MECHANICAL INSULATION CASE STUDY—TIMELY OPPORTUNITY FOR RETROFITS AND NEW CONSTRUCTION

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INTRODUCTION

"You won't find any issues in our newly constructed and retrofitted buildings," was the response that Lyndon Johnson, representative of the BC Insulators, got from the campus facility manager when explaining the poor state of practice of mechanical insulation, "let me show you one of our showcase buildings." The building in question had just undergone $80 million in upgrades and was designed to achieve LEED® Silver equivalent rating. The upgrades included a high-performance climate control system that allows for precise control of temperature and humidity in different rooms. "We toured the building and found many problems with the mechanical insulation," explained Mr. Johnson afterwards, "including substandard finish, adhesive tape lifting, and most disturbing, 20 feet of missing insulation on each floor of the building along the dividing line of the two phases of the project. One or both sets of contractors that worked on the job had completely left off the insulation. The saddest part is, this didn't surprise me given what we know about the state of the industry today."

KEYWORDS

mechanical insulation, building retrofits, new construction, energy savings, building codes, building energy modelling

CONTEXT

The condominium and commercial building industry in British Columbia (BC)—in particular the Lower Mainland Region that encompasses the City of Vancouver—has experienced a significant development boom over the past 20 years, not unlike many local markets throughout North America. The competition for land, tenants, and buyers—and the resulting pressure to meet deadlines and make profit—has created an environment where corners get cut and the checks and balances in the system of building codes, inspection, and best practice break down.

At the same time, goals to use energy more wisely and reduce greenhouse gas emissions have heightened the urgency and opportunity for taking action in the short term. British Columbia has in place some of the most aggressive greenhouse gas reduction targets in the

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FIGURE 1. Corrosion and condensation in new LEED Platinum multi-family residential building.

FIGURE 2. The top photo suggests the pipe is fully insulated. Underneath the PVC cover, however, there is no insulation around the fitting. (Public service organization building.)

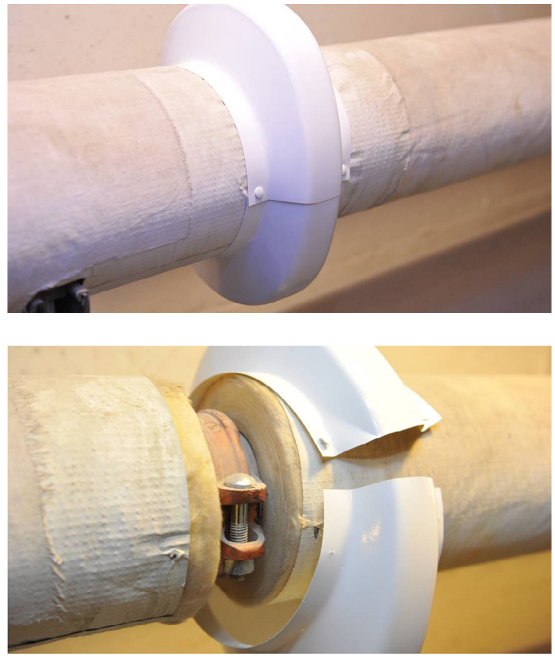

FIGURE 3. Sweating pipes with improper insulation and insufficient spacing in a medical building.

world. Energy-efficiency requirements have been increased in the BC Building Code and additional efficiency changes are anticipated in the near future. Provincial energy and climate change legislation, including the BC Climate Action Plan, Clean Energy Act of 2010, and the BC Clean Energy Plan, have set goals and established priorities for reducing energy and emissions through efficiency and economic development strategies, including "green collar jobs" that advance these goals. Mechanical insulators clearly fall into this category. Mechanical Insulation (MI) is the industry name for insulation applied to pipes, ducts, and mechanical equipment (such as boilers, storage tanks, and air-handling equipment). It is different from the insulation found in the walls, basement floor, and roof of a building.

