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# FREIGHT CONTAINERS AS IP-2 PACKAGINGS

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**Abstract** — A range of standard freight containers has been designed and manufactured to meet the needs of users and the requirements of the 1985 Edition of the IAEA Regulations for the Safe Transport of Radioactive Material for Industrial Packages. The development of freight containers as IP-2 Packagings (Industrial Package Type 2) is described.

## INTRODUCTION

In 1987, as a result of a major programme of improvements in the method of disposal of low level waste (LLW) at the Drigg site in Cumbria, British Nuclear Fuels plc (BNFL) introduced the requirement for containerisation of all LLW to be consigned to Drigg for disposal. Such LLW does not normally require to be shielded during normal handling and transport. Special freight containers were developed, initially, for the transport of this LLW to Drigg for disposal.

The advantages offered by the use of freight containers for the transport, handling and disposal of large volume consignments of both low specific activity (LSA) and surface contaminated objects (SCO) material within the UK were subsequently recognised. The benefits were that they could be manufactured economically and could be handled and transported using well developed systems. Freight containers are relatively low cost items, this being due primarily to the large number produced for dry cargo shipment of non-radioactive goods, and the well established and standardised manufacturing methods employed.

Economic arguments indicated that the largest packagings that could be used within dimensional and weight constraints were preferred, to maximise on the benefits offered by this type of container for the handling and transport of bulk LSA/SCO materials. Design specifications were developed for freight containers, to meet both user requirements and the IAEA Regulations for the Safe Transport of Radioactive Material, Safety Series No 6 (SS6)[1].

The publication of the 1985 Edition of the Transport Regulations[1] introduced performance requirements for packagings used to transport LSA and SCO materials. These materials, which under the 1973 Edition of IAEA Safety Series No 6[2] could be transported in simple packaging (such as drums or boxes), were now required to be carried within tested and approved packagings identified as Industrial Packages Type 1, 2 or 3.

When freight containers were introduced in 1987, for the transport and disposal of LLW, either the 1973 Revised Edition (As amended) or the 1985 Edition of the IAEA Transport Regulations could be used in the UK. Initially, freight containers were designed and manufactured to comply with the requirements for a Strong Industrial Package, which under the 1973 Edition of the Transport Regulations, included the requirement for retention of contents following performance tests. With the introduction of the 1985 Edition of the transport regulations, freight containers were required to be designed to comply with the more onerous performance requirements for Industrial Package Types 1, 2 and 3.

## REGULATORY REQUIREMENTS

Under the 1985 Edition of the IAEA transport regulations, LLW is generally classified as Low Specific Activity (LSA) material or Surface Contaminated Objects (SCO). LSA material by virtue of its nature has a limited specific activity; for LSA-II the average specific activity for solid material must not exceed $10^{-4}$ $A_2$ per g, and for LSA-III solids it must not exceed $2 \times 10^{-3}$ $A_2$ per g. For SCO, which is a solid object and which is not itself radioactive but has radioactive material distributed on its surface, limits for fixed and non-fixed contamination are defined in the Regulations.

Under 'exclusive use' transport the packaging standard required is Industrial Package Type 2 (IP-2). The 1985 Edition of the IAEA Transport regulations specify a performance standard, in terms of package testing and containment criteria, that is generally more onerous than that specified in the earlier 1973 Edition of the IAEA Transport regulations for the same radioactive contents. The main requirements for an IP-2 package are that it shall protect against the loss or dispersal of the radioactive contents and loss of shielding under routine and normal conditions of transport (including minor mishaps).

## PERFORMANCE STANDARDS

In the 1985 Edition of the IAEA Transport regulations, performance standards (which include design and test requirements) are specified for an IP-2 package. These requirements are intended to ensure that packages would not be significantly affected by the conditions which are likely to be encountered in both routine transport and normal conditions of transport including minor mishaps. For IP-2 packages, specific design requirements are stated (IAEA SS6 para 134):

(i) for a package (other than a tank or freight container),
(ii) for a tank, and
(iii) for a freight container.

