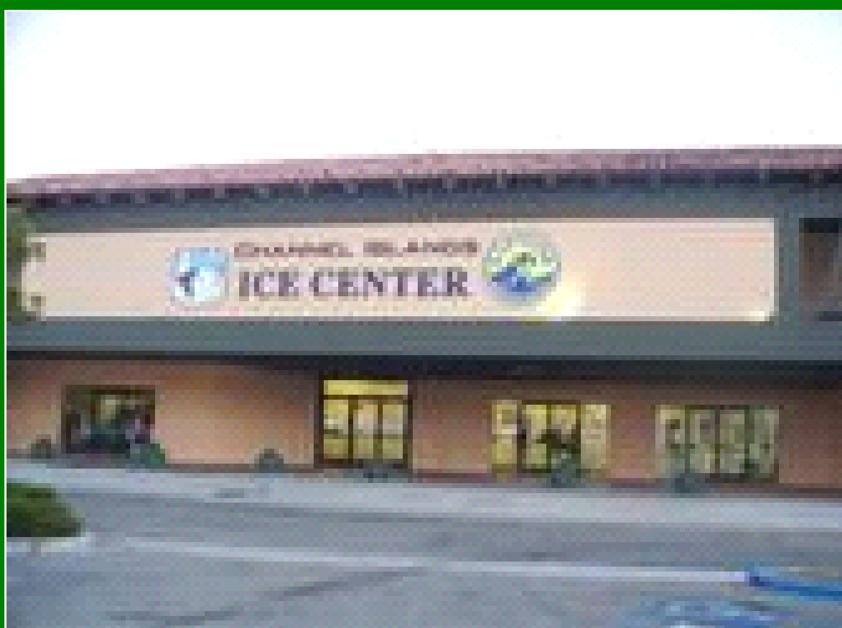
Ice Rink Vortex Water Treatment System Assessment

ET 09.07 Report



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December 22, 2010

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Acknowledgements

Southern California Edison's Design & Engineering Services (DES) group is responsible for this project. It was developed as part of Southern California Edison's Emerging Technology program under internal project number ET 09.07. DES' Charles Kim conducted this technology evaluation with overall guidance and management from Paul Delaney. Cypress, LTD. executed this project. For more information on this project, contact Charles.Kim@sce.com.

Disclaimer

ABBREVIATIONS AND ACRONYMS

° or Deg	Degree
Btu	British thermal unit
DES	Design and Engineering Services
F	Fahrenheit
Hr or hr	hour
IHL	Internal Heat Load
kW	Kilo-Watt
kWh	Kilo-Watt hour
MBtu	1,000 Btu
psi	Pound per square inch
SCE	Southern California Edison
T or Temp	Temperature

FIGURES

TABLES

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EXECUTIVE SUMMARY

Indoor ice rinks are used for many types of sports and recreational activities, including hockey, figure skating, speed skating, and basic ice skating. Depending upon the type of sports, demands for the ice quality vary widely. For example, hockey players like to have hard ice while figure skaters prefer soft ice. Furthermore, forming a good skating surface is not as simple as making a tray of ice. Freezing a rink correctly takes many steps, and ice that is the best quality for one sport may not be good enough for another. Beside the hardness of ice, water contaminants (such as minerals, chemicals, and dissolved air) affect the freezing temperature. Therefore, the water quality used to make the ice affects energy consumption in addition to ice quality[i].

The goal of this field assessment is to validate the potential energy savings by using treated water to make and maintain ice at the Channel Islands Ice Center located at 830 Wagon Wheel Road, Oxnard, California. The field assessment validates that treated water can:

- Provide electrical energy savings by reducing compressor run time for ice systems where the brine temperature of the ice system can change to enhance system operations. For the Channel Islands Ice Center, the annual electrical energy savings is approximately 4.6% or 21,076 kWh.
- Save natural gas by eliminating the need for hot water resurfacing. For the assessment site, the annual natural gas energy savings is up to 1,630 Therms; an added benefit of using treated water.
- Enhance the quality of ice. Based on ice hardness tests and survey results, the Realice ice quality did not deteriorate, and was considered better than previous water treatment methods.

This field assessment validates energy savings by treating ice rink water. However, it is imperative to note that accurate energy savings estimates must take into account many variables including: resurfacing frequency due to skate rink usage, occupancy variations, and temperature variations monitored over a three-month period.

In order to increase accuracy of estimating energy savings, this assessment recommends additional field-testing to include:

- Monitoring the facilities’ electricity consumption levels by comparing a year’s data of pre- treatment vs. a year’s data using the Realice water treatment system.
- Monitoring the flow rate of refrigerant and additional temperature monitoring of compressor systems.
- Comparing the freezing temperature, freezing time, and the hardness of ice of Realice water and tap water from the facility.

INTRODUCTION

Typical ice rinks use domestic water to build the ice. As a result, impurities and dissolved air are in the water and demand higher energy to freeze and to make ice less denser (e.g., there are micro bubbles inside of ice, therefore, it can be broken easily; more shaved ice on the surface after use). Thus, removing impurities and dissolved air from domestic water can save energy by allowing the water to transition into ice at a higher temperature. This concept could allow a chiller system to be operated at higher brine temperatures, which can reduce the overall compressor run time, and thus save energy.

According to ASHRAE's 2006 Refrigeration Handbook, it states:

> *Water quality affects energy consumption and ice quality. Water contaminants, such as minerals, organic matter, and dissolved air, can affect both the freezing temperature and the ice thickness necessary to provide satisfactory ice conditions. Proprietary treatment systems for arena floodwater are available. When these treatments are properly applied, they reduce or eliminate the effects of contaminants and improve ice conditions.*[2]

There is a wide range of technologies that can control compressor systems for building ice; however, a typical practice among ice rinks is simply deploying domestic water. Therefore, using the domestic water serves as the baseline[3]. The Channel Islands Ice Center's main driver for participating in this field assessment is reducing the energy usage without jeopardizing the quality of ice for their two ice rinks. Therefore, this project focuses on the feasibility of reducing energy consumption by removing impurities and dissolved air from the domestic water that builds ice without changing its quality.

There are many different ways to treat domestic water. Technologies based upon filters, reverse osmosis process, or membrane can treat domestic water; however, these technologies are not suitable for water delivery capacity or cost, for building or maintaining an ice rink. Currently, the vortex technology–based water treatment system is available in Europe that builds/maintains ice rinks. The Realice system, a vortex technology-based device, is designed to treat water for all types of ice rinks. Figure 1 illustrates the operation of the Realice system. When a stream of domestic water enters the vortex technology-based water treatment system, the "vortex generator" changes the fluid flow direction into a rapid swirling motion around a center called the "vortex." As the water swirls through a very tight coil of channels, its velocity increases rapidly. As a result, air bubbles and impurities are converged together around the vortex, and are separated from the water. The vacuum at the base of the "vortex generator" then rejects the converged air bubbles and impurities out of the water. Due to this separation of air bubbles and impurities from the water, treated water contains fewer air bubbles, which reduces the insulating capacity of the ice. Furthermore, the swirling action changes lime scale crystals from calcite to aragonite, entailing that they are no longer angular but round in shape and no longer attach themselves to other lime scale crystals or other surfaces. Therefore, the formation of lime scale deposits is avoided.

