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NRC·CNRC

Atrium research will improve energy savings and indoor environment

A comprehensive, multidisciplinary research effort by an IRC-led consortium is providing new and essential information on the way atrium environments operate, creating the potential for both increased energy savings and an improved indoor environment.

Atriums offer an attractive option to building designers, owners and occupants: at once shutting out the often harsh natural environment and yet benefiting from its natural light, they are increasingly being chosen for both new and renewal construction.

Until now, however, their characteristics have not been well understood, resulting in reported high energy costs and problems related to air movement, fire safety and noise levels. Understanding that reducing energy consumption could not take place without considering comfort and safety in the indoor environment, IRC launched a large research project that covers the characteristics and interactions of key environmental conditions: heating, cooling and ventilation, daylighting, acoustics and smoke movement. Because these interactions and design considerations are complex — for example, decreasing energy costs cannot be done at the expense of acoustical performance — the project required an integrated approach involving researchers from IRC's Indoor Environment Program and its Fire Risk Management Program.

IRC's research partners include the Société Immobilière du Québec, Public Works and Government Services Canada, Natural Resources Canada/CANMET, Hydro-Québec and Nortel Ltd., all of whom have contributed significantly to this ongoing project.

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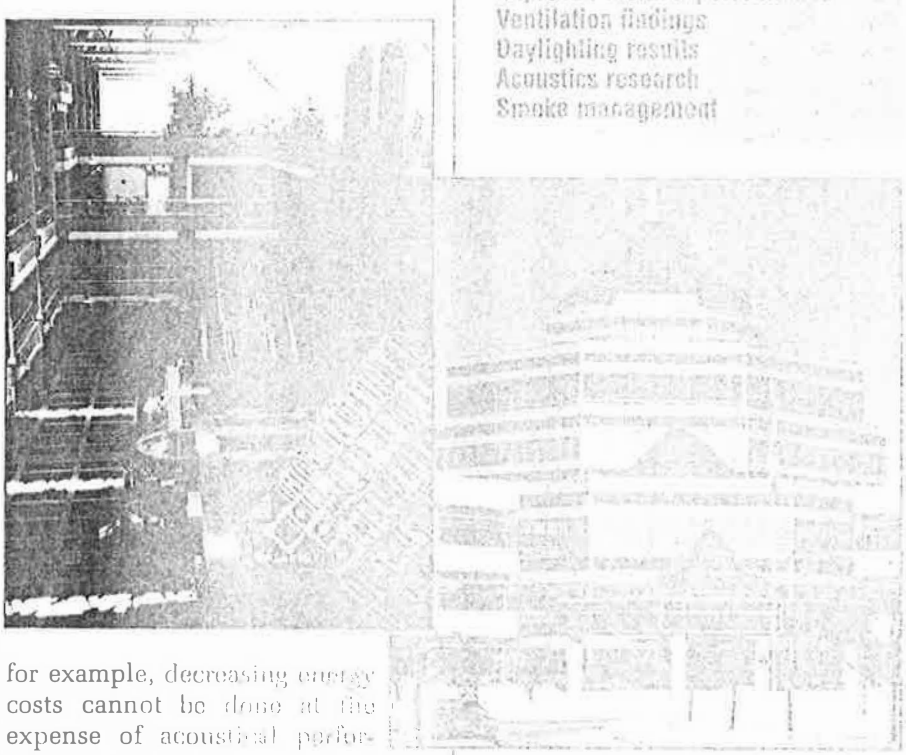
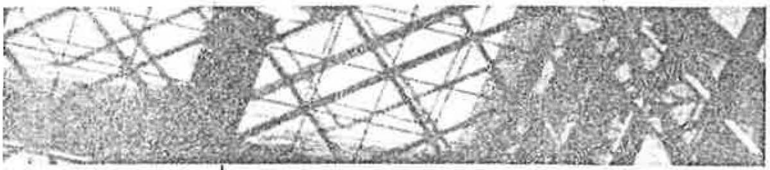


Two of the buildings that were investigated for the atrium research project

Featured in this issue



Atrium research project

IRC research paves way to improve thermal performance in atriums

Recent IRC research is demystifying thermal conditions inside atriums, giving building designers unprecedented data, and evaluating computer software to determine its effectiveness as a design tool for this type of building.

Unlike conventional office buildings, no energy design guidelines exist for atriums: while computer programs can help designers deal with construction complexities, they are limited without firm indications of how closely their results mirror reality. Until now, such field-measured data has been lacking.

