

Project Specification

This section comprises a model specification for the *Kingspan KoolDuct® System* of pre-insulated ductwork. Whilst reasonably comprehensive, this specification may not address all related subjects to the level of detail required. Nevertheless, it can be modified as required for use as the basis for an actual project specification in accordance with applicable project drawings and specifications.

The format of this specification is such that the universal provisions as laid out at the outset, make reference to the subsequent Appendices which relate to specific regional requirements, these regions being:

UK & Ireland (Appendix A)



Australia (Appendix B)



Middle East (Appendix C)



North America (Appendix D)



1 General

- 1.1 When pressure / leakage testing is known to be necessary, the ductwork system shall be designed to the testing pressure.
- 1.2 The contractor shall include for the manufacture, fabrication, supply, delivery and installation of materials necessary for the ductwork systems described in this specification.
- 1.3 All materials and finishes shall be free from defects and maintained in good condition throughout the duration of the works.
- 1.4 The materials used in the fabrication of ductwork from the *Kingspan KoolDuct® System* shall be inherently proof against rotting, mould, fungal growth and attack by vermin, be non-hygroscopic and in all respects be suitable for continuous use throughout the range of operating temperatures and within the environment indicated.
- 1.5 Any works of unacceptable standard shall be removed and replaced at no cost to the contract.
- 1.6 The fabrication and installation of ductwork fabricated from the *Kingspan KoolDuct® System* shall be carried out by a fabricator and installer that has successfully completed a specialist training course provided by Kingspan Insulation Ltd. The contractor shall fully acquaint itself with all the site conditions and programme of works and shall execute its works within such confines and programme. A list of registered fabricators and installers can be obtained from Kingspan Insulation Ltd.
- 1.7 Insulation material containing CFC's or HCFC's shall not be accepted.

2 Scope of Works

Unless otherwise indicated, the *Kingspan KoolDuct® System* is suitable for use in the following applications:

- a. warm air ventilation distribution ductwork (insulated to suit temperatures);
- b. air conditioning distribution ductwork (insulated to suit temperatures and vapour sealed);
- c. fresh air intake ductwork to plant (insulated to suit temperatures and vapour sealed);
- d. ductwork returning air to plant (insulated to suit temperatures);
- e. ductwork exposed in external locations (with an additional weatherproof finish); and
- f. ductwork for room temperature non-chemical exhaust.

3 Materials

- 3.1 The panels used in the fabrication of ductwork from the *Kingspan KoolDuct® System* shall be *Kingspan KoolDuct®* rigid phenolic insulation panels of nominal dimensions 2950 mm x 1200 mm / 9.68 ft x 3.94 ft or 3930 mm x 1200 mm / 12.89 ft x 3.94 ft and minimum compressive strength 200 kPa / 29 psi, as manufactured by Kingspan Insulation Ltd and detailed in App. A1 / B1 / C1 / D1 (delete as applicable) of this specification.
- 3.2 *Kingspan KoolDuct®* rigid phenolic insulation panels shall comprise a 55–60 kg/m³ / 3.4–3.75 pcf nominal density CFC/HCFC-free rigid phenolic insulation core with zero Ozone Depletion Potential (ODP), autohesively bonded on both sides to a 25 micron / 1 mil low vapour permeability aluminium foil facing reinforced with a 5 mm / 0.2" glass scrim.
- 3.3 *Kingspan KoolDuct®* rigid phenolic insulation panels are available in thicknesses of 22 mm / 7/8", 30 mm 13/16" and 33 mm / 15/16". For determination of the thickness required to achieve a specified thermal performance refer to App. A2 / B2 / C2 / D2 (delete as applicable) of this specification.
- 3.4 All other components required for the fabrication of ductwork from the *Kingspan KoolDuct® System* including the silicone sealant, contact adhesive, aluminium tape, self-adhesive gasket, ductwork reinforcements, closures, connectors and flanges shall be as approved / supplied by Kingspan Insulation Ltd.

4 Fire & Smoke Performance

- 4.1 The rigid phenolic insulation panels used in the fabrication of ductwork and / or ductwork sections fabricated from the *Kingspan KoolDuct® System* shall achieve the fire and smoke performance requirements as detailed in App. A3 / B3 / C3/ D3 (delete as applicable) of this specification.

Fabrication of Ductwork

- 4.2 All ductwork fabricated from the *Kingspan KoolDuct® System* shall be fabricated in accordance with methods as approved Kingspan Insulation Ltd.
- 4.3 Ductwork sections fabricated from the *Kingspan KoolDuct® System* shall not exceed permitted air leakage limits as detailed in App. A4 / B4 / C4 / D4 (delete as applicable) of this specification.
- 4.4 All internal seams must be fully sealed with an unbroken layer of silicone sealant.

- 4.5 Each ductwork section must be duly connected with a jointing system approved Kingspan Insulation Ltd., and sufficient silicone sealant should be applied in order to seal the rigid phenolic insulation panel and ensure minimum air leakage.
- 4.6 Ductwork reinforcement, if necessary, shall be applied to protect against side deformation from both positive and negative pressure.
- 4.7 All external seams where two separate panels join must be taped to achieve a permanent bond and a smooth wrinkle free appearance.
- 4.8 The design of ductwork fittings shall be in conformance with the appropriate ductwork construction standard as detailed in App. A5 / B5 / C5 / D5 (delete as applicable) of this specification.
- 4.9 Access doors shall be provided where shown on the drawings. These may be fabricated from the *Kingspan KoolDuct® System* or, a commercially available pre-insulated access door may be incorporated. This access door must be insulated to the same standard as the *Kingspan KoolDuct®* rigid phenolic insulation panel and the integrity of the vapour barrier must be maintained.

5 Storage & Handling

- 5.1 Care shall be exercised in the handling and transportation of ductwork sections and the *Kingspan KoolDuct®* rigid phenolic insulation panels from which they are fabricated, in order to prevent physical damage.
- 5.2 All ductwork sections, and the materials from which they are fabricated, shall be stored under cover, clear of the ground and protected from the weather and sunlight by an opaque and light coloured waterproof material. In cases where the ductwork sections are to be stored for prolonged periods, the open ends of the ductwork sections shall be sealed with a polythene sheet or other suitable material to prevent the ingress of foreign matter.

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6 Installation of Ductwork

- 6.1 Ductwork sections fabricated from the *Kingspan KoolDuct® System* shall be installed in accordance with methods approved by Kingspan Insulation Ltd.
- 6.2 The ductwork system shall be visually inspected before commencement of operation and ductwork sections fabricated from the *Kingspan KoolDuct® System* shall be verified as having been installed correctly.
- 6.3 Flexible connections shall be made between the ductwork and any item which is subject to vibration or movement.

Support

- 6.4 It shall be the responsibility of the installer to ensure that the ductwork system is properly and adequately supported. A number of support systems are approved for use by Kingspan Insulation Ltd. It shall be the responsibility of the installer to ensure that the chosen method of support is compatible with ductwork fabricated from the *Kingspan KoolDuct® System*.
- 6.5 With the exception of Tiger Supports, all metal support members in contact with the ductwork shall be separated by a soft gasket material.
- 6.6 Supports on straight runs of ductwork fabricated from the *Kingspan KoolDuct® System* shall be positioned at centres not exceeding 3 m / 10 ft for ductwork sections fabricated in 3 m / 10 ft lengths, and 4 m / 13 ft for ductwork sections fabricated in 4 m / 13 ft lengths.
- 6.7 Additionally, ductwork shall be supported at changes of direction, at branch duct connections, tee fittings and etc.
- 6.8 All ductwork accessories such as dampers shall be independently supported.

Internal Ductwork

- 6.9 All internal and exposed to view ductwork fabricated from *Kingspan KoolDuct® System* may be provided with a protective finish in addition to the factory applied reinforced aluminium facing. For details, refer to App. A6 / B6 / C6 / D6 (delete as applicable) of this specification.

External Ductwork

- 6.10 All externally mounted ductwork fabricated from the *Kingspan KoolDuct® System* must be installed with a slight fall so as to shed water from its upper surface and must be provided with a protective weatherproof finish that shields against the effects of wind and sunlight. For details, refer to App. A6 / B6 / C6 / D6 (delete as applicable) of this specification.

High Humidity Conditions

- 6.11 High humidity conditions may increase the risk of condensation forming on ductwork section jointing flanges. To combat this:
 - all flanges can be insulated to the same thickness as the ductwork insulation and fully vapour sealed; or
 - a tropical plastic flange can be used to replace the internal half of the aluminium grip flange, if specified.

In some high humidity conditions, a bloom may form on the surface of the ductwork. If this is likely to be visible, the ductwork can be painted with a suitable paint finish which does not compromise the factory applied reinforced aluminium facing or fire classification.

7 Testing for Air Leakage

Ductwork air leakage testing shall be conducted in conformance with the procedures as set out in the appropriate standard as detailed in App. A7 / B7 / C7 / D7 (delete as applicable) of this specification.

8 Commissioning & Operating Pressures

- 8.1 The commissioning process shall include for the testing and verification of functional performance, preparation of documentation, training of personnel for continued proper operation and maintenance of the ductwork system, and compilation of the final commissioning report.
- 8.2 The commissioning pressure shall not exceed the designed pressure limit when a ductwork system fabricated from the *Kingspan KoolDuct® System* is being commissioned.

9 Standards / References

App. A8 / B8 / C8 / D8 (delete as applicable)

Project Specification - Appendix A - UK & Ireland



Appendix A1 - Kingspan KoolDuct® Rigid Phenolic Insulation Panels

Description

Kingspan KoolDuct® rigid phenolic insulation panels have a CFC/HCFC-free rigid phenolic insulation core with a density range of 55–60 kg/m³. Manufactured by a continuous process, the quality of the insulation is constantly monitored and controlled. A closed cell structure makes the product non-wicking and highly resistant to moisture penetration and gives it excellent thermal properties. *Kingspan KoolDuct®* rigid phenolic insulation panels are faced on both sides with a protective low vapour permeability 25 micron aluminium foil reinforced with a 5 mm glass scrim which is extremely durable. *Kingspan KoolDuct®* rigid phenolic insulation panels are also available with a 23 micron black-coated aluminium foil reinforced with a 5 mm glass scrim facing on one side and the above mentioned aluminium foil on the other. *Kingspan KoolDuct®* rigid phenolic insulation panels are able to withstand temperatures from –20°C to +80°C. They also have an exceptional resistance to burning and spread of flame. The composition of *Kingspan KoolDuct®* rigid phenolic insulation panels is such that when subjected to fire the outer surface forms a carbonaceous layer which retards further flame spread and penetration.

Kingspan KoolDuct® rigid phenolic insulation panels satisfy the requirements of BS 5422: 2001, BS 5422: 2008, the TIMSA Guide and other major national specifications. *Kingspan KoolDuct®* rigid phenolic insulation panels are manufactured under a quality control system approved to BS EN ISO 9001: 2000 (Quality management systems. Requirements) and an environmental management system approved to BS EN ISO 14001: 2004 (Environmental management systems. Requirements with guidance for use).

Application

Kingspan KoolDuct® rigid phenolic insulation panels are a core component of the *Kingspan KoolDuct®* System of pre-insulated ductwork, which is an alternative to traditional sheet steel ductwork in Building Services / HVAC applications. The durable and puncture resistant aluminium foil facings on *Kingspan KoolDuct®* rigid phenolic insulation panels are used to prevent the ingress of moisture, dust and dirt into the insulation.

