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Determination of the Thermal Load and Design of an Air Conditioning System in the Auditorium of the Professional School of Electrical Mechanical Engineering

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Abstract– ***Air conditioning has been one of the inventions of mankind that seeks the comfort of the individual. This research aimed to determine the thermal load and design an air conditioning system in the auditorium of the Professional School of Electrical Mechanical Engineering UNA PUNO, taking into account that the thermal load means a set of parameters that involve the quality of heat that must be subtracted from the place in order to cool the environment or in any case maintain the desired temperature, cooling is a set of processes by which heat is subtracted and it is possible to maintain a lower temperature to the surrounding environment. The methodology used involves a study of action to the extent that focused on the solution to the problem of incorporating air conditioning to the auditorium environment of the Professional School of Electrical Mechanics of the National University of the Altiplano, this design is known as a proposal for improvement where the solution is not executed, but is proposed. The sample is understood as the environment, in this case the environment of the Auditorium of the new pavilion of the mentioned Professional School. The research will focus on determining the thermal load and designing an air conditioning system for the auditorium of the Professional School of Mechanical and Electrical Engineering of the UNA PUNO as a solution to the comfort of students and teachers who use the auditorium. This auditorium is located in the city of Puno, Peru, on the main campus of the Universidad Nacional del Altiplano (UNA PUNO). Solid documentation was obtained about the conductivity and thermal load as the pressurization of the air conditioning. It is recommended to implement the air conditioning system through a project based on this study.***

Keywords-- ***Air conditioning, Auditorium, Thermal load, Air conditioning, Comfort.***

I. Introduction

Understanding that the thermal load means a set of parameters that involve the quality of heat that must be removed from the place in order to cool the environment or in any case maintain the desired temperature, refrigeration is a set of processes through which Heat is removed and it is possible to maintain a lower temperature than the surrounding environment. One of the most significant applications of refrigeration consists of obtaining states and characteristics of pleasant comfort and convenience in auditoriums so that the necessary quality in the learning processes is guaranteed, since the lack of adequate thermal comfort can generate a lack of motivation and disinterest in learning (Carro Pérez et al., 2018). In this sense, it is necessary to invest in the acquisition of air conditioning equipment with the purpose of guaranteeing thermal comfort conditions and optimizing the performance and attention of university students in updating and training courses on the latest scientific advances, So the auditorium must maintain the environment between the parameters of 18 and 24 °C, because users will feel comfortable to the extent that they will experience a healthy thermal neutrality.

It is worth highlighting that an air conditioning system designed with technical and scientific specifications has a positive impact on any environment that is installed, which implies a challenge for Engineering in that it would be possible to ensure an environment with controlled requirements for the comfort of the users. users in addition to providing cleaner environments because it will be possible to control hygiene and the level of humidity in a sustainable way.

Energy supply is an important category for the industry and in this sense, heating, air circulation and ventilation models require compliance with certain parameters in order to regulate the temperature of the environments. Likewise, the identification of thermal loads is relevant as an initial phase to propose air conditioning models inside the environments, starting with the estimation of the thermal loads, the dimensions of the environments and the difficulties involved. Training in the line of ventilation, air conditioning and refrigeration is important within the training of a Mechanical Engineer or Mechanical Electrician due to the rapid growth of the industry, therefore, the determination of the thermal load and design of an air system conditioned in the auditorium of the Professional School of Electrical Mechanical Engineering of the National University of the Altiplano, implies the intervention of the Mechanical-Electrical Engineer based on his theoretical and practical knowledge that allows achieving a high level of comfort for the users of the Auditorium of the mentioned Faculty.

II. THEORETICAL FRAMEWORK

A. background of the research.

To achieve the objectives, it is necessary to carry out an extensive bibliographic review for the development of this thesis topic:

