

The conception of a multiparameter equipment for evaluation of agricultural machinery cabins

A concepção de um equipamento multiparamétrico para avaliação de cabinas de máquinas agrícolas

DOI:10.34117/bjdv8n12-200

Recebimento dos originais: 10/11/2022

Aceitação para publicação: 15/12/2022

José Carlos Lorentz Aita

Doctor in Engenharia Agrícola

Institution: Universidade Federal de Santa Maria (UFSM)

Address: Av. Roraima, nº 1000, Prédio 05, Colégio Técnico Industrial de Santa Maria, Cidade Universitária, Camobi, Santa Maria – RS, CEP: 97105-900

E-mail: aita.ctism@gmail.com

Leonardo Nabaes Romano

Doctor in Engenharia Mecânica

Institution: Universidade Federal de Santa Maria (UFSM)

Address: Av. Roraima, 1000, Prédio 07, Centro de Tecnologia, Cidade Universitária, Camobi, Santa Maria - RS, CEP: 97105-900

E-mail: romano@ufsm.br

José Fernando Schlosser

Doctor in Energia Maquinaria y Riegos

Institution: Universidade Federal de Santa Maria (UFSM)

Address: Av. Roraima, 1000, Prédio 42, Centro de Ciências Rurais, Cidade Universitária, Camobi, Santa Maria - RS, CEP: 97105-900

E-mail: josefernandoschlosser@gmail.com

Leandro Silveira Ferreira

Master in Engenharia Mecânica

Institution: Universidade Federal de Santa Maria (UFSM)

Address: Av. Roraima, nº 1000, Prédio 05, Colégio Técnico Industrial de Santa Maria, Cidade Universitária, Camobi, Santa Maria – RS, CEP: 97105-900

E-mail: leandro.ferreira@ctism.ufsm.br

Lidiane Bittencourt Barroso

Master in Engenharia Civil

Institution: Universidade Federal de Santa Maria (UFSM)

Address: Av. Roraima, 1000, Prédio 05, Colégio Técnico Industrial de Santa Maria, Cidade Universitária, Camobi, Santa Maria - RS, CEP: 97105-900

E-mail: lidianebarroso@ctism.ufsm.br

ABSTRACT

The functions of the cabin on agricultural machinery go beyond protecting against the risk of overturning and adverse weather conditions, such as wind and rain. The cabins must also have a shield against physical, chemical, and biological risks, present in crops.

In this context, the work aims to present the design of equipment capable of measuring atmospheric pressure, the incidence of ultraviolet radiation from the sun, temperature, and relative humidity of the air, inside and outside agricultural cabins, at the same time. The design methodology used in the development of the equipment demanded the definition of customer requirements, which were converted into design requirements. From the analysis of these, the design specifications were established. To meet the formulated specifications, the functional structure of the equipment was defined through a synthesis process (operating concept). The conception generated by the equipment, in two modules, inside and outside the cabin, allows the performance of differential comparative analyzes between the parameters in the two environments considered, serving as a tool for the development of cabin designs for safer agricultural machines.

Keywords: machinery design, occupational hygiene, environmental condition.

RESUMO

As funções da cabine nas máquinas agrícolas vão além da proteção aos riscos de capotamentos e condições climáticas adversas, como vento e chuva. As cabines devem apresentar, também, uma blindagem contra riscos físicos, químicos e biológicos, presentes em lavouras. Neste contexto, o trabalho tem como objetivo apresentar a concepção desenvolvida de um equipamento capaz de medir pressão atmosférica, incidência de radiação ultravioleta do sol, temperatura e umidade relativa do ar, no interior e exterior de cabines agrícolas, ao mesmo tempo. A metodologia de projeto utilizada no desenvolvimento do equipamento exigiu a definição de requisitos de clientes, os quais foram convertidos em requisitos de projeto. Da análise destes, foram estabelecidas as especificações de projeto. De forma a atender as especificações formuladas, definiu-se por meio de um processo de síntese, a estrutura funcional do equipamento (conceito de funcionamento). A concepção gerada do equipamento, em dois módulos, interno e externo a cabine, permite a realização de análises comparativas diferenciais entre os parâmetros nos dois ambientes considerados, servindo como uma ferramenta ao desenvolvimento de projetos de cabines para máquinas agrícolas mais seguras.

Palavras-chave: projeto de máquinas, higiene ocupacional, condições ambientais.

1 INTRODUCTION

All technological development applied to agricultural machinery and equipment and plant protection products aims to provide greater productivity in the primary sector, but it is also a fact that all this technology can expose rural workers to various potential risks, such as typical accidents and occupational diseases.

According to the Brazilian Association of Occupational Hygienists -ABHO (2018), the science that studies the influence of environmental factors (environmental risks) on worker health is Occupational Hygiene, from actions of anticipation, recognition, evaluation, and control of the conditions of workplaces, aiming to preserve the worker's health.