Availability

- Insulation panel dimensions: 2950 mm x 1200 mm
- Insulation panel thickness: 22 mm & 30 mm

General Physical Properties (Rigid Phenolic Insulation Core)

Property	Test Method	Typical Value
Colour		Pink
Minimum Closed Cell Content	(BS EN ISO 4590: 2003)	≥ 90%
Nominal Density Range		55–60 kg/m ³
Compressive Strength at 10% Compression	(BS EN 826: 1996)	200 kPa
Thermal Conductivity (22°C & 50% RH)	(ASTM C 518)	0.021 W/m·K
Water Vapour Resistance Z (23°C & 50% RH)	(BS EN 12086: 1997) Method A	617 MN·s/g
Operating Temperature Limits		–20°C to +80°C

Fire & Smoke Test Classifications (Rigid Phenolic Insulation Core)

Test	Test Method	Result
Fire Propagation	BS 476–6: 1989	Index of performance not exceeding 12 and sub index (i ₁) not exceeding 6*
Surface Spread of Flame	BS 476–7: 1997	Class 1*
Specific Optical Density of Smoke (Average)	BS 6401: 1983	22.7 with pilot flame 15 without pilot flame
Toxicity Index (Average)	Defence Standard 02–713: 2006	4.93

*The rigid phenolic insulation core of *Kingspan KoolDuct®* panels will achieve these results which enables it to be classified as Class 0 to the Building Regulations in England & Wales, Northern Ireland and the Republic of Ireland, and Low Risk to the Building Standards in Scotland.

General Physical Properties (Aluminium Foil Vapour Barrier Facing)

Property		Typical Value
Composition	Coated Aluminium	25 microns
	Glass Scrim	5 mm x 5 mm
	Glass Mat	49 g/m ²
Water Vapour Transmission		1.15 ng·N·s

Fire & Smoke Test Classifications (Aluminium Foil Vapour Barrier Facing)

Test	Test Method	Result
Fire Propagation	BS 476–6: 1989	Index of performance not exceeding 12 and sub index (i ₁) not exceeding 6*
Surface Spread of Flame	BS 476–7: 1997	Class 1*

*The aluminium foil vapour barrier facing of *Kingspan KoolDuct®* panels will achieve these results which enables it to be classified as Class 0 to the Building Regulations in England & Wales, Northern Ireland and the Republic of Ireland, and Low Risk to the Building Standards in Scotland.



Appendix A2 - Insulation Thickness Specifications

England & Wales and Northern Ireland – The TIMSA Guide

The 2006 editions of Approved Documents L2A & L2B to the Building Regulations in England & Wales and the 2006 edition of Technical Booklet F2 to the Building Regulations (Northern Ireland), refer directly and indirectly to the TIMSA “Domestic & Non-Domestic Heating, Cooling and Ventilation Guide” (the TIMSA Guide) as the reference document for the required thickness of duct insulation to control heat loss / gain.

The TIMSA Guide shows two tables for ductwork operating in different conditions:

- Table 6.2.4 Insulation for Warm Ducts; and
- Table 6.2.5 Insulation for Chilled & Dual Purpose Ducts.

The required thicknesses of insulation set out in the TIMSA Guide are shown in the tables below. (Please note that ductwork operating at temperatures outside those given in the tables will require specific calculations).

Air Temperature (°C)		Thickness (mm)		
Inside Duct	Ambient	Kingspan KoolDuct®	Mineral Fibre	Nitrile Rubber
35	15	18*	29	33
Estimated Mean Temperature of Insulation:				+20°C
Assumed Thermal Conductivity (k-value) of Insulation:				
Kingspan KoolDuct® (Low Emissivity Facing)			0.021 W/m·K	
Mineral Fibre (Low Emissivity Facing)**			0.035 W/m·K	
Nitrile Rubber (Class 0)			0.040 W/m·K	

Thickness (mm) of Insulation for Warm Ducting Service Areas to Control Heat Loss (Based on TIMSA Guide Section 6.2.4)

Air Temperature (°C)		Thickness (mm)	
Inside Duct	Ambient	Kingspan KoolDuct®	Mineral Fibre
13	25	30*	50
Ambient Air Temperature – Indoor:		+25°C	
Relative Humidity – Indoor:		80%	
Dewpoint Temperature:		+21.3°C	
Assumed Thermal Conductivity (k-value) of Insulation:			
Kingspan KoolDuct®		0.021 W/m·K	
Mineral Fibre**		0.035 W/m·K	

Thickness (mm) of Insulation for Chilled & Dual Purpose Ducting Service Areas to Control Heat Gain (Based on TIMSA Guide Section 6.2.5)

* Please note that the Kingspan KoolDuct® System is available in a 22 mm and 30 mm duct wall thickness only.

** At the average temperature of the insulation material, some mineral fibre duct insulation products may have a thermal conductivity lower than 0.035 W/m·K. For accurate thicknesses of those products please refer to a mineral fibre manufacturer. This table takes 0.035 W/m·K as a “safe” value.

It can be seen from the tables below that in all circumstances shown that:

- the 22 mm and 30 mm thick rigid phenolic insulation panels used in the Kingspan KoolDuct® System match or exceed the specification laid down in the TIMSA Guide; and
- the thickness of the 22 mm and 30 mm thick rigid phenolic insulation panels used in the Kingspan KoolDuct® System can be significantly less than the required thickness of mineral fibre (up to 40% thinner) or nitrile rubber (up to 33% thinner).

NB The Non-Domestic Heating, Cooling and Ventilation Compliance Guide refers to the TIMSA Guide for help with condensation control. The TIMSA Guide does not show a table of insulation thicknesses for the control of condensation on below ambient ductwork. Therefore, please refer to the table of thicknesses for the control of condensation on below ambient ductwork contained in BS 5422: 2001.

Republic of Ireland and Scotland – BS 5422: 2001

The 2008 edition of the Non-domestic Technical Handbook Section 6 to the Building Standards in Scotland, and the 2006 edition of Technical Guidance Document L to the Building Regulations in the Republic of Ireland, refer directly and indirectly to British Standard, BS 5422: 2001 (Method for specifying thermal insulating materials for pipes, tanks, vessels, ductwork and equipment operating within the temperature range –40°C to +700°C) as the reference document for the required thickness of duct insulation to control heat loss / gain.

NB An updated BS 5422: 2008 will be published late in 2008 and will supersede BS 5422: 2001. It is expected that the new BS 5422: 2008 will be used as the relevant standard in Scotland and the Republic of Ireland when it is published.

The insulation thickness tables for ductwork carrying warm air and for chilled and dual purpose ductwork in BS 5422: 2008 are identical to those shown in the TIMSA Guide. The insulation thickness table for condensation control for ductwork carrying chilled air in BS 5422: 2008 is identical to that shown in BS 5422: 2001.

BS 5422: 2001 shows two tables for ductwork operating in different conditions:

- Table 11 Insulation for Warm Ducts; and
- Table 10 Insulation for Condensation Control Ductwork Carrying Chilled Air in Ambient Conditions.



The required thicknesses of insulation set out in BS 5422: 2001 are shown in the tables below. (Please note that ductwork operating at temperatures outside those given in the tables will require specific calculations).

Temperature difference between air inside ductwork and ambient air (°C)	Thickness (mm)		
	Kingspan KoolDuct®	Mineral Fibre	Nitrile Rubber
10	20*	34	38
15	22*	37	42
25	27*	44	50
Estimated Mean Temperature of Insulation:			+20°C
Assumed Thermal Conductivity (k-value) of Insulation:			
Kingspan KoolDuct®			0.021 W/m.K
Mineral Fibre**			0.035 W/m.K
Nitrile Rubber (Class 0)			0.040 W/m.K

Environmental Thickness (mm) of Insulation for Ductwork Carrying Warm Air to Control Heat Loss (Based on BS 5422: 2001 Table 11)

Minimum air temperature inside ductwork (°C)	Thickness (mm)	
	Kingspan KoolDuct®	Mineral Fibre
15	16*	25
12	22*	37
10	28*	45
Ambient Air Temperature – Indoor:		+25°C
Relative Humidity – Indoor:		80%
Dewpoint Temperature:		+21.3°C
Assumed Thermal Conductivity (k-value) of Insulation:		
Kingspan KoolDuct®		0.021 W/m.K
Mineral Fibre**		0.035 W/m.K

Thickness (mm) of Insulation for Condensation Control Ductwork Carrying Chilled Air in Ambient Conditions (Based on BS 5422: 2001 Table 10)

* Please note that the Kingspan KoolDuct® System is available in a 22mm and 30 mm duct wall thickness only.

** At the average temperature of the insulation material, some mineral fibre duct insulation products may have a thermal conductivity lower than 0.035 W/m.K. For accurate thicknesses of those products please refer to a mineral fibre manufacturer. This table takes 0.035 W/m.K as a "safe" value.

It can be seen from the tables that in all circumstances shown that:

- the 22 mm and 30 mm thick rigid phenolic insulation panels used in the Kingspan KoolDuct® System match or exceed the specification laid down in BS 5422: 2001; and
- the thickness of the 22 mm and 30 mm thick rigid phenolic insulation panels used in the Kingspan KoolDuct® System can be significantly less than the required thickness of mineral fibre (up to 40% thinner) or nitrile rubber (up to 47% thinner).

Appendix A3 - Fire & Smoke Performance

The appropriate fire and smoke performance requirements for the UK & Ireland are detailed below.

Internal Ductwork

- BS 476-6: 1989 – of low contribution to fire growth with fire propagation index of performance (I) not exceeding 12 and sub index (i₁) not exceeding 6;
- BS 476-7: 1997 – of very low surface spread of flame (Class 1); and
- Class 0 / Low Risk to the Building Regulations / Standards.

External Ductwork

- BS 476-7: 1997 – of very low surface spread of flame (Class 1).

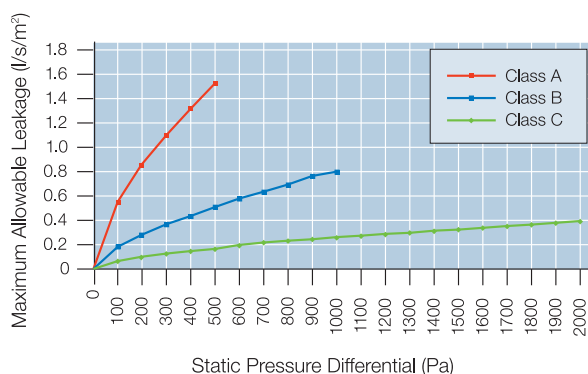
Appendix A4 - Air Leakage Limits

HVCA DW/144 details the maximum allowable air leakage as shown in the table below:

Duct Pressure Class	Static Pressure Limit (Pa)		Maximum Air Velocity (m/s)	Air Leakage Limits (l/s/m ²)
	Positive	Negative		
Low-Pressure (Class A)	500	500	10	0.027 x p ^{0.65}
Medium-Pressure (Class B)	1000	750	20	0.009 x p ^{0.65}
High-Pressure (Class C)	2000	750	40	0.003 x p ^{0.65}

p = static pressure differential (Pa)

Based on the limits set out in table above, the maximum allowable air leakage for each pressure class over a range of pressures from 0 to 2,000 Pascals (Pa) is plotted in the graph below. The leakage figures are given in litres of air per second per square metre (l/s/m²) of internally measured ductwork against a static pressure differential ranging from 100 Pa to 2,000 Pa.





Appendix A5 - Ductwork Fittings

The appropriate ductwork construction standard for the UK & Ireland is HVCA DW/144 (Specification for Sheet Metal Ductwork).

Appendix A6 - Finishes

Internal Ductwork

The finish shall be either:

- a) aluminium / zinc alloy coated sheet steel (0.7 mm) (e.g. Dobel Aluzinc or equivalent) which can be introduced during fabrication of the ductwork or installed in situ; or
- b) a suitable paint finish (must not compromise factory applied reinforced aluminium facing or fire classification) applied in situ.

External Ductwork

The finish shall be either:

- a) an aluminium cladding / jacketing system (e.g. Venture Clad or equivalent) which can be introduced during fabrication of the ductwork or installed in situ;
- b) aluminium / zinc alloy coated sheet steel (0.8 mm) (e.g. Dobel Aluzinc or equivalent) which can be introduced during fabrication of the ducting or installed in situ;
- c) a fibre reinforced plastic (e.g. Fibaroll GR Grade or equivalent) which is introduced during the fabrication of the ductwork; or
- d) a polymeric weather covering (for sheltered locations) installed in situ.

