Scottish Curling-Ice Group

THE CIRCLE FILES – Part One

Background

When the SCIG was formed six years ago, it was a very simple organisation with a very simple objective: how to make good curling ice. Nothing is ever that simple. Although the SCIG has progressed beyond all expectations the simple objective has remained to this day, but curling ice is a very complex subject not easily learned, and certainly not easily taught. Even amongst ourselves, who have learned together and worked together for so many years, the data we gather can be confusing and challenging, often taking years to understand and prove or disprove. It comes as no surprise that others, who have not studied the subject much at all, expect instant answers, and when we cannot provide these we stand accused of having none. Although we now have many answers they remain difficult to explain, and we will never have them all.

In our early years the ice we made was based on the knowledge of others. We listened and learned as best we could, and many ice makers of distinction were only too willing to help us. They gave us hints and tips, from painting to flooding, pebbling data, cutting patterns, the basics of water and ice and much besides. The surprise to us was not how much we learned from them, the surprise was that it didn't really work. Were they wrong, or were we doing something wrong? We simply had to dig deeper and learn more, by ourselves. This position is no different for other ice makers. These men and women who walk the ice every day usually work alone, far from any other ice makers, with little opportunity to communicate. They do the best they can, based on what they know and what has gone before, because "we've always done it that way". Every building is different, every area has a different (micro)climate, every rink has a different schedule. Because of the relative isolation a stubbornness sets in: "my way is the best way".

Even back then learning from each other was nearly impossible, and such literature as was available was totally unreliable with very few exceptions. It became the norm for experienced ice technicians (usually from Canada) to be invited to hold ice courses and teach as much as possible in a day or two, with ice makers despatched from all corners to attend the courses and learn as much as possible. Some bits stuck, but for the most part these courses proved less than adequate. There had to be a better way. The SCIG started having annual curling-ice conferences, open to all for a week in April, where aspects of curling ice could be examined in practice and endless discussions could follow afterwards well into the nights. This seemed to be working better and, considering the obstacles, much was learned over the years, especially through a few detailed experiments. However, beyond this small group of participants in the CICs, resistance was growing from other groups.

Although the SCIG is a non-political group, it cannot avoid the politics, not now, not then. When other bodies or individuals decided we were bad news they tried to shove us aside, discredit us or even close us down. We simply carried on with the work and kept a lower profile. As we made more and more progress we realised that we were considered a "threat" to the system, although we never understood why, and our work was being seriously hampered not only by the apathy of the system but also by the lack of information available to us. Meanwhile we had to make and maintain ice every day, often working with poor equipment or resistance from managers who pulled the purse strings, and it really wasn't much fun. Had it not been for the support of some eminent individuals who took our work more seriously, we would probably have given up.

The first real breakthrough was the new WCF manual, *Curling Ice Explained*. Determined to find more information I went to Füssen in 2002 where I met Leif Öhman, and within the week we agreed to work together on the manual – he had the knowledge, I had the English. The work would take us two long and difficult years of endless emails (before broadband, and some files could take an hour to download) and many hundreds of hours at the computers, but finally it was done and duly released. Suddenly the knowledge was available for all to learn, but we knew even then that the curling-ice world is a very small world and not many would understand the information or attempt to put it into practice. We were not far from wrong.

Another breakthrough came with the Canadian website InTheHack, where an ice maker's forum was set up. Initially it was simply a chat room for exchanging addresses and contacts, but it was better than nothing. Ice makers were very reluctant to provide any detailed information, mainly because they had none, and those who knew more were not participating or didn't want to give away their "secrets". As news of CIE reached Canadian ice technicians the usual reaction quickly appeared on the ITH forum: it can't be any good because it's European. They took it apart before they'd even seen it. I stood up for it, not in defence but simply to clarify their misguided information, and they took me apart as well. A debate developed on ITH that would last for two years, dealing with a multitude of ice problems never examined before, and resulting in the sale of all the printed copies of CIE as well as the subsequent reprint. Meanwhile, here in Scotland, it was simply never discussed or acknowledged – everyone who needed one had a copy, yet it didn't exist, nor did the science it contained. Everyone, it seemed, had a better idea, and very few Scottish technicians took part in the discussions on the ITH forum because they knew it all, or were simply not allowed to do so by their employers.

During the production of CIE the members of the SCIG were working hard in their own rinks to analyse the information and test many aspects, and after its release this work continued. Every aspect has now been tested and, four years later, we still cannot find fault with it. The knowledge is sound, the science is valid and the ice is much, much better. However, a multitude of new problems have come to the surface that are so complicated, there would be no point in even trying to explain these in CIE. It was time to take stock.
The breakthroughs that we made due to CIE were mostly dealing with the basic essentials of curling ice. The many problems of pebbling had to be studied, new equipment made, pebble heads found, techniques refined. The quality of water was next, and thanks to Dr Martin Chaplin we made huge progress on understanding the science behind this strange substance that we have to work with. Cutting patterns were developed and tested over many hundreds of ice miles until they were simple and foolproof, easy to learn and remember and easy to use. Cutting equipment too came under ever closer scrutiny, the angles and slants, the grinding and honing, the quality and hardness of the steel, and finding people sufficiently competent to provide us with excellent blades. Not a single aspect of basic ice making was left to chance, we studied them all, yet there were always a few more appearing on the horizon.

