SUPPLEMENT TO
TRAINING COURSE SERIES No.1

Safe Transport of Radioactive Material

Second Edition

INTERNATIONAL ATOMIC ENERGY AGENCY, VIENNA, 1996

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SAFE TRANSPORT OF RADIOACTIVE MATERIAL, SECOND EDITION
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FOREWORD

In 1991, the International Atomic Energy Agency published Training Course Series No. 1 (TCS-1), a training manual that provides in 20 chapters a detailed discussion of the background, philosophy, technical bases and requirements and implementation aspects of the Regulations for the Safe Transport of Radioactive Material. The Transport Regulations are widely implemented by the IAEA's Member States and are also used as the bases for radioactive material transport requirements of modal organizations such as the International Maritime Organization and the International Civil Aviation Organization.

Since publication, TCS-1 has been the basic material used at all IAEA transport safety training courses, which normally last three weeks. At such activities participants learn about the Transport Regulations primarily through lectures, but are also provided the opportunity for practical training through technical and scientific visits, case studies and open forum discussions with experienced regulators. The material used for case studies, which can be solved either as individual or group assignments is found in Appendix E of TCS-1.

The purpose of this supplement is to provide additional material in the form of learning aids and new exercises, that have been developed with the use of TCS-1 at succeeding IAEA training courses. The learning aids in the first part of the supplement are hitherto unpublished material that provide detailed guidance useful in solving the exercises presented in the second part. Solutions to the exercises are on file at the IAEA Secretariat and are available by arrangement to lecturers presenting IAEA training courses.

The IAEA wishes to express its thanks to Mr. Ronald B. Pope (USA) for developing the learning aids and exercises in this publication.

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EDITORIAL NOTE

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Throughout the text names of Member States are retained as they were when the text was compiled.

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1. INTRODUCTION

The IAEA periodically organizes for its Member States training courses on radioactive material transport. The courses aim to impart in-depth information on the philosophy and principles of the IAEA's Regulations for the Safe Transport of Radioactive Material (Safety Series No. 6) [1] and provide an opportunity for practical training on the various aspects of their implementation. The courses last between two and three weeks and are participated in by officials of national regulatory bodies or managers of technical staff from organizations undertaking the transport of radioactive material.

The subjects taught at these training courses are based on the IAEA publication Training Course Series No. 1 "Safe Transport of Radioactive Material, Second Edition" published in 1991 [2]. In that training manual, a set of exercises in Appendix E provide participants an opportunity to test the knowledge that they have gained from lectures. The exercises are usually administered as group work to allow the participants an opportunity to be more involved in arriving at solutions. Rather than passively listening to a class discussion, participants are encouraged by working in groups of three to five to be more active in determining answers and presenting and defending their solutions in an ensuing class discussion. In addition, group work provides participants the opportunity to get to know each other.

The current document supplements Appendix E of the training manual by providing:

- learning aids that summarize the regulatory requirements for
  - radiation levels, and
  - test procedures for packagings and packages; and
- a number of comprehensive exercises whose application can be tailored to the needs of students in specific courses.

Solutions to the exercises are available on request from the IAEA Secretariat.

The Sections and paragraphs referred to in this supplement are those in Safety Series No. 6, the IAEA Transport Regulations.

2. LEARNING AIDS

The learning aids provided in this section have been developed to better communicate to the course participants complex requirements arising from the Transport Regulations. The requirements on radiation levels appear explicitly and implicitly in many places throughout the Regulations. They have been summarized in part 2.1. The requirements and test procedures for packagings and packages are provided in Sections V and VI of the Transport Regulations, and are summarized in part 2.2.

2.1. Summary of radiation level requirements

Multiple requirements on radiation levels imposed on packages and conveyances are explicitly established in Sections IV and V of the Regulations. In addition, requirements on radiation levels at 1 m from a package surface are implicitly established through the transport index in para. 428 of Section IV. These are summarized in Tables 1 and 2. Table 1 summarizes radiation level limits on materials and packages, and Table 2 summarizes radiation level limits on overpacks, conveyances and vehicles.

The tables show the requirements for radiation levels at 1 m from the external surfaces of packages and overpacks when not transported under exclusive use. These requirements were established implicitly using the criteria specified in paras. 428 and 432, by relating the transport index based on radiation exposure control defined in para. 428 to the limit of 10 specified in para. 432:

$TI_{\text{rad exp control}} = RL_{1\text{-m(mSv/h)}} \times 100 < 10$, thus the $RL_{1\text{-m(mSv/h)}}$ limit = (10/100) mSv/h = 0.1 mSv/h;

and

$TI_{\text{rad exp control}} = RL_{1\text{-m(mrem/h)}} < 10$, thus the $RL_{1\text{-m(mrem/h)}}$ = 10 mrem/h.

