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Proposal for Monitoring and Control System of Oxygen Consumption for A Hospital Nurse in Manaus, Brazil

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ABSTRACT

In early January 2021, the health system of the city of Manaus, a metropolis in the Brazilian Amazon, faced the problem of a lack of medical oxygen for its patients. Health facilities due to overcrowding, caused by the Covid-19 disease, led to several deaths from suffocation. On January 14, 2021, with the shortage of input, there were 176 confirmed deaths in the city of Manaus. It was clear that the use and management of this input needed to be improved. In this sense, the general objective of this work is to present a proposal for a system for monitoring and controlling oxygen consumption for a hospital nurse in Manaus. The methodology used was the scientific-technological one, consisting of two parts. The first is scientific, producing the necessary knowledge for elaborating the second part of a technological nature. The first stage consisted of formulating the problem, collecting and organizing the data that allowed the generation of the answers sought; the second stage consisted of prototyping, which is the materialization of the responses obtained in the first part, where the structural and functional elements of the technology are presented. The intended results with the application of this proposal are a) the optimization of the use of oxygen, b) reduction of costs with this input, c) the introduction of intelligent schemes in the supply of the wards,d) and predictability of stocks for the supply chain and management body. The goal is the improvement of the functioning and management of health in the State of Amazonas.

Keywords: *Monitoring system; Control system; Hospital oxygen consumption; Ram 4.0; Scientific-technological method.*

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I. INTRODUCTION

In early January 2021, the health system of the city of Manaus faced the problem of a lack of medical oxygen for its patients. Health facilities due to overcrowding, caused by the Covid-19 disease, led to several deaths from suffocation. On January 14, 2021, with the shortage of input, there were 176 confirmed deaths in the city of Manaus. The scenario led family members to mobilize to buy, on their own, medical oxygen from a private company, thus meeting the needs of their hospitalized loved ones. It helps to supply empty oxygen cylinders and receive donations of full oxygen cylinders. The catastrophic situation experienced by the inhabitants of the capital of the state of Amazonas led to a social mobilization established on the internet as "SOS Manaus" and "Manaus Por Um Respiro."

The situation forced the transfer of more than 500 patients to other Brazilian states. The crisis shocked both Brazil and the world. It revealed the lack of management and failure in decision-making by the authorities who downplayed the dangerousness of the COVID-19 virus pandemic. The confrontation with the chaos that spread through the city of Manaus affected both the public and private sectors, even influencing the patients who had their home treatment. Based on this scenario (trying to work in a preventive way, in an attempt to avoid the absence of this essential input, but vital for the maintenance of life), the following guiding question of the research was established: what are the components of a system able to control and monitor the patient's oxygen consumption through the medical internet of things?

The lack of oxygen in the capital of the state of Amazonas caused several deaths from asphyxiation. This proposal tries to promote an alternative to prevent the non-occurrence of chaos in the city of Manaus in 2021. The idea is to create a monitoring and control system that can guarantee the measurement through an oxygen flow meter connected to a digital interface, which will generate consumption information in real-time every minute. The information goes through a database, where an algorithm will be created to analyze parameters of consumption of liters of oxygen per minute, consumption of liters of oxygen per hour, consumption of liters per day, and consumption of liters of oxygen per month, among others.

In this sense, the general objective of this work is to present a proposal for a system monitoring and control of oxygen consumption for a hospital nurse in Manaus. For this, we sought to a) highlight the advantages of the real-time oxygen consumption monitoring and control system, b) identify strategies that can reduce or eliminate the risks of medical oxygen shortages, and c) collect data that could represent the digital interface device that will generate information on medical oxygen consumption in real-time. The methodology used was the scientific-technological one, proposed by Nascimento-e-Silva (2020; 2021a; 2021b; 2021c).

As a medical gas control solution through IoT, the multi-sensor system with intelligent monitoring will be able to track real-time parameters of all equipment interconnected on a single platform. This system with IoT application will be able to satisfactorily evaluate different variables, such as compressed air, O2, N2O, and CO2, which fall within the ABNT NBR regulations responsible for medical gas inputs. Thus, the system will be adequate to the norms, being able to be executed in other types of hospitals of greater and lesser complexity.

This proposed system will provide information to facilitate the use of an automated mechanism that will control product stock levels and medical oxygen consumption trends. This data will be available in a visual panel and help control usage measurements for each patient. Due to the digital interface and connectivity with the nursing station, the system will promote optimizing the health team's process.