- **On an international level.**

carried out an investigation with the purpose of providing better levels of refrigeration to the medical products that exist in the warehouses of the Mogrovejo Hospital, for which an air-conditioned system is proposed within the medicine warehouse. In order to maintain a regulated temperature environment for the concentration of medical products and syrups. For the implementation, the temperature provided by the Ministry of Health was taken into account. The thermal load was estimated by identifying the dimensions of the elements and equipment with normalized location standards. It was concluded that by applying the aforementioned air-conditioned model, medicines are preserved efficiently. [1]
developed a research titled "Technical-economic evaluation of a DHW and air conditioning production system for a building", with the objective of generating several proposals for DHW and air conditioning production, evaluating how the most energetically sustainable one optimizes for the new use of In the facilities, the Vp Clima computer program created at the Polytechnic University of Valencia was used to more accurately calculate the thermal load of the building. with the internal and external conditions of the premises, the composition of the climatic screen, the load of equipment for each location, lighting, use, etc. With all this data, the total heating load can be found. The results of the cooling heat load is an air conditioning and ventilation system that is an independent hybrid system, air conditioning and ventilation will be carried out in two independent circuits. Concluding that Complying with the requirements of good environmental quality in buildings intended to carry out a work activity is an essential part of the design of any space. [2]
In their research entitled “Low-enthalpy geothermal energy in loessic soils: calculation and design for a case study”, the objective of this work was to highlight the use of low-enthalpy geothermal energy as an economic and ecologically friendly option for the collaboration in the air conditioning of environments. By using low-enthalpy geothermal energy as an economical and environmentally friendly option for environmental climate cooperation. Calculations and design are based on thermal properties between parameters, including the local soil and climate and the materials in the climate shield. The energy and economic analysis resulting from the use of a low-enthalpy geothermal system was determined using the free software BT6 heat balance from Dilasoft. Concluding that the results are satisfactory, since the implementation of this type of system provides an economical and efficient solution, since the use of low enthalpy geothermal energy through a system of buried tubes can be used anywhere in the world, there is only You have to know some characteristics of the location and the characteristics of the soil. [3]
developed the study “Design of an air conditioning system for the attorney general's office of the nation's judicial headquarters of Ibagué”, with the purpose of providing a comfortable environment for the users of this institution. Climatic factors, relative humidity and other internal factors were considered. Cooling methods were applied to condition the environment in the climatic aspect, comparing them with the thermal installations of buildings and the recorded information. On the other hand, the objectives and limitations of the system were identified to optimize the control of operation in accordance with the RITE regulations. In this sense, appropriate solutions are proposed for air conditioning, ventilation, and water flow systems based on a matrix analysis. It was concluded that the humidity and temperature levels present a state of non-conformity. [4]
In his research entitled “Design of a self-sustainable cooling system for a pit building”, he sought the purpose of analyzing and designing the self-sufficient air conditioning system of the Parcmotor Castellolí building, due to the fact that the temperature conditions in the summer season reach very high levels. high and make workers uncomfortable. The investigation began by analyzing the building's environments to implement the air conditioning system. The results indicate that 14 air units are required with a cooling capacity of 20 kW and an electrical consumption of 7.85 kW per unit. The initial investment required for this is 47,746.16 euros. It was concluded that it is necessary to use 46 solar tarps with a power of 144W. [5]
presented a work with the purpose of determining the technical and legal conditions of the implementation of an air conditioning system for an auditorium for the town of Salamanca. The research was basic projective type, descriptive level and non-experimental correlational design. The techniques used were the documentary review of the various air conditioning designs that were implemented in office environments of public and private institutions, as well as the budget assigned for the execution of the design project. It was concluded that it is feasible to execute the proposed design with a cost of €706,429.74. [6]
developed a study with the objective of designing an air conditioning system in block A at the Antonio Nariño University of Colombia based on the ASHRAE standard, the design began with the determination of built areas in order to estimate the interior thermal loads and exteriors. The technique used was the documentary review of the psychometric chart in each of the equipment to define the level of suitability required and the dimensions of the ducts according to the Technical Standards. A refrigerant condensation system using water was proposed, with the corresponding tectonic plans of the supply and return ducts to specify the transfer of the optimal trajectory that allows correct operation, in speeds and decibels in relation to the selection of equipment and supplies. [7]

- **At the national level.**

In his research titled "Design of a 14 kW air conditioning system by absorption and solar source to reduce operating costs in the third level computer center of the FIME-UNAC", the objective is to design a 14 kw air conditioning system 14KW for absorption and solar source to reduce operating costs in the third level computing center of the FIME-UNAC. The present research is of a technological type and simple descriptive design, the method applied is deductive logical analytical with a systemic approach. In a population of Absorption Air Conditioning System and solar source, with a sample of Absorption Air Conditioning System and solar source through database collection, the documentary technique was used, bibliographic records, temperature and radiation reports, manual of fundamentals [8], technical sheets -texts. First, in the school's computer center, the thermal load of the third stage was calculated and verified with the HAP software, and then the thermodynamic design of the selection of the necessary components of the absorption equipment and the air conditioning system was carried out. For the selection of solar collectors, calculations and choices were made based on the requirements of the ASHRAE system and the 2017 Solar Radiation Report in the Callao region. In addition, the operating costs of conventional equipment and the proposed system were compared. From the research carried out, it was concluded that the study environment can be conditioned using a single-acting H2O-LiBr absorption chiller by installing a 32 m2 solar collector area using vacuum tube collectors. [8]

