



# RECOMMISSIONING GUIDE FOR INDOOR PUBLIC POOL FACILITIES IN MINNESOTA

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## SUMMARY

### Purpose

This guide outlines for you as a recommissioning provider the most important energy saving measures that should be investigated for every indoor public pool facility in Minnesota. It outlines 17 operational checks that identify no cost, low cost, and moderate cost changes that can be made without major equipment upgrades. It also points out a few situations where more expertise and/or a little higher investment might be required to take advantage of an energy cost saving opportunity or solve a problem. The recommended actions are conservative to ensure that pool and space conditions are not negatively impacted.

This guide would ideally be applied with the support of a utility-funded Conservation Improvement Program (CIP). Some of the measures addressed are eligible for traditional utility equipment rebates (e.g. the installation of a variable speed drive on the pool pump), while many other items may be rebated through utility recommissioning programs (e.g. fixing a control programming issue that causes excess energy use), a behavior change program, or other progressive program design.

### Scope

The focus of this guide is on energy saving measures that require no or moderate capital cost, and which are appropriate for Minnesota's climate. It is not intended to systematically address water quality, air quality, or moisture condensation issues. It does not address all upgrades that might be possible as part of major upgrades or replacement of equipment.

In addition, this guide does not fully address water side operations related to water filtration and treatment that can impact energy use. This specialty subject is already addressed by numerous other resources, including the pool operators manuals listed on the next page.

### How to Use the Guide

While a one-time use of portions of this guide can yield energy savings, you will most effectively achieve long-term energy savings, comfort and minimal moisture condensation issues if:

- all applicable checks are conducted for a facility, and
- data is collected over the typical range of operating conditions—especially seasonal outdoor temperature variations and major variations in the pool activities schedule.

While each measure is individually worthwhile and written as a stand-alone item, there is a level of interdependence that makes completion of all applicable items significantly more effective. It is recommended that you follow these steps:

1. Systematically go through the guide to determine the applicability of each item for the facility being investigated.
2. Conduct all applicable measurements at a range of outdoor temperatures.
3. Follow through on the energy cost saving actions.
4. Confirm successful operation after the implementation of measures, and take any subsequent corrective action required.
5. Provide operations staff with clear and adequate documentation and

instruction regarding the improvement measures.

The checklist on the following page gives a summary of measures to be addressed in a pool recommissioning study. A summary of each of these measures appears in the Individual Measures section of this guide. The “Detail” column in the table also notes where more detailed information is available for

many of the items. Some specific measures have detailed instructions provided in Appendix 1 of this guide. A two character letter and number code is noted for each of these measure detail items. Note that while these measure-detail write-ups in Appendix 1 were designed for pool technicians, they still provide summary and investigation information that you will likely find valuable as a recommissioning provider.

# Indoor Pool ReCommissioning Checklist

Check	Identifying	How It Saves Energy	Detail
<b>Pool Area</b>			
<a href="#"><u>Optimal Relative Humidity</u></a>	Inspection & Monitoring	Keeping the humidity lower than necessary increases the evaporation rate and the energy usage of the dehumidifier.	<a href="#"><u>S1</u></a> ASHRAE
<a href="#"><u>Confirm Humidity Sensor Accuracy</u></a>	Inspection	Humidity sensors tend to fail quickly causing either unnecessary dehumidifier operation or high humidity.	<a href="#"><u>S2</u></a>
<a href="#"><u>Optimal Pool Water Temperature</u></a>	Inspection (& Monitoring)	Overheating the pool increases the pool evaporation rate, heating energy and dehumidification needs. Lowering it within the comfort range prevents this.	NSPF, Ch.12 NRPA, 10-3 ASHRAE
<a href="#"><u>Optimal Space Temperature</u></a>	Inspection & Monitoring	Overheating the pool area air above the pool water temperature causes excess air heating and evaporation. Reducing the air temperature within the comfort range prevents this.	NSPF, Ch.12 NRPA, 20-5 ASHRAE
<a href="#"><u>Lighting</u></a>	Inspection	LED lighting retrofits typically give a quick energy cost payback, plus the reduced maintenance costs are substantial.	-
<b>HVAC</b>			
<a href="#"><u>Dehumidifier Operation</u></a>	Inspection & Monitoring	Control problems can lead to over active dehumidification with excess energy use and equipment wear.	<a href="#"><u>H1</u></a>
<a href="#"><u>Energy Recovery Ventilator Operation</u></a>	Inspection & Monitoring	Where an ERV is present, improper control or breakdown can eliminate its energy cost savings—typically without any change in space conditions that would draw attention.	<a href="#"><u>H2</u></a>
<a href="#"><u>Outdoor Air Ventilation</u></a>	Inspection & Monitoring	Bringing in too much outdoor air increases energy costs, while bringing in too little can cause air quality problems, and excessive dehumidifier operation.	<a href="#"><u>H3</u></a> ASHRAE
<a href="#"><u>Compressor Heat Recovery Operation</u></a>	Inspection & Monitoring	All compressorized systems recover heat to reheat the dehumidified air, and some heat pool water as well. Sub-optimal control coordination of heat recovery often significantly reduces the savings achieved.	-
<a href="#"><u>ERV Retrofit</u></a>	Inspection & Monitoring	Using the exhaust air to preheat the fresh outdoor air provides substantial savings when high continuous outdoor air ventilation is needed.	-
<a href="#"><u>Compressor Heat Recovery Retrofit</u></a>	Inspection & Monitoring	Adding or re-establishing heat recovery for pool water heating may be cost-effective	-
<b>Water Side</b>			
<a href="#"><u>Pool Cover</u></a>	Interview, Inspection & Monitoring	Covering an unused pool to prevent evaporation is typically a large energy savings opportunity. The use of a liquid pool cover may provide savings in a similar way (although lower).	NSPF, Ch.12 NRPA, 10-5...
<a href="#"><u>Pool Pump VFD</u></a>	Inspection & Interview	Oversizing of pumps is often compensated for by choking down the flow. This uses more energy than slowing down the pump with a variable speed drive.	<a href="#"><u>W1</u></a>
<a href="#"><u>Correct Pool Filter Flow</u></a>	Inspection & Interview	Turning the pool over faster than the required 6 hour time frame required for most pools increases pump energy use.	NSPF, Ch.10, NRPA, Ch.5, Ch.8, Ch. 9
<a href="#"><u>Operation of Pool Water Heat Source</u></a>	Inspection & Interview	Long-term pool water heater under-performance can be masked by overheating of the air above the pool, which leads to excessive heating energy use.	NRPA, 10-2,3
<a href="#"><u>Pool Water Heat Source Change</u></a>	Inspection, Interview & Monitoring	High efficiency condensing pool heaters (or condensing boilers with a heat exchanger) can reliably provide substantial savings	-
<a href="#"><u>Scheduling of Pool Feature Pumps</u></a>	Inspection, Interview & Monitoring	Pumps serving special pool features (e.g. water slide or play features) may use much more energy than the circulating pump. These should be turned off when not needed.	-

# General Notes for Indoor Pool Facility Recommissioning

## HVAC REQUIREMENTS & TYPES

Typical primary requirements for indoor public pool air HVAC are:

- 1) Provide continuous outdoor air ventilation as needed to dilute and remove pool chemical breakdown products.
- 2) Provide adequate heat to maintain the space at temperatures of up to 85°F.
- 3) Provide dehumidification to maintain the space at a relative humidity of 45% to 60%.
- 4) Keep the pool area depressurized with respect to the adjacent portions of the building.

Note that the majority of existing indoor public pool HVAC systems in Minnesota do not have a means to provide comfort cooling only (e.g. the cooling coil's compressor has all of its heat put back into the pool area air through a fully condensing reheat coil). Those that do have cooling capacity generally only use the cooling-only mode for a very small percentage of the summer hours.

Larger pool rooms (e.g. in a school or fitness center) tend to be served by a single compressorized dehumidifier that uses refrigerant based cooling and reheat. These larger units have a wider variety of options and configurations that can include energy recovery ventilation, and outdoor condenser for getting rid of excess cooling/dehumidification compressor heat, heat reclaim for pool water heating and/or variable speed fans. Exhaust/relief air is often built into the single main air handler, but is also sometimes provided by separate exhaust system. Most of these large units have some capability to tie into a building automation system (BAS).

On the other hand smaller pool areas tend to have a single outdoor-air-only dehumidifier that simply brings in a varying amount of relatively dry outdoor air and heat it as needed to maintain the appropriate temperature in the space. Most of these have a direct-fired gas burner. The outdoor-air only units are often paired with an exhaust fan that has a variable speed drive. While one product line for smaller pool rooms does have a variety of options for heat recovery, heat rejection and remote data monitoring/control, most do not and this specific product line does not incorporate a heat source so that another, external heater is also required. It is also noteworthy that a small, but significant percentage of smaller units use electric heat. Most smaller HVAC units are installed with stand-alone controls that are not connected to a BAS in any way.

## WATER SIDE SYSTEMS & TYPES

Continuous circulation of pool water at a turnover rate of 6 hours is required in public pool facilities in Minnesota. This is for cleaning of the water through filters that have a significant pressure drop, and this continuous recirculation water stream is also used for pool heating, as well as water quality monitoring and treatment. This water flow rate is measured and recorded every day as part of a pool operations logs, but the pool water heat source often has only a portion of this recirculation water flow going through it.



Smaller systems tend to use a commercial, packaged gas-fired pool heater with a simple burner on/off control with a manually adjustable return water temperature setpoint that is displayed in degrees Fahrenheit. Some spas and small pools may have a residential style heater without electrical power. On the other hand, larger pools are often heated by a heat exchanger that receives heat from a steam or hot water boiler system. Typically this boiler system serves other loads in the building, but in some cases a dedicated pool boiler system uses a water to water heat exchanger.

### **SITE TO SITE-VARIATIONS IN SYSTEMS & OPPORTUNITIES**

We found a very wide variety of both system designs, and site-specific modifications and operations practices that have occurred since the original installation. This means that the preset list of potential measures and investigation approaches described in this manual should not be considered as an exhaustive list of what you should consider in your recommissioning efforts. An open-minded look at the existing systems based on an appreciation of the key energy impact items will uncover other site-specific opportunities. The typical list of recommissioning fundamentals apply, but with a slight twist on many items. The following is a list of key energy impact factors to keep in mind with recommissioning an indoor public pool facility:

- 1) Optimal outdoor air flow control balances its dehumidification potential against the need to heat it to the high space temperature maintained in a pool room.
- 2) Dehumidification needs and actual humidity achieved vary seasonally because of changes in outdoor air moisture levels and the surface temperatures of exterior windows and doors.
- 3) Evaporation represents the vast majority of pool heating load.
- 4) Scheduling opportunities are less than most facilities, but can still be worthwhile (especially covering the pool).
- 5) The specialized and/or complicated HVAC systems for pools are often not optimally controlled.
- 6) Heat reclamation opportunities are often worthwhile, but also often not optimally controlled or maintained.

Both HVAC and pool heating trend data should be analyzed over a range of outdoor temperatures and the variety of pool occupancy situations. Time series plots are valuable for observing control sequencing while a combination of regression and BIN analysis (where relationships are not linear over the range of observed conditions) is our recommended approach for the analysis of load and system energy use variables. Also note that while the full on-off cycle length of pool heat systems can be several hours, the actual burner on-time for gas-fired pool heaters tends to be only a very small fraction of this full on-off cycle length.

### **MONITORING CONSIDERATIONS**

Effective recommissioning of an indoor public pool facility may require the use of stand-alone data loggers instead of the reliance on trend logs from Building Automation Systems (BAS) that is typical for recommissioning. The specialized pool area HVAC units are often not linked into a BAS in a way

that provides adequate trend logging capability. Some sites do not have any link to a BAS, while some very common pool HVAC units used in larger facilities have been found to have BAS system integration issues across multiple sites and vendors. Pool facility specific tips related to the use of dataloggers and the logging of pool water heating equipment operation are outlined in the following paragraphs.

When choosing and installing datalogging equipment, careful consideration should be given to the potential for greatly accelerated deterioration due to high humidity and the presence of corrosive chemicals in pool area air. Sensors and/or loggers should be chosen accordingly. Where practical, the most reliable arrangement is typically to have only the sensor(s) in the pool return duct or pool area, and have them connect to a logger that is not directly exposed to the pool area air. However, pool maintenance room air is often not much better than pool air in regards to corrosive chemical vapors. If loggers are left in place for an extended period of time, the conditions of the sensors and loggers should be verified monthly—including verification of data consistency over time or against a reliable spot reading.

Gas-fired pool heaters only require a burner on/off status indicator via a connection to the burner control or power signal. Pool water heating energy use can then be simply calculated using the burner on-time fraction in connection with the burner's fixed input rate. You may also run across a smaller residential pool heater that doesn't have electrical power. In this case, a temperature measurement in the flue or vent (with a small gauge thermocouple read by a datalogger) can be used to tell when the burner runs.

