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REPORT NO: ACA – 131108

# A Survey of Thermal Performance of Flexible Duct

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**EXECUTIVE SUMMARY**

A Survey of the thermal performance of nine (9) lengths of flexible ductwork has been performed through the commissioning of independent sampling, measurement and testing. Of the nine (9) test specimens, none achieved their declared performance. The average measured thermal resistance of all specimens was 76% of that expected, with a largest result of 95% and a lowest of 62%.

The thermal performance values measured for all nine specimens in their unpackaged state can be attributed to a number of factors that individually and/or collectively contribute to a permanent loss of declared Material R-value. Whether as a consequence of these factors, or for some other reason, it must be recognised that the energy saving benefits attributed to these nine samples of flexible ductwork of declared Material R-value (R1.0), will not be achieved.

The significance of these results is highlighted in the second part of this survey where the effects of underperforming flexible ductwork are examined.

The Australian flexible duct industry continues to grapple with non-compliance issues identified by the Commonwealth Government in 2006. In 2007, space heating accounted for 38% of total residential energy consumption in Australia and continues to increase. Poorly insulated flexible ductwork contributes to excessive energy use and unnecessary generation of greenhouse gases. Energy losses through flexible ductwork of 30% are recognised for the purposes of underpinning government energy efficiency regulations.

Consumers are unwittingly continuing to pay for the installation of non-conforming flexible duct that will not deliver the promised performance, and is likely to go unnoticed for the life of the system.

Legislation exists to govern aspects of the regulation necessary for the Australian flexible duct industry. Reductions in the energy used for space heating and cooling systems can be achieved through the enforcement of existing regulatory requirements at State and Local Government levels. Enforcement of regulatory requirements remains the largest obstacle to achieving the benefits of reduced energy consumption.

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# 1 INTRODUCTION

A two-part survey, consisting of an experimental study and a literature review, of the thermal performance of flexible ductwork is presented in this report.

In the experimental study, the thermal performance results of a new survey of nine (9) lengths of flexible duct from nine (9) manufacturers/distributors are presented alongside their declared R-values.

The literature review expounds the importance of the thermal performance of flexible ductwork with regard to deliverables such as energy efficiency, regulatory compliance, and as a strategy to increase consumer protection.

Regulatory requirements of the National Construction Code, Building Code of Australia (NCC, BCA), Energy Efficiency provisions necessitate that insulation provided on ductwork shall comply with the requirements of AS/NZS 4859.1. i.e. For the case of ductwork, the material R-value of insulation blanket shall be measured prior to incorporation into the duct. Where a flexible duct manufacturer claims compliance with the thermal resistance requirements of the NCC, the “declared R-value” shall be the ‘Material’ R-value of the insulation blanket prior to secondary processing.

Currently there is no mandatory standard test method for determining the thermal resistance of completed flexible ductwork in the as-installed condition. While a number of test methods exist to assess the thermal performance of flexible ductwork as-installed, no consensus exists under Australian regulatory, or industry, frameworks as to how it should be measured.

## 2 THERMAL PERFORMANCE TEST PROGRAM

The primary goal of this test program is to determine the thermal performance of nine (9) lengths of flexible ductwork to an established standard. This has been achieved through the commissioning of independent sampling, measurement and testing.

While this test program is focussed on thermal performance, a complete list of regulatory and Australian Standards requirements for flexible ductwork is provided by the Australian Duct Manufacturers Alliance (ADMA) in their–"Flexible Duct Compliance Checklist".

The ADMA checklist provides members with the means of ensuring that their products comply with the relevant regulatory requirements of the Building Code of Australia. With regard to any claim of compliance with the thermal resistance requirements of AS/NZS 4859.1, these must be supported by:

1. Details of the means of demonstrating compliance:
    a. Evaluation by means of statistical sampling.
    b. The use of a product certification scheme.
    c. Assurance using the acceptability of the supplier's quality system.
    d. Other such means proposed by the manufacturer or supplier and acceptable to the customer.
2. A list of the tests that have been performed.
3. For each listed test,
    a. the name of the testing laboratory,
    b. the date(s) of test
    c. the designation of the test standard(s) or procedure(s), including the level and application of performance-affecting factors in AS/NZS 4859.1 Clause 2.3.3.2,
    d. the test report number(s), and
    e. the type of recognition held by the laboratory to perform the test.
4. Copies of the test report(s) available upon request.

