DANGEROUS GOODS PANEL (DGP)
WORKING GROUP MEETING (DGP-WG/17)

Montreal, 24 to 28 April 2017

Agenda Item 2:   **Development of recommendations for amendments to the *Technical Instructions for the Safe Transport of Dangerous Goods by Air* (Doc 9284) for incorporation in the 2019-2020 Edition**
2.6: Part 6 — Packaging Nomenclature, Marking, Requirements and Tests

REPORT OF THE DGP/IAEA WORKING GROUP ON PRESSURE DIFFERENTIAL REQUIREMENTS APPLICABLE TO PACKAGINGS CONTAINING RADIOACTIVE MATERIAL

(Presented by Rapporteur of Working Group on Pressure Differential)

REVISED

SUMMARY

This working paper presents the report of the DGP/IAEA Working Group on Pressure Differential Requirements Applicable to Packagings Containing Radioactive Material.

1.   **INTRODUCTION**

1.1   A working group on pressure differential requirements applicable to packagings containing radioactive material was convened from 21 to 22 April at ICAO Headquarters in Montréal.

2.   **PARTICIPATION**

2.1   The following participated in the working group:

K. Rooney, ICAO
D. Warden, advisor to DGP member nominated by the United Kingdom
D. Ferguson, Boeing, advisor to the DGP member nominated by ICCAIA
S. Schwartz, DGP member nominated by IFALPA
D. Mirko, DGP member nominated by the Russian Federation
D. Kurdchenko, advisor the DGP member nominated by the Russian Federation
M. Taal, ICAO
F. Kirchnawy, Austria, Austrian Ministry of Transport (video conference)
B. Desnoyers, WNTI, Safety Transport Expert

A. Presta, WNTI, Specialist advisor
K. Vermeersch, advisor the DGP member nominated by the Netherlands
R. Garg, Eng, CNSC, Canadian Nuclear Safety Commission, Transport Specialist
V. Fiacabrino, France (video conference)
G. Ferran, France (video conference)
M. Boehm, Observer, Austria, Civil Aviation Authority

Apologies
C. Bajwa, IAEA Transport Safety Unit

2.2　　　　This working paper contains the report of the meeting and includes the following appendices:

Appendix A　　WNTI Presentation — ICAO-IAEA Expert Working Group about Pressure Differential Requirement
Appendix B　　Russian Federation Presentation — Pressure differential requirements for dangerous goods by air
Appendix C　　WNTI Memo — Review of the Pressure Differential requirements applicable to packages containing Radioactive Material transported by air
Appendix D　　Draft guidance material

3.　　**HIGHLIGHTS**

3.1　　　　Self-introductions were made by the participants.

3.2　　　　**WNTI Presentation**

3.2.1　　　　The world nuclear transport institute (WNTI) presented its proposal regarding pressure differential standards for packages containing radioactive material in air transport. They reviewed the current regulations and an associated possible issue related to radioactive material transport by air (see Appendix A).

The current regulations

IAEA SSR-6 § 621 and ICAO-TI § 6;7.2.3

"Packages containing radioactive material to be transported by air shall be capable of withstanding, without loss or dispersal of radioactive contents from the containment system, an internal pressure that produces a pressure differential of not less than the maximum normal operating pressure plus 95 kPa."

Applies to all package types: excepted packages, industrial packages (IP-1, IP-2 and IP-3), type A, type B(U), type B(M) and type C packages) **independently of the physical form** (solid, liquid, gaseous)

The possible issue

The requirement stated above may be difficult to achieve, especially in the case of packagings of large dimensions, such as ISO freight containers which are commonly used as type IP-1 or IP-2 packages for

air carriage of tools and components as surface contaminated objects (SCO-I or SCO-II), and it may seem excessively severe for low activity materials with little risk even in case of dispersion, such as excepted packages loaded with solid radioactive materials for example.

The purpose of the experts working group

      a) To share views on the implementation of para. 621 (ICAO-TI § 6;7.2.3)

      b) To reach a consensus on the interpretation of para. 621

          1) If no consensus on the interpretation of para.621, and/or

          2) If the interpretation of para. 621 appears to be difficult to implement,

      c) To reach an agreement on the optimization of the pressure differential safety requirement which is needed.

      d) To review the IAEA SSG-26 & SSR-6 to assure that the wording accurately reflects the consensus on the interpretation of para. 621 and/or the optimization of the pressure differential safety requirement; to propose revision of SSR-6 (and ICAO-TI accordingly), if needed and revision of SSG-26 to provide additional guidance if needed.

4. **PLENARY DISCUSSION**

4.1   In 1996 Edition: IAEA extended the pressure differential requirements for air transport from liquid to all material.

4.2   In 1996 Revised Edition: the regulation was changed from a decreased of ambient pressure down to 5 kPa to a pressure differential of 95 kPa + MNOP

4.3   The intent of the pressure differential requirement is that a Radioactive material Package is required to prevent loss or dispersal of the radioactive material but not the maintenance of internal pressure.

4.4   Scope of the issue addressed in the meeting: SCO I/ LSA I material/ Excepted Packages/ Solid material.

4.5   Discussion about the IAEA definition of normal, routine, accident conditions related to radioactive material transport and package design

        ▪ IAEA SSR-6 — Edition 2012
            • Routine: every day/routine operations: incident free
            • Normal: minor mishaps
            • Accident

4.6 **Discussion about the probability of aircraft depressurization issue(s)**

4.6.1   According to the discussion with airworthiness and pilot representatives, the pressurization issues occur fairly regularly in transport aircraft but without fatal issues or major injuries to passengers or crews. Unexpected rapid loss of cabin pressure (or explosive depressurization) in passenger or freight aircraft is rare. Aircraft are manufactured in considering this type of unexpected event. However it should be noted that some emergency procedures for cargo aircraft may require intentional depressurization. Today's commercial aircraft commonly fly above 40,000 ft.

4.6.2   Two examples of depressurization incidents given in plenary: A330 – Toulouse 2006 and B747, N-W Manila, 2008. WNTI cited the study conducted by the Australian Transport Safety Bureau regarding depressurization accidents and incidents involving Australian Civil Aircraft from 1975 to 2006 resulting in 517 events reported. One resulted in the loss of the aircraft and fatal injuries to occupants and only 9 led to hypoxia or minor injury to occupants.

4.7 **Discussion about non-pressurized aircraft**

4.7.1   Some cargo-only aircraft are designed and operated such that the cargo compartment is not pressurized during flight. For these type of aircraft the normal rate of pressure change experienced by the cargo is the actual rate of aircraft climb and descent which is expected to be greater than the "normal" pressure change provided in the ISO standard 11242.

4.8 **Discussion about the presence of filters and valves on packages**

4.8.1   See Appendix C — WNTI Memo Appendix 1. Presentation by WNTI of the method for demonstrating compliance for cases where dispersal of the radioactive material is highly unlikely due to its form (Special form, SCO, Solid LSA in non-powder form, solid radioactive material in a Type A) and for LSA-I in powder form.

4.8.2   It is possible to use a packaging equipped with valves and filters to allow pressure equilibrium without dispersal of radioactive solid material content when the content can be subject to dispersal or to use a packaging equipped with valves without any supplementary equipment if the content is not subject to dispersal.

4.8.3   For solid package contents the consequence of exposure to a pressure differential must be considered to identify potential mechanisms for loss or dispersal of radioactive material. If "no loss of dispersal" can be justified when the package is exposed to the pressure differential the package design is considered to meet the requirement even if the internal pressure is not maintained.

4.9   **Discussion about the IAEA graded approach related to package types depending on transport conditions**

4.10   **Discussion about the different types of material to be transported as SCO I/LSA I/ Excepted Packages/Solid material**

4.11   **Review of ISO Standard 11242 – Aircraft – Pressure equalization requirements for cargo containers - 1996 Edition - Para 3.3 and 3.4**

4.11.1   Provides information on pressure environment on aircraft for some normal and some emergency conditions. However it should be noted that the overall pressure differential in this standard is not consistent with the ICAO regulatory requirement of 95 kPa.

4.11.2   There was discussion about contamination consequences and the difficulties involved with decontamination of the aircraft

4.12   **Russian Federation Presentation**

4.12.1   A presentation was given in plenary by the Russian Federation regarding the pressure differential requirements for transport of dangerous goods by air (see Appendix B).

5.   **CONCLUSIONS**

5.1   The meeting agreed a common interpretation of SSR-6 Edition 2012 Para 621 / ICAO - TI Part 6 Para 7.2.3: that a package design would meet the requirement if the pressure differential was not maintained due to leakage of air provided that there was no loss or dispersal of radioactive material.

5.2   Additional guidance on the existing regulatory requirements would provide clarification of the SSR-6 Edition 2012 Para 621 / ICAO -TI Part 6 Para 7.2.3.

5.3   No detailed information regarding the maximum normal operating pressure is provided in ICAO –TI.

5.4   Aircraft depressurization may result in very high airflow rates, and may result in greater contamination of aircraft than might result from ordinary leakage from a package containing radioactive material. It was noted that air transport of unpackaged surface contaminated objects is forbidden.

5.5   The mobility of solid radioactive material and its likely release under pressure differential conditions needs to be considered by the package designer. It should not be assumed that maintenance of the pressure differential is always the preferred design solution, particularly where the solid materials are immobile.

5.6   The proposed approach by the WG is to develop ICAO guidance text:

        a) to point the reader to existing guidance text:

            1) IAEA Advisory Material SSG-26 on loss and dispersal provided in para 648.3

2) IAEA Advisory Material SSG-26 on methods of demonstration of compliance para 701.1

3) ISO Standard 11242 - Para 3.3 and 3.4

Proposition of draft text: The pressure changes which may be experienced by a package in air transport, include the conditions of ISO 11242 para 3.3 and 3.4 (or IATA Standard Specification 80/2 para 3.2 and 3.3)

b) To submit the draft guidance text contained in Appendix D to this working paper to the ICAO DGP WG 17 for review before submission to the IAEA TRANSSC 34 for consideration.
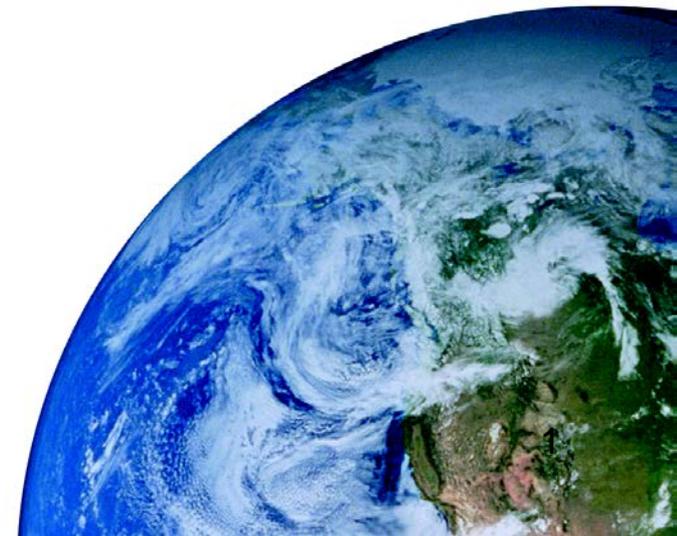
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APPENDIX A

PRESENTATION BY WNTI

International Civil Aviation Organization

ICAO-IAEA EXPERT WORKING GROUP ABOUT PRESSURE DIFFERENTIAL REQUIREMENT

World Nuclear Transport Institute

310-312 Regent Street, London, U.K.

Montreal – 21st to 22nd April 2017

Pressure differential in air carriage

- ## The current regulations

IAEA SSR-6 § 621 and ICAO-TI § 6;7.2.3

> *"Packages containing radioactive material to be transported by air shall be capable of withstanding, without loss or dispersal of radioactive contents from the containment system, an internal pressure that produces a pressure differential of not less than the maximum normal operating pressure plus 95 kPa."*

Applies to all package types: excepted packages, industrial packages (IP-1, IP-2 and IP-3), type A, type B(U), type B(M) and type C packages) independently of the physical form (solid, liquid, gaseous)

- ## The possible issue

The requirement stated above may be difficult to achieve, especially in the case of packagings of large dimensions, such as ISO freight containers which are commonly used as type IP-1 or IP-2 packages for air carriage of tools and components as surface contaminated objects (SCO-I or SCO-II), and it may seem excessively severe for low activity materials with little risk even in case of dispersion, such as excepted packages loaded with solid radioactive materials for example.

Pressure differential in air carriage

- **The proposal made by WNTI to solve the possible issue**
    - First proposal submitted by WNTI in the IAEA 2013 review cycle
    - Submitted for comments to the ICAO DGP in November 2013
    - Redrafted proposal submitted in the 2015 review cycle.
- **The decision taken by IAEA TRANSSC 31 in November 2015**

    "No action taken. Decision on the proposal is deferred to the IAG (Inter Agencies Group) and other appropriate aviation organizations for further discussion and development."

- **The WNTI suggestion to TRANSSC 32 in June 2016)**

    - Creation of a dedicated WG of experts from aviation organizations, IAEA, interested competent authorities and the industry

Pressure differential in air carriage

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- **The purpose of the experts WG**

  ✓ **To share views on the implementation of para. 621 (ICAO-TI § 6;7.2.3)**

  ✓ **To reach a consensus on the interpretation of para. 621**
    - If no consensus on the interpretation of para.621, and/or
    - If the interpretation of para. 621 appears to be difficult to implement,

    To reach an agreement on the optimization of the pressure differential safety requirement which is needed.

  ✓ **To review the IAEA SSG-26 & SSR-6 to assure that the wording accurately reflects the consensus on the interpretation of para. 621 and/or the optimization of the pressure differential safety requirement; to propose revision of SSR-6 (and ICAO-TI accordingly), if needed and revision of SSG-26 to provide additional guidance if needed**

  ✓ **To draft a working plan for further actions, if needed***

- **The pace of the experts WG**

  A two days meeting should be enough to provide the adequate recommendations to TRANSSC

- **The attendance of the experts WG**

  Dangerous Goods experts having some expertise in class 7 such as TRANSSC Members Sates representatives from Safety Authorities, WNTI, aircraft manufacturers and airworthiness experts.

*Actions, if needed can be implemented during the next IAEA review and revision cycle

Pressure differential in air carriage

ADDITIONAL INFORMATION

Pressure differential in air carriage

Current requirement:

- 621. *Packages* containing *radioactive material* to be transported by air shall be capable of withstanding, without loss or dispersal of *radioactive contents* from the *containment system*, <u>an internal pressure</u> that produces a pressure differential of <u>not less than maximum normal operating pressure</u> plus 95kPa.

1. How this requirement should be understood (engineer point of view)?
2. Current practices: three examples to illustrate the issue
   - Uranium ore samples.
   - Large contaminated equipment in ISO container as excepted package, IP-1 or IP-2
   - Solid radioactive material samples in excepted packages
3. Suggested list of items to be discussed by the WG

How the requirement in para.621 should be understood?

- Example of a package containing a solid object, solid radioactive material or radioactive material in a capsule (no thermal power, no expected radiolysis phenomena)
- What is required:
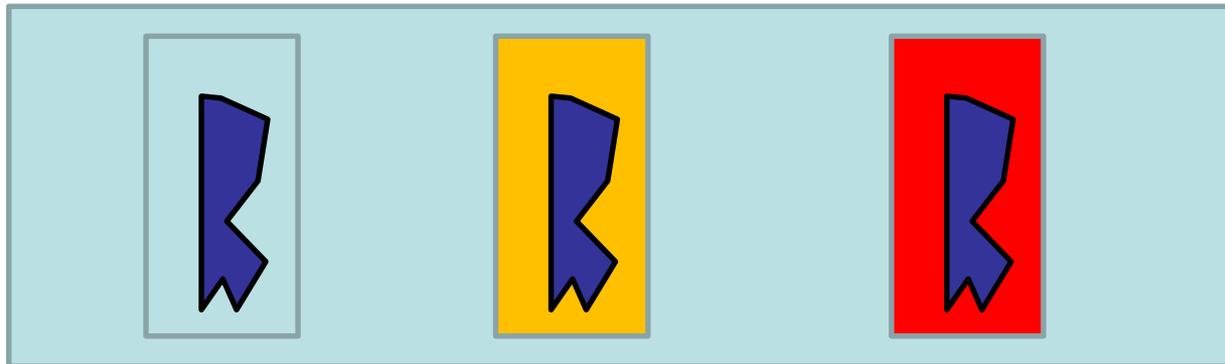
At loading: inner pressure = atmospheric pressure at 15°C ≈ 100 kPa

MNOP: increase of inner pressure between 15°C and 55°C = 14.1 kPa

MNOP + 95 kPa
= 14.1 + 95
= 109.1 kPa
≈ 110 kPa

- **Containment system shall be able to withstand a differential pressure of 110 kPa. <u>Are there other ways to demonstrate compliance?</u>**

Current practices – 1st example 1/3
Solid uranium ore samples:
What they look like?