One of the benefits that this treated water provides is that it can be frozen at higher temperatures. This is possible because impurities and dissolved air acts like an insulator when the water changes to ice. Thus, removing impurities and dissolved air from the domestic water can save energy by allowing the water to change to ice at a higher temperature and faster. This concept allows the chiller system to operate at a higher brine temperature that can reduce the overall compressor run time, and save energy.

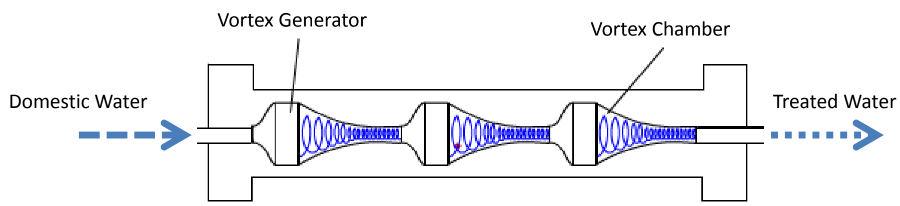


FIGURE 1. REALICE SYSTEM: A VORTEX TECHNOLOGY BASED WATER TREATMENT SYSTEM FOR ICE RINK

BACKGROUND

Years before hockey or the Winter Olympics, ice skating was a means of getting across the frozen waterways in northern Europe. It was only when ice became available year-round that sports such as hockey and figure skating took off.

The success of modern ice rinks owes a lot to Lester and Joe Patrick, two brothers who created hockey leagues in Canada in the early 1900s. On Christmas Day 1912, the brothers opened Canada's first indoor ice rink in Victoria, Canada. The arena cost $110,000 to build and seated 4,000 people. Three days later, the Patrick brothers opened another arena in Vancouver, Canada. This was a more expensive arena -- $210,000 to build -- and it could hold more than 10,000 people. Underneath the ice was the world's then-largest refrigeration and ice-making system.

Over the next few decades, the Patricks were responsible for creating arenas all across the northwest United States and throughout western Canada. Today, the United States has more than 1,700 ice rinks and new ones can cost hundreds of millions of dollars to build.

Today, indoor ice rinks are used for all sorts of sports and recreational activities, including hockey, figure skating and speed skating. In all of these sports the quality of the ice makes a big difference.

Forming a good skating surface isn't as simple as making a tray of ice cubes. Freezing a rink correctly takes no less than a dozen stages, with some stages laying ice that may be as thin as 1/32 of an inch (0.8 millimeters). Some layers require paint to create an attractive background and, in the case of hockey, provide clear markings. And ice that's best for one sport may be completely unacceptable for another.

The underlying technology behind indoor ice rinks is the same technology at work in refrigerators and air conditioners. The main difference in an ice rink, other than sheer size, is that the refrigerant does not cool the ice directly. Instead, it cools brine, a calcium-chloride solution that is pumped through an intricate system of pipes underneath the ice. The brine's chemical makeup keeps it from freezing. In most rinks, the pipes are embedded in a concrete or sand base.

This field assessment demonstrates energy savings by treating ice rink water using the vortex technology-based water treatment system, in this case Realice. However, it is imperative to note that accurate energy savings estimates must take into account many variables including: resurfacing frequency due to skate rink usage, occupancy variations, and temperature variations monitored over time. Figure 2 shows the configuration of a modern ice rink and its several layers[4].

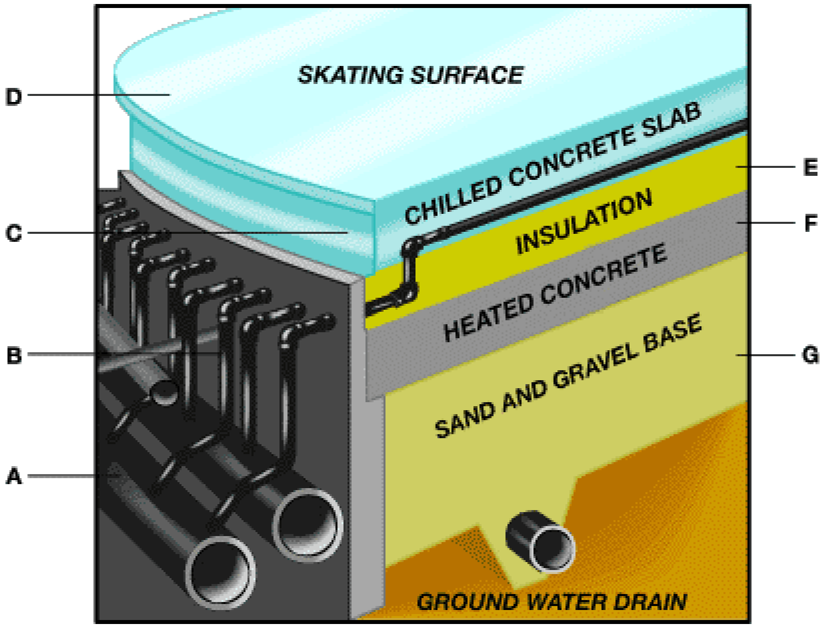


FIGURE 2. CONFIGURATION OF AN ICE RINK[5] NOTE: THE TEST SITE ICE RINK DOES NOT HAVE A CONCRETE SLAB

HOW IT WORKS WHEN THE RINK HAS A CONCRETE SLAB

The brine is pumped **(B)** into the pipes embedded in the ice-bearing concrete slab **(C)**. The ice-bearing slab sits between the skating surface **(D)** and a layer of insulation **(E)**, which allows the ice to expand and shrink as temperatures and time demand. The brine helps keep the ice-bearing slab's temperature just below 32° Fahrenheit (F) so that the water spread onto it can freeze.

Underneath the layer of insulation, a heated concrete layer **(F)** keeps the ground below the ice from freezing, expanding and cracking the rink structure. The entire rink sits on a base layer of gravel and sand **(G)** that has a groundwater drain at the bottom.

To defrost the skating surface, the brine is heated and pumped through the ice-bearing concrete slab. This heats the under layer of the ice, making it easier to break up and remove with front-end loaders.

THE ICE

Making an ice rink isn't as simple as flooding the floor with gallons of water. Water must be applied carefully and slowly, in order to ensure ideal thickness. An ice surface that is too thick requires more energy to keep frozen and is prone to getting soft on the top. A surface that is too thin is also dangerous because skaters risk cutting straight through the ice.

