TRANSPORTATION OF RADIOACTIVE MATERIAL BY PASSENGER AIRCRAFT

Report No. 1

of the

Special Panel to Study Transportation of Nuclear Materials

to the

Joint Committee on Atomic Energy

Congress of the United States

Ninety-Third Congress

Second Session

September 17, 1974

Printed for the use of the Joint Committee on Atomic Energy

U.S. Government Printing Office

Washington : 1974

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402 - Price 45 cents
MEMORANDUM OF THE CHAIRMAN AND VICE CHAIRMAN

On May 17,¹ we announced the selection of a special panel to study the transportation of nuclear materials from the standpoint of health and safety and the safeguarding of nuclear materials from the standpoint of loss and diversion. The first portion of this study which covers the transportation of radioactive material by passenger aircraft has been completed, submitted to the Joint Committee and is hereby published.

This effort was initiated to determine the adequacy of current regulatory provisions and practices to protect health and safety and to prevent diversion. The greatly increasing use of radioactive isotopes in medicine and industry makes such a review a matter of current importance. The increasing use of nuclear fuel for electric power generation will in a few years result in a significant increase in the flow of enriched uranium and plutonium in the commerce of our Nation which will require special efforts to assure protection against diversion and losses. Both the increasing use of such materials and the increased prevalence of terrorist activities which may become directed at the acquisition of enriched uranium and plutonium make it specially important that the proper safeguarding of such material be given attention.

The Joint Committee was most pleased to obtain the services of the following panel members:

Mr. John T. Conway (Chairman of the Panel) Executive Assistant to the Chairman of the Board of Consolidated Edison Company. Formerly Special Agent of the FBI and Executive Director of the Joint Committee on Atomic Energy. Mr. Conway is a lawyer and engineer.

Mr. Carmine S. Bellino, formerly Administrative Assistant to J. Edgar Hoover and in charge of the FBI's Accounting Unit. Mr. Bellino is a certified public accountant. He has performed a special survey of the safeguarding of nuclear materials for the AEC.

Dr. K. Z. Morgan, Professor, Nuclear Engineering Department, Georgia Institute of Technology, formerly Director of Oak Ridge National Laboratory, Health Physics Division (1943–72) and Cosmic Ray Physicist.

Mr. John G. Palfrey, Professor of Law at Columbia, formerly Dean, Columbia College, Atomic Energy Commissioner, Fellow Kennedy Institute of Politics at Harvard, and Chairman of the AEC’s Advisory Committee on Nuclear Materials Safeguards.

Dr. Theodore B. Taylor, Chairman of International Research and Technology Corporation. Formerly consultant to International Atomic Energy Agency on international safeguards of

nuclear materials, Deputy Director, Defense Atomic Support Agency, and staff member of the Los Alamos Scientific Laboratory.

Mr. William Wegner, Deputy Director of Naval Reactors Division of AEC with special responsibilities in regard to nuclear materials.

Reports on other areas of the study will be published as they are completed. The Joint Committee thanks the panel for its dedicated efforts to date and looks forward to the receipt of their findings and recommendations in the remaining areas of their study.

The publication of this report at this time does not signify the Joint Committee's endorsement of the panel's findings and recommendations. The Joint Committee has not had an opportunity to study the report nor explore the areas and findings. Although the committee plans to review the panel's report in detail and explore the various factors involved in Joint Committee hearings, it did not wish to delay making available the panel's findings. Accordingly, the report is being published in advance of such a review to assure that the panel's independent study be made available without delay to all interested Members of Congress, Government, industry, and the public.

MELVIN PRICE, Chairman.

JOHN O. PASTORE, Vice Chairman.
LETTER OF TRANSMITTAL  

SEPTEMBER 17, 1974.

Representative MELVIN PRICE, Chairman,
Senator JOHN O. PASTORE, Vice Chairman,
Joint Committee on Atomic Energy,
U.S. Congress, Washington, D.C.

DEAR MR. CHAIRMAN and MR. VICE CHAIRMAN: Transmitted herewith is Report Number One from the Special Panel to Study the Transportation of Nuclear Materials pertaining to Transportation of Radioactive Material By Passenger Aircraft.

In your letter of May 30, 1974 to me, you advised that the Joint Committee was particularly anxious to know if any changes are needed at the present time and that you wished the panel to concentrate its efforts on determining what, if anything, is now being done incorrectly. You pointed out, that to be of greatest value, the results of our deliberations should be made available at an early date so that legislative action, if necessary, could be taken this congressional session.

As the panel delved into the current regulations and practices pertaining to the transportation of radioactive materials, it recognized that many problems are particular to the specific mode of transportation used and type of material being shipped. The use of passenger aircraft for transporting radioactive material appeared to be of particular importance at this time since it had become the subject of great concern to many, including aircarrier personnel, and strong efforts were being made by some concerned individuals to totally ban such shipments. As discussed with the committee, it was agreed that the panel should initially concentrate its efforts in reviewing the use of passenger aircraft for transporting radioactive material.

The enclosed report, while it does touch upon some other areas of concern, primarily pertains to the transportation of radioactive material by passenger aircraft. Further reports by the panel will discuss other areas of transporting radioactive material and will be submitted to you as completed.

Respectfully yours,

JOHN T. CONWAY,
Chairman, Special Panel to Study the Transportation of Nuclear Materials.
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I. INTRODUCTION*

In 1973, an estimated 800,000 shipments of radioactive material were made in the United States, of which two-thirds—600,000—were made on passenger aircraft. Total shipments of radioactive materials are projected to reach 1 million for the year 1974 and to continue to increase significantly each year for the foreseeable future with passenger aircraft the predominant carrier.

Although some of the radioactive material in transit is related to industrial or research uses, the majority—more than 95 percent—of these shipped by air, are used in the medical profession. These medical isotopes mostly have short half-lives and to be effective must be transported relatively fast from pharmaceutical suppliers to hospitals and other locations for use by medical doctors. Because of their short half-lives, they must be regularly replenished, usually on a weekly basis.

The increasing use of radioisotopes—particularly by the medical profession—and the corresponding increase in the use of passenger aircraft for their transportation has caused some concern for the health and safety of the passengers and crew of the carrier aircraft as well as for the airline personnel who handle the cargo in transit. A number of known incidents—although very few in relation to total shipments—have occurred in which the transported radioactive material has breeched its container or has been improperly shielded by the shipper. These occurrences, some of which were not discovered until after receipt by the consignee, justifiably raise questions as to the adequacy of existing Government standards and enforcement of regulations for packaging and monitoring radioactive material in transit.

But beyond the concern over the potential hazard to the public and airline personnel from accidental release of radioactive material, infrequent as it may be, there is concern as to the radiation effects of this increasing amount of radioactive material being carried on passenger aircraft under normal conditions, i.e., where existing regulations have not been violated. This raises the question whether or not standards set by the Department of Transportation (DOT) and the Atomic Energy Commission (AEC) to regulate radioactive material in transit are sufficiently conservative in light of the growing number of such shipments and the increasing probability passengers and airline personnel will be exposed to low levels of radiation from these shipments. In other words, assuming full compliance with present regulations—which in actual practice the panel found one could not assume—are present regulations adequate to protect the public and transportation workers from radiation external to the package?

