v. 2, n. 6, 2022

Journal of
Engineering
Research

APPROACH TO DEHUMIDIFICATION IN COVERED POOLS BY REFRIGERATION AND OR DESICCANT WHEEL

Alexandre Fernandes Santos
Doctor in Mechanical Engineering. UBI (University Beira Interior-Portugal); Master in Engineering at LACTEC-UFPR; Professor FAPRO (Professional College).

Heraldo José Lopes de Souza
Specialist in HVAC Engineering; Professor FAPRO (Professional College).

Eliandro Barbosa de Aguiar
Specialist in Climatization Engineering; Professor FAPRO (Professional College).

Abstract: This is an approach to dehumidification systems in indoor pools, initially it is reported on the causes for the high relative humidity and condensation in this type of enclosure, what are the solutions for dehumidification. Two solutions are presented, dehumidification by re-frigeration and desiccant wheel, although the refrigeration system has a lower energy demand, the desiccant wheel system is easier to maintain and does not require Refrigerant Fluid.
Keywords: Dehumidifier, Condensation, Indoor pool.

INTRODUCTION

This article aims to demonstrate the data and surveys of ventilation and dehumidification for a study of dehumidification for an indoor pool, comparing a cooling system or desiccant wheel as an option for air drying in order to avoid condensation and proliferation of fungi.

One of the factors that generate the need for dehumidification in an indoor pool area is the evaporation of water, which is a natural process and is a critical Energy parameter for a pool design and control system.

To eliminate condensation on cold surfaces in a swimming pool, water vapor must be removed by an air conditioning system, either by refrigeration or by desiccant wheels [1].

The comparison will be between equipment with refrigeration dehumidification versus equipment with desiccant wheel, both have the purpose of dehumidifying a pool type the difference between them is that the refrigeration dehumidification equipment uses the direct expansion of the Re-frigerant Fluid to perform the air dehumidification and the other system uses a desiccant rotor, which is composed of silica with a resistor bank, the desiccant wheel is an important and crucial component that can be used in the construction of air conditioning and refrigeration systems to achieve savings. of relevant Energy [2].

The city used for the simulation is São Jose dos Pinhais has a Cfa climate according to Köppen (sub-tropical; mean air temperature in the coldest month below 18 °C and mean air temperature in the warmest month above 22 °C, with hot summers, infrequent frosts and a tendency of concentration of rain in the summer months, but without a defined dry season) [3].

External data:

External conditions	
City	São José dos Pinhais
Altitude (m)	906
Dry Bulb Temperature - summer (ºC)	31
Coinciding Wet Bulb Temperature - Summer (ºC)	23,2
Dry Bulb Temperature - Winter (ºC)	8,8

Table 1 - Climatic data - São José dos Pinhais [4].

Internal data:

Internal conditions	
Rule about this option	ASHRAE 62.1
Humidity Control	Sim
Internal Dry Bulb Temperature (ºC)	28ºC (+/-2ºC)
Indoor Relative Humidity	40% à 60%

Table 2 - Internal data - São José dos Pinhais [5-7].

According to EN 15288-14, the indoor pool air temperature must preferably be 0 to 4 K higher than the pool water temperature. In addition, the relative humidity of the air must be between 40% and 80%, and preferably less than 60%, and the air speed in the vicinity of the users must preferably be less than or equal to 0.10 m/s. [8].

High humidity can also affect air quality, providing an environment conducive to the growth of bacteria, fungi and viruses. Keeping the relative humidity in the range of 50 to 60% will reduce the number and activity of these organisms [9].

For the calculation of external air in the pool, the Ashrae 62.1 standard is used, which must be considered from 4 to 6 changes per hour in the entire volume of the indoor pool enclosure. indoor pool in the city of São José dos Pinhais, to calculate the volume of the pool, so the following flow was found [6]:

Flow: 429 m3 x 4 air changes per hour = **1.716m³/h** (1)

So, for air renewal, regardless of the system used, an exhaust fan was indicated to remove the air and an equipment that makes the inlet of external air with temperature control to guarantee the ideal temperature of comfort for the user.