Measurement of the thermal performance of a sample of flexible duct, in accordance with the test methods of AS/NZS 4859.1, requires that it be tested as a formed shape. ASTM C518 is listed as a standard method for determination of thermal properties of formed shapes. Thermal resistance measurement in accordance with this standard test method requires the sample to be laid flat in the test rig, a process which requires de-construction of the flexible duct.

The ASTM C518 Standard Test Method is equally applicable to traditional blanket insulated flexible ducts as to those incorporating insulation is pumped into helically-wound tubes attached to the inner core of the duct. As above, while there is no mandatory standard test method for determining the thermal resistance of flexible ductwork, this standard test method is deemed to be equally applicable for determining the thermal performance of both of the above method of thermal insulation available to the Australian market.

In lieu of a mandatory standard test method for determining the thermal resistance of flexible ductwork, the thermal performance of nine (9) number of samples of nominally identical flexible duct have been assessed in accordance with the standard test method described in ASTM C518, as per AS/NZS 4859.1. In relation to thermal properties of the samples tested, the characteristics that are most critical are the thickness, the density and composition of the material. The thermal resistance and physical properties of each of the samples have been measured and are presented herein.

# 3 COLLECTION OF SPECIMENS

Acronem Consulting Australia sourced nine (9) lengths of flexible duct for the purpose of conducting physical measurements and thermal resistance testing at CSIRO Infrastructure Technology, Thermal Test laboratory.

Care was taken to request ‘like’ product from each of 9 different manufacturers based on a request for a flexible duct that was:

- 300mm diameter,
- Material R-value R1.0,
- 6m length.

In all cases, specimens were randomly selected from warehouse stocks. Immediately following collection, the 9 specimens, in their original external packaging, were delivered to CSIRO Infrastructure Technology, Thermal Test laboratory. CSIRO performed inspections and testing on the specimens as submitted, and was not involved in their selection.

# 4 MEASUREMENT & TESTING

Measurements of the physical properties and thermal resistance of nine (9) insulation “flat plate” samples have been determined from testing at CSIRO Infrastructure and Technology, Thermal Test laboratory to ASTM C518 – Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus. Thermal resistance measurements were performed using a calibrated Fox 600 heat flow meter apparatus, incorporating two 254 mm-square heat flow meters. Thermal measurements, physical dimensions and construction of the air conditioning duct were reported.

## 4.1 Physical Measurements & Test Specimens

CSIRO removed each of the nine (9) flexible duct specimens from their original packaging for physical inspection and measurement of outer circumference. Specimens were then disassembled by slicing the outer sheath longitudinally along the duct. Further visual inspection was made of the insulation layer for inconsistencies, joins, gaps etc.

CSIRO disassembled each flexible duct sample, removing several sections of the insulation from the duct core for physical measurement and inspection of the construction. A section of the thermal insulation from the middle of the duct was randomly selected as a specimen for thermal measurements. Three samples of thermal insulation approximately 600 mm square were removed from each specimen for thermal testing. Care was taken to ensure the test samples were representative of the insulation, and no sample was taken from any edge of the insulation to avoid any possible reduction in thermal performance in these areas.

Samples typically consisted of the outer sheath, polyester thermal insulation material, and the inner core. The reinforcing of the inner core was removed from all samples prior to thermal testing to enable the sample to lie flat in the test apparatus. The mass per unit area of the insulating layer and outer sheath was determined for three sections of the duct. The density of each test sample (comprising the outer sheath, the insulating layer, and the inner core with wire reinforcing removed) was established via measurements gathered prior to thermal resistance measurement.

Tasks included:

- Measurement of the diameters of the outer sheath and the inner core to determine the gap available for insulation.
- Observation of any longitudinal gap between the edges of the insulation blanket.
- Observation of duct construction and continuity.
- Cut a cross-section and observe and report construction, reinforcing, consistency of product (i.e. weighing three sections to determine mass/$m^2$)
- Remove a 600 x 600 mm section from the duct. Measure thickness at 16 locations.
- Condition the 600 x 600 mm section in accordance with AS/NZS 4859.1:2002 Clause 7.2.1 (i.e. at 45˚C for 24 hours).
- Perform ASTM C518 standard test for thermal transmission properties.

