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A Case Study: Trane's Integration of the Storage Source Heat Pump System

The Storage Source Heat Pump System (SSHP) is a high-efficiency, electrified hydronic heating and cooling solution. It extends the operating range for efficient electrified heating beyond the limits of conventional heat pump systems and is ideal for systems with four-pipe hydronic variable flow distribution.

On the Trane campus in La Crosse, Wisconsin, the Storage Source Heat Pump System (SSHP) has been installed in the Emil Erickson Building (see page 11 for more information regarding the history of the buidling). This 80,000-square-foot mixed-use building, which includes office, training, and manufacturing spaces, is located in Climate Zone 5A. The area experiences cold temperatures, with a design heating outdoor air dry-bulb (OADB) temperature of -20°F, as specified by Wisconsin building code. The building has been retrofitted from central-plant supplied steam heating to electrified heating using the SSHP system. Additionally, the existing water-cooled chilled water plant has been replaced, eliminating the need for condenser cooling water and associated water usage.

The objectives for the retrofit include a seven percent reduction in water consumption and a CO_2 emissions reduction target of 20 metric tons per year. Additionally, by using more efficient heat pump heating paired with thermal energy storage for both heating and cooling, a 25 percent reduction in the building's Energy Use Intensity (EUI) is targeted. This newsletter aims to introduce the system, detail the upgrades made to the existing system, and focus on insights gained from various case studies involving the system.

What is the Storage Source Heat Pump System?

The use of a heat pump for heating in electrified systems increases the overall system heating coefficient of performance (see sidebar on COP on page 2). The water-to-water heat pump (WWHP) used in the system is a water-cooled chiller, but rather than operating to maintain a chilled-water supply fluid temperature, the unit operates to maintain a leaving condenser fluid temperature. This may also be referred to as a chiller-heater, however, throughout this newsletter the term WWHP will be used.

This system incorporates two key technologies:

- Thermal energy storage (TES) in the form of ice tanks
- Heat pumps – including reversible air-to-water heat pumps (AWHPs) and non-reversible chillers operating as heaters

It is important to note that the heating efficiency of a chiller operating in heating mode is significantly higher than either electric resistance heating or natural gas boilers.

Due to the inclusion of thermal energy storage, the system can recover heat even when the heating and cooling loads are not simultaneous. Heat energy can be stored in the TES and later used by the WWHP to meet the building's heating needs. Additionally, the AWHP can operate to add heat to the system and address any imbalances.

Additional information can be found in the Resource section located on page 10.

System Details

The SSHP system is comprised of four hydronic loops as shown in Figure 1 on page 2. See Table 1 on page 3 for system details (quantity, function, and capacity).

- Cooling distribution loop (source)
- Heating distribution loop (sink)
- Air-to-water heat pump (AWHP) loop (source/sink)
- Energy transfer loop (ETL)

Source (Cooling) Loop

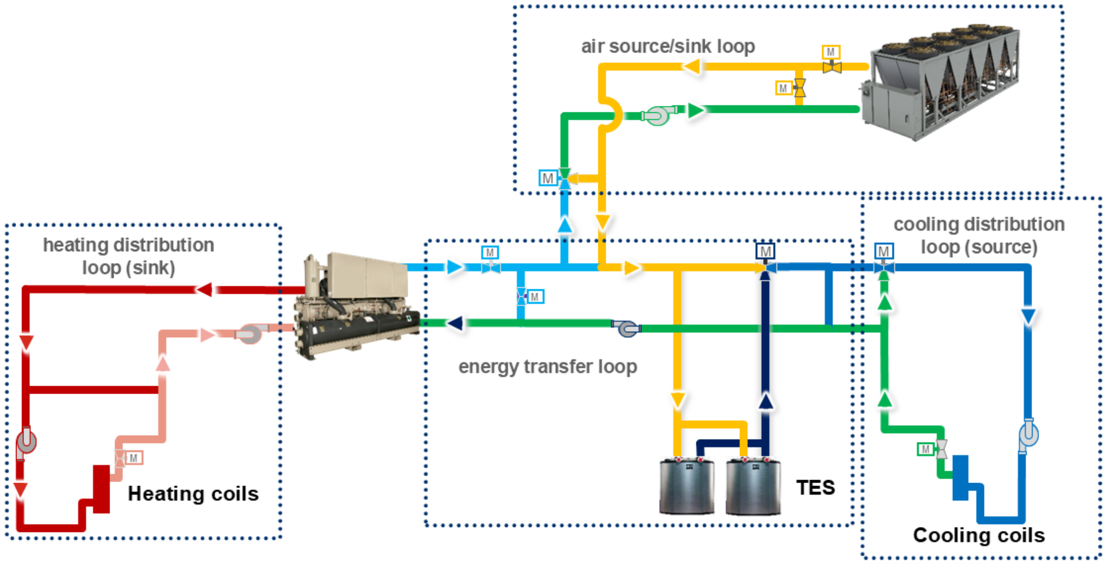
The cooling loop is a traditional variable flow distribution loop. It employs variable flow pumping to deliver chilled water to coils equipped with two-way valves. The heat absorbed by the coils is then used as an energy source for the Energy Transfer Loop (ETL). Each coil valve modulates fluid flow to maintain a leaving supply-air temperature. Supply fluid temperature reset controls help conserve cooling energy when appropriate, such as during low load or mild ambient conditions.

Trim and Respond logic is used to control the pump to a differential pressure in the system. The cooling loop connection to the ETL is decoupled and cooling can be provided using:

- Air-to-water heat pump direct cooling
- Thermal energy storage direct cooling
- Thermal energy storage + Air-to-water heat pump cooling

When cooling is provided by the WWHP, it is generally a byproduct of the unit operating in heating mode.