In assessing the problems associated with transporting radioactive material by passenger aircraft, the panel thought it best to obtain first hand information from persons and organizations engaged in the process and to witness the various separate activities that make up the entire process. Accordingly, the panel visited four different manufac-

*For a brief glossary of nuclear terms see page 23.
turing facilities where radiopharmaceutical products are manufactured and observed the methods by which these radioactive materials were packaged for shipment, including the monitoring to assure the packages meet Federal standards.

We visited cargo handling areas at the airport to talk with cargo handling personnel and observe the packages being loaded aboard planes. We talked with representatives from the Department of Transportation, including the Federal Aviation Authority and the Office of Hazardous Material and with representatives of the AEC from both the Regulatory and General Managers area. Also, we met with representatives of the Airline Pilots Association, and others who have been critical of the present situation as well as representatives from industry and the medical profession who use radioisotopes and who would be seriously hampered if the transportation of these products were severely curtailed. In addition, we met with representatives of the Environmental Protection Agency (EPA) who are concerned with the general problems of population exposure to ionizing radiation.

One person, a biophysicist, was of the opinion that the shipment of all radioactive material, including medical radioisotopes, should be prohibited from airline passenger vehicles, unless the medical profession demonstrated proof to his satisfaction that radioisotopes were as essential as their increasing utilization would suggest. Another person interviewed, a biologist, suggested that the solution to the problem should be left to the public; that no technical or scientific body of experts has the right to determine what levels of manmade radiation is acceptable to the public. All others with whom we conferred, recognized the necessity to use scheduled passenger aircraft, at least for some short-lived radioisotopes, otherwise we would deprive some areas of the country of an effective diagnostic and therapeutic medical tool and the need to adopt enforceable rules and regulations. As might be expected, there were divergent viewpoints as to what, if any additional restrictions or limitations should be placed on the types and amounts of radioactive material permitted on passenger aircraft. In a few instances, knowledgeable persons were of the opinion no changes were necessary to present AEC and DOT regulations.

By and large, the consensus was that a more conservative approach should be adopted for the future and that greater restrictions than heretofore mandated by DOT and AEC were needed. These changes are considered necessary due to the increasing number of shipments and the mounting evidence that population exposure should be kept as low as practicable because of the increasing risks of genetic and somatic damage that relate to the accumulated exposure.

It should be noted that while the panel was in the process of considering this matter, and formalizing its recommendations, the AEC on July 30, 1974, formally submitted to the FAA recommendations for revising present regulations governing the transportation of radioactive material in passenger aircraft which are more restrictive than existing regulations. The panel has reviewed and considered those recommendations in arriving at the recommendations contained in this report.
Although radioactive material is only one of numerous types of material that by DOT regulations are classified as hazardous, the shipments of which are specifically prescribed, the panel limited its review only to radioactive material and thus did not consider it within its purview to make recommendations concerning the other hazardous material.

However, since many of the individuals conferred with are familiar with the transportation of all types of hazardous material such as flammables, unstable chemicals, acids, and explosives, the panel did obtain some perspective as to the relative dangers between radioactive material and various other types of hazardous materials.

Without doubt, the potential danger to passengers and airline personnel from many other hazardous materials being carried on passenger aircraft today is far greater than from radioactive material shipments, and this should be borne in mind when reading this report and considering the recommendations contained herein.

Notwithstanding the apparent need for improvement in the regulation and control of other hazardous material—possibly a greater need than for radioactive material—the panel believes that the established national policy of exposing individuals to manmade radiation to a level as "low as practicable" should be adopted for each phase of the nuclear industry including the transportation field. The panel's recommendations as set forth in this report have been made in consonance with that policy which the panel believes to be the proper policy in that it is in the best interest of all concerned—the users and direct beneficiaries of nuclear material as well as the public at large.

II. DEVELOPMENT OF PRESENT REGULATIONS

The transportation of radioactive material by common carrier, including passenger aircraft, is regulated by DOT. Detailed regulations are issued by DOT as to packaging, labeling, and loading as well as to the maximum permissible level of radiation emitted external to the package. These regulations have been developed for the most part in cooperation with, and after review by, the AEC.

Present regulations limit the maximum external radiation levels of a package in routine commerce to 200 millirem per hour at the surface of the package and 10 millirem per hour 3 feet from the surface of packages. The level of radiation in millirem per hour at 3 feet from the surface of the package is called the package transport index (TI) and by current regulation may not exceed 10. By regulation a common carrier such as aircraft, truck, or rail car is not permitted to carry any single package with a TI greater than 10 nor any number of packages whose total TI will exceed 50. Minimum distances are supposed to be maintained between packages and airline passenger compartments to minimize radiation exposure to personnel and passengers.

The present DOT regulations governing the shipment of radioactive materials by aircraft originated in shipping regulations adopted on August 24, 1947, by the Interstate Commerce Commission based upon the technical specifications formulated by a seven-man National Research Council Committee of experts. At the time, the only official exposure limits to personnel were the March 17, 1934 occupational
levels of 100 millirem per day or 500 millirem per week which had been recommended by the Advisory Committee on X-Ray and Radium, the predecessor to the National Council on Radiation Protection and Measurement (NCRP). Since then, the NCRP, the International Commission on Radiological Protection (ICRP), the AEC, and the Federal Radiation Council (FRC) have lowered these levels by a factor of 5 for occupational workers, and by a factor of 50 for individual members of the public.

At the time the regulations were first being formulated in 1947, passenger airline transportation was not as common as it is today and the principal concern was not radiation exposure to passengers and crew but prevention of exposure to undeveloped photographic film to more than 14 millirem per hour at a distance of 30 feet in aircraft such as the DC-3 or Lockheed Lodestar.

Since the National Research Council first made its recommendations using the 1934 Advisory Committee on X-ray and Radium guide, the FRC and the AEC in addition to setting more conservative exposure levels for occupational workers and the public, have adopted the "as low as practicable" principle to conform with the basic concept that even the slightest amount of radiation exposure can be expected to do damage and hence a human being should not be exposed to any unnecessary radiation. The recent Report of the Advisory Committee on the Biological Effects of Ionizing Radiations (BEIR) of the National Research Council and the National Academy of Sciences also subscribes to and strongly supports the concept of keeping exposures as low as practicable. Although the AEC has proposed a guide of 5 millirem per year as being as low as practicable for limiting radiation to the general public for effluence from present civilian nuclear power plants, no such guide has been formulated for common carrier shipments of radioactive material.

III. BASIS OF PANEL'S RECOMMENDATION

It was obvious to the panel that with increasing numbers of radioactive material shipments, 200 millirem per hour at the package surface is too high and should be set at a lower limit to protect the cargo handlers who load and unload the shipments. Similarly the panel concluded that 10 Tp—10 millirem per hour at 3 feet—is not as low as practicable and should be lowered for the better protection of passengers and crew. It was equally obvious that what may be as low as practicable for civilian nuclear power plants—the 5 millirem per year—is not practicable for shipping radioactive material and the same guide limit may not be appropriate in the transportation industry.

In attempting to formulate its recommendation, the panel was guided primarily by two key general principles contained in the November 1972 report of the Advisory Committee on the Biological Effects of Ionizing Radiations (BEIR report):

(a) No exposure to ionizing radiation should be permitted without expectation of a commensurate benefit.

(b) The public must be protected from radiation but not to the extent that the degree of protection provided results in the substitution of a worse hazard for the radiation avoided. Addition-
ally, there should not be attempted the reduction of small risks
even further at the cost of large sums of money that spent other-
wise, would clearly produce greater benefit.

