Insulation

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The Kingspan KoolDuct® System

A SPECIFIER'S GUIDE

Fiber-free Core

UL LISTED

Kingspan®

Low Energy – Low Carbon Buildings

Contents

A Note about the Conversion of Values Used in this Document

The following has been applied, herein, regarding the use of US Customary Units () in the context of imperial measurements, and the use of the International System of Units (SI) in the context of metric measurements.

a. *The value shown to the left of the '/' is the imperial measurement, whilst the value shown to the right is the corresponding metric measurement.*
b. *In most circumstances shown, the metric value is the original value. As a result, the imperial value is converted from the metric value.*
c. *In all other circumstances, the opposite is applicable i.e. the metric value is converted from the imperial value. This is most notably where there is a reference to research or testing that has been conducted in the USA and / or in accordance with standards that utilize the imperial system.*
d. *For ease of reading, and where exacting precision is not critical, the converted value is rounded to the nearest appropriate figure.*

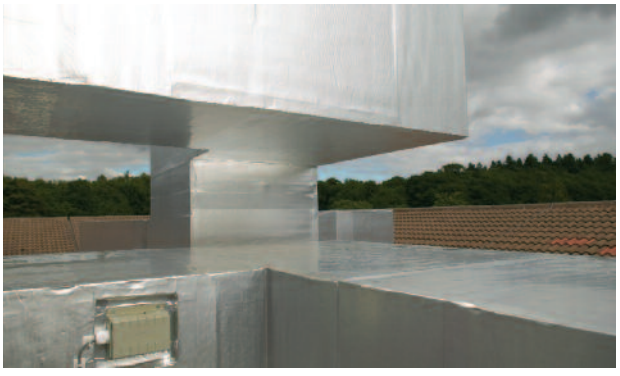
Introduction

Overview

The heating, ventilation and air–conditioning (HVAC) industry is in the midst of a dynamic era. However, air–distribution ductwork, a critical component of HVAC systems, has remained virtually unchanged since the early 1900s.

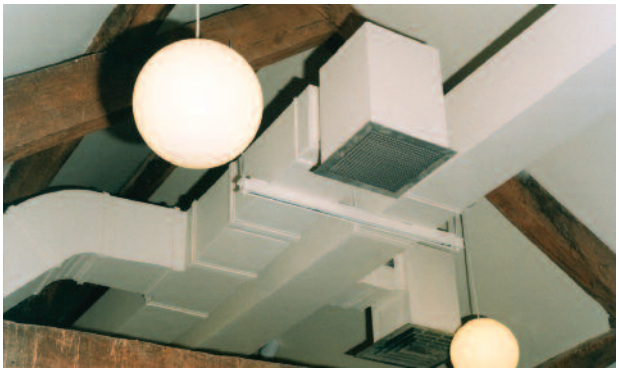
Several factors have introduced the need to revolutionize HVAC ductwork. Energy use has continued to escalate, and thus the demand for energy reducing solutions has intensified. Requirements for clean air are becoming increasingly prevalent. Speed of construction has become a valuable asset. Floor space and headroom are under constant pressure.

Traditionally, ductwork is constructed from galvanized sheet steel, which is installed first and then insulated separately as a second operation. The *Kingspan* **Kool**Duct® System however, is an advanced and innovative pre–insulated rectangular HVAC ductwork system, which is installed in a single–fix.



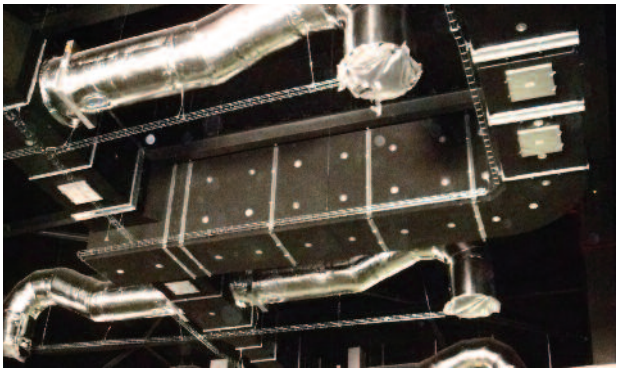
The *Kingspan* **Kool**Duct® System eliminates virtually all of the problems associated with galvanized sheet steel, fiber glass duct board and pre–insulated rigid polyiso (PIR) ductwork systems whilst, at the same time, offering additional advantages to the specifying engineer, the architect, the M&E contractor, the fabricator, the facilities manager, the property developer and the building owner.

Ductwork fabricated from The *Kingspan* **Kool**Duct® System was the first premium performance pre–insulated ductwork in the world to be UL Listed as a Class 1 Air Duct, to Standard for Safety UL 181 (Underwriters Laboratories: Factory Made Air Ducts & Air Connectors), when fabricated to a specification clearly defined by UL.



In addition, ductwork fabricated from The *Kingspan* **Kool**Duct® System can reduce air–leakage rates to a fraction of those typical of rectangular sheet metal ductwork. This cutting edge System thus offers the triple benefits of cutting energy use, cutting operational carbon dioxide (CO_2) emissions and cutting costs.

As a result, The *Kingspan* **Kool**Duct® System should be considered the ductwork system of choice, where low embodied environmental and low operational environmental impacts are key requirements.



Introduction

What is The *Kingspan* **Kool**Duct® System?

The *Kingspan* **Kool**Duct® System comprises premium performance *Kingspan* **Kool**Duct® panels, fabrication methods, coupling systems and a complete line of accessories to produce pre–insulated rectangular ductwork in sections up to 13 ft / 3.93 m long.

Kingspan **Kool**Duct® panels are available in the following standard thicknesses and corresponding installed R–values:

- 7/8" = R–6.0 ft²·hr·°F/Btu / 22 mm = R–1.047 m²·K/W; and
- 1 3/16" = R–8.1 ft²·hr·°F/Btu / 30 mm = R–1.428 m²·K/W.

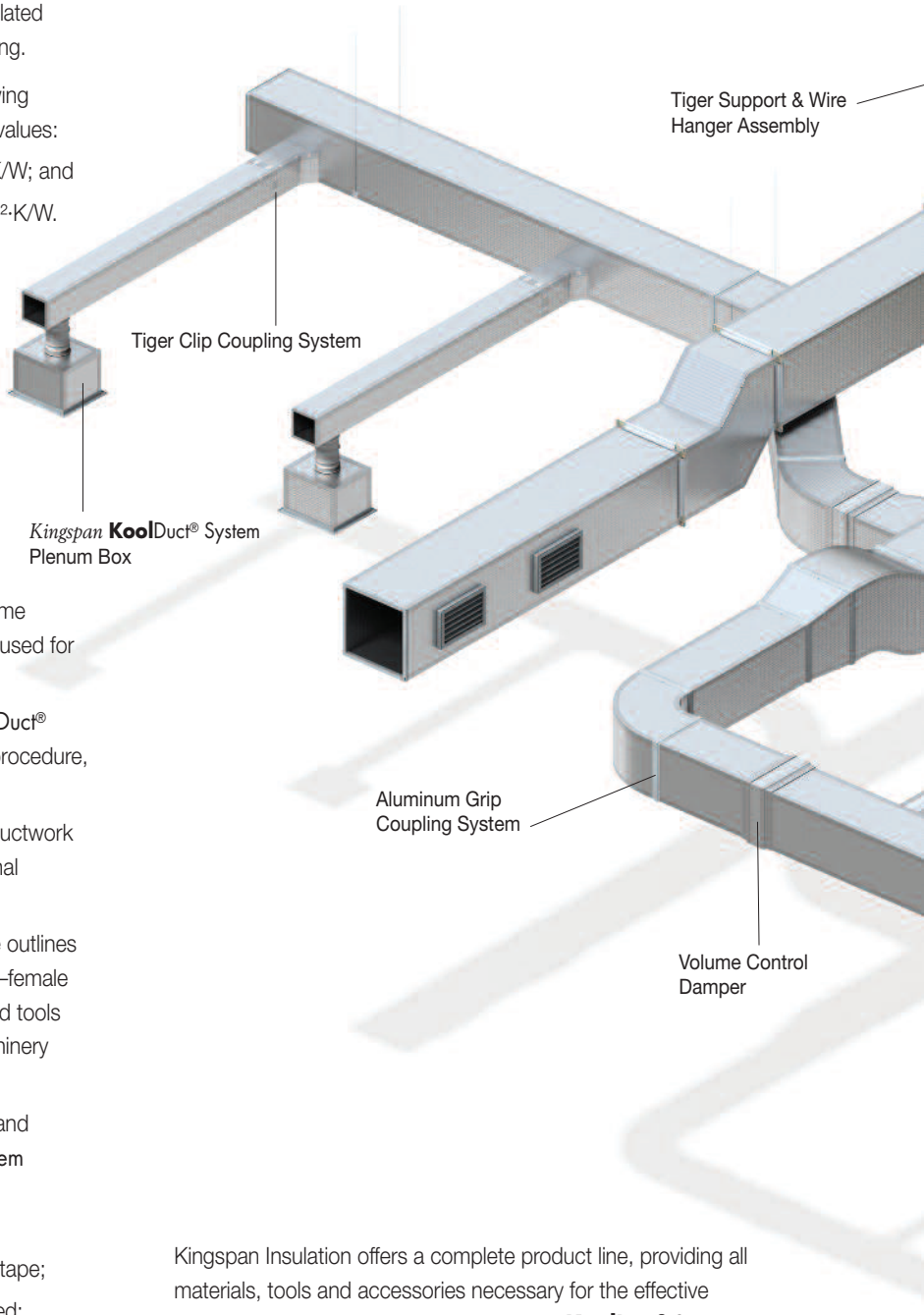
This allows ductwork to be fabricated with different wall thicknesses to suit different performance specifications.