TEMPERATURE: GOOD ICE VS. BAD ICE

When creating a new ice surface, **indoor conditions** are very important. The **outdoor temperature** can also affect the ice conditions. The arena and ice temperatures must change to compensate for the heat and humidity that will come in when the arena doors are opened to skaters. Ice conditions can vary greatly with a temperature change as small as one degree. The type of water also can change conditions. For example, ice made with water that contains dissolved alkaline salts may have a sticky feel to it and will dull skate blades. To counteract these problems, many rinks use water purifiers or add chemical conditioners to tap water.

MAINTAINING THE RINK

No matter how well-groomed the ice rink, the ice will eventually be cut and pitted, and dust and bugs will dull it. The ability to quickly and effectively resurface the ice is as important to skating as the development of indoor ice itself.

ICE-RESURFACING MACHINES

Before ice-resurfacing machines, ice rinks were resurfaced manually, using scrapers, towels, a water hose and squeegees. Resurfacing a regulation-size rink was time-consuming and labor-intensive. In the 1940s, Frank Zamboni began to experiment with building machines that would shave, scrape, wash and squeegee the ice surface all at once before putting down a fresh layer of water. The Zamboni machine, at the final step, spreads clean hot water on the ice. The heated water is about 140°F to 145°F. The hot water can create a more even ice surface by melting the top ice layer when the Zamboni machine cuts across it.

EMERGING TECHNOLOGY/PRODUCT

The Realice device, shown in Figure 3, is intended to create a vortex as the water enters the device. The vortex increases the velocity of the water to promote the separation of dissolved air and impurities from the water source. This separation allows the water to be "air bubble free". One of the benefits that this "air bubble free" water provides is that it can be frozen at higher temperatures. This is possible because impurities and dissolved air acts like an insulator when the water changes to ice. Thus, removing impurities and dissolved air from the domestic water can save energy by allowing the water to change to ice at a higher temperature. This concept allows the chiller system to operate at a higher brine temperature that can reduce the overall compressor run time, and save energy. The manufacturer has indicated that the device may be able to allow the facility to raise the brine temperature by up to 4°F. The potential temperature rise is dependent on a number of variables such as ice rink makeup and size, location (e.g., climate zone), chiller system design, system age, building age, and occupancy rates of the ice center. The following are additional benefits, indicated by the manufacturer:

- Using the device allows the facility to use ambient temperature domestic water for resurfacing and to build new ice. The typical resurfacing, for example, requires the water to be heated.
- The device lowers the viscosity of the water thereby making the water out flow easy despite using ambient temperature of added water.

- The device changes the lime scale crystals from calcite to aragonite, which changes the overall shape of the crystals in the water supply. This affect avoids the formation of lime scale deposits in the ice.
- The device improves the ice quality to be denser, more even, and more durable under usage conditions.

FIGURE 3. REALICE RETROFIT DEVICE

Currently, the vortex technology-based water treatment system for ice rinks is new to U.S. customers. Like any new product, it needs "early adaptors" in order to transform the market. The early adaptors will likely face two financial barriers. The first barrier is the equipment cost (approximately $29,000 per system). The second barrier is in the implementation phase. The implementation phase requires closing the ice rink from anywhere between a few days to two weeks to remove the existing ice. This means the rink must be closed during the implementation phase. Then the creation of new ice is applied in several layers, over time. Therefore, the installation and implementation of this device can provide significant financial and operational impacts to the customer.

ASSESSMENT OBJECTIVES

This project seeks to find a viable way to improve energy savings by retrofitting a water treatment device used to build and resurface ice. Water contaminants such as minerals, chemicals, and dissolved air can affect the freezing temperature. The treated water, therefore, can save energy by allowing water to be frozen at a higher temperature over a shorter period of time. The goal of this field evaluation is to:

- Address the feasibility of this technology for ice rinks
- Assess the possibility of energy savings by increasing the brine temperature with treated water that creates the ice
- Validate if the system can allow the facility to use treated water at room temperature for resurfacing, and
- Check the quality of ice (e.g., hardness test).

TECHNOLOGY/PRODUCT EVALUATION

BASELINE TECHNOLOGY

Typically, an ice rink uses domestic water supplied by the local utility. The baseline technology for this field evaluation is the use of domestic water to build ice using the existing chiller system. The Channel Islands Ice Center used domestic water to make their ice prior to installing the vortex technology-based water treatment system.

NEW TECHNOLOGY: TREATED WATER FOR ICE

A Realice® water system was installed at the Channel Islands Ice Center to examine potential energy savings by monitoring changes in electrical energy consumption by the compressors. The Realice system, shown Figure 4, connects between the cold domestic water supply line and the faucet in the rear of the facility, and facilitates separating air bubbles and debris from the water supply,

FIGURE 4. INSTALLED REALICE SYSTEM

FACILITY OVERVIEW

At the Channel Islands facility, its characteristics and typical operation practices are:

- The facility uses domestic water directly from the local utility. No water-treatment system was installed prior to the Realice installation.
- The facility has two ice rinks – both are approximately the same size (about 14,000 square feet), but the rinks do vary in thickness (from 2.5" - 3"). One rink is typically used for ice hockey while the other is used primarily for open/figure skating.
- The facility has one over 15-year old chiller system that operates three compressors based on brine temperature. The chiller system provides cold brine to each rink. Since one rink is located further away from the system, that rink was determined to be the limiting factor for maximum temperature increase using the Realice system.

- There is no automated control system for the facility. The operation is strictly manual for controlling the brine temperature.
- There is no data collection available at the facility for the flow of brine, the supply temperature, and the only indication of return temperature is a digital display. At the time of the pre measurements, the brine temperature was set at 19°F.
- While there is an occupancy schedule produced weekly, the schedule is not consistent, and open times allow for substantial variation in occupancy between the two rinks depending upon various programs (such as little league hockey practice schedules and games).
- The facility has a tankless water heater. From discussions with facility personnel, hot water resurfacing has been used sporadically, but typically, the facility already resurfaces the ice rinks with ambient temperature domestic water.

TEST METHODOLOGY

By reducing ice-freezing time, or raising the brine temperature to maintain the same quality of ice, energy savings are achieved because of reduced compressor/chiller system run time. If the brine temperature is increased, the result is a reduction in overall compressor run time to freeze the same quantity of ice.

In general, the overall actual run time and energy consumption are very dependent on a number of variables such as climate zones, frequency of ice resurfacing, occupancy, rink air temperature and humidity, ceiling radiation, lighting radiation and ground heat.. Given consistent variable input, however, the overall result of the device is to reduce the compressor run time in hours thus reducing energy. On the other hand, the peak demand cannot be reduced with the installation of the Realice system, as the compress run time will be longer than 15 minutes regardless of Realice.

