

**MEET THE MAXIMALLY EXPOSED MEMBER OF THE PUBLIC:
THE SERVICE STATION ATTENDANT FOR SPENT FUEL GOING TO YUCCA
MOUNTAIN**

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ABSTRACT

According to the 1999 Draft Environmental Impact Statement (DEIS) for the proposed Yucca Mountain repository site, members of the public along transportation routes by which spent nuclear fuel (SNF) and high-level radioactive waste (HLW) is shipped will receive annual radiation doses less than 100 mrem/yr, the international (ICRP) and national (Department of Energy, Nuclear Regulatory Commission) radiation limit for members of the public. For the "Mostly Truck" national transportation scenario, the DEIS specifically concludes that the maximally exposed member of the public, a service station attendant along the primary shipping route will receive no more than 100 mrem/yr, or 2.4 rem over 24 years.

Based on the assumptions in the DEIS scenarios, however, it is highly likely that service station attendants along shipping routes will be called upon to fuel and service the rigs carrying SNF and HLW to Yucca Mountain. After reevaluating the DEIS, and making realistic alternative assumptions where necessary, the authors conclude that these attendants are likely to receive substantially more than 100 mrem/yr external dose, and perhaps several times that dose (up to 500 mrem/yr), unless mitigating measures are adopted. This is particularly true in Western states where refueling opportunities are limited, and the distances between fuel sources in rural areas may be up to 100 miles.

In terms of risk, the DEIS substantially underestimates the major health risk to these attendants. As estimated by the authors, the maximum risk to an attendant approaches 10^{-3} /yr. This risk is at least 5 times higher than the annual risk of being a motor vehicle fatality (based on current National Safety Council accident statistics and census figures), a risk that in itself is considered intolerable and which intense efforts are underway to reduce.

INTRODUCTION

In 2000, M.H Chew and Associates (CAI), prepared a review of routine radiation exposure and health effects issues in the U. S. Department of Energy (DOE) DEIS for the proposed Yucca Mountain repository site. (1) This review, prepared under contract for the State of Nevada Agency for Nuclear Projects, will be published in 2002 as a technical reference in support of the State of Nevada Yucca Mountain Impact Report. The CAI review found that despite the

sophistication of the models used to calculate impacts, many of the basic underlying assumptions and inputs into the risk calculations in the DEIS are incorrect, and are based on outdated or non-conservative forecasts. The effects of these inconsistencies and errors on the estimated time integrated exposures to workers and members of the public along proposed transportation routes is substantial (2). This paper discusses and expands upon two issues identified in the previously referenced CAI review:

- Doses to critical groups such as service station attendants are not conservatively, and probably not even realistically, estimated on an annual basis;
- Radiation risk coefficients used in the DEIS are taken from ICRP 60 (3) and based on BEIR V estimates of cancer risk (4) that have taken credit for a factor of two cancer reduction when the dose is received at low, and more or less constant dose rates. CAI believes that these conversion factors are non-conservative. The supporting documentation for ICRP 60 (5) lists, and EPA recommends (6), the use of risk factors that take dose rate credit for leukemias but not solid tumors. Use of these factors results in fifty percent higher doses and collective health risks.

CAI calculated alternative upper end annual doses and the risks of latent cancer fatality (LCF) to maximally exposed individual (MEI) service station attendants are shown in Table I below, as values relative to the values in the DEIS, App. J and Chapter 6.

Table I. Relative Annual Doses and Risks from CAI Report, Relative to DEIS Values for Service Station Attendant due to Casual Dose Only and Both Casual and Active Service Dose

MEI Considered	Relative Dose (compared to DEIS estimate)	Relative Risk (compared to DEIS estimate)
Service station attendant (Casual Dose Only)	1.9	2.8
Service station attendant (Casual + Active Service Dose)	10.0	14.9

Note: includes multiplier of 1.5 for increased LCF risk factor as discussed above.

STATEMENT OF THE PROBLEM

This paper focuses upon the DEIS methods and approaches for estimating incident-free doses to maximally exposed individuals (DEIS, J-43 to J-44), specifically service station attendants at any service station utilized by a large number of SNF and HLW shipments. This topic deserves special attention for the several reasons.