MATERIALS AND METHODS

The pool needs controlled humidity, the ideal humidity for a pool is between 40% and 60%, to avoid condensation on the glass, using a base of an internal temperature of 28°C and a relative humidity of 60%, the temperature dew point using the ASHRAE Psychrome-tric Chart application, will be 19.1°C, this means that any outside air temperature input below the dew point will have condensation, if the relative humidity was 40%, the dew point would go to 12 °C, this small difference of 20% relative humidity represents a difference in condensation problems in the annual hours of 60 to 12.5%, that is, according to graph 1 in the condition of 60% relative humidity indoor in 60% of the annual hours the external air would be a problem for the condensation of the walls of the pool environment, already in a relative humidity of 40%, in only 12.5% of the annual hours the external air would be a factor for condensation of air in the indoor pool enclosure, figure 1 illustrates which s elements that are crucial in an indoor pool enclosure [10].

To calculate the amount of evaporated water, there are several factors that are important, among them we can mention:

- Indoor air temperature;
- Relative indoor air humidity;
- Speed of air displacement on the surface of the pool;
- Type of activity in the pool;
- Water temperature in the pool.

Using the table in the SPS Climatization Projects Manual, with a water temperature of 30°C and an indoor air temperature of 28°C, with a speed of 0.125 m/s, considering a public-use enclosure, the Usage Factor would be equal to 1, with these considerations the evaporation value would be 0.2142 kg of water per m², the simulation considered a swimming pool of 39 m² and a hydromassage of 4.6 m² [12].

$$Dehumidification\ index = \boldsymbol{area\ m^2\ X\ Evaporation\ factor\ in\ kg/m^2}$$
$$Dehumidification = \left(39\frac{m^2x0{,}2142kg}{m^2}\right)+\left(4{,}6\frac{m^2x0{,}2142kg}{m^2}\right) = 12{,}23\ kg/h$$

(2)

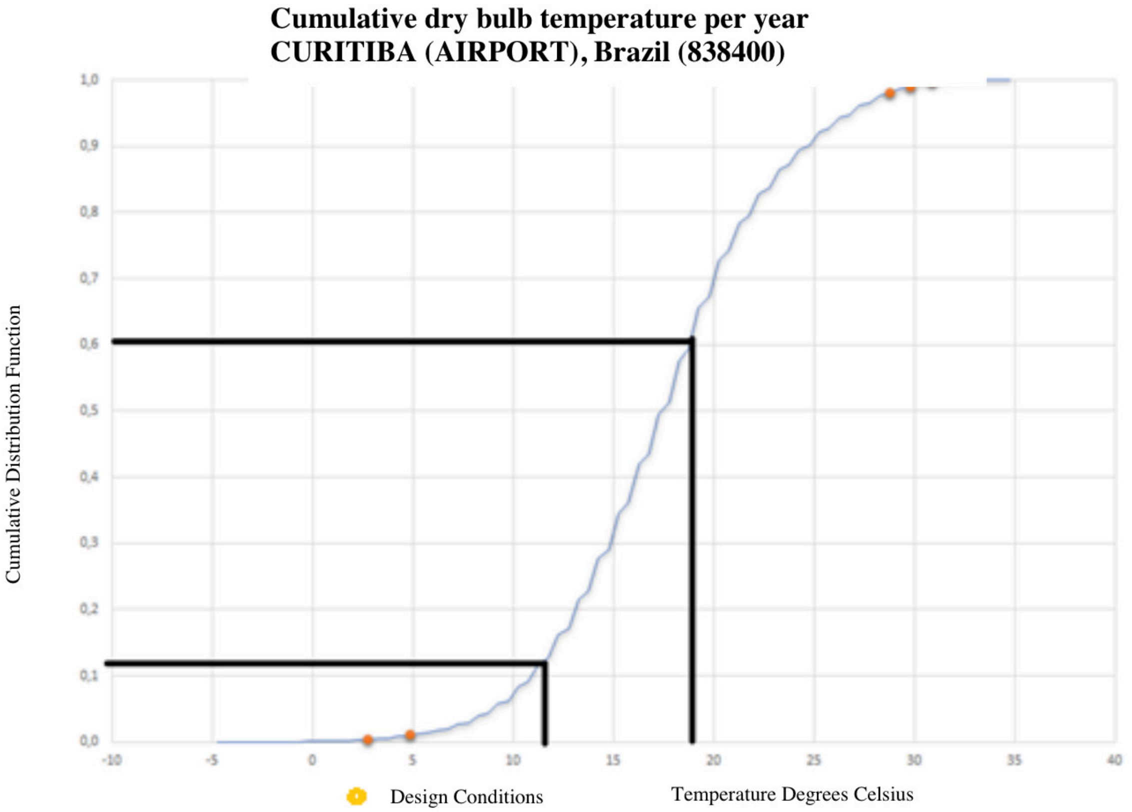
In the simulation in question, there is 12.23 kg/h of humidity to remove from the environment, in one day, the need is 293 kilos to remove. With this it is possible to compare the system between the dehumidification equipment with refrigeration or with desiccant wheel, to check in a decision map which will be more advantageous.

