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RETHINKING DUCTWORK

Luther Home of Mercy: Case Study

THE IMPACT OF DIFFERING HVAC DUCTWORK SPECIFICATIONS ON AIR LEAKAGE, ENERGY USAGE, CO_2 EMISSIONS & COSTS

Kingspan®

Low Energy – Low Carbon Buildings

Contents

Executive Summary

This study compares the performance and costs of two different air distribution systems in two buildings, which are virtually identical in all respects but their HVAC ductwork specification. One building is serviced by ductwork fabricated from the *Kingspan* **Kool**Duct® System, and the other by traditional sheet metal ductwork insulated with glass fiber wrap.

Ductwork fabricated from the *Kingspan* **Kool**Duct® System proved to be more airtight, with an air leakage rate 80% less than that of the glass fiber insulated sheet metal. This equates to an estimated energy saving of 24 MMBtu per annum – the equivalent of 188 tons of carbon dioxide (CO_2) emissions over a 30 year period.

Ductwork fabricated from the *Kingspan* **Kool**Duct® System also proved to be more cost-effective than the sheet metal equivalent, saving nearly 17% on capital cost. In addition, it is predicted to save 7.5% on operational cost, and, over a 30 year period, an estimated 14% on whole life cost.

The results show that the *Kingspan* **Kool**Duct® System should be considered the product of choice for HVAC ductwork systems where low operational environmental impact and low capital, operational and whole life costs are key requirements.

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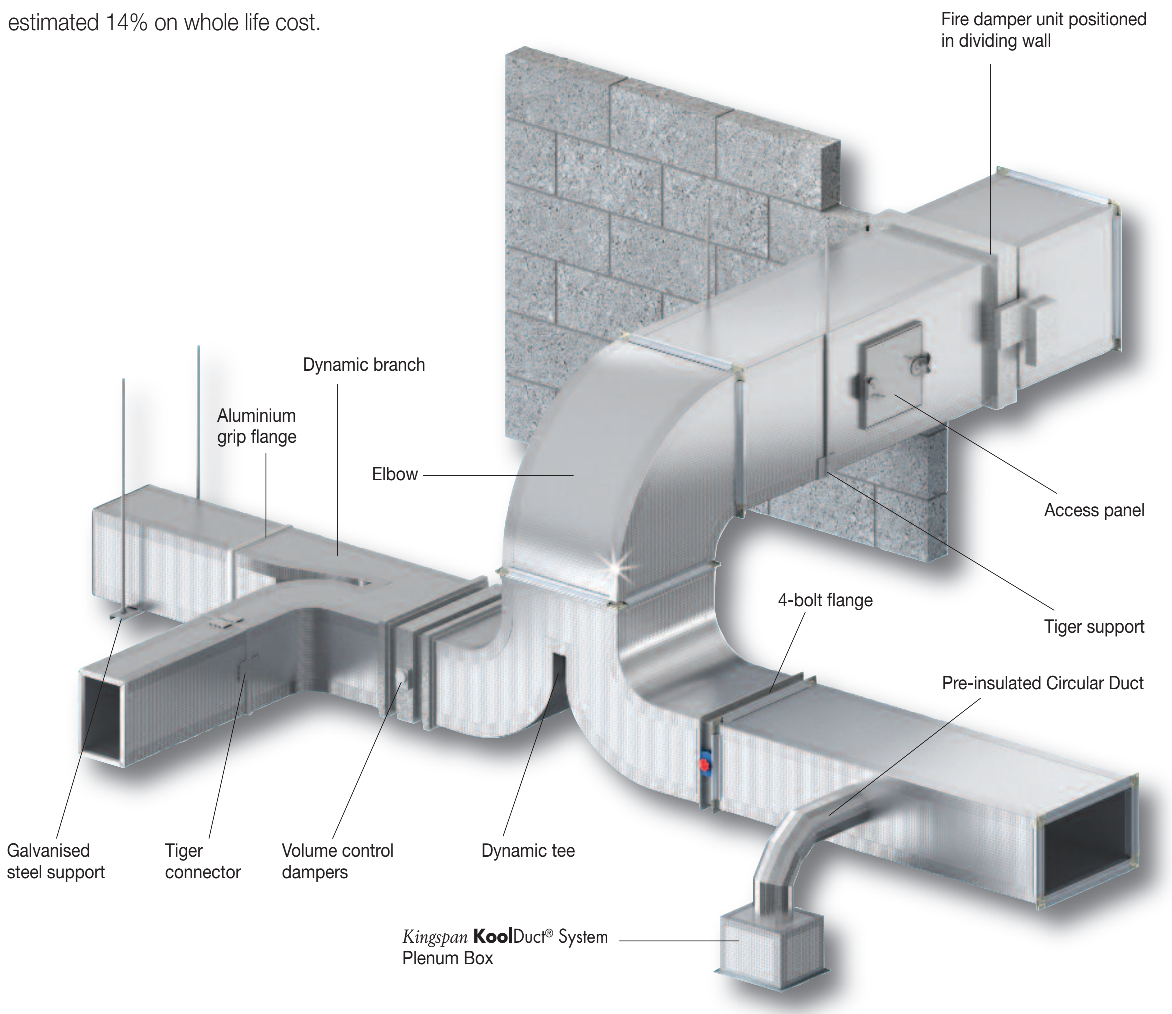