The focus of the recommendations is the MI found in industrial facilities, as well as larger commercial, institutional, and residential buildings. MI, as a component of building energy systems, plays an important role in:

- Energy efficiency, including mitigating greenhouse gas emissions and moving toward sustainable energy use;
- The economic performance of buildings, by minimizing spending on energy and increasing durability of buildings; and
- Health and safety—through fire stopping and protecting workers/building occupants from unhealthy indoor air quality (moisture-caused mould) and burn (exposed pipes).

Despite the numerous benefits of paying attention to MI, the state of practice has fared particularly poorly in the development boom—to the detriment of building energy efficiency and performance. Though some of the issues may be specific to British Columbia and MI, the situation described should sound familiar to building-industry professionals across North America and highlights the need for increased attention to MI, and more broadly, building energy performance into codes, standards, building rating systems, and best practice guidelines.

> "It has been estimated that 10 to 30 percent of all mechanical insulation is missing or damaged. This is a realistic estimate for most U.S. facilities. The Department of Energy's 'Save Energy Now' program has confirmed that the problem of missing or damaged insulation is more widespread than many would like to acknowledge."
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> —*Ronald King, past president of the National Insulation Association*

STUDY OVERVIEW

A handful of individuals and organizations that are closely connected to the mechanical insulation industry understand the current set of challenges and the opportunities for improving performance. The authors of this article were involved by the BC Insulators to conduct an independent assessment of the situation and to quantify the energy and GHG reduction benefits associated with good mechanical insulation practice.

METHODS

The methods employed consisted of the following: review of MI industry journals, reports, and publications; review of best practice guides, building codes, mechanical insulation specifications, and building handbooks; review of academic journal articles; modeling mechanical insulation energy, greenhouse gas (GHG) emissions and cost savings; and interviews with professionals in the MI industry.

As a means to establish independent estimates of the impact of good and poor MI installation practice on total building energy use, three building typologies—based on three real buildings—were chosen and modeled using the 3E Plus software program.[1] The North American Insulation Manufacturers Association developed 3E Plus to optimize insulation design through energy, environmental, and economic analyses. This program has been utilized to analyze the effects of pipe insulation on the energy performance of the three chosen building typologies. The three typologies were chosen as examples of where there is the greatest opportunity for improving current practice.

To assess the quality of mechanical insulation in new construction, we conducted a key informant survey of various building industry members and stakeholders. The interviews were designed to:

- Determine interviewees' knowledge of typical mechanical insulation industry practice and regulatory requirements;
- Assess the quality of mechanical insulation systems in new buildings, both in terms of code compliance and best practices in installation;
- Determine reasons for the level of good practice in the industry; and
- Determine opportunities to improve practices.

Input and opinions regarding the state of mechanical insulation practice and recommendations for opportunities to improve practice were also contributed by the authors and members of the BC Insulators. This input was based on a diversity of experiences in the industry gained from conducting MI installations and physical reviewing and auditing of hundreds of buildings.

FINDINGS

State of Practice

Industry literature suggests that there is significant noncompliance with building codes and best practices.[2] A broader survey that included interviews with building-industry members and stakeholders corroborated this and indicated that the reasons for poor practice in the industry are numerous, and include:

- Outdated or incomplete engineering specifications, or lack of knowledge of best practices by engineers, especially for newer, high-performance and low-temperature mechanical systems;
- Problems due to unqualified installers and inadequate training;
- Lowest-cost tendering and "value engineering," reducing costs below what is necessary for best practices, particularly when the developer is not the eventual owner or operator;
- A perception among some developers and engineers that mechanical insulation is not a critical building component. This may be due in part to lack of educational focus on this issue;
- Poor quality, lower-cost insulation materials on the market;
- Challenges related to engineering field review, including assessing whether installations meet code and design specifications;
- A fragmented design and construction process where engineers and installers do not typically work closely together; and
- Tight construction timelines and focus on drywall completion, which can prevent inspection of some systems.

Inspections during new building construction, walkthroughs of older buildings, and inspections at the time of major repairs and renovations, reveal that both mechanical rooms and laterals/risers frequently have mechanical insulation deficiencies. These deficiencies occur at the time of original installation (improper material selection, inadequate insulation thickness, missing insulation) and during mechanical system maintenance (removal of insulation). Mechanical insulation best practice guidance, training, and policies need to specifically address the deficiencies identified above.

