Scottish Curling-Ice Group

FRICTION VERSUS TEMPERATURE

Background

Since publication of *Why Do Curling Stones Curl* in 2006, two aspects have gradually acquired a higher significance than before, not because they are more important than any of the others, but because they represent two distinctly different ways of controlling the behaviour of curling stones over and above all the other factors involved. These are friction, which here means a "dry" friction where the running bands of the stones have to be roughened to increase friction between the stone and the ice surface, and temperature, where the running bands of the stones are left smooth and allowed to naturally mature and the temperature of the ice surface is manipulated to provide the required amount of curl. And, of course, there can also be a combination of the two methods.
It has become clear that friction is more common in cold countries or curling rinks with generally low humidity, such as Canada, while temperature is more common in warm countries or curling rinks with higher humidity, such as Scotland. This has led to the terms of Canadian Ice or Arena Ice, and Scottish Ice or Club Ice, with considerable disbelief from one side to the other between the two sets of ice technicians as to which method is best.

Parameters

In a cold rink there is often no heating of the air, or the heating is deliberately kept low, which means that the heat does not need to be extracted through the ice to prevent it from affecting the ice surface. In an arena, however, the heat can accumulate to very high levels and will have to be extracted, leading to a very cold ice surface. Humidity in a cold rink is usually not a problem if the outside air is cold and dry too, while in an arena the humidity will have to be controlled very well to prevent the effects of frost during a game. The frost under these conditions will be "powdery", fine and hard, and not difficult to sweep aside because it doesn't bond with the ice surface unless it is forced to.
In a warm rink with heated air the heating can be controlled to the required optimum, where only a small amount is extracted as surplus when necessary, allowing for a warmer ice surface. The warmer air can contain more moisture, but if the dewpoint is controlled through dehumidification the frost will not be a problem. In fact, a warm rink can have an RH of 90% and still provide excellent ice for a game, but if the ice is not resurfaced the frost will accumulate too much. This frost will be soft and amorphous (non-crystalline) and will certainly bond to the ice surface, making it very difficult to sweep aside, hence the accumulation.
The table below provides some theoretical scenarios based on experience and sensible deduction:

	OT (1.5m)	RT (**3**/8m)	AT (1.5m)	IST (0m)	FT (– 0.1m)	BT	ORH (1.5m)	RH (1.5m)	DPT (1.5m)
Cold	**– 10ºC**	**+ 1ºC**	**+ 3ºC**	**– 4.5ºC**	**– 6ºC**	**– 6ºC**	**20%**	**40%**	**– 8ºC**
Arena	+ 8ºC	+ 40ºC	+12ºC	– 4.6ºC	– 7ºC	– 9ºC	60%	40%	– 1ºC
Warm	**+ 8ºC**	**+ 20ºC**	**+ 7ºC**	**– 3.8ºC**	**– 6ºC**	**– 7ºC**	**70%**	**50%**	**– 2ºC**
Arena	+ 8ºC	+ 30ºC	+ 8ºC	– 4.2ºC	– 6ºC	– 9ºC	70%	45%	– 3ºC

For the cold rink with an outside temperature of – 10ºC (it could be even colder), there are problems. With no heating it will be difficult to warm up the ice, the humidity is too low, the ice will sublimate because the dewpoint temperature is too low, and the plant will hardly be needed. It is very unlikely that naturally-matured stones will curl much in this environment.
The cold arena with poor air conditioning will have a heat surplus from spectators, aggravated by a warm outside temperature. To compensate and extract as much heat as possible the plant will be working hard, the IST will be low but the ice will be fine for a competition, and the frost should be controllable. Here too it is unlikely that naturally-matured stones will curl much because the ice is very cold.
For the warm rink conditions are excellent. Naturally-matured stones will curl well in a graceful apple-shaped parabolic curve that curlers enjoy. The curling will be good.
The warm arena too will have excellent conditions. With its capable air-conditioning system the surplus heat can be removed and replaced with fresh, colder air of low humidity from outside, and the competition stones will have sufficient friction to curl even at this slightly colder ice temperature. These stones will be using both friction and temperature to curl, and the conditions will be very controllable.