When a water to water (or steam to water) heat exchanger is used for pool heating, it may not be possible to get a very accurate measurement of pool water heating energy use. There are some cases with heat exchangers where reasonably reliable estimates can be made:

- 1) the water flow rate is known (either constant or logged) and the temperature rise (or drop) of more than 6°F is logged with sensors inserted into the pipe; or
- 2) the boiler supplying water to the heat exchanger is dedicated to serving only the pool heating load (and the energy use of the boiler can be determined as noted above for a constant firing rate boiler or through logging of modulated firing rate).

The limited accuracy of individual water temperature sensors makes the measurement of smaller temperature rises (or drops) relatively inaccurate. There are only limited cases where strap-on pipe temperature sensors (with insulation wrapped around the outside) are useful in pool systems because most pool water piping is plastic. The piping adjacent to a heat exchanger can sometimes be an exception to this. While it is often easier to measure pipe temperatures on the boiler side of a heat exchanger, it is usually difficult to accurately estimate the water flow rate on that side of the heat exchanger. It is also common to not be able to reliably estimate the water flow through the pool side of the heat exchanger because of many of the systems having only a fraction of the full, measured recirculation flow going through the heat exchanger. The actual bypass flow rate tends to be constant

over time based on a manual bypass valve setting. This means that changes in pool heating load over time can be compared through temperature rise measurements, but the assumption of constant manual valve setting must be confirmed over the course of the monitoring period. Because of these various site to site challenges recommissioning efforts will sometimes not be able to make reliable direct measurement of pool water heating load and its dependence on multiple factors.

## Individual Measures

For those checks on the checklist that have a single letter and single number code in the detail column, a detailed check with that letter-number code can be found in this section. These specific items were chosen based on consideration of significant potential energy impact and/or a shortage of clear information available in other readily available pool technical resources. For a number of other items, the checklist refers you to specific parts of the two most prominent pool operator training manuals and/or an ASHRAE Handbook . These documents are:

- NSPF: National Swimming Foundation, Pool & Spa Operator Handbook, 2012, 2014, & 2017 Editions.
- NRPA: National Recreation and Park Association, Aquatic Facility Operator Manual, Revised 6th Edition.
- ASHRAE: ASHRAE Handbook—HVAC Applications, Chapter 5, Pages 5.6 – 5.8, 2011.

Also note that the checks are broken down into three categories, which are described in greater detail below.

### POOL AREA SETPOINTS & LIGHTING

Suboptimal control settings and/or inaccurate sensors commonly cause pool systems to use more energy than needed and lead to occupant discomfort. The measures in this section outline a few key items that commonly provide cost-effective savings opportunities:

**Optimal Relative Humidity** [[S1 in Appendix 1](#) has more information]

While pool operator training materials give guidance for pool room humidity based primarily on comfort considerations, facilities in Minnesota may need to seasonally maintain lower humidity levels to prevent condensation on windows, door frames, and other exterior surfaces. This condensation issue is much worse in severe cold weather, so the low humidity that is needed in these conditions does not necessarily need to be maintained at more mild conditions. Maintaining lower than required humidity during mild weather can significantly increase energy use and wear on dehumidification equipment. Also, in Minnesota the low wintertime moisture content of outdoor air that is continually brought in will typically bring the relative humidity below the setpoint in cold weather so relative humidity control setpoints may not even need to be based on the worst case design dewpoint/condensation thresholds. The optimal approach is usually to have a low relative humidity setpoint when it is very cold out, and then to have the relative humidity increase gradually

to a higher relative humidity in warm weather. The ability to accomplish such setpoint variation automatically will vary from site to site, but will more often be possible when a BAS is used. Where not possible, operations staff can be instructed to manually vary the relative humidity setpoint seasonally.

Identifying and addressing envelope condensation causes may also allow the relative humidity to be increased. Common areas of concern are door frames, window frames and structural steel or concrete that extend all the way through the exterior envelope without thermal protection. This leads to cold surfaces that can be below the dewpoint and have condensation. Having adequate supply air flow rate over such surfaces can also minimize condensation by raising the surface temperature. Supply airflow rate and diffuser distribution should also be investigated where there are doors, windows or other envelope components susceptible to condensation.

Long-term monitoring of pool area temperature and relative humidity over the extremes of outdoor temperature variation is recommended for investigation of this measure, as well as periodic spot-checking of controller humidity setpoints. Return or exhaust duct temperature and humidity may be substituted for pool area values when these are more readily available. When available, trending with a Building Automation System (BAS) is typically the easiest way to accomplish this (and setpoints can also typically be monitored as well), but the accuracy of the temperature and humidity sensors should be verified at the start of trending (see next item). If BAS trending cannot be used to capture seasonal variations, dataloggers may be used. Note that the chloramines in pool area air can lead to greatly accelerated corrosion, so sensors and/or loggers should be chosen accordingly. Where practical, the most reliable arrangement is typically to have only the sensor(s) in the pool return duct or pool area, and have them connect to a logger that is not directly exposed to the pool area air. However, pool maintenance room air is often not much better than pool air in regards to corrosion.

Estimation of savings should take into account the site-specific relationships between dehumidifier operation, outdoor temperature, and indoor relative humidity, besides the relationship between pool area humidity and outdoor temperature. The use of theoretical calculations of annual impact of pool area humidity changes should be conservatively with careful attention paid to assumptions about the impact of seasonal outdoor air absolute humidity on the HVAC unit dehumidification load.

**Confirm Humidity Sensor Accuracy** [\[S2 in Appendix 1\]](#) has more information]

Humidity sensor accuracy is critical in pool facilities, and the general tendency towards humidity sensor problems is greatly exacerbated in these facilities by the presence of chloramine gas in the pool room air. The investigation should both confirm that the relative humidity sensors used to control equipment is rated for a chlorinated environment and that it currently gives an accurate reading. As a recommissioning provider serving pool facilities, you should use a handheld relative humidity sensor with an accuracy of  $\pm 2\%$  that is recalibrated within the manufacturer's recommend interval. Since relative humidity measurements are very sensitive to both temperature and absolute humidity, it is crucial to have the handheld humidity sensor as close as possible to the BAS sensor or humidistat during a humidity sensor accuracy check. If there is a small bias in temperature, the adjustment noted

in S2 can be used; however, it is preferable to use a psychrometric chart or calculation when making an adjustment for such bias. Relative humidity readings can be slower to respond than temperature readings, so be sure and wait until both are steady before taking readings for a comparison between a reference probe measurement and the HVAC system's sensor. Also note that many humidity sensors perform poorly below 15-20% RH or above 80-85% RH, so a repeat check on the accuracy of the HVAC system sensor should be made at another time if the relative humidity is not between 20% and 80% at the time of verification. Use of a datalogger can be useful in situations like this or to compare against trend log data, but the datalogger's RH sensor accuracy should be verified against a calibrated probe at the beginning and end of its deployment. Industrial grade dataloggers and sensors are recommended to prevent premature failure due to exposure to high humidity and chloramine gas.

### **Optimal Pool Water Temperature**

While the mid to low 80's is the optimal temperature for comfort in most situations, pools that used exclusively for lap swimming and competition are generally maintained at the low end of this range, and sometimes in the very high 70's. Heating the pool warmer than necessary greatly increases energy use—primarily by increasing evaporation—so keeping it as low as possible without causing undo comfort issues is important for minimizing energy costs. Depending on the relationship between the capacity of the pool heating equipment and the pool water volume, it may be practical to set back the pool water temperature during long periods of non-use or to change the temperature for varying uses (e.g. senior aerobics class vs swim team practice).

Although it is generally very difficult to monitor pool water temperature with a temporary logger, most operators keep long-term logs of water temperature and spot measurements can be made quickly and easily. Pool operators are required to keep long-term logs of many pool water quality indicators and nearly always include pool water temperature in their logs. Spot measurements are useful as a reality check on the appropriate temperature and also to verify the accuracy of the pool water sensor or controller. The plastic piping used for pool water makes strap on sensors inaccurate (even if insulation is wrapped around it). Where pool water temperature is linked into a BAS, long-term trending can be useful.

### **Optimal Space Temperature**

While a number of resources suggest keeping the pool room temperature higher than the pool temperature, our findings indicate that energy use in Minnesota pool facilities is minimized with pool area temperatures that match the pool temperature (or are even lower within comfort levels). It appears that the assumptions behind recommendations in previous documents and calculators that focus on dehumidification loads do not take fully into account some key realities related to the annual operating season in Minnesota:

- 1) Outdoor Air Heating Loads. For the vast majority of the year in Minnesota, a pool space that is kept at a much higher temperature than a typical occupied space must heat the fresh outdoor



air that is continually brought in to provide adequate air quality (and the outdoor air is seldom cooled).

- 2) Humidity Often Below Setpoint. Previous analysis of pool evaporation and related energy use has generally assumed that the relative humidity will always be right at the controller's constant humidity setpoint when the temperature is changed. However, just brining in the minimum required outdoor air often causes the relative humidity to drift below the controller setpoint during the heating season in Minnesota. This is because the cold outdoor air is very dry (e.g. 25°F air has a relative humidity of 10% or less after being heated to 85°F). Therefore, the constant relative humidity assumption overestimated the sensitivity of evaporation rate to pool area air temperature for a majority of the operating season.
- 3) Average Activity Level Well Below Design Values. Activity levels used for worst-case design evaporation rate circumstances lead to overestimation of evaporation rates—and the energy impact of changes in evaporation rate—for the vast majority of the year.

The impact of these factors is reflected in our monitoring of the impact of space temperature on energy use. Our monitoring generally suggests that keeping the heating season air temperature as low as possible within an acceptable comfort range will provide the lowest energy costs. This is in contrast to previous suggestions that the combination of HVAC and pool heating energy use is minimized by keeping the air temperature 1°F to 4°F *above* the pool water temperature. We instead suggest that minimum energy use is achieved with air temperatures up to 5°F *below* the pool water temperature—especially during low and no occupancy periods. Of course minimum energy use must be balanced against comfort considerations for occupants wearing only swimming suits and being wet as they come out of the pool.

Using overnight setback in cool weather is a way to take advantage of the above relationship that has been misunderstood, but care must be taken to prevent inadvertent overuse of the dehumidification equipment. This is because with constant absolute humidity the relative humidity goes up as the air temperature goes down. Over-dehumidification during setback can be prevented through the use of dewpoint setpoint instead of relative humidity setpoint, or an increase in relative humidity setpoint as the temperature setpoint is reduced.

## Lighting

The replacement or upgrade of existing fixtures to LEDs is typically one of the best energy cost saving investments with a quick return on investment. Substantially reduced long-term maintenance costs are also a key benefit. This applies to both overhead (general area) lighting and underwater lighting, although special considerations for each are noted below.

For overhead lighting in pool areas, only fixtures that are specifically designed for such a harsh environment are recommended. Fixtures must be able to withstand possible splashing, high humidity, high temperatures, and corrosive chloramine vapor.

Our survey of existing facilities found that the actual use of underwater pool lighting can be inconsistent (i.e. some facilities that have underwater lighting only use it for a small fraction of the time, and some do not use it at all). When looking at the economics of underwater lighting upgrades, be sure to specifically confirm the expected operating hours of underwater lighting separate from the hours of overhead lighting and pool operation hours.

## **HVAC MEASURES**

The specialized HVAC equipment and control requirements for indoor public pools are too often not fully understood by designers, contractors, and operators. This can lead to a variety of energy wasting HVAC operating conditions that can be identified and corrected through recommissioning and subsequent implementation. The majority of cost-effective HVAC energy-saving opportunities found at the study sites can be identified through HVAC investigation efforts focused on the general issues noted in the checklist and repeated below. However, the large site to site variations in details of the equipment and problems encountered means that the specific opportunities related to these issues should not be limited to a pre-set list of possible corrective measures.

### **Dehumidifier Control** [[H1 in Appendix 1](#) has more information]

Indoor public pool spaces in Minnesota get significant inadvertent “economizer” dehumidification much of the year. This is because the high amount of outdoor air needed for adequate dilution of pool chemical breakdown products is relatively dry during cold weather (e.g. 25°F outdoor air has a relative humidity of 10% or less when heated to 85°F). Having too low of relative humidity setpoint, or numerous other control problems that lead to excessive operation of the dehumidifier, can greatly increase energy costs and accelerate deterioration of the dehumidifier. While the previous “Optimal Relative Humidity” portion of this document goes into greater detail regarding optimal seasonal changes in humidity setpoint, this item focusses on determining if excessive dehumidifier operation is occurring.

