



WORKING PAPER

**DANGEROUS GOODS PANEL (DGP)
WORKING GROUP MEETING (DGP-WG/26)**

Centurion, South Africa, 26 to 30 October 2026

- Agenda Item 2: Managing air-specific safety risks and identifying anomalies (REC-A-DGS-2029)**
2.2: Develop proposals, if necessary, for amendments to the Technical Instructions for the *Safe Transport of Dangerous Goods by Air* (Doc 9284) for incorporation in the 2029-2030 Edition

**AMENDMENT OF SPECIAL PROVISION A225 AND PACKING INSTRUCTION 222
ASSIGNED TO UN 3538 TO ALLOW THE TRANSPORT OF ROBUST ARTICLES
CONTAINING REFRIGERATED LIQUEFIED GAS**

(Presented by T. Muller)

SUMMARY

Under the current *Technical Instructions for the Safe Transport of Dangerous Goods by Air* (Doc 9284), large and robust articles containing refrigerated liquefied non-flammable gases (UN 3538) such as MRI systems are not permitted to be transported under normal conditions of transport. Their transport is permitted on cargo aircraft only, subject to the prior approval of the appropriate authorities of both the State of Origin and the State of the Operator. The safe transport of these systems is supported by a combination of inherent properties, engineered safeguards, and operational experience, including the inert and non-flammable properties of helium; robust cryogenic system design; multiple pressure-relief and pressure-control safeguards; predictable and limited helium venting under normal transport conditions; continuous aircraft ventilation, providing dilution of any released helium; and extensive operational experience demonstrating the performance of MRI systems during air transport. These factors provide multiple independent layers of risk control and limit the potential for helium accumulation and consequential oxygen depletion.

On this basis, the proposed transport conditions and performance requirements could provide an appropriate framework for the safe transport of these medical devices under the normal provisions of the Technical Instructions, without the need for individual approvals from the concerned authorities.

Action by the DGP-WG is in paragraph 4.

1. INTRODUCTION

1.1 Magnetic resonance imaging (MRI) systems are large, robust medical devices used globally for the diagnosis and treatment of patients. As essential medical devices, it is important that MRI systems can be transported and supplied worldwide in a safe, timely, and efficient manner. Reliable global transportation is essential to ensure that healthcare providers can access these devices without unnecessary delays.

1.2 Non-sealed MRI systems require significant quantities of liquefied helium to operate, making helium an integral part of the system. The superconducting wire within the magnet must be maintained at a temperature below approximately 5.0 K (-268.15°C). Helium becomes liquid at approximately 4.2 K at atmospheric pressure, which makes liquid helium suitable for cooling the superconducting magnet and maintaining the required operating temperature.

1.3 During transport, small quantities of helium gas may be released through designated pressure-relief or venting systems. The primary hazard associated with such a release is neither flammability nor toxicity, as helium is an inert and non-flammable gas. However, if helium accumulates in an inadequately ventilated enclosed space, it can displace oxygen and potentially create an oxygen-deficient atmosphere.

1.4 The UN number and proper shipping name that most accurately describe this item are UN 3538, **Articles containing non-flammable, non-toxic gas, n.o.s.** However, under the current Technical Instructions, these articles are not permitted to be transported under normal conditions of transport. Their transport is permitted on cargo aircraft only, subject to the prior approval of the appropriate authorities of both the State of Origin and the State of the Operator.

1.5 It is essential that these medical devices can be supplied globally in a timely and efficient manner without unnecessary delays. Experience to date has demonstrated that these devices can be transported safely when appropriate controls are applied. This working paper therefore proposes the introduction of specific performance requirements to control the associated risks, together with defined transport conditions within the Technical Instructions. The objective is to establish appropriate safety controls that would allow these articles to be transported under the normal framework of the Technical Instructions, without requiring individual approval from the relevant authorities.

