume the contaminated water during the period of maximum concentration.

Water for irrigation purposes is also assumed to be taken during the peak period when dilution is incomplete. For sprinkler type irrigation, about 35 percent of the strontium present in the water would be expected in the plant life as a result of direct uptake. About one percent of the original quantity deposited could be expected in succeeding years' crops. If crops were sprinkled with water (the equivalent of one inch of rainfall) containing $6 \times 10^{-3}$ μc Sr-90/cc, the expected contamination level in the current crop would be about $2 \times 10^{-3}$ μc Sr-90/g vegetation (dry weight) and in the succeeding several years' crops, about the same concentration of Sr-90/g dry vegetation.

Although the passage time of the highly contaminated water in the river may be short, there would be some uptake of Sr-89 and Sr-90 in the biota. An unknown fraction of the strontium would become adsorbed in the river sediments and would be available for accumulation in fish over a longer time interval.

BIBLIOGRAPHY

1. Smith, C. W., "Design Criteria and Hazards Evaluation, Fission Product Shipping Case," HW-65268 REV 1, December 28, 1962.

2. Knapp, H. A., "Cost and Safety Considerations in the Transport of Radioactive Materials," TID-7569.

3. Reid, D. L., et al, "The Release of Radiostrontium from Strontium Carbonate," HW-69692, June 1, 1961.

4. Watson, E. C., et al, "The Consequences of Accidental Releases During Shipments of Radioactive Cesium and Strontium," HW-69561 REV, June 1961.

5. DeMarrais, G. A., "Vertical Temperature Difference Observed Over an Urban Area," Annual Meeting of the American Meteorological Society, Cincinnati, Ohio, January 1961.

[redacted]

[redacted]



## INTRODUCTION

Large quantities of radiostrontium in the form of strontium carbonate have been shipped from HAPO in the HAPO-II shipping systems. Modifications have recently been completed to equip the two HAPO-I systems[1] for shipment of strontium. This report updates previous hazards evaluations[2] of such shipments, to account for the greater strontium inventory of the HAPO-I system.

## SUMMARY

The product container, cask and cask container combination, known as HAPO-IB, will withstand severe conditions of impact, fire, and loss of heat dissipation. Nevertheless, it is recognized that the integrity of the system could be breached under even more severe conditions. Recognizing that such conditions could occur, releasing a portion of the contents to the environment, estimates were made of the hazards involved.

Under very probable atmospheric conditions of release of 6000 curies of Sr-90 and associated Sr-89 could lead to a significantly contaminated area of up to 2000 square miles. During periods of greater atmospheric variability, the area affected could be much less; however, changes in quantity released, location, or conditions of the accident could produce changes of comparable magnitude.

## NATURE OF THE SHIPMENT AND CASK

The HAPO-IB casks were designed to ship fission product fractions of various compositions containing Sr-90, or alternately Ce-144, as the principal radioactive constituent. The materials will be shipped as a stabilized cerium or strontium salt. While the casks are capable of shipping either the cerium-rare earth product or the Sr-90 product, it is not planned to use the casks interchangeably.

The specifications of the customer indicate that the Sr-89 to Sr-90 activity ratio should be $<1$, and that other radionuclides should not exceed the following specifications in terms of c/g of Sr-90: Ce-144 0.15, Zr-95:Nb-95, Ru-106 and Cs-137 each $<0.03$. With the exception of Sr-89, the radioactive impurities present in previous shipments were probably an order of magnitude less than this specification. Gamma-emitting radionuclides were below the detection levels using gamma ray spectroscopy, preceded by removal of Sr-89 and Sr-90 to avoid the interference of Bremsstrahlung radiation.

[redacted]

[redacted]

# END

# DATE FILMED

12/29/92