To address the issue, an IRC consortium investigating atrium design examined thermal conditions in two atriums. They investigated temperature stratification, solar heat gains through atrium glazing, thermal comfort, and the impact of various HVAC-system operating modes and solar heat gain on thermal comfort.

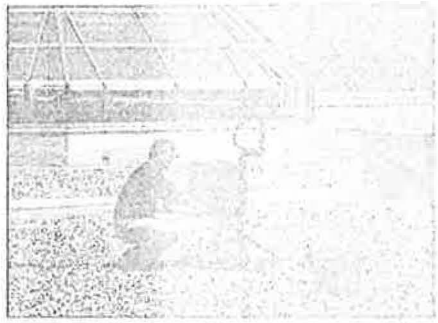
In both atriums, monitoring showed that winter thermal conditions were affected little by the outdoor climate. In the summer, however, indoor temperatures and temperature stratification depended directly on solar radiation: sunny days created solar heat gains and a substantial temperature increase from the atrium's bottom to its top.

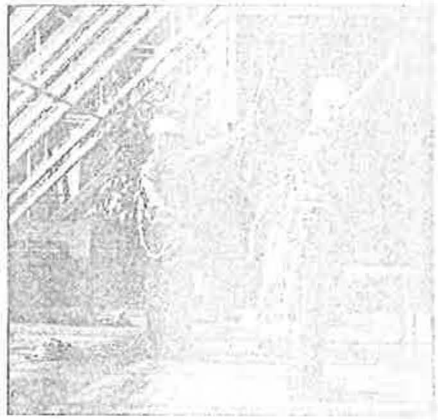
In addition, researchers found that heat gains in one atrium were also caused by a lighting system that provided lighting power densities well in excess of industry standards for adequate lighting.

The results also indicated that, in some cases, the atrium space itself need not be heated in winter, thus achieving significant energy savings.

Researchers then compared field measurements from one atrium to calculations from ESP-r, a building-energy and plant simulation software selected for its ability to handle the complexity of atrium design. The results showed reasonable agreement between measurements and predictions of solar radiation, temperature stratification and winter temperatures, but showed higher than predicted summer temperatures.

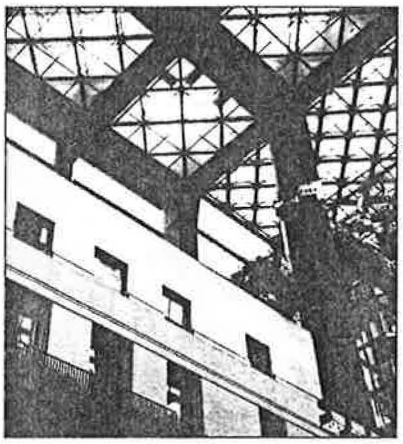
IRC's research into thermal conditions in atriums has provided hard data where little existed previously, and identified new opportunities for energy conservation. The research will provide architects, engineers and HVAC designers with design guidelines for selecting atrium skylights to optimize thermal performance, and with other information about atrium HVAC systems, thus paving the way to more energy-efficient designs.





Top: A weather station [illegible]
Bottom: "Spidermen" [illegible]
place testing equipment [illegible]

Specific questions can be directed to Dr. Morad Atif at [illegible], fax (613) 954-3733, or e-mail morad.atif@nrc.ca



IRC helps resolve atrium skylight problems

IRC's work on thermal environments in atriums is assisting Ogilvie and Hogg Architects to design an improved atrium skylight system for the Bank of Canada's head office building.

The current system requires replacement because of a history of breakage, leakage and numerous repairs. Condensation problems, for example, have damaged the paint and gypsum board below the skylights.

IRC's contribution involves winter and summer field measurements to analyze the condensation problem and investigate the atrium's thermal conditions as they affect comfort, plant growth on the atrium floor, and condensation on the skylight.

Findings so far indicate opportunities to modify the HVAC system to decrease condensation and frost formation on the skylights.

