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SAFETY ANALYSIS REPORT FOR PACKAGING WASTE CALCINING FACILITY FILTER CASK

by

R. L. Nebeker
C. W. Nielsen

ALLIED CHEMICAL CORPORATION
IDAHO CHEMICAL PROGRAMS – OPERATIONS OFFICE

August 1974

PREPARED FOR THE U. S. ATOMIC ENERGY COMMISSION
IDAHO OPERATIONS OFFICE
UNDER CONTRACT NO. AT(10-1)-1375 S-72-1

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R. L. Nebeker

C. W. Nielsen

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U. S. Department of Energy
Idaho Operations Office

ALLIED CHEMICAL CORPORATION
IDAHO CHEMICAL PROGRAMS - OPERATIONS OFFICE
IDAHO NATIONAL ENGINEERING LABORATORY
Idaho Falls, Idaho - 83401

Allied Chemical

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SUMMARY

A safety review of possible hazards associated with on-site (NRTS) shipment of radioactive materials in the Waste Calcining Facility (WCF) filter cask was completed. This analysis was required prior to certification of the cask by AEC-ID, as specified in Annex L of IDM Appendix 0500-1. The cask and transfer vehicle are described, and the transfer procedures and control methods are discussed. The safety analysis covering the credible consequences of radiation exposure, contamination, fire, explosion, and mechanical failure are presented. Criticality was not evaluated, because fissionable materials are excluded from transport in this cask. The safety analysis indicates that the cask can be used on the NRTS within the conditions evaluated without undue hazards. Other future uses of the cask may require additional evaluations prior to shipment if potential hazards more severe than those discussed in this report are postulated.

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I. DESCRIPTION OF CASK AND TRANSPORT VEHICLE

The Waste Calcining Facility (WCF) filter cask is used primarily to transfer radioactively contaminated WCF process off-gas filters, contained within enclosed filter housings, to the NRTS Radioactive Waste Storage Facility (RWSA) for disposal. The cask also occasionally is used to transport various types of solid waste (typically end pieces from fuel elements) from the fuel storage basin to the RWSA. A pictorial drawing of the cask, with a removable solid waste container inside, is shown in Figure 1. Only one cask of this type has been fabricated, and the cask is not used off the NRTS site. Markings indicating "NRTS USE ONLY" have been placed on the cask.

The cask shell consists of 1/2-in.-thick, type 304 stainless steel plate covering 6 in. of lead for shielding. The cavity dimensions are 2 ft-6 3/8 in. x 2 ft-10 1/2 in. x 4 ft-8 in. high, and the exterior dimensions, excluding lifting lugs, tie-down devices and trunnions, are 3 ft-8 3/8 in. x 4 ft-0 1/2 in. x 6 ft-3 in. high. The approximate weight of the empty cask is 36,200 pounds. Two 3/4-in.-thick steel plate lifting lugs are welded to the top cover for cover removal, and two 3/4-in. diameter eye bolts serve as a positive locking device to hold the cover in place. Two 3-in. diameter trunnions are welded to the side of the cask body to allow lifting of the cask with a crane. Tie-down brackets, 3/4-in.-thick, are welded to each corner of the cask for securing the cask to the truck during transit. Both the lid and bottom of the cask are stepped to prevent a direct path for radiation beams from the cask, and the lid fits about 3-in. into the cask, so that it will not swing loose if one fastening device fails. The bottom of the cask is a door, shown closed in Figure 2 and open in Figure 3, and may be used for unloading the cask out the bottom. Four skids, as an integral part of the door, provide ease of cask handling and some shock absorption for opening the door.

One side of the cask bottom door is hinged on two 2-in. diameter pins, and a release mechanism is located on the opposite side of the cask. The handle on the release mechanism is moved to open the bottom of the cask by turning a spur gear which moves 1-in. square locking bars on each side of the cask. When the locking bars move past a certain position, the bottom swings open, allowing the contents to fall by gravity. The handle on the release mechanism is a removable wrench, and is used only when the cask is to be bottom-dumped. This prevents accidental opening of the bottom dump mechanism during lifting or other operations. The filter may thus be unloaded out the top or dumped out the bottom of the cask, at the discretion of the RWSA personnel.

A standard, government-owned, lowboy trailer unit pulled by a long-haul tractor, is used to transport the WCF filter cask. The trailer, which weighs about 20,000 pounds, has permanently-attached tie-down connections to secure the filter cask in position and is used exclusively for on-site radioactive shipments.

The solid waste basket (Figure 4) is 29-in. x 33 1/2-in. x 52 in. tall and is constructed primarily of 16-gauge galvanized steel sheet metal. It is reinforced with angle iron bars and has a 1/2-in. lifting bar attached to the top. The bottom has fifty-six 1/4-in. diameter holes drilled in it to allow water to drain from the basket when it is loaded underwater.

