



# History of Mechanical Ventilation Technology

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Cleveland Clinic

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Lerner College of Medicine of Case Western Reserve University

# Disclaimer

- **All views expressed are my own opinion and not necessarily those of the Cleveland Clinic.**

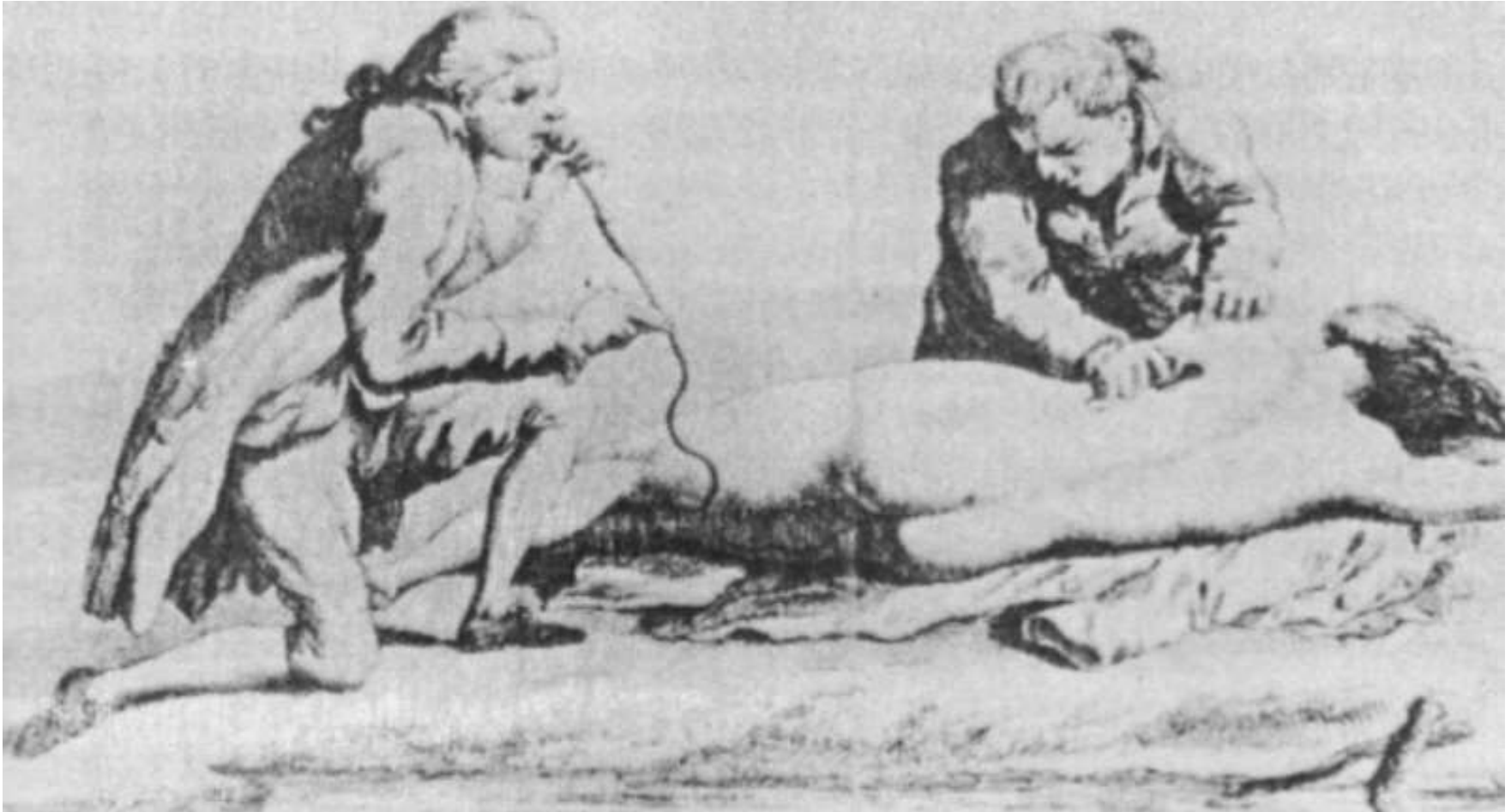
# Disclosure

- **I have affiliations with, special interests, or have conducted business with the following companies that in context with this presentation might possibly constitute a real or perceived conflict of interest: :**
  - IngMar Medical
  - DeVilbiss

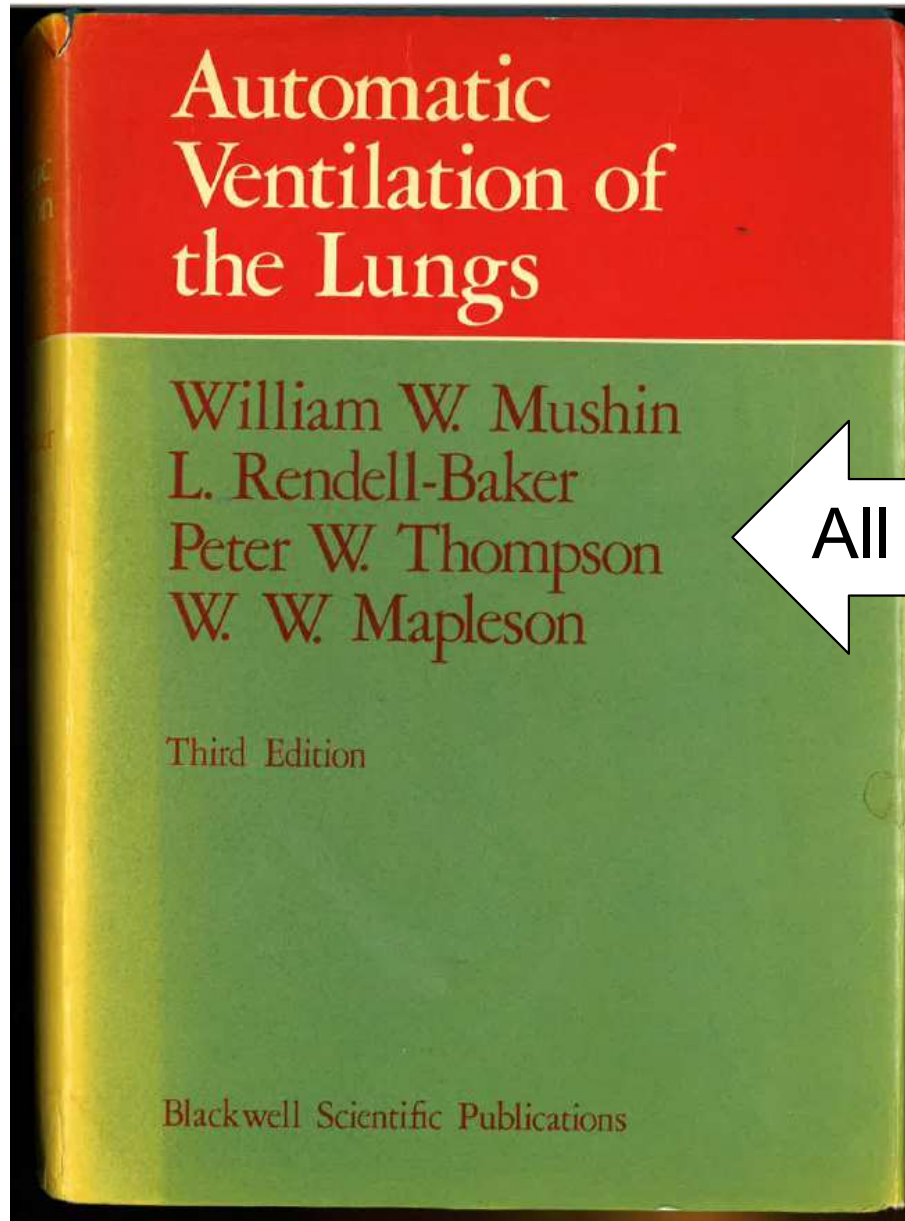
# History of Resuscitation



# Origin of the term “blowing smoke”???



# Original Bible of Mechanical Ventilation

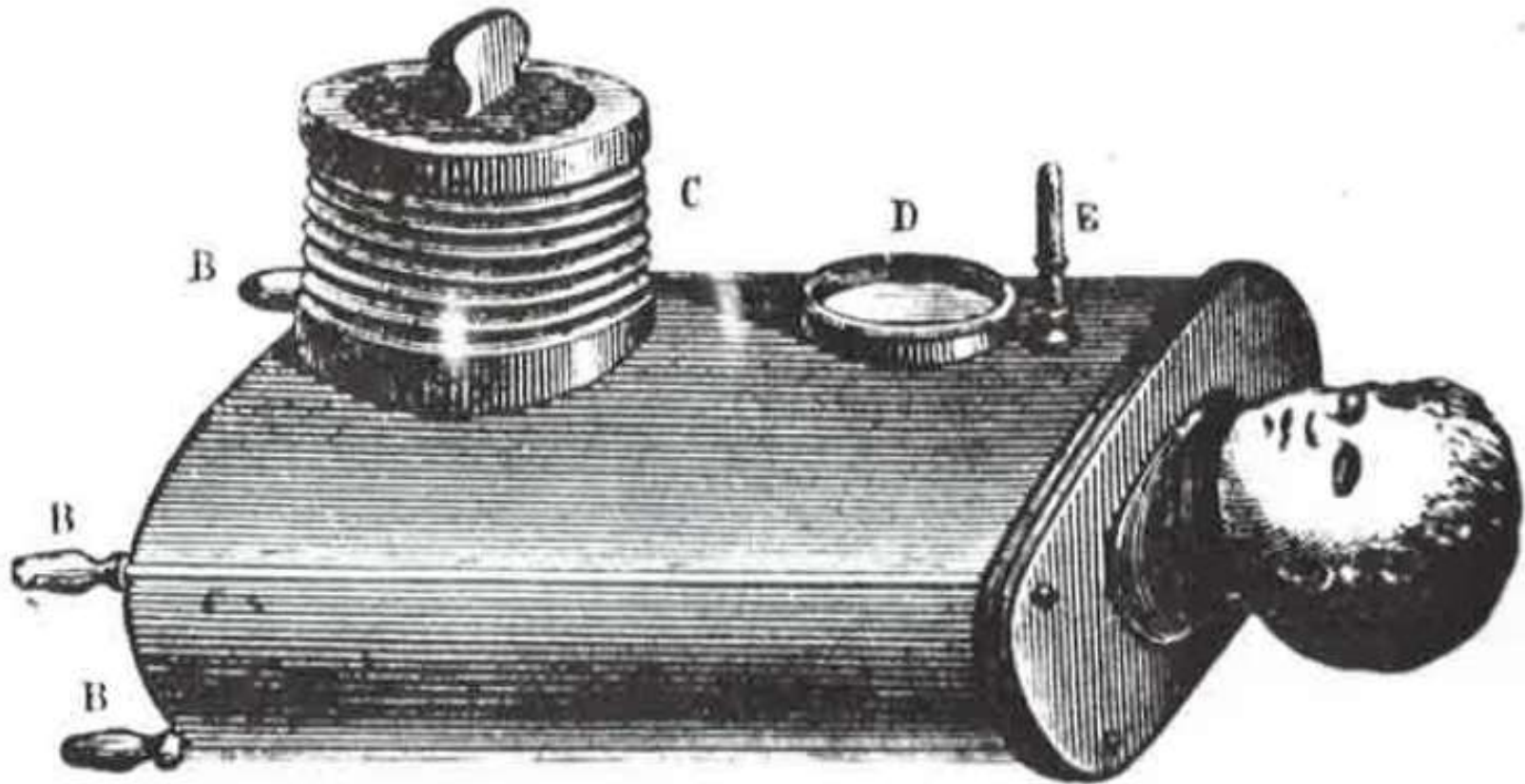


**London 1959**

All Anesthesiologists

**Detailed descriptions  
of 74 ventilators!**

# Wuillez's Spirophore (1876)



# Fell-O'Dwyer Apparatus (1888)



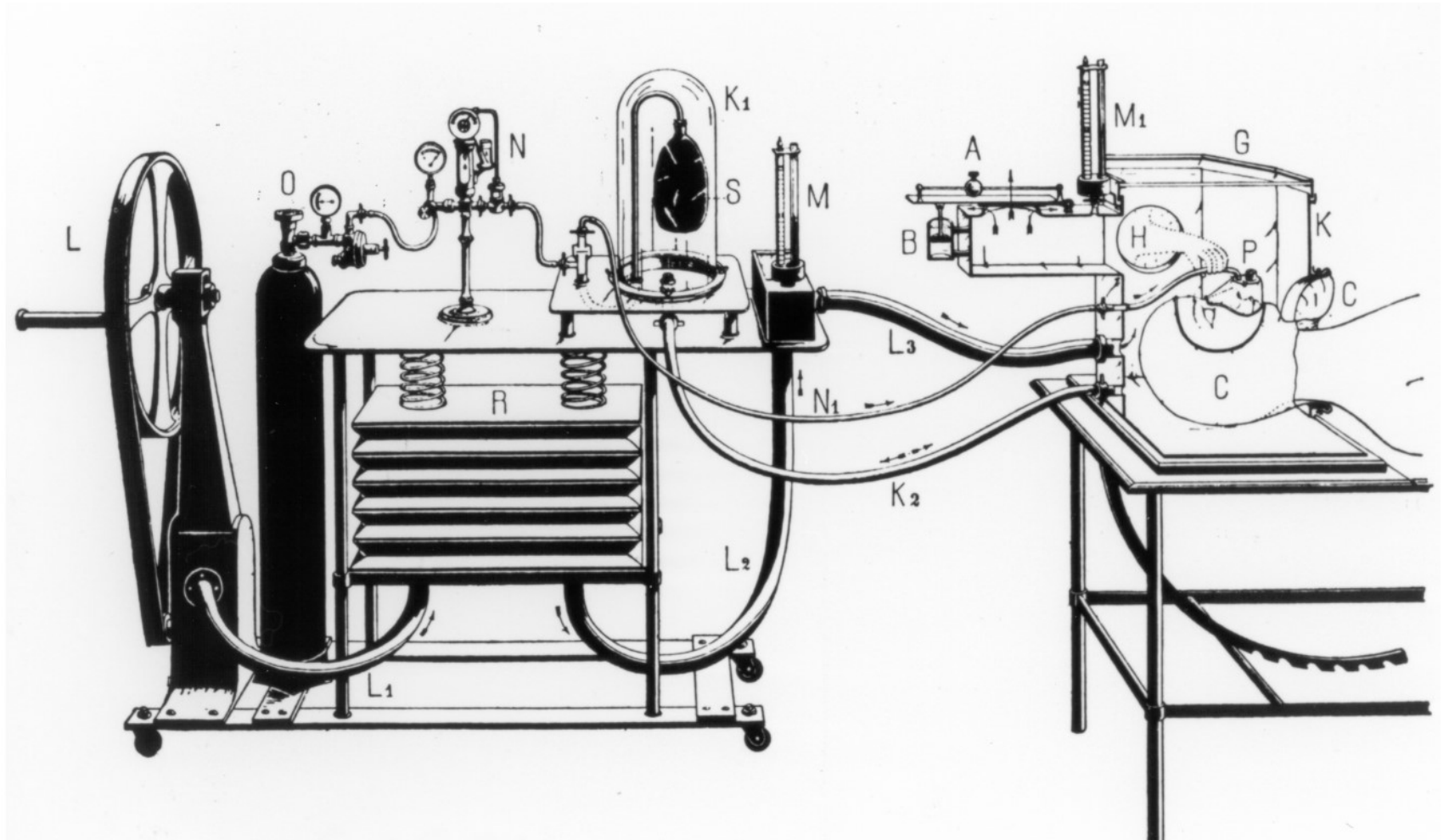
# Cleveland Respirator



*photo courtesy of Rich Branson*



# Early Operating Room Ventilator

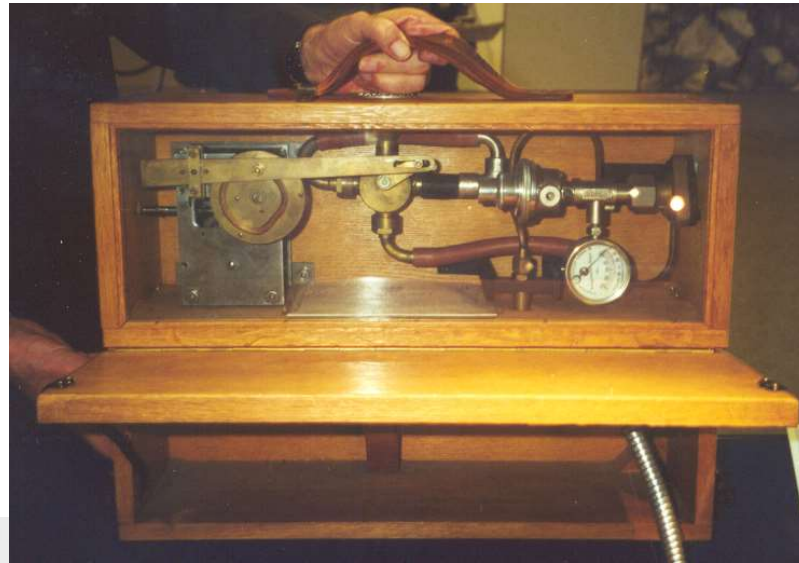


*photo courtesy of Rich Branson*

# Dräger Pulmotor (Germany 1907)

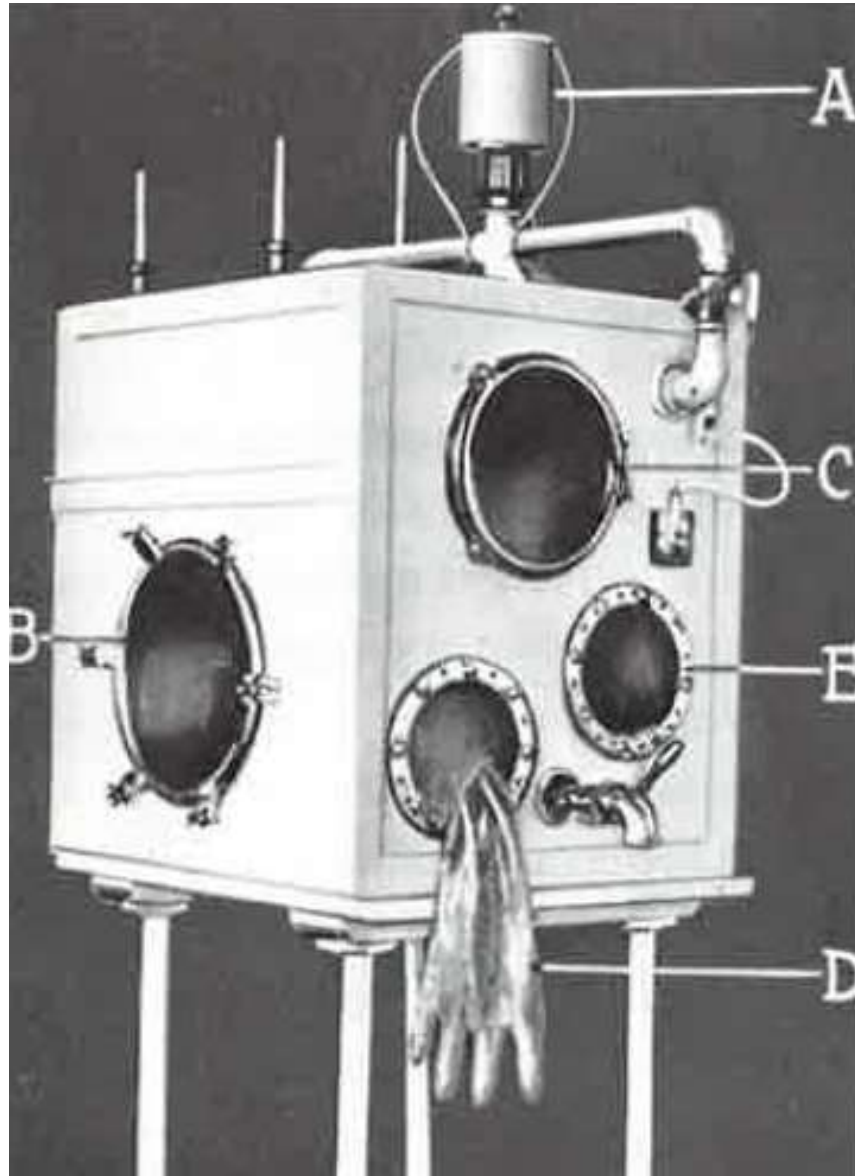


Heinrich Dräger

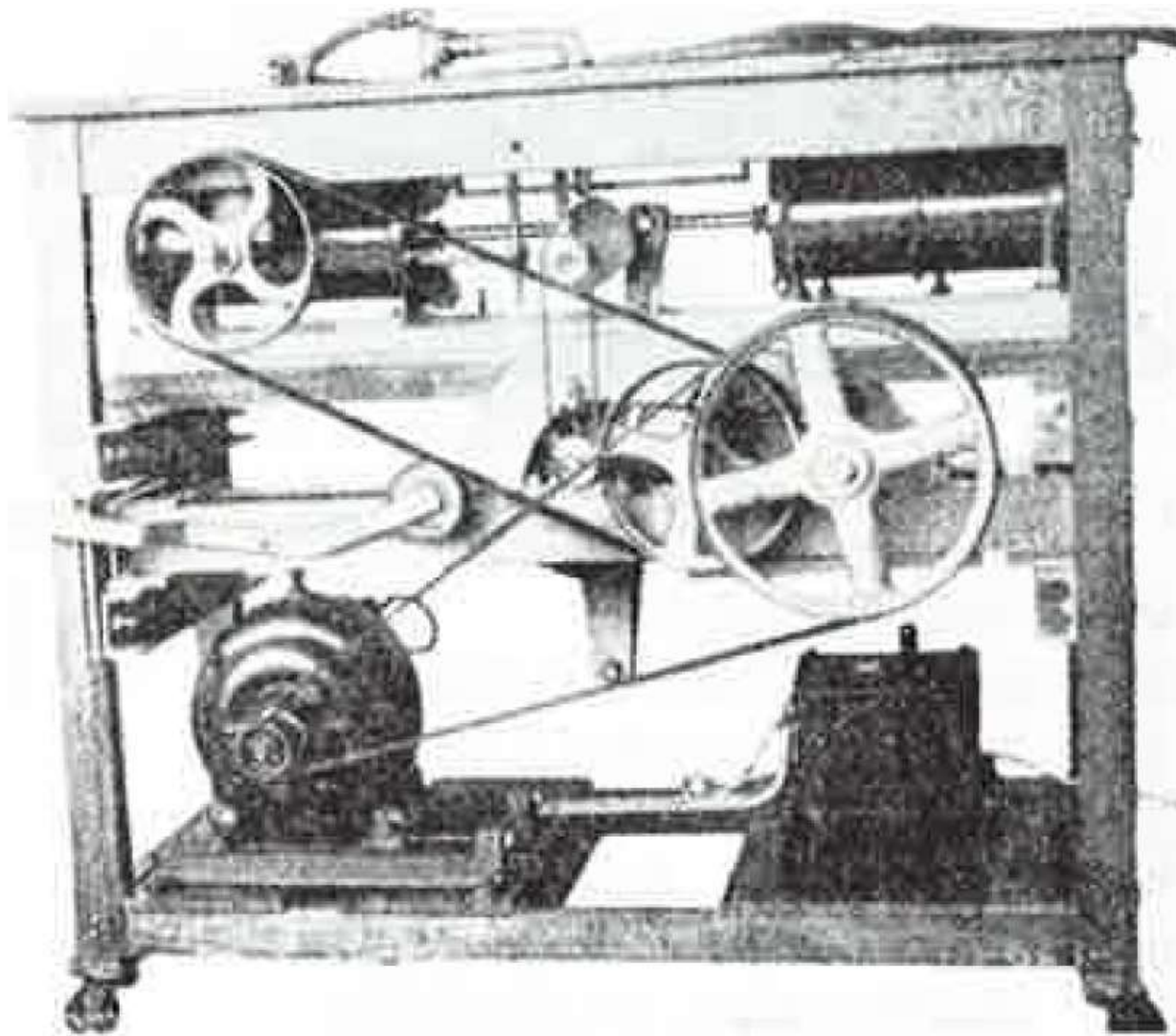


*photo courtesy of Rich Branson*

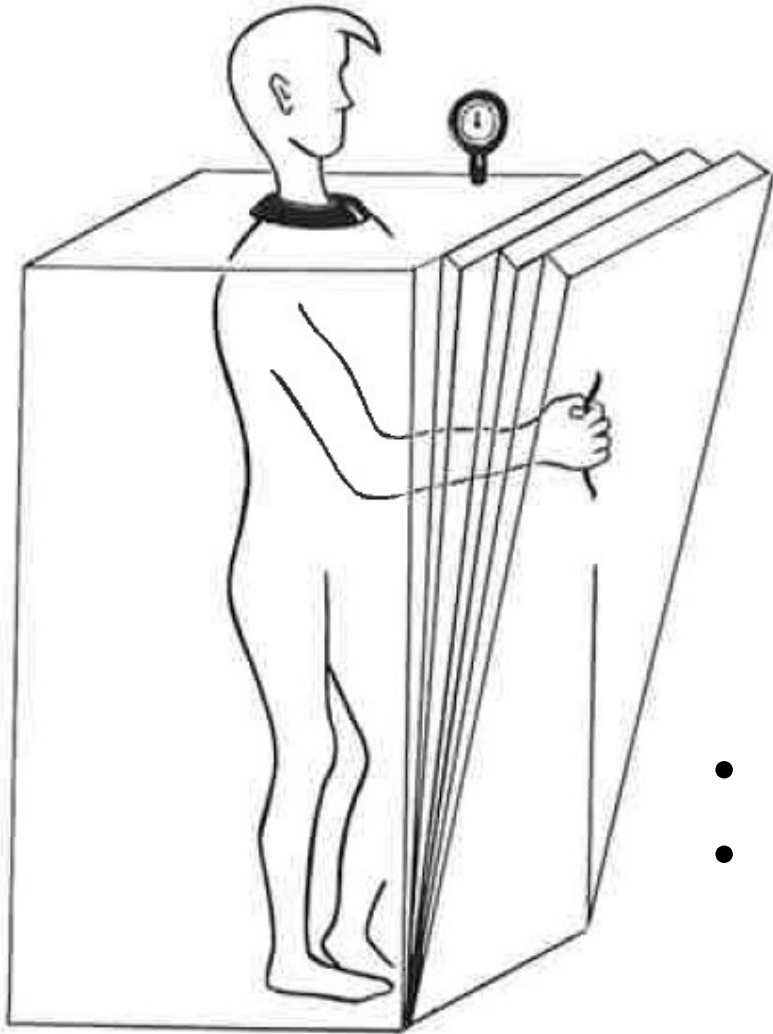
# Janeway-Green Rhythmic Inflation Apparatus (1909)



# Läwan - Sievers Anesthesia Apparatus (1910)

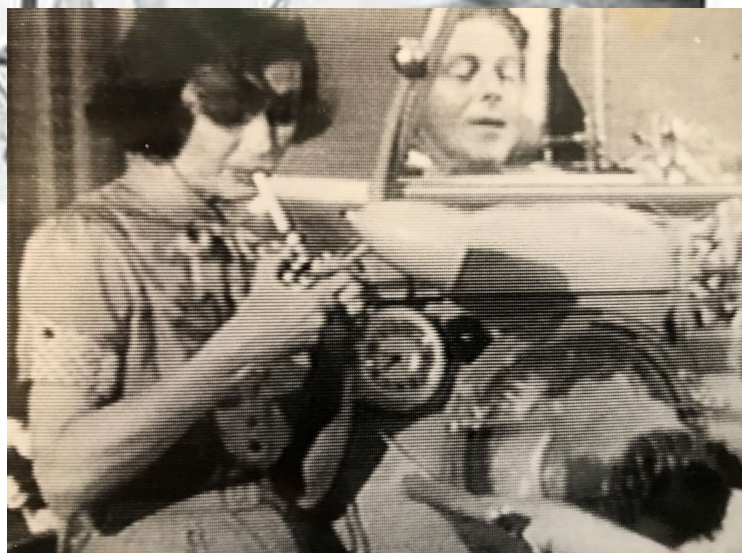
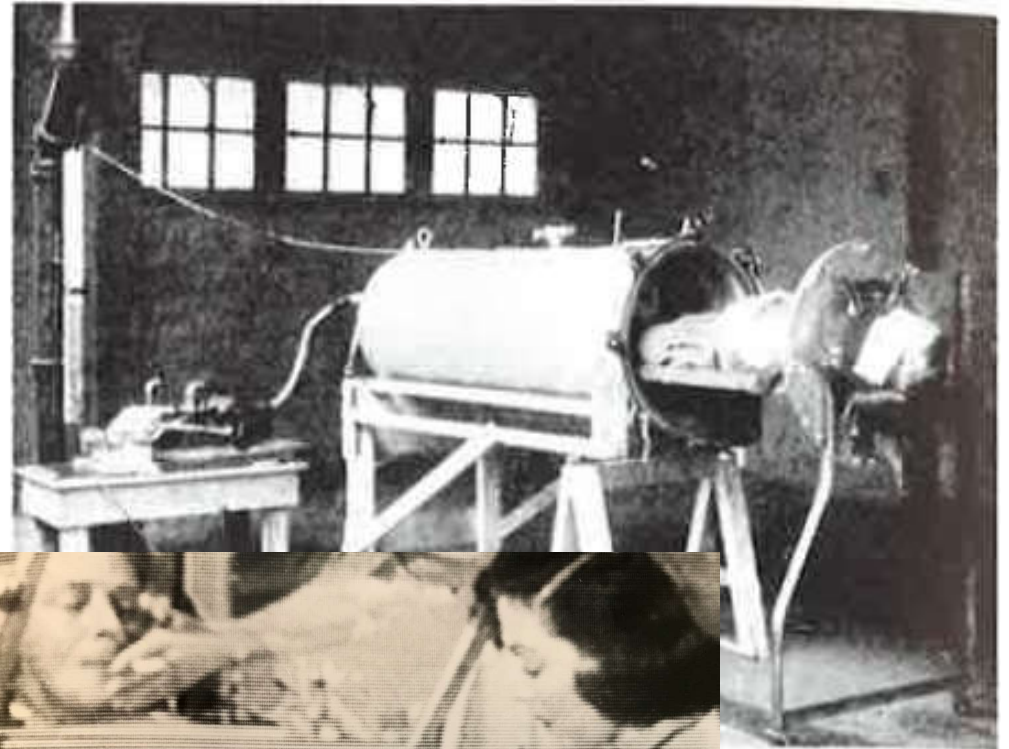
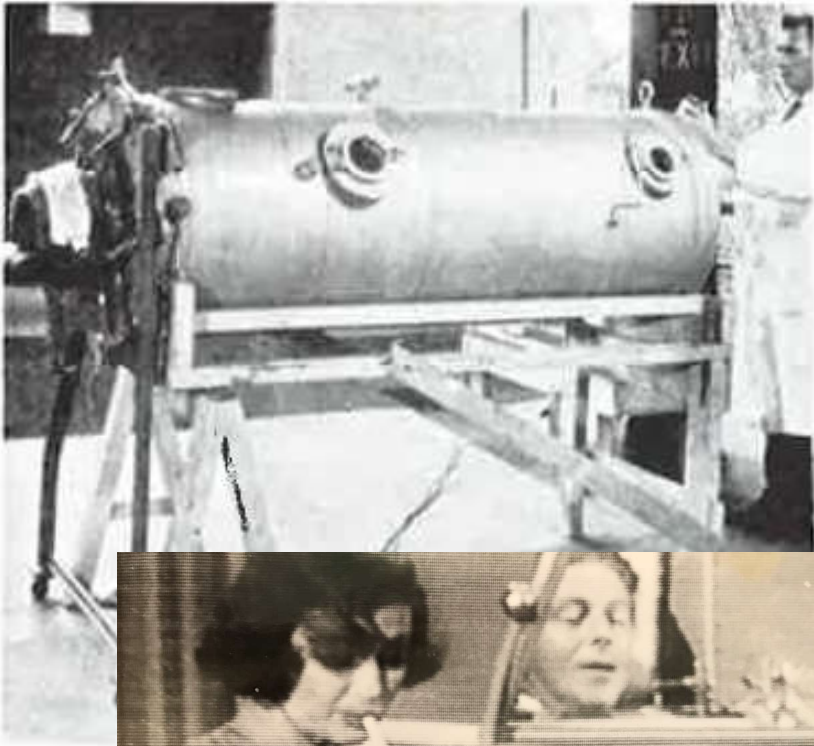