TABLE 1. Summary of Mechanical Insulation Deficiencies.

Time of Occurrence	Location of Deficiency	Deficiencies	Effects
Original Installation	• Mechanical Room • Risers and Laterals	• Improper material selection • Inadequate insulation thickness • Missing insulation	• Excessive heat transfer • Pipe or duct deterioration due to corrosion, exposure to environment • Risk of injury (burns, sharp corners) • Risk of property damage (pipe/valve failure) • Efficiency loss/poor energy performance
Maintenance	• Mechanical Room	• Removal of insulation without replacement	

Mechanical Insulation Best Practice

MI "best practice" consists of a combination of material choice and thickness, installation technique and practice, and maintenance. Material choice and insulation thickness is dependent on: the type of building and mechanical system; climate zone; energy performance objectives/standards; the specific location of each pipe/duct inside (or outside) of the building; the importance of appearance; and meeting human safety, flame-spread, and smoke-stopping requirements. Several of the most important elements of each area are highlighted below.

Material Choice

The type of MI material selected should be based on the temperature of the system and the specific subcomponent of the mechanical system (e.g., steam pipes, air ducts, roof drains, engine exhaust, chilled water). National and state/provincial government building codes set flame-spread, smoke-stopping, and human safety requirements that also dictate material choice.

Insulation Thickness

Building codes reference buildings standards, such as ASHRAE 90.1, that specify minimum R-values and thicknesses for pipe and duct insulation. To meet energy- and cost-savings objectives, the mechanical engineer should specify greater pipe and duct thicknesses. Tools such as the North American Insulation Manufacturers Association's 3E Plus[3] can be used to identify optimal thicknesses for different applications.

Installation Technique

There are numerous important details that comprise installation best practice. (Certified installers typically complete a four-year apprenticeship and 500 hours of coursework.) The installer, mechanical contractor, and mechanical engineer all play a role in ensuring good installation practice takes place. For the mechanical engineer and contractor, it is important to specify and install the pipes and ducts with adequate spacing to allow for installation of the MI and to ensure the building is dry and sealed from the weather before MI is installed. Some of the crucial points for installers include being meticulous about the elimination of gaps (however small), making sure vapor barriers on cold systems encompass all system components, and preventing any water from infiltrating the weather protection on outdoor system components.

Maintenance

MI should be regularly inspected for damage. This includes inspecting crawl spaces, valves, flanges, and all equipment after servicing/repair and on a regularly-scheduled basis.

Gaps in Codes and Standards

Within North America there is no single established code, standard, or best practice guide that comprehensively addresses all of the areas identified above.

- Neither the Canada National Building Code, nor the BC Building Code, include thickness tables for mechanical insulation, though they do contain fire and worker protection requirements.
- While the BC Building Code makes reference to ASHRAE Standard 90.1 2004,* the ASHRAE standard does not contain a section specifically dedicated to mechanical

*The American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) is an international technical society for all individuals and organizations interested in heating, ventilation, air-conditioning, and refrigeration. Standard 90.1 is an Energy Standard for Buildings excluding low-rise residential buildings.

insulation, nor does it address best practice. The ASHRAE 90.1 standard includes specification tables for mechanical insulation thicknesses, but these are not reproduced in the BC Building Code.

- ASHRAE Standard 189.1-2010 specifies mechanical insulation thermal resistance (R-values), and could in time supersede ASHRAE 90.1 in terms of building code references, though it appears there are no current plans for this to happen.
- The BC Insulation Contractors Association (BCICA) has created a Quality Standards for Mechanical Insulation manual that comprehensively covers installation practice, but does not reflect current best practices for insulation thicknesses.

The absence of mechanical insulation thickness specification tables in the BC Building Code creates confusion regarding what is required to meet "code." The need to consult a building code, a MI specification, and a MI best-practice manual in order to assemble the complete set of information needed to write a project specification and properly install MI creates for a burdensome process open to multiple interpretations of what is "good" and "best practice."

