SEVEN publicações acadêmicas

Modeling of thermal load sizing for an industrial room aiming at energy efficiency

Crossref doi
https://doi.org/10.56238/Connexpemultidisdevolpfut-174

Daniel Guzmán del Río
University of the State of Amazonas, Brazil
ORCID: https://orcid.org/0000-0003-4321-0465
E-mail: drio@uea.edu.br

Henrique Almeida Silva
Marta Falcão Wyden College, Brazil
E-mail: jneto@fmf.edu.br

Edry Antonio García Cisneros
University of the State of Amazonas, Brazil
ORCID: https://orcid.org/00000002-2395-8663
E-mail: edry1961cu@gmail.com

Israel Gondres Torné
University of the State of Amazonas, Brazil
ORCID: https://orcid.org/0000-0002-1267-1878
E-mail: itorne@uea.edu.br

João Evangelista Neto
University of the State of Amazonas, Brazil
ORCID: https://orcid.org/0000-0002-5100-0719
E-mail: jneto@uea.edu.br

Andre Luiz Printes
University of the State of Amazonas, Brazil
ORCID: https://orcid.org/ 0000-0001-7915-283X
E-mail: aprintes@uea.edu.br

Cláudio Duarte Silva Filho
University of the State of Amazonas, Brazil
ORCID: https://orcid.org/0000-0002-1013-2168
E-mail: cdsilva@hub-uea.org

Fabio de Sousa Cardoso
University of the State of Amazonas, Brazil
ORCID: https://orcid.org/0000-0001-7705-7169
E-mail: fcardoso@uea.edu.br

Angilberto Muniz Ferreira Sobrinho
University of the State of Amazonas, Brazil
ORCID: https://orcid.org/0000-0002-5558-3931
E-mail: asobrinho@uea.edu.br

ABSTRACT
The air conditioning in environments is one of the most important points when it comes to quality in obtaining products and comfort in an industrial environment. Spaces where there is a significant amount of people require adequate air conditioning to increase the productivity and well-being of individuals, but there are also spaces that, in addition to the amount of people, house equipment and machinery, which need to be for their optimal performance with the temperature controlled. In the present work, the study and modeling of the thermal consumption of an industrial metrology room, which contains devices that need to be in spaces with a controlled temperature in order not to affect the results of the tests and calibrations of high-precision equipment, is performed by means of calculations. In the methodology developed, basic concepts of refrigeration and air conditioning were used to assist in modeling and calculating the thermal load sizing, in order to choose the characteristics and quantities of air conditioning equipment necessary to meet the space and technical requirements of the laboratory.

Keywords: Thermal load, Air-conditioning, Metrologia, Energy efficiency.

1 INTRODUCTION

The rapid development of new utility technologies in the industrial sector has in recent years reached the attention of researchers and the market in the world. For example, today we have Industry 4.0, also called the Fourth Industrial Revolution, (Santos, B. P. et al., 2018); according to Ordinance N 0 2.091-SEI, December 17, 2018, when characterizing industry 4.0 states that it is:

> "[...] the integration of production facilities, supply chains and service systems to enable the establishment of value-added networks, involving technologies such as: big data analysis, autonomous (adaptive) robots, cyber-physical systems, simulation, horizontal and vertical integration, industrial internet, cloud computing, additive manufacturing and augmented reality, and comprising distributed systems such as: sensor networks, cloud systems, autonomous robots, and additive manufacturing connected to each other." (DOU, 2018, December, p. 144).

This fact is changing the forms of production and business models in Brazil and in the world. According to Guzmán et al, 2023, "the concern to obtain a product of high added value, capable of being at the level of international standards is a daily reality in the industry", so today solutions in energy efficiency in Industry 4.0 are important, (Ribeiro, & Pires Dos Santos, 2020).

In these contexts, one of the parameters used to assess the competitiveness of industries is the parameter of energy efficiency, which involves components of electrical and thermal systems; this is how there is today concern of governments and international organizations to standardize and regulate the correct and efficient use of energy resources (Procelinfo, 2021), conducting assessments and taking actions to mitigate the impacts on the environment.

In the industrial environment, metrology is one of the most important technical elements within a company, this reason is due to the high value of the equipment and the operating conditions necessary to create in the facilities where the processes and analyzes that guarantee the quality of the products are carried out. Having a standardized metrological process and within the imposed standards means that the company values the quality of its products and the satisfaction of its customers, this ensures a differentiated image in the market.