# Wilhelm Schwake Germany (1926)



- **Designed to improve synchrony**
- **“Negative pressure on the skin pulls out gaseous by-products”**

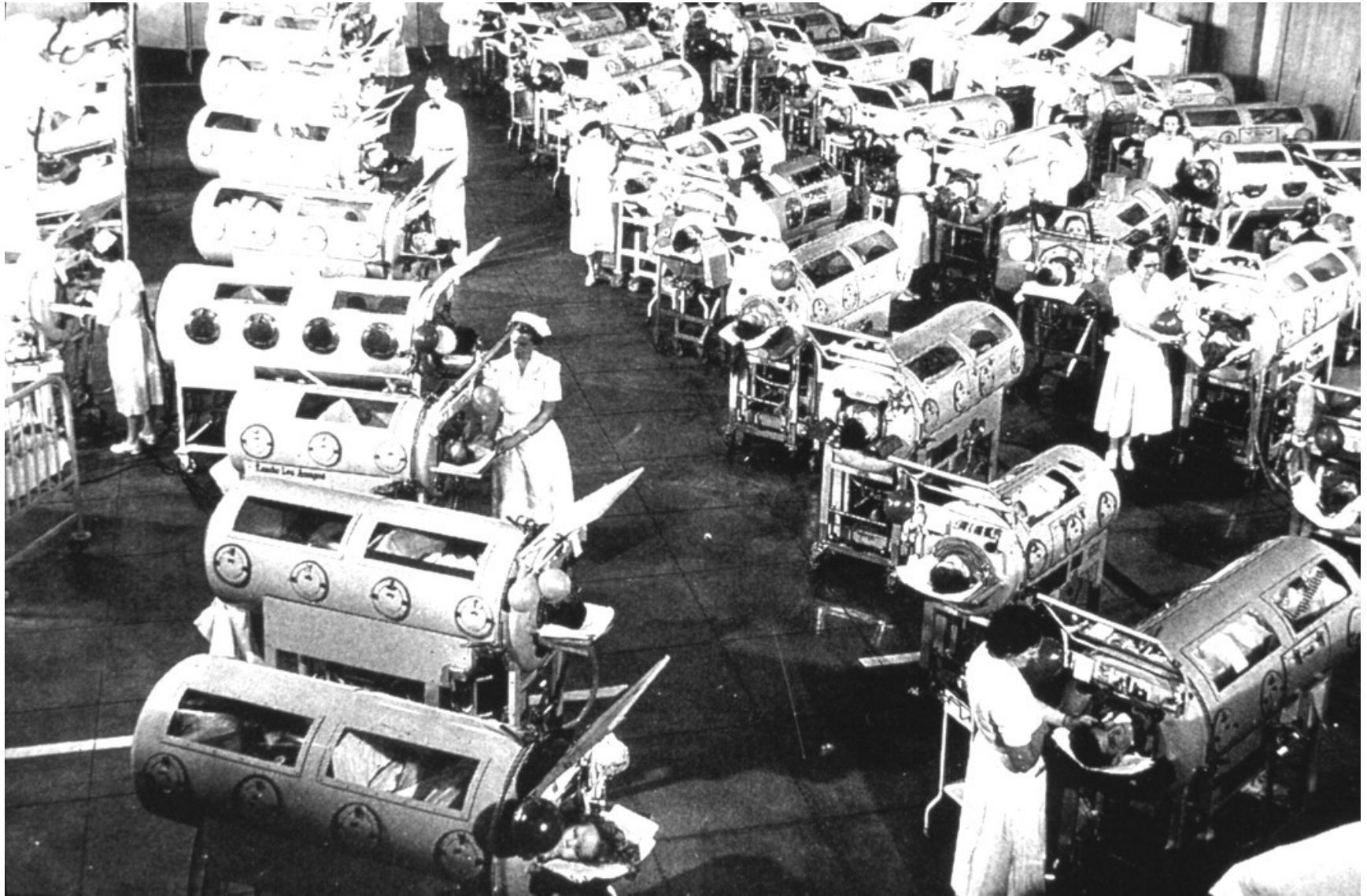
# Drinker-Shaw New Mechanical Respirator (USA 1929)



# First mass produced Iron Lung Dräger (1950)

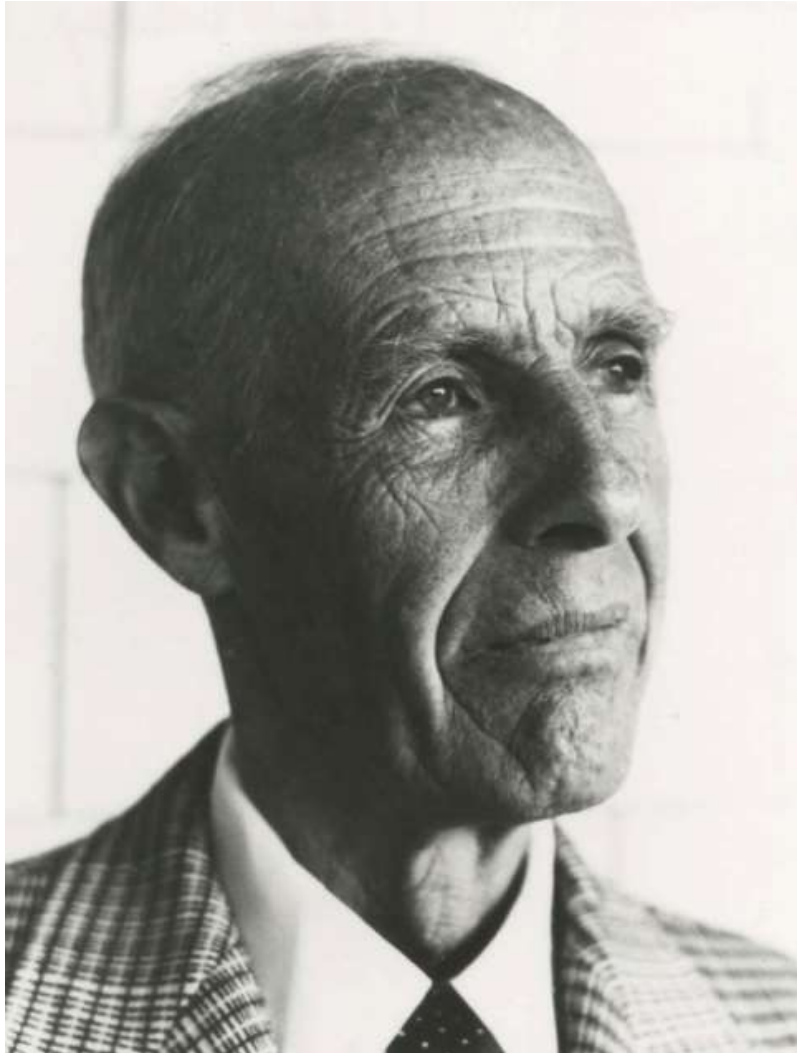


# Polio Epidemics

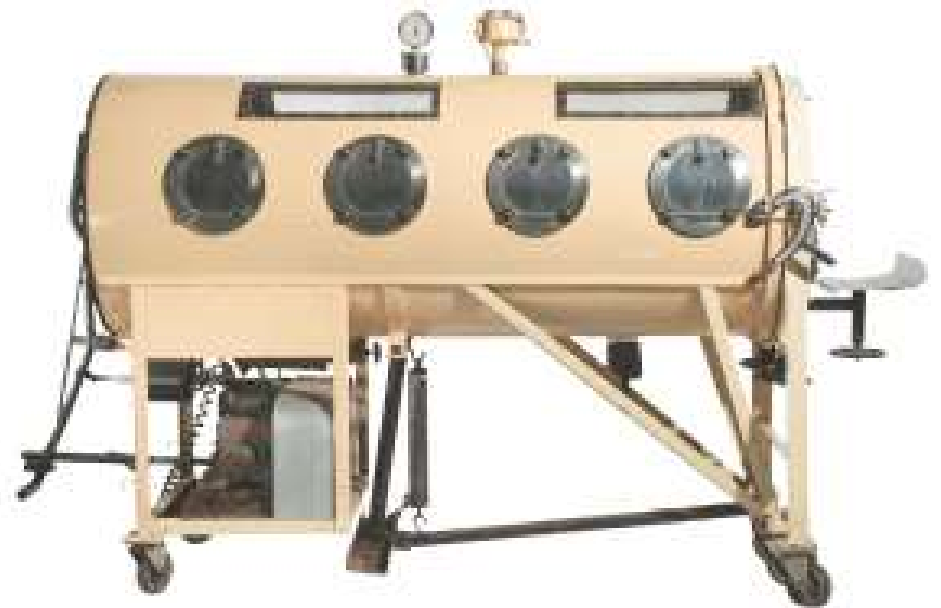




# John Haven "Jack" Emerson (USA 2/5/1906 – 2/4/1997)



**Pioneer of tank and  
piston ventilators**



# A Good Idea Never Dies

George Emerson



His mom





# Blease Pulmoflator, London (1955)

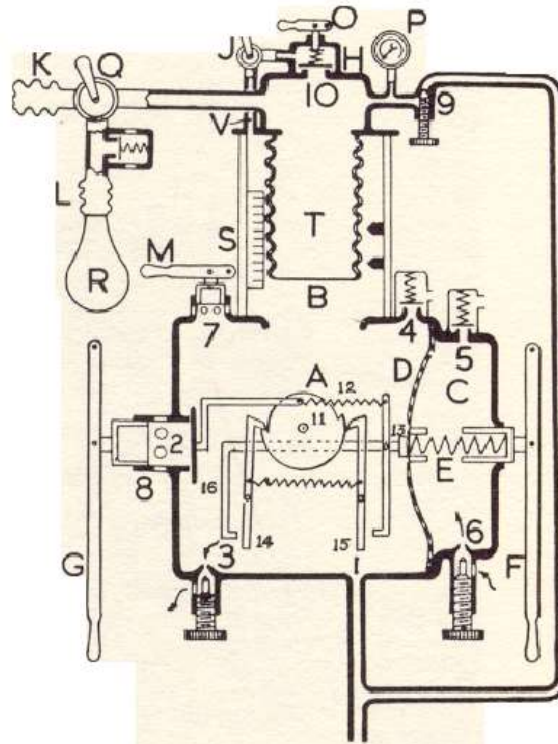
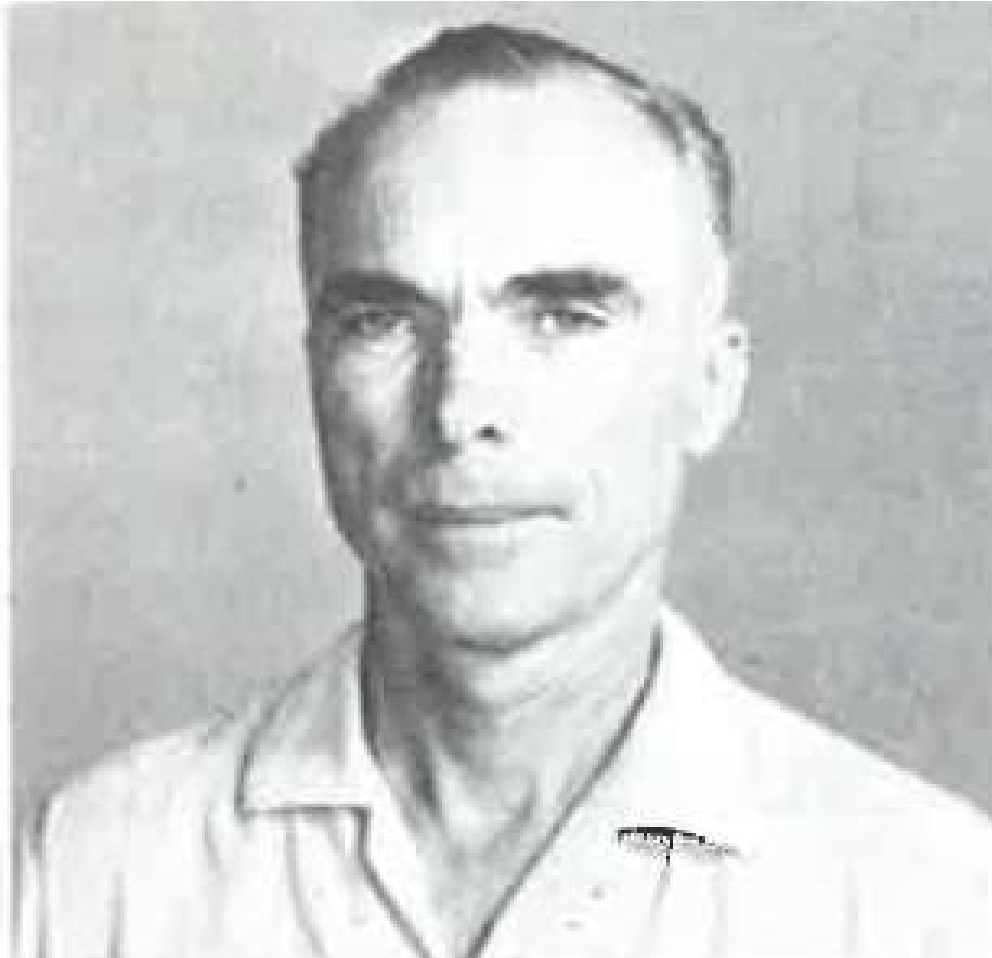


DIAGRAM OF BLEASE PULMOFLATOR

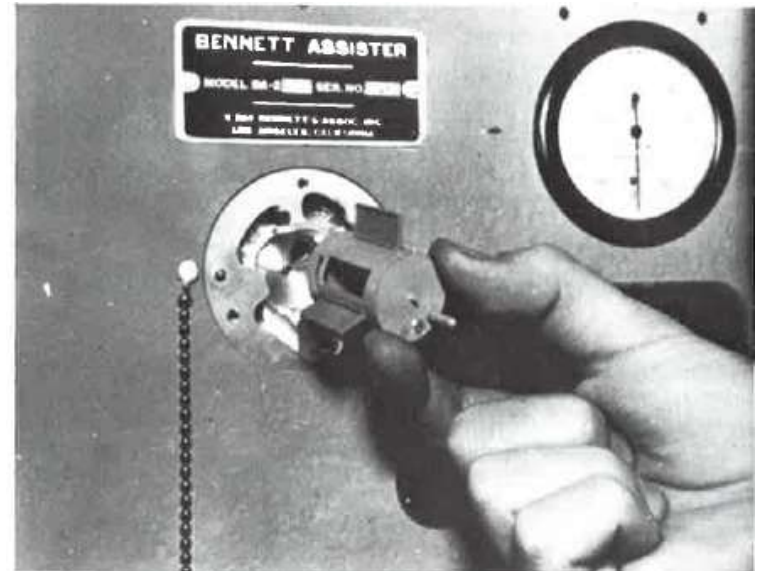


*photo courtesy of Rich Branson*

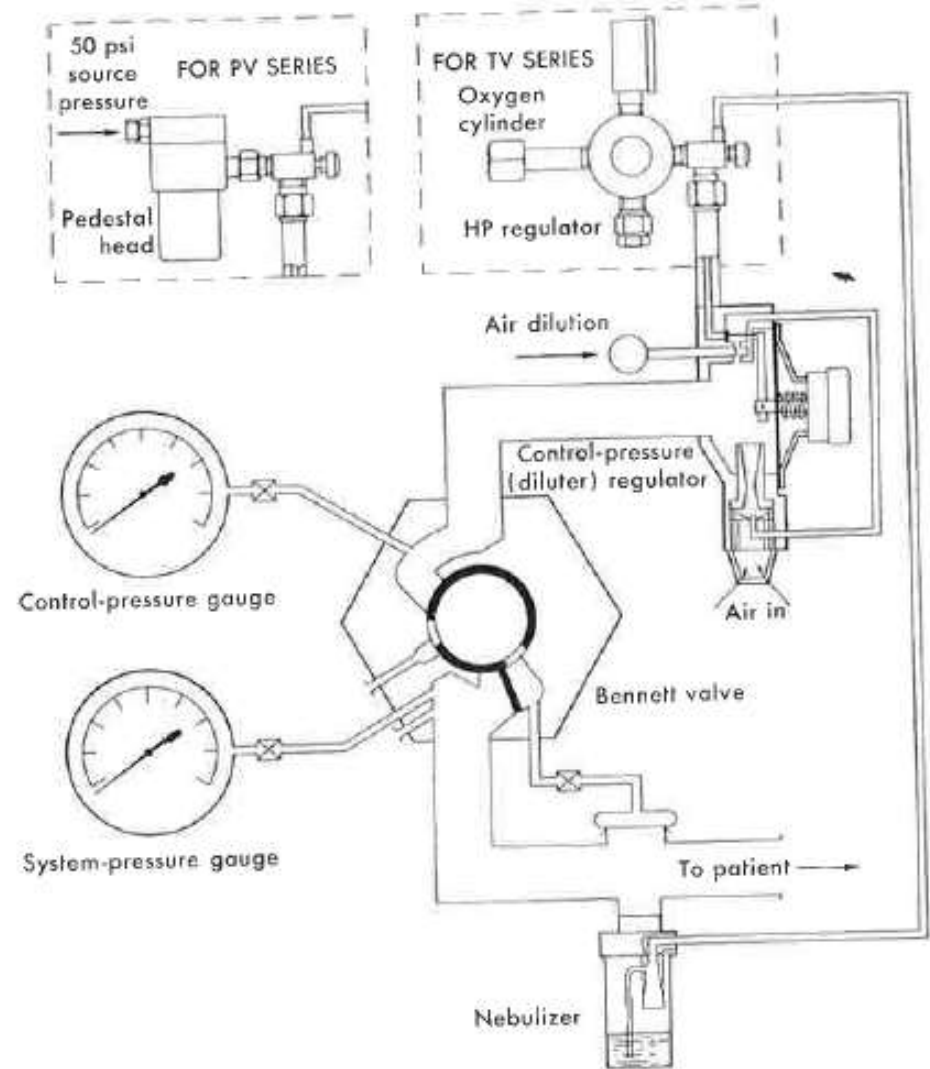
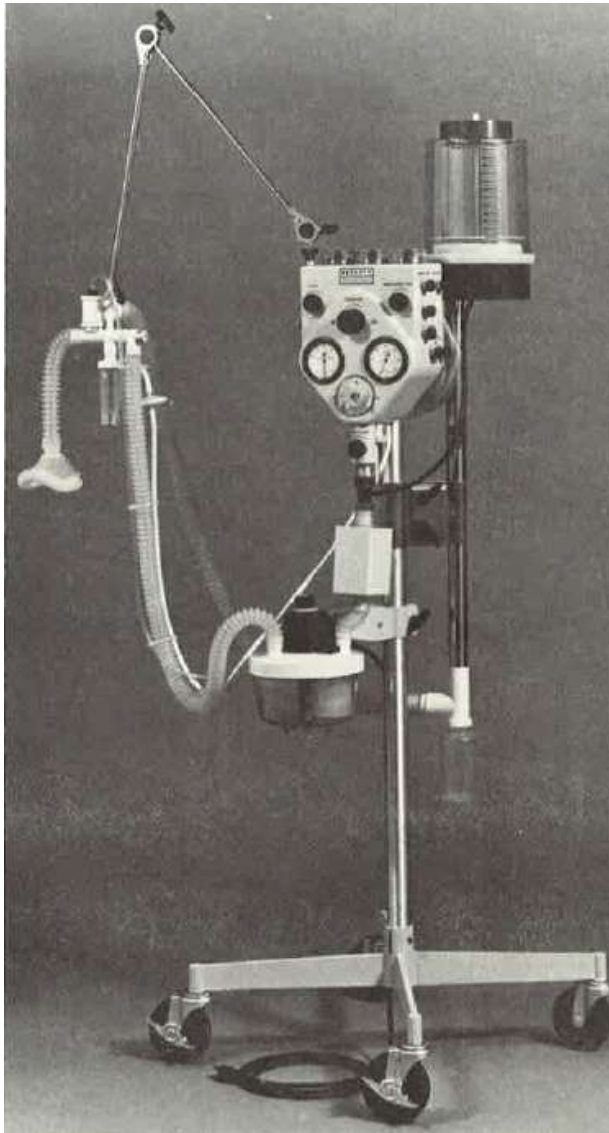
# Ray Bennett, USAF (1970)



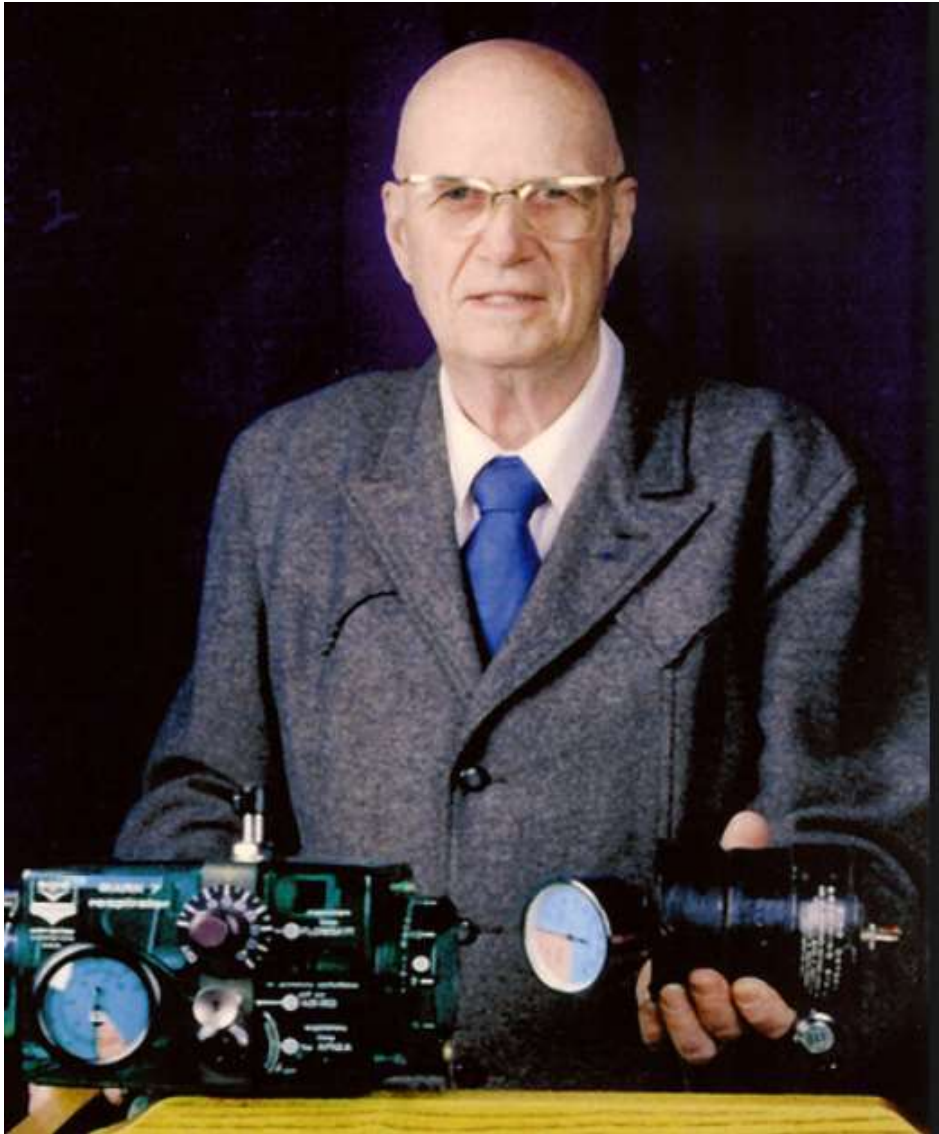
## Flow control valve (1947)



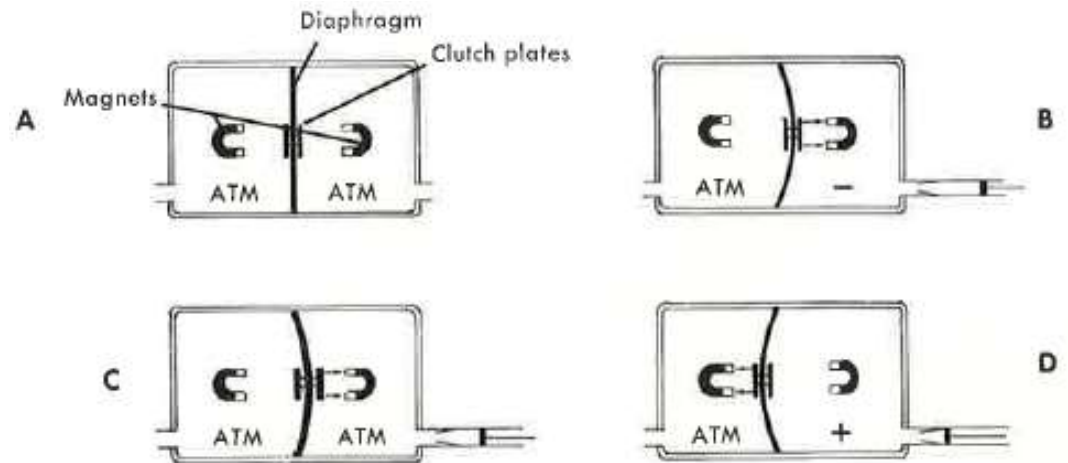
# PR Series Ventilators (1948-1990s)



# Dr. Forest Bird (1958)

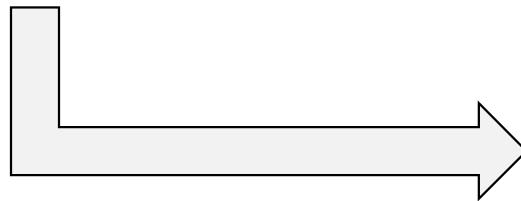


## Magnets and clutch plates



*photo courtesy of Rich Branson*

# Bird Prototype Mark 7 (1951)



*photo courtesy of Rich Branson*



# Bird Prototype IPPB (1949)

(1949) Initial prototype of the hand-operated IPPB device. Note the silver doorknob on top for actuation of the unit. There are two sets of springs, one in the center over the diaphragm and one on the right-hand side. Depressing the doorknob straight down activated the positive pressure (by depressing the diaphragm) and flow for nebulization of medications (by depressing the spring on the right-hand side). This allowed the patient to have nebulization, positive pressure, or both — depending upon the angle of force directed on the doorknob.

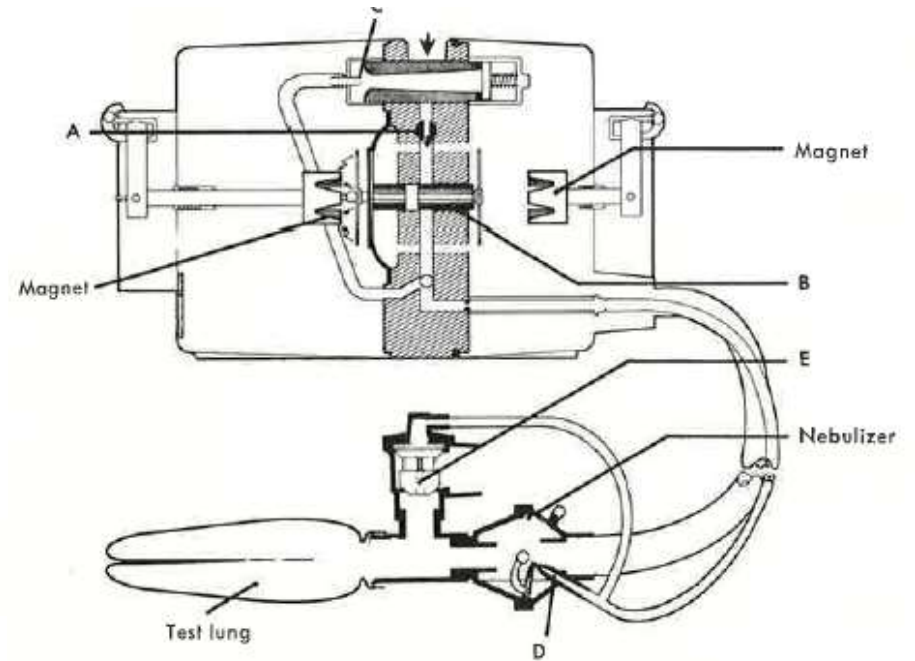


door knob

- positive pressure
- nebulization
- both

*photo courtesy of Rich Branson*

# Bird “Respirators” (1959 to present)



# Henri Coanda (1933)

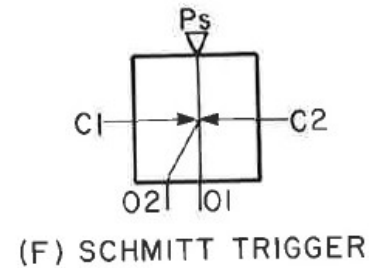
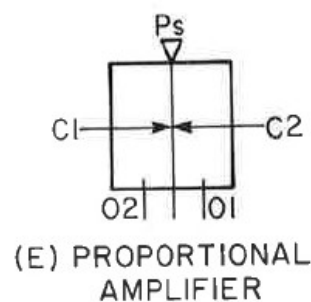
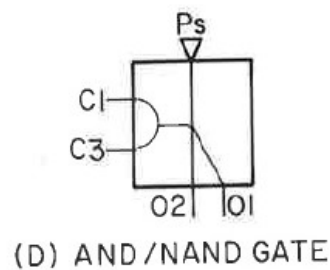
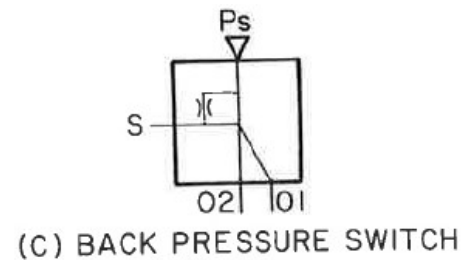
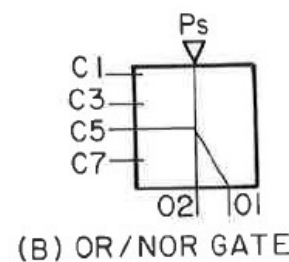
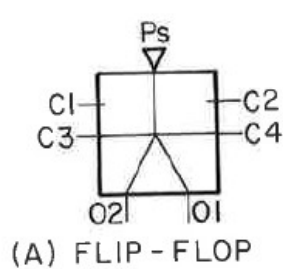
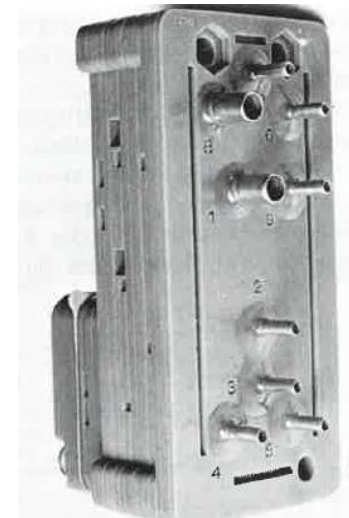
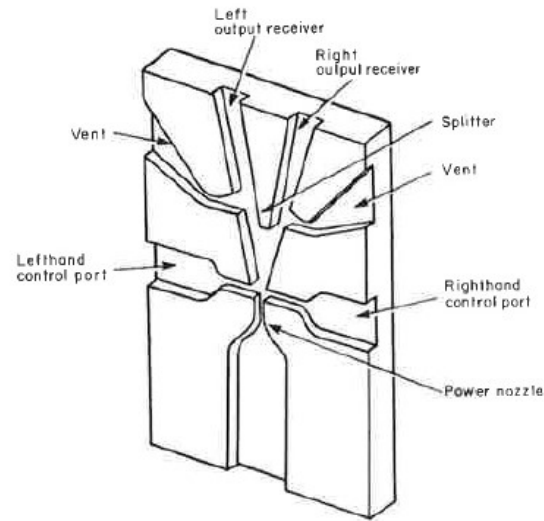
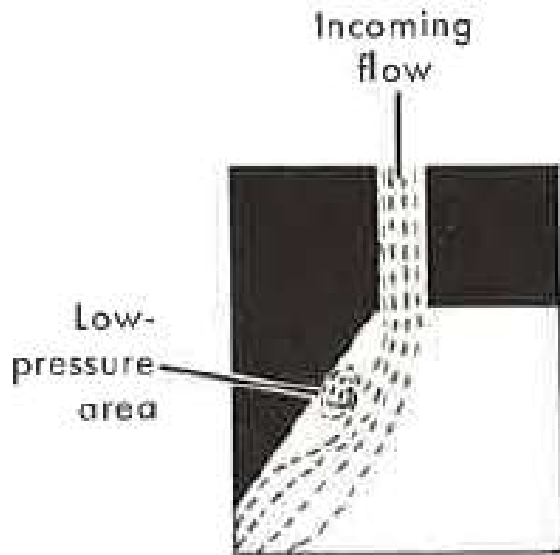
## Father of fluidic control devices