The problem for the cold rink is this: if it is so cold that the refrigeration plant is hardly needed, no heat is extracted and no surplus heat is available to recycle into the roof space to heat the air. If heating is going to be the answer, it will have to be paid for from somewhere else, and this is expensive. The curlers might not mind wearing extra clothing to keep warm, but they will mind the lack of curl. The only way this will improve is to have the stones refurbished with an aggressive running band, expensive but cheaper than heating.
The texture will gradually wear smooth and will be restored with another refurbishment, which now is less expensive because the technician knows how to do the job with a pack of sandpaper. Within a year or two the stones will need full refurbishment again, because the running bands will have been widened from the original 5mm to over 10mm, thanks to all the sanding. The technician is considered an expert, because he can make his stones curl on anything, and everyone starts following his example. No-one really wonders why the curl is a pear-shaped parabola with a wicked dive at the end, at least there's curl.
His skill is now so respected that he is asked to make the ice for the competition in the cold arena. He does all the work, only to find that the set of stones they delivered will not curl enough. This is not a problem to him, he waits for the quiet of night and doctors them a little with help from the "sand man". The stones curl well and he is hailed an expert yet again. Even the curlers from the cold countries said so, great ice, they were quite used to playing with stones that dive past the guards and come out the other side. Not his problem, not his stones, what does it matter, he had no choice.
This report is not trying to criticise expert arena technicians, so let us deal with them first. These technicians prove themselves over many years and know exactly what they are trying to do. Every venue is different to the previous one, and usually every set of stones will differ. It is becoming more common now for them to inspect both the venue and the stones well in advance to be able to devise a strategy, and they will sometimes even ask for the stones to be replaced or refurbished and "played in". The challenge will be to provide consistent conditions for a high level of curling over a period of about ten days, and this they will do their very best to achieve – usually they will succeed. The better the facility and the stones, the easier their task, the better the ice and the curling. The demands on a facility for the Olympics, for instance, will now require a brand new building to be constructed to specification – tested by another competition a year in advance – simply to ensure the best possible conditions, and only the very best elite technicians will be invited to make the ice. Even then it will require skill beyond the ordinary to succeed and they deserve every praise when they do, because they cannot fall back on the excuses of *Shades Of Grey*.
In a curling rink, on the other hand, the technician is dealing with one building, one broad set of parameters and one set of stones. He is there all season, every season, from year to year, and he will know the whole place better than anyone else. If he learns enough and tries enough he will develop a strategy that provides for his curlers good ice and good curling, but if he fails he will only have himself to blame. If his curlers and committees don't support him with adequate investment in the building or equipment they will have to share the blame, but they will still blame him. No wonder that these technicians have to resort to shaping the ice and sanding the stones when they cannot control the parameters, they have little choice. But is this really necessary? In some old, cold curling rinks it will be, but in the modern curling environment it should not be.

<u>Friction</u>

The finishing of stones after manufacture on a lathe is an expert job, and as such is a commercial subject. The manufacturers are not going to give their secrets away and no-one is asking them to. When a set of stones is refurbished the same principle applies, once they've reshaped the running bands they have to finish the surface. They will now give a choice to the customer too, call it rough, medium and smooth, and the set of stones will be fairly well matched when they arrive at the curling rink.
The technician will study how the stones behave and make some adjustments, probably by not nipping heavily and keeping the ice surface colder to keep the stones straighter. The stones will curl well and will usually have a good dive at the end, drawing about six foot, and if the finish is too rough they will even draw at strike weight. The curlers will be happy enough, it is quite fun playing with such big draws, and all will be well for a month or so. Then the stones will be "played in" and start diving less, but will still draw well. As the draw decreases the technician will return his ice temperature to what had been normal for him, and also adjust his Nipper to shave off a little more of the surface for a larger contact area. After a few months the stones will naturally mature (it takes years before they're fully mature), lose the artificial friction and play fairly straight again. The end of the season can't come soon enough for him, and back they go to the manufacturer for refurbishment ahead of the next season. Everyone praises the technician for his ice, which had very little to do with it, and as long as he doesn't make a mess of it by trying to doctor the stones himself no-one will make too much of a fuss.
That is the ideal scenario, with everyone happy. Unfortunately it doesn't work like that, because the consistency of a stone's behaviour doesn't endure. Also, many technicians DO try to increase the friction themselves and get it wrong, sometimes very badly. Other technicians decide they know best and think nothing of stones curling eight foot – what fun! – no matter what the WCF specifications say.