2. SAFE TRANSPORT OF MRI DEVICES

2.1 MRI systems differ fundamentally from portable pressure receptacles and tanks designed for the transport of gases as commodities. Portable pressure vessels may be transported hundreds or thousands of times and are routinely emptied, refilled, and returned to service. In contrast, an MRI magnet is typically transported to a specific customer location, where it remains installed for the duration of its useful service life. The helium contained within an MRI system is therefore not transported as a commodity or product. Instead, it forms an integral part of a highly engineered superconducting magnet system. Within the MRI system, helium performs an essential technical function by maintaining the cryogenic temperatures required for superconducting operation. The helium inventory is contained and managed by dedicated pressure-control and safety systems that are integral to the design of the equipment. These systems are specifically designed to control pressure and manage any potential release of helium during the transport and operation of the MRI system.

2.2 Helium possesses a number of characteristics that significantly limit its potential transport hazards:

- a) helium is non-flammable;
- b) helium does not support combustion;
- c) helium is non-toxic;
- d) helium does not undergo self-reactive decomposition;
- e) helium does not produce corrosive by-products; and
- f) helium does not create secondary fire hazards.

The only credible hazard associated with a release of helium is oxygen displacement resulting from the accumulation of sufficient quantities of gas within a confined and inadequately ventilated space. Consequently, the safety assessment for air transport focuses primarily on determining whether a credible helium release could result in significant oxygen depletion within an aircraft cargo compartment or any other occupied area of the aircraft.

2.3 MRI systems are designed in accordance with internationally recognized pressure-vessel and mechanical engineering standards such as the Pressure Equipment Directive (PED) 2014/68/EU and the ASME Boiler & Pressure Vessel Code, Section VIII, Division 1.

2.4 The cryogenic systems used in MRI equipment are robust, highly engineered installations incorporating multiple independent safety layers, including:

- a) vacuum-insulated cryostats;
- b) certified pressure-containing components;
- c) pressure-relief valves;
- d) controlled venting systems;
- e) redundant pressure protection devices.

These systems are specifically designed to safely manage pressure increases resulting from unavoidable heat ingress into the cryostat. Each pressure vessel is pneumatically tested during manufacture to the specified final test pressure and is appropriately marked to demonstrate compliance with the applicable requirements.

2.5 Under normal operating conditions, non-sealed MRI cryogenic systems are maintained at very low internal pressures, typically approximately 30 mbar above ambient pressure. Controlled venting maintains the pressure within this low operating range by releasing small quantities of helium generated through normal boil-off. Maintaining a slight positive pressure within the cryogenic system prevents the ingress of ambient air. This is important because the introduction of air or moisture could contaminate the cryogenic environment and adversely affect system performance. The cryogenic system incorporates redundant pressure-relief valves and an absolute pressure relief valve (APRV) to provide additional

pressure protection and to minimize helium boil-off during flight, including operation at altitude. (see picture Annex II).

2.6 MRI manufacturers routinely conduct extensive design verification, pressure testing, and conformity assessments before placing (new) equipment into service. The cryogenic vessel and associated safety systems are therefore subject to a significantly higher degree of engineering control than many conventional dangerous goods packages.

2.7 MRI systems transported under normal conditions exhibit highly predictable and relatively consistent helium losses. Small quantities of helium continuously evaporate as a result of unavoidable heat ingress into the cryostat. This phenomenon, commonly referred to as boil-off, is a normal and inherent characteristic of cryogenic systems. The rate of helium venting varies depending on the design and model of the magnet. It can be in the range of 1.0 – 6.5 liquid liters of helium per hour. These releases occur as part of the normal operation of the cryogenic system and are managed through the system's controlled venting and pressure-control arrangements.

2.8 The principal safety question is whether the expected helium release from an MRI system could accumulate within an aircraft cargo compartment to a level capable of causing hazardous oxygen depletion. This risk can be assessed quantitatively by comparing the maximum credible helium venting rate of the MRI system with the ventilation rate and effective volume of a representative aircraft cargo compartment. This comparison provides a basis for determining whether the expected helium release could result in a significant reduction in oxygen concentration under credible transport conditions.

At the highest expected boil-off condition, the MRI system vents approximately 6.5 liquid litres of helium per hour. When converted to its equivalent gaseous volume at standard conditions, this corresponds to approximately 4.69 m³ of helium gas per hour.