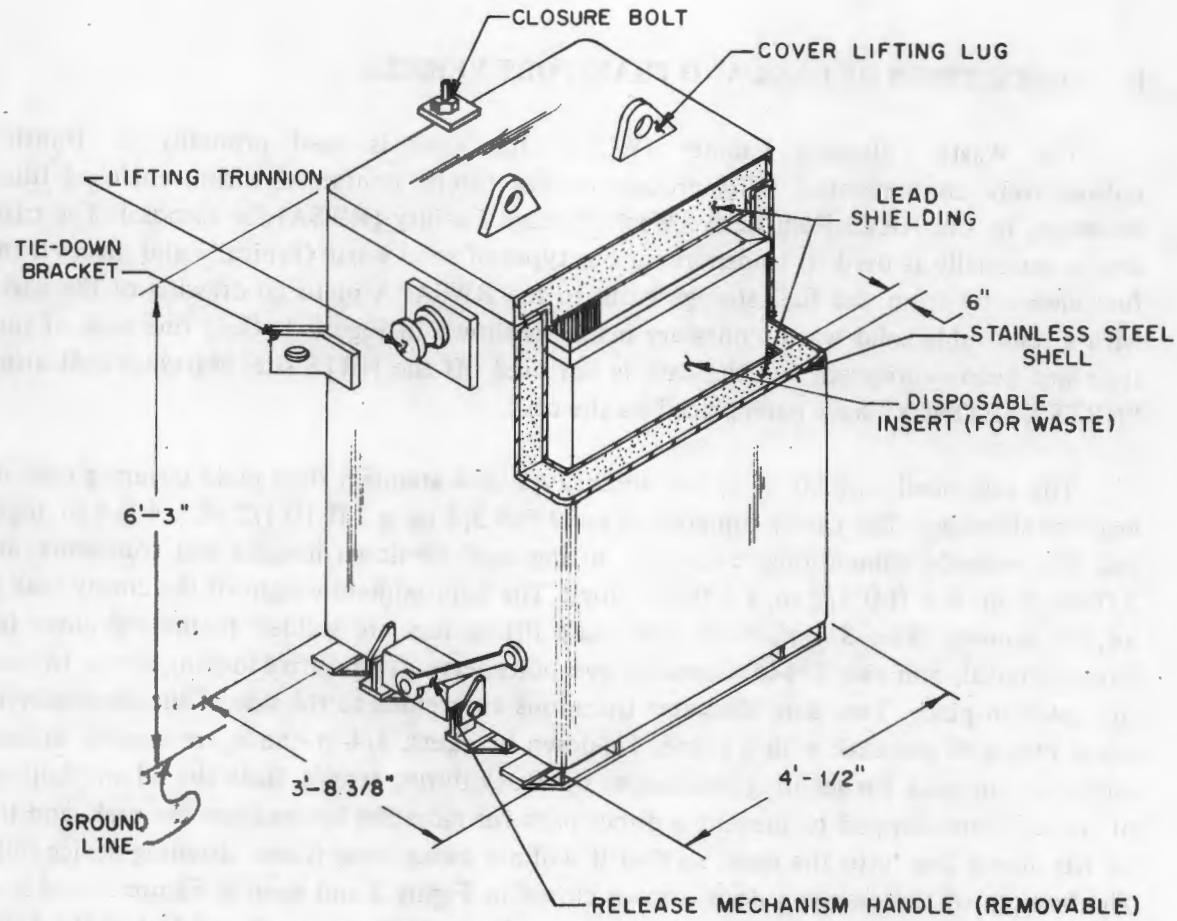

Fig. 1. WCF Filter Cask.

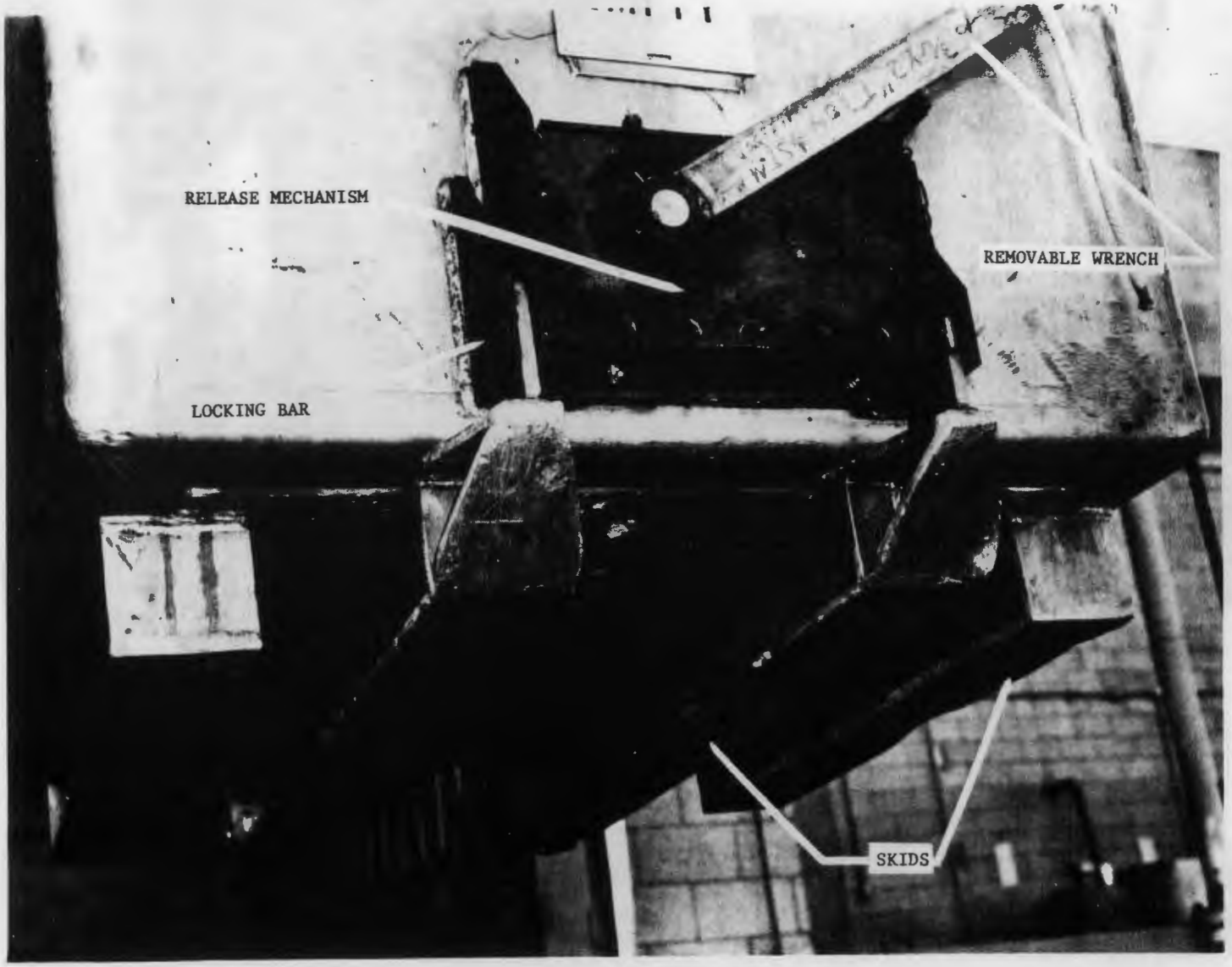

Fig. 2. Bottom dump mechanism - closed.