- These are solid natural mineral samples (rock, sand, soil,...) presenting no significant hazard except that their specific activity exceeds the exemption level for natural uranium (1 Bq/g ≈ 80 mg U/ kg of material)

Soil samples (few tens of grams per plastic bag)

Geologic carrots (rocks, 8 cm in diameter, up to 1 m long, up to 15 kg each) in plastic tubes closed by adhesive tape, or in plastic sleeves, placed in a rack, made of plywood or natural wood

Current practices – 1st example 2/3
Solid uranium ore samples:
How they are carried?

WNTI

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Plastic bags are gathered in fibreboard boxes (from few kg to few tens of kg each), placed in a plywood outer box. The whole package is UN2910

Several racks closed, placed in an outer steel box. The whole package is UN2910

Current practices – 1ˢᵗ example 3/3
**Solid uranium ore samples :**
Why are they carried by air?

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- The transport of these samples are needed for uranium exploration activities, often from geographical areas difficult to access (from everywhere in the world to few laboratories)

- It is necessary for the teams of geologists to know as soon as possible the results of analysis of their samples to continue their activities.

- Land transport combined with sea-carriage is not really adapted to meet these constraints.

- Carriage by air offers much more commodities for those shipments.

- Computer Numerical Controlled lathe used in NPPs for maintenance and/or repairing of control rod drive mechanism: in a 20-foot ISO container as excepted package, type IP-1 or type IP2 (SCO)
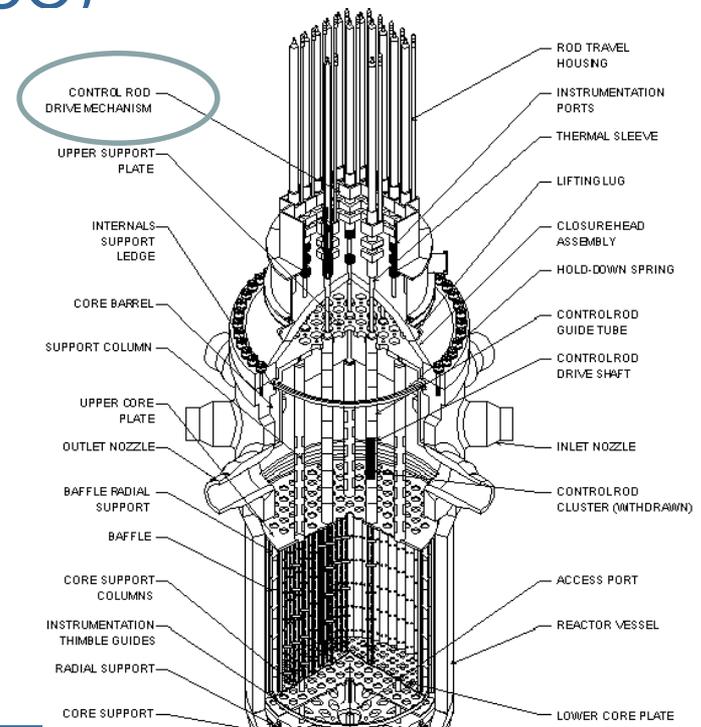
Current practices – 2nd example 2/4
Large contaminated equipment in an ISO container

- Other equipment used in NPPs for maintenance and/or repairing of control rod drive mechanism: in a 20-foot ISO container as excepted package, IP-1 or IP-2 (SCO)

Current practices – 2nd example 3/4
Large contaminated equipment
in an ISO container

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- ISO containers have holes fitted with high efficiency filters to allow the equalization of the pressure during the climb and descent phases (9 kPa/min)

- Equipment used during maintenance or repair operations on NPPs are sometimes cumbersome, often expensive and very specific and usually belong to companies specializing in this type of intervention.

- The distances involved to bring this material in the different NPPs served can be large, and the required delay for intervention may be incompatible with a land and maritime transport.

Current practices – 3rd example 1/2
Solid radioactive material samples in
excepted packages - *Old configuration*

- Solid radioactive samples in sample tubes (not able to withstand 95 kPa gauge pressure) leak tight up to 55°C in atmospheric ambiance

- 12 sample tubes in 1 intermediate packaging qualified for 95 kPa (MNOP considered as being nil …)

- One intermediate packaging in an outer packaging

Sample tube

Intermediate packaging

4GV/X box

- Closing at 15°C, heating at 55°C, pressure increase = 14kPa

- Max depressurization = 75kPa (ICAO-TI); 75+14 = 89 kPa < 95 kPa

Current practices – 3rd example 2/2 Solid radioactive material samples in excepted packages – *Current configuration*

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- Solid radioactive samples in sample tubes (not able to withstand 95 kPa gauge pressure) leak tight up to 55°C in atmospheric ambiance
- 2 Sample tubes in 1 intermediate packaging qualified for 150 kPa
- 3 intermediate packagings in an outer packaging

P10

Intermediate packaging

4GV/X box

- Closing at 15°C, eating at 55°C, MNOP = 14 kPa
- 14 kPa + 95 kPa = 109 kPa; 109kPa < 150 kPa
- **Strictly compliant with the rules, but more expensive and less practical than before**

What about other dangerous goods?

- Packagings for **solid dangerous goods**, even in powder form, are <u>not required to remain leaktight</u> when considering the pressure variations that can occur in an aircraft;

- Some of the packagings allowed for **liquid dangerous goods** are <u>not able to withstand a combination of those 3 conditions</u> : (see example for Ethanol, UN1070, Class 3, PGII, with the use of formulas (b) or (c) in 4;1.1.6 for inner packaging of combination packaging, or (b) or (c) in 4;1.1.16 or 6;4.5.3 for single packaging)

  - Filling and closing at 15°C at sea level (100 kPa),
  - Heating up to 55°C,
  - Ambient pressure decreased from 100 kPa to to 75 kPa (minimum pressure in a pressurized aircraft in normal flight conditions)

- **Only single packagings** for **PG-I liquid dangerous goods** are able to withstand the conditions described for emergency situations (rapid decompression) in IATA Std Specification 80/2 and in ISO 11242 Std. Inner packagings of combination packagings for PG-I liquid dangerous goods are <u>not able to withstand those conditions</u>

Non exhaustive list of items which could be discussed by the WG

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- Minimum ambient pressure inside cargo holds of a commercial aircraft: 25 kPa as stated in ICAO-TI ? or other value?

- Maximum pressure rate variation in cargo holds of a commercial aircraft in phases of climb and descent: 9 kPa per minute (2500 feet / minute) ? or other value?

- Shall depressurization incident be considered as part of normal conditions of transport ?

- Maximum ambient pressure decrease in case of depressurization incident? 50 kPa? 75 kPa? or other value?

- Which are the recommendations against the risk of over pressure for large packages or containers not able to withstand the pressure differential resulting of a depressurization incident ?

- Could/should the requirement and/or the guidance be amended ?

Graded approach in package design

WNTI

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The graded approach of IAEA SSR-6

Fissile material

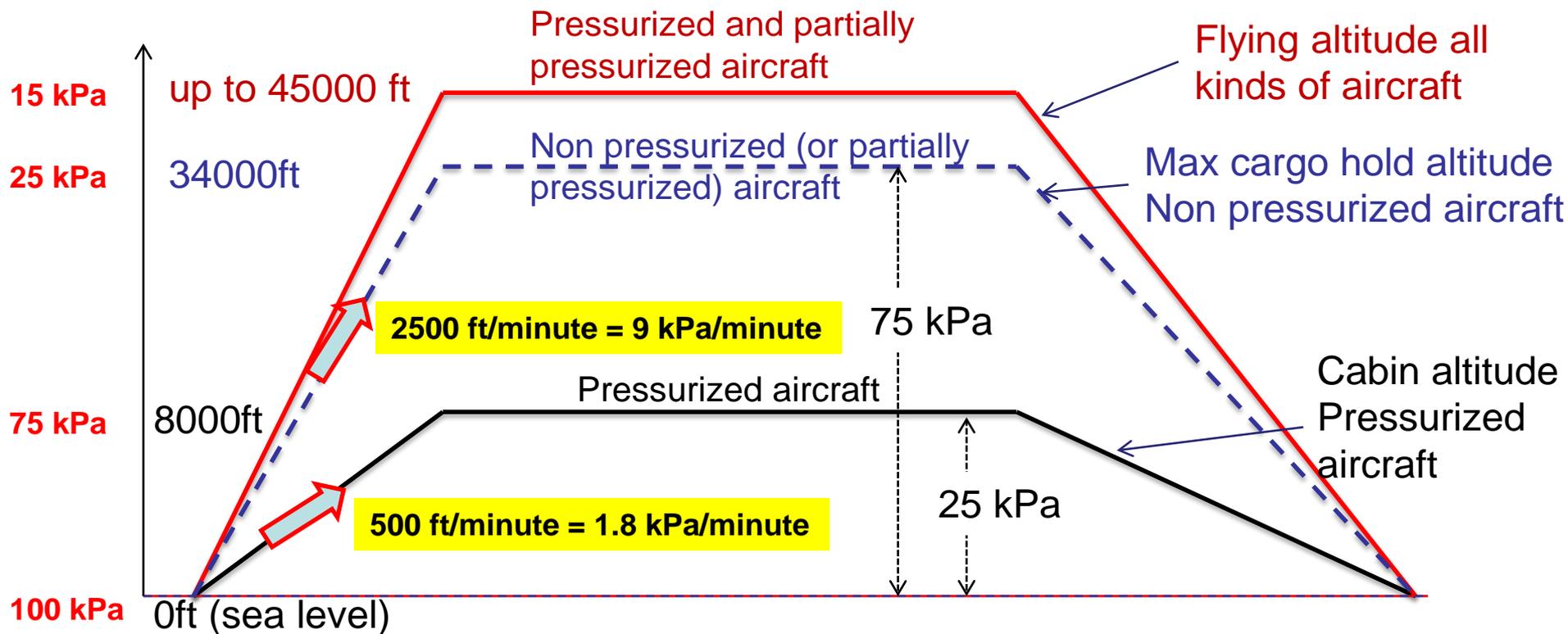| Content	Transport conditions	Approval
FISSILE	Routine + Normal + Accident	Approved package designs
FISSILE paras 674 or 675	Routine + Normal	Non approved package designs
Fissile excepted	Routine	

Activity of the content

Content	Package type	Transport conditions	Approval
> 3000 A_2	Type C	Routine + Normal + Accident	Approved package designs
> 1 A_2	Type B(M)		
> 1 A_2	Type B(U)		
1 A_2	Type A	Routine + Normal	Non approved package designs
LSA-III	Type IP-3		
LSA-II/SCO-II	Type IP-2		
LSA-I/SCO-I	Type IP-1	Routine	
≈ 1/1000 A_2	Excepted package		

UF6

Content	Transport conditions	Approval
≥ 0.1 kg UF6	Routine + Normal + Fire	Approved package designs
< 0.1 kg UF6	Routine	Non approved package designs

Pressure variation outside and inside an aircraft - routine

- Typical altitudes and pressure differentials

15 kPa	up to 45000 ft — Pressurized and partially pressurized aircraft — Flying altitude all kinds of aircraft
25 kPa	34000ft — Non pressurized (or partially pressurized) aircraft — Max cargo hold altitude Non pressurized aircraft

2500 ft/minute = 9 kPa/minute

75 kPa

75 kPa	8000ft — Pressurized aircraft — Cabin altitude Pressurized aircraft

500 ft/minute = 1.8 kPa/minute

25 kPa

100 kPa   0ft (sea level)

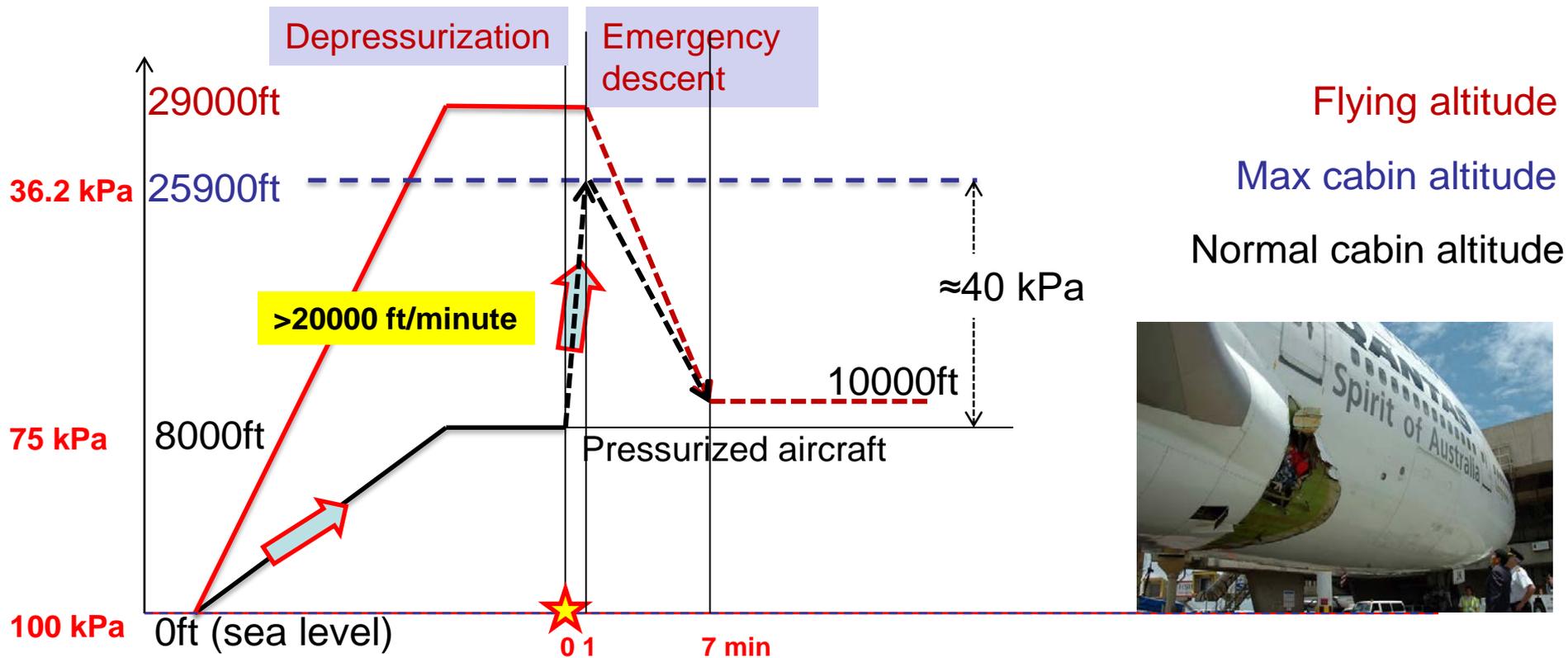# Pressure variation outside and inside an aircraft NCT or ACT?

