4/85
Revised

RISK COMPARISONS FOR THE TRANSPORTATION OF SPENT FUEL FROM NUCLEAR REACTORS

Andrew P. Hull and Edward T. Lessard
Safety and Environmental Protection Division
Brookhaven National Laboratory

INTRODUCTION

In the United States today, we enjoy a material abundance and a related longevity. Its provision depends on the extraction, processing, transport, utilization and disposal as waste of considerable quantities of materials. If not carefully controlled, this waste may be hazardous to workers and the public. Some of the above benefits are the result of the research conducted at nuclear reactors such as the High FLux Beam Reactor (HFBR) at Brookhaven National Laboratory on Long Island. Radioactive materials produced at nuclear reactors are also widely employed in industrial, medical and even domestic applications (i.e. luminous dials, smoke alarms). In contrast to many older technologies, nuclear activities have been conducted from their inception with their containment as a primary consideration at every step. This has included the transport of radioactive materials in general, and of spent reactor fuel in particular. The result has been a degree of safety unparalleled in any other human endeavour.

There have been 330 multi-element spent fuel shipments from Brookhaven National Laboratory to U.S. Government-owned reprocessing facilities between 1964 and 1976. About 5,000 spent fuel elements from nuclear power reactors have been shipped over these twenty-two years, without an accident which has resulted in the release of radioactivity to the environment. Yet, the possibility of such a release of such shipments remains a matter of public concern, as witnessed by the efforts of New York City to ban their transportation within its limits.

The indicated concern of New York City in the promulgation of this ban, has been the risk attendant with the ongoing shipments of spent reactor fuel from Brookhaven's High Flux Beam Reactor over its streets enroute from Long Island to DOE fuel reprocessing facilities. The HFBR is operated for research purposes at a thermal power level of 60 megawatts.⁽¹⁾ Half of its core, which contains 28 elements of highly enriched uranium (93% Uranium 235), is replaced about once a month. The modified shipping cask which Brookhaven currently utilizes holds 32 of these elements thus necessitating about 5 such shipments per year⁽²⁾. Although this is a larger number of elements than is

Research carried out under the auspices of the U.S. Department of Energy,
Contract No. DE-AC02-76CH00016

transported in a typical shipment of from one to four spent fuel elements from a nuclear power reactor, the radioactivity of the fission products in a BNL and in a commercial shipment is comparable. There is less plutonium in the highly enriched HFBR fuel on an equal burn-up basis than in commercial nuclear power reactor fuel.

The Brookhaven shipments currently use a modified cask similar to the type that is used for the shipment of fuel from commercial power reactors. Thus, this cask meets the pertinent regulations of the Department of Transportation for Class B shipments. They require a design analysis or type test so as to assure that casks so designed will withstand the following events in sequence.

1. A drop from 30' onto an unyielding surface
2. A free fall from 40" onto the end of a 6" diameter rod
3. A 1475° thermal environment for 30 minutes
4. Submersion under three feet of water for eight hours.

Thus, the risks attendant with the shipment of Brookhaven's irradiated fuel are less than those from the transport of spent fuel in general.

RISK ESTIMATES

As already indicated, the shipment of spent fuel during the past two decades has occasioned no radiation related fatalities or injuries. So it is not possible to base the risk of this practice on experience, as is possible for the risk of death or injury from motor vehicle accidents which happen quite regularly. However, the hypothetical probability of death or injury due to the routine transport of spent fuel or from that occasioned by a release of radioactivity during an accident has been estimated in several studies which have utilized models of the postulated phenomena. These models have been verified by physical tests of scale and full-sized casks at Sandia National Laboratory, in which they have survived intact from impacts from rail and highway accidents, from being subjected to prolonged intense heat and actual immersion. These tests have demonstrated that no radioactive material would have been released from them, if they had been loaded with actual spent fuel in a real accident.

An early study⁽³⁾ which was performed for the Regulatory Directorate of the USAEC in 1972 found that the probability of truck, rail or barge accidents was about 1:1,000,000 per vehicle mile. It found that, based on these statistics, a shipment of nuclear materials from a typical nuclear power reactor would be involved in a transportation accident about once each 5 years. Less than 1% of these accidents, or one each 500 years would involve a severe impact or fire. The study concluded that in a severe accident some radioactive material released due to the perforation of a fuel element was possible, the amount would be too small to produce immediate health effects (fatalities or sickness).

