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1.0 Introduction

Natatoria and recreation facilities are energy intensive buildings which should be planned carefully to ensure that energy consumption and operating costs do not exceed the design energy budget and the operating budget. A "Green" facility which is well engineered and is developed based on a comprehensive energy concept has the potential for providing the features desired by the public, while reducing operating costs and greenhouse emissions.

Uncertainty in energy markets, climbing energy costs, and the need to keep facility admission costs down is causing communities and municipalities to experience an upward trend in operating costs with stagnating revenues. This results in higher deficits due to higher operating costs without improving the level of community services.

The concentrated recoverable waste energy of these public facilities from the heated water drains of pools and showers, and the heated air exhausted from the ventilation and heating systems, make it possible to develop an economically viable energy use and heat recovery concept. Employing fundamental engineering principles in design has proven to result in easily buildable, energy and cost saving, and successful projects.

Through well defined energy saving steps a significant reduction of the primary (source) and secondary (site) energy consumption can be achieved. This is best achieved when a comprehensive audit and model of the individual energy users is developed. The model of the functioning facility is analyzed, and a wholly integrated system is developed which allows the waste energy from one process to be recovered by another energy user.

It will be shown that the overall energy consumption in Natatoria and Recreation Centers can be reduced by half (50%) by incorporating heat recovery systems. These systems have a history of high reliability and simple operation. The heat recovery systems are presented as incremental steps which can be installed independently or together in their entirety. The number of steps (stages) of heat recovery systems installed is defined during detailed design and analysis once the building plans, including water surface areas, temperatures, hours of operation, the recreation activities and other important factors, are developed.

Design energy targets, and systems required to achieve a design energy budget will be discussed. First, however, a basic explanation of the major energy users is presented in order to focus on the magnitude of the individual and overall energy savings desired.

2.0 Energy Users

There are several systems used to heat and ventilate indoor swimming facilities. These are the ventilation and dehumidification air handling systems, the pool water heating systems and the domestic hot water heating systems. The air handling systems are the most expensive to operate. Domestic hot water heating is the second most expensive, and the pool water heating is the third.

The ventilation, dehumidification and reheat air handling units are also used to heat (and sometimes cool) the Natatoria resulting in approximately 58% of the fuel heating energy demand during winter use. The domestic hot water heating systems require approximately 30%, and pool water heating around 12% of the winter heating energy demand.

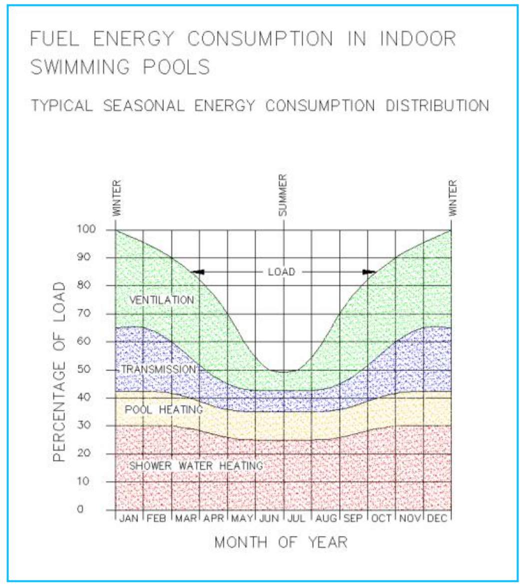


Figure 1:

3.0 Natatoria Ventilation Dehumidification and Reheat with Heat Recovery

The water in each pool is being maintained at a constant temperature and the Natatoria indoor air conditions are also constant. The ideal pool operates at the same indoor pool water and air conditions (steady state) throughout the year resulting in a constant water evaporation rate from the pool water surface. The conditions in the Natatoria, however, are not ideal. The water evaporation rate changes with bather activity, water and air temperature changes, attraction types, etc. Energy consumption and operating costs in aquatic facilities increase as the pool water evaporation rate increases. This is due to increased dehumidification and reheat loads on the ventilation system as well as the pool water heating system.

Most ventilation, dehumidification and heat recovery units are equipped with reheat components which substantially reduce operating costs. The air handling units should be provided with air to air heat exchanger(s) as well as dehumidification and waste heat reclaim capability. Waste heat generated by the dehumidification process can be used to reheat the cooled (dehumidified) air or the pool water. Some equipment is controlled to reheat the air as the first priority and then the swimming pool water as the second priority. When the return or space temperature sensor is satisfied the heat can be redirected to the pool water.

There are numerous manufacturers of pool dehumidification and heat recovery equipment. Many designs exist, and each has advantages and disadvantages. Although most maintain satisfactory indoor operating conditions, there are large differences in overall energy consumption.

Figure 2 shows six (6) air handler arrangements which have distinct features, and vary greatly in annual energy consumption and cost. Arrangements 1 and 4 are for cool, dry environments where cooling is not required during summer operation. Arrangements 2, 3, 5 & 6 are for warmer, humid environments where mechanical dehumidification and cooling is required.

Appendix A shows the projected annual energy consumption from the air handler arrangements presented. A brief description of each follows:

Arrangement 1 and 4: Offers the lowest annual energy consumption due to the lack of mechanical dehumidification capability. Basic air handler with ability for ventilation night setback. Cool, dry climates only.

