Construction Innovation

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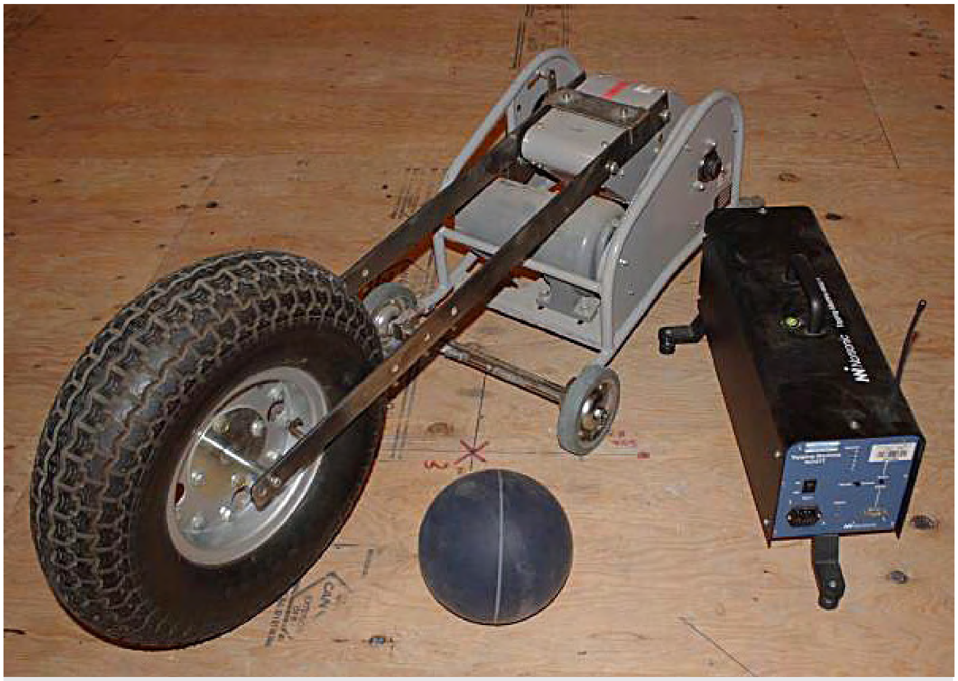
www.nrc-cnrc.gc.ca/ci

EXPORTING WOOD-FRAME HOUSING TECHNOLOGY TO JAPAN

NRC Institute for Research in Construction (NRC-IRC) researchers have recently completed a two-year project to develop acoustical design details that increase the potential for export of Canadian wood-frame technology to the Japanese market.

Carried out in collaboration with Canadian and Japanese partners (see box), the research is part of a larger initiative to export wood-frame, multi-family housing technology and Canadian lumber to Japan. Before this testing, the limited number of proven acoustical design details available in Japan was an impediment to the export of this technology.

NRC-IRC had already developed a best practice guide for airborne and impact sound insulation in wood-frame, multi-family construction in the North American market. It is not applicable, however, to the Japanese market, where they use different construction practices and materials. Another difference is that in carrying out evaluations of airborne and impact sound, Japan employs the bang machine. The bang machine (see photo) is a unique impact source used to assess the ability of the building to control low-frequency impact sound similar to that generated by children running or jumping.



Standardized sources for assessing impact sound insulation. From left to right – Bang Machine heavy impact source used in Japan and Korea, Rubber Impact Ball used in Japan, and ISO tapping machine used throughout the world. Each involves a falling object (tire, ball, or steel hammer) from a specified height onto the floor.

HIGHLIGHTS

To ensure practical results from the NRC-IRC project and rapid uptake, a steering committee of Japanese experts, chaired by the Japan 2x4 Home Builders' Association (Japan 2x4HBA), provided guidance on materials and practice, and sent non-wood-based materials to NRC-IRC for the testing.

The project produced approximately 50 coupled floor/wall design details. These details offer builders many construction options that achieve various grades of sound insulation. This is part of a voluntary quality indication system sponsored by the Japanese government to promote building practice that goes beyond the code minimum. The voluntary quality indication system is a key decision-making tool used by purchasers of new homes.