Fiber-free Core *Kingspan* **Kool**Duct® panels comprise a fiber-free rigid thermoset phenolic insulation core faced with silver aluminum foil on both sides. In addition, there are several coupling systems available to suit different installation and project specification requirements. They include the 4–bolt, aluminum grip and Tiger Clip systems.

The design of ductwork, including fittings, fabricated from The *Kingspan* **Kool**Duct® System, follows the same calculation principles and duct sizing methods as are used for ductwork constructed from galvanized sheet steel.

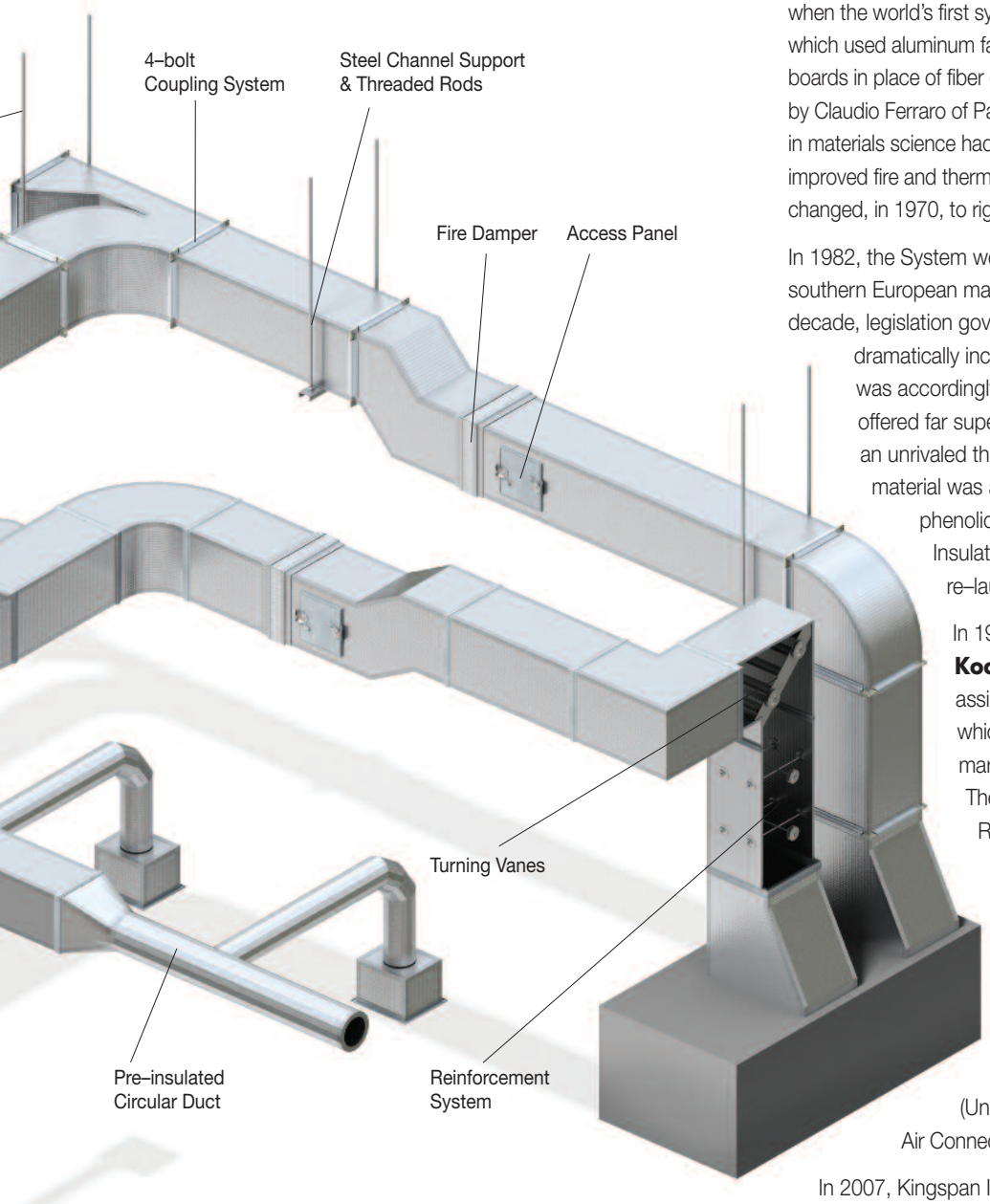
The fabrication of ductwork from The *Kingspan* **Kool**Duct® System is accomplished by following a standardized procedure, which incorporates the following processes:

- manually tracing / digitally nesting the outlines of ductwork sections, fittings and plenum boxes onto the internal surface of *Kingspan* **Kool**Duct® panels;
- cutting beveled edges at different angles along the outlines to form folded or butted miter joints, beveled male–female joints and non–beveled butt joints using either hand tools for manual fabrication, or CNC blade / router machinery for automated fabrication;
- assembling the cut pieces into the desired shape and securing into place with *Kingspan* **Kool**Duct® System Adhesive or Tiger Clips;
- taping joints and exposed insulation edges with a protective and durable aluminum foil vapor barrier tape;
- reinforcing ductwork sections and fittings, if required;
- sealing the internal side of all miter joints with *Kingspan* **Kool**Duct® System High Performance Silicone Sealant;
- coupling ductwork sections and fittings; and
- inspecting finished ductwork to ensure that it is fit for the purpose intended.



Kingspan Insulation offers a complete product line, providing all materials, tools and accessories necessary for the effective fabrication of ductwork from The *Kingspan* **Kool**Duct® System. Each component has been rigorously tested in the field, in a variety of ductwork applications, to the highest performance standards. Further details are contained in The *Kingspan* **Kool**Duct® System Component Catalogue.

Accurate fabrication and best practice installation are crucial in ensuring compliance with legislation, delivering required thermal performance levels and reducing air–leakage rates to a minimum.



History

The history of The *Kingspan* **Kool**Duct® System dates back to 1965 when the world's first system of pre–insulated HVAC ductwork, which used aluminum faced rigid polyurethane (PUR) insulation boards in place of fiber glass insulated sheet metal, was established by Claudio Ferraro of Pall. In the five years that followed, innovations in materials science had facilitated the development of insulants with improved fire and thermal performance. As a result, the insulant was changed, in 1970, to rigid polyiso (PIR).

In 1982, the System went global, having proved its success in southern European markets. However, by the end of the following decade, legislation governing fire safety in buildings had dramatically increased in stringency. In 1992, the insulant was accordingly upgraded to a new material that not only offered far superior fire and smoke performance, but also an unrivaled thermal performance. This cutting edge material was a premium performance rigid thermoset phenolic insulant, developed by **Kool**therm® Insulation Ltd. In that same year, the System was re–launched as The Pal **Kool**Duct® System.

In 1996, Kingspan Group plc acquired **Kool**therm® Insulation Ltd and eventually assimilated it into Kingspan Insulation Ltd, which subsequently became responsible for marketing the System in the UK and Ireland as The *Kingspan* **Kool**Duct® System. Responsibility in all other geographical regions was maintained by Pal International Srl, which continued to purchase the premium performance insulant from Kingspan Industrial Insulation.

Four years later, ductwork fabricated from the System became UL Listed to Standard for Safety UL 181 (United Laboratories: Factory Made Air Ducts & Air Connectors).

In 2007, Kingspan Insulation acquired the rights from Pal International Srl for the marketing and development of the System in all geographical regions, except for the USA and Canada. This swiftly changed in 2009, when Kingspan Insulation expanded its operations across these two countries, subsequently assuming full global responsibility for the System.

In 2010, the premium performance pre–insulated rectangular HVAC ductwork system was relaunched as The *Kingspan* **Kool**Duct® System, in all geographical regions.