It was noted that in recent public hearings before a subcommittee
of the Senate Commerce Committee, recommendations were made to
ban the shipment of all radioactive material by passenger aircraft
including short-lived radiopharmaceuticals.

One witness at those hearings, a biophysicist, voiced the belief that
75 percent of all medical isotope used was unnecessary. In contrast
however, medical doctors, hospital physicists and other representatives
of nuclear medicine, point to the growing use of radioisotopes in the
early diagnosis of serious diseases with resulting savings of lives.
According to the Society of Nuclear Medicine, approximately one
patient out of every three admitted to hospitals today is directly bene-
fitting from the use of medical isotopes, particularly the short-lived
technetium-99m which has a half-life of 6 hours and which is a decay
product of molybdenum-99. The latter has a half-life of 2.8 days.
Hospitals that are not in the immediate area of a radiopharmaceutical
supplier must generate their own technetium-99m from molybdenum-
99 generators.

According to the AEC, a majority of all radioactive material trans-
ported by passenger aircraft is the radiopharmaceutical molybdenum-
99 and the only practical way today of transporting this radioisotope
to many areas of the country is by scheduled passenger aircraft. A
somewhat similar situation pertains to such radionuclides as I-123
(13.2 hr.) and I-131 (8 days), components of nuclear medicines used
for both therapeutic and diagnostic purposes.

To ban the shipment of all radioactive material by passenger air-
craft would in effect deprive significant geographic areas of the United
States of the use of these important nuclear medicines. In some cases
it would force the medical profession to substitute longer-lived iso-
topes, as for example Iodine 131 for Iodine 123 resulting in signifi-
cantly higher radiation exposures to the patient. Obviously there are
significant benefits being derived from shipping short-lived isotopes
by passenger aircraft particularly for those one-in-three hospital
patients being serviced. The question is to what extent are these bene-
fits commensurate with the undesirable effects of airline personnel
and passengers being exposed to additional radiation from these
shipments?

It should be noted that levels of radiation external to the individual
packages of radioactive material in transit can be lowered as additional
shielding is placed between the radiation source and the passenger
and airline employees. Additional shielding could be used to lower
and even eliminate, for all practical purposes, any measurable radia-
tion external to the radioactive material package. However, the added
shielding increases the weight and causes logistic problems associated
with moving heavy packages and results in cost increases for the
product which in the final analysis, in the case of nuclear medicines,
will be borne by the patient. It becomes a matter of judgment then,
at what point these added costs associated with the additional shield-
ing are excessive and not commensurate with the benefits to be derived.
As the BEIR report points out "... there should not be attempted
the reduction of small risks even further at the cost of large sums of money that spent otherwise would clearly produce greater benefit."

The main increase in cost however would occur from the need for the pharmaceutical supplier to make major changes in its production line to accommodate the heavier and larger shipping casks. That need along with the necessity to design and manufacture the new casks would entail increased costs and leadtime. The panel learned from its visits and discussions with the nuclear pharmaceutical industry, that because the industry is rapidly developing and quick changing, production equipment is being depreciated in short periods of 2 to 5 years. Even without new more stringent regulations, technical improvements and competition is causing the suppliers to limit the useful life of much of their production equipment to less than 5 years.

A recent study by Dr. Gordon Brownell, Professor, Department of Nuclear Engineering, MIT, calculates the varying dollar cost increases associated with lowering the permissible radiation emanating from packages of radioactive material by means of adding increasing amounts of shielding. The Brownell report concluded that one could, by adding lead shielding, lower the TI (Millirems per hour at 3 feet) from the present maximum of 10 down to 1 but in the case of the large 500 millicurie molybdenum-99 generators this would nearly double the cost of shipping. However, shipping costs represent a very small portion of the total cost of this product to the patients—approximately 100 patients or more are treated from one 500 millicurie generator. A doubling of the shipping cost would represent approximately 25 cents to 50 cents per patient whose bill is usually about $100 per treatment.

IV. DISCUSSION OF FINDINGS AND RECOMMENDATIONS

A. PERMISSIBLE RADIATION LEVEL TO AIRLINE PASSENGERS AND CREW DUE TO SHIPMENT OF RADIOACTIVE MATERIAL IN CARGO SPACES

Observation:

The present standards permit passengers of U.S. commercial aircraft to receive a maximum radiation dose rate of 10 millirem per hour at the passenger compartment floor level. This standard was arrived at over twenty years ago on the basis that it would be unlikely for any one individual of the overall U.S. population to make more than one or two flights per year. On this basis the 10 millirem per hour was established more on its possible effect on photographic film which might be on the aircraft than its possible effect on people.

The panel considers that the 10 millirem per hour allowable rate is too high and should be reduced. In establishing the new rate it must be assumed that a large and increasing segment of the population will be using commercial aircraft for public transportation and that a substantial number of them will be making numerous flights per year.

\[2\] Impact on the Cost of Shipping Radiopharmaceuticals of varying the Package External Radiation Levels—A report to the U.S. Atomic Energy Commission by Gordon L. Brownell, Ph. D., Professor, Dept. of Nuclear Engineering, MIT, and Director, Physics Research Laboratory, Massachusetts General Hospital, with the Assistance of John A. Correia, Ph. D., Research Fellow, Physics Research Laboratory, Massachusetts General Hospital—July 8, 1974.

3 The 500 millicurie generator today is the largest sized unit being produced and shipped by radiopharmaceutical producers.
Consideration must also be given to airline stewards and stewardesses who are and will continue spending many hours per year in the passenger compartment of commercial aircraft. Tests have shown that pilots and crew members normally stationed in the flight control forward area are much less affected by radioactive material stowed in the baggage compartments and thus would be amply covered by any acceptable dose rate established for the passenger compartment.

The panel considered at length the determination of the proper radiation dose rate for passengers and flight crews. On one hand the panel agreed that 10 millirem per hour was too high a level to be acceptable. However, on the other hand, it was recognized that establishing a level of 0.1 millirem per hour would effectively preclude the shipment of radioactive material by passenger aircraft. The panel considers, for reasons discussed elsewhere in this report, that there is an overall benefit and requirement that radioactive material particularly for medical purposes be permitted to be shipped by passenger aircraft and that there is no reasonable alternative method of shipping.

Recommendation:

With regard to the permissible level of radiation the question of what is “as low as practicable” was reviewed taking into account the considerations previously discussed. Based on this review the panel considers that the applicable regulations should be revised to limit the radiation exposure to aircraft passengers and crew to 1 millirem per hour at the floor level. This limit was selected on the following basis:

1. It is in conformance with the concept of “as low as practicable.” If it is assumed that the maximum amount of time a passenger or crew member is subject to such radiation would be for 20 hours per week for 50 weeks a year, then that person would receive one rem per year on the lower extremities. If translated to the more critical vital organs of the body this dosage would be in the order of 300 millirem per year—a figure generally accepted as being below that which might cause a detectable effect on the human body. It is also recognized that not all passenger aircraft flights carry radioactive material and even in those that do, very few of the passenger seats are directly above the area where radioactive material is stowed.