Arrangement 2 & 5: Offers moderate annual energy consumption

FIGURE 2: NATATORIA VENTILATION, DEHUMIDIFICATION AND REHEAT AIR HANDLING SYSTEMS

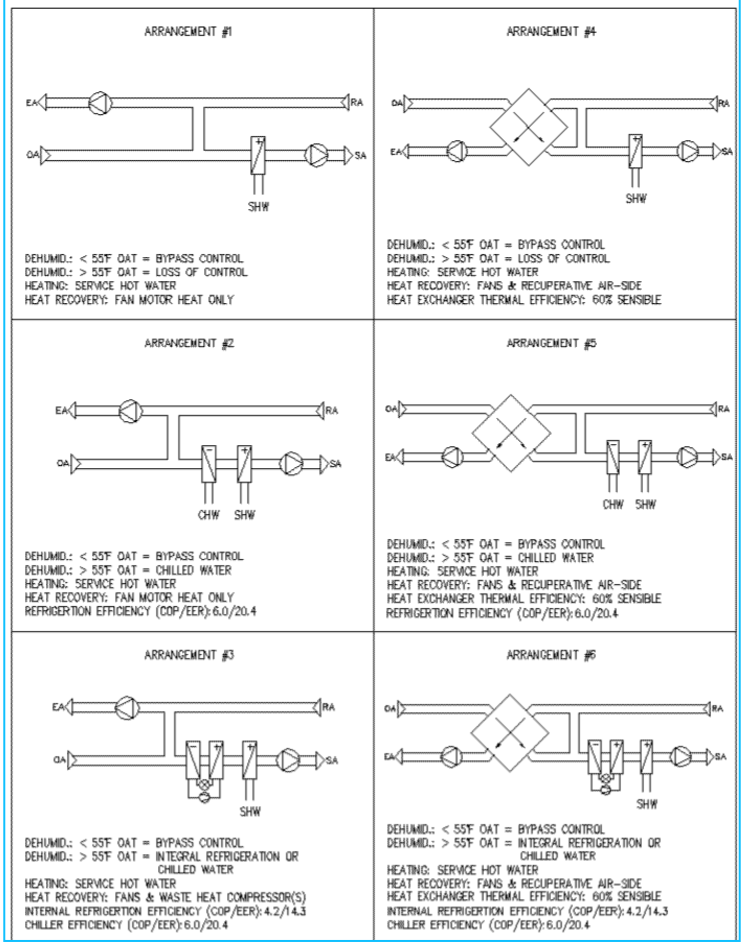


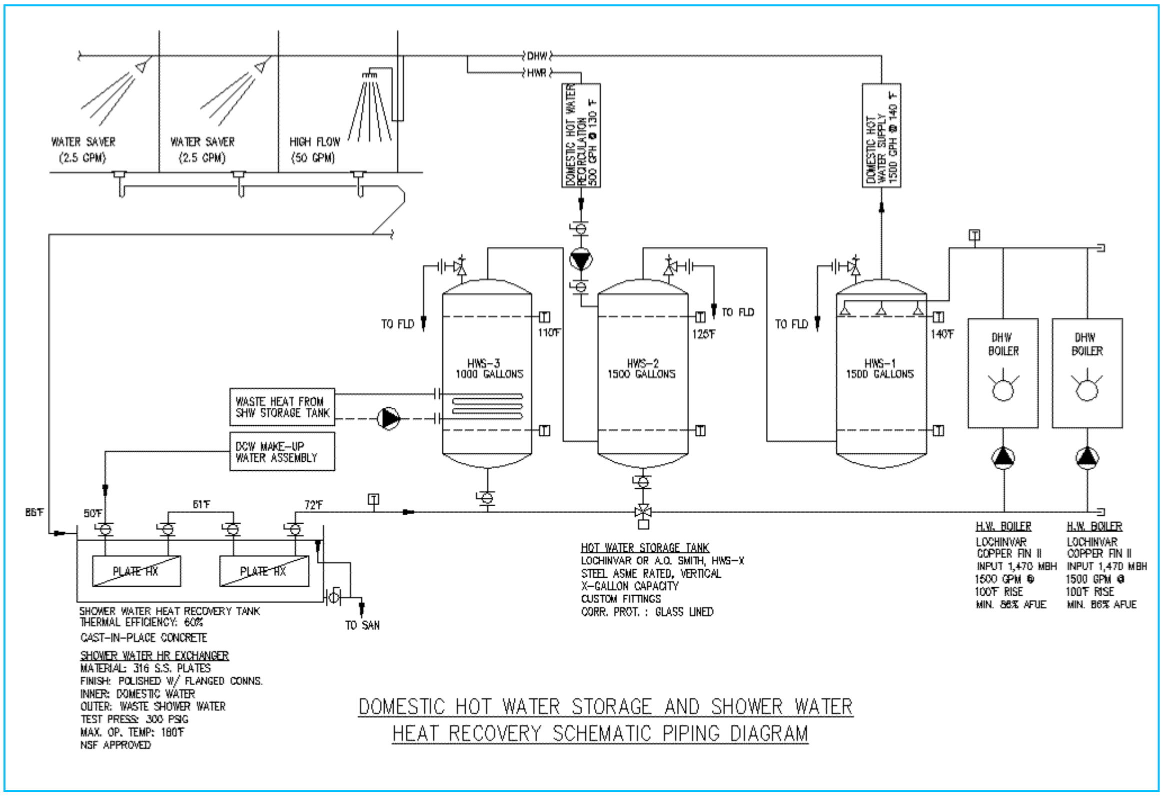
Figure 2:

savings due to the lack of mechanical refrigeration heat recovery when outdoor air temperature is greater than 55°F.

Arrangement 3 & 6: Offers the best annual energy consumption savings due to waste heat recovery from the mechanical dehumidification process whether from the chillers or internal refrigeration components. It should be pointed out that air handlers with internal refrigeration components cannot be supplied with ventilation night setback which saves considerable electrical energy when the night "calm" water evaporation rate in the Natatoria falls to approximately 1/5 of its' maximum design value. In addition, central chilled water distribution is far less complicated and less expensive than air handlers with built-in mechanical dehumidification and reheat controls.

Arrangement 4, 5 & 6: Cost more electrically per year than their Arrangement 1, 2 & 3 respectively due to the additional fan motor horsepower required to overcome the air flow resistance through the plate heat exchanger. However, this recuperative heat exchanger saves considerably more on fuel energy costs.

B2E Consulting Engineers, P.C. has developed in-house computer software that allows the designer to calculate the water evaporation rate inside the Natatoria, the airflow rate required to dehumidify the Natatoria, and the annual energy consumption for numerous air handling arrangements and optional system



DOMESTIC HOT WATER STORAGE AND SHOWER WATER HEAT RECOVERY SCHEMATIC PIPING DIAGRAM

Figure 3:

component combinations. The designer must input the physical characteristics of the Natatoria including the indoor air temperature, desired water temperature for up to 10 pools and attractions, water surface area of each pool or attraction, the activity factor as well as other important data. This software tool makes it easy to quickly look at various Natatoria program configurations, air handler arrangements and options, pool water attractions and controls to limit evaporation, sensitivity analysis for worst case airflow requirements and numerous other relationships affecting equipment size, initial cost, energy consumption, operating cost, etc. This software with its improvements and modifications has been used on over 100 million dollars worth of mechanical construction projects over the past 10 years with complete success.