- Typical depressurization incident (A330 – Toulouse 2006)
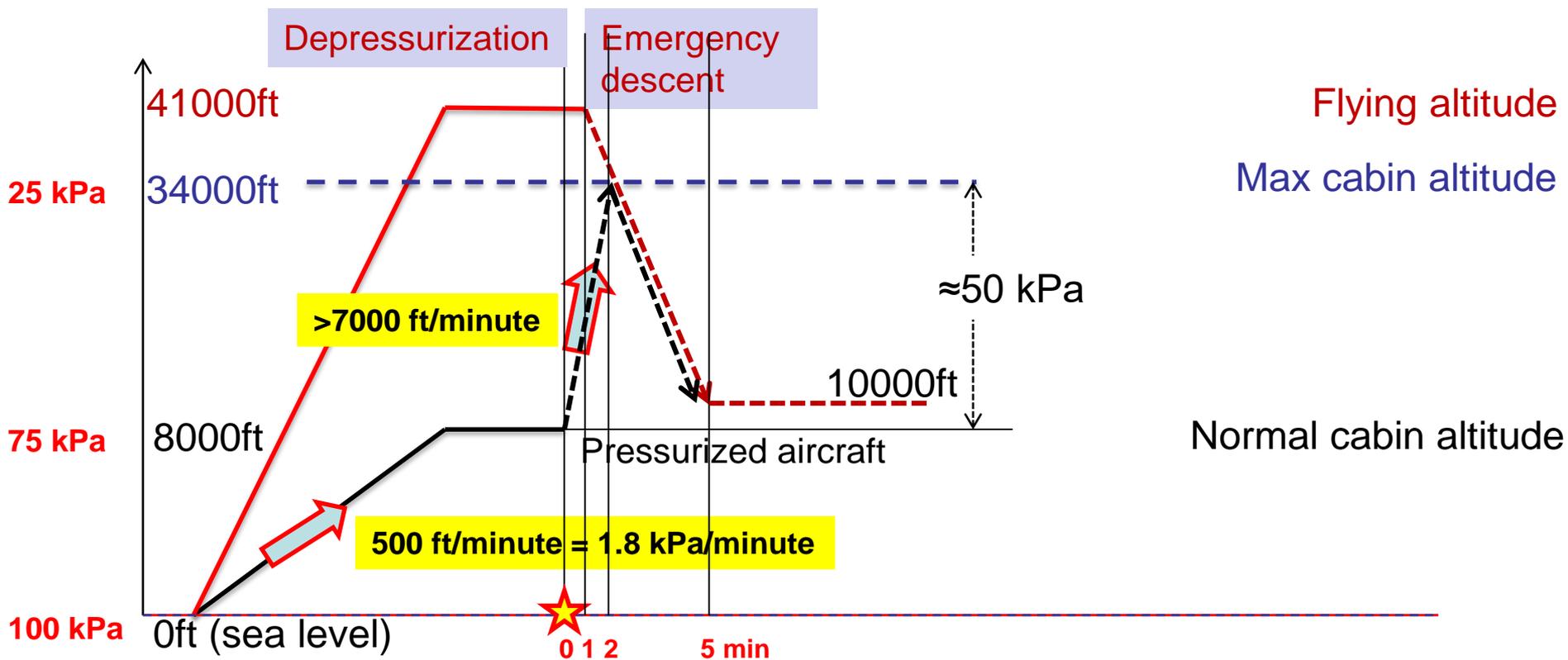
Depressurization

Emergency descent

41000ft — Flying altitude

25 kPa — 34000ft — Max cabin altitude

>7000 ft/minute

≈50 kPa

10000ft

75 kPa — 8000ft — Pressurized aircraft — Normal cabin altitude

500 ft/minute = 1.8 kPa/minute

100 kPa — 0ft (sea level)

0 1 2   5 min

Pressure variation outside and inside an aircraft NCT or ACT?

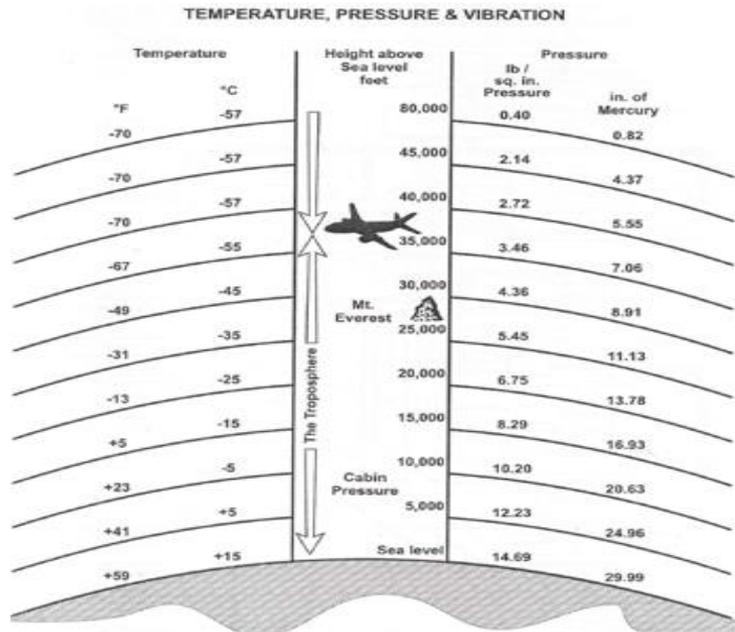- Typical depressurization incident (B747, N-W Manila, 2008)

Depressurization

Emergency descent

Flying altitude

Max cabin altitude

Normal cabin altitude

29000ft

36.2 kPa 25900ft

>20000 ft/minute

≈40 kPa

10000ft

75 kPa 8000ft

Pressurized aircraft

100 kPa 0ft (sea level)

0 1   7 min

APPENDIX B

**RUSSIAN FEDERATION PRESENTATION — PRESSURE DIFFERENTIAL REQUIREMENTS
FOR DANGEROUS GOODS BY AIR**

Pressure differential requirements for dangerous goods by air

Kurdchenko D.

Temperature and pressure on different altitude.

TEMPERATURE, PRESSURE & VIBRATION

Temperature		Height above Sea level feet	Pressure	
°F	°C		lb / sq. in. Pressure	in. of Mercury
	-57	80,000	0.40	0.82
-70				
	-57	45,000	2.14	
-70				4.37
	-57	40,000	2.72	
-70				5.55
	-55	35,000	3.46	
-67				7.06
	-45	30,000	4.36	
-49				8.91
	-35	Mt. Everest 25,000	5.45	
-31				11.13
	-25	20,000	6.75	
-13				13.78
	-15	15,000	8.29	
+5				16.93
	-5	10,000	10.20	
+23		Cabin Pressure		20.63
	+5	5,000	12.23	
+41				24.96
	+15	Sea level	14.69	
+59				29.99

The Troposphere

Operation of pressurized hold and limitation of its load.
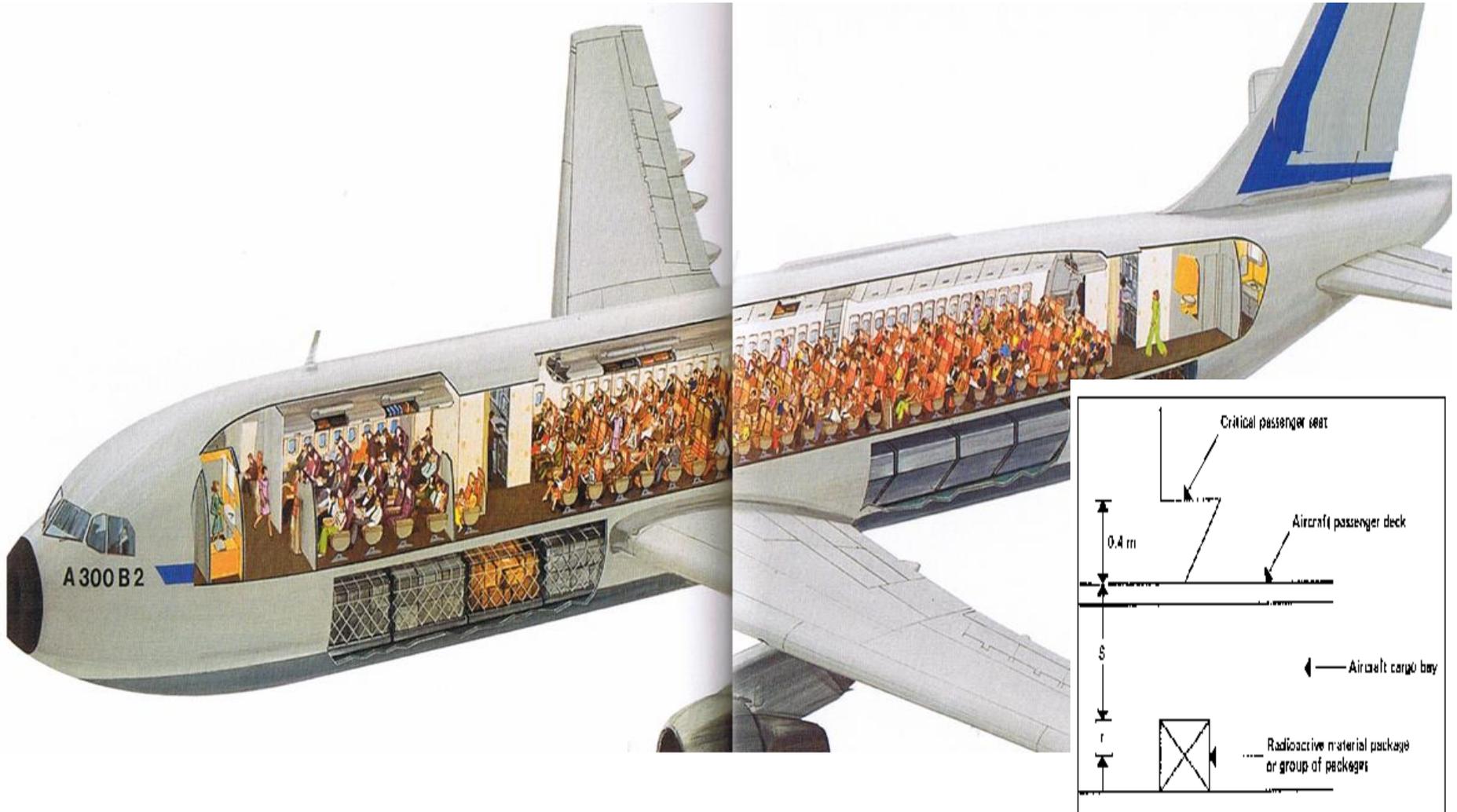
At high altitudes, a person loses consciousness after 15-20 seconds.

Высота, м	Состояние человека
12 000	Потеря сознания через 15—25 с
10 500	Потеря сознания через 35—40 с
9000	Потеря сознания через 80—90 с
7500	Потеря сознания через 5—8 мин. Неадекватность поведения
6000	Ослабление памяти, снижение внимательности, возможна потеря сознания через 5—8 мин
5000	Ослабление памяти и внимания. Затруднен анализ происходящего
4000	Ослабление памяти и внимания. Затруднен анализ происходящего
3000	Снижение работоспособности, усталость через несколько часов
1500	Снижение чувствительности к свету

Hight flight altitude reduce harmful aerodynamic drag and heat of the aircraft, increase the economy of engines, however, at high altitudes, a "high-altitude sickness" appears in a person, due to oxygen starvation caused by a drop in the partial pressure of oxygen.

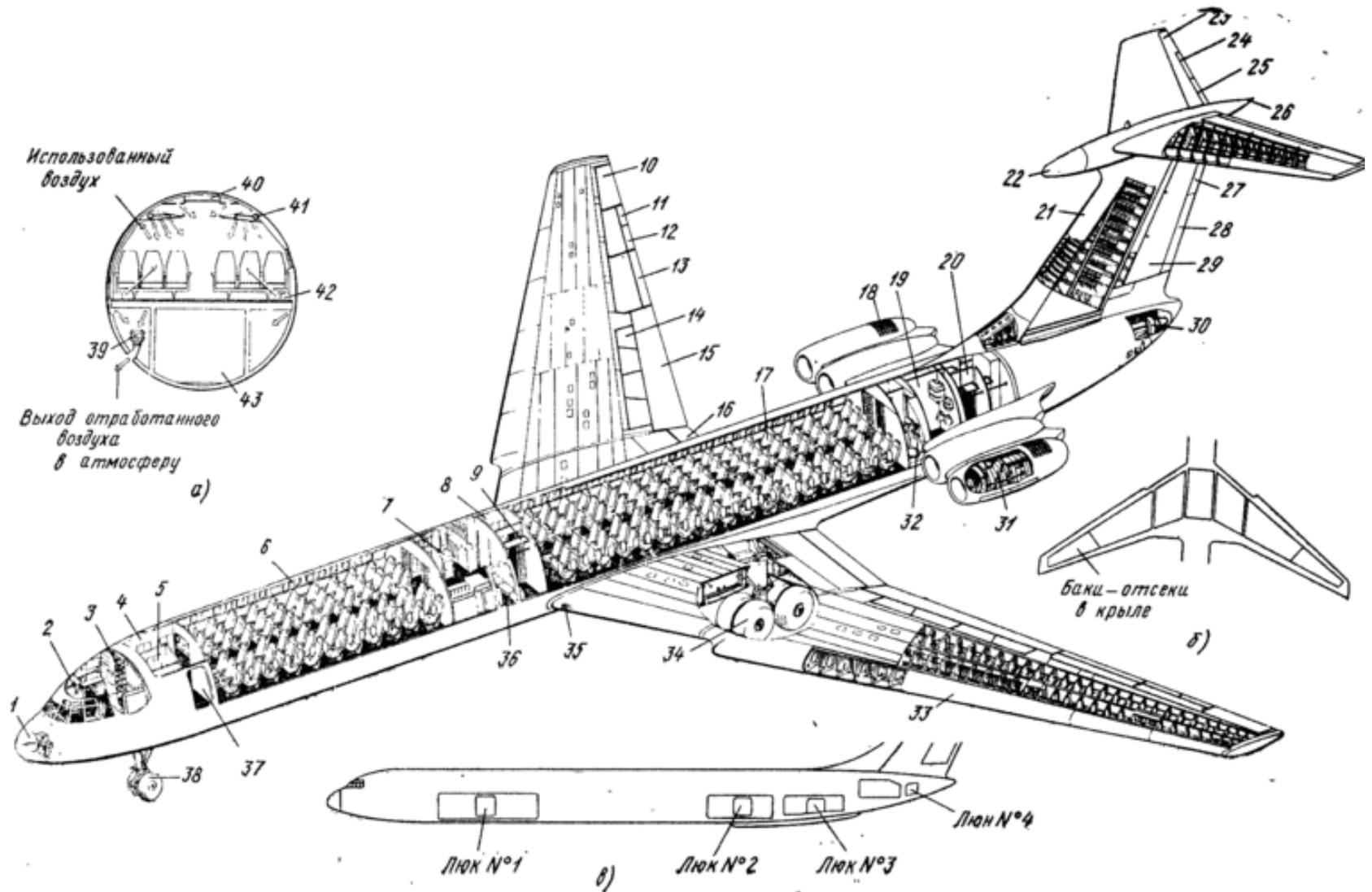# Automatic system for pressure and air conditioning.
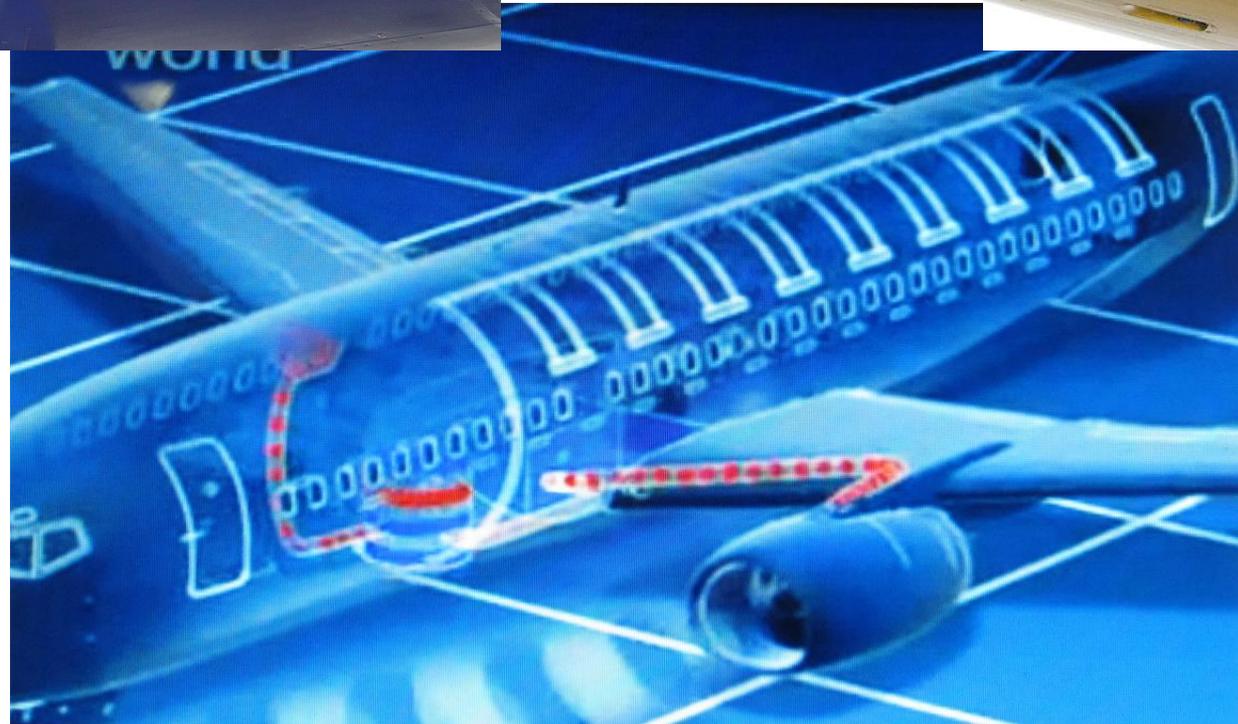
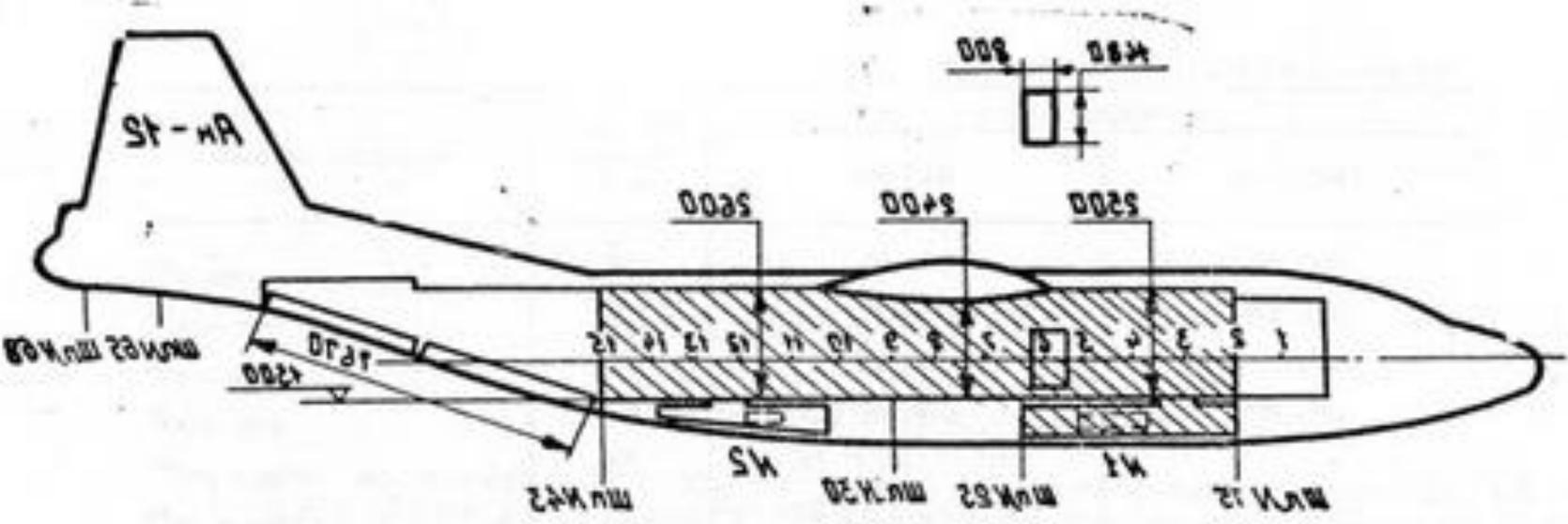# When the pressure changes, the packaging may be destroyed.