For illustrating the relationship between the helium release rate and aircraft ventilation capacity, a representative cargo aircraft ventilation rate of approximately **3900 m³ per hour** has been used. On this basis, the available ventilation flow would be approximately:

$$3900 \div 4.69 \approx 831 \text{ times the maximum helium gas generation rate.}$$

This calculation is provided as a representative example only. Aircraft cargo-compartment volumes, ventilation rates, air-exchange characteristics, and ventilation configurations vary between aircraft types and may also depend on the specific aircraft configuration and operating conditions. The calculated dilution factor should therefore not be considered universally applicable to all cargo aircraft.

Expressed differently, the helium released at the maximum venting rate would represent approximately 0.12% of the assumed hourly ventilation flow. This comparison indicates that, for the representative aircraft considered, the continuous ventilation capacity provides substantial dilution of the expected helium release and significantly limits the potential for helium accumulation within the cargo compartment.

Based on the maximum venting rate and the assumed ventilation capacity for this representative aircraft example:

- **Hazardous oxygen depletion is not expected under the assessed conditions**, as the aircraft ventilation capacity is approximately **831 times greater than the maximum helium gas generation rate**.
- **Significant accumulation of helium is not expected under the assessed conditions**, as the helium release represents only approximately **0.12% of the estimated hourly ventilation flow**.

The safety case is therefore primarily based on the controlled release of helium and its subsequent dilution through aircraft ventilation. The numerical comparison demonstrates that, for the representative aircraft and assumptions used in this assessment, even at the highest expected normal venting rate, the available ventilation capacity substantially exceeds the helium gas generation rate, providing a significant margin between the helium release rate and the ventilation capacity.

2.9 A particularly important consideration is the substantial history of safe operation and transportation of MRI systems containing liquid helium. Such systems have been transported internationally by air for several decades under the UN 1963 **Helium, refrigerated liquid** entry. This extensive operational experience provides valuable evidence regarding the behaviour of MRI cryogenic systems under actual transportation conditions. It complements the engineering and quantitative assessments described above by demonstrating how these systems perform in real-world air transport, rather than relying solely on theoretical assumptions. The accumulated operational experience indicates that:

- a) the cryogenic systems perform as designed during transportation;
- b) helium releases associated with normal boil-off remain controlled and predictable;
- c) aircraft cargo ventilation provides effective dilution of released helium; and
- d) no recurring or systemic safety issue associated with the transport of these MRI systems has been identified that would indicate a need for additional operational controls.

The longstanding record of successful transport operations, together with the inherent engineering controls and quantitative assessment of helium release and ventilation, provides supporting evidence that the residual risk associated with the air transport of non-sealed MRI systems can be effectively controlled.

2.10 From a risk-management perspective, the safe transport of non-sealed MRI systems is supported by a combination of inherent properties, engineered safeguards, and operational experience, including:

- a) the inert and non-flammable properties of helium;
- b) robust cryogenic system design incorporating multiple layers of protection;
- c) multiple pressure-relief and pressure-control safeguards;

- d) predictable and limited helium venting under normal transport conditions;
- e) the relatively large volume of aircraft cargo compartments;
- f) continuous aircraft ventilation, providing dilution of any released helium; and
- g) extensive operational experience demonstrating the performance of MRI systems during air transport.

Taken together, these factors provide multiple independent layers of risk control and limit the potential for helium accumulation and consequential oxygen depletion during air transport.

2.11 Taken collectively, these factors demonstrate that MRI systems containing refrigerated liquefied helium can be transported by air under controlled conditions while achieving a level of safety consistent with the objectives of the Technical Instructions for the transport of dangerous goods aboard cargo aircraft. The combination of inherent helium properties, robust cryogenic system design, multiple independent safety safeguards, predictable venting behaviour, aircraft ventilation, and extensive operational experience provide an effective basis for controlling the associated risks. On this basis, the proposed transport conditions and performance requirements could provide an appropriate framework for the safe transport of these medical devices under the normal provisions of the Technical Instructions, without the need for individual approvals from the concerned authorities. This would avoid the additional administrative steps and potential delays associated with obtaining such approvals, thereby facilitating the timely and efficient global distribution of these essential medical devices.

