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CNWRA 88-001

REVIEW OF THE LITERATURE RELEVANT TO THE TRANSPORTATION RISK STUDY

Prepared for

Nuclear Regulatory Commission
Contract NRC-02-88-005

Prepared by

Center for Nuclear Waste Regulatory Analyses
San Antonio, Texas

March 1988

Written by:

Edgar Oeters, Senior Research Engineer
Southwest Research Institute

Richard N. Pierce, Manager
Transportation/Special Projects &
Analytical Evaluation

Approved by:

Allen R. Whiting, Director
Waste Systems Engineering & Integration

Wesley C. Patrick
Technical Director

Bruce Mabrito, Director
Quality Assurance

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1.0 INTRODUCTION

The purpose of this report is to document the initial Literature Review, the first of four subtasks defined in reference 1 for accomplishing the Transportation Risk Study (TRS). The TRS is to produce an update of the most recent data on volumes, modes, and routes of shipments of radioactive materials (RAM) and projections of future shipments through the year 2005. The organization and conduct of the TRS is established in the four Subtasks: (1) this literature review, (2) evaluation, assessment, and recommendation, (3) investigation and implementation of computer codes and models, and (4) preparation of a formal report.

The literature review has started with a thorough review of NUREG-0170 (Final Environmental Statement...) with evaluation to determine content and establish a related data catalog system, and to establish routines and methods of analysis for use in identifying, collecting, and utilizing new data. Other principal reports including NUREG/CR-4829 (Shipping Container Response...the Modal Study), SAND84-7174 (Transport of Radioactive Material...), NUREG-0360 (Qualification...Package for Air Transport of Plutonium), and NUREG/BR-0111 (Transporting Spent Fuel...) have also been reviewed. A broad range of additional documents have been read or scanned and classified to identify information for use in the TRS. Full titles and citations for the reviewed documents are provided in Appendix A titled Literature List.

Documents in the list have been classified according to the TRS Statement of Work (reference 2) with allowance for certain new aspects including air transport of plutonium, Monitored Retrievable Storage (MRS), subseabed disposal, low specific activity (LSA) material, etc. identified in the NWPA amendment of 1987 (reference 3) or otherwise identified as potentially significant to the conduct of the TRS.

The remainder of this report is organized into a summary of the major information and conclusions of the most significant documents identified above, discussion of recent key literature, and the classification of the information documents according to the TRS Statement of Work.

2.0 PRINCIPAL RESULTS OF RAM TRANSPORTATION IMPACT STUDIES

The RAM transportation risk studies which have been performed in the past have shown that the adverse impact of RAM transportation is relatively small.

2.1 Results from NUREG-0170

Table 1 summarizes the normal transportation and transportation accident results presented in NUREG-0170. These are also illustrated in Figures 1 and 2. The table shows the population exposure of 9790 person-rems and the corresponding individual exposure expressed in latent cancer fatalities per year of normal transportation at the 1975 levels. This total and the breakdown according to the type of shipment are shown in Figure 1. The transportation of medical-use RAM is the largest risk category in Figure 1.

The impacts due to transportation accidents involving RAM, also shown in Table 1, are considerably smaller than the calculated normal transportation impacts. The annual societal risk of 5×10^{-4} early fatalities per year and 5×10^{-3} latent cancer fatalities per year of transportation at the 1975 levels are tallied in the table. The accident total and the breakdown according to the type of shipment are shown Figure 2. Note that the scale of Figure 2 covers one tenth the range of the scale of Figure 1. If the scale of Figure 1 had been used, the accident impacts would have been almost invisible in Figure 2. The additional impact of accidents is so much smaller than the small impact of normal RAM transportation because of the low frequency of accidents and the protection afforded by the required shipping containers appropriate to the radioisotopes and form transported. Figure 2 shows that the risks from transportation accidents are principally from the industrial and fuel cycle shipments, whereas normal transportation risks shown in Figure 1 are dominated by the medical-use shipments. NUREG-0170 estimated 2 nonradiological injuries per year and 0.2 nonradiological deaths per year of RAM transportation.

2.2 Results from SAND84-7174

The calculated risks are dependent on a number of factors including the number of shipments and packages shipped, the radioactivity of the package contents, and radiation exposure during normal and accident conditions. The statistics on shipment volumes have been updated in SAND84-7174 and other sources. Table 2 presents the numbers from SAND84-7174 and shows how the numbers were combined to form composite results of the licensee survey, DOE survey, and spent fuel data presented in the report. For purposes of this literature review and preliminary presentation of results, the three data sets were forced into the original presentation categories of NUREG-0170. The composite results are plotted in Figures 3 through 8. Figure 3 shows the annual number of RAM packages shipped per year based on the data assimilated in the report published in 1985. Figure 3 shows that the medical use package shipments on the order of 1.7 million packages are the largest in number while the spent fuel shipments on the order of 18 casks were the smallest in number, and invisible in Figure 3.

Table 1. NUREG-0170 Normal Transportation and Accident Risk Results

NORMAL TRANSPORTATION

	POPULATION EXPOSURE		INDIVIDUAL EXPOSURE
	PERSON-REM	PERCENT	LATENT CANCER FATALITIES(NOTE 1)
MEDICAL-USE RADIONUCLIDES	5101	52 %	0.6
INDUSTRIAL SHIPMENTS	2359	24 %	0.3
FUEL CYCLE SHIPMENTS	793	8 %	0.1
WASTE SHIPMENTS	1478	15 %	0.2
'LIMITED' PACKAGE SHIPMENTS	59	1 %	0.0
TOTAL	9790	100 %	1.2

TRANSPORTATION ACCIDENTS

	EARLY DEATHS(NOTE 2)	LATENT CANCER FATALITIES(NOTE 1)		EARLY DEATHS PLUS LATENT CANCER FATALITIES
MEDICAL-USE RADIONUCLIDES	0.00006450	0.000611	13 %	0.000675
INDUSTRIAL SHIPMENTS	0.00016892	0.001600	34 %	0.001768
FUEL CYCLE SHIPMENTS	0.00019532	0.001850	39 %	0.002045
WASTE SHIPMENTS	0.00006514	0.000617	13 %	0.000682
'LIMITED' PACKAGE SHIPMENTS	0.00000610	0.000057	1 %	0.000063
TOTAL	0.0005	0.0047	100 %	0.0052

NOTES: 1. LATENT CANCERS IN ABOUT 30 YEARS PER YEAR OF TRANSPORTATION AT 1975 LEVELS.
2. DEATHS PER YEAR OF TRANSPORTATION AT 1975 LEVELS.