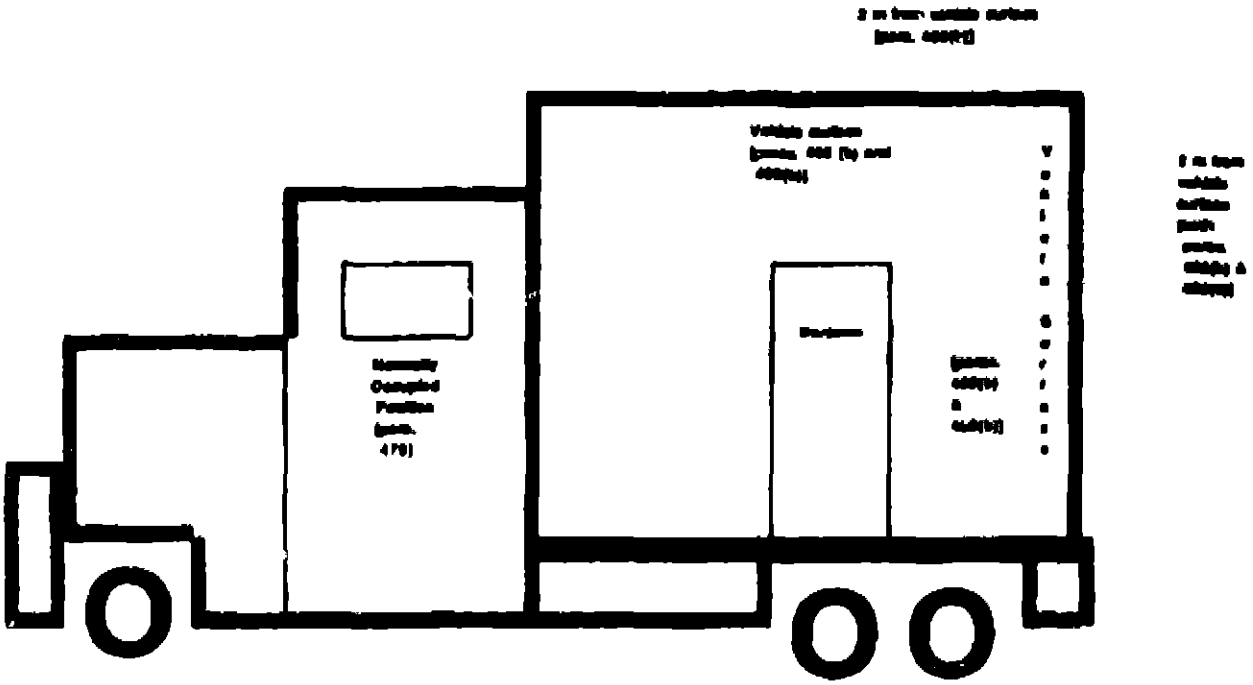
TABLE 1. SUMMARY OF RADIATION LEVEL REQUIREMENTS FOR MATERIALS AND PACKAGES

SAFETY SERIES No. 6, para. No.	TYPE OF REQUIREMENT	RADIATION LEVEL LIMIT	
		mSv/h	mrem/h
LIMITS ON MATERIALS			
422	Radiation level from LSA material or SCO in a single industrial package (of any type) shall not exceed limit	10	1000
418	Radiation level on surface of any unpackaged instrument or article to be shipped in an excepted package shall not exceed limit	0.1	10
LIMITS ON PACKAGES			
416	Radiation level on external surface of an excepted package shall not exceed limit	0.005	0.5
433	Radiation level on any external surface of a package *(not transported under exclusive use)*	2	200
434	Radiation level on any external surface of a package *(transported under exclusive use)*	10	1000
469(a)	Radiation level on external surface of a package *(transported under exclusive use)* by road or rail may only exceed para. 433 limit if (i) vehicle is equipped with enclosure, (ii) position of package in vehicle remains fixed during routine transport, and (iii) no loading or unloading operations between beginning and end of the shipment. If these conditions met, then radiation level shall not exceed exclusive use limit	10	1000
471	Radiation level on external surface of a package when being *transported under exclusive use* in or on a vehicle may be transported by vessels provided they are not removed from the vehicle at any time while on board the vessel	10	1000
471	Radiation level on external surface of a package when being *transported under special arrangement* by vessel	>2	>200
475	Radiation level on external surface of a package when being *transported under special arrangement* by air	>2	>200
428 & 432	Radiation level 1 m from the external surface of a package — established implicitly using TI based on radiation exposure control *(not transported under exclusive use)*	0.1	10
542	Radiation level 1 m from the external surface of a Type B package following exposure to accident-simulating tests	10	1000