<u>The XF pebble</u>

The biggest single breakthrough we made over all those years was the development of the extra-fine pebble, which deserves a page all on its own. Hitherto ice technicians were using anything that could spread water, from hoses to watering roses, and they certainly spread water. We knew this was wrong because uneven pebble could destroy a level ice pad in a few minutes, as could uneven cutting, and it would take days to repair. Poor pebble or poor cutting equals poor ice. These large drops of water were also very difficult to cut off and could really only be shaved into something called level, while small pebbles could be removed completely in a few minutes to restore a level ice pad to its true level. But we were afraid, it made no sense that a small pebble could last better than a large one, and it would be several months before I gathered sufficient courage to try it at least once. I was stunned when I saw the results, which were fantastic. After a while some of the other members gained confidence too and were equally impressed, and now it is all we use.
The XF pebble, which for us comes from a pebble head with 65 holes of 0.45mm made by Shorty Jenkins or to the same pattern, is a specialist item that has to be used correctly. This requires a specially modified pebble can and hose adapted to suit the user, who will spend many months or years practising until he gets it just right. He will then be able to distribute an even layer of pebble to a density or population on the pad of about one drop per square centimetre, with the pebbles about 1mm high and lightly nipped. Before he can rely on this to last he will have to have clean water, deionised or distilled, at the correct temperature of around 35ºC, applied at a walking speed of 40 seconds backline to backline (both directions) and an arm speed of two to-and-fro swings per second. He will also have to control the ice-surface temperature within 0.2ºC of – 3.8ºC, the air temperature at 7ºC and the humidity at 55% (RH). The parameters are not absolute because they fluctuate continuously, and here it will be the skill of the technician that will adjust one to compensate for another and still provide the required result. This is not the work of ice makers any longer, this is now the work of specialist curling-ice technicians, and the same formula is routinely used in many serious international competitions. Of course it is much more difficult to adjust the parameters in an arena, but that is what the specialists have to do.
The introduction of the XF pebble into our daily routines enabled us to maintain the ice both quicker and easier. An entire four-sheet rink can be cut and resurfaced in thirty minutes, but only if the workers know the job and the equipment is up to standard. It has now become a routine, a formula, that we can repeat endlessly without messing up the pad, and provide for all our customers the best ice possible. World championship ice has become the norm. Sadly, as ever before, the response from many ice makers all over the world has been negative, to say the least, and there are very few ice makers in Scotland who have the knowledge, equipment and expertise to use it here. Nor do we have the opportunity to teach them, because the only ice courses available to them are aimed at the broad basics.
By now the SCIG database had over a hundred addresses of people looking for information. The only way we could keep up was to establish our own website and make the files freely available to all. The database kept growing, the questions became more and more complicated and we were learning at every step, often from serious ice technicians and sometimes from very serious engineers and physicists. It surprised us that, in some strange way, we had made phenomenal progress in but a few short years, yet we had managed to avoid the politics and maintained our independence and integrity. To those who wanted to learn we had become an important source of information, while we simply did not exist to the rest. We couldn't prove what we were saying, because we didn't have the facility or the equipment – we had to find a way. The only proof we had was that curlers loved our ice, but those who didn't get the chance to play on it had no idea what we were doing.
When we started using the laser level, accurate to within 1mm, we realised that it simply wasn't good enough. We designed and had made the IcePOD (Precision Overhead Device), accurate to within 0.01mm over five metres, and suddenly we were learning again. We proved the heights of pebbles, the effects of nipping, the cutting patterns, the wear caused by curlers on Teflon soles. We found ways of measuring the ice-surface temperature accurately to within 0.05ºC, the roof temperature, air temperature, humidity, dewpoint and the very complex relationships between them, and as we learned we published the reports. Inevitably, eventually, we ran out of time, money, equipment and even employment – we needed a modern facility, without which we could do no more.

The facility

It was in Füssen in 2003, and again in Gävle in 2004, that the idea of a research centre was discussed, and it was this idea that became the Circle, a Curling-Ice Research Centre for Leisure and Excellence. During that same period there was much discussion about the building of a Centre of Excellence in Scotland and of course the financial implications. We didn't like the idea of being involved in the COE for many reasons, the biggest of which was the political quagmire that was evident at most levels of curling. Nevertheless we studied the specifications and tried to understand what the nation was trying to achieve, which seemed to be a facility capable of providing excellent ice to specification, available to the development squads more or less on demand.
For both the Circle and the COE, the primary question was the cost. Building a modern research facility and/or a modern facility of excellence would not be cheap, and would be expensive to run. Unless the WCF or one of the world's other governing bodies were prepared to pay for it, it simply would not happen. Even if the WCF could pay for it, where would it be built? Germany? Switzerland? Scotland? Sweden? Canada? After the initial building costs, who could afford the annual running costs? No-one. The facility obviously had to find its own building costs and would have to be self financing ever after. This was the reality and it was most disheartening, because it was not going to happen.
Approaching the problem from a different angle, what is a curling rink? It has to provide curling ice to curlers, in a curling environment, to enable curlers to play games of curling. What is curling ice? The WCF definition is the best there is, never mind everyone else's better idea. And the curling environment? Social, welcoming, competitive, local, independent. What are curlers? Ordinary people who wish to curl, as paying customers, receiving a product worthy of their payment called curling ice, to specification, in a curling environment. From those simple questions the logic developed: a curling rink has to be fit for the purpose of curling, as a restaurant is fit for the purpose of having a good meal with friends. All we needed to do was to find the right area in need of a curling rink with enough players that wanted to build – and contribute towards building – a curling rink fit for purpose. Dream on. So we had to find a governing body prepared to pay for it, one way or the other. Dream on. Everyone wants their own dreams to come true, and this one was not going to come true.
Although the concept of the COE could have inspired Scottish curling, there was now massive secrecy, deception and deliberate misinformation. Those who were in contact with governing bodies and/or funding bodies kept everything quiet, should the opposition gain the advantage by actually learning the specifications. The entire curling nation became so sick of the subject, they simply lost interest, and it was left to the Powerful People to chase their Impossible Dreams. One after one the proposals died the inevitable death, until only Stirling remained, and then even the Stirling proposal died. There was not going to be a COE, bids were now being invited for the National Curling Academy. Meanwhile we too had been active, discussing our ideas with important people and trying to learn all we could, and from this rather confused mixture of planning and failure a new interpretation of the Circle emerged. We were *only* trying to build a curling rink fit for purpose, because it would also be able to do almost everything else. The Circle would simply be a curling rink, fit for purpose.
The SCIG made an important decision: we do ice. We do not do fund raising, and we do not do politics. We had already been involved with three groups who wanted a curling rink, along with our knowledge and our efforts to raise funding and political backing, but not one of these groups knew what a curling rink was or should be. They want, if we can provide, and we simply cannot do everything. Another three groups gradually appeared who wanted much the same, and the answer was much the same: we do ice. All these groups were trying very hard, sitting through endless meetings of seemingly endless committees, and all their efforts were and still are commendable, and we are still in contact with several of them who may or may not succeed. The time we have gained by not having to sit through endless meetings we have used to learn all we can about curling rinks, and about the curling rink of modern specification that will be fit for purpose and will be called the Circle.
Building a modern curling facility in Scotland is not easy, because it has never been done before. Over the years we have come across or learned of curling rinks that do come close to a good facility, but some were in drier climates while others were the results of evolution and would soon be knocked down. A curling rink in the colder areas of Canada or Scandinavia does not have the same problems as one in the damp climate of Scotland, and keeping a 1000m² floor of water frozen is not as difficult or expensive. Although we have searched all over the world for a modern curling rink or data relating to one, we have not found anything worth copying – the data is either not available, or does not exist, nor does a modern curling rink fit for purpose.
If we compare this to our experiences of learning about curling ice, there have been few surprises. Not many people know what we are talking about, because they simply don't know much about modern curling ice – how can they possibly design a curling rink fit for purpose if they don't understand the purpose? For us it was simply a case of back to the drawing board, the basics, because there were no easy answers out there, no ready plans to copy, no prototype to follow. The Circle would have to be designed from scratch, in every aspect and department, to be fit for the purpose of producing and providing excellent curling ice for all – the Circle would have to be its own prototype. Such a facility would also be fit for research and excellence, but it could not be fit for large international competitions. Multi-purpose ice facilities cost multi millions – we wanted a prototype anyone could build and go curling, both for leisure and excellence, at a price that was affordable and fully justified.

