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INSTALLATION PROJECT OF A 5 TR ABSORPTION REFRIGERATION FOR AIR CONDITIONING

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Abstract. *Studies indicate that whether for residential, commercial and industrial buildings, climatization contributes to health and productivity, making sure that people are comfortable and processes are properly performed in certain specific conditions. However, the increase of refrigeration and air conditioning also causes a significant increase in electricity consumption. Since they are powered by any thermal energy source available instead electricity, the absorption chillers have several advantages that make them a good alternative. The objective of this work is to design an air conditioning system for two rooms at the Center of Research and Development Self-Sustainable Energy (NPDEAS) at the Federal University of Paraná, to describe the installation process, present a budget planning for the equipment and cost estimation including the maintenance plan, operation and control of the system. For the calculation of the heat load we considered parameters such as insolation, windows, walls, floor, roof and occupants. The Robur-W "LB" absorption chiller was the chiller chosen for this project, it has a capacity of 60.000 BTU/h (5 TR), operates on a water-ammonia gas absorption cycle and is able to chill temperatures from -5°C to 60°C. For the installation it will be necessary to use 2 fan coils, one of 32.000 BTU/h and other of 12.000 BTU/h capacity, a cold water reservoir of 1000 and 500 liters, a hot water reservoir of 1000 liters and 3 pumps. Thus, it can be concluded that using this data, it is possible to estimate the cost/benefit of installing a 5 TR absorption cooling system for the building*

Keywords: *installation project, thermal load, absorption cooling;*

1. INTRODUCTION

In the history of humanity, the climate is undoubtedly, an important factor to be considered. Since the beginning, humans have sought ways to protect themselves from cold and heat, seeking thermal comfort and well-being. It is easy to note that the need for acclimatized environments has become essential for the operation of various segments such as hospitals, supermarkets, pharmacies, among many others. The use of air conditioning contributes to the improvement of health and productivity being almost indispensable in the daily life of modern society.

During the pandemics of the new coronavirus (Covid-19), refrigeration is paramount for vaccine storage. According to the Ministry of Health (2021) that follows the vaccine conservation plan, each type of vaccine released or tested for the Covid-19 requires a type of refrigeration to keep it intact and ideal for the immunization of people. This is an essential to maintain the health and the guarantees of success of immunobiological prevention. Vaccines such as CoronaVac from the Instituto Butantan in partnership with the Chinese pharmaceutical company Sinovac need to be stored at temperatures between +2ºC to +8ºC.

Refrigeration is defined as the art or science related to the continuous transfer of thermal energy with the objective of cooling systems to temperatures lower than those available at a given place and instant (GOSNEY, 1982). The way it is known today, refrigeration is almost entirely performed by artificial means, highlighting the refrigeration by vapor compression, absorption, thermoelectric refrigeration and thermomagnetic refrigeration (HERMES, 2006; MARTINHO, 2013).

Absorption cooling systems are presented as an alternative to vapor compression systems presenting the advantage of using thermal energy, replacing the electrical energy input. This thermal energy can be obtained from any available heat source, such as waste heat from manufacturing processes, solar energy and burning fuels (SBRAVATI and SILVA, 2006). For the development of the present study we use a water-ammonia absorption system described in Figure 1, manufactured by the Italian company ROBUR. The equipment used is the GAHP-W model, which works simultaneously for cooling and heating water at - 5 ºC and 60 ºC, respectively. The cooling nominal capacity of the equipment is 17.5 kW and the heating nominal capacity is 35 kW (PEREIRA, 2006). The Figure 1 is a schematic of an absorption refrigeration cycle.