Specific questions can be directed to Dr. Morad Atif at [illegible], fax (613) 954-3733, or e-mail morad.atif@nrc.ca

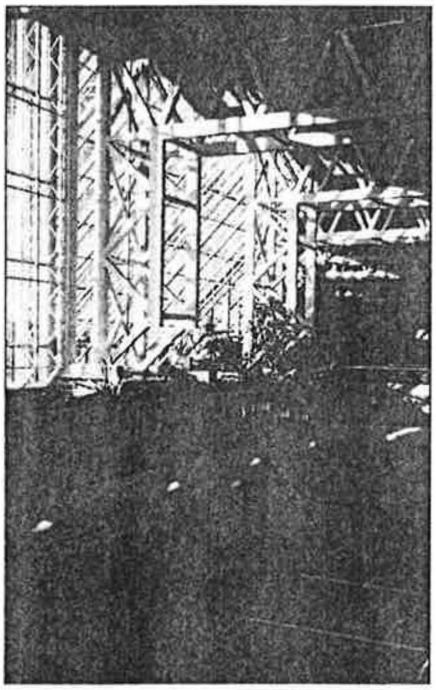
Atrium ventilation research demonstrates how HVAC systems affect air quality and energy consumption

IRC's research into the ventilation of atriums is developing our understanding of how air is distributed within these spaces, thus providing new testing techniques and the potential for improving indoor air quality (IAQ).

Specifically, IRC's work evaluated the distribution of air delivered by the heating, ventilating and air-conditioning (HVAC) system to the atrium space and the efficacy of existing testing methods, in order to recommend energy-efficiency and IAQ improvements.

In doing so, IRC examined two atrium buildings that are part of a comprehensive IRC-led research consortium project dealing with atrium design.

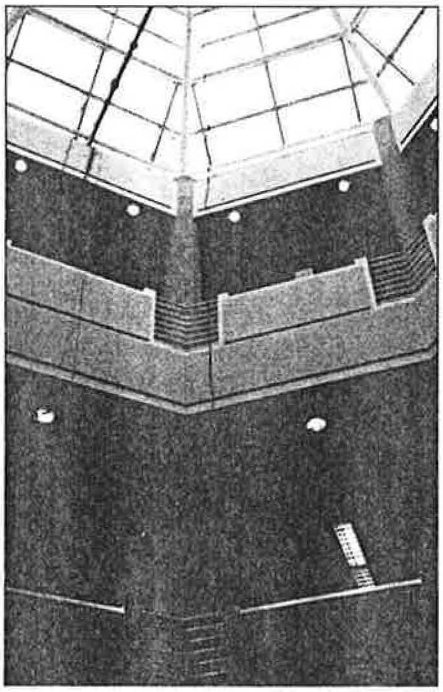
In one building, with a five-storey, pyramidal atrium, tracer-gas techniques assessed the distribution of ventilation air in winter, and the total air exchange rate for winter and summer conditions under a variety of HVAC-system operating modes. For most of the tests, it was the first time that these techniques had been successfully applied to the large, tall air spaces typical of atrium buildings.



These two atriums were studied to better understand how ventilation air is distributed in the large, tall spaces typical of atriums.

The results identified several potential problems related to the current operation of HVAC systems. As an example, when the outdoor air temperature and humidity were either too low or too high for the HVAC system to work effectively, the building's HVAC-system control strategy called for zero outdoor air supply. IRC recommended eliminating these periods of zero percent outdoor air, and increasing the HVAC system's heating and cooling capacities to support this recommendation.

Also, prohibiting smoking in the building would reduce the ventilation load and thereby further improve both IAQ and energy conservation.



In the other atrium — a three-storey octagonal structure — tracer-gas techniques were again used successfully to measure air distribution patterns and air change rates. As in the other atrium, the tracer-gas dose distributed evenly enough throughout the atrium space to allow the air change rate to be measured: in fact, researchers discovered that a more economical sampling approach, using fewer locations and less frequent samplings, would not compromise the accuracy of the results.

Both summer and winter research showed a general upward movement of air within the atrium core; good mixing of the air between the core and the perimeter walkways; and very little airflow from the core into surrounding closed rooms. This led the researchers to suggest that the supply systems at the upper floors of the atrium need not attempt to provide air to the ground floor, since this air never arrives there. They also suggested that the delivery grilles for the supply system on the ground floor of the atrium should be set close to the floor to take better advantage of the general upward movement of air.

This research has provided designers and engineers with a greater understanding of how HVAC systems affect the environment in atrium buildings, including recommendations for improving IAQ and energy conservation — recommendations that will improve occupant comfort and satisfaction, and also lower operational costs.