Figure 1: The *Kingspan* **Kool**Duct® System of Pre-insulated Ductwork

Case Study Background

Carbon reduction and energy efficiency have become an increasing focus for the world's major governments. As a result, legislation continues to target those activities which contribute most to CO_2 emissions. Buildings are responsible for over 40% of global energy use[1] and one third of global greenhouse gas (GHG) emissions[2], and have 'the most potential for delivering significant and cost-effective GHG emission reductions'[3] .

Indeed, in 2009, President Barack Obama committed the USA to a 17% reduction in emissions by 2020 by signing the Copenhagen Accord[4]. In addition, the President issued an Executive Order on Federal Sustainability, committing Federal agencies to improvements in energy efficiency and GHG emissions[5].

Against this legislative background, US state-wide building and energy codes are becoming increasingly stringent, with over 60% of states adopting at least IECC 2006 or equivalent, and over 70% of states committing to IECC 2009 or equivalent, by 2013[6].

Luther Home of Mercy is a not-for-profit organization, founded in 1928 for the purpose of caring for people with developmental disabilities. Located in Williston, Ohio, it serves approximately 250 people, in 10 residential cottages, across its purpose built campus and throughout the community in private homes and in family care facilities. Recent increases in demand created a need for two new 7000 sq.ft residential cottages (6A and 6B).

Commercial Comfort Systems Inc.[7] (CCS), a Sheet Metal Workers' International Association (SMWIA) union contractor, based in Maumee, Ohio, won the ductwork contract and intended to supply ductwork fabricated from the *Kingspan* **Kool**Duct® System for both cottages.

However, as the two cottages were to be identical, they concluded that the project presented a unique opportunity to compare ductwork fabricated from the *Kingspan* **Kool**Duct® System, with that fabricated from sheet metal and insulated with glass fiber. To this end, CCS altered the ductwork specification of one of the cottages to glass fiber insulated sheet metal, with the blessing of the ministry of Luther Home of Mercy.

Kingspan Insulation Ltd, in conjunction with CCS, commissioned MDA Engineering Inc.[8], the project's HVAC system designers, to undertake an independent study of both installations, to compare air leakage, energy use, associated CO_2 emissions and installed, operational and whole life costs.