Where did the consistency go? What went wrong? Why won't the stones curl? Why aren't they matched anymore? Call in the experts, there's something wrong! What is happening here?

1. When a set of stones is finished by the manufacturer, there is only so much he can do to create consistency. Even under a microscope it is difficult to see what happens, and very difficult – if not impossible – to do the same thing in the same way to each of say eighty stones. Only by playing them in for a while and then matching them on VERY good ice, can the technician match them into pairs and eights. This is a serious bit of work needing very good players (or stone-delivery machines), and the ice will have to be resurfaced several times to do it properly. From day one the stones will not be matched anyway, never mind the days after, and rematching a set of eighty stones takes time and costs money.
2. The work done to the running band will vary, from rough to almost smooth, but there will be damage to the surface in the form of scratches. Every scratch will scrape at the ice and gather ice, and if the scratch is deep enough the ice will stay within the scratched space. This is impossible to see with the naked eye (or any common magnifying instrument), and soon the amount of friction will change because most of the scratches have been filled in. Wipe the surface with a warm hand and much of the ice will disappear, for the friction to return. Where is the consistency here?
3. Cold ice rinks have cold frost, better thought of as deposition (frost is deposited) as opposed to condensation (moisture condenses and freezes). Cold frost is hard, strong and like dust, it is as good an abrasive powder as anything else. Should the curlers not sweep so well (as many club curlers do) the stones could be travelling up and down a sheet of frost powder some fifty times a day. No wonder the friction is gradually lessened, the frost is now sanding down the stone! Not much hope of consistency here either.
4. The stones have a rough running surface that grinds away at the tops of the pebbles. The pebble wears faster than expected, the contact area increases, the stones start drawing more and more, the curlers decide the ice has gone flat. They tell the technician, he adjusts the plant and runs the ice even colder. Even more frost forms but it works, for a while. Then he has to have the stones refurbished, they come back rough and start grinding away at the pebble again. Consistency become a word of the past, every week will be different, depending on which surface is grinding away more of the other surface.
5. This grinding of stone over pebble has another effect. The technician puts down the most beautiful pebble, strong, durable, small, even, consistent, recommended by the experts. The curlers play a few ends and the ice changes, because they were playing along similar lines and grinding the pebble down in those areas. The stones down those lines draw markedly more, but inconsistently, while on the lesser-played lines they're still playing the same. This is any player's nightmare, where to play, how much ice to take, what will the stone do, tell the iceman this ice is poor. So the technician tries different pebbles, different temperatures, different speeds, different anything, and invariably ends up with a small and a medium on top, or a medium with a small on top, or a 74 at 60ºC with a 76 at 40ºC on top followed by a 72 at 45ºC between games. All of this is extra work, extra cutting the next morning, extra confusion – who can keep track of this? Not the technician, and not the players.
6. When a stone is refurbished some of the stone is removed to reshape the running band and restore the width of the band to say 5.4mm. This band can be sanded once or twice without full refurbishment, but every time it will become wider and very soon will be 10mm wide. More of the stone will have to be removed to restore the width. This is serious deterioration and mindless waste of an item that costs well over £500 each! The manufacturers must be laughing all the way, they make a stone, get paid for it, then systematically help to speed the stone's destruction and get paid for that as well!
7. Why should the stones be refurbished, if they all deteriorate the same and still behave the same? Because they don't. Some sheets will be played more than others, so while some stones can travel down the ice with its frost powder 1000 times a month, others may only do so 500 times a month. Some will be played at strike weight, others at draw eight. Some will be swept, others not. Artificially matured stones will lose their consistency sooner than naturally matured stones, and they will always lose their consistency.

It can easily be argued that all the above has nothing to do with curling and everything to do with splitting hairs. The fact remains that consistency is what is required, yet with artificially matured stones consistency is very difficult to achieve and maintain and also very costly. The only positive side is that artificially matured stones will curl – through friction – on cold ice, where naturally matured stones won't. For those technicians who cannot heat their rinks, or will not, or choose not to, or don't know how to, friction is the only escape route.

