



## History of artificial lung ventilation apparatus development

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### Abstract

The paper deals with the history of artificial lung ventilation apparatus development. It should be noted that mechanical ventilation has a number of benefits, such as preservation of a stable airway, the possibility for the patient to get oxygen and to clear carbon dioxide. Moreover, it helps the patient not to work hard to breathe. The modernization of this apparatus is vital as it offers patients the chance of survival in hospitals especially during today's coronavirus crisis. This paper describes the history of mechanical ventilation and studies the types of ventilation apparatus. Presents the main differences between the 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup> generation ventilators, as well as the shortcomings of modern devices, which needs to be addressed.

*Keywords:* Artificial lung ventilation apparatus, first generation, second generation, third generation, hardware ventilation, microprocessor, turbine;

### 1. Introduction

The middle of the XIX and the beginning of XX centuries were marked by a significant scientific and technological progress, the first automated ventilators were created. The history of ventilators is conventionally divided into three stages: simple machine ventilation, ventilation improved by the possibility of manual adjustments by medical personnel, and ventilation that is automatically adjusted for a specific patient.

For several decades, the primary task of mechanical ventilation has been to provide ventilation. It was only in the 1970s when the approach was changed and the ventilation technique was based on eliminating lung damage. A modern ventilator is a complex device that requires special knowledge from doctors and service personnel.

### 2. Types of ventilation apparatus

Artificial ventilation of the lungs (ALV) is the basis of respiratory support and in this paper we study some stages of its development. Until the mid-1960s, lung ventilators (the first generation) were used to maintain an alveolar ventilation with a constant flow to control a breathing capacity and frequency and to increase the oxygen concentration in the respiratory gas mixture by means of a mechanical drive connected to a cylindrical bellows (Figure 1).

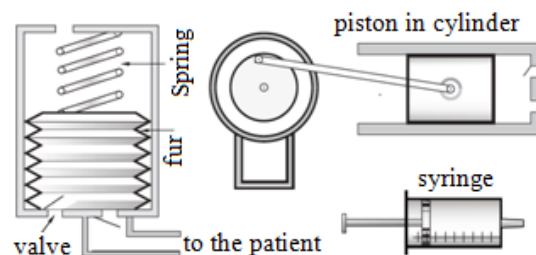


Figure 1 - Mechanism of the ventilator

In the apparatus scheme the main structural blocks can always be seen: 1) the inhalation generator is a source of gas supplied to the patient and it is usually made in the form of a pump, the working body of which is a fur, a piston or a membrane; 2) a switchgear with a mechanical, pneumatic or electromagnetic drive with a frequency equal to the breathing frequency and it sets the required directions of gas movement in different phases of the respiratory cycle; 3) a switchgear control mechanism. The apparatus scheme also contains blocks for heating, humidifying and purifying the inhaled gas, means for measuring the characteristics of the ventilation system.

The first automated ventilator was the Pulmotor, released in 1907 by a German company "Dräger". It was a compact "gramophone" ventilator [1] complete with an oxygen cylinder and a face mask (Figure 2).

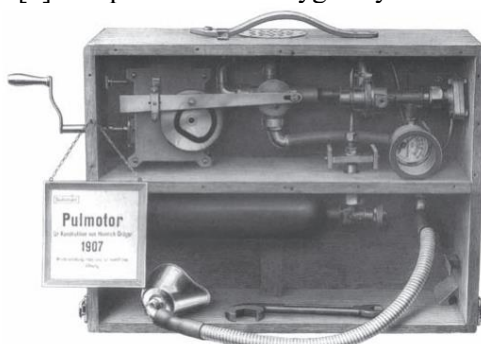


Figure 2 - "Pulmotor" ventilator

The technical innovation of the Pulmotor is the use of an injection type of the device: a suction nozzle for generating ventilation pressure, and a control mechanism for switching the phases of inhalation and exhalation.

This design was developed in the Assistor series. In Assistor 641, the timer of the ventilator was pneumatically actuated, while in Assistor 642 it was powered by electricity (Figure 3).

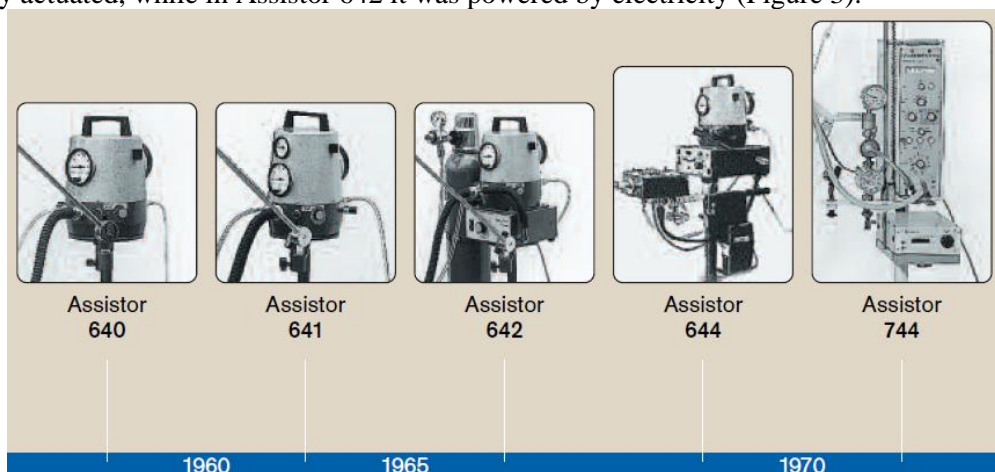


Figure 3 – The range of Assistors

The "Phase" apparatuses are also becoming widespread, where the inhalation generator is made in the form of a pump and can work with any respiratory circuit (half-open, half-closed, etc.), providing a controlled ventilation with passive exhalation, adjustable exhalation resistance, heating and humidification breathing gas supplied to the patient. The "Phase-5" device is considered the world's first serial mechanical ventilation of a compact class with an electric drive (since 1976).