4.0 Domestic Hot Water Heat Recovery

Natatoria and Recreation Centers consume large volumes of domestic hot water. Domestic water is expensive to heat and the 100°F plus water is usually discarded directly into the sanitary system. Since 1985 a very efficient method of recovering the heat from showers has been in use in numerous facilities throughout the world. A concrete tank is built on the lower level below the public showers through which waste shower water is directed before flowing into the sanitary sewer. Domestic cold water flows through pressure tested (leak proof) stainless steel plates flowing in the opposite direction.

The system has a proven thermal efficiency of 60%, which results in ~22°F rise in incoming domestic water temperature. This is roughly 25% of the total heat required to elevate the temperature to 140°F.

The system efficiency can be improved by adding a third domestic water storage tank. See HWS-3 in Figure 3. The water in this tank is heated using waste heat from another process. The domestic hot water recirculation keeps the water in HWS-2 heated to 125°F. The high efficiency boilers keep the entire system charged, (topped-off) with HWS-1 heated to 140°F. The system makes up the recovery temperature rise at night when the storage volume is depleted.

The shower water heat recovery system becomes very important when special high flow showers, which are actually Natatoria features/attractions are used. These special high volume “giant” showers can consume up to 50 gallons of hot water per minute. They are beloved attractions at most public European pools.

In order to maintain good hygienic pool water conditions (reduce chloramines) the pool guests should be required to shower-off completely before entering the pool. The guests also shower-off after leaving the pool therefore, increasing domestic hot water consumption. A Natatorium which expects 400 visitors per day can expect to use up to 8 - 10,000 gallons of domestic hot water per day (20 - 25 gallons per pool guest).

5.0 Geothermal (Ground Source) Pool Water Heating

Geothermal energy can be recovered from the earth using a buried closed loop heat exchanger. The closed-loop ground source (earth) exchanger is constructed by boring holes into the ground, installing high density polyethylene piping, and filling the annular space around the pipe and earth with bentonite (grout) material. The bentonite expands as it sets making a tight, thermo-conductive bond between the earth and the piping.

The earth exchanger can be envisioned as a large underground block perhaps 200 feet x 200 feet x 350 feet deep. The block contains mass and therefore energy in the form of heat. During winter the mass (block) is extracted (cooled) several degrees and during summer waste heat is rejected (heated) several degrees. This creates a regenerative or renewable energy system.

The mechanical system used to extract this renewable energy from the earth is a heat pump. A heat pump functions exactly like a refrigerator. Heat continually penetrates the refrigerator trying to warm its' contents and the refrigeration system (heat pump) pumps the heat back into the room. This is exactly what a geothermal heat pump is designed to do.

Water is pumped down into the earth (closed-loop) heat exchanger. When it leaves it is roughly 5-10°F warmer than when entering. The heat is extracted by the heat pump evaporator and pumped to a higher temperature by the compressor, where it is rejected to the service hot water heating system. The compressors are small to ensure approximately 50% run time and where the heat pumps cannot keep up with the load a natural gas-fired topping boiler makes up the excess heat losses from the pool(s).

This system has been installed successfully and has been measured to operate at a coefficient of performance (COP) of 2.7 with continuous duty. These systems are usually used for heated outdoor swimming pools where the pool is open all year long and pool guests are comfortable swimming outdoors through the winter season. The pool must be covered at night to reduce heat losses.

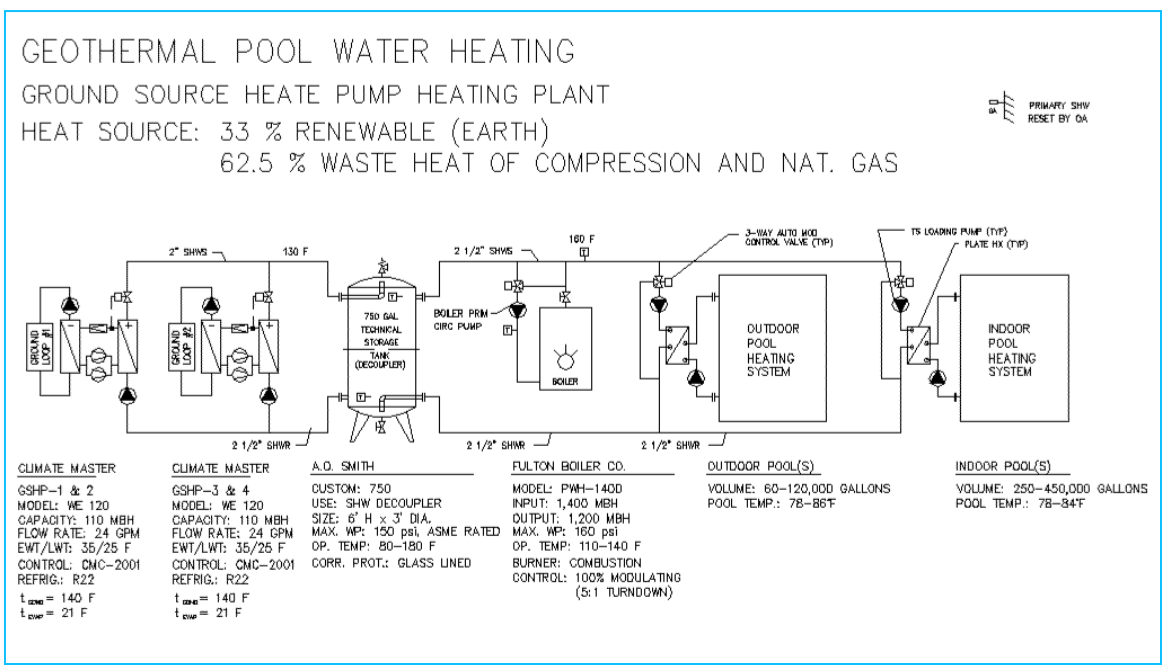
6.0 Pool Water Treatment Cycle

The pool water must be circulated (turned-over) once every four (4) hours or thereabouts depending on the pool type, bather load, temperature, etc. Competition pools are circulated less and children's and whirlpools are circulated more. No matter what the circulation rate, each pool water system is designed to a specific treatment cycle. Refer to Fig. 5 which shows the Complex Ozone water treatment cycle.