The NRC-developed design details form the technical basis for a design guide on low-frequency impact sound being developed by Japan 2x4HBA. The guide will provide numerous design options covering a broader range of acoustical performance. Japan 2x4HBA believes this will increase the number of wood-frame, multi-family units built, which will benefit Canada's wood industry by increasing the export of Canadian wood and housing technology.

Continued on page 4

SIGNIFICANT TECHNICAL CHANGES IN THE 2010 NATIONAL MODEL CONSTRUCTION CODES

The recently published 2010 National Model Construction Codes contain close to 800 technical changes that were approved by the Canadian Commission on Building and Fire Codes. Summarized below are the most significant technical changes. Free online presentations providing more detailed overviews of these changes will be available in February 2011 on the national codes web site (www.nationalcodes.ca). They replace the cross-country seminars traditionally offered during past model code launches.

National Building Code of Canada (NBC)

Part 3: Fire Protection, Occupant Safety and Accessibility

Protection Against Falls from Residential Occupancy Windows. A requirement has been introduced providing for a guard or a mechanism that prevents a window from opening more than 100 mm.

Part 4: Structural Design

Live Load Due to Use and Occupancy. Crane and vehicle loads are more explicitly defined. The minimum live loads for areas in arenas, grandstands and stadia having fixed seats with backs has been reduced and the requirement extended to include churches, lecture halls and theatres.

Wind Loads. Buildings with very long periods of vibration, one of the most important factors determining how a structure will respond to external forces, must now be designed by experimental methods; dynamic calculations are no longer acceptable.

Earthquake Design. Revisions were made to requirements related to site properties, irregularities, steel structures, static and dynamic procedures, and diaphragms.

Part 5: Environmental Separation

Structural Loads. Seismic effects will now be taken into account only for post-disaster buildings (i.e. buildings essential to the continued provision of services in the event of a disaster).

Part 6: Heating, Ventilation and Air-conditioning

Ventilation. New requirements relating to acceptable building air ventilation have been added. They specify maximum levels of particulate matter, ground-level ozone and carbon monoxide in air for building ventilation purposes.

Part 9: Housing and Small Buildings

Secondary Suites in Houses. Changes in requirements include limiting their size, making "secondary suite" a defined term, and inserting "house" into many requirements that previously only applied to dwelling units.

Lateral Loads. A probabilistic-based approach for exposure to wind and seismic forces using environmental load data was added, as were prescriptive requirements for high-load areas. The concept of braced wall panels was introduced. Requirements for fastening and framing based on local wind and seismic conditions have also been added.

Low Permeance Materials in the Building Envelope. A simplified approach to requiring the correct position and properties for low air and vapour permeance materials in building envelopes was introduced.

Garage Floors. Inconsistencies were resolved in the requirement that garage floors be sloped to the exterior to limit heavier-than-air gas inflow into habitable spaces below the garage floor level.

Tables A-9.10.3.1.A. and A-9.10.3.1.B. Two footnotes were added to clarify requirements for adhesives employed in finger-joined studs and prefabricated I-joists used in assemblies requiring a fire-resistance rating in buildings.

Parts 3 and 9

Spatial Separation between Buildings. Additional fire protection requirements were introduced relating to the construction of all buildings and houses in proximity to one another or to the property line.

Fire Alarm Systems and Smoke Alarms. New requirements and clarifications were introduced for smoke alarm placement, commissioning of life safety and fire safety systems, and when fire alarm components must be installed.

Penetrations Through Fire Separations. Definitions for "fire stops" and "fire blocks" have been added, as were several changes addressing penetrations through fire separations. Requirements involving attics that don't have sprinklers were clarified.

Exit Signs and Markings. Requirements addressing green pictograms conforming to ISO standards and photoluminescent exit signs were introduced.

Stairs, Ramps, Handrails and Guards. A set of 31 changes address inconsistencies between Part 3 and Part 9 regarding the respective requirements for stairs, ramps, handrails and guards. Many clarifications were also added.

Parts 5 and 9

Windows, Doors and Skylights. A new, harmonized North American standard for windows, doors and skylights is now referenced in the NBC. This resulted in a substantial reorganization of Sections 9.6. and 9.7.

Sealant Standards. Outdated standards for sealants were replaced with current ASTM standards that address relevant product categories and contain equivalent or similar performance criteria.