As the knowledge of the clinical physiology of respiration advanced and the design of mechanical ventilators improved, respiratory support became more sophisticated and specialized.

The second-generation ventilator contains a combination of breathing technologies and microprocessors to control ventilators. The first representatives of universal ventilators were UV-1,2 and EV-A [2]. They used valves with an electromagnetic drive and a traditional bag ventilation, but with an electronic control and monitoring. Microcomputers were able to create breathing patterns with graphical monitoring capabilities and it was unthinkable in the previous generation ventilator (Figure 4).



Figure 4 - Intensive ventilation with EV-A (1977)

With intensive care around the world, in 1971 the first SERVO 900 ventilator was introduced (Figure 5), designed by Björn Jonson. It was a small, noiseless and efficient electronic ventilator with a non-reversible breathing circuit, continuous gas exchange monitoring, metabolic assessment and a feedback system. It had a drive from the sources of compressed gases (oxygen, compressed air and nitrous oxide) and at the same time from the electricity mains supplying the control and measurement lines. For the first time, the device could deliver a given volume when ventilating.



Figure 5 - Ventilator SERVO VENTILATOR 900

Further development of ventilators can be observed in the products presented by the company PURITAN BENNETT. The ventilators were capable of ventilating and at the same time controlling the volume and pressure in invasive and non-invasive ways [3]. The Puritan Bennett 840 Ventilator (Figure 6) was equipped with a highly efficient pneumatic system, two microprocessors and a Dual View touchscreen, and an oxygen sensor of inspired oxygen.



Figure 6 - Puritan Bennett ventilator

Later, in 2008, the serial production of the ZisLine ventilator started at the Triton-Elektronik Systems. It has one of the greatest advantages - low cost of consumable materials and required maintenance service.

General multipurpose, monitoring and computer correction capabilities, display availability and communication capabilities, modular components that facilitate the repair are the main advantages of second-generation ventilators.

The main element of the latest generation of ventilators is the introduction of microprocessor technology into modern respirators and the use of an integrated turbine [4]. The applicable types of actuator electric drives are solenoid valve for airflow control, compressor electric drive for creating a constant airflow and air compressor electric drive with the ability to control the flow rate. The devices are usually equipped with sensors for monitoring respiration, flow, pressure, volume and derived parameters to provide careful care to patients with any kind of critical condition. At the same time, not all the possibilities of this technique are used to the full. Therefore, the classification, parameters, modes and features of work is essential for understanding the mechanisms of respiratory support.

A small part of devices with a built-in turbine for ventilation with ambient air will be studied as an example. This is an ENGSTROM 150 ventilator with modular gas monitoring; paramagnetic oxygen sensor; micro-pump nebulizer, spirometry functions and an additional pressure sensor (Figure 8-a).

Portable ventilator CARINA DRÄGER with an electronic oxygen mixer, providing an accurate dosage and control and a unique breathing valve with a programmed leakage control system (Figure 8-b).

In domestic samples of mechanical ventilation, the principle of constructing a switchgear on a combination of pneumo-mechanical and electromechanical actuators prevails, and many parameters of ventilation modes have to be adjusted manually.

Ventilator "AVENTA - M" (Figure 8-c) is equipped with an electric air drive and pneumatic oxygen drive and does not require external compressed air to operate. The general structure of the pneumatic system of the apparatus is shown in Figure 9 [5].



Figure 8 - Ventilators  
a) ENGSTROM 150 b) CARINA c) AVENTA – M

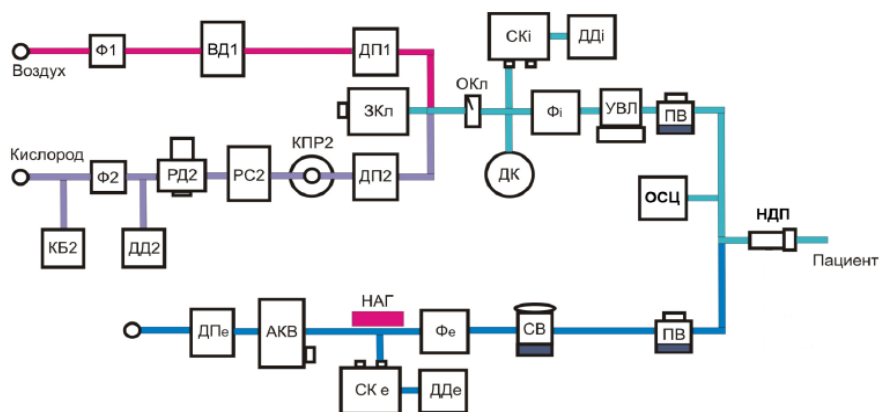


Figure 9 - The structure of the pneumatic system of the ventilator "AVENTA - M"

### 3. Conclusion

A significant drawback of the presented devices is the cost of parts and the lack of sufficient information on the use of new methods of ventilation. Doctors and nurses are faced with expensive, complicated machines with unclear instructions for their use. The setting, monitoring and interpretation of some parameters may be incorrect, and this can lead to potentially harmful, inappropriate use of these ventilation methods.

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