MECHANICAL INSULATION GUIDES, STANDARDS AND HANDBOOKS

As identified above, it is necessary to consult mutliple sources to assemble all of the best practice elements for MI. In the context of multi-unit residential, commercial and institutional buildings, the following are the most appropriate resources to consult.

Guide, Standard, Handbook	Description
ASHRAE 90.1 (2010) Standards and Handbooks, and ASHRAE 189.1 (2010) Standards and Handbooks	Specifies MI thicknesses and specifies minimum R-values for different piping and duct applications in order to meet minumum energy-efficiency standards. The ASHRAE website also has information on recommended insulation practices.
Midwest Insulation Contractors Association's *Commercial and Industrial Insulation Standards Manual*	A manual for designing, specifying, and installing thermal insulation products.
Mechanical Insulation Guide for British Columbia. BC Insulators (2012 forthcoming)	Focused on MI system design, materials, and quality guidelines. Intended to orient practitioners in British Columbia to the building code requirements, best practices, and standards that should be adhered to.
Thermal Insulation Association of Canada—*Mechanical Insulation Best Practices Guide*	A guide that includes insulation materials and properties, system design, fire-stopping and smoke-seal sytems, and examples of specifications for commercial systems. (Contains additional detailed content for industrial applications.)
The BC Insulation Contractors Association's *Quality Standards for Mechanical Insulation* (for Commercial and Institutional Buildings)	Provides material quality standards and workmanship to design, specification, and installation of MI systems. Also includes fire stopping and smoke seals guidance, asbestos removal, and maintenance guidance.
Whole Building Design Guide (WBDG) *Mechanical Insulation Design Guide*	A web-based guide that provides guidance on insulation thickness, material choice, installation practice, maintenance, and energy and economic calculations.
Sheet Metal and Air Conditioning Contractors' National Association (SMACNA) *Fibrous Glass Duct Construction Standards*	Provides the performance characteristics for fibrous glass board, as determined by the North American Insulation Manufacturers' Association (NAIMA) and Underwriters Laboratories (U.L.), as well as specifications for closures and illustrations of how to construct the full range of fittings.

Modeled Energy and GHG Reductions

The purpose of the building energy modeling exercise was to estimate the energy and greenhouse gas emission reduction opportunity associated with retrofitting three building types that are frequently in need of MI upgrades. It is challenging to estimate the impact that MI can have on building performance, including energy consumption, greenhouse gas emissions, and costs, given several important factors and uncertainties, including:

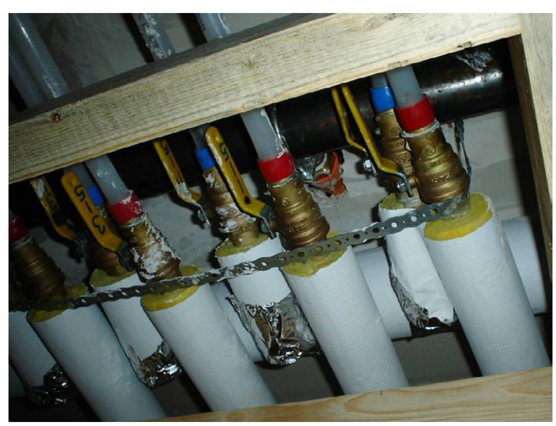
- The wide range of building mechanical system designs and operating conditions;
- The range of components within these systems that require MI; and
- The difficulty in estimating the performance effects of MI deficiencies, particularly those that are due to improper installation practices.

The energy modeling focused on hot water pipe insulation, comparing the performance in three buildings with and without insulation (equivalent to poor practice). The three buildings modeled were: 1) a 20- to 40-year-old four-story wood frame apartment; 2) a 10- to 20-year-old 25-story residential tower; and 3) a 45- to 65-year-old multi-story commercial retail store. The characteristics of each building were based on case-study buildings located in the greater Vancouver, BC, metropolitan area. The modeling represents a worst-case scenario equivalent to no pipe or duct insulation. In buildings 1 and 3, the mechanical insulation was assumed to be removed from mechanical rooms over the years during maintenance of pipes and the mechanical system and damaged/removed on exterior pipes/ducts. In building 2, it was assumed that some of sections of pipes were not insulated at the time of construction, while improper material selection and poor installation practice led to a steady deterioration in the sections of pipe/duct that were originally insulated.