- First, legal-weight truck (LWT) transport may be the primary mode for repository shipments. If the Yucca Mountain repository project goes forward, the "Mostly Truck" scenario described in the DEIS may be the operative transportation system. Yucca Mountain currently lacks rail access. Construction of a new rail access spur will be difficult and costly, as would heavy haul truck delivery of rail casks from an intermodal transfer station. All 77 utility and DOE storage sites can ship SNF and HLW by legal-weight truck, and LWT transport is

economically competitive with rail transport. DOE's "hot repository" thermal loading strategy, coupled with many utilities desire to ship SNF to the repository directly from wet storage, particularly favors LWT transport during the first 10 to 20 years of operation. Under the "Mostly Truck" scenario there could be an average of 2,100 to 2,500 LWT shipments per year, for 24 to 38 years. Over 38 years, there could be about 93,000 truck shipments of SNF and HLW, with an average distance of 1,980 miles per shipment.

- Second, service station attendants maybe required to refuel SNF trucks, in order to reduce radiation exposures to truck drivers. Under the "Mostly Truck" scenario, the DEIS identifies truck drivers as maximally exposed workers, and assumes that driver doses will be administratively regulated by a 2-rem-per-year dose limit (7) . Under the Federal motor carrier safety regulations for hazardous materials, drivers of SNF trucks are responsible for certain activities that will result in significant cumulative radiation doses. However, the regulations allow a person other than the driver to "be in control of the fueling process at the point where the fuel tank is filled" [49CFR397.15] (8). Assuming an average of 50 trips per year, and six fuelings per trip, the driver's annual dose could be reduced by 300 mrem or more by requiring the truck to be fueled by a service station attendant;
- Third, on the most likely truck routes to Yucca Mountain, there may be limited options for refueling. Service stations in rural Nevada and Utah are famous for "Last Chance Gas" billboards. In reality, refueling opportunities are (and will likely continue to be) extremely limited along the primary truck route identified in the Yucca Mountain DEIS, I-15 from Salt Lake City to Las Vegas, and along one potential alternative route (US93A, US93, US6, and US95 from West Wendover to Lathrop Wells). Routine refueling in Salt Lake City, Las Vegas, and other highly populated areas will be prohibited under the NRC safeguards regulations [10CFR73.37(a)(i)] (9). The limited number of diesel fuel sources in rural areas, coupled with long distances (up to 90 miles) between service stations, creates a strong likelihood of repeated fueling at a single location. Either one of these routes could credibly be used by 2,300 or more SNF trucks per year, for three or four decades.

RADIATION PROTECTION STANDARDS

DOE's DEIS for Yucca Mountain assumes that SNF and HLW shipping casks will operate under Nuclear Regulatory Commission (NRC) regulations which allow a routine radiological dose rate of 10 millirem (mrem) per hour at 2 meters. This dose rate results in exposures of about 0.2 mrem per hour at 30 meters and about 0.11 mrem at 60 meters. Two aspects of DOE's proposed action, large numbers of shipments (up to 2,500 legal-weight truck shipments per year) and use of routes through metropolitan Las Vegas, create the potential for unprecedented routine radiological impacts. Alternative routes through northern Nevada would similarly involve substantial routine radiological impacts because of the proximity of resident and non-resident populations to highways and rail lines. The large numbers of shipments would also result in substantial routine radiological exposures to transportation workers, safety inspectors, and security escorts.

The current DEIS does not appear to take into account the immense demographic changes that have taken place in the state of Nevada, much of it along the proposed transportation routes to

Yucca Mountain. In addition, advances in risk assessment methodology (e.g. BEIR V) have not been incorporated into the DEIS impact assessment. Finally, although generic collective risks from routine radiation doses have been assessed, both the exposure to the Maximally Exposed Individual (MEI) and the risks to exposed sub-populations (pregnant woman, children) may not have been completely characterized.

By and large, the radiation exposure standards of both DOE and NRC have been similar and developed in parallel with each other. With the publication of 10CFR835 in 1994, DOE set in place regulations essentially identical to those previously established by the NRC (10CRF20). The regulations that apply to members of the public are slightly different under the two sets of regulations, as shown in Table II below.

Table II. Comparison of 10CFR 20 (NRC) and 10CFR 835 (DOE) Regulations for Doses to Members of Public

Type of Limit	Agency	
	NRC	DOE
Dose Limit-Public	100 mrem onsite exposure (external + internal) §20.1301 50 mrem direct external radiation offsite (shine + releases, based on continuous exposure) §20.1302	100 mrem total any member of the public, on or off-site
Dose Limit-Occupational	5,000 mrem/yr effective dose (external + internal) Subject to being “as low as Reasonably Achievable” (Regulatory Guides compliance)	5000 mrem/yr effective dose (external + internal) DOE limit 2000 mrem/yr site limit (RadCon Manual) Site Management Guide (1000-1500 mrem/yr) Subject to being “as low as reasonably achievable” below this (RadCon Manual)