Reduced hot water energy, if applicable, is due to ambient temperature domestic water resurfacing instead of using heated water. This energy is typically comes from gas consumption using a traditional boiler or water heater.

FIELD TESTING OF TECHNOLOGY

TEST PLAN

The project entailed a number of steps that were necessary to establish the baseline and post installation conditions for estimating an overall energy savings, as follows.

Step 1: Physical assessment of the facility - A physical assessment of the facility and operation is completed. This provides the basis for establishing the overall method used to determine the best method of reasonable savings calculations. The test ice rinks produced the following observations:

- The facility has no automated control for the chiller/compressor system.
- The only indicator at the chiller/compressor system is the brine temperature.
- The chiller/compressor system is 15 years old.

Step 2: Establish methodology for savings assessment and monitoring variables – Step 1 is the bases for the following test methodology, since the Channel Island facility only has manual controls:

- Service entrance and chiller/compressor energy consumption is monitored for the pre and post periods.
- Outdoor air temperature at the cooling tower is monitored for both the pre and post periods. Since the cooling tower heat rejection is proportional to outdoor air temperature this can be used for a regression analysis, relating temperature variations to the energy usage.

- To eliminate any anomalies, monitoring of the indoor temperature at each rink occurred. Temperature monitoring validates whether internal heat loads varied significantly between the pre and post conditions and any failures of ice rink system.

Step 3: Monitor baseline data – This step establishes the baseline (or pre condition) monitoring. The brine temperature is maintained manually (setting only, the actual temperature of the brine varies over time depending on load) at 19°F. The monitoring period is between March 5, 2010 and April 14, 2010. The ice rink opens at 9:00 a.m. The closing time is different on each day of the week; however, it remained constant during the evaluation period.

Step 4: Test ice quality parameters for baseline conditions – Using a Schmidt hammer, the ice quality of pre-condition is measured by testing the ice's surface strength. Although not designed to measure the lower surface strength of ice accurately, this device allows a comparative test between pre and post.

Step 5: Install Realice system – Installed the Realice system between the faucet and the water pipeline in the Zamboni room. This is the area where domestic water is injected into the Zamboni for resurfacing.

Step 6: De-ice rinks and lay new ice with treated water - The owner supports replacing the existing ice with Realice-treated water to conduct the post condition measurements. The existing ice was removed (shaved down using the Zamboni), and rebuilt several layers of new ice using Realice-treated water. The ice rink is closed during this process, about two weeks.

Step 7: Stabilize ice conditions with treated water - The facility management team tested the quality of the new ice over a 24-hour period and accepted the results and reopened the rink.

Step 8: Raise brine temperature on established schedule by set amounts, and establish maximum increase in brine settings - The facility management team increased the brine temperature by 1°F every two to three days until the ice started to deteriorate. The temperature setting was returned to the previous setting where the ice condition was deemed acceptable. The new brine temperature was 21°F; a 2°F increase from the previous condition.

Step 9: Monitor post condition data - With the new ice (i.e., ice with treated water) in place, post monitoring of the same inputs were conducted between June and August of 2010. The operating hours remained the same.

Step 10: Test ice quality parameters for post conditions - The ice quality of pre-condition was measured by testing surface strength on contact using a Schmidt hammer at the same locations as the pre-condition.

Step 11: Complete data analysis - In addition to the test plan described above, this assessment followed the International Performance Measurement & Verification Protocol.

INSTRUMENTATION PLAN

PowerSight PS2500 is a power-quality measurement device that complies with IEC 61010-1 (2000). Its accuracy level is ±0.5% margin of error. The probe selected is an eFX6000 that complies with EMC EN61326-2-2:2006. Its accuracy level is less than a 3% margin of error. Temperature measurements were taken using the OnSet U10 data logger. All measurements were taken in 15-minute intervals.

The instrumentation calibrations are up to date.

ERROR ANALYSIS

Error analysis for such accurate meters and probes are not necessary when the collected data is from a few number of independent variables. For example, if a variable kW is dependant upon two independent variables (voltage “V” and current “I”), then calculating the error in kW is simply:

$$\left(\frac{\Delta kW}{kW}\right) = \sqrt{\left(\frac{\Delta V}{V}\right)^2 + \left(\frac{\Delta I}{I}\right)^2}$$

Therefore, the most inaccurate sensors drive the error in kWs. In this case, it is the current probe. Its accuracy level is 3%, which implies that the kW error is less than 3.1%.

RESULTS

DATA ANALYSIS

Due to the nature of random variables (i.e., daily occupancy use in and out of the ice rink) and monitoring, controllable variables cannot be measured cost effectively. This assessment makes the following assumptions prior to run analysis.

- Internal Heat Load (IHL) is consistent between the pre and post data-collection periods. In other words, the variation in heat load that can affect chiller efficiency is constant from pre to post conditions. The chiller/compressor system loading is consistent between pre and post periods for internal heat load and serves no load other than the refrigerant.
- Ice Thickness – variations in ice thickness are negligible.
- Changes in refrigerant flow – are consistent and therefore not included in the assessment in chiller/compressor power calculations.
- Changes in temperatures – are consistent with the changes in outside air temperature. While other factors affect the overall temperature variations and therefore no real direct correlation is calculated between inside air temperature vs. outside air temperature.
- Changes in outside air temperature – this is the swing variable in the analysis to determine the chiller energy usage for specific outside temperature readings.

Other variables not monitored can affect the performance of the compressor run time as well. In general, however, there is a relationship between the ambient temperature and the total power of the chiller/compressor system that is monitored, see Figure 5 and Figure 6.