As a result, ductwork from The *Kingspan* **Kool**Duct® System is only fabricated by specially trained fabricators who have completed The *Kingspan* **Kool**Duct® System Training Course, and whose competencies are regularly reviewed. The required standards of fabrication are detailed in The *Kingspan* **Kool**Duct® System Fabrication Manual series of publications.

Introduction

What is Different about The *Kingspan* **Kool**Duct® System?

The *Kingspan* **Kool**Duct® System offers numerous benefits in comparison with insulated galvanized sheet steel, fiber glass duct board and pre–insulated rigid polyiso (PIR) ductwork systems. Benefits include, but are not limited to, the following:

- UL Listed – was the first premium performance pre–insulated ductwork in the world to be UL Listed as a Class 1 Air Duct, to Standard for Safety UL 181 (Underwriters Laboratories: Factory Made Air Ducts & Air Connectors), when fabricated to a specification clearly defined by UL;
- low weight – weighs up to 72% less than ductwork constructed from galvanized sheet steel and insulated with fiber glass duct wrap – this makes it ideal for retrofit projects, where existing building structures have insufficient load capacities for new service loads;
- faster installation speeds – low weight ductwork fabricated in sections up to 13 ft / 3.93 m long, single–fix installation and no need to install insulation as a second operation, reduces project scheduling periods for insulated ductwork;
- space saving – typically saves up to 6–8" / 150–200 mm in a single dimension, since the space required to manually install a separate layer of insulation around the ductwork is eliminated – this allows ductwork to be installed flush to ceilings, walls and floors, as well as to surfaces within confined enclosures;

- installed cost savings – reduced labor and materials, including fixings and first level support members, can provide an ideal value engineered ductwork solution, without compromising performance;
- low air–leakage – rates can be reduced to a fraction of those typical of rectangular sheet metal ductwork;
- reduced energy usage and running costs – low ductwork air–leakage can yield significant electrical consumption savings, because of reduced heating and cooling loads, and fan energy usage;
- easily modified – ductwork configurations can be easily modified and adapted onsite to deal with unexpected changes to the design, which may be required to circumvent unforeseen obstructions and other building design issues;
- whole life cost saving – up to 20% over 30 years, compared with ductwork constructed from galvanized sheet steel and insulated with fiber glass duct wrap;
- lower embodied energy – up to 27% less than that of fiber glass insulated galvanized sheet steel ductwork;
- reduced operational carbon dioxide (CO_2) emissions – as a result of low ductwork air–leakage, and the subsequent reduction in operational energy use;
- reduced workshop–generated waste – computer aided fabrication can greatly reduce the volume of waste, compared with manual fabrication; and
- a fiber–free rigid insulation core – minimizes the risk of loose fibers entering the airstream through the ductwork, since distributed air does not come into contact with an insulation material that produces loose fibers.

Further information on each of the above can be found in the Benefits section of this document.

Applications

Suitability

The *Kingspan* **Kool**Duct® System is designed for use in building services / HVAC applications. It is suitable for both new build and retrofit projects in the residential, commercial, institutional, light industrial and leisure sectors. Moreover, it is especially suitable for use in non–ferrous applications such as MRI scanning units in hospitals, and on other high specification projects where insulants with a fiber-free core may be preferred, for instance, in

- the food, beverage and pharmaceutical industries;
- clean air and hygiene controlled environments;
- high relative humidity environments;
- swimming pools*; and
- sterile areas in medical research and healthcare facilities, as well as communication / server rooms in data centers.

**For swimming pools, non–standard applications and project specific advice, please contact Kingspan Insulation.*

Ductwork fabricated from The *Kingspan* **Kool**Duct® System can be installed indoors, outdoors, visibly mounted, concealed above false ceilings, concealed below raised floors or within confined enclosures such as pre–fabricated modules. Furthermore, its versatility enables individual system components, such as plenum boxes, risers and straight sections to be integrated with sheet metal ductwork, whilst larger sized ducts, with a cross–sectional dimension greater than 78" / 2 m, are easily fabricated.

Ductwork fabricated from The *Kingspan* **Kool**Duct® System has an intrinsic aesthetically pleasing appearance, which makes it particularly attractive for open–to–view applications.

Operating Recommendations & Limitations

It is recommended that ductwork fabricated from The *Kingspan* **Kool**Duct® System is used for operation as supply, return and exhaust air ductwork for heating, ventilation and air–conditioning systems within the following limits:

Mean Air Velocity (Max.)	5000 fpm / 25.4 m/s
Design Pressure (Max.)*	Positive: 4 in·w.g. / 1000 Pa Negative: 3 in·w.g. / 750 Pa
Temperature	Internal air temperature of –15ºF to +185ºF / –26°C to 85ºC during continuous operation.
Size	Unlimited (provided that *Kingspan* **Kool**Duct® System fabrication techniques and procedures are strictly observed).

Table 1: Operating Limits for Ductwork Fabricated from the *Kingspan* **Kool**Duct® System

These are maximum values and vary depending upon both the coupling system and the size of the ductwork. Refer to The Kingspan* **KoolDuct® System *Fabrication Manual series of publications for details.*

NB 'Mean Air Velocity' refers to the design airflow rate related to the cross sectional area of the ductwork. 'Design Pressure' relates to the actual total pressure of the relevant section of ductwork and not the fan static pressure. 'Total Pressure' is a combination of both static and dynamic pressures.

Ductwork fabricated from The *Kingspan* **Kool**Duct® System should not be used in the following applications:

- conveyance of solids;
- fire resistant ductwork;
- kitchen / grease hood exhaust systems;
- chemical, fume or smoke exhaust systems;
- where combustible matter readily collects inside the ductwork;
- adjacent to any mechanical / electrical sources of extreme heat;
- outdoor / underground use without mechanical and / or weather protection;
- where the failure of automatic control equipment may give rise to extreme temperatures; and
- with equipment of any type that does not include automatic maximum temperature controls.

Benefits

UL Listing

Ductwork fabricated from The *Kingspan* **Kool**Duct® System was the first premium performance pre–insulated ductwork in the world to be UL Listed as a Class 1 Air Duct, to Standard for Safety UL 181 (Underwriters Laboratories: Factory Made Air Ducts & Air Connectors). The UL Listing requires that ductwork is fabricated using:

- $^{25}/_{32}$"–1 $^{19}/_{64}$" / 20–33 mm *Kingspan* **Kool**Duct® panels, produced at Kingspan Insulation's Pembridge, UK, manufacturing facility, faced with silver aluminum foil autohesively bonded to the insulation core, on both sides, during their manufacture;
- either, or a combination of, the 4-bolt, aluminum grip and / or the Tiger Clip coupling systems; and
- an aluminum foil vapor barrier tape that is UL Listed A–P to Standard for Safety UL 181 A (Underwriters Laboratories: Standard for Closure Systems for use with Rigid Air Ducts).
- Kingspan High Performance Silicone Sealant / Caulk.

To meet UL Class 1 Air Duct requirements, ductwork fabricated from The *Kingspan* **Kool**Duct® System, and / or the individual components from which it is fabricated, must withstand the stringent conditions to which they are subjected in a series of rigorous physical tests. They include: surface burning characteristics; burning; flame penetration; mold growth and humidity; puncture; pressure; corrosion; erosion; static load; impact; collapse; air–leakage; and low and high temperatures.

The results of the UL Fire Test Standards achieved by *Kingspan* **Kool**Duct® panels, faced with silver aluminum foil on both sides, are shown in Table 2.

Standard	Result
UL 723 (Test for Surface Burning Characteristics of Building Materials)	Flame spread / smoke developed indices: < 25/50
UL 181 (Factory Made Air Ducts & Air Connectors)	Burning (as part of fabricated duct section): Pass
	Flame penetration: 30 Minutes

Table 2: Results of UL Fire Test Standards Achieved by *Kingspan* **Kool**Duct® Panels Faced with Branded Silver Aluminum Foil on Both Sides.

UL Listed ductwork fabricated from The *Kingspan* **Kool**Duct® System satisfies the requirements for:

- Class 1 Rigid Air Ducts, as defined by the National Fire Protection Assembly (NFPA) Standards for the Installation of Air–conditioning & Ventilating Systems (90A), and the Installation of Warm Air Heating & Air–conditioning Systems (90B); and
- Non–metallic Ducts and Factory Made Ducts, as defined by the International Mechanical Codes (IMC) and International Residential Codes (IRC), respectively, of the International Code Council (ICC).

To maintain the UL Listing for ductwork fabricated from The *Kingspan* **Kool**Duct® System, Kingspan Insulation must: deliver a program of production control; regularly provide samples for audit testing; and allow unannounced periodic inspections of the manufacturing facility that produces *Kingspan* **Kool**Duct® panels, by UL representatives.

Further details of the UL Listing for ductwork fabricated from The *Kingspan* **Kool**Duct® System are published at www.ul.com in the 'Online Certifications Directory'. To view the listing, type 'Kingspan Insulation' under the search parameter 'Company Name', followed by 'MH25124' under the search parameter 'UL File Number'.