The information in check H1 in Appendix 1 should be used as a guideline for determining whether dehumidifier operation can be reduced significantly. For recommissioning purposes, the actual amount of dehumidifier operation over a range of outdoor temperature conditions can be obtained through BAS trend logs in some cases, and will require the use of temporary dataloggers in other circumstances. Where datalogger(s) are required for monitoring of a compressorized dehumidifier, a CT (current transformer) on the dehumidification unit (or multiple CTs on individual compressors) can be used with a datalogger to determine the operating state of one or more compressors. For outdoor air only dehumidifiers, there are two approaches that might be possible depending on details of the unit configuration. The first approach is to use a datalogger that measures tilt and attach it to an appropriate portion of the damper actuator or damper. Where this is not practical, the second approach is to measure the temperature of the outdoor air intake and the air stream it is mixing with before and after the location where the outdoor air is introduced. Note that many dehumidifiers have configurations that make the locations of these measurements different than the typical return air, mixed air and outdoor air locations on other units, and/or make it impractical to measure a

representative average of all three of these temperatures (without a coil or heating element introducing an additional impact on one of the temperatures). No matter which approach is taken to monitor the operation of the dehumidifier, concurrent monitoring of pool room relative humidity and temperature, outdoor temperature, and other dehumidifier control details (e.g. reheat) are typically very important for understanding the cause and correction path should excessive dehumidifier operation be found.

Estimates of energy impact should involve use of the actual monitored data of current operation along with an educated estimate of the reduced dehumidifier operation that will be achieved. The information in H1 can be combined with an engineering calculation of reduced dehumidification loads if setpoint changes are to be made.

### **Energy Recovery Ventilator Operation** [[H2 in Appendix 1](#) has more information]

When an Energy Recovery Ventilator (ERV) is present, the information in check H2 should be used as a guideline for a basic determination of whether or not it is operating as it should be. The *Typical ERV On/Off Operation Ranges* chart in the Compare section of H2 shows the expected operation at different outdoor temperatures, while the Investigate section of H2 describes how ERV On and Off operation status is determined.

Of course recommissioning efforts should expand the spot determinations described in H2 to monitoring over a range of seasonal conditions through either BAS system trend logging or the use of temporary datalogger(s). Even though BAS or logger monitoring over time is important, direct physical observations of ERV on-off status (i.e. turning of a wheel or the position of face/bypass dampers) should also be done at least once for each status. Wherever possible, logged indicators of ERV on/off status (i.e. wheel motor operation as determined by control signal or current measures or a damper position indication) should be confirmed through concurrent data on the temperature of the various air streams. While further optimization of control is possible through recommissioning efforts, the vast majority of cost-effective savings from ERV recommissioning is obtained through the correction of issues related to this basic on/off status control. One exception where further measurement/investigation is recommended is the case of ERV units that have a variable speed drive on the exhaust side. In this case, logging of data should be adequate to compare VFD speed and/or exhaust side air flow against outdoor air flow and the total flow through the non-exhaust side of the heat exchanger. Significantly unbalanced flows can make the savings of the ERV feature dramatically less.

Wherever possible, estimates of savings from changes/corrections to ERV control should be based on site-specific monitored data of the amount of heat recovered at or near the expected operating conditions (as opposed to engineering calculations using rated effectiveness, etc.).

### **Outdoor Air Ventilation** [[H3 in Appendix 1](#) has more information]

Excess outdoor air and economizer operation are a typical focus of recommissioning efforts, and are even more important in indoor public pool facilities, with some unique twists. Outdoor air can provide “economizer” style dehumidification since it is dryer than the pool room for most of the year.



However, the high pool room temperature also means that for the same outdoor air flow, the heating load extends over many more hours and is greater at the same outdoor temperature than for other spaces. Therefore, the review of the control of outdoor flow air variations above the minimum required often identifies cost-effective improvement opportunities. Moreover, a high minimum level of outdoor ventilation is also needed for dilution of contaminants, except when the pool is covered. This high minimum outdoor air flow typically over-dehumidifies the pool room throughout much of the heating season, which increases the pool water evaporation rate and heating needs. Therefore, reducing the continuous outdoor air flow by even a modest amount can provide substantial energy cost saving benefits, both directly and indirectly. As a result, measurements and/or logging to verify that the minimum level of outdoor air flow is appropriate is critical in pool facilities. More information related to outdoor air for pool facilities can be found in the H3 operator's instructions document found in Appendix 1.

When scheduled activity levels and/or the use of a pool cover allows, it may be possible to reduce the outdoor air ventilation level at night. Using a variable speed drive on the supply fan with a lower "unoccupied" speed setting may be a cost-effective way to both reduce outdoor air ventilation and fan power.

### **Compressor Heat Recovery Operation**

Sub-optimal control of compressor heat recovery and/or a lack of coordination of other heat sources with heat recovery often reduce the savings achieved and provide a good recommissioning savings opportunity in pool facilities. Identifying these control opportunities requires simultaneous logging of compressor operation, heat reclaim operation, and primary heat source operation, and careful review of the data. For example, we found that independent control of an electric supply duct heater and hot-gas reheat increased the electric use. In this case, the dehumidifier could either reject heat via an outdoor condenser or a hot-gas reheat coil located right after the cooling coil. During mild summer weather when the compressor was cycling frequently, the unit was found to be rejecting most of the heat through the outdoor condenser instead of the reheat coil causing the electric heater in the supply duct to cycle on shortly after the compressor cycled off. Similarly, if heat is reclaimed for pool water heating, using this reclaimed heat as a first stage of heating while holding off use of the primary pool heat source until a second stage of heating is really needed to prevent an impact on comfort will maximize the energy savings from having the pool water heat reclaim feature. In each of the above cases, the key to finding these savings opportunities was to understand the HVAC unit thoroughly—especially the heat reclaim features and the primary heat sources they are supplanting when they operate—before beginning logging. This will ensure that the logging will capture all of the data needed to spot situations where both heat sources are operating simultaneously and/or cycling over the same time period.

### **Energy Recovery Ventilator (ERV) Retrofit**

Although a recommissioning study scope typically doesn't include such a significant design change and capital-intensive equipment upgrade, the high continuous outdoor air ventilation rates and high pool room temperatures may make an ERV retrofit cost-effective for an indoor public pool facility—

especially if there is a need to replace the dehumidifier anyway. When installed as part of a new or replacement unit, the use of an ERV may allow the heating and/or cooling capacity of the unit's primary systems to be substantially lower than for a unit without an ERV. Site-specific logging of outdoor air heating loads will yield a much more accurate energy cost savings estimate than design and engineering calculations alone.

### **Compressor Heat Recovery Retrofit**

For facilities with at least one dehumidifier compressor operating over the majority of the time in the summer months, the addition of compressor heat reclaim for pool water heating might be cost-effective. Actual logging of dehumidifier operation and pool heating energy use should be used as a basis for determining the site-specific savings potential. Savings should be estimated based on the lesser of each of the following values for each hour (or the average for those conditions when typical equipment cycle length is longer than an hour :

- 1) The pool water heating energy use;
- 2) the calculated heat rejection from the cooling compressors; and-
- 3) the proposed pool reclaim exchanger's capacity multiplied by the fraction of time that the compressor operates in that condition.

Controls must be carefully integrated to use the reclaimed heat as the first stage of heating during time periods that the waste heat is available (i.e. disable the primary heat source except when the reclaimed heat can't keep up). See the Compressor Heat Recovery Operation topic within this list for more information about compressor heat reclaim control issues.

## **WATER SIDE MEASURES**

This category addresses a number of items that can lead to more efficient operation of a pool facility. Some of these require no capital cost while others are aimed at finding specific facility conditions that may require significant capital, but which will typically yield a worthwhile return on the investment. Depending on the applicability in a particular facility, a couple of these items should be worked into regular operating procedures.

### **Pool Cover**

Although they require a daily commitment to operate and are prone to repair needs, the use of pool cover during unoccupied times is widely recognized by pool operators as providing substantial energy cost savings. Before making specific plans to implement, you should ask about a facility's history with using a pool cover as a number have used them at one time and then abandoned the practice due to problems with the cover, concerns about a lack of off-gassing of contaminants while the pool is covered, and/or inconsistent follow-through on the use of the cover. Site-specific concerns need to be recognized and addressed in order to achieve buy-in from the facility owner and staff. Whenever possible, actual monitored pool water heating energy use during unoccupied times should be used for estimating the site-specific energy cost savings of a pool cover. This is because the many assumptions that go into engineering calculation estimates of pool evaporation rates and the

subsequent energy costs do not always align well with the specific characteristics at a particular pool facility.

Using a pool cover during unoccupied times also provides an opportunity to reduce outdoor air flow rate, ventilation fan power, and the space temperature setpoint. However, ongoing care should be taken to ensure that the HVAC unit operation keeps up with pool operational schedule changes. If a BAS system is used, a reading of pool room humidity could be used as a backup to respond to times when the pool cover is not used or the activity schedule is changed. After the pool cover is put in place, continuous outdoor air ventilation will reduce the relative humidity of the space substantially – especially during the heating season.

There is also a liquid pool cover product that appears to have the potential to achieve a significant portion of a pool cover's energy savings without the expense and daily operation of a traditional pool cover. The liquid pool cover is thin film of clear liquid that floats on top of the water and acts as a barrier that reportedly reduces the pool water evaporation rate to about half of what it would otherwise be. During pool use it is relatively ineffective as it gets mixed in with the water, and then returns to the surface to form a thin layer again whenever the pool is not used for a period of time. While other studies<sup>1</sup> and anecdotal information have suggested that this product does provide a substantial benefit, our study of this in one recommissioned facility did show the achievement of significant savings.<sup>2</sup>

**Pool Pump VFD** [[W1 in Appendix 1](#) has more information]

The potential savings from adding a variable speed drive to the pool circulation pump varies substantially from site to site. Current pool code in Minnesota is generally interpreted as requiring a constant minimum circulation rate, so the primary source of savings potential is in using a variable speed drive to balance the system to the minimum flow rate instead of throttling main line valves. About one-quarter of sites surveyed were found to have the main line pump throttled at a 45 degree angle, so the use of a lower pump speed with the valve fully open would reduce the pump's pressure drop substantially while still providing the proper flow rate. More than 10 percent of the facilities surveyed were also found to have the pool circulation flow rate at least 20 % above the required flow rate, which provides an opportunity for savings through reduced pump flow rate via a variable speed drive reduction of pump speed. It is site specific instances like these where large variable speed drive pump savings is possible. Most of the savings can be achieved through manual, one-time adjustment during balancing.

When a variable speed drive is put in place to achieve better balancing, there is also some secondary savings potential that can be achieved by automatically adjusting the speed in response to a flow

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<sup>1</sup> One such study that showed energy saving is another Minnesota funded CARD Grant study conducted by Michaels Energy (Hotel Energy Efficiency: Market Potential for Minnesota's Hospitality Center, Bruce Dvorak, et al., 2015).

<sup>2</sup> It is hard to draw a firm conclusion from the combination of these two studies as the Michaels Energy study did not carefully consider the confounding impact of seasonal changes, and CEE's study could not definitively rule out the possibility of unintended changes in outdoor air ventilation that may have impacted the results.

measurement. This is because most systems use sand or similar filters that have a moderate swing in pressure between backwash cycles. The magnitude of this swing can be seen by looking at the history of pool operator logs to see the daily pressure and flow variations between backwash cycles that typically occur no more than once a week, and often less often than that.

### **Correct Pool Filter Flow**

It is common for public pool facilities to operate with a pool filter flow rate that is moderately or significantly higher than required by the current Minnesota Pool Code. For typical pools (not wading, zero, plunge or other special purpose) the code requires that the pool filter flow rate is adequate to recirculate the the full pool volume in 6 hours. In the industry, this is typically referred to as a 6 hour turnover rate. For public spas the required turnover rate is 30 minutes. Moderately or significantly faster turnover rates often provide an opportunity for reduced pool pump energy use. Proper balancing of the pool flow rate might be accomplished through simple balance valve adjustment, or through the installation of a variable speed drive with either a fixed speed control or a control that automatically adjusts the speed to provide the required flow rate (see previous checklist item for more information). All public pools will have an indicator of pool filter water flow rate and log this at least daily. Also, most pool operators either know the pool volume, or have it on reference material that is easily at hand (e.g. printed on the pool log book). This usually makes it relatively easy to determine the current pool turnover rate. When rates are higher than the code required level, there should also be inquiries to pool operations staff and review of design documents to investigate whether this pool has a special need for a recirculation rate that is higher than the code requirement.

### **Operation of Pool Water Heat Source**

Although infrequent, we did find multiple indoor public pool facilities that had woefully underperforming pool water heating. In these cases, significant overheating of the space compensated for the lack of adequate direct water heating capacity, but with a high energy penalty associated with the outdoor air heating load and increased envelope heat loss (as well as poor comfort for occupants). In one case this inadequate water heating only occurred seasonally when a different heat-exchanger was used, and the pool operations team did not appear to be aware of the problem. Because of the long cycles of pool water heating (a heat source cycle may last hours with the heat source only on for a period of minutes of that time period), this problem was identified through long-term datalogging, and then confirmed through targeted follow-up spot measurements.

