Dr. Bird’s concept for Intrapulmonary Percussive Ventilation (IPV®) was made possible by employing the fluidic logic employed in the Matrix Volumetric Diffusive Respiration (VDR®) family of ventilators with the full capabilities of ventilating routine or catastrophic patients from neonates through pediatrics to the largest adults.

The IPV® design mandates a near 1:2.5 i/e ratio at any selected frequency between 100 and 400 cycles per minute.

This inspiratory/expiratory timing ratio calibration provides for the most effective endobronchial percussion, accommodating a patho-physiological endobronchial secretion mobilization and raising sequence.

The ideal 1:2.5 i/e ratio provides for an automatic intrapulmonary wedge pressure to prevent peripheral airway collapse between percussive sub tidal volume deliveries. This is a major lung protective strategy directed toward the reduction of ventilator caused lung injury.
Classical IPV® wave format demonstrating the all important AUTOMATIC CPAP STABILIZER (intrapulmonary wedge pressure) maintained to prevent peripheral airway collapse between successive endobronchial percussive sub tidal volumes.

IPV® has been routinely used world-wide since the mid 1980’s within many medical institutions. At this writing (in 2005) there are thousands of IPV® devices serving routinely in medical facilities as well as in homes for home care.

However, the vast number of Clinical Pulmonologists have been led to believe that Intrapulmonary Percussive Ventilation (IPV®) is the same as IPPB or a High Frequency Jet Ventilator, with the same limitations.

The limited level of clinical knowledge about IPV® among the Pulmonologists may well be due to the high level of commercial competition in the respiratory care field and a limited marketing introduction of IPV® by the Percussionaire® Corporation.

The percussive intrapulmonary mixing of respiratory gases during the constant interchange of sub tidal volumes greatly enhances the blood gas interface at a reduced FIO2.
THE FOLLOWING INFORMATION IS PRESENTED TOWARD INTRODUCING THE PULMONOLOGIST TO THE CLINICAL CONCEPTS RELATING TO INTRAPULMONARY PERCUSSIVE VENTILATION (IPV®)

INTRAPULMONARY PERCUSSIVE VENTILATION (IPV®)

THE FDA ISSUED MARKETING RELEASE COVERING THE FAMILY OF INTRAPULMONARY PERCUSSIONATOR® DEVICES AND THEIR ACCESSORIES

HISTORICALLY
A DEDICATED SEARCH WAS STARTED BY DR. BIRD IN 1979 TO FIND A MEANS TO DELIVER "PERCUSSIVE ENDOBRONCHIAL SUB TIDAL VOLUMES" AT HIGHER FREQUENCIES INTO THE ENDOBRONCHIAL AIRWAYS.

Dr. Bird had introduced the variable "inspiratory flowrate concept" on his Bird Mark 7 Respirators in the 1950's. In the late 1970's he applied his knowledge of "FLUID DYNAMICS" toward developing a mechanical means for the high frequency PERCUSSIVE VENTILATION of the mammalian pulmonary structures.
This concept had to be accomplished without activating (firing) the Hering-Breuer stretch receptors located within the endobronchial walls. His technology was directed toward employing the "Tsunami tidal energy logic" (in single digit milliseconds) as a method of creating INTRAPULMONARY PERCUSSIVE VENTILATION (IPV®); which additionally is associated with a lung protective strategy.

The first challenge was to create a TIME CYCLED VARIABLE i/e RATIO fluidic valve that would repetitively "FULLY OPEN AND CLOSE" at cyclic rates of over 6000 cycles per minute; with over a billion-cycle reliability. This became a reality by 1981.

The next challenge was to develop a reciprocating INSPIRATORY INJECTOR/EXHALATION valve consisting of a sliding VENTURI TUBE VOLUME AMPLIFIER with near instantaneous opening and closing. This device had to interface with a near zero compliance and be small enough to be positioned at the proximal airway. Dynamically it had to be capable of producing near supersonic flow rates "in milliseconds" at the proximal airway, without firing the pulmonary stretch receptors.

This presented major challenges without successful conclusions until 1985, when Dr. Bird's precision Phasitron® mechanical/physiological interfacing concept became a functional, dependable reality.

Functionally, a cyclic high pressure pulsatile gas delivery is (near instantaneously) released into a servo chamber behind a diaphragm, overwhelming the captured orificed, convoluted diaphragm attached to a sliding encapsulated venturi.

This event creates a near instantaneous forward movement of the sliding venturi to close the encapsulated exhalation port, while simultaneously pressurizing the venturi jet.

Dr. Bird's conceptual design logic for his Intrapulmonary Percussive Ventilation (IPV®) protocol consisted of the following technological sequence of precisely controlled events:
A source of a constant high-pressure respiratory gas had to be capable of being precisely controlled by a differential (opening and closing) fluidic flow interrupter, in consortium with the Phasitron® injector device, with a near instantaneous injection and release action.