Environmental risks are formed by physical, chemical, and biological agents. Physical agents are the forms of energy such as noise, vibrations, abnormal pressures, and ionizing and non-ionizing radiation. Chemical agents are substances dispersed in the air in the form of dust, smoke, mist, fog, gases, and vapors. Biological agents are microorganisms such as viruses, bacteria, bacilli, and fungi (BRASIL, 2014).

In this sense, control actions and measures should always be implemented to eliminate, reduce, or mitigate environmental risks by acting on the source, the pathway, and the receptor - respectively in that order (PEIXOTO & FERREIRA, 2013).

According to Corrêa (2007), one solution found by the companies that manufacture agricultural machines was the adoption of cabins. These are the most evolved and complex forms of safety structures. Besides providing a physical barrier to the operator for typical accidents, they protect the worker from wind, rain, noise, dust, and sun exposure, among others. It offers safety, greater convenience, and comfort, and reduces the possibility of occupational illnesses.

For Kushwaha and Tiwari (2020), the closed cabin of an agricultural machine under certain conditions can act as a greenhouse, transforming its interior into technically uncomfortable for its operators.

Similarly, Zewdie and Kic (2016) emphasize that many machine and equipment operators, who are exposed to harsh climatic conditions, are affected by their work performance and also their safety concerning the physical, chemical, and biological hazards intrinsic to working with cabbed machines.

In the same line of reasoning, Meskhi et al. (2019) point out that the harmful effects caused by environmental factors are possibly aggravated by the fact that the operator is in a closed and limited cab environment, necessitating a system capable of reducing the effects of damage to the worker's health.

In Brazil, there are no official standards for evaluation of the protective efficiency of cabins, which allows domestic manufacturers of cabins for agricultural machinery do not need to submit their products for approval, nor to performance and conformity tests for further marketing. Thus, according to Schlosser and Corrêa (2011), the production of agricultural machinery and equipment becomes uncompromised with quality and safety, and they lose competitiveness in the international market, which has led agricultural mechanization technicians to advocate the reactivation of official tests for approval and certification.

However, there have been exceptions throughout history. According to Schlosser and Corrêa (2011), in Brazil - between 1937 and 1990 - agricultural machinery was subjected to tests to analyze its performance. The evaluation system was part of the guidelines of the Ministry of Agriculture and was practiced by the National Center for Agricultural Engineering (CENEA) - extinguished in 1990 - ending the obligation of official tests in Brazil.

Currently, even though domestic cab manufacturers are not obliged to perform tests on their products, Capacci and Rondelli (2016) defend the idea that the active protection offered by the cab is a fundamental requirement. Therefore, the importance of conducting an analysis of Brazilian agricultural cabins through the applicability of two international standards that address this issue is emphasized: BS EN 15695 (2009) and ISO 14269-5 (1997).

Thus, the reference for checking the safety provided by the cab used on agricultural tractors and self-propelled sprayers against the action of hazardous substances in the international standard BS EN 15695 (2009). This standard is divided into two parts: BS EN 15695-1 (Cabin classification, requirements, and test procedures) and BS EN 15695-2 (Filters, requirements, and test methods). The two parts define a classification for the different types of cabins produced, depending on the level of protection offered. According to BS EN 15695-1 (2009), cabins are classified into categories ranging from 1 to 4 considering physical and chemical hazards. Category 1 protects only against the weather (wind and rain). In category 2, the cabin must be equipped with a pressurization system and an air filtration system capable of retaining particulates, providing good quality filtered ambient air and no risk to the operator from inhaling dust. The category 3 cabin must be equipped with a pressurization and air filtration system capable of retaining solid particulates (dust) and aerosols. Finally, the category 4 cabin must be equipped with a pressurization and air filtration system capable of retaining solid particulates, aerosols, and plant protection product vapors.

The standard ISO 14269-5 (1997) determines the method for testing the pressurization system in the operator's compartment of tractors and self-propelled machines for agriculture and forestry. For the pressurization test, according to Marquez [12], the cab is pressurized by the air ventilation system when the system can maintain an internal pressure between 50 and 200 Pa above the external pressure.

An important factor to be considered has to do with the expectation of improved operator visibility, as companies in the agricultural machinery industry are using large

glass surfaces for this purpose. According to Márquez (2012), large glass surfaces help to improve operator visibility, but on the other hand, they allow greater incidence of sun rays inside the cab. Therefore, it follows that the use of large glazed surfaces helps to improve operator visibility and due to this two other problems may arise: the increase of the internal temperature, causing thermal discomfort; and, a greater exposure of the operator to ultraviolet radiation from the sun, which may be the cause of dermatological problems.