In the early stages of the development of the special freight containers and prior to the introduction of the 1990 Amendments, there were interpretational difficulties with the 1985 Edition of the IAEA Transport Regulations. The main difficulty arose in the application of para 523 which is specific to freight containers. Within para 523 it is stated that freight containers may be classified as IP-2 provided that they satisfy the design and test requirements of ISO 1496/1-1978[3]. However, within these ISO tests no specific containment criteria were specified, although there is a water spray test specified in the ISO tests (1496/1-1978) which is regarded as a rainwater in-leakage test and not a containment test. The omission of containment criteria was clearly at variance with the intent and philosophy of the regulations for this standard of packaging. Also, due to this anomaly, further unrelated concerns were raised as to the equivalence of the test conditions of the ISO tests (which are static tests) compared to the dynamic drop tests required for other industrial packages (excluding freight and tank containers).

The 1990 Amendment to the IAEA Transport Regulations included revisions to para 523 that provided for a containment criterion of 'no loss or dispersal' of the radioactive contents; this was the only change to paragraph 523.

The following IAEA regulatory requirements as defined in Paragraph 523 are adopted in the UK for IP-2 Freight Containers.

(1) Packages must meet the general requirements for all packagings and packages.
(2) Packages must be designed to conform to the requirements prescribed in the International Standard ISO 1496/1.
(3) When subjected to the tests in ISO 1496/1, packages must prevent:
    (a) loss or dispersal of the radioactive contents, and
    (b) loss of shielding which would result in more than a 20% increase in radiation levels.

## CONTAINMENT STANDARD

The containment standard specified for IP-2 packages (and for Type A packages) in the 1985 Edition of the IAEA Transport Regulations is that of 'no loss or dispersal' which has never been defined quantitatively in the regulations. The intent of the IAEA Transport Regulations in specifying a containment criterion for IP-2 packages, is to ensure that under normal conditions of transport the radioactive contents of the package cannot escape in sufficient quantities to create a radiological hazard.

In determining a practical and acceptable containment criterion for the IP-2 freight containers, due account was taken of the spirit of the IAEA Transport Regulations, guidance provided by the Advisory Material (Safety Series 37 — 1985 Edition)[4], and the advice of the UK Competent Authority. The IAEA Transport Regulations provide for comparable levels of safety for radioactive materials, of different radiotoxicities and different amounts, by relating the nature and amount of contents with graded packaging integrity requirements. The Explanatory Material (IAEA Safety Series No 7 paragraph E-519.1)[5] states that 'Release of contents considerations for IP-2 packages impose a containment function by the packaging for normal conditions of transport'. The Regulations also recognise that some simplification is possible with regard to containment standard for IP packagings, due to the nature of the LSA or SCO contents, as compared to the standard for Type A packagings that can contain an activity up to $A_2$ (not as special form radioactive material). The maximum activity of an IP package is limited by the package weight and allowable specific activity: for an ISO container carrying 20 tonnes of LSA-III material as waste, the activity limit is $40 \times 10^3$ $A_2$.

For small quantities of radioactive material (i.e. $< A_2$) within the Type A limits, that in slightly larger quantities would require a Type B package, the containment standard for the containment vessel is commonly taken to be that specified for normal conditions of transport of Type B packages. A Type B package can contain an activity in excess of $A_2$ (not as special form radioactive material). This containment standard is usually demonstrated by a gas leaktightness test at all the verification stages: that is Design (Prototype testing), Fabrication (Manufacture), Assembly (pre-shipment) and Periodic.

In the UK, it is accepted by the Competent Authority (Department of Transport) that solid particulate material would not be expected to leak from a seal having a gas leaktightness of $5 \times 10^{-4}$ bar.cm$^3$.s$^{-1}$ SLR[6]. The acceptance, of this level of gas leaktightness does not apply to specially produced fine powders, but in practice no such radioactive powders are produced. A capillary of 12 $\mu$m diameter and of 2 mm length has a gas leakage rate of $5 \times 10^{-4}$ bar.cm$^3$.s$^{-1}$ SLR: this leakage rate being that accepted in the UK as providing absolute containment for fine powders in relatively free form.

For Type A packages, leaktightness of the containment vessel is usually demonstrated by leakage tests performed at the Design, Fabrication and Periodic stages only. Design verification is carried out by leakage tests before and after testing of prototypes. Fabrication verification tests are carried out on manufacture to the same standard as Design verification. Periodic verification tests are carried out on maintenance after periods specified at the design stage and to the same standard as Design verification. Assembly verification of the containment system after loading the radioactive content is assured by operational checks and controls, and normally no actual leakage tests are performed.