Metrology is governed by standards, which are strictly complied with by organizations, a metrology laboratory requires that the thermal load of the spaces as a whole is properly in accordance with the established standards to ensure that quality and reliable products are delivered to the end customer, directly impacting the growth of the company. For example, the ABNT NBR ISO/IEC 17025 (2005) standard shows how laboratory operations should be developed so that the results of the analyses are not affected. Another important standard results in the NBR NM-ISSO 1:1997 standard, which helps to standardize, regardless of what is referred to in the manufacturers' manuals, a working temperature of the equipment to mitigate the uncertainties in the results of the measurements obtained that can affect the quality and reliability of the product, bringing losses to companies.

According to Creder (2013), thermal load is the sum of all heat sources present in a given environment that must be removed or placed in the enclosure in order to provide the desired comfort conditions. The thermal load can be affected by: driving, people, equipment and infiltration.

In the present work we present a case study of thermal load dimensioning for a metrology room of a company located in the industrial center of Manaus (PIM). In this laboratory room dimensional analyses and evaluations are carried out daily of parts manufactured in the company in a sample way, to ensure the quality of the products to the customer, in addition to that parts of new projects are also analyzed in detail in the first entry of the part in the company, this is to identify possible failures in the project and ensure a good performance in its progress.

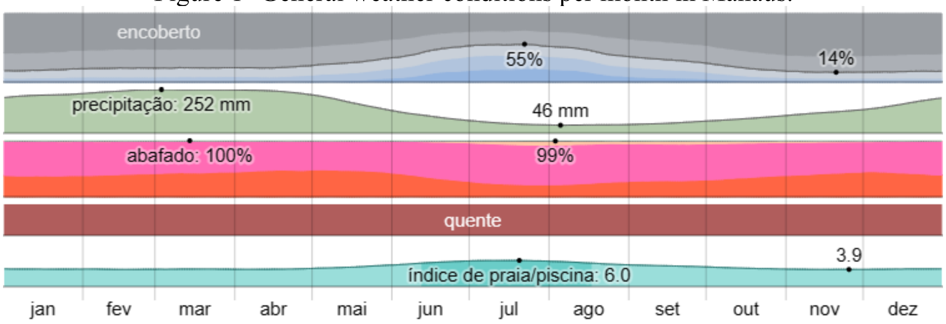
The objective of the present work is to demonstrate that it is feasible to model and calculate the sizing of the thermal load for a metrology room of a production company, as an example to follow for the search for energy efficiency in the management of Industry 4.0, an approach necessary to increase productivity, have a standardized metrological process, value the quality of products, customer satisfaction and reduce the impacts on the environment, allowing to produce with quality and sustainability.

2 MATERIALS AND METHODS

2.1 CHARACTERIZATION OF THE CLIMATE WHERE THE COMPANY'S METROLOGY ROOM IS LOCATED LOCATED IN THE INDUSTRIAL POLE OF MANAUS

Located in the northern radius of Brazil in an extensive zone of humid tropical climate, is the city of Manaus, where there is one of the largest industrial complexes in the country. According to Weather Spark, 2022, in this city and radius "[...] summer is short and hot; Winter is long, warm and with precipitation. Throughout the year, the weather is oppressive and overcast. Throughout the year, in general the temperature varies from *24 °C* to *33 °C and is rarely lower* than 23 °C *or higher than* 36 °C". as can be seen in Figure 1. The sensation of humidity in Manaus, measured by the percentage of time in which the comfort level of humidity is *muffled,* oppressive *or* extremely humid*, does not vary significantly throughout the year, remaining practically constant*, 100%, *the whole year, figure 1.*

Figure 1- General weather conditions per month in Manaus.

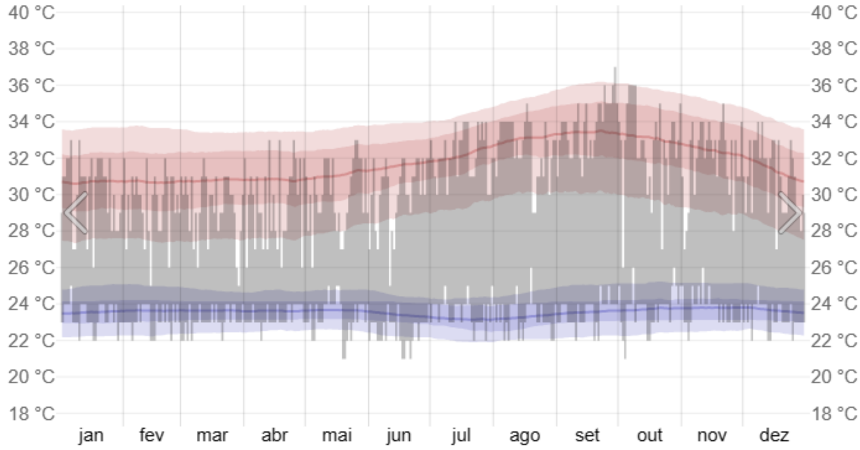


Source: Weather Spark-Manaus

In this context, while the temperature may drop at night, a muggy day is usually followed by a muggy night. Finally, the geographical coordinates of Manaus are: latitude -3.102°, longitude -60.025° and 20 m altitude. (Weather Spark, 2022).