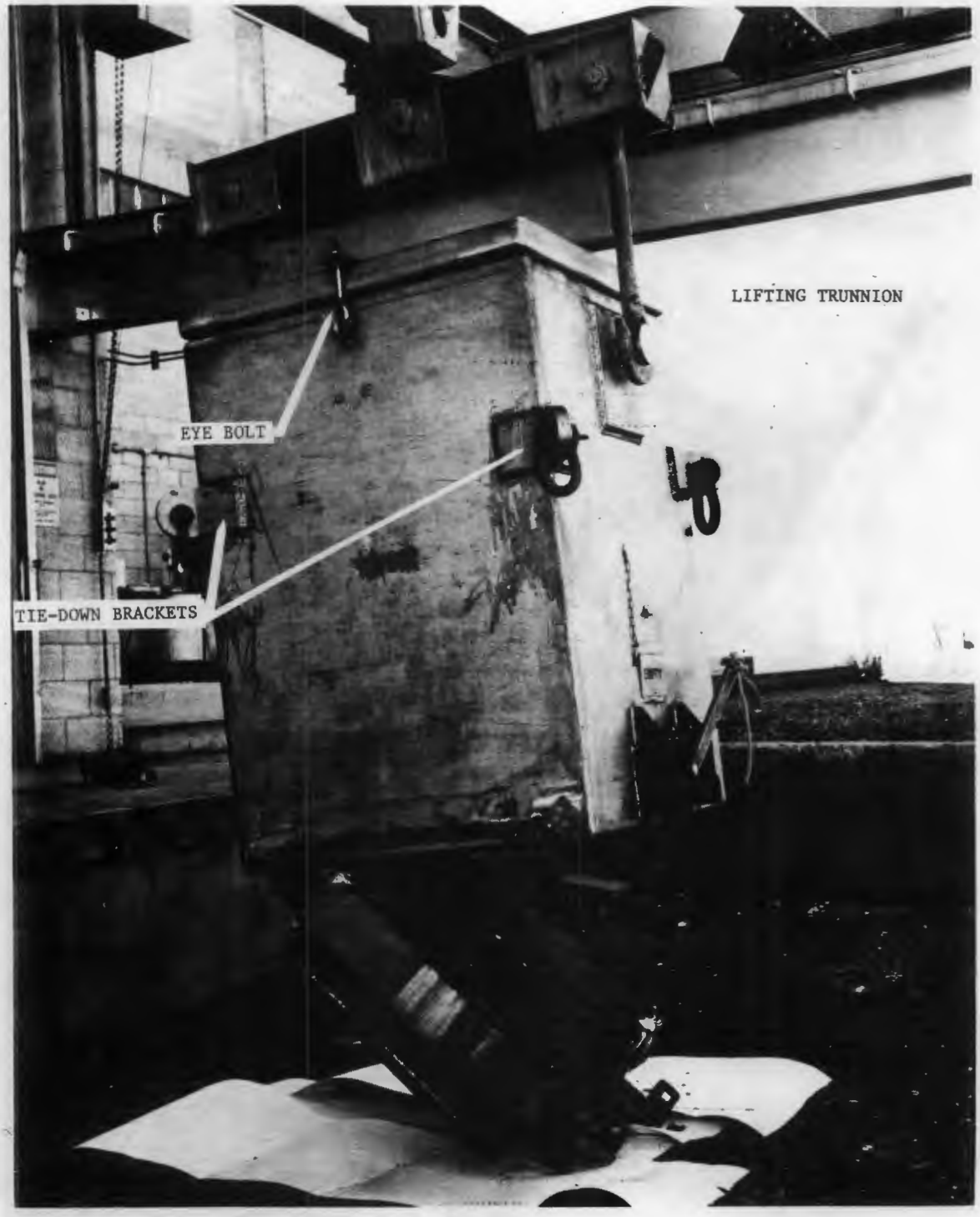

Fig. 3. Bottom dump mechanism - open.