In determining a containment standard for IP-2 packagings the general approach described above for Type A packagings was considered to be appropriate, but it was recognised that some simplification from that adopted for Type A packaging was possible within the spirit of the Regulations.

An important further consideration, is that the 1985 Edition of the IAEA Transport Regulations emphasises the application of effective quality assurance and compliance assurance programmes to achieve safety of both the public and transport workers with respect to the transport of radioactive material.

In essence, the Regulatory requirements are directed at the shipper, who is required to ensure that the package presented for transport will meet all the package design requirements, and specifically that the construction methods and materials used are in accordance with the design specification, and that all packagings are built to an approved design and periodically inspected, repaired and maintained in good condition so that they continue to comply with all relevant requirements and specifications, even after repeated use.

The 1985 Edition of the IAEA Transport Regulations advise (Ref IAEA SS37 Appendix IV[(4)]) that the Quality Assurance programmes should be commensurate with the complexity of the packaging and its components, and the degree of hazard associated with the contents that may be carried: to this effect a system of grading packages or components of packages is defined, where the grade relates to the safety significance of the package or component. For IP-2 and IP-3 packagings, features affecting containment and shielding integrity are specified to be subject to Grade 1. The grading required for containment for an IP-2 package is the same as that required for Type A and Type B packages.

To meet the requirements of the 1985 Edition of the IAEA Transport Regulations, and in particular the Quality Assurance requirements, verification of the containment standard is required at the stages of Design (Prototype Testing), Fabrication (Manufacture), Assembly (pre-shipment) and Periodically (normally annually in the UK but may be longer when justified) for reusable containers.

These stages of verification are seen as commensurate with the Grade and are consequently being used for the IP-2 freight containers designed to meet the 1985 Edition of the IAEA Transport Regulations.

## CONTAINMENT PERFORMANCE

The Advisory Material IAEA Safety Series 37, 1985 Edition advises (Para A548.1 to A548.15 and A617.6) that it is difficult to suggest a single containment test method due to the wide range of packagings and contents. However, it is suggested that a qualitative approach which involves testing, may be employed for IP and Type A packages. A method suggested for solid contents in particular, involves the measurement of pressure rise or drop under some type of vacuum or pressure test. A simple bubble test is suggested for gaseous contents[(4)].

In determining a design basis for IP-2 freight containers, and recognising that a qualitative approach must have a quantitative pass/fail criterion described, it was seen as appropriate that the containment standard should be expressed as a gas leakage rate and that this should be verified at the appropriate stages.

In determining an appropriate gas leakage rate the following factors were considered:

(i) what containment standard is appropriate for the form of the contents (i.e. LSA/SCO which, it is recognised, affords a degree of inherent safety),
(ii) what is practically achievable for large volume containment vessels,
(iii) what test method and test sensitivity is achievable in relation to practical manufacturing methods, and
(iv) some relaxation from the Type A (normal conditions for Type B) containment test criteria.

In arriving at a practically achievable test method and containment standard expressed as a leakage rate, an extensive test programme was carried out involving gas leakage testing and soap bubble testing of prototype freight containers. During the test programme a mass spectrometer was used to detect helium gas leaking from a pressurised freight container.

The development work performed concluded that a containment standard of around $10^{-1}$ bar.cm$^3$.s$^{-1}$ SLR, for individual leaks, was achievable in the manufacturing environment. It was also concluded that this leaktightness could be readily reproduced, did not impose significant constraints on the design of IP-2 freight containers and could, if required, be practically achieved and demonstrated at all stages of verification. Experience showed that all containment welds on the specially constructed freight containers could be readily leak tested to this standard. The development work provided useful information relating to the design of nominally leaktight freight containers. In particular, it was determined that it is necessary to ensure that all containment welds are accessible and are visible from outside the container. As a further development, a soap bubble technique using air as the test medium was found to offer comparable results. In practice, the containers are pressurised and all seal welds are coated with soap solution; the presence of air bubbles indicates defects. As the latter technique was easier and cheaper to perform, it was therefore adopted for the leakage testing of all production units of IP-2 freight containers.