2. One millirem per hour is in conformance with the current Code of Federal Regulations (Title 10, Part 20, Atomic Energy) (10CFR20) which defines permissible levels of radiation in unrestricted areas as:

(a) Radiation levels which, if an individual were continuously present in the area, could result in his receiving a dose in excess of two millirems in any one hour, or

(b) Radiation levels which, if an individual were continuously present in the area, a dose in excess of 100 millirems in any seven consecutive days.

This regulation further defines a “Radiation Area” as any area, accessible to personnel, in which there exists radiation, originating in whole or in part within licensed material, at such levels that a major portion of the body could receive in any one hour a dose in excess of 5 millirems, or in any 5 consecutive days a dose in excess of 100 millirems.
3. It is considered feasible and reasonable to apply this more restrictive level insofar as the shipment of radioactive isotopes are concerned. The panel investigated the effect of reducing the Transport Index necessary to achieve this level and even though increased shielding would be required which in turn causes a weight increase and ultimately results in higher shipping costs, it is concluded that it can be done with a relatively small increase in cost to the ultimate consumer.

B. RECOMMENDED MODIFICATION IN REGULATIONS FOR THE SHIPMENT OF RADIOACTIVE MATERIAL BY PASSENGER-CARRYING AIRCRAFT TO REDUCE EXPOSURES TO MEMBERS OF THE PUBLIC AND TO OCCUPATIONAL WORKERS

Observation:

As previously indicated, the levels of radiation exposure permitted by present regulations for the shipment of radioactive materials by passenger carrying aircraft are based on very early radiation protection standards that have long since been outdated. They are insufficiently conservative in terms of present radiation protection standards. Furthermore, a vast amount of research data has accumulated over the past three decades which strongly suggests that, contrary to early concepts, there is no safe threshold radiation dose below which there is no consequential radiation damage; that the risk of radiation damage such as cancer induction or genetic malformations increases more or less linearly with the accumulated population dose. Today there are far more members of the public exposed to radiation from the shipment of radioactive material than when the present shipping regulations were established. This has come about because there has been an increase by orders of magnitude both in the number of packages of radioactive material shipped by passenger aircraft and in the number of persons traveling by passenger aircraft.

The present practices in the shipment of radioactive materials by passenger carrying aircraft permit passengers to receive a maximum exposure of about 10 millirem per hour. This is accomplished primarily by limiting the transport index of any package to no more than 10 (TI=10), by an upper limit of transport indices on any one passenger aircraft of no more than 50 (total TI=50) and by requiring that there be spacing of the packages in the baggage compartment in accordance with minimum separation distances listed in a table published in the shipping regulations. As would be expected, however, this method of control has been less than satisfactory because in the rush of loading packages on aircraft, too often little attention is given to the spacing and separation distances of packages of radioactive materials in the cargo holds. The panel believes that there is need both to reduce this dose rate of 10 millirem per hour to an airline passenger or member of the crew and to simplify the required loading procedure by which this can be accomplished (i.e., eliminate the use of the table for spacing of the packages).

The present regulations tend to limit occupational exposure to airline employees who load and unload the packages of radioactive materials on aircraft by setting an upper limit of 200 millirem per hour at the surface of the package. The panel believes there is need to reduce
occupational exposure received by the cargo handling personnel who load and unload these radionuclides. This can be accomplished by reducing the maximum permitted surface dose on a package of radioactive material. The exposure rate for stewards and stewardesses, on the average, is about the same as that received by some of the passengers. The pilots and the other flight crew in the pilot's quarters are sufficiently distant from the baggage compartments so that the cargo contributes essentially no radiation to these personnel.

**Recommendations:**

1. In order to reduce the maximum rate of radiation exposure received by passengers and crew of passenger carrying aircraft to approximately 1 millirem per hour the panel recommends the following:
   a. The transport index (TI) limit of a package be reduced from 10 to 1.
   b. The transport indices permitted on a passenger carrying aircraft be reduced from 50. The panel considers a limit of approximately 10 be set, however it recommends that the DOT and AEC determine such level in order to meet the 1 millirem per hour limit to passengers.
   c. The radioactive packages of Category III * should be placed on the floor of a baggage compartment of the aircraft (i.e., they should not be stacked).

2. In order to reduce the occupational radiation exposure received by airline employees who handle the packages of radioactive materials the panel recommends that the present maximum dose rate limits of 200 millirem per hour at the surface of packages of Category III be reduced by 25% to 50%. The panel believes a maximum level between a limit 50 and 100 millirem per hour should be established, and recommends that the DOT and AEC determine the lowest practicable limit within those limits.

**TABLE 1.—RADIOACTIVE MATERIAL CATEGORIES—DOSE RATE LIMITS**

<table>
<thead>
<tr>
<th>Category</th>
<th>Label</th>
<th>At any point on accessible surface of package</th>
<th>At 3 ft from external surface of package (transport index)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Radioactive—White I</td>
<td>0.5</td>
<td>0</td>
</tr>
<tr>
<td>II</td>
<td>Radioactive—Yellow II</td>
<td>10.0</td>
<td>0.5</td>
</tr>
<tr>
<td>III</td>
<td>Radioactive—Yellow III</td>
<td>200.0</td>
<td>10.0</td>
</tr>
</tbody>
</table>

*Requires vehicle placarding. (This label mandatory for any fissile class III (173.389A) or large quantity package (173.389B), regardless of dose rate levels.)

C. REDUCING THE RISKS OF RADIATION EXPOSURE AND OF ENVIRONMENTAL CONTAMINATION

**Observations:**

Under present DOT and AEC regulations radioactive material may be transported by common carrier, including passenger aircraft, if the shipments conform to specific limitations as to type, and quantity of material, and to specifically designed packages.

*See Table 1.
The types of packaging are specified in the DOT and AEC regulations according to the types and quantities of radioactive materials being shipped and the degree of containment the packaging is designed to provide under normal and accident conditions in transport.

Radioactive materials are divided into two broad classes: (1) "Special form" which is a massive, solid material, or material confined in a high integrity capsule of inert material, and (2) "Normal form" which applies to all radioactive materials which are not "special form." Normal form radioactive materials are classified into seven groups of radionuclides based primarily on radiotoxicity of the radionuclides. Package limits for the seven transport groups and "special form" are shown in Table 2.

Small quantities of radioactive materials, certain concentrations, small quantities of radioactive materials in manufactured goods, and low specific activity materials are exempt from specification packaging, marking and labeling.

**TABLE 2.—TRANSPORTATION OF RADIOACTIVE MATERIALS—QUANTITY LIMITS AS RELATED TO PACKAGE REQUIREMENTS**

<table>
<thead>
<tr>
<th>Transport group: Examples</th>
<th>Exempt quantity (curies)</th>
<th>Type A package (curies)</th>
<th>Type B package (curies)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I: Pu, Cm</td>
<td>10⁻⁸</td>
<td>10⁻⁷</td>
<td>20</td>
</tr>
<tr>
<td>II: Pu, Cm</td>
<td>10⁻⁷</td>
<td>10⁻⁶</td>
<td>20</td>
</tr>
<tr>
<td>III: Cs, Ir</td>
<td>10⁻⁷</td>
<td>20</td>
<td>200</td>
</tr>
<tr>
<td>IV: Cm, Cm</td>
<td>10⁻⁷</td>
<td>20</td>
<td>200</td>
</tr>
<tr>
<td>V: Noble gases</td>
<td>10⁻⁷</td>
<td>20</td>
<td>5000</td>
</tr>
<tr>
<td>VI: Noble gases, uncompressed</td>
<td>10⁻⁷</td>
<td>1,000</td>
<td>50,000</td>
</tr>
<tr>
<td>VII: Tritium—as a gas or in luminous paint</td>
<td>25</td>
<td>1,000</td>
<td>50,000</td>
</tr>
<tr>
<td>Spec. form: Co for radiography, Pu-Be</td>
<td>10⁻⁷</td>
<td>20</td>
<td>5,000</td>
</tr>
</tbody>
</table>

1 A large quantity is defined as any quantity in excess of a type B quantity.

Type A quantities of radioactive materials must be shipped in packages, identified as Type A packaging, designed to prevent loss or dispersal of the radioactive contents and retain shielding efficiency and effectiveness of other safety features under normal conditions of transport.