-55°C
10000 m.

24 Kpa

CABIN ALTITUDE
3000 m.

CABIN PRESSURE
68 Kpa
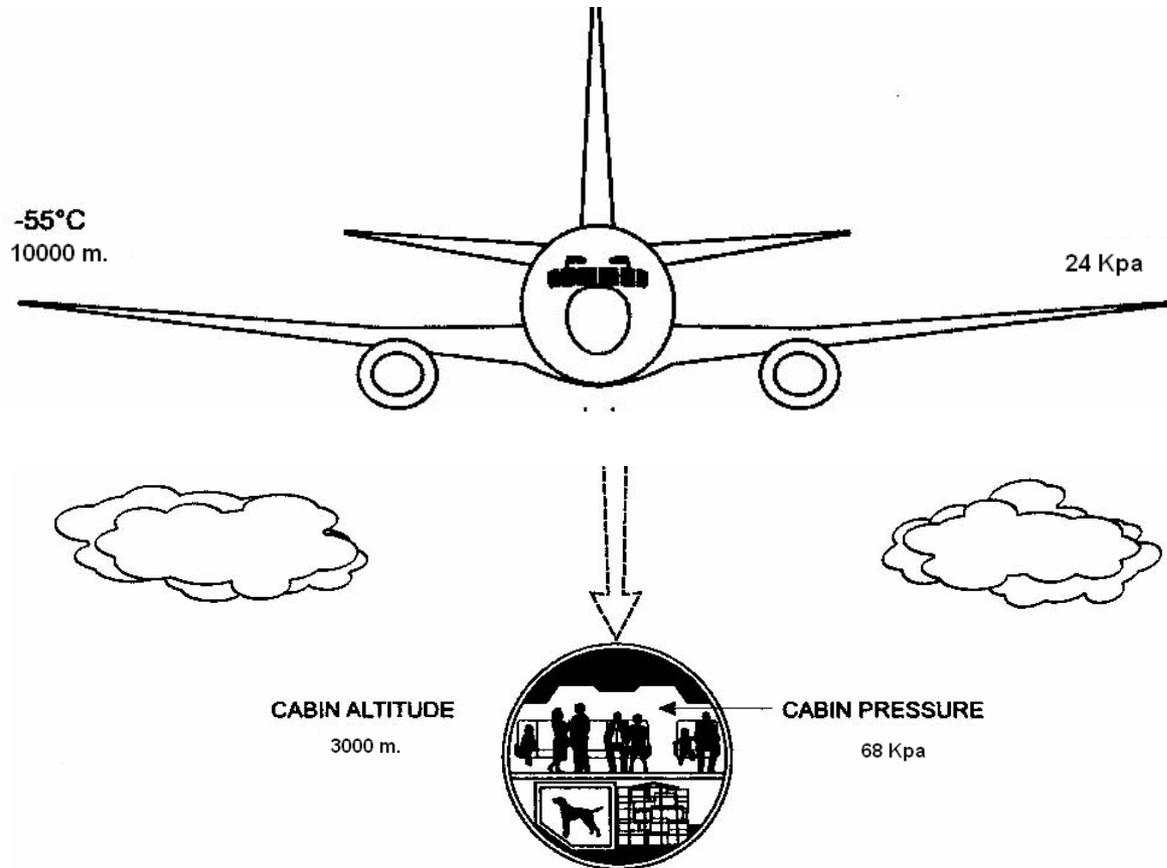
Air circulation in type C cargo compartment

Air circulation in type B cargo compartment

Использованный воздух

Выход отработанного воздуха в атмосферу

а)

Баки — отсеки в крыле

б)

Люк №1   Люк №2   Люк №3   Люк №4

в)

Air circulation in type E cargo compartment

Package and pressure – sea level

100 Kpa

100 Kpa

AT SEA LEVEL
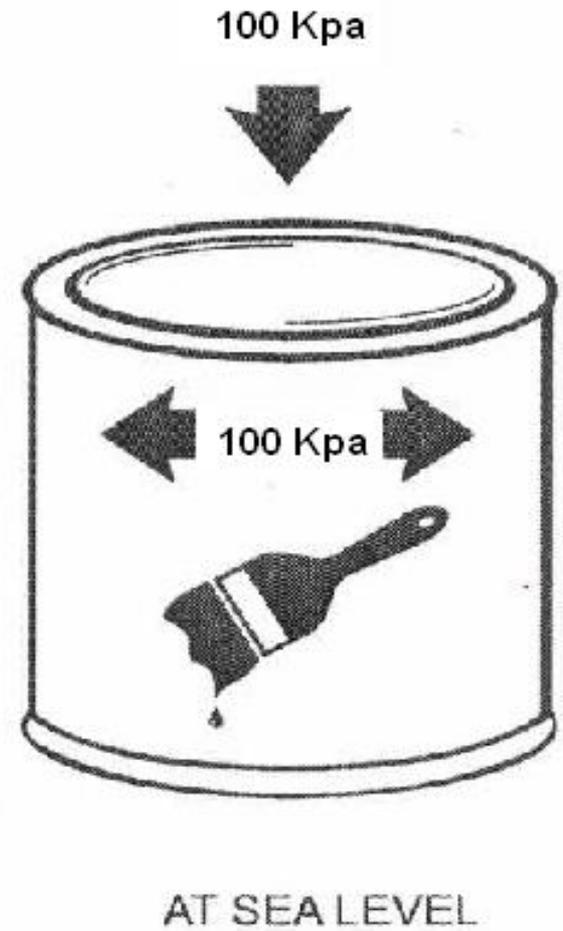
Boeing 737-800 / 900

100 Kpa -68 KPA
Pressure difference inside package in passenger aircraft =32Kpa

10.000 M

3.000 M

68 Kpa
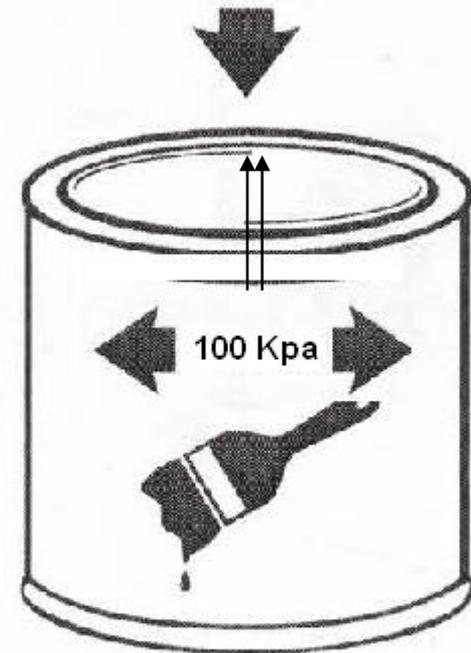
100 Kpa

INSIDE PRESSURISED AIRCRAFT

unpressurised cargo hold

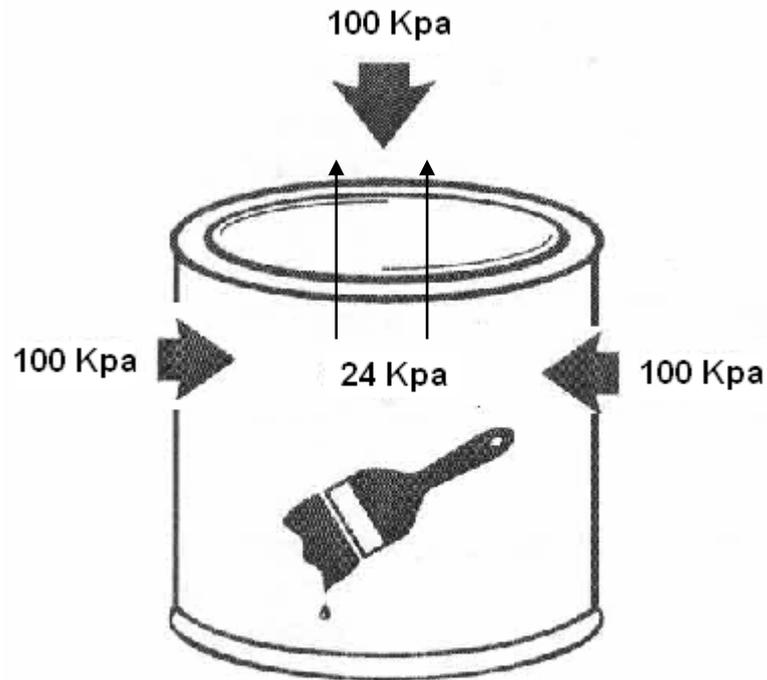100 Kpa -29 KPA

Pressure difference inside package in cargo aircraft =71 Kpa

Package damage on climbing process

Package damage on decending process

Descending
From 29 Kpa to 100 Kpa
Pressure difference inside package=71 Kpa

100 Kpa

100 Kpa   24 Kpa   100 Kpa

INSIDE UNPRESSURISED AIRCRAFT

APPENDIX C

**WNTI MEMO — REVIEW OF THE PRESSURE DIFFERENTIAL REQUIREMENTS
APPLICABLE TO PACKAGES CONTAINING RADIOACTIVE MATERIAL TRANSPORTED
BY AIR**

Review of the pressure differential requirements applicable to packages containing radioactive material transported by air

This technical note summarizes the issue in view of the dedicated technical meeting regarding the proposal submitted by WNTI during the last 2015 review cycle of the IAEA Regulations for the Safe Transport of Radioactive Material.

Bruno DESNOYERS – 05 April 2017

1. Introduction

The IAEA Regulations for the Safe Transport of Radioactive Material [1] in its paragraph 621 require that all packages of radioactive material (excepted packages, industrial packages IP-1, IP-2 and IP-3, type A, type B(U), type B(M) and type C packages) be designed to meet the following requirement:

- *"Packages containing radioactive material to be transported by air shall be capable of withstanding, without loss or dispersal of radioactive contents from the containment system, an internal pressure that produces a pressure differential of not less than the maximum normal operating pressure plus 95 kPa."*

This requirement may be difficult to achieve, especially in the case of packagings of large dimensions, such as ISO freight containers commonly used as Type IP-1 or Type IP-2 packages for carriage of contaminated tools, machines and components classified as surface contaminated objects (SCO-I or SCO-II), and it may seem excessively severe for low activity materials with little risk, such as excepted packages loaded with solid radioactive materials for example.

A first proposal was submitted by WNTI in the 2013 review cycle [2].

As recommended during the "Technical Meeting (TM) on the Environment to which Packages may be subject during Transport and related Issues Concerning the Regulations for the Safe Transport of Radioactive Material" (IAEA TM-44891) which took place from 15 to 19 July 2013 [3], the WNTI submitted for comment this first proposal to the Dangerous Goods Panel of ICAO [4] during its 24th meeting (28 October to 8 November 2013).

The comment made by the Dangerous Goods Panel was the following [5]:

- *"While some panel members understood the logic in developing different requirements based on the level of risk in that this approach was applied to other dangerous goods, they believed that breaking the requirements into three different categories would complicate the provisions and make them more difficult to understand. They did not feel there was sufficient justification for lowering the standards and that the current provisions should remain."*

A second proposal was submitted by WNTI during the 2015 review cycle [6]. Compared to the 2013 proposal, it was supported by more accurate justifications, and the final proposal was simplified. This proposal was revised during the review cycle to take account the

comments provided by participants during the IAEA TRANSSC Extraordinary meeting in September 2015 [7].

The resulting final proposal as submitted to the ordinary TRANSSC meeting of November 2015 is presented in Appendix 1.

At TRANSSC 31 Meeting, in November 2015, ICAO indicated that this proposal could not be accepted as proposed and requested that at least one further technical meeting between experts should be held prior to its acceptance by TRANSSC. As a result, this final proposal could not be accepted for the current 2015 review cycle.