CONVEYANCES AND VEHICLES

SAFETY SERIES No. 6, para. No.	TYPE OF REQUIREMENT	RADIATION LEVEL LIMIT	
		mSv/h	mrem/h
LIMITS ON OVERPACKS, CONVEYANCES AND VEHICLES			
413	Conveyances which have become shall be decontaminated such that radiation levels at surfaces of conveyance from fixed contamination shall be below limit	0.005	0.5
465(b)	Radiation levels at any point on external surface of the conveyance *(not transported under exclusive use)*	2	200
469(b)	Radiation levels at any point on the outer surfaces of a rail or road vehicle *(transported under exclusive use)*	2	200
428 & 432	Radiation level 1 m from the external surface of an overpack — established implicitly using TI based on radiation exposure control *(not transported under exclusive use)*	0.1	1000
465(b)	Radiation levels at any point 2 m from the surface of the conveyance *(not transported under exclusive use)*	0.1	10
469(c)	Radiation levels at any point 2 m from the vertical planes of the outer lateral surfaces of a rail or road vehicle *(transported under exclusive use)*	0.1	10
470	Radiation level at any normally occupied position in a road vehicle unless the persons occupying such positions are provided with personal monitoring devices *(road shipments transported under exclusive use)*	0.02	2

materials are depicted in Figure 1.



Package	(a) Radiation level on external surface of an excepted package shall not exceed 0.005 mSv/h (0.5 mrem/h) [para. 416] (b) Radiation level on any external surface of a package other than an excepted package shall not exceed 2 mSv/h (200 mrem/h) [para. 433] (c) Radiation level 1 m from the external surface of each package — requirement established implicitly using TI based on radiation exposure control 0.1 mSv/h (10 mrem/h) [paras. 428 and 432]
Vehicle surface	Radiation levels at any point on external surface of the conveyance 2 mSv/h (200 mrem/h) [paras. 465(b) and 469(b)]
2 m from vehicle surface	Radiation levels at any point 2 m from the surface of the conveyance 0.1 mSv/h (10 mrem/h) [para. 465(b)], and at any point 2 m from the vertical planes represented by the outer lateral surfaces of the vehicle [para. 469(c)]
Normally occupied position	Radiation level at any normally occupied position in a road vehicle unless the persons occupying such positions are provided with personal monitoring devices 0.02 mSv/h (2 mrem/h) [para. 470]

FIG. 1 Radiation level limits on road vehicle not under exclusive use.

The requirements for packagings and packages are presented in a hierarchical fashion in Section V of the Regulations, building from the "General requirements for all packagings and packages (paras. 505–514) to "Requirements for packages containing fissile material" (paras. 559–568). The specific test procedures for the various types of package designs are specified in a similar fashion in Section VI of the Regulations. The requirements and procedures for all packages except fissile packages are summarized in Tables 3, 4 and 5. Table 3 provides a detailed listing of the requirements from Section V for excepted packages through Type A packages. Table 4 provides a summary of those requirements and adds to them a summary of the test procedures which apply. Table 5 adds, in summary form, the perspective of what additionally is required for Type B packages. These three tables can be used to assist in understanding the hierarchical nature of requirements imposed on package designs — the more hazardous the contents, the more that is required of the package design.