Temperature

The first question must be: why heat a curling rink. In days gone by curling rinks were first built in colder countries, snow outside and – 20ºC, where the snow was interfering with the outdoor naturally-created ice of a lake or pond, and later in warmer countries, rain outside and + 8ºC, where rain was now the problem and the water had to be artificially frozen with refrigeration plant. For the first the humidity was low, with an RH of 20%, and by ventilating the rink with shutters this could be replicated inside the building too; for the second the RH could be 80% or higher and the moisture had to be kept outside, because the surplus would condense onto any surface colder than the dewpoint temperature (3ºC at 70% and AT of 8ºC). To control the dewpoint heating was introduced into the air of the rink to raise the temperature and lower the dewpoint (now – 2ºC at 50% and AT of 7ºC), believing that this would control the problem by "removing moisture". The moisture is not removed, it is still there at a level of over 3 grams of water per kilogram of air, but it worked for them and that's what they did.
The only way to remove the surplus moisture that causes frost on the ice surface is to extract it with a dehumidifier. By removing as little as 0.3 g/kg from the air (only 10% of the actual moisture), the RH drops to 45% and the dewpoint is lowered to – 3.7ºC, resulting in very little frost and a very pleasant curling experience. However, if the building is not "tight", meaning well sealed, moisture WILL migrate into the drier air of the rink to replace the moisture that is being removed, so the dehumidification becomes a continuous and an expensive process. At Forest Hills, for example, it was quite normal to extract about 80 litres of moisture every day from the rink, simply to maintain some kind of balance, and when it rained with an ORH of 100% this could rise to 120 litres. Paisley had the same problem during the Worlds Ladies in 2005, but without the equipment to solve it.
Heating is still considered to remove moisture, or at least to contain the dangers of it, but dehumidification has now become the norm – so much so that some modern rinks are designed and built without heating. This is strange, because surplus (free) heat from the refrigeration plant can easily be recycled into the roof space to do the job, and in well designed rinks this is what happens. However, before dehumidification there was heating, and heating became its own worst enemy. Introduce too much heat and the surplus has to be extracted through the floor before it melts the ice; remove too much heat and condensation will form on all cold surfaces. Without accurate measurement and control of both heating and dehumidification curling rinks will struggle to control the parameters needed for curling, and it can be an expensive struggle that few rinks can afford.
Fortunately modern equipment and science can now provide all that is needed for accurate control, and most modern curling rinks are built with computerised steering gear as standard. By controlling the amount of heat introduced into the roof space, the temperature at 1.5m can be controlled within 0.1ºC, while a good dehumidification system can control the RH at 1.5m within 1%. In this way an AT of 7ºC and RH of 50% can be achieved and maintained without wasting any money, and this is what competent curling-ice technicians now do every day. With the right equipment and a good, tight building this is achievable, and it is really not difficult at all.
To dig even deeper, why 7ºC. It is a figure of consensus, which could be much higher without serious consequences (some arenas survive at 18ºC!), or even lower (some rinks operate at 2ºC). The temperature has to be comfortable both to work in and play a game of curling, and the consensus is that 8ºC is getting too warm and 6ºC is too cold. At 7ºC the ice is not in danger and the molecular structure of the surface is strong and consistent, while warmer will affect the pebble and colder can make the ice too brittle. If the surplus heat has to be extracted the IST will drop too, and with surplus moisture there will be additional unwanted frost.
And why 50% RH, if 45% RH will result in less frost. Looking at *Why Do Curling Stones Curl*, frost plays an important part in the behaviour of naturally matured stones because of the MSMM/F event and the lubrication wedge – although the frost is only a micron or so thick (thin! 0.001mm!), it is there. This amorphous ice is more easily melted by the mass of the stone than crystalline ice, and it does improve the behaviour of the stones. Remove this thin layer by sweeping and the stones stay straighter and travel further, or, without this layer the stones will not draw so much and the ice can easily be "super fast". By controlling the amount of moisture and the relevant temperatures, an ice technician can – very accurately – control the behaviour of the stones.
Using the control of temperature as a means to control the behaviour of curling stones on ice is not new. Many rinks, if not all, have done that for many years, and have learnt what works in a certain climate and area, sharing the knowledge with each other and developing very good ice for that area. From the report *Shades Of Grey* it is unfortunately difficult to say whether the solutions they reach are the best ones, because the debates continue. In Scotland several rinks use temperature as their primary control and it works very well, but all these rinks are four-sheet rinks, while larger rinks are all adopting friction as their primary control. Why, when temperature has so many obvious advantages? Because it is not that simple – with curling ice nothing is ever that simple.