Fire Performance

Properties

The insulation core of *Kingspan* **Kool**Duct® panels is a rigid thermoset material and, unlike thermoplastic materials, it does not melt, drip or produce flaming droplets. Its intricately cross–linked structure makes it difficult to ignite and, when subjected to fire, its outer surface forms a strong carbonaceous layer that limits heat generation and retards further flame spread. Moreover, there is an almost complete absence of smoke, when subjected to a flame source.

In addition, the insulation core has a resistance to burning and spread of flame far superior to that of flexible elastomeric foam (FEF), rigid polyurethane foam (PUR) and rigid polyiso foam (PIR) insulants.

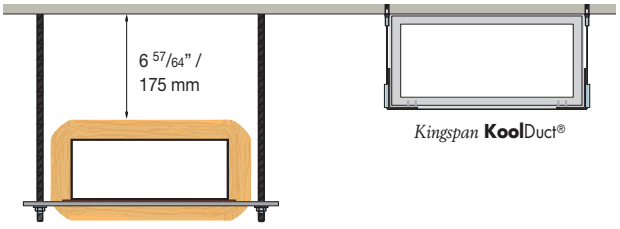
Ratings & Compliance

When subjected to the fire tests of ASTM E 84 (Standard Test for Surface Burning Characteristics of Building Materials), *Kingspan* **Kool**Duct® panels, faced with silver aluminum foil on both sides, achieve a flame spread index (FSI) of 10 and a smoke developed index (SDI) also of 10. These results exceed the commonly required 25/50 FSI/SDI rating for ductwork insulation materials.

Kingspan **Kool**Duct® panels, faced with silver aluminum foil on both sides, satisfy the requirements for the surface burning characteristics of foam plastic insulation, as defined by the International Building Codes (IBC) and the International Residential Codes (IRC) of the International Code Council (ICC).

Space

Ductwork fabricated from The *Kingspan* **Kool**Duct® System is space saving by virtue of eliminating the space required to manually install a separate layer of insulation around the ductwork. Moreover, ductwork fabricated from The *Kingspan* **Kool**Duct® System can be installed flush to ceilings, walls and floors, as well as to surfaces within confined enclosures. This can typically save 6–8" / 150–200 mm of valuable space, making it ideal for use in service runs, raised floors and pre–fabricated modules.



Thinner insulation, as a result of the insulating efficiency of *Kingspan* **Kool**Duct® panels, further contributes to space savings. The aged thermal conductivity (k–value / λ–value) of *Kingspan* **Kool**Duct® panels is 0.146 Btu·in/ft²·in·°F / 0.021 W/m·K at 50–77°F / 10–25°C mean (ASTM C 518 – Standard Test Method for Steady–State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus). This makes *Kingspan* **Kool**Duct® panels the most thermally efficient, and hence the thinnest, insulation product commonly used for pre–insulated HVAC ductwork. The installed and out–of–package material thermal resistance (R–value), of each of the different panel thicknesses (calculated by dividing the panel's thickness by its k-value), are shown in Table 3.

Thickness	Installed R–value
7/8" / 22 mm	6.0 ft²·hr·°F/Btu / 1.047 m²·K/W
1 3/16" / 30 mm	8.1 ft²·hr·°F/Btu / 1.428 m²·K/W

Table 3: Installed Material Thermal Resistances of *Kingspan* **Kool**Duct® Panels

A cost analysis of the benefits that the aforementioned space saving ability has on floor–to–floor dimensions, in UK multi–story buildings, was performed by independent consultants Rider Levett Bucknall. The results of the analysis showed that, if floor–to–floor heights can be reduced to take advantage of these space saving abilities, the use of ductwork fabricated from The *Kingspan* **Kool**Duct® System, as part of a variable air volume (VAV) air–conditioning system, can save 1–2% in overall project construction cost. This saving comes predominantly from reduced structure, cladding and internal wall, and wall finishing costs.

In addition, ductwork fabricated from The *Kingspan* **Kool**Duct® System can be supplied in flat form, ready for assembly onsite. Consequently, the load space required for the transportation of pre–assembled ductwork from the workshop to site, as well as the number of vehicles, could be reduced. This could provide a further benefit where the space and access required for the off–loading of goods from large vehicles may be restricted.

Further information can be found at:
www.kingspaninsulation.us/ductwork–space.

Weight

Ductwork fabricated from The *Kingspan* **Kool**Duct® System can weigh up to 72% less than ductwork constructed from galvanized sheet steel and insulated with fiber glass duct wrap.

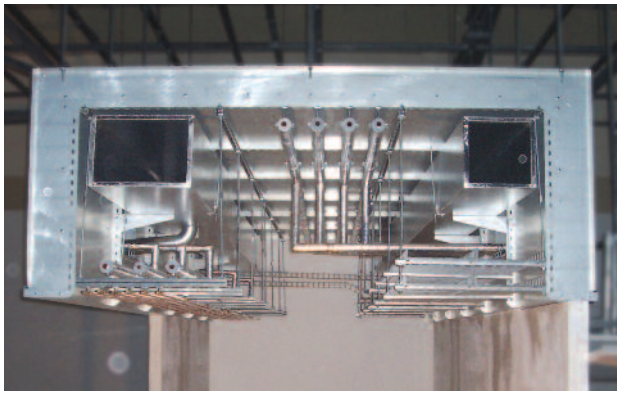
The low weight of ductwork fabricated from The *Kingspan* **Kool**Duct® System can enable easier installation and much lower handling costs, since fewer people are required to install a ductwork section. Two individuals can quickly and easily install large ductwork sections.

Most 13 ft / 3.93 m long sections of ductwork fabricated from The *Kingspan* **Kool**Duct® System, regardless of the choice of coupling system, weigh 50 lb / 23 kg or less. This is below the maximum manual handling and lifting weight limits for an individual in the workplace, as recommended by many health and safety regulatory authorities.

For instance, a 13 ft / 3.93 m long ductwork section, fabricated to meet the requirements for a 2 in·w.g. / 500 Pa low pressure HVAC system and having an internal perimeter of 32" / 800 mm, a wall thickness of 7/8" / 22 mm and using either the 4–bolt or aluminum grip coupling system, weighs less than 21 lb / 9.5 kg. A larger sized section, having an internal perimeter of 110 ¼" / 2800 mm and using the Tiger Clip coupling system, but otherwise the same as the aforementioned specification, can weigh less than 50 lb / 23 kg.

Tables of weights for ductwork sections fabricated from The *Kingspan* **Kool**Duct® System, of various dimensions and with the different coupling systems, are contained in the The *Kingspan* **Kool**Duct® System Fabrication Manual series of publications.

Benefits



The low weight of ductwork fabricated from The *Kingspan* **Kool**Duct® System makes it especially suitable for use in pre–fabricated modules, which may have to be transported long distances to site. Moreover, the requirement for specialized heavy–duty mechanical handling and lifting equipment can be reduced, which makes ductwork fabricated from The *Kingspan* **Kool**Duct® System particularly favorable for riser sections that span multiple stories in high–rise buildings.

Ductwork fabricated from The *Kingspan* **Kool**Duct® System can be easily supported by lightweight wire systems or low gauge metal hangers and supports. Furthermore, supports can be installed at larger centers than with ductwork constructed from galvanized sheet steel. The UL Listing for ductwork fabricated from The *Kingspan* **Kool**Duct® System allows for a maximum spacing of 13 ft / 3.96 m centers for supports. Galvanized sheet steel ductwork, on the other hand, often requires heavier and more robust support systems e.g. rolled steel channel, angle or profile bearer sections with drop rod, studding or stirrup hangers, installed at smaller centers.

Many older buildings undergoing refurbishment may not be designed to support the additional weight of retrospectively installed sheet steel ductwork and its insulation. In such circumstances, ductwork fabricated from The *Kingspan* **Kool**Duct® System can generally alleviate the requirement for additional structural support.

Research, conducted in the UK by independent consultants Rider Levett Bucknall, into a number of refurbishment projects in which ductwork fabricated from The *Kingspan* **Kool**Duct® System, comprising 7/8" / 22 mm *Kingspan* **Kool**Duct® panels and the aluminum grip coupling system, was installed, has shown that the main reason for its specification was that it could overcome severe constraints on structural loadings.

Further information can be found at:
www.kingspaninsulation.us/ductwork–weight.

Installation Speed

Ductwork fabricated from The *Kingspan* **Kool**Duct® System has a single–fix installation and eliminates the need to install insulation as a second operation, thus reducing time onsite and contractor management through faster installation speeds.