- **Locally.**

Developed research in order to analyze the feasibility of implementing low temperature geothermal energy for heating homes with an inexhaustible source of energy supplied by the earth through a system of internally heated pumps taking advantage of its high level of inertia. The use of monitoring and control of earth temperatures was proposed, and simulations executed using specialized computer programs to estimate indicative and technical values required for the feasibility of the implementation. As determining conditions, it will be necessary to calculate the power necessary for the heat pump, the use of the extracted heat, the integration of the system through a heat pump and the internal distribution system of the home necessary to provide adequate thermal conditions in the home. Likewise, the geothermal heat pump will be selected according to energy performance and sizing criteria. [9]

B. Thermal load.

Also referred to as cooling load, it is the amount of energy that is required to be overcome in an area to maintain certain temperature and humidity conditions for a specific application. It is the amount of heat that is removed from a defined space, it is expressed in BTU, the unit used commercially relates to the unit of time, Btu/hr.

When solar energy hits the walls and roof of the building, this energy is absorbed or reflected by the exterior surfaces of the building. This absorption contributes to an increase in the temperature of the external surface and part of it is transferred by convection to the external environment. The increase in temperature on the external surface of the building increases the conductive heat transfer in the walls of the building. The fraction of solar energy that enters the studied space depends on the windows, the direction in which they face, whether curtains or other devices that provide shading are used. Before calculating the cooling load, the heat contributed by the elements involved in the space to be cooled must be taken into consideration. Finally, the human occupancy rate is considered; people contribute sensible and latent energy (humidity) to the space. Furthermore, if there are sources that allow ventilation with outside air, the energy that must be removed from this air when it enters the building represents a significant portion of the total cooling load [10].

III. Materials And Methods

A. Research type

The nature of this research is classified as applied technology, since its objective is to implement an improvement in the installation of the air conditioning system in the Electrical Mechanics Auditorium (new pavilion) of the National University of the Altiplano. This improvement is based on previously acquired knowledge.

Quantitative approach because data collection and analysis are used to answer research questions and test previously established hypotheses, and it relies on numerical measurement, counting, and frequently the use of statistics to accurately establish behavioral patterns in a population.

B. Research design.

In this research its explanatory design since, through the proposal of an air conditioning system, this design, as its name says, is the proposed solution to a problem, a solution that shows the solution on paper but is not applied, [12]. This design is classified as non-experimental, since no manipulations were performed on the variables. Regarding its scope, it is considered descriptive, since it was proposed to measure the thermal load and electrical consumption of a specific air conditioning system for the Auditorium of the new pavilion of the Professional School of Electrical Mechanical Engineering.

C. Research method.

The research method for this study is action, which is a participatory research methodology. This methodology focuses on problem solving and improving practice and action in specific situations. In the action research method, the researcher works to identify a problem and design and implement an intervention to solve it in the future.

Variables

Variable 1: Thermal load.
X1: Building structure
X2: Lighting electrical power
X3: Capacity
X4: Characteristics of the environments

Variable 2: Design of an air system conditioned.
Y1: Team capacity
Y2: Fresh air flow
Y3: Sensitivity factor

D. The population

The population is the Professional School of Electrical Mechanical Engineering of the National University of the Altiplano (UNA PUNO). The National University of the Altiplano (UNA PUNO) is located in the city of Puno, Peru, in the Andean highland region at an altitude of more than 3,800 meters above sea level. The university was founded in 1856 and is one of the oldest and most prestigious universities in the country. The Professional School of Electrical Mechanical Engineering was created in 1969, in response to the need to train professionals trained for the design and management of electrical and mechanical systems in the region. Since then, the degree has evolved and updated its curriculum to adapt to technological changes and the needs of the labor market.

