LAPPING UP THE SUN: A VITAL SIGNS CASE STUDY OF WILLAMALANE AQUATIC CENTER (SPRINGFIELD, OR)

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ABSTRACT

Measurement of air temperatures at an indoor pool facility provides a platform for exploring the relationship between indoor climate and external conditions such as outdoor air temperature and solar gain. The Willamalane Aquatic Center located in Springfield, Oregon has all the conditions necessary for such a study: multiple pools maintained at three different temperatures, a zoned HVAC system, and a variety of enclosure treatments, including ample east-side glazing. Temperature readings were collected over a period of two weeks in November 2000, yielding two data sets, each spanning three full days.

The case study offers the hypothesis that indoor air temperature readings would show negligible changes during the diurnal cycle. This is not supported by study findings, which in fact show a significant indoor temperature gain on clear days, attributable to solar gain. Willamalane's HVAC system and maintenance schedule also impact the indoor temperature on a daily basis. Aside from these conclusions, the study addresses one question that could not be answered: is it the heated mass of the pool water or is it the HVAC controlled air temperature that is a driving force behind the climate of an indoor pool.

1. INTRODUCTION

The recently remodeled Willamalane Aquatic Center in Springfield, Oregon is an ideal laboratory for studying the role of 'unconsidered' solar gain in a system that is designed to maintain stable air and water temperatures. According to the project architect, the building's HVAC system was designed to provide complete control over the interior environment. This decision was based on an assumption (backed by previous project experience) that thermal transfer through the building envelope contributes just 15% to the total energy costs for operating the pool.(**1**) The result is that little consideration was given to glazing, solar exposure, and solar gains. However, this case study suggests that in a carefully regulated environment, even a small increase in solar heat gain can produce a noticeable change of indoor air temperature. Although the findings presented here are specific to a single building, the lessons learned are general, and could be applicable for any natatorium.

Fig. 1: East Wall of Aquatic Center

1.1 Building Description

The Willamalane Aquatic Center is an indoor public pool run by the parks and recreation division of Springfield, Oregon. The remodeled facility entered service in late Summer 2000. The Aquatic Center is a large space with a roughly square footprint, 180 x 150 feet (55 x 46 meters) and a 30 foot (9.1 meter) ceiling. The building is constructed of CMU perimeter walls. The floor is a poured concrete slab.

The East wall contains two large areas of glazing, which have minimal sun-shading. There is also a strip of glazing located high on the South wall, above the locker room building volume. Kalwall is installed horizontally above the spa pool. Kalwall on the West wall also provides some daylight. Willamalane has three pools: a lap pool, a diving pool, and an exercise pool, as well as a hot tub located at the South edge of the space. The target temperatures for the water in these pools are:

Exercise pool: 88 °F (31 °C)
Lap, Diving pools: 84 °F (29 °C)
Spa: 102 °F (39 °C)

2. HYPOTHESIS

The attraction to the Willamalane Aquatic Center emanated from the interest to explore issues of thermal mass. The natatorium looked like an ideal structure for this sort of analysis. Upon visiting the natatorium, there seemed to be a correlation between indoor air temperature variations and the different pool temperatures. The Exercise Pool is maintained at a higher water temperature, which corresponds with a noticeably higher ambient air temperature on the East side of the building. These initial observations led to the investigation of two specific issues:

(1) Does energy from insolation contribute significantly to the building's heat gains?
(2) Is the internal air temperature driven by the pool water temperature, or by the HVAC heater?

Although there are windows on the East wall, it was believed that the large thermal mass of the pools would drive the indoor air temperature, rather than solar gains through the windows. Thus, the following hypothesis was devised to guide the investigation: "The indoor air temperature of the Willamalane pool building will display a negligible diurnal temperature swing." This initial speculation did not prove entirely correct.

3. METHODOLOGY

Data was gathered using HOBO temperature dataloggers that were placed throughout the natatorium, and on the exterior of the building. Data was collected in two distinct time periods, each three days in duration, in November 2000. The dataloggers were distributed along three lines in the building, in order to capture temperature variations in East-West as well as North-South directions, as shown in Fig. 2.