This device replaces the manual flowmeter with a dashboard and digitally visualizes the patient's oxygen consumption data. If necessary, this consumption can be changed remotely, thus providing the measurement of the amount of oxygen prescribed by the doctor. This technological web will connect the concentrated oxygen system, the proposed device, and the nursing station. When an intercurrence occurs, an audible signal will be activated, alerting the responsible team that a particular situation needs attention.

II. MONITORING: LITERATURE SYNTHESIS

Arif et al. (2022) say monitoring is a continuous function. The term function, both in the mathematical and industrial sense, denotes responsibility over something to make that thing work. When you say that someone has the role of accountant, you are saying that he is responsible for the accounts of a particular organization. The function of monitoring is to collect data and information to feed management so that the decision-making process is based on this data and information. Monitoring provides managers and all organizational units with this data and information as their raw material for decisions or for carrying out their activities. In the case of monitoring in the medical field, the provision of data provides stakeholders with information about an event, helping with interventions that can be made before progress is lost. It is the case with the cardiac monitor. This device shows the health team the data referring to the patient's vital signs, allowing these professionals to have the opportunity to know the client's health status in the period related to the monitoring, thus being able to intervene if it's necessary.

Monitoring can also be seen as a regulator and decision-maker at the same time, as the study by Frendi and Pulungan (2022) shows. The idea of regulation stems from the understanding that the parameters offered for specific equipment must remain within their limits and consider the parameters of the systems that use them. If these data do not conform to those established, appropriate actions must be taken. In terms of monitoring, the data collected possibly guide interventions to achieve a satisfactory result. It is the case of the pacemaker, as well as the continuous monitoring of glucose, two different technologies, each with its well-defined functions, adopted for the management of diseases such as bradycardia and diabetes, respectively, whose data and information also serve to perform adjustments to specific treatments

The study by Dzięgielewska, Konarkowska and Górny (2022) shows a third way for science to view monitoring, equivalent to surveillance. The idea of surveillance stems from the fact that mechanisms and artifacts are used to collect data and information continuously, similarly to what guards and security and surveillance professionals do. In this case, surveillance can be assimilated in the medical field using different instruments and technologies, all connected with the same purpose, almost always for health promotion. If these instruments and technologies are not working correctly, the surveillance process will not occur properly, which can hamper the process and compromise the intended results.

The studies by Andrew et al. (2021) and Borrie; Bigart (2021) refer to monitoring as a repeated and systematic measurement. In the industrial environment, this type of measurement is required to ensure that processes operate efficiently, with quality, reaching the final product. In this way, the product ends up being measured in real-time at the location it is located. With adequate control of this technology, the consumption of raw materials will be monitored remotely and even in real time by its supplier. That's how the monitoring system works with the help of various equipment and software, favoring the monitoring of possible complications in a given location,as with ABPM, 24-hour ambulatory blood pressure monitoring. A blood pressure device is placed on the client's arm, connected to a meter, on the client's waist. This way, there will be regular measurements every 15 minutes, for 24 hours to map the client's blood pressure.

Monitoring can also be defined as an ongoing process, as the study by Abdullahi (2021) points out. During the industrial revolution, the production of a product takes place continuously. The system's supplyconstantly happens so that the formed product is discharged simultaneously. In this way, the raw material enters on one side, and the derived product leaves on the other side without stopping the system, thus ensuring more products are manufactured in a shorter period. The health area has a similar action. Continuing education brings new professionals different experiences, thus helping them to learn essential skills for their work process. The execution of this activity in the health area tends to encourage learning capacity development, causing permanent improvements in the quality of health care.

Monitoring can be defined as sampling (Tony, 2020). The sample is a common word used by the population of scientists. It ends up being defined by the data collected, referring to a people or procedure studied. In a course conclusion work, it analyzes an event it has selected to research. This way, exploring the entire population or choosing a procedure is unnecessary, so data manipulation is more straightforward, saving time and resources. Within this context is monitoring.It refers to the data set of a product or procedure.It has the status of completion, before, during, and after completion. It is the case ofdata transparency to combat the SARS-CoV-2 virus responsible for the COVID-19 disease. The country monitors these datato be aware of new disease cases, deaths related to the virus, and the number vaccinated against the disease.