The TRANSSC decision as recorded was the following (see proposal WNTI/2015/03 Rev.2 in [8]):

- *"No action taken. Decision on the proposal is deferred to the IAG (Inter Agencies Group) and other appropriate aviation organizations for further discussion and development."*

At TRANSSC 32 Meeting, 14-15 June 2016, WNTI provided a presentation in order to request the setting-up of an ad-hoc IAEA TRANSSC Working Group of Experts in association with appropriate aviation organizations (ICAO, IATA, …) to discuss the WNTI proposal and to propose a solution on the issue. A summary of the discussion of this issue that took place in the IAG was provided by the Chair of TRANSSC. It was concluded at the IAG that, since the issue related to air transport, ICAO needed to agree or disagree with the proposal, and discussions between ICAO and WNTI were likely to continue until resolution had been reached one way or the other.

The conclusions of the IAEA TRANSSC 32 meeting in June in Vienna were (see [9], paragraph 4.4):

- IAEA TRANSSC members are not opposed to the creation of a working group of experts,
- IAEA TRANSSC recommends WNTI holds a meeting with ICAO in order to get the agreement of ICAO DGP for the setting-up of this working group of experts, and define the Terms Of Reference of the group,
- TRANSSC members who wished to be a part of the discussions were invited to make this desire known to the TRANSSC Secretariat.

WNTI participated into the DGP/WG-16 held in ICAO headquarters in Montréal, from 17 to 21 October 2016, and submitted to the DGP the WP "Proposal for review of the pressure differential requirements applicable to packagings containing radioactive material" [10], inviting the DGP to discuss the setting up of this group of experts in order to solve the issue stated in the working paper and to propose revisions to the regulations accordingly.

The decision of the ICAO DGP/WG16 participants was to accept the setup of this working group and Members of the DGP with appropriate expertise were invited to join this experts group to address the issue, as well as advisers to members of the DGP with specialized radioactive material experience were encouraged to join the group. The Secretary noted the importance of having a balance of aviation safety and airworthiness expertise to complement radioactive material expertise (see [11] paragraph 3.2.6.1).

2. Objective

The objective of this technical document is to provide necessary information as required to initiate technical exchange on this issue between experts, as recommended by the IAEA TRANSSC and the ICAO DGP.

3. Intent of the initial proposals for change submitted by WNTI

The proposals submitted to IAEA by WNTI were intended to adapt requirements regarding the pressure differential, packagings containing radioactive material shall be able to withstand without release or dispersion of radioactive material, to the levels of risk presented by real contents of the packages, with regard to safety of the aircraft, passengers and crew members.

The proposals concerned mainly package designs not subject to approval and carrying solid substances or objects. The idea was to take advantage of the solid form of the radioactive materials and of their low hazard level to allow the use of alternative requirements permitting:

- the maintenance of the basic safety objectives for packages containing radioactive material during air transport: retention of their radioactive contents with account of the variations of ambient pressure in the cargo space of an aircraft as generated during transport by air by normal condition of flight (during climb and descent of the aircraft) or by emergency situations (rapid or explosive decompression of the aircraft cargo space at cruising altitude due to incidental event);
- the implementation of the pressure equalization requirements for aircraft and airtight shipping containers with an internal volume of 1 m^3 (35 ft^3) or more to avoid any hazardous situation of over pressure in the container when subjected to routine or incidental depressurization of the aircraft that can, in case of bursting of the container, become a major flight safety hazard (see [12] or [13])

4. Current regulatory requirements regarding resistance to pressure of packagings for transport of dangerous goods

The requirements summarized hereafter are those from the Regulations for the Safe Transport of Radioactive Material of IAEA [1] and from the Technical Instructions for the Safe Transport of Dangerous Goods by Air of ICAO [14].

a. Radioactive materials:

Para 620 of IAEA SSR-6:

Packages to be transported by air shall be so designed that if they were exposed to an ambient temperature ranging from -40°C to +55°C, the integrity of containment would not be impaired.

Para 7.2.2 of part 6 of ICAO-TI:

Packages must be so designed that, if they were exposed to an ambient temperature ranging from -40°C to +55°C, the integrity of containment would not be impaired.

Para 621 of IAEA SSR-6:

Packages containing radioactive material to be transported by air shall be capable of withstanding, without loss or dispersal of radioactive contents from the containment system, an internal pressure that produces a pressure differential of not less than the maximum normal operating pressure plus 95 kPa.

Para 7.2.3 of part 6 of ICAO-TI:

Packages containing radioactive material must be capable of withstanding, without loss or dispersal of radioactive contents from the containment system, an internal pressure that produces a pressure differential of not less than the maximum normal operating pressure plus 95 kPa.

Para 229 of IAEA SSR-6:

Maximum normal operating pressure *shall mean the maximum pressure above atmospheric pressure at mean sea level that would develop in the containment system in a period of one year under the conditions of temperature and solar radiation corresponding to environmental conditions in the absence of venting, external cooling by an auxiliary system or operational controls during transport.*

Para 3.1 of part 1 of ICAO-TI:

Maximum normal operating pressure. *For the transport of radioactive material, the maximum pressure above atmospheric pressure at mean sea level that would develop in the containment system in a period of one year under the conditions of temperature and solar radiation corresponding to environmental conditions in the absence of venting, external cooling by an auxiliary system or operational controls during transport.*

Corresponding explanatory material in IAEA SSG-26: see appendix 3

b. Infectious substances: (packing instructions 620 and 650 of ICAO-TI)

[…] the primary receptacle or the secondary packaging shall be capable of withstanding, without leakage, an internal pressure producing a pressure differential of not less than 95 kPa […].

c. Liquid dangerous goods: (paras 1.1.6 and 1.1.16 of part 4, and para 4.5.3 of part 6 of ICAO-TI)

Packagings for which retention of liquid is a basic function shall be capable of withstanding, without leakage, a rated internal pressure as shown below:

As required in para 1.1.6 of part 4 of ICAO-TI (valid for inner packagings of combination packagings). The pressure related to the vapour pressure must be determined as either:

(a). *$P = (P_{M55} \times 1.5)$ kPa with a minimum of 95 kPa or 75 kPa (liquids in packing group III of class 3 or division 6.1) ; or*

(b). *$P = (Vp_{50} \times 1.75) - 100$ kPa with a minimum of 95 kPa; or*

(c). *$P = (Vp_{55} \times 1.5) - 100$ kPa with a minimum of 95 kPa.*

As required in para 1.1.16 of part 4 and para 4.5.3 of part 6 of ICAO-TI (valid for packagings other than inner packagings of a combination packaging). The hydraulic pressure (gauge) applied, as determined by any one of the following methods, must be:

(a). *$PT = (P_{M55} \times 1.5)$ kPa with a minimum of 75 kPa (liquids in packing group III of class 3 or division 6.1), 250 kPa (liquids in packing group I), or 95 kPa (other liquids); or*

(b). *$PT = (Vp_{50} \times 1.75) - 100$ kPa with a minimum of 250 kPa (liquids in packing group I), or 100 kPa (other liquids); or*

(c). *$PT = (Vp_{55} \times 1.5) - 100$ kPa with a minimum of 250 kPa (liquids in packing group I), or 100 kPa (other liquids).*

Where

P = pressure to which inner packagings of combination packagings shall be capable of withstanding without leakage;

PT = test pressure in kPa (gauge) for single packagings;

P_{M55} = pressure measured (gauge pressure) in the filled packaging at the temperature of 55°C (with filling temperature of 15°C);

Vp_{50} = vapour pressure at 50°C;

Vp_{55} = vapour pressure at 55°C.

5. Basic examples for certain materials illustrating the use of the current regulatory requirements regarding resistance to the pressure of packagings for transport of dangerous goods

The examples developed are based on the following materials:

- A <u>solid</u> material (either radioactive or presenting another danger);
- Liquid having properties of <u>water</u> (either radioactive material or presenting another danger);
- Liquid having properties of <u>ethanol</u> (either pure – Class 3, PG-II, or contaminated by radioactive material).

The following assumptions are considered:

- Materials <u>do not produce heat</u>, and <u>do not emit gases</u> by radiolysis or thermolysis;
- Packagings are <u>filled and closed at 15°C</u>, at an <u>ambient pressure of 100 kPa</u> (the air + vapour pressure of the material at 15°C);
- The degree of filling for liquids is that prescribed in ADR [15] in para 4.1.1.4 (a) (according to the boiling temperature), degree of filling that allows to check that the <u>packaging is not completely filled at 55°C</u> (see § 1.1.5 of part 4 of the ICAO-TI);
- The maximum ambient temperature of <u>55°C is reached</u>;

The following calculations are made:

- Total pressure (absolute) in the package at 55 ° C (P_{55}), taking into account pressure increase due to:
    - The temperature increase of gases imprisoned at the closure of the packaging (increase from 15°C to 55°C);
    - The expansion of the liquids between 15°C and 55°C;
    - The increase of vapour pressure of the liquids between 15°C and 55°C;
- Maximum normal operating pressure (MNOP): gauge pressure developed in the packaging at 55°C (P_{M55})
    - $P_{M55} = P_{55} - 100$;

a. Solid material or object loaded in a packaging at 15°C and 100 kPa:

The only pressure generated is due to temperature increase of the gases imprisoned at closure, there is no dilatation (expansion) of the solids between 15°C and 55°C, and no vapour or gas produced:

$P_{M55} = P_{15} \times (55 - 15)/(273 + 15) = 100 \times (55 - 15)/(273 + 15) = 13.89$ kPa ≈ 14 kPa

MNOP = P_{M55} = 14 kPa

P or PT for Radioactive material: MNOP + 95 kPa = 14 + 95 = 109 kPa ≈ **110 kPa**

P or PT for solid infectious substances: **95 kPa**

P or PT for other solid dangerous goods: **Not applicable**

b. Water loaded in a packaging at 15°C and 100 kPa:

Physical data for water: see [16]

Degree of filling at 15°C (see 4.1.1.4 of ADR [15]): 94%

Density of water at 15°C: 0.999

Density of water at 55°C: 0.986

Degree of filling at 55°C: (0.999/0.986) x 0.94 = 0.9524

Vapour pressure of water at 15°C: 1.705 kPa;

Vapour pressure of water at 55°C: 15.760 kPa;

Air pressure at 15°C imprisoned in the package: 100 – 1.705 = 98.295 kPa

Pressure increase of the air imprisoned between 15°C and 55°C due to liquid expansion and increase in temperature:

$\quad$ 98.295 x (1 – 0.94)/(1 – 0.9524) x (273 + 55)/(273 + 15) – 98.295 = 42.815 kPa

Water vapour pressure increase between 15°C and 55°C: 15.760 - 1.705 = 14.055 kPa

Total pressure increase between 15°C and 55°C: P_{M55} = 42.815 + 14.055 = 56.87 kPa

$\quad$ MNOP = P_{M55} = 56.87 kPa rounded to 57 kPa

$\quad$ P or PT for Radioactive material: MNOP + 95 kPa = 57 + 95 = 152 kPa ≈ **155 kPa**

$\quad$ P or PT for liquid dangerous goods:

$\quad\quad$ (a) P or PT = (P_{M55} x 1.5) kPa = 57 x 1.5 = 85.5 kPa rounded to 90 kPa

$\quad\quad\quad$ => minimum P or PT = **90 kPa** , **95 kPa** or **250 kPa** (see following table)

$\quad\quad$ (b) P or PT = (Vp_{50} x 1.75) – 100 kPa = (12.352 x 1.75) – 100 = – 78.384

$\quad\quad\quad$ => minimum PT = **95 kPa** , **100 kPa** or **250 kPa** (see following table)

$\quad\quad$ (c) P or PT = (Vp_{55} x 1.5) – 100 kPa = (15.760 x 1. 5) – 100 = – 76.360

$\quad\quad\quad$ => minimum PT = **95 kPa** , **100 kPa** or **250 kPa** (see following table)

Nature of the liquid: <u>water</u>	P (Inner packaging of a combination packaging)	PT (Single packaging)
Class 7	155 kPa	155 kPa
PG III class 3 or division 6.1	(a): 90 kPa	(a): 90 kPa
	(b): 95 kPa	(b): 100 kPa
	(c): 95 kPa	(c): 100 kPa
PG III other classes or divisions + PG-II	(a): 95 kPa	(a): 95 kPa
	(b): 95 kPa	(b): 100 kPa
	(c): 95 kPa	(c): 100 kPa
PG I	(a): 95 kPa	(a): 250 kPa
	(b): 95 kPa	(b): 250 kPa
	(c): 95 kPa	(c): 250 kPa

c. Ethanol loaded in a packaging at 15°C and 100 kPa:

Physical data for ethanol: see [17]

Degree of filling at 15°C (see 4.1.1.4 of ADR [15]): 92%

Density of ethanol at 15°C: 0.795

Density of ethanol at 55°C: 0.758

Degree of filling at 55°C: (0.795/0.768) x 0.92 = 0.9523

Vapour pressure of ethanol at 15°C: 4.339 kPa;

Vapour pressure of ethanol at 55°C: 37.459 kPa;

Air pressure imprisoned in the package at 15°C: 100 – 4.339 = 95.661 kPa

Pressure increase of the air imprisoned between 15°C and 55°C due to liquid expansion and increase in temperature:

95.661 x (1 – 0.92)/(1 – 0.9523) x (273 + 55)/(273 + 15) – 95.661 = 87.06 kPa

Ethanol vapour pressure increase between 15°C and 55°C:

37.459 - 4.339 = 33.120 kPa

Total pressure increase between 15°C and 55°C: P_{M55} = 87.06 + 33.12 = 120.18 kPa

MNOP = P_{M55} = 120.18 kPa rounded to 121 kPa

PT for Radioactive material: MNOP + 95 kPa = 121 + 95 = 216 kPa ≈ **220 kPa**

PT for liquid dangerous goods:

(a) P or PT = (P_{M55} x 1.5) kPa = 121 x 1.5 = 181.5 kPa rounded to **185 kPa**

=> minimum PT = **185 kPa** , (see following table)

(b) P or PT = (Vp_{50} x 1.75) – 100 kPa = (29.598 x 1.75) – 100 = – 48.204

=> minimum PT = **95 kPa** or **100 kPa** (see following table)

(c) P or PT = (Vp_{55} x 1.5) – 100 kPa = (37.459 x 1. 5) – 100 = – 43.812

=> minimum PT = **95 kPa** or **100 kPa** (see following table)

Nature of the liquid: <u>ethanol</u>	P (Inner packaging of a combination packaging)	PT (Single packaging)
Class 7	220 kPa	220 kPa
PG II class 3	(a): 185 kPa	(a): 185 kPa
	(b): 95 kPa	(b): 100 kPa
	(c): 95 kPa	(c): 100 kPa

6. Conditions of pressure and pressure variation that may be encountered during air transportation

a. Maximum and minimum ambient pressure in aircraft cargo holds

The transport of goods by air is carried out either by means of:

- pressurized aircrafts (that is passenger aircrafts and cargo aircrafts adapted from passenger aircraft designs, such as Airbus and Boeing aircrafts), or,

- non-pressurized or partially pressurized aircrafts (usually aircrafts specifically designed for the transport of heavy and /or bulky cargo, such as the Antonov-124).

For reasons related to health and comfort of passengers and crew members, the cabin altitude (equivalent pressure) is limited in commercial pressurized aircrafts to 8,000 feet (about 2,500 m) corresponding to an ambient pressure of 75 kPa [18] [19]. Above this altitude, without additional oxygen in the air to breathe, there is a risk of hypoxia (hypoxia is a decrease in available oxygen below the amount required for normal functioning of the human body). There is no pressure differential between the cabin and the cargo compartments in these aircrafts.

