History of Intermittent Mandatory Ventilation prior to 1972. Part one. Special Article

Ronald R. Sanderson RRT [1]

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Abstract

Medical history is often overlooked as advances keep moving forward. Seldom is it that advances in medicine are truly new, unique ideas, but rather built on ideas that have been considered before. Even our latest developments will become history or forgotten as science and medicine advance.

This history of intermittent mandatory ventilation (IMV) is a two-part article in which the first part attempts to show that the concepts and apparatus that involve the now common mode of ventilation have been considered and described for nearly 200 years, if not earlier. This older history is not brought forward to diminish what has been done in the last 50 years, but to enhance awareness of how ideas and even mechanical ventilators change over time.

The second part will describe how those ideas and mechanics changed into what we now call IMV in its many forms.

Keywords: Intermittent Mandatory Ventilation, IMV, History of mechanical ventilation

Authors
1. Ronald R. Sanderson, RRT, DrPH, AE-C. Respiratory Center of Hawaii. Hawaii, USA

Corresponding author: Ron R. Sanderson: ronsan65@gmail.com
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Introduction

Winston Churchill said, "History will be kind to me as I shall write it". This being stated, this author is in part a primary source of this history of Intermittent Mandatory Ventilation (IMV) as I was present and participated to a lesser degree during the development IMV and its metamorphosis to Synchronized Intermittent Mandatory Ventilation (SIMV) which is the basis of most of the modes available on advanced mechanical ventilators today. [1]

I will make every effort to be factual and point out information that is speculative.

The purpose of this article is to trace the history of the IMV concept back through history prior to 1971. The article to follow will bring the history of IMV from about 1971 to the present. Both articles describe a time in the development of mechanical ventilation that is past and most of the "players" have retired or passed away. This time was pretty much the end of an era where front line practitioners could modify ventilators and "see how it worked". This is now highly regulated, and this type of development is primarily the province of ventilator manufacturers and perhaps a small group of research laboratories.

It was interesting to do a short general search of IMV and see the current state of its definition which reflects a current perception of history.

Google Search quote "Intermittent Mandatory Ventilation (IMV) allows the patient to breathe spontaneously between machine-cycled or mandatory breaths. This concept originated in 1955 with an unnamed ventilator designed by Engstrom". We will see that the concept originated much earlier than 1955.

Wikipedia Search quote "Intermittent Mandatory Ventilation (IMV) refers to any mode of mechanical ventilation where a regular series of breaths are scheduled but the ventilator senses patient effort and reschedules mandatory breaths based on the calculated need of the patient. Similar to continuous mandatory ventilation in parameters set for the patients' pressures and volumes but distinct in its ability to support a patient by either supporting their own effort or providing support when patient effort is not sensed. IMV is frequently paired with additional strategies to improve weaning from ventilator support or to improve cardiovascular stability in patients who may need full life support".

The most succinct simple definition among many may be:

"Intermittent mandatory ventilation (IMV) and Synchronized Intermittent Mandatory Ventilation (SIMV) modes combine mechanical breaths with spontaneous breaths. SIMV differs from IMV by synchronizing the initiation of the mechanical breaths with the patient's spontaneous effort. The use of non-synchronized IMV has dramatically decreased because the lack of patient-ventilator synchrony results in patient discomfort and increased work of breathing. Improvements in technology have enabled most ventilators to be synchronized to the patient's respiratory effort." [2]

Currently the most acceptable definition of IMV/SIMV appears in a ventilator mode taxonomy put forth in 2014 by Chatburn, and colleagues. [1] This definition is very clear, and precise, but perhaps too lengthy to be quoted in an introduction.

Did IMV exist before 1971?

Intermittent Mandatory Ventilation (IMV) did not exist prior to 1971; because the concept of allowing the patient on control ventilation to take a spontaneous breath was not called IMV before that time, the name given in 1971 has persisted. It is in common usage at the present time in the medical literature from research to textbooks and operator's manuals.

The concept and practice of allowing the patient on control ventilation to take a spontaneous breath has been around for decades if not over a hundred years. In the simplest example, think of a surgery patient on an anesthesia machine breathing spontaneously and the anesthesiologist squeezes the anesthesia bag to give the patient a mandatory breath. This augmented breath is mandatory to the otherwise spontaneously breathing patient. This is the IMV concept; even though, a little reversed.

Prior to 1971 the IMV concept, spontaneous breathing with mandatory mechanical breaths or continuous mechanical ventilation that allows spontaneous breaths existed.

There are descriptions of mechanical ventilator devices from the more distant past that show capability of the machine to interpose mechanical breaths with spontaneous breaths. Please note that this list is not exhaustive as there are undoubtedly ventilators that had this function that are less well known, particularly if they were developed in countries whose languages do not funnel easily into the English medical literature. In addition, it may be this history goes much further back into time. [3] So let's look back in time.