In all three of the case study buildings, the modeling showed that retrofitting the buildings with proper insulation results in significant annual energy savings (from 45.8 MWh to 475.9 MWh) and reduction in GHG emissions (8.4 metric tonnes CO_2e to 81.8 metric tonnes CO_2e). The simple payback calculations are the best argument for making sure mechanical insulation is done properly at the time of construction and when replacing major heating/cooling system components. We calculated a 4-year payback period for the

FIGURE 4. Example of *Building 1 Modeled Condition:* Detail showing heat exchangers used with domestic water system. Note the build up of deposits on the heat exchangers.

FIGURE 5. Example of *Building 2 Modeled Condition:* New domestic hot water pipes (risers) before drywall application—poor practice and material choice.



wood frame apartment building, 2.7 years for the residential tower, 6 months for the steam system of the large commercial retail store, and 5 years for the chilled water system on the same building.

Similar estimated energy savings and emissions reductions were calculated as a part of an energy audit of large institutional buildings owned by the state of Montana.[4] In this study, a payback period of 4.1 years was calculated, based on the replacement of damaged or missing insulation in the mechanical rooms of 25 buildings, if carried out. The retrofits would result in an 8% reduction in natural gas use, or 6 billion BTUs.

From the case study analysis it is clear that the costs of fitting MI on hot water and steam system pipes can be recovered quickly—usually in less than five years. The case studies also show that energy savings associated with pipe insulation can account for a significant proportion of overall building energy consumption. This suggests that without proper MI, buildings are consuming more energy and producing more greenhouse gas emissions than necessary.

FIGURE 6. Example of *Building 2 Modeled Condition:* New mechanical room—poor practice and material choice.

FIGURE 7. Example of *Building 3 Modeled Condition:* A section of an un-insulated supply air duct on a roof mounted make-up air unit.

Energy and GHG Impacts at a State/Provincial Level

Based on the combination of quantitative data from the case studies and qualitative data from the industry interviews and literature review from this study, we conducted a high-level analysis of energy savings and greenhouse gas reduction opportunities for British Columbia as a whole from improved mechanical insulation practice and standards. The calculations performed in this section are high-level, preliminary estimates. A more extensive survey of mechanical insulation deficiencies across multiple building typologies would be needed to confirm these numbers. British Columbia–wide estimated impacts are:

- Potential annual energy and greenhouse gas reductions from performing mechanical insulation retrofits on existing multi-unit residential and commercial buildings: **200 to 500 GWh** and **35,000 to 90,000 tonnes CO_2e;** and
- Potential energy and greenhouse gas reductions in the year 2020 from improving mechanical insulation practice and standards on new multi-unit residential buildings: **60 to 120 GWh** and **10,000 to 20,000 tonnes CO_2e.**

TABLE 2. Case Study Modeling Results.