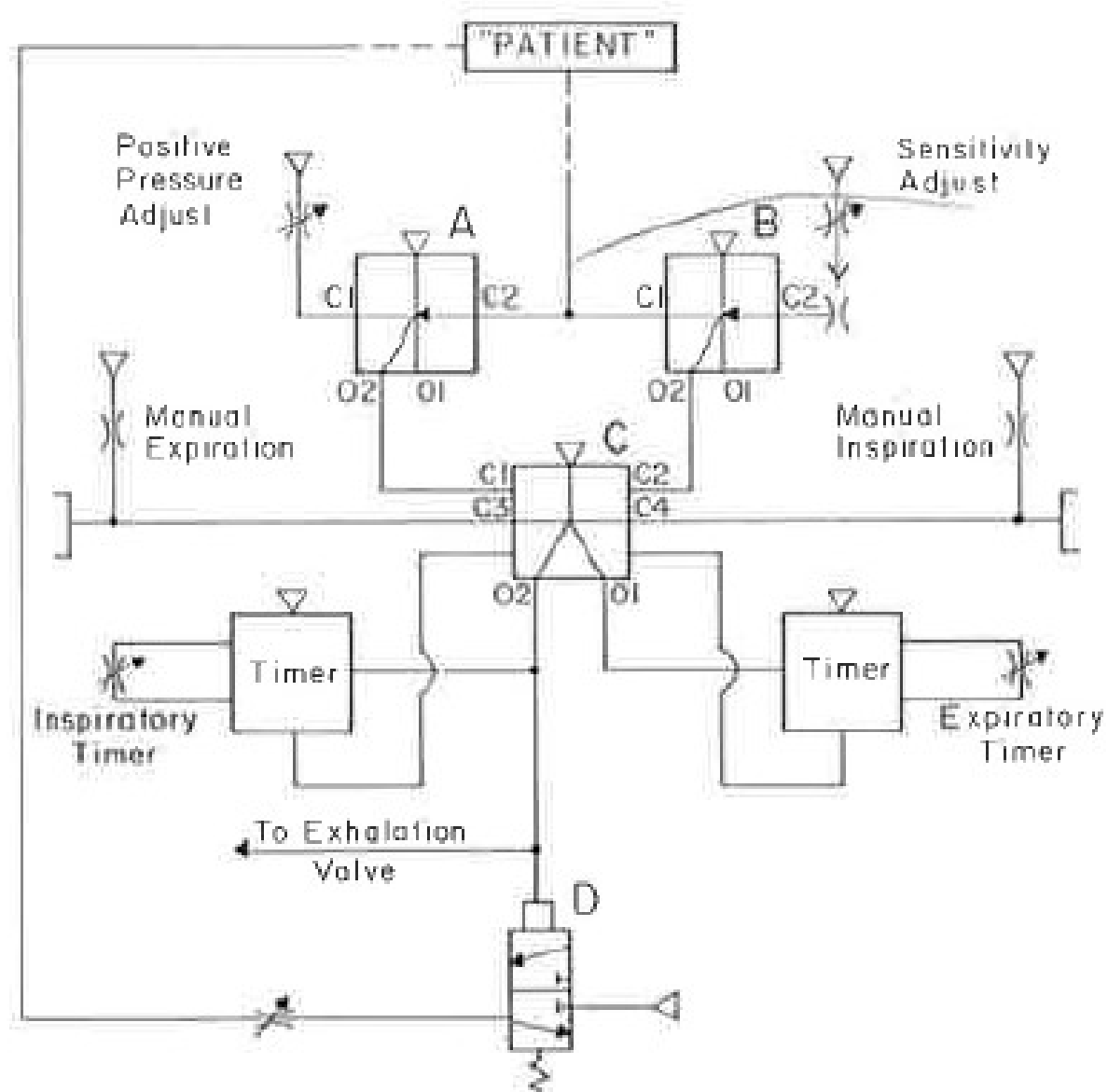
- Designer of early jet planes
- Discovered “wall attachment effect”  
– later named “Coanda Effect”

In his first and last jet test flight, the plane emerged from a sheet of flame and smoke. Coanda said “Apparently I had given it too much fuel. When I looked over the side I saw flames shooting out, and that should not be. I ducked inside to adjust matters. A moment later things felt very differently. I looked outside again to find myself many feet in the air. Straight ahead of me was the Paris wall. I didn’t know what to do. I pulled on the control wheels, the machine went up on one wing and I was thrown out. The plane crashed at the foot of the wall”

# Fluidic Logic Control Circuits



# Corning Fluidikit Ventilator Circuit (1980s)



# Dr. Jere Mead (1920–2009)

He established a whole new field of research.

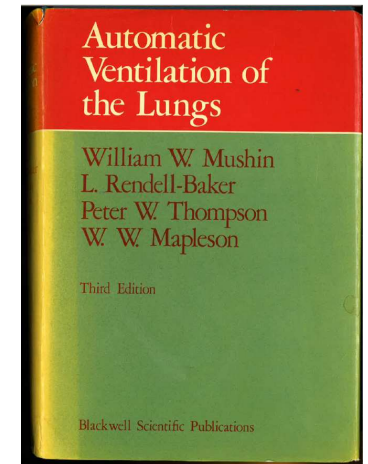
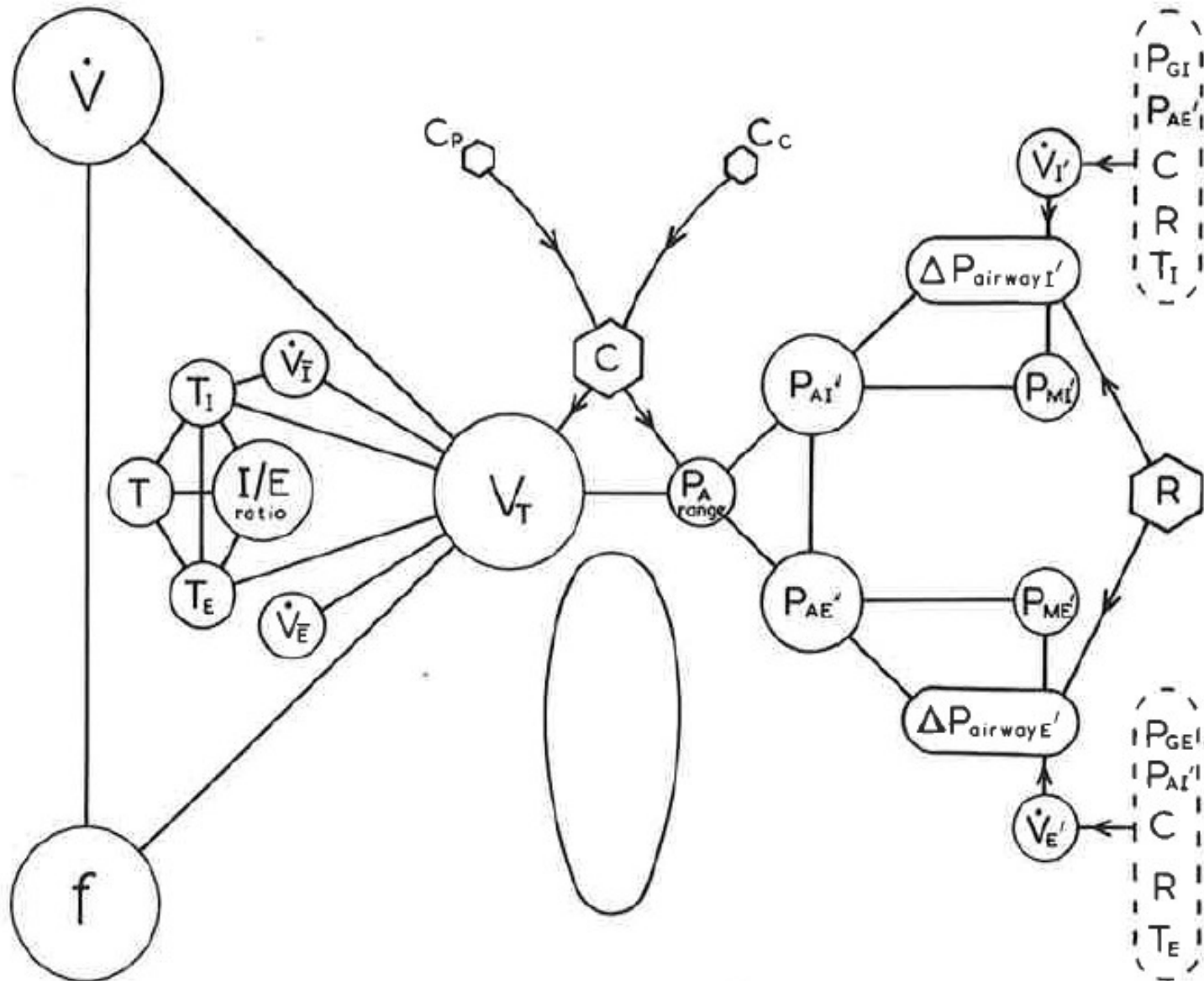
**Respiratory Mechanics** was his invention.

Was the first to use the term “compliance” in medicine  
an idea he borrowed from electronics (capacitance)

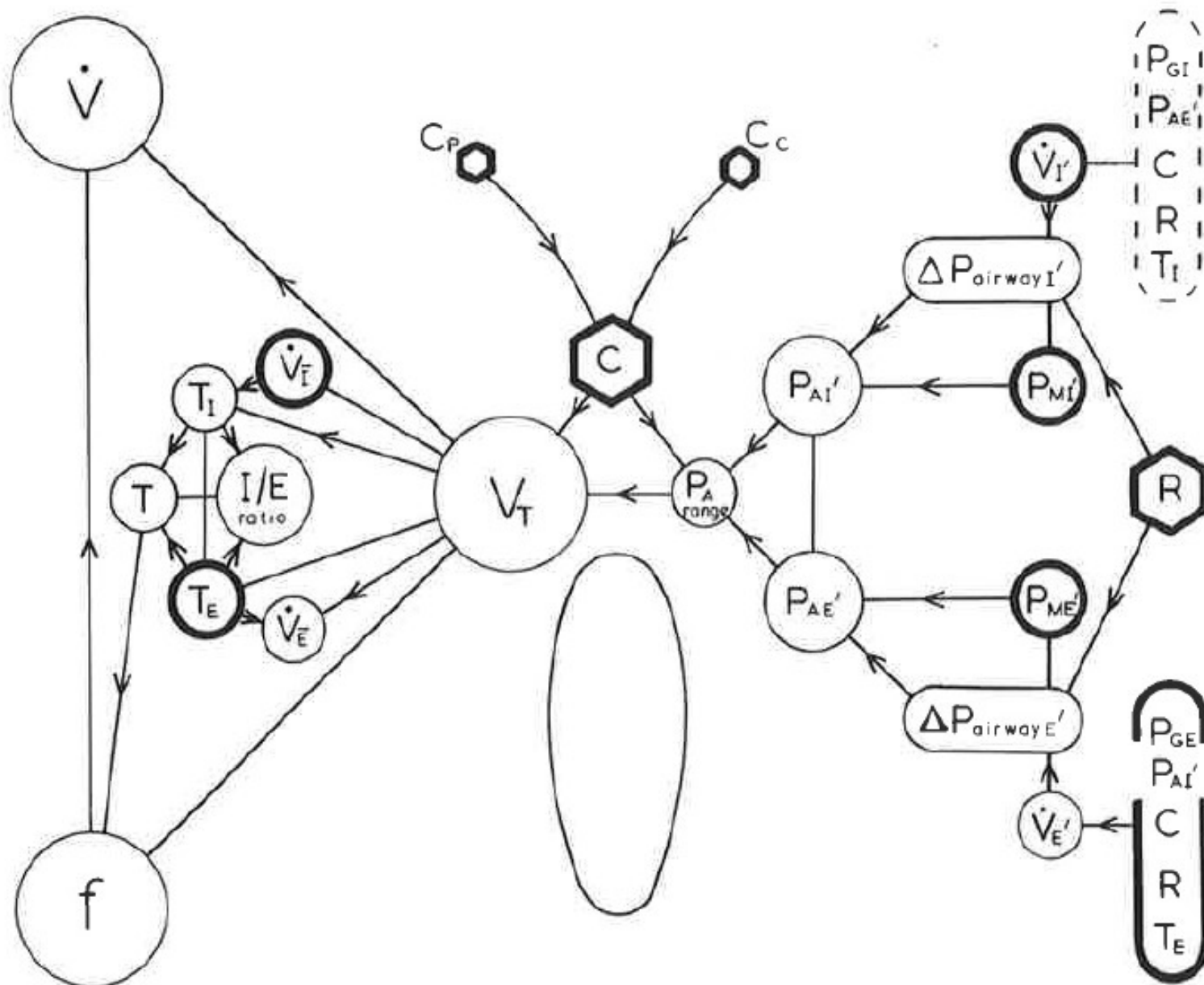


*Journal of Applied Physiology;107(6):1679*

# Mushin "Butterfly Diagram"

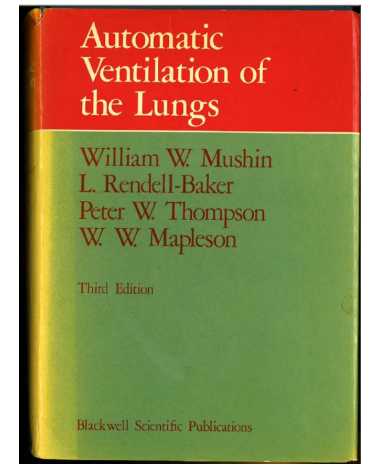
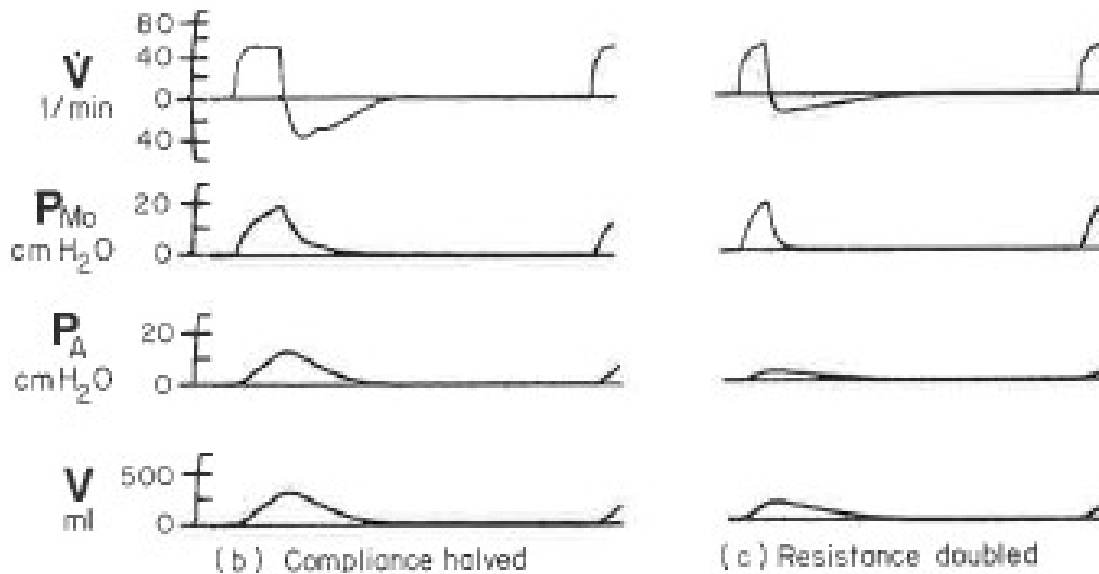
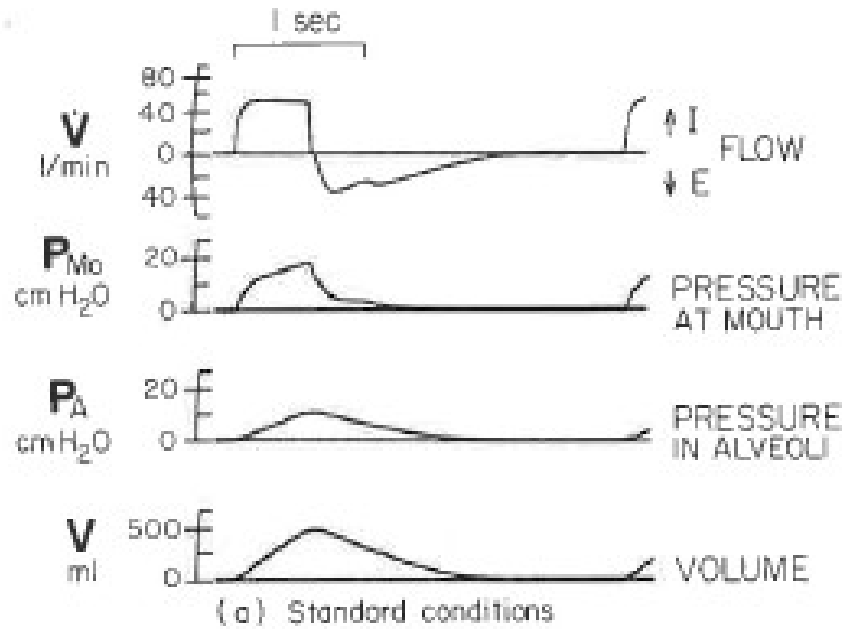


# Constant Flow – Pressure Cycled



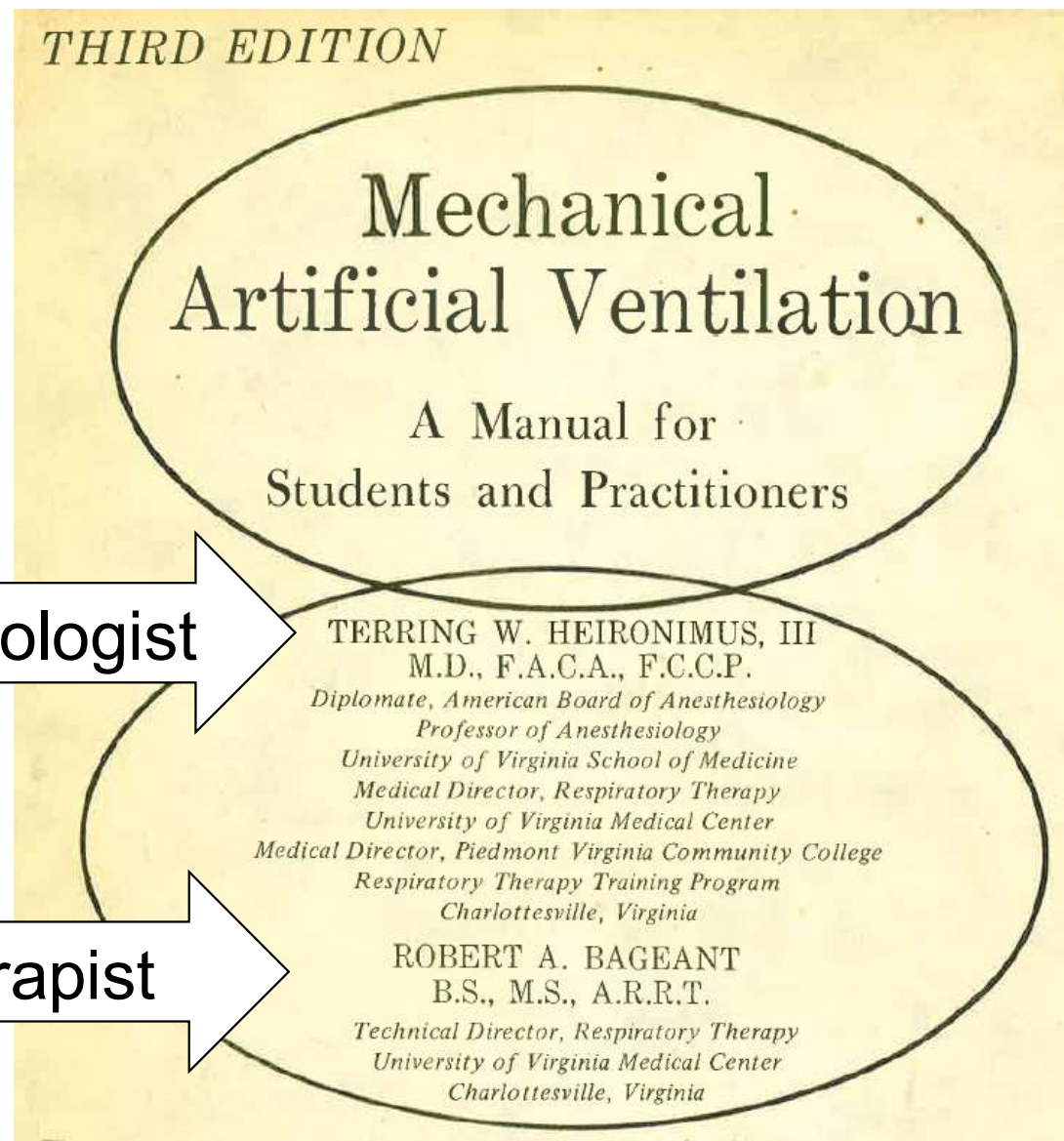


# Simulator-Based Waveforms



# 1977 Textbook on Mechanical Ventilation

## Described 10 ventilators



# CHAPTER 2 WHAT THE DESIGN, FUNCTION AND CARE OF RESPIRATORY THERAPY EQUIPMENT

*“As he picks up his beautiful new tool, however it is well for the modern biologist to remind himself how subtly and completely a fascination for gadgets can betray sound sense.”*

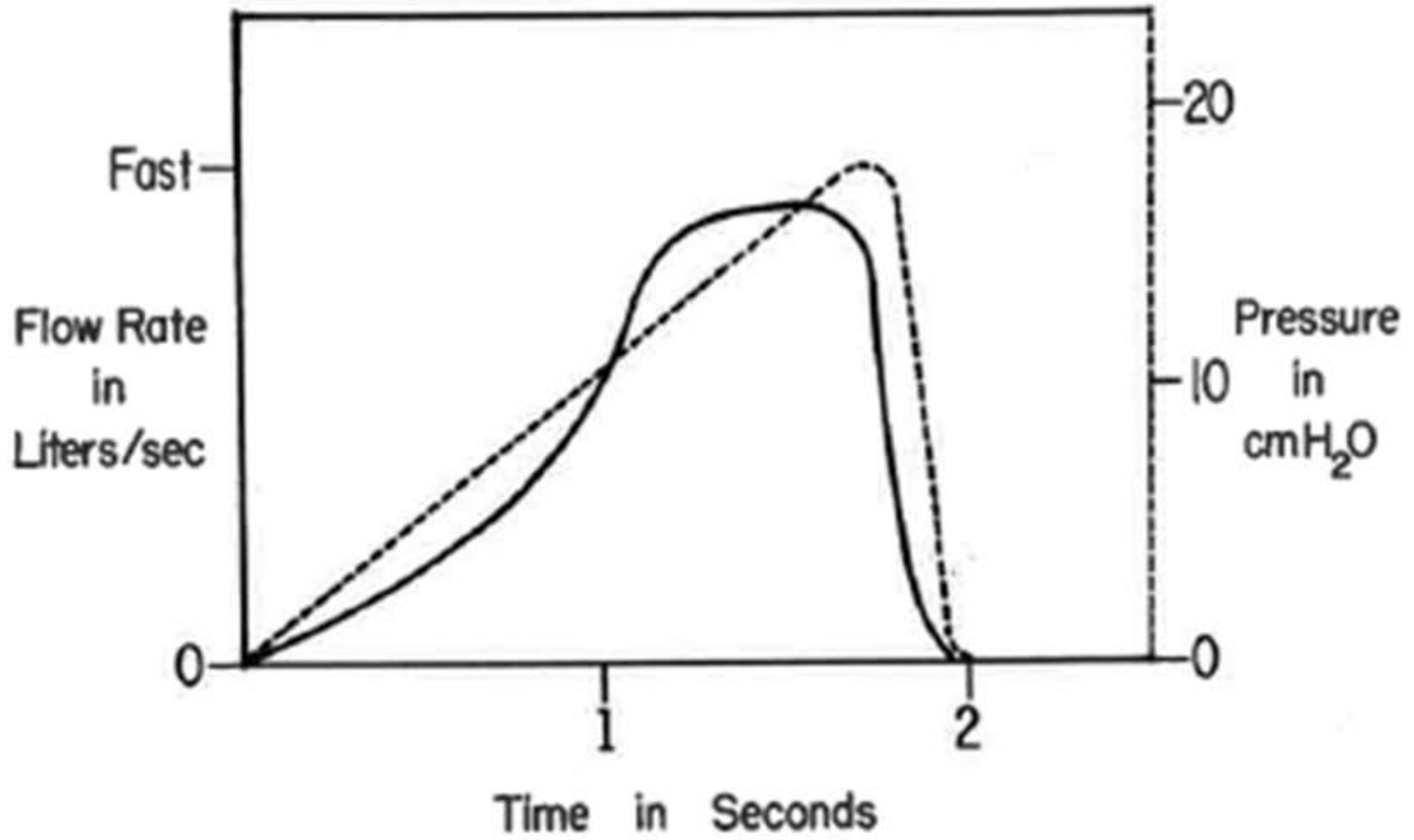
WILLIAM T. SALTER (1901-1952)

## THE VENTILATOR

### A. Classification

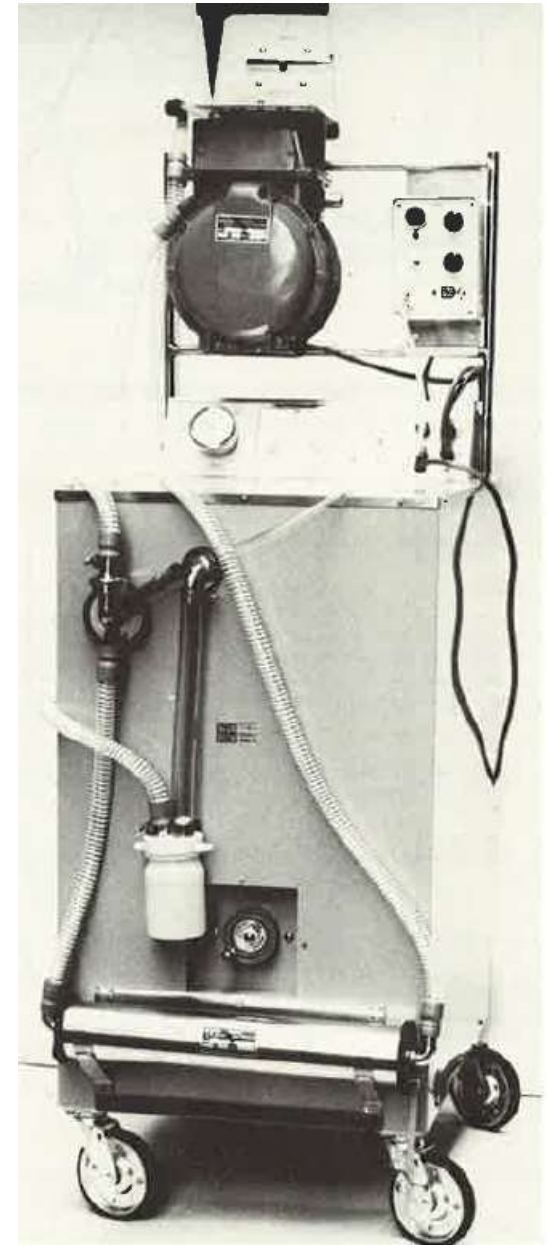
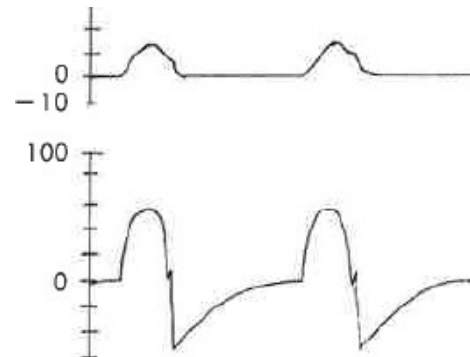
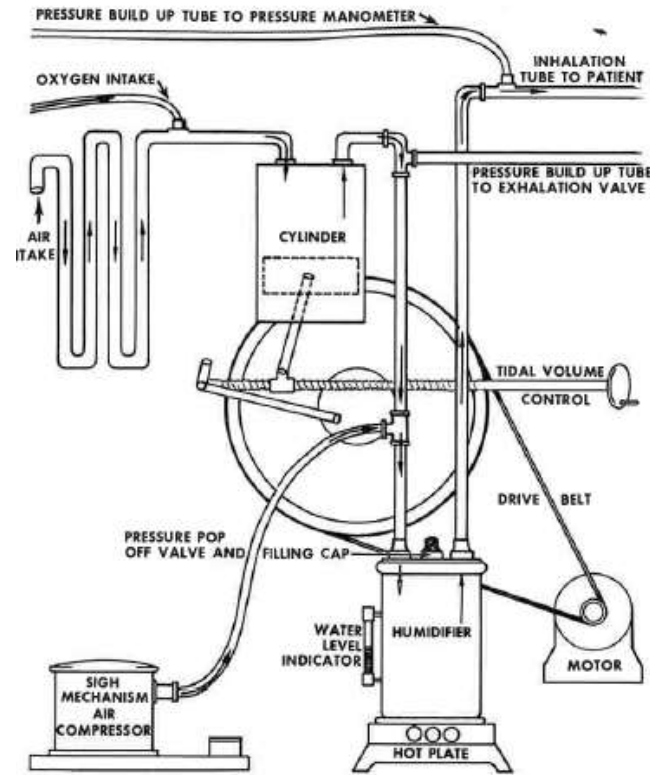
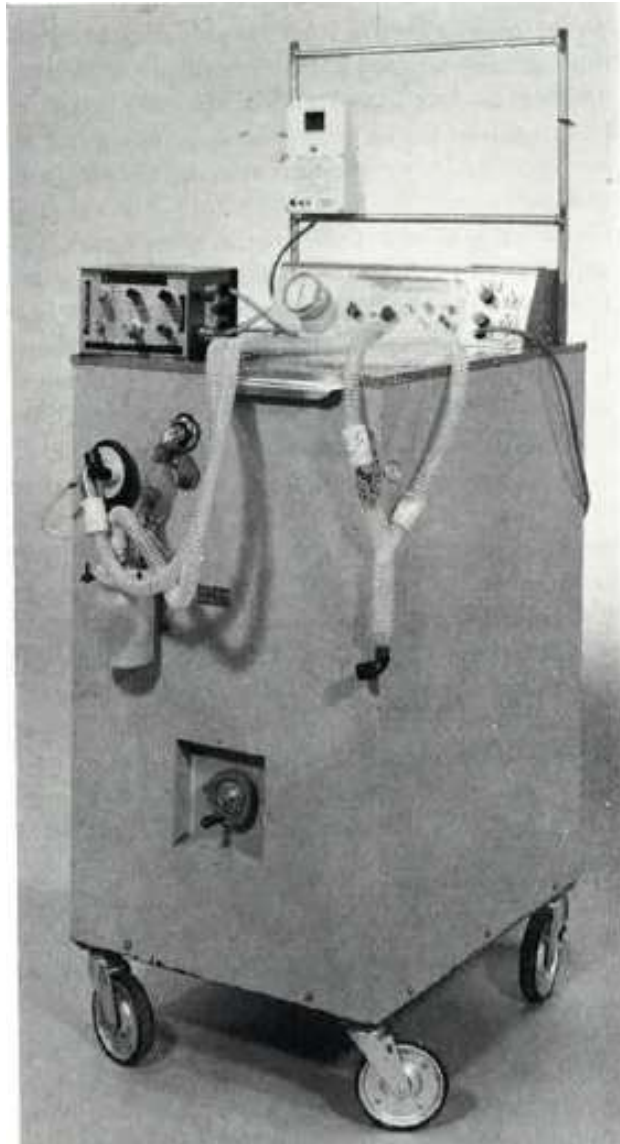
**T**HE MOST COMMONLY employed ventilators today are those that exert a positive pressure at the upper airway to effect the