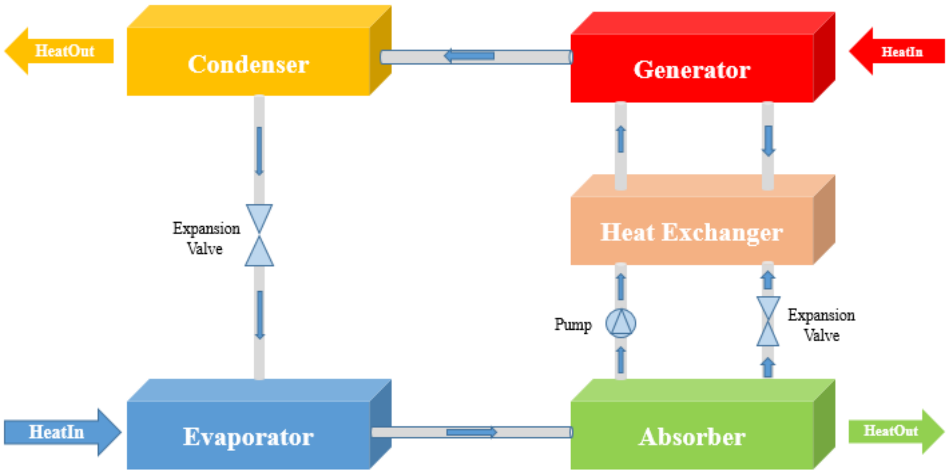

Figure 1: Basic absorption refrigeration cycle

2. Objectives

The objectives of this study are: (i) to determine the size of the rooms to be acclimatized at NPDEAS and define the equipment to be installed (ii) to describe the installation process and perform the maintenance, operation and control plan of the system and (iii) to perform the cost analysis of the installation and operation of the absorption cooling system;

3. THERMAL LOAD

Buildings are built in such a way to provide a safe and comfortable internal environment, regardless of external environmental conditions. A project is considered satisfactory if it sustains an affordable and steady internal condition. The thermal load is the denomination of set of effects acting in a certain environment, in which they raise the temperature and humidity in the case of summer, or reduce them in the case of winter CRUZ (2004).

The absorption refrigeration system of 5 Refrigeration Tons - TR (60.000 BTU/h) will be installed in 2 rooms, one being a classroom or computer lab and the other a meeting room, where they have the highest circulation of people, in other words, the highest thermal load of the Center for Research and Development of Self-Sustainable Energy - NPDEAS at the Federal University of Paraná - Curitiba/PR.

The NPDEAS is a conventional masonry building with a first floor and a ground floor. On the ground floor there are five rooms, the biogas plant and the outdoor area. On the first floor there is one classroom, two rooms with desks for research students, one conference room, one faculty office, one office for the administrative assistant, one coworking space, the 3D printing lab and the kitchen, in total 300 m².

For the calculation of the thermal load, the parameterized system introduced by Martinelly (2021) was used, based on parameters that influence the thermal comfort and the geographic factor of the city, in this case Curitiba. The parameters are: insolation of the windows, external and internal walls, external and internal spaces next to the building, doors or openings to non-air-conditioned areas, roof, floor, number of people who frequent the building and heat generated from appliances. These parameters will be entered into the system according to the factor indicated and all the values will be added and multiplied by the geographical factor. The Figure 2 and 3 shows the contribution of each parameter in the thermal load.

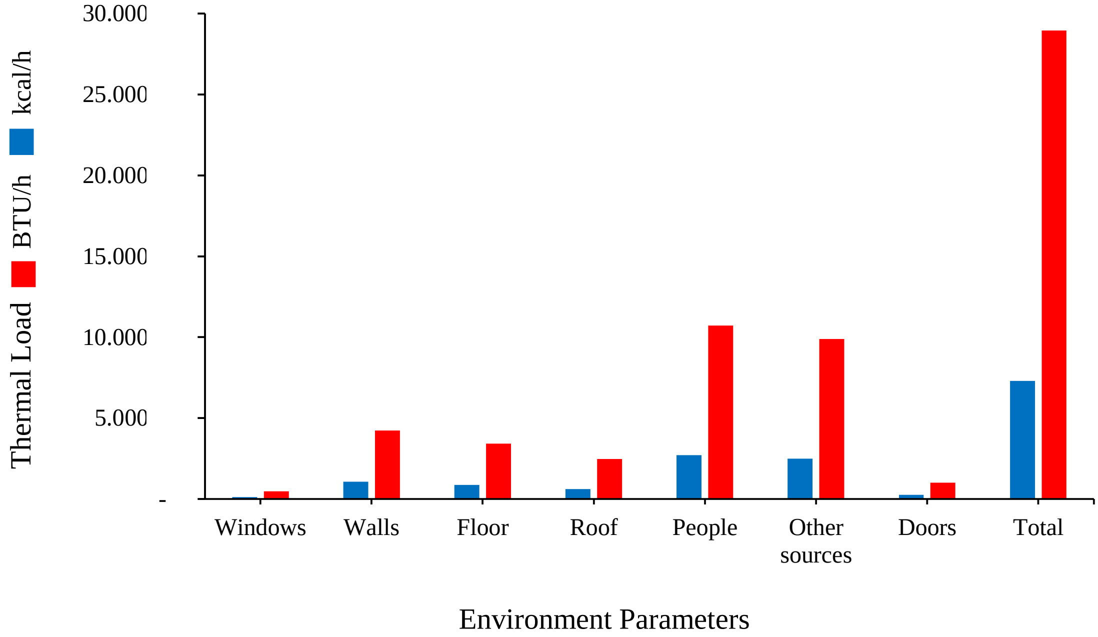

Figure 2: Thermal Load of room 1.