3. PROPOSED CHANGES TO THE TECHNICAL INSTRUCTIONS

3.1 This working paper proposes an amendment to Special Provision A225 to remove the exclusion applicable to refrigerated liquefied gases when they are contained as an integral part of large and robust articles.

3.2 This working paper also proposes an amendment to Packing Instruction 222 to introduce performance-based requirements and defined conditions for the transport of large and robust articles containing refrigerated liquefied gases allowing them to be transported under the applicable conditions established within the Technical Instructions without requiring individual approval from the authorities of the States concerned.

4. ACTION BY THE DGP-WG

4.1 The DGP-WG is invited to:

- a) consider the proposals to amend the Technical Instructions as shown in Appendix A to this working paper; and

- b) discuss if the proposals should be limited to MRIs containing Helium, refrigerated liquid or should be extended to all robust articles containing non-flammable refrigerated liquefied gases.

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APPENDIX A

PROPOSED AMENDMENTS TO THE TECHNICAL INSTRUCTIONS

Part 3

DANGEROUS GOODS LIST, SPECIAL PROVISIONS AND LIMITED AND EXCEPTED QUANTITIES

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Chapter 3

SPECIAL PROVISIONS

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A225

UN 3538 – **Articles containing non-flammable, non-toxic gas, n.o.s.** may be transported on passenger and cargo aircraft irrespective of the indication of “forbidden” in columns 10 to 13 of Table 3-1, provided that:

- a) with the exception of lithium cells or batteries and sodium ion cells or batteries that comply with Section II of Packing Instruction 967, Section II of Packing Instruction 970 or Section II of Packing Instruction 978, as applicable, the only dangerous goods contained in the article is a Division 2.2 gas without a subsidiary hazard, but excluding refrigerated liquefied gases and gases forbidden for transport on passenger aircraft;
- b) the articles are packed in accordance with Packing Instruction 222; and
- c) reference to Special Provision A225 is made on the dangerous goods transport document as required by Part 5;4.1.5.8.

Large and robust articles such as magnetic resonance imaging (MRI) scanners containing refrigerated liquified gases of Division 2.2 as an integral part of the system may be transported on cargo aircraft only irrespective of the indication of “forbidden” in column 13 of Table 3-1 provided that:

- a) with the exception of lithium cells or batteries that comply with Section II of Packing Instruction 967 or Section II of Packing Instruction 970, as applicable, the only dangerous goods contained in the article is the cryogenic liquid of Division 2.2 without a subsidiary hazard;

Editorial Note.— The following provision is in line with a new special provision (SP 414) that will appear in the 25th revised edition of the UN Model Regulations.

- b) the articles must be able to withstand all conditions to which they will be subjected during normal conditions of transport and must comply with all the requirements of Packing Instruction 222; and
- c) reference to Special Provision A225 is made on the dangerous goods transport document as required by Part 5;4.1.5.8.

All other provisions of these Instructions apply. If the above conditions are met, the requirements of Special Provision A2 do not apply.

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Part 4

PACKING INSTRUCTIONS

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Chapter 4

CLASS 2 – GASES

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4.2 PACKING INSTRUCTIONS

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Packing Instruction 222

Passenger and cargo aircraft for UN 3538 only

Introduction

This packing instruction is only permitted for articles which do not have an existing proper shipping name and which contain only gases of Division 2.2 without a subsidiary hazard, but excluding refrigerated liquefied gases (with the exception of large and robust articles such as MRI scanners allowed on cargo aircraft only) and gases forbidden for transport on passenger aircraft, where the quantity of the Division 2.2 gas exceeds the quantity limits for UN 3363 as prescribed in Packing Instruction 962. In addition to the Division 2.2 gas, the article may also contain lithium metal, lithium ion or sodium ion cells or batteries that comply with Section II of Packing Instruction 967, Section II of Packing Instruction 970 or Section II of Packing Instruction 978, as applicable. Cells or batteries identified as being damaged or defective in accordance with Special Provision A154 are forbidden for transport.