Manufacturers of Finishes

For Dobel Aluzinc aluminium zinc alloy coated sheet steel refer to:

SSAB Dobel Coated Steel Ltd
Narrowboat Way
Hurst Business Park
Brierley Hill
West Midlands
DY5 1UF
Tel: +44 (0) 1384 74 660
Fax: +44 (0) 1384 77 575
www.dobel.co.uk

For Venture Clad aluminium jacketing system refer to:

Venture Tape Europe Corp.
Units 5-6
Faraday Close
Drayton Fields
Daventry
Northamptonshire
NN11 8RD
Tel: +44 (0) 1327 876 555
Fax: +44 (0) 1327 876 444
www.venturetape.com

For Fibaroll FR Grade fibre reinforced plastic coating for insulation refer to:

FTi Ltd
Willmotts Business Park
Waterlip
Somerset
BA4 4RN
Tel: +44 (0) 1749 881 920
Fax: +44 (0) 1749 880 843
www.fibaroll.co.uk

Appendix A7 - Testing for Air Leakage

Approved Documents L2A & L2B to the Building Regulations in England & Wales, and Technical Booklet F2 to the Building Regulations (Northern Ireland), state that ductwork leakage testing should be carried out in accordance with the procedures set out in HVCA DW/143 on systems served by fans with a design flow rate greater than 1 m³/s, and for those sections of ductwork where the pressure class is such that HVCA DW/143 recommends testing and the carbon dioxide emissions rate of the building design assumes a leakage rate for a given section of ductwork that is lower than the standard defined in HVCA DW/144 for its particular pressure class. Technical Handbook Section 6 to the Building Standards in Scotland state that one way of carrying out ductwork leakage testing is to follow the procedures set out in HVCA DW/143.

HVCA DW/143 (A Practical Guide to Ductwork Leakage Testing) recommends the range and frequency of testing that it deems to be satisfactory.

It recommends the following:

- high pressure ducts (Class C) – all tested;
- medium pressure ducts (Class B) – 10% of the ductwork selected at random and tested; and
- low pressure ducts (Class A) – untested.

It is also recommended:

- for medium pressure ducts, in the event of test failure of the randomly selected section, the designer shall have the right to select two further sections at random for testing. Where successive failures are identified there shall be a right to require the contractor to apply remedial attention to the complete ductwork system; and
- in general for all ducts tested, that the air leakage rate for any section shall not be in excess of the permitted rate (as stated in HVCA DW/144) for that section. If a first test produces leakage in excess of the permitted maximum, the section shall be resealed and retested until a leakage not greater than the permitted maximum for that section is achieved.



Appendix A8- Standards / References

British Standards

BS 476-6: 1989

Fire tests on building materials and structures. Method of test for fire propagation for products

BS 476-7: 1997

Fire tests on building materials and structures. Method of test to determine the classification of the surface spread of flame of products

BS 6401: 1983

Method for measurement, in the laboratory, of the specific optical density of smoke generated by materials.

BS 5422: 2001

Method for specifying thermal insulating materials for pipes, tanks, vessels, ductwork and equipment operating within the temperature range -40°C to $+700^{\circ}\text{C}$

BS 5422: 2008

Method for specifying thermal insulating materials for pipes, tanks, vessels, ductwork and equipment operating within the temperature range -40°C to $+700^{\circ}\text{C}$

BS EN 826:1996

Thermal insulating products for building applications. Determination of compression behaviour

BS EN 12086:1997

Thermal insulating products for building applications. Determination of water vapour transmission properties

BS EN ISO 4590: 2003

Rigid cellular plastics. Determination of the volume percentage of open cells and of closed cells

BS EN ISO 9001: 2000

Quality management systems. Requirements

BS EN ISO 14001: 2004

Environmental management systems. Requirements with guidance for use)

American Standards

ASTM C 518: 2004

Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus

Other References

TIMSA Guide

TIMSA Domestic & Non-Domestic Heating, Cooling and Ventilation Guide

HVCA DW/144

Specification for Sheet Metal Ductwork

HVCA DW/143

A practical guide to Ductwork Leakage Testing

Defence Standard 02-713: 2006

Determination of the Toxicity Index of the Products of Combustion from Small Specimens of Material

Building Regulations / Standards

England & Wales

The Building Regulations 2000. Approved Document B2. 2006 Edition, Amended 2007. Appendix A, Paragraph 13.

The Building Regulations 2000. Approved Document L2A. 2006 Edition.

The Building Regulations 2000. Approved Document L2B. 2006 Edition.

Scotland

The Building Standards (Scotland) Regulations. Non-domestic Technical Handbook Section 2 (Fire). 2008 Edition. Annex 2C.

The Building Standards (Scotland) Regulations. Non-domestic Technical Handbook Section 6 (Energy). 2008 Edition.

Northern Ireland

The Building Regulations (Northern Ireland) 2000. Technical Booklet E. 2005 Edition. Paragraph 2.4

The Building Regulations (Northern Ireland) 2000. Technical Booklet F2. 2006 Edition.

Irish Republic

The Building Regulations 2006. Technical Guidance Document B. Appendix A. Paragraphs A11 and A12

The Building Regulations 2005. Technical Guidance Document L. May 2006 Edition.

Project Specification - Appendix B - Australia



Appendix B1 - Kingspan KoolDuct® Rigid Phenolic Insulation Panels

Description

Kingspan KoolDuct® rigid phenolic insulation panels have a CFC/HCFC-free rigid phenolic insulation core with a density range of 55–60 kg/m³. Manufactured by a continuous process, the quality of the insulation is constantly monitored and controlled. A closed cell structure makes the product non-wicking and highly resistant to moisture penetration and gives it excellent thermal properties. *Kingspan KoolDuct®* rigid phenolic insulation panels are faced on both sides with a protective low vapour permeability 25 micron aluminium foil reinforced with a 5 mm glass scrim which is extremely durable. *Kingspan KoolDuct®* rigid phenolic insulation panels are also available with a 23 micron black-coated aluminium foil reinforced with a 5 mm glass scrim facing on one side and the above mentioned aluminium foil on the other.

Kingspan KoolDuct® rigid phenolic insulation panels are able to withstand temperatures from –20°C to +80°C. They also have an exceptional resistance to burning and spread of flame. The composition of *Kingspan KoolDuct®* rigid phenolic insulation panels is such that when subjected to fire the outer surface forms a carbonaceous layer which retards further flame spread and penetration.

Kingspan KoolDuct® rigid phenolic insulation panels satisfy the requirements of BCA 2008 Specifications C1.10–9 and J5.2–3. *Kingspan KoolDuct®* rigid phenolic insulation panels are manufactured under a quality control system approved to BS EN ISO 9001: 2000 (Quality management systems. Requirements) and an environmental management system approved to BS EN ISO 14001: 2004 (Environmental management systems. Requirements with guidance for use).

Application

Kingspan KoolDuct® rigid phenolic insulation panels are a core component of the *Kingspan KoolDuct®* System of pre-insulated ductwork, which is an alternative to traditional sheet steel ductwork in Building Services / HVAC applications. The durable and puncture resistant aluminium foil facings on *Kingspan KoolDuct®* rigid phenolic insulation panels are used to prevent the ingress of moisture, dust and dirt into the insulation.

Availability

- Insulation panel dimensions: 3930 mm x 1200 mm
- Insulation panel thickness: 22 mm, 30 mm & 33 mm

General Physical Properties (Rigid Phenolic Insulation Core)

Property	Test Method	Typical Value
Colour		Pink
Minimum Closed Cell Content	(BS EN ISO 4590: 2003)	≥ 90%
Nominal Density Range		55–60 kg/m ³
Compressive Strength at 10% Compression	(BS EN 826: 1996)	200 kPa
Thermal Conductivity (22°C & 50% RH)	(ASTM C 518: 2004)	0.21 W/m·K
Material R-value		
22 mm		1.05 m ² ·K/W
30 mm		1.43 m ² ·K/W
33 mm		1.57 m ² ·K/W
Water Vapour Resistance Z (23°C & 50% RH)	(BS EN 12086: 1997) Method A	617 MN·s/g
Operating Temperature Limits		–20°C to +80°C

General Physical Properties (Aluminium Foil Vapour Barrier Facing)

Property		Typical Value
Composition	Coated Aluminium	25 microns
	Glass Scrim	5 mm x 5 mm
	Glass Mat	49 g/m ²
Water Vapour Transmission		1.15 ng·N·s

Fire & Smoke Test Classifications (Rigid Phenolic Insulation Core & Aluminium Foil Vapour Barrier Facing)

Test	Test Method	Result
Early Fire Hazard	AS 1530–3: 1999	Ignitability Index: 0* Flame Spread Index: 0* Heat Developed Index: 0* Smoke Developed Index: 0–1*
Surface Burning Characteristics	UL 723 / ASTM E 84-08a	< 25/50
Burning	UL 181	Pass*

**Kingspan KoolDuct®* rigid phenolic insulation panels as part of an assembled ductwork system, will achieve these results which enables them to comply with the Building Code of Australia (BCA) 2008 Specification C1.10–9.



Total Thermal Resistance (R_t) of Ductwork Fabricated From the Kingspan KoolDuct® System Including the Effect of Low Emissivity Facings

Panel Thickness (mm)	Application	Ambient Conditions	Calculated R_t ($m^2 \cdot K/W$)
22	Cooling Application ¹	Ambient Air Flowing at 0.5 m/s	1.18
		Still Ambient Air	1.52
	Heating Application ²	Ambient Air Flowing at 0.5 m/s	1.15
		Still Ambient Air	1.47
30	Cooling Application ¹	Ambient Air Flowing at 0.5 m/s	1.57
		Still Ambient Air	1.91
	Heating Application ²	Ambient Air Flowing at 0.5 m/s	1.53
		Still Ambient Air	1.85
33	Cooling Application ¹	Ambient Air Flowing at 0.5 m/s	1.72
		Still Ambient Air	2.06
	Heating Application ²	Ambient Air Flowing at 0.5 m/s	1.67
		Still Ambient Air	1.99

¹ Calculated using 13°C supply air and 26°C ambient environment.
² Calculated using 30°C supply air and 18°C ambient environment.
 R_t determinations based upon AS / NZS 4859: 2002.
 Assumed Thermal Conductivity (k-value) of insulation at 23°C mean temp: 0.021 W/m.K.

Appendix B2 - Insulation Thickness Specifications

Building Code of Australia (BCA) 2008

The Energy Efficiency Provisions of BCA 2008 specify the minimum required thermal performance standards for ductwork insulation, meeting the requirements of AS NZS 4859-1: 2002, installed on air conditioning ductwork in Class 5 to 9 buildings.

BCA 2008 Specification J5.2-3 shows two tables with the minimum required total R-value for ductwork operating in different climate zones and locations:

- Table 3a Combined Heating and Cooling Ductwork Systems greater than 65k Wr & 65 kW_{heating} Capacity; and
- Table 3b Heating / Cooling Only Ductwork & Fittings for Ductwork Systems less than 65k Wr & 65 kW_{heating} Capacity

The different climate zones are shown on the map to the right.



BCA 2008 Climate Zone Map for Australian Locations



Appendix B2 - Insulation Thickness Specifications (Continued)

The **Kingspan KoolDuct**® rigid phenolic insulation panel thickness required to achieve the specified thermal performance standards as set out in the BCA 2008 Specification J5.2-3 tables are shown below.

NB that, in some climates, the minimum energy efficiency requirements may not be sufficient for condensation control. In such cases, the risk of condensation should be assessed and calculated as appropriate.

