INTERNATIONAL CONFERENCE
ON NUCLEAR POWER AND ITS FUEL CYCLE
SALZBURG, AUSTRIA • 2–13 MAY 1977

IAEA-CN-36/563

# UNITED STATES EXPERIENCE IN THE TRANSPORTATION OF RADIOACTIVE MATERIALS

by

A. M. Platt
R. E. Rhoads
R. J. Hall
L. D. Williams

Battelle, Pacific Northwest Laboratory
PO Box 999
Richland, Washington 99352 USA

W. A. Brobst

US Energy Research & Development Administration
Washington, D. C. 20545 USA

L. B. Shappert

Oak Ridge National Laboratory
PO Box X
Oak Ridge, Tennessee 37830 USA

R. M. Jefferson

Sandia Laboratories
PO Box 5800
Albuquerque, New Mexico 87115 USA

In this fourth major world conference on nuclear power, it seems appropriate to address the subject of transport of radioactive materials with a broad overview perspective, rather than repeat details previously documented.

With this perspective, two conclusions are immediately apparent. First, since fission rather than chemical oxidation is involved, the quantities of materials being transported in a nuclear power cycle are small compared to fossil energy systems. Second, nuclear transport is an activity with an unparalleled record of safety. Since the first demonstration of electric power from fission at the Idaho National Reactor Test Station on the 20th of December, 1951, no serious injury or fatalities have occurred in the U.S. because of exposure to radioactive materials in transport. In contrast, about one million Americans have died in accidents involving the automobile.

## TRANSPORT NEEDS

Turning now to details of the U.S. experience on transport, most of you are aware that, at least in the U.S., we are seriously examining the LWR fuel cycle operated with a once through fuel cycle as a serious contender to conventional plutonium and uranium recycle.

Figure 1 indicates, for the discard cycle, the facilities, operations and annual material flows that require transport. The specialized transport requirements for this cycle are relatively modest and primarily constrained to the disposal of irradiated fuel.

Figure 2 shows the potential transport requirements for a full fledged recycle program. Many additional streams requiring specialized transport are involved. Particularly for this fuel cycle mode, transportation of radioactive materials is significantly impacted by the dispersion or co-location of the key facilities, e.g., reactors, interim storage, reprocessing plants, MOX plants and Federal waste repositories.

It should be noted that in both figures the material flows are for a reactor year. In the U.S. we anticipate nuclear power at 150 and 500 GWe-Yr in 1985 and 2000, respectively.

## REGULATORY REQUIREMENTS

The IAEA regulations,[1] first published in 1961 and with numerous changes since then, form the groundwork for the U.S.A. regulations.[2,3] Thus shipments meeting IAEA regulations can still move freely into and out of the U.S.A.

Basically, the regulations are attempting to control three things: (1) the release of nuclear materials both during an accident and also under the normal conditions of transport; (2) the exposure of people--transport workers and the general public--from radiation, mostly gamma