COMPARATIVE STUDY OF SYSTEMS

REFRIGERATION DEHUMIDIFIER

One method that has the advantage of recovering all the heat (latent and sensible) is refrigeration dehumidification. The latent

Journal of Engineering Research ISSN 2764-1317 DOI 10.22533/at.ed.317262221047



Graph 1 - Dry Bulb Temperature [11].

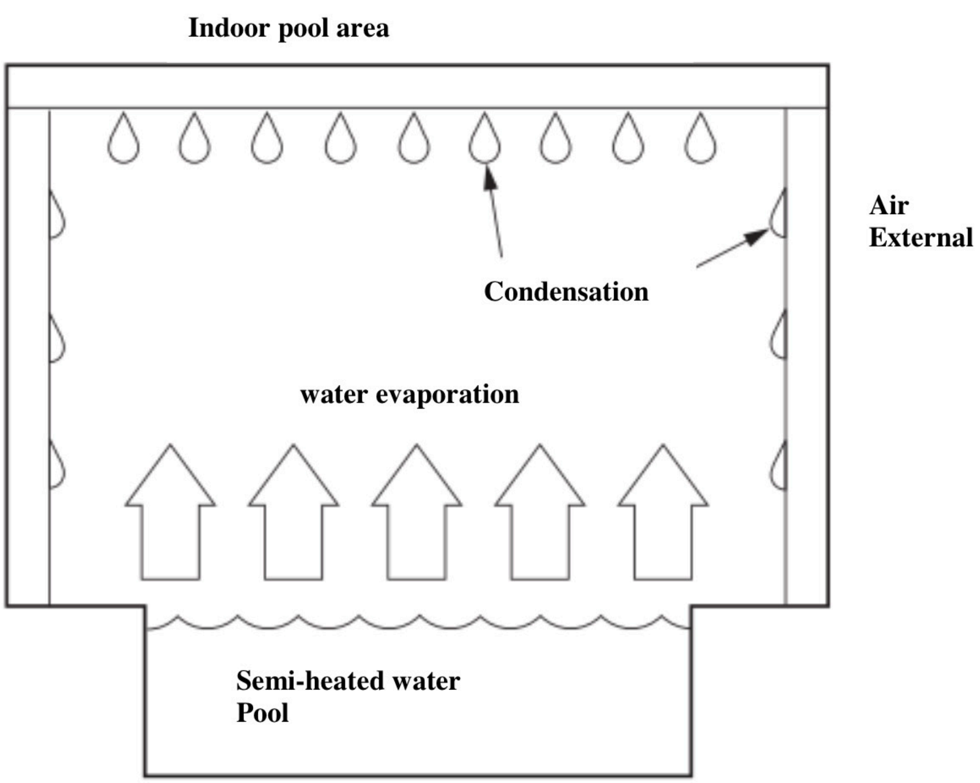


Figure 1 - Schematic Section Indoor Swimming Pool Enclosure [6].

heat (moist air) is condensed and cooled in a dehumidifying coil, transferring all the energy to a Refrigerant Fluid. Energy can be returned to the airflow in the reheat coil as sensible heat, thus recovering almost 100% Energy. This heat is returned to the interior, maintaining the proper air temperature. Additional heating is only needed to compensate for heat loss through windows and walls.

The system will first capture indoor air to pass through the first stage (G4 efficiency) and second stage (F5 efficiency) air filtration to remove airborne particles and contaminants. Partial filtered air will then enter the direct expansion dehumidification system to remove excess moisture. Excess moisture in the air will condense and turn into water. The water will be collected in a drain pan, where it will be pushed out with the help of the positive pressure of the processed air.