In this context, considering the importance of cabins' design for the maintenance of agricultural machinery operators' occupational health, the present work aims to present the conception developed for integrated equipment to measure atmospheric pressure, ultraviolet radiation incidence, temperature, relative humidity, simultaneously, inside, and outside of agricultural machinery cabins, to help to verify their protective capacity and quality.

2 DESIGN METHODOLOGY

Commonly, projects that comprise the development of industrial products are broken down into phases, which allow the gradual establishment of solutions while also facilitating the management and definition of action criteria, configuring the life cycle of a project. Given this, the methodology used to achieve the proposed objective was based on the Reference Model for the Development Process of Agricultural Machines (ROMANO, 2013). This methodology allows the whole project process to be thought out in coordinated phases that allow a protocol record, enabling the project team to fully understand and control the parameters involved. For the purpose of this work, the activities performed predominantly covered the informational and conceptual design phases described in Romano (2013) and Aita (2018).

Firstly, to characterize the design problem, a survey was conducted with the manufacturers of national agricultural cabins about how the machine cabins are designed, if they follow specific occupational safety standards, and how the cabins produced are verified regarding the fulfillment of their protective characteristics. Out of this research came a list of needs that were transformed into the technical language in the form of customer requirements. These were valued using the Mudge Diagram method to verify the relative importance of each customer requirement. This action allows the deepening of the design problem, clarifying what is necessary to meet in the equipment design. Once the customer requirements are known, they are converted into metrics, called design

requirements, which allow the understanding of aspects that are undesirable to the project. Thus, based on the idea that the equipment must simultaneously measure, for comparative evaluation purposes, temperature, relative humidity, atmospheric pressure, and the incidence of ultraviolet radiation inside and outside the cabin, the design specifications were defined, which translate the main customer requirements and their respective design requirements to be considered in the development of the conception.

Once the design specifications were known, the integrated conception of multi-parameter equipment was established in the conceptual design phase. This conception was based on the defined functionality principles (temperature, atmospheric pressure, relative humidity, and UV radiation) and on the constructive characteristics of the technical systems that compose the sensors, and that determined the constructive layout.

3 THE MONITORCAB CONCEPTION

The survey conducted with the manufacturers of national agricultural cabins on how the machine cabins are designed - whether they follow specific occupational safety standards and how the cabins produced are checked for compliance with their protective features -, allowed us to verify that the manufacturers design adapted cabins to existing agricultural machines, taking into consideration in the project only structural requirements, i.e., related to impact or rollover issues. As a result, the focus of this work is on the characteristics related to occupational safety. The definition of the design problem, according to Pahl et al. (2005), is the main result of the informational design phase, which is presented according to a list of requirements. When the customer needs are established, they must be transformed into a more technical language, taking the form of customer requirements and, subsequently, design requirements (metrics). In this way, you move from a qualitative definition to a quantitative one. The design requirements are the basis for decision-making regarding "what?" the technical system should look like, thus facilitating the planning of conceptual activities.

In this sense, according to the information obtained in the survey conducted with the manufacturers of cabins for national agricultural machines, two considerations must be observed: the conditions of the machine's operating environment (in the laboratory "or" in the field); the environments in which the equipment will be used (internal "and" external to the cabin).

Among the considerations raised for the equipment, its size and lightweight are facilitating factors for its construction, transport, and internal and external fixation to the

cabin. In addition to these factors, the equipment must be resistant, because if it is used in field measurements, it will be subject to shaking and jolts caused by soil irregularities. As with all equipment, it must have good accuracy and data storage capacity. Other factors to be considered include the reliability and durability of the components, reducing measurement error, and the need for maintenance.

The power supply system for the operation of the equipment uses the 12 Volt system commonly present in machines or can be autonomous when the agricultural machine does not have 12 Volt power available. It is also considered the interaction between the user and the equipment to allow the collected data (temperature, atmospheric pressure, relative humidity of the air, and UV radiation), time of measurement of the event, and energy source to be followed in real-time. From the point of view of its use and operation, the equipment should be robust and easy to handle (operation), not requiring calibration at each measurement event, since its sensors were calibrated during the equipment construction process. Another factor considered is that the measurement equipment must preserve the originality of the factory cabin, so as not to interfere with the measurement results. Thus, the requirements considered in the design are presented in Table 1.

Table 1 – Requirements for the design of multi-parameter equipment for evaluating agricultural cabins.