The ability to fabricate ductwork from The *Kingspan* **Kool**Duct® System in up to 13 ft / 3.93 m long sections, rather than the standard 4 ft or 5 ft / 1.2 m or 1.5 m lengths, as is the case with sheet steel ductwork, means fewer sections and less handling. This, combined with the low weight of ductwork fabricated from The *Kingspan* **Kool**Duct® System, the requirement for fewer supports and ease of handling, results in a fast–track installation.

Research, conducted in the UK by independent consultants Rider Levett Bucknall, into a number of retrofit projects in which ductwork fabricated from The *Kingspan* **Kool**Duct® System, comprising 7/8" / 22 mm *Kingspan* **Kool**Duct® panels and the aluminum grip coupling system, was installed, has shown that the main reason for its selection was that it could be installed up to three times faster than sheet steel ductwork – without even taking into account the time required to install insulation separately as a second operation. Rider Levett Bucknall also concluded that panel thickness has no effect on the speed of installing ductwork fabricated from The *Kingspan* **Kool**Duct® System.

Faster installation obviously means lower costs, less disruption for other trades onsite and, on applicable projects, both a reduction in the risk of incurring penalties for late completion of the insulated ductwork contract and an increase in the possibility of attaining rewards for early completion.

Further information can be found at:
www.kingspaninsulation.us/ductwork–speed.

Installed Cost

Research, conducted in the US, in 2010, by mechanical and electrical engineering services firm, MDA Engineering Inc., under the auspices of Luther Home of Mercy, into the installed cost of differing insulated HVAC ductwork specifications, showed the cost of ductwork fabricated from The *Kingspan* **Kool**Duct® System, to be less expensive than that of ductwork constructed from galvanized sheet steel and insulated with fiber glass duct wrap.

The research utilized empirical data derived from two HVAC ductwork installations in two separate new construction buildings of identical design, both belonging to Luther Home of Mercy. It compared ductwork fabricated from The *Kingspan* **Kool**Duct® System, comprising 7/8" / 22 mm *Kingspan* **Kool**Duct® panels and the Tiger Clip coupling system, with galvanized sheet steel ductwork insulated with 2" / 51 mm thick fiber glass duct wrap. The ductwork and HVAC system design, layout and performance specification were identical.

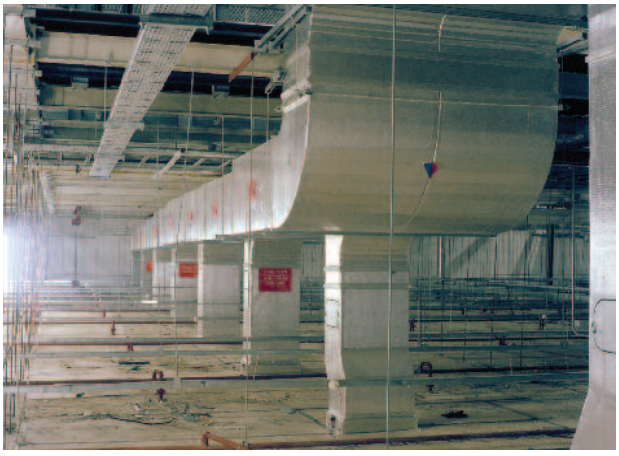
The total installed cost (comprising union certified labor and materials), for each ductwork system, is shown in Table 4.

Ductwork Specification	Installed Cost
Kingspan **Kool**Duct®	$25,404.00
Fiber Glass Insulated Galvanized Sheet Steel	$30,524.00

Table 4: Installed Cost Comparison between Ductwork Fabricated from The *Kingspan* **Kool**Duct® System & Fiber Glass Insulated Galvanized Sheet Steel Ductwork.

It can be seen from Table 4, that ductwork fabricated from The *Kingspan* **Kool**Duct® System made an installed cost saving of $5120.00, compared with the fiber glass insulated galvanized sheet steel ductwork, which was over 16% more expensive.

A key factor in the difference shown is in the cost of labor man–hours. The construction, installation and insulation activity of the sheet steel ductwork system, accounted for 714.75 hours. In contrast, the fabrication and installation of ductwork from The *Kingspan* **Kool**Duct® System, only required 513.75 hours – providing a labor man–hour saving of 28%.



Luther Home of Mercy is a not–for–profit organization based in Williston, Ohio. It serves the community by providing care services for people with developmental disabilities, and by supporting independent living in residential cottages across its purpose built campus, as well as in private homes and family care facilities throughout the neighborhood. This research was conducted at two of its campus based residential cottages.

Further information can be found at: www.kingspaninsulation.us/ductwork–luther.

Benefits

Frictional Resistance, Air-leakage, Energy Usage & Running Costs

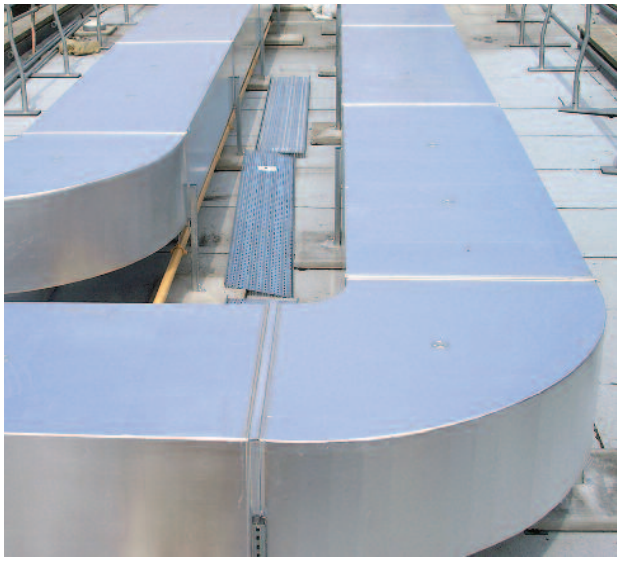
The frictional resistance of ductwork fabricated from The *Kingspan* **Kool**Duct® System is comparable with that of galvanized sheet steel ductwork. Testing, conducted in the UK by independent testing and research organization BSRIA, on ductwork sections of different sizes with a range of fittings, has shown that at velocities of 394–3937 fpm / 2–20 m/s, the resistance to airflow is almost identical.

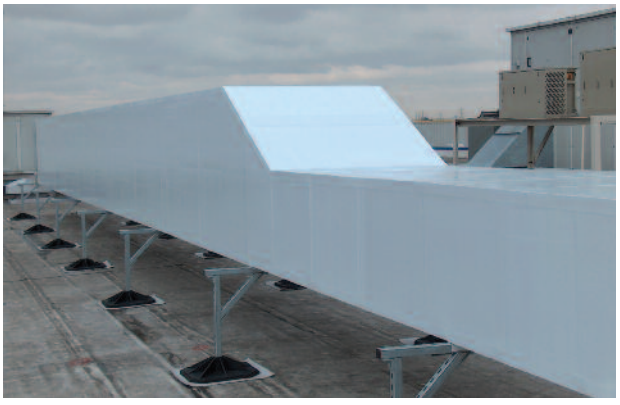
As a result, frictional pressure drop data for galvanized sheet steel ductwork may also be used when designing ductwork systems fabricated from The *Kingspan* **Kool**Duct® System.

Furthermore, The *Kingspan* **Kool**Duct® System produces pre–insulated ductwork where the air–leakage rate can be reduced to a fraction of that typical of sheet metal ductwork. A low air–leakage rate can yield significant electrical consumption savings, because of reduced heating and cooling loads, and reduced fan energy usage.

For ductwork systems designed to withstand a maximum static pressure of 4 in·w.g. / 1000 Pa, ductwork fabricated from The *Kingspan* **Kool**Duct® System, with different coupling systems, can easily achieve SMACNA (Sheet Metal & Air Conditioning Contractors' National Association) Air–leakage Class 3. Standard construction sheet metal ductwork, however, may find it difficult to achieve the same air–leakage class. Specifying the best ductwork air–leakage standards possible can be a relatively simple, yet inexpensive, step to take toward reducing the overall operational energy use of a building.

Research, conducted in the US by mechanical and electrical engineering services firm, MDA Engineering Inc., under the auspices of Luther Home of Mercy, has shown that HVAC system running costs can be dramatically reduced as a result of the low air–leakage rate of ductwork fabricated from The *Kingspan* **Kool**Duct® System.





The research utilized empirical data derived from the independent testing of two HVAC installations in two separate new construction buildings belonging to Luther Home of Mercy. Both buildings had a ground floor area of 7000 sq.ft / 650 m^2 and were identical in design. It compared an installation using ductwork fabricated from The *Kingspan* **Kool**Duct® System, comprising $^7/_8$" / 22 mm *Kingspan* **Kool**Duct® panels and the Tiger Clip coupling system, with an installation using galvanized sheet steel ductwork insulated with 2" / 51 mm thick fiber glass duct wrap. The ductwork and HVAC system design, layout and performance specification were identical.

