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Optimizing Medical Gas Pipeline Systems in Healthcare: Lessons from the COVID-19 Era

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Abstract: ***The article explores the implementation and importance of Medical Gas Pipeline Systems MGPS in healthcare, especially during the COVID-19 pandemic. It highlights the systems components, standards, and maintenance requirements. The focus is on ensuring uninterrupted, safe, and efficient delivery of essential medical gases, with a case study from a healthcare facility in India. The significance of MGPS in modern healthcare and the lessons learned from the pandemic are also discussed. Medical gas pipeline system was not a regular phenomenon before the covid 19 era in the Indian set up. It was limited only to few institutions of higher learning, and some private hospitals. Piped medical gases became life saviour during the pandemic and after. MGPS usually consists of a single source for each of following, from which various gases like oxygen, medical air, nitrous oxide and vacuum are supplied to multiple areas through rugged metal pipes. They are easy to operate from a single manifold in a room. This system needs daily review and periodic maintenance for its maximal efficiency. Though this system is initially expensive to construct and commission but when it is complete, it is very efficient, cost effective and long lasting. In our facility we have a MGPS system through which oxygen and vacuum is provided to 180 beds and supply of other gases along with the above mentioned two to operation theatre complex.***

Keywords: Hospital management, oxygen supply, nitrous oxide, compressed air, vacuum, COVID 19, healthcare infrastructure, Medical Gas Pipeline System

1. Introduction

Although MGPS has made the delivery of medical gases to various locations at the same time, very easy, but for the same their construction and maintenance needs to be of world class standards to ensure the long term safety and efficiency of system. The two main standards pertaining to MGPS are National Fire Protection Association 99 (US) and HTM 02- 01 (UK). Others are British Standards EN 737 (BS EN 737), Compressed Gas Association, Canadian Standards Association, and the International Standards Organization. Cylinders should follow American Society for Testing and Materials standards, and pipes should have Lloyd's certification as per BS 2871. [2, 3, 4, 5]

The manifold room must be monitored round the clock by trained professional and must have a generator back up, to avoid any untoward incident.[1] The location should be marked clearly for ease of identification in the event of an emergency.[7] It houses the control panel which allows a flow of 3000 L/min at 4.1 bar from the vacuum insulated evaporator (VIE) and relays alarm to secondary panels located throughout the hospital.[8]

Oxygen
Oxygen a life saving gas is the main requirement of any medical unit. Its demand increased significantly during the covid 19 era. According to BS EN 737-3:2000, there should be three independent supply sources.[6] A primary source, secondary source and a reserve source to ensure that there is uninterrupted supply of this life saving gas. In our set up we have a PSA plant installed in our premises with the capacity of 1000ltrs/min as a primary source, two banks of type-D oxygen cylinders each consisting of 20 cylinders in line as a secondary source and a reserve source consisting of 6 type-D cylinders. These sources were attached to an automatic exchanger to ensure that whenever the pressure of oxygen went down by the requisite level there was automatic shifting from one source to another. A contingency plan with the requirement for three days was prepared by having oxygen cylinders in rotation and kept in reserve. Other modes for providing oxygen are oxygen concentrators which are readily available in our setup. They can give oxygen to either one or two patients depending upon the make and model at the rates varying between 5 to 15 ltrs/min. Liquid medical oxygen (LMO) is an another option for providing oxygen which is initially though expensive to construct and maintain but when commissioned it is very economical as it can store large amount of oxygen in a very compact space. The colour coding of oxygen is green or white throughout the pipeline to ensure easy identification for fault recognition and preventing any hazard, which can occur due to any mismatch.

Compressed Air
It refers to the air used as medical air in OT, ICU for weaning the patients and various other purposes and surgical air in OT to run pneumatic drills. The plant must ensure a flow of 3 KL/min at 8 bar, reduced thereafter as per requirement. Medical air needs a flow rate of 80 L/min at 4 bar and surgical airflow at the rate of 350 L/min at 7 bar.[1] The medical air quality should meet the standards laid by the European Pharmacopoeia,[6] The medical air should be free from contaminants like nitrous and carbon monoxide. The colour of compressed air line is black.

Nitrous Oxide
Coded as blue pipeline in some of the MGPS systems it is mainly required in the operation theatre during general anesthesia procedures. In our setup we have a twin supply for it one at the manifold consisting of three cylinders and one in the OT complex itself to ensure uninterrupted supply.

Vacuum
Coded as yellow pipeline it is supplied to each bedside in every ward to ensure suction of the patient. Vacuum pressure

of −300 mmHg is required at the terminal unit with a flow of 40 L/min.[1]

Anesthetic Gases Scavenging system
it is usually coded as gray pipeline. The anesthetic gases are considered as hazardous substance therefore they need scavenging and proper disposal. To control the greenhouse effect of the anesthetic gases, the anesthetic gas scavenging systems should incorporate a canister system which captures the unused gases, filters, and recycles them. [9]

Pipeline system
These pipes are usually constructed from copper as per ASTM standards to ensure safety and durability. They are intercepted by the area valve service units (AVSUs) and area alarm panels (AAPs). These service units allow us to maintain a specific section without interrupting the whole supply system.

Figure 1: Area Valve Service Units

Figure 2: Area Alarm Panel

The final outline connection to the terminal points are secured by DISS (Diameter Index Safety System) along with colour coding. Every new installation needs to be tested and verified as per the laid guidelines before putting the system into use. [2, 6, 10] our system was checked thrice before commissioning with the following parameters:-

1) Pressure at each valve point and volume of the gas particularly oxygen delivered at the set calibrated value.
2) Whole system was checked and nitrogen flushed to ensure removal of any dirt particles.
3) Pipeline system was subjected to 1.5 times the working pressure for safe operations.

Even after all these arrangements a contingency plan must be made for back up as if there is system failure at any level it can result in a catastrophe. For this in our institution we made a provision of installing oxygen cylinders with double stage regulators and oxygen concentrators in each and every ward. For vacuum failure portable suction units were kept.

Even with best possible human efforts, errors are inevitable, therefore to reduce any error following things are carried out in our hospital:-

1) Log book is maintained daily with entries of stock of filled and empty cylinders, pressure and flow readings.
2) Manpower is trained to identify small faults. Staff is trained to identify any drop in flow and pressure at AVSU or AAP and inform the higher authorities
3) AMC is done with the company which has manufactured the system.
4) Manifold room is manned 24 hrs by a trained person.
5) Regular mock drills are conducted to ensure preparedness for any adverse event.

This system has saved lives during covid, eased lives of healthcare professionals, providing life saving oxygen gas when and where required. This system, crucial during COVID-19, requires ongoing maintenance and legal coverage, demanding strong leadership and thorough training for handlers.

The study underscores the critical role of MGPS in healthcare, especially highlighted by the COVID-19 pandemic. It emphasizes the need for high standards in construction, maintenance, and training for efficient and safe operations. The experience shared from a specific healthcare facility offers valuable insights for global healthcare management.

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