TABLE 3. SUMMARY OF REQUIREMENTS FOR PACKAGINGS AND PACKAGES (EXCEPTED PACKAGES THROUGH TYPE A PACKAGES)

SS No. 6 Para. No	BRIEF DESCRIPTION OF REQUIREMENTS	REQUIREMENTS APPLICABLE TO				
		Excepted Package	Industrial Pkg			Type A Pkg
			1	2	3	
505	Ease and safety of handling and securing	X	X	X	X	X
506	Lifting attachment adequacy	X	X	X	X	X
507	Lifting attachment adequacy	X	X	X	X	X
508	Protruding features and ease of decontamination	X	X	X	X	X
509	Prevent collection/retention of water	X	X	X	X	X
510	Added Transport features not to reduce safety	X	X	X	X	X
511	Acceleration/Vibration	X	X	X	X	X
512	Chemical Compatibility	X	X	X	X	X
513	Valve protection against unauthorized operation	X	X	X	X	X
514	Account for other dangerous properties of contents	X	X	X	X	X
515	Maximum surface temperature - air carriage only	X	X	X	X	X
516	Ambient temperature design -40°C to +55°C - air carriage only	X	X	X	X	X
517	Liquids - pressure differential requirements - air carriage only	X	X	X	X	X
525	Minimum package size		X	X	X	X
526	Package seal				X	X
527	Tie-downs				X	X
528	Component temperatures from -40°C to +70°C				X	X
529	Design, fabrication, manufacture to acceptable stnds				X	X
530	Containment System fastening				X	X
531	Special Form material inclusion				X	X
532	Containment system fastening independent of package				X	X
533	Radiolytic decomposition				X	X
534	Reduced ambient pressure requirement				X	X
535	Valve covers				X	X
536	Radiation shield fastening				X	X
537	No loss or dispersal of contents & <20% radiation increase after normal conditions of transport testing (paras 619 - 624)			X per 671	X	X
538	For liquids - provisions for ullage				X	X
539	For liquids - either absorbent material or double containment, with tests (para 625)					X
540	For gases - no loss or dispersal of contents, with tests (para 625)					X

PACKAGINGS AND PACKAGES
(EXCEPTED PACKAGES THROUGH TYPE A PACKAGES)

SS No 6 para No	BRIEF DESCRIPTION OF REQUIREMENTS	REQUIREMENTS APPLICABLE TO				
		Excepted Pkg	Industrial Pkg			Type A Pkg
			1	2	3	
REQUIREMENTS						
505 – 514	Handling, securing, lifting attachment, protruding features, ease of decontamination, collection/retention of water, features retain safety, acceleration/vibration, chemical compatibility, valve protection, and other dangerous properties	X	X	X	X	X
515 – 517	**For air carriage only** maximum surface temperature, modified ambient temperature, and increased pressure differential.	X	X	X	X	X
525	Minimum package size		X	X	X	X
526 536	Package seal, tie-downs, component temperatures, design/fabrication/manufacture standards, containment system fastening, special form material inclusion, radiolytic decomposition, reduced ambient pressure, valve covers, and radiation shield fastening.				X	
537	Limitations on loss and dispersal and on radiation level increase external to package after normal conditions of transport testing (paras 619 – 624)			X (per 519)	X	
538	**For liquids** – provisions for ullage				X	X
539	**For liquids** – either absorbent material or double containment, with tests (para 625)					X
540	**For gases** – no loss or dispersal of contents					X
TEST PROCEDURES						
619	Precedence of testing				X	X
620	Time intervals of testing				X	X
621	**Water spray testing**				X	X
622	0.3 to 1.2 m free drop testing – (Table XIV)			X	X	X
623	Stacking testing			X	X	X
624	1 m penetration testing				X	X
625	**For liquids and gases** – 9 m free drop testing, and 1.7 m penetration testing					X

TABLE 5. SUMMARY OF REQUIREMENTS AND TEST PROCEDURES FOR PACKAGINGS AND PACKAGES (EXCEPTED PACKAGES THROUGH TYPE B PACKAGES)