The building

A building is a very simple thing: foundations and floor, four walls and a roof. A building fit for curling cannot be much more difficult. Not so.
When we started making ice we were told simple things, flood the floor and wait. Water will find its own level and freeze, cut it smooth, throw some pebble on it and curl. We tried that, it didn't work too well, and several years later we managed to refine the XF formula that did work. If we managed to learn anything at all it was attention to every tiny detail, because they all mattered, and without getting all of them right it simply didn't work so well. The building fit for curling would need the same treatment.

The floor
In an era where sand floors are still common and concrete floors still a luxury, these are considered adequate for a modern curling rink. Yes, this is true, in the hands of a superior curling-ice technician excellent curling ice can be produced on such a floor, as is sometimes done. It will be extremely difficult, costly and almost impossible to maintain, especially once permafrost develops and the floor starts heaving, by which time the ice will have to be removed before the heaving destroys the building.
A modern ice pad is required to be level and even, within 0.05mm over the entire area of every sheet of ice (250m²), or it will be too difficult to maintain. Working back from there, the floor surface must be level within 5mm over its entire area (number of sheets times 250m²), or installing the ice pad becomes more difficult and the ice temperature could vary over the floor. Fortunately this is not too serious, as the heat conductivity of concrete is much the same as that of water, but the more level the floor surface the better. The most important level is that of the pipework in the floor, where some 20km (for four sheets) of plastic piping will distribute the secondary refrigerant, and these pipes have to be as level as possible, which is within 1mm over the top area of the pipes. If this is not achieved, the surface temperature of the ice will not be as even as modern curling requires.
Although it is possible to level the pipes they may not stay that way, because the concrete boys are going to be walking all over them to pour the concrete. So, under the pipes will be a level surface to support them, usually the layers of insulation, and under that will be the drainage system (also holding the heat mat to prevent permafrost), covered in fine gravel that is levelled to support the insulation. Just to make sure the pipes don't move they are now also covered in steel reinforcement and walkways for the workers – just one moved pipe can easily lead to a blockage, which is very difficult to fix and will always be affecting the ice surface. Many curling rinks have one, or two, or have been dug up in despair. And just to emphasise how important this is, the floor will have to last for at least thirty years, if not fifty, and if the concrete mixture is not right the floor won't last a year. The floor has to be exactly right in every detail, or it will not work too well.
To complicate matters further, the pipes have to be evenly and correctly spaced. The old way of laying them down the length of the floor in loops is now simply not good enough and laying them across the floor is becoming more common, but if they are too far apart the ice surface could well develop a washboard effect – our new DDF method should take care of that. At their ends all the pipes must be connected to header pipes, and the connections must not leak. The header trenches need covers for curlers to walk on, and carpets on the covers to keep the surfaces clean, and strips to the edges of the carpeting to prevent curlers tripping over them. It will have to be closed-loop carpet or the fibres will be walked onto the ice and cause many pickups, and the carpeting must be able to withstand the effects of water because it *will* get wet. Then the concrete floor will need concrete edges too to prevent water escaping during the flooding process, and these edges will need protection from the stones (and vice versa!), with bumpers at the ends (but what kind is best? More research!) and a ramp for the cutter and wheelchairs, and some paintwork that will last a while, considering it will be at about 3ºC and on the damp side for most its life, not to mention the battering from stones, brushes and curlers.
Of course, throw down a few lengths of plastic piping and cover them in sand to save a bit of money, they've done that for decades, but it will not work so well.