Figure 1. Storage source heat pump system loops



Coefficient of Performance (COP)

COP is a measure of heating efficiency, relating the kW of heat output to kW of input power. The input may be electricity or fossil fuel. In the equation below, the units used are kW, but any unit of energy can be used, as long as they match.

$$COP = \frac{\text{Heating Output (kW)}}{\text{Energy Input (kW)}}$$

The COP of a fossil fuel boiler ranges from 0.8 for a non-condensing boiler, to 0.9 to 0.95 for a condensing boiler. On the other hand, COPs on the order of 3 to 6 are possible by leveraging heat pumps in HVAC systems. For this reason, the overall system efficiency of the SSHP is increased over traditional heating technology. Within this system, heat energy from the AWHP (pulling from ambient air) is cascaded to the WWHPs to produce 105°F hot water for the heating distribution loop. In an AWHP system, the heating COP is dependent on the ambient air temperature and will decrease as the ambient source temperature drops. Backup heating equipment such as boilers are present to provide heat when the AWHP can not run. In a SSHP system, because the WWHPs source heat from relatively stable 32°F source temperature in the TES, the heating COP is higher as compared against AWHP-only systems.

Sink (Heating) Loop

The heating loop is controlled in the same manner as described in the cooling loop section and is similarly decoupled from the ETL. An interesting aspect of the heating loop in the Erickson building is that the supply hot fluid is maintained at 105°F which is much lower than previous traditional designs. Originally, the building was heated by a steam plant located on the campus. A local heat exchanger in the building transferred the heat energy from the steam to the heating distribution loop, with coils in the building receiving 180°F fluid. Later, we will discuss the changes required at the terminal units to accommodate the reduction in fluid temperature.

For now, it's worth noting that the existing steam coils were served by the campus steam plant two and half blocks away. This plant has been operational since the early 1980's. Given piping losses, the consulting engineer that designed the system in the Erickson Building estimated the efficiency of the steam delivery at 57 to 67 percent. While that's an unremarkable efficiency level, the expectation is that the new electrified heating system efficiency will dwarf the old system. System models predict annualized heating COPs above 2.

Air-to-Water Heat Pump Source/ Sink Loop

The AHWP source/sink loop adds or subtracts heat from the energy transfer loop. It runs as needed to balance the difference between the heating and cooling loads in order to achieve a target ice level in the TES tanks. An air-to-water heat pump (AWHP) is required in this loop. There may be one or more AWHPs and associated pump(s). The benefit of using TES within this system is that the heating and cooling loads are not required to be coincidental.

Depending on the application, a trickle heater may also be needed. Typically, this takes the form of an electric resistance or gas boiler, or a low-ambient temperature heat pump. The purpose of the trickle heater is to add heat to the TES when it is too cold outside to operate the AWHP. Operation of the trickle heater ensures there is sufficient water in the tanks from which the WWHP can source heating energy to serve the building heating loads.

The AWHP source/sink loop in the Erickson building includes a 180 ton Trane® ACX Ascend® heat pump, charged with R-454B. Additionally, this loop contains both electric resistance heaters (3 to 48 kW units) and a low ambient heat pump (10 ton nominal), also using R-454B.

In this design, each component operates on its own loop, with a decoupled connection to the ETL. Because this system includes some experimental components and there are plans to optimize system control, it differs from the system described in the Trane Thermal Battery™ Storage Source Heat Pump Systems application guide (APP-APG022*-EN).

The AWHP performs several key functions:

- Direct cooling (chilled water)
- Supplemental cooling (with ice)
- Build ice
- Melt ice
- Add heat to the ETL to ensure adequate fluid in TES to source WWHP heating

Energy Transfer Loop

The heart of the system is the energy transfer loop (ETL). This loop provides a hydronically decoupled path for heat energy to move between the various system loops.

The thermal energy storage (TES) tanks are located within the ETL. TES serves two purposes in the system. First, it can be used to cool the building during the summer and shoulder months by melting the ice inside the tanks when there are cooling loads. When the ice in the tanks melts, heat from the building is absorbed and stored in the ice tanks. This heat is then removed from the tanks as ice is built by the AWHP during off-peak periods. Refer to the Phase Change Materials sidebar below.

Second, it is used as a heat source for the WWHPs in the system. To source heat energy efficiently for the WWHP, there must be some water in the tanks. While melt ice is noted as a mode above, during heating months, the AWHP provides moderately heated fluid to melt ice in the tanks to source the WWHPs operating as heaters.

Another benefit of this intermediate loop is defrost cycle mitigation. When the outdoor ambient temperature is cold, the AWHP must occasionally defrost its air-to-refrigerant coil by operating in cooling mode and extracting energy from the ETL. Since the AWHP doesn't directly heat the building, this fluid is not sent into the heating distribution loop. Instead, it is buffered by the system and the TES volume. Note that the system in the Erickson Building does include provisions to heat directly with the heat pump.