III. THE PROBLEM

The severity of the disease does not determine the term pandemic. It refers to the geographic distribution of the disease. There are multiple outbreaks of COVID-19 in various countries and regions of the world. The bubonic plague, caused by the bacterium Yersinia pestis, which caused the Black Death, can spread through contact with infected fleas and rodents: it killed between 75 and 200 million people in ancient Eurasia. The Orthopoxvirusvariolae virus, responsible for the smallpox disease, spent three thousand years in circulation worldwide, eradicatingit in 1980. The first cholera epidemic was recorded in 1817, killing hundreds of thousands of people. Its bacterium *Vibrio cholerae* has undergone several mutations, causing other new epidemic cycles, thus being considered a pandemic. Its transmission is through consuming contaminated water or food, which is more common in underdeveloped countries. The Spanish flu, caused by a subtype of the influenza virus, may have killed between 40 and 50 million people. The symptoms were similar to the SARS-CoV-2 coronavirus, responsible for the disease COVID-19. And there was no cure either. In the 21st century, the first pandemic was caused by the H1N1 virus, which caused swine flu, and killed 16,000 people. It is transmitted through respiratory droplets in the air or on a contaminated surface.

Since the beginning of 2020, the world has been facing the pandemic arising from the COVID-19 virus. About 5 million people have died worldwide, surpassing 680 thousand in Brazil, due to the disease. It is an infectious disease caused by the SARS-CoV-2 coronavirus. It causes symptoms such as fever, tiredness,dry cough, loss of taste and smell, muscle pain, headache, throat, nausea or vomiting, and difficulty breathing in the most severe cases. The variants give the virus circulation in the world named alpha, beta, gamma, delta, and ômicron, in addition to the subvariants, which are being monitored, as they represent a greater risk for the population.

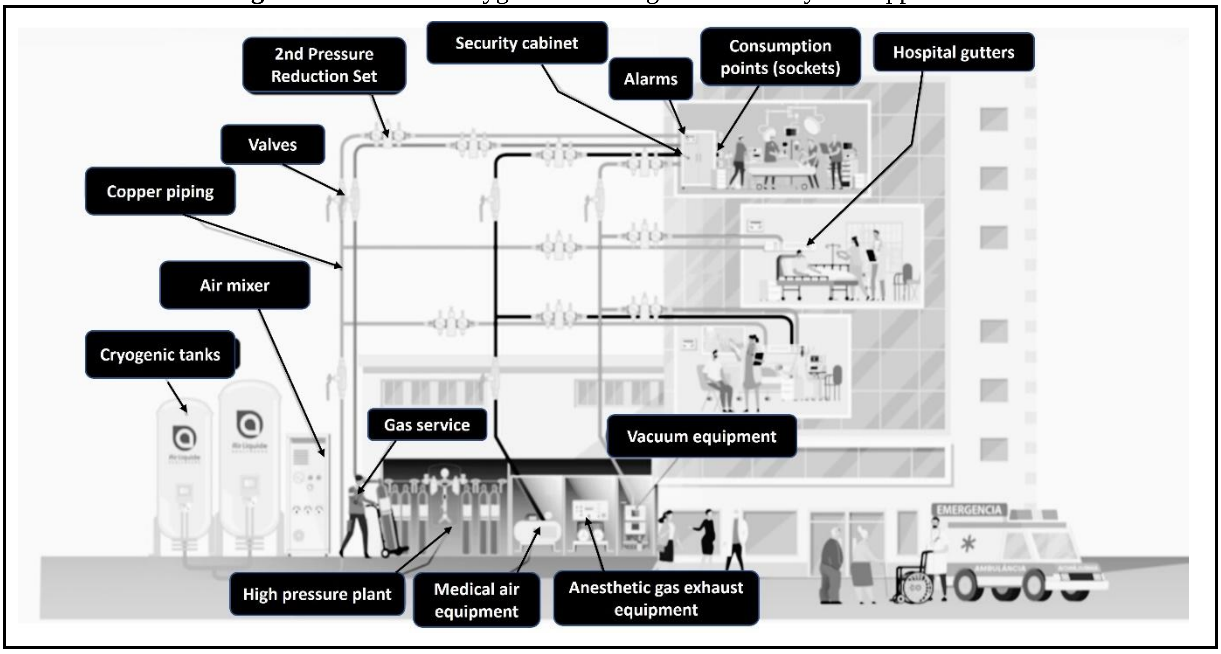
Coronaviruses, because they are everywhere, are the second leading cause of the common cold, although until the last few decades, for humans, they have not caused more than the common cold. Seven types of human coronaviruses that cause severe acute respiratory and Middle East respiratory syndrome have already been identified; in these, the SARS-CoV-2 is responsible for generating the disease of COVID-19. On January 30, 2020, the World Health Organization (WHO) determined the new coronavirus as a Public Health Emergency of International Concern (PHEIC). It is the highest alert level the WHO has, per the International Health Regulations, to try to stop the spread of the virus. The WHO characterized COVID-19 as a pandemic on March 11, 2020.