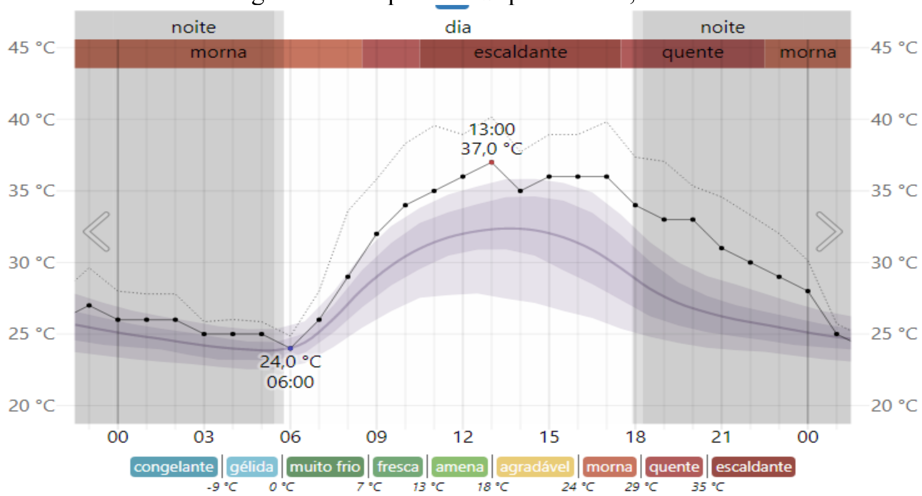
One way to ensure that the thermal sizing meets the needs of the site is to perform the calculation of thermal load for the hottest days of the year, which automatically supplies the other temperatures throughout the year, figure 2. Due to this information, the temperature of the hottest day of the year 2022, which was September 29, is used as a basis, as shown in Figure 3. On this day the temperature reached 37 ° C exceeding the annual average.

Figure 2- History of temperatures in Manaus – year 2022



Source: Site: Weather Spark-Manaus

Figure 3 - Temperature September 29, 2022

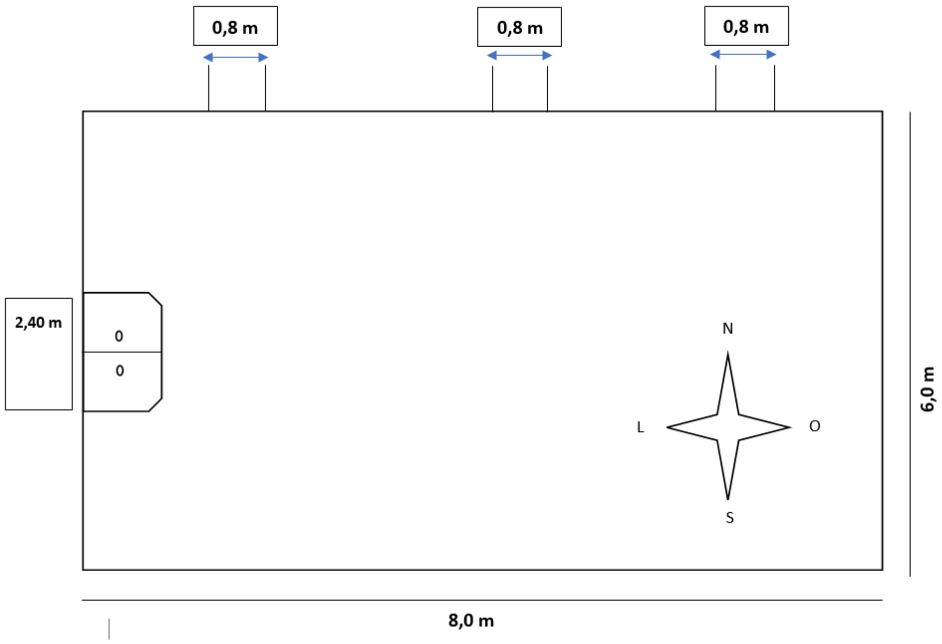


Source: Weather Spark website, 2022

2.2 CHARACTERIZATION OF THE AMBENTE OF THE INDUSTRIAL METROLOGY ROOM CHOSEN TO PERFORM THE THERMAL LOAD STUDY

The place chosen to carry out the thermal load study is a metrology laboratory located in a company of the Industrial Pole of Manaus, PIM. The laboratory is located in a secondary space where specific parts of high capacity products are manufactured and is awaiting the installation of air conditioning for its use. The space, figure 4, has a total area of 48 m², measuring 6 meters long by 8 meters wide. The walls on the east and south sides separate the laboratory from an air-conditioned factory environment, the wall on the west side separates the laboratory from a space used as a storage room for cleaning material and the north wall is the only side that catches solar incidence as it separates the laboratory with the outside of the factory. The laboratory room has three transparent glass and aluminum tippers that measure 80 cm x 80 cm that are located in the northern part, there is also only a single entrance to the laboratory with a double aluminum door measuring 2.10 m x 1.20 m each door sheet, so the entire door measures 2.10 m x 2.40 m. The walls of the installation were made of concrete block, the ceiling formed by concrete slab with thermal insulation of PVC (PVC lining) and the floor built of cement.