	1 Four Story Wood Frame Apartment Building	2 25-Story Residential Tower	3 Large Commercial Retail Store
Age	20–40 years old	10–20 years old	45–65 years old
Conditioned Building Area	4,500 m^2 (48,400 ft^2)	13,000 m^2 (140,000 ft^2)	60,000 m^2 (646,000 ft^2)
Water Heating System Assumptions	• Leaving water temperature (LWT) = 60°C (140 °F) • Entering water temperature (EWT) = 50°C (122 °F) • Heat source: direct fired gas water heaters with a nameplate efficiency of 80% • Indoor design temperature: 20°C (68 °F) • Heating season: September 15 to May 15 (8 months) • Gas cost: \$9.486/GJ • Service life: 20 years	• LWT = 60°C (140 °F) • EWT = 50°C (122 °F) • Heat source: direct fired gas water heaters with a nameplate efficiency of 80% • Indoor design temperature: 20°C (68 °F) • Gas cost: \$9.846/GJ • Service life: 20 years	• Steam system provides saturated steam at 10 psi • Heat source: central steam system located offsite with 80% efficiency • Chilled water leaving temperature = 10°C (50 °F) • Chilled water entering temperature = 16°C (61 °F) • Indoor design temperature: 23°C (73 °F) • Gas cost: \$9.846/GJ • Electricity Cost: \$0.0691/kWh • Chilled water and steam systems operate 4,000 hours per year • Remaining service life: 30 years for steam and chilled water piping
Total Annual Building Energy Consumption	726 MWh	2,249 MWh	33,000 MWh
Annual Energy Savings from Pipe Insulation	45.8 MWh, or 6.3% of total building consumption	320.1 MWh, or 14.2% of total building consumption	475.9 MWh, or 1.4% of total building consumption
Annual Greenhouse Gas Emission Reductions	8.4 metric tonnes CO_2e	58.8 metric tonnes CO_2e	81.8 metric tonnes CO_2e
Simple Payback (Years of energy savings to pay back capital costs)	4.0 years	2.7 years	Steam System: 6 months Chilled Water: 5 years

THE PATH FORWARD

Based on interviews with industry experts and analysis of policies and codes within and external to British Columbia, we developed a set of recommendations to improve mechanical insulation practice in BC and beyond. These recommendations target specific actions to be taken by provincial and state governments, individuals in the building and development industries, and utility companies.

From a strategic perspective, it is clear that a unified and compelling set of changes at the state/provincial government level, supported by local government policies, is needed to achieve a consistent, improved level of performance across jurisdictions. The reasons for MI deficiencies are complex and interrelated; therefore a single solution, such as regulatory changes alone, will probably not result in the best possible outcomes.

TABLE 3. British Columbia Mechanical Insulation Energy, Cost and GHG Reduction Estimates for Existing Buildings.

	Apartment ≥ 5 storys	Apartment ≤ 5 storys	Total Multi-Unit Residential Buildings	Commercial Buildings	Total Buildings
Units in British Columbia (2006) [5]	117,590	338,690	456,280	214,982	671,262
% of Total [6]	7%	21%			
Average Est. Energy Intensity kWh/m^2/year (kWh/ft^2/year) [7]	*173 (16)*	*173 (16)*			
Average Size m^2 (ft^2) [8]	*87 (940)*	*75 (810)*			
Total 2007 Energy Use (GWh) [9]	1,770	4,395	6,164	34,838	41,002
Total 2007 Est. Natural Gas Use (GWh) [10]	*970*	*2,400*	*3,400*		
Total CO_2e (tonnes)[11]	194,860	483,835	678,695	3,439,000	4,117,695
Energy Use (GWh) of Buildings Affected by MI Deficiencies (33%)[a]	*590*	*1,465*	*2,055*	*11,497*	*13,552*
Annual Energy Saving through Retrofit (GWh): 10% for residential, 1.4% for commercial[b]	59	146	205	75	280
Annual Cost Savings (Natural Gas = $0.034/kWh)[c]	$ 2,005,827	$ 4,980,436	$6,986,263	$2,798,981	$9,785,244
Potential Annual GHG Emission Reductions (Tonnes CO_2e)[d]	10,831	26,894	37,726	12,846	50,572

[a]Conservative assumption based on the range of results from interviews with industry.
[b]Percentages based on modeled hypothetical case studies.
[c]Calculated value based on natural gas cost savings.
[d]Calculated number based on reduction in natural gas use.

Building Codes

Revise provincial, state, and local government building codes to include specific, up-to-date requirements on mechanical insulation.

1. Add a clear, mandatory requirement for mechanical insulation in Part 3 of the Code, specifically referencing minimum insulation requirement tables for ASHRAE 90.1-2010 or ASHRAE 189.1.
2. Add a reference to mechanical insulation best practice standards that should be used for writing specifications and installing insulation
3. Add a requirement for minimum training/certification for mechanical insulation contractors and installers

Local, State/Provincial Government and Institutions

Building construction and retrofits—facilities and purchasing departments

Local governments can take steps to minimize energy and cost performance impacts of mechanical insulation deficiencies in their own buildings, as well as gaining experience and showing leadership on energy-efficient building practice. Cities, states/provinces, and large institutional organizations should incorporate policy and/or procurement guidelines that require mechanical insulation best practices to be included in construction and retrofit tenders.