As with friction, it is best to look at the individual problems in some detail. Most of these will overlap to some degree, perhaps best understood by studying *Water In A Curling Rink*.

1. Accurate measurement of the ice-surface temperature is not easy. One instrument can give an IST reading of – 3.8ºC, while another can give an IST of – 4.5ºC. Which one is correct? The most accurate instruments in use are overhead infrared lasers, calibrated with the help of a computer, to the freezing temperature of water at 0ºC. They are expensive and not yet in common use, except for serious competition – the handheld lasers vary considerably and are not as easy to calibrate. A fixed probe on the ice surface works well, but it gets in the way of curlers and stones and can easily be affected by air movement. The best in use today are simple wire probes embedded in the ice, with the tip of the probe just barely beneath the ice surface, and the instrument itself some distance away out of harms way. Once the probe is installed, usually overnight to allow the water molecules to bond to it properly, it gives a very reliable reading relative to its position – it might not be an absolute reading, but it will display a rise or fall in temperature within 0.1ºC of its position. These probes are not easily affected by air movement, although a heavy foot over it will render the reading useless.
2. Once a reading has been established, it has to be maintained. Add heat to the roof space and, in time, some of this heat will reach the ice and be absorbed to affect the reading. The same goes for any other heat introduced, as by a full complement of curlers – one energetic curler will contribute as much as half a kilowatt of heat to the rink. So, if thirty-two curlers are playing, some 16kW of heat will be surplus, therefore 16kW less heat must be introduced by the heating system, usually in advance by some thirty minutes. Otherwise an extra 16kW has to be extracted through the floor, also usually thirty minutes in advance. If it is not done in advance the surplus heat can affect the ice surface, and it will.
3. The weather outside can be a nightmare, because changes usually go unnoticed from the inside. The wind could change from warm to cold, or east to south, and if the ice hall is not well insulated this will change the roof temperature. The sun can come out from behind a tree or a cloud and hit the roof, sending the RT soaring from a comfortable 20ºC to an unwanted 40ºC, and once the heat is in the building it will have to be removed.
4. The heat in the roof space is moved around through thermal activity and also deliberately by using circulation fans. Turbulence caused by movement of curlers also have an effect, causing an IST of – 4.5ºC to plummet to – 3.8ºC in a few minutes. A combination of these can cause a downdraught of warm air onto a certain small area of the ice and actually cause it to melt, as can the outlet of the ducting from the dehumidifier blasting its warm air in a given direction. Air movement within a curling rink is a very serious matter, because it moves the heat with it.
5. Condensation releases energy, while evaporation absorbs energy. Should the humidity fluctuate there will be changes in the IST simply because of these two processes, and fluctuations of as much as 1ºC have been recorded in seconds. The humidity has to be kept constant or, more scientifically, the dewpoint temperature has to be very accurately controlled to prevent this from happening – the best way to do this is to track the actual moisture content of the air (the g/kg bit) with wireless thermohygrometers in various positions. Over a few days or weeks the statistics will reveal the trends and how to adjust to them, and control of the moisture does become possible and surprisingly accurate.
6. Once the required parameters have been achieved, control becomes a gentle business. The slower the changes, the better the control. Get it wrong and try to extract heat quickly by running the compressors to their limit, and the texture of the ice surface changes from a lovely, silky smooth to a harsh, abrasive surface that totally confuses the stones and the players – it is so noticeable, the players will immediately know that something has changed. Similarly, should players start slipping and falling over, the technician will know immediately that the ice surface has become too warm. He will ask: why? Sudden condensation? Plant failure? Miscalculation? It is not a good feeling, because he is the only one who can do anything about it!
7. It is fortunate that there is a degree of safety within this method of control. Perfection is achievable in a good building by a good technician, but usually things are not so good. It is to their credit that competent curling-ice technicians can achieve control even in an asbestos barn with a sand floor and very poor equipment, regardless of the weather. As long as they can keep the heat down, the humidity low and the ice frozen they will tweak the system and find what works, and they will control the IST between – 4.2ºC and as warm as – 3.2ºC, the latter directly related to the amount of heat in the air. In that zone, the stones will curl well and the ice will be keen enough for very good curling.
8. This zone relates to naturally matured stones. When the stones are new, or newly refurbished, they will curl much more because friction will also come into play. As an experiment, a pair of stones was sent to Canada for refurbishment by their standards – these curled over ten foot, compared to