Figure 4 - Layout of the plant of the metrology laboratory.



Source: Author

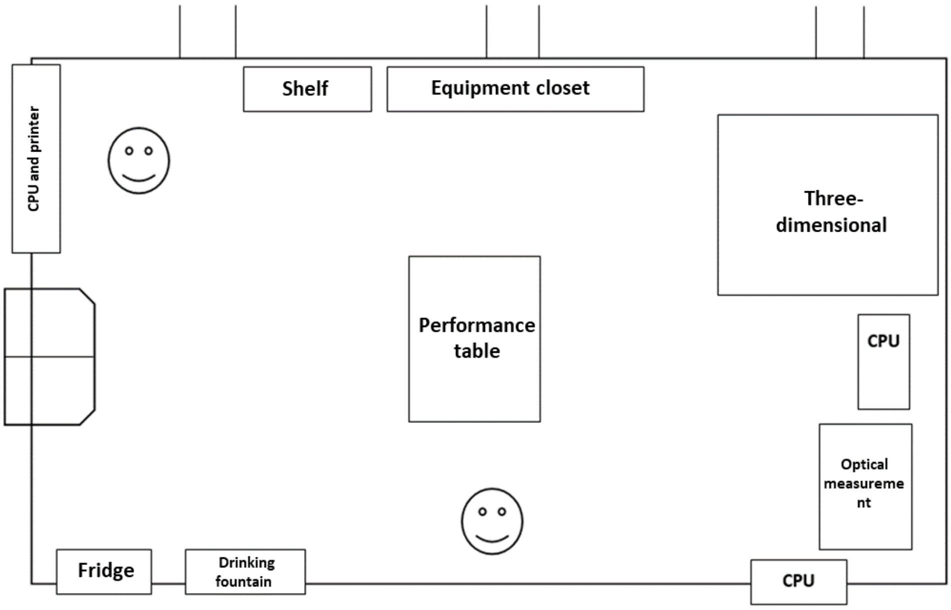
The laboratory inside contains several devices, some of which are operated with electricity, releasing heat to the environment, as follows in table 1 and figure 4, where the type and quantity of these devices is shown. The laboratory is to be used by two fixed people daily, but because it is a place where people transit, it is considered that there is a traffic of five people on average per day, in addition to the fixed people who work daily in this room.

Table 1 - Devices contained in the laboratory

Contain from the lab	Quantity
Three-dimensional with a computer	1
Optical coordinate measuring machine	1
Performance desk	1
Desktop computers (CPU)	2
Printer	1
Minibar	1
Electric drinking fountain	1
32W LED Luminaires	12

Source: Authors.