FIGURE 1

# THE LWR FUEL CYCLE
# URANIUM & PLUTONIUM RECYCLED

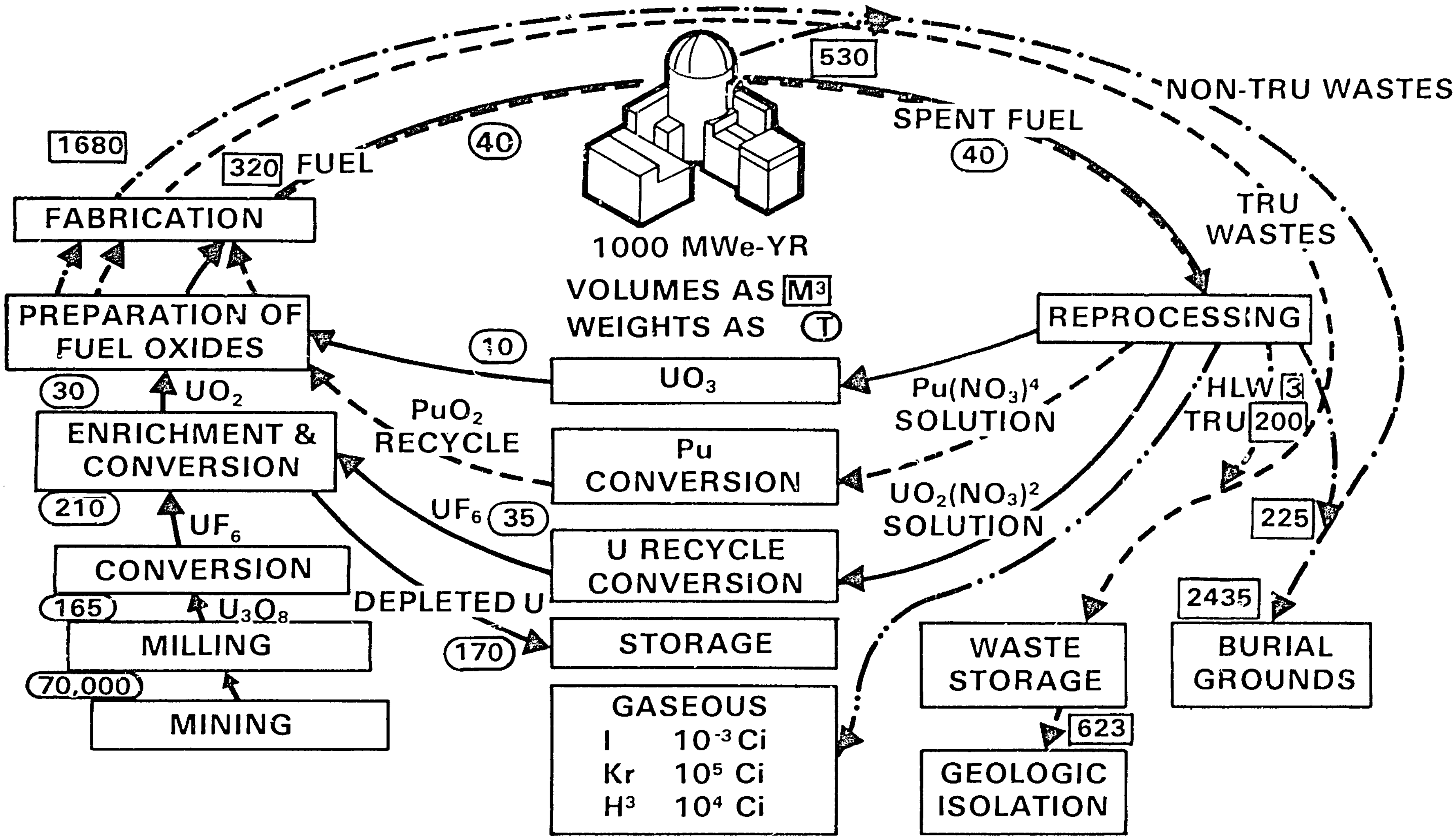
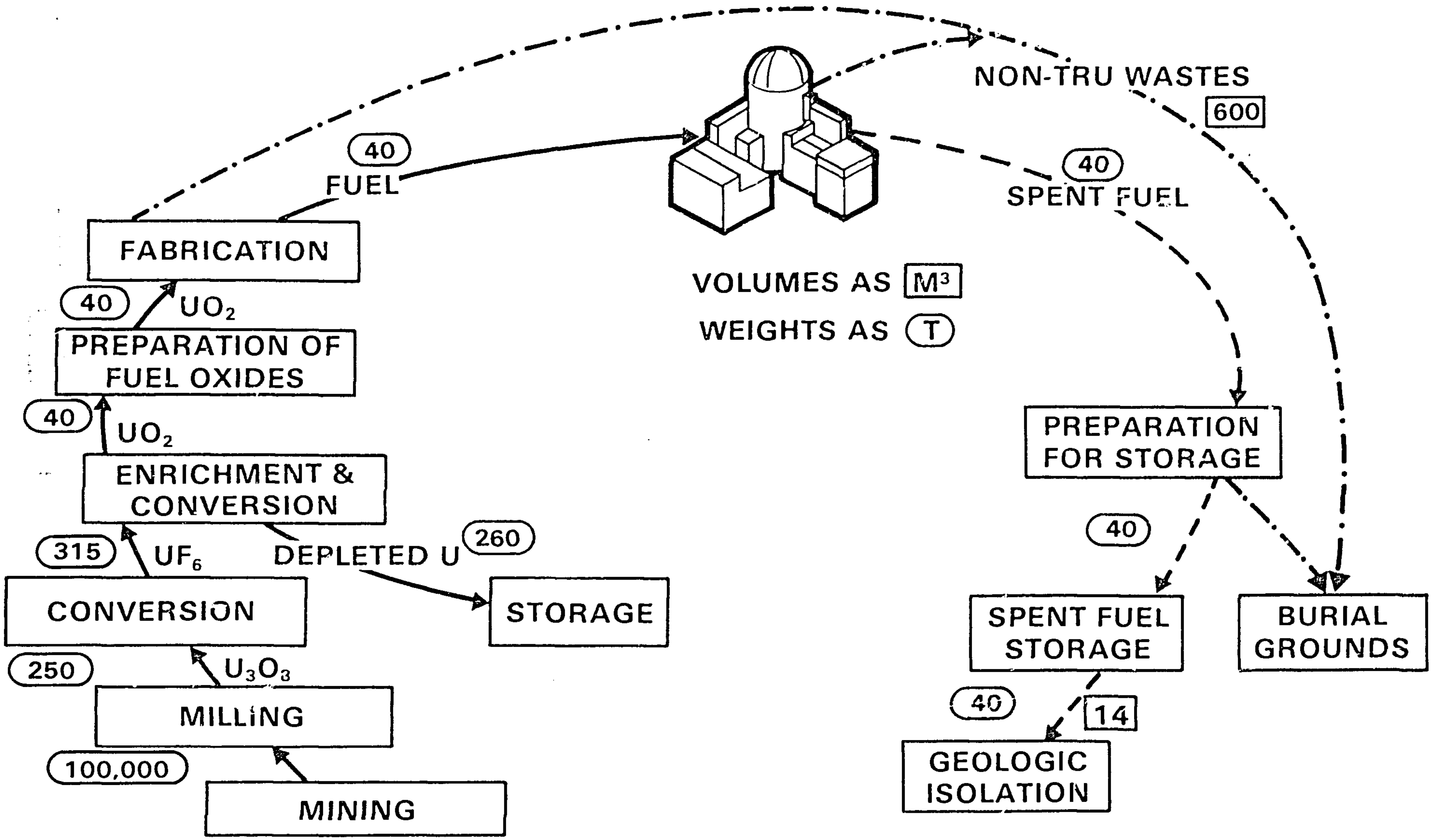