naturally matured stones curling four foot. Canadian ice is obviously very different! New stones from Kays curled some eight foot, but were straightened a little by running the ice colder by 0.5ºC until they were played in – a month later they were beginning to play like "normal". Once the zone is established, it is really quite easy to control the behaviour of stones simply by controlling the set parameters and adjusting the ice temperature, and a competent curling-ice technician can do this very well.

9. If the ideal IST for curling is – 3.8ºC, this is within 0.5ºC of too warm – under certain conditions this could be within 0.1ºC, which isn't very much at all. Simply cleaning the running band of a stone with a bare hand can warm up the area sufficiently to cause a problem: the stone will probably not reach the hogline, because the warmer temperature of the running band is causing the ice surface to melt too much in the MSMM/F event, creating too much of a lubrication wedge. Cleaning the stone with a brush or pad does not however cause the same problem.
10. Should the ice surface become too warm by as little as 0.1ºC, the stone will draw more than usual for the same reason. This can happen very suddenly, the one moment all is well and the next there's an extra two foot of draw. Usually this isn't a serious problem, but if it is allowed to continue the pebble will wear and the ice will become "flat", which is a serious problem that cannot be addressed until the game is concluded.
11. Should the IST not be controlled, all sorts of problems can occur. Too warm and the stones dive, too cold and they sail on with less draw – or a frost problem causes them to dive as well. It is not always possible to tell what is happening, so players speculate amongst themselves and the ice technician's reputation comes under scrutiny. The IST simply HAS to be controlled, and often ice technicians will simply run the ice colder and leave the curlers to their lot. This is the first stage of the spiral that leads to a need for friction and a pack of sand paper, something far too many technicians prefer simply because of their inability to control the IST.
12. Naturally matured stones do not do the same damage to pebble as stones with an aggressive running band. Generally speaking, if there is only a thin layer of amorphous ice to deal with, they do very little damage and two full games can be played on the same pebble. This means less work for the technician, less time wasted between games and a high degree of consistency throughout all games. This also means that smaller pebble can be applied, and the extra-fine pebble (0.45/65 or 77 head) has proved itself ideal. Again time can be saved, because the pebble can will hold enough water to pebble four sheets twice, saving time on the refill, and less clean water will be needed – deionised water costs money.
13. Also, with virtually no abrasion between stone and ice the stones too will last a very long time – once a stone is fully matured, it will maintain its drawing characteristics for many years. Provided the ice surface is kept clean of dust, fine grit and powder frost, the stones will be travelling on a thin film of water for most its life on the ice, which could be as long as twenty years! Because there is so little wear the stones only need to be matched when a problem develops, perhaps once a season, and their behaviour equalises to such an extent that rogue stones are easily spotted and dealt with. There is a consistency between naturally matured stones that cannot be replicated in any other way, and certainly not by refurbishment.
14. After a game in a full rink the IST will be around – 3.6ºC, which is a full degree warmer than the ice in a cold rink. At this temperature the ice is softer and easier to cut, and the cutter's blade will not be blunted so quickly – cutting ice at – 4.5ºC can blunt a blade within minutes. To the technician this is very important because the blades are nowadays ground to precision and finished to be as sharp as a razor, but once blunted they're useless until the next regrind. It is now common to warm up the ice overnight or in the morning for this reason, to be able to cut at an IST of about – 3ºC , which is much quicker and easier too. An added bonus if the extra-fine pebble is used is that there is much less to cut off, again saving time and blade, and the quality of the level of the ice pad is more controllable and greatly enhanced. The XF pebble can be cut down to the pad in five minutes per sheet, but in the cold rink with the larger pebble it will take at least twice as long and blunt the blade much faster. So, if the ice is at – 3.6ºC at the end of a game during a competition, the entire area of four sheets of ice can be resurfaced in half an hour, providing the best playing conditions for all games, and this is now becoming the norm.
15. By using an extra-fine pebble at the correct parameters, a very sensitive surface is created that will challenge any curler. Any flaw in delivery will not give the required result and even the sweeping will be raised to a new standard. This kind of ice provides a consistency and as high a standard as Olympic ice at its best, a joy to play on and as good a test of curling skill as can be created. This is the best curling ice there is, produced by science, practice, skill and hard work over many years of learning, with the highest "smile factor". Because it is not difficult to produce, once the essentials are mastered, it can be provided every day, for every game, for every player. But it cannot be bought in a shop, it has to be learnt the hard way.