### **Pool Water Heat Source Retrofit**

While the high capital cost of replacing heating equipment is beyond the scope of a recommissioning study, it may be considered in certain circumstances. High efficiency condensing pool heaters and/or dedicated high efficiency condensing boiler-heat exchanger combinations are often much more efficient than existing pool heaters or central boiler systems. Besides having a higher efficiency rating than the boilers in most central boiler plants, the operating conditions of dedicated pool heating equipment make the achieved operating efficiency of high efficiency condensing equipment much higher than a similar boiler serving typical building heat loads. This is because the low temperature of the pool water compared to boiler water temperatures needed for most space-heating applications

in Minnesota is ideal for condensing boilers and pool heaters. In one site, we even found an opportunity to achieve substantial savings by simply using the boiler that was installed for summer-only operation (to allow the central boiler plant to be shut down) on a year-round basis. The results of site-specific logging of pool water heating loads will provide much more accurate estimates of the potential energy cost savings than engineering estimates.

### **Scheduling of Pool Feature Pumps**

Pool features such as water slides, waterfalls, and play features require the use of pumps that are typically even larger than the primary pump used for filtering the pool water. Limiting their hours of operations to only those times that they are needed can provide substantial energy cost savings. This savings is primarily directly through reduced pump energy use, but depending the type of feature, the evaporation rate may be reduced substantially as well (e.g. air jets in a spa). Beyond shutting features off during unoccupied times, a number of facilities limit the operation of specific features to posted, scheduled times. For facilities that are not doing so, a recommissioning report should quantify the potential savings from doing so to facilitate an informed decision by the facility owner. Spot measurements of pool feature pump motor current or power is recommended to increase the reliability of savings estimates. This is because the custom nature of pool feature design and pump selection may cause the load factor (ratio of actual motor load to nominal rated load [i.e. brake horsepower: nameplate horsepower]) to be substantially different from the typical 0.8 load factor assumption.

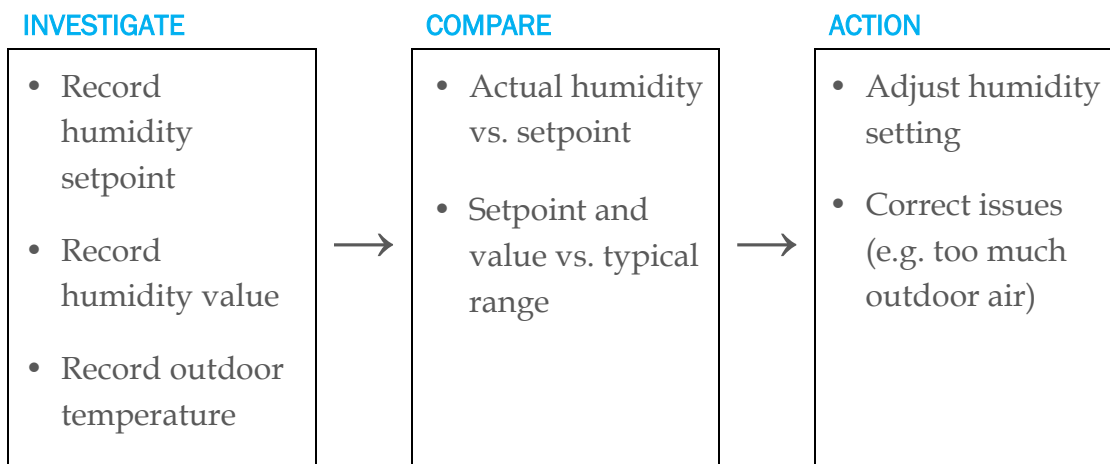
## Appendix 1. Operator Inspection Instructions for Select Measures

The following documents were prepared for the purpose of providing pool operators and contractors with guidance for spot-checking the operation of an indoor public pool facility to see if there are opportunities to save energy through low or no cost operational changes. Much of the material is also useful a useful reference for recommissioning providers. Specific documents are referenced by their two character reference ID in the summary checklist and the individual measure sections of the guide.

# S1. Optimal Relative Humidity

While too high of humidity at the wrong time can cause familiar condensation problems, being too aggressive at maintaining a low humidity can also significantly increase energy use and make it feel uncomfortably cold for swimmers after they exit the water. Also, humidity far above or below the setpoint can be a symptom of a problem that is preventing the HVAC system from performing as intended or performing in a way that uses more energy than necessary.

## WHEN TO CHECK: EVERY 2 MONTHS



### INVESTIGATE

Record Humidity Setpoint \_\_\_\_\_% RH

- Depending on the unit and controls arrangement, the humidity sensor display may be accessible at a few different locations.
- Often the humidity setpoint is accessed either through a control display at the HVAC unit itself, on a control device attached to the return duct, or through a Building Automation System (BAS) interface.
- Sometimes, a thermostat-like device in the pool room has an accessible setpoint, although there would typically be a locking cover, or some other way to limit access. If a device in the pool room displays humidity but does not have arrow buttons, a dial, or a lever for adjusting, it is probably only displaying the current value and is **not** displaying the setpoint.

Record Actual Humidity Value \_\_\_\_\_% RH

- Depending on the unit and controls arrangement, the current sensor reading may be accessible at a few different locations.
- Often the current reading for the humidity sensor is visible either through a control display at the HVAC unit itself, on a control device attached to the return duct, or through a BAS interface.



- Sometimes, a thermostat-like device in the pool room has a display that shows the current humidity. If a device in the pool room has arrow buttons, a dial, or a lever for adjustment, it may display the setpoint instead of (or in addition to) the current sensor reading. If so, look carefully to be sure that you do not confuse the RH setpoint for the current value.

#### Record Outdoor Temperature \_\_\_\_\_ °F

- Outdoor temperature can be measured on-site via a BAS sensor or thermometer (in the shade)
- Or, you can use a cell phone app (or website) to get a current nearby weather station reading.

### COMPARE

#### If the RH Setpoint and RH Value Differ by More Than 6%

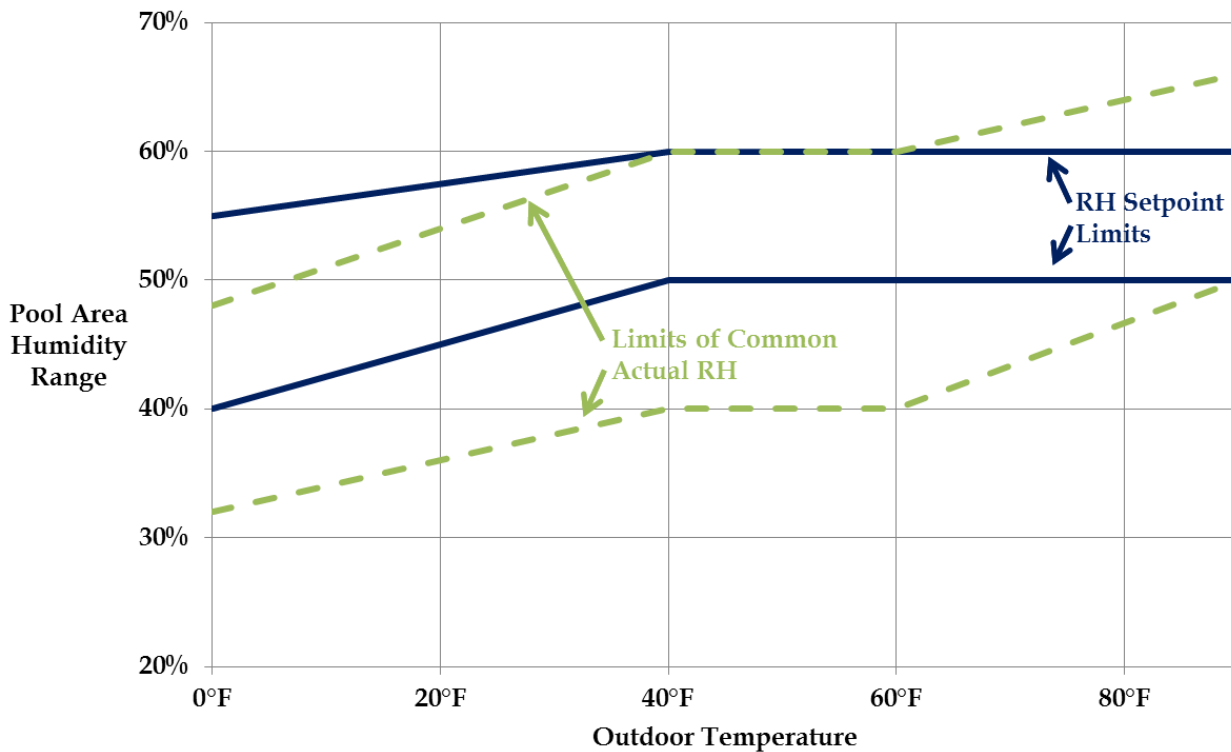
- If there's no compressor, the RH is above setpoint, and it's above 60°F outside, the unit may be functioning as designed, but it has a limited ability to maintain a RH well below 60% in warm weather. If the HVAC unit is bringing in its maximum possible outdoor air (see [H1](#) for more information), then no action is needed to address this discrepancy.
- If the RH is above setpoint and it's above 75°F outside, the unit may be functioning as designed, but it has a limited ability to maintain a RH well below 60% in hot, humid weather. If the dehumidifier appears to be operating at its maximum capacity (see [H1](#) for more information), then no action is needed to address this discrepancy.
- If the RH is below setpoint and it's below 50°F outside, the unit may be functioning as designed, but the dry outdoor air needed for air quality reasons is providing more inadvertent dehumidification than is needed. If the HVAC unit is not trying to dehumidify (see [H1](#) for more information), then no action is needed to address this discrepancy.
- If the RH is well above or below setpoint under other circumstances, take the associated steps noted in the action list for this check.

#### Typical Humidity Control Chart

- The chart shows the typical range of pool area relative humidity setpoints and actual values.
- The solid, dark blue lines show the suggested range of RH setpoint.
- The dashed green lines show the range of actual RH values that are somewhat common to see.
- The higher observed humidity levels at high outdoor temperatures tend to occur for outdoor air only dehumidifier systems. HVAC units with cooling coils and/or desiccant dehumidification tend to control the humidity better at these extreme conditions.



### Typical Relative Humidity Ranges



### Compare Humidity Setting and Value to Chart Ranges

- Setting the HVAC unit to provide a lower humidity than suggested by the “setpoint” range significantly increases energy use, pool water evaporation, and wear on any compressors. This should only be done to the extent that site-specific experience has shown a need to do so to prevent condensation problems. Note that condensation problems are far worse in very cold weather, when the inside part of exterior surfaces can get cooled below the dew point of the humid, pool room air. So higher a RH setpoint during mild winter weather may be fine in a facility that needs lower humidity in very cold weather to prevent condensation problems. If a setpoint is unnecessarily below the suggested range, see the associated action.
- Humidity setpoints above the range are not recommended due to the likelihood of condensation and/or comfort issues. If a setpoint is unnecessarily above the suggested range, see the associated action.
- Actual RH values below the range shown suggest that there may be more outdoor air ventilation than is needed. Take the associated action to investigate and correct if needed.
- Actual RH values above the range shown suggest that there may be less than the needed amount of outdoor air ventilation. Take the associated action to investigate and correct if needed.

## ACTION

### If Direction to Action for RH Setpoint versus Value Discrepancy

- To degree to which it is possible, check on dehumidifier operation (see [H1](#) for more information) to see the extent to which it is actively trying to dehumidify.
- If the RH is above setpoint **and**:
  - If the HVAC unit is not trying to dehumidify as much as possible, then a qualified technician should inspect for what is probably a controls issue; **or**
  - If the unit is trying to dehumidify as much as possible under conditions for which it is expected to keep up, then a qualified technician should inspect for what is probably an equipment issue.
- If the RH is below setpoint **and**:
  - If the HVAC unit is not trying to dehumidify, check for excessive outdoor air; **or**
  - If the unit is still trying to dehumidify when it is not needed, a qualified technician should inspect for what is probably a controls issue.

### If Directed to Action for a RH Setpoint Outside of Suggested Range

- Change the setpoint to a value within the suggested range.
- If the setpoint control is right on the unit or a thermostat like device, it will probably have a fixed setpoint. This may need to be manually changed seasonally to get the optimal balance between comfort, energy use, and condensation.
- Many BAS (and some stand-alone controllers) will have the capability to automatically adjust the relative humidity setpoint in response to outdoor air temperature. If so, this will probably provide the best approach. However, note that the control logic should be verified as much as possible to confirming the proper setpoint on displays and that such automatic control is also susceptible to any errors in the outdoor sensor readings and should also be checked periodically.