## 4.2 Thermal Test Method

Thermal measurements have been performed using a heat flow meter apparatus in general accordance with ASTM C518 Standard Test Method as referenced by AS/NZS 4859.1. The suitability of the ASTM C518 standard test method and the correctness of the designation of a single sample of blanket-like insulation material extracted from a flexible duct as a “formed shape” is appropriate. The fact that the insulation in a duct might be “low density fibrous”, by loose description, does not place it in this category in terms of AS/NZS 4859.1.

While it may initially appear that such a sample is better classified as “low density fibrous”, and tested to ASTM C653, testing in accordance with this standard is only applicable to designated lot sizes of packs of compressed fibrous insulation. In addition, ASTM C 687 requires making 9 separate R-value measurements, either of 3 samples at 3 different compressions, or of 9 different samples at full thickness, the samples having been selected in a prescribed way from material in a lot of compressed packs. There is a variation in AS/NZS 4859.1 that allows the number of measurements to be reduced to 3. It is conceivable that one might attempt to duplicate this aspect of ASTM C 687 by obtaining up to 3, 600mm x 600mm samples from a length of duct and following the same overall procedure. Such a series of measurements would have some of the spirit of ASTM C 687 but would fundamentally not comply because the starting material and the selection process are necessarily different.

# 5 RESULTS

The basic construction of the nine (9) flexible duct specimens consisted of an outer sheath, insulation layer and inner core. Identifying details are omitted from this report as they do not contribute to the purpose of this program; to survey the thermal performance of nine (9) lengths of flexible duct, sourced from nine (9) local manufacturers/distributors, with respect to their declared R-value.

The results of measurements performed by CSIRO are presented in the following tables. These measurements relate only to the specimens tested and no inference is made as to whether these samples are representative of the manufactured population.

As presented in Table 2, the greatest and smallest measured values of mean thermal resistance were R0.957 ($m^2K/W$) and R0.625 ($m^2K/W$) respectively. The average measured thermal resistance of all specimens was R0.763 ($m^2K/W$) with a standard deviation of 0.10 ($m^2K/W$).

To a large degree, the measured mean thermal resistance can be attributed to the critical material characteristics of thickness and density, both of which are presented in Table 2. In 7 of the 9 specimens, the measured "Annulus Gap (radial)" was less than the insulation thickness. Where the available "Annulus Gap (radial)" between the Outer sheath and the Inner core is less than the thickness, the effectiveness of the insulation is reduced. The largest measured reduction in thickness was for Specimen #2 at 32%. This corresponded to a measured mean thermal resistance (R-value) of 33% less than the declared Material R-value (achieved by the insulation blanket prior to its incorporation into the flexible duct).

While the obvious solution to manufacture the outer sheath and inner core to allow an "Annulus Gap" large enough to allow full thickness recovery of the insulation, this will result in a significant gap between the insulation and the outer sheath until the insulation has had sufficient time to recover. While the insulation blanket is 'loose' within the flexible duct, the likelihood of longitudinal gaps forming between the join in the insulation increases. Longitudinal gaps in the insulation blanket will reduce the overall thermal performance of the flexible duct by a significant degree.

With regard to the presence of a visible gap between the outer sheath and the insulation, observations were made at the ends of the unpackaged specimen. Discrepancies between this observation and the average thickness of the insulation compared to the "Annulus Gap" reported in Table 1 are accounted for by the variation of thickness of the insulation along the length of the specimen. In all cases, the 600mmx600mm samples for physical and thermal measurements were taken from each specimen "avoiding the edges of the material" where the thickness may have been reduced.

In all cases, the results presented apply only to the nine (9) samples tested under the stated criteria and conditions. Acronem shall have no liability for deductions, inferences or generalisations drawn by the client or others. This report shall not be used to claim, constitute or imply product endorsement.

Results for the particular samples given in this report might be used to infer the performance properties of products or materials that the samples are said to represent. Whilst this may be the reasonable intent of AS/NZS 4859.1, it does not mean that the results presented apply to any particular product or material simply because the test samples are said to have the same formulation or design. These results apply only to test samples as measured, and as such it is outside the scope of this report to infer these are the properties of other products or materials. Support for such inferences requires an assessment of quality assurance, accreditation or other compliance scheme. This typically involves the auditing of raw materials procurement, and the manufacturing process which is outside the scope of this report.

