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A Review Paper on Low Cost Ventilator Design in The COVID-19 Pandemic Condition

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Abstract — *this paper describes a review on design of a low-cost portable mechanical ventilator for use in mass casualty cases and resource-poor environments in Covid-19 pandemic condition under INR Rs. 1 Lakh. Ventilator device are external devices that are designed to assist a patient to perform a particular task. The act of moving air into and out of the lungs is called breathing, or, more formally, ventilation. It is to keep up or improve a breathing ability of a person if he encounters problem in his own breathing. Based on this study it is possible to understand and get a clear map of need of low-cost ventilator in this covid-19 outbreak condition.*

Keywords-*Covid-19; Ventilator; breathing; low-cost; pandemic condition.*

I. INTRODUCTION

A mechanical ventilator is an automatic machine designed to provide all or part of the work the body must do to move gas into and out of the lungs. The act of moving air into and out of the lungs is called breathing, or, more formally, ventilation.

The simplest mechanical device we could devise to assist a person's breathing would be a hand-driven, syringe-type pump that is fitted to the person's mouth and nose using a mask. A variation of this is the self-inflating, elastic resuscitation bag. Both of these require one-way valve arrangements to cause air to flow from the device into the lungs when the device is compressed, and out from the lungs to the atmosphere as the device is expanded. These arrangements are not automatic, requiring an operator to supply the energy to push the gas into the lungs through the mouth and nose. Thus, such devices are not considered mechanical ventilators.

Automating the ventilator so that continual operator intervention is not needed for safe, desired operation requires three basic components:

1. A source of input energy to drive the device;
2. A means of converting input energy into output energy in the form of pressure and flow to regulate the timing and size of breaths; and
3. A means of monitoring the output performance of the device and the condition of the patient.

1.1 Inputs

Mechanical ventilators are typically powered by electricity or compressed gas. Electricity, either from wall outlets (e.g., 100 to 240 volts AC, at 50/60 Hz) or from batteries (e.g., 10 to 30 volts DC), is used to run compressors of various types. Batteries are commonly used as the primary power source in the home-care environment but are usually reserved for patient transport or emergency use in hospitals.

1.2 Conversion and Control

The input power of a ventilator must be converted to a predefined output of pressure and flow. There are several key systems required for this process. If the only power input is electrical, the ventilator must use a compressor or blower to generate the required pressure and flow.

1.3 Flow-Control Valves

To control the flow of gas from a compressor, ventilator engineers use a variety of flow-control valves, from very simple to very complex. The simplest valve is just a fixed orifice flow resistor that permits setting a constant flow to the external tubing that conducts the gas to the patient, called the patient circuit.

1.4 Control System

In the simplest terms, the control system of a ventilator is comprised of components that generate the signals that operate the output valve and the exhalation manifold to obtain the desired output waveforms and modes of ventilation. Control systems may be based on mechanical, pneumatic, fluidic, or electronic components.

1.5 Outputs

Just as the study of cardiology involves the use of electrocardiograms and blood pressure waveforms, the study of mechanical ventilation requires an understanding of output waveforms. The waveforms of interest are the pressure, volume, and flow.

1.6 Operator Interface

The operator interaction with the ventilator mainly happens through the ventilator display. The display or interface has evolved in parallel with the ventilators. The key to this evolution are the technological advances in the last three decades. The microprocessors, the digital displays, and the interactive screens have all permeated from other technological advances into the ventilator world.

There are different Input:

1. Operator Inputs
a. Inspired Gas Concentration
b. Oxygen
c. Heliox
d. Nitric Oxide
2. Trigger Variables
a. Time
b. Pressure
c. Flow
d. Volume
e. Diaphragmatic Signal
3. Target Variables
a. Pressure
b. Inspiratory Pressure
c. Rise Time
d. Tidal Volume
e. Minute Ventilation
f. Inspiratory Flow
4. Alarms
5. Ventilators Outputs (Display)
a. Numeric Value
b. Trends
c. Waveforms and Loops
d. Advanced Graphics

II. LITERATURE REVIEW

2.1 Covid-19 Outbreak (Public Health Emergency of International Concern declared by WHO)

Coronavirus disease (COVID-19) is an infectious disease caused by a new virus. The disease causes respiratory illness (like the flu) with symptoms such as a cough, fever, and in more severe cases, difficulty breathing. There is no vaccine for the disease.