3.1 Series 1

For Series 1, Seven HOBOs were installed inside the structure and one outside. Of the indoor HOBOs, five were placed under the bleachers, out of direct sunlight, on the East (E1, E2, E3) and West (W1, W2) sides of the pool room. One was installed on the south column near the spa pool (C2). The last was installed on the north central column (C1). Outside the building, a HOBO was placed on an east facing column (EXT) where direct sunlight would cause a temperature spike, thus providing an indication of insolation on the East glazing. Ambient air temperature was logged every 2.5 minutes.

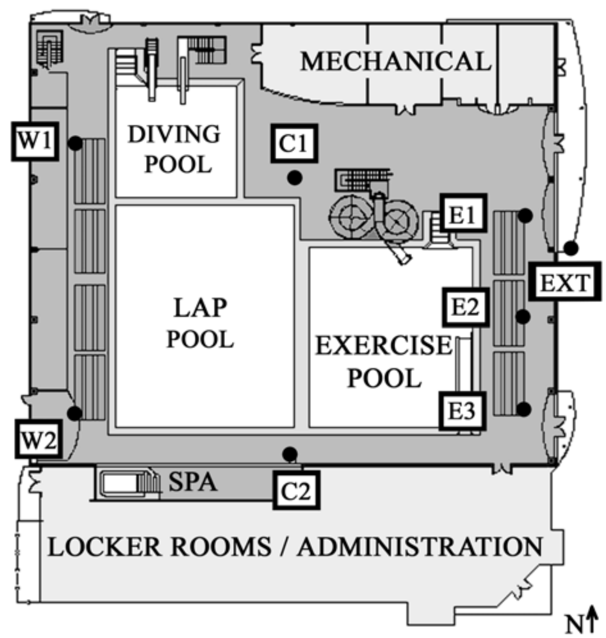

Fig. 2: Floor plan of pool showing locations of HOBO dataloggers

3.2 Series 2

Equipment placement was identical to Series 1 except that only one HOBO was placed on the East side of the building (at location E3).

3.3 Other Data

The computer controlled HVAC system provided another source for temperature data in the building. System setpoints for the different zones within the building provided a good correlation with HOBO data. The HVAC system operated at a reduced level when the building was unoccupied, so knowing the building schedule was a key data point. Data logged from the HVAC system was also obtained for the temperature in each of the three pool volumes.