1963
Amsterdam Infant Ventilator

It appears that the Amsterdam infant ventilator (Figure 1) allowed the infant to breathe spontaneously in 1963. The Amsterdam ventilator had a continuous flow of gas for spontaneous inspiration at the injector head near the patient's airway. (Diagram 1: inflating gas line 11) This ventilator was still in use in the early 1970. [4] Unfortunately, I did not have an opportunity to use it.

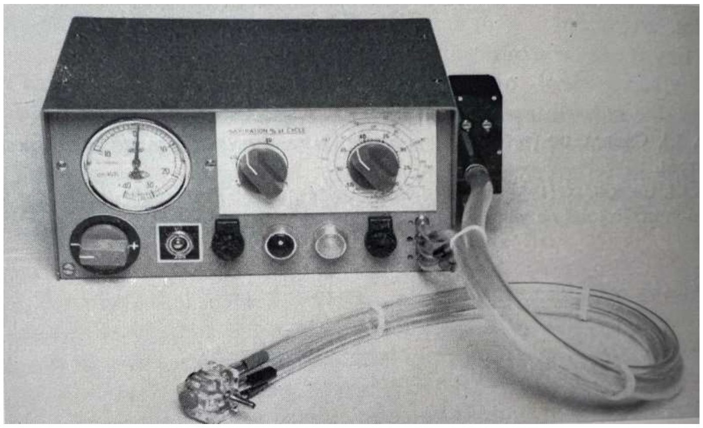


Figure 1: Amsterdam infant ventilator

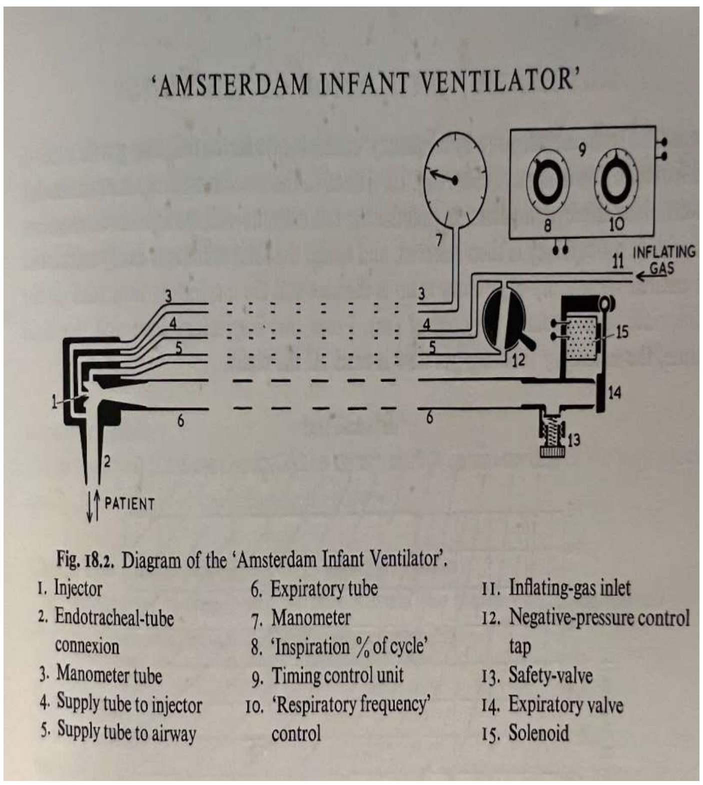


Diagram 1: Amsterdam ventilator schematic

1951
Engstrom Universal Ventilator Model 150

The Google search result of the definition of IMV was partially correct in that the Engstrom universal ventilator Model 150 (Figure 2) gave the patient the ability to breathe spontaneously in 1955 and as early as 1951. The Engstrom ventilator using positive pressure an "occluder" on top of the one-way inlet valve (Diagram 2: valve 5) opened. Then the patient could breathe room air spontaneously.

Since this ventilator was also capable of negative pressure ventilation there was a small window of opportunity for spontaneous breathing during the expiratory phase by drawing gas from the reservoir bag (Diagram 2: bag 23).