The recorded air–leakage rate of the HVAC installation using ductwork fabricated from The *Kingspan* **Kool**Duct® System was 79% less than that using fiber glass insulated galvanized sheet steel ductwork. Furthermore, the former exceeded the requirements of SMACNA (Sheet Metal & Air Conditioning Contractors' National Association) Air–leakage Class 24, with a leakage rate 64% of the maximum allowable. In contrast, the latter failed to meet the requirements with a leakage rate more than 3 times that allowable.

An analysis of the results showed that the substantial reduction in air–leakage, achieved by the ductwork fabricated from The *Kingspan* **Kool**Duct® System, yielded a correspondingly significant 70% reduction in projected first year running costs relating to energy use – predicting that it would save 24 MMBtu / 7120 kW·h per annum, or 720 MMBtu / 213,600 kW·h over 30 years.

This substantial saving in energy equates to a CO_2 emissions saving of 6.3 short tons / 5.7 metric tons per annum, or 188 short tons / 170 metric tons over 30 years.

As a result, it is estimated that the ductwork fabricated from The *Kingspan* **Kool**Duct® System would reduce CO_2 emissions by 1.79 lb/sq.ft / 8.74 kg/m^2 of building floor area.

Further information can be found at:
www.kingspaninsulation.us/ductwork–luther.

Kingspan Insulation commissioned a separate review, in the UK, by independent testing and research organization BSRIA, of the implication of ductwork specification and different ductwork air–leakage rates on energy consumption. The methodology given in BSRIA's report was used to compare a 328 ft / 100 m long run of ductwork fabricated from The *Kingspan* **Kool**Duct® System, with a 328 ft / 100 m long run of galvanized sheet steel ductwork. Both runs had cross–sectional internal dimensions of 24" x 24" / 600 x 600 mm.

BSRIA's methodology demonstrated that ductwork fabricated from The *Kingspan* **Kool**Duct® System can save 31% of the energy, and thus cost, required to run a fan in a HVAC system, with a typical design flow rate of 1476 fpm / 7.5 m/s. This saving can be even greater for lower design flow rates.

Kingspan Insulation commissioned a review by independent consultants, Rider Levett Bucknall, of the implications of reduced fan power on actual energy usage. Rider Levett Bucknall concluded that for a 328 ft / 100 m long run of ductwork, with cross–sectional internal dimensions of 24" x 24" / 600 x 600 mm and an air velocity of 1476 fpm / 7.5 m/s, ductwork fabricated from The *Kingspan* **Kool**Duct® System could save 10.5 MMBtu / 3100 kW·h per annum.

This energy saving equates to a saving of 1.43 short tons / 1.3 metric tons of CO_2 equivalent emissions per annum, or 43 short tons / 39 metric tons over 30 years.

Rider Levett Bucknall carried out a further review of the implications of reduced fan power, this time on fan size and capital cost. The conclusion was that an 11.6% reduction in the size of the fan could be achieved, yielding a 10% capital cost saving.

Further information can be found at:
www.kingspaninsulation.us/ductwork–cost.

Modifications & Repairs

Ductwork fabricated from The *Kingspan* **Kool**Duct® System can be easily modified and adapted. For this reason, it is ideal for instances when the configuration of a HVAC system needs to be altered onsite e.g. to accommodate changes to the design of a building during the construction period.

Furthermore, the ability to modify and adapt ductwork fabricated from The *Kingspan* **Kool**Duct® System with ease, makes it especially suitable for buildings undergoing refurbishment e.g. where space to manoeuvre is restricted, or unforeseen obstacles, discovered only after the works have started or after the building structure has been fully exposed, could cause delays and subsequent increases in associated project costs.

In addition, its low weight, flexibility and ability to be fabricated both onsite and offsite, allows modifications to be carried out quickly and with minimal disruption to business. This can be particularly important in the retail, manufacturing and light industrial processing sectors where disturbances can result in unnecessary expense.

Research, conducted in the UK by independent consultants Cyril Sweett, has showed that ductwork fabricated from The *Kingspan* **Kool**Duct® System is subject to minimal damage, thus requiring minimal repairs, particularly where ductwork is installed within a ceiling void.

Nevertheless, localized damage to ductwork fabricated from the *Kingspan* **Kool**Duct® System can be repaired in–situ, in an efficient and economical manner. This is opposed to replacing an entire ductwork section, which could be the case with some other ductwork systems and, which could also prove to be costly.

Benefits

Maintenance & Cleaning

It is generally deemed good practice for mechanical ventilation systems, including ductwork, to be maintained in an efficient state, in efficient working order and in good repair. This includes being cleaned, as appropriate.

Poorly maintained and dirty ducts could contribute to increased costs. For instance, the accumulation of dust and debris could negatively affect the volume of airflow at registers or diffusers, subsequently increasing HVAC system energy usage, and therefore operating costs.

Ductwork fabricated from The *Kingspan* **Kool**Duct® System can be easily and economically cleaned to industry standards, as required by NADCA ACR: 2006 (National Air Duct Cleaners Association: Assessment, Cleaning & Restoration of HVAC Systems), using many of the dry and non–abrasive cleaning methods offered through professional HVAC ductwork cleaning specialists.

Suitable cleaning methods include the following:

- an air nozzle, comprising a perforated plastic ball placed on the end of a flexible hose, which uses low or high volume compressed air;
- an air lance, which directs low volume compressed air locally through an air gun with a trigger;
- mechanical brushing with a soft and non–abrasive rotary brush to brush the surface of the ductwork;
- hand wiping and manual brushing with soft and non–abrasive materials; and
- electric / manual vacuuming to gently remove dust and debris through suction.

Other methods, depending upon the nature of the deposit to be removed, may be also suitable. For verification of cleaning methods not listed above, please contact Kingspan Insulation prior to usage.

NB Ductwork fabricated from The Kingspan **Kool**Duct® System *is unsuitable for wet cleaning methods and any techniques considered as being abrasive e.g. hard brushing, scraping or compressed air systems using metal balls. Dust, debris and particulates should be collected using an air movement and containment device with appropriate filtration for contaminants.*

Durability & Lifespan

Ductwork fabricated from The *Kingspan* **Kool**Duct® System is rigid, strong and self–supporting. When *Kingspan* **Kool**Duct® panels are permanently formed to the desired shape, they have sufficient strength to maintain that shape. This has been demonstrated in the field, and in the following tests within Standard for Safety UL 181 (Underwriters Laboratories: Factory Made Air Ducts & Air Connectors):

- puncture – the walls of ductwork sections preventing complete penetration of a 2 lb / 0.9 kg free–falling steel plunger;
- pressure & collapse – coupled ductwork sections resisting rupture and excessive deformation when subjected to positive and negative pressures 2 ½ times their maximum rating;
- erosion – the ductwork, and its individual components, showing no sign of cracking, flaking, peeling or delamination, when tested with an air velocity of 12,500 fpm / 63.5 m/s (mean) – 2 ½ times its maximum rating;
- static load – coupled ductwork sections not sagging, permanently deforming or being damaged, with joints and seams remaining intact and not fracturing, as a result of withstanding the applied static loadings; and
- impact – coupled ductwork sections maintaining their integrity when subjected to impact from a 15 lb / 6.8 kg sandbag.

Notwithstanding the above, the integrity, and thus the lifespan and associated costs of the ductwork are dependent upon it:

- continuing to operate within its original design parameters;
- not being subjected to external influences that may cause damage; and
- being subject to a regular maintenance program.

Whole Life Cost

'Whole life costing' takes account of the total cost of an item over its life including, but not limited to, capital, operating and maintenance costs. Kingspan Insulation commissioned two separate analyses of the whole life costs of differing HVAC systems.

One analysis was performed by mechanical and electrical engineering services firm, MDA Engineering Inc., under the auspices of Luther Home of Mercy, in the US. The analysis utilized empirical data derived from the independent testing of two HVAC installations, in two separate buildings of identical design. It compared an installation using ductwork fabricated from The *Kingspan* **Kool**Duct® System, comprising 7/8" / 22 mm *Kingspan* **Kool**Duct® panels and the Tiger Clip coupling system, with an installation using galvanized sheet steel ductwork insulated with 2" / 51 mm thick fiber glass duct wrap. The ductwork and HVAC system design, layout and performance specification were identical.

The other analysis, performed by independent consultants Cyril Sweett, utilized a combination of empirical and published data based upon a commercial building in the UK. It compared ductwork fabricated from The *Kingspan* **Kool**Duct® System, comprising 7/8" / 22 mm *Kingspan* **Kool**Duct® panels and the aluminum grip coupling system, with ductwork constructed from galvanized sheet steel and insulated with 1 37/64" / 40 mm thick mineral fiber. Both ductwork specifications were designed to meet the same performance standards.

The analysis of the US ductwork installations showed that, over 30 years, ductwork fabricated from The *Kingspan* **Kool**Duct® System is predicted to save an estimated 14% on whole life cost.