# Pressure Control Waveforms

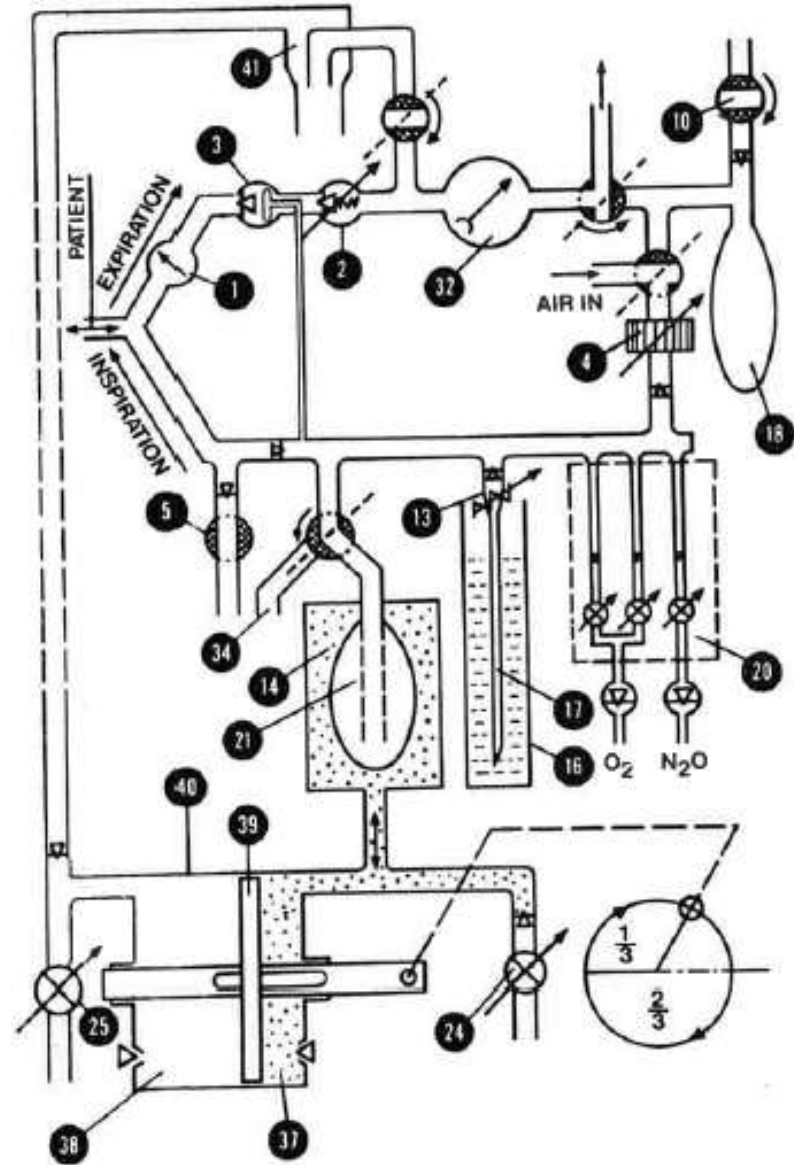
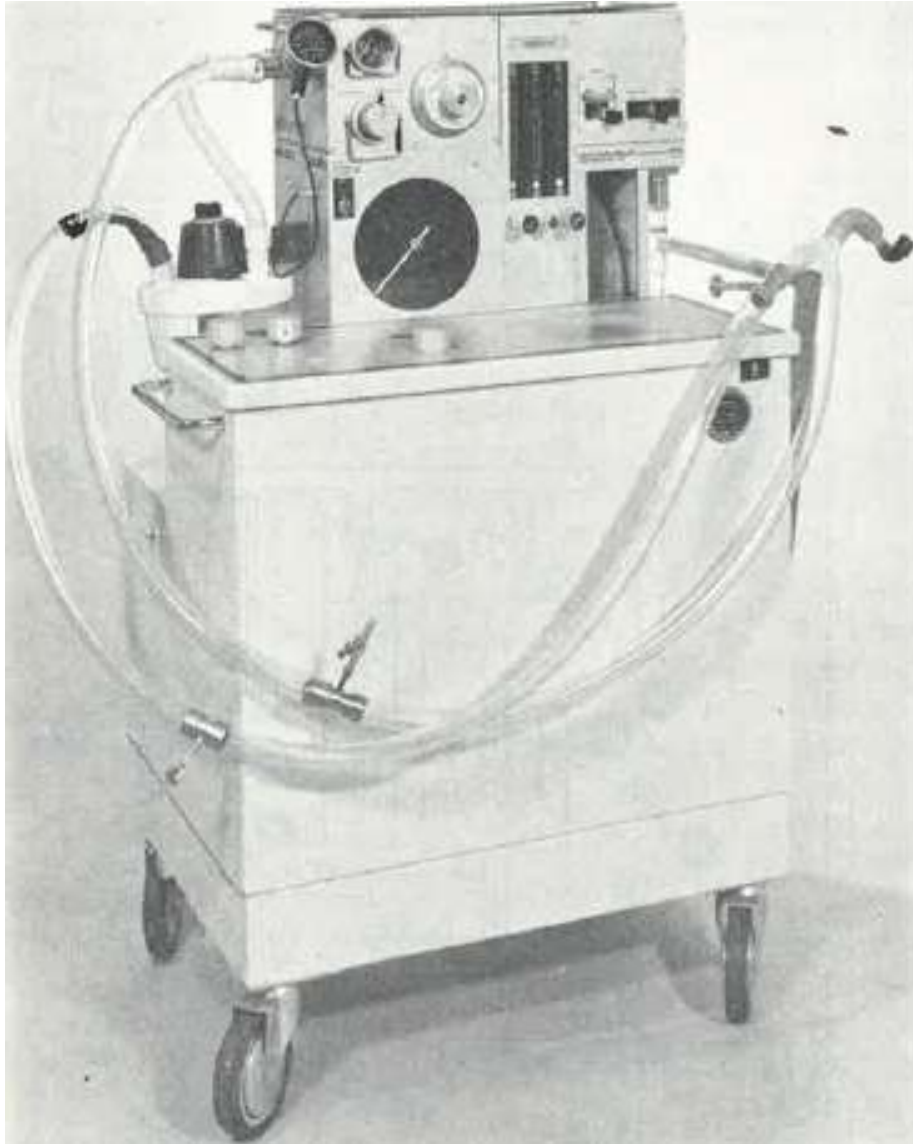




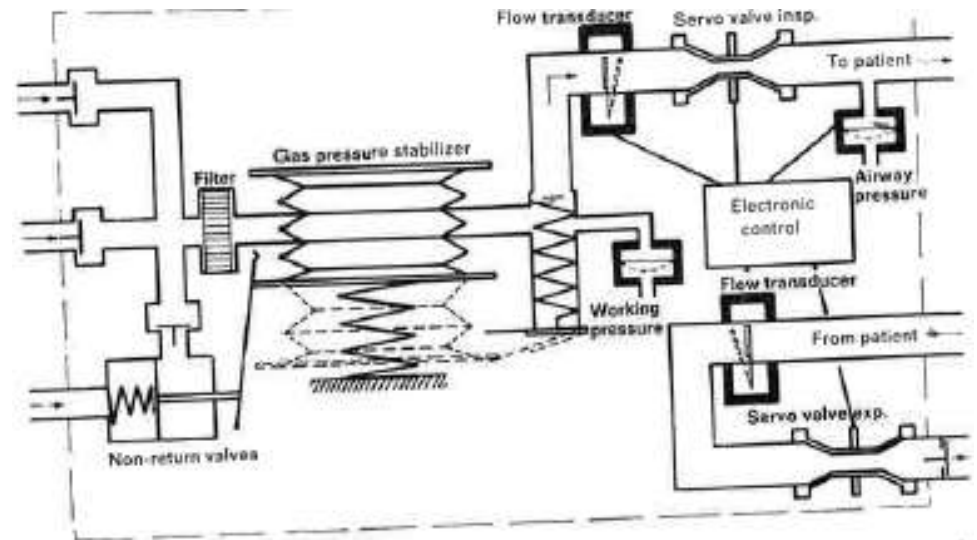
# Emerson Post-Op and 3-PV (USA)



# Engström (Denmark)

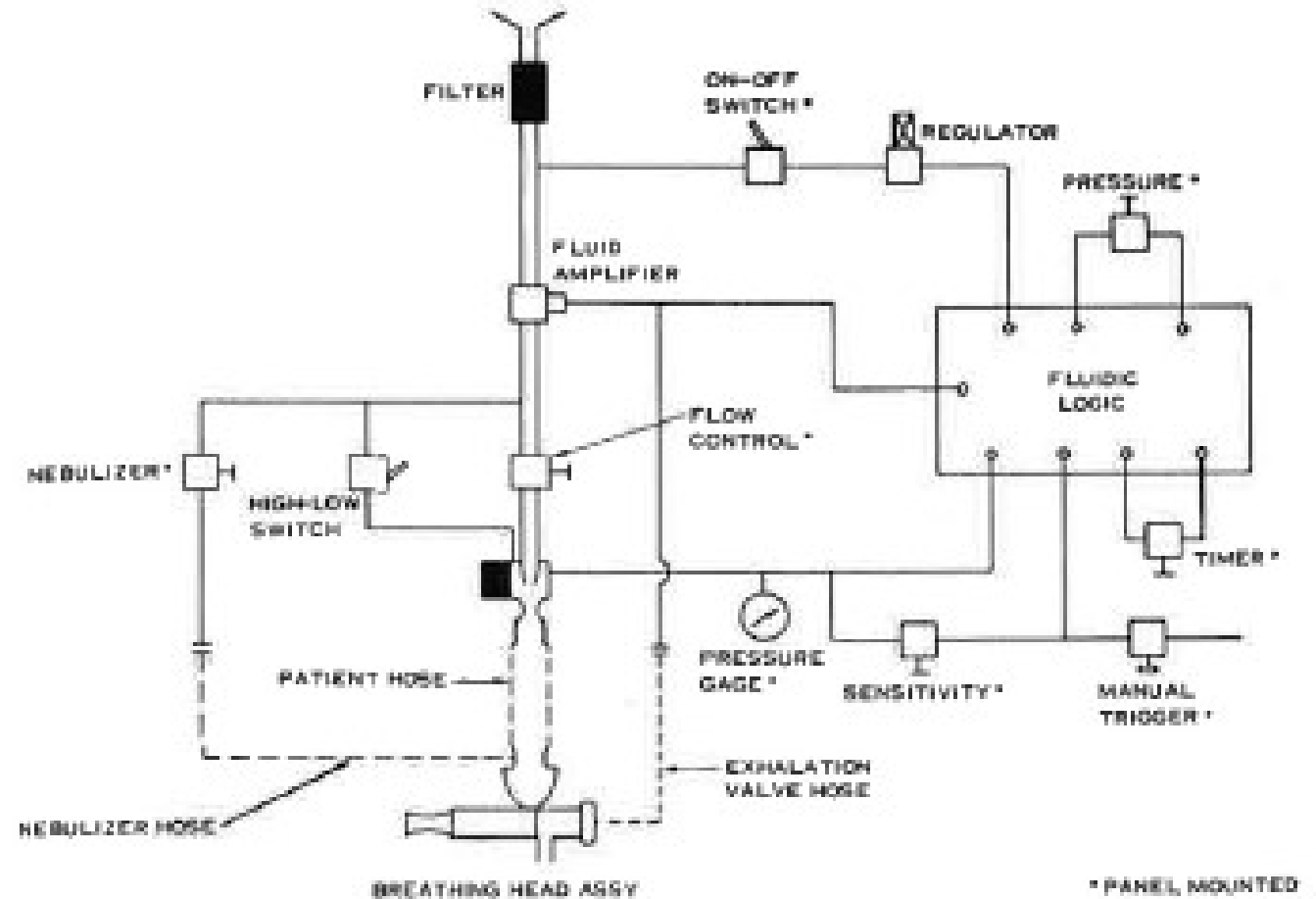
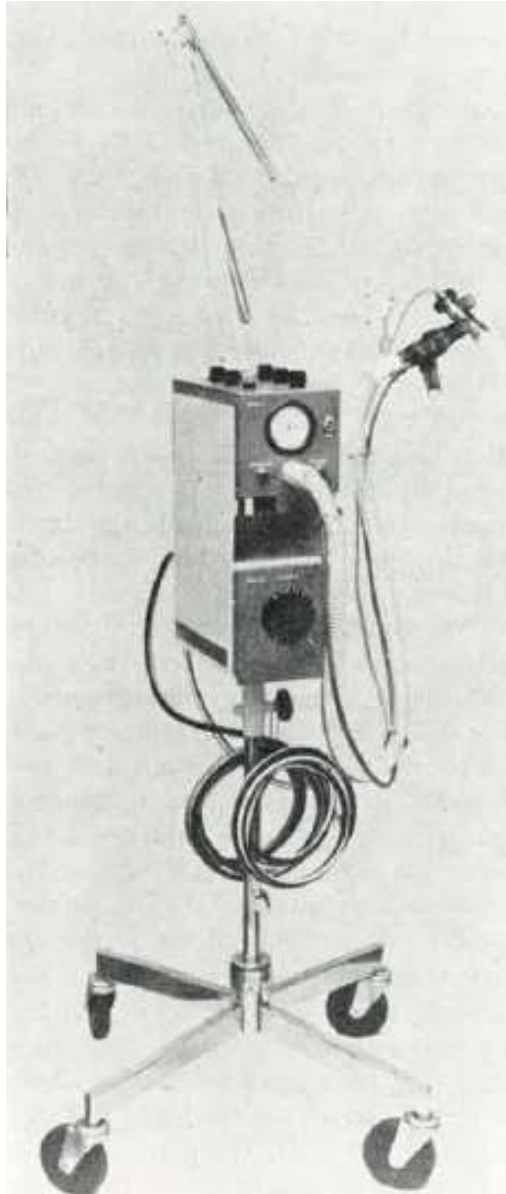


# Servo 900 series Sweden (1970s)

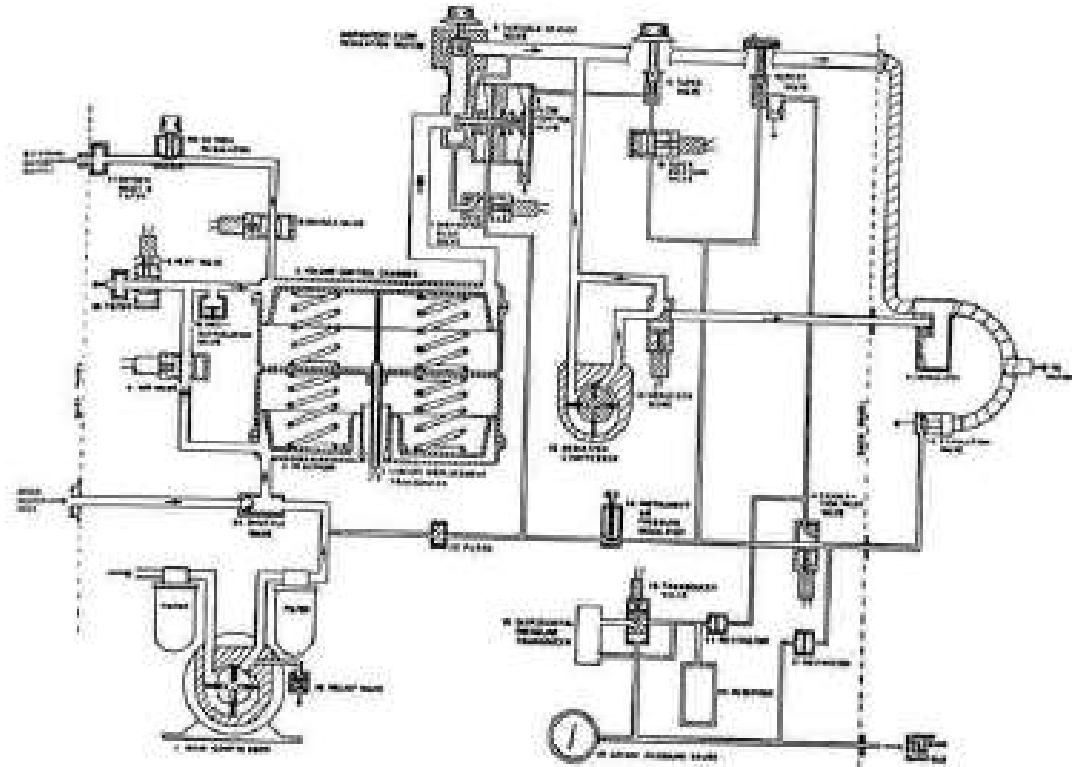




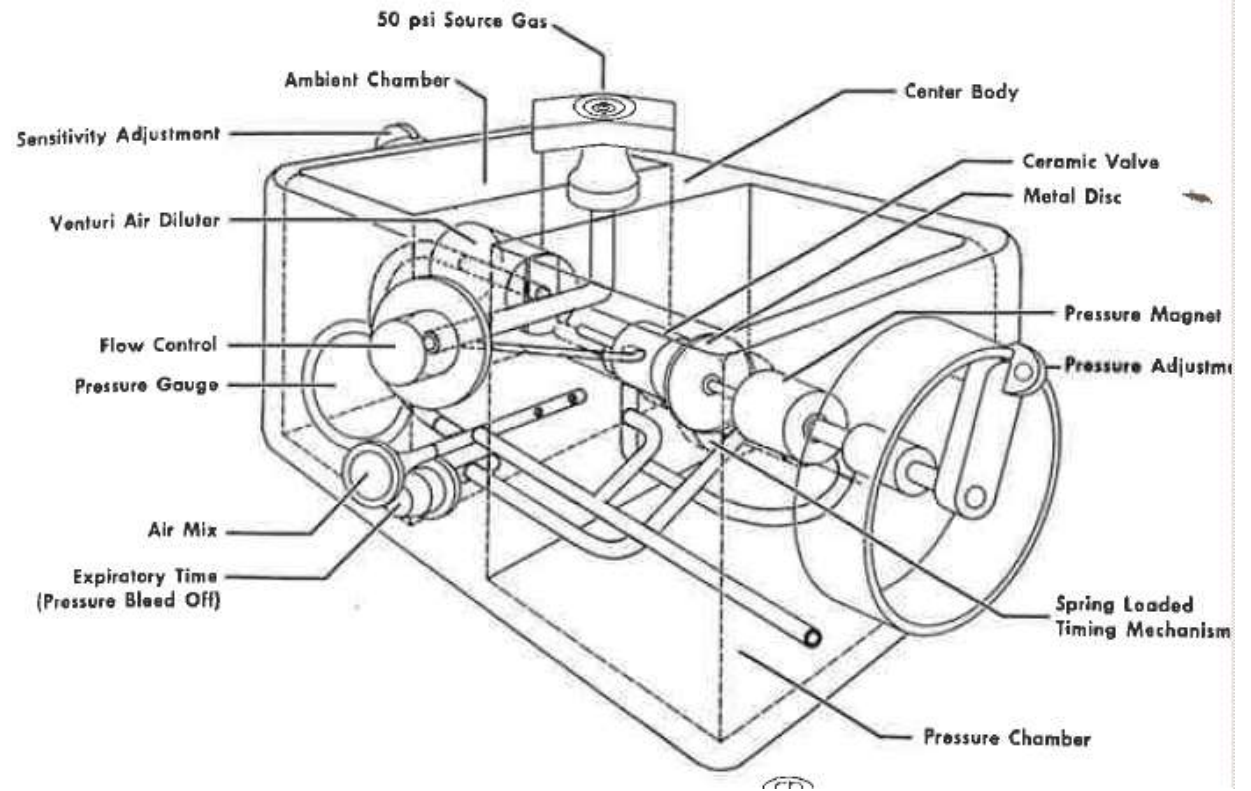
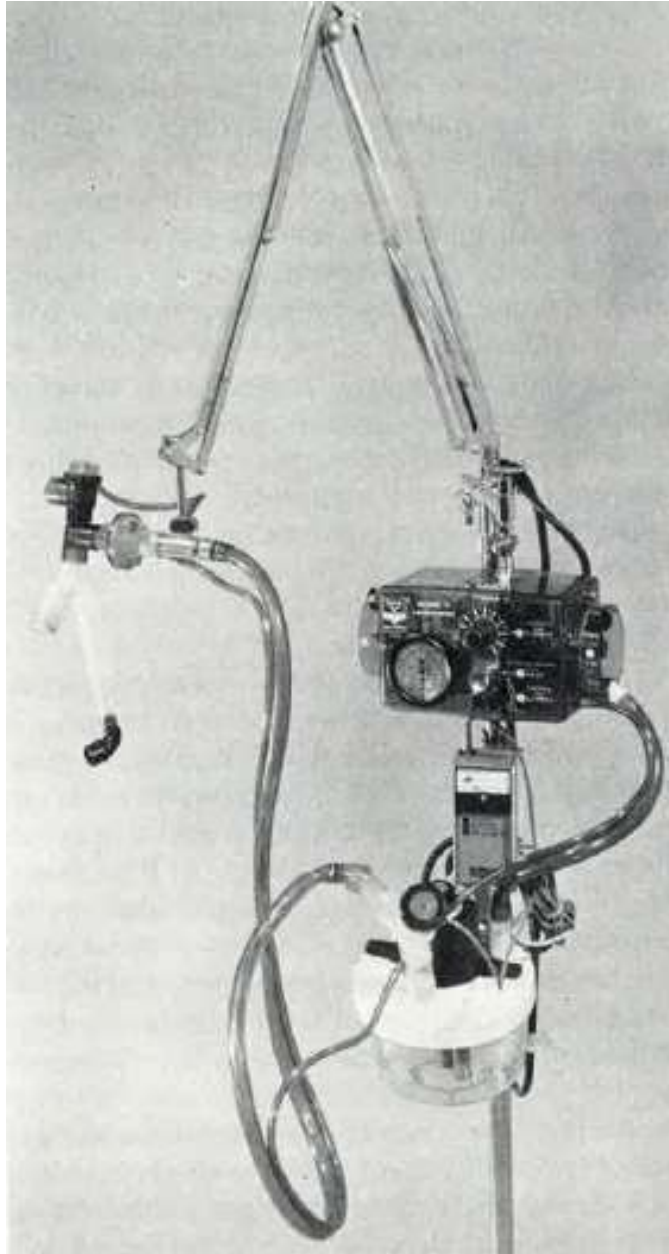
# Vanguard Pad-1 Fluidic



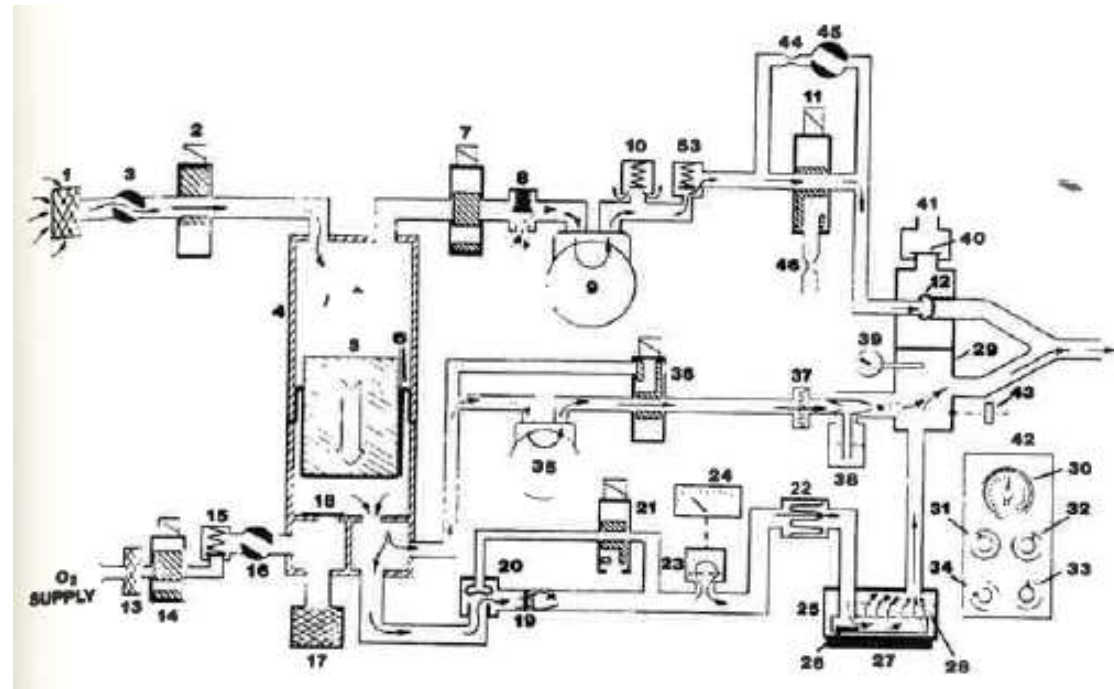
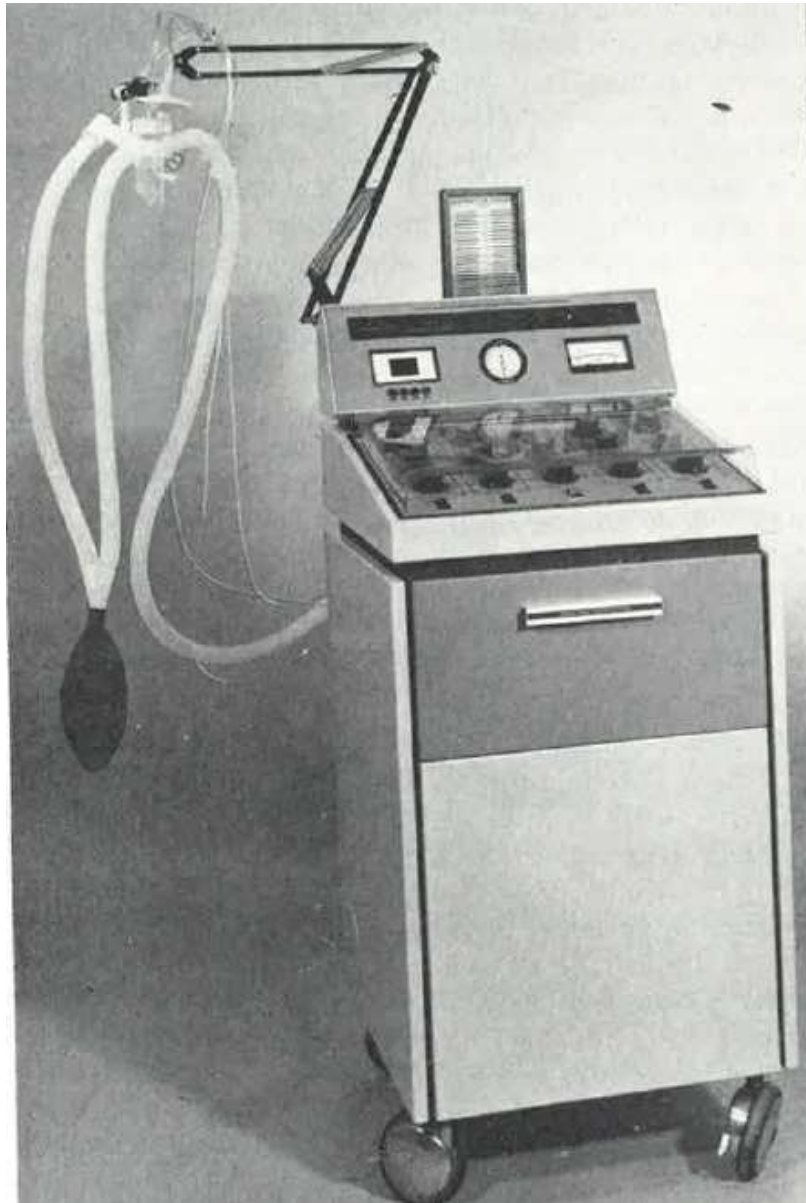
# Searle



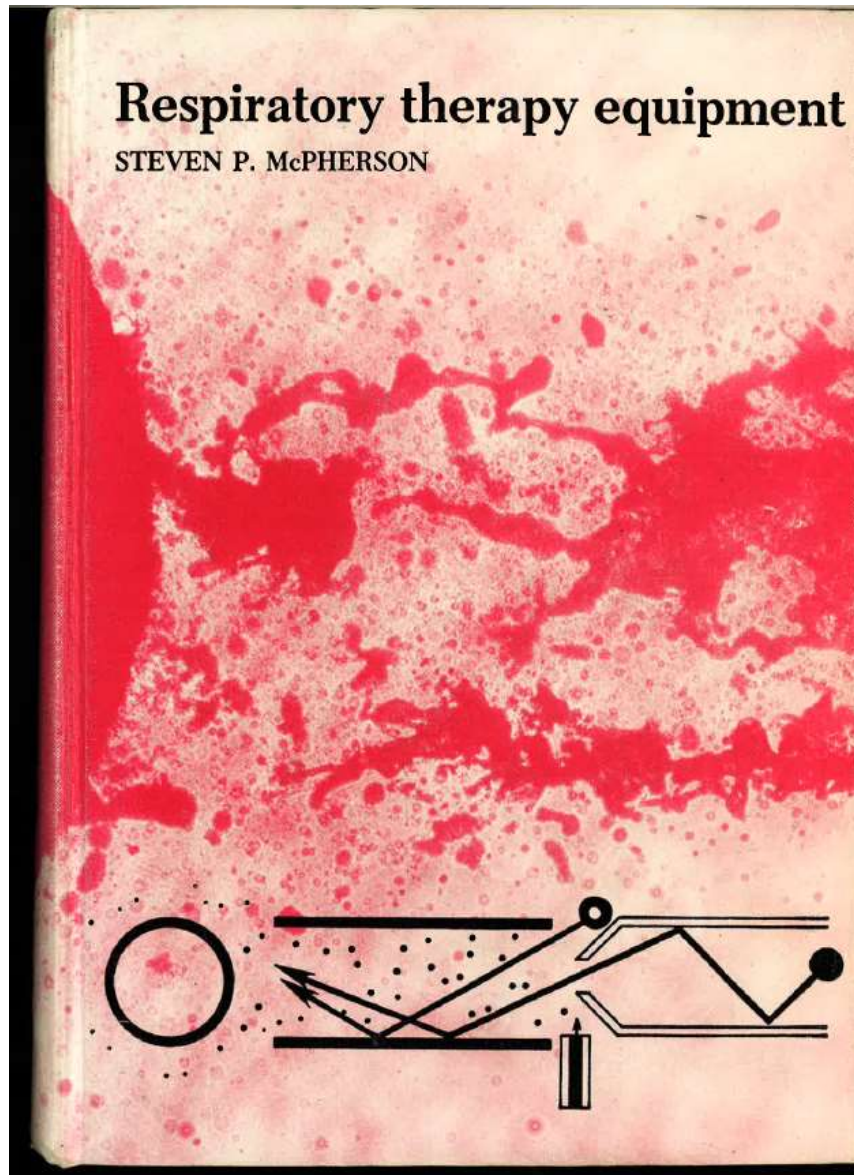
# Bird Mark V11



# Gill 1



# The First RT Equipment Book (1977)

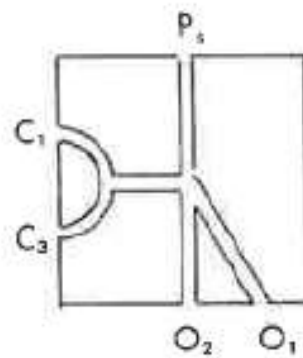
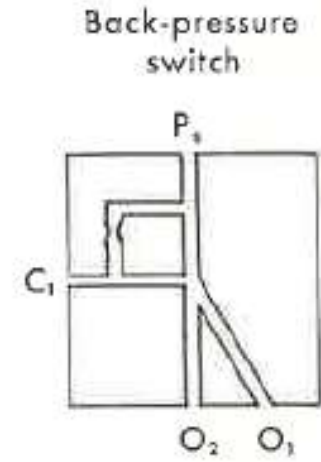
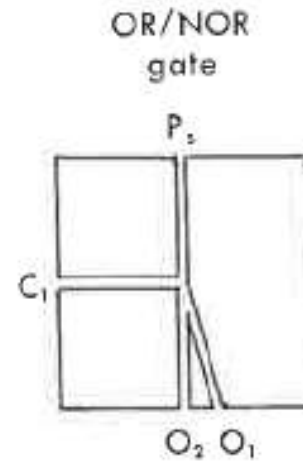
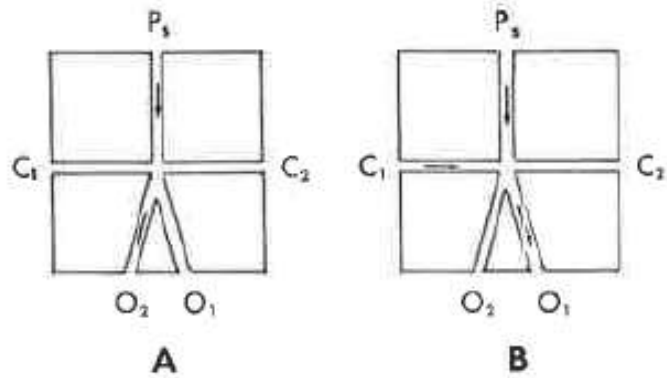