Figure 2: Cottage 6A, Luther Home of Mercy

Figure 3: Cottage 6B, Luther Home of Mercy

[1] *UNEP 2009. Buildings and Climate Change: Summary for Decision Makers. UNEP DTIE Sustainable Consumption and Production Branch. p3*

[2] *Ibid.*

[3] *Ibid., p4*

[4] *United Nations Framework Convention on Climate Change. Available at: http://unfccc.int/files/meetings/application/pdf/unitedstatescphaccord_app.1.pdf. Accessed November 9th, 2010.*

[5] *The Whitehouse. Available at http://www.whitehouse.gov/assets/documents/2009fedleader_eo_rel.pdf. Accessed November 9th, 2010.*

[6] *US Department of Energy. Available at: http://www.energycodes.gov/states/state_status_full.php Accessed November 9th 2010.*

[7] *www.commercialcomfort.com*

[8] *MDA Engineering Inc. is a mechanical, electrical and telecommunications engineering services firm based in Maumee, Ohio. www.mdaengr.com*

Methodology

The ductwork system design and layout for both installations were identical (Appendix A), with a total duct surface area of 1926 sq.ft. Both ductwork systems were specified to meet the following standards:

- 2 in.w.g pressure class;
- SMACNA air leakage Class 24;
- ANSI / ASHRAE / IENSA 90.1 2004; and
- IECC 2006.

The ductwork fabricated from the *Kingspan* **Kool**Duct® System was manufactured by CCS.

Whilst CCS usually fabricates and installs its own sheet metal ductwork, in the interests of impartiality and price competitiveness, the sheet metal job was subcontracted to the lowest bidding union contractor. The insulation work was also subcontracted to the lowest bidding union contractor.

Air leakage testing of both installations was performed by an independent testing, adjusting and balancing (TAB) contractor, certified by the Associated Air Balance Council (AABC). In order to provide a more accurate reflection of the actual volume of air leakage, including that from the accessories connected to the ductwork, the testing was carried out on the entire ductwork run (as opposed to the standard industry practice of testing a sectioned off portion), from furnace discharge to registers, using new, certified Oriflow testing equipment.

The ductwork air leakage measured during testing was adjusted downwards for the measured operating pressure. This leakage was then evenly allocated across each system.

The subsequent analysis, of operational energy usage, CO_2 emissions and cost, was conducted using TRANE Trace 700. Three building models, sharing the same physical characteristics, were created. Model 1 was a building with perfect ductwork and no leakage, whilst models 2 and 3 represented the two Luther Home of Mercy cottages, each with their respective tested operating air leakage rates.

Simulations were run for 8,760 hours (1 year), using utility rates provided by real energy bills and actual weather data from the Toledo, Ohio weather file. In addition, each model was analysed in four equal orientations, 90 degrees apart, with findings averaged to create energy uses that are independent of orientation.

HVAC operating energy usage and costs in each building were determined by subtracting lighting energy usage and costs from the total building energy usage and electrical costs. The whole life cost analysis of each building included labor costs, finance costs, a 5% interest rate, a 3% inflation rate (applied to energy), and a 10% discount rate.

Finally, because the buildings and the ductwork installations are a long-term investment for Luther Home of Mercy, financing and project life were set at 30 years.

Figure 4: Cottage 6A, *Kingspan* **Kool**Duct® System Ductwork Installation

Figure 5: Cottage 6B, Glass Fiber Insulated Sheet Metal Ductwork Installation

Summary of Results

The recorded air leakage of the ductwork fabricated from the *Kingspan* **Kool**Duct® System, at the specified static pressure of 2 in.w.g, was 469 CFM. This represents 6.7% of the operating supply total air volume (6985 CFM). The recorded air leakage of the glass fiber insulated sheet metal ductwork was 2306 CFM, representing 33% of the total air volume.

	Total Air Volume (CFM)	Max. Allowable Air Leakage of SMACNA Class 24 (CFM)	Total Actual Air Leakage (CFM)	Actual Leakage as a proportion of Total Air Volume (%)	Actual Leakage as a proportion. of Max Alowable Leakage (%)
Kingspan **Kool**Duct®	6985	732	469	6.7	64
Sheet Metal & Glass Fiber	6985	732	2306	33	315

When these rates were corrected to the actual average duct operating pressure of 0.1325 in.w.g, they represent 1.73% of the supply CFM for the ductwork fabricated from the *Kingspan* **Kool**Duct® System, and 8.5% for the glass fiber insulated sheet metal ductwork. The air leakage rate, of the ductwork fabricated from the *Kingspan* **Kool**Duct® System, was therefore 79% less than that of the glass fiber insulated sheet metal system.