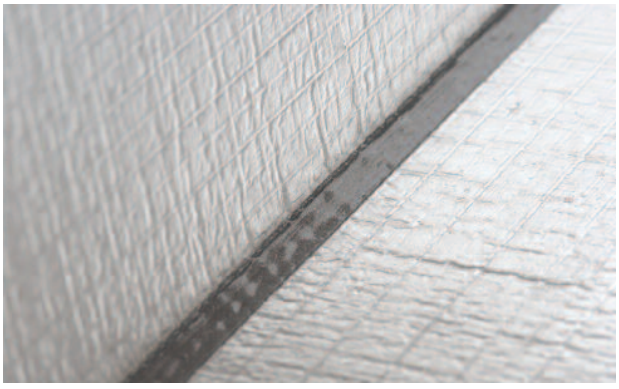
Further information can be found at:
www.kingspaninsulation.us/ductwork–luther.

Likewise, the analysis of the UK ductwork specifications showed that, also over 30 years, ductwork fabricated from The *Kingspan* **Kool**Duct® System can provide a whole life cost saving of over 20%.

Further information can be found at:
www.kingspaninsulation.us/ductwork–wlc.

Indoor Air Quality (IAQ)

Kingspan **Kool**Duct® panels have a fiber–free insulation core and are odorless, non–tainting, non–deleterious, and chemically inert and safe to use. They will also resist attack from mold and microbial growth. Similarly, *Kingspan* **Kool**Duct® System High Performance Silicone Sealant is resistant to mold growth. At the end of the test period in the mold growth and humidity test within Standard for Safety UL 181 (Underwriters Laboratories: Factory Made Air Ducts & Air Connectors), ductwork fabricated from The *Kingspan* **Kool**Duct® System showed no visible signs of mold growth beyond the areas of innoculation.



In addition, ductwork fabricated from The *Kingspan* **Kool**Duct® System has been tested in the US by independent testing and research organization Air Quality Sciences Inc. The results have shown that emissions of volatile organic compounds (VOCs), formaldehyde, total aldehydes and total phthalates are negligible and well below the maximum allowable limits deemed safe for schools in the US.

Furthermore, air distributed through ductwork fabricated from The *Kingspan* **Kool**Duct® System does not come into contact with an insulation material that produces loose fibers. When sheet metal ductwork that is insulated with fiber glass leaks air, loose fibers could get blown off the duct into the general environment, and then into recirculation systems and back into the air–handling system. Similarly, for ductwork operating at negative static pressures, the loose fibers could potentially get drawn into the airstream flowing inside the duct, by entering through the seams.

Nevertheless, it is best practice to ensure that ductwork, and all parts of a HVAC system, meet specified levels of cleanliness. This includes newly installed ductwork prior to commissioning and / or handover, such that any surplus material remaining from the fabrication and installation process is fully removed. This is particularly important for applications in sensitive areas, where a hygiene–controlled environment is required e.g. in clean rooms, operating theaters, hospitals, food processing facilities and pharmaceutical manufacturing plants.

Benefits

Environmental Impact & Responsible Sourcing

Ozone Depletion Potential (ODP) & Global Warming Potential (GWP)

The insulation core of *Kingspan* **Kool**Duct® panels is manufactured with a CFC / HCFC–free blowing agent that has zero Ozone Depletion Potential (ODP) and low Global Warming Potential (GWP).

Waste

Computer aided fabrication of ductwork from The *Kingspan* **Kool**Duct® System can enable a sizeable reduction in the volume of workshop–generated waste, compared with manual fabrication. Furthermore, the ability to pre–fabricate ductwork sections and fittings in the workshop, to be supplied in flat form ready for assembly onsite, minimizes site–generated waste.

Responsible Sourcing

Kingspan **Kool**Duct® panels produced at Kingspan Insulation's Pembridge, UK manufacturing facility, are certified 'Very Good' to BES 6001 (Framework Standard for the Responsible Sourcing of Construction Products).

Copies of the certificate can be found at:
www.kingspaninsulation.us/certification.

Embodied Energy

In comparing the embodied energies of building products, the concept of a functional unit must be taken into account. In the case of ductwork insulation, the functional unit depends upon firstly, the density of the insulation and secondly, the thickness of insulation required to limit a defined heat loss / gain. This thickness will vary depending upon the thermal conductivity (k–value / λ–value) of the insulation material.

The embodied energy content of mineral fiber and rigid thermoset phenolic insulants vary significantly. Some mineral fiber insulants have been quoted as having an embodied energy content of 5.9–11.8 MJ/lb / 13–26 MJ/kg, whilst rigid thermoset phenolic insulants are quoted as having an embodied energy content of 45.4 MJ/lb / 100 MJ/kg. Whilst these figures would seem to suggest that the mineral fiber insulant is the more 'environmentally friendly' product, since it has the lower embodied energy content per unit mass, this is not the case.

If a comparison is to be made between ductwork fabricated from The *Kingspan* **Kool**Duct® System, and ductwork constructed from galvanized sheet steel and insulated with fiber glass duct wrap, then the functional unit must not only include the insulation as specified above, but also the sheet steel, which is absent from ductwork fabricated from The *Kingspan* **Kool**Duct® System.

On this basis, the embodied energy of ductwork fabricated from The *Kingspan* **Kool**Duct® System can be less than that of ductwork constructed from galvanized sheet steel and insulated with fiber glass duct wrap – up to 27% less.

Further information can be found at:
www.kingspaninsulation.us/ductwork–embodied–energy.

Operational Environmental Impact & Associated Carbon Dioxide (CO_2) Emissions

For buildings designed to today's energy use standards, the embodied environmental impacts of all of the materials and labor used to construct a building are insignificant in comparison with the lifetime operational environmental impacts of that building, and are thus of very limited importance.

In the case of insulated HVAC ductwork, saving energy, by specifying the best ductwork air–leakage and heat loss / gain standards possible, is the most environmentally sustainable action to take when specifying ductwork and its insulation, since it is operational energy use that creates the vast majority of operational environmental impact.

Low ductwork air–leakage is known to have a beneficial impact on the energy consumption of the fan delivering the air into the ductwork, and therefore on HVAC system energy usage and associated operational CO_2 emissions. This relates not only to the air–distribution HVAC system, but also to the building in which it is installed.

The significance of a low ductwork air–leakage rate in cutting operational energy use, and thus associated CO_2 emissions, is clearly demonstrated by the findings from both the US and UK research programs described in the Frictional Resistance, Air–leakage, Energy Usage & Running Costs section of this document. For details, refer to page 12.

This figure could be even greater if reinforcement, coupling and support systems were to be included. For instance, the ability to support ductwork fabricated from the *Kingspan* **Kool**Duct® System by lightweight wire systems or low gauge metal hangers and supports, installed at larger centers, in contrast to insulated galvanized sheet steel ductwork, which often requires heavier and more robust support systems, could make a substantial difference.

LEED®

Ductwork fabricated from The *Kingspan* **Kool**Duct® System can contribute points towards achieving credits, including pilot credits, in many of the LEED® (Leadership in Energy & Environmental Design) rating systems, developed by the USGBC (United States Green Building Council).

Clearly, thermal insulation and ductwork air–tightness are two highly effective ways to reduce a building's operational energy demand, energy consumption and CO_2 emissions.

For further information on how ductwork fabricated from the *Kingspan* **Kool**Duct® System can contribute towards the achievement of credits in the different LEED® rating systems, please contact Kingspan Insulation.

Sustainability & Responsibility

Kingspan Insulation has a long–term commitment to sustainability and responsibility: as a manufacturer and supplier of insulation products; as an employer; as a substantial landholder; and as a key member of its neighboring communities.

Further information can be found at:
www.kingspaninsulation.us/sustainabilityandresponsibility.

Management Systems' Standards

UL Listed *Kingspan* **Kool**Duct® panels are manufactured to the highest standards under a management system certified to ISO 9001: 2008 (Quality management systems. Requirements), ISO 14001: 2004 (Environmental management systems. Requirements), BS OHSAS 18001: 2007 (Occupational health & safety management systems. Requirements) and ISO 50001: 2011 (Energy management systems. Requirements).

Copies of the certificates can be found at:
www.kingspaninsulation.us/certification.

Technical Advisory Service

The *Kingspan* **Kool**Duct® System is supported by a complementary and comprehensive technical advisory service for designers, specifiers, fabricators, installers, building services managers and facilities managers. Expert guidance is provided to make specification and installation, operation and maintenance of ductwork fabricated from The *Kingspan* **Kool**Duct® System, as straightforward as possible. Project specific advice and solutions for non–standard applications and complex technical issues are also offered. Amongst other services, heat loss / gain, condensation / dew point risk and required insulation thickness can be calculated.