SS No 6 para No	BRIEF DESCRIPTION OF REQUIREMENTS	REQUIREMENTS APPLICABLE TO:					
		Excepted Pkg	Industrial Pkg			Type A Pkg	Type B Pkg
			1	2	3		
	REQUIREMENTS						
505 - 514	Handling, securing, lifting attachment, protruding features, ease of decontamination, collection/retention of water, features retain safety, acceleration/vibration, chemical compatibility, valve protection, and other dangerous properties	X	X	X	X	X	X
515 - 517	For air [illegible]age only) maximum surface temperature, modified ambient temperature, and increased pressure differential	X	X	X	X	X	X
525	Minimum package size		X	X	X	X	X
526 - 536	Package seal, tie-downs, component temperatures, design/fabrication/manufacture standards containment system fastening, special form material inclusion, radiolytic decomposition, reduced ambient pressure, valve covers, and radiation shield fastening				X	X	X
537	Limitations on loss and dispersal and on radiation level increase external to package after normal conditions of transport testing (paras 619-624)			X (per 519)	X	X	X [illegible]
538	For liquids – provisions for ullage				X	X	X
539	For liquids – either absorbent material or double containment, with tests (para 625)					X	
540	For gases – no loss or dispersal of contents					X	
541 558	Package pre-test and post-test quantified radiation level, containment, shielding, and thermal performance criteria, specific requirements for unilaterally approved package designs including specifications for water immersion for irradiated nuclear fuel packages, no pressure relief, and maximum normal operating pressures; and allowances for multilaterally approved package designs						X
	TEST PROCEDURES						
619 - 625	Normal conditions of transport testing include specifying precedence of testing, time intervals of testing, water spray testing free drop testing, stacking testing, penetration testing (enhanced testing for packages design for liquids and gases)				X	X	
627	Accident-simulating mechanical tests: (1) 9 m drop test and 1 m puncture test or, (for light weight/low density packages containing > 1000 A, (not as special form)), (2) 1 m puncture test and 500 kg mass dropped 9 m onto package (dynamic crush test)						X
628	Accident-simulating thermal test (30 minutes fully engulfing exposure to 800°C thermal source)						X
629	Water immersion (15 m depth for 8 hours)						X
630	Water immersion (200 m depth for 1 hour, for irradiated nuclear fuel of > 37 PBq)						X

3. EXERCISES

The intent of these exercises is to provide a means by which an instructor can measure how well students have grasped the essence of a lecture and to keep their interest in the subject at hand. The first exercises start quite easily, to get the students familiar with the documents being used and then progress to more difficult assignments requiring a deeper understanding of the provisions of the Transport Regulations. It is suggested that at first the students be asked to solve the exercises individually and then prompt class interaction on the results obtained. For the more complex problems students can be assigned to work in groups that are asked to present progressing parts of the solution in an ensuing discussion that involves the whole class. This allows the students ample opportunity to interface with each other.

The types of exercises provided are:

(a) Class exercises — These start with quick and simple exercises that students can solve individually in a short time. Then there are more complicated exercises that require research to arrive at the solutions; for these exercises, it is recommended that the class be split into small groups of from three to five students. The instructor presents the problem, explains the questions and makes sure that all groups understand what work is required of them. Time is allocated for small groups of students to discuss and work together to obtain answers to the questions being asked. Group discussions may or may not take place during class hours (some more complex problems are probably better assigned for the students to take home and work over during an evening). Sufficient class time needs to be allocated to allow each group to present its solution and, finally, for the class to discuss the correct solution. These exercises allow the instructor to measure how well the students are grasping concepts presented at lectures by the consistency of the solutions being presented.

(b) Homework (out-of-class) exercises — These are exercises that students are expected to work out individually (or as groups) outside of class hours. The instructor can ask a few students (or groups) to present their solutions before a class discussion takes place to arrive at the correct solution. Alternatively, the instructor may discuss the solution and solicit voluntary inputs from the students.

Exercises are presented which cover all of the sections of the Regulations, and also some of the subjects found in Safety Series No. 7 [3], Safety Series No. 37 [4], and the Training Manual. They are presented in the order in which it is recommended they be used at a training course. The exercises and the subject areas covered are summarized in the following:

TABLE 6. SUMMARY OF EXERCISES AND SUBJECT AREAS COVERED

EXERCISE NO.	SAFETY SERIES NO 6. Section No							TRAINING MANUAL Chapter
	1	2	3	4	5	6	7	6.2
Class Exercise No. 1	x							
Class Exercise No 2								6.2
Class Exercise No. 3								6.4[c]
Class Exercise No 4								6.5
Class Exercise No. 5				x[a,c]				6.5
Class Exercise No 6			x					
Class Exercise No 7			x					
Class Exercise No. 8				x				6.5
Class Exercise No. 9			x	x				
Class Exercise No 10			x	x				
Class Exercise No 11			x					
Class Exercise No. 12				x				
Class Exercise No. 13				x				
Class Exercise No. 14				x				
Class Exercise No. 15					x	x		
Class Exercise No. 16					x			
Homework Exercise No 1	x[a,c]				x	x	x	
Homework Exercise No 2	x		x	x				
Homework Exercise No. 3				x			x	
Homework Exercise No. 4				x[c]				
Homework Exercise No 5				x				
Homework Exercise No 6				x				

[a] Also covers Safety Series No 37 (Advisory Material), Appendix 1.
[c] Also covers Safety Series No. 7 (Explanatory Material).