The modern pool water treatment cycle includes the following:

- Proper pool water hydraulics to maintain adequate residual disinfectant flow across all pool surfaces.
- Collection of pool water effluent in over flow gutters and a surge tank.
- Coarse filtration in the surge tank and pool strainers.
- Circulation at the main pool water circulation pumps.
- Optional: Injection of flocculant to improve the mechanical efficiency of the high rate sand filters.
- Injection of ozone (O_3) into the water treatment system.
- Reaction of ozone in pool water treatment system (min. 3 minutes).
- Ozone generator cooling water heat recovery.
- Removal of ozone, residual chlorine and other impurities in mixed-granular activated charcoal (GAC) and high rate sand filter.
- Addition of fresh water intake and pool water heat recovery system.
- Addition of Waste Heat from another process to the pool water return loop.

Figure 4:



- Addition of Service Hot Water from SHW piping loop (various users) to the pool water return loop.
- Option: Removal of heat from the competition pool using the service chilled water piping loop for cooling the pool by 4°F within 10 hours for competition swimming events. The waste heat is recovered to the service hot water storage tank for use by another energy user.
- Pool water return to pool hydraulic distribution, and pool water attractions.

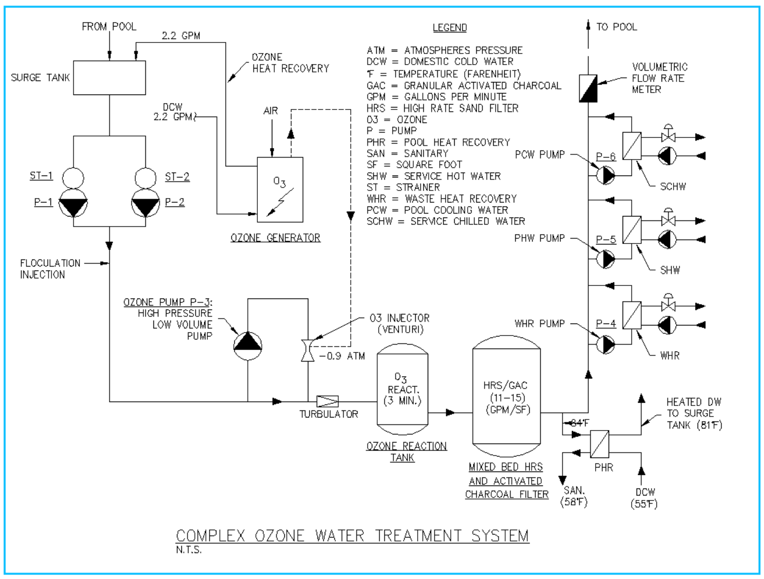
6.1 Fresh Water Intake For Pools

The pool water must be heated continuously to account for evaporation, transmission and displacement losses as well as for fresh water intake. Fresh water intake is required to dilute impurities from the pool water. This helps to reduce concentrations of chloramines, halomethanes and dissolved salts. Chloramines evaporate with the water, become airborne (aerosols) and deposit on condensing surfaces. Aerosols containing monochloramine (NH_2Cl) are acidic and are corrosive to metal surfaces (ie. standard grade steel, copper and aluminum). The concentration of combined chlorine (chloramines) in the pool water should be maintained between 0.3 - 0.5 ppm. Pool ventilation unit manufacturers will not warranty their equipment if the chloramine concentration in the pool water exceeds these recommended values. Most public swimming pool operators find it difficult to maintain concentrations of less than 1 ppm and many operate above 4 ppm. It has been determined by Professor W. Roeske of Germany that when the chloramine concentration in the pool water exceeds 4 ppm eye irritation occurs causing burning, itching and characteristic red eyes. The noticeable "classic" pool odor is also caused by chloramine build up.

In order to reduce the concentrations of urine and sweat and other impurities in the pool water, brought in by guests (~ 50 ml urine per bather) a manually adjustable fresh water intake system is used.

This is a very inexpensive system to install and maintain. Roughly 50 liters (13 gallons) of fresh potable water per person should be introduced into the pool daily. For example if the pool has 400 bathers per day [(400 x 13) ÷ (24 x 60) = 3.6 gpm] then 3.6 gallons per minute of fresh water should be introduced into the pool. Some of this fresh water enters the pool during the backwash cycle. However, this usually amounts to less than 0.5 gpm of continuous intake. The remaining 3 gpm of continuous intake would cost approximately $8,000 per year for a 25 meter, 8-lane competition pool using natural gas as the heating energy source.

Figure 5:



6.2 Pool Water Heat Recovery

A plate frame heat exchanger can be used to create a pool waste water heat recovery system. The waste water is piped to the plate frame heat exchanger after the filter and then to a sanitary drain. The fresh (potable) water intake is piped through the other side of the heat exchanger and to the surge tank. No additional pumping is required on either side of the heat exchanger. Water flow is controlled by two-way, two-position control valves.

This system is 90% efficient and will save roughly $7,000 per year as compared to the direct fill fresh water intake system. Similar to fresh air intake in a building, fresh water intake in a pool will improve the quality of the water. It also improves the ability to balance the pool water. In addition, it will also reduce chloramine concentrations which can lead to expensive architectural, structural and equipment damage to the building.