Figure 2: Engstrom universal ventilator model 150

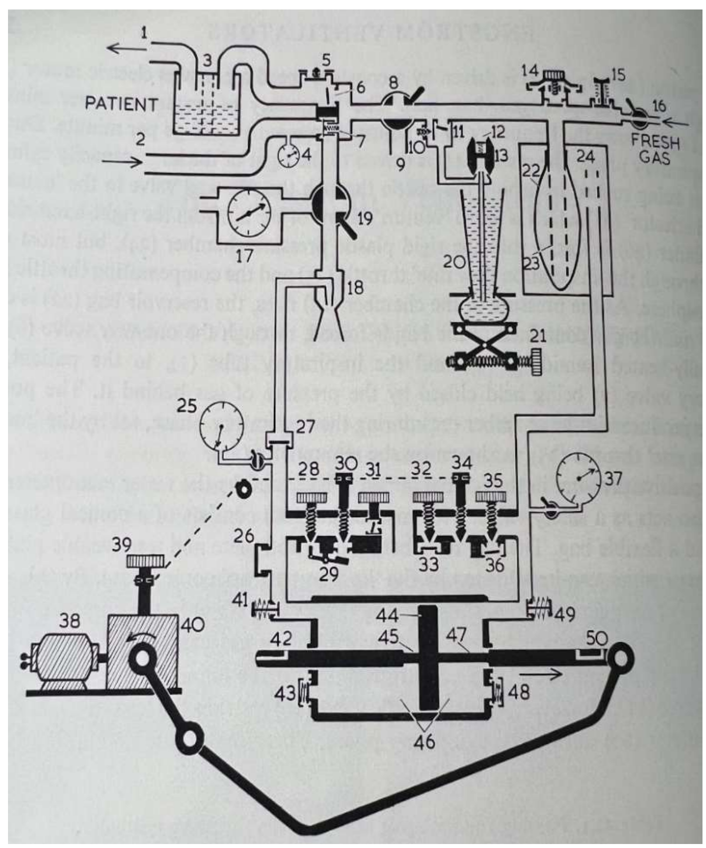


Diagram 2: Engstrom ventilator model 150 schematic

1945
Blease All Purpose Pulmoflator D.3

Even earlier the Blease 'All Purpose Pulmoflator' Deansway Three (D.3) (Figure 3) seemed to have mechanical ability to let the patient take spontaneous breaths as "Fresh Gas" came in through inlet 21 (Diagram 3: #21) when open/closed circuit valve 20 (Diagram 3: #20) activated the open circuit. Spontaneous breathing might have been possible when the ventilator was in closed circuit use in anesthesia as the "fresh outlet" (Diagram 3: #16) is connected to the closed-circuit manifold near the "reservoir bag for manual inflation". (Diagram 3: #29).

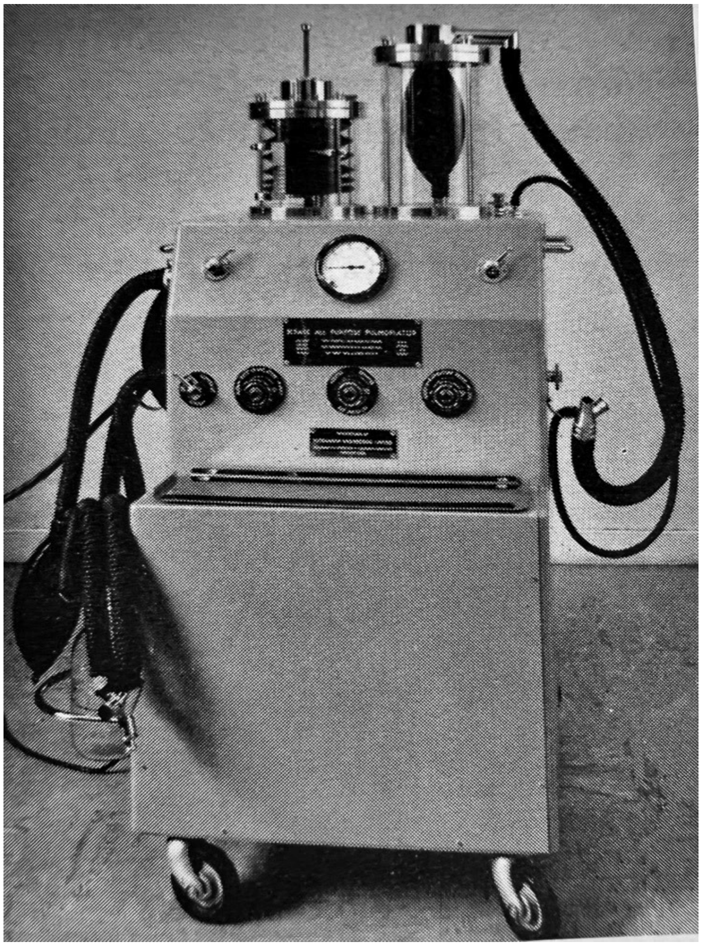


Figure 3: Blease Pulmoflator

1937
Ayre's T-piece

In 1937 Ayre's T-piece [4,5,6] was described and used. Depicted in its most simplistic form (Diagram 4), this was clearly an IMV concept device even though the operator had to provide the mechanical breaths by occluding the exhaust with their thumb. Ayre's T-piece has had many modifications over the years and is still in use. It was from the Ayre's T-piece that the first Baby Bird prototype was developed according to Dr. Robert deLemos (personal communication).