Ductwork Element	Different Duct Insulation Thicknesses (mm) for the Minimum Required R-values for Ductwork in Each Climate Zone						
	Evaporative Cooling System	Heating / Refrigerated Cooling Only System			Combined Heating & Refrigerated Cooling System		
	All Zones	Zones 1,3,4,6 & 7	Zones 2 & 5	Zone 8	Zones 1,3,4,6 & 7	Zones 2 & 5	Zone 8
Ductwork	R-0.6 22 / 25	R-1.0 22 / 38	R-1.0 22 / 38	R-1.5 30 / 50	R-1.5* 30 / 50	R-1.0 22 / 38	R-1.5 30 / 50
Fittings	R-0.4 22 / 25	R-0.4 22 / 25	R-0.4 22 / 25	R-0.4 22 / 25	R-0.4 22 / 25	R-0.4 22 / 25	R-0.4 22 / 25

**The minimum total R-value required may be reduced by R-0.5 for combined heating refrigerated cooling systems in climate zones 1,3, 4, 6 & 7 if the ductwork is located:*
 (a) under a suspended floor with an enclosed perimeter; or
 (b) in a roof space that has insulation of not less than R-0.5 directly beneath the roofing.
 Blue: Kingspan KoolDuct®: Assumed R-value : 22 mm (R-1.05); 30 mm (R-1.43); 33 mm (R-1.57).
 Red: Mineral Fibre: Assumed R-value: 25 mm (R-0.7); 38 mm (R-1.0); 50 mm (R-1.4); 75 mm (R-2.0).

Table B1 – Minimum Insulation Required to Achieve the Total R-values for Ductwork & Fittings in Each Climate Zone for Systems Less than 65 kW_{heating} Capacity (Based on BCA 2008 Spec J5.2-3 Table 3a)

Location of Ductwork & Fittings	Different Duct Insulation Thicknesses (mm) for the Minimum Required R-values for Ductwork in Each Climate Zone				
	Evaporative Cooling System	Heating / Refrigerated Cooling Only System			
	All Zones	Zones 1,3 & 4	Zones 2 & 5	Zones 6 & 7	Zone 8
Within a conditioned space other than where the space is the only or last space served	Nil	R-1.0 22 / 38	R-1.0 22 / 38	R-1.3 30 / 50	R-1.5 30 / 50
All other locations	R-0.9 22 / 38	R-1.8* 33 / 75	R-1.5 30 / 50	R-1.8 33 / 75	R-2.0 N/A / 75

**The minimum total R-value required may be reduced by R-0.5 for heating / refrigerated cooling only system ductwork and fittings in all other locations in climate zones 1,3 & 4 if the ductwork is located:*
 (a) under a suspended floor with an enclosed perimeter; or
 (b) in a roof space that has insulation of not less than R-0.5 directly beneath the roofing.
 Blue: Kingspan KoolDuct®: Assumed R-value : 22 mm (R-1.05); 30 mm (R-1.43); 33 mm (R-1.57).
 Red: Mineral Fibre: Assumed R-value: 25 mm (R-0.7); 38 mm (R-1.0); 50 mm (R-1.4); 75 mm (R-2.0).

Table B2 – Minimum Insulation Required to Achieve the Total R-values for Ductwork in Each Climate Zone for Systems Greater than 65 kW_{heating} Capacity (Based on BCA 2008 Spec J5.2-3 Table 3b)

It can be seen from the tables above that:

- in all circumstances shown that the 22 mm, 30 mm and 33 mm thick rigid phenolic insulation panels used in the **Kingspan KoolDuct**® System match or exceed the specification laid down in BCA 2008; and
- the thickness of the 22 mm, 30 mm and 33 mm thick rigid phenolic insulation panels used in the **Kingspan KoolDuct**® System can be significantly less than the required thickness of mineral fibre (up to 56% thinner).



Appendix B3 - Fire & Smoke Performance

The appropriate fire and smoke performance requirements for Australia are:

- AS 1530-3: 1999 – early fire hazard rating of low smoke developed index not exceeding 3 and flame spread, ignitability and heat evolved indices not exceeding 0; and
- UL 181 – of low contribution to fire growth to pass the burning test.

Air handling ductwork systems which meet the performance requirements as detailed above are defined as meeting the requirements of AS 4254: 2002 in compliance with the Building Code of Australia (BCA) 2008 Specification C1.10-9.

Appendix B4 - Air Leakage Limits

BCA 2008 Specification J5.2-3 refers to AS 4254: 2002 (Ductwork for air-handling systems in buildings) for ductwork sealing, and requires all ductwork installations to be made sufficiently airtight to ensure quiet and economical operation of the system. Currently for Australia, the Energy Efficiency Provisions of BCA 2008 do not refer to a standard / guidance document that clearly defines mandatory air leakage limits.

It is however, recommended that the maximum allowable air leakage limits as detailed in HVCA DW/144 (Specification for Sheet Metal Ductwork) or the SMACNA HVAC Air Duct Leakage Test Manual are not exceeded.

HVCA DW/144

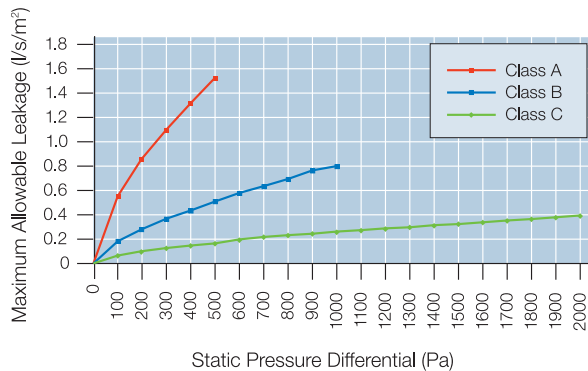
HVCA DW/144 details the maximum allowable air leakage as shown in the table below:

Duct Pressure Class	Static Pressure Limit (Pa)		Maximum Air Velocity (m/s)	Air Leakage Limits (l/s/m ²)
	Positive	Negative		
Low-Pressure (Class A)	500	500	10	$0.027 \times p^{0.65}$
Medium-Pressure (Class B)	1000	750	20	$0.009 \times p^{0.65}$
High-Pressure (Class C)	2000	750	40	$0.003 \times p^{0.65}$

p = static pressure differential (Pa)

Based on the limits set out in table above, the maximum allowable air leakage for each pressure class over a range of pressures from 0–2000 Pascals (Pa) is plotted in the graph

below. The leakage figures are given in litres of air per second per square metre (l/s/m²) of internally measured ductwork against a static pressure differential ranging from 100–2000 Pa.



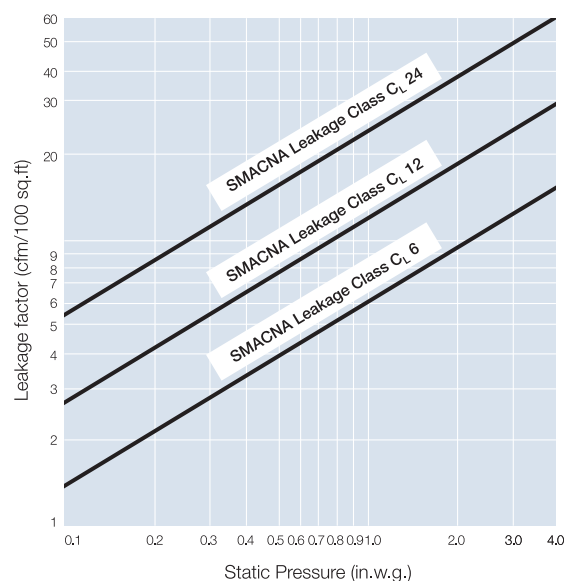
SMACNA HVAC Air Duct Leakage Test Manual

The SMACNA HVAC Air Duct Leakage Test Manual details the maximum allowable air leakage as shown in the table below:

Seal Class	Air Leakage Class (C _L)	Static Pressure (in.w.g.)	Air Leakage Limits (cfm/100 sq.ft)
A	6	≥ 4	$6 \times p^{0.65}$
B	12	3	$12 \times p^{0.65}$
C	24	≤ 2	$24 \times p^{0.65}$

p = static pressure (Pa)

Based on the limits set out in table above, the maximum allowable air leakage for each pressure and seal class is plotted in the graph below over a range of pressures from 0–4 in.w.g. (0–1000 Pa). The leakage figures are given in cubic feet of air per minute per one hundred square feet (cfm /100 sq. ft) of internally measured ductwork against a static pressure ranging from 0–4 in.w.g. (0–1000 Pa).





Appendix B5 - Design of Ductwork Fittings

The appropriate ductwork construction standard for Australia is AS 4254: 2002 (Ductwork for air-handling systems in buildings).

Appendix B6 - Finishes

Internal Ductwork

The finish shall be either:

- a) aluminium / zinc alloy coated sheet steel (0.7 mm) which can be introduced during fabrication of the ductwork or installed in situ; or
- b) a suitable paint finish (must not compromise factory applied reinforced aluminium facing or fire classification) applied in situ.

External Ductwork

The finish shall be either:

- a) an aluminium cladding / jacketing system which can be introduced during fabrication of the ductwork or installed in situ;
- b) aluminium / zinc alloy coated sheet steel (0.8 mm) which can be introduced during fabrication of the ducting or installed in situ;
- c) a fibre reinforced plastic which is introduced during the fabrication of the ductwork;
- d) a polymeric weather covering (for sheltered locations) installed in situ. or
- e) no. 10 open weave glass cloth embedded between two coats of trowel applied mastic.

Appendix B7 - Testing for Air Leakage

Currently for Australia, the Energy Efficiency Provisions of BCA 2008 do not refer to a standard / guidance document for ductwork leakage testing. However, if required, ductwork leakage testing shall be carried out in accordance with the procedures set out in HVCA DW/143 (A practical guide to Ductwork Leakage Testing) or the SMACNA HVAC Air Duct Leakage Test Manual.

HVCA DW/143

HVCA DW/143 recommends the range and frequency of testing that it deems to be satisfactory.

It recommends the following:

- high pressure ducts (Class C) – all tested;
- medium pressure ducts (Class B) – 10% of the ductwork selected at random and tested; and
- low pressure ducts (Class A) – untested.

It is also recommended:

- for medium pressure ducts, in the event of test failure of the randomly selected section, the designer shall have the right to select two further sections at random for testing. Where successive failures are identified there shall be a right to require the contractor to apply remedial attention to the complete ductwork system; and
- in general for all ducts tested, that the air leakage rate for any section shall not be in excess of the permitted rate (as stated in HVCA DW/144) for that section. If a first test produces leakage in excess of the permitted maximum, the section shall be resealed and retested until a leakage not greater than the permitted maximum for that section is achieved.

SMACNA HVAC Air Duct Leakage Test Manual

The SMACNA HVAC Air Duct Leakage Test Manual does not require testing for air leakage where adequate methods of assembly and sealing are used.

It recommends the following:

- high pressure ducts ≥ 4 in.w.g. (≥ 1000 Pa) – tested, if justified by the designer; and
- low – medium pressure ducts ≤ 3 in.w.g. (≤ 750 Pa) – untested.



Appendix B8- Standards / References

Australian / New Zealand Standards

AS / NZS 1530-3: 1999

Methods for fire tests on building materials, components and structures – Simultaneous determination of ignitability, flame propagation, heat release and smoke release

AS / NSZ 4859-1: 2002 / Amdt 1: 2006

Materials for the Thermal Insulation of Buildings – General Criteria and technical provisions.

AS 4254: 2002

Ductwork for air-handling systems in buildings

British Standards

BS EN 826:1996

Thermal insulating products for building applications.
Determination of compression behaviour

BS EN 12086:1997

Thermal insulating products for building applications.
Determination of water vapour transmission properties

BS EN ISO 4590: 2003

Rigid cellular plastics. Determination of the volume percentage of open cells and of closed cells

BS EN ISO 9001: 2000

Quality management systems. Requirements

BS EN ISO 14001: 2004

Environmental management systems. Requirements with guidance for use)

American Standards

ASTM C 518: 2004

Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus

Other References

HVCA DW/144

Specification for Sheet Metal Ductwork

HVCA DW/143

A practical guide to Ductwork Leakage Testing

SMACNA

HVAC Air Duct Test Leakage Manual

Building Codes

Building Code of Australia (BCA 2008)

Volume 2 Class 5 to 9 Buildings Specification C1.10-9

Building Code of Australia (BCA 2008)

Volume 2 Class 5 to 9 Buildings Specification J5.2-3

Project Specification - Appendix C - Middle East



Appendix C1 - Kingspan KoolDuct® Rigid Phenolic Insulation Panels

Description

Kingspan KoolDuct® rigid phenolic insulation panels have a CFC/HCFC-free rigid phenolic insulation core with a density range of 55–60 kg/m³ / 3.43–3.75 pcf. Manufactured by a continuous process, the quality of the insulation is constantly monitored and controlled. A closed cell structure makes the product non-wicking and highly resistant to moisture penetration and gives it excellent thermal properties. Kingspan KoolDuct® rigid phenolic insulation panels are faced on both sides with a protective low vapour permeability 25 micron / 1 mil aluminium foil reinforced with a 5 mm / 0.2" glass scrim which is extremely durable. Kingspan KoolDuct® rigid phenolic insulation panels are also available with a 23 micron / 0.9 mil black-coated aluminium foil reinforced with a 5 mm / 0.2" glass scrim facing on one side and the above mentioned aluminium foil on the other.