FIGURE 2

# THE LWR FUEL CYCLE SPENT FUEL DISCARDED



rays, coming from the surface of the package; and (3) the maintenance of a safe geometry for fissile materials. Other regulations also attempt to control the risk from sabotage or terrorism during transport.

The regulations provide for three types of packaging integrity; exempt, Type A, and Type B. Shipments that contain very small quantities of radioactivity, or materials where the concentration of radioactivity is very low, are of such low risk that the packages are exempt from most of the provisions of the IAEA regulations. This category of materials covers things like uranium ore, natural uranium hexafluoride, and low level nuclear waste, and are contained in normal industrial packages such as drums, fiberboard boxes.

The next category involves stronger, Type A packages which contain larger amounts of materials such as most radiopharmaceuticals and small industrial radiography sources. If, in an accident, all of the contents were released, or the sealed source were to be spilled out of the package, it would be possible for someone to receive a technical overexposure, but the likelihood of injury would be small, and the likelihood of more serious consequences would be essentially zero.

If the package contains enough radioactivity to really present some potential of serious hazard from the nuclear characteristics, then the package must be able to withstand serious transport accidents without releasing its contents. These Type B, specially designed and accident-resistant packages include such things as spent fuel flasks; lead and steel pigs for kilocurie gamma ray sources, large technicium generators, and insulated birdcages for plutonium oxide.

Type A packages and "strong industrial packages" may be built along the IAEA recommendations and testing procedures under the responsibility of the manufacturer. However, Type B packages require approval of the competent authority of the country where the package design originates. The applicant has to demonstrate by destructive testing of prototypes that high speed impact, puncture, fire and water immersion tests and/or calculations that all the safety requirements are met.