Figure 5 - Separation of equipment in the metrology room

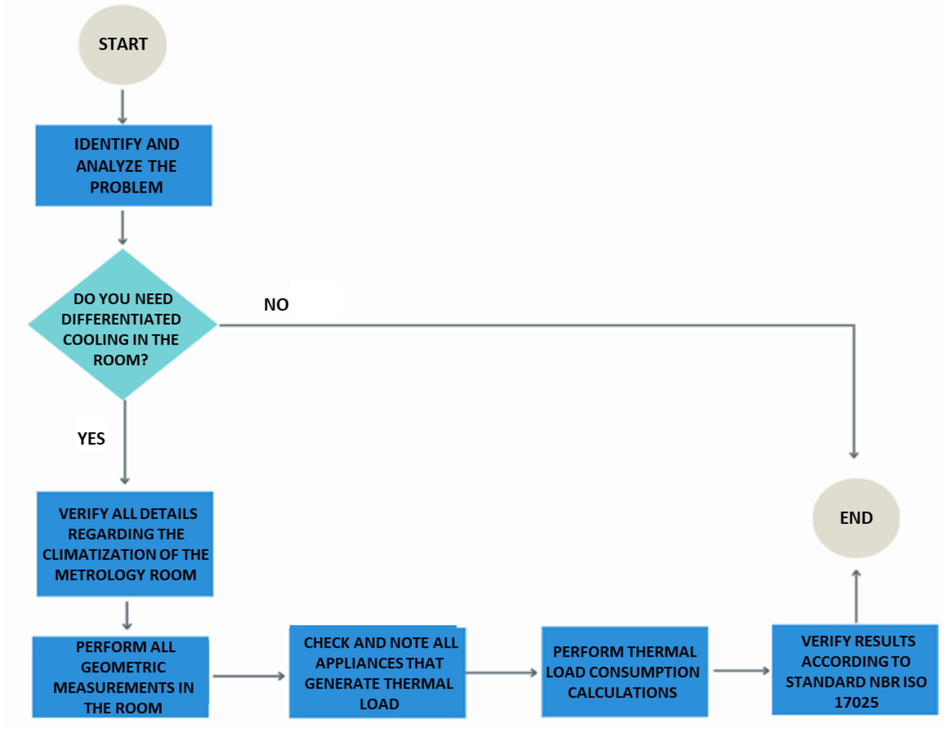


Source: Author

2.3 FLOWCHART FOR THE STUDY AND MODELING OF THE THERMAL LOAD IN THE METROLOGY ROOM

The following is the flowchart of the steps followed to perform the study and modeling of the thermal load in the metrology room.

Figure 6 – Flowchart for the study of thermal load in the metrology room.



Source: Authors, 2022.

In the initial stage it is necessary to carry out a study of the necessary theoretical elements that cover the area of the research in question, in this case the study of the thermal load in the metrology room, completing with the outline of objectives.

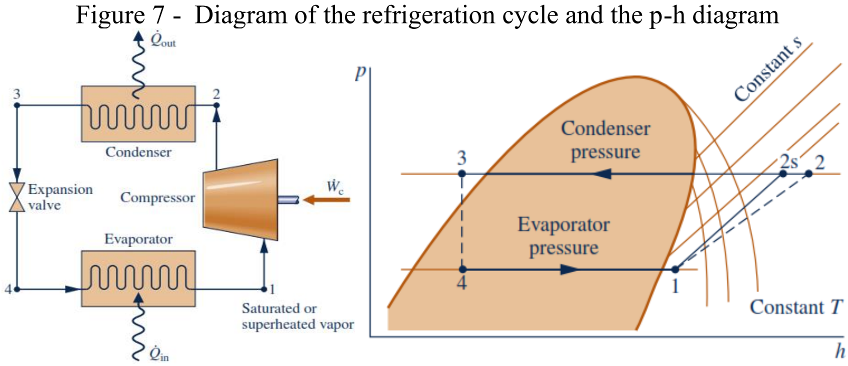
For the preparation of the study of the thermal load it is necessary to verify whether or not it is necessary to establish a differentiated cooling in the room, in case it is not necessary then ends here the study, otherwise it is necessary to verify all the details regarding the climatization of the room, making a modeling and characterization of the room from performing all the geometric measurements and describe its ubiquity or location in the radius and in the industrial environment, making in addition a survey of all the devices that generate thermal load, thus performing the calculations of thermal load; all this is concluded and verified from its correspondence with the ABNT NBR ISO/IEC 17025 (2005) standard, concluding with calculations and necessary tests of the energy parameters involved.

When analyzing the thermal load of a metrology room it is necessary to remove heat from the environment, the heat can be transferred in three different ways: conduction, convection and radiation. All modes of heat transfer require the existence of the temperature difference and all occur from the highest to the lowest temperature. According to Çengel & Ghajar, (2012, p. 17), conduction is the transfer of energy from the most energetic particles of a substance to adjacent less energetic neighboring particles, as a result of the interaction between them, where convection is the mode of energy transfer between the solid surface and the adjacent liquid or gas that is in motion and which involves the combined conduction and motion effects of a fluid, radiation is the energy emitted by matter in the form of electromagnetic waves (or photons) as a result of changes in the electronic configurations of atoms or molecules. Unlike conduction and convection, heat transfer by radiation does not require the presence of an intervening medium (Wilen, Sonntag, & Borgnakke, 1995).

According to Creder (2013), thermal load is the sum of all heat sources present in a given environment that must be removed or placed in the enclosure in order to provide the desired comfort conditions. The thermal load can be affected by driving, people, equipment and infiltration.