Kingspan KoolDuct® rigid phenolic insulation panels are able to withstand temperatures from –20°C to +80°C / 4°F to + 176°F. They also have an exceptional resistance to burning and spread of flame. The composition of Kingspan KoolDuct® rigid phenolic insulation panels is such that when subjected to fire the outer surface forms a carbonaceous layer which retards further flame spread and penetration.

Kingspan KoolDuct® rigid phenolic insulation panels satisfy the requirements of the UAE Ministry of Interior Dubai Civil Defense, BS 5422: 2001 (Method for specifying thermal insulating materials for pipes, tanks, vessels, ductwork and equipment operating within the temperature range –40°C to +700°C / –40°F to –1292°C) and ANSI / ASHRAE / IESNA 90.1: 2007 (Energy Standard for Buildings Except Low-Rise Residential Buildings) and other major specifications. Kingspan KoolDuct® rigid phenolic insulation panels are manufactured under a quality control system approved to BS EN ISO 9001: 2000 (Quality management systems. Requirements) and an environmental management system approved to BS EN ISO 14001: 2004 (Environmental management systems. Requirements with guidance for use).

Application

Kingspan KoolDuct® rigid phenolic insulation panels are a core component of the Kingspan KoolDuct® System of pre-insulated ductwork, which is an alternative to traditional sheet steel ductwork in Building Services / HVAC applications. The durable and puncture resistant aluminium foil facings on Kingspan KoolDuct® rigid phenolic insulation panels are used to prevent the ingress of moisture, dust and dirt into the insulation.

Availability

- Insulation panel dimensions: 3930 mm x 1200 mm / 12.89 ft x 3.94 ft
- Insulation panel thickness: 22 mm / 7/8" & 30 mm / 1 3/16"

General Physical Properties (Rigid Phenolic Insulation Core)

Property	Test Method	Typical Value
Colour		Pink
Minimum Closed Cell Content	(BS EN ISO 4590: 2003)	≥ 90%
Nominal Density Range		55–60 kg/m ³ / 3.43–3.75 pcf
Compressive Strength at 10% Compression	(BS EN 826: 1996)	200 kPa / 29 psi
Thermal Conductivity (23°C / 75°F & 50% RH)	(ASTM C 518)	0.021 W/m·K / 0.146 Btu-in/ft ² ·hr·°F
R-value:		
22 mm / 7/8"		1.05 m ² ·K/W / 6.0 ft ² ·hr·°F/Btu
30 mm / 1 3/16"		1.43 m ² ·K/W / 8.1 ft ² ·hr·°F/Btu
Water Vapour Transmission (23°C / 75°F & 50% RH)	(ASTM E 96)	617 MN·s/g / 0.34 grains/hr·ft ²
Operating Temperature Limits		–20°C to +80°C / –4°F to + 176°F

General Physical Properties (Aluminium Foil Vapour Barrier Facing)

Property		Typical Value
Composition	Coated Aluminium Glass Scrim Glass Mat	25 microns / 1 mil 5 mm x 5 mm / 0.2" x 0.2" 49 g/m ² / 30 lb/3000 ft ²
Water Vapour Transmission		1.15 ng·N·s / 0.02 perm (grains/ft ² ·hr·in·Hg)

Fire & Smoke Test Classifications (Rigid Phenolic Insulation Core & Aluminium Foil Vapour Barrier Facing)

Test	Test Method	Result
Surface Burning Characteristics	UL 723 / ASTM E 84–08a	< 25/50*
Burning	UL 181	Pass*
Fire Propagation	BS 476–6: 1989	index of performance not exceeding 12 and sub index (i ₁) not exceeding 6**
Surface Spread of Flame	BS 476–7: 1997	Class 1**
Specific Optical Density of Smoke (Average)	BS 6401: 1983	22.7 with pilot flame & 15 without pilot flame
Toxicity Index (Average)	Defence Standard 02–713: 2006	4.93

* These results from a series of tests enables the Kingspan KoolDuct® System to be UL Listed as a Class 1 Air Duct to Standard UL 181.

** The rigid phenolic insulation core of Kingspan KoolDuct® panels will achieve these results which enables it to be classified as Class 0 to the Building Regulations in England & Wales, Northern Ireland and the Republic of Ireland.



Appendix C2 - Insulation Performance Specifications

The installed insulation thickness shall be in accordance with the requirements of the relevant jurisdiction.

BS 5422: 2001 or ANSI / ASHRAE / IESNA 90.1: 2007 are often used as the minimum ductwork insulation thickness standard.

NB that, in some climates, the minimum energy efficiency requirements may not be sufficient for condensation control. In such cases, the risk of condensation should be assessed and calculated as appropriate.

BS 5422: 2001

BS 5422: 2001 shows two tables for ductwork operating in different conditions:

- Table 11 Insulation for Warm Ductwork; and
- Table 10 Insulation for Condensation Control Ductwork Carrying Chilled Air in Ambient Conditions.

The required thicknesses of insulation set out in BS 5422: 2001 are shown in the tables below. (Please note that ductwork operating at temperatures outside those given in the tables will require specific calculations).

NB An updated BS 5422: 2008 will be published late in 2008 and will supersede BS 5422: 2001. It is expected that the new BS 5422: 2008 will be used as the relevant standard when it is published.

Temperature difference between air inside ductwork and ambient air (°C)	Thickness (mm)		
	Kingspan KoolDuct®	Mineral Fibre	Nitrile Rubber
10	20*	34	38
15	22*	37	42
25	27*	44	50
Estimated Mean Temperature of Insulation:		+20°C	
Assumed Thermal Conductivity (k-value) of Insulation:			
Kingspan KoolDuct®		0.021 W/m-K	
Mineral Fibre**		0.035 W/m-K	
Nitrile Rubber (Class 0)		0.040 W/m-K	

Environmental Thickness (mm) of Insulation for Ductwork Carrying Warm Air to Control Heat Loss (Based on BS 5422: 2001 Table 11)

Minimum air temperature inside ductwork (°C)	Thickness (mm)	
	Kingspan KoolDuct®	Mineral Fibre
15	16*	25
12	22*	37
10	28*	45
Ambient Air Temperature – Indoor:		+25°C
Relative Humidity – Indoor:		80%
Dewpoint Temperature:		+21.3°C
Assumed Thermal Conductivity (k-value) of Insulation:		
Kingspan KoolDuct®		0.021 W/m-K
Mineral Fibre**		0.035 W/m-K

Thickness (mm) of Insulation for Condensation Control Ductwork Carrying Chilled Air in Ambient Conditions (Based on BS 5422: 2001 Table 10)

* Please note that the Kingspan KoolDuct® System is available in a 22 mm and 30 mm duct wall thickness only.

** At the average temperature of the insulation material, some mineral fibre duct insulation products may have a thermal conductivity lower than 0.035 W/m-K. For accurate thicknesses of those products please refer to a mineral fibre manufacturer. This table takes 0.035 W/m-K as a "safe" value.

It can be seen from the tables that in all circumstances shown that:

- the 22 mm and 30 mm thick rigid phenolic insulation panels used in the Kingspan KoolDuct® System match or exceed the specification laid down in BS 5422: 2001; and
- the thickness of the 22 mm and 30 mm thick rigid phenolic insulation panels used in the Kingspan KoolDuct® System can be significantly less than the required thickness of mineral fibre (up to 40% thinner) or nitrile rubber (up to 47% thinner).

Project Specification - Appendix C - Middle East



Appendix C2 - Insulation Performance Specifications (Continued)

ANSI / ASHRAE / IESNA 90.1: 2007

ANSI / ASHRAE / IESNA 90.1: 2007 shows two tables with minimum required R-values for ductwork insulation operating in different conditions:

- Table 6.8.2A Heating / Cooling Only Supply & Return Ductwork; and
- Table 6.8.2B Combined Heating & Cooling Supply & Return Ductwork.

The *Kingspan KoolDuct*® rigid phenolic insulation panel thickness and mineral fibre duct wrap thickness required to achieve the specified thermal performance standards as set out in the ANSI / ASHRAE / IESNA 90.1: 2007 tables are shown below.

Different Duct Insulation Thicknesses for the Minimum Required Insulation R-values for Ductwork Operating in Different Conditions						
Condition	Ductwork Location					
	Exterior	Ventilated Attic	Unvented Attic Above Insulated Ceiling ¹	Unvented Attic with Roof Insulation ²	Unconditioned Space ³	
Heating Only Ductwork						
Very Hot & Dry / Humid	Nil	Nil	Nil	Nil	Nil	
Hot & Dry / Humid	R-3.5 <i>7/8" / 1 1/2"</i>	Nil	Nil	Nil	Nil	
Warm & Dry / Humid	R-3.5 <i>7/8" / 1 1/2"</i>	Nil	Nil	Nil	Nil	
Cool & Dry / Humid	R-6.0 <i>7/8" / 2 3/16"</i>	R-3.5 <i>7/8" / 1 1/2"</i>	Nil	Nil	Nil	
Cooling Only Ductwork						
Very Hot & Humid	R-6.0 <i>7/8" / 2 3/16"</i>	R-6.0 <i>7/8" / 2 3/16"</i>	R-8.0 <i>1 3/16" / 3"</i>	R-3.5 <i>7/8" / 1 1/2"</i>	R-3.5 <i>7/8" / 1 1/2"</i>	
Very Hot & Dry / Humid	R-6.0 <i>7/8" / 2 3/16"</i>	R-6.0 <i>7/8" / 2 3/16"</i>	R-6.0 <i>7/8" / 2 3/16"</i>	R-3.5 <i>7/8" / 1 1/2"</i>	R-3.5 <i>7/8" / 1 1/2"</i>	
Hot & Dry / Humid	R-6.0 <i>7/8" / 2 3/16"</i>	R-6.0 <i>7/8" / 2 3/16"</i>	R-6.0 <i>7/8" / 2 3/16"</i>	R-3.5 <i>7/8" / 1 1/2"</i>	R-1.9 <i>7/8" / 1 1/2"</i>	
Warm & Dry / Humid	R-3.5 <i>7/8" / 1 1/2"</i>	R-3.5 <i>7/8" / 1 1/2"</i>	R-6.0 <i>7/8" / 2 3/16"</i>	R-1.9 <i>7/8" / 1 1/2"</i>	R-1.9 <i>7/8" / 1 1/2"</i>	
Cool & Dry / Humid	R-3.5 <i>7/8" / 1 1/2"</i>	R-1.9 <i>7/8" / 1 1/2"</i>	R-3.5 <i>7/8" / 1 1/2"</i>	R-1.9 <i>7/8" / 1 1/2"</i>	R-1.9 <i>7/8" / 1 1/2"</i>	
Return Ductwork						
All	R-3.5 <i>7/8" / 1 1/2"</i>	R-3.5 <i>7/8" / 1 1/2"</i>	R-3.5 <i>7/8" / 1 1/2"</i>	Nil	Nil	

1 Insulation R-values, measured in ft²·hr²·°F/Btu, are for the insulation as installed and do not include film resistance. The required minimum thicknesses do not consider water vapor transmission and possible surface condensation. Where exterior walls are used as plenum walls, wall insulation shall be as required by the most reflective condition of 6.4.4.2 or section 5 of ANSI / ASHRAE / IESNA 90.1: 2007. Insulation resistance measured on a horizontal plane in accordance with ASTM C 518 at a mean temperature of 75°F at the installed thickness.