Covid-19, in its most severe form, can affect several organs and is characterized as a systemic disease. Of all patients diagnosed with covid-19, 20% ended up with the moderate or more severe form of the disease. It can cause pneumonia, an infection that affects the lungs, and that can have several causes, including can be a complication of COVID-19. It causes respiratory discomfort in people. The amount of oxygen in the bloodstream of 89% is the minimum acceptable to keep cells healthy. A collection of substances has formed occupying the spaces between the alveoli and the blood because oxygen cannot make the crossing. This way, the SARS-CoV-2 infection spreads and damages the alveoli and surrounding tissues. As the immune system tries to fight the disease, fluid and dead cells can build up in the lungs. In other cases, people can develop acute respiratory distress syndrome (ARDS), a progressive type of respiratory failure that occurs when the sacs in the lungs fill with fluid and make breathing difficult. In many cases, people end up needing the help of mechanical ventilation. In situations like these, a way to monitor and control oxygen consumption is required, whose technological feasibility can be provided by the Rami architecture, more precisely, via the internet of things.

The introduction of IoT into the oxygenation concentrator system is how the system's sensors and actuators interconnect on the web, many embedded with ubiquitous intelligence and controlled by the internet. It intends to create a system based on IoT, which will make the connection in real time of people and objects with the help of technology, acting invisibly in the intervention in the deliberations in remote times of the human being. The result will be its intense integration with the control and operation of medical gas equipment. Developments in underlying technologies allow "things" to be signaled, detected, and monitored remotely, as shown by studies by Jenal et al. (2022), Balouch, Wafa and Ahmad (2022) and Oliveira et al. (2022).

In the hospital sector, the IoT emerges as a powerful mechanism to help control all levels of supply chains for medical gases and life support equipment. It is a tool capable of uniting production detection and monitoring, analyzing the development of hospital infrastructure, and equipment performance in realtime. It also evaluates the procedures and stock control of medical gases and projects the demand so that there are no problems of lack of supplies and improve the control and management of hospital environments. It is, therefore, a sophisticated technology of remote operation that can ensure a better quality of operation of the supply center, effectively supervising the quality, quantity, and traceability, and even the conditions of medical gases, as can be seen from the studies by Mishra and Rasool (2019), Muneeswaran et al. (2021), Muratyan et al. (2023) and Sowbaranika et al. (2022). Figure 1 shows an oxygen control and monitoring scheme in a hospital unit.

Figure 1. Scheme of oxygen monitoring and control system application



Source: Availablein https://pt.healthcare.airliquide.com/equipamento/instalacoes-gases-medicinais

The internet of things tends to improve the traditional internet, aiming to interconnect devices that are handled daily (SHARAKHIN; LEVCHENKO;RENZIN, 2021; HUANG; WANG; LIN, 2019; SHABBIR et al., 2020). IoTmakes it possible for devices/devices/environments to communicate, which optimizes people's time and can be controlled via cell phone, generating several opportunities and increasing sectors such as health, keeping everyone connected, and interacting with each other. Its applications are divided into several areas of the world economy, such as industrial, residential automation (home automation), transport, logistics, hospital, and commercial, among many others. The Internet of Things was internationally standardized to take advantage of the best technologies already in existence and used in the market.

Among the sectors, health has been investing more and more in new technologies, thus promoting innovation. Using digital devices to monitor diseases is more practical and less invasive, increasing the patient's quality of life. In healthcare, there are three main groups of intelligent machines: external devices, which use biosensors that are in contact with the patient's skin to monitor their health status; internal devices, implanted to replace or help an organ or biological structure that has a particular problem; and fixed devices, which are machines and devices present in clinics and hospitals, operated by specialists and handled by patients only with proper medical supervision. Currently, for example, there is a mechanism called "artificial pancreas" that not only monitors the conditioning of the diabetic's body but also keeps the insulin that must be applied continuously through the data provided, certifying that the rate of this hormone remains at the levels suitable (ZHOU; ISAACS, 2022; VALLIS; HOLT, 2022; HETTIARACHCHI et al., 2022; VAN VELDHUISEN et al., 2022).