6.3 Ozone Generator Heat Recovery

Corona discharge ozone generators are the only type which can generate an adequate quality of ozone at a sufficient rate to properly disinfect public pool water. The corona discharge process generates ozone (O_3) from oxygen (O_2). Ozone is the most effective oxidizer next to elemental fluorine in the natural world. It reduces (destroys) impurities in the pool water like the exoskeletons of dead (disinfected) microbial organisms which accumulate in the pool water. These exoskeletons and other irritants evaporate with the pool water and are breathed as aerosols by pool guests and workers. It has been shown that exposure can cause Hypersensitivity Pneumonitis a bronchial condition in some

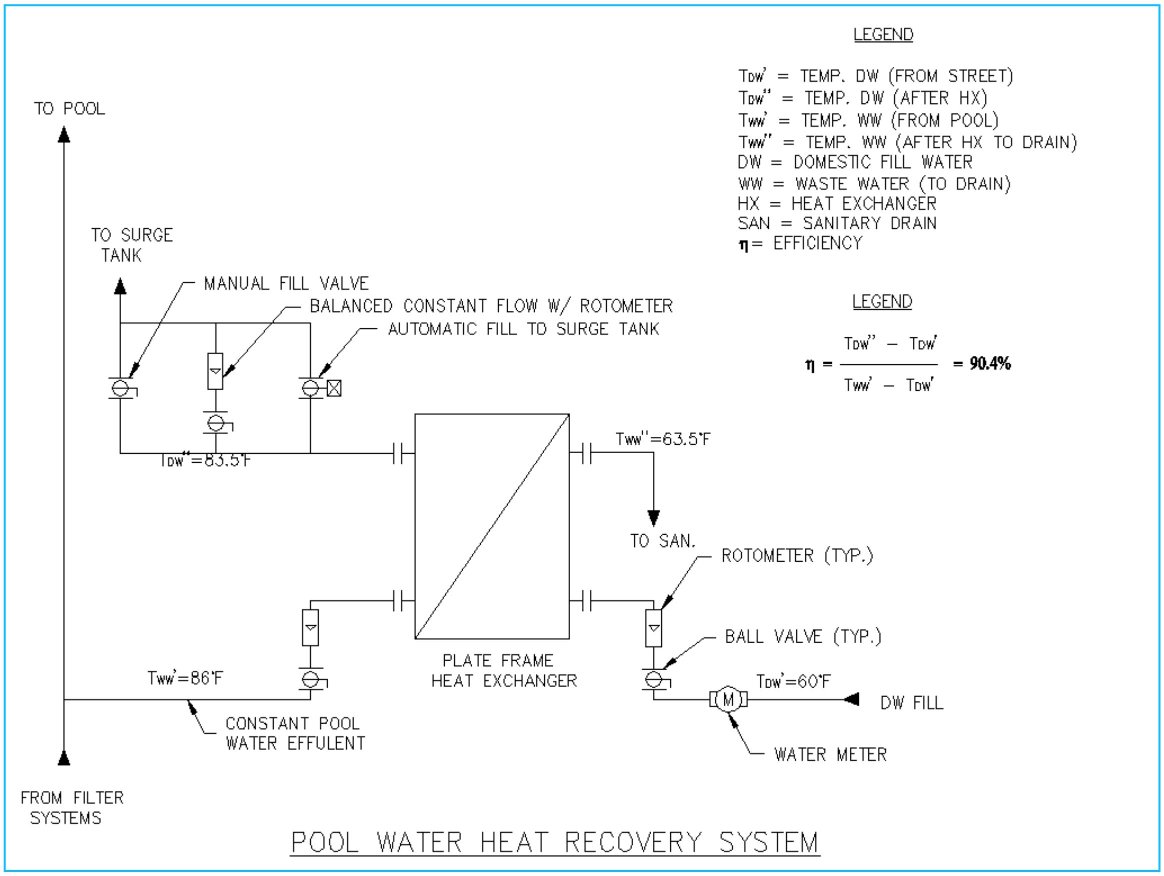


Figure 6:

people. The ozone destroys the little organic impurities, therefore rendering them harmless, and the freshwater intake system mentioned in the previous section dilutes these impurities away to the sanitary system.

The corona discharge ozone generator dries air to a very low moisture content, as if it were at minus 76°F. This dry air is pulled by vacuum across glass tubes. The tubes are charged with up to 14,000 volts (@ 2 to 3 amps) and the energy excites the oxygen in air to become ozone. The ozone has a very short half-life and is quickly pulled into the pool water system using a venturi. The ozone is mixed and reacted whereby it must remain in contact with the water for a minimum of 3 minutes. It is then stripped off using a layer of granular activated charcoal (GAC) in the mixed bed filter.

The glass tubes in the corona discharge generator must be cooled with domestic water. The domestic water is strained and filtered prior to entering the ozone generator and leaves the generator at roughly 85°F, which is 35°F warmer than the entering temperature. Since the pools like to be between 78°F and 86°F this waste heat is piped into the surge tank where it is used as heated fresh water intake.

7.0 Natatoria Control and Energy Recovery

The heart of the Natatoria and Recreation Center is the heating and cooling (HVAC) system. The guests expect a good level of quality and service for a reasonable price. The quality is related to air and pool water hygiene, which includes the obvious physical parameters of temperature, odor, humidity issues as well as the actual microscopic parameters of air and pool water.

The pool water quality must be well controlled. Chemical concentrations in the pool water should not exceed health department requirements by wide margins. The more chemicals added to the water, the more aggressive is the pool water vapor in the air. The water vapor comes in contact with people and building surfaces. If excess chemical is added to pool water, people who visit for a few hours may notice some discomfort, but the building materials and systems are affected continually. Building materials and systems are especially susceptible to damage when the relative humidity in the Natatoria exceeds 70%. In order to control the Natatoria environment properly energy must be consumed. Where energy and cost is attempted to be conserved from a building not properly designed to conserve energy, the quality is compromised and occupants and the building materials and systems suffer. The best facilities provide good air and water quality where the guests and the building itself is comfortable.

7.1 Energy Dynamic

There is an energy dynamic which occurs between air and pool water heating and cooling systems in Natatoria buildings. It is synergetic. If the ventilation system allows the air temperature to approach (equal) the

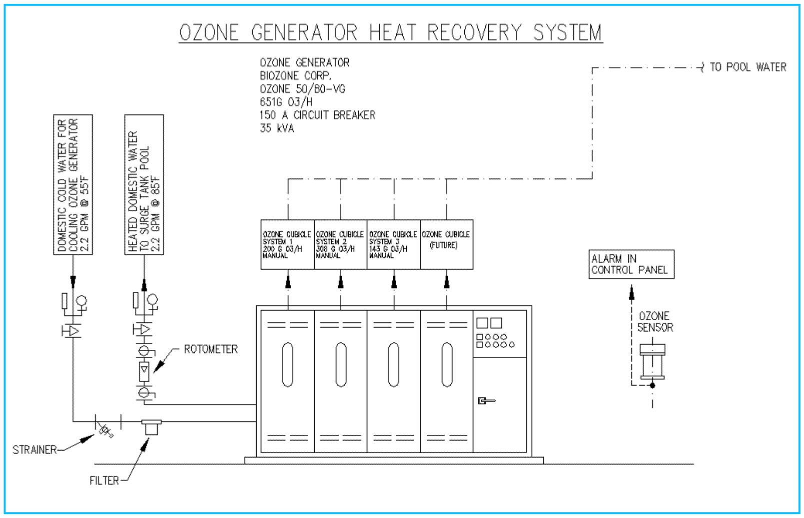


Figure 7:

pool water temperature, evaporation and therefore energy costs increase. The air temperature must never be less than 3 or 4º F above the average pool water temperature based on water surface area.