Table 1. System heating and cooling equipment

Equipment	Qty	Capacity (nominal)	Function
Air-to-water heat pump	1	180 ton	Cooling/ice maker
Water-to-water heat pump (water-cooled chillers)	2	110 ton	Heater
Thermal energy storage tanks	7	162 ton-hours	Thermal energy storage
Electric boiler	3	48 kW	Trickle-heater
Low ambient air-to-water heat pump	1	10 ton	Trickle-heater

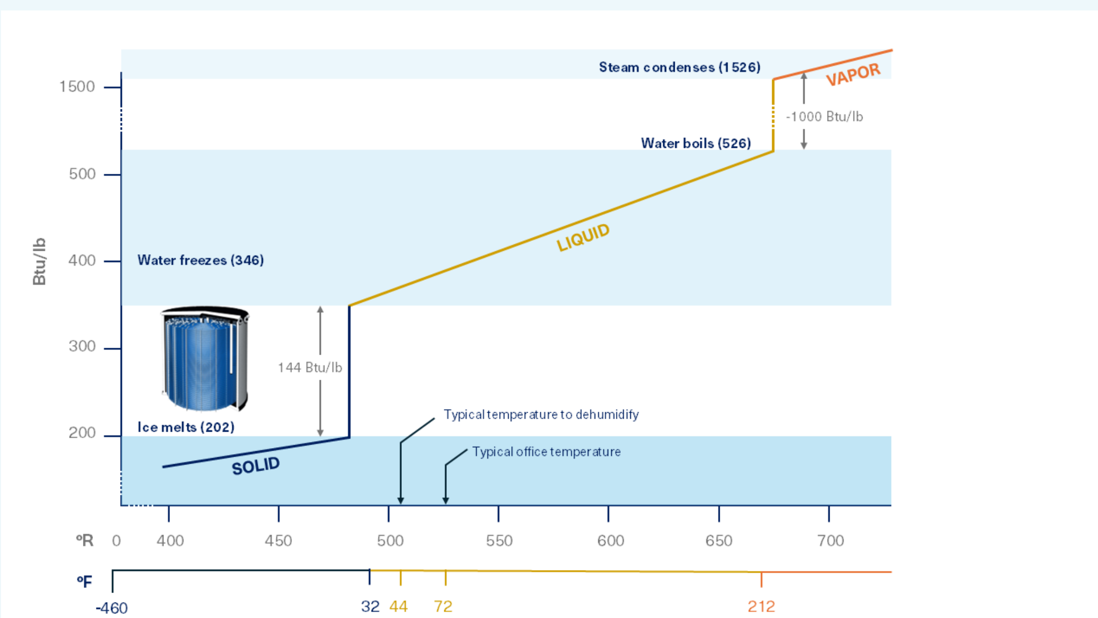
Phase Change Material

Trane Thermal Battery TES uses water/ice as the phase change material (PCM). Water changes from a liquid to a solid at 32°F (0°C). During this phase change a tremendous amount of heat is released by the water. When moving from solid to liquid, energy must be added to the water.

One British Thermal Unit (btu) is the amount of energy required to elevate one pound of water by one degree Fahrenheit. In contrast, to change the phase of solid water (ice) to liquid water, 144 btus are required – the latent heat of fusion of water. The same occurs when moving from liquid to gas. Refer to Figure 2.

By leveraging the phase change of water in the TES, more energy can be stored (or extracted) using much less mass (and subsequent volume).
With respect to the temperature at which various PCMs experience phase change—water's phase change temperature is close to that used in traditional hydronic comfort cooling systems.

Figure 2. Heat of fusion and vaporization of water



Learning Laboratory

The Trane Customer Experience Center located in the Erickson Building has been designed as a “learning laboratory.” In addition to the SSHP system, it also features new learning opportunities. Three key features of the learning laboratory include the low ambient temperature AWHP, a dynamic buffer tank in the hot-fluid distribution loop, and the ability to directly heat from the source/sink loop using the ACX AWHP. The site is also used as an initial test site for the Hydronic Branch Conductor.

Low ambient temperature AWHP. This unit uses series scroll compressors to produce heated fluid to the system. It is capable of functioning as a trickle heater down to –20°F ambient and uses the low GWP R-454B refrigerant. Two compressors in series enable the unit to generate the hot fluid temperature, even at very low ambient temperatures. The heat pump is intended for use as a trickle-heater, collecting heat at a low rate into the ETL when the primary AWHP cannot operate due to ambient limitations. At the Erickson Building, it can also be used for reheat to avoid cycling the WWHP at low loads.

Direct heating via trickle heaters. The system is also configured for direct heating by either AWHP or electric boilers. Both configurations are used to compare the efficiencies of cascaded versus direct heating under specified conditions, as well as to evaluate the use of a smaller unit for reheat instead of the WWHP.

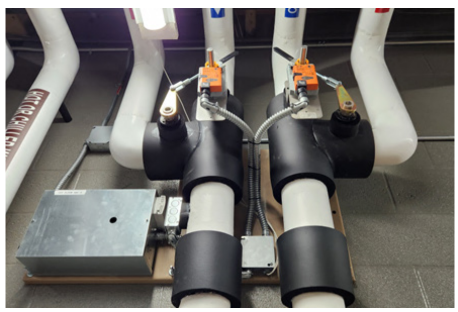
Dynamic Buffer Tank (DBT). The DBT is located in the hot fluid supply line of the distribution system. It is intended to be a stratified tank, serving to increase loop time, add system stability, and moderate hot fluid temperature. As mentioned, the AWHP installed in the Erickson Building is capable of direct heating. The tank provides for thermal buffering during the defrost cycles.

The tank is instrumented to study temperature stratification and identify the thermocline. Understanding the thermocline allows for more efficient thermal storage by preserving adequate hot water storage in the upper layers of the tank. This data will be used to validate internal models of this equipment.

Hydronic Branch Conductor. The Hydronic Branch Conductor is a new system component developed by Trane. It reduces piping installation in four-pipe systems by enabling two-pipe distribution by thermal area. It provides zoned comfort and efficient hydronic water distribution using lower hot-water temperatures. Coils receive either hot or cold fluid depending on the predominate mode in a given thermal area and the unit determines which supply pipes are providing the necessary temperature. Included within the conductor is a unit controller that regulates the changeover at the unit.