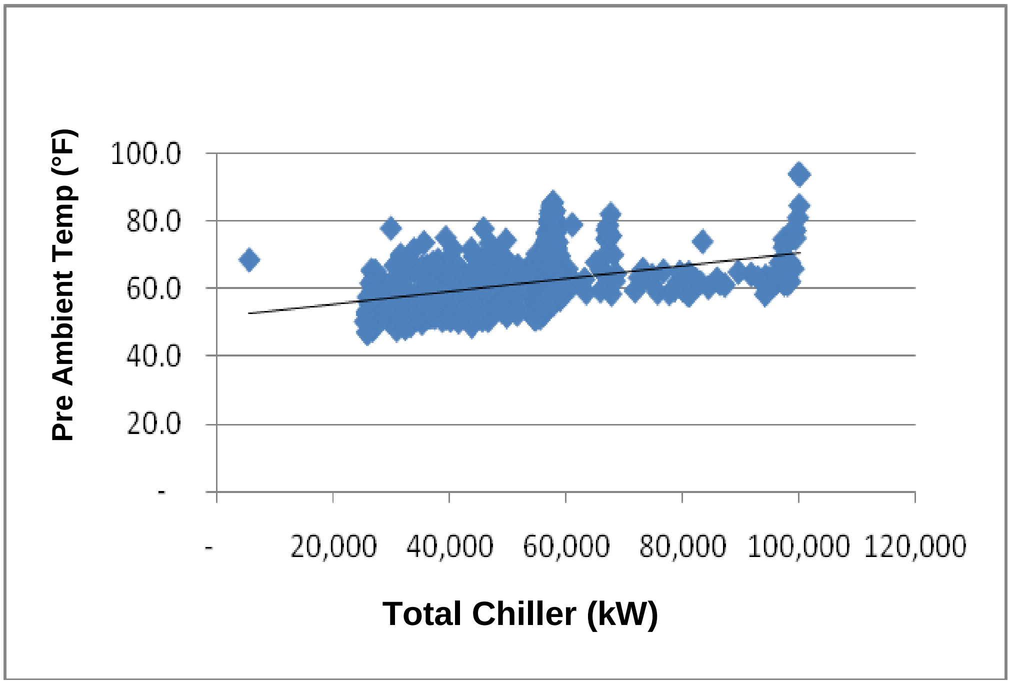


FIGURE 5. PRE CONDITION: AMBIENT TEMPERATURE VS TOTAL CHILLER/COMPRESSOR POWER

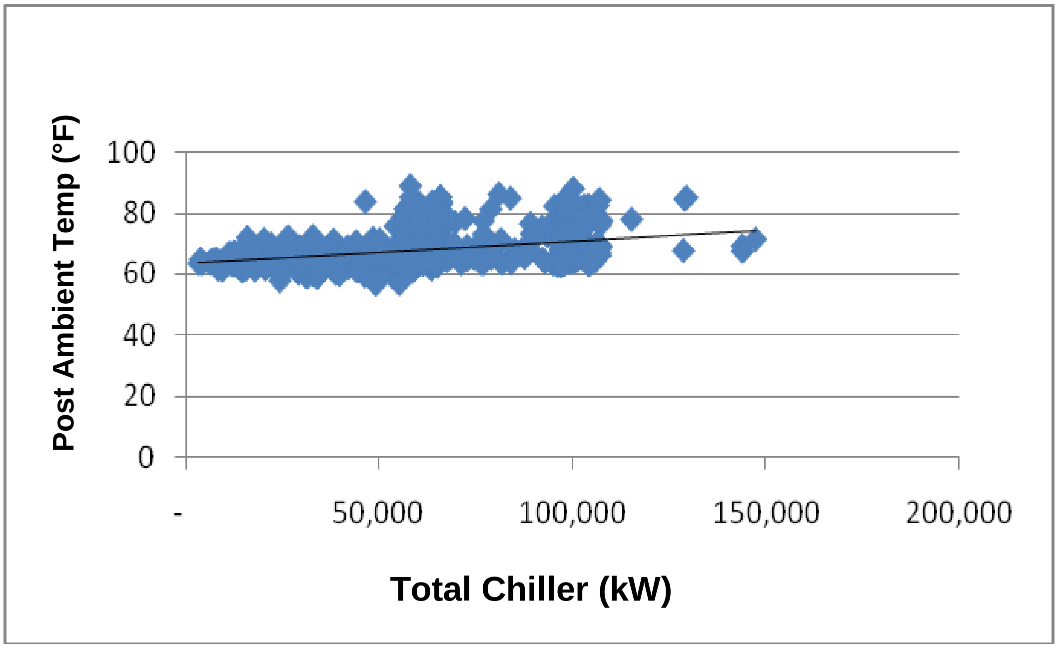


FIGURE 6. POST CONDITION: AMBIENT TEMPERATURE VS TOTAL CHILLER/COMPRESSOR POWER

It is important to note:

- While the chart shows a different slope in terms of the total kW measured versus the outside air temperature (trend lines), this does not tell how many compressors are on line at each point collected. In other words, the other variables would certainly affect the conditions on the "total" kW measured. For example, at a given temperature two compressors can be running while only one compressor runs on the other day(s). This variation is taken into account by assessing how many compressors are on at any one particular hour.
- The chart does illustrate a general trend in terms of total kW and outside air temperature – this implies that higher outside air temperatures require more kW per compressor or chiller.

DETERMINING THE KW PER COMPRESSOR TO USE

In order to have an effective analysis, the kW for each compressor to input must first be established; this provides a consistent base for the analysis to compare the pre and post conditions. The methodology taken is as follows:

- For purposes of establishing a consistent number, the pre data is used to establish the kW per compressor values to be used.
- The pre data is sorted by total kW monitored.
- At the initial installation, a spot measurement of one (1) compressor operating is taken to determine a general level of kW at that particular point in time.
- The pre data is then sorted to determine when another compressor is on line. For example, the spot data showed that one compressor used about 28 kW. The pre data can indicate a large jump from say 28 kW to 56 kW when the second compressor comes on line. The data showed that one compressor at a higher temperature actually was running at 33 kW. Clearly, this is below two compressors and therefore due to part load efficiency changes causing the need for more kW for output.
- This data is then analyzed to determine the approximate kW needed for each chiller at specific temperature intervals.

  Table 1 summarizes the results of the above analysis.

TABLE 1. SUMMARY OF KW PER COMPRESSOR

Temp Range	KW/Compressor
< 60 Deg F	25.98
60-70 Deg F	27.80
70-80 Deg F	28.16
80-90 Deg F	29.01
>90 Deg F	33.41

This is the relationship between outside air temperature and the overall kW per compressor based on collected data used for analysis. This overall relationship takes into account that the other variables are not measured. It should be noted that the kW/compressor is the average over the range of temperatures indicated. This type of analysis is known as BIN analysis where temperatures are grouped into "bins" of specific temperature ranges and averaged for purposes of savings calculations. This method is accepted in the energy field as appropriate for this type of application.

DETERMINING THE NUMBER OF COMPRESSORS ON LINE

The next step in the analysis is to determine the pre and post data-collection period, and the number of compressors on line each hour of the day. This is accomplished by assessing the kW/compressor range and applying it to the monitored data. Table 2 shows a one-day assessment of the kW/compressor.