Parts 5, 6 and 9

Radon. The new Health Canada guideline of 200 Bq/m^3 for indoor radon concentration has been referenced in the Appendix. Parts 5 and 6 now require that engineers and designers consider radon protection in their designs. Air barrier requirements in Part 9 were consolidated and prescriptive measures on providing a rough-in for a future radon mitigation system added.

Appendix C, Table C-2

Seismic Values and Climatic Data. Climatic data and localities were updated and the equation derived to fit the seismic observational data was improved.

National Fire Code of Canada (NFC)

Leak Detection and Monitoring. Changes dealing with leak detection and monitoring, as well as handling of certain dangerous goods, have been introduced. Existing requirements relating to the detection and monitoring of storage tanks, sumps, and piping systems containing flammable and combustible liquids were revised and new ones added.

Storage of Flammable and Combustible Liquids in Buildings. Limits to quantities of flammable and combustible liquids stored within buildings have been updated. New passive and active fire protective measures have been added.

Fire Safety at Demolition and Construction Sites. Adjacent buildings or facilities must now be protected from fires originating from demolition or construction sites. Requirements for fire safety plans and fire department access to sites were improved. Specific requirements on the commissioning and decommissioning of standpipe systems, as well as restrictions on rooftop bitumen kettle placement, have been added.

NBC and NFC

Care Occupancies (NBC Part 3, NFC Part 2). A new occupancy classification for residential care facilities has been created (Group B3 occupancy) that relaxes requirements for smaller care occupancies having a limited number of occupants. New construction, sprinkler, emergency power and fire alarm requirements were added.

Relocation of technical requirements. To draw a clear line between the roles of the NBC and the NFC, building design requirements presently in the NFC were moved to the NBC (except for spill control measures). Appropriate cross-referencing between the two codes was added.

National Plumbing Code of Canada (NPC)

Water Pipe Sizing. Pipe sizing requirements were updated to accommodate the current standard practice of using water-conserving appliances and fixtures in buildings and facilities.

Next steps for updating Canada's national energy codes

Comments received during the fall 2010 public review of the National Energy Code for Buildings (NECB) are now under review by the Standing Committee on Energy Efficiency in Buildings. Final recommendations will be prepared by the committee and submitted to the Canadian Commission on Building and Fire Codes in time for a 2011 spring vote. The committee is also working on guidelines to help the provinces and territories tailor the NECB 2011 to suit their own policy needs. These guidelines will be developed in consultation with the Provincial/Territorial Policy Advisory Committee on Codes. The NECB is scheduled for release in November 2011.

Work is also progressing on incorporating energy efficiency requirements for housing and small buildings into a separate section of Part 9 of the National Building Code, a project being carried out in partnership with the provinces and territories. These requirements will use the same objectives and functional statements as the NECB 2011, and the same policy principles. This includes setting an energy performance target for non-residential buildings that is 25% better than the Model National Energy Code for Buildings 1997 and a target for housing equivalent to EnerGuide 80. (An EnerGuide rating shows a standard measure of a home's energy performance.) The revised technical requirements for Part 9 buildings are expected to be available for public review in fall 2011.

For more information, contact Cathy Taraschuk at (613) 993-0049 or e-mail cathleen.taraschuk@nrc-cnrc.gc.ca.

CCBFC RENEWS ITS MEMBERSHIP FOR THE 2010-2015 CODE CYCLE

The membership of the Canadian Commission on Building and Fire Codes (CCBFC) was recently renewed for the 2010-2015 code development cycle. The CCBFC is an independent committee appointed by the National Research Council to provide direction and oversight on the development of Canada's National Model Construction Codes. These Codes comprise the National Building Code (NBC), the National Fire Code (NFC), the National Plumbing (NPC) Code and the National Energy Code for Buildings (NECB).


Mr. Chris Fillingham

The new members were appointed to the CCBFC on September 1, 2010 (see www.nationalcodes.ca/eng/ccbfc/members.shtml). The Commission's new Chair, Mr. Chris Fillingham, appointed at the same time, will guide the CCBFC during the next five years.

Members of the CCBFC and its subcommittees are volunteers chosen for their expertise rather than as representatives of any specific organization. They are selected to provide broad representation from industry, the regulatory community and the general public throughout Canada.

The new Commission will meet for the first time in spring 2011. Its immediate priorities will include approval of changes to the NECB scheduled to be published in November 2011, and development work to incorporate energy efficiency requirements for houses into Part 9 of the NBC in 2012.