TITLE: **Class Exercise No. 1**

SUBJECT: Safety Series No. 6, Section I
PROBLEM: To which types of activities do the Regulations *not* apply?

TITLE: Class Exercise No. 2

SUBJECT: Training Manual, Sections 6.1 and 6.2

PROBLEM: What are the four primary objectives of the Regulations, and how are these accomplished?

TITLE: **Class Exercise No. 3**

SUBJECT: Training Manual, Section 6.4
Safety Series No. 7, Appendix I

PROBLEM: The Q-System is the basis for the activity limits A_1 and A_2 for individual radionuclides. What exposure pathways are considered in the Q-System?

TITLE: **Class Exercise No. 4**

SUBJECT: Training Manual, Section 6.5

PROBLEM: (A) Using Safety Series Nos. 6, 7 & 37, how can you quickly define and understand all regulatory requirements for a given topic?

(B) Using Safety Series Nos. 6, 7 & 37, how can you quickly define and understand *all* regulatory requirements for a given topic? For example, what are all the requirements for an *Empty Packaging*?

TITLE: **Class Exercise No. 5**

SUBJECT: Safety Series No. 6, Section 3

PROBLEM: Identify the packages required for:

(a) 1 TBq of Cs-137 in special form

(b) 1 TBq of Cs-137 in other than special form

(c) 1000.0 Ci of Fe-55 in other than special form

(d) An unknown mixture of radionuclides in special form with a total activity of 0.05 TBq

(e) An unknown mixture of radionuclides in other than special form with a total activity of 0.05 TBq

TITLE: **Class Exercise No. 6**

SUBJECT: Safety Series No. 6, Section 3

PROBLEM: Identify the types of packages required for:

(a) 2 TBq of Gold (specific radioisotope unknown) in special form

(b) 8 TBq of Au-195 in special form

(c) 102.0 Ci of Mo-99 in other than special form

(d) 0.2 TBq of mixed fission products in special form

(e) A mixture of 4 Ci of Cs-137 and 0.28 Ci of Sr-90 in other than special form

SUBJECT: Safety Series No. 6, Section 3

PROBLEM: A consignor plans to prepare a consignment of a single package. The package is to contain Ac-227, Cm-246, Th-228, and W-181. The total activity in the package will be 1.0×10^{-4} TBq.

(a) If the material is in other than special form, what type of package will be required to ship this material?

(b) If the material is in special form, what type of package will be required to ship this material?

SUBJECT: Safety Series No. 6, Section 4
Training Manual, Section 6.5

PROBLEM: (A) A Type B irradiated fuel flask is made of steel. It is used a number of times for shipping spent fuel where it is loaded and unloaded underwater After multiple uses, all irradiated fuel is removed from the flask, the inside of the flask is "vacuumed" of any debris, the flask is well maintained, and the outer surface of the flask is cleaned such that the radiation level on the external surface of the package is 0.002 mSv/h. After sealing the lid of the flask, may it be shipped as an empty package? If not, why not? If so, what other requirements must be satisfied?

(B) What advantages are to be gained by shipping an unloaded Type B package as an empty package?

SUBJECT: Safety Series No. 6, Sections 3 and 4

PROBLEM: A consignor plans to prepare four consignments. Each consignment will use a single package. The packages are individually to contain:

(A) 0.01 TBq of Ni-59 as a metal alloy where the alloy has not been tested to demonstrate that it satisfies the requirements for special form.

(B) 0.1 TBq of Ni-59 as a metal alloy where the alloy has been fabricated into a manufactured article as defined in para 418, but does not satisfy the requirements for special form.

(C) 10 TBq of Ni-59 as a metal alloy where the alloy has not been tested to demonstrate that it satisfies the requirements for special form.

(D) 100 TBq of Ni-59 as a metal alloy where the alloy has been tested to demonstrate that it satisfies the requirements for special form.

What type of package is required for each of the contents specified?

SUBJECT: Safety Series No 6, Sections 3 and 4

PROBLEM: In Class Exercise No. 9 part b, a consignor planned to prepare a consignment of a manufactured article consisting of a metal alloy of 0.1 TBq of Ni-59 in the article. The article does not satisfy the requirements for special form.

(a) Can more than one article be shipped per package? If so, how many?

(b) What additional requirements must be satisfied, if any?