## Table 1: Physical Measurements

| **Specimen #** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** |
|---|---|---|---|---|---|---|---|---|---|
| Outer sheath diameter (mm) | 382 | 382 | 419 | 369 | 380 | 392 | 397 | 394 | 382 |
| Inner core diameter (mm) | 307 | 312 | 300 | 310 | 307 | 306 | 311 | 304 | 308 |
| Annulus Gap (radial) (mm) | 37.5 | 34.6 | 59.3 | 29.5 | 36.6 | 43.2 | 42.8 | 45.1 | 36.7 |
| Visual inspection (qualitative) | No gap between outer sheath & insulation blanket. No longitudinal gap/overlap of insulation. | No gap between outer sheath & insulation blanket. No longitudinal gap/overlap of insulation. | No gap between outer sheath & insulation tube. No longitudinal gap/overlap of insulation. | Gap between outer sheath & insulation blanket. No longitudinal gap/overlap of insulation. | No gap between outer sheath & insulation blanket. Longitudinal overlap of insulation at mid-length. | Gap between outer sheath & insulation blanket. Longitudinal overlap of insulation at mid-length. | Gap between outer sheath & insulation blanket. Longitudinal overlap of insulation at mid-length. | Large gap between outer sheath & insulation blanket. No longitudinal gap/overlap of insulation. | No gap between outer sheath & insulation blanket. No longitudinal gap/overlap of insulation. |
| Average insulation thickness (mm) | 51.3 | 51.1 | 54.7 | 35.2 | 50.3 | 58.9 | 53 | 43.4 | 43.5 |
| Average Mass ($g/m^2$) | 470 | 466 | 705 | 597 | 461 | 621 | 679 | 601 | 472 |
| Conditioned at 45˚C for 24 hours | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Consistency of insulation (qualitative) | No gaps or variation in thickness observed | No gaps or variation in thickness observed | No gaps or variation in thickness observed | No gaps or variation in thickness observed | Variable thickness, patches where it was partially transparent. | No gaps or variation in thickness observed Longitudinal overlap at mid length. | Gaps between outer sheath & insulation. Longitudinal overlap at mid length. | Gaps between outer sheath & insulation. Reasonably uniform thickness. | Gaps between outer sheath & insulation. Reasonably uniform thickness. |
| Thermal resistance marking on (Packaging / Duct outer sleeve) | Yes / Yes | Yes / No | Yes / No | No / Yes | Yes / No | Yes / Yes | No / No | No / Yes | Yes / No |

**Table 2: Thermal Measurements**

| Specimen # | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Plate spacing (mm) | 37.5 | 34.6 | 54.7 | 29.5 | 36.6 | 43.2 | 42.8 | 43.4 | 36.7 |
| Sample hot surface temperature (°C) | 33.0 | 33.0 | 33.0 | 33.0 | 33.0 | 33.0 | 33.0 | 33.0 | 33.0 |
| Sample cold surface temperature (°C) | 13.0 | 13.0 | 13.0 | 13.0 | 13.0 | 13.0 | 13.0 | 13.0 | 13.0 |
| Sample temperature difference (°K) | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 |
| Sample mean temperature (°C) | 23.0 | 23.0 | 23.0 | 23.0 | 23.0 | 23.0 | 23.0 | 23.0 | 23.0 |
| Mean heat flow ($W/m^2$) | 31.99 | 29.72 | 20.40 | 30.78 | 26.07 | 24.43 | 24.25 | 24.04 | 27.48 |
| Mean variation between upper and lower heat flows (%) | 0.5 | 0.2 | 1.2 | 0.2 | 1.0 | 1.2 | 0.5 | 0.3 | 2.0 |
| Mean thermal conductance ($W/m^2.K$) | 1.599 | 1.486 | 1.049 | 1.539 | 1.303 | 1.222 | 1.212 | 1.202 | 1.374 |
| Apparent thermal conductivity (W/m.K) | 0.0598 | 0.0514 | 0.0571 | 0.0454 | 0.0478 | 0.0528 | 0.0518 | 0.0522 | 0.0504 |
| Mean thermal resistance (R value) ($m^2.K/W$) | 0.625 | 0.673 | 0.957 | 0.650 | 0.767 | 0.818 | 0.825 | 0.832 | 0.728 |

# 6 ENERGY USE

Energy losses through flexible ductwork of 30% are recognised for the purposes of energy consumption calculations (DEWHA 2008, Table 69, p220 & Table 73, p224). Poorly insulated flexible ductwork contributes to excessive energy use and unnecessary generation of greenhouse gases (ADMA et.al. 2009).