For the establishment of the necessary refrigeration in a room, air conditioners or air conditioners are currently used. Air conditioners have ceased to be new for a few decades, their production and commercialization has been a market of global amplitude in constant expansion, where the industries of the sector began to invest in technological development and novelties in products. In the case of the devices they became more compact, quieter and the remote control was introduced to increase the convenience of users. Came the concern with the consumption of electricity, making the appliances more economical and efficient. Window conditioners have evolved into the split system, allowing for greater versatility in installations. As the great focus of the present day the attention to the environment has led to the development of devices that use ecological gas, which does not harm the ozone layer. These devices, which use the inverter system, keep the environment with a minimum temperature variation and are more economical compared to conventional ones. According to Pimenta (2015, p. 16) "[...] Due to a number of practical considerations, such as: technical simplicity, space occupation, maintenance, operation, control, energy consumption, temperature and others, refrigeration by means of mechanical compression of vapors is the most widespread technique on the market." These systems use the so-called refrigeration cycle, (Moran & Shapiro, 2013), figure 7, which involves the stages of Expansion (Process 3-4), Vaporization (Process 4-1), Compression (Process 1-2) and condensation (Process 2-3):

Figure 7 - Diagram of the refrigeration cycle and the p-h diagram



Source: Moran & Shapiro (2013)

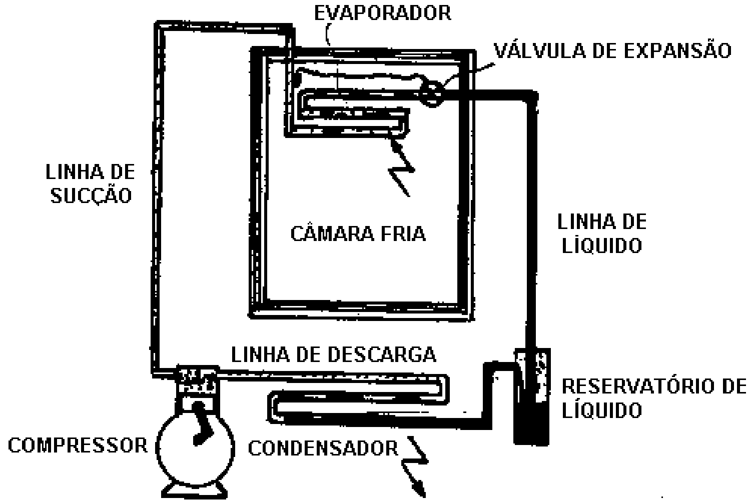
Thus, mechanical refrigeration systems employ several individual processes to produce a continuous refrigeration cycle, capable of maintaining the temperature of a space in precise conditions.

A schematic diagram of a simple cooling system proposed by Ferraz (2008) is shown in (figure 8); The main components of the system in this diagram are:

> "... Evaporator: It is a heat exchanger that receives the liquid refrigerant at low pressure. Along the evaporator pipe the liquid vaporizes by absorbing heat from the inner space of the chamber." "... Suction line: It is the refrigeration pipe used to transport the cold steam, connecting the evaporator to the compressor and theoretically it is assumed that the refrigerant crosses this line without exchanging heat." "... Compressor: This is an electromechanical device that is used to develop and maintain the flow of fluid through the refrigeration system." "... Discharge line: It is the refrigeration pipe used to transport the superheated steam at high pressure, connecting the compressor to the condenser and theoretically we will admit that the steam at high pressure and temperature cross this line without exchanging heat." "... Condenser: It is a heat exchanger that receives steam at high pressure and temperature and causes its condensation by removing heat from it through a condensing medium, usually water or air." (Ferraz (2008).

Figure 8 below shows the main components of the typical refrigeration cycle of an air conditioner and how they are distributed.

Figure 8 – Refrigeration cycle



Source: Ferraz, (2008).

3 RESULTS

For the sizing of air conditioning in any predetermined location, it is necessary to estimate the thermal load present in the environment. External, internal and other miscellaneous loads will be included in the calculations.

This section considers all internal loads on site, such as electronics, appliances, people, lighting and others.

For the calculation of various loads (electrical and electronic) the following equation (1) is used:

$$Qds = Pt \times 0.86 \quad (1)$$

Where:

Qds – Miscellaneous loads; kcal/h.

Pt – Total power dissipated; W.

0.86 – Power conversion factor in kcal/h.

Performing the calculations of the thermal load of the existing electrical equipment in the metrology room we have, according to table 2, the following:

Table 2 - Thermal load by electrical appliance.

Appliance Type	Pt, W	Quantity	Qds, kcal/h
LED Luminaire	32	12	330,24
Optical measurement	1640	1	1.410,40
Printer	45	1	38,7
CPU + Monitor	470	3	1.212,6
Minibar	106	1	91,16
Electric drinking fountain	97	1	83,42
Total			**3.166,52**

Source: Authors, 2022.

At the end of the calculation there is 3,166.52 kcal/h of loads consumed only from electrical equipment, converting this value to Btu/h has a total of 12,557.36 Btu/h.

In the case of the calculation for people, table 1 is used, which is found in chapter 1 of ABNT NBR 16401-1, 2008. To obtain the amount of sensitive heat and latent heat released by people, one has:

Table 1 - Latent and sensitive heat value by activity

Activity level	Sensitive heat, W	Latent heat, W
Moderate work	75	55

Source: Standard ABNT NBR 16401-1, 2008.