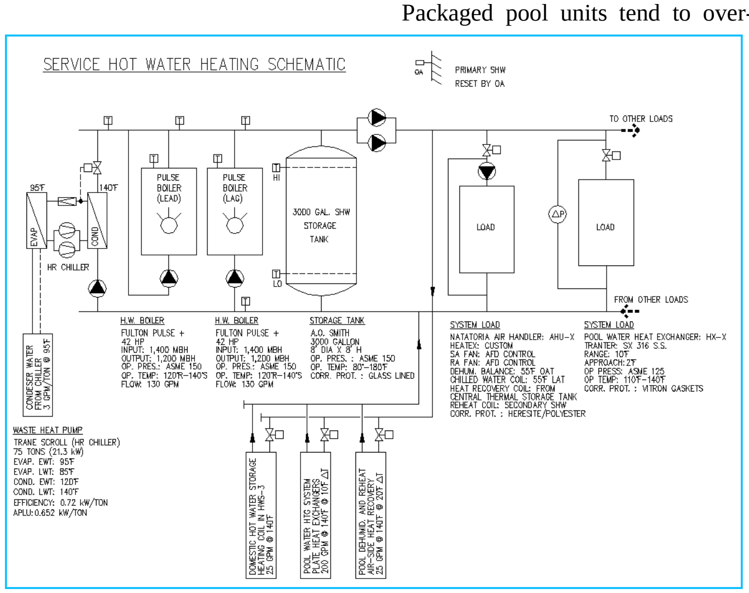
If the Natatoria ventilation, dehumidification and heat recovery units have integral refrigeration and heat recovery controls, the waste heat has limited possibilities for use when the air and water temperatures are satisfied. In this case the heat must be rejected outside and energy is wasted. Where a central chilled water system is used, the heat of removal and waste heat of compression can be recovered and redirected to any energy user in the system.

Where competition pools are concerned there is an interesting method used for energy transfer and recovery. When a competition swimming event on the weekend requires that the water temperature be 78º F, but the usual weekly quests prefer 84º F then special systems are required. The pool is cooled using the central chilled water plant, and the heat is recovered (transferred) to the service hot water (SHW) heating system. The SHW heating system is used to transfer energy to other systems, such as domestic hot water heating, pool water heating, and the HVAC systems.

7.2 Service Hot Water (SHW) Heating

The service hot water heating systems should use condensing boilers or condensing pulse boilers. In new buildings it is recommended to start saving at the energy user (load) and work backwards to the plant. Reducing energy consumption at the energy users will reduce the heating demand. This method will result in the largest reduction in heating plant capacity, and therefore lower mechanical system initial cost. The boiler efficiencies may vary from an air fuel utilization efficiency (AFUE) of 80% to 96%. Refer to fig. 8.

Figure 8:



The waste heat pump (HR Chiller) receives condenser water from the central chiller system. The chillers are enabled above 55º F OAT and normally reject heat to the cooling towers. When the automatic temperature control system decides that the service hot water tank needs charging and the chillers are "on". The Heat Recovery (HR) chiller is base loaded and runs. The HR chiller provides 140º F SHW to the heating system by rejecting heat to the loop through the condenser.

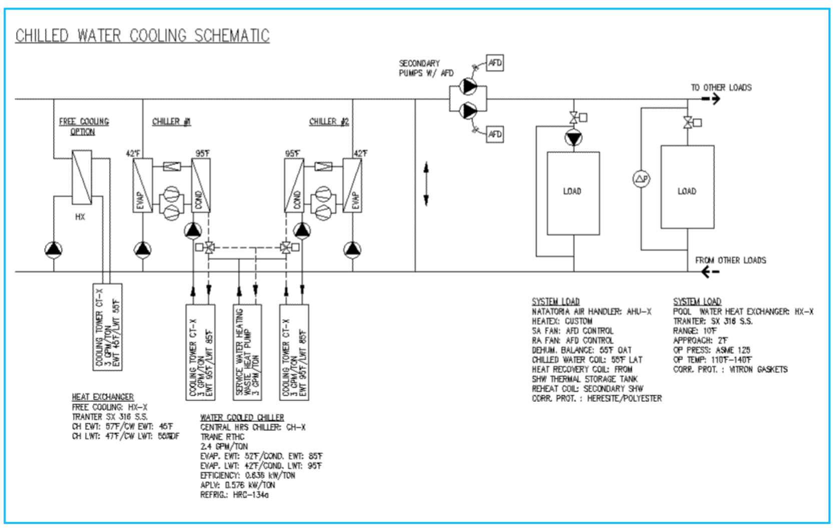
7.3 Chilled Water Cooling

The Natatoria and Recreation Center is best served cooling energy by use of a central chilled water system. The chillers are enabled to run when the outside air temperature (OAT) is above 55º F the Natatoria and Recreation Center will be dehumidified and cooled using fresh air. Energy recovery heat exchange in the air handling units will recover up to 70% of the heat content of air leaving the building and transfer the energy to the air introduced into the buildings.

The concept is very efficient, offers simple maintenance, and improves indoor air quality. The system is efficient because the large compressor motors run fewer hours. The excess waste heat can be used by any energy user in the building. Heat recovery is not only limited to heating Natatoria air and pool water. Packaged pool units tend to over-heat the Natatoria air and pool water resulting in uncomfortable conditions during warm weather operation. The chilled water system is easier to maintain than expensive packaged pool units with integral refrigeration, which require more complicated maintenance, and complex controls. The chilled water systems require standard corrosion protected air handlers with few moving parts, standard chillers with normal maintenance contracts from the local vendors, simple automatic temperature controls from any owner approved vendor. If a chilled water air handler goes bad it is much easier and less expensive to replace than a packaged pool unit, and the chiller, piping, valves, controls, etc. will outlast the packaged pool unit by several lifetimes. The indoor air quality is also improved because the system operates with more fresh air, and is capable of thoroughly flushing the Natatoria during superchlorination.