TABLE 2. EXAMPLE OF kW PER COMPRESSOR FOR ONE DAY

* Date	Time	Comp Hr	Chillers On (1,2,	KW/Chille
3/5/2010	0:45:00	55,488	2	27,744.00
3/5/2010	1:45:00	55,219	2	27,609.60
3/5/2010	2:45:00	54,618	2	27,308.80
3/5/2010	3:45:00	54,541	2	27,270.40
3/5/2010	4:45:00	49,947	2	24,973.60
3/5/2010	5:45:00	35,363	2	17,681.60
3/5/2010	6:45:00	33,382	1	33,382.40
3/5/2010	7:45:00	25,510	1	25,510.40
3/5/2010	8:45:00	31,667	1	31,667.20
3/5/2010	9:45:00	27,762	1	27,761.60
3/5/2010	10:45:00	26,466	1	26,465.60
3/5/2010	11:45:00	31,947	1	31,947.20
3/5/2010	12:45:00	46,230	2	23,115.20
3/5/2010	13:45:00	49,862	2	24,931.20
3/5/2010	14:45:00	51,114	2	25,556.80
3/5/2010	15:45:00	45,986	2	22,992.80
3/5/2010	16:45:00	55,898	2	27,948.80
3/5/2010	17:45:00	55,770	2	27,884.80
3/5/2010	18:45:00	55,667	2	27,833.60
3/5/2010	19:45:00	55,872	2	27,936.00
3/5/2010	20:45:00	56,141	2	28,070.40
3/5/2010	21:45:00	56,282	2	28,140.80
3/5/2010	22:45:00	56,243	2	28,121.60
3/5/2010	23:45:00	56,448	2	28,224.00

ESTABLISHING A DAILY LOAD PROFILE

Once the number of compressors per hour on line is established, and the average temperature for that hour is also a known quantity, the analysis created a daily load profile that shows the number of compressors on line per hour each day per temperature. The Figure 7 shows the pre and post data for this assessment:

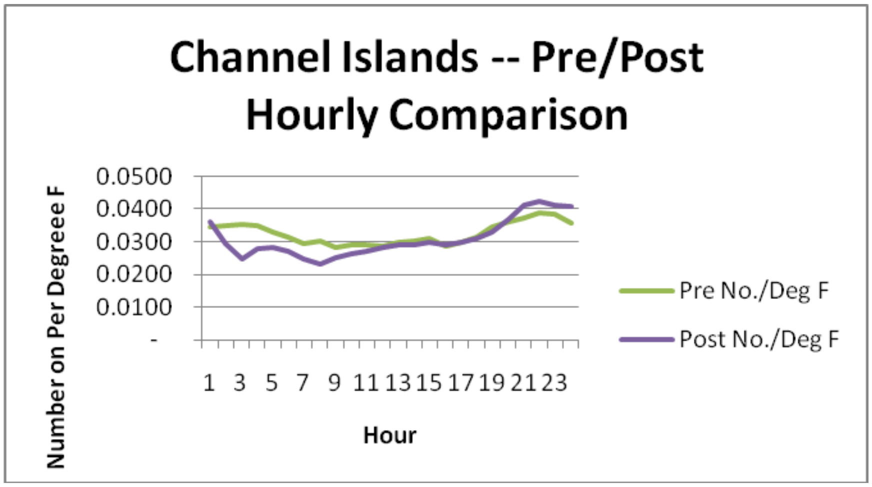


FIGURE 7. PRE AND POST COMPRESSORS/DEG F COMPARISON

Figure 7 illustrates that on average for hours between 2:00 a.m. and 3 p.m. the vortex technology based water treatment system requires less kWh because of less run time per compressor. For hours between 3:00 p.m. to 7:00 p.m., the vortex technology based water treatment system does not provide less compressor run time, and there are a few hours where the new system actually decreases the overall savings because of increased run time. This is because the brine temperature is increased to 21°F for the post condition.

ESTABLISH AN ANNUAL PROJECTION

The assessment to this point has clearly identified the hourly load profile for the facility in terms of number of compressors per °F for each hour. The next step is to establish the temperature for each hour during a given year. For this assessment, the actual weather data[6] was obtained for each hour of year 2009. Applying results, displayed in Table 1 and Table 2, hourly kWh can be calculated for both pre and post conditions. Table 3 shows one day in the year using this method.

TABLE 3. EXAMPLE OF CALCULATING HOURLY KWH

Date	Time	Temp	Hourly Pre	Hourly Post	Pre Hr * Temp	Post HR * Temp	KW for Temp	Pre KW	Post KW
2/1/2009	0:00:00	48.00	0.03448964	0.036171981	1.66	1.74	25.98	43.02	45.12
2/1/2009	1:00:00	48.90	0.035033983	0.029298085	1.71	1.43	25.98	44.52	37.23
2/1/2009	2:00:00	48.00	0.035200939	0.024842676	1.69	1.19	25.98	43.91	30.99
2/1/2009	3:00:00	46.90	0.035026418	0.027977328	1.64	1.31	25.98	42.69	34.10
2/1/2009	4:00:00	48.90	0.033065716	0.028256253	1.62	1.38	25.98	42.02	35.90
2/1/2009	5:00:00	48.00	0.031332043	0.027268142	1.50	1.31	25.98	39.08	34.01
2/1/2009	6:00:00	46.00	0.029285534	0.024753966	1.35	1.14	25.98	35.01	29.59
2/1/2009	7:00:00	46.00	0.030132869	0.023021405	1.39	1.06	25.98	36.02	27.52
2/1/2009	8:00:00	48.90	0.028146338	0.025148119	1.38	1.23	25.98	35.76	31.95
2/1/2009	9:00:00	55.00	0.029173816	0.026178093	1.60	1.44	25.98	41.69	37.41
2/1/2009	10:00:00	57.90	0.028965798	0.027056438	1.68	1.57	25.98	43.58	40.71
2/1/2009	11:00:00	57.90	0.028635386	0.028232861	1.66	1.63	25.98	43.08	42.48
2/1/2009	12:00:00	60.10	0.029675217	0.028975052	1.78	1.74	27.80	49.57	48.40
2/1/2009	13:00:00	59.00	0.030271588	0.029161216	1.79	1.72	25.98	46.41	44.71
2/1/2009	14:00:00	60.10	0.030887881	0.029655131	1.86	1.78	27.80	51.60	49.54
2/1/2009	15:00:00	59.00	0.028613643	0.029031353	1.69	1.71	25.98	43.87	44.51
2/1/2009	16:00:00	59.00	0.029943056	0.02971842	1.77	1.75	25.98	45.91	45.56
2/1/2009	17:00:00	57.00	0.031405377	0.030880669	1.79	1.76	25.98	46.52	45.74
2/1/2009	18:00:00	54.00	0.034345089	0.032897182	1.85	1.78	25.98	48.19	46.16
2/1/2009	19:00:00	53.10	0.035970984	0.036919215	1.91	1.96	25.98	49.63	50.94
2/1/2009	20:00:00	52.00	0.037429279	0.041337718	1.95	2.15	25.98	50.57	55.86
2/1/2009	21:00:00	51.10	0.038924627	0.042476284	1.99	2.17	25.98	51.69	56.40
2/1/2009	22:00:00	48.90	0.038375946	0.041149995	1.88	2.01	25.98	48.76	52.29
2/1/2009	23:00:00	50.00	0.035621416	0.040860901	1.78	2.04	25.98	46.28	53.09

The calculated data for pre and post condition is summed for the entire year, and the output is shown in Table 4 as the estimated annual KWH savings using the vortex technology based water treatment system.