Quantities exceeding Type A quantities must be shipped in Type B packaging. Type B packaging must be designed to withstand normal transport conditions without loss of contents or shielding efficiency and to suffer no more than a specified loss of contents or shielding efficiency if subjected to a specified sequence of accident damage test conditions. Large quantities, exceeding Type B quantities, are not permitted to be shipped aboard passenger aircraft.

The panel notes that the risks of radiation exposure and its effects and of environmental contamination to passengers and crew increase (1) with the quantities (curies) of radionuclides shipped on passenger carrying aircraft as specified in the shipping regulations for the various Transport Groups and (2) as the radioactive half life of the radionuclide increases from a few days or weeks to months or years.

**Recommendation:**

Because of the desirability of reducing all radiation exposure to the lowest practicable level and in consideration of the expanding number of air shipments of radioactive packages, the panel recom
mends that the shipping regulations be modified so that (1) the quantities (curies) of radionuclides of Transport Groups I through IV and including Special Forms be reduced by a factor of at least ten below the present limits for Type A Packages and Type B Packages, and (2) the shipment of quantities in excess of Exempt Quantities by passenger carrying aircraft be prohibited if the radioactive half life of the radionuclide is between 30 days and $10^8$ years.

The exclusion of shipments of large quantities of radioactive materials and especially those of longer half lives from shipment by passenger carrying aircraft would greatly reduce the risk of exposure to the more dangerous radionuclides such as Sr$^{90}$, Cs$^{137}$, Ra$^{226}$, Pu$^{238}$ and Pu$^{239}$, Am$^{241}$ and Am$^{243}$, etc. Also, it would prohibit the shipment of neutron sources such as Ra–Be, Pu–Be, Cf$^{246}$, Cf$^{248}$, Cf$^{252}$ or Cf$^{254}$, where radiation risks are greater than those from gamma emitting radionuclides and the problems of shielding and radiation monitoring can be somewhat difficult.

In the case of leakage of the radionuclide from the shipping container, the risk of seriously contaminating the aircraft and baggage and of releasing significant quantities of airborne radioactive dust or fumes into the passenger section of the aircraft with consequential internal exposure of the passengers and crew would be reduced by an order of magnitude by recommendation (1) above and by many orders of magnitude by recommendation (2). (The upper limit of half-life of $10^8$ years is specified in order not to needlessly restrict the shipment of natural thorium and of natural uranium and, of course, of stable isotopes whose half lives approach infinity.)

D. MONITORING RADIOACTIVE SHIPMENTS

Observation:

Under current AEC and DOT regulations, there is no requirement for radioactive material to be monitored by instrumentation to assure the package is complying with radiation standards, from the time the package leaves the facility in which the radioisotope was produced and packaged until it arrives in the hands of the addressee, the licensed user. In the interim period, it may have moved on a number of trucks and airplanes and have been loaded and unloaded by cargo handlers numerous times. It undoubtedly would have been stored for varying periods of time in interim cargo storage facilities as it passed from one location to another. If, the radioactive material has not been properly packaged, or if, for any reason, it began to leak, there would be no way of knowing this without some visible sign of the material coming from the package. Although the design of most packages used to transport radioactive material goes through a review process by AEC and DOT, and sufficient absorbent to prevent leakage is required, there have been occasions when material did leak, the source was not properly shielded or was transported in a position outside the shield, with resultant violations of radiation protection standards.

Concern for this problem, recently caused one airline—Delta—and one local agency—Minneapolis-St. Paul Metropolitan Airports Commission—each to establish its own personal monitoring system for radioactive material in transit. Delta Airline, as a result of two serious violations in the last three years in which material was not properly
packaged and as a consequence of a continuing series of minor incidents, is training cargo handlers to use radiation monitoring equipment to verify that all packages identified as carrying radioactive material meet Federal regulations at the time of acceptance by the airline. This involves an extensive training program to qualify Delta personnel in the use and care of the sensitive instruments needed to accomplish this task. It raises a question as to the cost and duplication of effort if all other airlines subsequently follow or are made to follow the same practice. The more serious question is whether or not adequate training can be provided and maintained for all the radiation monitors that will be required if all airlines adopt this monitoring procedure now being implemented by Delta.

On April 25, 1974, the FAA published for comment in the Federal Register new regulations, which would among other things, require airline companies to survey, by instrumentation, all radioactive material at the time it is received from the shipper to assure the radioactive measurements are not greater than what the shipper's documents claim and are within the DOT standards. The new regulations would also require the airlines to survey passenger and cargo space using radioactive detection instruments to assure compliance with Federal radiation standards. The panel has reviewed and taken into account this proposed new regulation in the recommendations contained in this report.

Recently, the Minneapolis-St. Paul Metropolitan Airports Commission (MAC), a local agency, assumed the responsibility for the monitoring of the radioactive material coming through airports within its jurisdiction, whether incoming or outgoing. In practice, the MAC is requiring the carrier to do the actual monitoring. One central monitoring station presumably could service all airlines within the Minneapolis-St. Paul International Airport. This would seem preferable to having each airline maintaining redundant capability at each airport. However, having local agencies assume the responsibility would not appear to be the most desirable approach unless it is done in conformity with national or international rules and regulations.

While the panel considers the action taken by Delta and MAC to be proper and timely, the panel has concern that if each local government or airline were to set up a monitoring system, the multiplicity of rules and regulations and standards, which might eventually develop in different sections of the United States, would cause confusion and unnecessarily hinder the interstate transportation of radioactive material. What is needed is an effective and standardized Federal program of enforceable regulations.

Recommendations:

To prevent the multiplicity of State and local regulations and the potential for varying standards as well as possible conflicting regulations, the Federal Government should assume the overall responsibility for establishing and enforcing the regulations incident to the transport of radioactive material on a preemptive basis. No local, State, or independent agency should be permitted to establish regulations which are not in conformance with these Federal regulations. A Federal agency (some branch of the DOT such as FAA, for example, or the
AEC) should be given the specific responsibility to monitor radioactive packages and certify them prior to being delivered to the carrier.

This function by the Federal Government would be similar to that function performed by the Food and Drug Administration in certifying Federal standards on meat and other food products requiring a Federal inspection. The panel recognizes that implementation of this recommendation will entail careful study and could require the addition of a large number of Federal employees. However, the panel also recognizes that there are a limited number of facilities that produce and ship radioactive isotopes. There is also a rather limited number of airports that receive these packages of radioactive material for shipment.