2 Includes both ventilated and non ventilated crawlspaces.

3 Includes return air plenums with or without exposed roofs above.

Blue: Kingspan KoolDuct®: Assumed Installed R-value: 7/8" (R-6.0); 1 3/16" (R-8.1).

Red: Mineral Fibre: Assumed Installed R-value @ 25% Compression: 1 1/2" (R-4.2); 2 3/16" (R-6.0); 3" (R-8.4).

Table C1 – Minimum Required Insulation R-value¹ for Heating & Cooling Only Supply & Return Ductwork (Based on ANSI / ASHRAE / IESNA Standard 90.1: 2007 Table 6.8.2A)



Different Duct Insulation Thicknesses for the Minimum Required Insulation R-values for Ductwork Operating in Different Conditions					
Condition	Ductwork Location				
	Exterior	Ventilated Attic	Unvented Attic Above Insulated Ceiling ¹	Unvented Attic with Roof Insulation ²	Unconditioned Space ³
Supply Ductwork					
Very Hot & Humid	R-6.0 <i>7/8" / 2³/₁₆"</i>	R-6.0 <i>7/8" / 2³/₁₆"</i>	R-8.0 <i>1³/₁₆" / 3"</i>	R-3.5 <i>7/8" / 1¹/₂"</i>	R-3.5 <i>7/8" / 1¹/₂"</i>
Very Hot & Dry / Humid	R-6.0 <i>7/8" / 2³/₁₆"</i>	R-6.0 <i>7/8" / 2³/₁₆"</i>	R-6.0 <i>1³/₁₆" / 2³/₁₆"</i>	R-3.5 <i>7/8" / 1¹/₂"</i>	R-3.5 <i>7/8" / 1¹/₂"</i>
Hot & Dry / Humid	R-6.0 <i>7/8" / 2³/₁₆"</i>	R-6.0 <i>7/8" / 2³/₁₆"</i>	R-6.0 <i>1³/₁₆" / 2³/₁₆"</i>	R-3.5 <i>7/8" / 1¹/₂"</i>	R-3.5 <i>7/8" / 1¹/₂"</i>
Warm & Dry / Humid	R-6.0 <i>7/8" / 2³/₁₆"</i>	R-6.0 <i>7/8" / 2³/₁₆"</i>	R-6.0 <i>1³/₁₆" / 2³/₁₆"</i>	R-3.5 <i>7/8" / 1¹/₂"</i>	R-3.5 <i>7/8" / 1¹/₂"</i>
Cool & Dry / Humid	R-6.0 <i>7/8" / 2³/₁₆"</i>	R-6.0 <i>7/8" / 2³/₁₆"</i>	R-6.0 <i>1³/₁₆" / 2³/₁₆"</i>	R-1.9 <i>7/8" / 1¹/₂"</i>	R-3.5 <i>7/8" / 1¹/₂"</i>
Return Ductwork					
All	R-3.5 <i>7/8" / 1¹/₂"</i>	R-3.5 <i>7/8" / 1¹/₂"</i>	R-3.5 <i>7/8" / 1¹/₂"</i>	Nil	Nil

1 Insulation R-values, measured in ft²·hr·°F/Btu, are for the insulation as installed and do not include film resistance. The required minimum thicknesses do not consider water vapor transmission and possible surface condensation. Where exterior walls are used as plenum walls, wall insulation shall be as required by the most reflective condition of 6.4.4.2 or section 5 of ANSI / ASHRAE / IESNA 90.1: 2007. Insulation resistance measured on a horizontal plane in accordance with ASTM C 518 at a mean temperature of 75°F at the installed thickness.
2 Includes both ventilated and non ventilated crawlspaces.
3 Includes return air plenums with or without exposed roofs above.
Blue: Kingspan KoolDuct®: Assumed Installed R-value: 7/8" (R-6.0); 1³/₁₆" (R-8.1).
Red: Mineral Fibre: Assumed Installed R-value @ 25% Compression: 1¹/₂" (R-4.2); 2³/₁₆" (R-6.0); 3" (R-8.4).

Table C2 – Minimum Required Insulation R-value¹ for Combined Heating & Cooling Supply & Return Ductwork (Based on ANSI / ASHRAE / IESNA Standard 90.1: 2007 Table 6.8.2B)

It can be seen from the tables above that:

- in all circumstances shown that the 7/8" (R-6.0) and 1³/₁₆" (R-8.1) thick rigid phenolic insulation panels used in the Kingspan KoolDuct® System match or exceed the specification laid down in ANSI / ASHRAE / IESNA 90.1: 2007; and
- the thickness of the 7/8" and 1³/₁₆" thick rigid phenolic insulation panels used in the Kingspan KoolDuct® System can be significantly less than the required thickness of fiber glass (up to 60% thinner).

Appendix C3 - Fire & Smoke Performance

The appropriate fire and smoke performance requirements for the Middle East are:

- BS 476-6: 1989 – of low contribution to fire growth with fire propagation index of performance (I) not exceeding 12 and sub index (i₁) not exceeding 6;
- BS 476-7: 1997 – of very low surface spread of flame (Class 1); and
- Class 0 to the Building Regulations in England & Wales, Northern Ireland and the Republic of Ireland.
- ASTM E 84-08a – unfaced or composite (insulation, facing and adhesive) of low contribution to fire growth not exceeding 25 Flame Spread and 50 Smoke Developed indices;
- UL 723 – unfaced or composite (insulation, facing and adhesive) of low contribution to fire growth not exceeding 25 Flame Spread and 50 Smoke Developed indices; and
- UL 181 – UL classification as a Class 1 Air Duct.



Appendix C4 - Air Leakage Limits

Ductwork system air leakage shall be in accordance with the requirements of the relevant jurisdiction.

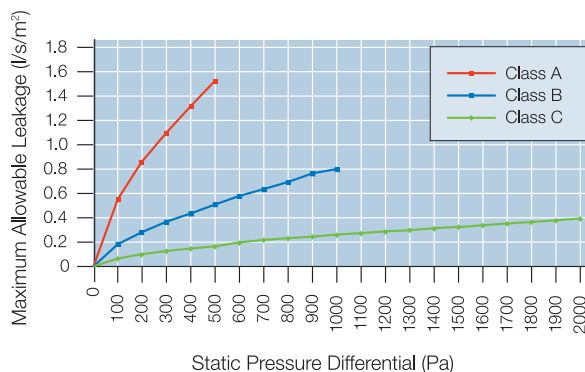
The maximum allowable air leakage limits as detailed in HVCA DW/144 (Specification for Sheet Metal Ductwork) or the SMACNA HVAC Air Duct Leakage Test Manual are often used.

HVCA DW/144 details the maximum allowable air leakage as shown in the table below:

Duct Pressure Class	Static Pressure Limit (Pa)		Maximum Air Velocity (m/s)	Air Leakage Limits (l/s/m ²)
	Positive	Negative		
Low-Pressure (Class A)	500	500	10	$0.027 \times p^{0.65}$
Medium-Pressure (Class B)	1000	750	20	$0.009 \times p^{0.65}$
High-Pressure (Class C)	2000	750	40	$0.003 \times p^{0.65}$

p = static pressure differential (Pa)

Based on the limits set out in the table above, the maximum allowable air leakage for each pressure class over a range of pressures from 0 to 2,000 Pascals (Pa) is plotted in the graph below. The leakage figures are given in litres of air per second per square metre (l/s/m²) of internally measured ductwork against a static pressure differential ranging from 100 Pa to 2,000 Pa.



SMACNA HVAC Air Duct Leakage Test Manual

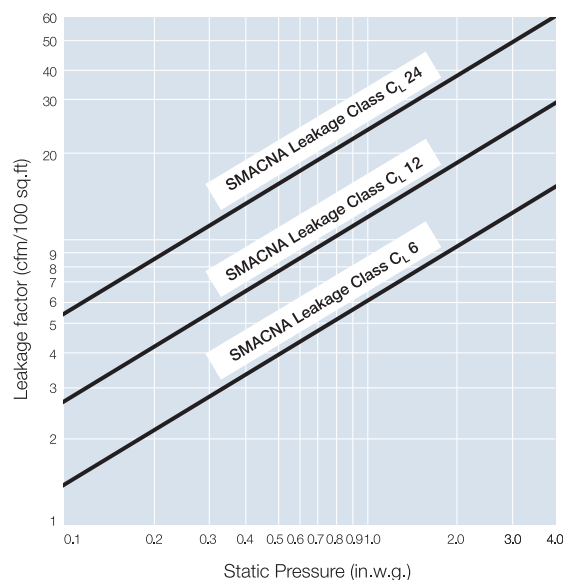
The SMACNA HVAC Air Duct Leakage Test Manual details the maximum allowable air leakage as shown in the table below:

Seal Class	Air Leakage Class (CL)	Static Pressure (in.w.g.)	Air Leakage Limits (cfm/100 sq.ft)
A	6	≥ 4	$6 \times p^{0.65}$
B	12	3	$12 \times p^{0.65}$
C	24	≤ 2	$24 \times p^{0.65}$

p = static pressure (in.w.g.)

Based on the limits set out in the table above, the maximum allowable air leakage for each pressure and seal class is plotted in the graph above right over a range of pressures from 0–4 in.w.g.

The leakage figures are given in cubic feet of air per minute per one hundred square feet (cfm/100 sq. ft) of internally measured ductwork against a static pressure ranging from 0–4 in.w.g.



Appendix C5 - Ductwork Fittings

The appropriate ductwork construction standard is HVCA DW/144 or the SMACNA HVAC Duct System Design Manual.

Appendix C6 - Finishes

Internal Ductwork

The finish shall be either:

- aluminium / zinc alloy coated sheet steel (0.7 mm / 0.028") which can be introduced during fabrication of the ductwork or installed in place; or
- a suitable paint finish (must not compromise factory applied reinforced aluminium facing or fire classification) applied in place.

External Ductwork

The finish shall be either:

- an aluminium cladding / jacketing system which can be introduced during fabrication of the ductwork or installed in place;
- aluminium / zinc alloy coated sheet steel (0.8 mm / 0.032") which can be introduced during fabrication of the ducting or installed in place;
- a fibre reinforced plastic which is introduced during the fabrication of the ductwork;
- a polymeric weather covering (for sheltered locations) installed in place; or
- no. 10 open weave glass cloth embedded between two coats of trowel applied mastic.



Appendix C7 - Testing for Air Leakage

Ductwork air leakage testing shall be carried out in accordance with the requirements of the relevant jurisdiction.

Ductwork leakage testing shall be carried out in accordance with the procedures set out in HVCA DW/144 or the SMACNA HVAC Air Duct Leakage Test Manual

HVCA DW/143

HVCA DW/143 recommends the range and frequency of testing that it deems to be satisfactory.

It recommends the following:

- high pressure ducts (Class C) – all tested;
- medium pressure ducts (Class B) – 10% of the ductwork selected at random and tested; and
- low pressure ducts (Class A) – untested.

It is also recommended:

- for medium pressure ducts, in the event of test failure of the randomly selected section, the designer shall have the right to select two further sections at random for testing. Where successive failures are identified there shall be a right to require the contractor to apply remedial attention to the complete ductwork system; and
- in general for all ducts tested, that the air leakage rate for any section shall not be in excess of the permitted rate (as stated in HVCA DW/144) for that section. If a first test produces leakage in excess of the permitted maximum, the section shall be resealed and retested until a leakage not greater than the permitted maximum for that section is achieved.

SMACNA HVAC Air Duct Leakage Test Manual

The SMACNA HVAC Air Duct Leakage Test Manual does not require testing for air leakage where adequate methods of assembly and sealing are used.

It recommends the following:

- high pressure ducts ≥ 4 in.w.g. (≥ 1000 Pa) – tested, if justified by the designer; and
- low – medium pressure ducts ≤ 3 in.w.g. (≤ 750 Pa) – untested.