For more information, contact Anne Gribbon, Secretary to the CCBFC, at (613) 993-5569 or e-mail codes@nrc-cnrc.gc.ca.

Continued from cover

Results of this project have been communicated at several bilateral meetings of the Canada Japan Housing Committee, the Building Experts Committee and other groups. The technologies and design details will also be used to enhance the quality and range of designs for the North American market.

For more information, contact Trevor Nightingale at 613-993-0102 or trevor.nightingale@nrc-cnrc.gc.ca.

Project Partners

The Japan project was a partnership with Canadian funders Canada Wood Export Program, Council of Forest Industries, and Forestry Innovation Initiative, and a technical steering committee in Japan composed of Japan 2x4 Home Builders' Association, Building Research Institute, General Building Research Corporation, and the Advanced Institute for Science and Technology.

CRACKING THE KOREAN MARKET

The Korean Building Code requirements for sound insulation are extremely stringent, and there are virtually no wood-frame design details that have been shown to achieve the Code minimum. Currently, there is no Code requirement for sound insulation when there are less than 20 multi-family dwellings on a site, but such small scale is rarely economically viable in Korea, owing to the high cost of land. As a result, Canada is unable to export lumber and multi-family housing technology to this lucrative market.

With the successful completion of the project for Japan, a similar undertaking has been launched to develop the acoustical design details necessary to enable use of wood-frame, multi-family construction in Korea. Project partners include the NRC Institute for Research in Construction, Canada Wood Export Program, Council of Forest Industries, Forestry Innovation Investment, and the Korea Wood Construction Association. The three-year project is now in its second year.

DO SILL PANS POSE RISKS TO CONDENSATION ON WINDOWS?

Evaluating the potential for condensation to form on the glazing, or at the window frame perimeter, was the focus of a window research project completed by the NRC Institute for Research in Construction (NRC-IRC) together with Canadian Mortgage and Housing Corporation (CMHC). It concentrated on windows installed with a sill pan and related building details.

Even a well-installed window can develop deficiencies with time and allow water to enter. If not properly managed, this water can enter wall components below the window and lead to material degradation. Sill pans are placed beneath the window at the sill to protect the rough opening by collecting and draining water that enters at the window and preventing it from reaching the interior of the wall assembly. Proper installation of a sill pan requires leaving an area open and free of insulation to encourage drainage out of the sill area.

Standard window condensation tests were performed on non-operable PVC windows with and without integral mounting flanges, and having a sealed double-glazed insulated glass unit. These windows were chosen because they are widely available and typical of those used in Canadian construction practice. The testing subjected the windows to a constant cold temperature of -30°C on the exterior, and to 20°C on the interior.

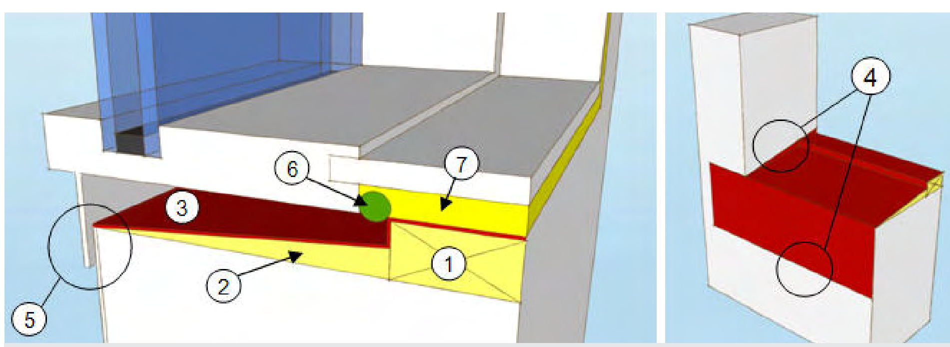
The tests simulated conditions that represented a mild wind buffeting the exterior of the assembly. Deficiencies were purposely created in the wall-window interfaces – one at the exterior to promote air leakage into the sill area, and another similar-sized deficiency atop the window towards the interior of the assembly. Additionally, scenarios evaluated for potential window condensation included both a non-insulated cavity between the window frame and rough opening and a cavity containing either glass fibre insulation or spray-in-place polyurethane foam.