Specific questions can be addressed to Dr. James Reardon at (613) 993-9700, fax (613) 954-3733, or e-mail james.reardon@nrc.ca

Atrium research project

Daylighting research in atriums indicates potential for significant energy savings

IRC's research into the effects of natural light, or daylighting, in atriums has the potential to significantly increase energy savings, assisting building owners, managers and occupants as well as building designers.

Daylighting is a source of light that can be used as an alternative to electric lighting, thereby reducing energy consumption.

Two atriums were the focus of the work, which formed part of an ongoing IRC-led consortium research project on atrium design. One atrium featured an on/off electric lighting control system, while the other had a continuous dimming system. The studies used field monitoring and computer modelling to evaluate:

- the daylight contribution to the atrium floor and adjacent spaces
- the associated electrical energy savings
- the performance of the daylight-linked electric lighting systems.

The results will be used to recommend improvements to the daylighting performance of atrium buildings.

In the atrium with an on/off automatic lighting system, monitoring results showed a high daylight contribution at the atrium perimeter at each of its three floor levels, in both winter and summer. However, this contribution decreased on both the ground and second floors as distance from the perimeter increased. Only on the third floor was the daylight contribution into the adjacent spaces significant all year round.

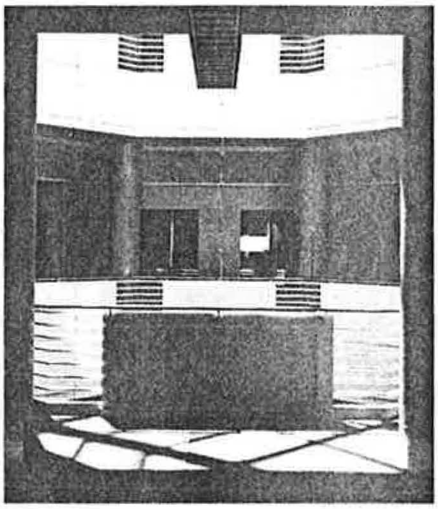
While the existing daylight-linked on/off control performed relatively well in summer, it performed very poorly during the winter because of the location of the control photocell under a skylight covered by heavy snow or frost. In addition, the installed lighting power density for this atrium was found to be substantially higher than that recommended by current lighting standards.

IRC recommended improving the existing lighting system's energy savings by relocating the photocell, or at least clearing the skylight, and reducing the installed lighting power density.

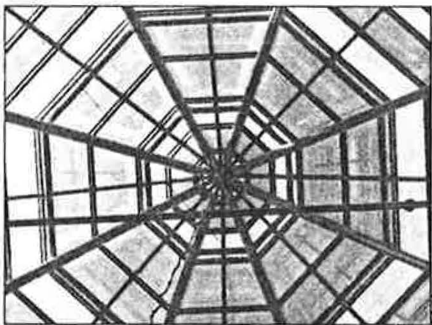
Data analysis and computer simulations suggest that replacing the on/off system with a dimming system would increase savings even further.

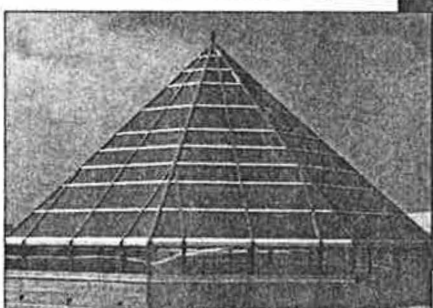
In the atrium with the continuous dimming system, the results indicated that, except for some areas on the second and third floor walkways of this five-floor atrium, the illuminance from daylighting alone was not high enough to meet accepted lighting criteria for a significant period of time during the day.

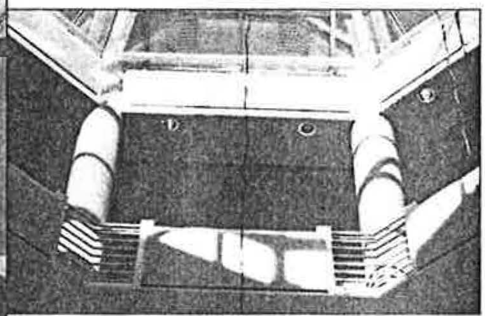
This suggests that an on/off automatic lighting control system would have been an impractical

