The good, the bad and the frustrating: designing and implementing a climate control system at the Royal Ontario Museum

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Abstract

The significant renovations and expansion currently in progress at the Royal Ontario Museum have provided the opportunity to take a fresh look at the provision of humidity-controlled air to display cases. The planning process began in 2002, and the first of the new galleries opened in December 2005. When the last of the galleries reopens, the building will comprise sections of architecture built at four different periods from the 1914 west wing to the new Michael J Lee-Chin Crystal. Though the four spaces are for the most part physically contiguous, each imposes its own constraints on the environmental conditions.

Arriving at the finished system has involved many steps, beginning with the assessment of the RH needs of the more than 19,000 objects destined for display in the new galleries. Planning the controlled cases and piping layouts has had to take into account the varying needs of the objects, the large volumes of some of the display enclosures, the power of the control systems in relation to the distance that the air must travel, and the leakage rate of the cases.

Achieving the desired results to date has required compromise, flexibility, and the ability to re-think processes in the face of the empirical evidence. This paper follows the course of the process from the ideals of the initial planning to the realities of the final implementation, and passes on some lessons learned the hard way, as Phase 2 of the expansion continues.

Figure 1. The Michael J Lee-Chin Crystal, Royal Ontario Museum, opened June 2, 2007

Figure 2. New Chinese Gallery, opened December 2005

Introduction

This is a case history, but very much a story still in progress. The Royal Ontario Museum (ROM) in Toronto is presently undergoing a massive renovation and expansion, with a signature design by Daniel Libeskind resulting in 28,000 m^2 of renovated and newly constructed space, allowing for the display of almost twice as much of the collections as could be seen before the project began.

Called RenROM (an abbreviation of Renaissance ROM), planning began in 2001. The first group of new galleries, housed in refurbished locations in the heritage building, opened in December 2005.

Figure 3. Future Phase 2 gallery space, prior to case construction

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Phase 2 galleries, in the brand-new Michael J Lee-Chin Crystal, are scheduled to open in stages from November 2007 to March 2008.

Phase 3, which renovates the remainder of the heritage wings, is still further from completion. By the time the project ends in 2009 only one floor of one wing of the pre-2001 building will remain completely untouched and unchanged. However at the time of writing, less than half of the new galleries are open.

This is a story of the climate control challenges encountered in renovating an existing building, part of which is nearly 100 years old, and the problems introduced by the architectural design of the new expansion: iconic, striking, and decidedly non-traditional. At the end of the RenROM project, we will have a composite building dating from four different periods over the past 100 years – 1914, 1933, 1984, and 2007.

The ROM galleries experience a wide annual fluctuation in RH; in some areas as much as 50% change from a winter low of 25%, (when the risk of damage to the fabric of the older parts of the building make it inadvisable to humidify to a higher level), to a summer high of 70% or more. RH specifications for the new part of the building, known as the Michael J Lee-Chin Crystal, call for a level of 45% ± 5% year-round, though it is hard to see how this can be reliably maintained, since the Crystal is not an isolated space. Every level of the Crystal has walkways to the older wings, and though some of these links have doors separating the old building from the new, the walkways are also open from floor to floor. The Spirit House, as the central spine of the Crystal is known, forms a void, open from the ground floor up to the fourth floor.

Given that some degree of humidity control is necessary to mitigate the extremes of the range for the most sensitive artefacts, the choice was between refitting whole gallery spaces to permit better control of ambient conditions, and controlling the individual cases. Our preference would have been for control at the gallery level, but in the older parts of the building the relative cost of renovating gallery spaces versus that for installing humidity control systems for limited numbers of display cases dictated that the existing space was upgraded in only one gallery area, principally to permit the display of organic materials without case enclosures. It is anticipated that the ambient humidity in the new Crystal galleries will be more stable than in the older wings, but we are nevertheless installing humidity control systems in the art and archaeology galleries regardless of whether they are in the old or new sections.

Past practice in RH control at the ROM

Mechanical control of RH within display cases (as opposed to the passive use of silica gel), has been in place at the ROM since 1985, when small micro-climate generators (MCG) were first introduced to the galleries. These small machines recirculate air within the case, adding or removing moisture as necessary. Control is provided by a sensor located within the display volume. The capacity of these machines, up to about 17 m^3, depending on the leakage rate of the display case, is such that in most instances one machine controls only one case volume. Their great advantage is that the RH levels can be set individually for each machine and therefore each display case.