The walls and roof
Essentially a wall could be one of two things, or both in one. It could provide the structure that would support the roof, like concrete blocks, that could then also be covered either inside or outside to provide additional insulation or protection, or it could be both structure and protection in one. It could be simplified, as many Canadian rinks have been, by erecting a Quonset hut, which uses curved corrugated steel panels. It could be more complicated by building a steel portal frame and fitting walls between the uprights, and the walls can then be further insulated with a false ceiling of low emissivity, very common in Scotland. All these options have problems, usually to do with condensation and heat loss/gain, because none take into account the peculiar environment of a curling rink. The floor is below freezing, the roof is well above freezing and the whole is filled with water as a gas, liquid or solid. If the climate within, which is affected by the climate outside, cannot be accurately controlled, the building cannot be considered to be a modern curling rink.
To understand how other refrigeration industries cope with these problems we looked at cold-storage facilities. They use insulated panels of one kind or another, usually erected as a box within a structural box, with the inner box providing insulation and the outer box the protection and structural strength. The structural strength could be provided by a steel frame to support the roof, with the spaces filled with concrete blocks or cladding.

The primary requirement for the curling rink will be insulation, which here means that no heat or moisture must migrate in either direction unless it is controlled or cannot be controlled – for the latter it must be remembered that curlers have to enter and leave the rink, for which doors have to open and close. Furthermore, moisture and temperatures within the rink must be controllable within very small margins, which needs accurate positioning of equipment and ducting and a very clear understanding of what curling ice is all about. Most engineers can design buildings, but very few have this specialist knowledge. Essentially all surplus heat or moisture has to be removed, while any shortage of heat or moisture has to be introduced, and without excellent insulation this will become both difficult and – in modern terms of high energy costs – very expensive. Virtually all shortcomings of curling rinks, whether old or modern, are directly related to these two aspects.

For a variety of reasons the steel portal frame and the box of insulated panels hold the only sensible answer, with the outer cladding a totally separate issue related to other considerations that have precious little to do with the curling rink itself. Not only do the walls need excellent insulation but also the roof, or in this case what will be the ceiling, hence the word "box". Fortunately modern systems are now readily available to make this possible and the better ceilings are in fact strong enough to walk on, although they still need suspension in places from the steel frame that also supports the roof. Such an insulated ceiling should not need a low-E ceiling to prevent radiation, because there will be very little surplus heat to radiate.

The next problem is the composition of the insulated panels. Once the required thickness is established for a given climate, which is not too difficult, the material used to contain the insulation becomes important. Again the outer cover will be less important and will largely depend on what is added to the outside for protection, and usually it will be possible to ventilate the cover sufficiently to prevent accelerated decay. On the inside, the temperature that this lining is exposed to can vary from freezing to over 30ºC, with the relative humidity easily varying from 40% or less to 90% or more, and 100% if the dehumidifiers fail. The inside cover of the panels have to cope with these influences and changes for the life of the building, or be replaced at great expense at least once. The problem is not so much the changes or variations of humidity, which can be controlled, but the changes in temperature which cause changes in the relative humidity and so the dewpoint temperature at which condensation takes place.

As a starting point, to understand the problem, one cubic meter of air can hold about 1gm of water per degree Celsius. So air at 5ºC can hold 5g of moisture at 100% RH or say 3g at 60%. Warm the air to 25ºC at the ceiling and the air can hold (at 60%) 15g of moisture. This is what commonly happens when thirty-two curlers enter the rink and play a game of curling, introducing some 16kW of heat that lowers the RH for a while and then adding moisture that raises the RH again. Remove the curlers and their extra heat, and the RH will rise as the temperature drops – if the surplus moisture is not removed, there will be condensation on any surfaces colder than the dewpoint temperature, usually starting from the bottom of the walls and working upwards as the temperature of the air rises towards the ceiling. Furthermore, the coldest surface is the ice floor, which will absorb a large amount of moisture as frost, whether through condensation or deposition, and this will go largely unnoticed by players.

Generally speaking, all organic materials are hygroscopic, and will absorb or release moisture until a balance is reached with the surrounding air at a given temperature. If these materials become too dry they can shrink, crack or even split, and should they become too moist they will swell, buckle and usually grow mould. Even inorganic materials are affected by moisture, corrosion being the most obvious effect. The ideal RH for rinks is between 40 and 65%, with materials more affected in warmer air, and mould growing after 70%. It is clear that, at least at times in the life of the walls and ceiling, the materials *will* be affected, and obviously more so in a poorly designed facility than in a modern and technically advanced facility. To complicate matters even further, players will dehydrate quicker at 40% and, if fresh air is not introduced, will also run out of reasonable levels of oxygen after two or three hours; the ice will begin to sublimate (evaporate) and moisture too will need to be introduced to prevent this or at least control it. In any curling rink there *will* be condensation to some degree.

For these reasons many different "warm" materials like wood have been used to prevent condensation onto "cold" surfaces, and it does help to do so. But whether the material is wood, brick or concrete, it will have to be sealed to prevent the penetration of moisture, and the sealant will invariably deteriorate. Once mould starts growing it is virtually impossible to eradicate, so before long the massive cleaning and paint job becomes a regular aspect of maintenance. Not many curling rinks look bright and clean after a few years, and this is the reason why. The remaining alternatives are colder materials like plastic or aluminium weather boarding, or the modern painted steel surfaces now common on insulated panels – the latter might be cold and will so collect condensation before the warmer materials, but they are easily cleaned and, eventually, easily repainted. Glass too is regularly used and will have to be for viewing, but usually this is higher up and seldom a problem, as long as it doesn't allow sunlight (as infrared heat) to reach the ice hall.