E. The sample

The atmosphere of the Auditorium of the new pavilion of the Professional School of Electrical Mechanical Engineering of UNA PUNO. The research will focus on determining the thermal load and designing an air conditioning system for the auditorium of the Professional School of Electrical Mechanical Engineering of UNA PUNO. This auditorium is located in the city of Puno, Peru, at the headquarters of the National University of the Altiplano (UNA PUNO). The building that houses the Professional School of Electrical Mechanical Engineering has a modern and adequate infrastructure for the development of academic and administrative activities. However, one of the main challenges facing the building is the cold and dry climate that predominates in the region for much of the year, which makes it necessary to use heating and air conditioning systems to guarantee thermal comfort for the different areas. activities carried out in the auditorium.

Data Collection Technique

In this research, the technique that was applied is documentary analysis as a data collection technique.

Data collection instruments

For documentary analysis, a documentary review form was used.

Procedures

The investigation began by collecting physical information from the administrative staff of the Professional School of Electrical Mechanical Engineering. In the next stage, corresponding to the development of the project, design calculations were carried out using the collected data. Two air conditioning systems were considered: one conventional and another that incorporated a high-efficiency heat exchanger called HPHE (High-Performance Heat Exchanger). This system uses a heat exchanger to efficiently transfer heat between the air and the refrigerant fluid used to cool the environment.

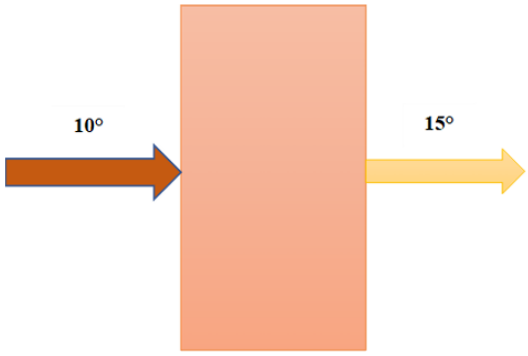

Fig. 1 Auditorium wall; The walls of the Auditorium of the Professional School of Electrical Mechanical Engineering have an average temperature of 15ºC, which is optimal for hosting events.

Parameters such as temperature, relative humidity and the number of air changes were established, in accordance with current international regulations, for the interior of the faculty auditorium. The average outdoor temperature data of the environment to be air-conditioned were also taken into account. Next, a comparative analysis of the thermal load consumption for each of the systems was carried out.

The study place

Professional School of Electrical Mechanics, is part of the Faculty of Mechanical, Electrical and Electronic Engineering of UNA PUNO, which aims to train professionals capable of designing, developing and managing electrical and mechanical systems, as well as using modern technologies for the solution. of problems related to energy and industrial processes, which includes theoretical and practical subjects in areas such as electricity, electronics, mechanics, thermodynamics, automation, among others. In addition, students have the opportunity to carry out pre-professional internships in companies in the energy and mechanical sectors.

It is located in the city of Puno, Peru, in the Andean highland region at an altitude of more than 3,800 meters above sea level. The university was founded in 1856 and is one of the oldest and most prestigious universities in the country. It was created in 1969, in response to the need to train trained professionals for the design and management of electrical and

mechanical systems in the region. Since then, the degree has evolved and updated its curriculum to adapt to technological changes and the needs of the labor market, standing out for its commitment to quality education and the training of leading professionals in various areas of knowledge. The university has a wide range of undergraduate and postgraduate courses, as well as outstanding work in research and university extension.

Materials

- Maximum and minimum thermometers
- Psychrometer (dry bulb and dry bulb thermometer) wet)
- Thermohygrograph.
- Barometer
- Pluviometer.
- Actinograph.
- Heliograph.

Materials for the study

The data will be processed through calculations, the resources necessary for this section are the following:

- Computer
- Excel Software
- ASHRAE HANDOBOOK 2005
- Manuals
- Catalogs
- Internet.

IV. Result And Discussion

Results

Environment description

The National University of the Altiplano of Puno is a public university located in the city of Puno. It was founded in 1856 at the request of the residents of the aforementioned department, currently it has 37 professional schools. The altitude of the Puno region reaches 3810 meters above sea level, with a climate whose extremes are: maximum 21°C and minimum -22°C.

Location.

The auditorium of the Professional School of Electrical Mechanics is located in the pavilion of the Professional School of Electrical Mechanics, within the National University of the Altiplano in the city of Puno.

Equipment and uses of the auditorium.

Desks
Chairs
Podium
Electric blackboard
Projector
Speakers

Dimensions of the auditorium.