Coronavirus disease spreads primarily through contact with an infected person when they cough or sneeze. It also spreads when a person touches a surface or object that has the virus on it, then touches their eyes, nose, or mouth.

WHO Director-General Dr. Tedros Adhanom Ghebreyesus declared the 2019-nCoV outbreak a Public Health Emergency of International Concern, the Committee noted that early detection, isolating and treating cases, contact tracing and social distancing measures – in line with the level of risk- can all work to interrupt virus spread.

In the worst case scenario India will require up to 200000 ventilators to serve for the COVID-19 patients if the country starts experiencing communal spread (Local Transmission). And right now the country has no more than 57,000 ventilators as per a Brookings report. And a large portion of the existing ventilators are to be dedicated for other emergencies such as Heart attack, Stroke etc. According to a report by WHO, about 5% of the COVID-19 patients require ventilators as the lung failure is one of the dangerous outcomes of infection

2.2 Available Ventilator

2.2.1 DHAMAN- I

Dhaman-I is built with most essential features to support the patient in critical time of breathing and completely user friendly for Medical Personnel. Team Jyoti is enable the first in India to protect the people against COVID- 19 pandemic situations.

Figure: 1 Dhaman- I

Available modes in DHAMAN-I Ventilator

a. PCV (Pressure Control Ventilation)
b. APCV (Assistant Pressure Control Ventilation)
c. CPAP (Continuous Positive Airway Pressure)
d. HFNT (High Flow Nasal Therapy)
e. CPAP

2.2.2 PREVAIL NY by JMA

PREVAIL NY is designed to augment the existing ventilator supply in the short term when no other traditional U.S. Food and Drug Administration (FDA)-approved ventilation options are available, providing key basic ventilation functions to relieve doctors of the need to make life-and-death decisions due to ventilator shortages.

Figure: 2 PREVAIL NY

The system supports the low tidal volume ventilation strategy for acute respiratory distress syndrome, as used in patients with COVID-19. This device provides control of three key ventilation functions: respiratory rate (breaths per minute), tidal volume (how much air is delivered) and inspiratory/expiratory (inhale to exhale) ratio. The device is compatible with components that retain humidification and offer HEPA filtration.

III. FUTURE WORK

We can develop the ventilator by considering these all the required parameter and basic function which are necessary to treat the corona virus infected patient.

3.1. Better Operator Interface

As modes have become more complex, the operator interfaces on ventilators with computer like displays has become complicated. Multiple options for control settings tend to get lost in layers of different screen views. Worse, screen views are often customizable such that if strict control is not exerted by an individual hospital department, each ventilator will be “stylized” by individual operators and chaos will ensue.

Very few studies have been published on ease of use or the problems with current displays. We need to identify optimal ways for ventilator displays to provide three basic functions: to allow input of control and alarm parameters, to monitor the ventilator’s status, and to monitor the ventilator–patient interaction status.

3.2. Better Patient Interface

The interface between a modern ventilator and the patient is a piece of plastic tubing, that is, the “patient circuit,” whose design has not changed much in several decades. Certainly, humidification systems using heated wires and automatic-temperature control have evolved, but we still are not capable of measuring and directly controlling a primary variable of

gas conditioning: humidity. Indeed, after all this effort at evolving humidification systems, there are data to show that simple, unheated circuits provide better humidification of inspired gas.

3.3. Better Targeting System

Provides a conceptual framework and suggestions for better targeting systems of the future. In essence, evolution in this area involves more and better sensors and the software algorithms required to manage the data they provide. The clear trend here, both in basic research and commercial applications, is to develop "closed-loop" targeting systems based on mathematical models of physiologic processes, or artificial intelligence, or combinations thereof, with the goal of automating the moment-to-moment adjustment of ventilator output to patient needs.

IV. CONCLUSION

On the basis of this study it can be concluded that it is aimed at replace a high cost ventilator by the low cost ventilator during this COVID- 19 pandemic condition. It has all the characteristics what are required during the treating the corona virus infected patient. This can be developed in short time around 10 days and manufacture it under a cost of INR Rs. 1 Lakh. This ventilator has a minimum operator input and necessary digital display with optimum function to treat the corona virus infected people.

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