SUBJECT: Safety Series No. 6, Section 3

PROBLEM: Safety Series No. 6 Para. 110 indicates that A_1 is the maximum activity of special form radioactive material permitted in a Type A package; while A_2 is the maximum activity of radioactive material, other than special form radioactive material, permitted in a Type A package.

(A) What other limits are established using the A_1 and A_2 values?

(B) Is there a maximum activity value specified in Safety Series No. 6 for a Type B package?

TITLE: **Class Exercise No. 12**

SUBJECT: Safety Series No. 6, Section 4

PROBLEM: For a Type B(U)F package, it is determined:

- using the methods in paras 562–568 that an unlimited number of packages of this design is subcritical;
- that the maximum radiation level at 1 m from the surface of the package is 0.005 mSv/h; and
- that the maximum radiation level is 0.02 mSv/h.

(A) What is the Transport Index for the package?

(B) What is the Category of the package?

TITLE: **Class Exercise No. 13**

SUBJECT: Safety Series No. 6, Section 4

PROBLEM: A consignment of four containers of a mixture of liquid radionuclides is presented for multi-modal transport, by both road and inland waterway. The radionuclides in the liquid are not fissile. It is determined that:

- the specific activity is 4×10^{-6} A_2/g;
- the radiation level at 3 m from the unshielded material in each container is 5 mSv/h;
- the contamination on the external surfaces of each container is less than 0.1 Bq/cm^2;
- the A_2 value for the mixture is 1.7 TBq;
- each container holds 20 TBq; and
- the maximum radiation level at 1 m from the external surface of each package is 0.08 Sv/h.

(a) What minimum package design requirements must each container satisfy?

(b) What is the TI for each package?

(c) What is the TI for the consignment?

(d) Can all four containers be carried on a single conveyance?

TITLE: **Class Exercise No. 14**

SUBJECT: Safety Series No. 6, Section 4

PROBLEM: Three packages have the following characteristics:

Package 1: Is a Type B(M)F package; the value of N determined according to para. 567 is 25; the maximum radiation level at 1 m from the surface of the package (RL_{1m}) is 0.01 mSv/h; and the maximum surface radiation level (RL_s) is 0.09 mSv/h.

Package 2: Is a Type B(U) package;
RL_{1m} = 1 mrem/h; and RL_s = 4 mrem/h.

Package 3: Is a Type B(M) package;
RL_{1m} = 12 mrem/h; and RL_s = 225 mrem/h.

(a) What is the TI for each package?
(b) What is the Category of each package?
(c) Can the three packages be combined into a single consignment and if so what requirements must be satisfied?

TITLE: **Class Exercise No. 15**

SUBJECT: Safety Series No 6, Sections 5 & 6

PROBLEM: A package is to be designed with the following features:

Mass = 400 kg

Volume (based on external dimensions) = 1 m^3

Contents = 40 TBq of beta- and gamma-emitting nuclides whose specific identity is unknown.

What tests are to be used to demonstrate the ability of this package to withstand accident conditions of transport?

TITLE. **Class Exercise No. 16**

SUBJECT: Safety Series No. 6, Section 5

PROBLEM: An application is made to a competent authority for a fissile material package design which is to contain material with the following properties:

(a) an H/X value of 8000,

(b) the concentration of the fissile material is [illegible] g/L, and

(c) the mass of material is 600 g consisting of a mixture of 4% U-233 and 96% U-235, by mass.

Should this design be approved by the competent authority?

TITLE: **Homework Exercise No. 1**

SUBJECT: Familiarization with use of Series Nos. 6, 7 and 37

PROBLEM: Using SS6, SS7 and SS37, determine paragraphs which define:

1. what is special form radioactive material;
2. why it is defined that way; and
3. how the characteristics of a material may be used to demonstrate it is (or is not) a special form radioactive material.

Using SS6 only, determine paragraphs which define:

4. the requirements for special form radioactive material; and
5. the tests to qualify a material or capsule as special form radioactive material.

Using SS6 only, determine paragraphs which define where to find:

6. the approval requirements for special form radioactive material; and
7. the certification requirements for special form radioactive material.

TITLE: **Homework Exercise No. 2**

SUBJECT: Safety Series No. 6, Sections 1, 3, and 4

PROBLEM: (A) A waste processor solidifies liquid radioactive material with concreting mix into 1.8 m diameter × 1.8 m long steel cylinders. To accomplish this, a sacrificial mixer of 3217 liters of solidifying material is used to provide a solid, uniformly mixed mass inside the steel cylinder. The total mass of the loaded cylinder is 8570 kg.