It is considered 9 meters wide, 7 meters long and 3.5 meters high. The auditorium is located in the new pavilion of the professional school of Mechanical Electrical Engineering.

Audience requirements.

The auditorium in question requires optimal ventilation and conditioning to incorporate correct climatic components for talks and classes, which will allow students and teachers to perform in the best climatic conditions, while guaranteeing the conservation of equipment and avoiding fatigue. of the users who are within the environment.

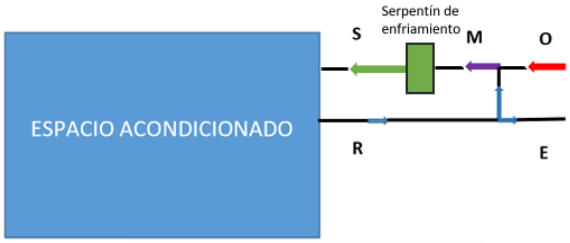

Fig. 2 Scheme of a system for mixing outside air with return air.

According to Carnicer, the desirable average temperature in closed environments that is equivalent to the comfort zone implies parameters of 22° C and 27° C in addition to 40% to 60% relative humidity. It is necessary to mention that there are direct relationships between the variables: comfort, indoor climate, humidity levels, among others.

In every auditorium, adequate air renewal is required, because inside there are users who consume oxygen, so it must be taken into account that even though there is a comfortable temperature, it is very likely that users will fall asleep and do not attend to the exposures, precisely due to the lack of air renewal, which requires the ventilation air per person to be renewed between 10 to 15 cubic feet per minute.

What is sought with the execution of this project is to optimally integrate the air circulation conditions with the appropriate parameters for a pleasant auditorium environment, with an average permanent temperature of 18° C, with a relative humidity of less than 60%. .

Parameters for thermal load calculation

- Degrees of latitude of the building location: 18°
- Outdoor temperature (average maximum): 10°C
- Outdoor relative humidity: 40%
- Temperature in auditorium: 15°C
- Humidity in auditorium: 20%
- Temperature at 3 p.m.: 20°C
- Temperature variation in 24 hours: 8°C
- Color coefficient of exterior wall face: 0.78

Thermal loads.

In order to make the corresponding estimate, it is necessary to use heat transfer equations.

In this regard, the global heat transfer equation is presented.

$$Q = UA \Delta T \quad (1)$$

Where:

Q: is the heat transferred

U: is the overall heat transfer coefficient

A: is the external surface area

Δ T: is the temperature difference between the outside and inside of the classroom.

However, depending on the type of heat transfer, the parameter U can vary due to the presence of various considerations such as the properties of the inputs, fluid displacement, density, among others.

Regarding radiation, the mathematical expression is similar where U is replaced by HR, which depends on the Stefan Boltzmann constant, the temperature, the form factor and the surface where the radiator impacts.

These processes are used to determine the different thermal loads, taking into account that the aforementioned processes are the ones to which the ASHRAE Handbook – Fundamentals applies.

ASHRAE corresponds to a manual in which several techniques and methodologies are suggested for estimating the cooling loads of the environment to be conditioned. The differences in the methods are displayed in the calculation of the elements of the heat transfer equation. In this study, the Radiant Time Series (RTS) method will be used, which is supported by the Thermal balance method.

TABLE I. Interior Thermal Loads of the Auditorium

No.	Thermal Load	Amount
1	Computer equipment	3
2	Capacity (Number of people)	80
3	Electric blackboard	1
4	Speakers	2
5	Melanin Desk	6
6	Projector	1
7	Metal Wardrobe	4
8	Luminaires	24
9	TV 32”	1

Prepared by the work team. Exterior thermal loads are the flow of heat through floors, walls, windows and doors, from the outside of the auditorium of the Professional School of Electrical Mechanical Engineering to the interior.

General hypothesis testing.

- Ha: There is a significant relationship between the thermal load of the auditorium of the Professional School of Electrical Mechanical Engineering at UNA Puno and the adequate design of an air conditioning system.
- H0: There is no significant relationship between the thermal load of the auditorium of the Professional School of Electrical Mechanical Engineering at UNA Puno and the adequate design of an air conditioning system.

TABLE II. Correlation of the Thermal Load Variable and Air Conditioning System.