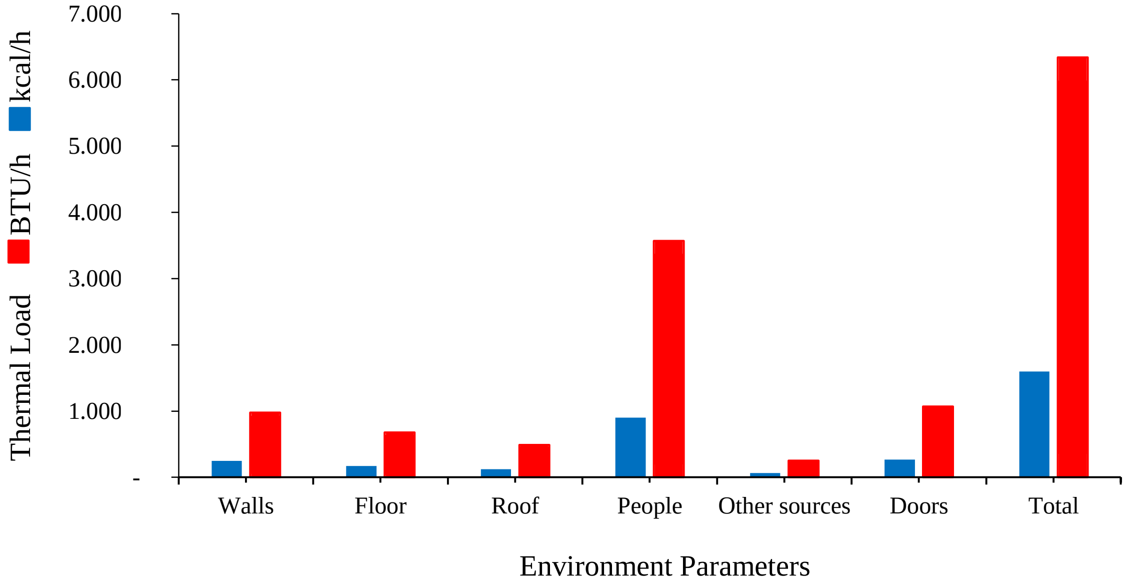

Figure 3: Thermal Load of room 2.

4. EQUIPMENT

As previously mentioned, the selected system to be installed in NPDEAS is the ammonia absorption cooler - ROBUR-W "LB" shown in Figure 4a. The system was designed specifically to recover heat from external source as well as use heating and cooling energy simultaneously limiting the consumption of electricity. Two fan coil units of the hydronic cassette-type were also selected shown in the Figure 4b, one with 32.000 BTU/h for the room 01 and the other with 12.000 BTU/h for the conference room. As main advantage in the use of this type of fan coil we have the coil of the cooled water fan be designed and manufactured with advanced technology, because it has super thin design, having space saving and easy installation, as they have large volume of airflow, can increase the frequency of ventilation of the site.

(a)

(b)

Figure 4: (a) ROBUR- GAHP W "LB" and (b) cassette fan

Another extremely important equipment are the hydraulic machines, classified into three groups: the driving machines, the generating or operating machines and the mixed machines. The dies have the function of converting hydraulic energy into mechanical work (turbines, hydraulic wheels). The dies receive mechanical work and transform it into hydraulic energy, giving the fluid an increase in pressure potential and kinetic energy. The circulation of water in chilled water systems and chillers is usually carried out by centrifugal pumps. Furthermore, in absorption refrigeration systems, pumps are used to promote the displacement of the liquid refrigerant-absorber solution (PANNO, 2020). The installation of this refrigeration system required three centrifugal pumps, one of 3 hp and two 1 hp power. Another important item is the cold water reservoir. It is where the heat transfer occurs, that is, the ambient water becomes colder. To maintain it at constant temperature, the reservoir must be insulated using spray foam or injectable Styrofoam. To control and operate the refrigeration system, temperature sensors, manometers and safety valves will be used, as well as manual flow control and gas meters.