General requirements

Part 4;1.1.1, 4;1.1.3, 4;1.1.12 and 4;2 requirements must be met.

UN number and proper shipping name		Maximum net quantity of gas – passenger	Maximum net quantity of gas – cargo
UN 3538	Articles containing non-flammable, non-toxic gas, n.o.s.*	75 kg	150 kg
UN 3538	Articles containing non-flammable, non-toxic gas, n.o.s.*, refrigerated liquefied gases only	Forbidden	[500 kg]

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ADDITIONAL PACKING REQUIREMENTS FOR LARGE AND ROBUST ARTICLES CONTAINING REFRIGERATED LIQUEFIED GASES

Cargo aircraft only

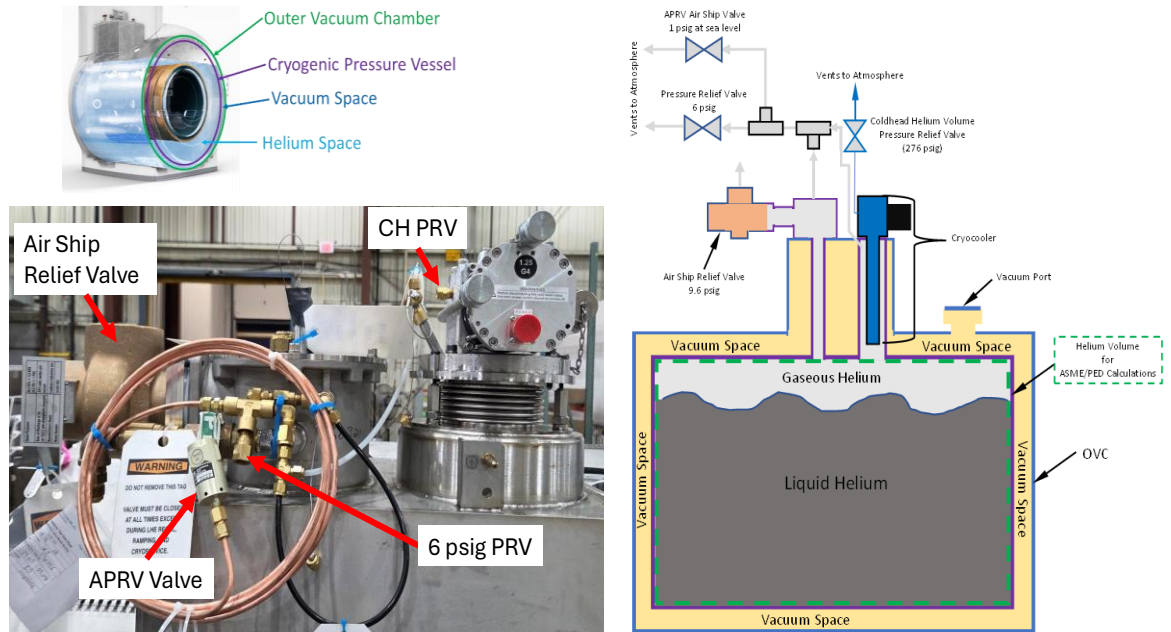
- Receptacles within articles containing refrigerated liquefied gases must meet the requirements of 4;4.1.1 and 6;5 as appropriate or meet a national or regionally recognized pressure receptacle standard such as the European Pressure Equipment Directive (2014/68/EU) or ASME Boiler & pressure Vessel Code Section VIII, Division 1 that is capable of providing an equivalent level of protection as Packing Instructions 202.
- Cryogenic receptacles must have a reclosing pressure relief device (absolute pressure relief valve) having a set to discharge pressure not exceeding [17 psia] or [as alternative a reference to these Instructions: "Pressure relief devices must meet the requirements of 6;5.1.3.6.4 and 6;5.1.3.6.5"]
- Maximum venting of [6.5 L cryogenic liquid / Helium] per hour.

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APPENDIX B

MRI Air Transport Configuration



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