The air leakage rate of the ductwork fabricated from the *Kingspan* **Kool**Duct® System was 79% less than that of the glass fiber insulated sheet metal system.

In addition, the ductwork fabricated from the *Kingspan* **Kool**Duct® System exceeded the requirements of SMACNA Class 24, with an air leakage rate 64% of the maximum allowable.

In contrast, the glass fiber insulated sheet metal system had an air leakage rate more than 3 times that allowable. This was despite the ductwork having been:

- constructed offsite to SMACNA seal Class B;
- fabricated using longitudinal Pittsburgh lock seams sealed with RTV adhesive, and transverse joints comprising drive slip to the sides and 'S' slip to the top and bottom; and
- assembled and sealed onsite with an industrial grade duct sealant (Hardcast Duct-Seal 321).

This suggests that, whilst the ductwork fabricated from the *Kingspan* **Kool**Duct® System performs as specified, sheet metal ductwork insulated with glass fiber can be much leakier than it is assumed to be.

The air leakage rate from the glass fiber insulated sheet metal system was more than 3 times the maximum allowable air leakage of SMACNA Class 24.

A 2005 study, for the US Department of Energy, by the University of California at Berkeley, investigating large scale commercial 'low pressure' ductwork systems confirms this, finding that, out of 10 systems examined, 7 had air leakage of 9-26%. They concluded that "there may be a significant number of leaky duct systems in the building stock", adding that "leakages should be measured rather than assumed".

Such a gap between specified and actual performance could prove costly for a small scale residential system but, when scaled to a large commercial system of several thousand square feet, it could prove to be a significant expense.

In some instances, where enhanced commissioning is required, such as Credit EA Pre-requisite 1 in LEED 3.0 for Commercial Buildings,[9] the failure of a system to meet its specified performance may well result in costly remedial action being required.

[9] *LEED 2009 for New Construction and Major Renovations Rating System, US Green Building Council; November 2010.*

The analysis, conducted using TRANE Trace 700, showed that the substantial reduction in air leakage, achieved by the ductwork fabricated from the *Kingspan* **Kool**Duct® System, yielded a correspondingly significant reduction in energy usage, when compared with the glass fiber insulated sheet metal system.

Using the above figures, the analysis predicted that ductwork fabricated from the *Kingspan* **Kool**Duct® System would save 24 MMBtu per annum, and 720 MMBtu over a 30 year period. This equates to an annual emissions saving of 12,528 lb of CO_2, or an emissions saving of 188 tons of CO_2.

Ductwork fabricated from the *Kingspan* **Kool**Duct® System was projected to save 188 tons of CO_2 emissions over a 30 year period.

The table in Appendix B shows all costs relating to the installation and performance of the ductwork systems. As can be seen, costs relating to the ductwork fabricated from the *Kingspan* **Kool**Duct® System are lower than those relating to the ductwork fabricated from sheet metal and insulated with glass fiber.

The capital costs (including materials and labor) were 16.8% less; first year operating costs 70% less; with overall HVAC operating costs 7% less; and whole life costs over a 30 year period were predicted to be 14% less.

The costs relating to the ductwork fabricated from the *Kingspan* **Kool**Duct® System are lower than those relating to the ductwork fabricated from sheet metal insulated with glass fiber.

This reduction in projected operational cost is derived largely from the reduction in fan power required to drive the ventilation system.

The lower capital cost results primarily from the lower labor cost associated with the *Kingspan* **Kool**Duct® System, largely a result of the increased speed with which it can be installed. This is a result of the fact that the *Kingspan* **Kool**Duct® System is a single fix installation, and eliminates the separate manual process of wrapping the insulation around the ductwork.