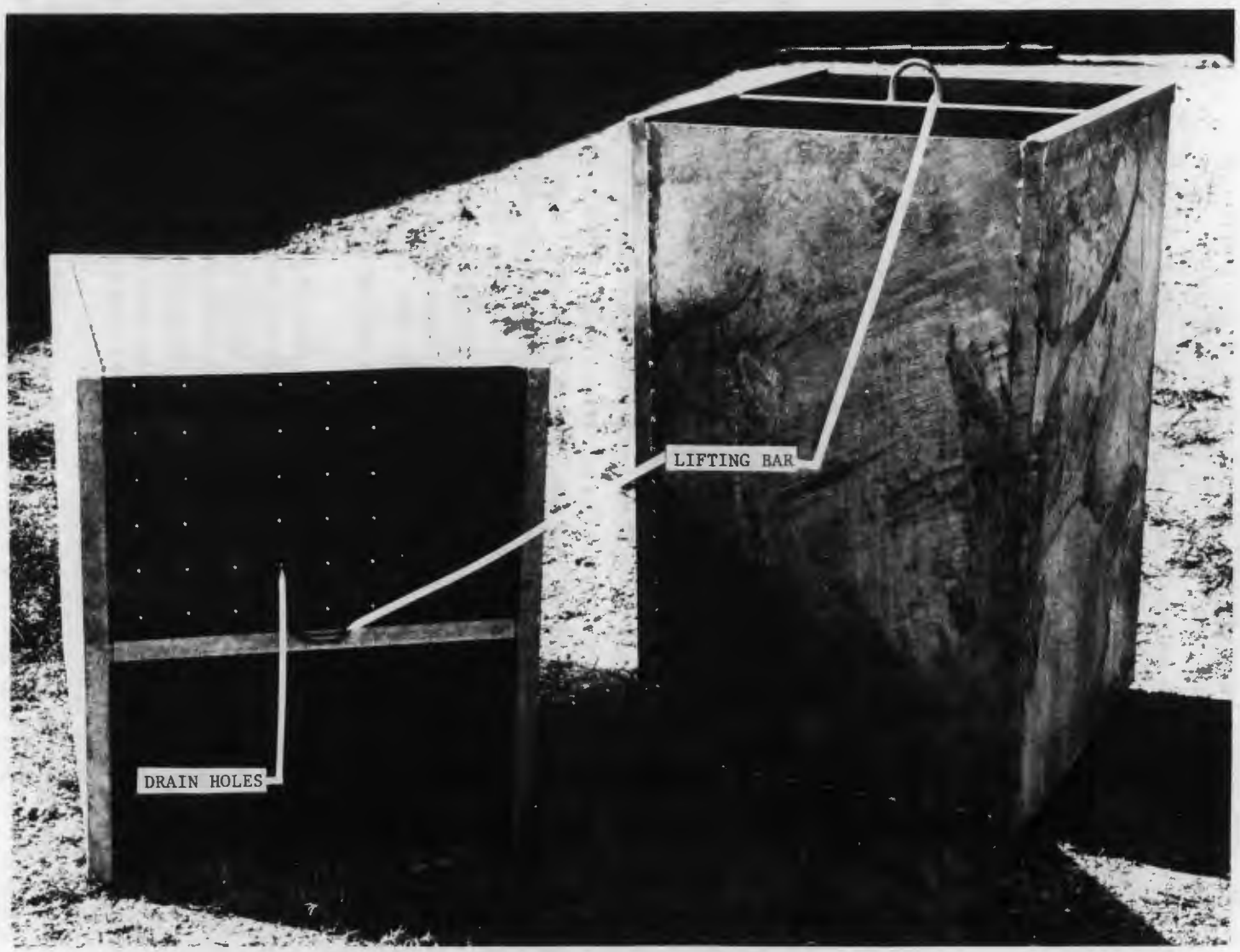

Fig. 4. Solid waste basket.

II. TRANSFER PROCEDURES

The WCF filter cask is used primarily to transfer contaminated filters from the WCF to the RWSA. All operations involving close contact with the filter and filter housing are done remotely. When a filter is to be replaced, the cask is positioned on the decontamination pad in the filter removal room of CPP 603 and the lid is removed. The filter is then taken out of service, the inlet and outlet lines are purged to the exhaust duct with clean air to remove any loose contamination, and the internal inlet valve in the filter housing closed. With Health Physics personnel monitoring, the filter cell hatch plug is removed and the cask is moved into the filter cell behind the housing. The filter housing is then removed from the off-gas line, the inlet and outlet ports of the filter housing are covered with heavy tape, the filter housing is inserted into a polyethylene bag[(a)] and the filter housing inside the plastic bag is lowered into the cask.

The poly bag is then closed with a drawstring, the drawstring is clipped, the cardboard box (if used) is taped shut, and the lid replaced on the cask. The cask is then removed from the filter cell and placed on the decontamination pad in the filter removal room, and the lid tightened. The cask is checked for radiation and external contamination and decontaminated, as required, to meet specified guidelines[1]. Following decontamination, the cask is wrapped in plastic to provide additional protection against spreading contamination during transport and the cask is marked as being loaded. When the cask is ready to be transported to the RWSA, it is placed on a standard lowboy truck used for radioactive shipments and fastened to the truck with eight doubled 3/8-in. steel alloy chains[(b)]. Figures 5 and 6 are photographs of the cask tied down on the lowboy truck. The cask then is transferred to the RWSA with a security escort where the filter is removed from the cask, either by lifting the cask off the truck and dumping the filter out the bottom, or by lifting the filter out the top of the cask while the cask is still on the truck. The cask is then marked as being "empty", the cask and truck are decontaminated as necessary, and returned to CPP.

When the cask is used to transfer fuel end pieces, it is lowered into the fuel transfer basin and the removable basket containing the fuel end pieces is loaded into the cask. Since the cask is loaded wet, the excess water must be removed by raising the cask above the basin and allowing the excess water to drain out through the bottom of the cask. The cask then is removed from the basin where it is washed down, decontaminated, monitored, and wrapped in plastic for shipment. The cask is placed on the truck on a 6-in. deep x 5 ft-5 3/4-in. square metal tray, the bottom of which is covered with heavy blotting paper, so that any remaining water in the cask will be collected and will not be spread during the shipment should the plastic fail. In case of failure of the plastic, the amount of water that would be released from the plastic is so small that it would be absorbed by the blotting paper, and not

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(a) A possible additional safeguard will be the use of a cardboard box container inside the cask. This will be used only if high contamination levels continue.

(b) If fasteners other than the specified 3/8-in. steel alloy chains are used, they will have an equal or higher tensile strength.

(Figure 5 will be sent to recipient of this report at a later date.)

Fig. 5. WCF filter cask on lowboy truck.

(Figure 6 will be sent to recipient of this report at a later date.)

Fig. 6. WCF filter cask on lowboy truck.

be splashed out of the pan during transit. This small amount of water would be cleaned up during decontamination of the cask. At the RWSA, the cask is unloaded from either the top or the bottom, marked "empty", decontaminated as necessary, and returned to CPP.