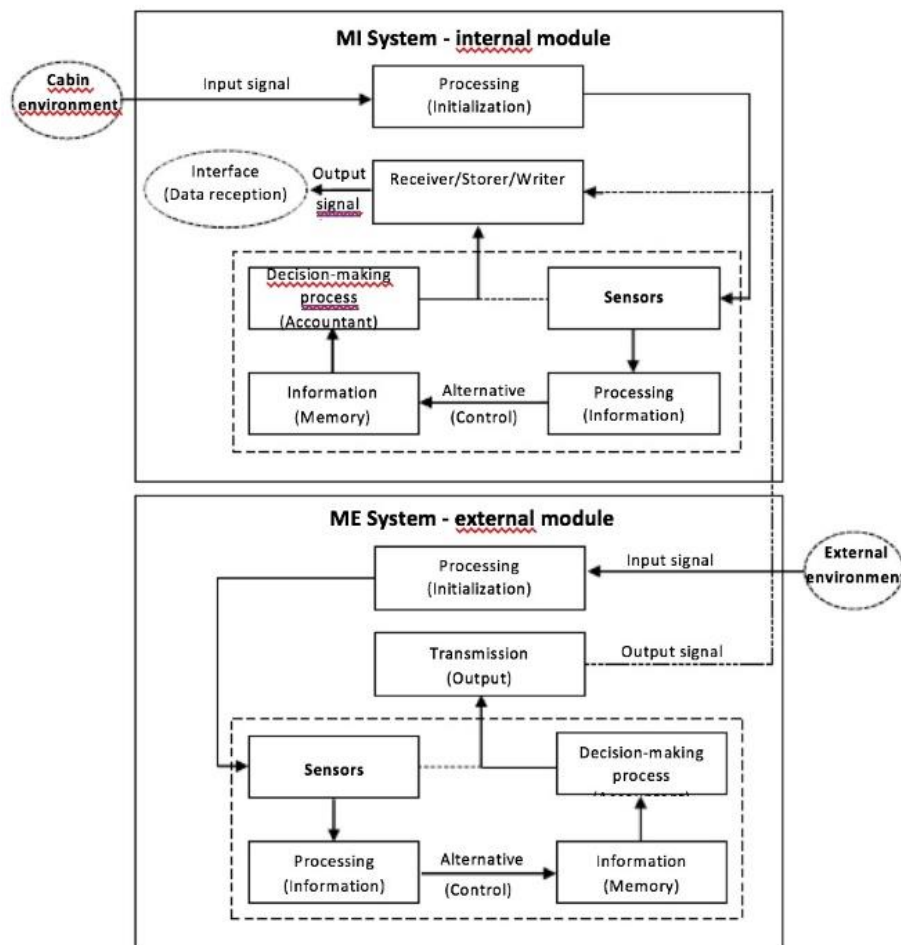
Customer requirements	Design requirements (measurement unit)	Undesirable aspects
Read pressure inside and outside the cabin	Pressure internal and external (Pa)	Measurement failure
Read ultraviolet radiation inside and outside the cabin	Ultraviolet radiation internal and external (mW/cm ²)	Measurement failure
Read temperature inside and outside the cabin	Temperature internal and external (°C)	Measurement failure
Read relative humidity inside and outside the cabin	Relative humidity internal and external (°C)	Measurement failure
Be easy to manufacture	Cost (R\$)	High cost
To be light	Weight (kg)	Difficult transport/installation
To be compact	Height, length, width (mm)	Difficulty positioning
Easy to build and assemble	Assembly time (s)	High cost of assembly
Provide power supply	Voltage (V)	Burn-in of sensors
Allow data reading without violating the cabin	Data transmission frequency, wireless (GHz)	Communicate outside the transmission range allowed by the regulatory agency
Allow data acquisition	Data storage capacity (MB)	Low data storage capacity
Having protection for the components	Mechanical Resistance (kgf/cm ²)	Damage from bumps and jolts
Easy to install and uninstall	Installation time (s)	Inefficient installation, damage due to poor fixation
Allows monitoring of the measurement (time, voltage, measurement parameters)	Number of lines of alphanumeric display (dimensionless unit)	Not showing real-time information

Have good quality components	Reliability (%)	Unreliable measurements
The durability of the components	Component life (year)	High cost of equipment

Source: Adapted from Aita (2018).

In this sense, considering the design requirements established in the Informational Design phase, the conception of the equipment was idealized from a functional diagram, presented in Figure 1. As it can be seen, it is defined in two modules – one to take measurements inside the cabin (Internal Module, MI) and the other to measure the parameters in the external environment (External Module, ME), simultaneously – meeting the requirement of simultaneous data collection in two distinct environments, as recommended by Márquez (2012), as well as the criterion of inviolability of the cabin structure by the passage of cables and connecting wires between the modules. Thus, the option was to adopt a data transmission system via wireless communication between the control and data recording units of modules ME and MI, which were called MonitorCab.