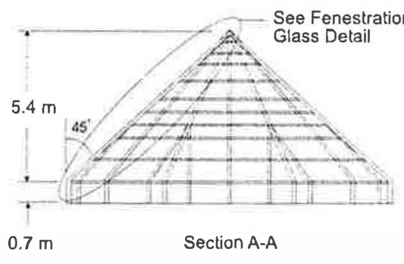


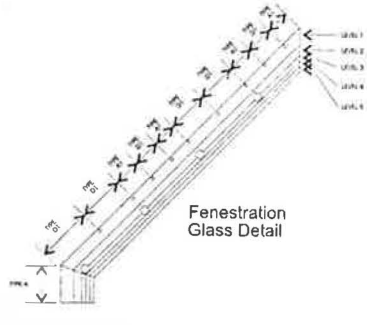
Daylight in a second floor conference centre in the atrium











Indoor and outdoor views of atrium skylight solution, and that the installed continuous dimming system is an appropriate lighting control strategy for achieving energy efficiency.

However, the researchers found that the dimming system did not perform according to the manufacturer's claims and that the adjustment of the lighting system's electrical phases was incorrect.

Field measurements and calculations show that these problems, if corrected, would increase the dimming system's energy savings — now estimated at 46 percent annually (or $6,550) — to 73 percent.

IRC's work in obtaining field data on the contribution of daylighting to energy savings and in evaluating computer models for buildings with atriums provides a firm basis for energy conservation strategies. Results from this research, in the form of design guidelines for the selection of skylights, will help building designers optimize the potential of daylighting, both as a source of lighting, and as a means of saving energy and money.

Specific questions can be directed to Dr. Morad Atif at (613) 993-9629, fax (613) 954-3733, or e-mail morad.atif@nrc.ca

Atrium research will improve energy savings and indoor environment

Continued from cover page

The study has three key phases:

- a review of the literature to examine current practice and its effectiveness
- field research and computer simulations, and
- the development of design guidelines that will optimize both energy consumption and the quality of the indoor environment.

With the first two phases largely complete, work is continuing on the third and final phase.

The field work required both innovation and creativity on the part of IRC researchers, as much of this work had never been done before. Ten atriums were involved in various parts of the research, with two of them providing key locations for research across most of the areas of interest.

Researchers worked on a one-to-one basis with building owners and managers, examining building specifications to determine how the atrium was built, and how the heating, ventilating and cooling systems operated in each atrium. The buildings' technical officers provided vital assistance, often going well beyond the call of duty in order to provide the researchers with the necessary information about building systems and clearances, and with set-up assistance.

To conduct the field work, IRC literally moved in, sometimes for weeks at a time, hiring "spidermen" equipped with suction cups in order to place testing equipment around the atrium, and building an exterior station for monitoring the weather.

The complex combination of computer modelling, field monitoring and physical-scale modelling has allowed IRC researchers to obtain factual measurements and assess the validity of computer software tools as they apply to atriums, in many cases providing the world's first hard data.

As a result, methods can now be developed that will realize the atrium's potential — optimizing the interface of energy efficiency and daylighting with acoustics, indoor air quality and smoke control.

The design guidelines are expected to be available by September 1999.

Specific questions can be addressed to Dr. Morad Atif at (613) 993-9629, fax (613) 954-3733, or e-mail morad.atif@nrc.ca

Dr. Sherif Barakat named new Director General of IRC

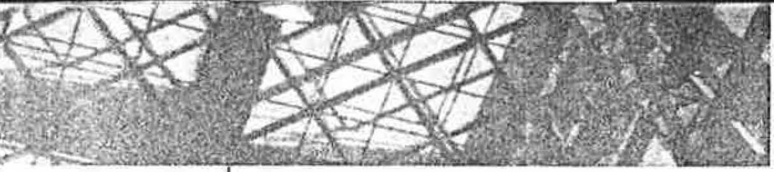
Dr. Sherif Barakat, IRC's newly appointed Director General

In April of this year, Dr. Sherif Barakat became the new Director General of the Institute for Research in Construction (IRC). He had been acting in this position since October of last year, following the departure of George Seaden.

Dr. Barakat began his research career at IRC working on active solar systems after completing his doctorate in mechanical engineering at the University of Manitoba in 1977. He became responsible for IRC's research on passive solar heating in 1980, and was named program manager for the Ventilation and Air Movement in Buildings Program in 1985. Dr. Barakat was then appointed as head of the Building Performance Laboratory, and later, as director of the Indoor Environment Program.