For reasons related to safety of crew members, the cruising altitude of non-pressurized aircrafts, or cabin altitude in the cargo compartments of partially pressurized aircrafts, is maintained below 34,000 feet (10360 m) (the pressure of oxygen in the lungs at 34,000 feet altitude, when breathing pure oxygen, is the same as that for a person breathing air at sea level, 34,000 feet is therefore the highest altitude at which a person would be provided complete protection from the effects of hypoxia [20] by use of pure oxygen to breathe). This altitude corresponds to an atmospheric pressure of 25 kPa. For the health and comfort of the crew, either they are supplied with oxygen, or the aircraft has a pressurized cabin separated from the cargo bay, as is the case of the Antonov-124.

Thus, as indicated in note 3 of the preliminary notes to Part 4 of the ICAO TI [14], under routine transport conditions, the ambient pressure around packages transported in an aircraft may vary:

- from 75 kPa to 100 kPa in a pressurized aircraft, and,

- from 25 kPa to 100 kPa for a non-pressurized or partially pressurized aircraft.

This note 3 was incorporated in the 2011/2012 Edition the ICAO TI on the base of a working paper related to the "transportation of dangerous goods in non-pressurized cargo holds and pressure differentials in flight", presented at a Dangerous Goods Panel of ICAO in May 2009 [20].

b. Maximum pressure rate variations in cargo holds of aircrafts under routine conditions of transport

Climb and descent phases of an aircraft induce variation of pressure inside the aircraft (decrease from 100 kPa to 75 kPa in the climb phase or rise from 75 kPa to 100 kPa in the descent phase of a pressurized aircraft, decrease from 100 kPa to 25 kPa in the climb phase or rise from 25 kPa to 100 kPa in the descent phase of a non-pressurized or partially pressurized aircraft).

In a non-pressurized or partially pressurized aircraft, the variation of pressure inside the cargo bay is close to the change in air pressure around the aircraft corresponding to its rate of climb or descent. The rate of climb of commercial aircraft in normal operation is of the order of 2,500 feet per minute, which corresponds to a decrease in pressure of 150 Pa/s or 9 kPa per minute [12][13].

In pressurized aircraft, for the comfort of passengers and crew members (in particular to avoid barotrauma – ear pain), the rate of climb in cabin altitude is limited to 500 feet per minute which corresponds to a pressure decrease of 30 Pa/s or 1.8 kPa per minute, and the rate of descent is limited to 300 feet per minute, which corresponds to a pressure increase of 18 Pa/s or 1.1 kPa per minute [19].

In "normal flight condition", which could be considered as "routine conditions of transport", packages are then subjected to a maximum variation of ambient pressure of 1.8 kPa per minute or 9 kPa per minute depending on whether transported in a pressurized aircraft or a non-pressurized or partially pressurized aircraft.

Those conditions are summarized in Figure 1.

Figure 1:
Typical altitudes, pressures and variations in an aircraft in normal operation
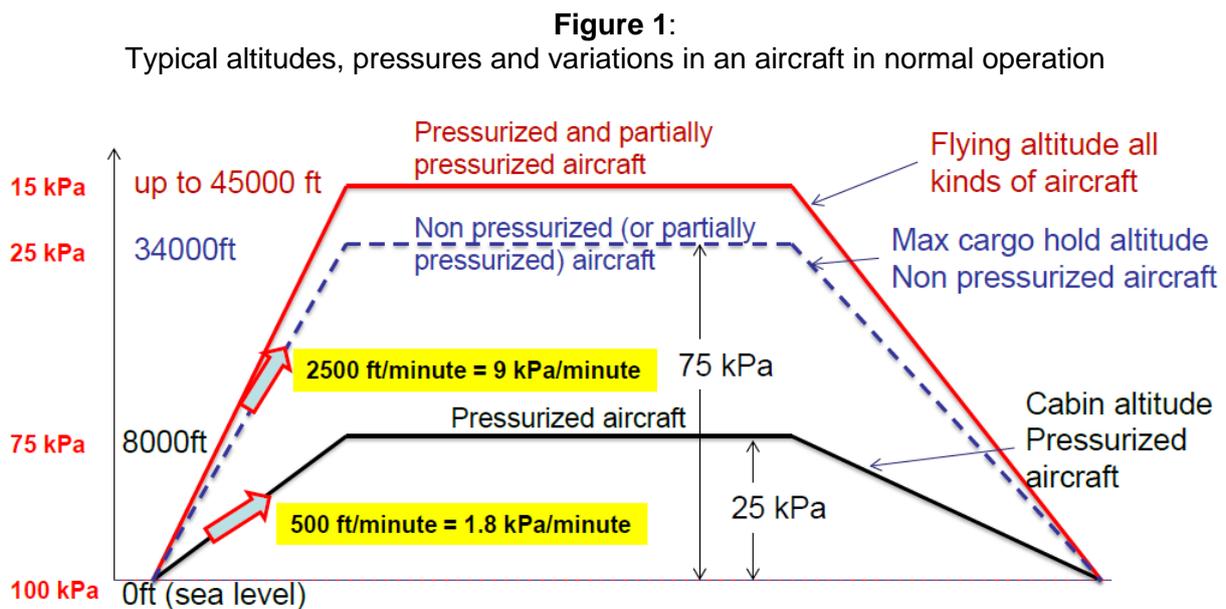
c. Pressure rate variations in cargo holds of aircrafts in case of abnormal depressurization (rapid or explosive depressurization)

Rapid depressurization (also known as "explosive depressurization"), is usually the result of a hardware failure of the aircraft (dysfunction of the pressurization system, inadequate closure of a door, failure of a seal leading to leakage, cracking or loss of a window ...). This phenomenon only really concerns pressurized aircraft. It leads to triggering of alarms and engagement of an emergency procedure by the crew, consisting in particular in descending of the plane as rapidly as possible to an altitude such that crew members and any passengers find normal breathing conditions (at 10,000 feet if feasible).

These are situations that occur fairly regularly (such events occur every year, only the most spectacular cases being relayed in the media) for which usually the aircraft, passengers and crew survive, and often without major injury. For example, for a total of 517 events involving Australian aircraft in the period from January 1975 to March 2006, only one resulted in the loss of the aircraft and fatal injuries to occupants and only 4 led to serious injury to occupants according to a specific study by the Australian Aviation Authority [21].
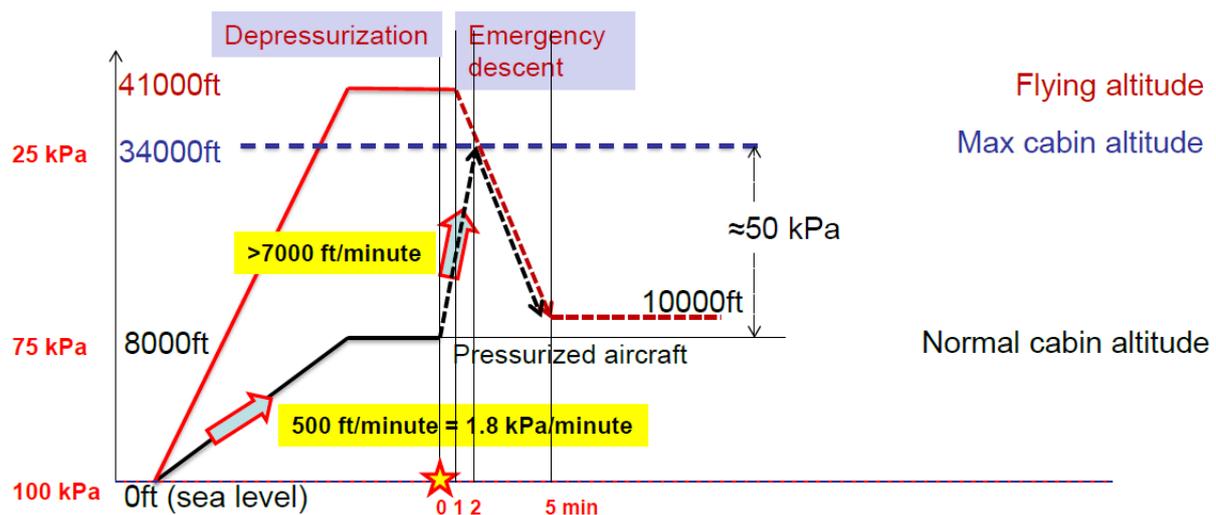
Depressurization examples:

A first example of what may be considered a serious depressurization event is that which occurred on November 21, 2007 over the South of France to an Airbus A330 at an altitude of 41,000 feet (12 500 m) during a demonstration flight prior to delivery to an airline [22]. Tests were related to pressurization systems. Malfunction of the valve command system occurred, leading to a sudden reduction in cabin pressure. The cabin altitude increased from 7,500 feet to 30,500 feet in a little more than 2 minutes, corresponding to a rate of climb of over 10,000 feet per minute (a decrease of pressure from 76.7 kPa to 29.4 kPa) according to the graph of the cabin altitude records. These values rank this event amongst those considered as explosive depressurizations. Two people who were not immediately fitted with oxygen masks fainted, several people suffered from barotrauma (ear pain), but finally no serious injuries occurred. The flight was stabilized at 10,000 feet (3050 m, 69.5 kPa) a little more than 5 minutes after the beginning of the incident. The aircraft suffered no damage. Typical altitudes and pressures for this event are represented in figure 2.

Figure 2:
Typical altitudes, pressures and variations in an aircraft in a severe depressurization incident


A second example of what may be considered a serious depressurization event occurred on 25 July 2008 to a Boeing 747 aircraft carrying 369 passengers and crew cruising at altitude of 29,000 ft, over sea, 475 km north-west of Manila, Philippines [23]. The aircraft rapidly depressurized following the forceful rupture of one of the aircraft's emergency oxygen cylinders in the forward cargo hold. The pressure inside the aircraft dropped from 75 kPa (8,000 feet) to 36.2 kPa (29,500 feet) is less than 1 minute. Following an emergency descent to 10,000 ft, the flight crew diverted the aircraft to Ninoy Aquino International Airport, Manila,

Philippines, where it landed safely. None of the passengers or crew sustained any physical injury. Typical altitudes and pressures for this event are represented in figure 3.

Figure 3:
Typical altitudes, pressures and variations in an aircraft in a severe depressurization incident
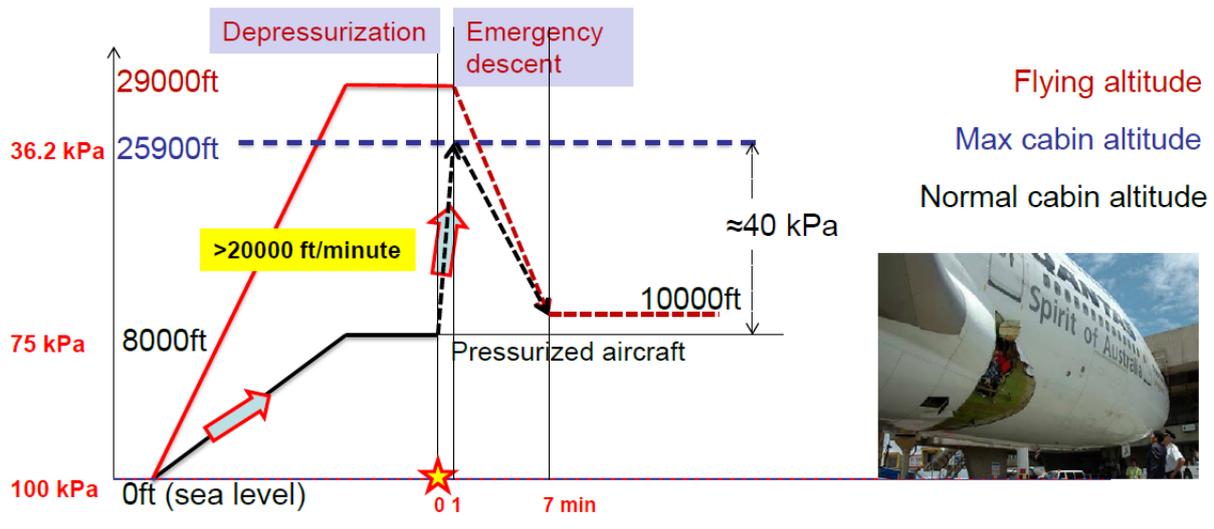
In the Australian study [22] mentioned above, no event, among the 39 for which data on cabin pressure were available reached this cabin depressurization rate (the maximum recorded in this study was 6500 feet per minute). The depressurization events suffered by the Airbus A330 over France and the Boeing B747 over sea off the Philippines coasts may be considered as being among the most severe events.

These events confirm, as does the ASTB report, that any people involved may survive, without serious injury, a pressure reduction rate of almost 0.5 bar (50 kPa) in 1 or 2 minutes, following a depressurization incident at cruise altitude where the ambient pressure is very low (17.7 kPa at 41,000 feet). It also reveals that the minimum pressure in the cabin after the event is not necessarily that prevailing outside the aircraft at the start of the event, and, at least for those 2 examples and for the cases studied in the ASTB report, that it remains higher than the minimum ambient pressure indicated in note 3 of the preliminary notes to part 4 of the ICAO TI (25 kPa).

It also illustrates the need for large volume containers or packagings to either:
- be fitted with quick-opening pressure-equalization systems in order to balance pressure without risk of bursting of the container (which could adversely affect the safety of persons on board and endanger the safety of the aircraft), or,
- be designed to withstand the pressure differential generated by this kind of event.

An IATA Standard Specification [12], and an ISO standard [13], specifically address this issue. These standards apply to airtight shipping containers with an internal volume of 1 m^3 (35 ft^3) or more.

In these standards, normal flight conditions are described as follow:

- Maximum Climb Rate in cabin altitude: 2,500 ft/mn (- 150 Pa/s = - 9 kPa/mn);

- Maximum Descent Rate in cabin altitude: - 1,500 ft/mn (+ 90 Pa/s = + 5.4 kPa/mn);

The emergency (rapid decompression) conditions are described as follow:

- Linear drop of the cabin pressure from 81 kPa (equivalent altitude of 6,000 ft) to 15 kPa (equivalent altitude of 45,000 ft) in a duration of 1 second;

The drop in ambient pressure is considered to be not more than 66 kPa.

The question raised during TRANSSC 31, and to which experts should answer is as follows:

Shall rapid and explosive depressurizations be considered as part of the "normal conditions of transport" as defined by the IAEA, or should it be considered as part of "accident conditions of transport"?

Other data that may be used for defining of conditions to be considered as representative of normal conditions of transport:

Certification standards applicable to large aircrafts [24] [25] (see Appendix 2) require that:

- If certification for operation above 25,000 feet is required, the aircraft must be designed so that occupants will not be exposed to cabin pressure altitudes in excess of 15,000 feet after any probable failure condition in the pressurization system.
- Failures or a combination of failures which expose occupants to: (1) cabin altitudes in excess of either 25,000 feet for more than 2 minutes, or (2) cabin altitudes that exceed 40,000 feet for any duration, shall be shown to be extremely improbable.
- The absolute pressure at 15,000 feet is 57.2 kPa, at 25,000 feet is 37.65 kPa and at 40,000 feet is 18.7 kPa.

7. Comparison between the performance required for packagings and pressure variations that may be encountered during air transport

The **Table 1** summarizes various situations that are covered by the requirements for packagings against ambient pressure variations around packages during air transport (decrease of 25 kPa for pressurized aircraft, 75 kPa for non-pressurized or partially pressurized aircraft = routine conditions of transport) when considering increase of ambient temperature from 15°C to 55°C for the three examples of material for which the required pressure test (PT) has been determined in paragraph 5 above (solid, water and ethanol).

Under normal flight conditions (routine conditions of transport) requirements regarding the pressure resistance of packagings containing liquid dangerous goods (other than class 7), and what they shall be able to withstand without leakage, may be unsufficient for situations where the maximum increase of ambient temperature (15°C to 55°C) and the maximum decrease of ambient pressure around the packages (100 kPa to 25 kPa) occur simultaneously (this is verified for water PG-II or III in non-pressurized aircraft and for ethanol when formulas (a), (b) or (c) are used).

The fact that the formulas provided in paras 1.1.6 and 1.1.16 of part 4, and para 4.5.3 of part 6 of ICAO-TI [14] are still considered as satisfactory shows that combination of the highest decrease in ambient pressure with the highest increase in ambient temperature around the package is certainly of low or very low probability.