A gas leakage rate of $10^{-1}$ bar.cm$^3$.s$^{-1}$ SLR is equivalent to a single capillary of about 40 μm diameter and of length of 2 mm (freight container wall thicknesses are nominally 3 mm). Because of the extremely small size of the leakage path, having a gas leakage rate of

$10^{-1}$ bar.cm$^3$.s$^{-1}$ SLR, it was considered unlikely to be the cause of powder leakage from freight containers because:

(i) there is virtually no driving pressure for leakage;
(ii) the radioactive material is not concentrated powders but powder mixed (diluted) with a spectrum of non-radioactive materials;
(iii) the formation of aerosols containing radioactive material was considered to be unlikely due to the absence of significant mechanisms for making any radioactive powders airborne, and because of the nature of the contents.

The closure systems of the IP-2 freight containers described above, are so designed that the containment standard of the closure seals can be verified independently of the container body. This is achieved by the use of a seal design that can be independently leak tested.

The arrangement currently in use consists of two elastomeric seals separated by an interspace. The resultant interspace volume can be pressurised and the pressure drop recorded over a period of time. This provides a measurement of the leakage rate of the seals. As this technique provides a measure of the aggregated leakage rate for the seals (i.e. not individual leaks), a relaxation of a factor of 10 was adopted, resulting in an acceptance containment standard of 1 bar.cm$^3$.s$^{-1}$ SLR.

Filtered vents are provided on 'larger' containers to allow for changes in ambient temperature and pressure.

## DESIGN SPECIFICATION

As a result of the considerations on meeting the performance requirements for IP-2 freight containers, as required by the 1985 Edition of the IAEA Transport Regulations for freight containers, the following generic design specification has been adopted:

(1) Containment vessels to be designed and tested to meet the requirements of ISO 1496/1.
(2) Containment vessels to be fabricated in steel and continuously seal welded.
(3) Closures (e.g. lid or door) to be fabricated from steel and be of a seal welded construction.
(4) Elastomeric seals to be used between the containment vessels and closure system.
(5) Closure seal should be designed to be leak testable by the gas pressure drop test, by use of double seals with an interspace volume.
(6) Containment vessels (including lid or door) to be accessible to enable leak tests by the soap bubble method.
(7) Internal tie-down arrangements to be provided for contents.

## DEMONSTRATION OF CONTAINMENT PERFORMANCE

To demonstrate compliance with the advice given by the IAEA regulations and to ensure that the containment performance requirements described above are achieved:

(1) Freight container closures are designed with double elastomer seals which allow for the gas leak testing of both the containment vessels and closure seals at all appropriate stages.
(2) The containment standard is usually verified at the following stages:
 (a) Design (prototype testing).
 (b) Fabrication (manufacture).
 (c) Assembly (pre-shipment).

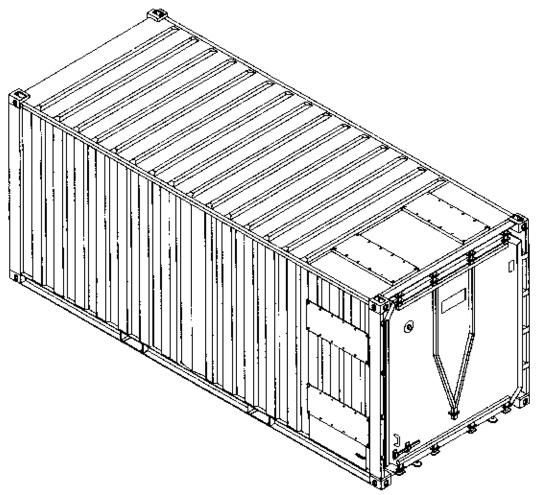

Figure 1. Reusable single end door container (6 m × 2.4 m × 2.6 m).