As the molecules of the high pressure jet flow are ejected from the orifice through the venturi throat, they create a sub ambient pressure which is retrograded into an encapsulated entrainment port with access to an ambient respiratory gas with a known FIO2.

The entrainment ratio (at any millisecond of functional time) is determined by the distal "venturi pressure regression" created as pulmonary airway inflow velocity is converted from "velocity to pressure to flow" against constantly changing endobronchial resistances.

The value of the sub ambient venturi throat pressure is controlled by the selected constant venturi jet flow velocity and the physiological overriding "variable regressive pressures at the distal end of the venturi tube" delivering into the proximal physiological airway.

The entrainment of ambient gas molecules into the venturi throat provides for inflow amplification. The ratio of venturi jet induced flow to ambient entrainment is controlled by the selected pulsatile venturi jet ejection pressure and the resistance to outflow at the distal end of the encapsulated sliding venturi. Automated regulation of the ambient entrainment gradient (from 1:5 to zero) provides for a variable inspiratory flowrate; near instantaneously responding to distal venturi tube pressure change, which in turn is regulated by the constant fluctuations of endobronchial inspiratory inflational resistances.

This concept prevents the timed constant endobronchial inflow (flow x time = tidal volume), when obstructed, from causing a potentially barotramatic pressure rise within the pulmonary structures.

The selected velocity of accelerated outflow from the distal end of the venturi into the physiological airway can be at the upper limits of sub sonic flow.

The interface (boundary layer) of the high velocity "sub tidal endobronchial injection" creates a semi circular (bullet shaped) laterally expanding shock wave as velocity is increasingly exchanged for pressure as the shock wave penetrates successive airway bifurcations.
The velocity of the descending shock wave creates a cavitation within patent airways” as it travels toward the peripheral pulmonary units.

The central cavitation within the descending airways provides steering pathways for the intrapulmonary distribution of the injected "high energy Sub Tidal Mass".

The "flow surges" into airways with peripheral narrowing or obstruction cause acute conversions of the inflow velocity into pressure rise, creating an acute distending pressure effect upon the involved airway proximal to the "bottleneck" or obstruction, thus providing for a recruitment force.

The scheduled pressure drop (injection pressure) across the venturi jet is programmed to provide a velocity sufficient to satisfy the pressure conversion required to deliver a tidal exchange within the pulmonary alveoli without hyper expansion.

During the induced descending travel of conic airway inflow, a Newtonian (Newton's third law) countercurrent is created along the walls of the peripheral airways, providing for a "unique displacement outflow" from the peripheral pulmonary units into the upper airways during the repetitive pulsatile percussive inflow deliveries.

Airfoils are employed in aircraft structures in both fixed and rotary designs. They are designed to convert flow velocity to positive or sub ambient pressures dependent upon unique displacement design. Fluid dynamics encompass the body of knowledge that explains the physical characteristic of directed airflows.

In analogy, the reversible induced air flow within the endobronchial airways is directed though descending or ascending bifurcations which create physiological rudimentary fixed airfoils. Therefore, certain aspects of overall pulmonary "endobronchial dynamics" are described within the realm of "fluid dynamics"

Following Bernoullian logic, each pulmonary airway bifurcation forms a rudimentary venturi effect in opposing directions, following the direction of predominant airflow.
As the programmed (timed) inspiratory peripheral pulmonary gas exchange cycle is accommodated, the sustenance of the proximal airway inflow gradient created by the venturi "near instantaneously" collapses (as the differential inflow valve snaps closed) creating an immediate flow gradient reversal from the peripheral lung structures to ambient.

As the peripheral pulmonary airways are depressurized by the distal/proximal expiratory flow gradient, recruited peripheral airway collapse is prevented by the initiation of the next cyclic inspiratory injection of a "sub tidal volume" before peripheral airway depressurization reaches a critical level.

This near instantaneous flow gradient reversal is determined by the near 1:2.5 i/e ratio, which is automatically selected in relation to the selected inspiratory injection time.

The programmed "inspiratory interval" consists of a selected series of percussive "sub tidal" volume deliveries during the scheduled increase in lung volume, followed by a programmed percussive oscillatory apneustic plateau.

A mass convective Tidal Exchange (for CO2 wash out) can be created by an overriding spontaneous respiration "shifting the pulmonary baseline" during physiological gas exchange, or by the scheduled intermittent interruption of the percussive inspiratory interval.

Understanding the technological uniqueness of the IPV® concept allows the clinician to precisely program IPV® to each patient's existing cardiopulmonary patho-physiology for maximum clinical efficacy.

DIFFUSION- is created by "percussive endobronchial mechanical mixing" to effect a peripheral recruitment secondary to a descending oxygen delivery and an ascending carbon dioxide mobilization.

CONVECTION- is created by an effective distal to proximal pulsatile Newtonian flow gradient as well as by an "induced mass pulmonary tidal exchange" by controlling the timed inspiratory and expiratory intervals.