These examples also highlight that the formulas provided in (a), (b) and (c) are somewhat "approximate":

- in not considering directly the reduction of ambient pressure in the formulae (a), (b) and (c), situations may occur that, even with account taken of the minimum test pressure, the final pressure specified is not sufficient (this is the case for water);
- by neglecting the effect of imprisoned air at closing of the packagings, formulas (b) and (c) may lead to serious underestimation of the minimum pressure the packaging used shall be able to withstand, especially in case of liquid with low vapour pressure at 15°C (this is the case for ethanol).

In the case of the rules specified for Class 7 transports, these examples show that the margin is always greater than 20 kPa.

The rule applicable for Class 6.2 shows that minimum pressure of 95 kPa in case of solid material is sufficient against all situations (the margin is always greater than 6 kPa).

The proposal for Class 7 to replace the "*internal pressure that produces a pressure differential of not less than the maximum normal operating pressure plus 95 kPa*" by "*the maximum gauge pressure that may be developed in the package at 55°C when it has been filled at 15°C (or the maximum normal operating pressure) plus 75kPa, with a minimum of 95kPa*" was based on these findings.

This proposal covers all situations of the routine conditions of transport (normal flight conditions) with a positive margin.

The minimum total pressure difference of 95 kPa allows to cover the case of solid (non-heating, without gas production) packed with air at an ambient temperature of 15°C at sea level, without need for any supplementary justification.

Considering now the emergency (rapid decompression) situations as described in [12] and [13], the **Table 2** summarizes various situations that are covered by the requirements for packages against ambient pressure variations around packages during rapid decompression of a pressurized aircraft occurring at maximum cruise altitude (increase of the cabin altitude from 6,000 ft to 45,000 ft in one second = decrease of the ambient pressure from 81 kPa to 15 kPa in one second = normal conditions of transport or accident conditions of transport?)

All the packagings meeting the Class 7 requirement are able to withstand the maximum differential pressure resulting of this situation.

Except the particular case of liquid PG-I material in a single packaging, none of the packagings allowed for other dangerous goods are able to withstand the maximum differential pressure resulting of this situation.

Table 1: Situations of the three examples against "routine conditions of transport"

Material	P_{M55}	Class	PT	$P_{ambient}$ decrease *	ΔP maxi	Margin
Solid	14 kPa	7	110 kPa	- 25 kPa	39 kPa	+71 kPa
				- 75 kPa	89 kPa	+21 kPa
		6.2	95 kPa	- 25 kPa	39 kPa	+56 kPa
				- 75 kPa	89 kPa	+6 kPa
		Other than 6.2 and 7	Non required	- 25 kPa	39 kPa	-39 kPa
				- 75 kPa	89 kPa	-89 kPa
Liquid (water)	57 kPa	7	155 kPa	- 25 kPa	82 kPa	+73 kPa
				- 75 kPa	132 kPa	+23 kPa
		3, PGIII 6.1, PGIII All packagings	90 kPa (a)	- 25 kPa	82 kPa	+8 kPa
				- 75 kPa	132 kPa	-42 kPa
		All PGI, all PGII and other PGIII Inner packaging	95 kPa (a) (b) (c)	- 25 kPa	82 kPa	+13 kPa
				- 75 kPa	132 kPa	-37 kPa
		3, PGIII 6.1, PGIII Inner packaging	95 kPa (b) (c)	- 25 kPa	82 kPa	+13 kPa
				- 75 kPa	132 kPa	-37 kPa
		All PGII and all PGIII Single packaging	100 kPa (b) (c)	- 25 kPa	82 kPa	+18 kPa
				- 75 kPa	132 kPa	-32 kPa
		All PG I Single packaging	250 kPa (a) (b) (c)	- 25 kPa	82 kPa	+168 kPa
				- 75 kPa	132 kPa	+118 kPa
Liquid (ethanol)	121 kPa	7	220 kPa	- 25 kPa	146 kPa	+74 kPa
				- 75 kPa	196 kPa	+24 kPa
		PG II class 3 all packagings	185 kPa (a)	- 25 kPa	146 kPa	+39 kPa
				- 75 kPa	196 kPa	-11 kPa
		PG II class 3 inner packaging	95 kPa (b) (c)	- 25 kPa	146 kPa	-51 kPa
				- 75 kPa	196 kPa	-101 kPa
		PG II class 3 single packaging	100 kPa (b) (c)	- 25 kPa	146 kPa	-46 kPa
				- 75 kPa	196 kPa	-96 kPa

* -25 kPa in case of pressurized aircraft, -75 kPa in case of non-pressurized aircraft

Table 2: Situations of the three examples against "normal conditions of transport"

Material	P_{M55}	Class	PT	$P_{ambient}$ decrease *	ΔP maxi	Margin
Solid	14 kPa	7	110 kPa	- 85 kPa	99 kPa	+11 kPa
		6.2	95 kPa	- 85 kPa	99 kPa	-4 kPa
		Other than 6.2 and 7	Non required	- 85 kPa	99 kPa	-99 kPa
Liquid (water)	57 kPa	7	155 kPa	- 85 kPa	142 kPa	+13 kPa
		3, PGIII 6.1, PGIII All packagings	90 kPa (a)	- 85 kPa	142 kPa	-52 kPa
		All PGI, all PGII and other PGIII Inner packaging	95 kPa (a) (b) (c)	- 85 kPa	142 kPa	-47 kPa
		3, PGIII 6.1, PGIII Inner packaging	95 kPa (b) (c)	- 85 kPa	142 kPa	-47 kPa
		All PGII and all PGIII Single packaging	100 kPa (b) (c)	- 85 kPa	142 kPa	-42 kPa
		All PG I Single packaging	250 kPa (a) (b) (c)	- 85 kPa	142 kPa	+108 kPa
Liquid (ethanol)	121 kPa	7	220 kPa	- 85 kPa	206 kPa	+14 kPa
		PG II class 3 all packagings	185 kPa (a)	- 85 kPa	206 kPa	-21 kPa
		PG II class 3 inner packaging	95 kPa (b) (c)	- 85 kPa	206 kPa	-111 kPa
		PG II class 3 single packaging	100 kPa (b) (c)	- 85 kPa	206 kPa	-106 kPa

* -85 kPa in case of pressurized aircraft (drop of the ambient pressure to 15 kPa = 45,000 ft altitude)

There is no requirement for minimum pressure resistance for packagings containing solid dangerous goods other than Class 7 and Class 6.2 in the ICAO-TI [14]. However, with the exception of Class 7, the maximum net quantity of solid dangerous goods per package is generally limited to 200 kg or less, with some exceptions of up to 400 kg as for UN3335, which means that the corresponding packagings are of size less than 1 m^3.

Packagings used for radioactive materials are not submitted to such mass or volume limitations. In particular, freight containers may be used as IP-2 or IP-3 package, as permitted by para 629 of IAEA SSR-6 [1] and by para 7.4.4.2 of Part 6 of ICAO-TI [14]. Such freight containers are much larger than 1 m^3, and are clearly not designed to sustain significant differential pressure (at most a few kPa).

For containers larger than 1 m^3, carried by air, ISO and IATA standards applicable to the design and testing of air freight containers contain requirements to avoid dangerous overpressure of the containers under normal flight conditions [12] [13] which could endanger persons on board or the aircraft itself in the event of break-up: so either the container is designed to sustain such a differential pressure or the container is equipped with valves or venting allowing equalization of inner and external pressure during climb and descent phases of the flight with a maximum climb rate of 2,500 ft/minute (150 Pa/s = 9 kPa/minute).

The proposal for an alternative requirement for solid material or objects of low radioactive hazard (*(a) packages containing only special form radioactive material, SCO-I or SCO-II; (b) excepted packages, industrial packages and type A packages, containing solid radioactive material, excluding powders; (c) packages containing LSA-I material in powder form*) takes account of these facts, with a minimum requirement to guarantee an equivalent level of safety: *The packages shall be able to prevent loss or dispersal of their radioactive contents with a reduction of ambient pressure to 25kPa.* The necessary recommendations and guidance for filters and valves was provided in para 621.2 of the proposal (see appendix 1). In particular the following conditions were considered to represent "routine conditions of transport":

- temperature of filling: 15°C, maximum temperature during transport: 55°C

- maximum decrease of ambient pressure in cargo holds of an aircraft: 75 kPa;

- minimum ambient pressure in cargo holds of an aircraft: 25 kPa;

- maximum pressure rate decrease during climb phase: 9 kPa/minute (non-pressurized or partially pressurized aircraft) or 1.8 kPa/minute (pressurized aircraft).

In the case of depressurization incident as illustrated in Figures 2 and 3, the maximum resulting decrease in ambient pressure remains equal or less to 50 kPa (the ISO and IATA standards specify 66 kPa). The results in the table presented in paragraph 7 above, show that, except <u>all packagings</u> for Class 7 and <u>single packagings</u> for liquid PG-I dangerous goods, most packagings used for liquids will not be able to support such a pressure differential (drop of the ambient pressure down to 15 kPa) when combined with the maximum increase of the ambient temperature (from 15°C to 55°C).

The question which may arise is:

Taking into account the fact that most packagings authorized for the transport of liquid dangerous goods by air are unable to withstand, without leakage, the rapid and explosive depressurization of a pressurized aircraft, is it then justified to consider that rapid and explosive depressurization as specified in ISO and IATA standards should nevertheless be considered as

representing "normal conditions of transport" <u>for all types</u> of package containing radioactive material?
Or could these rapid and explosive depressurization conditions be divided into "normal conditions of transport" for the less severe ones, and "accident conditions of transport" for the most severe ones?

For packagings with equipment permitting equilibrium of pressure during the climbing phase, the figures 2 and 3, the report [20] and the standards [12] and [13] show that the maximum pressure variation during a depressurization event at cruise altitude may be considered as being less than 66 kPa:

- Either the packaging shall be able to sustain such a pressure differential without explosion,
- or the packaging shall be equipped with emergency valves or vents as required in IATA Standard Specification [12] or in ISO standard [13] to avoid any over-pressurization of the package in these emergency situations.

8. Graded approach

The IAEA SSR-6 [1] considers a graded approach which may be summarized as shown in Figure 4 below:

Figure 4:
Graded approach used in IAEA SSR-6
(Requirements adapted to the risk level presented by the package content)

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Based on a similar graded approach, taking into account the level of danger of the content and its potential to escape from the package in case of leakage, and that depressurization incidents should be considered as normal conditions of transport could be:

(a). withstand a <u>pressure differential of at least MNOP + 95 kPa (unchanged requirement)</u> without loss <u>of shielding</u> or dispersal of the radioactive contents

- o Non-special forms in type B(U), type B(M) and type C packages,
- o Packages containing fissile material (IF, AF, B(U)F, B(M)F and CF) with the exception of those containing fissile-excepted material,
- o Packages containing uranium hexafluoride,
- o Liquid LSA-I, liquid LSA-II, LSA-II powders,
- o Liquid or gas in excepted packages or in Type A packages,

(b). <u>prevent loss of shielding or dispersal</u> of the radioactive contents <u>in case of depressurization accident</u> (drop of the ambient pressure to 15 kPa in 1 second) (covering all conditions of transport):

- o Special forms in Type B(U), B(M) or C

(c). prevent loss of shielding or dispersal of the radioactive contents with a <u>reduction of ambient pressure to 25kPa</u> (pressure rate variation of 9 kPa/minute – routine conditions of transport) and <u>in case of depressurization incident</u> (drop of the ambient pressure from 75 kPa to 25 kPa in 1 minute – normal conditions of transport) (covering routine and normal conditions of transport):

- o Special form in Type A,
- o LSA-III, solid LSA-II excluding powders, SCO-II, solid material in a Type A

(d). prevent loss of shielding or dispersal of the radioactive contents with a <u>reduction of ambient pressure to 25kPa</u> (pressure rate variation of 9 kPa/minute) (covering routine conditions of transport only)

- o Solid LSA-I or SCO-I in an IP-1, solid material in an excepted package

(e). In case of (c) and (d) above, a packaging or a container larger than 1 m^3 shall be equipped with emergency valves or vents as required in IATA Standard Specification [12] or in ISO standard [13] to avoid any hazardous over-pressurization of the package in case of drop of the ambient pressure from 81 to 15 kPa in less than 1 second (exceeding normal conditions of transport).

9. References

[1]   IAEA - Safety Standards - Regulations for the Safe Transport of Radioactive Material – No. SSR-6 – 2012 Edition

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[3]   IAEA - TM-44891 - final report - Technical Meeting on the Environment to which Packages May be Subject During Transport and Related Issues Concerning the Regulations for the Safe Transport of Radioactive Material - IAEA Headquarters, Vienna, 15 to 19 July 2013

[4] ICAO - DGP/24 – WP/42 – Internal pressure for packages of radioactive material transported by air (presented by WNTI) – Montréal, Canada, 28 October to 8 November 2016

[5] ICAO - DGP/24-WP/81 – Twenty fourth Meeting - Report folder - Agenda item 2, para 2.6.3

[6] IAEA - Transport Regulations 2015 Review Cycle – WNTI proposals

[7] IAEA – proposal WNTI/2015/03 (rev.2) (also referenced INF-05bWNTI201503Rev 2)

[8] IAEA - TRANSSC 31 Decisions Record (Rev.1)

[9] IAEA TRANSSC 32 Meeting Report

[10] DGP-WG/16-WP/53 – 13/10/2016 - "Proposal for review of the pressure differential requirements applicable to packagings containing radioactive material"

[11] DGP-WG/16-WP/54 - 21/10/2016 - Dangerous Goods Panel (DGP) Working Group Meeting (DGP-WG/16) - Report of the meeting

[12] IATA Standard Specification 80/2 – Pressure equalization requirements for aircraft and shipping containers

[13] ISO11242:1996 – Aircraft – Pressure equalization for cargo containers

[14] ICAO – Technical Instructions for the Safe Transport of Dangerous Goods by Air – 2017-2018 Edition

[15] European Agreement Concerning the International Carriage of Dangerous by Road (ADR) – applicable as from 1st January 2017:

[16] Physical data of water – CELSIUS

[17] Physical data of ethanol – CELSIUS

[18] US-FAA Advisory circular AC25-20

[19] US FAA Aviation Maintenance Technician Handbook – Airframe - Chapter 16 - Control of Cabin Pressure - Pressurization Modes

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[21] Australian Transport Safety Bureau – ATSB - Research and Analysis Report B2006/0142 - Depressurisation Accidents and Incidents Involving Australian Civil Aircraft - 1 January 1975 to 31 March 2006" by Dr David G. Newman – June 2006

[22] BEA - Report BEA F-WWKK - November 21, 2007 – (only available in French) - Incident survenu le 21 novembre 2007 - Secteur sud de la France, croisière (FL) 410, à l'Airbus 330-202 immatriculé F-WWKK exploité par Airbus, livraison à Air Mauritius.

[23] ATSB Transport Safety report - Aviation Occurrence Investigation - AO-2008-053 - Oxygen cylinder failure and depressurisation 475 km north-west of Manila, Philippines 25 July 2008 - Boeing Company 747-438, VH-OJK

[24] US FAA FARs Part 25 Section 25.841

[25] EU EASA CS25 Section 25.841

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Appendix 1

Proposed amendment of the para 621 of IAEA SSR-6 and of the para 621.1 and following of IAEA SSG-26 submitted by WNTI in 2015

The final proposal of WNTI as it was presented at the 31st regular meeting of the IAEA TRANSSC in November 2015 was:

621. Packages containing radioactive material to be transported by air shall be capable of withstanding, without loss or dispersal of radioactive contents from the containment system, an internal pressure that produces a pressure differential of not less than the maximal gauge pressure that may be developed in the package at 55°C when it has been filled at 15°C (or the maximum normal operating pressure) plus 75kPa, with a minimum of 95kPa. This requirement is not applicable to the following packages provided they would prevent loss or dispersal of their radioactive contents with a reduction of ambient pressure to 25kPa:

(a) packages containing only special form radioactive material, SCO-I or SCO-II;

(b) excepted packages, industrial packages and type A packages, containing solid radioactive material, excluding powders;

(c) packages containing LSA-I material in powder form.