Results of the sill pan research reveal that insulating the cavity between the window rough opening and the frame with glass fibre insulation or polyurethane foam slightly increased window surface temperatures and slightly reduced the risk of condensation on the window. Thus sill pans can be installed without undue concern for risk to the formation of condensation on window components.

The most important aspect in regards to the likely formation of condensation on the window is the window itself, not the installation of a sill pan. Window installation details should, nonetheless, include insulation in the stud cavity, to ensure continuity in thermal resistance at window penetrations and minimizing heat loss at these critical points of the assembly. Insulation should be installed with care so as not to obstruct water drainage out of the assembly, allowing the moisture management system to work as intended.

This research, along with a previous study that assessed the robustness of specified window installations (see Construction Innovation, June 2006 and June 2010) clearly demonstrate that the installation of sill pans and similar components used to protect the sill beneath windows should be part of a moisture management and protection strategy that minimizes the risk of water entry into walls.

For more in-depth information, visit: www.nrc-cnrc.gc.ca/eng/projects/irc/condensation.html or contact Dr. Michael Lacasse at 613-993-9715 or michael.lacasse@nrc-cnrc.gc.ca.



1) Back dam 2) Sloped sill 3) Sill flashing membrane wrapping up the jambs and over the sheathing membrane at the sill 4) Proper lapping of flashing layers and the sheathing membrane 5) Drainage gap behind the window flange 6) Backer rod and sealant to provide continuity of the air barrier 7) Insulation to the interior side of the sill, leaving the drainage path unobstructed

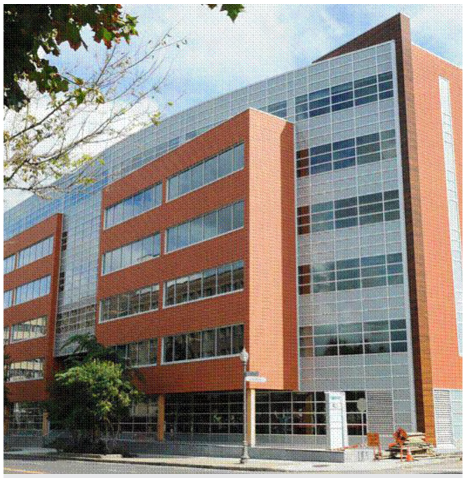
NRC to host 10th International Vacuum Insulation Symposium

Energy efficiency of the built environment greatly depends on the performance of the insulating materials used in the building envelope construction. Vacuum insulation panels (VIPs) offer thermal resistance properties that can enhance the energy efficiency of the insulating systems and provide savings in energy consumption.

Abstracts are being accepted until December 31, 2010 for the 10th Annual International Vacuum Insulation Symposium (IVIS-X) being held September 15-16, 2011. Hosted by the National Research Council in Ottawa, the symposium will provide a platform for international VIP experts, researchers, manufacturers, builders, architects, design engineers, and energy managers to discuss the adaptation of VIP in various aspects of construction and development of VIP-based innovative products.

For more information, visit the website at www.ivis2011.org or contact Phalguni Mukhopadhyaya at 613-993-9600 or phalguni.mukhopadhyaya@nrc-cnrc.gc.ca.

INCREASING THE USE OF ENGINEERED WOOD IN MID-RISE BUILDINGS



A 6-storey glulam post-and-beam structure with reinforced concrete cores in Quebec City, Quebec. Photo Credit: CSN-FONDACTION/ Nordic Engineered Wood

A new strategic network for innovative wood products and building systems called NEWBuildS (Network on Engineered Wood-based Building Systems) has been established to develop design methods and construction technologies for wood-based products as a primary structural material for mid-rise buildings.

The National Building Code and most provincial codes currently limit wood-frame construction to four storeys in most applications. For wood to be accepted as one of the primary structural materials in mid-rise buildings (5-12 storeys), designers must demonstrate that structures built with wood-based products, or wood in combination with other structural materials, meet all key objectives of the national and provincial building codes.