Therefore, the sensitive and latent thermal load using five people, as previously stated, is shown in the following table 3.

Table 3 - Sensitive and latent load released by people.

Type thermal load	Quant. People	Heat type, W	Thermal load, W	Conversion to kcal/h
Sensitive thermal load, Qts; W	5	75	375	322,5
Latent thermal load, Qts; W	5	55	275	236,5

Source: Authors, 2022.

In the analysis of the external thermal loads of the perimeter of the laboratory, the walls, windows and doors are taken into account. For the calculation of external loads it is accepted to use the height of a standard right foot which is 2.5 m and the following equation 2.

$$Qn = A.\ U.\ \Delta T \quad (2)$$

Where:

A – Wall area, m2

U – Global heat transfer coefficient for building materials – Gerner; kcal/h.m².

ΔT – Temperature differential used in projects; °C.

Table 4 - Thermal load of the walls.

Type of orientation of the walls	A, m2	U, kcal/h.m²	ΔT, °C	Qn, kcal/h
North face in contact with the external environment	18,08`	2,71588	9,4*	461,56
South Face in contact with the internal environment	20,0	2,71588	5,5**	298,74
East Face in contact with the internal environment	9,96``	2,71588	5,5**	148,77
West Face in contact with indoor environment	15	2,71588	5,5**	224,06

*Exterior walls. **Partitions. 'No includes the door area. "No includes the window area.
Source: Authors, 2022.

In the case of the analysis of the thermal loads of the roof and tippers we have:

Table 5 - Thermal load of the walls.

Type of surface	A, m2	U, kcal/h.m²	ΔT, °C	Qn, kcal/h
Ceiling of the laboratory or room	48	2,41895	5,5**	638,6
A tipper	0,64	2,70175	9,4*	16,25
Total of 3 tippers of the same size that exist in the laboratory	29,88	2,71588	5,5**	48,76

* Glass with external contact, ** Partitions.
Source: Authors, 2022.

The analysis of the insolation on opaque surfaces is carried out, for this purpose the calculation of the surfaces that absorb heat in the thermal impact with the external environment to the internal environment, such as walls and windows, is carried out. For the calculation we have:

$$Q(ins) = UA\,[(Te - Ti) + \Delta t] \ (3)$$

Where:

Q – Insolation loads by opaque surfaces, W;

U – Global heat transmission coefficient, kcal/h.m²;

A – surface area, m2;

Te – outside temperature, °C;

Ti – interior temperature, °C;

Δt – addition to the temperature differential, °C, obtained according to Creder, 2004, by table 2 below.

Table 2 - Addition to the universal temperature differential

Surface	Color oscura	Medium color	Colour white
	°C	°C	°C
Roof	25	16,6	8,3
Wall L or O	16,6	11,1	5,5
Wall N	8,3	5,5	2,7
S Wall	0	0	0

Source: Creder, 2004.

The calculation is then performed for the only wall that has solar incidence which is the north face. Solar irradiation is taken from the table of SHGF values for glasses (ASHRAE, 1989). Using the month of September, where we had the hottest day of the year so far, we have the solar factor with the value of 123 on the north face.

Table 6 - Thermal load of opaque surfaces.

Type of surface	A, m2	U, kcal/h.m²	ΔT, °C	Text, °C	Tint, °C	Qn, kcal/h
Wall that has solar incidence (single north face)	18,08	2,71588	2,7	37	21	918,22
Glass surface (including 3 tippers)	1,92	**Solar factor**: 123				236,16

* Glass with external contact, ** Partitions.

Source: Authors, 2022.

Compiling all the results, according to Table 7, we have:

Table 7 - Total thermal load consumption.

Types of loads	Qn, kcal/h	Qt, Btu/h
Internal loads	3.722,52	14.774,1711
External loads	2.056,65	8.155,98869
Total	5.782,17	22.930,1598

Source: Author, 2023

It can be observed that the total thermal load consumption is close to 23 thousand BTU/h. Therefore, the recommendation to meet the requested parameters and keep the metrology laboratory within the standards, would be an air-conditioning well above the thermal load consumed. In the market there are high capacity air conditioning machines of 36, 48 and 60 thousand BTU/h. Using any of the 3, according to the thermal load consumed, the laboratory would have enough air conditioning to keep the environment at comfortable temperatures for work and for the care of the equipment.