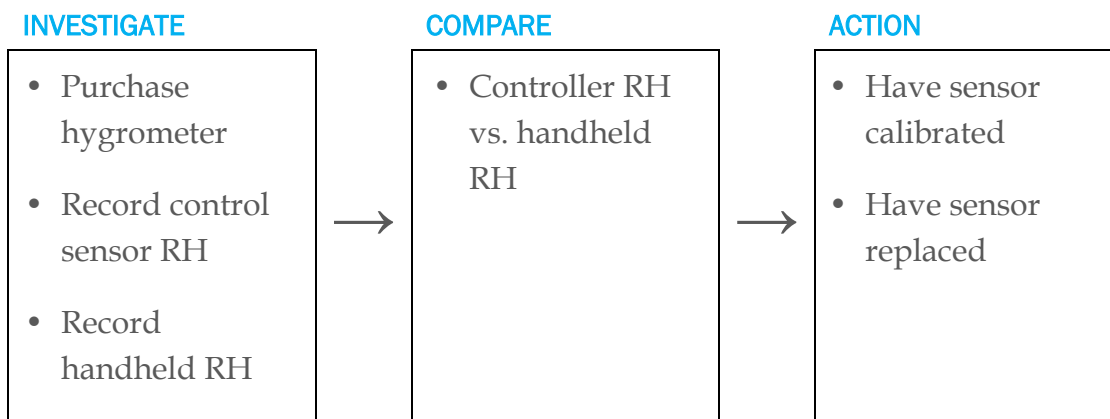
### If Directed to Action for an Actual RH Value Below Expected Range

- Check for excessive or inadequate outdoor air by first seeing if a motor-driven outdoor air damper has a problem with the actuator or linkage that is causing it to be open or closed farther than it should be based on the expected control. If so, have this corrected by a qualified technician.
- If the outdoor airflow is a fixed value or at its expected value, it is suggested that the airflow be checked by someone who is qualified to assess the desired minimum outdoor air ventilation rate and measure the actual outdoor airflow rate. If outdoor air ventilation is found to be significantly above or below the amount needed, have it corrected.

## S2. Confirm Humidity Sensor Accuracy

Relative humidity sensors are notorious for failing and leading to control problems. For pool areas humidity control is more critical than in many other situations, and the presence of chloramines and high humidity make humidity sensor life even more problematic in pool systems. This check gives detailed guidance on how you should regularly confirm the accuracy of the humidity sensor used to control the pool dehumidifier.

### WHEN TO CHECK: QUARTERLY



### INVESTIGATE

#### Obtain and Maintain Hygrometer (i.e. Relative Humidity Meter)

- A handheld hygrometer that measures RH with an accuracy of  $\pm 3\%$  can be purchased from many different industrial suppliers or retail suppliers for less than \$150. If the pool area's humidity sensor has a case that can hold up a small desktop type hygrometer, the price may be even lower.<sup>3</sup>
- DO NOT STORE THE HYGROMETER IN THE POOL EQUIPMENT ROOM. Doing so would greatly accelerate the failure of this meter. It is best stored in a conditioned indoor environment that does not experience extremely high humidity levels.
- The accuracy of the handheld hygrometer should be checked periodically. A convenient way to get a rough confirmation of a handheld hygrometer is against a nearby weather station reading obtained from a website, news report, or mobile phone app. Don't do this comparison if the outdoor RH is below 15% or above 80%. Also note that the RH reading is dependent on temperature, so this comparison will only give a close match if the meter's temperature reading is within 2°F to 3°F of the weather station temperature.

<sup>3</sup> A hand-held sling psychrometer is a moderately lower cost alternative that will not need to be calibrated. During each use of a sling psychrometer, the sock on a wet-bulb thermometer must be wetted and the thermometers must be spun for a few minutes until the wet-bulb temperature stops going down. Then the relative humidity is found from the wet-bulb temperature and a dry-bulb temperature (on the same device) using a slide rule that is on the psychrometer, or that comes in the same package.

Also note that site-specific conditions (e.g. sunny versus cloudy or a nearby lake) can cause discrepancies between the weather station and the handheld hygrometer.

#### Record Handheld Hygrometer Humidity and Temperature Values \_\_\_\_\_% RH \_\_\_\_\_°F

- The dehumidifier will have a humidity sensor either in the pool room itself or within the ductwork that returns air from the pool room to the HVAC unit. If the sensor is in the room itself, measure the RH right where the sensor is located. If the control sensor is in the return duct, hold the handheld sensor as close to the return grill as possible. (Although return grills are often near the ceiling so you may not be able to get very close.)
- Note that humidity sensors can be sensitive to temperature or RH fluctuations caused by your breathing or body heat. Take care to avoid breathing on the device and whenever possible stand at arm's length while taking the reading.
- If there is a convenient and safe place to set the portable hygrometer on top of the control sensor case, set it there for at least five minutes before taking a reading. If that's not possible, hold the portable device as close to the control sensor as possible and wait at least two minutes to record the values. If either the RH or temperature are still changing every few seconds, wait until they are both steady (being careful to breath away from the sensor).

#### Record Control Sensor Humidity and Temperature Values \_\_\_\_\_% RH \_\_\_\_\_°F

- Take the control sensor readings as soon as possible after taking the handheld meter readings.
- Depending on the unit and controls arrangement, the current sensor reading may be accessible at a few different locations.
- Often the humidity sensor is visible through a control display at the HVAC unit itself, either on a control device attached to the return duct or through a BAS interface.
- Sometimes, a thermostat-like device in the pool room has a display that shows the current humidity. If a device in the pool room has arrow buttons, a dial, or a lever for adjustment, it may display the setpoint instead of (or in addition to) the current sensor reading. If so, look carefully to be sure that you don't confuse the RH setpoint for the current value.
- Humidity sensors can be sensitive to temperature or RH fluctuations caused by your breath or body heat. If you are taking a reading directly from the display of a thermostat-like device in the pool room, take care to avoid breathing on the device and whenever possible stand at arm's length while taking the reading.

### COMPARE

#### Put Inputs into RH Comparison Calculations Below

- Enter the temperature and RH measurements you recorded above into the blanks by the blue highlighted labels in the first calculation table below.

- Use the control sensor RH value to find the “adjustment factor” from the calculation table on the right hand side. Enter this “adjustment factor” into the calculation in the blank below the orange highlighted label.

#### Perform the Calculations as Laid Out

- Be careful to carry and negative (minus) sign from one box to the next. If both numbers being multiplied together are negative, the adjustment value will be positive.
- An example calculation appears immediately after the blank calculation table.

#### Compare Adjusted Handheld RH to Control Sensor RH (Two Value on Bottom Row)

- If there is less than a 5% discrepancy, no action is needed.
- If there is a 5% to 8% discrepancy, you should consider checking again soon and making the seasonal dehumidifier operation check to see if it contributes to unusual control.
- If the discrepancy is more than 8%, take action as noted in the next subsection.

### Humidity Comparison Calculations

Control Sensor Temp	°F		Adjustment Factor (From Table)		Adjustment
Handheld Temp	—	°F			
	= ±	°F	X	—	% per °F
				=	± %

Handheld RH	%
Adjustment	± %
<b>Adjusted Handheld RH</b>	<b>= %</b>

**VS**

<b>Control Sensor RH</b>
%

Control Sensor RH	Adjustment Factor
< 40%	-1 % per °F
40 - 50%	-1.5 % per °F
> 50%	-2 % per °F

### Sample Humidity Comparison Calculations

Control Sensor Temp	84 °F		Adjustment Factor (From Table)		Adjustment
Handheld Temp	—	81 °F			
	=	3 °F	X	-1.5 % per °F	
				=	-4.5 %

Handheld RH	54 %
Adjustment	± -4.5 %
<b>Adjusted Handheld RH</b>	<b>= 49.5 %</b>

**VS**

<b>Control Sensor RH</b>
<b>48 %</b>

### ACTION

#### If >20% - 25% discrepancy

- Replace the humidity sensor.
- Adjust control setting to compensate in the meantime

#### If 15% - 25% discrepancy

- Calibrate or replace the humidity sensor.
- Adjust control setting to compensate in the meantime
- Repeat checks on this sensor more often than the typical frequency.

#### If 8% - 15% discrepancy

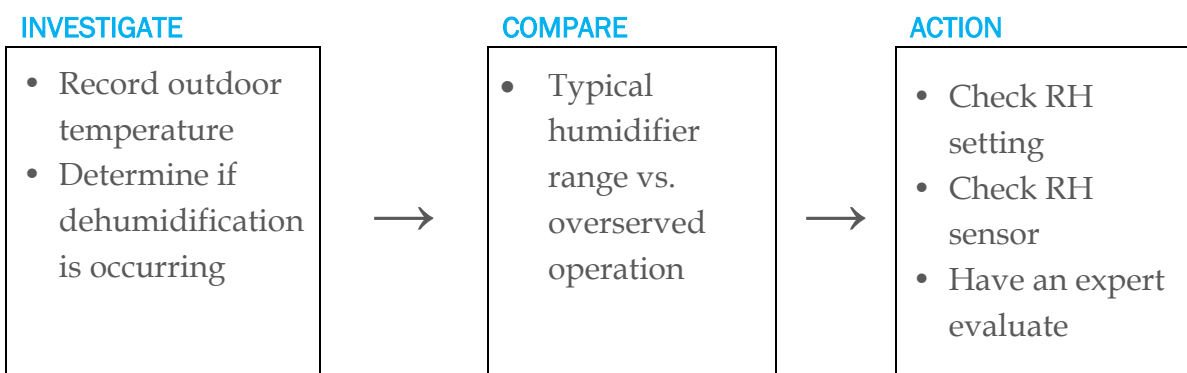
- Have the humidity sensor calibrated.
- Adjust control setting to compensate in the meantime

- Repeat checks on this sensor more often than the typical frequency.

# H1. Seasonal HVAC Operation

Indoor public pool facilities in Minnesota get adequate “free” dehumidification much of the year. This is because a certain amount of outdoor air must be continuously circulated through the pool area to keep the air fresh, and for most of the year the outdoor air is much dryer than the humid pool area air. Some HVAC systems dehumidify a pool area by simply bringing in enough dry, out outdoor air to keep the indoor humidity in check, while others use air conditioning compressors to cool and then reheat the air. Whichever, approach is used, excessive operation of the dehumidifier in cool (dry air) weather can cause both excessive energy use and accelerated deterioration of the dehumidifier. Here’s how to check for this excessive operation.

## WHEN TO CHECK: QUARTERLY (EXCEPT IN THE SUMMER)



### INVESTIGATE

#### When to Measure

- It’s best to check when there hasn’t been unusual activities that increase load.
- Wait until at least two hours after unusually high activity levels to do your check.

#### Record Outdoor Temperature \_\_\_\_\_ °F

- Outdoor temperature can be measured with a BAS sensor or thermometer (in the shade)
- Or, you can use a cell phone app (or website) to get a nearby weather station reading.
- If dehumidifier operation is monitored over a period of time, record the outdoor temperature periodically (being sure to get a high and low reading).

#### Record HVAC Operation Status

- For systems with variable outdoor air dampers, observe outdoor and return air dampers. Outdoor Air \_\_\_\_\_% open; Return Air \_\_\_\_\_% open and/or exhaust fan variable speed drive (if it has) \_\_\_\_\_Hz ÷ 60 Hz = \_\_\_\_\_% speed
- For systems with compressors, observe which compressor(s) run and roughly the percentage of time that they run [see compressor observation tips].  
#1 \_\_\_\_\_% on; #2 \_\_\_\_\_% on; #3 \_\_\_\_\_% on; #4 \_\_\_\_\_% on

## COMPARE

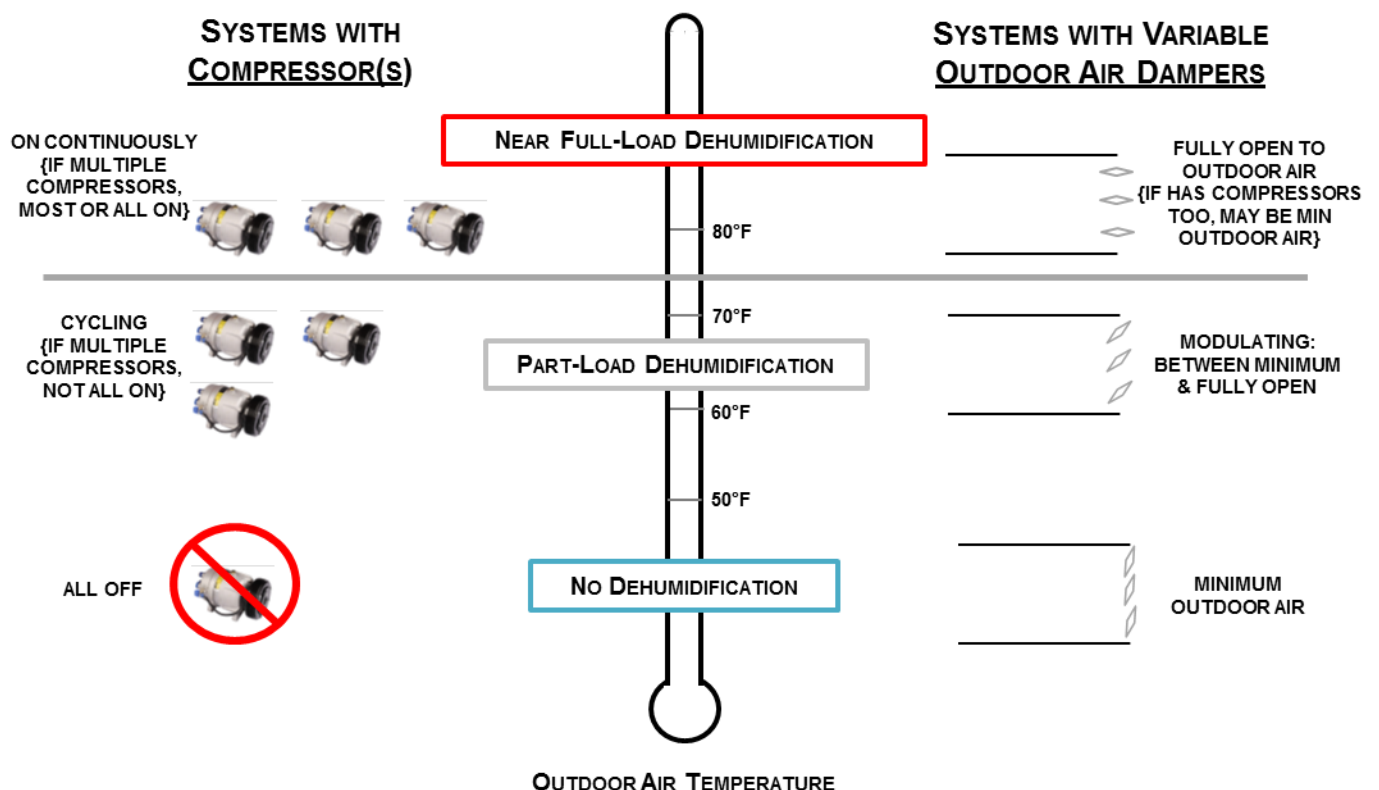
### Typical Dehumidifier Operation Chart (below)

- The chart shows how the typical dehumidifier load varies seasonally in Minnesota, where the fresh outdoor air needed for ventilation is cold and very dry in the winter, but carries in more moisture in warmer weather.
- Dehumidifiers that use compressors are represented on the left. [See “[Compressor Observation Tips](#)” for more information about how to know if a compressor is running or cycling.]
- Dehumidifiers that vary the outdoor airflow to dehumidify are represented on the right.