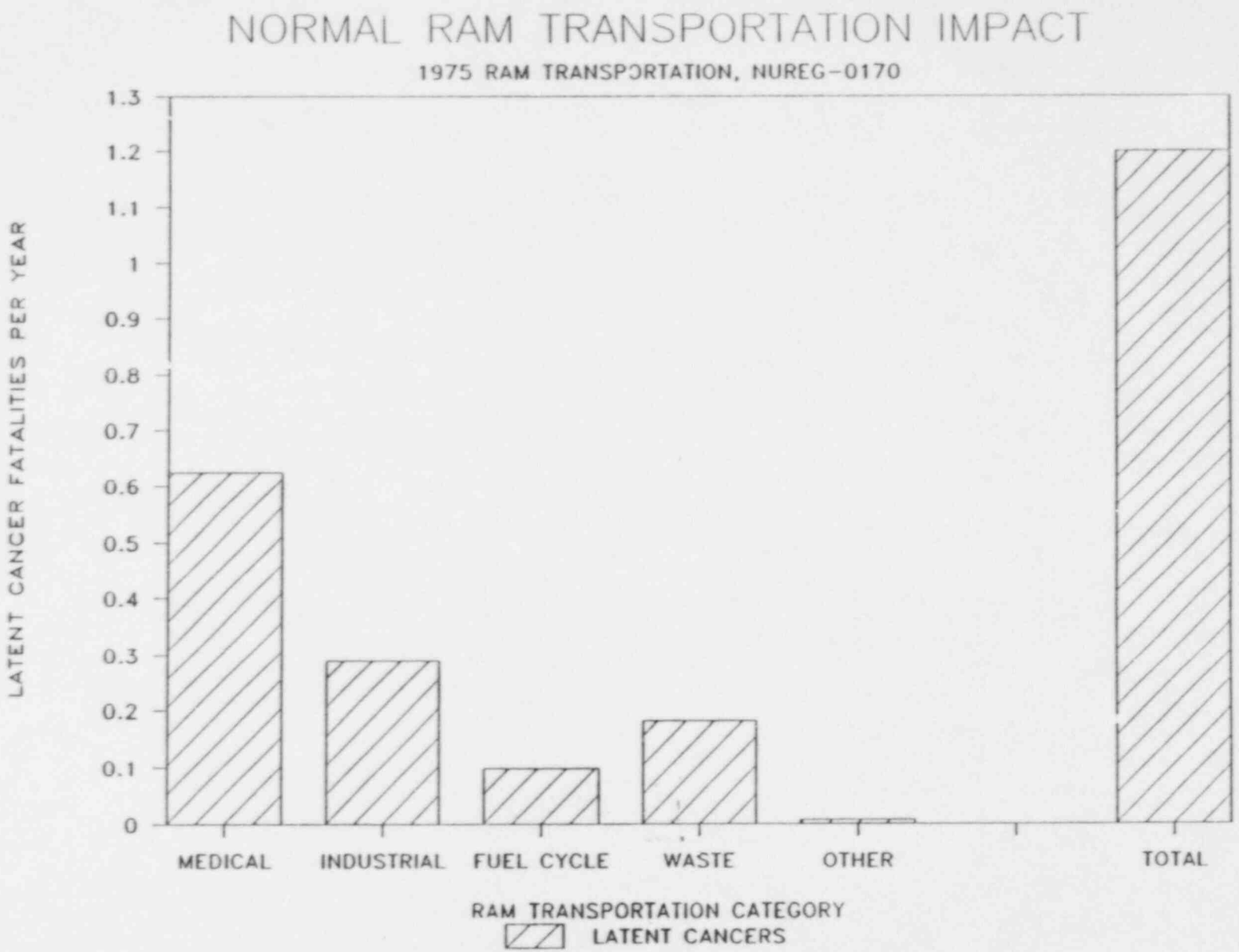

Figure 1. Normal RAM Transportation Impact

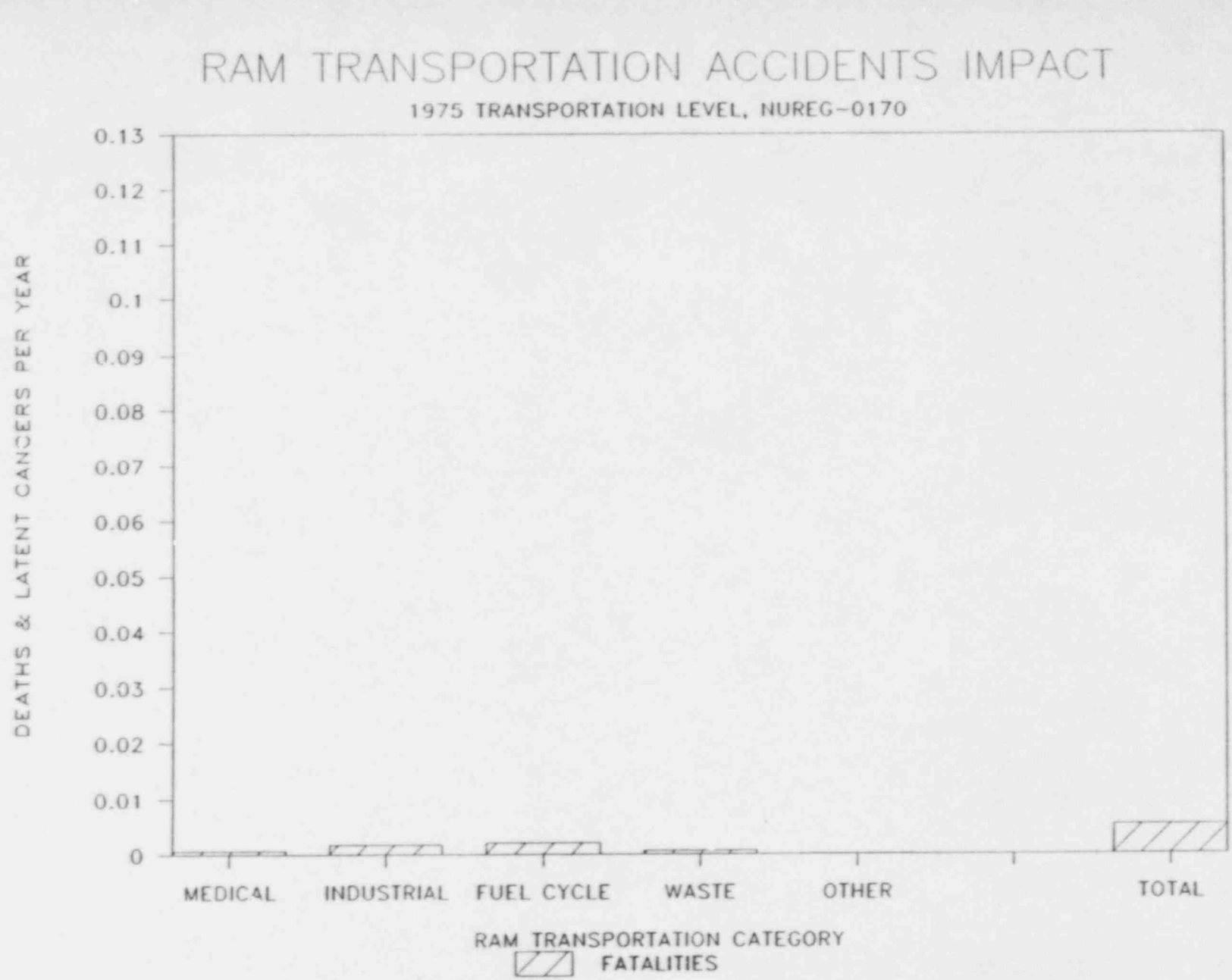

Figure 2. RAM Transportation Accidents Impact

Figures 4 and 5 illustrate the radioactivity of the package contents expressed in curies per package. The figures show that the spent fuel casks contain the largest inventories of RAM in terms of curies. Figure 5 with spent fuel curies off-scale shows the relative activity of the other shipment categories. The transportation index (TI) illustrated in Figure 6 is a measure of radiological dose rate external to the shipment packages expressed in millirems per hour (mr/hr). The illustrated TI's are from SAND84-7174 with the exception of the 10 mr/hr value for the spent fuel casks. This number is representative of the 10 mr/hr at 3 feet (0.914 m) from the cask surface reported in Table 2-4 of NUREG-0170 and at 2 meters (6.6 feet) from the external surface of the vehicle or trailer reported on page A-4 in volume II of the DOE/RW-0073 environmental assessment.

Figure 7 illustrates the annual total curies transported in the SAND84-7174 time frame. These numbers are the source of the curies per package numbers which were shown in Figures 4 and 5 when the number of packages shipped are considered. Figure 7 shows that the industrial shipments such as irradiator and radiography sources dominated the total annual curies transported. Figure 8 illustrates both the annual number of packages and curies transported expressed as percentages. The figure shows industrial curies to be the dominant source by about 7:1. The number of spent fuel shipments will increase under the NWPA and the spent fuel curies are expected to become dominant in Figure 8 in subsequent years.

While the data has been condensed into only 5 presentation categories for purposes of this report, the TRS analyses and presentations will utilize a more detailed breakdown. The detail will be consistent with the data sources, and controlled in combined categories to accomplish a meaningful risk analysis. Later presentations will employ tables, graphs, and corresponding narrative at several levels of detail for effective communication.

The surveys reported in SAND84-7174 provided RAM transportation samples of differing sample sizes from several sources. A careful review of the treatment of uncertainties will be a necessary element of the TRS. The outside-U.S.-origin, and low-level waste (LLW) shipments data involved the largest uncertainties. These areas, and low specific activity (LSA) RAM shipments will be included in the TRS in a framework of sensitivity and uncertainty models addressing all the RAM transportation categories. The spent fuel transportation survey reported in SAND84-7174 covered only a two year period. Subsequent documentation provides a comprehensive assessment of historical spent fuel shipments. The September 1987 paper by Stiegler, Allen, and Cashwell titled "Spent Fuel Transportation System Limitations and Opportunities" provides a summary of spent fuel transportation and it points to significant data sources including SAND85-7246, the DOE Energy Information Administration Spent Fuel Data Base, and the DOE Radioactive Materials Incident Report Data Base. Whereas prediction of spent fuel and other RAM shipments through 2005 will involve considerable uncertainty, this is not a caveat for the TRS. Since the TRS is a generic risk assessment it will provide the reference results necessary to evaluate impact for a range of projected shipment volumes and category mixes. Thus the TRS need for accurate projection can be limited to determining likely ranges of category volumes and their ratios.

Table 2. SAND84-7174 Composite Transportation Data

SAND84-7174 TABLE 4 NRC AND AGREEMENT STATE LICENSEE SHIPMENT DATA

SAND84-7174 CATEGORY	NO. PACKAGES	CURIES PER PKG	TI PER PKG	TYPE	CURIES	TIPR
INDUSTRIAL RADIOGRAPHY	84300	60.400	0.867	INDUSTRIAL	5070000	73088
OTHER INDUSTRIAL	129000	4.590	0.627	INDUSTRIAL	594000	80883
MEDICAL	1730000	1.790	0.545	MEDICAL	3080000	942850
POWER	114000	0.540	0.527	INDUSTRIAL	60900	60078
R&D/ACADEMIC	17100	0.669	0.790	INDUSTRIAL	11400	13509
WASTE*	181000	0.794	1.310	WASTE	137000	237110
OTHER	519000	0.027	0.102	OTHER	13300	52938
UNKNOWN/UNSPECIFIED	7550	0.553	0.145	OTHER	4170	1095
	2781950	3.225	0.525		8970770	

SAND84-7174 MODE	NO. PACKAGES	CURIES PER PKG	TI PER PKG	MODE	CURIES	TIPR
AIR	603000	2.930	0.333	AIR	1770000	200799
HIGHWAY	2160000	3.340	0.703	TRUCK	7150000	1518480
INLAND WATERWAYS	0	-	-	SHIP	0	0
RAIL+	3850	0.150	0.840	RAIL	578	3234
SHIP	0	-	-	SHIP	0	0
MAIL	5650	0.020	0.001	TRUCK	113	6
OTHER	13900	3.790	0.239	OTHER	52500	3322
UNKNOWN/UNSPECIFIED	34	0.015	-	OTHER	1	0
	2786434	3.220	0.619		8973192	

NOTES: 1. TI PER PKG MEANS AVERAGE TRANSPORTATION INDEX OF PACKAGES IN THE CATEGORY.
2. * -- IN SAND84-7174 THE ESTIMATE OF WASTE SHIPMENTS FOR THIS CATEGORY WAS EXPLAINED TO BE LOW.
3. + -- IN SAND84-7174 THE NUMBER OF PACKAGES IN THIS CATEGORY WAS EXPLAINED TO INVOLVE UNCERTAINTY DUE TO AN UNSAMPLED LARGE SHIPMENT POSSIBILITY.
4. TIPR IS THE PRODUCT OF TI PER PKG AND NO. PACKAGES. IT IS USED HERE IN COMBINING CATEGORIES.