III. CONTROL METHODS AND PROCEDURES

Various methods and procedures are used to assure all transfers are made safely. Procedures have been written for the operations, and all operations are monitored closely by Health Physics personnel. Preventive maintenance checks are made at least annually to assure the integrity of the cask is maintained. These items are discussed in more detail in the following sections.

A. Administrative Procedures

Standard Operating Procedures (SOP's) issued by Allied Chemical Corporation, govern the loading, tie-down, and shipment of materials for the WCF filter cask. These procedures apply to all ACC organizations and personnel who control or perform operations connected with cask shipments. Strict supervisory control and rigid adherence to procedures are maintained at all times to assure safety during transfers. These SOP's, which are written by personnel intimately familiar with the processes, are listed in Table I. A DOP[a] is also issued by Aerojet Nuclear Corporation governing the unloading procedure at the RWSA.

TABLE I
ALLIED CHEMICAL CORPORATION
SOP's RELATING TO TRANSFERS IN THE WCF FILTER CASK

SOP No.	Title
1.6.7.11	Radioactive Shipment Tie-Down
1.6.7.12	Radioactive Shipments
1.6.7.13	Inspection & Maintenance Program for Radioactive Materials Shipping Casks and Containers
4.31.10	Final Filter Changeouts

(a) "Handling and Unloading of CPP WCF Filters", DOP 36.3.2.106.

SOP 1.6.7.12 defines the duties of the personnel responsible for making radioactive shipments, including the originator, the loader, the ICP shipment coordinator, the safety engineer, and health physics personnel. A Form ID-109, which outlines any specific controls and assures compliance with radiation and contamination control, is prepared for all on-site shipments. The package is reviewed by Health Physics personnel prior to leaving ICPP, and the HP also surveys the shipment and transporter before it leaves CPP. Personnel responsible for shipping the WCF filter cask have completed special training to prepare them for this task.

The Safety and Health Physics personnel also are responsible for assuring that radioactive shipments are in compliance with applicable regulations. The working strength of the tie-down assembly must equal or exceed the weight of the article being tied down, and tie-downs must withstand the forces imposed when the vehicle decelerates at a rate of 32.2 ft/sec^2 (1 g). Various configurations and sizes of chains or cables are allowable as long as these criteria are met. These tie-downs are listed in SOP 1.6.7.11 and are discussed in Appendix A.

Training assures that operators participating in radioactive transfer operations are qualified to perform their duties safely. The safe handling and transport of radioactive materials is one part of the ICPP operator training program, and a special shippers and loaders school has been held to acquaint responsible personnel with the appropriate procedures and regulations required by Annex L[1].

B. Radiation and Contamination Control

The direct radiation from the cask is controlled by the shielding design of the cask, and any radiation is detected by monitoring vital phases of the procedures. The cask is checked by Health Physics personnel twice—once when loaded at the WCF and once at the main gate (a low background area) prior to leaving CPP—to assure compliance with contamination and radiation guidelines. All shipments are checked for compliance with Annex L requirements prior to leaving CPP, upon arrival, and prior to leaving the RWSA.

C. Preventive Maintenance

A regular inspection and preventive maintenance program is administered by ICPP Operations and is conducted by maintenance personnel. This program assures that the cask is in good condition whenever it is used. All moving parts are routinely inspected, tested, adjusted, and serviced, and the cask is examined for defects and repaired as necessary. The responsibility for routine inspection and preventive maintenance is established in SOP 1.6.7.13, which defines the responsibilities of various ICP organizations and specifies the inspection frequency. All records and drawings are maintained by the ACC cask coordinator.

D. Quality Assurance

A Quality Assurance Procedure[2] has been written to describe and reference the control of quality related to all ICP shipping containers. This procedure applies to the various activities, including maintenance of containers used for the on-site transport of radioactive materials. It discusses testing and retesting of containers, maintenance inspection, and quality assurance records. The responsibility for quality assurance functions for radioactive shipments also is discussed.

IV. SAFETY ANALYSIS

A safety analysis was conducted to evaluate the consequences of postulated abnormal occurrences associated with radioactive transfers in the WCF filter cask. The results are summarized in Table II and are discussed in the following paragraphs. Because fuel end pieces are transferred infrequently (generally about once every year), and because the potential hazards are similar but less severe, emphasis has been placed on WCF filter transfers.

A. Fire and Explosion

Evaluation of the potential fire and explosion hazards in transporting radioactive material in the WCF filter cask showed that no unacceptable hazards exist. Neither the WCF filter elements nor the fuel end pieces contain combustible or explosive materials. The filter consists primarily of glass fibers and the fuel end pieces are metal. Although plastic bags and a cardboard box may be used during transport for contamination control, these materials are not present in sufficient quantities to be considered a serious fire hazard. However, there is the potential for a fire from the diesel or gasoline (generally diesel) fuel and other combustible materials used in the trucks.

A major fire could occur only if the transfer vehicle collided with a tanker carrying gasoline or fuel oil and if the gasoline or oil ignites. Such an accident is improbable on most NRTS roads because of the speed restriction on the transfer vehicle (25 mph), which limits the probability and consequence of a collision. The worst case accident that could conceivably occur would be when the truck crosses U. S. Highway 20 on the way to the RWSA. At worst, such an accident would result in the release of some fission products, as discussed in Section F.