### Compare Actual Dehumidifier Operation to Chart

- Does the actual compressor/outdoor air match chart closely? **Okay as is.**
- Is the actual compressor/outdoor air > chart (or <)? **Take Action to save**
- If Outdoor Air % Open + Return Air % Open  $\neq$  100% ( $\pm 20\%$ ) **Take Action to save**

### Typical Dehumidification Operation Chart





## ACTION

### Check Humidity Control Settings [see [S1](#)]

- If it's lower than it needs to be, adjust and repeat observations to confirm reduced dehumidifier operation.
- If it checks out okay, continue on to the next action on the list.

### Check the Humidity Sensor for Accuracy [see [S2](#)]

- If it's inaccurate, replace and repeat observations to confirm reduced dehumidifier operation
- If it checks out okay, continue on to the next action on the list.

### Have an Expert Evaluate the System for Other Issues and Solutions Such As:

- Not enough outdoor air to ensure good air quality.
- Minimum outdoor air is too high (likely if compressor runs much less than chart).
- Damper actuator failure.
- Suboptimal control sequencing.

#### SAMPLE OF SAVINGS — FITNESS CENTER

**\$20,700 PER YEAR**

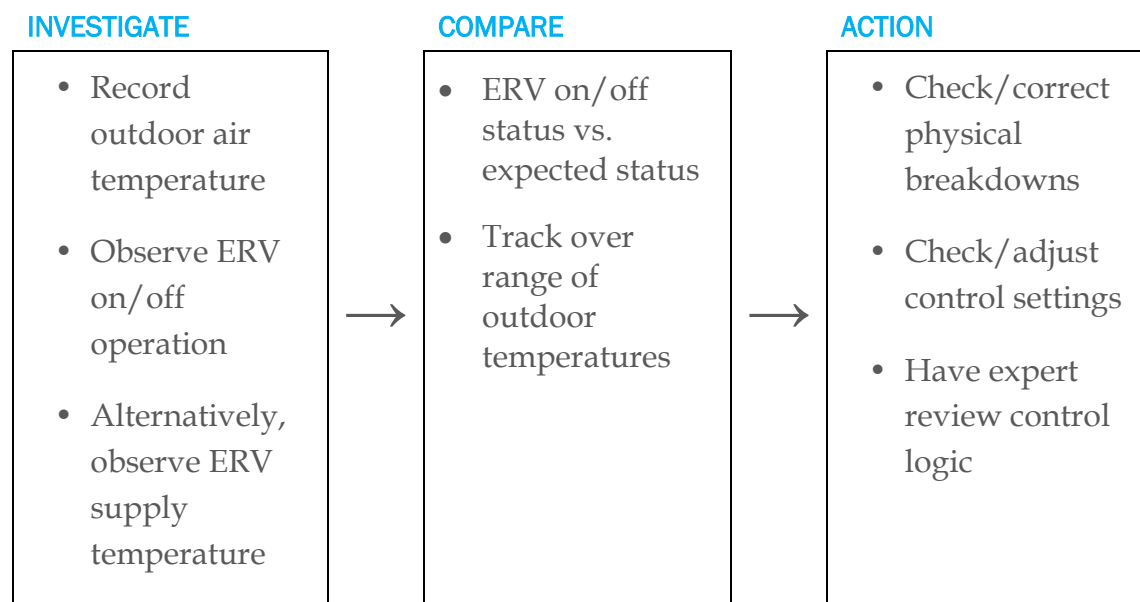


One fitness center had poor control of the hot water heating coil that caused the compressor to run continuously in the winter for heating purposes. Besides dramatically increasing the energy costs, this was causing the compressor to fail an average of every two years at a replacement cost of \$30,000.

## H2. Energy Recovery Ventilator Basic Check

Energy recovery ventilators (ERV) provide dramatic energy cost savings for public pool facilities because of the need for high continuous outdoor air ventilation rates. When present, ensuring proper operation of an ERV is typically the most important energy saving check. This is because, although they have a dramatic impact on energy use, their failure usually doesn't cause any other adverse effects that would alert an operator of a problem. Another heating source typically picks up the slack without there being any impact on pool room conditions. This check outlines how you can quickly confirm that an ERV is operating as intended.

### WHEN TO CHECK: QUARTERLY (EXCEPT IN THE SUMMER)



### INVESTIGATE

Record Outdoor temperature \_\_\_\_\_ °F

- This can be measured on-site via a BAS sensor or thermometer (in the shade), or you can use a cell phone app (or website) to get a current nearby weather station reading.

Fixed Plate ERV Face and Bypass Damper Control \_\_\_\_\_ On (face) or Off (bypass)

- Fixed plate ERV units turn the heat recovery "on" or "off" by having air flow through the heat exchanger (i.e. face) or around the heat exchanger through an alternative airflow path (i.e. bypass). When an ERV is "on," the face damper is open to allow air to flow through the heat exchanger, and the bypass damper is closed.
- The face/bypass damper arrangement is usually on only one air stream – either the fresh outdoor air stream or the exhaust air stream.
- Some systems will vary the ERV capacity with an "on" condition that allows a portion of airflow through both the face and bypass dampers at the same time. If this is observed, record: \_\_\_\_\_% open to heat exchanger and \_\_\_\_\_% open to bypass.

- BAS displays will often have a graphic that notes the intended damper position. While this can provide a good indication of the intended control, it is recommended that you make a direct observation of the dampers to the degree that this is possible. On some systems, opening a specific panel will provide a clear view of damper positions. Clear indications of damper positions might also be possible by looking at the damper actuator and linkage assembly.

#### **Recovery Wheel Control \_ On (Wheel Spinning) or Off (Wheel is Still)**

- Systems with wheels for recovering energy turn “on” or “off” by having the recovery wheel rotate or not. Complex systems may even vary the wheel rotation speed instead of having it simply on or off. If the control system displays a wheel speed, record that here: \_\_\_\_\_ wheel speed as % of maximum.
- BAS displays will often have a graphic that notes the intended damper position. While this can provide a good indication of the intended control, it is recommended that you make a direct observation of the wheel itself to confirm that it is actually rotating or not.

#### **Alternative ERV Recovery Status Observation      On or Off**

- If direct observation of the face/bypass or recovery wheel operation is not possible, it is sometimes possible to get a good indication of its operation status by looking at a BAS or control panel readout of the preheated (or precooled if in hot summer weather) air temperature after the recovery section and before any other heating or cooling coils.
- It is typically possible to get a BAS readout on a “preheated” temperature for recovery wheel units. However, this is often not possible on plate ERV units because a true indication of the preheated temperature for plate ERV units can only be observed after the face and bypass airflows mix together. Many units have a heating or cooling coil immediately after the heat exchanger and this changes the air temperature before the face and bypass flows mix back together. Any heating or cooling provided by this coil makes it impossible to get a true “preheated” air temperature that is a representative average of all of the fresh outdoor air coming through the unit.
- Where a representative “preheated” air temperature is available, you can tell the ERV’s on/off status by comparing this temperature to the outdoor and pool room temperatures. If the “preheated” air temperature is closer to the pool room than to the outdoor temperature, the ERV is “on.” If the “preheated” temperature is closer to the outdoor temperature, then the ERV is “off” or operating at a reduced capacity

### **COMPARE**

#### **Typical ERV On/Off Operation Ranges**

- The next figure shows when a pool ERV should be “on” or “off”.
- While the ideal exact transition points will vary somewhat based on site and equipment specific details, operation that is clearly inconsistent with this should be addressed.

#### **ERV On Ranges**

- During most cold weather periods and very hot weather periods the ERV should be operating to preheat or precool the outdoor air. The energy savings that can be achieved

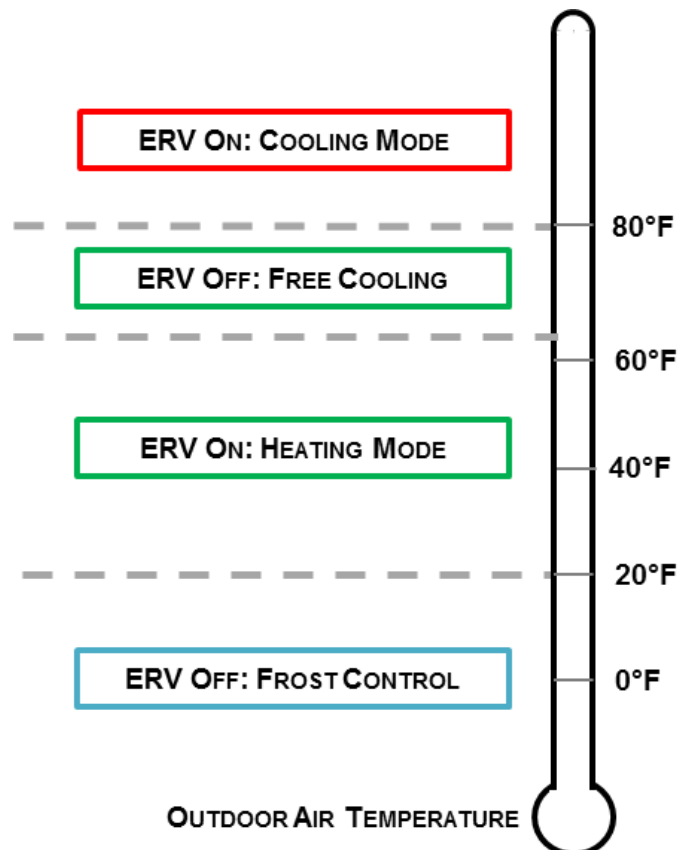
by operating during these time periods is the reason that an ERV is installed. If there is significant ERV “off” status in these ranges, take action to correct this.

- Depending on the HVAC unit arrangement, a failure of the ERV to operate in cooling mode can cause comfort problems with either the humidity or temperature drifting up beyond the desired range, and action should be taken to address this.

### ERV Off Ranges

- Significant operation of the ERV in the “ERV Off: Frost Control” range could lead to problems with icing up of the ERV that cause damage, prevent adequate ventilation, or greatly reduce the ability of the unit to recover heat. Some units will vary the capacity in this range to allow for some heat recovery without frost problems. In either case, watch for ice build-up and take action to correct if there are signs of frosting.
- The “ERV Off: Free Cooling” zone of operation is more variable based on site and system details. If the ERV is “on” in this area, it is not necessarily a sign of a problem. The possible drawback is overheating, which could either cause the pool room to be warmer than desired or cause extra compressor use for cooling. If either of these issues is suspected see “Have Control Evaluated By and Expert” section within the action items.

Typical ERV On/Off Operation Ranges



## ACTION

### Check for Physical Malfunctions

- For fixed-plate ERVs, check that ERV face and bypass damper linkages are all securely attached and that there are no visible problems with the damper assemblies. As necessary, have an expert evaluate damper actuators and linkages.
- For wheel-type ERVs, check for a loose or broken belt or gear assembly and make sure that the wheel motor is operational. As needed, have an expert evaluate and/or repair the wheel rotor assembly.

### Check/Adjust ERV Settings

- See if the frost control settings or economizer settings are significantly different from expected in the previous table. If so, make adjustments and/or work with a qualified expert to make control changes.