Table 2. SAND84-7174 Composite Transportation Data (continued)

SAND84-7174 TABLE 8 DOE LICENSEE SHIPMENT DATA

SAND84-7174 CATEGORY	NO. PACKAGES	CURIES PER PKG	TI PER PKG	TYPE	CURIES	TIPR
MEDICAL	16	0.030	1.580	MEDICAL	0	25
POWER	6246	2.010	1.350	INDUSTRIAL	12600	8432
R&D	1802	14200.000	0.815	INDUSTRIAL	25578000	1469
WASTE	1146	230.000	0.178	WASTE	264000	204
OTHER/UNSPECIFIED	22580	64.100	0.270	OTHER	1447000	6097
	31790	858.811	0.510		27301600	

SAND84-7174 CATEGORY	NO. PACKAGES	CURIES PER PKG	TI PER PKG	MODE	CURIES	TIPR
AIR-FREIGHT	1217	123.000	1.390	AIR	150000	1692
AIR-PASSENGER	140	9070.000	0.953	AIR	1270000	133
FREIGHT FORWARD(AIR)	132	6850.000	0.830	AIR	904000	110
GOVERNMENT TRUCK	659	1.340	0.095	TRUCK	883	63
MOTOR FREIGHT	26074	956.000	0.471	TRUCK	24922000	12281
RAIL	3052	2.650	0.611	RAIL	8070	1865
OTHER/UNSPECIFIED	516	64.900	0.252	OTHER	47000	130
	31790	858.822	0.512		27301953	

NOTES: 1. TI PER PKG MEANS AVERAGE TRANSPORTATION INDEX OF PACKAGES IN THE CATEGORY.
2. TIPR IS THE PRODUCT OF TI PER PKG AND NO. PACKAGES. IT IS USED HERE IN COMBINING CATEGORIES.

Table 2. SAND84-7174 Composite Transportation Data (continued)

SPENT FUEL (1981 & 1982)

MODE	NO. SHIPMENTS	NO. PACKAGES	CURIES PER PKG	TI PER PKG	MODE	CURIES	METRIC TONS	PWR ASSEMBLIES	BWR ASSEMBLIES
TRUCK	35	35	-	-	TRUCK	-	-	27	9
RAIL	2	-	-	-	RAIL	-	-	13	0
	37	35				12100000	20.6	40	9

SPENT FUEL (1981 & 1982 ANNUAL AVG)

MODE	NO. SHIPMENTS	NO. PACKAGES	CURIES PER PKG	TI PER PKG	MODE	CURIES	METRIC TONS	PWR ASSEMBLIES	BWR ASSEMBLIES
TRUCK	18	17.5	-	-	TRUCK	-	-	14	5
RAIL	1	-	-	-	RAIL	-	-	7	0
SPENT FUEL	19	18	345714		SPENT FUEL	6050000	10.3	20	5

Table 2. SAND84-7174 Composite Transportation Data (continued)

COMBINED LICENSEE & DOE SURVEYS

SAND84-7174 CATEGORY	NO. PACKAGES	CURIES PER PKG	TI PER PKG	TYPE	CURIES	TIPR
MEDICAL	1730000	1.790	0.545	MEDICAL	3080000	942850
MEDICAL	16	0.030	1.580	MEDICAL	0	25
MEDICAL	1730016	1.780	0.545	MEDICAL	3080000	
INDUSTRIAL RADIOGRAPHY	84300	60.400	0.867	INDUSTRIAL	5070000	73088
OTHER INDUSTRIAL	129000	4.590	0.627	INDUSTRIAL	594000	80883
POWER	114000	0.540	0.527	INDUSTRIAL	60900	60078
R&D/ACADEMIC	17100	0.669	0.790	INDUSTRIAL	11400	13509
POWER	6246	2.010	1.350	INDUSTRIAL	12600	8432
R&D	1802	14200.000	0.815	INDUSTRIAL	25578000	1469
INDUSTRIAL	352448	88.884	0.674	INDUSTRIAL	31326900	
WASTE*	181000	0.794	1.310	WASTE	137000	237110
WASTE	1146	230.000	0.178	WASTE	264000	204
WASTE	182146	2.202	1.303	WASTE	401000	
OTHER	519000	0.027	0.102	OTHER	13300	52938
UNKNOWN/UNSPECIFIED	7550	0.553	0.145	OTHER	4170	1095
OTHER/UNSPECIFIED	22580	64.100	0.270	OTHER	1447000	6097
OTHER	549130	2.667	0.109	OTHER	1464470	

NOTES: 1. TI PER PKG MEANS AVERAGE TRANSPORTATION INDEX OF PACKAGES IN THE CATEGORY.
2. * -- IN SAND84-7174 THE ESTIMATE OF WASTE SHIPMENTS FOR THIS CATEGORY WAS EXPLAINED TO BE LOW.
3. TIPR IS THE PRODUCT OF TI PER PKG AND NO. PACKAGES. IT IS USED HERE IN COMBINING CATEGORIES.

Table 2. SAND84-7174 Composite Transportation Data (continued)

COMBINED LICENSEE & DOE SURVEYS SUMMARY

SAND84-7174 CATEGORY	NO. PACKAGES	CURIES PER PKG	TI PER PKG	TYPE	CURIES	TIPR	METRIC TONS	PWR ASSEMBLIES	BWR ASSEMBLIES
MEDICAL	1730016	1.780	0.545	MEDICAL	3080000	942875			
INDUSTRIAL	352448	88.884	0.674	INDUSTRIAL	31326900	237459			
SPENT FUEL	18	345714.286	10.000	SPENT FUEL	6050000	175	10.3	20	5
WASTE	182146	2.202	1.303	WASTE	401000	237314			
OTHER	549130	2.667	0.109	OTHER	1464470	60129			
TOTAL	2813758	15.041	0.525	AVERAGE	42322370				

SAND84-7174 CATEGORY	PERCENT OF PKGS	TYPE	PERCENT OF CURIES
MEDICAL	61	MEDICAL	7.3
INDUSTRIAL	13	INDUSTRIAL	74.0
SPENT FUEL	0	SPENT FUEL	14.3
WASTE	6	WASTE	0.9
OTHER	20	OTHER	3.5
TOTAL	100	AVERAGE	100.0

NOTES: 1. TI PER PKG MEANS AVERAGE TRANSPORTATION INDEX OF PACKAGES IN THE CATEGORY.
2. TIPR IS THE PRODUCT OF TI PER PKG AND NO. PACKAGES. IT IS USED HERE IN COMBINING CATEGORIES.
3. TIPR NUMBERS SHOWN WERE CALCULATED BY ELECTRONIC SPREADSHEET WITH UNROUNDED VALUES.