## ACCIDENT EXPERIENCE

Within the past several years, there have been a number of studies made on the accidents involving radioactive material shipments. The most recent one[4,5] was carried out by Battelle Northwest Laboratories which indicated that approximately 2,500,000 packages containing radioactive material are shipped annually in the U.S. Of this number, 1,500,000 were shipped by groups classified as "non-source, source, and special nuclear materials shippers." The types of packages shipped and the mode of shipment were summarized by Grella[6] and are shown in Tables I and II.

Table I

Package Types by Per Cent of Packages Shipped

| Package Type | Per Cent of Packages |
|---|---|
| Type A-Fissile | .23 |
| Type A | 69.18 |
| Type B-Fissile | 3.04 |
| Type B | 1.39 |
| Exempt | .53 |
| Large Source | .14 |
| Low Specific Activity (LSA) | 25.49 |
| Total all types | 100.00 |

Table II

Major Transport Modes by Per Cent of Packages Shipped

| Transport Mode | Per Cent of Packages |
|---|---|
| Aircraft | 34.10 |
| Auto and Bus | 0.50 |
| Truck | 50.40 |
| Rail | 13.63 |
| Water Vessel | 1.04 |
| Postal | 0.33 |
| Total all modes | 100.00 |

Almost all air shipments noted in Table II involved Type A quality radioisotopes for medical purposes.

Considerable effort has gone into categorizing and studying accidents (incidents) as well as their consequences.[7-9] In a recent analysis of incidents occurring between 1971-1975, Grella[6] noted that of the more than 32,000 Hazardous Materials Incident (HMI) reports that were submitted in accordance with U.S. Department of Transportation regulations, only 144 (0.45%) involved the radioactive materials' category. Of these 144 reports (which are required even if release of contents is only suspected), only 36 actually involved some loss of contents. The information is summarized in Table III according to transport mode.

Table III

HMI Reports for RAM by Mode with Number of Releases

| Transport Mode | No. Reports | No. with Release Indicated |
|---|---|---|
| Air carriers and forwarders | 74 | 12 |
| Highway carriers | 65 | 22 |
| Rail carriers | 5 | 2 |
| | 144 | 36 |

Of the releases that occurred when air shipment was the indicated mode, most involved the dropping of Type A packages onto the floor and then crushing them with the handling vehicle; that is, the aircraft itself was not involved.

In the case of highway carriers, vehicular accidents were the most frequent cause of suspected or actual release of radioactive materials in transit.

Rail carriers submitted five HMI reports. Two involved derailments, but in both cases no material was released. For the two cases in which material release occurred, low specific activity material was involved.

In no case has a Type B package released activity to the environment as a result of an accident.(9,10) There have been cases in which some material has escaped from Type B packages, but this has been a result of faulty packaging procedures. This, of course, points up to the need for complete quality assurance procedures for preparation of shipments and the maintenance of containers, and a good education program for shipping and handling personnel.

## RISK ASSESSMENT

In spite of the general feeling among technical experts that the IAEA packaging standards are very strict, and provide much safety, we in the United States have been looking into the relationships between those regulations and actual serious transport accidents.

ERDA currently is using an evaluation technique employing the concept of risk to assess safety from the standpoint of accidental release of radioactive material during transport. Risk is used here as the product of the probability of potential events that could release radioactive material and the consequence of such postulated release.

Potential release of material is a function of the stresses involved in an incident, the possibility of a substandard package and the chemical and physical characteristics of the material. Probablistic accident scenarios, expressed in terms of types and severities of forces, have been developed.(11) Standard mechanical and thermal analysis are then used to determine packaging failures. The likelihood of substandard packages is determined from records and surveys of the receivers of actual shipments. The amount of material that might be released is determined by engineering judgement and analysis.

Assessment of the consequences of package failure and subsequent release to the environment requires understanding: (1) the behavior of the hazardous material under accident and environmental forces; and (2) its effect on, and pathway to, the portion of the environment under consideration. Evaluation of the consequences of a release, in terms of exposure to man through the airborne pathway, requires information on release characteristics, probabilistic weather conditions, population distributions, and the effect of exposure on man.

This type of evaluation outlined above permits a realistic understanding of the risk and allows identification of the dominant contributors to system risk. Such contributors are further characterized through sensitivity studies where system parameters are systematically varied to extreme values and observing its effect on total system risk and options for design or operating variables identified.