In 1994, Dr. Barakat won an NRC Outstanding Achievement Award for his contribution to the Energy Code Project, which culminated in the publication of the Model National Energy Codes. He has also won IRC awards for his research expertise and for his administrative and operational achievements.

"Dr. Barakat's distinguished career as both a researcher and a research manager has prepared him well for the challenges he will face as the new Director General of IRC," said Jacques Lyrette, NRC Vice-President of Technology and Industry Support.



Atrium research project

Acoustics research will produce useful, innovative information for designing atriums

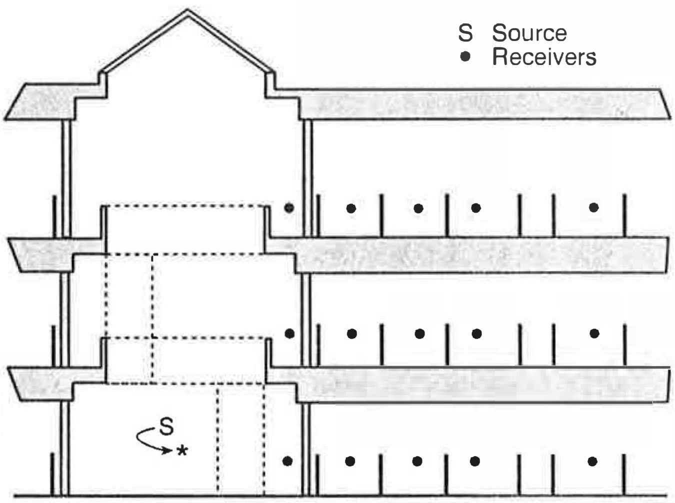
IRC's field-based research into the acoustical characteristics of atriums is shedding new light on designing these spaces to accommodate various uses. At the same time, it is helping to evaluate computer simulations of atrium acoustics, providing designers with tools they can rely on to assess different acoustical treatments.

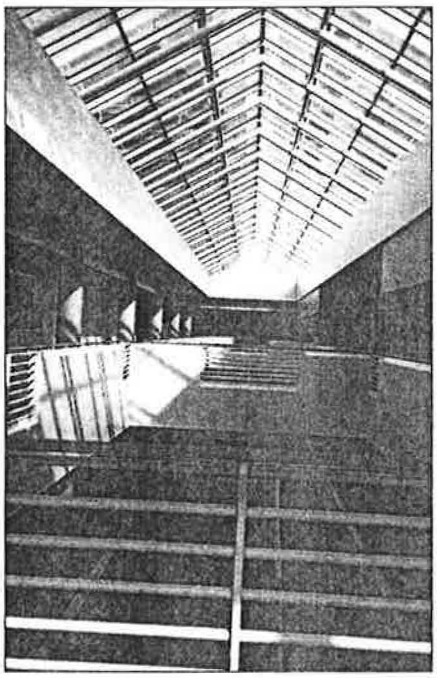
The research forms part of a larger atrium design project currently being conducted by IRC and funded by a consortium (see cover story). In ongoing studies, IRC researchers are investigating the acoustical characteristics of ten atriums. Measurements include ambient noise levels during typical working days, room sound decays, room sound propagation, and sound propagation into or out of the atrium. The measurements will be compared to computer simulation studies to assess the effectiveness of these design tools.

Results to date indicate that, acoustically, atriums perform differently than other large, open spaces such as auditoriums. For example, the propagation of sound in atriums decreases more rapidly with distance than in other large indoor spaces. This is particularly important given that atriums often feature ambient noise sources, such as fountains, restaurants and cafeterias, which can interfere with communication.

Researchers usually measure the acoustical characteristics of large spaces by the reverberation time — that is, the length of time a sound persists in a space after it has been made. Long reverberation times can cause one word to blur into the next.

Reverberation, or the reflection of sound waves off surfaces, is generally controlled by adding sound-absorbing material to a space; however, the large spaces typical of atriums can preclude taking this approach because of the large quantities of material required.





A section and photo of one of the atriums studied. The section shows (sound) source positions in the centre of the atrium and receiver positions in the open-plan office area.

In fact, the researchers found that although reverberation times are long in atriums, this does not necessarily lead to communication difficulties. Results indicate that reverberation times are greatest at intermediate frequencies, because the large areas of atrium glass absorb low frequency sound. Levels of unwanted sounds in large atriums were found to be not very high, with smaller, more reverberant, atriums creating more acoustical problems than large ones.