← Respiratory therapist author

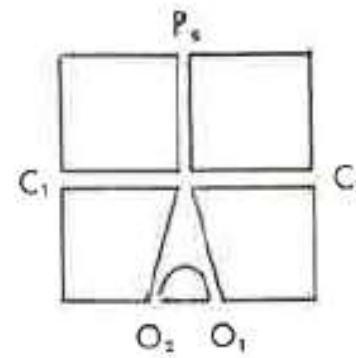
**Detailed descriptions  
of 31 ventilators**

**Only mentions  
3 modes!**

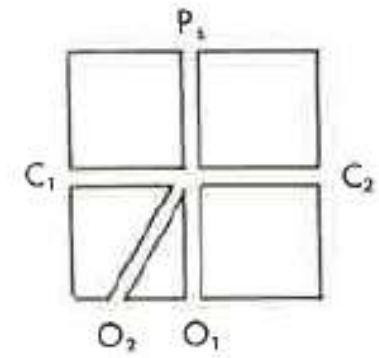
# Fluidic Logic Control Circuits (again)



AND/NAND gate



Proportional amplifier

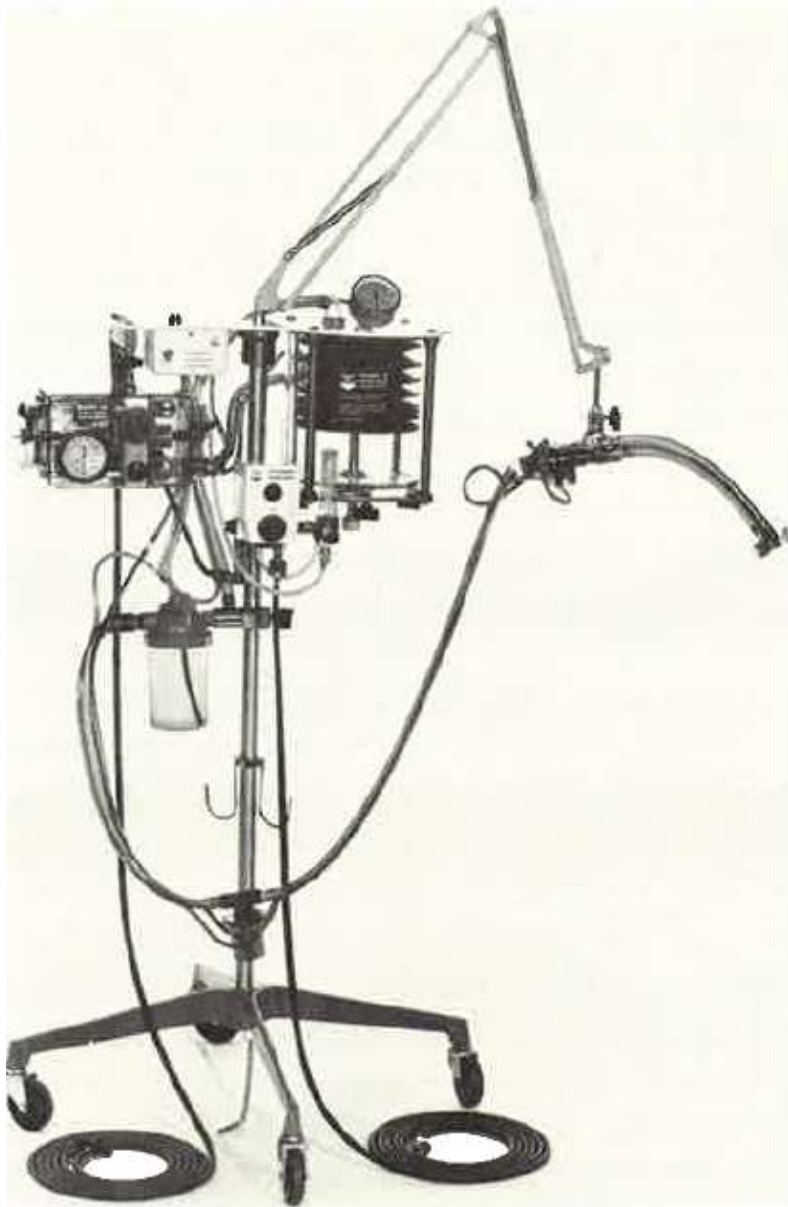


Schmitt trigger

# Emerson Cuirass



## Bird Mark 14-6



1980s philosophy:  
*Normalize blood gases  
no matter what the  
inspiratory pressure*



# Ohio 550

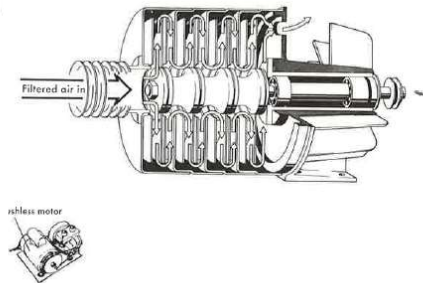
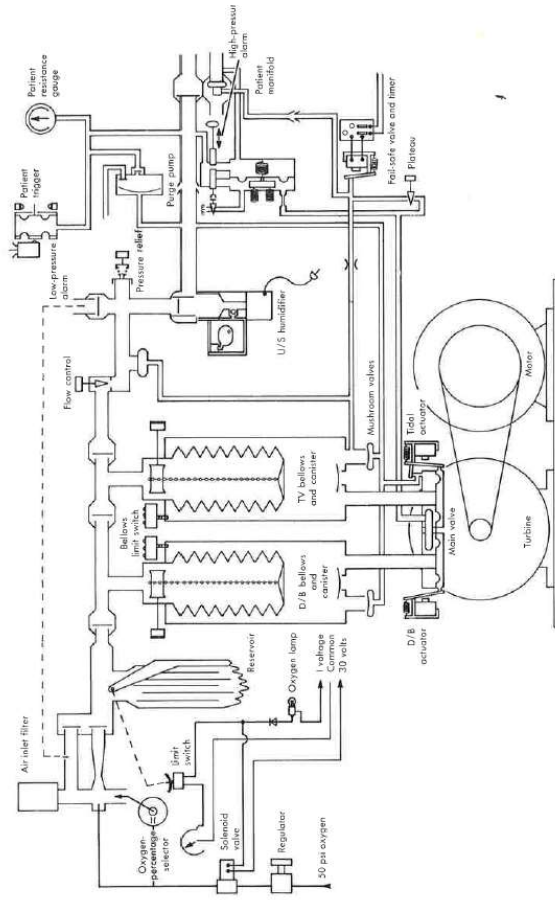
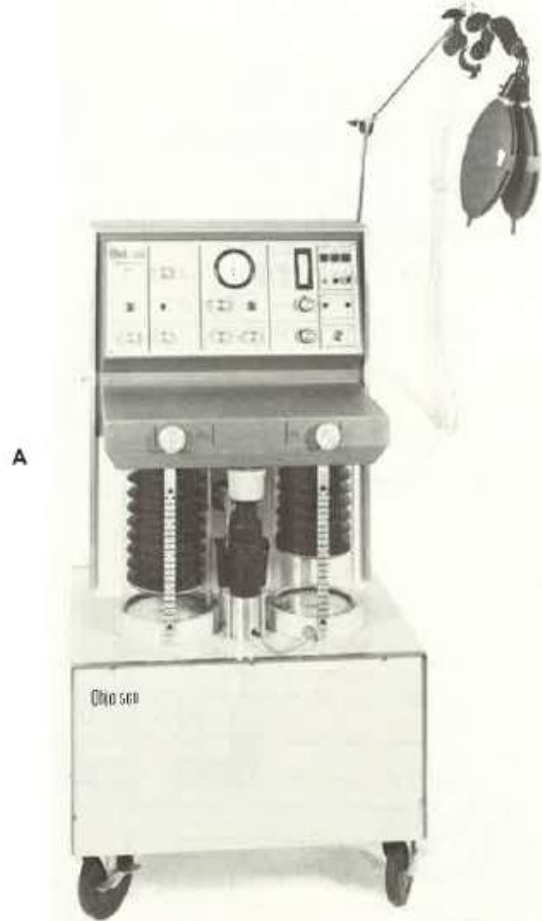
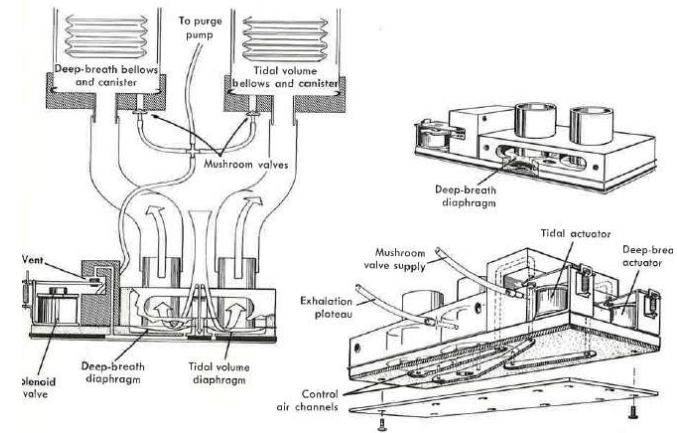
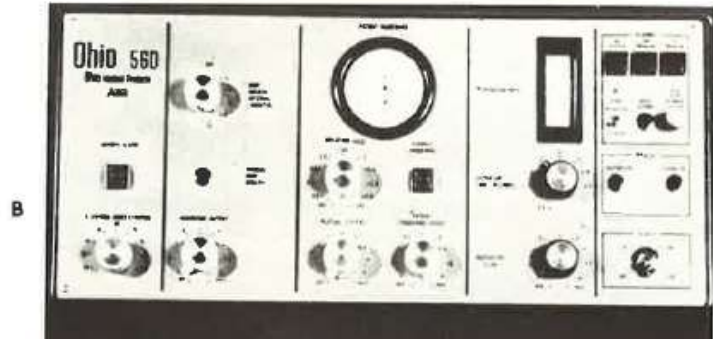
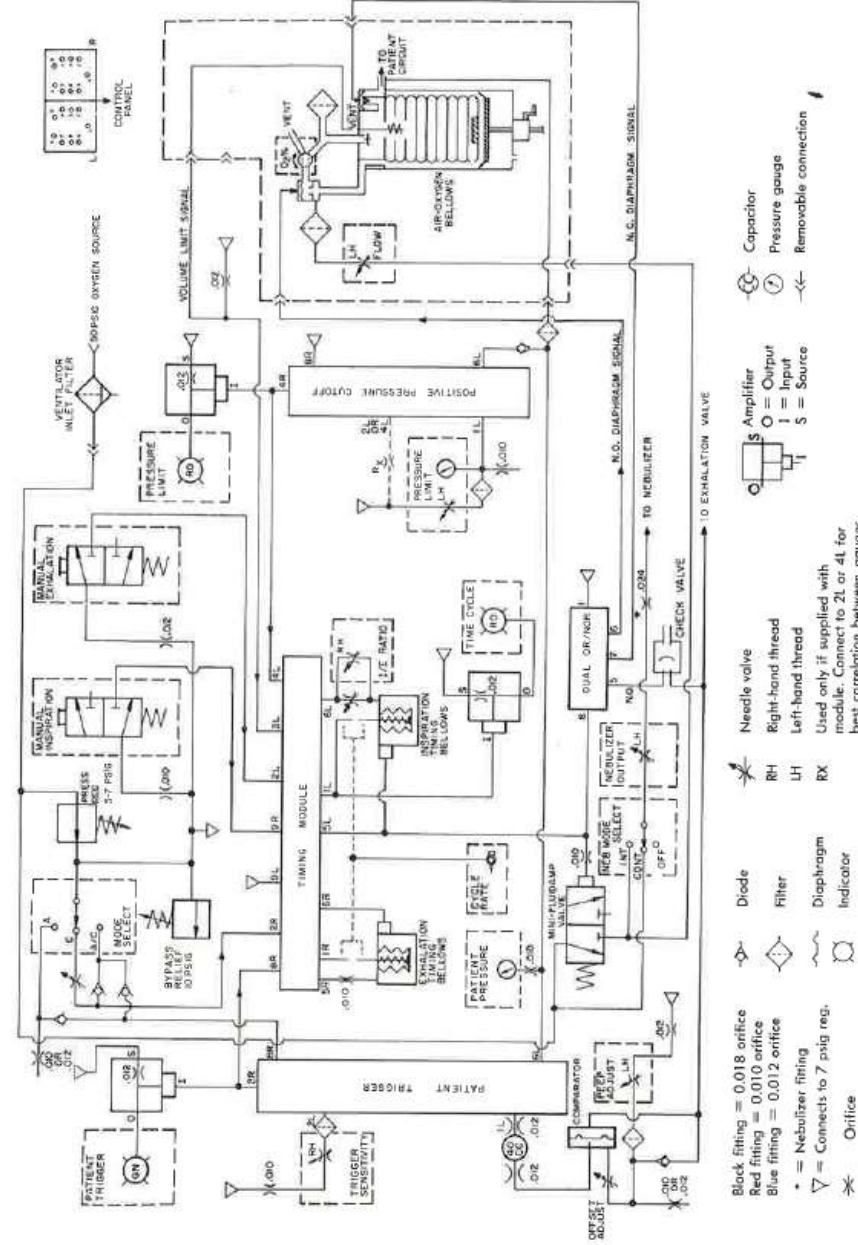
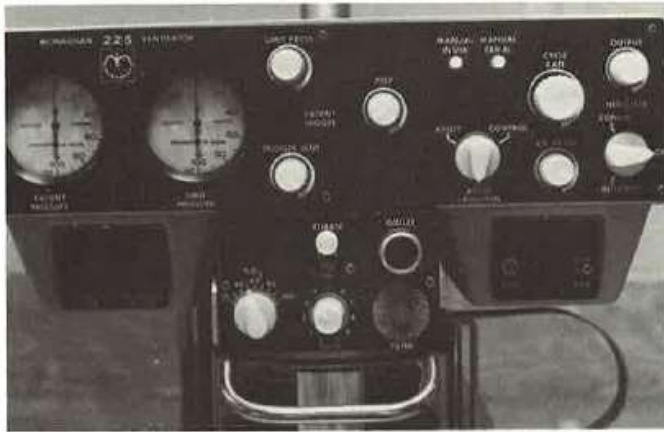
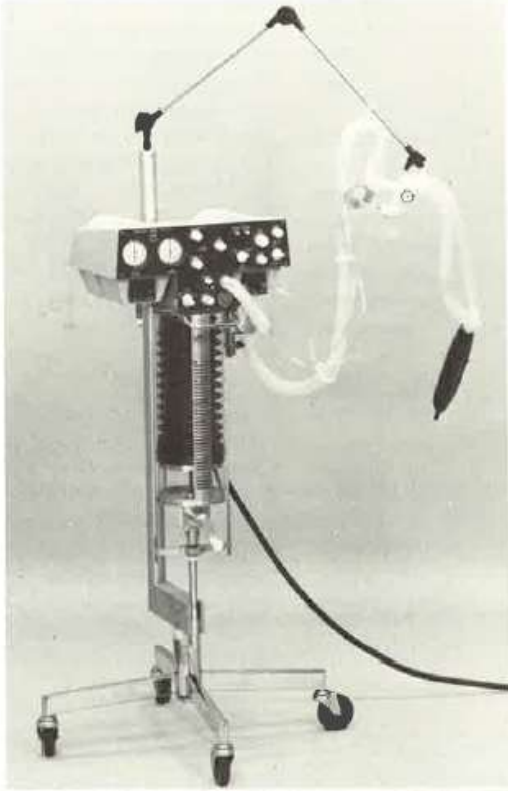


Fig. 12-23. Functional diagram of Ohio 560's rotary compressor. (Courtesy Ohio Medical Products, Inc., Madison, Wis.)



# Monaghan 225

A



# Bourns BEAR Series (1980s 1990s)



**Bear 1**

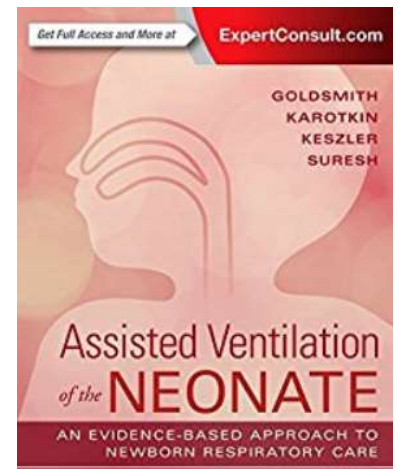
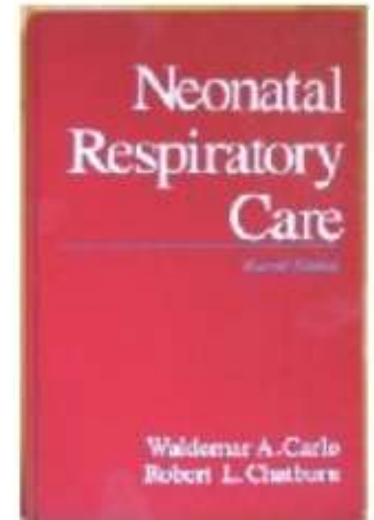


**Bear 5**

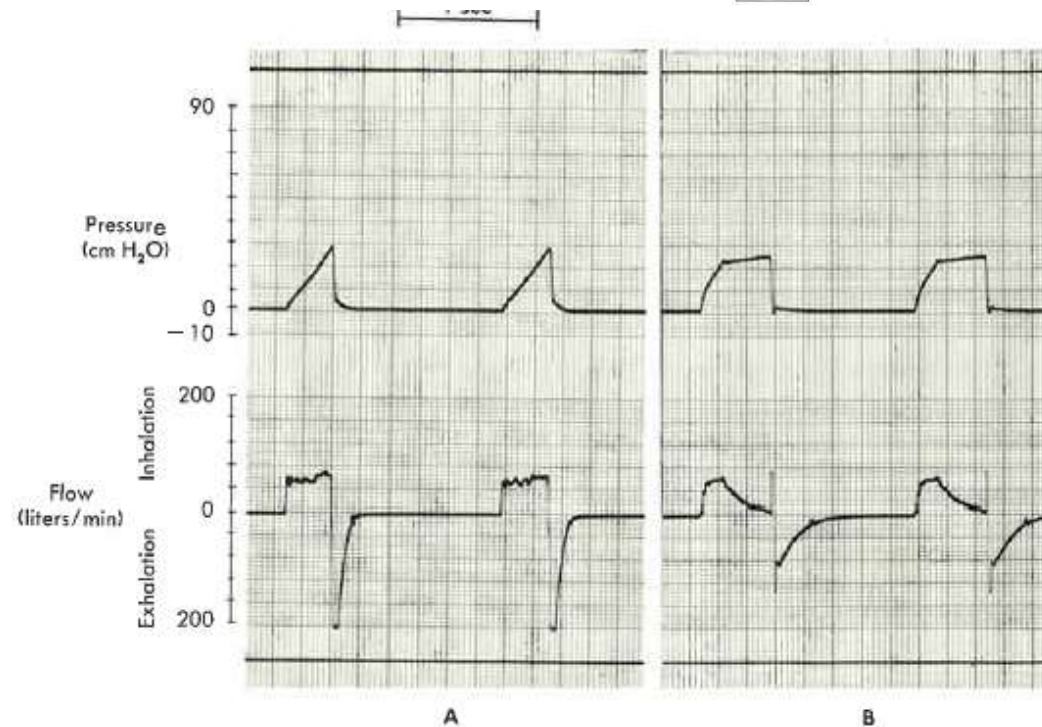
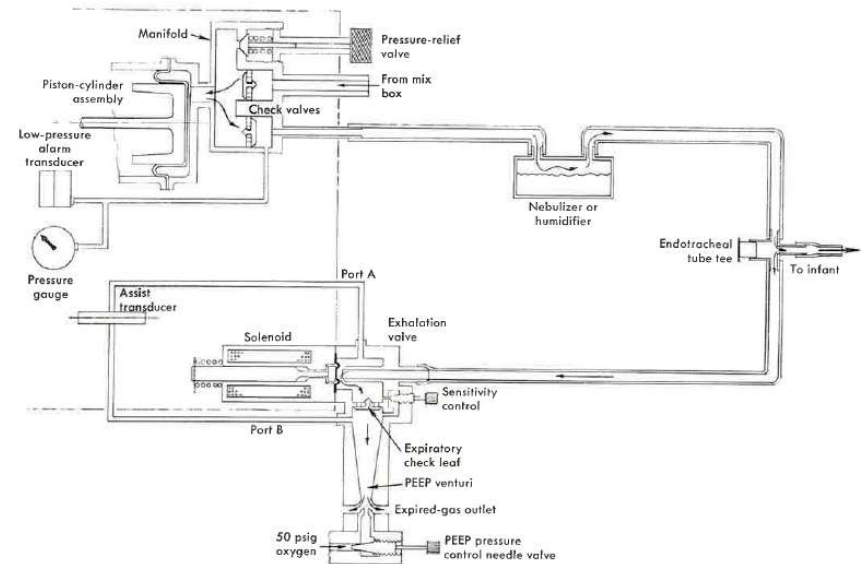
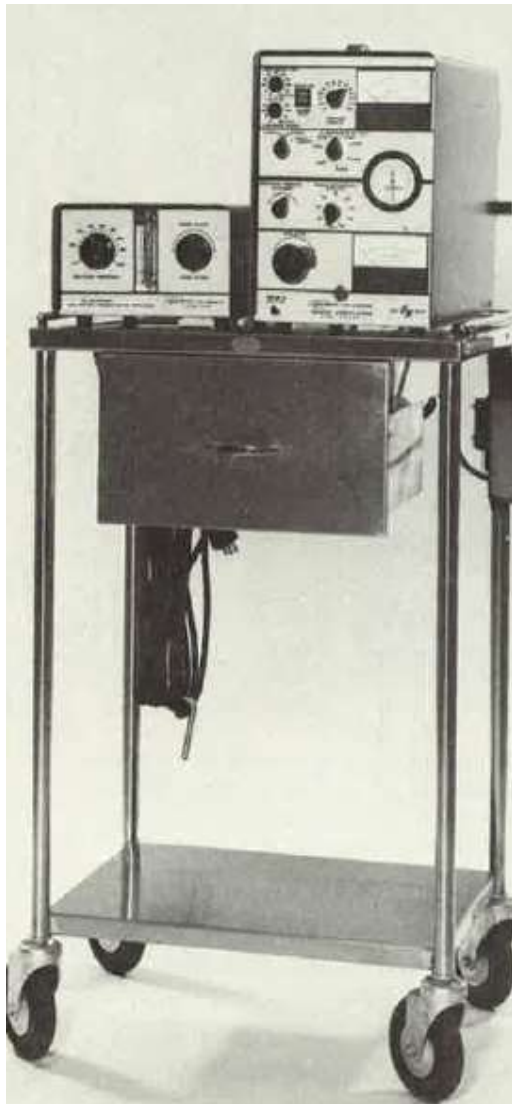


**Bear 1000**

# The First Infant Ventilators

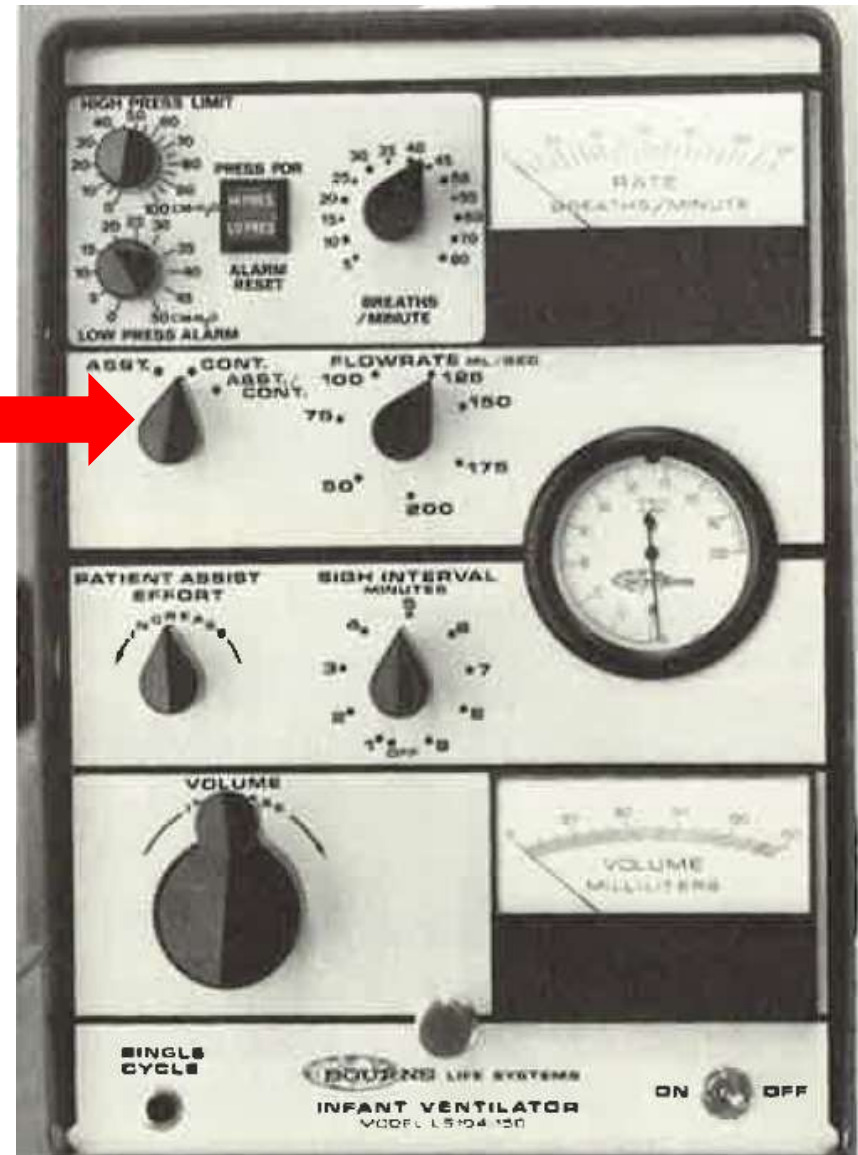


# Bourns LS104-150 US (1960s)

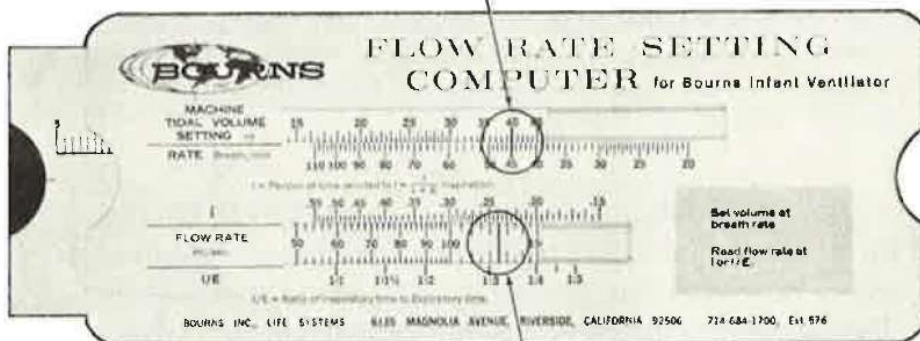


# First ventilator with mode selection?

**Assist  
Control  
Assist/Control**

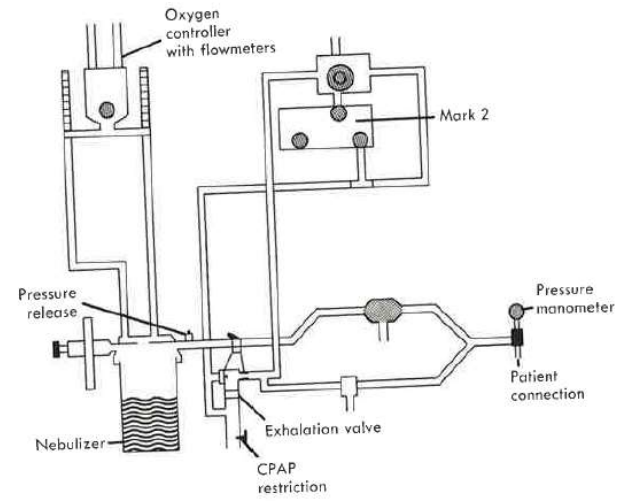
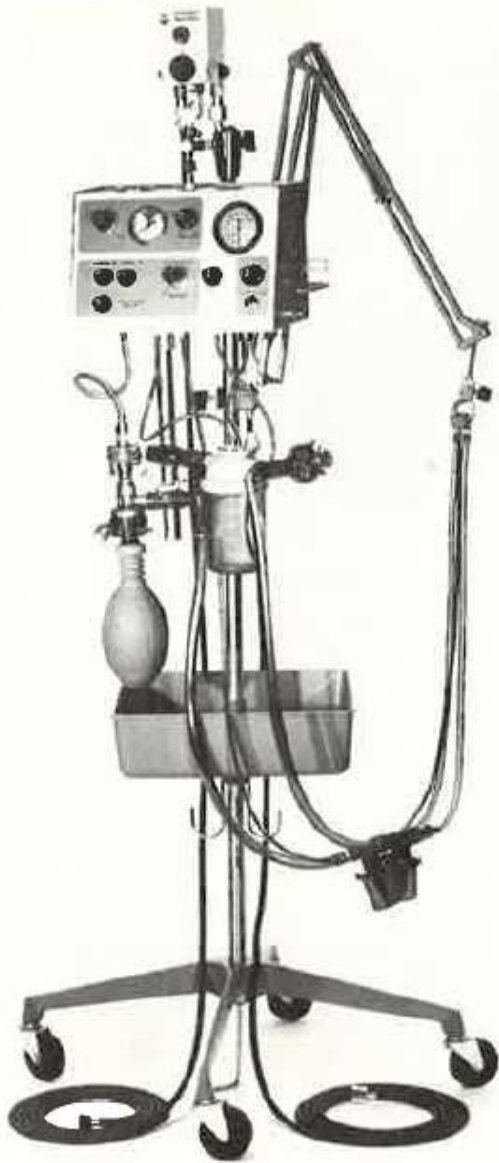


Set slide so that ventilator tidal volume is directly above breathing rate reading.