Appendix C8- Standards / References

British Standards

BS 476-6: 1989

Fire tests on building materials and structures. Method of test for fire propagation for products

BS 476-7: 1997

Fire tests on building materials and structures. Method of test to determine the classification of the surface spread of flame of products

BS 6401: 1983

Method for measurement, in the laboratory, of the specific optical density of smoke generated by materials.

BS 5422: 2001

Method for specifying thermal insulating materials for pipes, tanks, vessels, ductwork and equipment operating within the temperature range -40°C to $+700^{\circ}\text{C}$

BS EN 826:1996

Thermal insulating products for building applications. Determination of compression behaviour

BS EN 12086:1997

Thermal insulating products for building applications. Determination of water vapour transmission properties

BS EN ISO 4590: 2003

Rigid cellular plastics. Determination of the volume percentage of open cells and of closed cells

BS EN ISO 9001: 2000

Quality management systems. Requirements

BS EN ISO 14001: 2004

Environmental management systems. Requirements with guidance for use)

American Standards

ASTM C 518: 2004

Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus

ASTM E96 / E96M-05

Standard Test Methods for Water Vapour Transmission of Materials

ASTM E 84-08a

Standard Test Method for Surface Burning Characteristics of Building Materials

UL 723

Test for Surface Burning Characteristics of Building Materials

UL 181

Standard for Safety Factory Made Air Ducts and Connectors

Other References

HVCA DW/144

Specification for Sheet Metal Ductwork

HVCA DW/143

A practical guide to Ductwork Leakage Testing

SMACNA HVAC Duct System Design Manual

SMACNA HVAC Air Duct Leakage Test Manual

ANSI / ASHRAE / IESNA 90.1: 2007

Energy Standard for Buildings Except Low-Rise Residential Buildings Sections 5 & 6

Project Specification - Appendix D - North America



Appendix D1 - Kingspan KoolDuct® Rigid Phenolic Insulation Panels

Description

Kingspan KoolDuct® rigid phenolic insulation panels have a CFC/HCFC-free rigid phenolic insulation core with a density range of 3.43–3.75 pcf. Manufactured by a continuous process, the quality of the insulation is constantly monitored and controlled. A closed cell structure makes the product non-wicking and highly resistant to moisture penetration and gives it excellent thermal properties. *Kingspan KoolDuct®* rigid phenolic insulation panels are jacketed on both sides with a protective low vapor permeability 1 mil aluminum foil reinforced with a 0.2" glass scrim which is extremely durable. *Kingspan KoolDuct®* rigid phenolic insulation panels are also available with a 0.9 mil black-coated aluminum foil reinforced with a 0.2" glass scrim jacket on one side and the above mentioned aluminum foil on the other.

Kingspan KoolDuct® rigid phenolic insulation panels are able to withstand temperatures from -4°F to + 176°F. They also have an exceptional resistance to burning and spread of flame. The composition of *Kingspan KoolDuct®* rigid phenolic insulation panels is such that when subjected to fire the outer surface forms a carbonaceous layer which retards further flame spread and penetration.

Kingspan KoolDuct® rigid phenolic insulation panels satisfy the requirements of ANSI / ASHRAE / IESNA 90.1: 2007 (Energy Standard for Buildings Except Low-Rise Residential Buildings) and IECC (International Energy Conservation Code) 2003 & 2006 and other major national specifications. *Kingspan KoolDuct®* rigid phenolic insulation panels are manufactured under a quality control system approved to BS EN ISO 9001: 2000 (Quality management systems. Requirements) and an environmental management system approved to BS EN ISO 14001: 2004 (Environmental management systems. Requirements with guidance for use).

Application

Kingspan KoolDuct® rigid phenolic insulation panels are a core component of the *Kingspan KoolDuct®* System of pre-insulated ductwork, which is an alternative to traditional sheet steel ductwork in Building Services / HVAC applications. The durable and puncture resistant aluminum foil jacket on *Kingspan KoolDuct®* rigid phenolic insulation panel is used to prevent the ingress of moisture, dust and dirt into the insulation.

Availability

- Insulation panel dimensions: 12.89 ft x 3.94 ft
- Insulation panel thickness: 7/8" (R-6) & 1 3/16" (R-8.1)

General Physical Properties (Rigid Phenolic Insulation Core)

Property	Test Method	Typical Value
Color		Pink
Minimum Closed Cell Content	(BS EN ISO 4590: 2003)	≥ 90%
Nominal Density Range		3.43–3.75 pcf
Compressive Strength at 10% Compression	(BS EN 826: 1996)	29 psi
Thermal Conductivity (75°F & 50% RH)	(ASTM C 518)	0.146 Btu-in/ft ² -hr-°F
Material R-value:		
7/8"		6.0 ft ² -hr-°F/Btu
1 3/16"		8.1 ft ² -hr-°F/Btu
Water Vapor Transmission (75°F & 50% RH)	(ASTM E 96)	0.34 grains/hr-ft ²
Operating Temperature Limits		-4°F to + 176°F

General Physical Properties (Aluminum Foil Vapor Barrier Jacket)

Property		Typical Value
Composition	Coated Aluminum Glass Scrim Glass Mat	1 mil 0.2" x 0.2" 30 lb/3000 ft ²
Water Vapor Transmission		0.02 perm (grains/ft ² -hr-in-Hg)

Fire & Smoke Test Classifications (Rigid Phenolic Insulation Core & Aluminum Foil Vapor Barrier Jacket)

Test	Test Method	Result
Surface Burning Characteristics	UL 723 / ASTM E 84-08a	< 25/50*
Burning	UL 181	Pass

These results from a series of tests enables the Kingspan KoolDuct® System to be UL Listed as a Class 1 Air Duct to Standard UL 181 in accordance with NFPA (National Fire Protection Association) Standards 90A & 90B.



Appendix D2 - Insulation Performance Specifications

The installed insulation thickness shall be in accordance with the requirements of the relevant jurisdiction. (Consult the DOE (US Department of Energy) ComCheck / ResCheck or the relevant authority for applicable codes / standards).

ANSI / ASHRAE / IESNA 90.1: 2007 and IECC 2003 & 2006 are enforced by many, but not all, North American jurisdictions as the minimum ductwork insulation thickness standard.

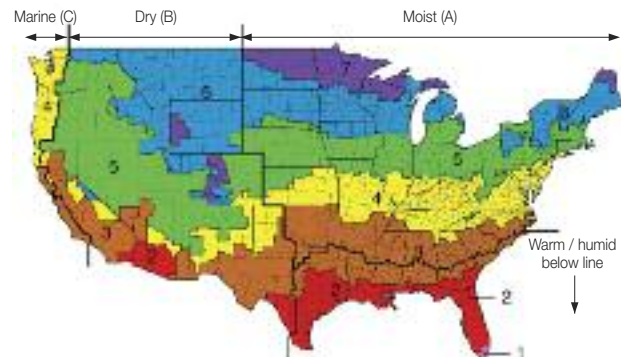
ANSI / ASHRAE / IESNA 90.1: 2007 shows two tables with minimum required R-values for ductwork insulation operating in different climate zones and locations:

- Table 6.8.2A Heating / Cooling Only Supply & Return Ductwork; and
- Table 6.8.2B Combined Heating & Cooling Supply & Return Ductwork.

The different climate zones are shown on the map to the right.

The **Kingspan KoolDuct®** rigid phenolic insulation panel thickness and fiber glass duct wrap thickness required to achieve the specified thermal performance standards as set out in the ANSI / ASHRAE / IESNA 90.1: 2007 tables are shown below.

NB that, in some climates, the minimum energy efficiency requirements may not be sufficient for condensation control. In such cases, the risk of condensation should be assessed and calculated as appropriate.



Zone 1 includes Hawaii, Guam, Puerto Rico, and the Virgin islands
 All of Alaska in Zone 7 except for the following Boroughs in Zone 8:
 Bethel Northwest Arctic Dellingham
 Southeast Fairbanks Fairbanks N. Star Wade Hampton
 Nome Yukon-Koyukuk North slope

ANSI / ASHRAE / IESNA Standard 90.1: 2007 Climate Zone Map for US Locations

Climate Zone	Different Duct Insulation Thicknesses for the Minimum Required Insulation R-values for Each Climate Zone				
	Exterior	Ventilated Attic	Unvented Attic Above Insulated Ceiling ¹	Unvented Attic with Roof Insulation ²	Unconditioned Space ³
Heating Only Ductwork					
1	R-6.0 <i>7/8" / 2 3/16"</i>	R-6.0 <i>7/8" / 2 3/16"</i>	R-8.0 <i>1 3/16" / 3"</i>	R-3.5 <i>7/8" / 1 1/2"</i>	R-3.5 <i>7/8" / 1 1/2"</i>
2	R-6.0 <i>7/8" / 2 3/16"</i>	R-6.0 <i>7/8" / 2 3/16"</i>	R-6.0 <i>7/8" / 2 3/16"</i>	R-3.5 <i>7/8" / 1 1/2"</i>	R-3.5 <i>7/8" / 1 1/2"</i>
3	R-6.0 <i>7/8" / 2 3/16"</i>	R-6.0 <i>7/8" / 2 3/16"</i>	R-6.0 <i>7/8" / 2 3/16"</i>	R-3.5 <i>7/8" / 1 1/2"</i>	R-3.5 <i>7/8" / 1 1/2"</i>
4	R-6.0 <i>7/8" / 2 3/16"</i>	R-6.0 <i>7/8" / 2 3/16"</i>	R-6.0 <i>7/8" / 2 3/16"</i>	R-3.5 <i>7/8" / 1 1/2"</i>	R-3.5 <i>7/8" / 1 1/2"</i>
5	R-6.0 <i>7/8" / 2 3/16"</i>	R-6.0 <i>7/8" / 2 3/16"</i>	R-6.0 <i>7/8" / 2 3/16"</i>	R-1.9 <i>7/8" / 1 1/2"</i>	R-3.5 <i>7/8" / 1 1/2"</i>
6	R-8.0 <i>1 3/16" / 3"</i>	R-6.0 <i>7/8" / 2 3/16"</i>	R-6.0 <i>7/8" / 2 3/16"</i>	R-1.9 <i>7/8" / 1 1/2"</i>	R-3.5 <i>7/8" / 1 1/2"</i>
7	R-8.0 <i>1 3/16" / 3"</i>	R-6.0 <i>7/8" / 2 3/16"</i>	R-6.0 <i>7/8" / 2 3/16"</i>	R-1.9 <i>7/8" / 1 1/2"</i>	R-3.5 <i>7/8" / 1 1/2"</i>
8	R-8.0 <i>1 3/16" / 3"</i>	R-8.0 <i>1 3/16" / 3"</i>	R-8.0 <i>1 3/16" / 3"</i>	R-1.9 <i>7/8" / 1 1/2"</i>	R-6.0 <i>7/8" / 2 3/16"</i>
Return Duct					
All	R-3.5 <i>7/8" / 1 1/2"</i>	R-3.5 <i>7/8" / 1 1/2"</i>	R-3.5 <i>7/8" / 1 1/2"</i>	Nil	Nil

1 Insulation R-values, measured in ft²-hr²-°F/Btu, are for the insulation as installed and do not include film resistance. The required minimum thicknesses do not consider water vapor transmission and possible surface condensation. Where exterior walls are used as plenum walls, wall insulation shall be as required by the most reflective condition of 6.4.4.2 or section 5 of ANSI / ASHRAE / IESNA 90.1: 2007. Insulation resistance measured on a horizontal plane in accordance with ASTM C 518 at a mean temperature of 75°F at the installed thickness.

2 Includes both ventilated and non ventilated crawlspaces.

3 Includes return air plenums with or without exposed roofs above.

Blue: Kingspan KoolDuct®; Assumed Installed R-value: 7/8" (R-6.0); 1 3/16" (R-8.1).

Red: Fiber Glass; Assumed Installed R-value @ 25% Compression: 1 1/2" (R-4.2); 2 3/16" (R-6.0); 3" (R-8.4).