B. Nuclear Criticality

Nuclear criticality is not applicable to the WCF filter cask because it is used only for transporting nonfissionable materials (WCF filters or fuel end pieces). The use of the cask is controlled by administrative procedures and personnel involved in using the cask have received special training and are aware of the limitation on the cask. The words "WCF Filter Cask" and "Nonfissionable Material Only" are written on the cask. It is physically different from other casks used at the ICPP, and it is inconceivable that it would be

TABLE II
POSTULATED ABNORMAL OCCURRENCES FOR WCF FILTER CASK

Normal Operation	Postulated Abnormal Occurrence	Cause	Normal Prevention: Primary Safeguard	Normal Prevention: Secondary Safeguard	Detection	Correction and/or Control	Possible Consequences of Abnormal Occurrences: On this System	Possible Consequences of Abnormal Occurrences: On Related Systems
Cask Loading	Radiation exposure	Highly radioactive (overloaded filter) or trash basket.	Adequate shielding for expected use.	Constant HP monitoring during loading and again before shipping. Loading done remotely.	Radiation alarm or HP monitoring	Return filter to basin or cell and develop a plan for transport.	Possible radiation exposure to personnel	None
Cask Transport	Cask falls & breaks open releasing filter.	Severe traffic accident	Adequate tie-down strength, low truck speed.	Low traffic density	Visual	Reposition filter in cask with mobile crane.	Cask damage	Radiation exposure and minor local contamination.
Cask Transport	Fire	Crash with oil truck followed by fuel or cargo	Driver training, low traffic density access to NRTS restricted.	Speed limit control	Visual	Extinguish fire.	Minor fission product release, cask and truck damage.	Minor local contamination; possible radiation exposure to personnel.
Cask Transport	Collision with large or fixed object.	Vehicle malfunction or driver error.	Training of drivers	Preventive maintenance of vehicle. Low speed.	Visual	Use mobile crane to reposition cask.	Possible cask damage	Possible minor spread of contamination in immediate area.
Cask Transport and Unloading	Contamination spread.	Cask surface contamination or migration of filter contents.	Careful handling; wrap cask in plastic before shipping; wrap filter housing in plastic and/or place housing in a cardboard box.	HP monitoring during loading prior to ship-shipping and during unloading.	HP monitoring	Clean up contaminated surface.	Contamination; possible low exposure from airborne contaminants.	None
Cask Loading or Unloading	Cask drop	Crane failure or operator error.	Careful handling and operator training.	Periodic inspection and maintenance of crane.	Visual	Reposition cask with mobile crane	Possible cask damage	Possible contamination release to immediate area or radiation exposure to personnel.
Cask Loading or Unloading.	Bottom opens unexpectedly releasing contents.	Release handle catches on something.	Release handle is removed during handling except when needed for bottom dumping.	Careful handling	Visual	Reposition contents in cask and ensure closure.	Contamination - radiation exposure to personnel.	Contamination
Cask Loading	Criticality	Fuel loaded into cask.	Placards stating name of cask, and nonfissionable material only on cask.	Operator training.	HP monitoring.	Remote cleanup.	Radiation exposure, contamination	Radiation exposure, contamination.

TABLE II (Cont'd)

Normal Operation	Postulated Abnormal Occurrence	Cause	Normal Prevention		Detection	Correction and/or Control	Possible Consequences of Abnormal Occurrences	
			Primary Safeguard	Secondary Safeguard			On this System	On Related Systems
Cask Transport	Water (rain or snow) gets inside the cask and leaks out.	Excessive rain or snow.	Cask is wrapped in plastic, lid is stepped.	Catch pan is used to collect any water. Loaded cask is not left outdoors for prolonged periods of time.	Visual	Clean up contamination in pan.	Small amounts of contamination	None

mistaken for a fuel cask and used to transport fissionable materials. Therefore, formation of a critical system in the cask is not possible when it is used for these transfers.

C. Direct Radiation

The WCF off-gas filters normally are kept in service until the pressure drop across the filter unit reaches about 10 inches of water, at which time the filter is removed and a new filter is installed. The amount and composition of activity on the filter varies with each WCF run, and individual filters for the same run also vary in activity. Radiation fields directly around the unshielded filter typically are about 60 to 100 R/hr at contact. Radiation fields from the cask loaded with the contaminated filter typically are 2 mR/hr to 20 mR/hr at 3 ft. When fuel end pieces are shipped, typical radiation fields are 10 to 20 mR/hr at 3 ft, as measured prior to shipping. All transfers are made under controlled conditions and the cask is carefully monitored twice before each transfer. Consequently, no radiation hazard from normal transfers are expected.

D. Contamination from Mechanical Failure and Leakage

The potential for contamination spread was evaluated because the filter contains radioactivity which, if the cask and filter housing failed, could conceivably contaminate the immediate environment. As stated, the material on each filter varies considerably. A calculated inventory of material expected on the filter totals about 200 curies and is shown in Table III. This inventory is based on measured atmospheric releases[3], reported filter decontamination factors[3,4], and normal fission product ratios integrated over the number of days the filter remains on line.

Before the filter is removed from service, the inlet and outlet lines are purged with clean air to the exhaust duct to remove loose activity, and the flapper valve inside the filter housing is closed to prevent activity from spreading. In addition, the cask is lined with plastic which is closed after insertion of the filter housing. These actions minimize the amount of leakage or "creeping" of the fine radioactive powder from the filter into the cask, as well as minimizing the amount of contamination that would be released if the cask were to fail. The filter housing is then placed in the cask for transfer to the RWSA. The cask is securely tied to the transfer vehicle with chains, and a speed limit of 25 mph is imposed on the carrier while carrying the cask. Release of significant quantities of contamination would require failure of the cask, the plastic wrapping, the cardboard box (if used), the filter housing (or the flapper valves in the filter housing), and release of activity from the filter fibers. Detailed mechanical calculations were performed to determine the consequences of an accident on the filter cask, and is shown to be within Annex L (on-site shipping) regulations. The cask is fastened securely to the transfer vehicle using the number and size of steel alloy chains required to assure safe transport of the cask (see Figure 5). As a minimum, two double 3/8-in. alloy chains are used to tie each corner of the cask to the lowboy (a total of 16 chains). Under these conditions, the working strength of the tie-down assemblies (52,800 pounds) exceeds the weight of the cask and the assembly is capable of withstanding the forces imposed when the vehicle decelerates at a rate of 32.2 ft/sec^2 (1 g)

TABLE III
ESTIMATED FISSION PRODUCT INVENTORY ON WCF FILTER

Nuclides	Curies
Ru-106	60
Rh-106	60
Cs-137	15
Ba-137m	15
Ce-144	6
Pr-144	6
Sr-90	20
Y-90	20
Total	202

(see Appendix A). This tie-down configuration is quite conservative. First, the breaking strength of the tie-down chain is about five times greater than the working strength, so the chains should withstand a 5 g, rather than 1 g, deceleration without breaking. In addition, deceleration during stopping is normally less than 1 g. The required braking deceleration for a large vehicle is 0.43 g[5], and the observed maximum braking deceleration on a good surface for a car is 0.90[6] and would be less for a large truck.