Dry air will then pass through the final stage of the filter to remove micron-sized particles and airborne bacteria. The final outlet air will be clean and dry. The same process will continue until the ambient air reaches the desired humidity level set point.

The refrigeration dehumidification equipment works from direct expansion, via refrigerant gas serpentine. Copper coils suffer drastically from the corrosive effect of chlorine in the air.

For the purpose of simulation, a 4Pool model 240C equipment was used, which dehumidifies 120 kg/day per day, to meet the demand of 293 kg/day, it will be necessary to use 3 equipment.

For the use of the refrigeration dehumidification equipment in this simulated case of the 4pool brand, the company Status Automação provided the following initial costs:

a) Initial Cost:

Quantity	Description	Total value
3	Dehumidifying Equipment with Digital Controller	R$ 110.638,59
1	Pipeline Installation	R$ 40.300,00
1	Budget for installation	R$ 36.000,00
Total:		R$ 186.938,59

Table 3 – Initial cost.

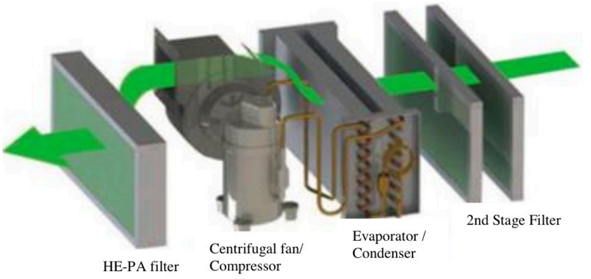


Figure 2 - Airflow 4Pool Equipment [13].

DESICCANT WHEEL DEHUMIDIFIER

Adsorption dehumidifiers, or desiccants, work by means of a desiccant rotor coated with a hygroscopic material (with high adsorbent capacity) to remove moisture from the air as needed, as shown in the following figure:

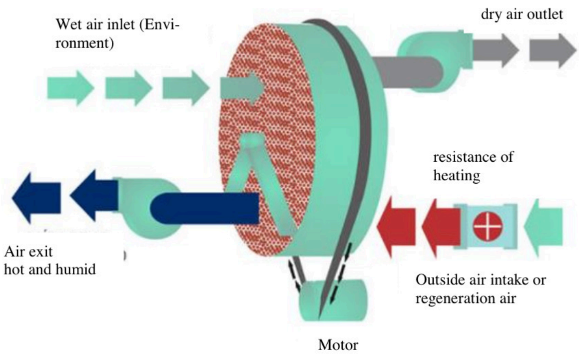


Figure 3 - Schematic view of a desiccant wheel [14].

Journal of Engineering Research ISSN 2764-1317 DOI 10.22533/at.ed.317262221047

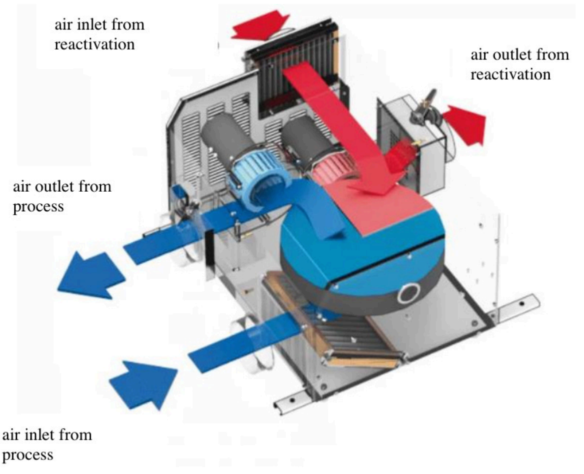


Figure 4 - Internal view of a desiccant wheel [15].

The advantages of the desiccant wheel are [15]:

- Long service life;
- Precise Control and digital as required by the application;
- Automatic adjustment to adjust the RH of the area according to the environmental conditions;
- Operates without loss of performance in environments whose temperature varies between 0°C to 45°C;
- High performance in critical situations that demand precision;
- There is no accumulation of water in the compartment;
- Greater investment due to durability;
- Very low maintenance.

The dehumidifier shall be capable of operating even without energizing the reactivation heater for extended periods without damage to the desiccant cylinder.