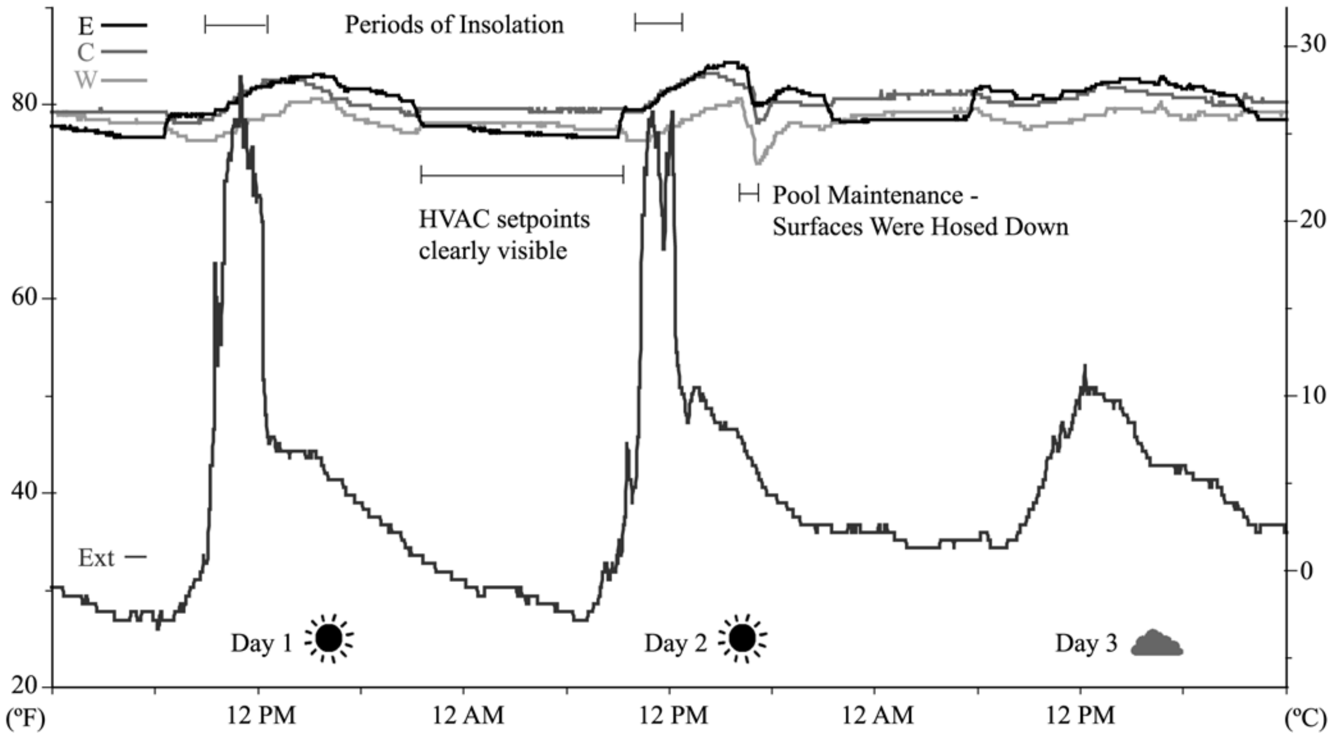

Fig. 3: Series 1 Data

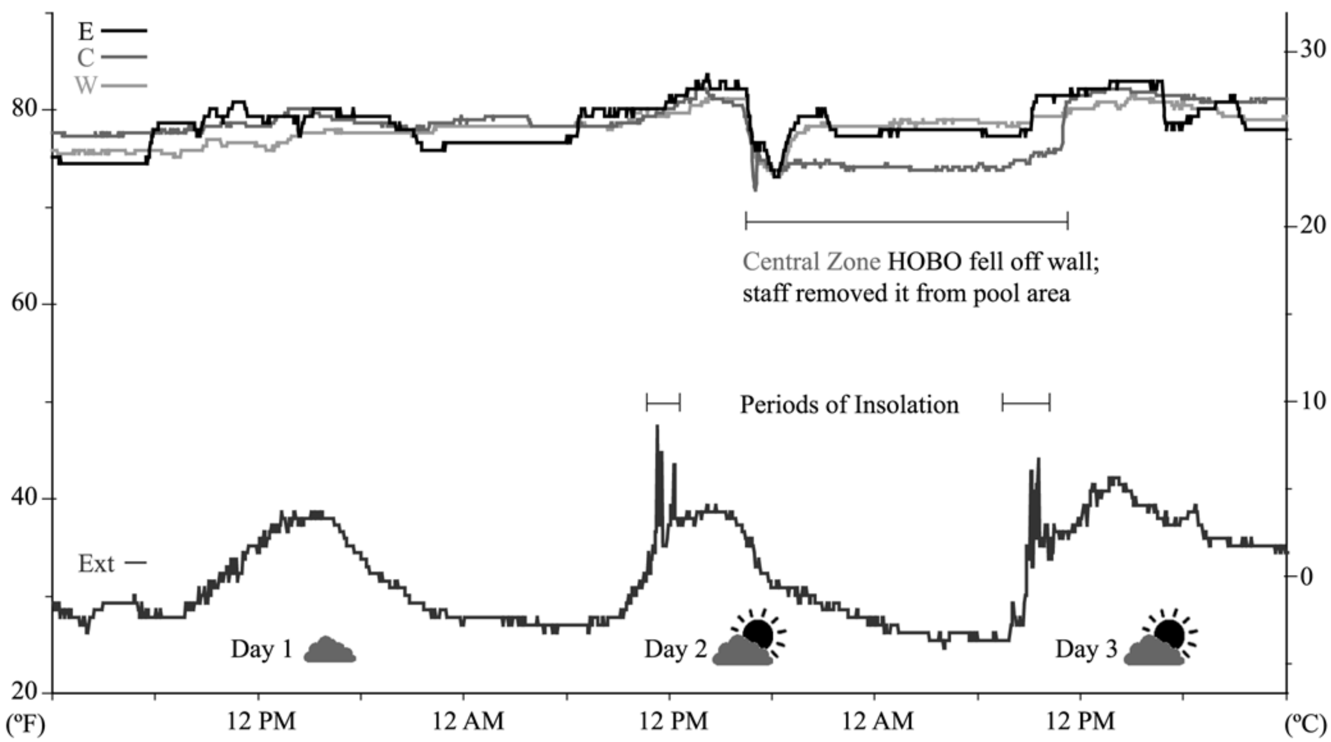

Fig. 4: Series 2 Data

Fig. 5: Insolation

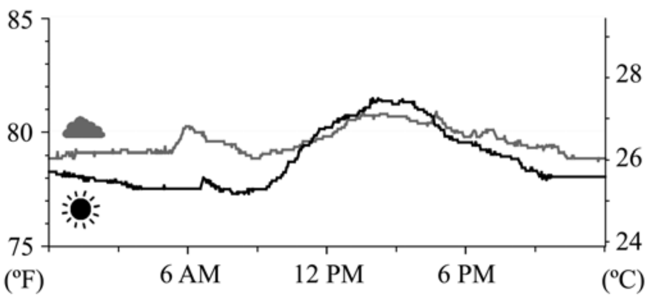

Fig. 6: Graph comparing average indoor air temperature for a typical sunny and cloudy day

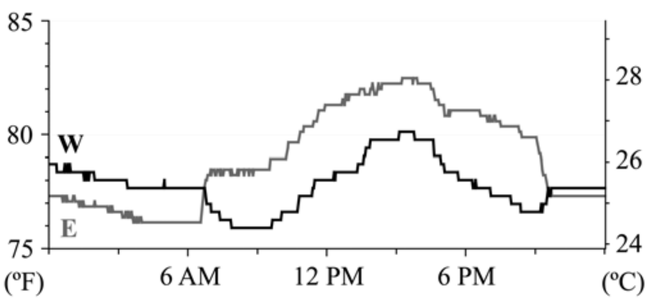

Fig. 7: Graph comparing indoor air temperature in East and West zones for a typical day

Finally, archives of local climate data proved useful as a check on general weather conditions in the area. These records provided a value from zero to nine indicating average sky conditions ranging from clear to total cloud cover.

4. RESULTS AND ANALYSIS

Temperature readings collected at Willamalane Aquatic Center are presented in Figures 3 and 4. The data reveals a number of factors affecting the indoor air temperature. The strongest of these are:
(1) Pool temperatures
(2) Outdoor conditions
(3) HVAC hours of operation
(4) Maintenance Schedule

The diurnal temperature variations clearly indicate that our original hypothesis is incorrect. The data does reveal information that suggests answers to several questions posed during the initial visit to the facility.

4.1 Insolation

The effect of direct sunlight is apparent on both charts, particularly Series 1, when comparing Day 1 (a clear day) with Day 3 (mostly cloudy). The large temperature spike denotes the time period that the outdoor HOBO (located on the east side of the building) received full sunlight. Local weather records indicate that the sky remained clear all day, allowing sun to enter the natatorium through south- and west-facing clerestory windows. This correlates well with the gradual increase in indoor air temperature observed for Day 1. In contrast, when clouds move in on Day 3, a more constant daytime temperature profile results from a lack of direct sunlight.

4.2 East-West