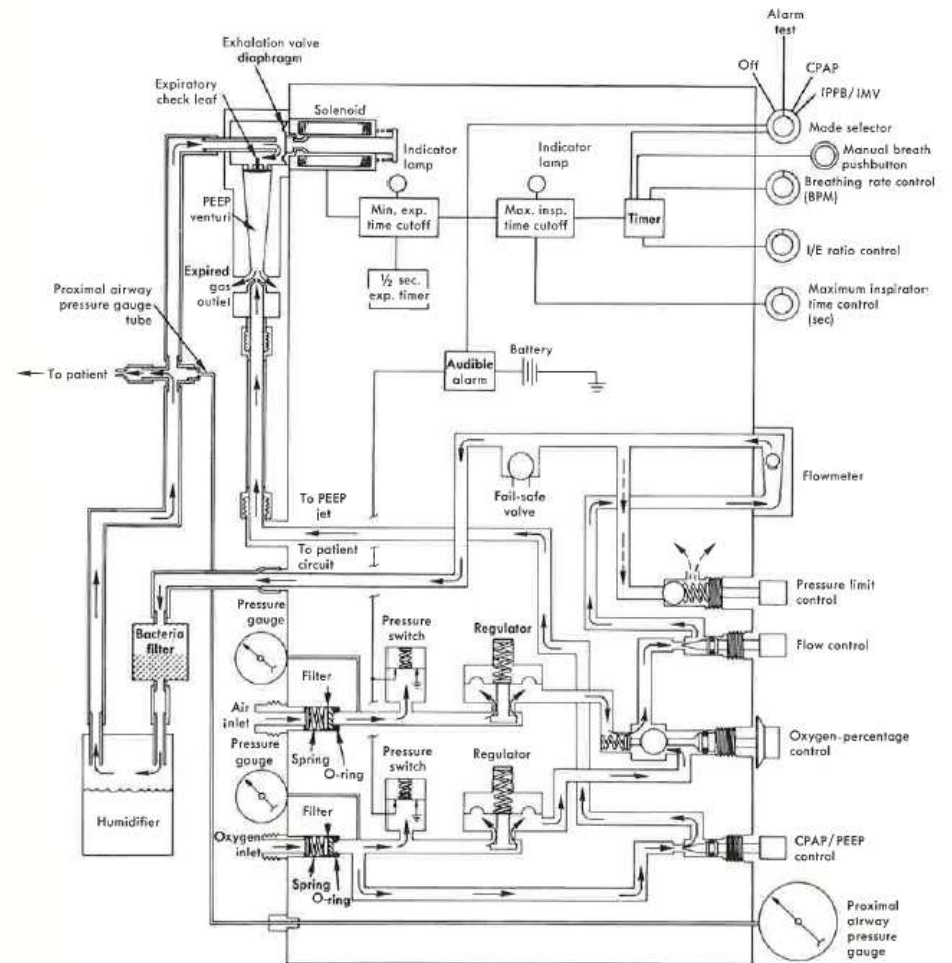


Read I/E ratio directly below flow rate.

# Babybird Ventilator US (late 1970s)



# Bourns BP200 (late 1970s)

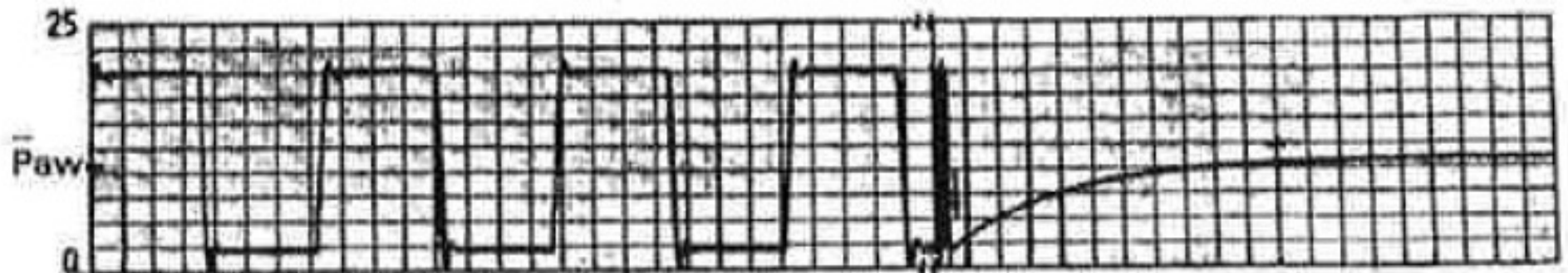
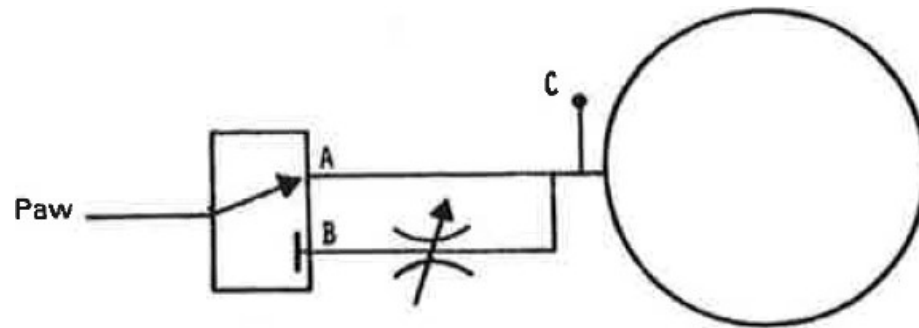




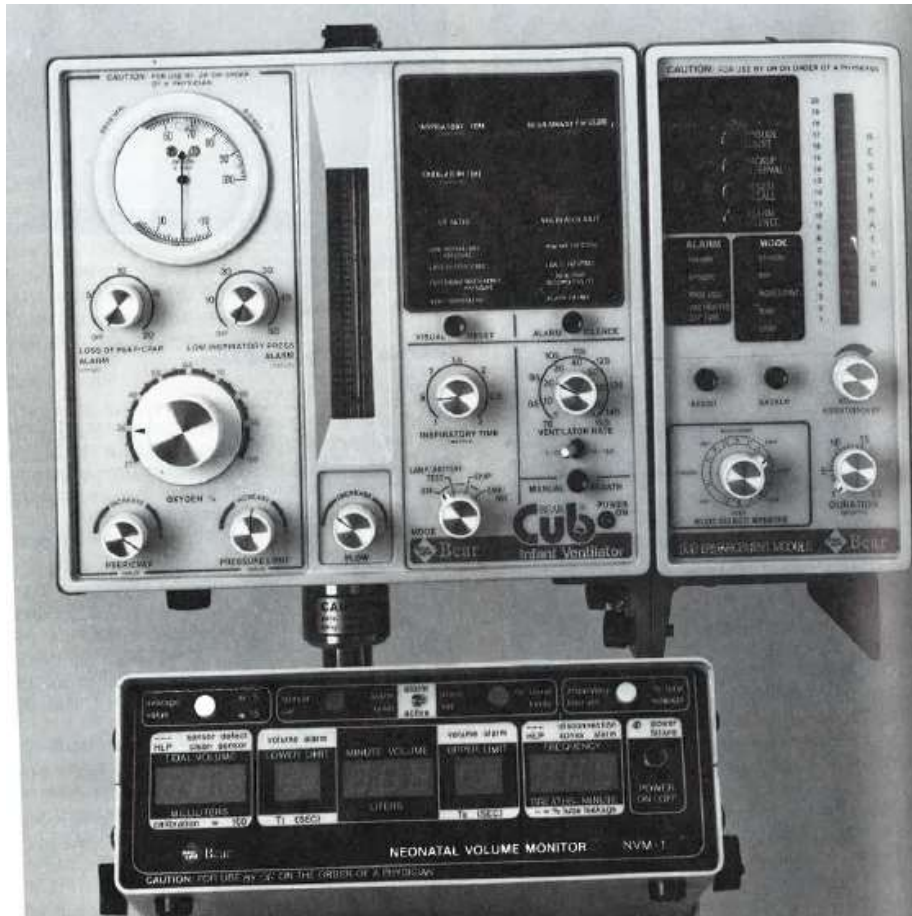
# The First Mean Airway Pressure Device

## Modification of a Ventilator Pressure Monitoring Circuit To Permit Display of Mean Airway Pressure

Robert L Chatburn RRT, Marvin Lough RRT,  
and Frank P Primiano Jr PhD



# Bear Cubs (1990s)

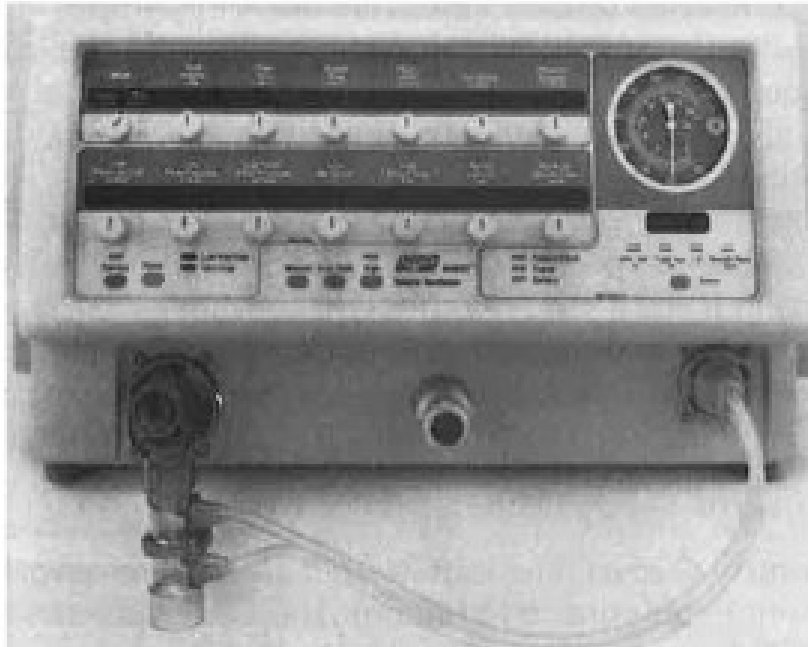


**Bear Cub**

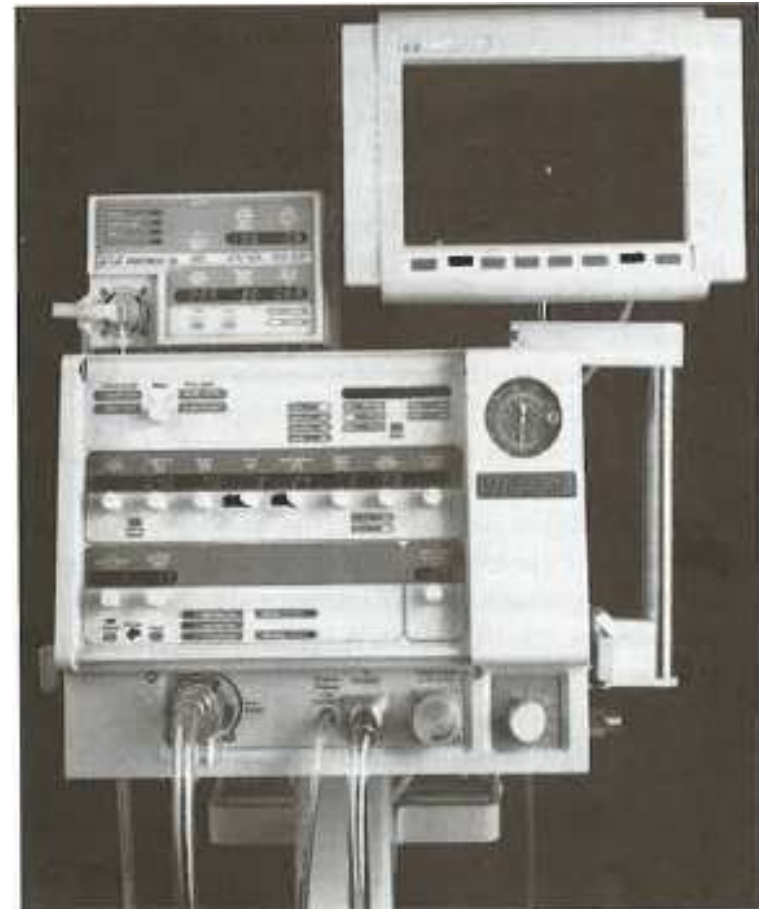


**Bear Cub 750**

# Bird Corporation Ventilators (1990s)

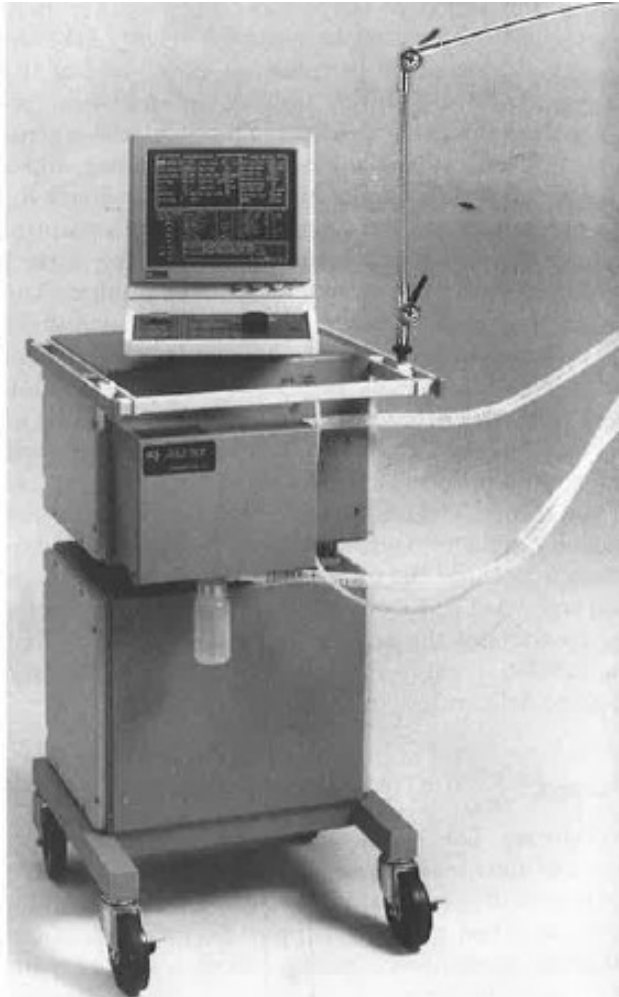


**Bird 840 ST**



**Bird V.I.P infant  
ventilator**

# Infrasonics Ventilators (1990s)



**Adult Star**

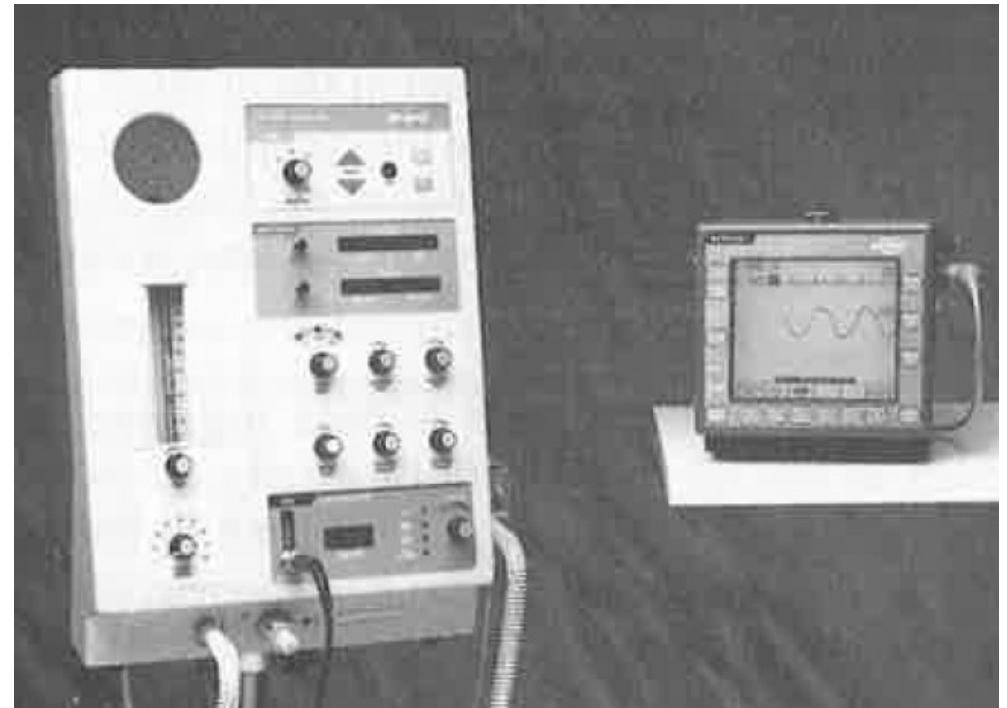


**Infant Star**

# Sechrist ventilators (1990s)



**IV-100B**



**SAVI**

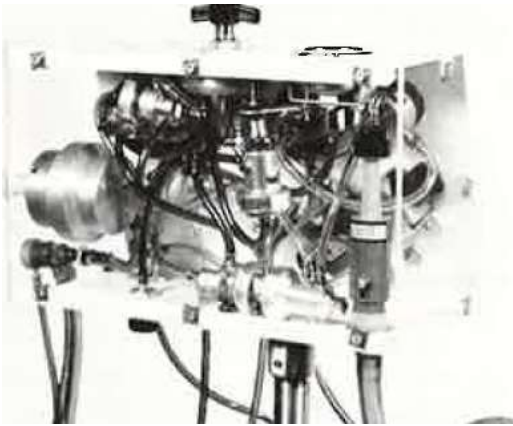
# Healthdyne (1990s)



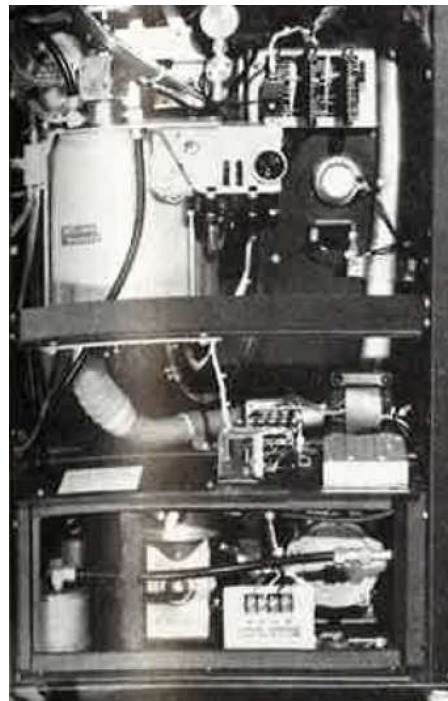
**105 Infant Ventilator**

# Respiratory Care Journal – 1976

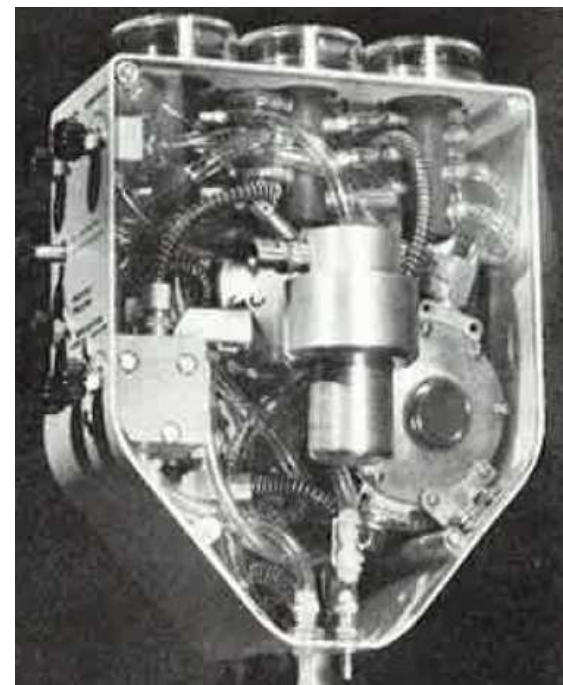
## Plexiglas Modification of Respiratory Therapy Equipment for Teaching Purposes



Baby Bird



MA-1



PR-2

# Respiratory Care Journal – 1973

## The origin of IMV – first used in pediatrics

### Continuous-Flow Ventilation as an Alternative to Assisted or Controlled Ventilation in Infants

ROBERT KIRBY, LT. COL., USAF (MC)\*

ELMO ROBISON, MAJOR, USAF (MC)†

JIMMY SCHULZ, A.A.I.T.†

ROBERT A. deLEMOS, LT. COL., USAF (MC)†

★ ROBERT R. KIRBY, Lt. Colonel, USAF, MC graduated from the School of Medicine of the University of California in San Francisco and served as a Resident in Anesthesiology at Wilford Hall USAF Medical Center, San Antonio, Texas. He is currently Chief of the Anesthesiology Service at the USAF Medical Center, Keesler AFB, Mississippi.



### Intermittent Mandatory Ventilation: A New Approach to Weaning Patients from Mechanical Ventilators\*

*John B. Downs, M.D.; E. F. Klein, Jr., M.D.; Dave Desautels, A.R.I.T.;  
Jerome H. Modell, M.D., F.C.C.P.; and Robert R. Kirby, M.D.*



# Respiratory Care Journal – 1976

Intermittent Demand Ventilation (IDV): A New Technique  
for Supporting Ventilation in Critically Ill Patients

Barry A Shapiro MD, Ronald A Harrison MD, John R Walton BS CRTT ARRT,  
and Richard Davison MD

**The origin of VC-SIMV using the Searle Ventilator**

# 1976: Ads in Respiratory Care Journal

**DISPOSABLE I·M·V SET-UPS**  
*(Intermittent Mandatory Ventilation)*

I·M·V . . . The Process Whereby the Spontaneously-Breathing Patient May Have His Respirations Augmented, At Predetermined Time Intervals, by a Programmed Ventilator-Delivered Deep Breath (Sigh). An Efficient Tool for Use in the Weaning Process, as well as an Effective Alternative to Continuous Mechanical Ventilation.

It is recognized that the transition period during which the patient is weaned from Mechanical-to-Spontaneous Ventilation can be both difficult and traumatic. To respond to the need for a Disposable I·M·V Set-Up that would incorporate Superior Design, Easy and Safe Application, and a Multitude of Possible Assemblies, HUDSON introduces its new Disposable I·M·V Manifold/Set-Ups. So versatile they will satisfy your patients' many requirements be they High Density Aerosol, Humidified and Warmed Inspired Gas, or Precise Control of the Inspired Oxygen Level (FIO<sub>2</sub>). The HUDSON Disposable I·M·V Manifold/Set-Up . . . definitely in a class by itself.

**MODEL NO. 1654 I·M·V Set-Up . . . Includes:**  
 Basic I·M·V Manifold, 4 mm Adaptor and I·M·V Adaptor.

**MODEL NO. 1652 I·M·V Set-Up . . . Includes:**  
 Basic I·M·V Manifold, 4 mm Adaptor, I·M·V Adaptor 3 Liter Non-Conductive Reservoir Bag, 12" Large Bore Tubing and 10" Small Bore Tubing.

For detailed information, specifications, and suggested Set-Ups, write or call:




See us at AART  
Booths No. 402 and 404



**HUDSON**  
 OXYGEN THERAPY SALES CO.  
 27711 Diaz St. Temecula, Calif. 92390 (714) 676-5511  
 2016 Seville Road, Wadsworth, Ohio 44281 (216) 334-2531



# 1976: Ads in Respiratory Care Journal

## The CV 2000 provides optimum patient care with every significant ventilatory technique.

If the ventilator you're considering doesn't offer all these features, consider the one that does: the CV 2000.

- **Synchronized IMV** prevents asynchronous mandatory breaths.
- **Demand Valve** eliminates cumbersome reservoir system.
- **T<sub>I</sub> and T<sub>E</sub> Independently Controllable**, providing precise calibrated control over the components of ventilation.
- **Uninterrupted Continuous Flow (CPAP) Mode** with rapid switch-over to control modes when necessary.
- **Custom-Calibrated Controls** for wide and accurate ranges.
- **All Pneumatic** for extended life and reliability.
- **A Price Well Below** that of other ventilators with fewer capabilities.

Don't settle on any ventilator until you judge the CV 2000 for yourself. Simply write or call for a trial evaluation.



## The IMV Machine

# 1976: Ads in Respiratory Care Journal

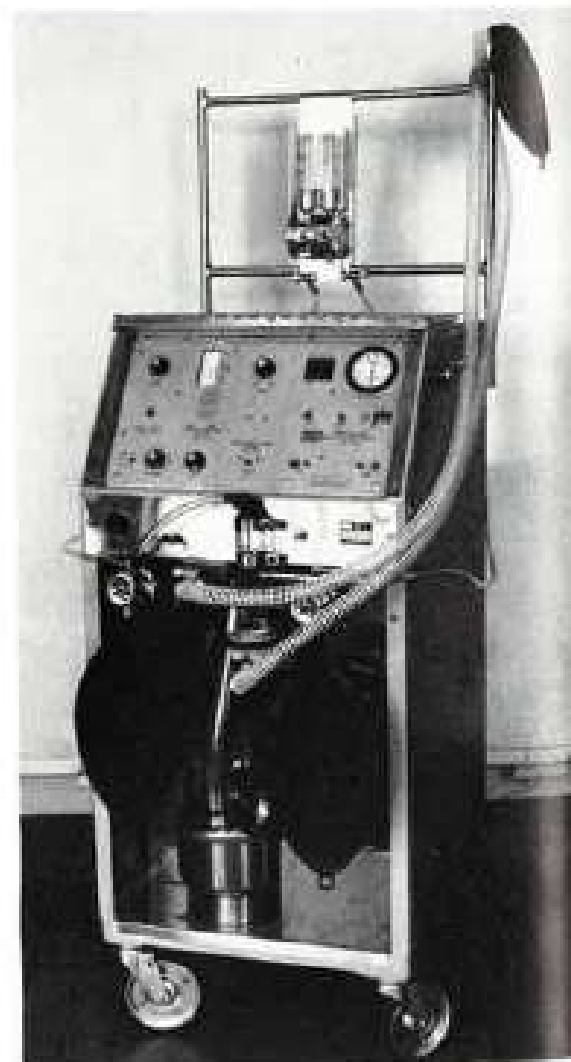
## **EMERSON** IMV Ventilator

**Designed specifically for IMV, to gain the maximum benefit from this new concept.**

Air fully humidified flows continuously to a reservoir bag, and is available for unobstructed inspiration by the patient. PEEP may be added to keep the lungs expanded. At intervals the ventilator delivers a "mandatory" breath, which supplements the patient's own breathing and increases minute volume. The patient maintains his own homeostasis, without interference from drugs or hyperventilation.

At first the ventilator is generally set to supply mandatory breaths at a normal controlled rate. This is then gradually changed, by lengthening the interval between breaths as the patient's condition improves. Eventually mandatory breaths are spaced so far apart that the patient scarcely relies on them at all — and "weaning" is completed.

**J. H. EMERSON COMPANY**  
22 COTTAGE PARK AVENUE, CAMBRIDGE, MASSACHUSETTS 02140



*Please request Form 3-MV*

# 1976: Ads in Respiratory Care Journal

## Intermittent Demand Ventilation\*



The image shows a Searle Ventilation Mode Controller (VMC) unit. It is a yellow, hexagonal-shaped device with a white control panel. The panel features three large black knobs labeled 'APNEA WARNING SENSITIVITY', 'IDV FREQUENCY', and 'VENTILATION MODE'. Below the knobs are several smaller controls: a red 'APNEA WARNING' button, a yellow 'POWER' button, and a green 'APNEA WARNING' button. The Searle logo and 'VENTILATION MODE CONTROLLER' are printed on the top left of the panel.

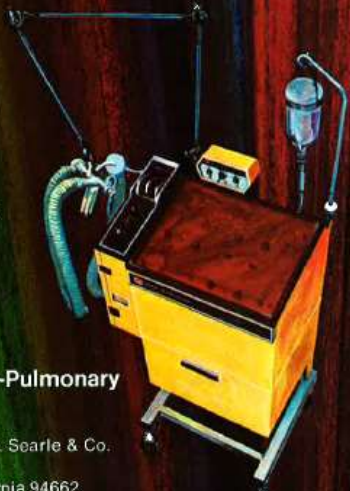
### Exclusively with the Searle VMC/VA™

\* IDV is a ventilation mode in which the mandatory (or forced) breath is given in response to patient demand.

The Searle VMC—ventilation Mode Controller—also features:

- STANDARD
- CPAP
- Apnea Warning in all modes

Contact your Searle Cardio-Pulmonary Systems representative or write for complete details.



The image shows the Searle VMC/VA unit mounted on a yellow cart. The cart has a red top surface and is equipped with various respiratory therapy components, including a humidifier and tubing.

**SEARLE** Searle Cardio-Pulmonary Systems Inc.

Subsidiary of G. D. Searle & Co.  
Box 8068  
Emeryville, California 94662

# 1976: Ads in Respiratory Care Journal

## The Ventilator that won't be outmoded

Now you have some choices: the versatile Searle VVA; the Ventilation Mode Controller which provides Intermittent Demand Ventilation, CPAP (or "blow by"), selectable control back up and apnea warnings in all modes; the AUTOWEDGE™ Spirometer for breath by breath monitoring; the unique TIDAL™ Humidifier; the Power Pack for patient transport. The VVA/VMC. It won't be outmoded. Call or write.

**SEARLE**

**Searle Cardio-Pulmonary  
Systems Inc.**

Subsidiary of G. D. Searle & Co.  
Box 8068  
Emeryville, California 94682  
(415) 853-2100



# 1976: Ads in Respiratory Care Journal

**dependable**  
...anywhere



**MONAGHAN**  
**225/SIMV\***  
**Volume Ventilator**



Trouble-free fluidic principle operates on 50 psig from wall outlet, tank, or compressor ... in room, ambulance, plane.

- higher flow, volume and pressure capabilities
- ✱ synchronized intermittent mandatory ventilation
- completely portable
- lighter, more compact
- fewer moving parts
- costs substantially less

Evaluate Monaghan 225/SIMV...  
Call Donald Burgett collect.  
(303) 770-2700



**MONAGHAN**  
A DIVISION OF SANDOZ, INC.  
4100 East Dry Creek Road,  
Littleton, Colorado 80122  
Telephone (303) 770-2700

# 1976: Ads in Respiratory Care Journal

**better  
patient  
protection**  
with any ventilator



**MONAGHAN 700**  
**Improved Ventilation Monitor**

Versatile new concept adapts to any pressure or volume ventilator or can be used without ventilator as ideal weaning aid. Displays TV, MV, Rate individually or sequentially every six seconds... activates visual and audible alarms if adjustable parameters are exceeded.





# 1976: Ads in Respiratory Care Journal

## The FOREGGER<sup>®</sup> 210 Volume Ventilator.



**1. IMV:** IMV lets you remove a patient from the ventilator through a gradual weaning process. With most ventilators, you must add extra equipment to attain this benefit. But with the new FOREGGER 210 Volume Ventilator, IMV is built-in, not added on. So you can administer IMV without taping or untangling wires.

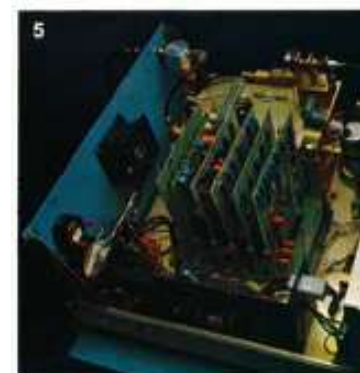
**2. I:E Ratio:** The unique cluster of Inspiratory: Expiratory Time ratio, Inspiratory Time, and Airway Flow rate dials, enables you to maintain a preset I:E ratio (1:1 to 1:4). You can also adjust Breaths Per Minute and Tidal Volume independently. Gives you greater flexibility in critical patient care.

**3. Alarm System:** The FOREGGER 210 Volume Ventilator has an alarm for all anticipated clinical contingencies. THESE ALARMS INCLUDE HIGH AIRWAY PRESSURE, HIGH SIGH PRESSURE, APNEA, INTERNAL FAILURE, POWER FAILURE, LOW GAS PRESSURE, AND HIGH AND LOW MINUTE VOLUMES. Alarms are both audible and visual so the operator can ascertain ventilator status from a distance and react quickly if a change occurs. In addition, press-to-test and audio-off controls are included.