Around 1995, a larger version of the MCG was developed by the same company [1]. Not only were the new units capable of controlling multiple cases, rather than just one or perhaps two, but they were also attached directly to the water supply, thereby removing the need for manual refilling or draining of water reservoirs every week. Each of the new machines was capable of controlling more than 100 m^3 of display volume. In addition, they did not recirculate air taken from the display cases, but drew their intake from the room in which they were housed, creating a slight positive pressure within the cases, which were therefore less affected by leakage. To the extent that there were drawbacks, they were that all the cases supplied by one machine had necessarily the same RH level, which inevitably reduced flexibility.

Designing for RenROM

Each method of RH control employed thus far has had some drawbacks and limitations: the use of silica gel is labour intensive, and only really effective in relatively small, airtight display cases. The small MCGs were rendered less effective by case leakage and also required significant staff time manually to fill or drain the water reservoirs every week. The use of larger MCGs to supply multiple cases was in some ways more limiting than the smaller versions, which could be individually set.

RenROM seemed to be the perfect opportunity to implement a climate control system that would deal with some of the limitations of earlier control methods, and more fully meet the needs

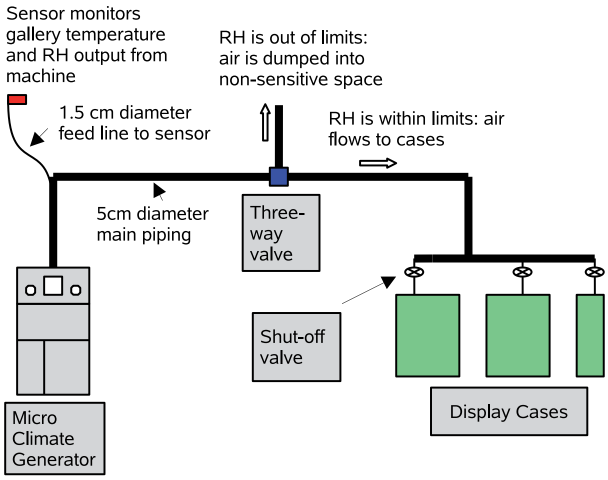

Figure 4. Schematic of MCG and piping to display cases

of the objects. The project team had agreed to the installation of climate control systems where specified by Conservation, the exhibit designers professed themselves prepared to work with us to provide the best possible conditions, and display cases from Glasbau Hahn promised a suitably low air exchange rate.

Research on possible control systems revealed nothing that seemed preferable to the newest designs from the manufacturer of our present systems. Their new generations of MCGs are ever more sophisticated. In the early versions one simply set the required RH level or dewpoint, and let the machine run. Variations in temperature within the display volume, usually caused by case lighting, resulted in unstable RH levels, and in variations from case to case. In addition, in the absence of a proper alarm system, faults in the machine resulting in humidity levels outside the acceptable range might go unnoticed for hours or even days.

In the latest generation of the machine, the MCG 40, a sensor located in the gallery space monitors the RH output from the machine and the ambient temperature, and allows the MCG to adjust its output to maintain a stable RH level even with fluctuating temperatures. This is an advance on the earlier systems, but still not a completely satisfactory situation, since it means one must assume (a) that the temperature is constant throughout the gallery, and (b) that the temperature is the same in all display cases serviced by the same machine, since the sensor does not monitor individual case interiors.

Figure 5. Two MCG 40s serving the Japan Gallery. On the closer machine can be seen the air filter (white grille), ion exchange cylinder and protective three-way valve (black unit on top of the machine)

The same sensor, coupled to a three-way valve, also provides critical fail-safe protection for the artefacts in the cases. So long as the supplied RH falls within the set limits, air flows to the cases. If the RH deviates from the acceptable range, the valve rotates to block the air flow to the cases, routing it instead into a non-sensitive space such as a mechanical equipment room, until such time as the RH of the supply air is restored to acceptable levels. Thus in the event of mechanical failure of a machine, or a power interruption followed by a restart, the displays are protected from the