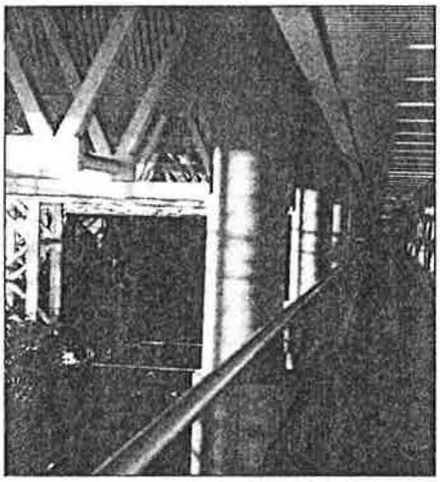
In addition, several of the atriums were found to have sound-absorbing treatments — glass fibre panels, for example — that effectively reduced reverberation in the atrium.

The research has also indicated that sound propagating from an atrium into adjacent open office space was significantly attenuated, and was usually less disturbing than sounds from adjacent workstations. Sound coming from a small distance outside the atrium was reduced in level at all positions inside the atrium.

Of course, the way in which the atrium space is used determines how restrictive acoustical conditions need to be. Ambient noise and reverberation would need to be controlled more carefully in an atrium that contained a reception desk, for instance, than in one that simply connected different building spaces. But even in a leisure-oriented space, such as the latter, a trade-off may have to be made between the requirements for high-quality speech communication and improved speech privacy.

The combined results of this field-based and computer model research on atrium acoustics will be used to develop a design guide for engineers and designers containing recommendations for acoustical best practice in new or renovated atrium spaces.

Specific questions can be directed to Dr. John Bradley at (613) 993-9747, fax (613) 954-1495, or e-mail john.bradley@nrc.ca



IRC researchers investigated the effects of sound propagating from an atrium into adjacent spaces since atriums often feature ambient noise sources, such as fountains, restaurants and cafeterias, which could interfere with communication.

Change in atrium use can affect smoke management

New and renovated atriums have become popular in commercial, office and residential buildings in Canada because they can provide high marketing value with their environmentally controlled, naturally lit spaces.

The large volume of space found in atriums is particularly attractive to owners and managers. They sometimes view this space as under-utilized, and therefore decide to make better use of it. The intensification of use, however, can unwittingly lead to spaces that no longer meet the requirements of the National Building Code of Canada (NBC) and the National Fire Code of Canada (NFC).

As part of a larger, comprehensive project, IRC fire researchers examined two existing atriums to understand how different kinds of uses (and hence, different fuel loads) would affect smoke movement in these spaces.

The researchers first established that the atriums met the requirements of the NBC. (These included requirements that the building is sprinklered, that smoke venting for fire-fighting purposes is provided, and that combustibles on the floor of the atrium are limited.) Next, they looked at fuel loads and the types of combustibles in the atrium spaces. They found that, in both cases, these conformed to the NBC and NFC.

In order to find out how new uses for these atriums would affect smoke movement in each of them, the researchers had to look at the available tools for determining acceptability. The most widely used of these tools is the NFPA 92B engineering guide (published by the National Fire Protection Association), which is based on U.S. practice and is a guideline for the design of smoke-management systems. The critical variable in the NFPA 92B guide is the fuel load, which determines the size of the design fire (i.e., its heat release rate) and thus the rate of smoke build-up.

In short, the research demonstrated that when increased use or activity in an atrium is contemplated, fuel loads have to be limited in order to maintain life safety.

When the researchers applied these design guidelines, they learned that if the use of the atrium changes, the size of the design fire, the rate of smoke build-up, and the size of exhaust fans required changes as well. That is, the smoke-management system required to meet the intent of the NBC depends on the use of the atrium space.

In short, the research demonstrated that when increased use or activity in an atrium is contemplated, fuel loads have to be limited in order to maintain life safety. In this context, the viability of egress routes is of particular concern. It also showed that there are suitable tools available to evaluate the changes that would have to be made to the smoke-management system for a particular use, or to assess the feasibility of a proposed use.

Perhaps most importantly, the research highlighted the need for building owners and operators to be knowledgeable and diligent in assuring that the intent of the NBC and NFC are met when any change in atrium use is considered.

Specific questions can be directed to Dr. Gary Lougheed at (613) 993-3762, fax (613) 954-0483, or e-mail gary.lougheed@nrc.ca