The radiation level (all gamma radiation) 3 m from the outside surface of the loaded steel cylinder is 10.5 mSv/h. The activity measurements indicate that the specific activity of the solidified mixture is 8×10^{-5} A_2/g.

- Does this loaded cylinder satisfy the requirements for LSA?

(B) The waste processor solidifies liquid radioactive material with concreting mix into *a second* 1.8 m diameter × 1.8 m long steel cylinder. The sacrificial mixer of 3217 liters of solidifying material is used to provide a solid, uniformly mixed mass inside the steel cylinder. The total mass of the loaded cylinder is 8570 kg, and the mass of the concreted mixture is 7710 kg.

The radiation level 3 m from the outside surface of the solidified material (without the steel cylinder) is determined to be 6 mSv/h. An assay shows that the radioactive material in the cylinder is:

2.40 TBq of Cs-137
0.37 TBq of CS-134
0.37 TBq of Sr-90

- What is the A_2 value of the mixture?
- For the second loaded cylinder, is it LSA and, if so, which type of LSA and what are the packaging requirements?

TITLE: **Homework Exercise No. 3**

SUBJECT: Safety Series No. 6, Section 4 and 7
(To follow completion of Class Exercise No. 14)

PROBLEM: Using the results of Class Exercise No. 14, which deals with three Type B packages, and *assuming* each package has a mass greater than 50 kg:

(A) What are the marking requirements for these three packages?

(B) What are the labelling requirements for these three packages?

(C) *Assuming* all three packages contain material described as Radioactive Material N.O.S. (with appropriate designation for fissile or not fissile), what are the placarding requirements for (i) the consignment where all three packages are loaded onto a roadway vehicle, and (ii) the consignment where all three packages are loaded into a freight container?

(D) What are the approval requirements for the individual packages and the consignment?

(E) If the packages were certified to earlier editions of the Regulations as shown below, and manufactured in the year shown below, can they be used at this time for shipments, and what certification requirements must be satisfied?

Package	SS6 Edition Certified	Manufacture Date
1	1967	1971
1	1967	1988
2	1973 (As Amended)	1975
2	1973 (As Amended)	1989
3	1985 (As Amended 1990)	1986

SUBJECT: Safety Series No. 6, Section 4 and Safety Series No. 37

PROBLEM: A package is being prepared for transport. It is checked for non-fixed contamination by taking a dry wipe of 300 cm^2 of the package surface with a piece of filter paper. The beta and gamma activity measured on the wipe is 900 Bq. Assuming this value is as low as practicable, does the package comply with Safety Series No. 6 requirements for shipment (a) as an excepted package, or (b) as other than an excepted package?

SUBJECT: Safety Series No. 6, Section 4

PROBLEM: A consignment of non-fissile LSA material is prepared for shipment in a freight container. The freight container is 2 m wide, 2 m high and 4 m long. Radiation level measurements are taken at multiple points, 1 m from the surface of the freight container. The maximum radiation level measured is 0.02 mSv/h.

What is the TI of this consignment?

SUBJECT: Safety Series No. 6, Section 4

PROBLEM: A consignor prepares 10 Type A non-fissile packages and 20 Type A fissile material packages for shipment. Each non-fissile Type A package has a TI of 0.5. Each fissile material Type A package has a TI for nuclear criticality control of 0, and a TI for radiation exposure control of 0.05. The consignor places all 30 packages into a rigid overpack, measures a maximum radiation level at 1 m from the surface of the overpack of 0.031 mSv/h, and records on the shipping papers that the TI for the overpack is 3.1.

(A) What is the TI for the fissile material packages?

(B) Is this consignment consistent with the Regulations?

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Regulations for the Safe Transport of Radioactive Material, 1985 Edition (As Amended 1990), Safety Series No. 6, IAEA, Vienna (1990).
[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Safe Transport of Radioactive Material, Second Edition, Training Course Series No. 1, IAEA, Vienna (1991).
[3] INTERNATIONAL ATOMIC ENERGY AGENCY, Explanatory Material for the IAEA Regulations for the Safe Transport of Radioactive Material (1985 Edition), Second Edition (As Amended 1990), Safety Series No. 7, IAEA, Vienna (1990).
[4] INTERNATIONAL ATOMIC ENERGY AGENCY, Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material (1985 Edition), Third Edition (As Amended 1990), IAEA, Vienna (1990).