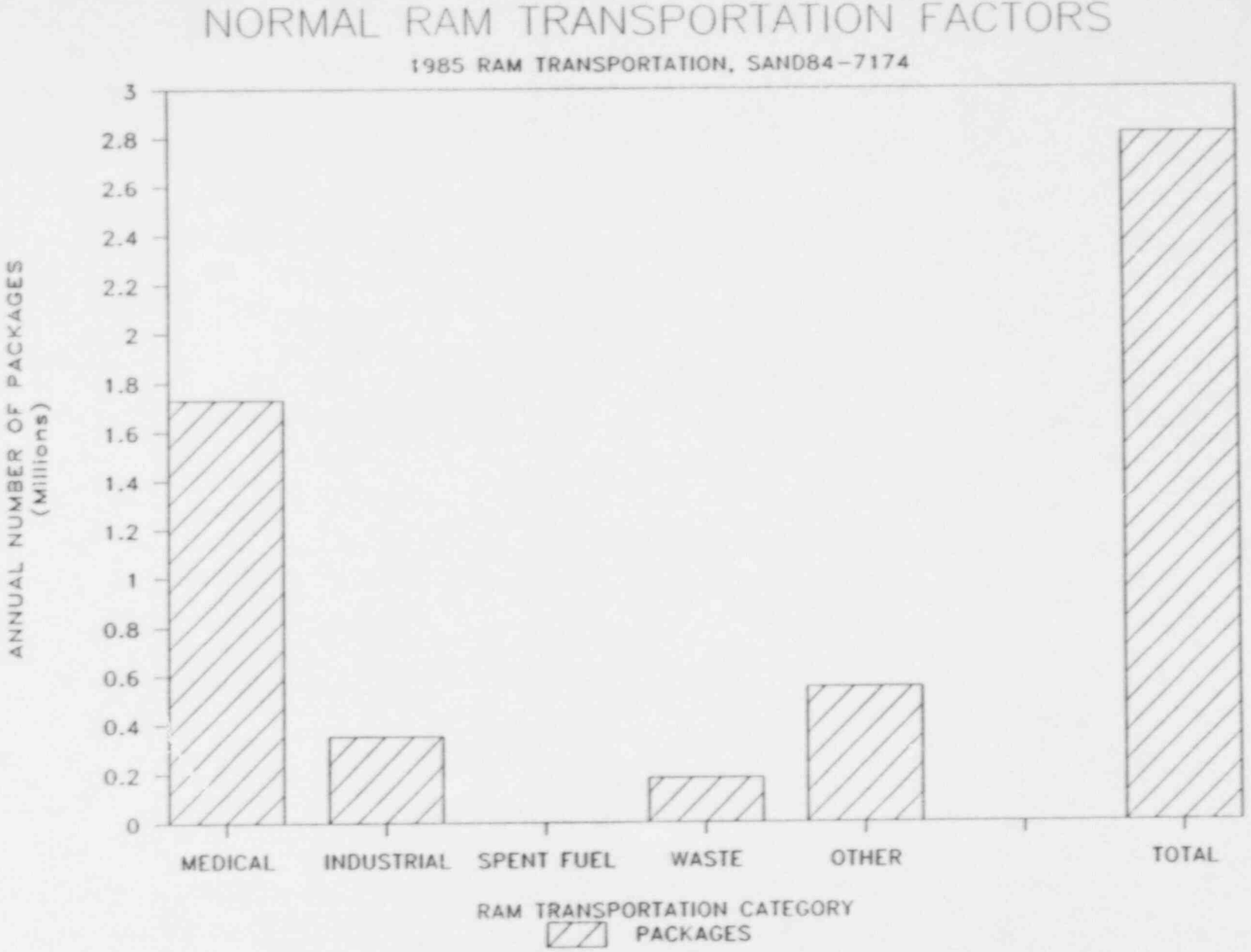

Figure 3. Normal RAM Transportation Package Factor

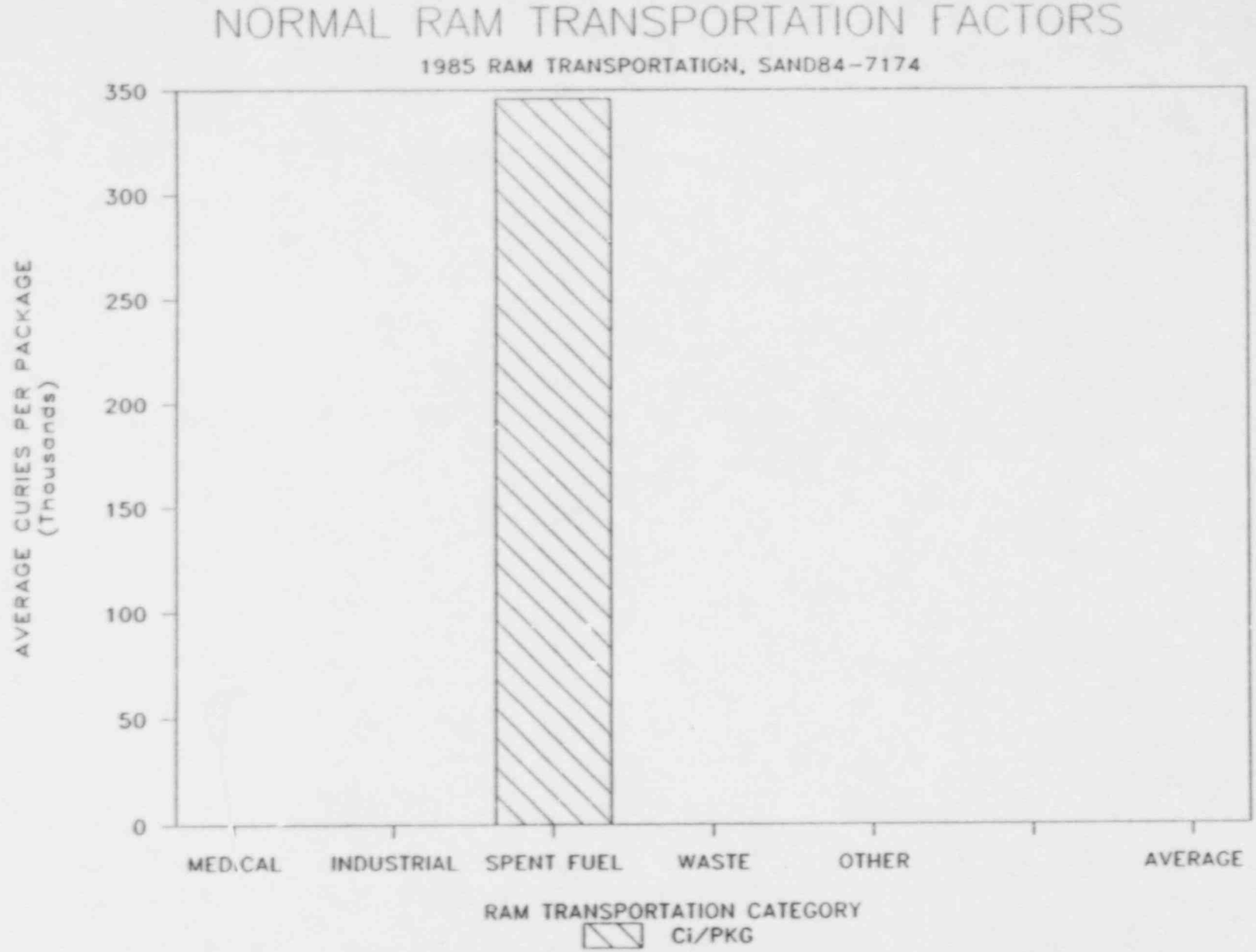

Figure 4. Normal RAM Transportation Curies Per Package Factor

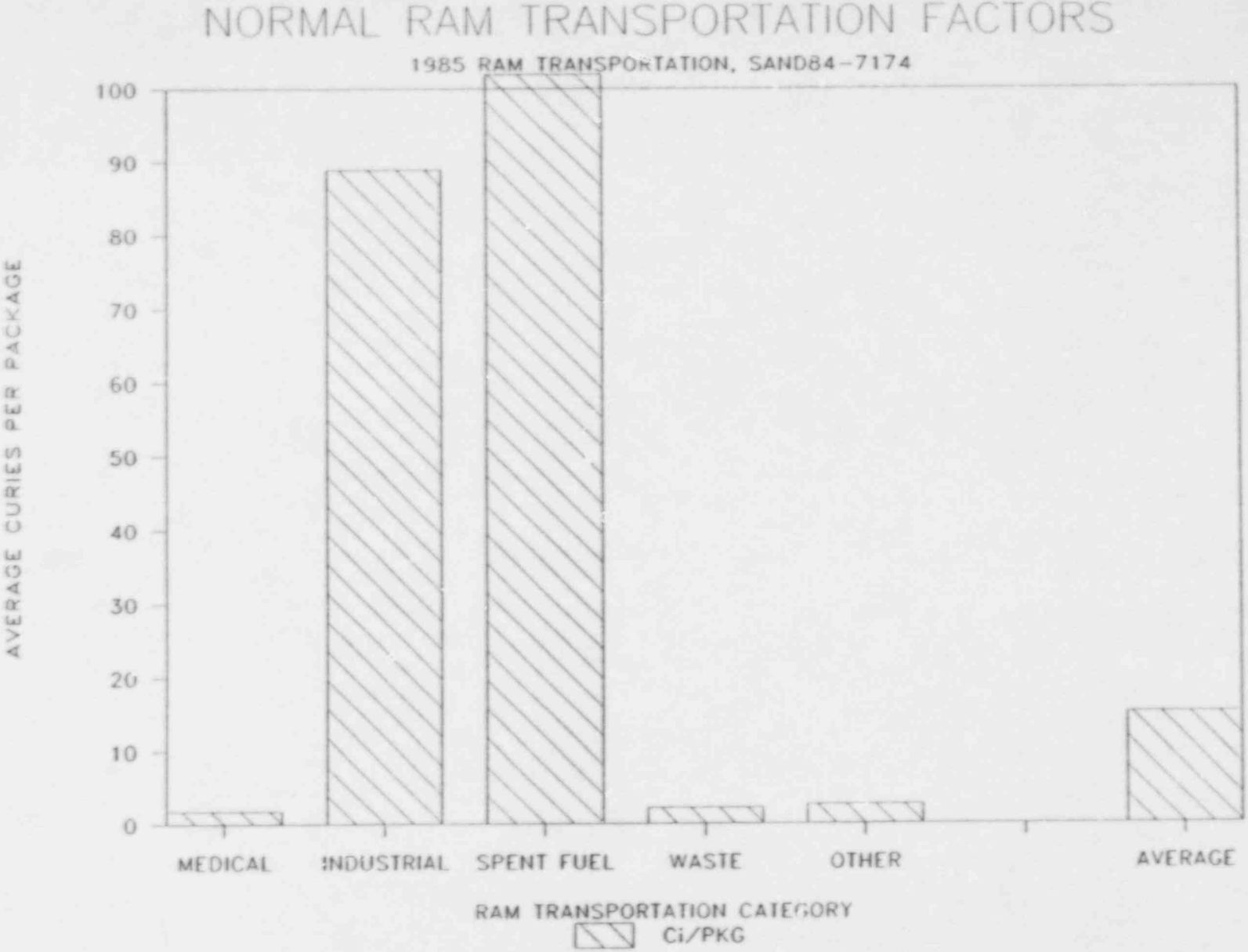

Figure 5. Normal RAM Transportation Curies Per Package Scaled Factor

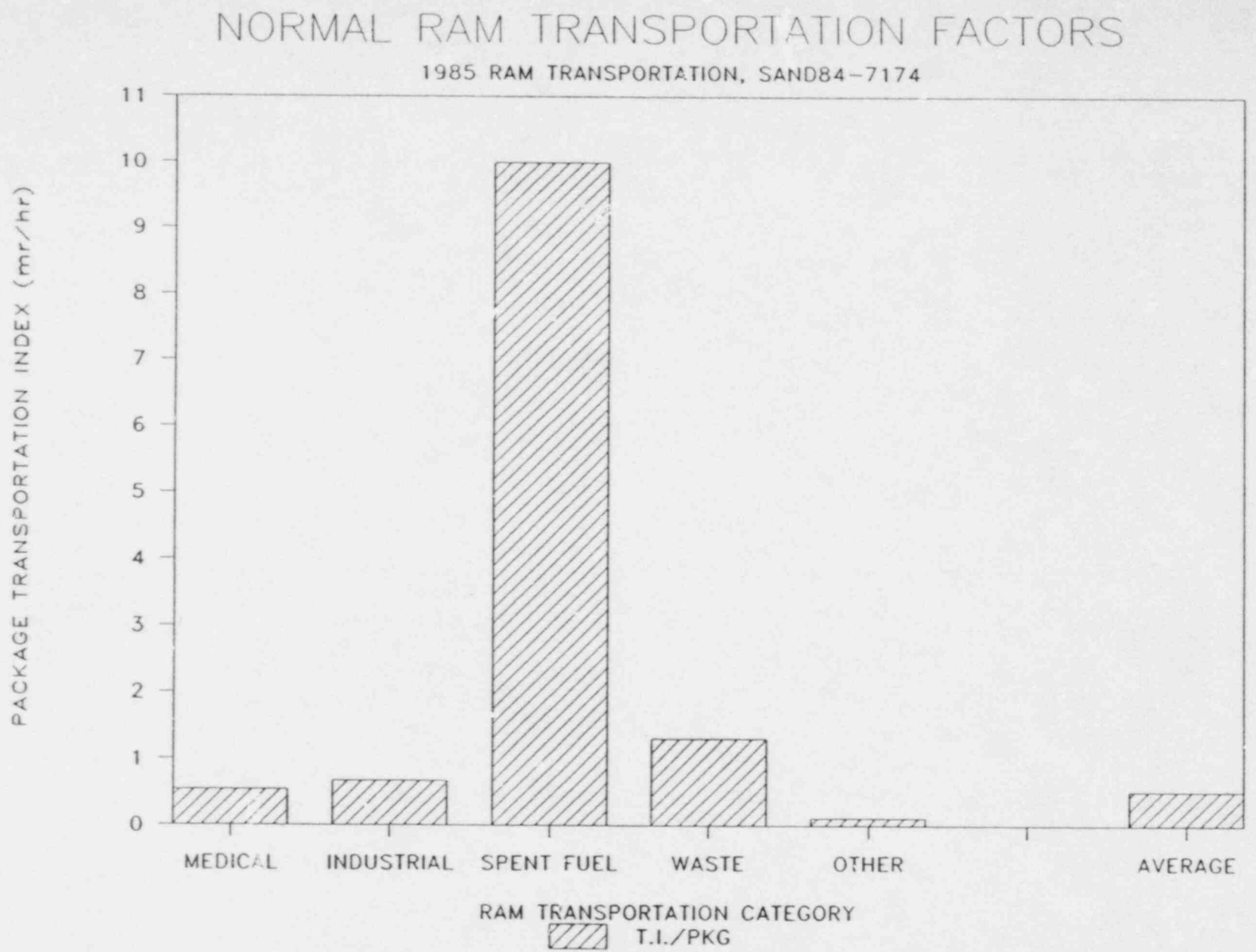

Figure 6. Normal RAM Transportation Transportation Index Factor

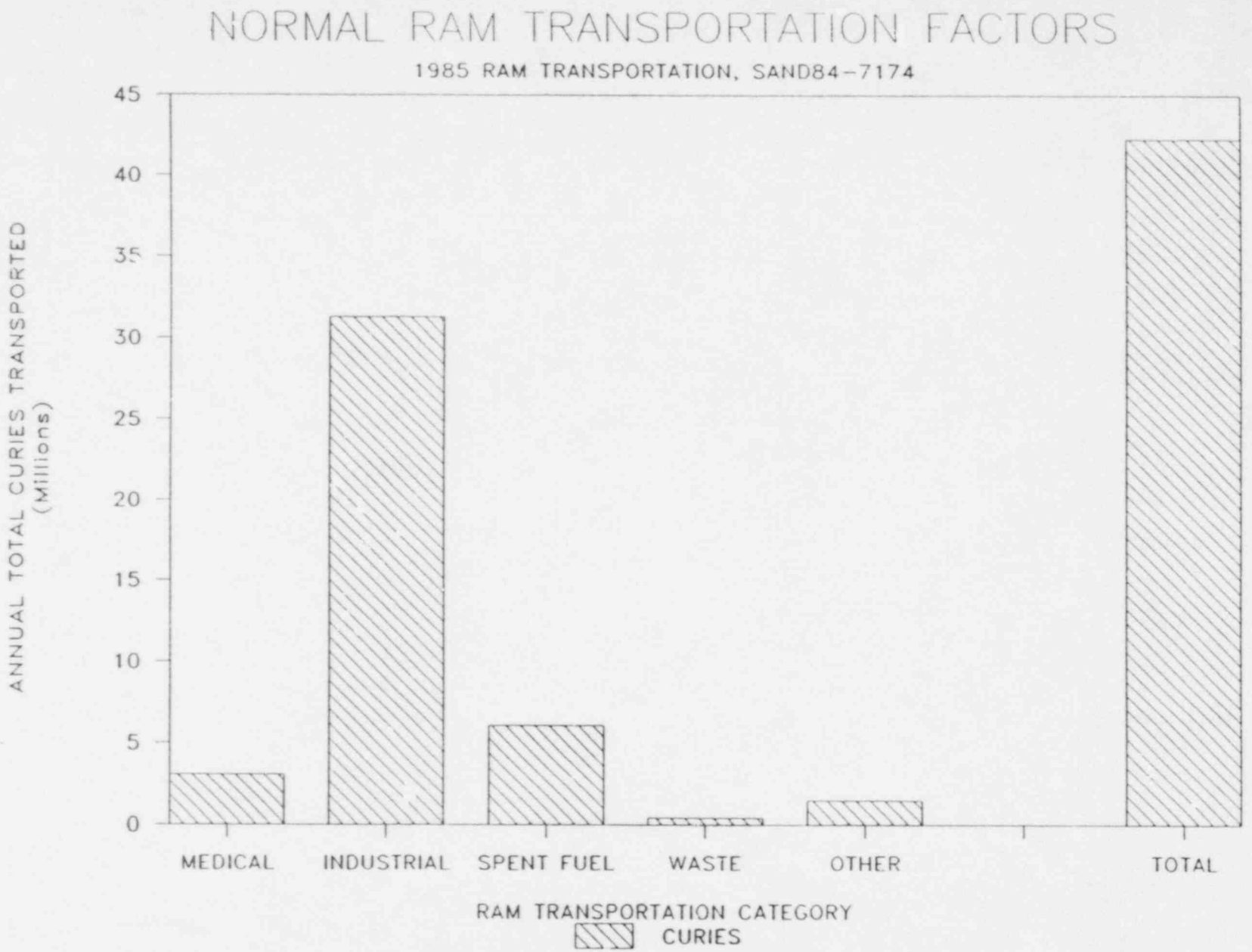

Figure 7. Normal RAM Transportation Curies Activity Factor

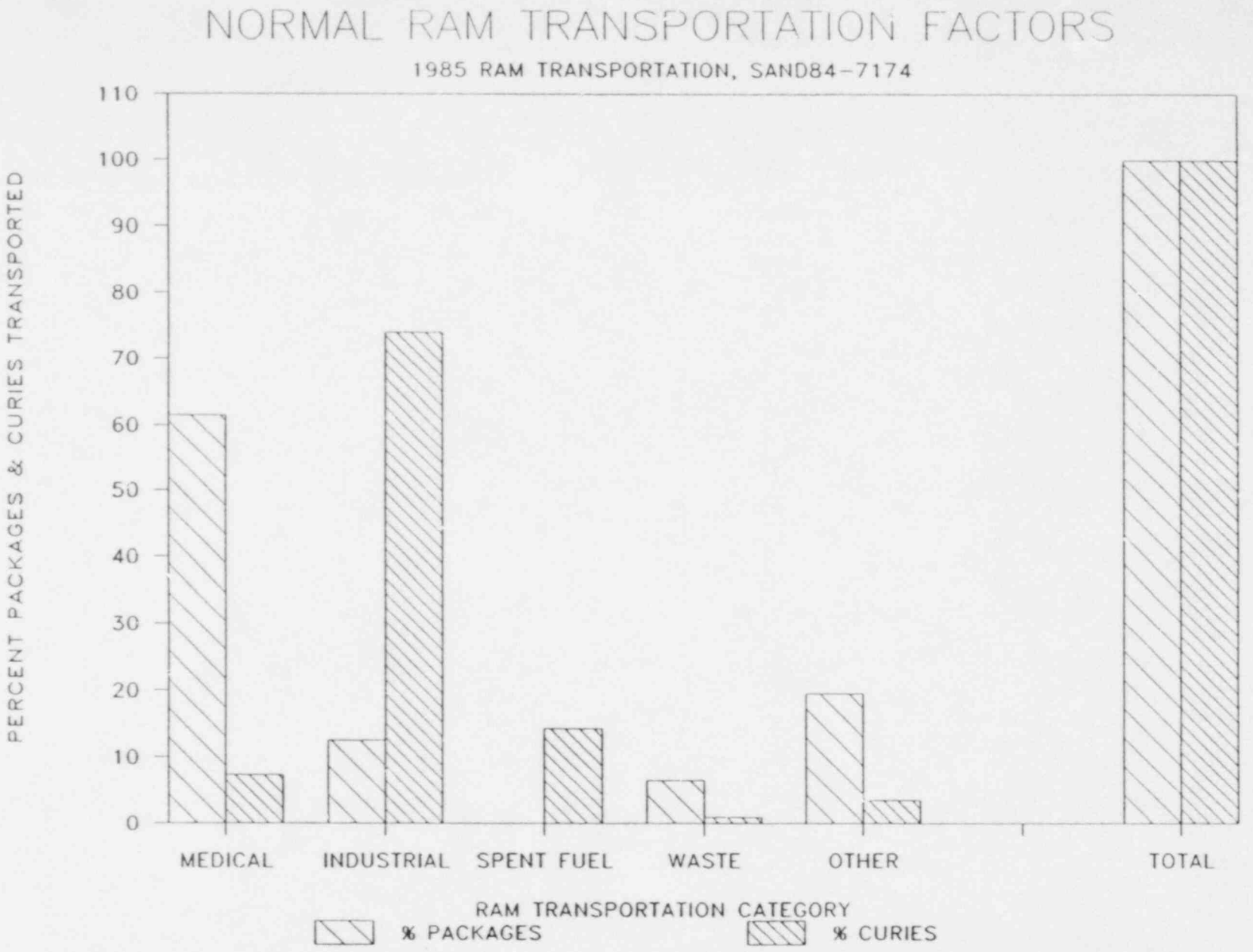

Figure 8. RAM Transportation Package and Activity Percentages

2.3 Results from NUREG/CR-4829 (Modal Study)

The "Modal Study" reported in NUREG/CR-4829 investigated the relationship between NRC's spent fuel package performance standards and actual transportation accident conditions. The likely responses of representative cask designs to the principal accident parameters, force and temperature, were determined. The study included highway and railway accident rates, collision and non-collision accident impact hardness data, fire duration and temperature effects, and frequencies and probability distributions of events and parameters incorporated in the analyses. Although the spent fuel shipments will increase substantially, the new information included in the Modal Study indicate that the transportation accident unit risk factors employed in the NUREG-0170 study were substantially overestimated.