The dehumidifier consists of a high-efficiency desiccant cylinder "Ecodry" type, in this case the simulated equipment is from the Bryair brand, mounted on a horizontal arrangement and a fixed axis.

a) Initial Cost [16]:

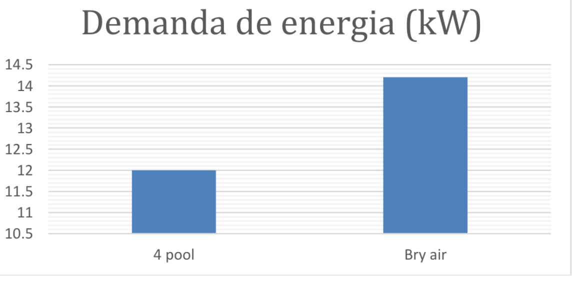
Quantity	Description	Total value
1	Dehumidifier Equipment with Digital Controller	R$ 71.910,00
1	Process Noise Attenuator	R$ 5.510,00
1	Reactivation Noise Attenuator	R$ 3.170,00
1	Pipeline Installation	R$ 9.264,00
1	Budget for installation	R$ 12.000,00
Total:		R$ 101.854,00

Table 4 – Costs.

Figure 5 - Equipment:FFB-300 [17].

ANALYSIS AND DISCUSSION

In terms of energy consumption, there is a small increase when it comes to the desiccant wheel equipment, as shown in the chart below:



Graph 2 - Demand for Energy.

Equipment with a desiccant wheel has a nominal consumption of 20.25 kW, in normal operating situations, consumption is around 70% of the nominal according to the manufacturer, in this case 14.2 kW.

Refrigeration dehumidification equipment consumes approximately 3.9 kW per equipment (according to manufacturer), totaling approximately 11.7 kW.

Below is the cost of maintenance and system operation of the systems:

- Dehumidification by refrigeration;
- Number of hours in a year: 8,760 hours;
- Energy consumption: 11.7 kW;
- Energy cost: R$ 0.830646 [18];
- Usage Factor: 0.5;
- Monthly maintenance: 500.00 (per machine).

Energy Cost: 8760 annual hours x11.7 kWx R$ 0.830646x0.5 (building utilization factor)

$$\textit{Energy cost} = \text{R\$ } 42.567{,}28 \tag{3}$$

Annual Maintenance Cost: 500.00 x 12 x 3 = R$18,000.00

Total OPEX (operating cost): R$42,567.28 +R$18,000.00=R$60,567.28.

- Dehumidification by desiccant wheel;
- Number of hours in a year: 8,760 hours;
- Energy consumption by 70%: 14.2 kW;
- Energy consumption at 100%: 20.25 kW;
- Energy cost: R$ 0.830646 [18];
- Usage Factor: 0.5;
- Monthly maintenance: 500.00 (per machine).

Energy cost:

$$\Big(\Big(\big(8.760\ horas\ x0{,}7\ (equipment\ usage\ factor\ with\ 70\%\ of\ capacity)\big)x14{,}2\ kW\Big) + \big((8.760\ x0.3\ hours\ (utilization\ factor\ at\ 100\%\ capacity)x20{,}25\ kW)\big)\Big)\ x0{,}830646x0{,}5\ (building\ utilization\ factor)\ (4)$$

$$Energy\ Cost = R\$58.264{,}58$$

(4)

Annual Maintenance Cost: 500.00 x 12 = R$6,000.00

Total OPEX: 58,264.58+6,000.00=R$ 64,264.58

The equipment with desiccant rotor is composed of silica and other materials. The operation of its fans is continuous, however the resistor bank works intermittently, not using the full rated capacity. The equipment has a low incidence of the corrosive effect of chlorine as it does not have copper coils.

The refrigeration dehumidification equipment works from direct expansion, via refrigerant gas serpentine. Copper coils suffer drastically from the corrosive effect of chlorine in the air. Taking into account the 1500 m³/h flow of the 3 equipment, a total flow of 4500 m³/h is obtained, which requires a much larger infrastructure compared to the 1500 m³/h of the dehumidifier with desiccant wheel.