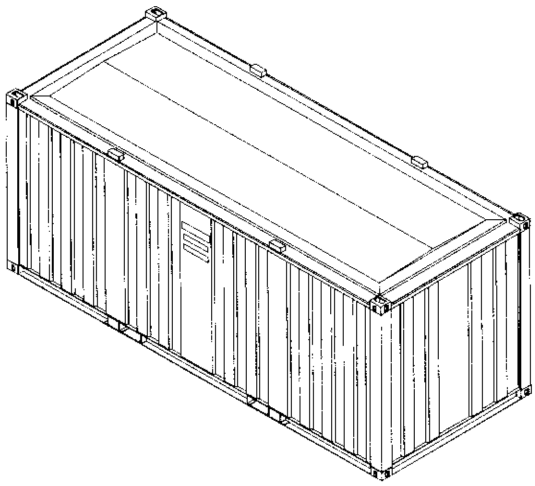

Figure 2. Top opening container (6 m × 2.4 m × 2.5 m).

assured by operational checks and controls, and normally no actual leakage tests are performed.

In determining a containment standard for IP-2 packagings the general approach described above for Type A packagings was considered to be appropriate, but it was recognised that some simplification from that adopted for Type A packaging was possible within the spirit of the Regulations.

An important further consideration, is that the 1985 Edition of the IAEA Transport Regulations emphasises the application of effective quality assurance and compliance assurance programmes to achieve safety of both the public and transport workers with respect to the transport of radioactive material.

In essence, the Regulatory requirements are directed at the shipper, who is required to ensure that the package presented for transport will meet all the package design requirements, and specifically that the construction methods and materials used are in accordance with the design specification, and that all packagings are built to an approved design and periodically inspected, repaired and maintained in good condition so that they continue to comply with all relevant requirements and specifications, even after repeated use.

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To meet the requirements of the 1985 Edition of the IAEA Transport Regulations, and in particular the Quality Assurance requirements, verification of the containment standard is required at the stages of Design (Prototype Testing), Fabrication (Manufacture), Assembly (pre-shipment) and Periodically (normally annually in the UK but may be longer when justified) for reusable containers.

These stages of verification are seen as commensurate with the Grade and are consequently being used for the IP-2 freight containers designed to meet the 1985 Edition of the IAEA Transport Regulations.

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In determining a design basis for IP-2 freight containers, and recognising that a qualitative approach must have a quantitative pass/fail criterion described, it was seen as appropriate that the containment standard should be expressed as a gas leakage rate and that this should be verified at the appropriate stages.

In determining an appropriate gas leakage rate the following factors were considered:

(i) what containment standard is appropriate for the form of the contents (i.e. LSA/SCO which, it is recognised, affords a degree of inherent safety),
(ii) what is practically achievable for large volume containment vessels,
(iii) what test method and test sensitivity is achievable in relation to practical manufacturing methods, and
(iv) some relaxation from the Type A (normal conditions for Type B) containment test criteria.

In arriving at a practically achievable test method and containment standard expressed as a leakage rate, an extensive test programme was carried out involving gas leakage testing and soap bubble testing of prototype freight containers. During the test programme a mass spectrometer was used to detect helium gas leaking from a pressurised freight container.

The development work performed concluded that a containment standard of around $10^{-1}$ bar.cm$^3$.s$^{-1}$ SLR, for individual leaks, was achievable in the manufacturing environment. It was also concluded that this leaktightness could be readily reproduced, did not impose significant constraints on the design of IP-2 freight containers and could, if required, be practically achieved and demonstrated at all stages of verification. Experience showed that all containment welds on the specially constructed freight containers could be readily leak tested to this standard. The development work provided useful information relating to the design of nominally leaktight freight containers. In particular, it was determined that it is necessary to ensure that all containment welds are accessible and are visible from outside the container. As a further development, a soap bubble technique using air as the test medium was found to offer comparable results. In practice, the containers are pressurised and all seal welds are coated with soap solution; the presence of air bubbles indicates defects. As the latter technique was easier and cheaper to perform, it was therefore adopted for the leakage testing of all production units of IP-2 freight containers.

A gas leakage rate of $10^{-1}$ bar.cm$^3$.s$^{-1}$ SLR is equivalent to a single capillary of about 40 μm diameter and of length of 2 mm (freight container wall thicknesses are nominally 3 mm). Because of the extremely small size of the leakage path, having a gas leakage rate of

(d) Periodic (maintenance).