The chilled water cooling system should use high efficiency CFC-Free chillers with 0.636 kw/ton thermal efficiency or lower. If the building automatic temperature control system determines that any heating load exists, than the chiller leaving condenser water shall be redirected to the service hot water heating waste heat pump (HR chiller). The waste heat shall be recovered from the chilled water system to the service hot water heating system.

Figure 9:



8.0 Natatoria and Recreation Center Energy Consumption

Natatoria and Recreation Centers are energy intensive facilities by nature. Numerous energy efficient heating and cooling systems specifically designed for these facilities have been presented in previous sections. These systems have been installed in many public facilities through out the world, and extensive energy consumption data exists for these buildings. Each system previously discussed is part of an overall stepped energy recovery concept. In order to simplify the analysis of the building for energy efficiency the following steps are identified. See figure 10.

1. No heat recovery, just motor heat regain.
2. Air side (air-to-air) heat recovery.
3. Air side and pool water heat recovery.
4. Airside, pool water and shower water heat recovery.
5. Air side, pool water, shower water, and condensing boilers heat recovery.

8.1 Calculation Methods

Complex calculation methods have been developed to determine the annual energy consumption of Natatoria. B2E Consulting Engineers P.C. has been involved in more than 8,000,000 SF of energy conservation and life-cycle cost analysis and design for projects in the United States and Europe since 1994. We use DOE 2.1E and Carrier HAP 4.0 as well as in-house software specifically developed for Natatoria HVAC systems. It is very important to realize that the energy consumption in the Natatoria is proportional to each pound of water evaporated from the pool(s). Therefore, indoor attractions which increase water evaporation also increase energy consumption. Where many attractions are desired a control system should be use which limits water evaporation during peak bather loads such as by time clock or as a button with time-out feature. These effects must be carefully modeled in order to properly size the Natatoria HVAC units. Once the units are sized the annual energy consumption of the Natatoria HVAC system(s) can be accurately calculated.

The Natatoria HVAC systems with integral refrigeration (packaged pool units) should not be sized for max. bather loads plus all attractions for optimal energy performance. This makes optimal selection of packaged pool units selection difficult. Many designers will select for maximum conditions, which result in oversized compressors, poor indoor temperature control and inefficient system operation. The central chilled water system is superior to a packaged pool unit, because the chiller can load and unload to match any Natatoria load without compromising efficiency or cycling excessively.

The correct method of analyzing the specific energy consumption for an energy intensive building such as a Natatoria and Recreation Center is in kBTU/ft^3 or kWh/m^3. It is better to describe the energy consumption of the Natatoria as a measure of volume instead of area. The area method is misleading because these facilities tend to have concentrated energy uses and varying roof heights. Since the air flow rates in Natatoria must meet minimum air change rates the building volume has an effect on overall energy consumption.

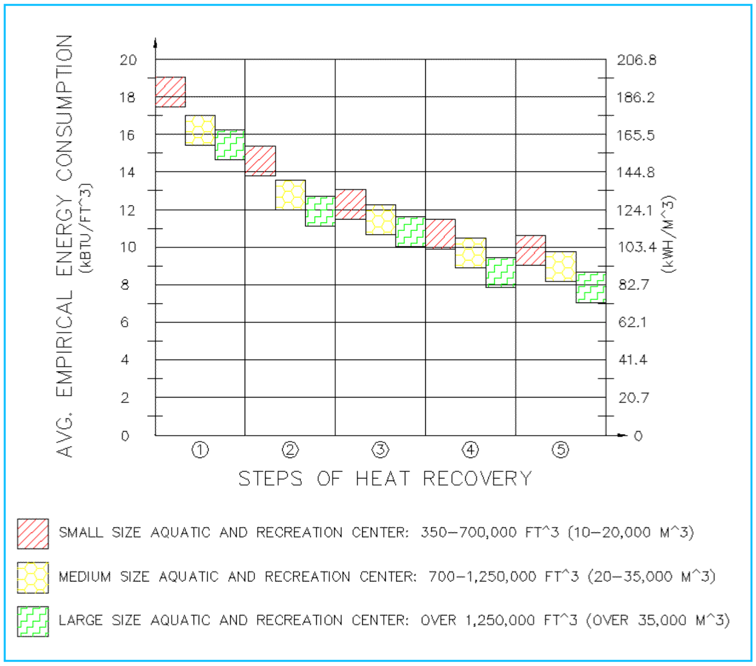


Figure 10:

8.2 Historical Energy Consumption

The energy consumption for each step of energy recovery discussed in previous sections in given in Figure 10. The data is broken down by facility volumetric size and by energy recovery step. The annual specific energy consumption values shown are calculated for the Washington, DC area based on actual 30 year TMY weather data. The following graph represents the energy consumption for Natatoria and Recreation Centers into three (3) sizes. These are small, medium, and large. As the building volume increases the annual energy consumption rises more gradually. A medium size Natatoria and Recreation Center building is between 700-1,250 thousand cubic feet or roughly 45-85,000 square feet. The medium size building will require an annual energy consumption for electricity and fuel similar to the values given in the table below.

Medium Size Facility		**Heat Recovery Steps**				
		1	**2**	**3**	**4**	**5**
Less Efficient	KBTU/CF	17	13.6	12.2	10.4	9.7
	KBTU/SF	260	212	190	162	151
More Efficient	KBTU/CF	15.5	12.1	10.7	8.9	8.2
	KBTU/SF	241	166	166	138	128

Note: Assumes average building height of 15 ft.