In the Erickson Building, four Hydronic Branch Conductors are installed which serve five air rotation units within the weld training lab. Two of the air rotation units have ventilation ducted to them for contaminant mitigate in the weld lab and braze training areas. These are used to validate unit controls.

Figure 3. Hydronic branch conductor



For full details around the Hydronic Branch Conductor, reach out to your Trane account manager for access to the Trane Hydronic Branch Conductor application guide (APP-APG024*-EN).

Modes of operation. The SSHP system efficiently meets heating and cooling demands with minimal energy input, adapting to seasonal and occupancy changes. Economizer logic and TES capacity adjust based on the time of year and load demands. To enable control flexibility, 15 operating modes are described in the Trane Thermal Battery™ Storage Source Heat Pump Systems application guide (APP-APG022*-EN).

In the Erickson Building, additional operating modes are included for direct heating as discussed earlier. The existing steam-to-hot-water heat exchangers remain in place, allowing the system to revert back to steam heating as long as steam is available in the building.

Electrified hydronic heating system challenges. When considering electrified hydronic systems, there are several obstacles that may be project-specific or dependent on the driver for electrified heating. Often local or statewide regulatory pressures drive the need to ‘get off the gas’. Some jurisdictions have implemented bans on new gas installations to mitigate climate change due to carbon emissions. In some cases, corporate environmental, social and governance (ESG) goals require electrified heating solutions. Both apply to the Erickson Building.

Some sites may have limited electrical infrastructure supplying power and upgrades to delivery can be costly. They may be subject to excessive lead times—on the order of years in some cases—to acquire higher capacity transformers and switchgear. In retrofits, this is a common hurdle. For new sites, up-front planning can aid in system selection that fits within the expected power delivery system.

Electrified heating generally increases peak electrical demand, especially in colder months. For this reason, system heating efficiency should be carefully considered. The use of resistance heat **IS** an electrified solution, but due to its COP of approximately 1, it has a higher peak demand than a heat pump solution. In the SSHP system, because heating is provided using the WWHPs, and the source temperature remains relatively constant, heating efficiency is generally improved by three to four times versus fossil fuel boilers (See COP sidebar on page 2)

Sites may be constrained by carbon equivalent or greenhouse gas emission regulations. To accurately evaluate the emissions reduction for a specific electrified heating system, it is essential to model the system’s performance and utilize pertinent grid emissions data. Tools, including TRACE® 3D Plus are being developed to accurately model this system. The emissions rates can be determined either using regional data from the Electricity Generation and Resources Integrated Database (eGrid) or potentially using data directly from the utility supplying power to the site. If data is available around forecasted regional emissions reductions, it can be included.

A conversion to fully electrified heating may or may not be less emissive than locally supplied fossil fuel heating. Actual emissions are dependent upon the emissions rate and system efficiency at the site.

Space limitations for indoor and outdoor equipment, including thermal energy storage tanks can become a constraint. It's important that sizing exercises are undertaken early, preferably using known or modeled load profile information, in order to select equipment and TES for space and site planning. One benefit of the SSHP over AWHP-only systems is that the number of AWHPs located outside can be decreased significantly. Because these units are sized based on the daily heating cumulative load, rather than the peak hourly load, fewer units are required, saving outdoor space.

Often heat recovery is the first step in electrified heating systems. However, unless there are process or service hot-water loads to be met, or the building is a hospital, many buildings have insufficient simultaneous load to perform both duties. Heat recovery equipment may not be available in small enough incremental capacities to cover this load. The SSHP system overcomes this limitation because it does not require the heating and cooling load to occur concurrently. By using TES to store and reuse heat energy at times when heating and cooling demand do not occur simultaneously, this challenge can be overcome.

AWHP-only heating systems are also at the mercy of outdoor conditions. In colder climates, readily available units at reasonable costs are often incapable of providing hot fluid when temperatures are below 0°F. As the temperature falls below the rating point of most air-source equipment, 47°F, the available fluid temperature drops. In the SSHP system, this limitation is overcome using the WWHP sourced by the relatively stable ETL temperature.

Heating fluid temperature often becomes a challenge, especially in retrofit solutions, as the existing coils may have been selected for 160°F to 180°F. This makes project planning more challenging, especially if equipment is aging out and action must be taken before the distribution system can be fully addressed. It is often possible to reduce fluid supply temperature to existing coils since they are frequently oversized. Consider conducting a stress test on the building to determine the lowest supply fluid temperature that can maintain comfort levels.