Having found a suitable material for the inner lining, which will be smooth and hard, a new problem arises: sound reflection and/or transmission. Some insulated panels can conduct sound very well from the outside and this will have to be prevented, while all hard surfaces will be reflecting sound and lead to a very noisy curling rink. Fortunately sound-absorption panels are available to deal with this, especially if fitted to the ceiling in strategic positions, and they should need little or no maintenance as long as they are secured properly. Fitting sound absorption to the sides will risk damp penetration, not to mention condensation running down the walls into the panels, and should not really be necessary.

As with the XF pebble and the modern floor, the modern curling rink requires very high specification. It is not particularly difficult or expensive, but it has to be done right or it won't work so well.

Equipment

Refrigeration
Refrigeration is the process of heat removal under controlled conditions. In a curling rink sufficient heat must be removed from water as a liquid to turn it into a solid, and then sufficient heat has to be removed from the air in the rink, through the floor, to keep the frozen water solid. For both these tasks a refrigerant is used which evaporates and condenses in a continual closed cycle (not "continuous" yet), under influence of compressors, evaporators and condensers. An indirect system is commonly employed, where the primary refrigeration is used to lower the temperature of a secondary refrigerant, which is then pumped through the pipes in the floor to remove heat from its surface and deliver the heat to the refrigeration plant. This secondary refrigerant is a liquid, usually either a brine of calcium chloride or a glycol. Although refrigerants and equipment have changed over the years and will keep changing, the process itself has changed very little, except perhaps for an increase in energy costs.
For the purpose of providing good curling ice maintained at a surface temperature of – 3.8ºC, this is not the ideal way of doing things. The plant will do its work, remove some heat, and switch off. The floor warms up, and the plant switches on again. This continual cycle can be say six minutes on and four minutes off (it varies a great deal), leading to variations of about 0.5ºC, and in the hands of a very skilled operator he will have to run the plant manually to minimise the variation. To overcome the problem there are now computerised steering systems, varying from simple electronic controllers to highly sophisticated and automated control gear, but these have primarily been designed to maximise energy efficiency and not ice efficiency. The compressors are usually quite large to be able to freeze large volumes of water, which is simply too large for the continuous extraction of surplus heat in the rink. This on-off business also has an effect on the plant, with components shaken at every start and sections heated and cooled or cooled and heated with every cycle, leading to mechanical stress and failing gaskets anywhere in the system. No wonder gas leaks are common in a plant room.
Another problem already identified is that the hydrogen bonding of water molecules will be influenced by the speed of refrigeration. Freeze the liquid fast and the crystals will be hard and brittle, while more gentle freezing will result in stronger bonding that will be more durable when attacked by endless lumps of granite. Add to this the fact that the molecules can recrystallise as the surface warms and cools, and the surface becomes anything but constant. We know this happens, but we don't yet fully understand all the hows and whys – what we do know is that continuous extraction of heat will be a very good way forward, and that this technology is already used by cold stores through racks of smaller compressors as well as staged (stepped) compressors and screw compressors. Considering that the Circle will have excellent insulation and accurately controlled heating, it should not be too difficult to find a system that will work well, and once such a system is installed and fully tested we will learn more. Dealing with the same problem, speed of secondary refrigeration must also be taken into account. With racks of small compressors this shouldn't be too serious, but when it comes to the secondary refrigerant the heat-transfer coefficient has to be taken into account. Calcium chloride is the more efficient but is highly corrosive and awkward to work with, while glycol is less efficient but much cleaner. It could well prove to be better using glycol to "stabilise" the overall extraction of heat by doing it more slowly.

Dehumidification
In the past there was widespread belief that heating removed moisture, but of course it only raised the temperature to prevent condensation. With warm air capable of "holding" more moisture the humidity will in fact gradually increase, and the only answer is to remove the surplus moisture through dehumidification. For Scotland's mild, damp winter weather this usually means a very large system capable of lowering the RH from 100% to 40% in a matter of hours, extracting some 100 litres of water, and these units are very expensive. Add to this a few holes in the walls and roof and the dehumidifier will be dealing with the moisture from outside rather than inside, using even more energy that largely goes wasted. On the other hand the weather can be very cold and frosty with the RH plummeting to 30%, and introducing a few litres of water into the air to compensate is not all that easy.
Again, thanks to the superior insulation and design of the Circle, very little moisture will be able to enter the rink unless it is introduced by curlers or equipment. Instead of a very large dehumidifier two smaller ones can now be used, at the same initial cost – one unit will dehumidify as needed, while the other can be used to help or, on occasion, can be reversed to humidify the rink. The ducting will be smaller and less intrusive, and the noise factor will be insignificant, while the airflow from the units will be gentle and unlikely to affect the ice surface in any way. Controlled dehumidification and humidification will enable us to maintain the quality of the ice surface to a very high standard, so much so that we will be able to learn exactly how much moisture is really needed to ensure that naturally matured stones curl as they should. Control equals quality.
The luxury of two dehumidifiers will make it possible to introduce fresh air when needed. The problem of IAQ (indoor air quality) has not yet become an important one to curling rinks, but it is destined to do so, and during a competition where the rink is occupied for some twelve hours a day the oxygen levels will fall. Because we have not yet found a well-sealed building within which to do these experiments, it will be interesting to learn more about IAQ in the Circle.
It is now generally accepted that desiccant dehumidification is the better option in curling rinks as opposed to mechanical dehumidification. The equipment is more reliable, needs less maintenance and uses much less space.