Such an analysis has been performed to evaluate the risk in the shipment of plutonium by truck[12] and indicate that the risk from plutonium dioxide shipment will be less than the risk of being killed by a meteorite. Assessments of the risk in the shipment of plutonium by rail[13] and air[14] will be published soon. Work is in progress on evaluating the risk in spent fuel and $UF_6$ shipments.

The accident environment experienced by a package in ocean transport is quite different from the land transport environment. Although spent fuel casks and plutonium shipping packages appear to be highly resistant to the impact, puncture and crush forces experienced in an accident at sea, there have been some questions about the ability of these packages to withstand shipboard fires followed by sinking into the ocean. A study is underway in the United States to assess the consequences of such accidents. The preliminary results that have been reported[15] indicate that the 50-year population dose from a fire-damaged plutonium package lost at sea are about 100 man-rem for a package lost in shallow water and less than 1 man-rem for a package lost in the deep ocean. A badly fire-damaged spent fuel cask could release much of its radioactivity and produce a population dose of 100,000 man-rem or more if lost in shallow water and about 100 man-rem if the accident occurred in the deep ocean. Although these doses are much less than the annual population dose in the U.S. of 25,000,000 man-rem from natural background, the distribution of the dose within the population has not been determined.

## SAFETY TESTING

While studies of the probability of accident occurrence and the distribution of accident severity are essential parts of the safety analysis of the transportation of radioactive materials, it is also important to understand the relationship between accident severities and package damage to enable regulators to establish realistic and defendable engineering qualification tests requisite to package certification.

Activities directed toward developing this understanding are being carried on at a number of ERDA laboratories. These include the obsolete cask testing program at Oak Ridge, the scale model testing program at Battelle Memorial Institute, and the full-scale vehicle test program at Sandia Laboratories. These three programs, along with an analytical modeling program underway at Los Alamos are intended to lay the groundwork for studies relating package damage to accident severity.

The most significant result of these programs thus far has been the corroboration of the fact that analytical modeling and scale modeling can be used to adequately predict the response of full scale systems to known loadings. After a series of analytical studies and scale model crashes, the full-scale vehicle test program will begin a series of full-scale transportation accidents in January 1977. The first of these full scale tests will involve a spent fuel cask mounted on a 40-foot flat bed trailer, towed by a standard highway diesel tractor, impacting a reinforced concrete, earth-backed target at a speed of approximately 60 mph. The second in this series of crashes is to involve a 70 to 80 mph collision between a moving locomotive and a stationary truck-mounted spent fuel shipping cask positioned across the railroad tracks. The final test in this series, as currently planned, involves the crash of a 150-ton rail cask and car into a reinforced concrete, earth-backed target at a speed of approximately 70 mph followed by a pool fire. The 1/8-scale model tests of these accidents have indicated that the truck-mounted casks will be damaged but will not be breached and that the rail cask will suffer essentially no damage. Additional full scale tests have been planned but are not yet funded.

## SAFEGUARDS SYSTEMS

Because of a perceived increase in the threat of terrorism throughout the world, there is a growing concern for the protection of nuclear materials against theft, diversion, or sabotage. While most people will concede that the safeguarding of materials at fixed sites is not unreasonably difficult, great concern has been expressed about protecting materials in transit. As a result, many proposals for strengthening one aspect or another of the safeguards in transportation have been advanced.

## PROBLEMS OF PUBLIC ACCEPTANCE

There is one problem involving nuclear shipments that requires a swift and coordinated action. This is the lack of public understanding and acceptance of the safety rules and practices. For years, we have dealt with the technical issues of transport safety and have largely ignored the effects of social values on our efforts. It has become increasingly and painfully obvious that the social values by which the public judges adequacy of safety differ widely from our technical values. We are still facing one of our very most important tasks--that of "selling" our product to the public who is still not as convinced as we are that these shipments are really as safe as they should be. It is useless for us to stand back and take the stuffy position that "we know what's best" and "the public is not being logical." The public is controlling more and more of what we do and how we do it. We must solve this problem, not in our own terms, but in terms that the public can understand and will accept.