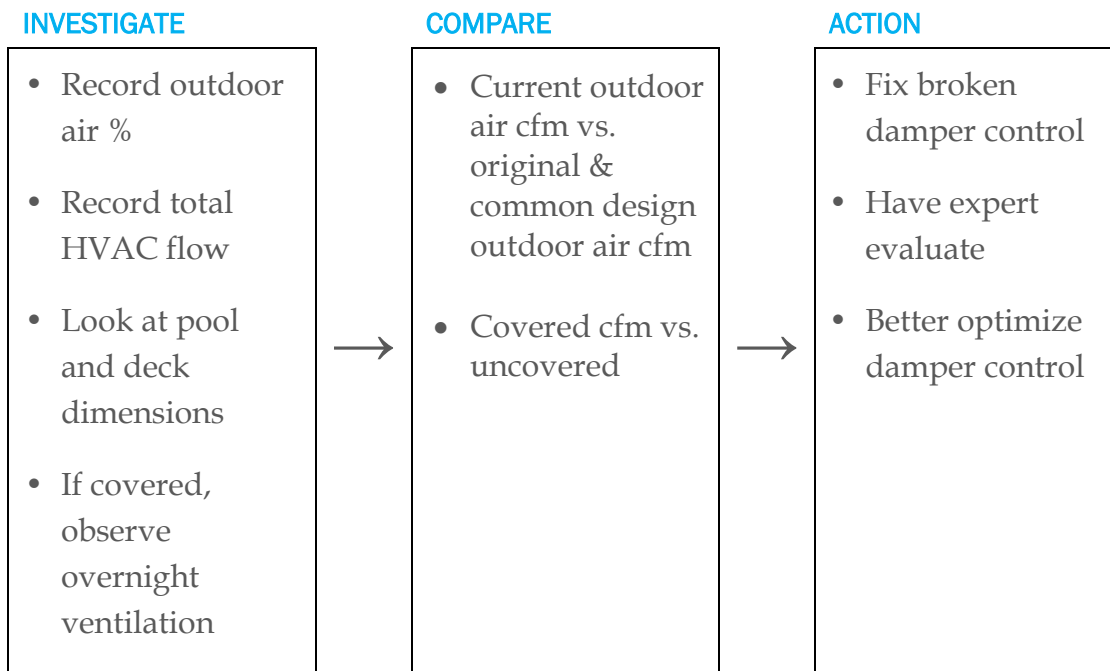
### Have the Control Evaluated By an Expert

- ERV controls often do not have the frost control and/or economizer control logic clearly shown on BAS system screens or other control diagrams, so it may be difficult to determine what the controls are trying to do.
- As necessary, consult an expert to evaluate and correct ERV controls that are causing significantly different operation (more than 10°F variance from outdoor temperature ranges) than what is outlined in the table.

## H3. Outdoor Air Ventilation Rough Check

Continuous outdoor air ventilation to a certain degree is required in pool rooms to prevent air quality problems. Having too much outdoor air ventilation can greatly increase energy use and cause comfort problems, while not providing enough outdoor air can contribute to air quality problems and condensations issues, as well as extra dehumidifier energy use and wear. Here is how you can check to see if this is an issue.

### WHEN TO CHECK: QUARTERLY (EXCEPT IN THE SUMMER)



### INVESTIGATE

#### Observe Current Minimum % Outdoor Air Damper % Open Outdoor Air Damper

- For systems connected to a BAS system, a careful look through the display screens may clearly show the minimum outdoor air damper setting and current intended damper position. A manual observation of the damper position should be carried out to confirm the actual current percent outdoor air.
- If the weather outside is cool, the system is likely already at the minimum outdoor air so there may be no need to do anything special to observe the minimum outdoor air control condition.
- If necessary, the dehumidifier control can typically be temporarily set to a humidity setpoint that is 15% to 20% RH above the current sensor reading. This should disable any dehumidification efforts by the HVAC unit and may cause it to operate at the minimum outdoor air. However, some economizer control features will make it difficult to force the unit to temporarily control to the minimum outdoor air, especially in mild weather.

- For systems with variable outdoor air dampers, observe outdoor and return air damper temperatures  
Outdoor\_Air \_\_\_\_\_% open; Return Air \_\_\_\_\_% open
- Note that some HVAC units are not designed to bring in 100% outdoor air even when the outdoor air opening is fully opened. If the outdoor air opening has a smaller area than the supply duct, record the dimensions of the outdoor air opening \_\_\_\_\_inches by \_\_\_\_\_inches; and supply duct \_\_\_\_\_inches by \_\_\_\_\_inches

#### Find Pool HVAC Unit Total Design Flow (cfm)

- The HVAC unit total supply flow may be shown on the equipment's nameplate, on plans (look at the mechanical schedules which are usually the last M pages), equipment documentation within a 3-ring binder, or on a BAS display screen.
- If it cannot be found by any of the above means, find the unit's manufacturer, model number, and serial number from the nameplate and contact the manufacturer to find out (start with a local manufacturer's representative if available).

#### Obtain Pool and Wetted Duck Dimensions \_\_\_\_\_ft by \_\_\_\_\_ft

- Do not include spectator areas, which are generally meant for people that are not swimming; only measure the area of the pool and around the pool that is designed for swimmers to occupy.

#### If Pool Cover is Used, Investigate Outdoor Air Control during the Covered Pool Time

- If there is BAS control of the HVAC unit, there may be an indication in the BAS screens or documentation about the intent to control outside air differently when the pool is covered. If so, it is still recommended that you actually observe that the system follows this intent at a time when the cover is in place and the ventilation is to be reduced.

### COMPARE

#### Current Minimum Outdoor Air Ventilation Rate

- If the outdoor air opening is smaller than the supply duct, calculate the ratio of opening sizes:

$$\frac{\text{outdoor air duct area (____inches} \times \text{____inches)}}{\text{supply air duct area (____inches} \times \text{____inches)}} = \text{____\% max outdoor air (OA)}$$

- Calculate current outdoor air flow:

$$\text{Total flow ____cfm} \times \text{OA damper ____\% open} \times \text{max outdoor air ____\%} = \text{____cfm Actual OA}$$

#### Common Design Outdoor Air Ventilation Rate

- Calculate the wetted pool area as the product of the pool area dimensions: square feet.
- Calculate a current typical outdoor air design flow (not considering spectator area):  
 $\text{Wetted pool room area ____ square feet} \times \text{0.5 cfm per square foot} = \text{Typical ____ OA cfm.}$
- If the actual outdoor air cfm and typical outdoor air cfm are more than 20% different, the take action to have an expert determine if a change is warranted.



### Other Indicators of Possible Outdoor Air Amount Issues

- An inability to keep adequate pool area temperatures, or low discharge air temperatures, could be symptoms of the system providing too much outdoor air.
- Also, if *Outdoor Air % Open + Return Air % Open  $\neq$  100% ( $\pm 20\%$ )*, take action to save energy and reduce control problems.
- Indicators of potential over- and under-ventilation are also noted in the S1 check.

### Compare Pool Covered Ventilation to regular Occupied Ventilation

- If the outdoor air ventilation rate is not reduced significantly during most of the time that the pool is covered, take action to take advantage of this opportunity.

### ACTION

#### If Referred to Action Because of Improper Combination of Outdoor Air and return Damper Positions

- Inspect any linkages between dampers to look for loose connections. If simple tightening of a linkage doesn't provide a solution, have a qualified technician check the damper actuators and controls to identify and solve the problem.

#### If Mismatch between Actual and Typical Design Outdoor Air cfm, Consult an Expert and Possible Adjust Outdoor Air Damper Control

- Providing adequate outdoor air ventilation is critical so a qualified expert should be consulted to confirm the potential to change the minimum outdoor air flow, if this was suggested by the comparisons.
- The minimum outdoor air position is typically set via automatic modulating damper controls that receive a signal from a central BAS system or controls that are at the HVAC units. Where a comparison has found improper outdoor air flow control, modify the setpoints and/or programming to correct the issue.
- Sometimes the outdoor air is manually controlled or fixed with an opening that only has a manual balancing damper or no damper. If adjustable, this damper can be adjusted to obtain the proper outdoor airflow.
- Where sizable spectator areas are present, this can cause a need for higher ventilation rates during the events when a large number of spectators are present. A means to automatically or manually provide adequate outdoor airflow during these infrequent events should be provided. However, the needs during these infrequent events should not cause the pool area to receive more outdoor air ventilation than is needed during the rest of the year.

#### If Referred to Action for Not Reducing Ventilation When the Pool is Covered

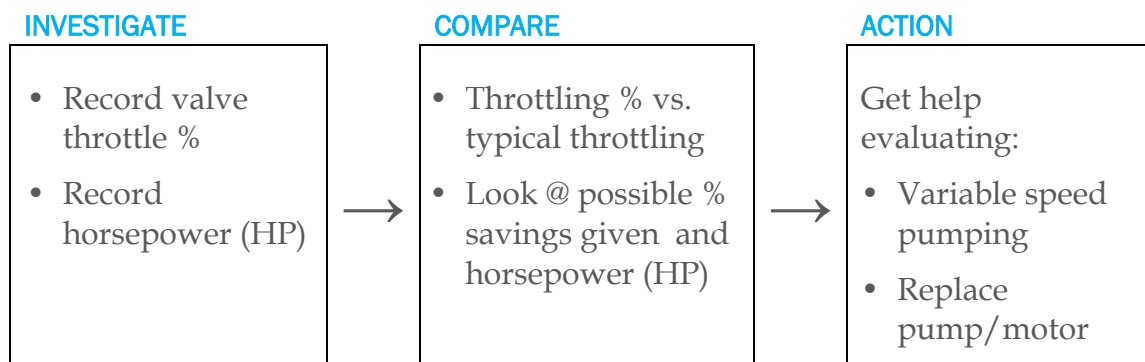
- Explore options for reducing the outdoor air ventilation rate when the pool is covered.
- Ideally, a reduced, pool-covered, ventilation rate would be enabled and disabled by a reliable form of feedback about whether or not the cover is being used. An interlock with the pool cover mechanism is ideal.



# W1. Main Valve Throttling

Many public pools end up with pumps larger than what is actually needed because of safety factors in design and the limited selection of pump and motor sizes. For example, going from a 1 HP motor to a 1.5 HP motor (the next largest size) is a 50% jump in capacity. When dramatic oversizing occurs, the pool water flow rate is usually still limited to the minimum needed for adequate turnover by severely choking down the flow with a throttling valve. In such cases, the pump must work against a high pressure caused by the throttling and it uses much more energy than is really needed. Here's how to see if your system has severe throttling that may be worth correcting through pump motor control and/or replacement.

## WHEN TO CHECK: ANNUALLY



## INVESTIGATE

### Locating Main Line Valves

- Although main line valves that may be throttled are typically located near the outlet of the pump, they could be anywhere along the main piping line that comes the pool to the pump, from the pump to the filter, and from the filter to the pool.
- Ignore throttling of valves along the main line that are used to force some water through smaller bypass lines (smaller pipes located just before and after the valve) that divert some of the main flow to the heater. (See [Valve Throttling Reference](#) for more detail.)
- Ignore any throttling of valves in the piping of a booster pump.

Record % Throttled for Each Valve: # 1 \_\_\_\_\_%; #2/Spa\_\_\_\_\_%; #3\_\_\_\_\_%; #4\_\_\_\_\_%

- Note the percentage closed above for each main line valve based on where the valve handle points between perpendicular to the pipe (100%) and parallel to the pipe (0%).
- See "[Valve Throttling Reference](#)" for more detail on valve position.

### Record Pump Horsepower (HP)

- Record pump nameplate HP (look on the pump or motor nameplate) for the pump corresponding to each valve noted above Valve # 1\_\_\_\_\_HP; Valve #2\_\_\_\_\_HP; Valve; #3\_\_\_\_\_HP; Valve #4\_\_\_\_\_HP

## COMPARE

- If any main line valve is throttled 25% or more, use the table in “Valve Throttling Reference” to estimate potential annual kilowatt-hour (kWh) savings using the percent throttling value in combination with pump horsepower.
- Also use the table if a pump larger than 5 HP has a valve throttled 10% or more.
- Estimate potential cost savings by multiplying the kWh savings by \$0.11 per kWh (or another available representative utility rate that includes usage and demand savings).
- If the potential energy savings is significant enough, take action to save energy.

## ACTION

- Consider the installation of a variable speed pump or the addition of a variable speed drive to the pump motor. Operating at a lower pump speed with the previously throttled valve wide open can provide the required flow while using less energy.<sup>4</sup>
- If the economics of the variable speed drive retrofit based on the above estimate is questionable, have an engineer or other qualified individual perform a detailed analysis of the potential to replace the pump and/or motor with one selected to provide the design flow without significant throttling.

### Example of a Variable Speed Drive for a Pump



<sup>4</sup> More information about variable speed pool pump control can be found in NSPF, Ch.10 and NRPA, 7-6 to 7-7.

