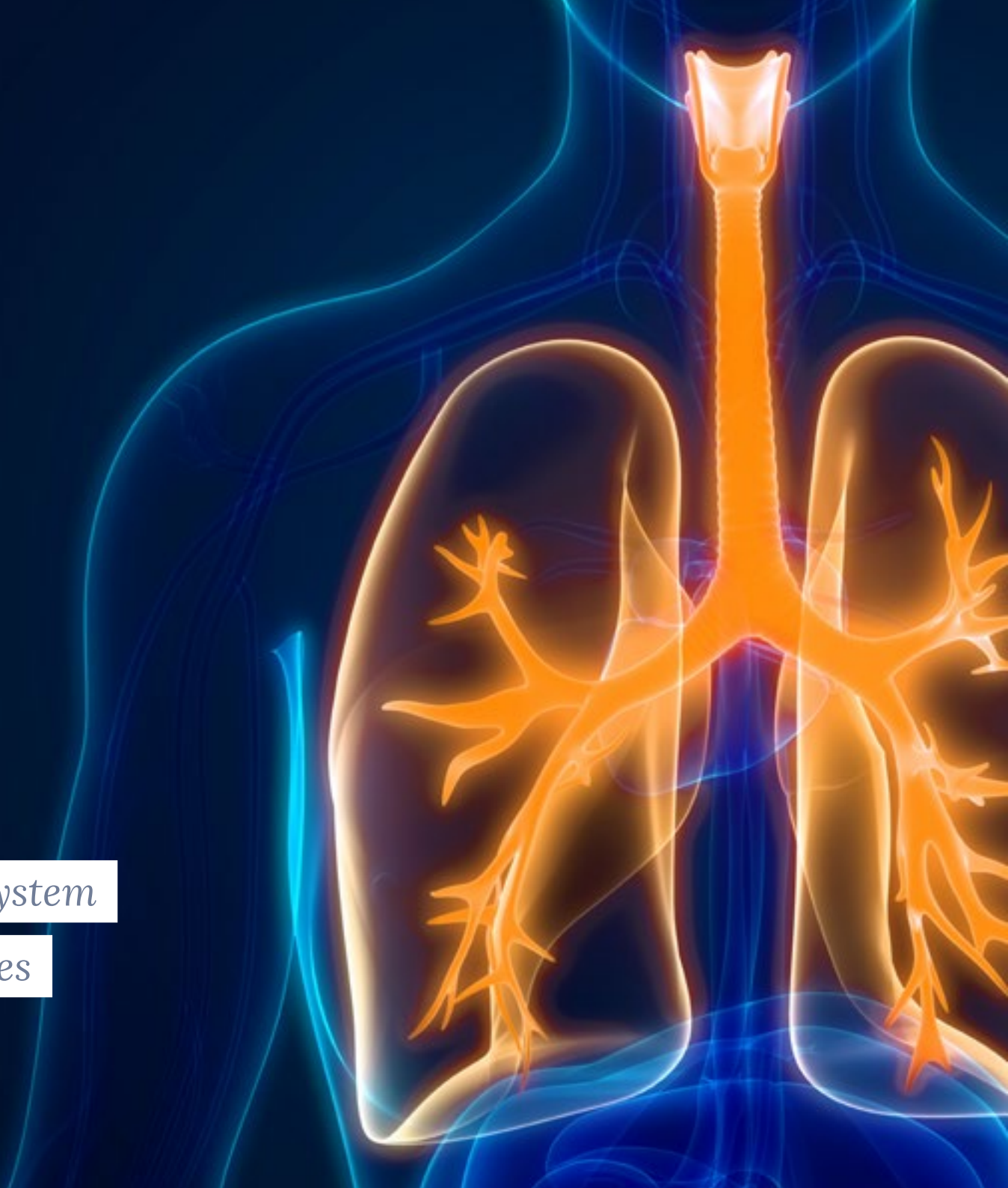




MASSVENTIL
PROJECT

Designing a Mass Ventilator System

for Treatment of Group Illnesses



Chapter I.

Executive summary

A KTG-type mass patient ventilator, that has four essential features:

(1)

no need for a dedicated machine for each patient, meaning that one ventilator can ventilate several patients at a time;

(2)

patient ventilation parameters (such as oxygen concentration, pressure, respiration rate, PEEP) can be adjusted individually for each patient according to the doctor's treatment strategy;

(3)

transporting exhaled infectious air from the common airspace, thereby significantly reducing the risk of infection for all medical staff;

(4)

the equipment may be installed on an ad-hoc basis in a non-hospital environment, without any hospital infrastructure.