**4. Multiple Function:** We provide the latest state of the art versatility. This includes Manual Start, IMV, I:E Ratio, Sigh, Multiple Sigh, Manual Sigh, Assist, Inspiratory Pause and PEEP.

**5. Service:** Because of all-electronic circuitry, most factory servicing can be done right in the hospital. And, emergency response can be provided within 48 hours on a regional level by specialized technicians. So you get fast, expert service.

**6. In-Service Training:** To help you become more familiar with our new Volume Ventilator, we've put together



# 1976: Ads in Respiratory Care Journal

What's  
New?

**BIO-MED IC-2 VENTILATOR.**  
The IC-2 Adult Intensive Care/  
Transport Ventilator is said by the



## **BOURNS BP200 VENTILATOR.**

An electronically controlled and pneumatically operated time-cycled device, the Bourns Model BP200 Infant Pressure Ventilator is a continuous flow generator that serves as a controller. It provides ZEEP, PEEP, CPAP, IMV, or inspiratory pause. Pressure limit may be controlled in any mode. Rate is adjustable from 1 to 60/min, I/E from 4/1 to 1/10, flow from zero to 20 l/min, CPAP/PEEP



from zero to 20 cm H<sub>2</sub>O, pressure limit from 10 to 80 cm H<sub>2</sub>O. The ventilator has a heated humidifier, integral oxygen blender, manual breath capability, and audible alarms for gas supply pressure failure and power failure. It weighs 35 lbs, measures 9" high by 9" wide by 13" deep, and can be placed on a table or counter or mounted on a castored stand. *Bourns Inc Life Systems Division.*

**IMVbird.** The IMVbird is pneumatically powered, time cycled, and offers tidal volume determination by inspiratory time and flow-



rate, pressure limiting, CPAP, PEEP, IMV, demand acceleration and flow acceleration, with a minimum of controls and absence of gadgetry. *bird Corporation.*

# 1976: Ads in Respiratory Care Journal

Over-engineered at Case Western Reserve University



# 1976: Ads in Respiratory Care Journal

**Bennett AP-5 . . . A Standard of Excellence**

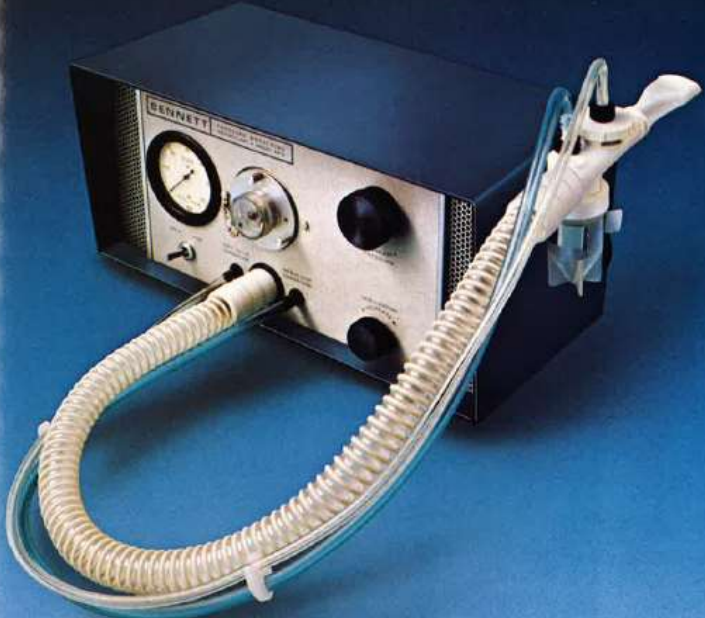
The Bennett AP-5 is a portable electric IPPB Therapy Unit expressly designed and manufactured to give you years of trouble-free service. The AP-5 features:

- Long life motor/compressor
- Flow Sensitive Bennett Valve
- Full line of optional accessories
- Full two year warranty

When you buy Puritan-Bennett products, you buy reliability, craftsmanship, service and concern for quality unequalled in the industry.

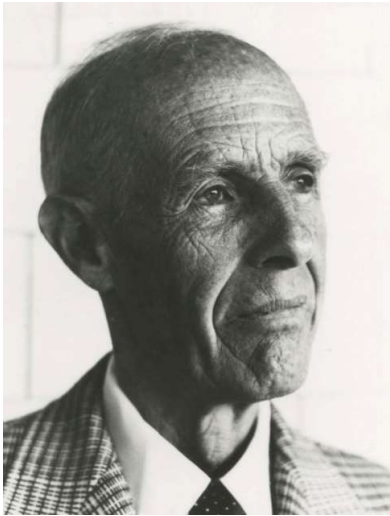
**P**  
PURITAN-BENNETT  
CORPORATION

Puritan-Bennett Corporation  
General Offices  
Oak At Thirteenth Streets  
Kansas City, Missouri 64106

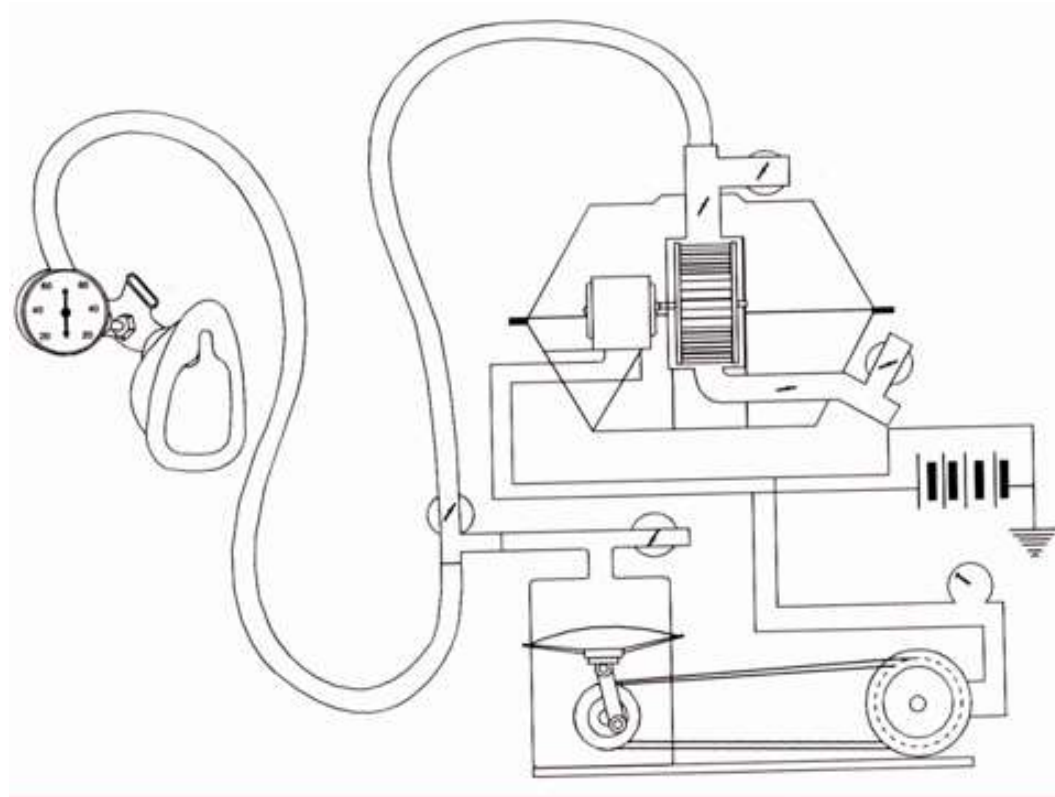


# High Frequency Ventilators

# First High Frequency Oscillator (1950s)



**Jack Emerson**



*photo courtesy of Rich Branson*

# Rainbow Jet Makes the News

## Niles Man's Respirator Device Hailed by Medical Society

**EMILY WEBSTER**

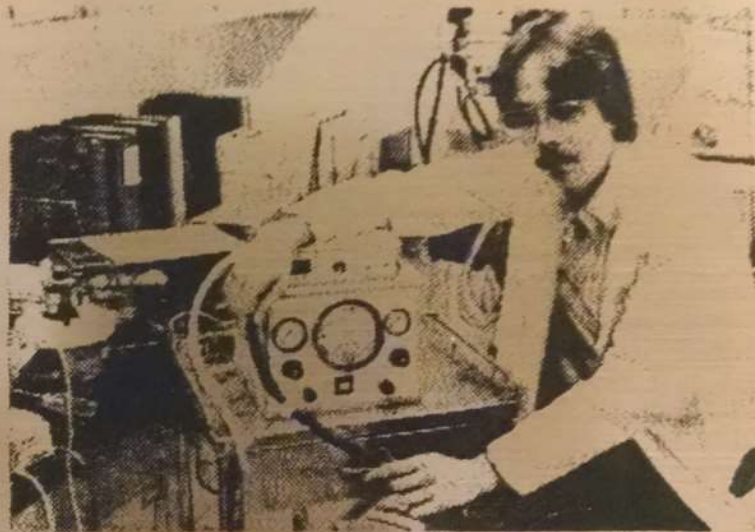
*Vindicator Trumbull County Staff*

**NILES** — A city resident is receiving credit for developing a new respirator for use on premature and newborn babies.

Rob Chatburn's "high-frequency jet ventilation" device has already been credited with saving the life of at least one baby. It has been the subject of articles in several professional journals and has generated an expanding lecture tour for the Niles McKinley High School graduate.

He is currently director of clinical research in the respiratory department at Rainbow Babies and Children's Hospital in Cleveland.

Put in simple terms, the HFJV device warms and humidifies air and then ad-



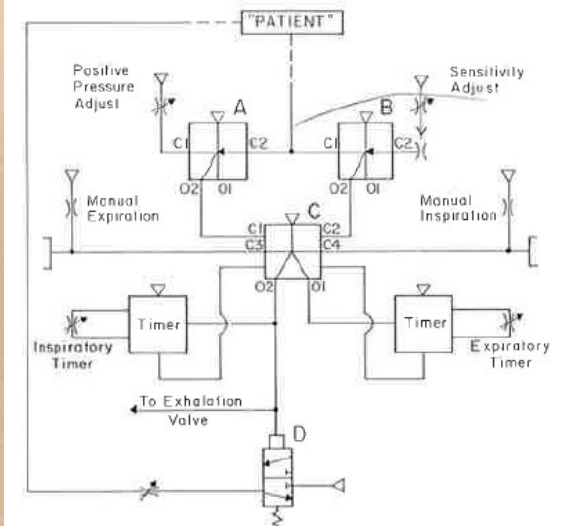
**Rob Chatburn**

people with great success," he says, and uses the case of an 8-month-old patient as illustration.

The child was hospitalized with bronchitis and placed

gineer, he transferred his ideas into a reality that has made a positive impression on fellow researchers — some of whom thought the idea of heating and humid-

## Fluidic logic control circuit

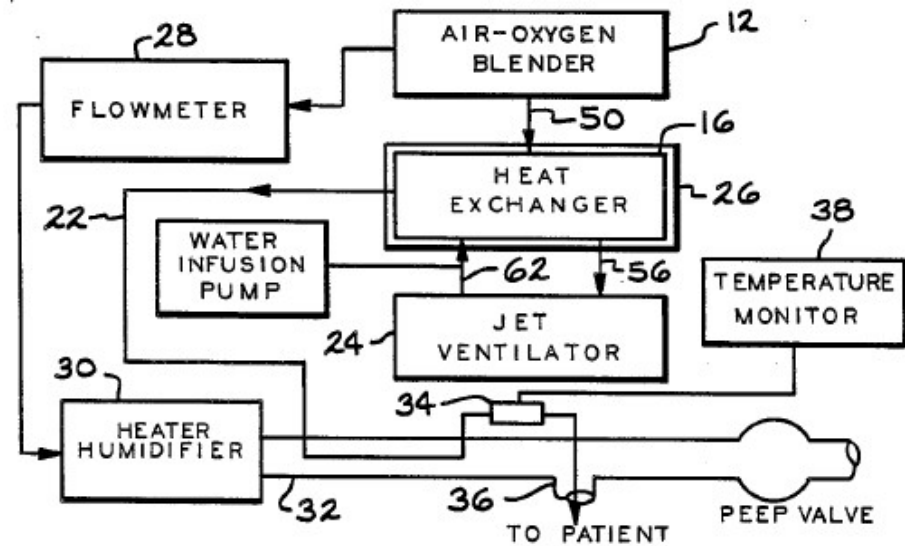


# Rainbow Jet Ventilator 1980s

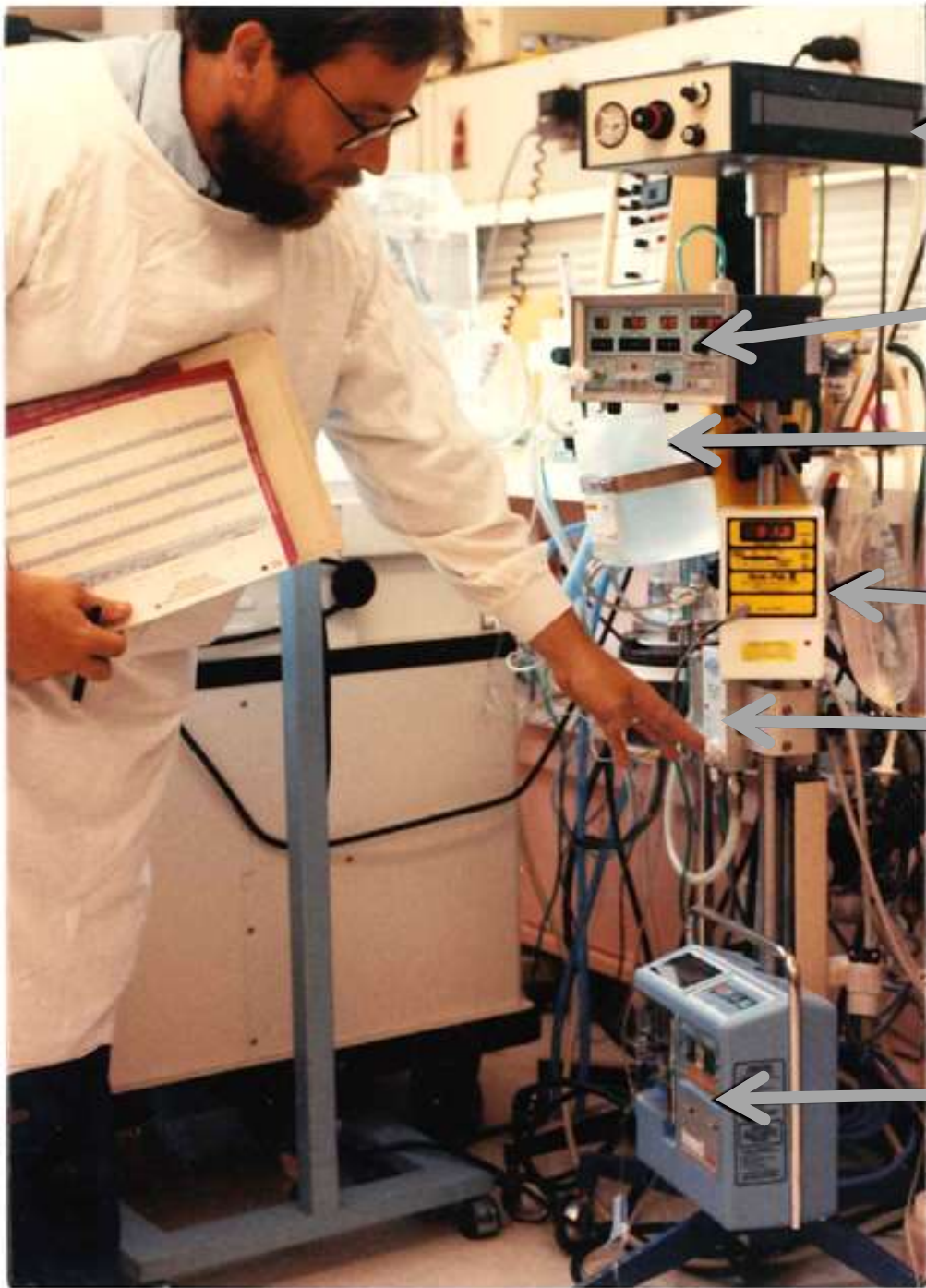


United States Patent [19]  
Chatburn et al.

[11] Patent Number: 4,589,409  
[45] Date of Patent: May 20, 1986







Ventilator

Novamatrix  
Pressure Monitor

Concha  
Humidifier

Airway Temp  
Monitor

Blender

Infusion Pump for  
Injecting Water  
into the Jet  
Stream

# First Commercial Jet Ventilator (1980s)



# Second Commercial Jet Ventilator (1980s)

## Bunnell LifePulse Infant Jet Ventilator



# First Commercial Oscillator (1980s)



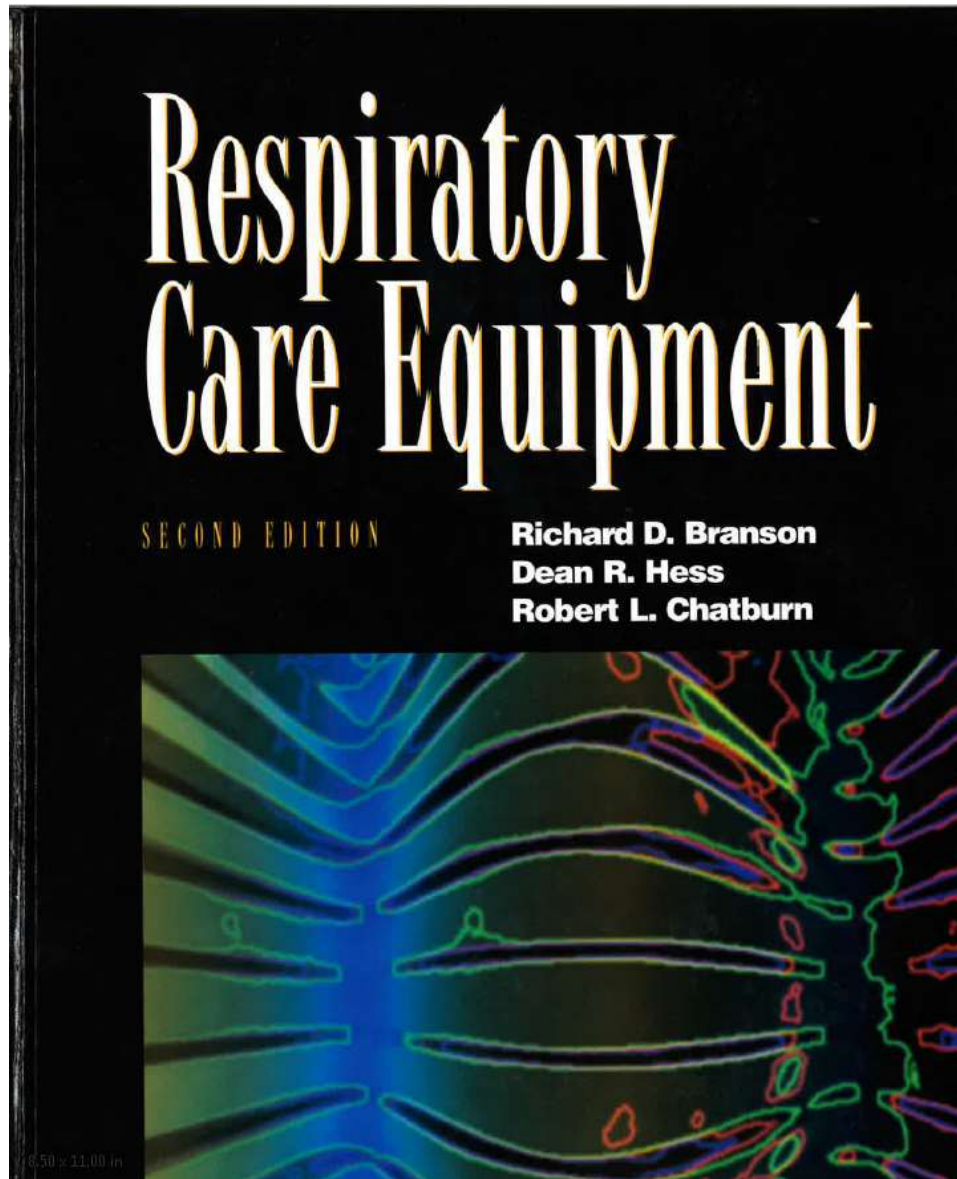
# Dr. Bird - Sinusoidal Percussionator



Last

First

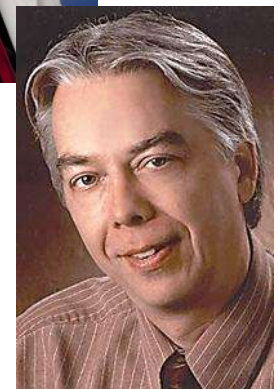
# The Leading Equipment Book of 1990s



**Rich  
Branson**



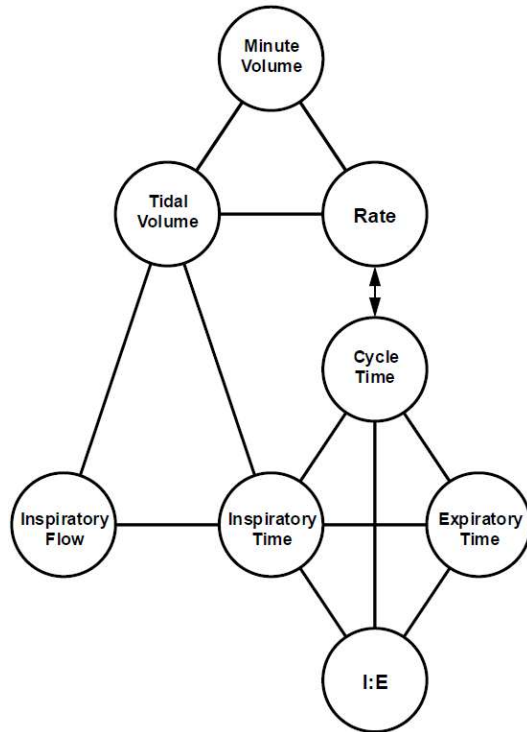
**Dean  
Hess**



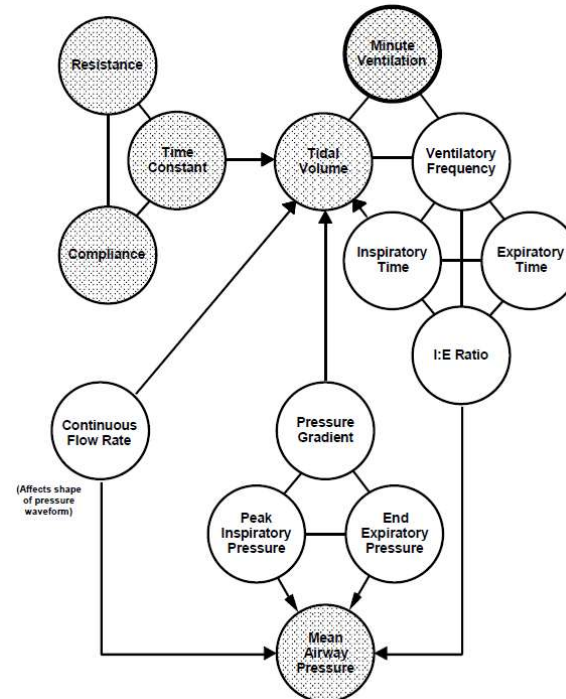
**Rob  
Chatburn**

# Branson Book Innovations

## Volume Control

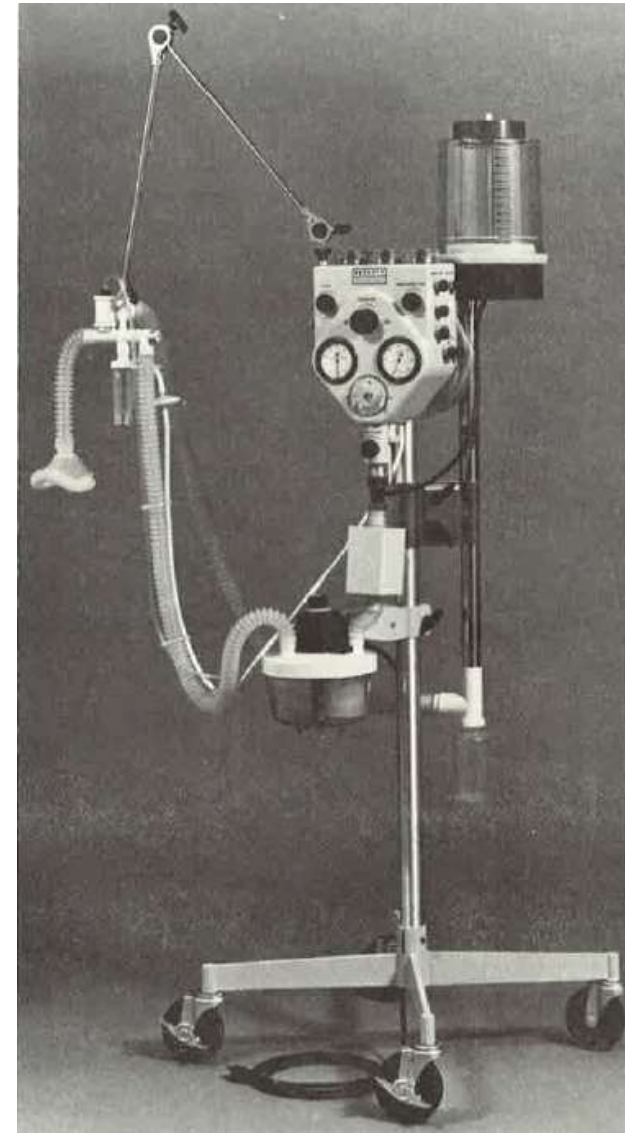


## Pressure Control



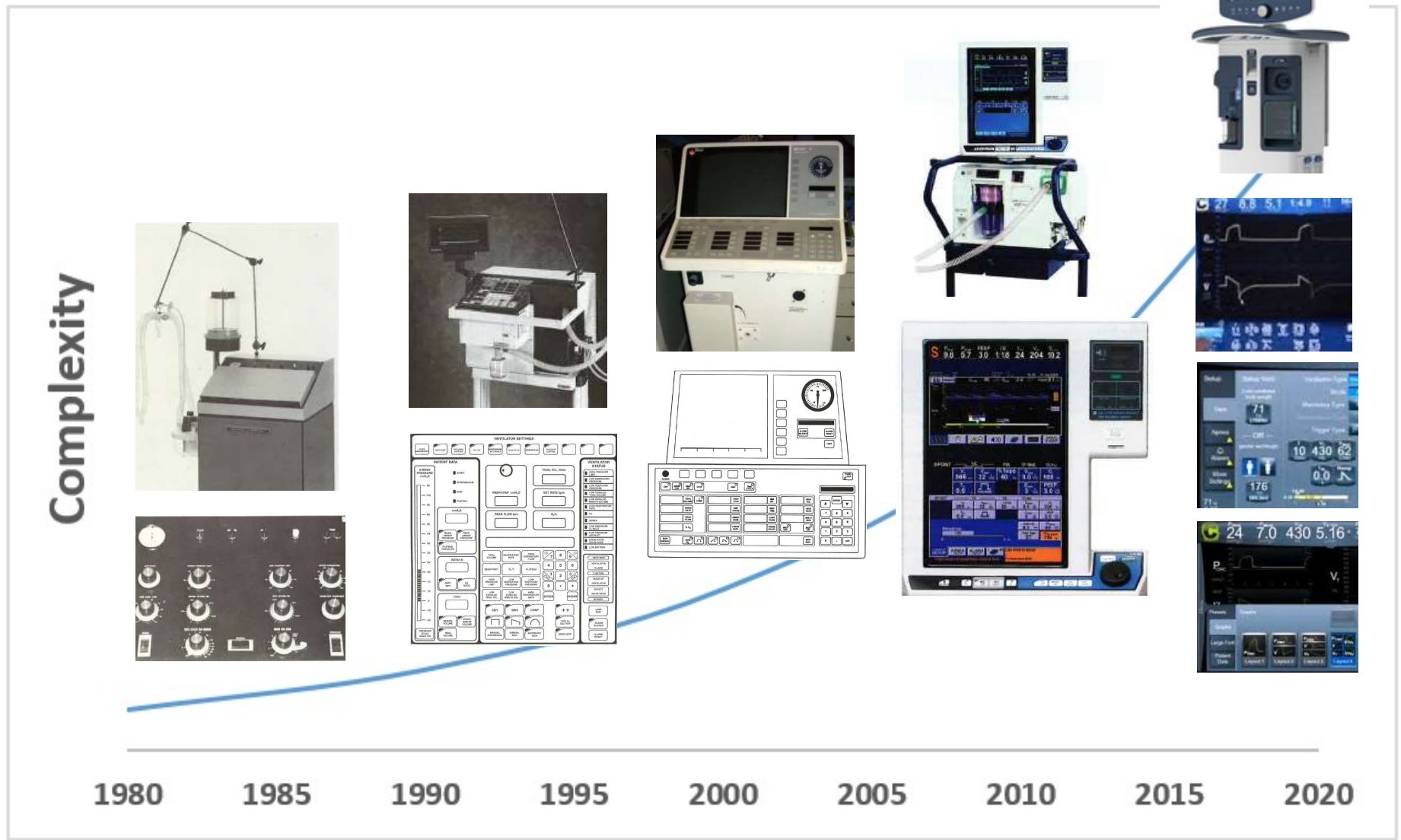
$$P_{vent} + P_{mus} = E \times V + R \times \dot{V}$$