Heating
Just as many curling rinks have been built with no provision for dehumidification, in the belief that heat would solve the problem, many have also been built with no provision for heating, thinking that dehumidification will solve the problem. Both are in fact needed, but to solve two different problems. Dehumidification is needed to control the moisture content of the air, while heating is needed for three main reasons: to prevent condensation on colder surfaces, to provide comfort for the players, and to maintain the optimum ice surface for curling.
Condensation is directly related to the dewpoint temperature (DPT) of everything in the rink. For example, if the air temperature (AT) (at 1.5m) is at 7ºC and the RH (at 1.5m) is 50%, the DPT will be – 2.4ºC, which means that condensation will form on any surface colder than that. The ice surface could be at – 4ºC, therefore there will be condensation as frost that will gradually become a problem (but in this case not too serious). The walls will be at 7ºC or warmer and will have no condensation, nor will anything else in the rink. Should the heating fail and the AT fall to 4ºC the RH will rise to 62% and the DPT to – 2.3ºC, which is still not too serious. But if the surplus moisture is not extracted the RH will rise, easily as high as 80%, which at 4ºC will give a DPT of + 0.85ºC. If the dehumidifier too should now fail and the RH rises to 100%, the DPT will also be + 4ºC, leading to fog in the air and condensation on the walls, and soon rain from the ceiling as this continues to cool down. While it takes both dehumidification and heating to control the situation, the fact remains that they are doing two very different jobs. It helps to remember, especially in a curling rink, that the moisture content of the air is more important than the relative humidity – for an AT of 7ºC and 50% RH the moisture content is 3.12 grams of moisture per kilogram of air, while for an AT of 4ºC and 50% RH the moisture content is 2.53g/kg, nearly 20% less, and at an AT of 10ºC and 50% RH the moisture content will be 3.82g/kg, some 22% more. The RH stays the same, but the moisture content varies, and everything over 3.5g/kg can easily become a big problem.
The height of measurement at 1.5m is by consensus, and is roughly also the area most important to the human body: the heart, lungs and brain. If it becomes too cold, and 6ºC is considered cold, the body is under stress. Should it become too warm, say 10ºC, the body is again under stress and with exercise will start sweating. The temperature of 7ºC is as comfortable as can be achieved without wasting energy, because all surplus heat will have to be extracted through the floor. Again it is a figure of consensus, but our own experiments have shown that it is a very good compromise between what is needed and what can be achieved. Consider that a roof temperature of 40ºC in an uninsulated building is not uncommon, this can raise the AT to 12ºC or more. On the other hand a well insulated roof can be heated to only 10ºC without affecting the AT, thereby minimising the amount of surplus heat. Without controllable heating this temperature cannot be maintained.
The optimum ice surface for curling is a highly complex thing and beyond the purpose of this report. What is however clear is that some heat is needed not only to help prevent frost, but also to keep the ice-surface temperature under control. For more information on this please refer to *Why Do Curling Stones Curl.*
When the heating system fails in a curling rink the effects are not immediate and will usually only be noticed after a few hours. This suggests to us that the temperatures within a rink can be very accurately controlled, provided the heating is introduced gradually and not suddenly. Our own experiments support this, and we have been able to control the AT within 0.1ºC during an entire weekend – regardless of the amount of curlers entering and leaving the rink – simply by controlling the amount of heat introduced by the heating system. The heating system for the Circle will therefore use a simple piped hot-water system, the temperature of which can be accurately adjusted by thermostat to provide only as much heat as is needed in a gentle, gradual manner. The system will also be able to incorporate the small, but free, amount of heating introduced by the desiccant dehumidifiers when they are running as well as heat from lighting and curlers, and the load on the refrigeration system will be as low as we can get it without causing unwanted discomfort or fluctuating conditions for the ice surface. Because the temperatures will become very stable, continuous extraction also becomes easier, and in time the true balance will be established for excellent curling ice.

There is a downside to all this: the heat has to come from somewhere, or be created by using expensive energy. It is now the norm to incorporate any form of "green" energy wherever possible, along with improved insulation. For a curling rink this means a heat-exchange system on the refrigeration plant, where every 1kW of electricity used for refrigeration can provide 2kW of heat energy, which can be captured and recycled. Many rinks already do this and use the heat for swimming pools or central heating, by capturing the heat in a large tank of water and distributing it as needed. Unfortunately there is very little actual data available and, with the superior insulation of the Circle, we are in uncharted territory – on the one hand the plant will not be working as hard as the current norm, while on the other hand less heating will be required for the building itself.
After studying all the other options available for additional "green" heat, we have already dismissed geothermal systems and wind power. The options we favour are solar panels, expensive to install but the heat will then be free, and biomass burners as backup, also expensive and with continued fuel costs, but at least the energy will be from a renewable source. Distributing the heat from these sources will be relatively straightforward in winter, but there will be a surplus in summer that will have to be sold to an outside user. Currently our strategy is to develop the system a step at a time, putting the basics in place and then adding components as we learn more. What is already clear is that the Circle will spend as little money as possible on heating, using as much as it can from free sources, while everything else will be from renewable sources.

Water
It is now accepted that curling ice should be made from clean water, which is water free of salts and impurities. A salt, in chemistry, is defined as the product formed from the neutralisation reaction of acids and bases. Salts will lower the freezing point of water, which will then have to be colder to freeze, and can be removed from water either through distillation, deionisation or reverse osmosis. Water used for pebble certainly has to be as clean as possible, but as yet we have no real evidence that clean water is essential for the ice pad, or that a small amount of any particular salt(s) might be beneficial. The cleaning processes are also expensive (like distillation or deionisation) or wasteful and slow (like reverse osmosis), and we have for some years now experimented with different ways of going about the problem.
For the Circle we have decided to initially work with rain water. Thanks to a very large roof area over the curling rink it will not be too difficult to catch the water in large quantity, and by installing a tank of 30,000 litres there will be sufficient water in storage for a total installation of the ice pad, even if it doesn't rain in those two weeks. We can then deionise a small amount of this water for pebbling, which is not too expensive, or experiment with salts if we choose to, or install a deioniser or an RO unit at a later stage.
The cost of installing such a massive tank will be recovered within three years, but if we can fill it again before the cold period of the winter the same tank will serve as the secondary heat store, from which water can be pumped around the building for background heating. It can also feed the primary heat store at the plant to preheat the water needed for central heating, or extract heat from the primary tank as surplus and store it rather than waste it. This is quite a complicated setup, but any competent heating engineer will be able to install the system.
Thanks to the installation of these storage tanks, it will also be possible to heat a tank of flooding water to the desired temperature prior to flooding, at virtually no additional cost. The advantages of heating the flooding water are significant, especially regarding viscosity, surface tension and oxygen content, and because the temperature can be controlled we will be able to undertake many long-term experiments that will refine our levelling techniques beyond what is currently achievable.