NEWBuildS, supported by Natural Sciences and Engineering Research Council of Canada multi-year funding, brings together 40 researchers from eleven universities, FPInnovations, the Canadian Wood Council and the National Research Council Institute for Research in Construction (NRC-IRC). These researchers, representing various disciplines such as structural engineering, fire science and building physics, will develop innovative building solutions and confirm the application of solutions used in low-rise wood buildings to mid-rise construction. The diversity of expertise involved in this strategic network will help ensure key performance attributes demanded by the building codes are considered in the context of 5–12 storey construction projects.

NRC-IRC's Indoor Environment program will lead a project on sound insulation. The fire behaviour of cross-laminated timber panels will be investigated by NRC-IRC's Fire Research program, while the Building Envelope and Structure program will assess moisture management of the exterior envelope.

The research team will train 50 to 60 graduate students and post-doctoral fellows over the five years of the project. These graduates are expected, in turn, to help implement the research results in the construction industry.

For more information, visit www.NEWBuildSCanada.ca or contact Trevor Nightingale at 613-993-0102 or trevor.nightingale@nrc-cnrc.gc.ca.

University Partners

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Five-storey wood-frame construction in Library Square in Kamloops, BC. Photo credit: Stephanie Tracey @ Photography West c/o WoodWORKS! BC

Build with the times!

Purchase the 2010 National Model Construction Codes Today

The 2010 National Building, Fire and Plumbing Codes of Canada are now available! Incorporating close to 800 technical changes that address technological advances, as well as health and safety concerns raised since 2005, these Codes are used as models for virtually all building and fire regulations in Canada. They provide minimum requirements for a safe and healthy built environment and are an indispensable source of information for building, fire and plumbing officials, as well as construction professionals and educators.

Published by the National Research Council of Canada, the 2010 National Model Construction Codes were prepared under the direction of the Canadian Commission on Building and Fire Codes, in partnership with the provinces and territories.

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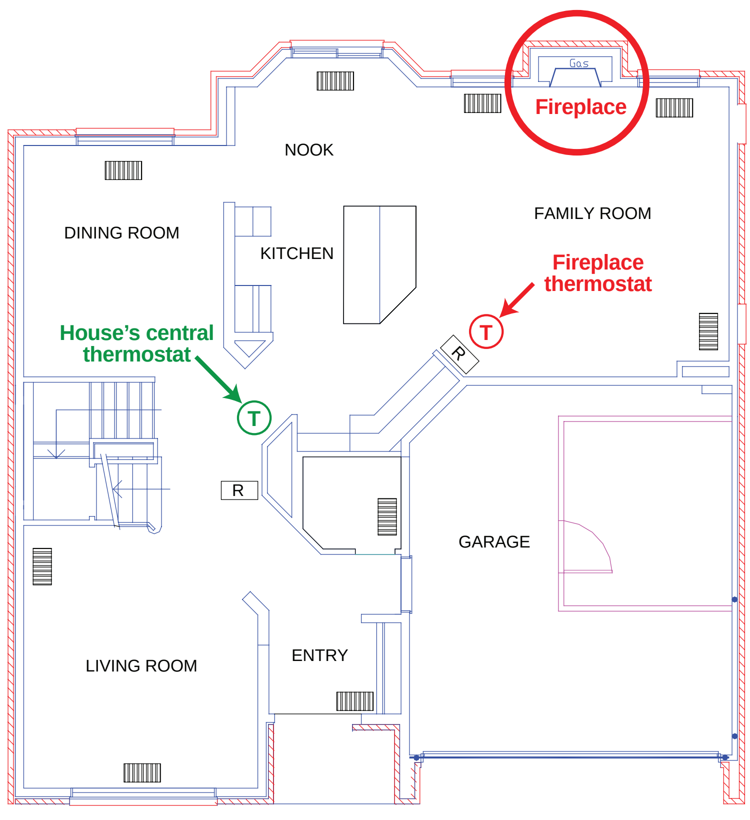
DOES RUNNING YOUR GAS FIREPLACE IN WINTER COST YOU ENERGY?

It is estimated that almost a quarter of Canadian homes have a gas-burning fireplace, many of which are used daily during the heating season (2007 Natural Resources Canada Survey of Household Energy Use).

When a fireplace is operated in close proximity to the house's central thermostat, the heat introduced by the fireplace can cause the heating system to delay its normal cycle of operation, affecting energy consumption in the home. As a result, the fireplace ends up essentially replacing the furnace as the main source of heat in the home. Not only is the fireplace usually less efficient than the furnace, but it also directs heat to a single room – and can leave other rooms cooler in the process.