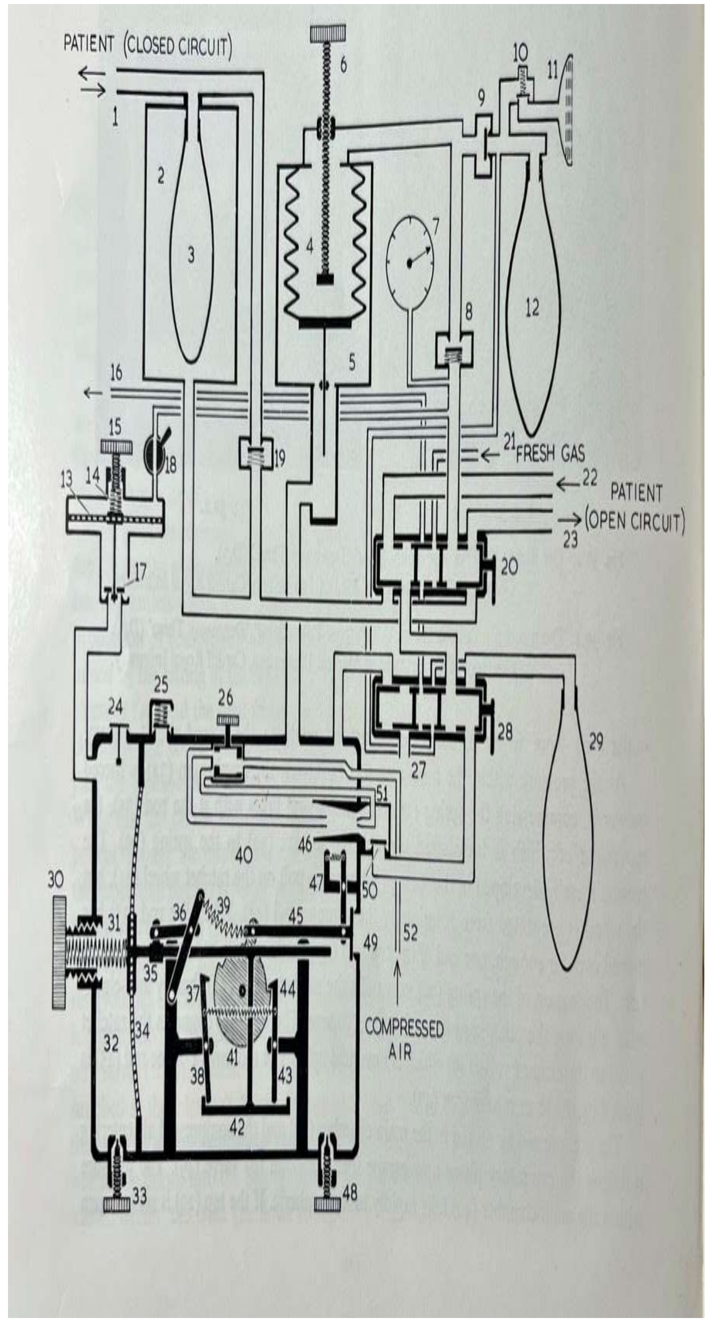


Diagram 3: Blease Pulmoflator ventilator schematic

Looking at the BabyBird it can be seen as just a machine to provide a constant flow of gas to the infant for spontaneous breathing with a mechanism to intermittently close off the flow and direct the gas into the infant's lungs for a mechanical breath at some appropriate mandatory rate, perhaps a mechanical thumb? By the way the BabyBird was the one of the most popular IMV mode ventilators after 1971 and is credited for saving the lives of thousands of premature infants by reducing mortality from Infant Respiratory Distress Syndrome (IRDS) from 70% to 10%. [7]

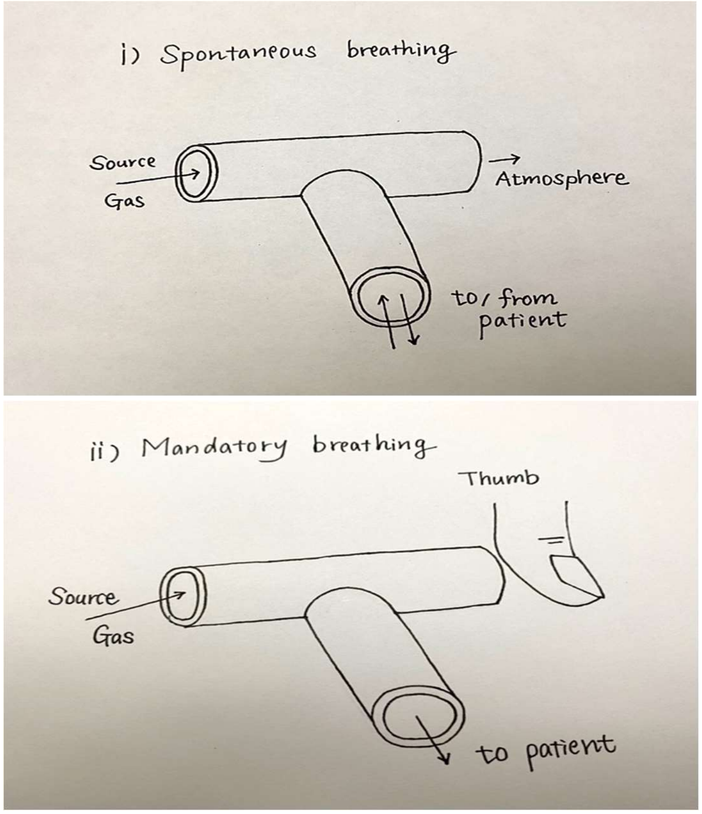


Diagram 4: Ayre's T-piece

1905
Brauer's Positive Pressure Apparatus

Brauer's positive pressure apparatus (Figure 4) is also described as allowing for spontaneous breathing with control positive pressure mechanical ventilation.