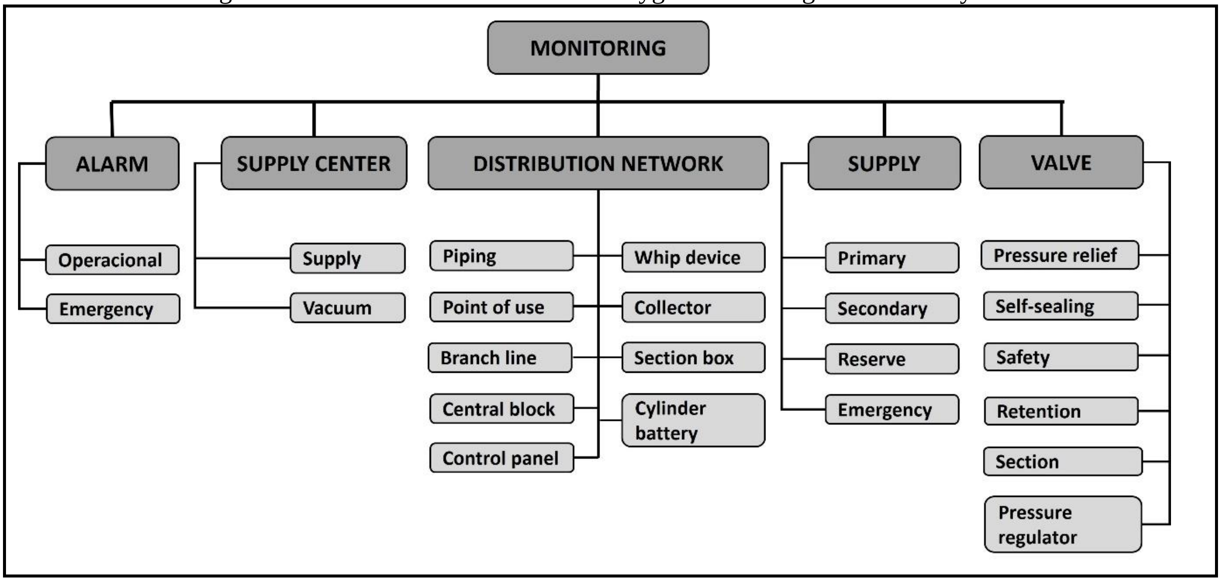
At the height of the pandemic, many countries faced the collapse of their healthcare systems due to high contamination. The situation is further aggravated by the fact that more and more people need to be hospitalized without the infrastructure to guarantee all reception. There was a lack of beds, equipment, and even a workforce. It was to help health professionals and offer them possibilities for optimizing their work. There may be facilitation in these aspects, that another segment within the IoT emerged, the internet of medical things (IoMT). Smart beds are examples of this (ZHOU et al., 2021; SILVA et al., 2021; SHARMA; MITTAL; DUBEY, 2022). These technologies can monitor remotely, through more than 30 crucial patient data, such as weight, body temperature, heart rate, oxygen level, and blood pressure, as well as the patient's reactions and how often they get up or need to be turned. It issues an alert for those who have reduced mobility or are at risk of falling, providing safety and awareness to the responsible team and the patient.

Considering the lack of beds, as happened at the height of the pandemic, an intelligent bed has an integrated system that can notify the availability of new mattresses as they are released. The medical internet of things acts on the possibility of equipment communication and the automation of processes, affecting a man/machine interaction (MA et al., 2022; MARTIN, 2022; AWONTUNDE et al., 2022). All this information is stored in the cloud (SUJITH et al., 2022; ZHANG et al., 2022; GOSWAMI; JADAV; SONI, 2022), thus contributing to a better constitution of the patient's history, in a more complete and practical way. be shared with the necessary professionals. It can reduce hospital stay and costs, as well as patient safety and comfort. It is, therefore, at the patient's side, inside and outside clinics and hospitals.

IV. MONITORING SYSTEM COMPONENTS

The construction of the oxygen consumption monitoring and control system follows the logical scheme of the whole system, understood as a scheme for transforming inputs and outputs (EMBLEMSVÅG; EMBLEMSVÅG, 2022; HIDAYAT et al., 2022; TRYFONAS et al., 2022;). In this sense, here, the components of the system will be specified, with brief information about their fundamental functions to generate the results (outputs) of the system. Structurally, its components are alarms, a central supply subsystem, a distribution network, and valves. Each component, in turn, presents its essential subcomponents, as shown in the data in Figure 2.