Lessons Learned

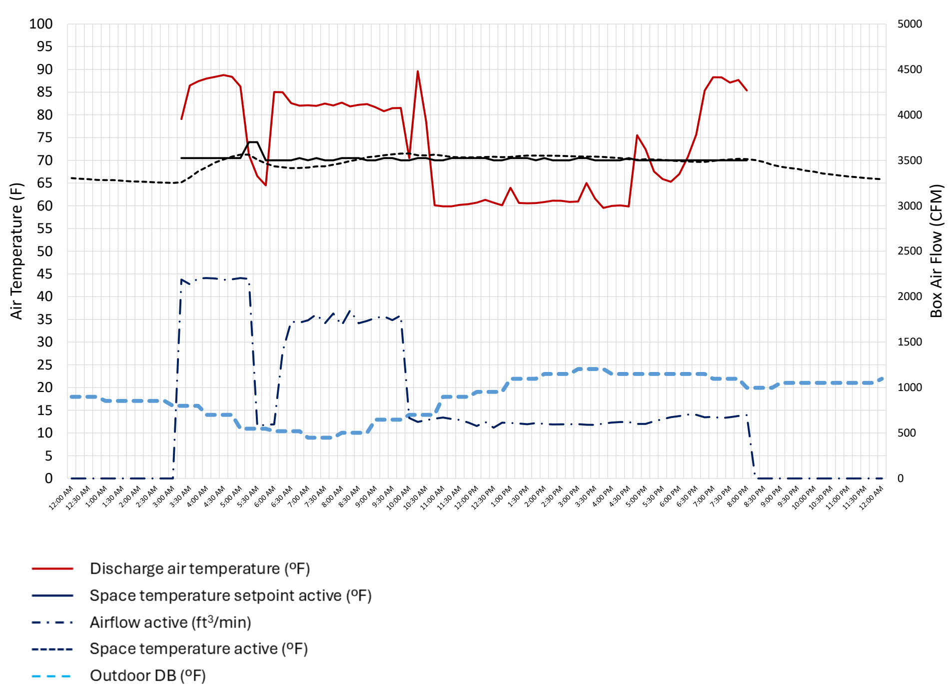
Reduced heating fluid temperatures

Electrified heating systems are often designed with lower fluid temperatures than most designers are accustomed to. For more information about reduction of supply fluid temperatures, refer to the Trane *Engineers Newsletter*, "Heating with Lower-Temperature Hot Water" (ADM-APN084-EN). In the case of the Erickson Building, the new VAV terminal coils were selected for 105°F supply fluid, which is in-line with the recommendations from the publication. These are four row coils with a design heating supply air setpoint of 83°F to 88°F, depending on the terminal. The minimum flow position of the airflow damper is set for 30 percent of design supply air volume. These terminals employ the dual-max control as defined in ASHRAE® Guideline 36.

When the terminals are at the minimum airflow setting, the fluid flow is modulated to maintain the supply air temperature at the terminals. At this condition, the heating fluid delta T at the coils varies from 20°F to 30°F. As the space requires more heating, the damper is opened to allow more airflow into the space. At this condition, the heating fluid delta T varies from 12°F to 18°F. Since the system is piped in a decoupled configuration, it can react to the varying distribution delta T.

One study looked at the space temperature control to prove that heating can be accomplished using lower than traditional heating fluid temperatures. The space represented in Figure 4 is allowed to drift during unoccupied periods. The chart reflects the discharge air temperature (DAT) in red at the top. The solid black line is the setpoint, active only during scheduled occupied hours and the dashed black line is the space temperature. At the bottom of the graph is the airflow at the terminal and the outdoor DB temperature is plotted using the light blue dashed line.

Figure 4. Space temperature control using large VAV box (student lounge in November)



As the system enters morning warm up from 3 to 5 AM, the DAT and airflow increase to bring the space out of drift and to the setpoint of 70°F. During the occupied period, space control is stable, except for some overshoot while bringing the space up to the occupied setpoint temperature. When the space temperature drops a bit, around 6 AM prior to students arrival, the airflow is increased to maintain the setpoint. The occupied period, after 10:30 AM, the space remains under control while the airflow is maintained at the minimum volume. Once the space is scheduled unoccupied at 8 PM, the air handler is shut down and no airflow is measured at the terminal. In this case, the fluid entering the heating coil is supplied at 105°F.

The design team wanted to verify that the terminal continued to provide adequate space heating when the air handler supply discharge temperature was lowered. Opportunities may exist to use an airside economizer to cool interior spaces in the building. However, if economizing causes the supply air temperature (SAT) to drop below 60°F, will the space heating setpoint still be maintained?

Figure 5 includes data for the same VAV terminal we saw previously, but over a longer period, for eight days in January. The data show that even with 55°F air entering the VAV terminal, the space setpoint is still maintained at 70°F.

Adding more heat exchanger surface, such as additional coil rows, increases the airside pressure drop that supply fans must overcome. To analyze the potential impact on fan energy, a full year of VAV box airflow data was considered. Occasionally, when retrofitting terminals to include more coil rows, the box is oversized. In this instance, that was not the case, the coil pressure drop is 0.64” water at design airflow. While this may seem high, it’s important to recognize that for a dual-max box, the airflow is at design volume. It’s worth noting that this terminal supplies 85°F airflow in heating mode.

During morning warm up, as shown in Figures 4 and 5, the airflow is at full heating design flow for about 17 percent of annual operating hours. The vast majority of operating hours, about 40 percent of the hours, are at the minimum airflow setting (see Figure 6). In fact, there was no airflow for 24 percent of operational hours. Because fan power is proportional to the cube of the fan speed, and subsequently the airflow supplied, we can determine the approximate increase in fan energy used. For an 8000 cfm VAV fan system, increasing the pressure drop from 0.3” w.g to 0.6” w.g. adds 0.5 kW of fan power at design airflow.

However, because reduced supply fluid temperatures were used in this case, there are savings to be had. Producing 105°F hot water uses 45 percent less power using the WWHP than supplying 135°F fluid—which would be required if two-row coils were used. To produce the required heating supply fluid for two-row coils requires 8 kW more heat pump input energy. Compared against the 0.5 kW increase in fan power, 16 times the energy increase in fan energy is saved in WWHP energy.

It’s important to analyze the system impacts and make trade-offs when necessary to design the most efficient system.