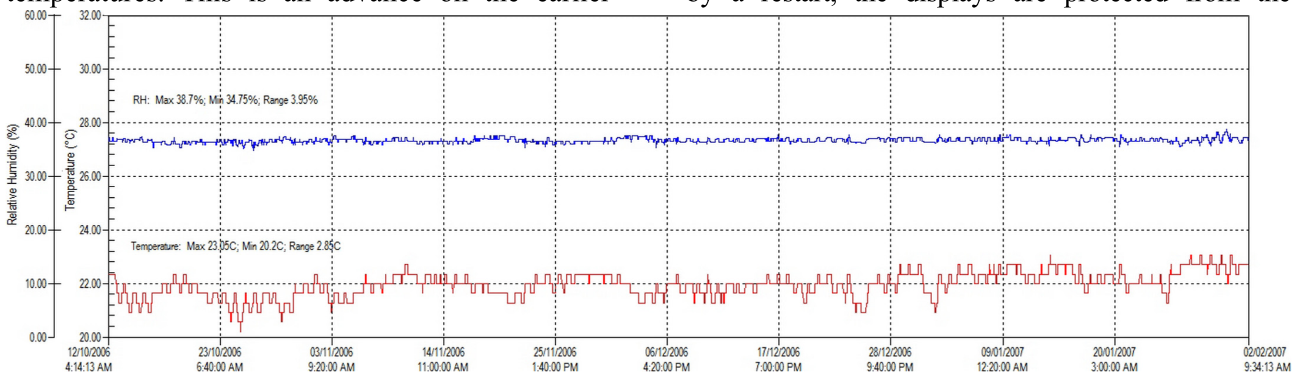

Figure 6. Sample datalogger chart from a display case in the China gallery

possibility of a dangerously high level of humidity being pumped into the cases while the machine is working towards achieving the set RH value.

The MCGs also improve the quality of the air being pumped into the display case. Incoming air is filtered at the machine intake to eliminate dust and contaminants, and the water supply is purified by a combination of reverse osmosis and ion exchange. The majority of the display cases containing RH-sensitive material in the new galleries are now controlled by these MCGs.

The Phase 1 galleries have been open for nearly two years now, and the results from the humidity control are in general very acceptable. The RH within the cases is extremely stable, varying by at most a couple of percent.

Even the handful of cases still using silica gel because they were too small or too inaccessible to run piping are extremely stable. However, reaching that point of acceptability has not been without its frustrations and difficulties. The issues that we have encountered so far, and will continue to encounter as the project progresses, result from several causes.

Artefact considerations

The ROM is a general museum, with collections in art and archaeology and the natural sciences, though almost all the need for RH control is on the material history side. Setting humidity levels for display is most easily accomplished where a display case houses materials of a like nature, requiring the same optimum RH level. However, in a museum with mixed collections, the storyline and design favoured by curators rarely allows for this neat separation of materials, and some compromise is necessary.

Given budgetary and space constraints, for most of our RenROM display cases there has been a choice of at most two generated RH levels as alternatives to ambient RH. In many areas of the old galleries, which feature relatively small display cases, we have indeed been able to separate organic materials from metals in order to provide each type of material with the optimum RH range and the new China and Japan galleries, for example, have display cases maintained at 30%, 40%, or 50% RH, depending on contents. In contrast, a major feature of the Crystal galleries has been the large volume of some of the display cases, which has required a different approach to RH control. The storyline created by curators and designers, and the sheer case

Figure 7. Large display case in Canada's First Peoples Gallery. Some cases in the Gallery of Africa, Americas and Asia Pacific will be larger still

size, necessitates mixing materials, and therefore imposing a compromise RH. So in the Canadian First Peoples gallery, all controlled cases are supplied with 40% RH, as a compromise between the lower value desired by the metals conservator, and the higher value desired for organic materials.

Achieving the best possible environment for as much of the displayed material as possible has involved negotiation, the provision of sealed partitions in cases, silica gel control for some small-volume cases, and substitution, or even removal, of certain artefacts from the final selection for display.