This proposal was completed by the following changes in the recommendations to be introduced into the IAEA guide SSG-26:

621.1. This is a similar provision to that required by the ICAO [10] for packages containing liquid dangerous goods or infectious substances intended for transport by air. The basic requirement is that the package shall be capable of withstanding, without loss or dispersal of radioactive contents from the containment system, an internal pressure that produces a pressure differential of not less than the maximal gauge pressure that may be developed in the package at 55°C when it has been filled at 15°C (or the maximum normal operating pressure - MNOP) plus 75kPa, with a minimum of 95kPa. The pressure of 75kPa corresponds to the highest pressure differential between sea level and the pressure within a non-pressurized or partially pressurized cargo compartment of an airplane (see note 3 in introductory notes of Part 4 of ICAO-TI 2015-2016 Edition). An alternative requirement is proposed for the cases where dispersal of the radioactive material is improbable due to its form (special form, SCO, solid LSA in non-powder form, solid radioactive material in a Type A), and for LSA-I in powder form, in these cases it is required that the package shall retain its radioactive contents under a reduction of ambient pressure to 25kPa. This pressure corresponds to the pressure at sea level (100kPa) less 75kPa. It also corresponds to the pressure existing at an altitude of about 10350 m above sea level. The minimum differential pressure of 95kPa is the same as the one specified for solid infectious substances (UN2814, UN2900 and UN3373) and liquid dangerous goods from other classes.

621.2 Several possibilities to comply with the requirement may be used:

• In the case of solid radioactive material in non-approved packages, for which, except the increase of pressure of the content gases (air or other gas) due to heating of the package from 15 to 55°C, no other source of increase of the pressure is expected (low activities, no heating by the radioactive content, no production of gases by radiolysis phenomenon),

packaging able to withstand a pressure differential of 95kPa comply to the requirement: the differential pressure of 95kPa covers the cumulative effect of the highest pressure differential between sea level and the pressure within a non-pressurized or partially pressurized cargo compartment of an airplane (75kPa) and the increase of air pressure due to increase of temperature between 15°C and 55°C (15kPa).

- *In the case of use of the alternative requirements, it is possible to use a packaging equipped with valves and filters to allow pressure equilibrium without dispersal of radioactive solid material content when the content can be subject to dispersal like LSA-I, or small dispersal like SCO-I and SCO-II, or to use a packaging equipped with valves without any supplementary equipment if the content is not subject to dispersal, like special form.*

- *However, the characteristics of the filter must be such that the pressure differential due to the presence of the filter during the phases of depressurization and pressurization of the aircraft in normal flight conditions does not exceed the capacity of containment of the package. It can be assumed, in routine and normal conditions of transport, that the variation of the pressure does not exceed 30Pa/s (1.8kPa/min corresponding to a cabin altitude rate of 500ft/min in normal flight conditions) inside a pressurized aircraft or 150 Pa/s (9kPa/min corresponding to a cabin altitude rate of 2500ft/min in normal flight conditions) inside a non-pressurized or partially pressurized aircraft. When filters are needed, they should be mounted in series with each of the valves or equivalent devices used to equalize the pressure in normal flight conditions.*

- *In addition, packages and containers having internal volume greater than 1 m³, for which those alternative requirements are used, should be designed to be able to ensure high flow pressure equalization in the event of a rapid decompression at cruise altitude without creating a hazard to the cargo compartment or aircraft structure. A rapid decompression is a situation, due to an incident or accident, where the indoor ambient pressure of an airplane pressurized at its cruise altitude drops suddenly to the external pressure at the altitude of the aircraft flight. Rapid decompression is neither routine nor normal condition of transport as defined in para. 106 of SSR-6. See ISO 11242:1996 standard (Aircraft – Pressure equalization requirements for cargo containers) for detailed conditions and requirements.*

Appendix 2

Extracts from US and EU certification specifications for large aeroplanes

US FAA – FARs – Part 25 – Section 841 – Pressurized cabins:

(a) Pressurized cabins and compartments to be occupied must be equipped to provide a cabin pressure altitude of not more than 8,000 feet at the maximum operating altitude of the airplane under normal operating conditions.

  (1) If certification for operation above 25,000 feet is requested, the airplane must be designed so that occupants will not be exposed to cabin pressure altitudes in excess of 15,000 feet after any probable failure condition in the pressurization system.

  (2) The airplane must be designed so that occupants will not be exposed to a cabin pressure altitude that exceeds the following after decompression from any failure condition not shown to be extremely improbable:

  (i) Twenty-five thousand (25,000) feet for more than 2 minutes; or

  (ii) Forty thousand (40,000) feet for any duration.

  (3) Fuselage structure, engine and system failures are to be considered in evaluating the cabin decompression.

(b) Pressurized cabins must have at least the following valves, controls, and indicators for controlling cabin pressure:

  (1) Two pressure relief valves to automatically limit the positive pressure differential to a predetermined value at the maximum rate of flow delivered by the pressure source. The combined capacity of the relief valves must be large enough so that the failure of any one valve would not cause an appreciable rise in the pressure differential. The pressure differential is positive when the internal pressure is greater than the external.

  (2) Two reverse pressure differential relief valves (or their equivalents) to automatically prevent a negative pressure differential that would damage the structure. One valve is enough, however, if it is of a design that reasonably precludes its malfunctioning.

  (3) A means by which the pressure differential can be rapidly equalized.

  (4) An automatic or manual regulator for controlling the intake or exhaust airflow, or both, for maintaining the required internal pressures and airflow rates.

  (5) Instruments at the pilot or flight engineer station to show the pressure differential, the cabin pressure altitude, and the rate of change of the cabin pressure altitude.

  (6) Warning indication at the pilot or flight engineer station to indicate when the safe or preset pressure differential and cabin pressure altitude limits are exceeded. Appropriate warning markings on the cabin pressure differential indicator meet the warning requirement for pressure differential limits and an aural or visual signal (in addition to cabin altitude indicating means) meets the warning requirement for cabin pressure altitude limits if it warns the flight crew when the cabin pressure altitude exceeds 10,000 feet.

  (7) A warning placard at the pilot or flight engineer station if the structure is not designed for pressure differentials up to the maximum relief valve setting in combination with landing loads

(8) The pressure sensors necessary to meet the requirements of paragraphs (b)(5) and (b)(6) of this section and §25.1447(c), must be located and the sensing system designed so that, in the event of loss of cabin pressure in any passenger or crew compartment (including upper and lower lobe galleys), the warning and automatic presentation devices, required by those provisions, will be actuated without any delay that would significantly increase the hazards resulting from decompression.

<u>EU - EASA CS25 - CS 25.841 - Pressurised cabins</u>

(a) Pressurised cabins and compartments to be occupied must be equipped to provide a cabin pressure altitude of not more than 2438 m (8000 ft) at the maximum operating altitude of the aeroplane under normal operating conditions. If certification for operation over 7620 m (25 000 ft) is requested, the aeroplane must be able to maintain a cabin pressure altitude of not more than 4572 m (15 000 ft) in the event of any reasonably probable failure or malfunction in the pressurisation system.

(b) Pressurised cabins must have at least the following valves, controls, and indicators for controlling cabin pressure:

(1) Two pressure relief valves to automatically limit the positive pressure differential to a predetermined value at the maximum rate of flow delivered by the pressure source. The combined capacity of the relief valves must be large enough so that the failure of any one valve would not cause an appreciable rise in the pressure differential. The pressure differential is positive when the internal pressure is greater than the external.

(2) Two reverse pressure differential relief valves (or their equivalents) to automatically prevent a negative pressure differential that would damage the structure. One valve is enough, however, if it is of a design that reasonably precludes it's malfunctioning.

(3) A means by which the pressure differential can be rapidly equalised.

(4) An automatic or manual regulator for controlling the intake or exhaust airflow, or both, for maintaining the required internal pressures and airflow rates.

(5) Instruments at the pilot or flight engineer station to show the pressure differential, the cabin pressure altitude, and the rate of change of the cabin pressure altitude.

(6) Warning indication at the pilot or flight engineer station to indicate when the safe or pre-set pressure differential and cabin pressure altitude limits are exceeded. Appropriate warning markings on the cabin pressure differential indicator meet the warning requirement for pressure differential limits and an aural or visual signal (in addition to cabin altitude indicating means) meets the warning requirement for cabin pressure altitude limits if it warns the flight crew when the cabin pressure altitude exceeds 3048 m (10 000 ft).

(7) A warning placard at the pilot or flight engineer station if the structure is not designed for pressure differentials up to the maximum relief valve setting in combination with landing loads.

(8) The pressure sensors necessary to meet the requirements of sub-paragraphs (b)(5) and (b)(6) of this paragraph and CS 25.1447 (c), must be located and the sensing system designed so that, in the event of loss of cabin pressure in any passenger or crew compartment (including upper and lower lobe galleys), the warning and automatic presentation devices, required by those provisions, will be actuated without any delay that would significantly increase the hazards resulting from decompression.

Appendix 3

Current paragraphs 620.1 to 621.3, 578.1and 229.1 to 229.3 of IAEA SSG-26

620.1. The ambient temperature range of –40°C to 55°C covers the extremes expected to be encountered during air transport and is the range required by the ICAO [11] for packaging any dangerous goods, other than 'dangerous goods in excepted quantities', destined for air transport.

620.2. In designing the containment, the effect of ambient temperature extremes on resultant surface temperatures, contents, thermal stresses and pressure variations should be considered to ensure containment of the radioactive material.

621.1. This is a similar provision to that required by the ICAO [11] for packages containing certain liquid dangerous goods intended for transport by air. This includes the requirement for the package to withstand, without loss or dispersal of radioactive contents from the containment system, a pressure differential of 95 kPa. In the 1996 Edition of the Transport Regulations the provision was expanded to include all forms of radioactive material.

621.2. Pressure reductions due to altitude will be encountered during flight (see para. 578.1). The pressure differential that occurs at an increased altitude should be taken into account in the packaging design. The pressure differential of 95 kPa plus the MNOP (see paras 229.1–229.3) is the pressure differential to be accommodated, without loss or dispersal of radioactive contents from the containment system, by the package designer. This design specification results from a consideration of aircraft depressurization at a maximum civil aviation flight altitude together with any pressure already inside the package, with a safety margin.

621.3. If, within the definition of MNOP, the phrase "conditions of temperature and solar radiation corresponding to environmental conditions" is interpreted to include consideration of conditions specific to air transport (para. 620), then the MNOP does provide a suitable basis for specifying this requirement. If the temperature range contained in para. 620 (–40°C to 55°C) is used, self-heating of the package contents is taken into account, and the solar radiation input is considered to be zero, as the package is inside an aircraft, and hence the MNOP is consistent with the ICAO approach.

578.1. The special conditions of air transport would result in an increased level of hazard in the case of the types of packages described in para. 578. There may be a considerable reduction in ambient air pressure at the cruising altitudes of aircraft. This is partially compensated for by a pressurization system, but that system is never considered to be 100% reliable.

Maximum normal operating pressure

229.1. The maximum normal operating pressure (MNOP) is the difference between the containment system maximum internal pressure and the mean sea-level atmospheric pressure for the conditions specified below.

229.2. The environmental conditions to be applied to a package in determining the MNOP are the normal environmental conditions specified in paras 656 and 657 or, in the case of air transport, in para. 620. Other conditions to be applied in determining the MNOP are that the package is assumed to be unattended for a one year period and that it is subject to its maximum internal heat load.

229.3. A one year period exceeds the expected transit time for a package containing radioactive material; besides providing a substantial margin of safety in relation to routine conditions of transport, it also addresses the possibility of loss of a package in transit. The one year period is arbitrary but has been agreed upon as a reasonable upper limit for a package to remain unaccounted for in transit. Since the package is assumed to be unattended for one year, any physical or chemical changes to the packaging or its contents which are transient in nature and could contribute to increasing the pressure in the containment system need to be taken into account. The transient conditions that should be considered include: changes in heat dissipation capability, gas buildup due to radiolysis, corrosion, chemical reactions or release of gas from fuel pins or other encapsulations into the containment system. Some transient conditions may tend to reduce the MNOP, such as the reduction in pressure with time caused by a decrease in internal heat due to radioactive decay of the contents. These conditions may be taken into account if adequately justified.

APPENDIX D

DRAFT GUIDANCE MATERIAL

Technical Instructions

Part 6

PACKAGING NOMENCLATURE, MARKING, REQUIREMENTS AND TESTS

. . .

Chapter 7

REQUIREMENTS FOR THE CONSTRUCTION, TESTING AND APPROVAL OF PACKAGES FOR RADIOACTIVE MATERIAL AND FOR THE APPROVAL OF SUCH MATERIAL

. . .

7.2   ADDITIONAL REQUIREMENTS FOR PACKAGES TRANSPORTED BY AIR

. . .

7.2.3   Packages containing radioactive material must be capable of withstanding, without loss or dispersal of radioactive contents from the containment system, an internal pressure that produces a pressure differential of not less than maximum normal operating pressure plus 95 kPa.

Note.— The intent of this requirement is to avoid loss or dispersal of radioactive material out of the package during its carriage in an aircraft taking into account of the pressure variation that can be encountered in in the cargo hold of an aircraft. [(see Supplement xxx for further guidance].]

Location of the following text needs to be determined

The normal conditions of flight and the emergency flight conditions are defined in ISO Standard 11242 as follows:

Normal flight conditions: Flight conditions with cabin/cargo compartment pressure decreasing from standard sea level 100 kPa to minimum cruise flight cabin altitude pressure 75 kPa (8000 ft) during climb at minimum rate of 150 Pa/s (2500 ft/min), and increasing back to standard sea level during descent, at minimum rate of 90 Pa/s (1500 ft/mn). Some cargo-only aircraft are designed and operated such that the cargo compartment is not pressurized during flight. For these type of aircraft the normal rate of pressure change experienced by the cargo is the actual rate of aircraft climb and descent which is expected to be greater than the "normal" pressure change provided in the ISO standard 11242.

Emergency (rapid decompression) flight conditions: Cabin/cargo compartment atmosphere dropping linearly from a minimum normal equivalent altitude of 6000 ft, i.e. a maximum normal pressure of 81 kPa in cruise flight, to the standard ambient pressure of 15 kPa at 45000 ft altitude in a duration of 1 s.

The maximum normal operating pressure (MNOP) is at least the gauge pressure developed in the containment system of the package at 55°C (primary receptacle, or intermediate packaging or outer packaging), i.e. the absolute pressure developed in the package at 55°C less 100 kPa.

The differential pressure of MNOP + 95 kPa results from a consideration of aircraft depressurization at a maximum civil aviation flight altitude together with any pressure already inside the package, plus a safety margin.

In the particular case of solid material, in order to comply with Part 6, 7.2.3 other means of demonstration than pressure resistance may be used by the designer of a package design.

If "no loss or dispersal" can be justified when the package is exposed to pressure differential the package design is considered to meet the requirement even if the internal pressure is not maintained.

ICAO-TI Part 1, 3.1: definition of Maximum normal operating pressure (MNOP)

Maximum normal operating pressure. For the transport of radioactive material, the maximum pressure above atmospheric pressure at mean sea level that would develop in the containment system in a period of one year under the conditions of temperature and solar radiation corresponding to environmental conditions in the absence of venting, external cooling by an auxiliary system or operational controls during transport.

ICAO-TI Part 6, 7.2.2:

Packages must be so designed that, if they were exposed to an ambient temperature ranging from -40°C to +55°C, the integrity of containment would not be impaired.

IAEA SSG-26 para

621.3.   If, within the definition of MNOP, the phrase "conditions of temperature and solar radiation corresponding to environmental conditions" is interpreted to include consideration of conditions specific to air transport (para. 620), then the MNOP does provide a suitable basis for specifying this requirement. If the temperature range given in para. 620 (–40°C to 55°C) is used, self-heating of the package contents is taken into account and the solar radiation input is considered to be zero, as the package is inside an aircraft, and hence the MNOP is consistent with the ICAO approach.

— END —