Stones
Due to the increase in ice quality over recent years, the behaviour of stones has become a very important issue. If a constant ice surface can be created, and this is now possible to an unprecedented degree, the behaviour of stones due to the texture of their running bands can be accurately studied. For the Circle this will mean at least two sets of stones with different surfaces, and one of these will be stored at a cold temperature while the other is in use. For the storage we have devised a system within the ice hall that will keep them at the same temperature and humidity as those in use, so that they can be moved onto the ice when needed and used immediately without the usual acclimatisation period.
This will enable us to manipulate the parameters and replicate virtually any ice conditions, while still able to achieve the requirements of the WCF for speed and draw. In years to come this will become the most important aspect of curling as the requirements become ever more important, and we are confident that the Circle will provide the lead in these experiments and collection of specific data. Considering that the Circle will have a stone-delivery machine and monitoring equipment installed to track both the velocity and trajectory (plane curve) of played stones, this will be invaluable to players, coaches, technicians and interested curlers alike.

Lighting
The Circle will be fitted with high-resolution cameras, both for broadcasting purposes and for coaching, research and social videos. These will require lighting to TV standard (1000 lux at 45º), which will be provided by rows of T4 fluorescent tubes positioned over the sidelines and sideboards. The lights will be in four "banks", with two banks alternating in pairs and the pairs also alternating. This will enable all the tubes to be used only as needed and the use of the four individual banks can be recorded by hour usage. One bank of tubes can be renewed every year to ensure maximum quality of light, while the older tubes will be used elsewhere in the building.
The lights will be suspended from the ceiling at a height below the eye line of a seated viewer upstairs, and above the eye line of a standing viewer downstairs to minimise glare. The walls and ceiling, and of course the ice, will be white, therefore maximum efficiency of lighting can be assured. It is not yet clear how many banks will be needed for normal curling, but we expect that two will be adequate.

Maintenance
Maintaining the ice surface and its surrounds is becoming more and more specialised. We have already been forced to develop our own equipment in most areas simply because there is either nothing readily available, or what is available is totally inadequate.
For flooding we now use a length of Tricoflex hose (19mm ID) that can reach all corners of the rink during flooding, fitted with a pressure gauge, in-line flow meter and special flooding stick/pipe. It is stored on a reel and can be used by one person, and thanks to a special overhead rail in the Circle the hose will not have to lie on the ice surface (especially useful when flooding with warm water). We have also made a pressure boom that connects to the same hose, for spraying sheets in five-metre widths when sealing or painting, and here too the suspended hose will need fewer staff to keep it off the ice.

The recent advances in powered cutters have resulted in several new models on the market, all of which were designed for the Canadian market and ice conditions. New machines are heavier and automated in several ways, which we do not need. Unfortunately our preferred machine is no longer being manufactured and another unit will have to be modified specifically to suit Scottish conditions, incorporating some of the advances in battery technology but keeping most of the older advantages of lightness and manoeuvrability. This machine will be modified further when we receive it, to simplify blade removal and protection. It will be stored in a special area where only the blade assembly will be chilled, to avoid the development of condensation and rust on the rest of the machine. This should also eliminate the problem of the blade assembly warping due to changes in temperature.
Blades too are becoming ever more important. Modern blades are required to be accurate within 0.04mm over their length, which is no longer adequate as we are trying to work within 0.02mm over the same distance, but the invention of our bi-directional brace enables us to true most blades in either direction. We have also made much progress on the science of regrinding and can now keep blades razor sharp for months longer than before, but we still have much to learn. If possible we will install our own precision grinding bench to do our own blades and try to improve on the standard of grinding.
Through the development of these precision blades we have already been able to refine cutting patterns that do not destroy the level of the ice pad. By using the IcePOD at regular intervals we can monitor the changes, accurate within 0.01mm over the width of 5m, and it soon becomes obvious where the small problems are accumulating. This kind of precision has never been possible before, and this is how we can be sure that an ice pad is being properly maintained, and can be maintained for the full season without flooding. It is this work, along with new pebbling techniques, that has also enabled us to use the XF pebble with such confidence. This is control of curling ice to modern standard, and without these measures it simply will not work so well.
Another problem we have to address in the Circle will be the accumulation of dust. On the ice surface this is usually removed by frequent cutting, but on all other surfaces a vacuum cleaner is our best solution. We will study data from manufacturers before proceeding, but if a vacuum cleaner cannot be found that does not – by guarantee – expel dust that it has just collected, we plan to install a piped system with an outlet outside the curling rink. These have been used for decades in stately homes and work very well. Additional filters on the ducting should also contribute towards the cleanest possible environment and the cleanest possible ice surface. The principal reason for taking dust so seriously is that moisture readily condenses onto dust in the air and then the larger drop freezes to the ice surface, where stones and brushes loosen it to create unwanted pick-up problems. The only dirt allowed in the Circle must come from the players, not the environment.