Correlations				
Spearman's Rho	thermal load	Correlation coefficient	1,000	.593 *
		Sig. (bilateral)	.	.016
		N	16	16
	Air conditioning system	Correlation coefficient	.593*	1,000
		Sig. (bilateral)	.016	.
		N	16	16
The correlation is significant at the 0.05 level (two-sided).				
Prepared by the work team.				

In table 2 of Sperman, it is observed that it has a value of 0.593, indicating a moderate significant correlation, and with the value p=0.016, which is less than the standard error of 0.05, with this we can reject the null hypothesis, therefore the Ha hypothesis is accepted. There is a significant relationship between the thermal load of the auditorium of the Professional School of Electrical Mechanical Engineering at UNA Puno and the adequate design of an air conditioning system.

Testing of specific hypotheses.

Specific hypothesis 1:

- Ha: There is significant variability in the thermal conductivity of the materials present in the auditorium of the Professional School of Electrical Mechanical Engineering at UNA Puno.
- H0: There is no significant variability in the thermal conductivity of the materials present in the auditorium of the Professional School of Electrical Mechanical Engineering at UNA Puno.

TABLE III. Correlation of the Thermal Load Variable and Thermal Conductivity.

Correlations				
Spearman's Rho	thermal load	Correlation coefficient	1,000	674 *
		Sig. (bilateral)	.	.011
		N	16	16
	Thermal conductivity	Correlation coefficient	.674 *	1,000
		Sig. (bilateral)	.011	.
		N	16	16
*. The correlation is significant at the 0.05 level (two-sided).				
Prepared by the work team.				

Table 3 shows that it has a value of 0.674, indicating a moderate significant correlation, and with the value p=0.011, which is less than the standard error of 0.05, with this we can reject the null hypothesis, therefore the Ha hypothesis is accepted. There is significant variability in the thermal conductivity of the materials present in the auditorium of the Professional School of Electrical Mechanical Engineering at UNA Puno.

IV. Conclusions

The implementation of an air conditioning system is a crucial aspect to guarantee performance and thermal comfort in different environments. Research carried out by [7] and [2] highlight the importance of having air conditioning systems in a data center and in administrative offices, respectively. Both studies demonstrate how the lack of an adequate air conditioning system can negatively affect the performance of spaces and generate discomfort for users.

In the case of [7] and [2], their research focuses on the implementation of an air conditioning infrastructure under the TIA-942 standard in a data center. Their results show that, by having the required equipment and following the technical specifications, it is possible to meet the air conditioning needs of said environment. This highlights the importance of following specific regulations and standards to ensure optimal and efficient operation of the air conditioning system.

On the other hand, Rodas' research focuses on the design of a low-cost air conditioning system for the administrative offices of a building. In their study, aspects such as the climatic conditions of the site, the orientation of the building and other relevant technical factors were considered. The conclusion obtained was that, to regulate the temperature in these spaces, it is necessary to take into account the characteristics of the environment and execute a project according to these needs.

Both studies also highlight the importance of evaluating different options and considering the costs associated with the purchase, operation and maintenance of air conditioning systems. This is especially relevant in terms of economic viability and energy efficiency.

Research provides strong evidence of the importance of having adequate air conditioning systems in different environments. The findings of these studies support the need to consider aspects such as design, technical standards, climatic conditions and costs when implementing an air conditioning system. These factors are essential to ensure optimal performance, thermal comfort and energy efficiency in the spaces studied.

By relating these findings to our research on the thermal load and the air conditioning system in the auditorium of the Professional School of Electrical Mechanical Engineering in Puno, we can highlight the relevance of considering both the technical and regulatory aspects as well as the economic and energy efficiency aspects. when designing and implementing an air conditioning system. This will allow us to provide a comfortable environment for students and teachers, improve the performance of the auditorium and meet the required quality and thermal comfort standards.

Importantly, the results and conclusions of these investigations support and enrich our own research, providing a solid basis for discussion and possible approaches to consider in the design and implementation of the air conditioning system.

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Firstly, I thank the Universidad del Nacional del Altiplano for having accepted me to be part of it and opening its doors to study my degree, as well as the different teachers who provided their knowledge and support to move forward. I thank my mother with all my heart, because without her I would not have achieved it. Your blessing daily throughout life protects me and leads me on the path of good. To my father Pedro, for understanding my decisions and supporting me despite everything. To my colleagues at the Professional School of Electrical Mechanical Engineering for their friendship and trust during the five years of study.

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