Figure 2. Structural architecture of the oxygen monitoring and control system



Source: prepared by the authors.

Alarms are sound signals composed of operational and emergency units. A center is a system control unit directed to control supplies and vacuum. The supply unit comprises four subunits (primary, secondary, reserve, and emergency) to guarantee the supply of oxygen demand in the hospital unit. The distribution network shall consist of nine subunits (pipe, use station, control panel, branch, central block, harness, collector, cylinder batteries, and section box) through which the supply is made and monitored. Valves are regulation and safety mechanisms composed of six subunits (pressure relief, self-sealing, safety, pressure regulator, retention, and section). Let us briefly look at each of these units and their respective subunits.

4.1 Alarm

A device emits visual and audible signals to indicate any abnormal occurrence requiring intervention.

4.1.1 Emergency alarms

It is an alarm that indicates the need for intervention by the health team. It must be identified, and the worker at the observation site must be adequately instructed on the measures to be taken when such alarms are triggered. Identified as such and independent of the operational alarm, which act when the gauge pressure of the distribution network reaches the minimum operating value. The building's electrical grid must power it. It must also have its power switched automatically to the independent emergency source of the alarm itself or the health service, within a maximum of 15 s, in the event of a power failure.

4.1.2 Operational alarms

It is an alarm that indicates failure in the primary supply and the need for intervention by the technical team. It must be labeled as an "operational alarm" and audible and visual, the latter of which can only be canceled by re-establishing the predetermined operating pressure. The building's electrical network must power it. It must also have its power switched automatically to the independent emergency source of the alarm itself or the health service, within a maximum of 15 s, in the event of a power failure.

4.2 Central

This plant is a set formed by the supply center, distribution network, and use stations intended to provide a continuous supply of oxygen, nitrous oxide, air, and vacuum to the system.

4.2.1 Supply Center

The reserve supply's stock control is the health service's responsibility. It must have a primary and reserve supply consisting of controls, pressure switches, and valves, and the SCO must follow the provisions of ABNT NBR 13587. The reserve supply must be dimensioned according to the average adequate consumption of the health service or, if this is unknown, the maximum likely consumption and supplier distribution variables. This storage must be at least 150% of the average adequate consumption of the replacement period of the reserve supply established between the health service and the supplier.

4.2.2 Vacuum center

It must contain a primary supply with one or more pumps, with a total capacity of 100% of the maximum probable health service consumption, and a secondary supply, with one or more pumps with equivalent power. It must be designed to maintain a pressure below atmospheric pressure of at least 39.97 or 61.33 kPa of maximum absolute pressure at the use points furthest from the vacuum center. It must have two bacteriological filters in parallel for treating the air to be released into the atmosphere, installed before the vacuum reservoir. Or must have another system to treat the aspirated and exhausting fluid, which prevents microbiological contamination of the environment.

4.3 Supply

It is recommended that, when located near incinerators, boilers, and other heat sources, this source must be protected so that it maintains a temperature below 54 C°.

3.3.1 Primary supply

The primary supply source to the distribution network consists of a battery of gas cylinders, gas concentrating equipment, cryogenic tank, vacuum generator, air compressor, or gas mixing system. Table 1 shows the functional characteristics of all components and subcomponents of the proposed approach.