5. INSTALLATION PROCESS

The absorption refrigeration system of 5 TR, with measures height x length x depth (1.28 m x 84.2 cm x 70 cm) will be installed in the machine room of NPDEAS - UFPR, considering the distance measurements for installation, with spacing of 45 cm on the right and left sides, front and back with a distance of 80 cm. The cold water reservoir will be installed next to the machine room, where a 500 liter water tank will be placed inside another 1000 liter water tank. The gap between the two reservoirs will be filled with thermal insulator (spray injectable foam or Styrofoam). The 500-liter reservoir will store a mixture of 75% water and 25% ethylene glycol so that the fluid temperature can reach negative values for a better climate control in the rooms. PT 250 PSI polyethylene hoses with a 1" diameter will be used to transport the coolant, as suggested by the manufacturer's manual, along with one 1 hp centrifugal pump, manometer, thermometer, safety valve and manual valve for flow control.

An already existing 10 000 liters water tank will store the hot water at NPDEAS. The hot fluid will pass through a polyethylene hose with a diameter of 1" and PT 300 PSI, along with centrifugal pump 1 hp, pressure gauge, thermometer, safety valve and manual valve for flow control. After the heat transfer process in the cooler, the coolant will leave the cold water tank, using PVC pipes with a diameter of 1¼" where the pipe will travel a distance of 30 meters towards the rooms to perform the air conditioning. The fan coil of 32.000 BTU/h will be installed to cool the entire room (room 01) of 47 meters. After acclimatization of the room, the fluid will return to the reservoir. The same process will happen for room 02 (conference room).