The results support the initial observation that the East side of the natatorium was several degrees warmer than the West. At that time, it was thought that this might be caused by proximity to the warmer activity pool, or perhaps a thermal lag associated with the sun reaching the East side first. However, a closer examination of the data suggests otherwise. At night the east side temperature is just slightly lower than the west, which makes sense considering the thermal loss through the East glazing. The trend suddenly reverses each morning, immediately after the programmed HVAC startup time. East side temperatures remain consistently higher throughout the day until the building closes. When the HVAC fans spin down, temperatures revert to nighttime levels. The temperature difference observed during the day could be explained by HVAC duct locations. The West side of the natatorium is served by two ducts, one running under a mezzanine, which puts the warm air supply much closer to floor level. Over the East side, a single duct, located at ceiling height, has to serve the entire zone.

4.3 Driving Forces

Willamalane's maintenance director explained that the natatorium's HVAC heating capacity had rarely been fully utilized during Fall 2000 since warm pool temperatures keep the indoor air temperature steady.(**2**) The theory that the thermal mass of the pools drive the indoor air temperature is supported by data collected near the small alcove containing the 102 °F (39 °C) spa. Temperature readings here were generally higher than the rest of the natatorium, especially at night when ventilation fans were at their lowest setting. If one considers the spa alcove to be a microcosm of the entire natatorium, it is reasonable to believe that the thermal mass of the pools define a narrow indoor air temperature range. This is most clearly visible in the Series 1 Data (Fig. 3), where the night-time Central Zone air temperature is clearly much higher than other areas of the Aquatic Center. Other factors, such as ventilation, thermal transfer through the building envelope, and occupant activity then dictate how air temperature varies within the range defined by the thermal mass.