Piping and airflow factors

The next major issue to be faced resulted from the design of the new building, and the sheer size and scope of the renovation. The current MCGs are designed to provide a constant 700 l/min air supply at the output point. Depending on the configuration of cases and piping, this is sufficient to control up to 170 m^3 of display case at a leakage rate of 4 air changes per day (acd). Display cases for the new galleries are designed and installed by Glasbau Hahn to a specification of 0.1 acd for an uncontrolled case, and 0.3 acd for a case supplied with conditioned air. The larger leakage rate is designed to avoid possible over-pressure of the controlled cases by permitting a small amount of leakage. In fact, that leakage rate has proved to be still too airtight for controlled cases under positive pressure; in setting up the systems in the Phase 1 galleries, we found that large cases could require as much as a week to establish the specified RH level. Future modifications will insert a relief valve to permit flushing of the case volume when RH levels need to be established or re-established quickly. However, on the plus side, an undisturbed display case can hold its RH level for at least a similar length of time, permitting shutdown and maintenance of the machines without adversely affecting the cases.

Though the cases are sufficiently airtight that they require only a very low airflow to maintain the required RH level, some of our largest display cases are between 60 and 120 m^3, which clearly drastically reduces the number of cases that can be controlled by any one machine. Also to be taken into account is the distance the air has to travel to reach the display case. According to the manufacturers' specifications, the nominal maximum distance from machine to the furthest display case is 160 m in a straight line. Every time the piping must undergo a change in direction in its course from MCG to display case, the airflow is diminished, and so, potentially, is the total controllable volume. Thus, though simple mathematics would seem to show that a much greater volume can be controlled at 0.3 acd than at 4 acd, the reality is less straightforward.

The situation is acceptable in the heritage wings, in which the machines are almost all physically located adjacent to the gallery space, and the furthest distance from machine to case is perhaps 60 m on the same level of the building. However, in the Crystal, the gallery design does not allow for mechanical room spaces next to the galleries, and so all the MCGs will be located in one space in the basement. Since some of the galleries are on the third floor, the humidified air must travel large distances from the generating machine before it reaches the gallery level at all, let alone the display cases. The flow of conditioned air is further affected by the angled walls of the Michael Lee-Chin Crystal, and in designing the main piping runs, insufficient attention was given by the engineers to minimising direction changes in order to provide the maximum airflow. Tracing the path of the main piping is not easy, but even a cursory inspection shows that the piping makes four or five ninety-degree turns before it rises up the face of the Crystal, and up on the third floor it appears to make at least five more right angle turns in three dimensions before heading off into the gallery. Not only is the distance to reach the furthest case in the South Asia gallery quite considerable, but the airflow will be substantially reduced by the number of angles in the piping run. The combination of volume and distance seems set to push to the limit the theoretical capacity of the MCGs supplying the Crystal galleries.

There is one further concern relating to the supply piping: accessibility for maintenance or modifications. In the heritage galleries the piping

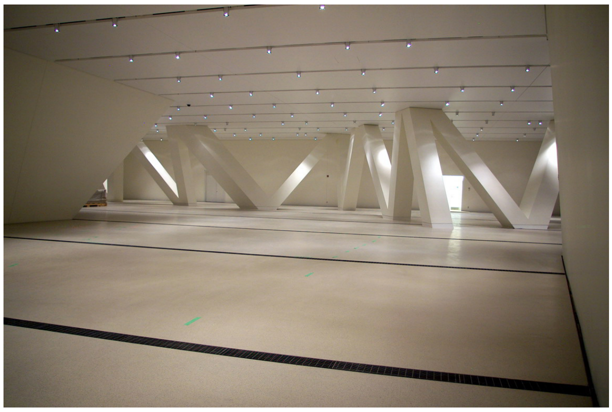

Figure 8. Garfield Weston Exhibit Hall, showing HVAC air supply grilles in the floor

runs in open cable trays above the cases, and drops down to a specially designed flow valve. In addition there are shut off valves for each case so that they can be isolated from the main run. Adjustments are easily performed. In the Crystal, all the services run below the floor, sandwiched between layers of concrete, in a space which is actually the supply air plenum for the HVAC system. A series of grids runs at 16 ft intervals across the floors to allow air into the gallery, from where it is exhausted at ceiling level. The RH control piping runs through the plenum and comes out under the grid a foot or so outside the perimeter of the display cases, to allow access to the shut-off valve, before being routed under the case to come up through the case floor into the display volume. Not only is the piping much less accessible, it will also be heated in the winter and cooled in the summer by the HVAC system.