MAXIMALLY EXPOSED INDIVIDUALS: THE SERVICE STATION ATTENDANT SCENARIO

Among the highest annual doses and instantaneous dose rates to members of the public will be those received by service station attendants, assumed in the Draft EIS to be located near the Mercury, Nevada, gate (DEIS Section 6.2.31, p. 6-24). The doses are significant by virtue of the long refueling times and the occasional need for attendants to provide trailer or tractor service. The dose to a worker (attendant) can be thought of as having two components:

$$\text{Attendant Total Dose} = (\text{Casual Dose}) + (\text{Active Service Dose}) \quad (\text{Eq. 1})$$

where:

- Casual Dose is that received in a service Bay or office while the truck is parked at the station (in the DEIS this is assumed to be at a 20 m distance from anyone, per J 1.3.2.2, p. J-43);
- Active Service Dose (not considered by the DEIS) is that received by an attendant who is refueling or otherwise servicing the trailer or tractor rig (e.g. replacing a tire, adjusting brakes, etc.). Only the Casual Dose component was assessed in the DEIS and was estimated to be about 100 mrem/yr (p. 6-24).

These assumptions are shown below in Figure 1 below:

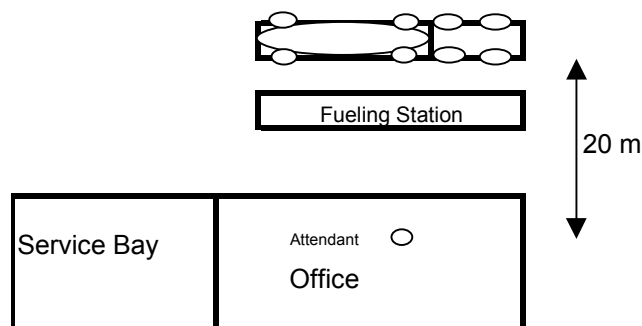


Fig. 1. Typical Service Station Layout and Dimensions for the Service Station Attendant Scenario

Both components of the doses to service station attendants can be calculated by assuming the following (references are to page numbers in the DEIS):

- One attendant does all refueling and tire or other minor cask trailer servicing;
- The attendant works 1,800 hours/yr (DEIS p.6-24)
- The truck stop is a “last chance” before YM scenario and all 2,100 trucks/yr (DEIS p. 6-24) stop there (this number may actually be as high as 2,500 shipments/yr)
- 5% of trucks also require tire changing or other trailer servicing (typical industry figure).

Casual Dose Estimate

The DOE estimate of the Casual Dose component is reasonable and can be assessed by using the maximum dose rate from the generic cask in Table G-5 of ANL/EAD-1 (11): Using a cask surface distance of 20 meter the maximum dose rate (radially along the axial midline) would be about 0.188 mrem/hr, as shown below in Table III.

Table III. Maximum Dose Rate(mrem/hr) as a Function of Distance from Side of Cask, from the Generic Cask in Table G-5 of ANL/EAD-1

Distance from Cask Surface, m	Total dose rate, mrem/hr
2	10
5	2.5
10	0.731
20	0.188

The annual doses (Casual and Active Service) can be calculated by assuming that shipments coming in for refueling and service are more or less evenly distributed throughout the day and year; therefore the fraction of the total number of shipments service by any one attendant is the fraction of the year spent working. Assuming 2,100 struck shipments/yr and 1,800 working hrs/yr the annual Casual Dose can be calculated as follows.

Defined Quantities

N_{SS} = Number of shipments serviced by any one attendant per year

N_R = Number of trucks repaired per year = $0.05N_{SS}$

D_{ac} = Annual Casual Dose (mrem/yr)

D_{aa} = Annual Active Service Dose (mrem/yr)

D_T = Attendant Total Annual Dose (mrem/yr)

D_{ac}^* = Adjusted Annual Casual Dose (mrem/yr) = $D_{ac}/3$

\dot{D} = Dose rate at assumed distance (mrem/yr)

T_s = Stop time (hr)

Number of Shipments Serviced by any one attendant:

$$N_{SS} = (\text{Number shipments/yr}) \times (\text{fraction of year attendant is on the job}) \quad (\text{Eq. 2})$$

$$= (2,100 \text{ sh/yr}) \times (1,800 \text{ work hr/yr}) / (24 \text{ hr/d} \times 365 \text{ d/yr})$$