In 2007, space heating accounted for 38% of total residential energy consumption in Australia. Nationally, the proportion of dwellings with whole-house (ducted) heating systems is projected to increase, with Victoria by far the largest contributor (DEWHA 2008, Fig. 22, p37). These original projections remain in reasonable agreement with additional modelling performed in 2012; both in terms of the breakdown of state based energy consumption and forecast increases (EnergyConsult 2011, EnergyConsult 2012).

Energy demand for residential space heating and space cooling has been demonstrated, and remains forecast to rise over the period between 1990 and 2020, with space cooling forecast to grow most rapidly at an average growth of 16.1% per annum. Additional research on ducted losses is needed to establish the performance of the ducting in ducted gas and air conditioning systems and the rate of losses from such systems. This increased energy demand corresponds to a 61% increase in the number of residential households and a projected increase in residential floor area of 145% is forecast over this period (DEWHA 2008). Over the same period, the share of dwellings with space cooling is projected to continue to rise significantly. While space cooling may only represent a relatively small percentage of total energy consumption, it creates major problems with regard to electricity generation, transmission and distribution on peak summer days (DEWHA 2008).

An investigation of possible Building Code of Australia adaptation measures for climate change identified the main impacts of climate change with implications for Australian buildings as, increased energy consumption due to higher temperatures, and adverse health effects on building occupants caused by over-heating due to higher temperatures (ABCB 2010). These findings, referenced within the Productivity Commission Inquiry Report, Barriers to Effective Action on Climate Change Adaption (Productivity Commission 2012), contributed to recommendation that the Council of Australian Governments’ Building Ministers’ Forum should provide formal direction to the Australian Building Codes Board to revise the standards in the National Construction Code to take into account these projections where this delivers a net benefit to the community.

As at April 2014, the ABCB have published their preliminary views on the resilience of buildings to extreme weather events within the context of assessing future modifications the National Construction Code (ABCB 2014). The report, *'An Investigation of Possible Building Code of Australia Adaptation Measures for Climate Change'* identified there is a reasonable level of confidence that new buildings constructed to the BCA can withstand current climate hazard design events, and will cope reasonably well with future events that are slightly more severe under a low emissions scenario. It recognised the largest concern is in relation to existing buildings constructed prior to today's contemporary building standards, where these buildings are likely to be vulnerable to current climate hazard events, so would be even more vulnerable when faced with the prospect of more severe future events. In addition, the BCA provisions affected by increased ambient temperatures would be priority areas for consideration of further investigation. The report found that the main impacts of climate change with implications for Australian buildings included increased energy use due to higher temperatures, and adverse health effects on building occupants caused by over-heating due to higher temperatures. Under a high emissions scenario, the need for buildings to be more resilient to these impacts becomes more critical as climate related events have the potential to be more extreme. For example, heat stress may become a critical factor impacting on public health and wellbeing, which could necessitate significant improvements in building passive design and ventilation. This supported the initial findings of potential further investigation needs identified in the 2010 ABCB Adaptation Report including the review BCA energy efficiency provisions and other measures to reduce risk of heat stress related health impacts on occupants.

With household electricity costs likely to rise above current predictions due to the impact of climate change (Saman et.al 2013), this impact can be minimised by ensuring compliance with existing regulatory requirements.

The largest impact on energy usage for space heating and cooling can be delivered with a net benefit to the community through the replacement of older space conditioning ducting with better insulated and better sealed ducting with an estimated scope for retrofit of 0.5 million households. With state and territory government based energy efficiency schemes aimed at addressing energy use, significant benefits to householders and the community are available through upgrading of insulated ductwork (EES 2012).

The opportunity remains to reduce the energy consumption of space heating and cooling systems through the reduction of energy losses through flexible ductwork through the achievement of the existing minimum mandatory thermal performance provisions as specified in the National Construction Code. Due to market failure, this objective is not currently being achieved. Compliance and enforcement of state and territory legislation and local government by-laws is essential to the closing this loophole.

# 7 THE FLEXIBLE DUCT INDUSTRY

The flexible duct market in Australia is highly fragmented. Barriers to entry are low as are capital costs for duct making machinery. As a result there is a high degree of competition across all levels which may be typically defined as Manufacturers/Wholesalers, Resellers and Assemblers.