If the cask did fall from the truck, and if it landed directly on the edge of the cover by one of the eye bolts, the eye bolts would probably fail. In this case, the cover might come off. Whether it would come completely out of the cask, allowing the filter to be removed from the cask, is unknown. The calculations (see Appendix A) show that the other fastening devices will not fail even if the cask falls from the truck. The pins on the bottom door of the cask will not fail nor will the locking bars fail. Also, the calculations show the filter housing will not fail, since enough force will not be developed to rupture the 1/4-in. thick plate of the housing body. If the inlet valve assembly on the filter housing were struck with a direct blow in the accident, it conceivably could fail. However, the possibility of this happening is low since the assembly is recessed 5/8 inch and there is an angle iron guard around the perimeter of the housing at the level of the inlet assembly. Figure 7 shows the arrangement of the filter housing and the inlet assembly.

Consequently, if a severe accident occurred, it is conceivable that the filter housing could fall from the cask but the housing would not fail. Some minor contamination might

Fig. 7. Filter housing.

occur in the immedate area, and high radiation fields would occur in the immediate area (60 to 100 R/hr at contact). However, fission product releases would be minimized by the filter housing. These calculations are discussed further in Appendix A.

E. Temperature Rise from Decay Energy

Because of the low fission product loading on the filter and the large area of the cask available for heat transfer, the fission product decay heat will not raise the temperature of the cask appreciably. Based on the fission product inventory shown in Table III, a total decay energy of about 7 Btu/hr (see Appendix B), corresponding to a heat flux for the cask of 0.07 Btu/hr/ft^2, was calculated. This amount of heat, corresponding to about 2 watts, is not significant enough to cause unacceptable temperature rises. Even if no heat transfer occurs (perfect insulation), the decay heat is so small that the cask temperature would rise less than 0.2^{o}F per day. Even if the temperature should rise (from an external fire, etc.), there is no flammable material in the filter housing or the solid waste basket, or any material that would release large quantities of fission products if it were to melt. Also, there is no fissionable material that could melt and flow into a more reactive configuration.

F. Maximum Credible Accident

The maximum credible accident is defined as one in which fission products on the filter are released to the environment. This accident is conceivable but extremely unlikely. A major vehicular accident must first occur, causing the filter to fall from the cask. Both the filter integrity and the housing integrity would have to be lost and the retained fission products then would have to be released by a fire. The only conceivable way such an accident could occur would be during a high-velocity impact accident with another large vehicle. For calculational purposes, such an accident was assumed to occur on U. S. Highway 20, as the truck carrying the filter cask crossed the highway and collided with an oil tanker. The speeds of the trucks are immaterial to the accident consequences since the worst accident results have been assumed. A fire was assumed to result, but even under these conditions only about 10% of the fission product inventory would be released, based on incinerator studies[7,8]. For these conditions, the doses in Table IV would occur in Howe, Arco, and the nearest site boundary. These doses are well within the maximum permissible annual dose rates for *normal operation* as given in AECM 0524[9].

These calculated doses are based on the release of 10% of the fission products on the filter (see Table II) as particles with an Activity Median Aerodynamic Diameter (AMAD) of 1 μ[10]. (The off-gas from the WCF flows through a silica gel bed prior to reaching the filters. Consequently, the larger particles are removed before reaching the filter.) The analysis was made assuming 10% of the filter inventory was released at a height of 1 1/2 m, and doses were calculated at 8000 m (distance to nearest site boundary) and 2.8 x 10^4 m (distance to Arco or Howe), assuming the wind was blowing in that direction. Both lung and bone doses were calculated. The releases were assumed to occur during Class F meteorological conditions (the most conservative) with a 2 m/sec wind velocity. Table IV

TABLE IV

CALCULATED EXPOSURES FROM WCF FILTER CASK ACCIDENT[a]

Distance	Dose, rem[b]	Organ
8000 m[c]	0.05	lung
	0.07	bone
2.8×10^4 m[d]	0.008	lung
	0.01	bone

(a) Class F meteorology, 2 m/sec windspeed
(b) Annual dose rate for normal (as opposed to accident) conditions is 0.5 and 1.5 rem/yr to the bone and lung, respectively, for individuals in uncontrolled areas.
(c) Distance to nearest site boundary.
(d) Distance to Howe and Arco

gives the total dose someone would receive while the entire plume passes over, assuming the person had a high breathing rate ($3.47 \times 10^{-4} m^3$/sec) during the entire passage of the plume. By comparison, the yearly whole body dose from natural background is about 0.1 Rem. The security escort, in a separate vehicle, has a radio and would immediately notify the fire department and health physics personnel, who would arrive on the accident scene within minutes, thus minimizing or preventing radiation exposures to the public.

The probability of such an accident is extremely low. Studies[11] indicate that the probability of a serious accident (one involving a major fire or explosion) is only about 1/115,000 for every 1000 miles of shipment. Since the trip to the RWSA is only ten miles and the maximum frequency of shipment is once every two weeks, one would expect one accident to occur over a period of 441,000 years. Because of this low probability, it is highly unlikely that a serious accident of the type postulated will occur during the lifetime of the NRTS.