(fraction of total hours spent working)

$$N_{SS} = (2,100) \times (0.205) = 430 \text{ shipments serviced/yr}$$

Calculation of Annual Casual Dose:

$$D_{aa} = N_{SS} (\text{sh/yr}) \times D (\text{mrem/hr}) \times T_s (\text{hr}) \tag{Eq. 3}$$

$$D_{aa} = (430) (0.188) (1) = 81 \text{ mrem/yr}$$

This dose is conservative due to the assumption that all 2,100 shipments per year stop at a given station. The overall level of conservatism of the calculation is diminished by the possibilities that:

- A given worker may well work over 1,800 hrs/yr (e.g. the owner of a small station or a worker taking extra shifts; DOL statistics show that service workers in low-paying jobs frequently work ~25% or more overtime);
- Annual shipment rate to YM may be as high as 2500/yr (Module 1 or 2 scenarios)
- The assumption that the truck spends the entire hour at a 20 m distance. At most smaller service stations, some pumps may be within 10 m or so from the office.

The Active Service Dose

A more serious deficiency in the MEI dose calculation in the DEIS is the tacit assumption that the service station attendants will not receive active service dose, that is, will not be involved in the refueling operation or in any vehicle maintenance (i.e. the DEIS assumes no Active Service Dose). Assuming that refueling and maintenance are mainly handled by attendants rather than the drivers, the annual dose may be calculated if the typical times required to refuel and replace a tire are known.

Sandquist et al in 1985 (12) estimated the service station worker doses from these activities involving a generic truck cask (similar to a NAC LWT) (Sandquist, Table 2-1). The doses for the generic cask used by RISKIND (similar to a GA-4) is used instead (11), and the typical doses obtained are shown in Table IV below.

Table IV. Doses for LWT Refueling and Servicing based on Sandquist (1985)

Description	Distance to Center of Cask, meters ¹	Exposure time ¹	Maximum Dose Rate; Total Dose
Truck Servicing Action			
Refueling	7 m (at tank)		27µrem/min (1.6 mrem/hr)
-1 nozzle from 1 pump		40 min	1.1 mrem
-2 nozzles from 1 pump		20 min	0.53 mrem
Load inspection/enforcement	3 m (near personnel barrier)	12 min	130 µrem/min (7.8 mrem/hr); 1.6 mrem
Tire change or repair to cask trailer	5 m (inside tire nearest cask)	50 min	52 µrem/min (3.1 mrem/hr); 2.6 mrem

Notes: ¹ Exposure times and distances were taken from Sandquist (1985), Table 2-1. The dose rates were developed from Table G-2 (GA-4 cask) of ANL/EAD-1 (Yuan, 1995) using the same distances (mid-line for the GA-4) used by Sandquist.

Calculation of Active Service Dose

$$D_{aa} = N_{SS} \text{ (sh/yr)} \times 1.1 \text{ (mrem/sh)} + N_R \times 2.6 \text{ (mrem/sh)} \quad (\text{Eq. 4})$$

$$D_{aa} = (430) \times (1.1) + 21 \times (2.6) = 528 \text{ mrem/yr}$$

This calculation is slightly conservative because the dose rates used in **Table IV** above were calculated using the table of mid-line dose rates given in ANL-EAD-1, Table G-5 (doses off the mid-line are not given in the table). Sandquist used off-midline dose rates for fueling and servicing, as calculated using the PATHRAE code and listed in his Table A-2. These doses are somewhat smaller than the mid-line doses in the same tables.

Thus, the doses in the table above, and the annual estimated dose for the service station attendant are somewhat conservative, but probably not by more than ~25-33%. (for actual casks, the mid-line dose variation with distance is less rapid than the off-midline dose; in Sandquist Table A-2, for example, the dose rate drops off most quickly along the cask axis--i.e. at either end--most slowly along the midline and at a rate intermediate between the two along any other ray extending from the cask center). The conservative assumption above that there is only one service attendant on duty at a time may be realistic for smaller stations or truck stops.