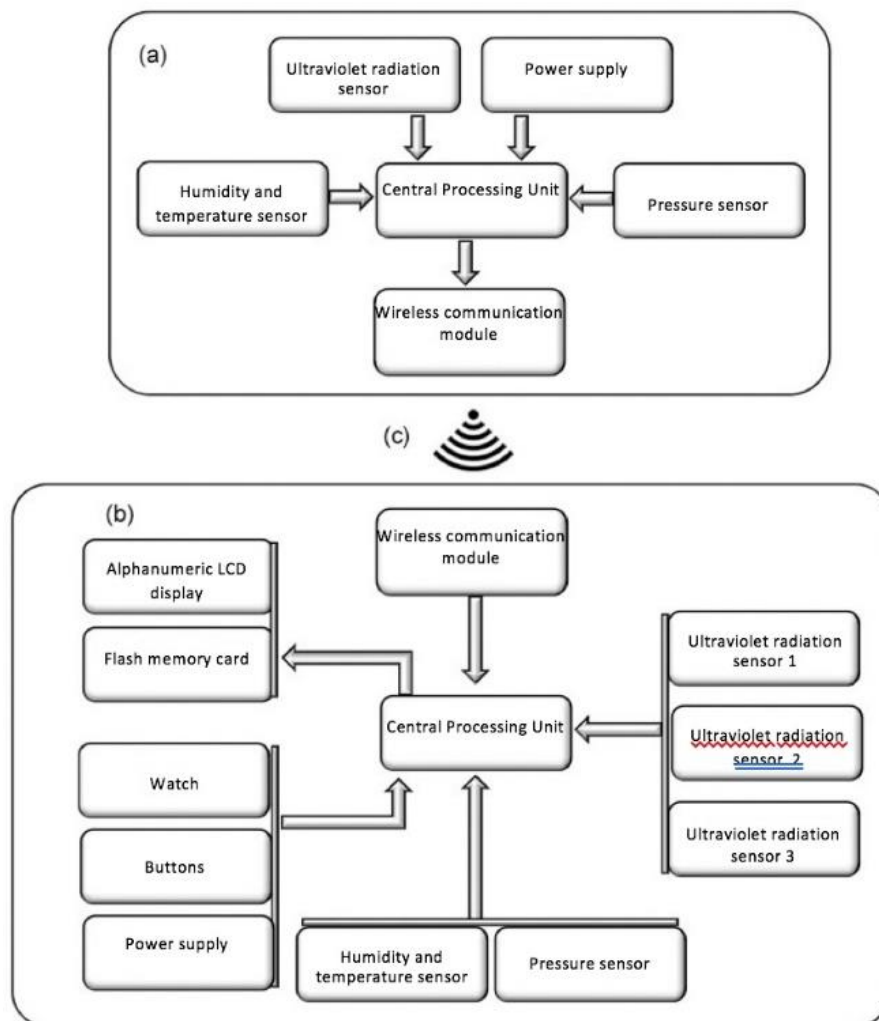
Figure 1 – Functional diagram of the internal and external modules.



Source: Adapted from Aita (2018).

All data obtained by the sensors from the MI and the ME modules are written to a central storage unit of the MI. These data can be transferred to computers and interpreted through the application of graphic software and/or visualized using the communication interface designed so that the user of the equipment has the information in real-time on atmospheric pressure, ultraviolet radiation, temperature, and relative humidity. Figure 2 shows the block diagram of the functional elements of the equipment, as well as the flow of information between the components, according to the direction of the arrows.

Figure 2 – Design of the multiparameter measurement equipment – block diagram of the functional elements: (a) External module; (b) Internal module; (c) Wireless connection.



Source: Adapted from Aita (2018).

The external module (a) is responsible for collecting data from outside the cabin and is composed of a central processing unit, an atmospheric pressure sensor, a temperature sensor, a relative humidity sensor, an ultraviolet radiation sensor, an autonomous power supply (12V), a communication unit and data transmission via

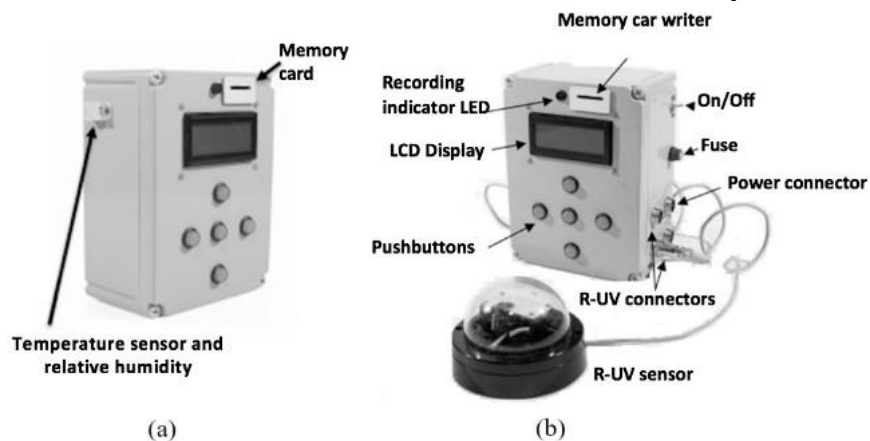
wireless technology. As programmed, the sensors cited perform simultaneous measurements every 15 seconds, which are managed in the central data processing unit of the external module that sends them to the central processing and recording of the internal module (b) via wireless transmission system (c).