TABLE 4. SUMMARY OF FIELD ASSESSMENT RESULTS

Real Ice -- Savings Summary		
Description	**Value**	**Units**
Electrical Energy Summary		
Annual Compressor Energy w/o Real Ice	455,310	KWH
Annual Compressor Energy w/Real Ice	434,235	KWH
Annual Energy Savings	21,076	KWH
Rate Used	$ 0.14	$/KWH
Annual Electrical Savings ($)	$ 2,951	
Annual Electrical Savings (%)	4.6%	
Natural Gas Potential Savings Summary		
Tankless Heater -- Annual Therm Savings	1,631	Therm
Tank Type Heater -- Annual Therm Savings	3,731	Therm
Tankless Heater -- Annual $ Savings	$ 1,794	
Tank Type Heater -- Annual $ Savings	$ 4,104	

GAS ENERGY SAVINGS

The gas energy savings (i.e., using ambient temperature water instead of heated water) is based upon the following conditions:

- Two resurfacing machines (Zamboni)
- Each resurfacing machine holds 75 gallons of hot water
- The rinks are resurfaced eight times per day, on average
- The rinks are resurfaced 7 days per week
- The resurfacing is completed for 50 weeks a year (2 weeks downtime per rink).
- The machines use 60% of the holding capacity on average for each resurface. The remaining 40% is either used for the next resurfacing or discharged
- The supply temperature in Oxnard is 60°F.
- The needed hot water temperature is 140°F
- The heater efficiency is 87% if a tank type is used and 97% if a tankless heater is used.
- Tank losses are assumed to be based on a 3°F temperature change between the tank and the ambient air temperature
- The rate assumption is $1.10 per therm.

Using the tankless water heart, approximately, 1,630 Therms of gas energy can be saved, see Table 5.

TABLE 5. GAS SAVING RESULTS

Input Assumptions

Description	Quantity	Units
Annual Volume of Water Required		
No. Of Resurfacing Machines	2	No. Machines
Gallons/Machine	75	Gallons/Machine
No. Resurfaces per day	8	Resurface/Day
Days/Week	7	Days/Week
Weeks/Year	50	Weeks/Yr
Average % of Volume Used per Resurface	60%	
Calculated Annual Volume of Water Required	252,000	Gallons/Yr

Description	Quantity	Units
Water Assumptions		
Supply Temperature of Water	60	Deg F
Heated Temperature of Water	140	Deg F
Heater Efficiency (Tankless)	97%	
Heater Efficiency (Tank Type)	87%	
Delta T (Tank/Ambient -- Tankless)	-	Deg F
Delta T (Tank/Ambient -- Tank Type)	3	Deg F
Heat Loss		

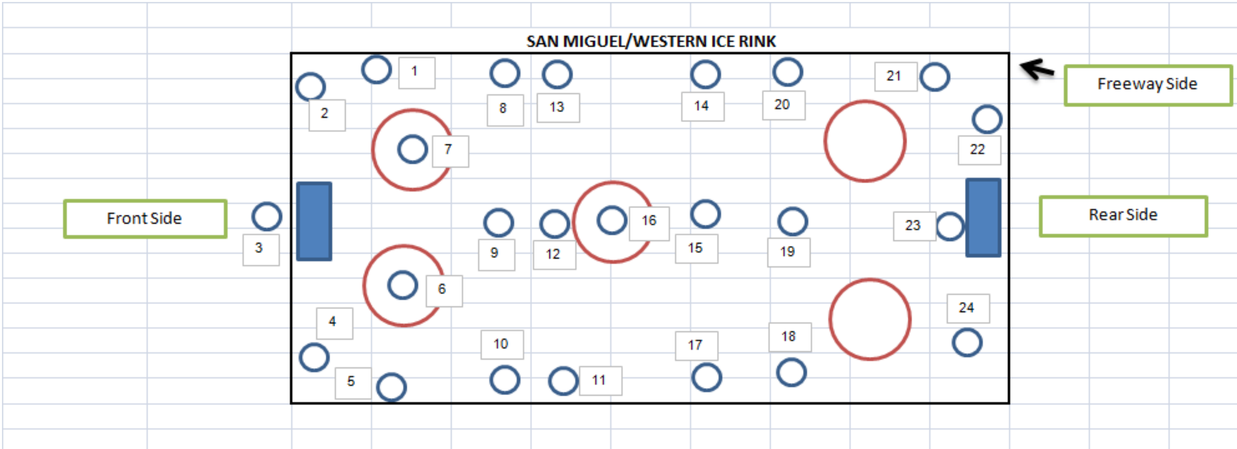
Equations:	
Heating Requirements	Volume X 8.34 X Delta T/Eff
Supply Loss	Volume X Heat Loss (%) X Delta T

Tankless Water Heater -- Calculated Savings		
Heating Requirements Savings	163,090.37	MBTU
Heating Requirements Savings	1,630.90	Therms
Tank Loss	0	Therms
Total Savings	1,630.90	Therms
Rate	$ 1.10	$/Therm
Savings	$ 1,794	

Tank Water Heater -- Calculated Savings		
Heating Requirements Savings	146,276.93	MBTU
Heating Requirements Savings	1,462.77	Therms
Tank Loss	2,268	Therms
Total Savings	3,730.77	Therms
Rate	$ 1.10	$/Therm
Savings	$ 4,104	

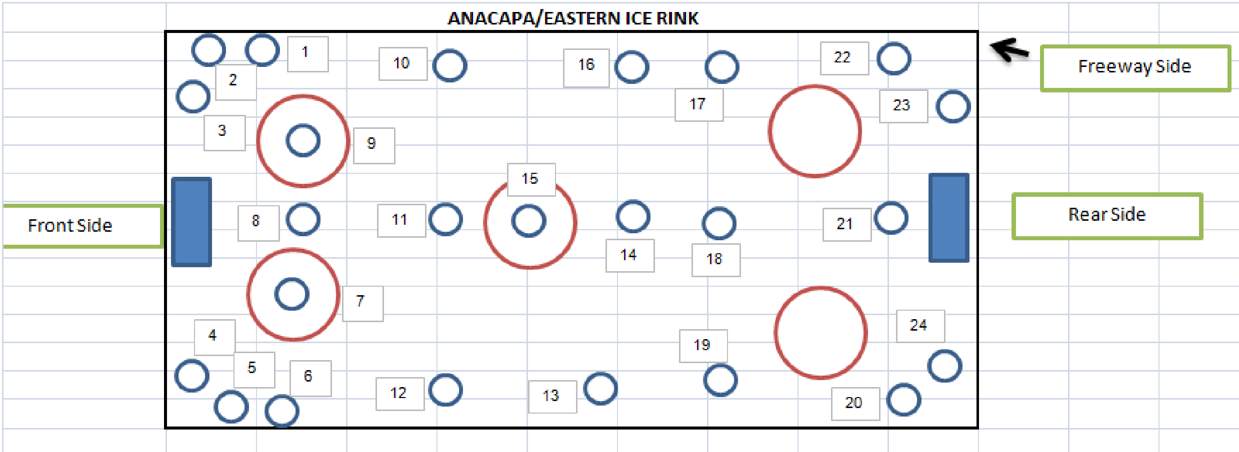
ICE QUALITY TESTING

The premise of the evaluation is that the ice would be of equal or better quality upon installation of the vortex technology based water treatment system. The ice quality of pre condition is measured by testing surface strength of contact using a Schmidt Hammer. While this device is not designed to measure the lower surface strength of ice accurately, this device allows a comparative test between pre and post conditions. Figure 8 and Figure 9 illustrate the ice quality testing results in terms of ice surface strengths.