During the past two winters, researchers have used the Canadian Centre for Housing Technology's (CCHT) twin houses to measure the impact of operating a gas fireplace on energy consumption and on room temperatures.

Three different modes of fireplace operation were examined: continuous evening fireplace operation from 18:00 to 24:00 with the furnace providing continuous air circulation; continuous evening fireplace operation from 18:00 to 24:00 with no continuous air circulation provided by the furnace; and fireplace operation by dedicated thermostat. Additionally, the impact of fireplace pilot light operation was investigated.



CCHT Research House – FIRST FLOOR

Evening operation of the gas fireplace heated the main floor family room, the location of the gas fireplace, well above the 22°C set-point of the furnace thermostat. During this time, furnace gas consumption and furnace fan electrical consumption decreased. However, evening fireplace operation resulted in an increase in total energy consumption (natural gas and electricity for fan operation) by 12.5 per cent for continuous furnace fan operation and 11.6 per cent without continuous fan operation. In addition to this, the temperature in the second floor bedroom furthest away from the fireplace dropped by up to 2°C in the evening.

Operation of the fireplace by dedicated thermostat control resulted in an average increase in total heating system energy consumption of 9.8 per cent during the experiment. Despite this increase in consumption, the total heat output from the furnace and fireplace combined was 2.3 per cent lower. Because of the near continuous operation of the fireplace, temperatures in the bedrooms on the second floor were 1 to 2°C cooler than the rest of the house, on average.

The pilot light also had an impact on energy use. It released some heat into the home and reduced furnace operation, resulting in an average increase of 5.0% in total energy consumption for heating.

While other models of fireplace and other house layouts would likely give different results, this experiment highlights the potential for a gas fireplace to actually increase home energy use, and reduce room temperatures.

This project was funded by Canada Mortgage and Housing Corporation.

The Canadian Centre for Housing Technology is jointly operated by the National Research Council, Natural Resources Canada, and Canada Mortgage and Housing Corporation.The full project report is available at www.ccht-cctr.gc.ca/eng/projects/fireplace.html. For more information, contact Marianne Armstrong at 613-991-0967 or marianne.armstrong@nrc-cnrc.gc.ca.

IMPROVING RAIL TANK CAR SAFETY

St. Hillaire, Quebec rail car derailment and fire. Photo courtesy of TSB.

The transport of dangerous goods such as propane, ammonia and chlorine is commonly done using rail tank cars. During a derailment or other accident, these tanks can be exposed to fire and, in extreme cases, may explode. Fires and explosions not only endanger lives but can damage bridges, tunnels and other critical transportation infrastructure, resulting in significant economic losses.

Fire researchers at the NRC Institute for Research in Construction (NRC-IRC) are working with Transport Canada on a project to measure emissivities of rail tank cars and their contents. Rail tank cars consist of a steel tank which holds the contents under pressure, an insulation layer which protects the tank from heat, and an exterior steel jacket which protects the insulation from impact. A pressure release valve in the tank is designed to keep the tank from exploding as fire heats its contents. Engineers and regulators use computer risk assessment models to predict how quickly heat transfers from a fire to the tank and its contents.