Similarly, the internal module (b) takes simultaneous measurements of the external module every 15 seconds. The internal module consists of an atmospheric pressure sensor, a temperature sensor, a relative humidity sensor, three sensors for ultraviolet radiation (position referring to the operator's face and the right and left arms), a central data processing unit, a wireless reception unit and a 12V power supply - autonomous or the agricultural machine's own system. Besides a few more sensors, the internal module differs from the external module by the fact that it also has an alphanumeric display, a data recorder for a flash memory card, a clock, and buttons (communication interface) used as a means of entering data (date and time) and, when necessary, perform the calibration procedure of the equipment.

The materials and components of the internal and external modules were selected to meet the established design requirements. Parallel to the definition of the equipment configuration, control software and hardware (printed circuit boards) could be created, both for the MI and the ME.

The printed circuit board, components, and sensors of the internal module were assembled in a Patola box; model PBL 202 IP65, with dimensions 200 x 150 x 90 mm (Figure 3).

Figure 3 – Internal Module (IM) - (a) left view: temperature-humidity sensor, pressure sensor internal to the module and memory card; (b) right view: recording LED, LCD, pushbuttons, UVR connectors, power connector, fuse, and On/Off switch; R-UV sensor connected by cable

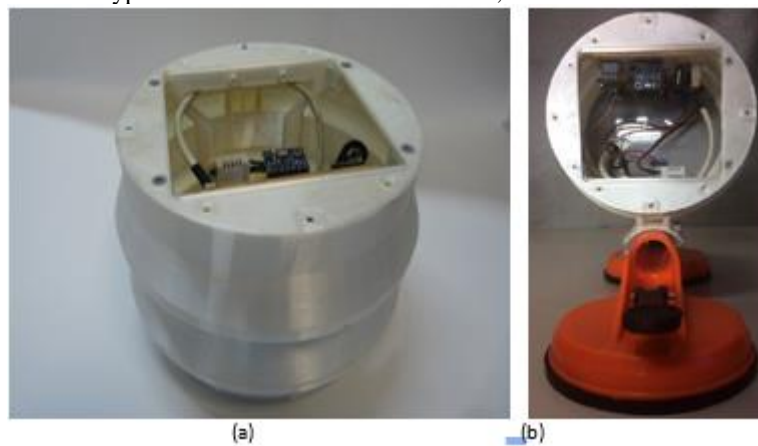


Source: Adapted from Aita (2018).

In the external module, the printed circuit board, components, and sensors were mounted in a chamber designed and manufactured by 3D printing in PLA thermoplastic polymer (polylactic acid) with the protective purpose of the components and sensors (Figure 4). The protective chamber has a diameter of 140 mm, a height of 110 mm, and is 3 mm thick. For its fixation, a double suction cup was used to facilitate the installation on smooth surfaces.

Due to the portability characteristics of the developed equipment, it can be arranged in different ways regarding the positioning of the modules inside and outside the cabin for the execution of the data collection process for temperature, relative humidity, atmospheric pressure, and ultraviolet radiation.

Figure 4 - External module: (a) protection chamber; (b) top view of protection chamber with suction cup type element for attachment on a flat, smooth surface.



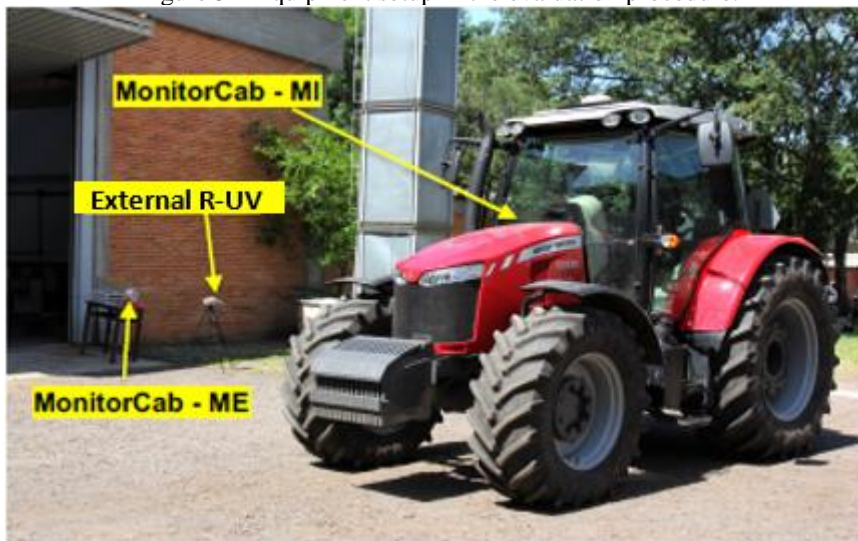
Source: Adapted from Aita (2018).