The Brauer's apparatus was a head container that sealed around the patient's neck and was connected to a nearby compressor. This ventilator was primarily used for anesthesia. It appears the space between the head of the patient table and the compressor on the left made room for the anesthesiologist to move around the patient and access the sealed side ports of the head container allowing the hands to reach in to provide anesthesia or perhaps keep the airway open.

1888
Fell-O'Dwyer Apparatus

The Fell-O'Dwyer apparatus is a beautifully simple ventilator, however, requiring the medical provider to be actively present holding the metal laryngeal tube in place while periodically occluding the expiratory orifice with the thumb and stepping on the foot operated bellows to deliver a mandatory breath to the otherwise spontaneously breathing patient.

It was used for anesthesia during surgery and well as resuscitation. The metal laryngeal tube looks ominous; however, numbing solutions could be dripped on it before insertion "by touch".

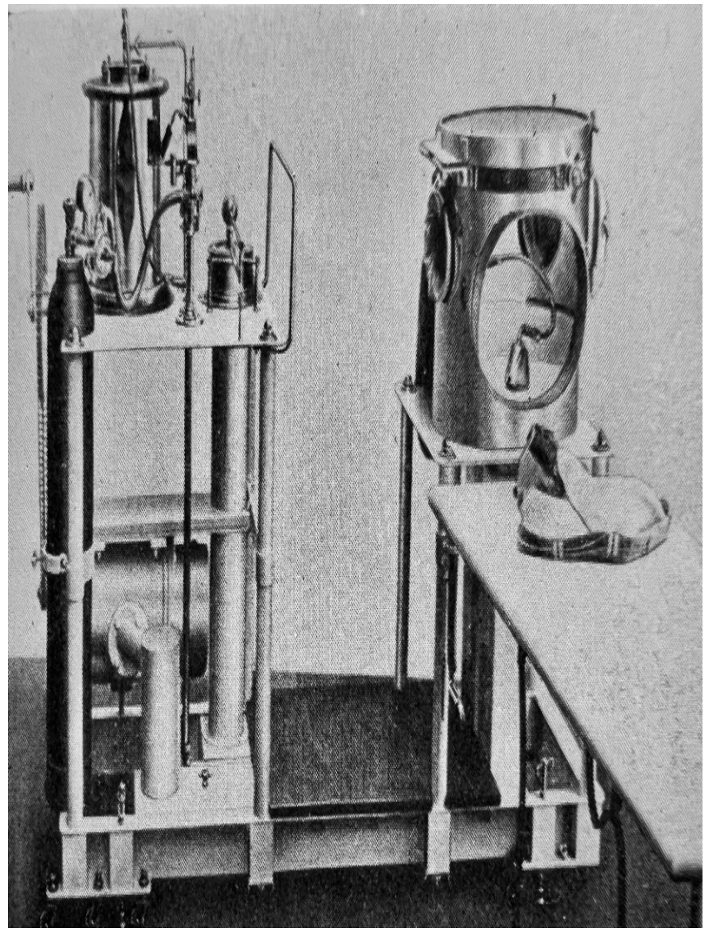


Figure 4: Brauer's positive pressure apparatus

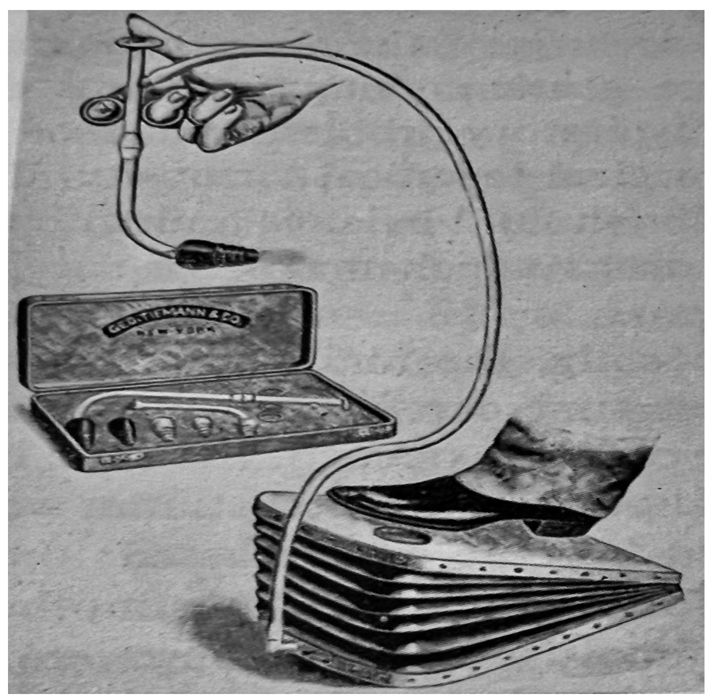


Figure 5: Fell-O'Dwyer apparatus

1887
Four Older Devices

The Handbook of General Therapeutics, Vol 3, 1887 by H. Von (Hugo) Ziemssen [8] very clearly describes at least four devices for the mechanical delivery of "condensed" air to patients via a positive pressure device that was usually interfaced to the patient with a non-invasive face mask much like modern day non-invasive ventilators "BiPAP" machines.