Sensor considerations

As described earlier, sensors located in gallery ambient conditions sample the air coming from the machines through a small-diameter pipe, and direct the MCG to adjust its output to compensate for temperature fluctuations. Resistance to airflow in the small pipe has been a significant concern in the Phase 1 galleries, in which the three-way valve is mounted directly on the machines. The air feed to the sensor must be led off the main piping before the position of the three-way valve, i.e. close to the machine output, (see Fig 4) and yet the sensor needs to be located somewhere representative of normal conditions in the gallery, probably at some distance from the MCG. The length of small diameter piping, and therefore the resistance to airflow can be considerable. In the Crystal galleries, where the distance from MCG to gallery is many times greater, such a configuration would be completely non-functional. In these circumstances the sensor and

Figure 9. Narrow windows in Crystal gallery. Some windows have a larger open area, but they predominantly face north

three-way valve are both located in the gallery. At the time of writing the MCGs for the Crystal have not been installed and started up, and therefore there is no hard evidence, but in anticipation of difficulties in getting the conditioned air to both sensor and to the cases, all the new machines have been provided with a more powerful blower motor than is usual.

Light and heat factors

The whole design concept for RenROM has centred around openness and light, and as planning began, it was evident that a significant proportion of the Crystal construction was intended to be clear glass. In addition, the plan called for the uncovering of the west-facing windows in the west wing, which had been blacked-out for many years. Despite extensive computer modeling of changes in sunlight through an annual cycle, it seemed unlikely that it would be possible to keep light entering from outside to a level low enough for light-sensitive materials. Furthermore, sunlight falling on a display case will cause a rise in temperature and a corresponding fall in RH.

So it has proved. In the Crystal, the situation is actually better than we originally anticipated. Much of the open window area faces north, and receives no direct sunlight, or illuminates galleries containing objects insensitive to light. In addition, the wall of the Crystal is extremely thick, so that light entering by the narrow windows is kept to a minimum. The major temporary exhibit space is below ground level and receives no natural light at all, while in the fourth floor rotating exhibit space, windows are blacked out as necessary.

In the older building, the west windows have been opened but conservation concerns have been partly met by locating light-sensitive materials, as far as the story-line permits, in display cases away from the windows. In addition, the windows are fitted with blinds which block 95 % of exterior light from entering. These are motorized, and in theory will respond to changing light intensity outside. In reality the amount of light falling on those windows is such that the blinds are always closed, and the motors inactivated.

However, even with the blinds down, we have recorded unacceptably high light intensities or "hot spots" in some areas at some times of the year, even in cases on the opposite side of the gallery from the windows, and modifications are currently underway to further decrease the amount of light entering the galleries.

Communication factors

One of the main lessons to be learned from our recent experience is that good communication is paramount between all parties and at all stages. I have barely touched on some of the problems we have faced, but several of them might have been lessened, and much frustration avoided, had there been better communication both internally, and with the MCG manufacturer, both in the planning and construction stages.

In the first stages of planning, a number of staff teams were created, tasked with evaluating the design and reporting back to the main design team on topics such as movement of collections around the building, access for exhibit installation, display case layout, visitor flow, etc. Initial plans were widely distributed, and comments were encouraged. However as time passed, it was noticeable that fewer plans were sent out, and at increasingly lengthy intervals. Within two years of the beginning of the project, these teams had ceased to meet, and significant changes in the plans occurred without notification to stakeholders.

In at least one instance, this lack of communication might have had (and may still have, since the Crystal galleries are not yet installed), a disastrous outcome. I discovered purely by chance, while talking to a contractor about something totally unrelated, that the plans called for the installation of under-floor heating at the outer edges of the Crystal galleries to compensate for any temperature drop close to the outer walls. By comparing floor plans, it was possible to see that the heating grid would in some places run underneath parts of display cases.

The likely temperature difference between heated and unheated areas of the floor could be considerable, and might cause problems not only with the RH control within the cases, but also with the fabric of the cases themselves. A redesign has moved the perimeters of the heated area, but only experience, once the cases are constructed, will show whether there is still a problem to be resolved.

Conclusion

This has been a very limited look at just some of the hurdles to be overcome in setting up RH control systems in the 'new' ROM. For the Phase One galleries we have largely identified the difficulties in the system, and corrected or compensated for them, but for the Crystal galleries, though we can predict where some of the problems will occur, undoubtedly there are other unforeseen challenges to be found as we move towards the gallery opening dates. By the end of Phase 3 of RenROM there will be more than 25 large-volume MCGs in operation. The future seems certain to be interesting.

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Notes

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