Initially, this program of Federal monitoring can be implemented by identifying the major airports through which the majority of radioactive material pass from the shipper to the air carrier. Based upon experience obtained and the continued growth of radioactive material shipments the Federal monitoring service could be expanded and eventually encompass ground transportation as well to the extent that no package carrying radioactive material other than exempted quantities, will be transported by common carrier without a Federal certification that it has been inspected and meets applicable standards for the health and safety of the public.

In addition to inspecting and certifying the individual packages, the Federal monitors should, by spot inspections, verify that the packages are being loaded aboard individual aircraft in accordance with prescribed rules and regulations to assure minimum radiation exposure to passengers and crew. All airport cargo ground storage space should have installed some gross (high level) instrumentation that would alert cargo handling personnel if radioactive material not properly identified is in the area.

As the standards for transporting radioactive material become more restrictive, it is important that some means be developed to detect attempts to circumvent the regulations by disguising the package or not properly identifying them as containing radioactive material. Surveillance of cargo storage and cargo loading areas with detecting instruments should also be the responsibility of the Federal monitoring agent, at the airport. The administration and operating cost of the monitoring service could be paid for by the individual shippers and the transportation industry, either through a fee based upon the number of packages certified for transportation and/or the licensing fee of the common carrier or shipper.

E. TRANSPORTATION OF PLUTONIUM BY AIRCRAFT

Observation:

Under present AEC regulations, plutonium in quantities greater than 20 grams may not be shipped on passenger aircraft. This is a special limitation placed upon plutonium because the AEC properly is concerned that it not be diverted for illegal purposes. When a wave of airline "highjacking" occurred in the early 1970's, the AEC became concerned that one of the highjacked planes might have plutonium aboard and the highjackers knowingly or unknowingly transport this material out of the country.
Plutonium, in addition to being used in nuclear explosives, can be dangerous to the public health in that it is an alpha emitting radionuclide of long radioactive half-life and if inhaled even in small amounts—micrograms—can do serious harm. Therefore, in addition to safeguarding plutonium from possible diversion, it is important that it be safely controlled so as not to constitute a risk to the health and safety of the public. All the other actinide radionuclides present risks similar to those of Pu$^{239}$ when taken into the body, so precautionary measures applicable to Pu$^{239}$ should be applied also to Pu$^{238}$ and Pu$^{240}$, Am$^{241}$ and Am$^{243}$, Cf$^{252}$, etc.

Light water slightly enriched uranium reactors in operation in the United States today produce plutonium as a byproduct. When the fuel element is reprocessed, the plutonium is separated from the uranium fuel. Relatively little plutonium has been separated from civilian nuclear reactor fuel elements in the United States to date, so the problem of transporting plutonium currently is not as pressing as it is destined to become in the future. As more nuclear power plants come into operation—by 1980 AEC estimates over 100 larger plants will be in operation in the United States—reprocessing plutonium will be moving from reprocessing plants to fabrication facilities and elsewhere in the nuclear industry. The strict control of this material particularly in transit will be a major problem that requires careful attention and will be addressed in the panel’s next report. In the meantime, however, it is essential that even the relatively small amounts of plutonium and other actinide radionuclides in the civilian market not be permitted to constitute an unreasonable health and safety threat to the public.

Recommendation:

In addition to the reevaluation of maximum amounts permitted by regulation for A and B type packages, and the reevaluation of the levels of exempt amounts as recommended elsewhere in this report, the panel recommends that the AEC and DOT prohibit the shipment by air—air cargo as well as passenger aircraft—of other than exempt quantities of plutonium and other Transport Group I material unless a determination is made that the air shipment is necessary for the security of the Nation. The danger of an aircraft accident and resulting risk of contamination from plutonium, other actinides and other Category I material is sufficiently grave as to warrant their total restriction to ground and water transportation.

The panel recognizes that such a prohibition will cause an increase in the time these materials will be in transit and that ground and water way shipments of hazardous materials constitute separate risks but is of the opinion these risks are not as grave as those incurred by air transport. In a future report, the panel will be prepared to recommend improvements in the control and administration of ground shipments for radioactive materials including plutonium and other Transport Group I material from both a safeguards as well as health and safety viewpoint.
F. Radioactive Material Packaging Design Review and Approval

Observation:
In accordance with their memorandum of understanding and their respective regulations, the AEC reviews and issues approvals for the designs of packages used in shipping significant amounts of radioactive material including fissile materials which are authorized by DOT regulations for use by shippers. However, certain Type B containers and fissile material "Specification Containers" are authorized for shippers' use even though they have not been reviewed and approved by the AEC, i.e., they have received what is referred to as a "grandfather exemption". These include certain containers authorized by special DOT permits issued prior to July, 1973. In addition, prior to 1969 when DOT published the standards for the Type B containers many containers were in use under a so-called Specification 55 which permitted the use of metal-encased lead or uranium metal shielded containers. Under a "grandfather clause" DOT regulations permitted continued use of those "Spec 55" containers used prior to 1969, if the material is in special form and not more than 300 Curies.

The 1971 Delta aircraft incident involved one of the special permit packages in existence prior to July, 1973 and thus was not of the type required to be approved by the AEC. Also the container involved in the July 1974 Delta aircraft incident in which the iridium source was not properly contained was a DOT Spec 55 container, Type C10, not reviewed and approved by the AEC.

Recommendation:
The panel recommends that all special permits and "Spec 55" containers that otherwise would be subject to AEC review and approval prior to use should be canceled and the use of these containers for transporting radioactive material in interstate commerce should be prohibited until such time as the AEC has reviewed and approved their use.

VI. SUMMARY OF MAJOR CONCLUSIONS AND RECOMMENDATIONS

1. The maximum permissible level of radiation exposure for persons on passenger aircraft due to shipment of radioactive material stored aboard the aircraft should be one millirem per hour as measured anywhere within the passenger and crew compartments.

2. Present maximum levels of radiation permitted for radioactive material in transit aboard passenger aircraft should be lowered. The maximum permissible Transport Index of 10 (10 millirem per hour at 3 feet) should be lowered to a Transport Index of one (1 millirem per hour at 3 feet) and the maximum permissible level of 200 millirem per hour at the package surface should be lowered by a factor of \( \frac{1}{4} \) to \( \frac{1}{2} \) (50 to 100 millirem per hour). Total maximum permissible quantities of curies of radionuclides per package should be lowered by a factor of at least 10 below present limits.
3. Shipment by passenger carrying aircraft of radioactive material in excess of exempt quantities should be prohibited if radioactive half life of the radionuclide is between 30 days and 10 years. This would not apply to radioactive devices implanted in the human bodies of passengers, e.g., pacemakers.

4. The shipment by passenger and non-passenger aircraft of plutonium and other Transport Group I category material in excess of exempt quantities should be prohibited unless the air shipment is required for national security reasons.

5. All approvals or permits issued by DOT for shipping containers for radioactive material based upon “grandfather clauses” should be revoked pending review and approval by AEC.

6. The use of radium, accelerator products and certain other naturally occurring radioisotopes presently not being regulated by the AEC should be brought under AEC regulation.

7. Packages containing radioactive material for air shipment should be monitored subsequent to leaving the supplier and prior to being loaded aboard the aircraft to assure compliance with applicable Federal regulations. This responsibility should be assigned to a single Federal regulatory agency responsible for enforcement of the regulations and not upon the airline carrying the cargo. The responsible Federal agency should also be responsible for periodic inspections to assure all regulations pertaining to air transportation of radioactive materials are being complied with.