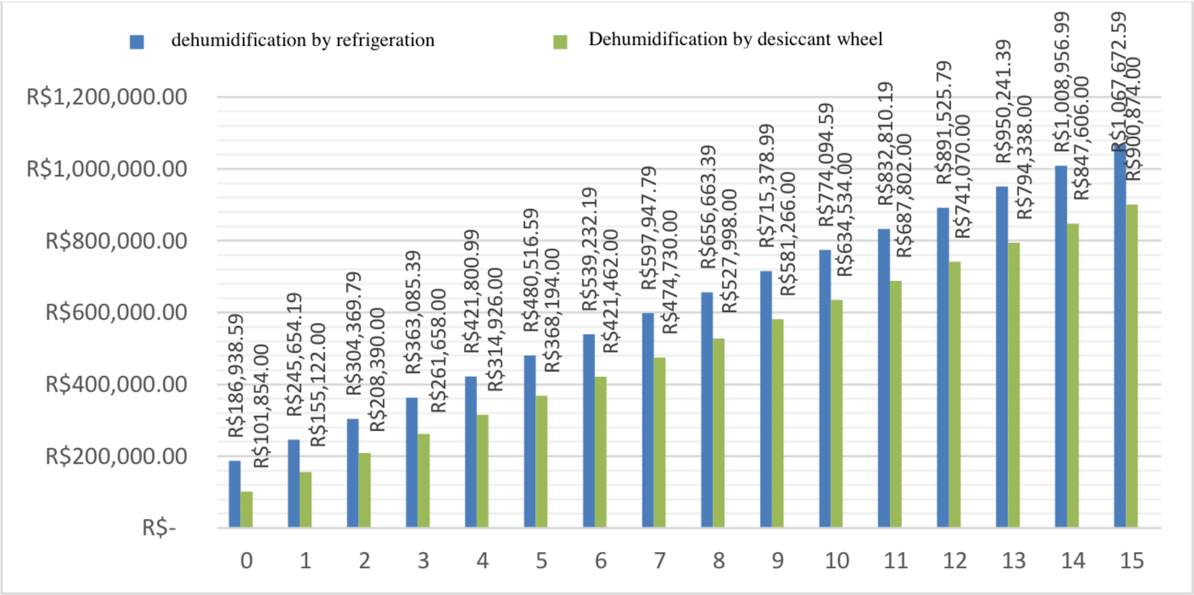
Looking only from the point of view of Capex (Acquisition cost) and Opex, the best decision is to use a desiccant wheel, even with a higher consumption of Energy, the initial cost is lower and after 15 years when the comparative systems are simulated, joining CAPEX and OPEX, the desiccant wheel is the equipment with the best cost-benefit, useful life and maintenance.

For a better comparison between the systems, a decision table was created with the following Weights:

Feature	Weight
Energy	10
Capex	5
Refrigerant Fluid	5
Noise level	5
Ease of Maintenance	5
Precise Control	5

Table 5-Decision Table.

In this table, energy started to have a greater weight, the initial investment (Capex) a weight of 50% of the energy, the refrigerant that has damage to the ozone layer and the greenhouse effect, so it was also considered



Graph 3- Comparison between systems.

Feature	Weight	Refrigeration	Desiccant Wheel
Energy	10	10	5,78
Capex	5	2,73	5
Refrigerant Fluid	5	0	5
Noise level	5	4	5
Ease of Maintenance	5	4	5
Precise Control	5	4	5
		24,73	30,78

Table 6 – Comparison of Dehumidification by Refrigeration and by Desiccant Wheel.

in the decision table, the level noise and maintainability issues (ease of maintenance), in addition to precise humidity control [19].

This table generates a better view as it does not only focus on money, but also on values connected with sustainability such as the refrigerant issue.

In this case the comparison was: (Table 6).

CONCLUSION

Swimming is one of the most practiced sports on the planet, its demand is increasing regardless of age, it is necessary for health, leisure, physical preparation and even survival. The five states with the highest HDI-M in Brazil are, respectively, Distrito Federal (0.844), São Paulo (0.814), Rio Grande do Sul (0.809), Santa Catarina (0.806) and Rio de Janeiro (0.802). in the range of high human development, 04 of these five states have a representative winter and the need for indoor and artificially heated pools is essential, and as soon as the pool is indoors, the issue of condensation control is essential, among the most common technologies for the control of humidity are the refrigeration systems and desiccant wheels, analyzing exclusively the energy demand the refrigeration system is much more efficient, but it has the disadvantages of many moving parts in high rotation like compressor, evaporator, condenser and element of expansion, in addition to the issue of refrigerant charge which has a high GWP (Global Warming Potential), for example the GWP of the R 404 A is 3922 kg CO2, while the wheel system of this cante does not have a refrigerant fluid, in addition to having a longer useful life because it does not have a copper coil which is more corrosive compared to a silica desiccant rotor, looking from a holistic point of view through the decision map the best system for dehumidification of swimming pools is the one of desiccant wheel.