Where Manufacturers/Wholesalers will typically only sell flexible ductwork, Resellers will sell total installed systems to the consumer, including the heating or cooling unit, the ducting, black goods and white goods, and also arrange the installation services through a contractor. Some Resellers will also manufacturer of their own ducting rather than procuring it from a dedicated Manufacturers/Wholesaler. This leads to the situation where flexible ductwork is manufactured and installed by the one company.

Flexible duct assemblers typically procure pre-made inner cores from local manufacturers or by importing it in from overseas. Manufacture is completed by simply wrapping the inner core with an insulation blanket (procured independently) and sheath it with an outer sleeve. Assemblers may be large independent contractors who assemble ducting for their own operations rather than for retail sale.

There is however, significant overlap where any of these participants can potentially produce and retail their own finished product directly to the consumer.

## 7.1 Australian Duct Manufacturers Alliance (ADMA)

With the introduction of Energy Efficiency provisions in the Building Code of Australia, including minimum mandatory thermal performance requirements for flexible ducts, the Australian Greenhouse Office (AGO), in conjunction with ACCC, ABCB and Trade Practices Organisation, advised the Flexible Duct Industry of an awareness of the widespread national lack of conformance and regulation regarding the thermal performance of flexible duct. ADMA was created by Heating and Cooling Alliance of Australia (HCAA), as part of the Master Plumbers and Mechanical Services Association of Australia ( MPMSAA) to represent duct manufacturers/assemblers with the aim of developing an industry regulated system of addressing non-compliance to the required standards for ADMA members (ADMA 2014).

### 7.2 Energy Losses of Flexible Ductwork

Energy losses due to ductwork are composed of thermal losses, which are caused by the unwanted propagation of heat through the duct walls and fittings, and leakage losses, which are due to unwanted air leaks in duct, fittings and equipment. When flexible ductwork is installed in new buildings, the National Construction Code Energy Efficiency Provisions set:

- Minimum thermal performance requirements,
- Ductwork sealing requirements.

Where flexible ductwork is installed in retro-fit applications, there are no requirements with regard to energy losses.

### 7.3 Standard Test Methods for Finished Flexible Duct

Standard methods for testing the thermal performance of flexible air ducts used for indoor comfort heating, ventilating and air conditioning applications have been available to the flexible duct industry for many years. The Air Diffusion Council (ADC) Flexible Duct Test Code – FD 72-R1 establishes the requirements for the determination of data on air friction loss, sound, leakage, heat transfer properties and static pressure-temperature behaviour for flexible air ducting used as a means of conveying conditioned air in HVAC systems. The requirements regarding the selection and preparation of test equipment and procedures to be used, the installation of test specimens and accumulation of test data and the format of presentation of the results are available at Australian based facilities.

# 8 GOVERNMENT POLICY AND LEGISLATION

Legislation exists to govern aspects of the regulation necessary for the Australian flexible duct industry. Enforcement of regulatory requirements remain the largest obstacle to achieving the benefits of reduced energy consumption, reduced GHG emissions and increased energy efficiency of equipment which underpin these government initiatives.

## 8.1 National Construction Code (NCC)

State and Territory Building Acts give legal affect to the National Construction Code, maintained by the Australian Building Codes Board, containing provisions for the thermal insulation and sealing of flexible ductwork.

AS/ NZS 4859.1 Materials for the thermal insulation of buildings (Standards Australia 2002) and AS 4254.1 Ductwork for air handling systems in buildings – Flexible Duct (Standards Australia 2012) address thermal performance, mandatory labelling, fire hazard performance, workmanship. Thermal Insulation, Ductwork Sealing and Fire hazard Properties aspects are adopted in the NCC.

The regulatory requirements of NCC Energy Efficiency provisions have been clearly defined by the Australian Duct Manufacturers Association (ADMA 2013a).

In addition to minimum thermal performance requirements the BCA also dictates safety requirements with minimum fire performance standards for all flexible ducting. While these compliance requirements have been stipulated in the BCA, historically there has been little to no policing or enforcement of these regulations. This has prompted the industry, represented through the Australian Duct Manufacturers Association (ADMA), to raise concerns over the consistency and quality of flexible duct in relation to construction, fire standards, labelling and thermal performance. These concerns have been brought to the attention of the Department of Climate Change (formerly the Australian Greenhouse Office or AGO) and the Australian Competition and Consumer Commission (ACCC) (ADMA, 2014), and the expectation is that this industry sector will be more closely policed for compliance to the BCA. An opportunity therefore exists for flexible ducting products that deliver on all facets of compliance.