The panel believes that with the exception of No. 6 above, which will require congressional action—specifically amendment to the Atomic Energy Act of 1954—all of the above recommendations can be adopted through Administrative action as they would be within existing statutory authority. Recommendation No. 7 above, if adopted, would increase significantly the present level of monitoring and enforcing Federal regulations. It might be more appropriate if this were accomplished by legislative mandate rather than being left to Administrative determination.

VII. ADDITIONAL RECOMMENDATIONS

1. It is apparent that in some degree the heavy dependence on passenger aircraft for transporting radioisotopes for medical purposes is because of convenience rather than necessity. Even recognizing the need to transport short half-life isotopes without delay, the use of land transportation could be more effectively used particularly for relatively short haul distances. The panel recommends that shippers of radioactive isotopes make a greater effort to develop and use land transportation wherever possible.

2. Recognizing the need to continue the competitive nature of the production and sale of radiopharmaceuticals, the panel recommends that users such as hospitals and doctors, attempt to purchase their short half-life radioisotopes from the closest supplier. This would not only reduce the number of air shipments but would significantly reduce the amount in curies of radioactive shipments by passenger aircraft.
3. Information provided to the panel indicates that the current practice in the medical profession is to have the Mo⁶⁹ generators available at the hospital beginning on each Monday morning for use through the following Friday. This provides the most effective use in the hospital because of the short half-life feature of the isotope. Because of this, most radiopharmaceutical producers manufacture their product on Thursday or Friday and ship late Friday or Saturday. In order to insure that the ordered quantity (in curies) is available on Monday morning, a sufficient excess quantity to compensate for the amount lost by radioactive decay must be produced and shipped. In some cases the hospital will request sufficient quantities of the radioisotope in order to have a full supply available on Friday rather than Monday. The panel was told, for example, that in order to insure that the hospital has 500 millicuries of Mo⁶⁹ at the hospital on Friday morning, the producer ships approximately 2,500 millicuries on the previous Friday or Saturday. The panel considers that by properly revised scheduling the quantities (in curies) of radioisotopes shipped by passenger aircraft can be reduced. The panel saw little evidence of any effort on the part of the producers or users to do this.

4. The panel noted that in the packaging of liquid radioisotopes for shipment there is no requirement to place the bottle in a sealed plastic bag before insertion into the shielded container. This is an inexpensive step generally followed throughout the nuclear industry today and should be incorporated into the packaging requirements.

5. As an added precaution against gross mishaps or illegal shipments of radioactive material, the panel recommends the installation of high-level radiation monitors in cargo handling spaces and perhaps other areas of major airports. Such a device would have immediately detected the recent incident involving the air shipment of an unshielded industrial isotope.

6. The panel considers that the airlines should voluntarily assume a more active role in monitoring their operation with regard to shipping radioactive material. There appears to be a general feeling among the airline companies that the responsibility for safe shipment of radioactive material rests with the shipper and the Federal Government. Although the panel is not recommending the AEC licensing of air carriers, it does feel that the airlines can and should take a more active role. It would not be unreasonable to expect each airline to hire one or two persons trained and qualified in health physics to provide airline management with some surveillance capability. Such capability would provide the airline with some assurance that required procedures are being followed within their own operations.

7. Until and unless carriers become licensed to handle radioactive material, shippers must be held responsible for safe shipment of such material until it reaches its destination. The panel is of the opinion that some shippers of radioisotopes to a large degree consider their responsibility complete once they have packaged their product in accordance with the requirements and have turned it over to the carrier, even though he is not trained in the proper control of radio-
active material. Although unsubstantiated, it was reported to the panel that some shippers are aware and condone illegal practices followed by some land carriers once their shipments have been turned over to that carrier. However, the panel did observe one manufacturer who aggressively supervised all phases of the transportation cycle until the product was in the hands of the licensed user. The panel was unable to find any evidence where the Federal Government (AEC) inspected or regulated the operation of land carriers who transport radioisotopes from the shipper to the airports for air shipment. The panel recommends that this situation be corrected; that the enforcement of the shipper's license to handle radioactive material be extended to cover all truck or auto movement of the radioactive material until it is received by another licensed activity.

8. The requirement exists that pilots be advised in writing of the presence of radioactive shipments on their flights. The panel notes that this requirement is not consistently being followed in that cargo manifests do not always show the existence of such shipments. The panel recommends that airlines review their current procedures to ensure compliance with this requirement.

9. The panel recommends that airline passengers, if they ask, be told whether or not radioactive material is being carried on their particular flight. If, because of this, they chose not to fly on that flight, the choice is theirs. The panel does not consider that the airlines should, under such circumstances, be required to provide the passenger with so-called “bumping rights.”

10. Although no requirement exists, the panel considers it prudent that a film badge or TLD be installed on selected aircraft, passenger and cargo. This monitor could be installed in an inconspicuous location in the passenger area and be read each thirty days. A monitor should also be placed in an appropriate location in the cargo handling spaces of major airports where radioactive material is stored. The individual airlines should conduct this surveillance and report their results to the FAA.
APPENDIX A

List of individuals with whom the Panel conferred in connection with the problems discussed in this report.

Dr. Calvin Brantly, Chairman, AIF Isotope Committee.
Capt. William H. Briner, Duke University Medical Center (Society of Nuclear Medicine-Transportation Committee).
Dr. Jerry Bruno, E. R. Squibb & Sons, Inc.
Mr. William J. Burns, Director of Hazardous Materials, Department of Transportation.
Dr. Barry Commoner, Director, Center for Biology of National Systems, Washington University.
Mr. John F. Derr, Products and Systems Development, Director, E. R. Squibb & Sons, Inc.
Mr. Sam Edlow, Edlow International Associates.
Dr. Meril Eisenbud, NYU Environmental Health Laboratory.
Mr. Joseph A. Ferrarese, Chief, Flight Operations Division, Flight Standards Service, Federal Aviation Administration.
Mr. Ken George, Senior Research Scientist, E. R. Squibb & Sons, Inc.
Mrs. Margaret Glos, Executive Director, Society of Nuclear Medicine.
Mr. Kenneth J. Green, Manager, Radiopharmaceutical Distribution, Mallinckrodt Nuclear Corp.
Mr. Saul Harris, Chief, Radiation Bureau, Department of Health, New York City.
Mr. Dean B. Holzgaf, Manager, Nucleonics Business, E. R. Squibb & Sons, Inc.
Miss Pat Kennedy, Aviation Consumer Action Project.
Mr. Peter M. Kirby, Director, Federal Legislation, Air Transport Association of America.
Mr. Clifford J. Konnerth, Chief, Health Physics, E. R. Squibb & Sons, Inc.
Mr. Sam Langford, Aviation Safety, Federal Aviation Administration.
Gerald M. Mayo, Esq., Legal Division, Delta Air Lines, Inc.
Dr. Gerald McDonald, Good Samaritan Hospital in California.
Mr. James J. McGovern, Superintendent, Nuclear Operations, E. R. Squibb & Sons, Inc.
Mr. Robert B. Minogue, Deputy Director, Directorate of Regulatory Standards, Atomic Energy Commission.

Kathleen O'Neill, Esq., Attorney, Air Transport Association of America.

Mr. Harold T. Raven, Transportation Manager, E. R. Squibb & Sons, Inc.

Mr. Harry Richardson, President, NSI, Baton Rouge, La.