8.3 Energy Flow Diagrams

The flow of site energy through the building can be visualized using an energy flow diagram. These types of diagrams are useful for illustrating exactly where the energy is used throughout the year. These diagrams must be drawn to relative scale for comparative purposes. The tables provided in Appendix B give the typical energy users for a medium size Natatoria and Recreation Center with no heat recovery systems in place (Step 1) and one with all heat recovery systems installed (Step 5). The values given in these tables are represented by the energy flow diagrams as figure 11 and 12. Comparing the energy flow diagrams will show that the energy needed to satisfy the energy users is the same for both. The difference is that the energy consumption (site energy input) is greatly reduced for step 5 heat recovery, because so much heat is recovered and redistributed to energy users before rejected from the building. A thorough analysis of the energy consumption for the entire facility should be performed using energy simulation software. The results of these calculations should be used in further analysis, including life-cycle costing, system selection and sizing.

9. Summary

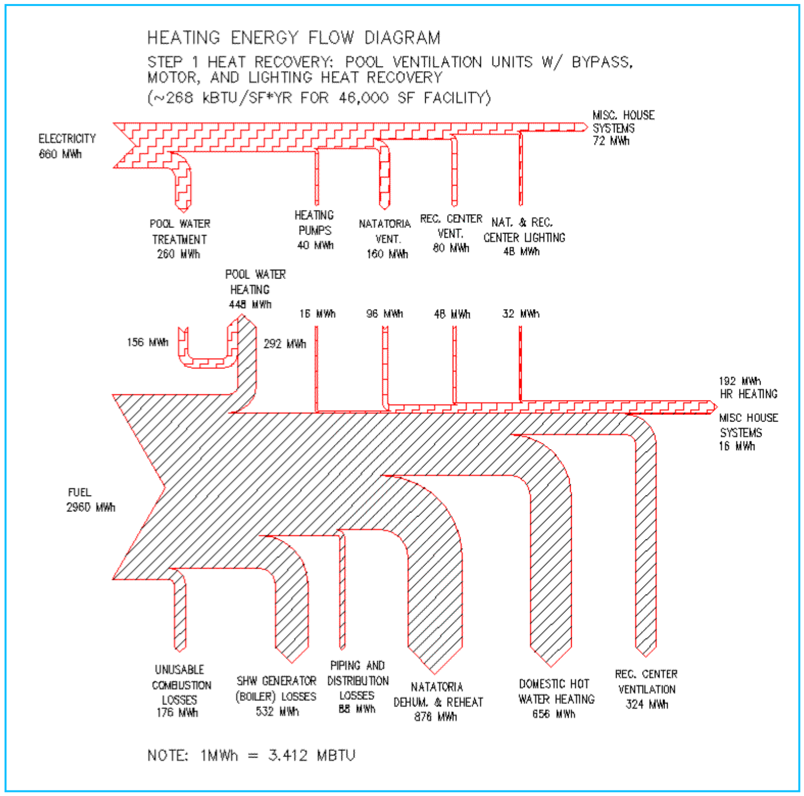
Natatoria and Recreation Centers are energy intensive buildings. Careful planning is required to develop an energy efficient and cost effective concept which is customized for the actual features and functions of the facility. The individual systems presented in the previous sections are one part of the overall energy concept. Each system should be modeled on energy simulation software. Once the model is complete many variables can be tested through the user of parametric analysis (sensitivity analysis) to optimize the energy efficiency design of the building systems. The heat recovery systems can be installed with any priority, but should be selected based on a life-cycle cost analysis. The prioritization process should follow the National Institute of Standards and Technology (NIST) Building Life-Cycle Cost Handbook (NIST 135) and other relevant publications.

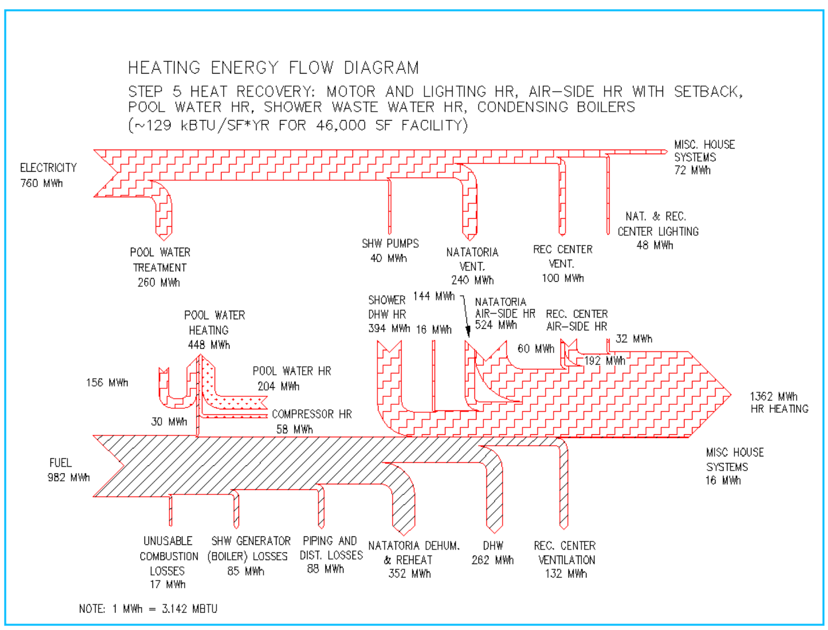
The proper economic measures and calculation tools must be used to prioritize the heat recovery systems. Important economic measures which should be calculated, include present value Building Life-Cycle Cost (BLCC), Net Savings (NS), Savings to Investment Ratio (SIR), Adjusted Internal Rate of Return (AIRR), Simple Payback Period (SPB), and Discounted Payback Period (DPB). In order to develop an accurate BLCC analysis detailed costing and energy rate calculations must be preformed. In addition, the latest operation and maintenance cost data for the system components must be compiled and evaluated for the systems considered for installation.

Once the systems are selected, and constructed the Engineer should be retained to provide systems demonstration (Commissioning) services. Each control point for each system should be checked-out. The entire process should be documented so that the proper system setpoints can be reset to their original default conditions at a later date.

The engineer should provide a systems demonstration matrix checklist, and the contractor should be required to accompany the Engineer as often as necessary for multiple (minimum of 3) on site system demonstrations. These demonstrations should occur during peak summer and peak winter seasons. As the systems are brought on-line they should start saving energy and operating cost for the owner immediately. The owner will have a system and facility that is state-of-the-art, and customized specifically to operate for optimal energy and maintenance cost savings.

Figure 11 & 12:





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