4 CONCLUSIONS

In the work it was shown that through the study of thermal load consumption in an environment, it is possible to verify and identify which air conditioning device is necessary to meet the need of the environment. Therefore, it can be observed that the total thermal load consumption is close to 23 thousand BTU/h. Therefore, the recommended to meet the parameters required to keep the metrology laboratory within the standards would be an air-conditioning well above the thermal load consumed. In the market there are high capacity air conditioning machines of 36 thousand, 48 thousand and 60 thousand BTU/h, using any of the three, according to the thermal load consumed, the laboratory would be air-conditioned enough to keep the environment at comfortable temperatures for work. However, as a safety factor, it is particularly recommended a machine with at least twice the thermal consumption exerted by the laboratory, because then it would be covered for the hottest days than normal, given the climate of the Amazon region, and for eventualities that may occur with the transit of materials and people in the enclosure. A point to comment on in the work is the larger three-dimensional that can be verified in figure 4, it did not enter into the calculation of thermal load, because the operation is by compressed air, being only its control computer what emanates heat flow due to the presence of electronic devices and force in the power.

From the results obtained, the information of thermal load consumed by the metrology laboratory is passed on to the responsible sector, for the installation of an air-conditioning that meets the needs of the room, after a time of exploration with a new study it is verified if it meets the restrictions and provisions imposed by the standard, if this need is not achieved, It will be necessary to change the air conditioning to one of greater thermal capacity, making the room conform to the parameters imposed.

ACKOWLEDGMENT

Thanks to the PD&I Projects "Lato Sensu Post-Graduation in Smart Industry Management" and "Training for Improvement and Development of Resources in Additive Manufacturing and Intelligent Production Processes under the Context of Industry 4.0", Laboratory of Embedded Systems and GPA Project of the School of Technology of the University of the State of Amazonas.

REFERENCES

Moran, M. J; Shapiro, H. N. Princípios de Termodinâmica para Engenharia. Editora: LTC; 7ª edição. 2013.

Portaria nº 2.091-SEI, de 17 de dezembro de 2018. DOU número 244. Seção 1. Port_MDIC_2091_2018.pdf(mctic.gov.br). https://antigo.mctic.gov.br/mctic/export/sites/institucional/legislacao/Arquivos/Port_MDIC_2091_2018.pdf. Acessado 23 de Janeiro de 2023.

Santos, B. P. et al. (2018). Indústria 4.0: Desafios e oportunidades. Revista Produção e Desenvolvimento, 4(1), 111-124. Recuperado a partir de: http://revistas.cefet-rj.br/index.php/producaoedesenvolvimento.

Centro Brasileiro de Informação da Eficiência Energética. (2021). PROCELINFO. O Programa. Recuperado a partir de http//:www.procelinfo.com.br.

Creder, H. (2004). Instalações de Ar Condicionado. 6. ed. Rio de Janeiro LTC.

Ribeiro, S. A. & Pires Dos Santos N. N. (2020). Soluções em Eficiência Energética na Indústria 4.0: Estudo de caso em acionamento de bombas para testes hidrostáticos. São Carlos, 2020. (Monografia Graduação). Universidade de São Paulo. Escola de Engenharia de São Carlos.

Çengel, Y. A. & Ghajar, A. J. (2012). Transferência de calor e massa. Quarta Edição. Mc Graw Hill.

Wilen V., G. J., Sonntag, R. E. & Borgnakke, C. (1995). Fundamentos da Termodinâmica. 5ª edição, São Paulo: Editora Edgard Blücher Ltda.

Pimenta, P.H.N. (2015). Avaliação da influência da pressão de condensação no desempenho de sistemas de refrigeração industrial. Trabalho de Conclusão de Curso - Universidade de Rio Verde, Goiás.

Guzmán del Río, D. et al. (2023). Análise da eficiência energética por meio da simulação de processos industriais: uma abordagemcomplementar na Indústria 4.0. *PEER REVIEW*, v.5, p.245 - 258.

Ferraz. F. (2008). Sistemas de refrigeração. Apostila (Refrigeração). Centro Federal de Educação Tecnológica. Disponível em: REF1_TOTAL.PDF (wordpress.com). Acesso em: 13 abril 2023.

Ashrae (1989). Handbook. Fundamentals. SI Edition. *American Society of Heating, Refrigerating & Air Conditioning Engineers, Incorporated.* Disponivel em: https://openlibrary.org/books/OL11379858M/1989_ASHRAE_Handbook. Acesso: 13 de abril de 2023.

Weather Spark. Clima, condições meteorológicas e temperatura média por mês de Manaus (Brasil). Disponivel em: pt.weatherspark.com. Acesso: 2023.

ABNT- Associação Brasileira de Normas Técnicas NBR 16401-1 Instalações centrais de ar-condicionado para conforto - Parâmetros básicos de projeto. 2008.

ABNT-Associação Brasileira de Normas Técnicas NBR ISO/IEC 17025, Requisitos gerais para competência de laboratórios de ensaio e calibração. 2005.

ABNT- Associação Brasileira de Normas Técnicas NBR NM ISSO 1:1997 Temperatura padrão de referência para medições industriais de comprimento. 1997.