5. CONCLUSIONS

The hypothesis proved to be incorrect. While the indoor air temperature did stay within a fairly narrow range, significant variations took place over the course of the diurnal cycle. The HVAC system was partly responsible for these variations, with the most noticeable change occurring when the HVAC system switched in and out of "building occupied" mode each morning and night. The ideal situation for studying the natatorium would be at a time when the HVAC heater is inactive, so there are fewer variables affecting the indoor temperature. As it turned out, unseasonably cold weather triggered heating needs during most of the observation period. This makes it difficult to draw conclusions about the complex interactions between the conditioned air and heated pool water. However, it does seem clear that pool water played a significant role in determining the local air temperature profiles in the natatorium. This is well supported by analysis of nighttime air temperatures in the spa alcove. Outdoor conditions also had a significant effect, particularly on clear days when direct sunlight warmed the interior areas. (As shown in the thermal lag observed for East Side temperature profiles).

5.1 Seasonal Variation

The pattern of thermal behavior presented in this paper is representative of pool buildings in heating seasons—the temperature differential between inside and outside almost always leads to heat losses from the building, and the need to add more heat to the conditioned space inside. This situation is most forgiving of a building that is susceptible to solar gains, as the solar contribution merely reduces the building's heating load and slightly increases the ambient air temperature.

The effects of solar gains in a cooling season, e.g. Summer, could be significantly worse. If the building is not able to lose heat to the outdoor air, or only very slowly, the effects of solar gains on the indoor environment could be much more dramatic.

Fig. 8: Sun on the pool surfaces

5.2 Recommendations

The analysis presented here relies on the assumption that a majority of heating energy is aimed at pool water and ventilation requirements. Cost analysis did not therefore call for highly insulated walls, and decisions about glazing were made on the basis of daylighting needs as opposed to thermal needs. These decisions have tangible consequences such as local warming due to solar gain on the East Side of the building. Since it is easy to detect these periods of solar gain, auxiliary heating load could be reduced proportionally, providing energy savings as well as a greater degree of control over the thermal environment. For example, it might be possible to save energy in the winter by anticipating the thermal lag effect, and cutting off heat during periods of insolation. Use of passive solar design techniques could provide even more dramatic savings. The results of this case study suggest that the potential benefits of direct solar gain are worth exploring for natatorium design, even during the cloudy winters of Springfield, Oregon.

5.3 Future study

In order to build on the results presented by this case study, it would be helpful to gather data at times when certain variables affecting the natatorium could be controlled. For example if the pools were drained and refilled with cold water, would the indoor air temperature behave differently? Tarps have been ordered for the pool, which, according to studies of other indoor pools done by the project's mechanical engineers, should help save energy on pool heating costs.(**3**) It would be interesting to see if indoor temperature readings are different when these tarps are in use. Additionally, what happens if the HVAC system is turned off for a holiday weekend. Will the thermal mass of the pool keep the indoor air temp relatively stable in absence of the heaters?

Finally, HVAC systems for indoor pool facilities are interesting enough by themselves to merit further investigation. For Willamalane it would be interesting to study the efficiency of the system, and if the zoning scheme is effective.

6. REFERENCES

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(3) Huizenga, R., Personal Interview (November 2000)

7. ACKNOWLEDGEMENTS

Quentin Hogan, *Maintenance Director*, Willamalane Pool; **Robert Huizenga**, *Project Engineers*, Systems West Engineers Inc.; **Carl Sherwood** AIA, *Project Architect,* Robertson/Sherwood/Architects; **The staff** of the Willamalane Aquatic Center; **Christina Bollo**, *Graduate Teaching Fellow*, University of Oregon ; **Alison Kwok & James Wasley,** *Professors*, University of Oregon

Note: This paper is based on a Vital Signs case study by the authors; the text of the original study is available online: http://www.uoregon.edu/~hof/f00lapping/