The Modal Study results expressed in curies of released radioactive material are smaller than the results that had been obtained in the more conservative analyses reported in NUREG-0170. The Modal Study's released curies results are about 5 times smaller for gaseous materials, 34 to 39 times smaller for vapors, and 3 or 4 times smaller for direct radiation. The Modal Study also computed the small fraction of curies released as particulate matter which had not been separately presented in NUREG-0170.

3.0 KEY LITERATURE ADDRESSING THE TRS STATEMENT OF WORK TASKS

Additional and more recent literature citations have been classified according to a system based on the structure of the TRS Statement of Work (SOW). The automated version of the classification system is presented in 4.0. In this section the major SOW categories are identified and recent or key literature relevant to the TRS task is discussed.

3.1 RAM Transportation Volumes and Projection

In addition to the material presented in 2.2, a number of other sources will be consulted for the TRS update and projection of RAM transportation. A number of operating databases are available to enhance the capabilities of surveys such as the one of SAND84-7174. These are addressed in 3.10.

The Shipment Mobility/Accountability Collection Project Summary that was prepared for DOE by Science Applications International Corporation (Oak Ridge) lists data on 1986 shipment reports. The summary presents tables of 1986 DOE shipments number, tonnage, and cost by commodity and carrier. Origin states, destination states, and numbers of shipments are presented.

Key documents for information on projections of shipment under NWPA and its amendment include the September 1987 paper discussed in 2.2 by Stiegler, Allen, and Cashwell. Other sources are summarized and cited in the recent DOE primer (i.e., document number 217 listed in Appendix A) on spent fuel and HLW transportation, and the repository site environmental assessments. Further information on defense transuranic waste transportation, including volume projections through 2013, and the Waste Isolation Pilot Plant (WIPP) is available in the Rockwell report (number 240 in Appendix A). The paper by V.J. DeJong entitled "1986 WIPP Overview and Accomplishments" presented at the Waste Management '87 conference also addresses WIPP.

SAND86-1295C, Estimated Annual Worldwide Shipments of Radioactive Material, June 1986, provides one basis for comparing U.S. RAM transportation to the global picture.

3.2 New Information for Impact Analyses

In the area of safeguards and emergency response, a paper presented by L.H. Harmon, E.J. Habib, J.D. Henley, and R.D. Carlson for Waste Management 88 conference summarized the TRANSCOM system. The system is being developed to monitor movement of radioactive material shipments throughout the U.S. The system is to enhance DOE's oversight and control of sensitive RAM, and to address state and local government concerns regarding public safety. TRANSCOM will utilize the Coast Guard LORAN-C Navigation System, transport vehicles equipped with on board electronics and antennas, satellites and satellite earth station, a commercial communication service database, a Control Center with its database, and a user community equipped with appropriate hardware and software.

Less recent literature addressing severe accident tests and sabotage tests are identified for this SOW category in the Appendices. The sabotage tests and requirements for certain safeguards measures addressed concerns

which were raised by analyses conducted in the mid-seventies. This included SAND77-1927, Transport of Radionuclides in Urban Environs, in which it was suggested that the sabotage of spent fuel shipments had the potential for producing serious radiological consequences in areas of high population density. The Modal Study addressed in 2.3 had incorporated the results of these programs.

3.3 Shipments Under NWPA

The SOW states that the TRS should consider all aspects of the impacts of spent fuel shipments and other shipments projected for the DOE system under NWPA. Literature in other categories addresses this requirement. Assessments of risks associated with spent fuel reprocessing and recycling are outside the SOW scope.

3.4 Generic RAM Transportation Risk Assessment

The TRS is to assess generic risks to public health and safety from spent fuel transportation to and from storage facilities and the repository. The approach used will be to incorporate assessment statistics, studies, analytical models, and results sufficiently spanning the aspects and factor space of RAM transportation to provide an authoritative source. The TRS is not to assess specific impacts of transportation. Literature addressing the requirement is classified within the other SOW paragraph categories.

The Waste Management '86 paper by T.A. Wolff titled "Development and Use of Generic Documents for Assessing the Impacts of Transporting Nuclear Materials" discusses development of compendia of information to assist those who must deal with transportation issues in specific documents or who have a need for general information or keys to more detailed information.

3.5 Presenting Risk Assessment to the Informed Layman

The Waste Management 88 conference paper by J.D. McClure, R.E. Luna, and F.P. Falci presents a basic thesis that the fears of the general public about RAM transportation can be reduced by effective communication of engineering data. The point is developed that RAM usage is beneficial and transportation is necessary to achieve waste management objectives. The paper presents several examples of information on packagings and the RAM transportation process. The examples are in the areas of historical records, standards, testing, and design of packages, comparison with other hazardous materials, and on-going or recent studies.

A number of other references and citations of examples of previous work in this area are presented in the Appendices.

3.6 LLW, LSA, Decommissioning and Life Extension RAM

Shipments of RAM to existing licensed disposal sites for LLW at Barnwell, South Carolina, Beatty, Nevada, and Richland Washington totaled 2.7, 1.8, and 2.7 million cubic feet in 1985, 1986, and 1987 respectively. These volumes available from the Waste Treatment Projects Division, Office of Remedial Action and Waste Technology of DOE were reported in the March 1988 issue of

Nuclear News. The article by E.M. Blake also presented status of development of the regional compacts, and site selection. The conclusion of the existing scenario points to the possibility of 11 to 20 LLW disposal facilities. Whereas there are only seven regional compacts of member states which have been ratified by Congress, the larger number of likely disposal sites results from the interstate approach to LLW siting with its tendency to make states go on their own to propose new compacts or to ignore the LLW problem. Apart from the number of sites involved, an interesting development for the transportation assessment is the present plan of the Northeast Compact. Connecticut and New Jersey each would provide a disposal site--one for Class A waste only, and the other for Classes B and C. Waste of both types would be transported through New York, not a member of the compact. The characteristics and status of the other regional compacts, proposed compacts, unaffiliated states which plan their own disposal and will not be empowered to ban LLW from other states, and states and possessions with little or no LLW which have or may negotiate access contracts are presented in the article.

The Waste Management 88 paper by A.W. Grella indicates likely changes in definition of the categories of low specific activity (LSA) material which may be adopted by DOE and NRC. The probable impacts are that Type B packages may be required in many cases, for example for spent resins, where NRC-certified LSA greater than Type A packagings are currently used. Presently certified Type B designs and the number of units is insufficient, and cask loadings of existing packages will need to be lowered, resulting in more total shipments.

3.7 MRS, FIS, Offsite and Away-from-Reactor Storage

The December 1987 "Implementation Plan for Deployment of Federal Interim Storage (FIS) for Commercial Spent Nuclear Fuel" by the DOE Office of Civilian Radioactive Waste Management presents recent status of spent fuel interim storage and the relationship to on-site storage and the now delayed or eliminated MRS facility. The NWPA of 1982 authorized an FIS program for power reactor spent fuel. Utilities have primary responsibility for providing storage and maximizing use of its existing capacity. The DOE has responsibility to encourage and expedite this usage and additions to the capacity, and to provide storage for excess spent fuel at available government facilities, or construction of capacity at reactor sites. The DOE services would be made available when the NRC has determined that the reactor owners and operators cannot reasonably provide the necessary storage. The paper goes on to detail considered FIS alternatives, existing facilities, commercial shipping capability, need, and deployment plan. As of December, the NRC had not received any applications for determination of eligibility for FIS services.

The 1987 Amendments to the NWPA instituted certain changes with regard to FIS and MRS. Developments in this area will be monitored to assure the TRS adequately bounds the range of likely scenarios that are expected to occur with regard to on-site, away-from-reactor (AFR), FIS, and/or MRS facilities.

3.8 Biological Effects of Ionizing Radiation, Health Effects

The effect of radiation doses from RAM transportation normal and accident conditions are assessed with the Biological Effects of Ionizing Radiations (BEIR) models. BEIR III, The Effects on Populations of Exposure to Low Levels of Ionizing Radiation: 1980, provides the high dose data models and both the alternative linear and quadratic extrapolation models to the low dose probable effects. BEIR III deals with the effects of radiation from external x rays and gamma rays which is applicable to exposure from normal transportation.

BEIR IV, Health Effects of Radon and Other Internally Deposited Alpha-Emitters, extended the results of BEIR III to include new data on the health effects of ingested alpha-emitting radionuclides and their decay products. The provided models span the spectrum required by transportation considerations of normal transportation, and accident conditions involving gaseous, vapor, and particulate releases, and direct radiation.