Pre Readings				Post Readings				% Change			
Number	Reading	Number	Reading	Number	Reading	Number	Reading	Number	Reading	Number	Reading
1	10	13	12	1	16	13	16	1	160%	13	133%
2	10	14	14	2	16	14	16	2	160%	14	114%
3	13.5	15	10	3	15	15	16	3	111%	15	160%
4	12.5	16	16	4	16	16	18	4	128%	16	113%
5	10.5	17	12.5	5	16	17	16	5	152%	17	128%
6	13	18	12	6	18	18	18	6	138%	18	150%
7	10	19	10	7	16	19	16	7	160%	19	160%
8	11.5	20	12	8	16	20	16	8	139%	20	133%
9	12.5	21	10	9	16	21	18	9	128%	21	180%
10	12.5	22	13.5	10	16	22	16	10	128%	22	119%
11	13	23	10	11	16	23	16	11	123%	23	160%
12	10	24	13	12	18	24	16	12	180%	24	123%
Pre Deviation				Post Deviation							
Max	16			Max	18						
Min	10			Min	15						
Avg	11.8333			Avg	16.375						
Deviation	51%			Deviation	18%						

FIGURE 8. ICE QUALITY TESTING RESULTS FOR SAN MIGUEL ICE RINK OF THE TESTING SITE



Pre Readings				Post Readings				% Change			
Number	Reading	Number	Reading	Number	Reading	Number	Reading	Number	Reading	Number	Reading
1	12	13	11.5	1	18	13	18	1	150%	13	157%
2	12.5	14	14	2	15	14	16	2	120%	14	114%
3	11	15	12.5	3	18	15	18	3	164%	15	144%
4	11	16	12	4	15	16	16	4	136%	16	133%
5	10	17	11	5	16	17	18	5	160%	17	164%
6	11.5	18	11.5	6	15	18	16	6	130%	18	139%
7	11	19	11.5	7	18	19	16	7	164%	19	139%
8	11	20	10	8	16	20	16	8	145%	20	160%
9	11	21	10	9	18	21	18	9	164%	21	180%
10	12.5	22	10	10	16	22	16	10	128%	22	160%
11	13	23	10.5	11	18	23	16	11	138%	23	152%
12	12	24	12	12	16	24	16	12	133%	24	133%
Pre Deviation				Post Deviation							
Max	14			Max	18						
Min	10			Min	15						
Avg	11.4583			Avg	16.625						
Deviation	35%			Deviation	18%						

FIGURE 9. ICE QUALITY TESTING RESULTS FOR ANACAPA RINK OF THE TESTING SITE

Specific items of note for this assessment are:

- A reading on the Schmidt Hammer® corresponds to an approximate strength of 1500 psi. It does not provide a relationship curve below a reading of 20 and below. This is the main reason that the test should only be used on a comparative basis.
- The conclusion is that the rebound numbers are as good or better after the installation of the vortex technology based water treatment system, which meets the intent of the M & V process.
- The overall uniformity of ice strength is much better after the installation of the vortex technology based water treatment system.

EVALUATIONS

The field assessment demonstrated that it is feasible to save energy by treating water (e.g., removing resolved air) which allows the water to be frozen at a higher temperature. Overall, the estimated energy saving is 4.6% or 21,076 kWh for the testing site. To take a full advantage of increased brine temperature of 2 °F, the ice rink needs to have automated compressor controls. The advanced automated controller can provide consistent ice conditions and can controlled the compressor time in a way that the compressor can run harder during the off peak periods.

In addition to the electrical energy savings, there are also gas energy savings. This occurs in cases where the vortex technology based water treatment system allows the rink to use ambient temperature domestic water for resurfacing. Lastly, there also seems to be an increase in the quality of ice (or increase ice surface strength) produced.

Currently, the vortex technology based water treatment system is new to the U.S. customers. Like any new products, it needs "early adaptors.[7]" in order to transform the market. The early adaptors will face financial barriers. The first barrier is the equipment cost (approximately $29,000 per system). The second barrier is coming from the implementation phase. The implementation of this system requires closing the ice rink for anywhere between a few days to two weeks, in order to remove the existing ice. The new ice then needs to be created in several layers. Therefore, the installation of this device can provide significant financial and operational impacts to the customer.

RECOMMENDATIONS

The field assessment demonstrated the feasibility of energy savings using a vortex technology-based water treatment system. However, the accurate measurement and attribution of energy savings were challenging due to the number of variables involved in this assessment. Further testing, both field and lab are highly recommended in order to establish better energy savings estimates:

- More field tests should be conducted and the flow rate of refrigerant and additional brine temperature monitoring of compressor systems (e.g., refrigerant temperature before and after the condenser)
- Historical (one year) customer billing data, showing the customer's electricity consumptions at the facility level, will allow a better comparison for pre and post treatment energy usage, which can give an indication of energy savings.
- Conduct a laboratory test to compare the freezing temperature, freezing time, and the hardness of ice using water treated with the Realice system and tap water from the facility.

Because the device appears to reduce contaminants and reduce air within the water stream, there is a potential for the vortex technology based water treatment system to be applied to other applications such as preventing hard water scales build up from water heaters, dishwasher, cloth washer, various water pipelines that could yield energy savings by reducing flow resistance.

REFERENCES

[i] ASHRAE, 2006 ASHRAE Handbook—Refrigeration, p. 35.10

[2] id, p. 35.10

[3] A "pre-condition" word is be used interchangeably thought out the document

[4] The test site, like many ice rinks within SCE's service territory, does not have heated concrete, insulation or chilled concrete slabs beneath the ice like modernized ice rinks do.

[5] HowStuffWorks.com – Ice Rinks

[6] Weather Underground data www.weatherunderground.com, 2009 Oxnard Airport

[7] A group in the "diffusion" business model. Diffusion is the process by which a new idea or new product is accepted by the market