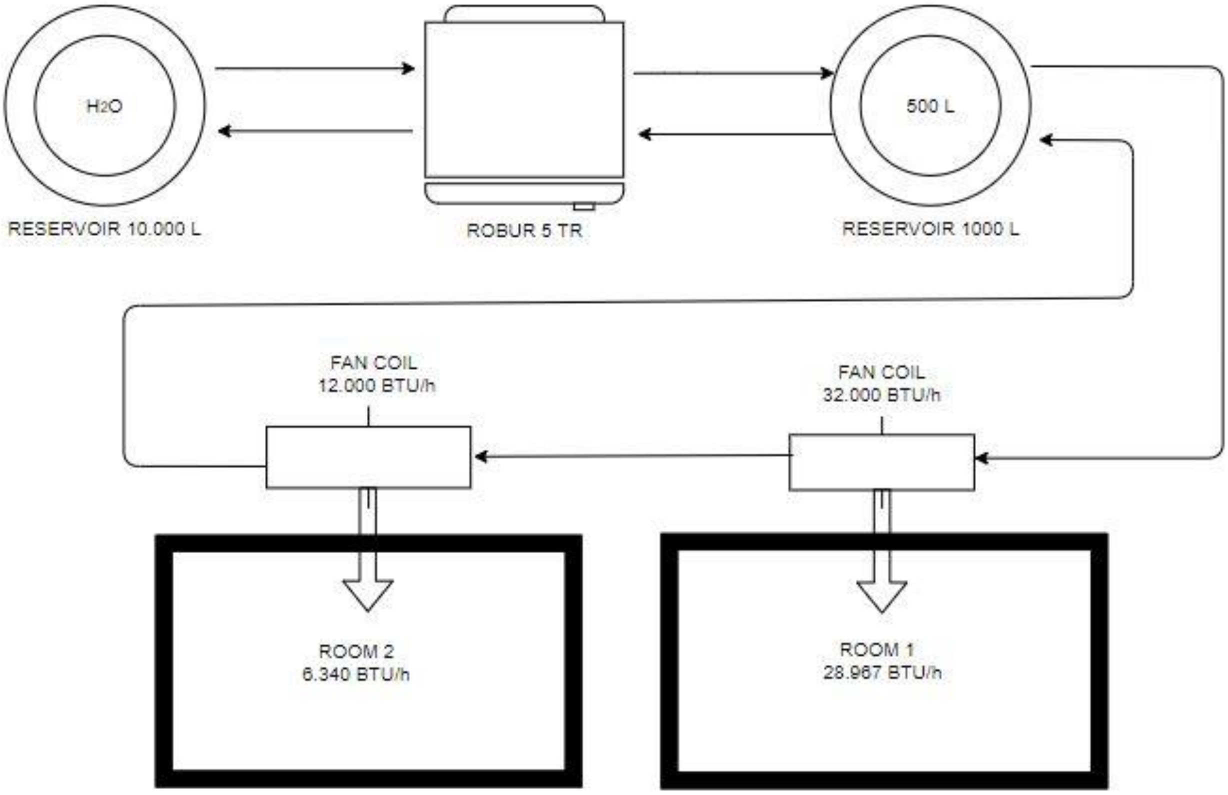

Figure 6: Diagram of installation of the system at NPDEAS.

6. OPERATION AND CONTROL MAINTENANCE PLAN - OCMP

The maintenance, operation and control plan are specifically designed for the ammonia absorption refrigeration system using water with refrigerant.

The plan developed follows the requirements of the ordinance 3.523 of August 28, 1998 from ANVISA. It is important to emphasize that the periodicity tables will not be filled out, but only after the system has been installed in the building.

6.1 Identification of the Environment:

Name (Building)	Núcleo de Pesquisa e Desenvolvimento Energia Autossustentável - UFPR
Complete Address	Francisco H dos Santos, S/N Centro Politécnico, Setor de Tecnologia
Neighborhood	Jardim das Americas
City: Curitiba	UF: Paraná

6.2 List of Climatized Environments

Type of activity	Number of fixed occupants in the environment	Environment Identification	Climate-controlled area Total	Thermal Load
Room 01	18	Computer lab	47.78 m	28.967 BTU/h
Room 02	6	Conference room	9.5 m	6.340 BTU/h

6.3 Maintenance and Control Plan

Activity Description **Periodicity**
a) Cold Water Type Air Conditioner
Check and eliminate dirt, damage, and corrosion on the cabinet, serpentine frame, and tray; Quarterly
Clean the coils and trays; Quarterly
Check the operation of the flow controls; Monthly
Check Tray water drainage operation; Biweekly
Check the conservation status of the thermal-acoustic insulation; Bimonthly
Check the sealing of the enclosure closing panels; Quarterly
Check the tension of the belts to prevent slippage; Monthly
Wash the trays and coils with removal of the biofilm (sludge), without the use of corrosive products; Annual
Check the air filters; Biweekly
Air filters (dry); Biweekly
Check and eliminate dirt, damage, and corrosion; Monthly
Check and eliminate gaps in the filters; Monthly
Clean (when recoverable) or replace (when disposable) the filter element; Monthly
Notes: 1 – It is not recommended to use a spray air humidifier that has a water basin inside the supply duct or in the conditioner cabinet. 2 – It is necessary to have an air damper on the return and external air intake to ensure the correct air flow in the system.
b) Ducts, Accessories and Full Air Box
Check and eliminate dirt (internal and external), damage, and corrosion; Monthly
Check the sealing of the inspection doors in normal operation; Monthly
Check and eliminate damage to the thermal insulation; Monthly
Check the sealing of the connections; Monthly
• Air inlets for insufflation and return air
Check and eliminate dirt, damage, and corrosion; Monthly
Check the fixation; Monthly
Measure the flow; Monthly
Locking and Balancing Device; Bimonthly
Check and eliminate dirt, damage and corrosion; Quarterly
Check the operation; Weekly
c) Air-conditioned environments

Check and eliminate dirt, unpleasant odors, noise sources, infiltrations, chemical storage, sources of excessive heat radiation, and sources of microorganism generation; Weekly
Notes: 1) The above maintenance practices should be applied in conjunction with the mechanical maintenance recommendations of NBR 13.971 - Refrigeration Systems. 2) All products used for cleaning the components of the air conditioning systems should be biodegradable and duly registered with the Ministry of Health for this purpose. 3) Every verification should be followed by the necessary procedures for the correct functioning of the HVAC system.