# First Generation Ventilators (early 1900s)





# Growth in Ventilator Complexity



2<sup>nd</sup> gen

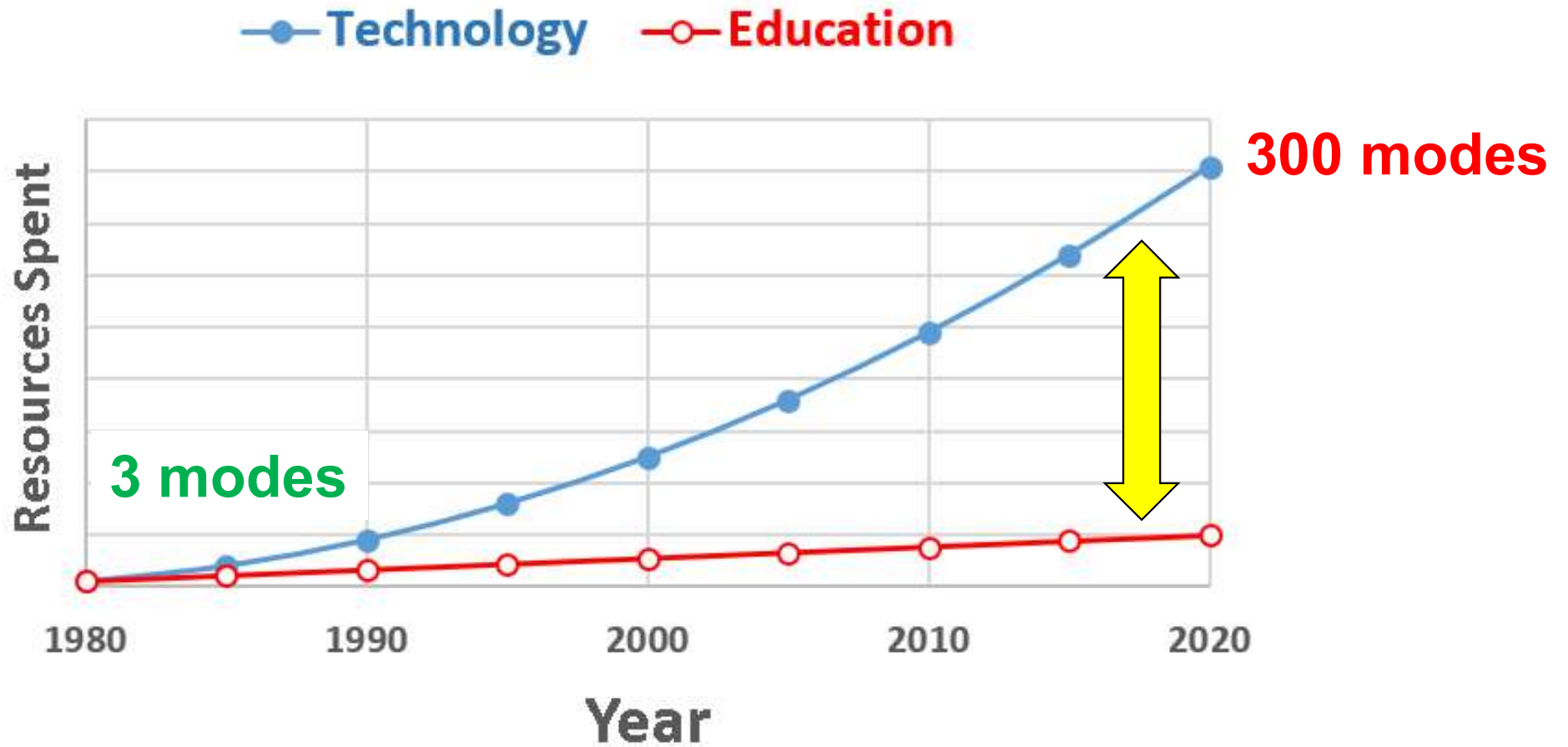
3<sup>rd</sup> gen

4<sup>th</sup> gen

5<sup>th</sup> gen

6<sup>th</sup> gen

# Growing Knowledge Gap

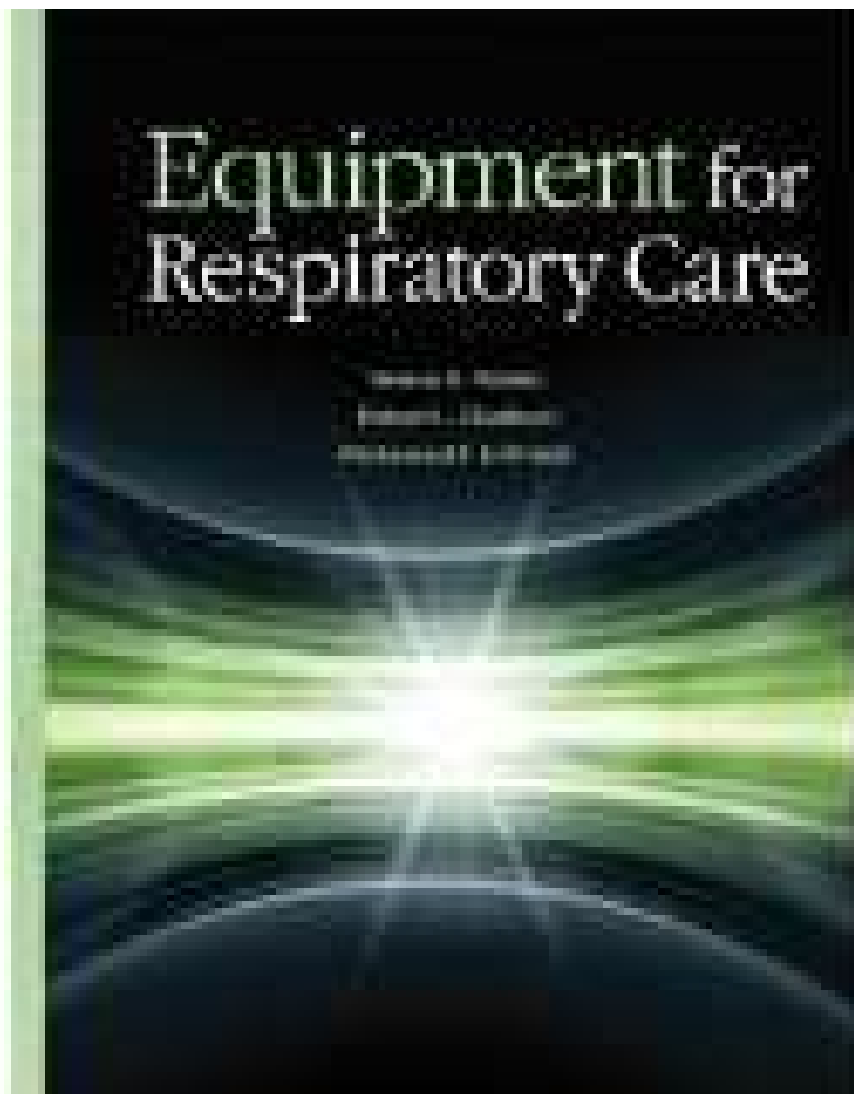


# Like Driving a Sports Car in 1<sup>st</sup> Gear Only



# Most Recent RC Equipment Book (2016)

AC PCV  
Adaptive Flo  
Adaptive Sup  
Airway Press  
APV SIMV  
Assist/Contr  
Automatic Ti  
Automode (F  
AutoMode(V  
BiLevel  
BiPAP S/T  
CMV  
CMV+AutoF  
CMV+Presst  
CPAP  
DuoPAP  
Flow Adaptiv  
Mandatory M  
PC-A/C  
PCV+



**35 ventilators**  
**300 modes**



**Terry  
Volsko**

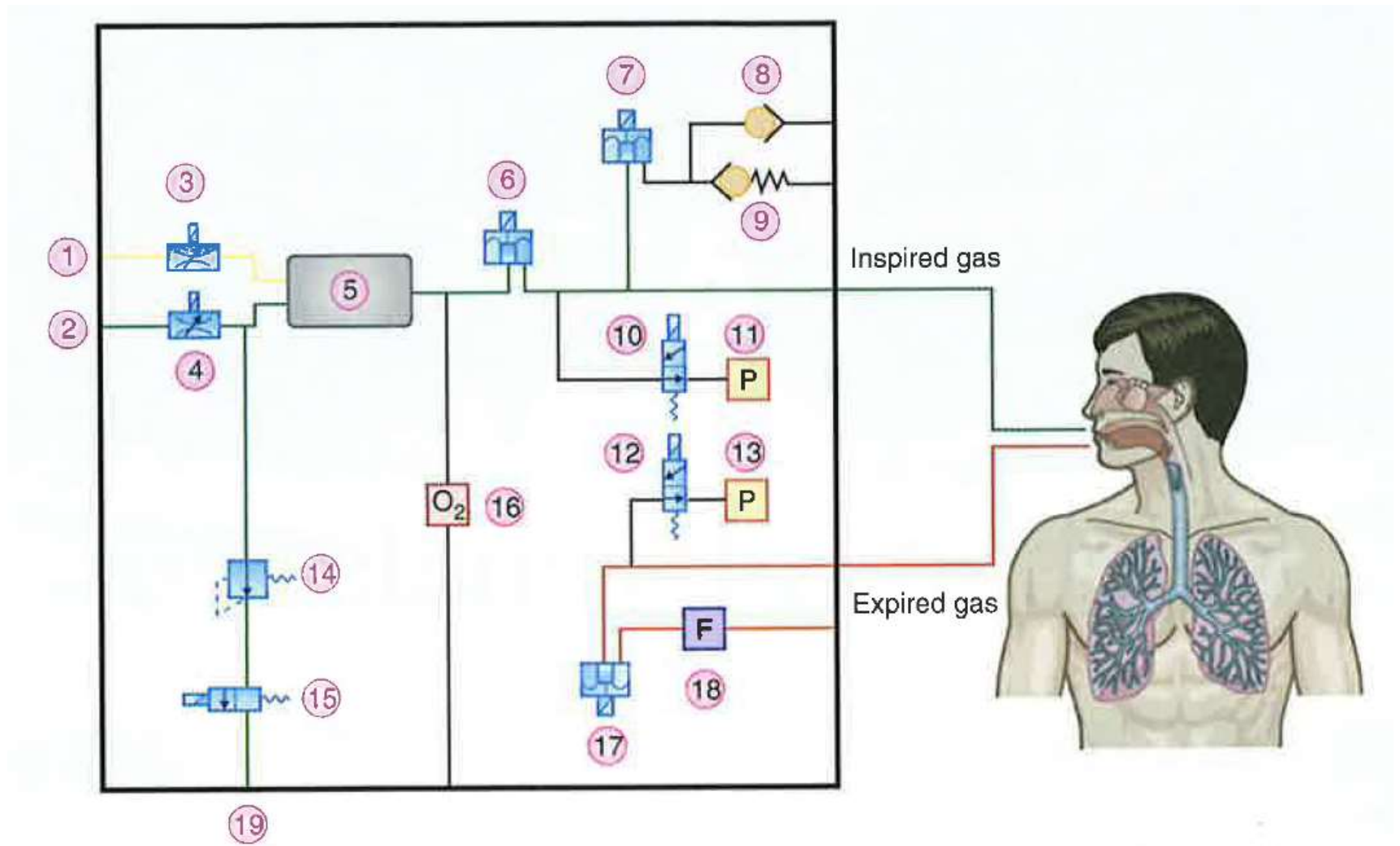


**Mohamad  
El Khatib**

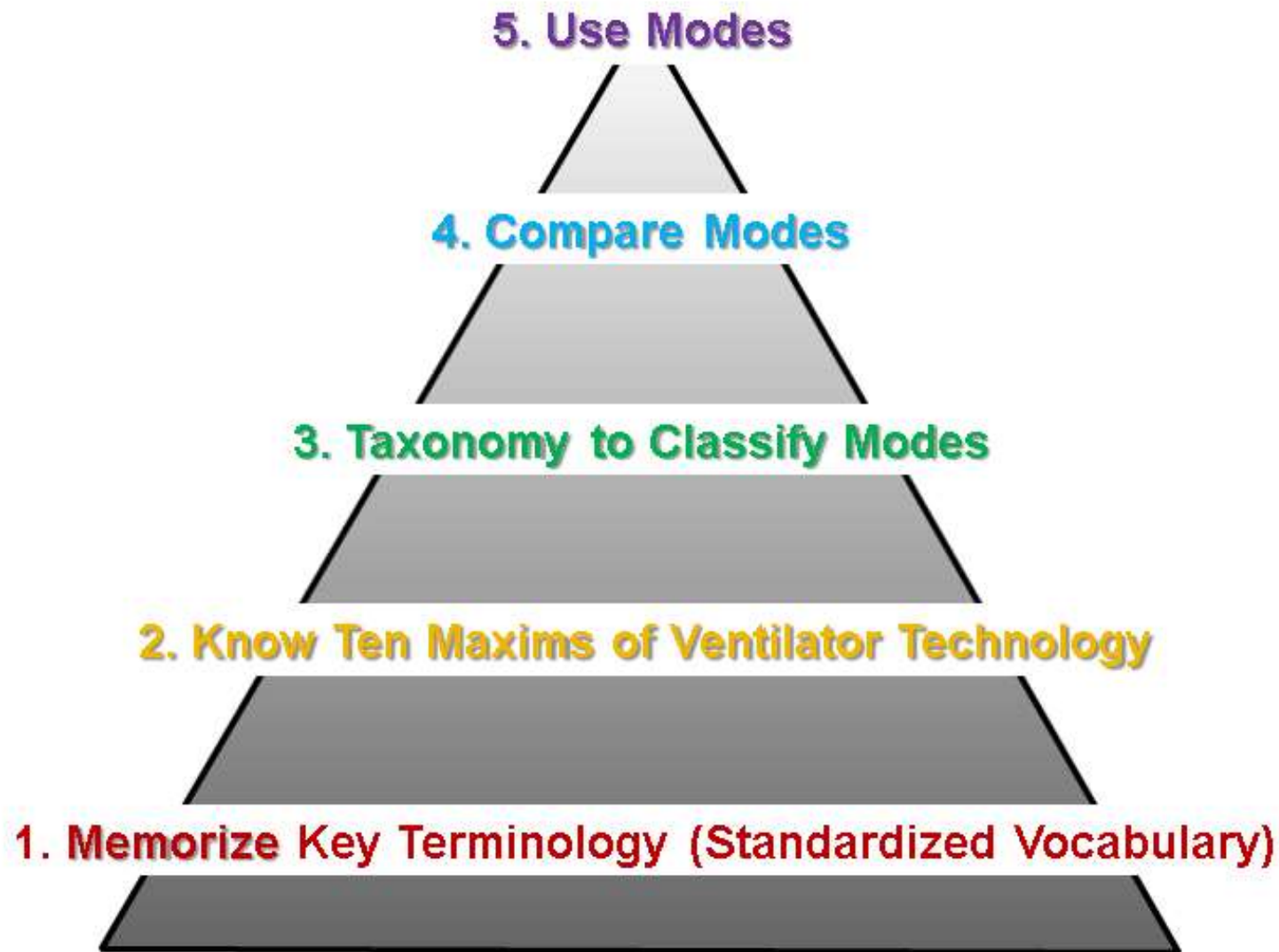


**Rob  
Chatburn**

# No More Schematics!

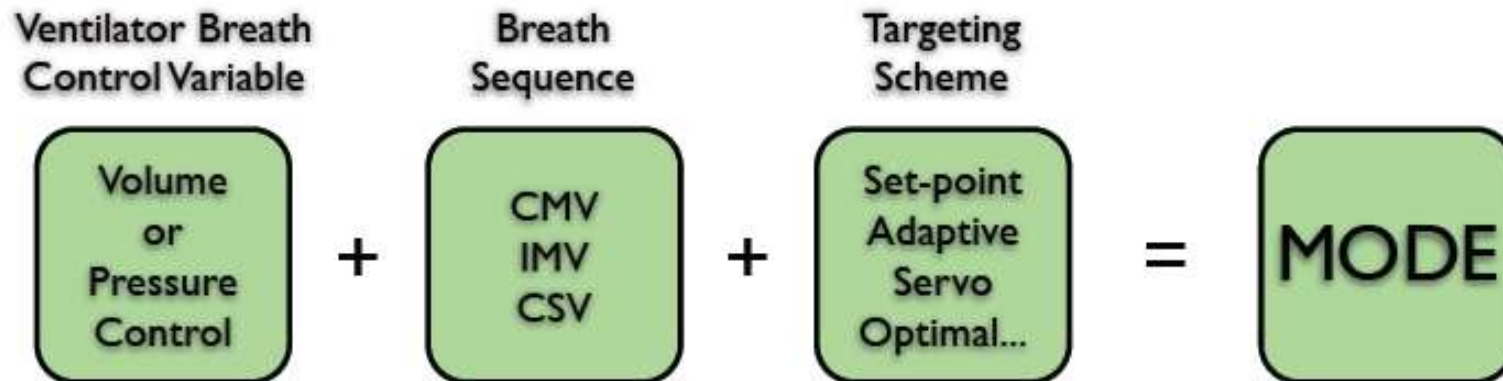


# Volsko Book Innovations



# Ventilator Mode Taxonomy

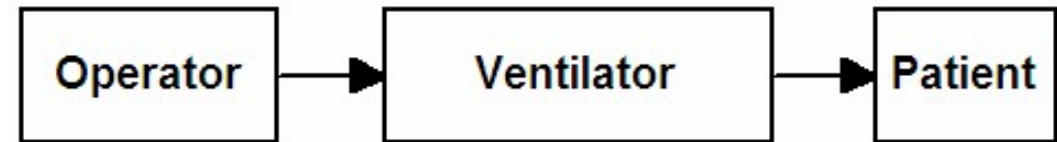
- **Mode:** predetermined pattern of patient-ventilator interaction
  - Mode name: arbitrary name coined by vendor
  - Mode tag: classification of mode using a taxonomy



# Targeting Schemes

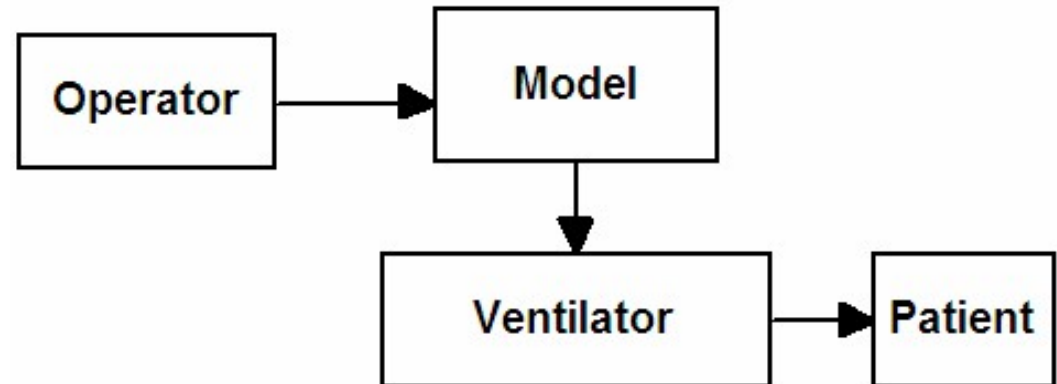
## Manual

- *setpoint (PC-IMV)*
  - *dual (Pmax, Flow Adapt)*
- operator-selected, static setpoints



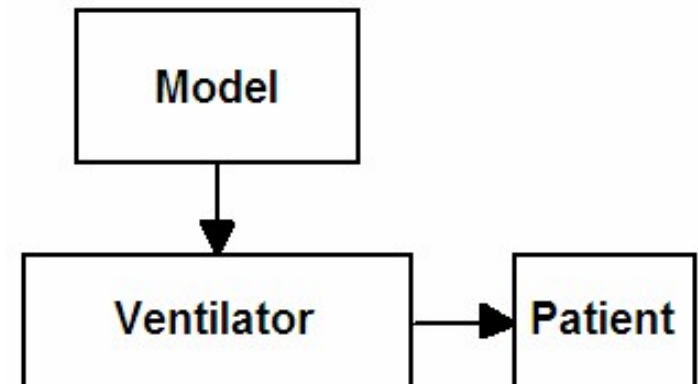
## Semi-Automatic

- *servo (proportional assist)*
  - *bio-variabile*
  - *adaptive (CMV+AutoFlow)*
  - *optimal (ASV)*
- ventilator-selected, dynamic setpoints  
static model



## Advanced Total Automatic

- *intelligent (SmartCare, IntelliVent)*
- ventilator-selected, dynamic setpoints  
dynamic model





# The Ultimate in Targeting Schemes



# The Future is Now

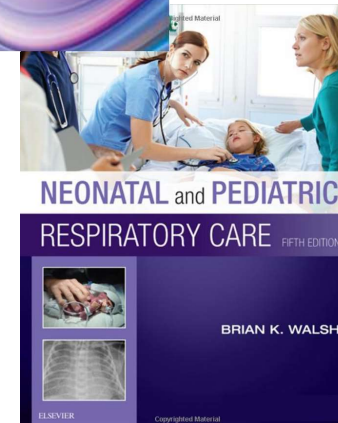
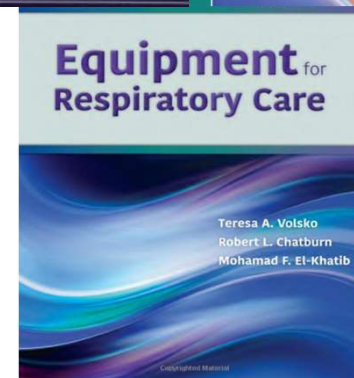
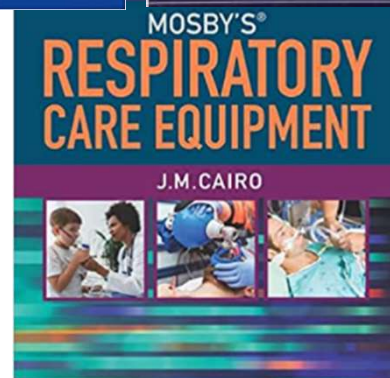
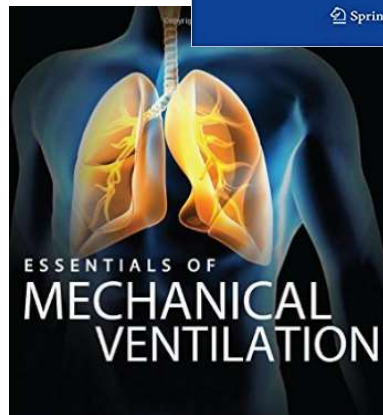
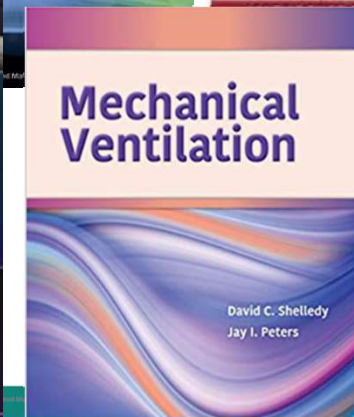
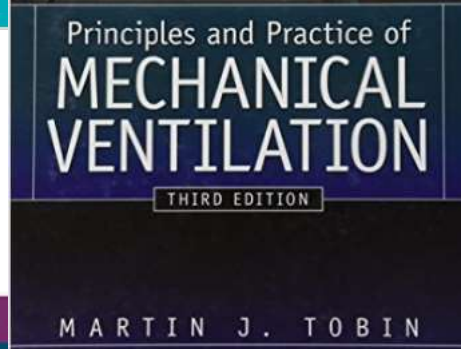
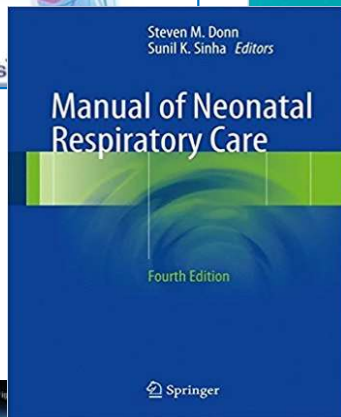
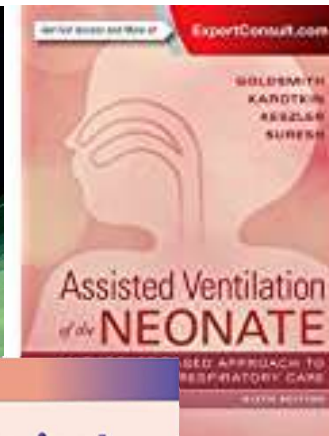
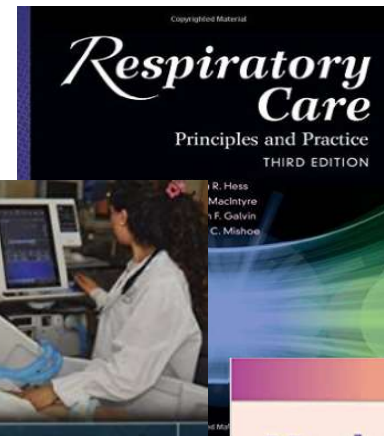
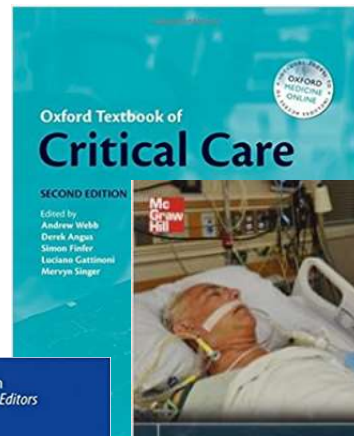
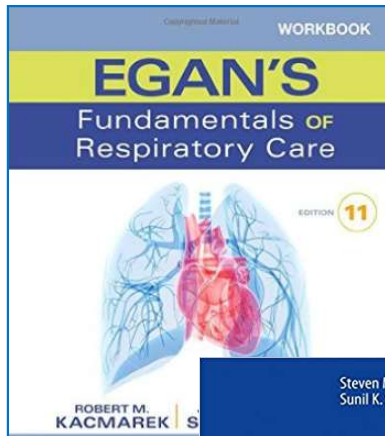
## Riemannian Geometry Applied to Detection of Respiratory States from EEG Signals: the Basis for a Brain-Ventilator Interface

X. Navarro-Sune, A.L. Hudson, F. De Vico Fallani, *Member, IEEE*, J. Martinerie, A. Witon, P. Pouget, M. Raux, T. Similowski and M. Chavez

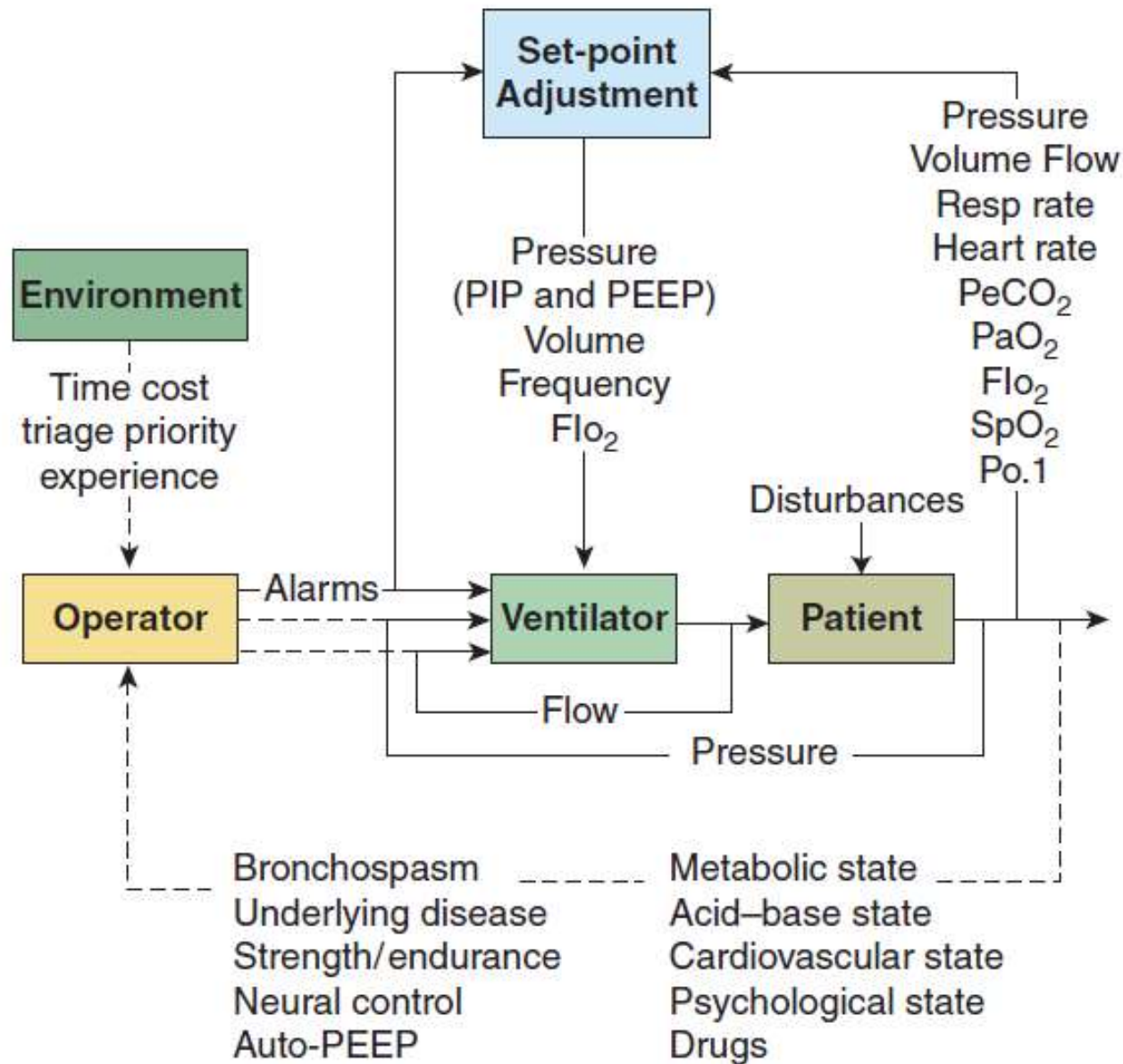
*IEEE transactions on bio-medical engineering* (2016)

*Significance:* The proposed framework opens the door to **brain-ventilator interfaces** for monitoring patients' breathing comfort and **adapting ventilator parameters to patient respiratory needs.**

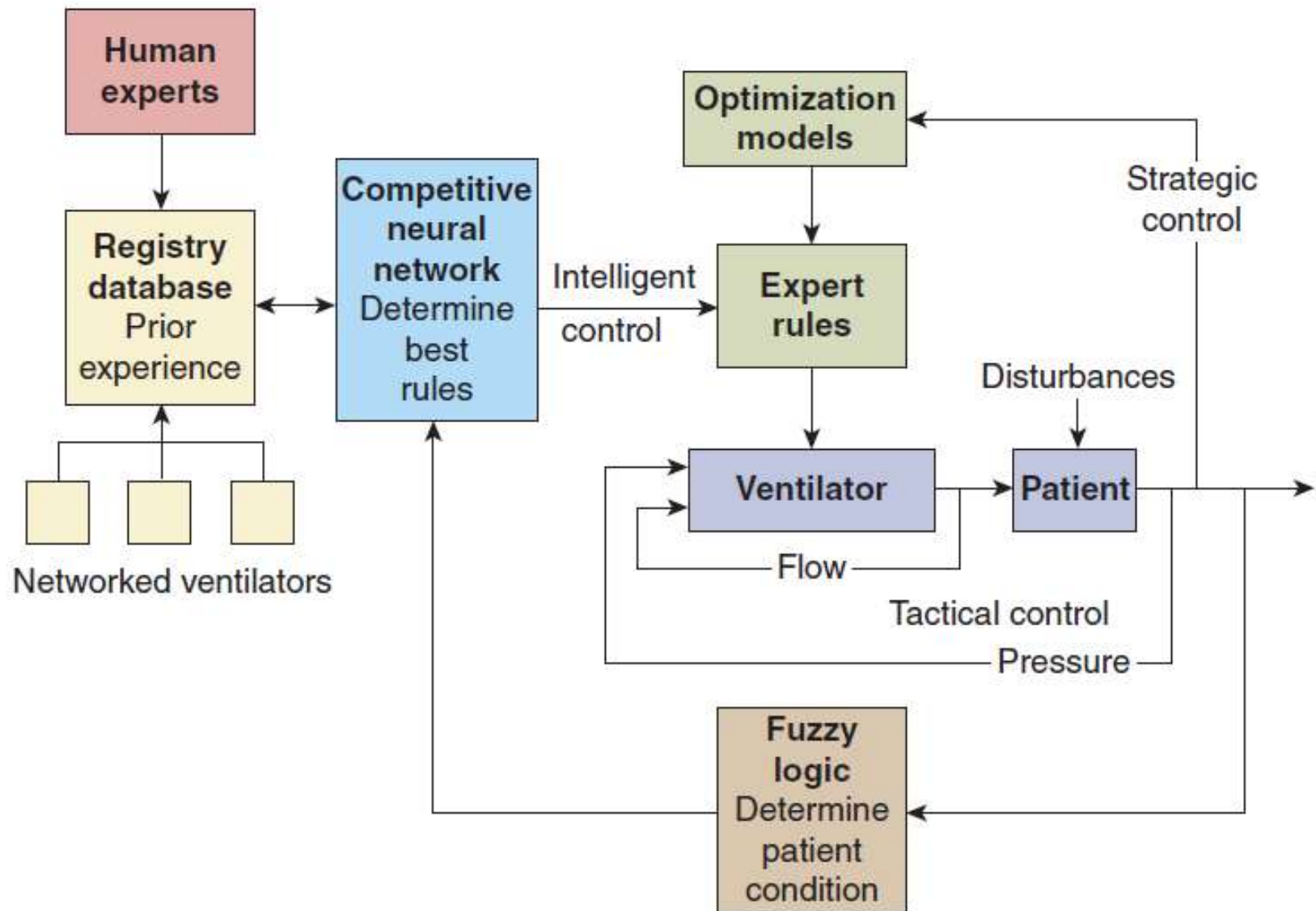
# Rewriting the Books



# The Challenge of Total Computer Control



# The Ventilator of the Future (black box)



# Ventilator AI Becomes Self-Aware



**Terminator**

# The Newest Kid on the Block



**V**entilation **O**xygenation **C**ough-assist **S**uction **N**ebulization

# Rainbow B&C Legacy



**Marvin Lough**

Father of pediatric  
and neonatal respiratory care

**Pediatric  
Respiratory  
Therapy**

**Neonatal  
Respiratory  
Therapy**



**Robert L. Chatburn**

Your Humble Narrator



**Tom Kallstrom**

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