<u>The customers</u>

Many, or most, or even all, ice technicians do their best to make good ice and please their customers. Unfortunately many ice rinks do not provide a product that is to the liking of its customers, which leads to the inevitable drop in numbers and eventual financial struggles. The simple reasons are easy to see. First, making ice is not the same as making good curling ice, and modern curling ice is a step further yet. Second, not all customers are as fussy as some, because they either don't know better from curling in the same place all the time, or it is not that important to them – modern curling now requires a very high standard of ice not only from the elite, but also from fast-improving club players. Once a curler has played on excellent ice, anything else becomes a bit of a struggle and eventually better avoided.
Curling rinks with very good ice are generally oversubscribed, which results in less time to make good ice and the rinks become victims of their own success. The common attitude now is to build larger rinks to accommodate more customers, but *all* our research shows that this does not work too well – such are the dimensions of the larger buildings that control becomes more difficult, if not impossible, and the increase in the workload invariably leads to a decrease in quality due to a lack of time and skill. On the other hand we have found *no* real evidence that larger rinks are more cost effective, or that they can produce excellent ice on a daily basis. However, the customer should be considered, and we have found a compromise where a five-sheet rink can be run much on the same basis as a four-sheet rink, *provided* there are sufficient curlers to support the rink and so provide the additional money for extra staff. Therefore we came to the conclusion that the Circle will be a four-sheet rink by design, but if it has to be built in a busy area it can be a five-sheet rink. Anything larger will not be cost effective to build or run, and as most serious competitions are now held in seated arenas there is simply no justification in trying to compete. These analyses are also on our website under *Four vs. Six* and *Five vs. Four & Six.*
As the years went by with the search for the COE and NCA, we were relieved to see that those specifications also leaned towards the smaller rink. But the new question was now whether the Circle could provide what the NCA required. We took a new look at the potential customers and very soon realised that the Circle would be fit for the purpose of curling and for *any* curling customer, but the NCA would not. Elite curlers will identify with the NCA, while the other 90% of curling customers – who effectively will pay for the Circle over its entire future – will not care much for the elitism. This convinced us that the Circle could provide facilities for the NCA as one set of customers, while the NCA on its own would become a white elephant. Should the NCA be built as well as possible or as a six-sheet rink, if the Circle was built as well it would be better. This was not very comfortable. On the one hand the funding bodies could insist that we built the Circle to their specifications, ignoring all our research, or they could easily simply refuse funding to ensure that we didn't build the Circle that could degrade their NCA.

By now several other groups, interested in building their own curling rinks, were trying to incorporate the NCA in order to secure the substantial additional funding. We knew already from our own research that curling ice is no longer that simple, and that the Circle will provide the best opportunity for the NCA to have excellent ice whenever required. Proving this, however, is not that easy either, and any other rink could make the same claim. We decided simply to accept our own research and rely on the integrity of the reports we had managed to publish on our website. Unfortunately the other groups were not so confident and started whispers to dismiss our work, discredit our plans and strengthen their positions. Of course, it quickly became clear that none of them really knew much about modern curling ice, and unless they had access to someone more knowledgeable than us we had little to worry about on the knowledge side.

Everything was soon to change. After I submitted my "last" report to the RCCC on the matter of building the Circle and providing a home for the NCA, the specifications changed again. Now the RCCC also wanted their new offices and the national curling museum included in the plans, which would represent a major political problem for the Circle. Club curlers and blue blazers do not readily mix too well, and with the RCCC reputation at present in the shaky zone this could be seriously dangerous territory. Did we want to do our work next to the RCCC? *Could* we do our work alongside their offices, yet more customers with yet more differing requirements?

When we studied their new specifications we all, separately, noticed that these specifications were in fact our own, presented to them through our reports. They had added to these a copy of the WCF specifications, which were not as specific as ours, and it became clear that we had a very strong position. After very careful thought I realised that they needed us as much as we needed them – it was no longer a case of *could* we work together, we simply *had* to work together. I soon found a way to accommodate their offices and museum in the plans without affecting the ideals of the Circle or its curlers, and within another week we had designed a management structure that could run the complex effectively and safeguard the independence of every department.

There was only one remaining problem: we had nowhere to build the complex. Although we had by now discussed our plans with six groups and were still involved with three, none of these were suitable for the location of the RCCC, NCA and museum. Fortunately we heard of an effort by Montgomery Hotel Group to rebuild the rink at Kinross and secured a meeting with them, soon to result in full collaboration and a formal presentation to the RCCC to build a five-sheet rink in Kinross, adjacent to the two hotels. This one ticked *all* the boxes, from accommodation to excellence, accessibility and ambience. This complex would serve all its customers in equal measure and provide not only quality, but also economy and a home to Scottish curling in a way that we could not have planned ourselves. It seemed that common sense was prevailing, evolution had come good, and although all the eggs were in one basket risking disaster it could work supremely well, as long as we could safeguard our own technical specifications that would deliver the full Circle.

The SCIG

It is a humble group of ice makers, no more, no less, and the fact that we would develop into specialist curling-ice technicians was always inevitable. Through hard work, expensive research and years of perseverance we developed the XF pebble and the technical specifications for the Circle – this was also always inevitable. That others now feel that we have no position, no knowledge, no right to "their" money, is equally inevitable. We do believe the members of the SCIG represent the best possible opportunity for success in this venture, the Circle represents the best possible option for a curling rink of the future, and the location in Kinross perhaps the only option worth considering.

If we are allowed to build the complex, we will prove it. We will do so for the remainder of our working lives, because that is what it will take, and we will leave a legacy of excellence that every curler and curling-ice technician can learn from and be proud of. The Kinross Circle will give Scotland the lead in facility design, a national statement that will echo on the international scene. It will do the National Curling Academy proud.

We will do this for curling, it is after all what we do: we make good ice, for good curling.

John Minnaar
20 May 2008

To follow: THE CIRCLE FILES – Part Two