The updated models are expected to be incorporated in computer programs such as RADTRAN for transportation risk studies. RADTRAN III utilizes the health effects models which were implemented for the WASH-1400 Reactor Safety Study.

3.9 NUREG-0170 Chapter Categories

The Waste Management 88 paper by A.W. Grella summarizes the highlights of the major changes of the 1985 IAEA edition of its standard Safety Series Number 6 (SS6-86). The NRC and DOE regulations are expected to be revised within the next two or three years to reflect these changes. The highlights include revisions in the Type A package maximum permissible activity for the special form (A_1) and non-special form (A_2) categories, a deep water immersion test for spent fuel casks, a crush test for lightweight Type B packages, established or revised definitions of categories and packaging standards for LSA and surface contaminated objects (SCO), and control of radiation exposure to transport workers. The changes will possibly result in required reductions in cask loadings and consequently in a greater number of total shipments.

The SOW NUREG-0170 Chapter categories are also addressed by other SOW paragraph categories, and relevant literature citations have been identified in Appendix A and categorized in Appendix B.

3.10 TRS Related Computer Codes and Data Bases

The single most comprehensive and applicable source of the specialized computer models, databases, and tools needed for the TRS is thought to be that maintained by the Sandia National Laboratories (SNL) Transportation Technology Center (TTC). This includes RADTRAN III which is designed to calculate the RAM transportation impacts by combining incorporated or input meteorological, demographic, health physics, transportation, packaging, and material factors for normal transportation and accidents. This code is presently undergoing improvements by addition of a radionuclide database, expansion of the accident categories matrix, and revisions of output format including additional intermediate results. The Waste Management 88 paper by J.W. Cashwell, C.M. Erickson, and E.A. Kern summarizes these recent

developments and similarly explains supporting databases and codes available through the TTC.

RADTRAN III (SAND84-0036 and SAND82-2681) computes radiological impact expressed in terms of level of consequence, probability of occurrence, and corresponding risk. Consequences are expressed in terms of health effects, early and latent, and economic impacts for accident conditions. Impact due to normal RAM transportation is computed as dose to four categories of occupational workers and four categories of the general public. Significant inputs to the code that influence the manner in which it can be applied in the TRS include transported material characteristics, transportation scenario, accident conditions and package release fractions, meteorological values, population distribution, and health effects parameters and computational techniques. A number of documents are available which provide guidance and examples of the use of RADTRAN. Among these are SNL reports on sensitivity analysis, food ingestion exposures, rail-stop exposure, truck transportation, and the nine repository site transportation impact analyses, and the Rockwell report on transuranic defense waste transportation.

Other references cited in the Appendices point to related computer codes and databases. The 1983 Battelle report PNL-SA-10815 reviews earlier risk analysis methodologies for RAM transportation, and other computer codes based on RADTRAN include METRAN which evaluates risk of transportation in urban areas, and INTERTRAN, the risk-assessment tool of the International Atomic Energy Agency (IAEA).

Identified shipment databases include the DOE's Spent Fuel Database and RAM Incident Database both mentioned in 2.2 above, the TTC survey database summarized in SAND84-7174, the NRC's listing of spent fuel shipments under 10 CFR 73.37 requiring advance notification of truck shipments, and DOT post-notification of highway route controlled quantity shipments contained in the Radioactive Materials Routing Report (RAMRT) database of DOT's Office of Hazardous Materials Transportation. The RAMRT includes data from the NRC Division of Safeguards, DOE Division of Operations and Transport, and NRC-licensed shippers. The LLW data available from the Waste Treatment Projects Division, Office of Remedial Action and Waste Technology of DOE (see 3.6 above) provide information on LLW. Use of a commercial database on LLW is marketed by the Utility Data Institute, Inc. (UDI). UDI provides commercial access to the database of U.S. Ecology, Inc., the operator of the LLW disposal sites at Beatty and Richland.

4.0 DOCUMENT CLASSIFICATION

4.1 Document Classification System

A broad range of documents have been classified to identify information for use in the TRS. The literature list is contained in Appendix A where citations for the reviewed documents are provided. The list was developed from the key documents identified in the TRS Statement of Work, the Center library's developing document list, significant references in reviewed material where further detail seemed appropriate, and identification in keyword searches. The numbers assigned to the documents listed in Appendix A are consistent with the numbering system initiated for the Center library's document list and additional materials acquired in the course of this initial literature review for the TRS. Regular surveillance of information sources is an on-going task in the TRS subelement.

A simple classification system for the documents was established by direct relationship of the subject matter to specific paragraphs and subparagraphs in the TRS Statement of Work.

4.2 Document Classifications

Documents in the list (Appendix A) were classified according to the TRS Statement of Work with allowance for certain new aspects including air transport of plutonium, Monitored Retrievable Storage (MRS), subseabed disposal, low specific activity (LSA) material, etc. identified in the NWPA amendment of 1987 (reference 3) or otherwise identified as potentially significant to the conduct of the TRS. The document classification in this draft preliminary report is presented in Appendix B where the TRS Statement of Work paragraphs are listed with subparagraph breakout in certain areas. The identification numbers of the documents defined in Appendix A are listed in the appropriate TRS category in Appendix B. This classification can be changed according to evolution of the statement of work and further classification of identified or new documents.

4.3 Automated Literature Searches

Preliminary automated keyword searches were run employing the DIALOG Information Services, Inc. system to search the NTIS, COMPENDEX, DOE ENERGY, NSA, and TRIS files. The keyword search logic used "transportation" intersected with "nuclear" or "radioactive" or "spent fuel". The number of counted documents in the automated search is presented in Table 3. The indicated total number of documents in Table 3 is on the order of 7400, but the degree of overlap was not determined. A number of the most recently cataloged titles from each group were used to identify documents of immediate interest in the formative stages of the TRS. These are incorporated in the Appendices.

Because of the large number of existing documents, a sorting scheme based on keywords was constructed. The objective was to try an electronic sorting according to the TRS SOW paragraph categories for subsequent reference as needed in conducting the TRS. A sample comprising the 1317 most recent documents (1982-1988) from the NTIS file were sorted according to scheme

presented in Table 4. A scan of sampled recent titles in each of the categories indicated that the initial try resulted in perhaps 75 percent effectiveness in assigning documents to the appropriate category. About 90% of the titles were automatically sorted to one of category sets S11 through S22 of Table 4. Further work on the search and sorting scheme is planned during the conduct of the TRS in a manner co-ordinated with LSS activities in DOE (document number 219 in Appendix A).

The method of automated search provides an approach to periodically update the literature search, to screen, sort and review all documents newly cataloged to the accessed library files since the previous update.

Table 3. Automated Search Document Numbers

File	Time Period	Number of Documents
NTIS	1975-1988	2639
COMPENDEX	1975-1988	960
DOE ENERGY	1983-1988	2434
NSA	1948-1976	476
TRIS	1970-1987	916

Table 4. Initial Keyword Sort of NTIS Sample

Category Set	Number of Documents	Category/Keyword Definition
S1	53893	TRANSPORTATION
S2	198139	NUCLEAR OR ATOMIC OR RADIOACTIVE
S3	3121	SPENT()FUEL
S4	2638	S1ANDS2
S5	2639	S1AND(S2ORS3)
S6	1317	S5/870235-9999999
S7	949	S5/475138-870234
S8	373	S5/000001-475137
S10	402	S6 AND (VOLUME OR PROJECT? OR ESTIMAT?)
S11	39	S6 AND (VOLUME AND (PROJECT? OR ESTIMATE?))
S12	439	S6 AND (CASK OR ACCIDENT? ? OR TEST OR MALEVOLENT OR SABOTAGE)
S13	152	S6 AND (REPOSITORY OR MONITORED()RETRIEVABLE()STORAGE OR MRS OR FEDERAL()INTERIM()STORAGE OR FIS)
S14	23	S6 AND GENERIC
S15	0	S6 AND (LAYMAN OR UNDERSTANDABLE)
S16	307	S6 AND (CORRIDOR? ? OR ROAD? ? OR RAIL OR BARGE OR SEA OR MAXIMALLY()EXPOSED()INDIVIDUAL? ?)
S17	3	S6 AND ((MRS OR MONITORED()RETRIEVABLE()STORAGE) AND (INCREASE OR DECREASE))
S18	37	S6 AND (ONSITE OR OFFSITE OR AWAY(1W)REACTOR OR AFR OR FIS OR INTRA()UTILITY)
S19	65	S6 AND (LLW OR LOW()LEVEL()WASTE? ? OR LIFE()EXTENSION OR LSA OR LOW()SPECIFIC()ACTIVITY)
S20	20	S6 AND (BEIR OR (BIOLOGICAL()EFFECT? ? AND IONIZING()RADIATION) OR HEALTH()EFFECT? ? OR COMPUTER()MODEL??)
S21	723	S6 AND (WASTE OR SPENT()FUEL)
S22	348	S6 AND (REGULATION? ? OR CFR OR CODE(1W)FEDERAL()REGULATION? ?)
S23	145	S22 AND (NRC OR DOT OR DOE OR FEMA OR INDIAN? ? OR TRIBE? ?)
S24	3	S22 AND (BARGE OR (DOE AND NWPA))
S25	88	S6 AND RADIOLOGICAL
S26	866	S6 AND (TEST OR SABOTAGE OR MALEVOLENT OR WASTE OR SPENT()FUEL OR ACCIDENT)
S27	153	S6 AND (ALTERNATIVE? ? OR OPTION?)
S28	66	S6 AND (SECURITY OR SAFEGUARD? ?)
S29	1146	11-28/OR (NUMBER OF SORTED DOCUMENTS)
S30	171	6NOT29 (NUMBER OF DOCUMENTS NOT SORTED)

5.0 CONCLUSION

The foregoing accomplishes the purpose of this report to document the initial Literature Review, the first of four subtasks of the TRS.