V. CONCLUSIONS

Based on the WCF filter cask design and the transport procedures, it is concluded that radioactive shipments can continue safely using the WCF filter cask. Even if the maximum credible accident occurred during transport, doses would be within established guidelines.

REFERENCES

1. U. S. Atomic Energy Commission, Idaho Operations Office, *Appendix 0500-1, Annex L, Standard Health and Safety Requirements for the On-Site Transport of Radioactive and Fissile Materials* (March 1973).

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APPENDIX A

MECHANICAL CALCULATIONS

1. Tie-Downs

SOP 1.6.7.11 lists the maximum weight of a cask that can be transported using specific sizes of chains. These numbers are based on the following analysis. To withstand a 1 g deceleration, the load in the chain is:

$$\frac{W}{n(\cos \alpha)} = L \text{ (lbs)} \tag{A-1}$$

where

w = weight of loaded cask = 37,000 pounds

n = number of chains securing cask = 8

α = angle between chain and truck, specified to be 45° or less.

Here only eight chains are assumed to be holding the cask, since the front eight would be slack when the truck was decelerating. Consequently, the load in the chains is

$$\frac{37{,}000}{8(0.707)} = 6{,}540 \text{ lbs.}$$

Since this is essentially the same as the working strength (1/5 the value of breaking strength) for the 3/8-in. steel alloy chains that are used (6,600 pounds), the tie-down arrangement is safe.

2. Eye Bolts

The energy the eye bolts are capable of absorbing is:

$$U = AL \frac{\sigma^2}{2E} \tag{A-2}$$

where

U = energy to be absorbed in the elastic range

A = cross-sectional area of bolt, 0.44 in.^{2}

L = length of bolt, 8 in.

σ = yield stress, 30,000 psi

E = modulus of elasticity, 28 x 10^6 psi

or U = 57 in.-lbs. The energy required to rupture the bolt would be greater than the energy to be absorbed in the elastic range by an unknown amount. However, it appears that the eye bolts will fail if the cask falls from the truck and lands on its edge by an eye bolt.

3. Closure Pins

The pressure required to shear the pins was calculated from equation (A-3):

$$P_{shear} = L\tau_s T \qquad \text{(A-3)}$$

where

P_{shear} = pressure to shear pin, lbs

L = length to be sheared, 2-in.

T = thickness 1-in.

τ_s = shearing stress 0.75 (σ_u) = 0.75 (85,000) = 63,750 psi

or P_{shear} = 2 x 1 x 63,500 - 127,500 lbs.

The calculated dynamic force caused by the cask falling from the truck and landing on the hinge was calculated as 11,400 lbs. Consequently, the locking bar will not fail. Since the hinge pins are larger in cross-sectional area than the locking bar, they also will not fail.

4. Filter Housing

The force required to fracture the filter housing was calculated from equation (A-4):

$$W = \frac{S_u\, 8\, \pi\, t^2}{3(3 + \nu)} \qquad \text{(A-4)}$$

where

π = constant

W = force to puncture the housing wall, lbs

S_u = ultimate stress, 75,000 lbs/in^2

t = metal thickness, 0.25 in.

ν = poisson's ratio, dimensionless, 0.29

or W ≅ 11,900 lbs.

The maximum force generated when the filter housing falls through a distance of 3 feet was calculated to be 3,500 lbs. Consequently, the housing will not fail if it falls from the truck.

The inlet assembly may fail if it receives a direct blow during the accident. However, since the door is recessed 5/8 inch (see Figure 7), and since the housing is normally protected by the cask, such a blow is unlikely.

APPENDIX B

DECAY ENERGY CALCULATIONS

The decay energy was calculated for a fission product inventory as shown in Table III of the report. Decay energies from the Handbook of Nuclear Research and Technology[B-1] were used to calculate the total decay energy. Because of the low heat flux involved, detailed calculations were not performed. Rough calculations, which follow, show negligible temperature rises because of the decay heat, and there is no material inside the cask to melt and release significant quantities of fission products. The pertinent information is summarized in Table B-I.

For the worst case, if no heat is transferred from the cask, the temperature rise in the cask from the decay heat can be calculated as follows:

$$Q = W C_p \Delta T$$

or

$$\Delta T = \frac{Q}{WC_p} \qquad \text{(B-1)}$$

where

ΔT = increase in cask temperature, $^{o}F/hr$

Q = decay heat released, Btu/hr

W = weight of cask, 36,200 lbs

C_p = heat capacity of cask, assumed to be 0.03 Btu/lb^{o}F (value for lead)

or, for the WCF filter cask,

$$\Delta T = \frac{6.6}{36{,}200 \times 0.03} = 0.006\ ^{o}F/hr = 0.15\ ^{o}F/day \qquad \text{(B-2)}$$

It is therefore concluded there is no danger from decay heat buildup.

TABLE B-I

ESTIMATED WCF FILTER CASK DECAY ENERGY

Nuclide	Curies	dps	E Decay mev/dis.	Total E, mev/sec
Ru-106	60	2.2×10^{12}	0.04	8.9×10^{10}
Rh-106	60	2.2×10^{12}	3.53	7.8×10^{12}
Cs-137	15	5.6×10^{11}	1.17	6.5×10^{11}
Ba-137m	15	5.6×10^{11}	0.662	3.7×10^{11}
Ce-144	6	2.2×10^{11}	0.32	7.0×10^{10}
Pr-144	6	2.2×10^{11}	2.98	6.6×10^{11}
Sr-90	20	7.4×10^{11}	0.54	4.0×10^{11}
Y-90	20	7.4×10^{11}	2.27	1.7×10^{12}

Total decay energy	=	1.2×10^{13} mev/sec
	=	6.6 Btu/hr
	=	2 watts
Cask exterior area	=	101.4 ft^2
	=	0.065 Btu/hr/ft^2

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B-1 *Nucleonics Handbook of Nuclear Research and Technology*, New York: McGraw-Hill, Inc.