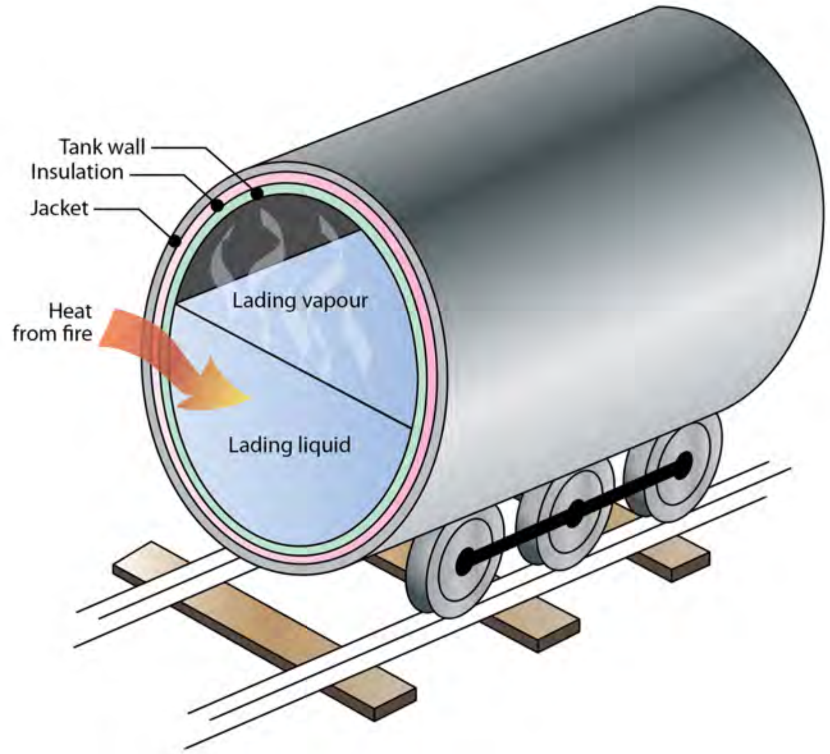
One important parameter used in these models has been emissivity, a number representing the fraction of radiation absorbed by the tank and its contents. The emissivity values currently used in models are based on laboratory measurements; emissivity has never been measured for an actual rail car. Transport Canada, which develops and enforces rail tank car safety regulations and standards, sought more accurate values for the emissivities of rail tank cars and the goods they carry in order to improve risk assessment models.

Over the course of two days, NRC-IRC researchers, using an infrared camera and temperature sensors, measured the emissivities of the outside and inside surfaces of three empty rail tank cars. Although infrared cameras are routinely used to inspect rail tank cars for potential defects, NRC-IRC was the first to use them to measure emissivities.

Because of the nature of radiative heat transfer, even small uncertainties in emissivity can lead to significant changes in the predicted response of rail tank cars to fire. Higher emissivities allow the fire to heat the tank and its contents more quickly, leading to a greater risk of explosion. The measured emissivities taken during testing were found to be higher than the values currently used in the risk assessment models. Small but significant variations were also found between the emissivities of the outside and inside tank walls owing to differences in the two surfaces.

The emissivity measurements obtained by NRC-IRC are the first step in a larger research effort to improve the accuracy of risk assessment models for rail tank cars. Plans include measuring tank car emissivities at high temperatures, measuring the emissivities of liquefied gases, and conducting full-scale fire tests on tank cars.

For more information, contact Cameron McCartney at 613-993-9775 or cameron.mccartney@nrc-cnrc.gc.ca.



Cross-section of a rail tank car.

Upcoming Events

JANUARY/FEBRUARY

29 Jan-2 Feb - ASHRAE 2011 Winter Conference, Las Vegas, Nevada. http://www.ashrae.org/events/page/2650

JANUARY/FEBRUARY

31 Jan-2 Feb - 12th Fire and Materials Conference 2011, San Francisco. http://www.intersciencecomms.co.uk/html/events/fm11cfp.htm

FEBRUARY

8-10 - First Middle East Conference on Smart Monitoring, Assessment and Rehabilitation of Civil Structures (SMAR 2011), Dubai, UAE. http://smar.empa.ch/

APRIL

11-13 - ASCE International Conference on Vulnerability and Risk Analysis and Management (ICVRAM) & the Fifth International Symposium on Uncertainty Modeling and Analysis (ISUMA 2011), Hyattsville, Maryland. http://content.asce.org/conferences/icvram2011/index.html

JUNE

21-26 - International Structural Engineering and Construction Conference (ISEC-6), Zurich, Switzerland. http://www.isec-society.org/ISEC_06/index.htm

JULY

3-8 - 2011 ICCC – XIII International Conference on the Chemistry of Cement, Madrid, Spain. http://www.icccmadrid2011.org/

JULY

10-15 - 13th International Conference on Wind Engineering (ICWE13), Amsterdam, Netherlands. http://www.icwe13.org/

AUGUST

1-4 - 11th International Conference on Applications of Statistics and Probability in Civil Engineering, Zurich, Switzerland. http://www.ibk.ethz.ch/fa/icasp11/

SEPTEMBER

15-16 - 10th Annual International Vacuum Insulation Symposium (IVIS-X), Ottawa. http://www.ivis2011.org

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www.nrc-cnrc.gc.ca/ci

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