The stabilization time allows the determination of variations in the data obtained by the sensors. It is known that factors such as wind and direct sunlight on certain sensors can cause differences in the data obtained concerning the actual measurement. For this reason, the external module must be positioned in the measurement environment, controlled or not, close to the displacement region of the machine. Care must be taken so that the internal and external modules are within the range of action of the wireless communication system being used, which in the case of the MonitorCab is approximately fifty (50) meters, tested in an open field.

To obtain data representative of the incidence of ultraviolet radiation emitted by the sun on the operator's workstation, the sensors must be placed in the position normally assumed by the machine operator. Figure 5 illustrates the placement of the external module (MonitorCab-ME) near the tractor and the internal module (MonitorCab-MI)

inside the cab. The external R-UV sensor was connected by cable to the external module that is on a table along with the power supply (12V). In the tractor cab, the internal module (MonitorCab-MI) was installed on the floor. Connected by cable to the MonitorCab-MI are the R-UV sensors, which were positioned at the height of the left and right arms, and near the operator's face, to allow the collection of data that will indicate the operator's exposure to the conditions of the cab's internal environment, which is exposed to the weather conditions measured by the MonitorCab-ME.

Figure 5 – Equipment setup in the evaluation procedure.



Source: Adapted from Aita (2018).

Before collecting the data, the sensors are stabilized and exposed to the conditions of the measurement environments. Once the stabilization procedure is completed, the simultaneous collection of atmospheric pressure (Pa), temperature (°C), relative humidity (%), and ultraviolet radiation (mW/cm²) data (inside and outside the cabin) takes place. The results are presented and analyzed separately in a spreadsheet. As an illustration in this work, the results presented are relative to the behavior of atmospheric pressure. Figure 6 shows the graph of the atmospheric pressure behavior inside the cabin (blue line) and outside the cabin (red line) in a proof-of-concept test of the developed equipment. The test was composed of five different phases for data collection:

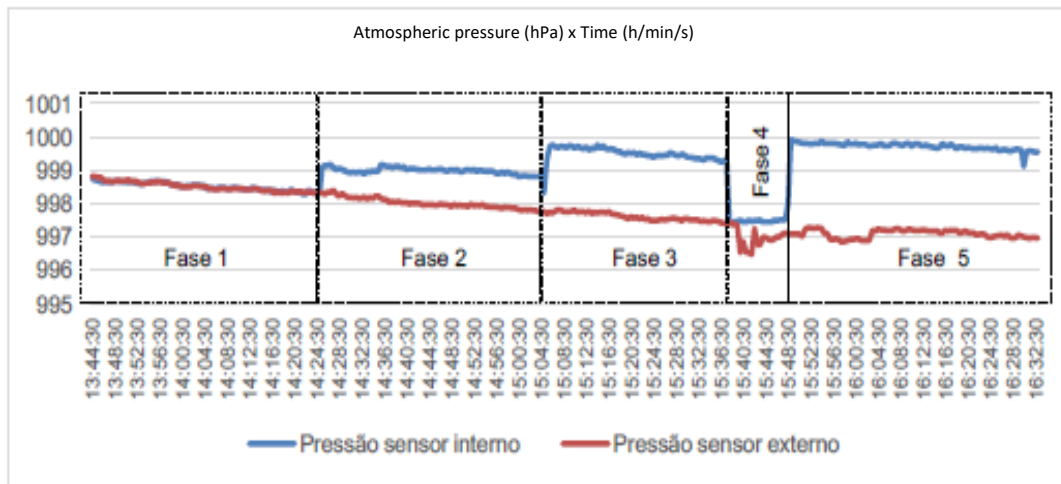
- Phase 1. Tractor stopped and cabin door open for sensor stabilization.
- Phase 2. Tractor stopped and cabin door closed, ventilation system at full power, air circulation system open with the outside with dirty air filter and rear window of the machine partially open.

Phase 3. Tractor stopped and cabin door closed, ventilation system at full power, air circulation system open with the outside and clean air filter and window closed (ISO 14269-5:1997 standard).

Phase 4. Tractor stopped and cabin door opened for operator entry/exit.

Phase 5. Tractor moving and cabin door closed, ventilation system at full power, air circulation system open with the outside and clean air filter and window closed (ISO 14269-5:1997 standard).

Figure 6 – Behavior of atmospheric pressure (internal and external) as a function of the weather



Source: Adapted from Aita (2018).

Considering the design generated and described above, it is reinforced that the decision-making process of the equipment design determines parameters for internal and external measurement of the agricultural machine cab. According to Marquez [12], through a simultaneous collection of data – external and internal – one obtains the conditions for a real comparison of the data with each other, allowing the analysis and evaluation of the agricultural cabin.