Utility Companies

Utility financial incentives for mechanical insulation retrofits and new construction

Natural gas and electricity utility companies should put in place mechanical insulation rebate programs for new construction and retrofits for commercial and multi-family residential customers. The costs to the utility companies to provide an attractive rebate on insulation would be less than many of the other products that are currently included in financial incentive programs because of the low cost of insulation compared to the mechanical systems that they are associated with.* A few jurisdictions in North America offer incentive programs.

Building and Development Industry

Build capacity and awareness through the creation of a third-party inspection program

Engineers and contractors that were interviewed for this study identified the need for an independent verification system and body to inspect mechanical insulation. The creation of such a system, while far from simple, could in many jurisdictions be implemented with fewer obstacles than expanding the scope of building inspectors to include mechanical insulation. Two keys to successfully implementing a third-party inspection system are:

- A training and certification program for the verifiers that ensures proper qualifications for performing the inspections; and
- Promotion and endorsement of the program by industry associations, state/provincial government, and local governments in order to create sufficient market demand for the verification service.

Other industries have faced the same challenges as mechanical insulation and successfully addressed these through third-party inspection programs. One example is the Roofing Contractors Association of British Columbia (RCABC) Guarantee Corp's (RGC) Guarantee Program for Industrial, Commercial, and Institutional Roofs—the first such program in Canada. The British Columbia Insulation Contractors Association is currently working with the BC Heat and Frost Insulators and the British Columbia Institute of Technology to establish a third-party inspection program based on the structure of the RGC. Similar partnerships and initiatives are needed across North America.

POSTSCRIPT

"We are all working on the happy ending, and there is light at the end of the tunnel, but at the moment there is work to be done," are the words of Mr. Johnson from the BC Insulators. The outlook for the industry is better today than it has been for some time with the renewed interest in energy efficiency and efforts underway by industry insiders in British Columbia and elsewhere in North America. The authors of this article are currently partnering with the BC Insulators to write a new mechanical best practice guide intended to address a full range of multi-unit residential, commercial, and institutional buildings. A partnership has also been established with the natural gas utility, FortisBC, to study mechanical insulation's contribution to building energy use in the City of Vancouver and conduct retrofits of buildings to demonstrate energy and cost savings. A follow-up article reporting on the results of the mechanical insulation retrofit pilot project will be forthcoming in 2013.

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*The cost of installing mechanical insulation following best practices and using appropriate materials and thicknesses is typically less than 1% of total new building construction costs.

MECHANICAL INSULATION CHECKLIST

When engineers, building inspectors and third-party inspectors inspect mechanical insulation, they should look for:

New Buildings[12,13]	Existing Buildings[14,15]
• The specification adheres to ASHRAE 90.1 or the most appropriate standard for the conext and environment • All appropriate systems insulated - Hot water - Heating - Cooling - Ventilation • "Value engineering" of the MI system did not take place • Insulation materials are designed for application • Insulation is the specified thickness • Proper installation practice took place - The MI was installed in a dry building after roof and windows were in place - Clean finish without gaps - On cold systems, vapor barrier mastic was used to seal the fittings, valves, strainers, valve stems, etc. - Pipes supported by hanger system that will not crush the insulation • Jacket/protective covering in place • Weather protection properly installed so that water will not run into the system • Clean jobsite that adheres to safety regulations	• Damage/wearing of the outer jacketing/finish • Penetrations to the insulation system are not sealed • Insulation is missing • Insulation supports are failing • Ice, mold, mildew • Wetness, condensation • Discoloration • "Fish mouthing" of the outer jacketing seams • Securements are missing or becoming loose • Sagging or pulling away of the insulation system • "Hot Spots" in the insulation system • Joints in the insulation are opening • Expansion or contraction joints not functioning correctly • Inspect crawl spaces • Inspect valves, flanges, and equipment

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