Figure 5. Space temperature control using large VAV box (student lounge in January)

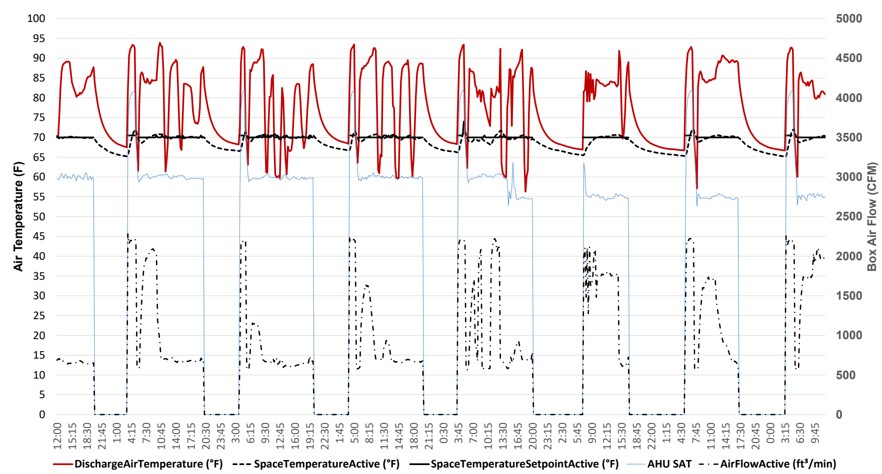
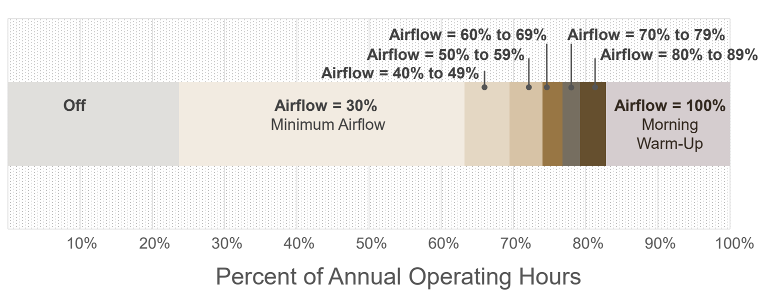


Figure 6. Percent of operating hours at specific airflow



Load Profile Validation

Prior to building retrofit, the building was instrumented with flow meters and temperature sensors while steam was used to heat the Erickson Building. Data collection for the second half of the 2022-2023 winter heating season is shown in Figure 7, in which each dot representing one hour of load. Notably, the measured heating load during this period is around 600 MBh—significantly less than the peak load calculation of 1687 MBh. A few key factors driving the differences include changing use patterns in the building (which differ from modeled inputs) along with relatively mild winters in La Crosse the past couple years. Data will continue to be collected as the usage changes and weather becomes more typical of the climate here.

Of note in the chart is the relatively scattered load profile pattern, often there is are marked peak 'arms' displayed as OADB drops, one for occupied and one for unoccupied periods. The data points are more scattered than expected. The highest observed load was nearly 600 MBh, significantly less than the aforementioned prediction. Notably, La Crosse can reach into the low negative twenties, if not colder—considerably colder than the minimum observed temperature slightly above 0°F.

It's too early to draw a conclusion based on this data set, and as the building occupancy patterns are still being established, stronger load profile conclusions are likely to be made after a more typically winter period.

As the usage of the building changes, the models will need to be updated to reflect occupancy.

TES Tank Target Levels

It is straightforward to see how the energy transferred in and out of the tanks follows the building heating and cooling needs (Figure 8). During the summer, the tank level reflects ice in the tank. While a building cooling load exists, the heat is moved from the building, into the tanks, melting the water. On the same chart, during morning warm up, the water in the tanks is frozen, increasing the ice level in the tanks to serve the heating load.

The tank target level is a control strategy driving further development work. The Erickson Building serves as a test lab for new algorithms that use forecasted weather data to predict how much water or ice should be in the TES, and the equipment will operate with the intent of meeting that target.

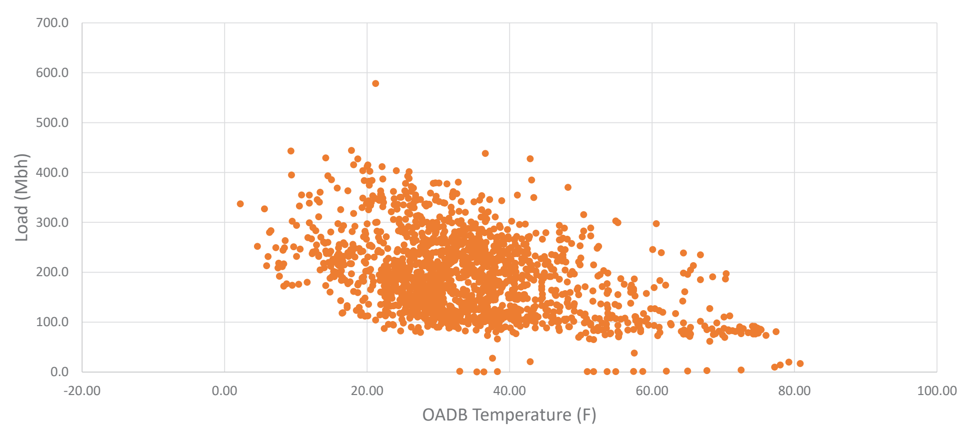
Smart Pump Flow Measurements

The pumps selected are to provide direct flow readings as well as control flow based on power measurements (i.e. sensorless control). Flow meters were installed in the system and a study was undertaken to evaluate these features. Distribution pumps on both the hot and cold fluid loops were used in the analysis.