4 CONCLUSION

The article presented the design developed for multi-parameter equipment for verification of the protective capacity of agricultural machinery cabins – MonitorCab. The equipment allows data collection for the evaluation of cabins by employing differential comparative analysis between parameters (atmospheric pressure, ultraviolet radiation, temperature, and relative humidity) measured inside and outside the cabin, presenting itself as a useful resource to be used in the inspection and/or certification and homologation tests, which contributes to the identification of problems in existing

products and improvements in new cabin designs committed to quality and safety protection.

REFERENCES

ABHO. ASSOCIAÇÃO BRASILEIRA DE HIGIENISTAS OCUPACIONAIS (ABHO). Available at: <http://www.abho.org.br/abho/> Accessed on: Dec. 14, 2018.

AITA, José Carlos Lorentz. **Desenvolvimento de equipamento de medição de pressão, radiação ultravioleta, temperatura e umidade relativa em cabines de máquinas agrícolas**. Tese apresentada ao Curso de Pós-Graduação em Engenharia Agrícola, da Universidade Federal de Santa Maria (UFSM-RS), 2018.

BRASIL. Ministério do Trabalho. Norma regulamentadora n° 15 (NR 15): Atividades e operações insalubres. Diário oficial da República Federativa do Brasil, Brasília, 2014. Available at: <https://www.gov.br/trabalho-e-previdencia/pt-br/composicao/orgaos-especificos/secretaria-de-trabalho/inspecao/seguranca-e-saude-no-trabalho/ctpp-nrs/norma-regulamentadora-no-15-nr-15#:~:text=A%20NR%2D15%20estabelece%20as,adicional%20de%20insalubridade%20aos%20trabalhadores.> Accessed on Jul. 14, 2022.

BS EN 15695-1:2009. Agricultural tractors and self-propelled sprayers. Protection of the operator (driver) against hazardous substances. Cab classification, requirements, and test procedures. 2009.

CAPACCI, Enrico; RONDELLI, Valda. Tractor cab to protect the operator from hazardous substances in spray application. **International Conference of Agricultural Engineering**, July/2014, Zurich. Available at: <http://www.geyseco.es/geystiona/adjs/comunicaciones/304/C03720001.pdf> Accessed on: Jul. 27, 2016.

CORRÊA, Maria. Cabines – Segurança para o operador. **Revista A Granja**, edição 706, out/2007.

ISO – INTERNATIONAL STANDARD. ISO 14269-5. **Tractors and self-propelled machines for agricultural and forestry–operator enclosure environment**. Part 5 Pressurization system test method. 1997.

KUSHWAHA, S. K.; TIWARI, A.C. Evaporative cooling comfort in agricultural tractor cabin. **Revista da Sociedade Brasileira de Ciências e Engenharia Mecânica**. Technical Paper, outubro 2015. Available at: <https://link.springer.com/content/pdf/10.1007/s40430-015-0442-1.pdf>. Accessed on: Jul. 01, 2020.

MÁRQUEZ, Luiz. Tractores agrícolas: tecnología y utilización. Ed. B&H (Blake y Helsey Espanã S. L., editores) – Madri, Espanã. 2012. ISBN 978-84-935183-5-6.

MESKHI, B.; Bulygin, Y.; Shchekina, E.; Maslensky, V. Elements of microclimate normalization system in the cabin of TORUM grain mandy combine. **XII International Scientific Conference on Agricultural Machinery Industry**. IOP Conf. Series: Earth and Environmental Science 403 (2019) 012089 doi:10.1088/1755-1315/403/1/012089. Available at: <https://iopscience.iop.org/article/10.1088/1755-1315/403/1/012089/pdf>. Accessed on: Jul. 07, 2020.

PAHL, Gerhard; BEITZ, Wolfgang; FELDHUSEN, Jorg; GROTE, Karl-Heinrich. **Projeto na engenharia: fundamentos do desenvolvimento, eficaz de produtos, métodos e aplicações**. São Paulo: Blucher, 2005.

PEIXOTO, Neverton H.; FERREIRA, Leandro S. **Higiene Ocupacional I**. Santa Maria: UFSM, CTISM; Rede e-Tec Brasil, 2013. ISBN 978-85-63573-19-3.

ROMANO, Leonardo Nabaes. **Desenvolvimento de máquinas agrícolas: planejamento, projeto e produção**. Ed. Blucher Acadêmico, São Paulo, 2013. ISBN 978-85-8039-084-1.

SCHLOSSER, José Fernando; CORRÊA, Maria Ila. Perspectiva de ensaios de máquinas agrícolas no Brasil. **Agri World**, ano 2, nº 3, p.100-106. 2011.

ZEWDIE, R; KIC, P. Microclimate drivers' cabin of combine harvesters. **6th International Conference on Trend in Agricultural Engineering**. 7-9 September 2016, Prague, Czech Republic.