Figure 6: Sheet metal ductwork requires a separate manual wrapping operation

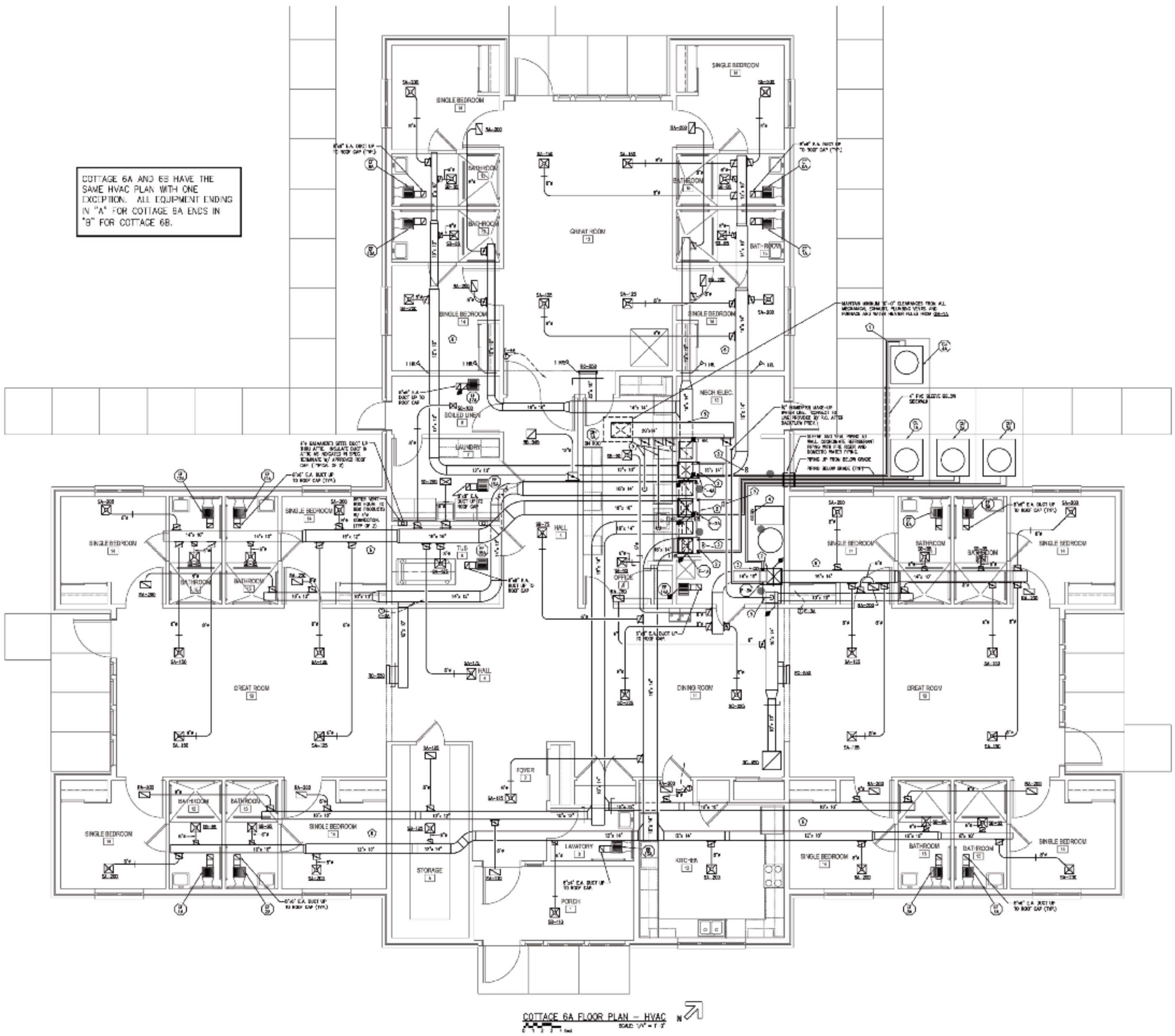
Ductwork sections fabricated from the *Kingspan* **Kool**Duct® System can also be fabricated in lengths up to 13 ft long, as opposed to 5 ft in the case of sheet metal ductwork.
This can mean fewer sections and less handling. These factors, coupled with increased support centres and ease of handling, result in fast track installation.