In the U.S.A., this lack of public understanding, arising largely from a lack of public knowledge, has led to restrictive regulations by state and city governments, and prohibitive tariffs by the railroads. Although these barriers are being challenged by the Federal government and the nuclear industry, they still indicate the potential prices of not dealing effectively with this question.

# REFERENCES

1. "Regulations for the safe transport of radioactive materials, IAEA Safety Series No. 6 (1973 Rev Edition).
2. U.S. Department of Transportation Regulations, Title 49, CFR, Pt 170-189.
3. U.S. Nuclear Regulatory Commission Regulations, Title 10, CFR, Pt 71.
4. Simmons, J.L., et al., Survey of Radioactive Material Shipments in the U.S., Battelle, Richland, Washington (1976) BNWL-1972
5. Transport of Radioactive Material in the U.S.--A Detailed Summary of Survey of Radioactive Material Shipments in the U.S., BNWL-1972, Office of Standards Dev., U.S.N.R.C., Washington (1976) NUREC-0073.
6. Grella, A. W., "A review of five years accident experience in the U.S.A. involving nuclear transportation," Design, Construction and Testing of Packaging for the Safe Transport of Radioactive Materials (Proceedings of the IAEA Seminar) Vienna IAEA-SR-10/5 (1976).
7. Patterson, D. E., "Accident experience of the USAEC in the shipment of radioactive material," Packaging and Transportation of Radioactive Materials (Proceedings of the Second International Symposium) Gatlinburg, Tenn., CONF-681001, pp 199-209 (1968).
8. McCluggage, W. C., "The AEC accident record and recent changes in AEC Manual Chapter 0529," Packaging and Transportation of Radioactive Materials (Proceedings of the Third International Symposium) Battelle, Richland, Washington, BNWL-SA-3906, p 108.
9. Grella, A. W., "Accident experience with Type B packaging in the United States of America," IAEA-SM-147/19 Tests on Transport Packaging for Radioactive Materials (Proceedings of Seminar) IAEA, Vienna (1971).
10. Langhaar, J. W. "Transport experience with radioactive material," Management of Wastes from the LWR Fuel Cycle (Proceedings of the International Symposium) Denver, Colo., CONF-76-0701, p. 472 (1976).
11. Clarke, R. K., et al., Severities of Transport Accidents, SLA-74-00001, Sandia Laboratories, Albuquerque, NM (1976).
12. McSweeney, T. I., R. J. Hall, et al., An Assessment of the Risk of Transporting Plutonium Oxide and Liquid Plutonium Nitrate by Truck, BNWL-1846, Battelle, Richland, Washington (1975).
13. Hall, R. J. et al., An Assessment of the Risk of Transporting Plutonium Oxide and Liquid Plutonium Nitrate by Train, BNWL-1996 (Draft), Battelle, Richland, WA (1976).
14. McSweeney, T. I., J. F. Johnson, An Assessment of the Risk of Transporting Plutonium Oxide by Cargo Aircraft, BNWL-2030 (Draft), Battelle, Richland, WA (1976).
15. Heaberlin, S. W., et al. "Evaluating the loss of an LWR spent fuel or plutonium shipping package into the sea," Design, Construction, and Testing of Packaging for the Safe Transport of Radioactive Materials, (Proceedings of the IAEA International Symposium) Vienna, Austria (1976).

## General References

Proceedings of the International Symposium for Packaging and Transportation of Radioactive Materials, Sandia Laboratory, Albuquerque, NM, SC-RR-65-98 (1965).

Proceedings of the Second International Symposium on Packaging and Transportation of Radioactive Materials, Gatlinburg, TN, CONF-681001 (1968).

General References (Cont'd)

Proceedings of the Third International Symposium on Packaging and Transportation of Radioactive Materials, Richland, Washington, CONF-710801 (Vol. 1 & 2) (1971).

Proceedings of the Third International Symposium on Packaging and Transportation of Radioactive Materials, Richland, Washington, BNWL-SA-3906, (Vol. 3) (1971).

Alternatives for Managing Wastes from Reactors and Post-Fission Operations in the LWR Fuel Cycle, ERDA-76-43 (Vol. 1 - 5) (1976).

Management of Wastes from the LWR Fuel Cycle (Proceedings of the International Symposium) Denver, Colorado (1976).