Hauke's boiler apparatus (Figure 6) depicted as Figure 18 on pages 591-592 of The Handbook of General Therapeutics, has the ability to allow the patient to interpose spontaneous breaths with the mechanical breaths provided by the device through a hand operated valve on the top of the unit. Hauke's pneumatic apparatus (Figure 7) had a similar manually operated valve near the face mask.

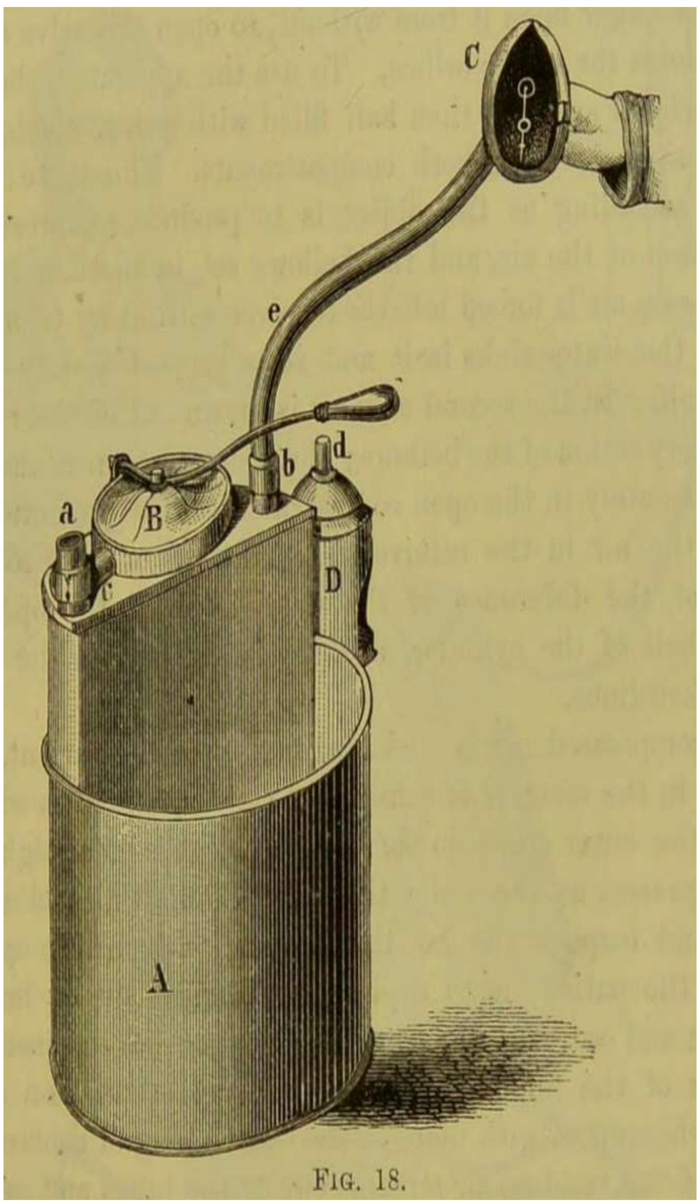


Figure 6: Hauke's boiler apparatus

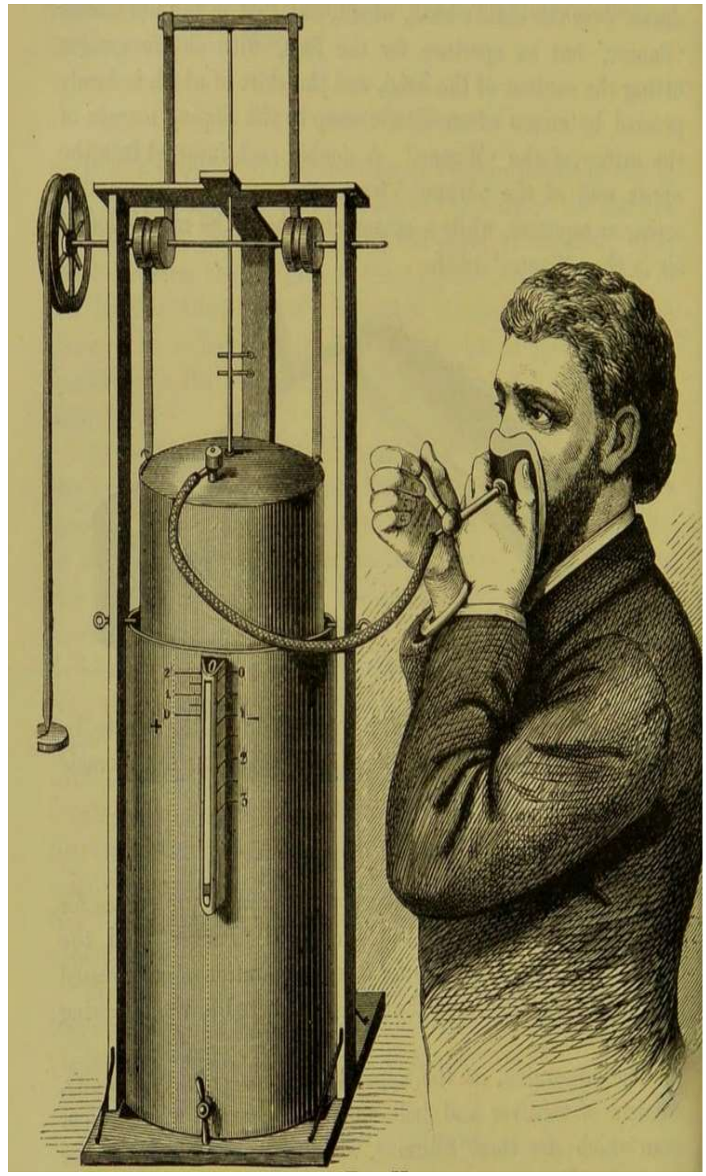
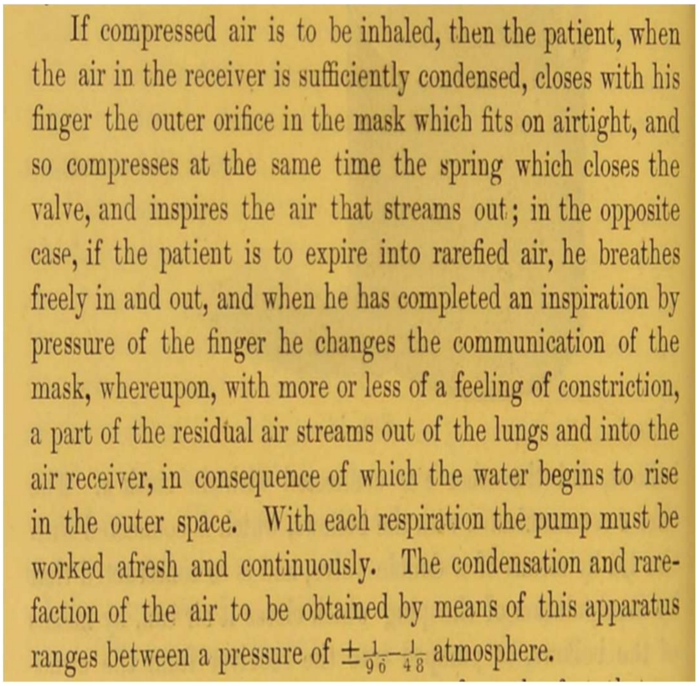


Figure 7: Hauke's pneumatic apparatus

It is interesting to note that these positive pressure breathing devices were primarily used for the provision of "condensed" air to the patient for shorter periods of time than we usually think of for life support ventilators. "Condensed air" appears from the descriptions in the "Handbook" to describe air that has been "condensed" often by the addition of vapors or aerosols of various medications including camphor, thymol, iodine, mercury, and arsenic in addition to various amounts of oxygen, nitrogen and positive pressure.

The text appears to refer to "rarefied air" as air that is neither compressed or condensed, perhaps room air or negative pressure air. "Compressed air" in this handbook seems to be the same as our current usage of the term. The following excerpt regarding Hauke's apparatus describes its use at fractions of atmospheric pressure 1/96 and 1/48 or about 8 and

16 mmHg. It also describes the alternation between mechanical positive pressure breaths and spontaneous breaths.



If compressed air is to be inhaled, then the patient, when the air in the receiver is sufficiently condensed, closes with his finger the outer orifice in the mask which fits on airtight, and so compresses at the same time the spring which closes the valve, and inspires the air that streams out; in the opposite case, if the patient is to expire into rarefied air, he breathes freely in and out, and when he has completed an inspiration by pressure of the finger he changes the communication of the mask, whereupon, with more or less of a feeling of constriction, a part of the residual air streams out of the lungs and into the air receiver, in consequence of which the water begins to rise in the outer space. With each respiration the pump must be worked afresh and continuously. The condensation and rarefaction of the air to be obtained by means of this apparatus ranges between a pressure of $\pm\frac{1}{96}$–$\frac{1}{48}$ atmosphere.