Appendix A – Building Plan

Description

The plan below shows the layout of Cottage 6A. However, the design of both cottages was identical with each consisting of common areas, single bedrooms, an office, restrooms, a tub area and a laundry area.

In addition, both HVAC installations incorporate four high efficiency furnaces, cooling system condensing units and ductwork located in the vented attic, allowing for any air leakage to be expelled outdoors and made up from outdoor air, either directly though ventilation, or by infiltration.



Appendix B – Table of Results

Description

The tables below show the source data and a summary of the results from the analysis of the three building models each with differing HVAC ductwork installations.

Study Life	30 yrs
Ductwork Surface Area	1926 sq.ft
Building Floor Area	7000 sq.ft
Blended Electric Rate	9.53 ¢/kW·h
Blended Natural Gas Rate	99 ¢/Therm
Loan Interest Rate	5%
General Inflation Rate	3%
Utility Inflation Rate	3%
Discount Rate	10%

	Unit	Model 1 Theoretical Cottage No Leak Ductwork	Model 2 Cottage 6A *Kingspan* **Kool**Duct®	Model 3 Cottage 6B Metal Ductwork	*Kingspan* **Kool**Duct® Savings over Metal Ductwork %	Value
Air Leakage						
Operating Leakage	CFM	0	121	594	473	79.6
Capital Costs						
Material Cost	$	0	9888.00	8364.00	–	–
Labour Cost	$	0	15516.00	22160.00	–	–
Project Cost	$	0	25404.00	30524.00	5120.00	16.8
Labor Man Hours	hr	0	513.75	715.75	201.00	28.1
Financing						
Project Difference Costs	$	0	0	5120.00	5120.00	–
Financed	%	0	0	80.00	–	–
Down Payment	$	0	0	1024.00	–	–
Financed	$	0	0	4096.00	–	–
Electricity Usage - HVAC System						
Thermal Energy Consumption	MMBtu/yr	41.30	41.90	43.40	1.50	3.5
Electrical Energy Consumption	kW·h/yr	12107.00	12269.00	12707.00	438.00	3.5
Electricity Cost	$/yr	1154.00	1169.00	1211.00	42.00	3.5
Electricity Usage - Ductwork Air Leakage						
Thermal Energy Consumption	MMBtu/yr	0	0.60	2.10	1.50	73.0
Electrical Energy Consumption	kW·h/yr	0	163.00	601.00	438.00	73.0
Electricity Cost	$/yr	0	15.00	57.00	42.00	73.0
Natural Gas Usage - HVAC System						
Thermal Energy Consumption	MMBtu/yr	208.30	218.10	240.60	22.50	9.4
Electrical Energy Consumption	kW·h/yr	2102.00	2201.00	2428.00	228.00	9.4
Electricity Cost	$/yr	2081.00	2179.00	2404.00	225.00	9.4
Natural Gas Usage - Ductwork Air Leakage						
Thermal Energy Consumption	MMBtu/yr	0	9.80	32.30	22.50	69.7
Electrical Energy Consumption	kW·h/yr	0	99.00	326.00	228.00	69.7
Electricity Cost	$/yr	0	98.00	323.00	225.00	69.7
Energy Consumption						
Building	Btu/sq.ft/yr	46731.00	48173.00	51527.00	3354.00	6.5
Source	Btu/sq.ft/yr	83601.00	85270.00	89205.00	3935.00	4.4
GHG Emissions						
CO_2	lbm/yr	174563.00	179951.00	192479.00	12528.00	6.5
SO_2	gm/yr	1480.00	1526.00	1632.00	107.00	6.5
NO_X	gm/yr	362.00	373.00	399.00	26.00	6.5
Life Cycle Data						
HVAC Life Cycle Cost	$	40453.00	41846.00	48665.00	6820.00	14.0
Ductwork Air Leakage Life Cycle Cost	$	0	1393.00	8212.00	6820.00	83.0
Ductwork Air Leakage Energy Cost Savings (First Year)	$/yr	–	–	–	267.00	70.2
Simple Air Leakage Payback	$/yr	N/A	Immediate	None	–	–

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