The HVAC Technical Service Department can be contacted directly by calling 1800-241–4402 or emailing hvactechnical@kingspaninsulation.us.

Prestige Projects

Project Name:	Luther Home of Mercy
Location:	Ohio, USA
Building Use:	Residential Care – Rehabilitation Cottages
Client:	Mercy Outreach Ministries II
Architect:	Normand Associates, Inc.
M&E Engineer:	MDA Engineering, Inc.
Ductwork Contractor:	Commercial Comfort Systems (CCS), Inc.
Delivery Partner:	Delta Air Systems LLC

Project Name:	Icehouse
Location:	Philadelphia, USA
Building Use:	Multi–Family Low–Rise Residential Complex
Client / Developer:	EnVision Realty Group LLC
Consulting Engineer:	Wachter & Associates
Architect:	Continuum Architecture & Design, Inc.
Ductwork Contractor:	RP Rex Heating & Cooling
Delivery Partner:	PTM Manufacturing LLC

Project Name:	Villaggio Shopping Mall
Location:	Doha, Qatar
Building Use:	Retail & Leisure – Shopping Complex & Restaurants
M&E Contractor:	Voltas Ltd
Delivery Partner:	Qatari Industrial Equipment (QIE) WLL

Prestige Projects

Project Name:	Four Seasons Hotel
Location:	Doha, Qatar
Building Use:	Leisure – Hotel
Architect:	Smallwood, Reynolds, Stewart, Stewart, Inc.
MEP Engineers:	Drake & Scull
Main Contractor:	Construction Development Company (CDC)
Delivery Partner:	Qatari industrial Equipment (QIE) WLL

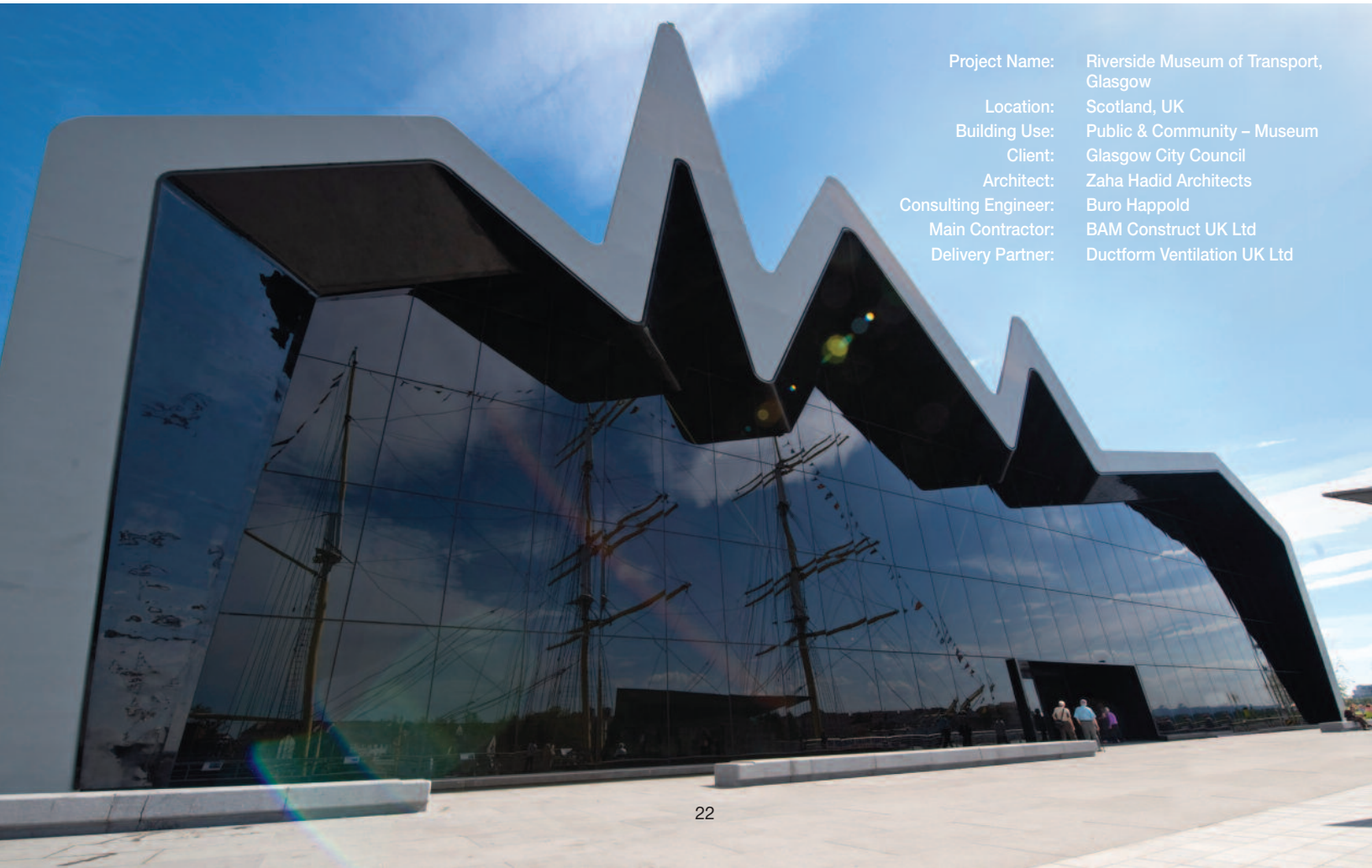
Project Name:	Chester Balmore
Location:	London, England
Building use:	Residential
Architect:	Rick Mathers Architects
Client:	Camden Council
Fabricator & Installer:	RDS Ductwork Contractors

Project Name:	Atlantis, The Palm, Dubai
Location:	Dubai, UAE
Building Use:	Leisure – Resort Hotel
Architect / M&E Consulting Engineer:	NORR Group Consultants International Ltd
M&E Contractor:	BK Gulf LLC / Rotary HUMM Services LLC
Ductwork Contractor:	Seagull HVAC Industry LLC

Prestige Projects

Project Name:	Alfardan Towers
Location:	Doha, Qatar
Client:	Alfardan Real Estate Company
Building Use:	Residential – High Rise
Architect:	Arab Engineering Bureau (AEB)
Consulting Engineer:	Shaker Consulting Group
Main Contractor:	Construction Development Company (CDC)
Delivery Partner:	Qatari industrial Equipment (QIE) WLL

Project Name:	Riverside Museum of Transport, Glasgow
Location:	Scotland, UK
Building Use:	Public & Community – Museum
Client:	Glasgow City Council
Architect:	Zaha Hadid Architects
Consulting Engineer:	Buro Happold
Main Contractor:	BAM Construct UK Ltd
Delivery Partner:	Ductform Ventilation UK Ltd



Project Name:	Angsana Hotel & Suites (The Damas Towers)
Location:	Dubai, UAE
Building Use:	Residential & Leisure – Hotel & High–Rise Apartments
Architect / Consulting & M&E Engineer:	Eng.Adnan Saffarini
Main Contractor:	Bin Zayed Contracting

Prestige Projects

Project Name:	RLI Corp. Headquarters
Location:	Illinois, USA
Building Use:	Commercial – offices
Architects:	Dewberry Architects Inc.
Delivery Partner & Fabricator:	Delta Air Systems LLC
Ductwork Installer:	PIPCO Companies Ltd

Project Name:	SECC
Location:	Scotland, UK
Building Use:	Exhibition Conference Centre
Architect:	Foster & Partners
Consulting Engineer:	Hulley & Kirkwood Ltd
M&E Contractor:	Brankin Engineering Ltd

Project Name:	Shangri–La Hotel
Location:	Dubai, UAE
Building Use:	Leisure – Hotel
Main Contractor:	Al Habtoor Engineering Ltd / Murray & Roberts
Architect / M&E Consulting Engineer:	NORR Group Consultants International Ltd
M&E Contractor:	Sensaire Services LLC
Ductwork Contractor:	Seagull HVAC Industry LLC

Prestige Projects

Project name:	Fanar, Qatar Islamic Cultural Center
Location:	Doha, Qatar
Building Use:	Public & Community – Arts, Culture, Education & Religion
Delivery Partner:	Qatari Industrial Equipment (QIE) WLL

Project Name:	BBC Glasgow
Location:	Scotland, UK
Building Use:	Commercial – Broadcast Centre & Offices
Architect:	David Chipperfield Architects Ltd
Consulting Engineer:	Arup
M&E Contractor:	Balfour Beatty Engineering Services Ltd (formerly Balfour Kilpatrick)
Delivery Partner:	Ductform Ventilation UK Ltd

Project Name:	One New York Street
Location:	Manchester, UK
Building Use:	Commercial & Retail – Offices & Shops
Client:	Bruntwood
Architect:	Denton Corker Marshall
Consulting Engineer:	Buro Happold
Ductwork Contractor:	Cranworth Engineering Ltd

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SG–KDUCT