The graphical and narrative presentations of the principal findings of NUREG-0170, NUREG/CR-4829, SAND84-7174, and other key literature were made. The TRS is to produce an update of the most recent data on volumes, modes, and routes of shipments of RAM and projections of future shipments through the year 200[illegible] Background literature and databases useful to this task were identified and described. A broad range of additional documents were read or scanned and classified to identify information for use in the TRS. Titles and citations for the reviewed documents are provided in the Appendix A. Documents were classified according to the requirements of the TRS tasks. The classification is presented in Appendix B.

Development of an automated literature search and sorting procedure was initiated. The automated procedure will complement other sources in identifying literature significant to the TRS, and in cataloging identified documents for use in the appropriate area of the TRS project. The system is expected to provide a degree of assurance that significant information has not been overlooked. Its further development will strengthen this initial literature review, provide an efficient means of updating the literature lists, and focus information where needed in conduct of the TRS.

The organization and conduct of the TRS is established in the four Subtasks: (1) this literature review, (2) evaluation, assessment, and recommendation, (3) investigation and implementation of computer codes and models, and (4) preparation of a formal report. The evaluation, assessment, and recommendation Subtask has been initiated following the initial literature review.

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APPENDIX A

LITERATURE LIST

LITERATURE LIST

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APPENDIX B

DOCUMENT CLASSIFICATIONS

Selected Literature Classification According to the TRS Statement of Work

SOW 2.1.1 Determine how transportation of radioactive material has increased from 1975 to date and how it is projected to increase in the future through the year 2005 (i.e., 1985, 1995, and 2005). Start with the updated estimates of the Sandia report, SAND 84-7174 (April 1985) and make modifications, if needed, to incorporate any improved estimates that may become available.

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180-129
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180-387
182-483
182-489
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SOW 2.1.2 Update the estimates of transportation radiological impacts through 2005, compare with the previous estimates in NUREG-0170, and identify significant changes and trends in transport impacts over the 1985-2005 period. The impact estimates shall include consideration of new information since NUREG-0170 was published, including but not limited to the observed responses of spent fuel and high-level waste casks in severe accidents in the Sandia and British tests; sabotage tests; and the results of NRC's Study of Shipping Container Response to Severe Highway and Railway Accident Conditions (so-called Modal Study).

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SOW 2.1.3 The analysis should consider all aspects of the impacts of spent fuel shipments and other shipments projected for the DOE waste management system under the NWPA. Assessments of risks associated with spent fuel reprocessing and recycle are unnecessary.

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SOW 2.1.4 Provide the data needed by the NRC to assess the generic risks to public health and safety from spent fuel transportation to and from an MRS facility, and to provide reference data for the NRC's review of the transportation aspects of an MRS license application. The specific impacts of transportation to and from the MRS site chosen for the license application will be analyzed in the applicant's environmental report and the NRC's independent Environmental Impact Statement, and need not be assessed in this study.

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SOW 2.1.5 The assessment of risks to the public is being performed, in part, to be responsive to public concerns and fears about radioactive material transportation: emphasis is therefore to be placed on presenting the information in a manner designed to be readily understandable to the informed layman.

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180-137
180-163
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181-117
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182-83
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SOW 2.2.1 Shipments of radioactive material to the regional disposal sites for low-level wastes and to the monitored retrievable storage facility and the national repositories for high-level wastes will tend to funnel into corridors along the main highways and rail linss to the site. Reported estimates of the increased traffic and the routing of shipments through transportation corridors to waste storage and disposal sites should be reviewed. The performing organization shall evaluate generically the impact of routine transportation and accident conditions on a maximally exposed individual who resides or works along a corridor.

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SOW 2.2.2 If authorized by Congress, a Monitored Retrievable Storage facility would serve as a transportation focal point in the routing of shipments from reactors to the high level waste repository. Shipments from the reactors would first be sent to the MRS for consolidation and then sent on to the repository by rail using special trains. Some public comments on the plan for the MRS facility have suggested that the facility may actually increase transportation requirements, since the spent fuel must be shipped twice. It has been noted that the site chosen for the MRS facility may bring an increase in transportation in states which otherwise might not be on the route for so many shipments. Others have pointed out that the MRS facility may decrease transportation impacts by consolidating the fuel and thus reducing the number of shipments. Considering these conflicting views, the performing organization shall thoroughly evaluate the impacts of MRS transportation.

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SOW 2.2.3 As utility spent fuel storage space approaches being filled to capacity, a decision regarding whether to store spent fuel onsite or to transport it offsite must be made. Some utilities have opted for increasing their onsite storage capacity based on financial or other consideration; others have shipped spent fuel offsite for storage at other locations. The performing organization shall determine the impacts of such intra-utility or offsite shipments.

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SOW 2.2.4 The impacts of low-level waste transportation shall be evaluated by the performing organization for shipments of waste to the LLW disposal sites established under regional compacts. (Low specific activity RAM included here.) This evaluation should consider wastes originating from decommissioning (and life extension) activities.

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182-13
182-39
182-141
182-175
182-183
182-189
182-195
182-205
182-243
182-267
182-311
182-317
182-339
182-347
182-385
182-427
182-453
182-465
182-469
185-475
182-495
182-531
182-591
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SOW 2.2.5 The performing organization shall apply the best available method for estimating possible health effects from transportation accidents and sabotage, prepare updated estimates by this method, and justify the selection of models used for estimating and explain any changes made to improve them. (Computer programs, databases also included here.)

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104-43
180-575
181-477
181-535
181-545
182-249
182-255
182-259
182-423
182-433
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SOW 2.3
Specific Comments on the Use of Assumptions and Methods from NUREG-0170

Chapter 1 Introduction

o Add information and emphasis on low-level and high-level radioactive waste shipments and spent fuel shipments, and on the low-level disposal sites, including those developed under regional compacts, and the high-level waste facilities, including the Monitored Retrievable Storage facility and the permanent HLW disposal sites.

o Recast Table 1-1, perhaps combining it with Table 1-2, to show types of shipments, rather than radioisotopes shipped, and to give more emphasis to the radioactive waste and spent fuel shipments.

o Provide a general discussion of types; of shipments showing that there are comparatively few HLW or spent fuel shipments, more LLW shipments, most medical and other small size shipments.

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180-129
181-417
181-489
182-483
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Chapter 2 Regulations Governing the Transport of Radioactive Materials

o This section needs a major rewrite to update the discussion of regulations.

A2, A4, 73, 104-02, 182-705, 199, 234

o Add a general description of the regulatory authority of the following agencies:

NRC - radioactive material shipping package requirements and performance criteria (Type B), and safeguards for spent fuel.

A2, A5, 104-04, 104-21, 104-27, 104-32, 128, 180-315, 182-263, 202

DOT - shipment carriers for highway, rail, and air transport; vehicle safety, route safety, driver and handler safety; Type A (and other) package requirements.

104-08, 104-09, 151

DOE -Defense shipments of all types; NWPA shipments.

53, 62, 64, 113, 121, 135f, 180-143, 180-253, 181-277, 181-287, 202, 240

FEMA -training and assisting state and local authorities for emergency response to transportation accidents involving radioactive materials.

104-14

State - aspects of transportation subject to state and local and regulation.

73, 104-04, 104-09, 128, 180-29, 180-203, 180-211, 180-227

o Discuss regulations that would apply to barge transport.

104-40, 104-41, 180-387, 191

o In discussing regulations and package requirements, give more emphasis to radioactive waste and spent fuel shipments.

152

o Reduce the amount of detail regarding package labeling, vehicle placarding and reporting of i..cidents.

o Emphasize regulations dealing with safety and environmental protection, especially those concerning radioactive wastes and spent fuel.

A2, A5

o Discuss the DOE program under NWPA.

111, 112, 113, 180-15, 202

Chapter 3 Radiological Effects

o Condense general introductory material on types of radiation, natural background and radiation effects.

o Expand discussion of types of radiological effects expected to be encountered in transporting radioactive material.

o Expand discussion of how U. S. population impacts are calculated.

o Generally sharpen focus on transportation impacts.

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104-22
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Chapter 4 Transport Impacts Under Normal Conditions

o Add specific discussions of radioactive wastes and spent fuel, including transportation corridors.

o Reduce the emphasis on air transport and expand discussion of transport by road, rail and barge.

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104-35
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180-387
180-405
180-411
108-417
180-423
181-441
182-135
182-249
182-305
182-385
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Chapter 5 Impacts of Transportation Accidents

o Update this section to reflect results of the Modal Study of accident consequences by Lawrence Livermore National Laboratory and the results of actual accident tests performed by the British.

o In Figures 5-2, 5-3, and 5-4, the accident severity scheme is no longer adequate. Spent fuel accidents require a new scheme.

o Sharpen the focus on radioactive waste transportation and spent fuel shipments.

o Discuss the sabotage and malevolent acts.

o Near the beginning the chapter, give the latest authoritative and realistic estimates of the likelihood that an accident will happen and the potential impacts if one does occur.

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104-35
104-36
104-42
104-43
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180-387
180-423
180-437
181-403
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Chapter 6 Alternatives

o Review alternatives section in the light of recent developments, eg. NWPA, MRS, (and subseabed disposal transportation included here) authorization.

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104-06
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180-417
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181-441
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181-495
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182-201
182-351
182-495
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Chapter 7 Security and Safeguards

o Reduce the emphasis on plutonium and expand the discussion of spent fuel transport.

o Update to reflect regulatory changes recently made or now contemplated.

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104-19
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104-36
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Appendix A

Standard Shipments Model

o Update and improve the model explaining more fully how the model works and what it is used to calculate.

Appendices B-I

o Update and revise as necessary

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A2
A3
A5
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Volume 2

o Nothing required from the performing organization