Summary

There will always be advantages and disadvantages for two methods aiming to achieve a similar result. On the one hand a technician will be severely restricted in his options because of an inadequate building, inadequate equipment and a lack of knowledge; on the other hand a good ice technician will over the years learn how to change small things and turn the balance in his favour to produce better ice. If he goes down the friction road it might well be the only road open to him, while the temperature option could be the only road open to others. The fact remains that in an average smaller curling rink both options are open, but this becomes more complicated in a larger facility. The purpose of this report is not to decide how to run an arena, but investigate one aspect of how to run a curling rink properly and cost effectively for the enjoyment of its customers. What is clear is that friction does not work on warm ice and MSMM/F does not work on cold ice, forcing the technician to choose between the two – but is he simply choosing the one which suits him best, or does he look at the actual requirements of the game of curling?

The first requirement is **comfort**, both for the ice technicians and the curlers, and to be able to provide an air temperature of 7ºC heating will be needed. With a heat-exchange system installed in a facility where the plant will run at least six hours a day, the heat will be more or less free. Introduce more heat than is needed and the plant will run for longer to extract it, wasting a large amount of energy and defeating the argument. However, removing too much of the heating to save energy simply because the manager says so will reduce the comfort – asking a chef to half-cook the food to save on gas is not a good idea at all.

The next requirement is **consistency**, to provide a fair and constant playing field for the unique game we call curling. The specifications exist and technicians have to try and achieve the required result in draw and speed for every stone, and it is clear from the above that it is easier to achieve not by friction, but through accurate control of temperatures along with the other parameters. Those who are forced to use friction will simply have to work harder, but it doesn't mean it is the better way.

Overall **cost** is a factor too. Many technicians have no idea what their energy costs are and probably don't care, it is not their problem, but the best technicians WILL know and will be looking at every possible way of reducing cost. Spending money on refurbishing stones to save money on heating does not add up as sensible, and saving money on heating to pay for refurbishment is plain stupid. The fact, tried and tested and proven, is that it is easier and cheaper to run a curling rink properly through control of parameters, because it is less work, less wear and tear and much more pleasant for everyone – it is the smile factor that brings customers back through the door for more games of curling, and ultimately they pay the costs.

The biggest single requirement within a curling rink is **control** over the behaviour of the stones, not only for one game but for all games, year after year. This report clearly shows that with friction this is very difficult, but with temperature it is much, much easier. There will be those who argue that it doesn't matter, curlers will get used to it, it's the same for both sides, it's the nature of the game – curling is now an international precision sport that requires the very highest standard of ice and stones, and this must be provided. Already those who do so are prospering, while those who don't are not. Then there are those who hear about the new gadget they call the Nipper which will solve all their problems – a Nipper can help to finish the surface quickly before a game and can also contribute to the amount of draw, but it cannot solve the problems of friction versus temperature.

Finally, it is vital to remain aware of the unique properties of water, whether a gas, liquid or solid. At certain temperatures it behaves in certain ways and at a critical point – within 0.1ºC – it works at its best. By using these properties to their maximum advantage the game of curling is a joy to play and to watch, but break the laws of physics and it doesn't work so well. Why make it difficult when it really is quite simple.

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