REFERENCES

1. TURZA, Róbert, FÜRI, Belo B. **EXPERIMENTAL MEASUREMENTS OF THE WATER EVAPORATION RATE OF A PHYSICAL MODEL.** Slovak Journal of Civil Engineering Vol. 25, 2017, No. 1, 19 – 24 DOI: 10.1515/sjce-2017-0003.

2. ANTONELLIS, Stefano de; Joppolo, Cesare M.; Molinaroli, Luca. **Simulation, performance analysis and optimization of desiccant wheels.** Dipartimento di Energy, Politecnico di Milano, Via Lambruschini, 4, 20156 Milan, Italy. Revista : Energy and Buildings.

3. CLIMATE. **Clima de São José dos Pinhais – Brasil**. Disponível em https://pt.climate-data.org/america-do-sul/brasil/parana/sao-jose-dos-pinhais-4495/. Acessado em 20/04/2022.

4. ABNT. **ABNT-NBR 16401-2018**. Instalação de ar condicionado – Sistemas centrais e unitários. Parte 1- Projetos de instalações. ICS 91.140.30. ISBN 978-85-07-00889-7.

5. ASHRAE (2011). **ASHRAE Handbook - HVAC Applications. Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc**., p.5.6-5.9.

6. ASHRAE 62.1 – 2016. **Ventilation for Acceptable Indoor Air Quality** Table 6.2.2.1 Minimum Ventilation Rates in Breathing Zone ISSN 1041-2336.

7. KIM, Michael; Dahl, Knudsen; Steffen, Petersen. **Building Performance Analysis Conference and SimBuild co-organized by ASHRAE and IBPSA-USA Chicago**, IL September 26-28, 2018 PEAK LOAD REDUCTION OF DISTRICT HEATING BY CONTROL OF INDOOR PUBLIC SWIMMING POOL. Aarhus University, Aarhus, Denmark.

8. EN 15288-1:2018. **Swimming pools for public use - Part 1: Safety requirements for design**. ICS 97.220.10 - Sports facilities.

9. DESERT AIR. **Swimming Pool Dehumidifier Sizing**. Application Note 10. Optimizing solutions through superior dehumidification technology. 110 2019/01.

10. ASHRAE- 2022. Carta Psicrométrica. Disponível em https://www.ashrae.org/technical-resources/bookstore/psychrometrics. Acessado em 20/04/2022.

11. ASHRAE WEATHER DATA VIEWER. International Weather for Energy Calculations, version 2.0.

12. HOURAHAN, Glenn. **SPS Manual HVAC Design for Swimming Pools and Spas**. 2010.

13. 4POOL. **Catálogo Técnico 4Pool**, 2022.

14. THERMOMATIC. Como funciona um desumidificador dessecante. Disponível em https://www.thermomatic.com.br/fique-por-dentro/como-funciona-um-desumidificador-dessecante.html#:~:text=Os%20desumidificadores%20de%20adsor%C3%A7%C3%A3o%2C%20ou,de%20acordo%20com%20cada%20segmento. Acessado em 20/04/2022.

15. BRYAIR. Desumidificador mecânico ou dessecante qual escolher na hora de comprar. Disponível em https://www.bryair.com.br/blog/desumidificador-mecanico-ou-dessecante-qual-escolher-na-hora-de-comprar/. Acessado em 20/04/2022.

16. STATUS AUTOMAÇÃO. **Custos**. Disponível em https://www.statusautomacao.com/. Acessado em 20/04/2022.

17. BRYAIR. **Catálogo de produto FFB300**. 2022.

18. COPEL. **Tarifa da Energy elétrica. Companhia Paranaense de Energy.** Copel 04/2022.

19. SANTOS, A.F.; GASPAR, P.D.; DE SOUZA, H. J. L. **Evaluating the Energy Efficiency and Environmental Impact of COVID-19 Vaccines Coolers through New Optimization Indexes: Comparison between Refrigeration Systems Using HFC or Natural Refrigerants**. Licensee MDPI, Basel, Switzerland. 2022. Doi.org/10.3390/pr10040790.