The pump's native controller accepts input coefficients for the pump and system curves which were initially set at the factory. Based on power draw, it can report the flow rate directly. However, because the pump power curve is essentially flat in the lower flow range, small errors in the power measurements result in large fluctuations in reported flow data. Highly accurate power measurements would be required in order to adjust for this scenario. This is cost prohibitive and therefore the use of this flow sensing technology is best-suited when flow will not be reduced much below the design setpoint. Large fluid temperature ranges can also impact flow accuracy and should also be considered.

This pump type can be used to perform standalone pump control in systems that do not have a system level controller or BAS that would normally be used. Because the Erickson Building includes an automation system that includes Trim and Respond logic, performance and stability is improved over the standalone pump control.

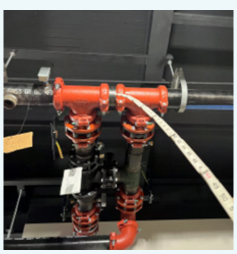
Figure 7. Outdoor temperature load profile



Sidestream Decoupling
The connections into the ETL from connected loops uses sidestream decoupling. This includes the connections to the AWHPs, the electric boilers, and to the cooling distribution loop. Because the decoupler feeds back into the ETL, the classic decoupler sizing rules do not apply. For details on traditional and sidestream decoupler piping guidance, refer to APP-APG-022*-EN.

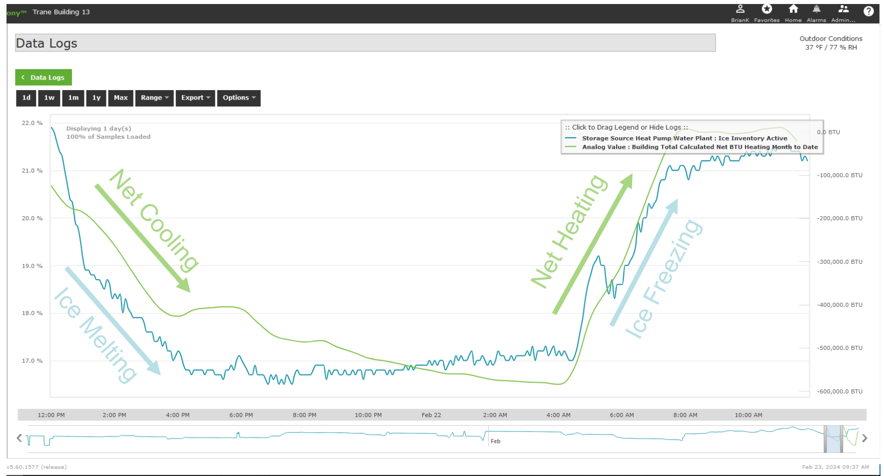
Within the Erickson Building, the pipe fitter was not provided piping constraints. Shown in the **Before** picture below. While the original piping was compact, this does not lend itself to an effective decoupler pipe. The pipes had to be reworked to provide proper hydraulic decoupling at the connections to the ETL. The final arrangement (green decoupling piping), with black insulation applied is shown in the second **After** picture below. Ensure these constraints are communicated and full comprehended prior to installation to avoid costly and potentially project delaying rework.

Before



After

Figure 8. Thermal energy storage energy flow



System Level COP

The expected system level annual heating and cooling COPs are 2.5 and 4.6, respectively, based on modeled data. COPs are calculated using the relevant equipment, loads and operating modes. The equations below are used to provide daily, monthly and annual values.

$$\text{COP (cooling)} = \frac{\text{Cooling (kW)}}{\text{Electric cooling (kW)}}$$

where:

$$\text{Cooling (kW)} = \frac{\text{Chilled water total system calculated Btu/hr}}{3412.14}$$

Because all components involved in cooling impact the system level COP, pump energy in three of the loops must be included in the cooling COP calculation.

Electric cooling (kW) = AWHP 1 kW + CP 1 Electric kW + CP 4 Electric kW + CP2 Electric kW

To calculate the system efficiency over the course of a given period, all heating and cooling components must be included.

$$\text{COP combined} = \frac{\text{Cooling kW + Heating kW}}{\text{Electric heating kW + Electric cooling kW}}$$

As noted above, the building has not been operating at design heating loads. That coupled with the incremental retrofit and commissioning schedules has made direct comparison challenging. Even so, incremental measurements are tracking expected values and we anticipate that 2024-25 should provide a more stable measurement environment.

Acoustics

Two separate acoustical analyses were conducted in support of the retrofit project. The Erickson Building is zoned as an industrial property but situated within a residential neighborhood which necessitated an outdoor acoustical analysis to ensure property line sound did not exceed the requirements set forth by the City of La Crosse. Inside, an analysis was performed to help select materials and installation methods for the storage source heat pump equipment viewing room.

Outdoor Acoustical Analysis

The City of La Crosse has established a series of sound ordinances that account for zoning type and time-of-day. During the daytime hours, the sound pressure limit at property lines is 50 dBA and during the overnight hours, the sound pressure limit is reduced to 40 dBA. The outdoor AWHPs are expected to operate during both day and night, so the design team selected the conservative requirement and chose to design the system to maintain 40 dBA or lower at the property lines.

During schematic design, four different installation locations were evaluated for the two AWHPs. The Trane Acoustics Program (TAP™) was used to evaluate each location using the source-path-receiver method. This software program uses power-to-pressure transfer functions to predict sound pressure at a prescribed distance from the sound source. It also allowed the design team to account for vertical reflecting surfaces, such as building walls, and vertical sound barriers.