Gas leakage testing provides an objective and verifiable method of demonstrating the containment standard at the appropriate stages:

(1) Design verification. The containment standard for the containment vessel and seals is demonstrated before and after the ISO tests as prescribed in ISO 1496/1. The containment standard of the closure seals is also demonstrated during the ISO racking tests.
(2) Fabrication verification. Each ISO freight container is leak tested during manufacture.
(3) Assembly verification. This is provided by the combination of fabrication verification and written procedures. If repair of the closure system is required after manufacture, the double seals enable leakage tests to be carried out to ensure that the repair is satisfactory.
(4) Periodic verification. On re-usable containers the containment standard of both the containment vessel and seals are verified annually.
(5) Leaktightness levels, currently adopted are: $10^{-1}$ bar.cm$^3$/s$^{-1}$ SLR for containment vessel (individual leaks detected) and 1 bar.cm$^3$.s$^{-1}$ SLR for closure seals (aggregated leaks detected).

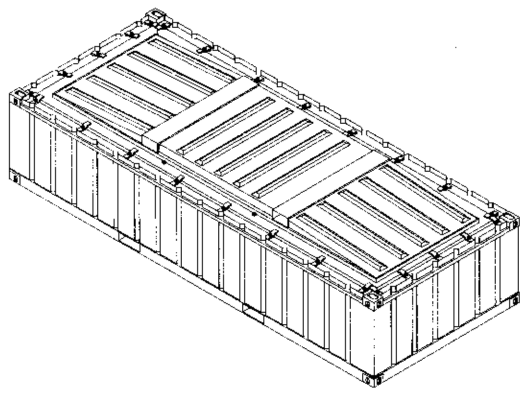

Figure 3. Top opening disposal container (6 m × 2.4 m × 1.2 m).

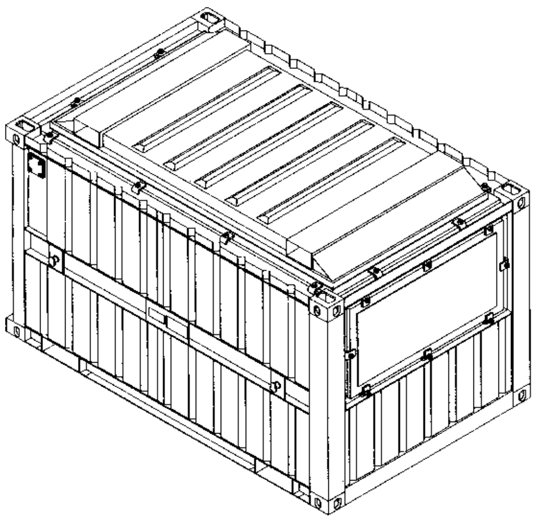

Figure 4. Combined top and end opening container.

## FREIGHT CONTAINER DESIGNS

A range of IP-2 freight container designs has been developed and manufactured, based on a range of standard sizes, in accordance with the above Design Specification.

The IP-2 freight container designs developed are of two broad generic types: top lid and single end door designs (Figures 1 and 2) although, designs have also been produced which feature both top and end closures in a single container.

The width of the freight containers are normally at 8 ft (2.43 m) or 8 ft 2 in (2.5 m), although some designs have been produced with widths outside of these sizes.

Freight containers with a single end door are manufactured in lengths of 10 ft, 20 ft and 40 ft (3 m, 6 m and 12 m) and are of a height of 8 ft 6 in (2.6 m).

Freight containers with a top lid are manufactured in lengths of 10 ft and 20 ft (3 m and 6 m) and are of heights ranging from 4 ft to 8 ft 6 in (1.2 m and 2.6 m).

Figures 3 and 4 are by courtesy of British Nuclear Fuels plc.

## CONCLUSION

Freight containers within the UK are used as IP-2 packagings for the transport of Low Specific Activity material (LSA-II/III) and Surface Contaminated Objects (SCO-II), which is either drummed or contained within loose wrapped material, and for the transport and disposal of unpackaged LLW as solid LSA and SCO.

A range of IP-2 freight containers has been designed and built, to the above design specification and is in use in the UK. Over 2000 units have been manufactured to date. The range of containers consist of top lid designs, single end door designs, and designs which include combinations of end and top openings. Container lengths range from 3 m (10 ft) to 12 m (40 ft), widths of 2.43 m (8 ft) and 2.5 m (pallet wide), and heights from 1.2 m (4 ft) to 3.6 m (12 ft).

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