## Appendix 2. Detailed Savings Calculation Guidance for Select Measures

The following pages provide detail regarding recommendations related to energy savings calculation recommendations for the measures listed below:

### Recommended Minnesota TRM Manual Additions

- 1) variable speed pool pumping
- 2) high efficiency pool heater
- 3) pool cover

### Recommended Savings Calculation Approaches

- 4) reducing outdoor air
- 5) modifying pool room temperature control
- 6) modifying pool room humidity control

## RECOMMENDED MINNESOTA TRM MANUAL ADDITIONS

### 1) Variable Speed Pool Pumping (Commercial)

#### Site Specific Savings

For site-specific estimates of savings for variable speed pool pumps, follow the energy savings calculation procedure for the measure *Electric Utility Infrastructure - Variable Speed Drives (non-HVAC)* in version 2.1 of Minnesota's TRM with the following modification.

- Calculate the Energy Savings Factor as the difference between the current and proposed conditions in the Table of PLR Values below. (This replaces the use of the TRM's Table 5 with multiple load factor and % of design flow values per the format of the TRM's Tables 1 and 2.)

Table of PLR Values

Min % of Wide Open Flow		Max % of Wide Open Flow	Throttle Valve PLR	Variable Speed Drive PLR
0%	To	10%	0.8	0.05
10%	To	20%	0.81	0.06
20%	To	30%	0.82	0.09
30%	To	40%	0.83	0.12
40%	To	50%	0.85	0.18
50%	To	60%	0.87	0.27
60%	To	70%	0.9	0.39
70%	To	80%	0.93	0.55
80%	To	90%	0.96	0.75
90%	To	100%	1	1

- The following equations will apply with Wide Open Flow being defined as the pool water flow rate at full pump speed with any throttling valves wide open

$$ESF = PLR_{Throttle\ Valve, current} - PLR_{VSD, proposed}$$

$$\% \text{ of Wide Open Flow}_{proposed} = \% \text{ of Wide Open Flow}_{current} \times \frac{\text{Code Required Flow}}{\text{Current Flow}}$$

$$\begin{aligned} & \text{Code Required Flow}[\text{gallons per minute}] \\ &= \frac{\text{Pool Volume}[\text{gallons}]}{60 \left[ \frac{\text{minutes}}{\text{hour}} \right] \times \text{Code Turnover Time}[\text{hours}]} \end{aligned}$$

- c) Reference the current Minnesota Swimming Pool Code for the maximum time to run the pools entire volume through the filtering and treatment system. The table below summarizes the maximum turnover time requirement in the code volume published in 2009 and in force as of December of 2017.<sup>i</sup>

Table of Code Turnover Time

Pool Type	Max Turnover Time
General	6 hours
Wading	2 hours
Spa	0.5 hours
Dedicated Plunge	1 hour
Zero Depth	2 hours (for area < 3 feet deep)

- d) For indoor pools in hospitality buildings, fitness centers, and other buildings that keep the pool open year-round, assume 8,760 operating hours per year and a coincidence factor of 1. For schools and other facilities with seasonal pool shutdown, base the hours and coincidence factor on the facility's reported schedule.

### **Preliminary Program Level Savings Estimate**

For building type-specific estimates of savings of variable speed pool pumps, follow the energy savings calculation procedure for the measure *C/I HVAC - Variable Speed Drives* in version 2.1 of Minnesota's TRM with the following modification.

- a) Use the following values for Energy Savings Factor (ESF) in place of the TRM's Table 3.

$$ESF_{\text{hospitality, multifamily}} = 0.45$$

$$ESF_{\text{school, fitness}} = 0.51$$

The potential number of applicable facilities should be based on an assumed 35 percent of pools (same value for all building types).

- b) For indoor pools in hospitality buildings, fitness centers, and other buildings that keep the pool open year-round, assume 8,760 operating hours per year and a coincidence factor of 1. For schools assume 7,665 operating hours [i.e. pool shut down for 1 ½ months] and a coincidence factor of 0.78.

## **2) High Efficiency Pool Heater (Commercial)**

For indoor public pool heater savings in Minnesota, the following savings calculation should be used.

$$Savings [therms] = BTUH_{In} \times \left[ \frac{1}{Eff_{Base}} - \frac{1}{Eff_{High}} \right]$$

Where:

$BTUH_{In}$  = maximum input rating of the new pool heater [in units of BTU per hour]

$Eff_{base}$  = Baseline pool heater efficiency (78% [0.78] code minimum for new heater)

$Eff_{High}$  = Efficiency of the new high efficiency pool heater efficiency [as a decimal value (e.g. 0.95 for 95% efficiency)]

### 3) Pool Cover (Commercial)

For indoor public pool cover savings, the following savings calculation should be used for Minnesota.

$$Savings [therms] = \frac{0.9 [therms/ft^2]}{Pool Heater Efficiency} \times Pool Area [ft^2]$$

If the pool heater efficiency is not known, it should be assumed to be 80% (0.80).

For the use of a liquid pool cover, the preliminary suggestion is to assume 50% of savings for a traditional pool cover – as calculated above. However, it is recommended that additional measurement and verification be conducted before using this assumption for large-scale program implementation.

## Recommended Savings Calculation Approaches

- 4) reducing outdoor air
- 5) modifying pool room temperature control
- 6) modifying pool room humidity control

For these last 3 measures addressed by this appendix, we recommend a particular, rigorous approach for CIP program savings calculations (e.g. custom rebates or recommissioning savings estimates). In particular we recommend that savings estimates be based on detailed hourly or BIN calculation models that address the real interactions between these factors – plus the pool evaporation rate – with assumptions that have a sound basis in the actual design and operating conditions. A degree of iteration needs to be used to accurately estimate the savings from changing any one of these factors because each of these key pool room or HVAC system parameters has an impact on the others. Because of these interactions, some assumptions that have commonly been used in engineering calculations can cause misleading savings estimates. For example, the actual relative humidity may be higher or lower than the setpoint leading to a poor estimation the pool heating and dehumidification loads. Thus, setpoints should be used as a starting point for iterative analysis of the actual conditions as they are influenced by the other operating conditions and system limitations. The key interactive effects that need to be taken into consideration are outlined below, as well as guidance and references to detailed formulas and tables from Chapter 1 of the 2017 ASHRAE Fundamentals Handbook.<sup>ii</sup>

## Key Interactive Effects

- a) **Impact of Pool Room Temperature & Relative Humidity on Pool Room Humidity Ratio.** While relative humidity is the most commonly used indicator of moisture level in the air for purposes of comfort discussions, humidity ratio is the measure of the amount of water in air that is ultimately used in most engineering calculations. This is because humidity ratio gives a direct indication of the amount of water vapor in air. It is defined simply as the ratio of the mass of water vapor to the mass of dry air. On the other hand, relative humidity indicates the ratio of how much water is in the air compared to the maximum amount of water vapor that air can hold at its current temperature.

The humidity ratio of air can be calculated from the relative humidity, temperature, and atmospheric pressure. As one might expect, increasing the relative humidity for a given temperature increases the humidity ratio proportionally. However, the humidity ratio also goes up with the air temperature if the relative humidity is held constant. The warmer the air is, the more sensitive the humidity ratio is to changes in temperature (if the relative humidity stays constant). Below are the steps for calculating humidity ratio using equations in Chapter 1 of the ASHRAE Fundamentals Handbook.

- i. Using the temperature, calculate the partial vapor pressure of water vapor in air at saturation [the point where water starts to condense out of the air],  $p_{ws}$ , using Table 3 or equation (6).
- ii. Using this pressure,  $p_{ws}$ , and relative humidity,  $\phi$ , calculate the actual partial vapor



pressure of water in the air,  $p_w$ , using equation (22) [ $\phi = p_w / p_{ws}$  given here due to a handbook error in some versions].

iii. Using this  $p_w$  and the atmospheric pressure [in units of psia and can be estimated from Table 1 in the handbook],  $p$ , calculate the humidity ratio,  $W$ , using equation (20).

- b) **Impact of Pool Temperature, Pool Room Humidity, and Pool Room Temperature on Pool Evaporation Rate.** Pool water evaporation rate is a key determinant of a pool facility's energy use for both pool heating and dehumidification. Although it happens in a less intense process, evaporation of water at any temperature draws about as much energy from the surrounding water as boiling water does from its heat source. This energy needs to be made up via the pool water heater. Likewise, the water vapor that evaporates must be removed from the pool room with a dehumidifying HVAC unit to keep the room's humidity in check. Therefore, the evaporation rate is the primary determinant of the loads on the both pool water heating and pool room dehumidification equipment.

The two key inputs for calculating the evaporation rate of an indoor pool are pool temperature and pool air moisture level. Here the steps for calculating the pool water evaporation rate following the ASHRAE Fundamentals Handbook and the Natatoriums section within Chapter 5 of the ASHRAE Applications Handbook.<sup>iii</sup>

- Using the pool water surface temperature, calculate the saturated vapor pressure of water at the pool surface,  $p_w$ , using Table 3 or equation (6) from Chapter 1 of the ASHRAE Fundamentals Handbook [ignore the difference in subscript for  $p$ ].
- Find the pool room's partial vapor pressure of water in the air,  $p_a$ , calculated from ii in a) above (using pool room temperature and relative humidity).
- Based on the pool type and activity, choose an appropriate activity factor,  $F_a$ , from the table right after equation (2) in the Natatoriums section of the ASHRAE HVAC Application Handbook. (This ranges from 0.5 for an unoccupied pool to 1.5+ for special water features.)
- Using the above vapor pressures and activity factor--along with the pool area--to calculate the pool water evaporation rate,  $w_p$ , using the equation below [equation (2) in Natatoriums section of handbook].

$$w_p \left[ \frac{lbs}{hr} \right] = 0.1 \times Pool Area [ft^2] \times (p_w - p_a) F_a$$

This pool evaporation rate can be used directly to calculate the evaporation impact on pool water heating rate [in units of Btu/hr] by multiplying the evaporation rate by 1,000 [BTU/lb.]

- c) **Outdoor Air Flow and Humidity Ratio Impact on "Free Dehumidification" and Pool Room Humidity Ratio.** In Minnesota's climate the outdoor air is usually much dryer than pool room air. This means that the high, continuous outdoor air ventilation needed to dilute and remove pool off-gassing provides significant "free" dehumidification throughout most of the year. The amount of dehumidification provided by the outdoor

air flow can be calculated using the steps outlined below.

- i. Using the outdoor temperature and humidity, calculate the outdoor air humidity ratio,  $W_{OA}$ , following the calculation steps i through iii outlined in a) above.
- ii. Using the outdoor air flow rate along with pool room and outdoor humidity ratios, calculate the moisture removal rate with the equation below.

$$\text{Moisture Removal Rate} \left[ \frac{\text{lbs}}{\text{hr}} \right] = \text{Outdoor Air Flow} \left[ \frac{\text{ft}^3}{\text{min}} \right] \times 0.075 \left[ \frac{\text{lb dry air}}{\text{cubic foot}} \right] \times 60 \left[ \frac{\text{min}}{\text{hr}} \right] \times (W_{room} - W_{OA})$$

If the above calculated dehumidification provided by outdoor air (i.e. moisture removal rate) is greater than the pool water evaporation rate, then the assumed pool room humidity level should be lowered until these two values match. If, however, the calculated dehumidification provided by outdoor air is less than the pool water evaporation rate, then the remaining dehumidification load will be the difference between these two. If outdoor air ventilation is the only (or first, economized) source of dehumidification, then the outdoor air flow rate would be increased (up to the system's maximum outdoor air flow rate) so that the calculated moisture removal rate matches the pool water evaporation rate. If the moisture removal rate calculated from the outdoor air, plus any compressorized dehumidifier at its maximum capacity, is less than the calculated pool evaporation rate, then the pool room humidity level must be assumed to increase until these two calculated values match.

Note that as outdoor air flow increases to provide dehumidification, the energy needed to heat the outdoor air also increases. The relationship between outdoor air flow and energy used to heat the outdoor air can be reasonably approximated with the equation below.

$$\begin{aligned} \text{Outdoor Air Heating Energy} \left[ \frac{\text{Btu}}{\text{hr}} \right] \\ = 1.08 \times \text{Outdoor Air Flow} \times (T_{room} - T_{OA}) / \text{Eff} \end{aligned}$$

where  $\text{Eff}$  = heating efficiency (90% for a gas direct-fired make-up air unit)

The above relationships often need to be used iteratively to find what the actual conditions and loads will be. Depending on how the HVAC system capacity and operation matches the loads, the modeling will generally use the pool room setpoints as a starting point, and then adjust them where outdoor air flow and system limitations will lead to a drift above or below the setpoint. Note that while it only happens for very few hours in the year, the pool room temperature may similarly increase above the setpoint due to outdoor air being brought in that is warmer than the pool room temperature.

## References for Appendix 2

- i Minnesota Administrative Rules, Section 4717.2560 Recirculation Rate. The Office of the Revisor of Statutes. May 11, 2009.
- ii ASHRAE Handbook 2017 Fundamentals (I-P Edition). ASHRAE, Atlanta, GA.

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