Eventually, the design team decided upon a location east of the building on the edge of the employee parking lot, just north of Trane Plant 2. This location provided ideal access to the equipment and better acoustical performance compared to some of the rejected locations. Acoustical barriers would need to be constructed to maintain property line sound north and east of the equipment.

Using TAP, the design team was able to iterate between equipment-to-barrier distance and barrier height. The design team selected a 14-foot acoustical barrier to ensure sufficient attenuation while also ensuring adequate equipment service and airflow clearances. The team evaluated both prefabricated acoustical barriers and onsite masonry and chose the latter. The masonry walls were constructed with 8-inch hollow cell concrete block with a brick veneer face. There are no openings or gaps. The L-shaped barrier was constructed on the northern and eastern exposures to attenuate sound traveling to the property lines.

Indoor Acoustical Analysis

The facility was designed to be a showcase, which meant that the water-to-water heat pumps, thermal energy storage, pumps, buffer tanks, and other hydronic devices would be on display. Early on, the design team wanted to have a viewing area immediately beside the mechanical equipment room housing the WWHPs.

The design team selected NC 40 and 45 dBA/65 dBC as equipment viewing room indoor sound pressure targets. These sound targets are based upon the open-plan office space design guidelines published in Table 1 of Chapter 49 of the 2023 ASHRAE® Handbook of HVAC Applications. These targets would allow verbal communication within the viewing room with a reasonable amount of background HVAC noise.

The design team determined the WWHP sound pressure, based upon AHRI Standard 575. Pump sound pressure was obtained through both the equipment manufacturer and estimated by TAP. The louder sound pressure values were used to provide a worst-case scenario. Working closely with the architect and mechanical contractor, a baseline case of standard wall and window constructions was established.

Composite transmission loss was calculated for the window and wall system, then evaluated within TAP to predict the sound pressure in the equipment viewing room. The baseline window and wall system resulted in a prediction above the sound targets, so the team began investigating alternatives. The team chose to use a dense concrete masonry wall with steel studs and resiliently-mounted gypsum board. Because so much of the wall system is viewing windows, the team selected triple-pane insulated windows. Finally, acoustical ceiling tiles with a high noise reduction coefficient were selected. The acoustical analysis was repeated using the new window and wall properties with the sound target being achieved.

Summary

While some case studies are complete, several additional tests are scheduled. The system is under full automated control and the building is being heated using fully electrified sources at significantly higher efficiency levels that the past heating system delivered. This comes not only from using more efficient equipment, but also through the energy storage enabling non-coincident heat recovery.

In the summer, ice is used to cool the building in tandem with the AWHPs. The addition of TES used for both heating and cooling presents future opportunities for the building to react to grid signals—when the local utility becomes capable — to function as a grid-interactive building. This could present opportunities for energy cost savings through agreements with utility providers as the building may be capable of reducing demand when requested.

This building is intended as a showcase and learning laboratory for not only Trane, but also engineers and consultants who visit. Lessons learned provide insight for those considering the Storage Source Heat Pump for heating projects going forward.

By Sarah Hilden with contributors Rick Heiden Ronnie Moffit, Eric Sturm, and Juan Torres from Trane. To subscribe or view previous issues of the Engineers Newsletter visit trane.com. Send comments to ENL@trane.com.

Resources

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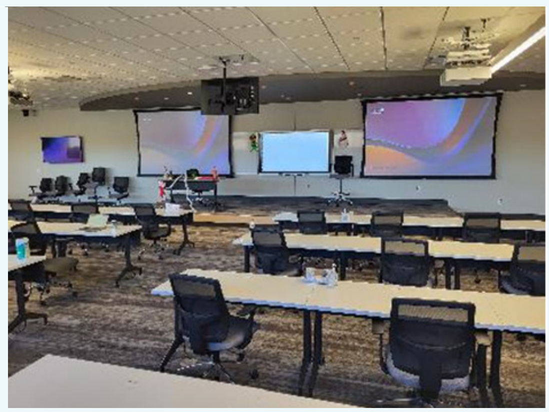
Erickson Building History and Renovations

The Emil Erickson Building has served many purposes on the La Crosse Trane campus. It originally housed the Manufacturing Department headquarters. In the 1980s-1990s the building served as Trane's Aftermarket Business Unit headquarters. Prior to the 2023 renovation, the first level consisted of a print shop, a tool room used to support La Crosse Manufacturing with tool design and maintenance, and a weld training lab used for training and development of new welding procedures—including instructor offices and student training areas. The second level was an infrequently used space with a large conference room, offices, and cubicle areas.

In the 2023 renovation, most areas, except the weld training and machine shop, were retrofitted with VAV terminals to enable space heating at lower supply temperatures than those provided by the steam heat exchangers. The upper floor was remodeled into a new training center for Trane's Graduate Training Program and retrofitted with four-row VAV terminal heating coils. The space includes common work areas, a lounge/break room, and new auditorium. Offices, conference rooms, and breakout work areas were also included in this phase. During this phase the mechanical equipment room was constructed on the first floor. Here, the WWHPs, pumps, boilers, and controls were located. Also included was an adjacent viewing room for tour visitors to see the indoor plant equipment. The TES tanks were installed into an underutilized storage room on the first floor, with one in the viewing room. The AWHPs were placed on a new pad on the south side of the building (refer to the acoustical considerations for that area.) Provisions were made to allow defrost drainage from the AWHPs outside to the city sewer.

The second renovation was completed in late 2024. This included the removal of the print shop, updating the lobby area, and new meeting and cubicle spaces. New air-turnover units in the weld training lab and machine shop were also included. The system was designed with flexibility and excess capacity to accommodate modified space usage and load profiles due to changes in occupancy and usage patterns.



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