Table 1. Components and their functionalities applied to oxygen consumption

Components	Applied functioning
1. Alarm	
1.1 EmergencyAlarms	It indicates the need for intervention by the health team.
1.2 OperationalAlarms	They indicate failure in the primary supply and the need for intervention by the technical team.
2. Central	
2.1 Supply Center	It must have a primary and reserve supply composed of commands, pressure switches, and valves.
2.2 Vacuum center	It must contain a primary supply with one or more pumps, with a total capacity of 100% of the maximum probable health service consumption.
3. Supply	
3.1 Primarysupply	It is the primary source of supply to the distribution network.
3.2 Secondarysupply	For immediate and automatic use, replace and complement the primary supply.
3.3 Reserve supply	For immediate and automatic use in case of failure or maintenance of the primary and secondary supply.
3.4 Emergencysupply	Locations where life support equipment is usually used, should be provided with emergency supplies for each centralized system.
4. Distribution network	
4.1 Piping for gases and clinical vacuum	Piping for medical gas, medical device gas, and vacuum cannot be supported by other piping.
4.2 Point of use	They must comply with ABNT NBR 13730, ABNT NBR 13164, and ABNT NBR 11906.
4.3 PressureControlPanel	They are intended to control gas supply pressure.
4.4 Extension	Derivation of the distribution network.
4.5 Central Block	Set formed by pressure regulating valves, pressure gauges, maneuver, block, and check valves.
4.6 Whip device	It makes the interconnection of cylinders to the collector.
4.7 Collector	The tube is intended to connect the cylinders to the supply system.
4.8 CylinderBattery	Set of compressed gas packaging cylinders.
4.9 Section box	Box with a tamper-evident, transparent window, large enough to allow handling of the valve installed inside.
5. Valves	
5.1 Pressurereliefvalve	It is a valve that allows gas to escape to the outside.
5.2 Self-sealingvalve	Valve for the automatic and immediate blocking of gas flow (flow).
5.3 Safetyvalve	Pressurereliefvalve.
5.4 Pressureregulatingvalve	Valve capable of regulating and reducing the existing pressure in the plant.
5.5 Checkvalve	It is a valve that allows the passage of gas or vacuum in only one direction.

Components	Applied functioning
5.6 Sectionvalve	It is installed right after the switchboard exit and before the first branch, in an accessible place, to be operated in an emergency.

Source: data collected from NBR 12188 and RW Engineering.

4.3.2 Secondary supply
Supply source for immediate and automatic use in substitution and complementation of the primary supply in a rotation system, consisting of a battery of gas cylinders, cryogenic tank, vacuum generator, or air compressor.

4.3.3 Reserve supply
Supply source for immediate and automatic use, in case of failure or maintenance of the primary and secondary supply, consists of a battery of gas cylinders, cryogenic tank, vacuum generator, or air compressor. This type of source is not intended for regular operation and does not rotate with other kinds of supplies.

4.3.4 Emergency supply
Locations where life support equipment is usually used, must be provided with emergency supplies for each centralized system. The medical gas cylinder intended to meet the emergency supply must be equipped with a pressure regulator in immediate use conditions. It must be transported exclusively in an appropriate car.

4.4 Distribution network
Set of pipes, valves, and safety devices intended to supply gases or vacuum through branches to places where appropriate use stations exist.

4.4.1 Piping for gases and clinical vacuum
It is used to dimension the distribution network of medical gases and gases for medical devices.The maximum inlet pressure is 8 gf/cm^2 and the minimum pressure at each point of use is 4 kgf/cm^2, except nitrogen, whose full pressure inlet must be 20 kgf/cm^2, and the minimum pressure at each point of service must be 7 kgf/cm^2. The nominal distribution pressure between 4 kgf/cm^2 and 5 kgf/cm^2, the pressure at each use station less than 110% of the normal distribution pressure, with the system operating at zero flow, and greater than 90% with the system operating at the design flow. Piping for medical gas, medical device gas, and vacuum cannot be supported by other piping. It must be supported by appropriate hooks, clamps, or endorses and placed at intervals conditioned to the pipe's weight, length, and material so that it does not displace the installed position.

4.4.2 Point of use
They must comply with ABNT NBR 13730, ABNT NBR 13164, and ABNT NBR 11906. It must be equipped with a terminal (pipe or billet), a self-sealing valve, and a legible label with the name, abbreviation, symbol, or chemical formula, with color according to ABNT NBR 11906. It must indicate the primary source: O2 93 for medical oxygen 93, and O2 99, for medical oxygen 99. It must be provided with a sealing and protection device at the outlet when not in use.

4.4.3 Pressure control panel
Set of devices intended to control the gas supply pressure.

4.4.4 Extension
Derivation of the distribution network, which directly supplies one or more points of use

4.4.5 Central block
Set formed by pressure regulating valves, pressure gauges, maneuvering, blocking, and retention valves, and other safety and control devices.

4.4.6 Whip
It is a device intended for the interconnection of cylinders to the collector.

4.4.7 Collector
Tube intended to connect the cylinders to the supply system using coils, harnesses, or flexible hoses to conduct the gas to the central block.

4.4.8 Cylinder battery
Set of high-pressure compressed gas packaging cylinders connected to a collector before the central block.