An independent study, Transportation Accident Risks in the Nuclear Power Industry 1975-2020⁽⁴⁾ was prepared by Holmes and Narver for the Environmental Protection Agency in 1974. They concluded that the risks from accidents involving spent fuel would dominate the overall transport release frequency during the entire period. However, they stated:

"The average annual population dose from transportation accidents of the nuclear power industry is insignificant, less than one person-rem per year from all sources in 1975. A release, if one should occur, is most likely to result in a relatively small exposure to individuals near the accident, on the average not exceeding the thresholds for biological effects. The resulting population dose is a very small part of the natural background population dose received by all persons in the vicinity of the accident. Only in the worst and most unlikely cases of release can lung exposure exceed thresholds for biological effects. The probability of any such event is estimated to be no more than one per 90 thousand years or less"

A more detailed study was made in the Environmental Impact Statement on the Transportation of Radioactive Materials by Air or Other Modes,⁽⁵⁾ which was prepared by the USNRC in 1977. In order to examine the environmental impact of the alternatives to air transport, other modes of transportation were examined. This study concluded that the overall radiological impact to the public from transportation accidents involving packages of radioactive material would be small, with an expected value of one latent cancer fatality or one genetic effect for 200 years of shipping radioactive materials at 1975 rates. About half of this was attributed to the nuclear fuel cycle. No early fatalities were expected due to accidents involving spent fuel.

A more detailed assessment, The Environmental Consequences of the Transportation of Radioactive Materials in Densely Populated Urban Areas,⁽⁶⁾ was performed by Sandia National Laboratory for the NRC in 1979-1980. The boroughs of Manhattan, Brooklyn and Queens in New York City were used as a base case and the results were scaled to other urban locales throughout the U.S. The results were expressed as expected numbers of health effects per shipment-year. For the base line case they estimated a 1/500,000 yearly likelihood of early morbidity, a 1/1,000 yearly likelihood of a latent cancer fatality and a 1/1,000 yearly likelihood of a genetic effect. These estimates were consistent with the previous NRC study.

Particular attention was paid to the material which could be released from a spent fuel shipping cask. After consideration of test data on cask responses to severe accidents, the authors concluded that the previous assumption that a fraction of the entire cask contents would be released and aerosolized was not reasonable. Thus they decided to base their analysis on the assumption that the major source of the radioactivity which could be released in a severe accident would be the material deposited on the interior of the cask and the exterior of the fuel elements while they were in the reactor. These are the so called corrosion products, principally Cobalt-60. Their hypothetical release was calculated to contribute about 45% of the overall shipment related health effects. Almost all of the remaining health effects from transport accidents were expected to originate from accidents involving radionuclides used in medical procedures.

Another approach to the estimation of the probability of spent fuel accidents was based on the transported volume and incident/accident experience since 1971, in a report prepared by Sandia Laboratories for the Department of Energy in 1981.⁽⁷⁾ It indicated that about 2,000,000 shipments of radioactive materials packages are currently made each year. From 1969 to 1979, when spent commercial fuel was being processed in the U.S., 4,797 fuel assemblies were shipped. There was one reported accident in which the driver was fatally injured, but there was no release of radioactive materials. With an estimate of the mileage traversed by all those fuel shipments, an expectation of one such accident in each 2,000,000 miles was calculated. This is about a factor of two lower than previously estimated. The likelihood of an accident that would cause cask failure was estimated at one each 500,000,000 miles travelled. No estimates of release fractions and consequences was attempted.

RISK COMPARISONS

Some perspective on the risk to an individual from the transport of spent reactor fuel may be obtained from information provided in the NRC's 1977 environmental statement, from which the following table is derived.

Table I

Individual Risk of Early Fatality by Various Causes

<u>Accident Type</u>	<u>No. of Fatalities Per Year</u>	<u>Individual Average Risk Per Year</u>
Motor Vehicle	55,000	1 in 4,000
Homicide	19,000	1 in 10,000
Falls	18,000	1 in 10,000
Fires	7,500	1 in 25,000
Drowning	6,200	1 in 30,000
Air Travel	1,800	1 in 100,000
Falling Objects	1,300	1 in 160,000
Electrocution	1,100	1 in 180,000
Lightning	160	1 in 1,300,000
Tornadoes	91	1 in 2,500,000
Hurricanes	93	1 in 2,500,000
Spent Fuel Shipments	.0002	1 in 1,000,000,000,000

The foregoing analysis suggest that by any reasonable standard, the transportation of spent nuclear fuel is an extremely low risk activity.