Table D1 – Minimum Required Insulation R-value¹ for Combined Heating & Cooling Supply & Return Ductwork (Based on ANSI / ASHRAE / IESNA Standard 90.1: 2007 Table 6.8.2B)

Project Specification - Appendix D - North America



Climate Zone	Different Duct Insulation Thicknesses for the Minimum Required Insulation R-values for Each Climate Zone				
	Ductwork Location				
	Exterior	Ventilated Attic	Unvented Attic Above Insulated Ceiling ¹	Unvented Attic with Roof Insulation ²	Unconditioned Space ³
Heating Only Ductwork					
1 & 2	Nil	Nil	Nil	Nil	Nil
3	R-3.5 <i>7/8" / 1 1/2"</i>	Nil	Nil	Nil	Nil
4	R-3.5 <i>7/8" / 1 1/2"</i>	Nil	Nil	Nil	Nil
5	R-6.0 <i>7/8" / 2 3/16"</i>	R-3.5 <i>7/8" / 1 1/2"</i>	Nil	Nil	Nil
6	R-6.0 <i>7/8" / 2 3/16"</i>	R-6.0 <i>7/8" / 2 3/16"</i>	R-3.5 <i>7/8" / 1 1/2"</i>	Nil	Nil
7	R-8.0 <i>1 3/16" / 3"</i>	R-6.0 <i>7/8" / 2 3/16"</i>	R-6.0 <i>7/8" / 2 3/16"</i>	Nil	R-3.5 <i>7/8" / 1 1/2"</i>
8	R-8.0 <i>1 3/16" / 3"</i>	R-8.0 <i>1 3/16" / 3"</i>	R-8.0 <i>1 3/16" / 3"</i>	Nil	R-6.0 <i>7/8" / 2 3/16"</i>
Cooling Only Ductwork					
1	R-6.0 <i>7/8" / 2 3/16"</i>	R-6.0 <i>7/8" / 2 3/16"</i>	R-8.0 <i>1 3/16" / 3"</i>	R-3.5 <i>7/8" / 1 1/2"</i>	R-3.5 <i>7/8" / 1 1/2"</i>
2	R-6.0 <i>7/8" / 2 3/16"</i>	R-6.0 <i>7/8" / 2 3/16"</i>	R-6.0 <i>7/8" / 2 3/16"</i>	R-3.5 <i>7/8" / 1 1/2"</i>	R-3.5 <i>7/8" / 1 1/2"</i>
3	R-6.0 <i>7/8" / 2 3/16"</i>	R-6.0 <i>7/8" / 2 3/16"</i>	R-6.0 <i>7/8" / 2 3/16"</i>	R-3.5 <i>7/8" / 1 1/2"</i>	R-1.9 <i>7/8" / 1 1/2"</i>
4	R-3.5 <i>7/8" / 1 1/2"</i>	R-3.5 <i>7/8" / 1 1/2"</i>	R-6.0 <i>7/8" / 2 3/16"</i>	R-1.9 <i>7/8" / 1 1/2"</i>	R-1.9 <i>7/8" / 1 1/2"</i>
5 & 6	R-3.5 <i>7/8" / 1 1/2"</i>	R-1.9 <i>7/8" / 1 1/2"</i>	R-3.5 <i>7/8" / 1 1/2"</i>	R-1.9 <i>7/8" / 1 1/2"</i>	R-1.9 <i>7/8" / 1 1/2"</i>
7 & 8	R-1.9 <i>7/8" / 1 1/2"</i>	R-1.9 <i>7/8" / 1 1/2"</i>	R-1.9 <i>7/8" / 1 1/2"</i>	R-1.9 <i>7/8" / 1 1/2"</i>	R-1.9 <i>7/8" / 1 1/2"</i>
Return Ductwork					
All	R-3.5 <i>7/8" / 1 1/2"</i>	R-3.5 <i>7/8" / 1 1/2"</i>	R-3.5 <i>7/8" / 1 1/2"</i>	Nil	Nil

1 Insulation R-values, measured in ft²·hr·°F/Btu, are for the insulation as installed and do not include film resistance. The required minimum thicknesses do not consider water vapor transmission and possible surface condensation. Where exterior walls are used as plenum walls, wall insulation shall be as required by the most reflective condition of 6.4.4.2 or section 5 of ANSI / ASHRAE / IESNA 90.1: 2007. Insulation resistance measured on a horizontal plane in accordance with ASTM C 518 at a mean temperature of 75°F at the installed thickness.
2 Includes both ventilated and non ventilated crawlspaces.
3 Includes return air plenums with or without exposed roofs above.
Blue: Kingspan **KoolDuct**®. Assumed Installed R-value: 7/8" (R-6.0); 1 3/16" (R-8.1).
Red: Fiber Glass: Assumed Installed R-value @ 25% Compression: 1 1/2" (R-4.2); 2 3/16" (R-6.0); 3" (R-8.4).

Table D2 – Minimum Required Insulation R-value¹ for Heating & Cooling Only Supply & Return Ductwork (Based on ANSI / ASHRAE / IESNA Standard 90.1: 2007 Table 6.8.2A)

It can be seen from the tables above that:

- in all circumstances shown that the 7/8" (R-6.0) and 1 3/16" (R-8.1) thick rigid phenolic insulation panels used in the **Kingspan KoolDuct**® System match or exceed the specification laid down in ANSI / ASHRAE / IESNA 90.1: 2007 and IECC 2003 & 2006; and
- the thickness of the 7/8" and 1 3/16" thick rigid phenolic insulation panels used in the **Kingspan KoolDuct**® System can be significantly less than the required thickness of fiber glass (up to 60% thinner).



Appendix D3 - Fire & Smoke Performance

The appropriate fire and smoke performance requirements for North America are:

- ASTM E 84-08a – unfaced or composite (insulation, facing and adhesive) of low contribution to fire growth not exceeding 25 Flame Spread and 50 Smoke Developed indices;
- UL 723 – unfaced or composite (insulation, facing and adhesive) of low contribution to fire growth not exceeding 25 Flame Spread and 50 Smoke Developed indices; and
- UL 181 – UL/ULC classification as a Class 1 Air Duct to NFPA Standards 90A & 90B.

Appendix D4 - Air Leakage Limits

Ductwork system air leakage shall be in accordance with the requirements of the relevant jurisdiction. (Consult the DOE (US Department of Energy) ComCheck / ResCheck or the relevant authority for applicable codes / standards).

Ductwork installations are required to be made sufficiently airtight to ensure quiet and economical operation of the system. The SMACNA HVAC Air Duct Leakage Test Manual, ANSI / ASHRAE / IESNA 90.1: 2007 and IECC 2003 & 2006 are referred to in many, but not all, specifications in order to determine the air leakage limits for ductwork systems.

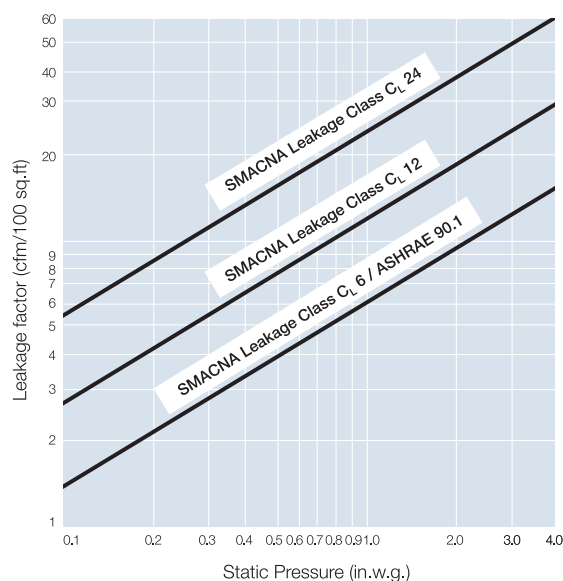
The maximum allowable air leakage for all Class 6 (C_L6) rectangular ducts is $6 \times P^{0.65}$ as defined by ANSI / ASHRAE / IESNA 90.1 and IECC 2003 & 2006 section 503.2.7.

The SMACNA HVAC Air Duct Leakage Test Manual details the maximum allowable air leakage as shown in the table below:

Seal Class	Air Leakage Class (C_L)	Static Pressure (in.w.g.)	Air Leakage Limits (cfm/100 sq.ft)
A	6	≥ 4	$6 \times p^{0.65}$
B	12	3	$12 \times p^{0.65}$
C	24	≤ 2	$24 \times p^{0.65}$

p = static pressure (in.w.g.)

Based on the limits set out in table above, the maximum allowable air leakage for each pressure and seal class is plotted in the graph above right over a range of pressures from 0–4 in.w.g. The leakage figures are given in cubic feet of air per minute per one hundred square feet (cfm/100 sq. ft) of internally measured ductwork against a static pressure ranging from 0–4 in.w.g.



Appendix D5 - Ductwork Fittings

The appropriate ductwork construction standard for North America is the ASHRAE Design Fundamentals Handbook Chapter 35 or SMACNA HVAC Duct System Design Manual.

Appendix D6 - Finishes

Internal Ductwork

The finish shall be either:

- aluminum / zinc alloy coated sheet steel (0.024") which can be introduced during fabrication of the ductwork or installed in place; or
- a suitable paint finish (must not compromise factory applied reinforced aluminum facing or fire classification) applied in place.

External Ductwork

The finish shall be either:

- an aluminum cladding / jacketing system which can be introduced during fabrication of the ductwork or installed in place;
- aluminum / zinc alloy coated sheet steel (0.032") which can be introduced during fabrication of the ducting or installed in place;
- a fiber reinforced plastic which is introduced during the fabrication of the ductwork;
- a polymeric weather covering (for sheltered locations) installed in place; or
- no. 10 open weave glass cloth embedded between two coats of trowel applied mastic.



Appendix D7 - Testing for Air Leakage

Ductwork air leakage testing shall be carried out in accordance with the requirements of the relevant jurisdiction.

ANSI / ASHRAE / IESNA 90.1 requires that ductwork designed to operate at static pressures > 3 in.w.g be tested for air leakage and that testing is performed on \geq 25% of the total installed duct area. It refers to the SMACNA HVAC Air Duct Leakage Manual as an industry accepted test procedure for air leakage.

The SMACNA HVAC Air Duct Leakage Test Manual does not require testing for air leakage where adequate methods of assembly and sealing are used. It recommends the following:

- high pressure ducts \geq 4 in.w.g. – tested, if justified by the designer; and
- low – medium pressure ducts \leq 3 in.w.g. – untested.

Appendix D8 - Standards / References

American Standards

ASTM C 518: 2004

Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus

ASTM E96 / E96M-05

Standard Test Methods for Water Vapor Transmission of Materials

ASTM E 84-08a

Standard Test Method for Surface Burning Characteristics of Building Materials

UL 723

Test for Surface Burning Characteristics of Building Materials

NFPA 90A

Standard for the Installation of Air Conditioning and Ventilating Systems

NFPA 90B

Standard for the Installation of Warm Air Heating and Air-Conditioning Systems

UL/ULC 181

Standard for Safety Factory Made Air Ducts and Connectors

British Standards

BS EN 826:1996

Thermal insulating products for building applications. Determination of compression behaviour

BS EN ISO 4590: 2003

Rigid cellular plastics. Determination of the volume percentage of open cells and of closed cells

BS EN ISO 9001: 2000

Quality management systems. Requirements

BS EN ISO 14001: 2004

Environmental management systems. Requirements with guidance for use)

Other References

US Department of Energy (DOE)

ComCheck & ResCheck

ANSI / ASHRAE / IESNA 90.1: 2007

Energy Standard for Buildings Except Low-Rise Residential Buildings Sections 5 & 6

ASHRAE Design Fundamentals Handbook Chapter 35

SMACNA HVAC Duct System Design Manual

SMACNA HVAC Duct Construction Standard

SMACNA HVAC Air Duct Leakage Test manual

Building Codes

The IECC (International Energy Conservation Code) 2003 & 2006

The IECC (International Energy Conservation Code) 2003 & 2006 503.2.7