Table 1: Preventive maintenance plan for absorption chillers

7. INSTALLATION AND OPERATION COST

For the installation process of the refrigeration system, information was gathered about the necessary equipment as the useful accessories for the installation of the chiller in NPDEAS. The following is a table of the items:

Item	Description	Unit.	Quantity	Unitary - R$	Total - R$
				Material	**Material**
1	**EQUIPAMENT**				
1.1	Centrifugal Pump 3m³/h	u	1	**R$ 1.700**	**R$ 1.700**
1.2	Centrifugal Pump 1m³/h	u	2	**R$ 809.00**	**R$ 1.618.00**
1.3	Manometer	u	3	**R$ 54.00**	**R$ 162.00**
1.4	Thermometer	u	3	**R$ 58.00**	**R$ 174.00**
1.5	Safety valve	u	3	**R$ 70.00**	**R$ 210.00**
1.6	Manual flow control valve	u	3	**R$ 57.90**	**R$ 173.70**
1.8	Reservoir 1000 Liter	u	1	**R$ 400.00**	**R$ 400.00**
1.9	Reservoir 500 Liter	u	1	**R$ 250.00**	**R$ 250.00**
1.10	Fan Coil 32.000 BTU/h	u	1	**R$ 4.195.00**	**R$ 4.195.00**
1.11	Fan Coil 12.000 BTU/h	u	1	**R$ 2.705.00**	**R$ 2.705.00**
1.13	Cold water hose 1. 1/4"	m	16	**R$ 11.00**	**R$ 176.00**
1.14	Hot water hose 1. 1/4"	m	18	**R$ 11.00**	**R$ 198.00**
2	**MATERIAL**				
2.2	Thermal Insulation	m	5	**R$ 917.20**	**R$ 1.917.20**
TOTAL VALUE					**R$ 12.878.20**

Table 2: Equipment needed for installation of the chiller

The cost of operation of the system was budgeted as budget as follows: i) LPG gas: the absorption cooler burns LPG fuel for heat generation. The properties of this fuel well known by the scientific community (BEJAN, 1988). According to SUPERGASBRAS (2020), LPG is made up of a mixture of 50% propane and 50% butane. For this system, it will be necessary to purchase 4 cylinders of LPG of 45 kg each (Pereira, 2006), that costs R$340.00 according to commerce and retail companies in Brazil; and ii) Ammonia R$ 877.11 Reais per ton. This study did not include the labor for installing the refrigeration system.

7.1 Price of electric energy

The electric energy tariff was calculated based on the Homologating Resolution 2,704, of June 23, 2020 equivalent to June 23, 2021, which establishes the energy tariffs - TE and tariffs for distribution system - TUSD referring to Copel

Distribuição S.A. - Copel-DIS. The tariffs of Copel-DIS are readjusted by 0.41%, corresponding to the average tariff effect to be perceived by the consumers/users/supplied agents of the distributor. Thus, represented by Eq. (1):

$$C = P \times t \times m \tag{1}$$

where C is the energy consumption, P is the power of the refrigerator (17.5 kW), t is the amount of time per day that the refrigerator will be turned on (6 h) and m is the number of months that the refrigerator will be operating (20 months). Thus, the value of energy consumption (2.100.00 kWh/month) is multiplied by the energy concessionaire's tariff, to obtain the monthly consumption in Reais (R$):

$$M_C = C \times T_R \tag{2}$$

where M_c is the monthly cost of operation of the refrigeration system (R$ 1.575), C = 2.100 kWh/month and T_R is R$ 0.75. Therefore, the monthly consumption for this system is M_c = R$ 1.575.

8. CONCLUSION

For the installation of the cooling system we will use ROBUR model W "LB" which is a heat pump, as mentioned above. The thermal load was calculated to be 36,000 BTU/h, and the ROBUR has a capacity of 60,000 BTU/h, thus the chosen chiller is capable of acclimatizing the two proposed rooms as well as other rooms depending on their thermal load.

The OCMP plan was directed to the chiller, which will establish a method of cleaning and maintenance that results in better and less expensive way to operate the machinery. KAMINAGAKURA (2017) states that the effects of the implementation of an OCMP can be noticed in a refrigerator that remained working uninterruptedly, a reduction in electricity consumption was observed.

The operation cost of this type of system in comparison to the traditional refrigeration systems still have a high cost of installation (Table 2). The cost for installation of the absorption refrigeration system is R$ 12,878.20 plus the cost of LPG gas R$ 1,360,00 or a total of R$ 14,238.20, not considering the price of ROBUR itself. However, the monthly electricity cost is less than the vapor compression chillers. The absorption chiller has a monthly consumption of R$ 1,575.00. Thus, it can be concluded that even though the absorption chiller has a high cost for installation it will still have a lower monthly electricity cost.

9. ACKNOWLEDGEMENTS

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