Figure 8: Description of the use of Hauke's pneumatic apparatus

Figures 9 and 10 depict similar devices used at this time that by description in the text of the handbook and the excellent diagrams show the ability to interpose positive pressure breathing and spontaneous breaths. On Schnitzler's Apparatus this is accomplished by activating a valve or orifice labeled "N".

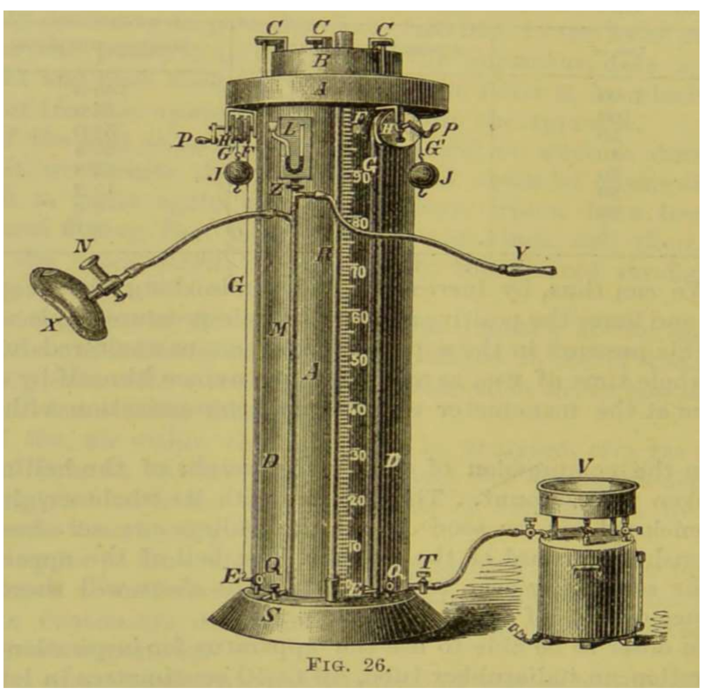


Figure 9: Schnitzler's apparatus

Weil's Double Apparatus seems open for spontaneous breaths by manipulation of a manual lever or handle located near the patient interface. Curiously the lever is in a slightly different location in Ziemssen's illustrations labeled 23 and 24.

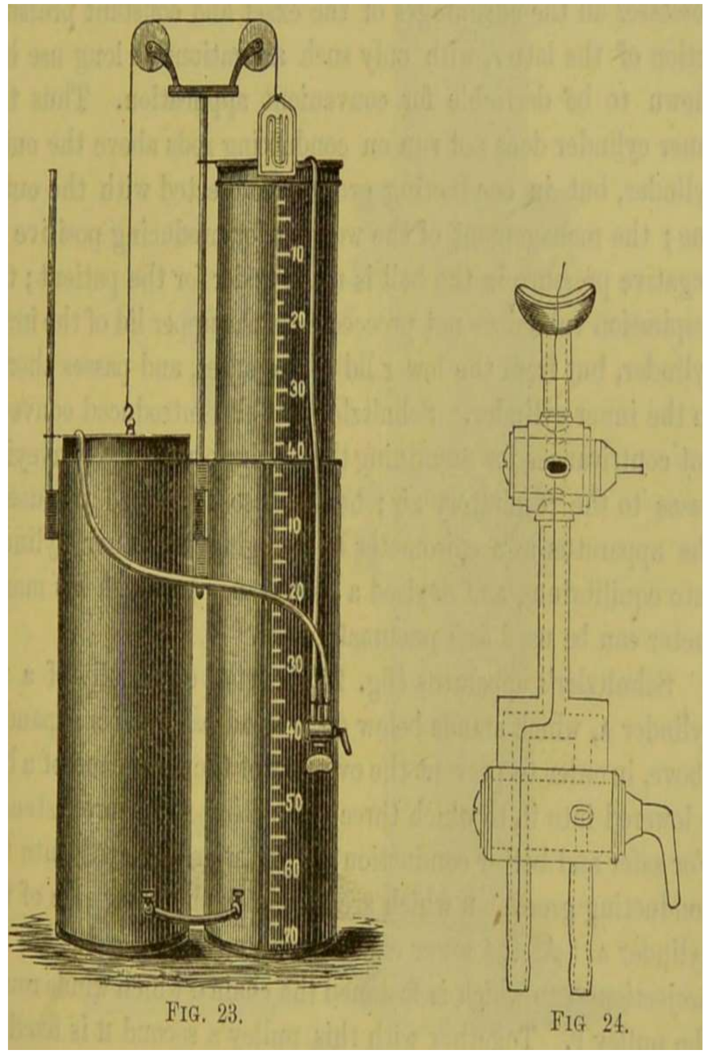


Figure 10: Weil's double apparatus

Conclusion

In conclusion it can be seen that the concept of IMV has been around for a very long time. It is likely that history goes back further if we could follow the literature.

The use of IMV/SIMV became widespread after a very influential paper in the journal Chest [9] in 1973. The second of these two articles will attempt to document the history of IMV at about that time and to the present, 2021.

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