4.4.9 Section box
Box with a tamper-evident, transparent window, large enough to allow handling of the valve installed inside.

4.5 Valve
Valves are devices capable of modifying the pressure or flow (flow) of gases or vacuum in the centralized system.

4.5.1 Pressure relief valve
It is a valve that allows gas to escape to the outside if the pressure in the system reaches levels above the pre-established level.

4.5.2 Self-sealing valve
It is a valve for the automatic and immediate blocking of the flow (flow) of gases and vacuum when any accessories are disconnected from the point of use.

4.5.3 Safety valve
Pressure relief valve.

4.5.4 Pressure regulating valve
Valve capable of regulating and reducing the existing pressure in the significant or distribution network to a pressure compatible with that of use.

4.5.5 Check valve
It is a valve that allows the passage of gas or vacuum in only one direction.

4.5.6 Section valve
A section valve must be installed in the network and distribution immediately after the exchange's exit and before the first branch, in an accessible place, to be operated in an emergency. It must be located so that it is safe from any damage. They must be arranged in such a way that, when the gas supply to one branch is closed, the supply to the other branches is not affected.

4.6 Regulatory Standards
Given the nature of the technology application intended to create, a series of regulatory norms and standards need to be obeyed. Among them, IEC 62443, IEC 62890, IEC 61360, IEC 61987-1:2006 and automationML stand out. Let's see briefly what each one is.

4.6.1 IEC62443
This international series of standards address safety for industrial automation and control systems. This standard presents a series of norms, technical reports, and information that specify the procedures necessary to protect an industrial automation and control system (IACS). ISA/IEC62443 defines lifecycle requirements for developing products intended for use in the IACS environment to meet the cybersecurity requirements described for each element. The lifecycle description includes defining security requirements, dark design, secure implementation (including coding guidelines), verification, validation, defect management, patch management, and the product's end-of-life.

4.6.2 AutomationML
It is associated with a series of open standards (IEC62714) to describe production plants or plant components. These standards provide a data exchange format for industrial automation systems engineering.

4.6.3 IEC 62890
This standard establishes the basic principles for managing the life cycle of systems and components used in industrial processes' measurement, control, and automation. These principles apply to various industrial sectors. The standard also provides definitions and reference models related to the life cycle of a type of product and the lifetime of an instance of a product. It defines a consistent set of generic models and terms of reference. The main models depicted are life cycle, structure, and compatibility.

4.6.4 IEC 61360
This standard specifies principles for defining properties and associated attributes and explains methods for representing verbally expressed concepts with appropriate data constructs available in IEC 61360-2. It also

describes the principles for establishing a classification hierarchy from a collection of classes. Each of these classes represents either a technical concept in the electrotechnical domain or a domain related to electrotechnology.

4.6.5 IEC 61987-1:2006
This standard defines a generic structure in which the characteristics of industrial process measurement and control equipment products with analog or digital output must be arranged. Its purpose is to facilitate understandingof product descriptions when they are transferred from one party to another. It applies to the production of process measurement equipment catalogs provided by the product manufacturer and helps the user to formulate their requirements.

V. CONCLUSION

This study presented a proposal for an oxygen consumption monitoring and control system for a hospital ward in the city of Manaus, a metropolis in the Brazilian Amazon, which suffered heavy loss of life during the height of the Covid-19 pandemic. This system takes into account both structural and functional aspects. In the first case, it points out the constituent elements of the technology; in the second, it shows how each works to generate the expected partial and global results. His proposition followed the ties of Industry 4.0, which has its philosophy and implementation recommendations in the Rami 4.0 architecture.

Implementing this proposed monitoring system can enable local hospitals and the entire state of Amazonas to use oxygen more appropriately and rationally. This procedure, in turn, tends to reduce as much as possible the costs of operations of hospital systems while allowing more predictability about the available stock and the optimized functioning of the supply process. The purpose of these rationalizing and optimizing procedures is, first of all, to guarantee patients' health, help to maintain their lives, and their satisfaction as customers and users of the system.

This conception only became possible due to the understanding of the Rami 4.0 architecture as a reference for implementing operations systems following the guidelines of industry 4.0. The system implemented follows the dictates of the necessary connections between the product, the operations system, management schemes at different levels and layers, and interconnections with the supply systems, suppliers, and internal logistics. In this way, by applying the guidelines of the Rami 4.0 architecture to hospital systems, this proposal intends to improve the functioning and management of health in the State of Amazonas.

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