There are no current calls to increase the stringency of NCC Energy Efficiency provisions with regard to the minimum performance levels as the largest opportunity to reduce energy use in space heating and cooling systems remains in the enforcement of compliance to existing State and Territory Building Regulations in order to fulfil the original objective of developing nationally consistent, cost effective, energy efficiency regulations for the BCA.

### 8.2 Greenhouse and Energy Minimum Standards (GEMS) Act

The GEMS Act implements the decision of the Australian Government and the Council of Australian Governments to establish national legislation to regulate energy efficiency and labelling standards for appliances and other products. The goal of the act is to provide a nationally consistent legislative and policy framework that includes the regulation of equipment and appliances that affect the energy used by other products. One key function of the Australian GEMS Regulator is to enforce compliance with the GEMS Act which is targeted towards responsible parties including equipment manufacturers, importers and suppliers. Administrative, civil, and criminal responses to contraventions are all available to the GEMS regulator to address a contravention and resolve matters (Aust. Govt., 2013). The applicability of GEMS Act to the flexible duct industry is under current investigation.

### 8.3 Equipment Energy Efficiency (E3) Program

The Commonwealth Government Equipment Energy Efficiency (E3) Program has mainly dealt with electrical appliances and equipment in the past; it is now considering the feasibility of more formally regulating the energy performance of a range of gas appliances. This work forms part of the Switch on Gas Strategy approved by the Ministerial Council on Energy in 2004.

Energy consumed in the operation of equipment and appliances is a major source of energy demand and greenhouse gas emissions within the Australian and New Zealand residential, commercial and industrial sectors. The Australian and New Zealand governments have both recognised the substantial reductions in energy use which can be made by improving the efficiency of domestic products. Improved efficiency will reduce the demand for energy and have flow-on effects for security of energy supplies, less reliance on fossil fuels to meet peak demands and a reduced cost to the end user (EnergyConsult 2012). Recommendations included further investigation into gas space heaters and decorative appliances being added to the E3 MEPS programme based on the size of theoretical energy savings and greenhouse gas reductions. Options for governments to drive improvements to energy efficiency of new gas space (room) or decorative heaters sold into the Australian and New Zealand markets, including the possibility of implementing mandatory minimum energy performance standards (MEPS) and/or energy labelling via the Equipment Energy Efficiency (E3) Program are underway (as at April 2014), and include the possible inclusion of insulated flexible ductwork in the context of Commonwealth Greenhouse and Energy Minimum Standards (GEMS) Act 2012, which gives power to set standards for products that affect the amount of energy used by another product.

### 8.4 Victorian Plumbing Regulations

In addition to NCC Energy Efficiency requirements, Victorian Plumbing Regulations 2008 implement Plumbing Code of Australia provisions to specify objectives and performance requirements related to the installation of heating, ventilation and air-conditioning systems. The Deemed-to-Satisfy provisions include:

- AS 4254-2012 Ductwork for air-handling systems in buildings Part 1: Flexible duct and Part 2 Rigid duct (PIC 2013), and
- Standards Australia Handbook HB276-2004, "A Guide to Good Practice for Energy Efficient Installation of Residential Heating, Cooling & Air Conditioning Plant & Equipment" (Standards Australia, 2004).

Victorian Plumbing Regulations 2008 require residential heating, cooling and air-conditioning equipment, including flexible ductwork, to be installed in accordance with the above requirements in order to support the Government's initiatives to reduce greenhouse gas emissions via reduction in energy consumption.

In Victoria, anyone who undertakes plumbing work is required to be licensed or registered with the Victorian Building Authority. Plumbing work is generally defined under eight types and installation of flexible ductwork is addressed under a 'Mechanical Services' classification. Mechanical services includes the construction, installation, replacement, repair, alteration, maintenance, testing or commissioning of a mechanical heating, cooling or ventilation system in a building, which is associated with the heating, cooling or ventilation of that building and includes any valve, regulator, register, pipe, duct, flue, tank, heating or cooling pipe or surface, boiler, burner, solid fuel heater, coil or other item that is used in the system.