Meanwhile there are many hazardous substances, besides spent fuel, which are routinely shipped in far larger quantities throughout the United States, including the streets of our urban centers, with little or no public concern. Some comparisons of those occasioned by the transport of energy related materials are available from recent studies by Pacific Northwest Laboratory. They were summarized in 1981 in a Pacific Northwest Laboratory report Risks in U.S. Energy Material Transportation,⁽⁸⁾ from which Table II is adapted.

Table II

Comparison of Risks for Transportation of Selected
Energy Materials in the U.S.

<u>Substance</u>	<u>Approximate Number of Yearly Shipments</u>	<u>Fatalities Per Year</u>	<u>Estimated Maximum No. of Fatalities</u>
Gasoline	14,000,000	29	40
Propane	3,000,000	15	800
Chlorine	55,000	9	600
Spent Reactor Fuel	2,000	0.0001*	0 (acute) 100 (latent cancer)

*Estimated

Although the sort of detailed analysis which has been made for spent nuclear fuel shipments has not been performed for the transport of the many other hazardous substances which are also shipped routinely, we do know that it is not risk free. Some specific illustrations are available.

The statistics kept by the Chlorine Institute⁽⁹⁾ indicate that in 71 years, 250 persons (75% public and 25% workers) have been exposed and 9 killed (all public) by large chlorine spills from rail tank cars. We are aware of the train accident in Canada in 1979, involving the release of chlorine and phosgene, which led to the precautionary evacuation of 250,000 persons from a suburb of Toronto. From 1971 to 1975, there were 3 incidents in which chlorine truck tankers were involved. Two resulted in leaks, in which 5 persons were exposed to chlorine gas.

A survey of the risks of the transport of gasoline was made in California, following the accident in the Caldecott Tunnel. It disclosed that between 1976 and 1980, 480 persons had been killed and 3,500 injured in accidents in which highway tankers loaded with gasoline were involved.⁽¹⁰⁾

SUMMARY

In summary, on the basis of calculated estimates, tests and accident statistics, the transport of spent nuclear fuel by whatever means has been shown to represent an infinitesimally small risk to the public, wherever they may be located enroute. This conclusion is based on three points 1) the probability of an accident involving spent fuel is small, 2) the probability that this hypothetical accident releases radioactive materials is even smaller and 3) the public-health consequences of such a release are trivial. It hardly seems to warrant the extensive assessment that it has received. If the risk to the public is of concern, this attention and analysis might have been more profitably spent on the improvement of the safety of the transport of a wide variety of other hazardous substances, which at present are given little if any prior scrutiny.

ACKNOWLEDGEMENT

The assistance and/or advice of S.C. Morris, Jr., P. Tichler and V.L. Sailor of the staff of Brookhaven National Laboratory and Robert Luna of Sandia National Laboratory is gratefully acknowledged.

REFERENCES

1. Tichler, P.R., "Addendum to the High Flux Beam Reactor FSAR, Report for 60 MW Operation", April, 1982.
2. "Safety Analysis Report for Packaging of TRIGA and MTR Fuel Assembly in MH-1A Spent Fuel Shipping Casks," Ridiholgh, Eggers and Assoc, Inc. for DOE, Albuquerque Operations Office, January 28, 1985.
3. USAEC, "Environmental Survey of Transportation of Radioactive Materials to and from Nuclear Power Plants," USAEC, Directorate of Regulatory Standards, December 1972.
4. USEPA, "Transportation Accident Risks in the Nuclear Power Industry, 1975-2020," PB-258 277, Holmes and Narver, Inc. for EPA Office of Radiation Programs, USEPA, November 1974.
5. USNRC, "Final Environmental Statement on the Transportation of Radioactive Material by Air and Other Modes," NUREG-0170, Vols. 1 and 2, NRC Office of Standards Development, December 1977.
6. Finley, N.C., et al, "Transportation of Radionuclides in Urban Environs: Draft Environmental Assessment," NUREG/CR-0743, July 1980.
7. McClure, J.D., "The Probability of Spent Fuel Transportaton Accidents," SAND 80-1721, July 1981.
8. Franklin, A.L., et al, "Risks in Energy Material Transportation," PNL-SA-8545, May 6, 1981.
9. Helmaste, R.J. and C.R. Phillips, "A Risk Evaluation of the Chlorine Industry in North America", Risk Analysis, 1.4 pp. 259-266 (1981).
10. Mills, M.P., "Transporting Radioactive Materials," Science Concepts, September 1982.