PERFUSSION- is created by percussively (mechanically) augmenting the physiological "Vesicular Peristalsis" within the three intrathoracic circulations, namely, the Bronchial, Pulmonary and Lymph circulations.

Ongoing European studies have served to elucidate the existence of an enhanced physiological “vesicular peristalsis”.

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The above data, obtained with a Swan Catheter, serves to confirm the existence of a mechanically induced intrathoracic “vesicular peristalsis” during Intrapulmonary Percussive Ventilation (IPV®).
IN SUMMARY

Dr. Bird's concept for Intrapulmonary Percussive Ventilation (IPV®) is a unique combination of traditional convective mechanical ventilation balanced with an induced endobronchial diffusion created by percussive mechanical gas mixing without firing the endobronchial “Hering-Breuer” stretch reflexes. Additionally, a regulated, selected topical aerosol can be precisely delivered throughout the tracheobronchial tree.

While Intrapulmonary Percussive Ventilation (IPV®) continues to become increasingly routinely used institutionally and in home care throughout the world, a limited number of clinicians understand the rudimentary physical and physiological principals employed to provide for the high levels of clinical efficacy displayed in various therapeutic applications.

When Dr. Bird's concept for a Demand Continuous Positive Airway Pressure (D-CPAP™) is combined with Intrapulmonary Percussive Ventilation (IPV®), a combined therapeutic modality called Oscillatory Demand Continuous Positive Airway Pressure (OD-CPAP™) is created. The function of this combined therapy is directed toward a reduction in the “work of breathing” in a dyspneic patient while providing for a diffusive gas exchange.

OD-CPAP can be administered invasively or non-invasively to assist a spontaneous respiration by stabilizing the pulmonary structures while percussively providing for intrapulmonary recruitment by mechanically mixing the intrapulmonary gases.
There are a number of options among the family of IPV® Percussionator® ventilators manufactured by Percussionaire® Corporation:

THE IPV-1C IS THE INSTITUTIONAL WORK HORSE OF THE IPV® FAMILY OF INTRAPULMONARY PERCUSSIVE VENTILATION DEVICES

THE PHASITRON® DUO™ COMBINATION IPV™ BREATHING CIRCUIT IS “THE INSTITUTIONAL CHOICE” FOR ROUTINE INSTITUTIONAL IPV® THERAPY

VARIOUS IPV® BREATHING CIRCUITS PROVIDE FOR INVASIVE OR NON-INVASIVE AIRWAY INTERFACING INCLUDING MOUTHPIECES, MASKS, UNDER LIP SEALS AND AVAILABLE INDWELLING AIRWAY CATHETERS.
THE IPV®-2C IS AN ADVANCED VERSION OF THE IPV®-1C WITH ALL THE SAME BASIC FEATURES. THE IPV®-2C DESIGN EXTENSION PROVIDES FOR EXTENDED PATIENT CARE WITH SELECTABLE INSPIRATORY TIME AND CYCLING FREQUENCY AS WELL AS DEMAND/CPAP. THIS IS AN IDEAL HIGH FREQUENCY VENTILATOR FOR STABILIZING ANY PATIENT’S SPONTANEOUS RESPIRATION.

THE CONE INTERFACE BREATHING CIRCUIT ENHANCES THE PROGRAMMING OF CONVECTIVE INTENSIVE CARE (volume oriented) CMV VENTILATORS BY PROVIDING A DIFFUSIVE VENTILATORY COMPONENT TO ENHANCE ENDOBRONCHIAL GAS MIXING.
THOUSANDS OF RUGGEDIZED SELF CONTAINED IMPULSATOR® PERCUSSIONATORS® PROVIDE IPV® THERAPY “THE WORLD OVER”, IN INSTITUTIONS WITH LIMITED AVAILABILITY OF RESPIRATORY GAS SOURCES AS WELL AS FOR HOME CARE PATIENTS WITH COPD.

ALL IPV® PERCUSSIONATOR® VENTILATORS CAN BE USED WITH INVASIVE OR NON-INVASIVE AIRWAYS. ADDITIONALLY, INTUITIVE INTEGRATED PROGRAMMING CAN BE ESTABLISHED FOR OPERATIONAL EASE.

DR. BIRD’S INTRAPULMONARY PERCUSSIVE VENTILATION (IPV®) CONCEPTS CONTINUE TO PROLIFERATE BY DEMONSTRATING THE VERY EFFECTIVE VENTILATION OF OBSTRUCTED LUNGS WITH SUPERIOR ENDOBRONCHIAL SECRETION CLEARANCE ABILITIES.

For medical facilities without available OXYGEN OR AIR SUPPLIES, the self-contained Percussionator® IMPULSATOR® TXP®- IPV® Ventilator will ventilate any lung capable of being mechanically ventilated, from neonates through pediatrics to large adults. Programming includes airway recruitment with Intrapulmonary Percussive Ventilation (IPV®) and a Time Cycled CMV ventilator.