The Victorian Energy Efficiency Target (VEET) Regulations are a market-based mechanism for emissions reductions which places a legal requirement on energy retail companies through the Victorian Energy Efficiency Target Act 2007. The Victorian Energy Efficiency Target Regulations 2008 determine a range of matters essential to the operation of the scheme. The Energy Saver Incentive is administered by the Essential Services Commission, which is the independent regulator of the retail energy industry in Victoria. Its role is to oversee compliance and performance reporting by energy businesses, and to accredit business and products and appliances which are eligible under the Energy Saver Incentive scheme. Proposed additional prescribed activities include the installation of new and replacement space heating ductwork (VEET 2010) where, ductwork must meet all the requirements for insulated flexible ductwork set out in the Australian Duct Manufacturers' Alliance document Victorian Energy Efficiency Target Scheme: Guidelines for retrofit of ductwork for gas ducted heating systems.

### 8.5 Conformance with Regulatory Requirements

As reported by ADMA as late as September 2013, the Australian flexible duct industry is still grappling with the compliance issues identified by the Commonwealth Government in 2006 and continues to see the regular exploitation by members of the industry for their own benefit (ADMA 2013b). ADMA has continued to seek to be included in Commonwealth and State Government initiatives to provide tighter regulatory control over the flexible duct market to eradicate "unregulated, non-compliant, under-insulated Flexible duct being produced locally and imported" (ADMA 2013b).

The Australian Industry Group revealed the widespread use of non-conforming products across the building and construction sector where the majority of non-conforming products were reported as not meeting regulatory, Australian or industry standards. Products have been found to be not fit-for-purpose, are of unacceptable quality, contain false or misleading claims or are counterfeit product (AIG 2013).

## 9 CONSUMER PROTECTION

Energy losses through flexible ducting in space heating and cooling installations contribute significantly to increased householders' energy consumption, energy costs, and increased greenhouse gas emissions.

Energy losses between 26 to 58% in Victorian residential heating ductwork have been reported (Palmer 2008). Palmer also reported "Many studies have been conducted in North America on similar systems, and have shown that losses typically range from 25 to 40%, however there have been no published studies up to date in Australia that have quantified the losses in Australian systems."

The consumer, interestingly, has little to do with the selection of ducting and duct fittings other than diffusers (white goods) which have an aesthetic impact on the ceiling of houses. While there remains little interest in the energy under-performance of flexible ducting that has the ability to impact so markedly on the ongoing cost of space heating and cooling, consumers continue to pay for these large energy losses in every utility bill. Consumers are unwittingly continuing to pay for the installation of non-conforming flexible duct that will not deliver the promised performance, and is likely to go unnoticed for the life of the system.

# 10 CONCLUSION

Flexible duct is supplied compression packaged. The insulation material used in the manufacture of flexible duct, is expected to exhibit substantial variation in density, thickness, resiliency, thickness regain, and can exhibit slow thickness regain when unpackaged. To negate these effects, the standard procedure to accelerate re-lofting prior to thermal resistance measurement has been followed. In all nine (9) specimens, the measured thermal resistance was less than the R1.0 requested at the time of sourcing. The measured average thermal resistance of all specimens was R0.763.

Based on the assumption that the declared Material R-value of the insulation at the time of manufacture of the nine flexible ducts was R1.0, the reduced thermal performance values measured for all nine specimens in their unpackaged state could be attributed to a permanent loss of declared thermal resistance values as a result of the manufacturing and/or packaging processes. Alternatively, if the measured Material R-values of insulation specimens had not been adversely affected by the manufacturing and/or packaging processes, it could be concluded that the declared Material R-value of the insulation at the time of manufacture was less than R1.0 for all nine flexible duct specimens.

Whether as a consequence of either of these conclusions, or as the result of some combination of these, or for some other reason, the measured thermal performance of all nine specimens that have been sourced from the marketplace is less than the declared thermal performance of insulation. As a consequence, it must be recognised that the energy saving benefits attributed to these nine samples of flexible ductwork of declared Material R-value (R1.0), will not be achieved. While the declared thermal performance of the insulation immediately prior to flexible duct manufacture may be as stated, this has not been transferred to the thermal performance of the flexible duct when unpackaged.

The significance of these results is expounded in the second part of this survey where the effects of underperforming flexible ductwork with regard to energy use, government policy and legislation, regulatory compliance, and consumer protection are enunciated. The importance of these findings reinforces the need for the effective enforcement of compliance through the adoption of a method of verifying the as-installed thermal performance of flexible ductwork.

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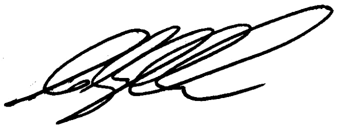

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