Mr. William Robb, Quality Assurance–Radiopharmaceuticals, Mallinckrodt Nuclear Corp.

Dr. William Rowe, Environmental Protection Administration.

Mr. Don Soldan, Radiation Safety, Mallinckrodt Nuclear Corp.

J. G. Speth, Esq., Natural Resources Defense Council, Inc.

Dr. Arthur Tamplin, National Resources Defense Council, Inc.

Dr. Robert Zimmerman, Consultant to Delta Airlines.
APPENDIX B

JOINT COMMITTEE ON ATOMIC ENERGY,
UNITED STATES CONGRESS,

Mr. JOHN T. CONWAY,
Executive Assistant to the Chairman of the Board, Consolidated Edison Co. of New York, N.Y.

DEAR JOHN: We want to thank you and your colleagues for taking on the difficult task of looking into the problems of transporting nuclear material to assure that it is properly safeguarded and that adequate safety and security precautions are taken.

The Joint Committee looks forward to the results of your deliberations. We are particularly anxious to know if any changes in present activities are needed at the present time. Accordingly, it would be appreciated if you would concentrate your efforts on determining what, if anything, is now being done incorrectly. We would also suggest that you inform the committee of impending problems you foresee in the future as our nuclear activities increase in order that they may be given attention in the future.

In order for your work to be of greatest value to the committee, it would be appreciated if results of your deliberations were made available in about two or three months. We then could, if deemed necessary, take any legislative action that is required in the present congressional session. Also, since the handling and transportation of nuclear weapons is significantly different from the procedures for other types of nuclear material, it would appear appropriate that you exclude the handling and transportation of weapons from the scope of your study. However, you are authorized to review the transportation and handling of nuclear weapons to whatever extent you believe necessary or helpful in arriving at your recommendations.

Sincerely,

MELVIN PRICE, Chairman,
JOHN O. PASTORE, Vice Chairman.
GLOSSARY

Absorbed dose. When ionizing radiation passes through matter, some of its energy is imparted to the matter. The amount absorbed per unit mass of irradiated material is called the absorbed dose, and is measured in rem and rads.

Actinide series. The series of elements beginning with actinium, Element No. 89, and continuing through lawrencium, Element No. 103, which together occupy one position in the Periodic Table. The series includes uranium, Element No. 92, and all the man-made transuranic elements. The group is also referred to as the "Actinides".

Alpha particle. A positively charged particle emitted by certain radioactive materials. It is made up of two neutrons and two protons bound together, hence is identical with the nucleus of a helium atom. It is the least penetrating of the three common types of radiation (alpha, beta, gamma) emitted by radioactive material, being stopped by a sheet of paper. It is not dangerous to plants, animals or man unless the alpha-emitting substance has entered the body.

Beta particle. An elementary particle emitted from a nucleus during radioactive decay, with a single electrical charge and a mass equal to %837 that of a proton. A negatively charged beta particle is identical to an electron. A positively charged beta particle is called a positron.

Curie. The basic unit to describe the intensity of radioactivity in a sample of material. The curie is equal to 37 billion disintegrations per second, which is approximately the rate of decay of 1 gram of radium. A curie is also a quantity of any nuclide having 1 curie of radioactivity.

Gamma rays. High-energy short-wavelength electromagnetic radiation. Gamma radiation frequently accompanies alpha and beta emissions and always accompanies fission. Gamma rays are very penetrating and are best stopped or shielded against by dense materials, such as lead or depleted uranium. Gamma rays are essentially similar to X rays, but are usually more energetic, and are nuclear in origin.

Genetic effects of radiation. Radiation effects that can be transferred from parent to offspring. Any radiation-caused changes in the genetic material of sex cells.

Isotope. One of two or more atoms with the same atomic number (the same chemical element) but with different atomic weights. An equivalent statement is that the nuclei of isotopes have the same number of protons, but different numbers of neutrons. Thus, $^{12}$C, $^{13}$C, and $^{14}$C are isotopes of the element carbon, the subscripts denoting their common atomic numbers, the superscripts denoting the differing mass numbers, or approximate atomic weights. Isotopes usually have very nearly the same chemical properties, but somewhat different physical properties.

Isotopic enrichment. A process by which the relative abundances of the isotopes of a given element are altered, thus producing a form of the element which has been enriched in one particular isotope. Example: enriching natural uranium in the uranium-235 isotope.

Maximum loading. The maximum number of packages of radioactive material that can be transported in a cargo compartment of an aircraft, in terms of the total of the transport indexes on those packages.

Millicurie (see curie). $\frac{1}{1000}$ of a curie.

Millirem (see rem). $\frac{1}{1000}$ of a rem.
Neutron. An uncharged elementary particle with a mass slightly greater than that of the proton, and found in the nucleus of every atom heavier than hydrogen. A free neutron is unstable and decays with a half-life of about 13 minutes into an electron, proton, and neutrino.

Radiation. The propagation of energy through matter or space in the forms of waves and fast-moving particles.

Radioactive labels. Labels bearing the unique trefoil radiation warning symbols which are required to be placed on two opposite sides of each package of radioactive material. Each radioactive label shows the contents, the amount of radioactivity in curies, and on radioactive yellow-II and radioactive yellow-III labels, the number of transport indexes. Labels are divided into:

1. radioactive white-I label—for each package not exceeding 0.5 millirem per hour at any point on the external surface of the package, not authorized for Fissile Class II packages;
2. radioactive yellow-II label—for each package exceeding limits of radioactive white-I label, but not exceeding 10 millirems per hour at surface and not exceeding TI of 0.5; and
3. radioactive yellow-III label—for each package exceeding limits of radioactive yellow-II label, each Fissile Class III package, each large quantity package, and each package being transported under a DOT permit.

Half-life. Time required for a radionuclide to lose 50 percent of its activity by decay. Each radionuclide has a unique half-life.

Radionuclide. An unstable isotope of an element that decays or disintegrates spontaneously, emitting ionizing radiation.

Rem (Acronym for roentgen equivalent man.) The unit of dose of any ionizing radiation which produces the same biological effect as a unit of absorbed dose of ordinary X-rays.

Roentgen [Abbreviation r] A unit of exposure to ionizing radiation. It is that amount of gamma or X-rays required to produce ions carrying 1 electrostatic unit of electrical charge (either positive or negative) in 1 cubic centimeter of dry air under standard conditions.

Separation distances. The distance between the passenger side of the floor or partition of the passenger compartment and the nearest surface of a package of radioactive material stowed in the cargo compartment.

Somatic effects of radiation. Effects of radiation limited to the exposed individual, as distinguished from genetic effects.

Spacing-out. A configuration for loading packages of radioactive materials in the cargo compartment of an aircraft which allows an aircraft to carry several groups of packages simultaneously; the spacing-out configuration limits the number of packages in each group and specifies minimum separation distances and distances between groups of packages.

TLD. Thermoluminescent dosimeter.

Transmission factor. The fraction of radiation passing through the aircraft structures between the radiation source and the dose point of interest.

Transport index (TI). The number placed on the label of a package of radioactive material to designate the degree of control to be exercised by the carrier during transportation. The transport index is equal to the larger of the following:

- the highest radiation dose rate, in millirem per hour at three feet from any accessible external surface of the package; or
- for fissile material packages, the number 50 divided by the number of similar packages which may be transported together under AEC rules.