The Attendant Total Dose

The DEIS scenario assumed ~1 hour of casual exposure per shipment scenario. If ~40 minutes of this time is actually spent in active service, as in Table IV above, then the time that this particular attendant is sitting in the office is reduced by the active service. Using a 1 hour total stop time (unless additional servicing is required, which would result in a larger stop time), the 40 minutes (of the 60 total) spent refueling would reduce the casual exposure time to 20 minutes, and the casual dose above is reduced to:

$$D_{ac}^* = N_{SS} \times (\text{Stop time adjusted for service time, hr}) \times (0.188 \text{ mrem/hr}) \quad (\text{Eq. 5})$$

$$D_{ac}^* = (430) \times [(60 \text{ min} - 40 \text{ min})/60] = 27 \text{ mrem/yr}$$

And thus, the calculation for total annual dose from Eq. 1 above becomes:

Calculation of Total Annual Dose

$$D_T = D_{ac}^* + D_{aa} \quad (\text{Eq. 6})$$

$$D_T = 27 \text{ mrem/yr} + 528 \text{ mrem/yr} = 555 \text{ mrem/yr}$$

or over five times the NRC/DOE annual limit for members of the public (100 mrem/yr) in 10CFR20 and 10CFR835, respectively.

This is not the most conservative scenario that might represent actual upper end attendant dose. An attendant working 25% overtime (50 hr/wk) would receive 25% more than 555, or 694 mrem/yr. If trucks refuel primarily during day and evening (8 AM- 12 AM), this means that 50% more trucks refuel during those hours; i.e. an attendant working 1800 hr/yr would refuel 645 trucks/yr (rather than 430). The corresponding upper-end doses are shown in Table V below.

Table V. Service Station Attendant Annual Doses if Overtime Hours and 8 AM-12AM Refueling are Assumed

Scenario	Total Annual Dose
Baseline (no overtime and 24 hour refueling)	555
25% Overtime, and 24 hour refueling	694
Normal (1800 hours/yr), 8 AM-12 AM refueling	832
25% Overtime and 8 AM-12 AM refueling	1041
25% Overtime and 8 AM-12 AM refueling (Casual Dose Only)	152

Thus, even removing some of the conservatism built into the equation above (e.g. assume that there are always at least two attendants available to refuel trucks on every shift and only 50% of the cask trucks stop at any one station), it is still very likely that the annual dose will significantly exceed the 100 mrem limit if service station attendants are drawn into vehicle refueling or servicing.

HEALTH RISKS TO MAXIMALLY EXPOSED INDIVIDUALS

Based on the 81 mrem/yr estimate, DOE has estimated the health risk (latent cancer fatality) to a service station as 5×10^{-5} /yr, (DEIS, Table 6-6) based on the use of the recommended risk factors (or conversion factors, C.F.) from ICRP 60.

EPA has reviewed the conclusions of ICRP and the bases for these conclusions in the 1990 BEIR V report. Based on their own review of the data, they recommend a risk factor of 7.6×10^{-7} LCF/mrem, or 50% higher than the value recommended in ICRP 60 and used by DOE (the difference is based upon the validity of ICRP's assumption that radiation at low dose rate has only 50% as much ability to cause cancer as radiation at the higher dose rates seen in most studies. EPA feels that the evidence does not warrant more than a ~25% cancer rate reduction). If the higher risk factors are applied to radiation doses received by the public due to HLW and SNF transportation, DOE's risk estimate for the service station attendant and other exposed members of the public increases by 50% to the values shown in Table VI below.

Table VI. Comparison Of Risk Estimates To The Service Station Attendant In the DOE DEIS and the CAI Report

Scenario (Annual Effective Dose)	Estimated Risk (1999 DEIS C.F.)	Service Station Attendant Annual Risk (CAI 2001)
Base Case (81 mrem/yr)	4×10^{-5}	6×10^{-5}
Active Service Dose Base Case (555 mrem/yr)	--	4.22×10^{-4}
Worst Case Exposure (1021 mrem/yr)	--	7.91×10^{-4}

The DEIS has quantified risks to workers and the public based on collective numbers of LCF's expected and the maximum risk to an individual worker or member of the public (MEI). The authors believe that the risk factors for all these effects, and thus the risk levels themselves, should be increased by 50% to be in line with the more conservative recommendations of ICRP. To put these risks in perspective, they are more than 5 times higher than the average annual risk for death in an automobile accident (13), a risk that is considered intolerable and which intense efforts by many state and Federal agencies are directed to lower.

CONCLUSIONS

The DEIS clearly underestimates potential exposures and health effects for the maximally exposed member of the public, the service station attendant along the primary shipping route. The DEIS should be revised to adequately reflect the realistic ranges of exposures likely to occur and the higher risk factors recommended. In addition, the DEIS dose and risk calculations should consider more vulnerable members of the public such as pregnant females.

While it is not within the scope of this paper to determine the manner in which compliance with the public dose limit might be achieved, the authors believe that the DEIS should have considered methods to prevent the annual doses to service station attendants from exceeding the limit for members of the public.

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