Mass Ventilator System

The Hungarian Invention Could Save Lives

The life of many seriously ill people infected by the life-threatening Coronavirus could be saved worldwide by a mass respiratory system, developed by a team of Hungarian research and development engineers, doctors and mathematicians in recent weeks.

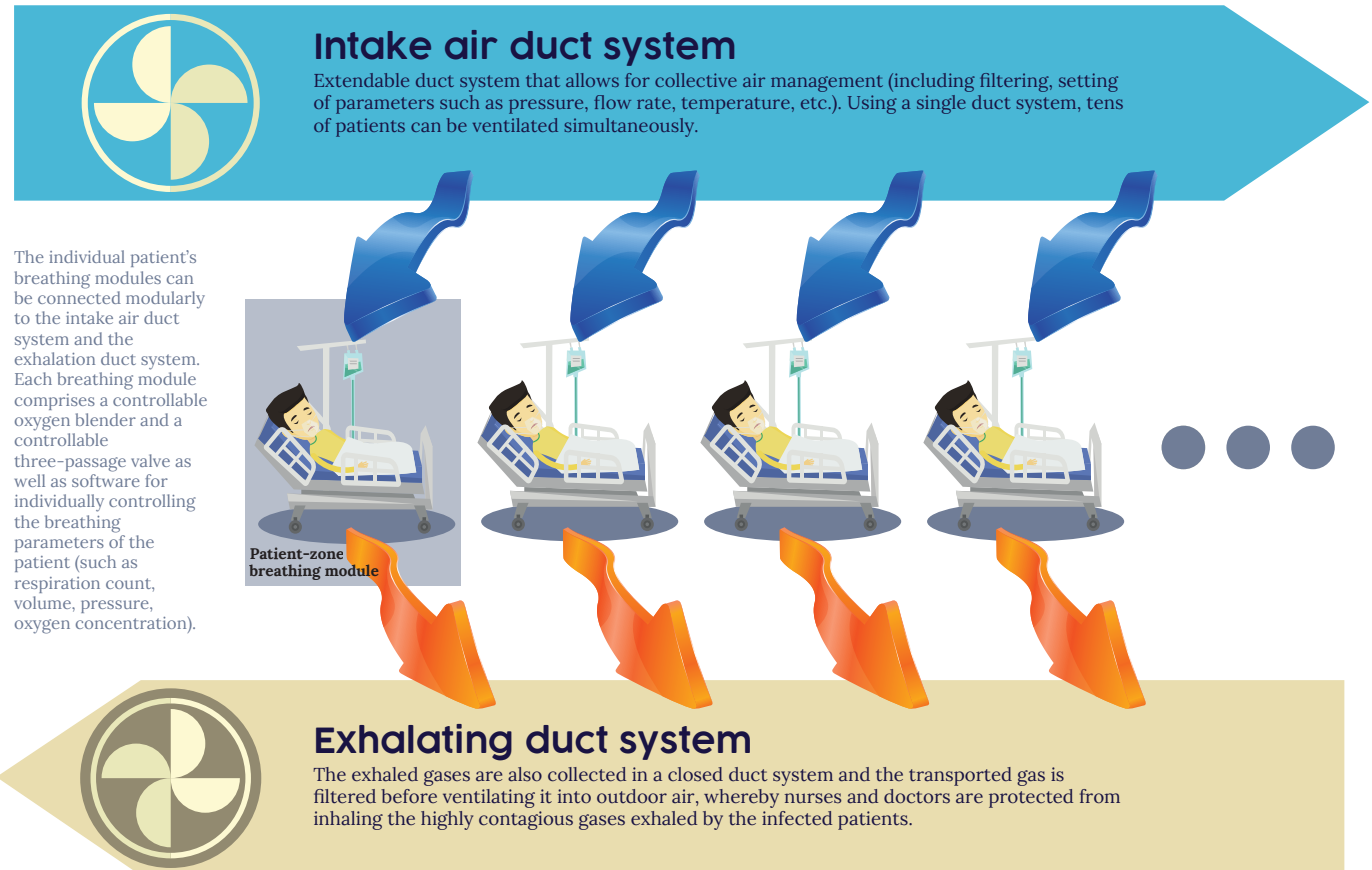
The revolutionary development can play a particularly important role in the global fight against the spread of COVID-19.

The MassVentil system, which has now been developed and tested in a laboratory environment, will be able to simultaneously ventilate 5 people at the moment and up to 50 or more in the future, while protecting healthcare professionals. The new solution is mobile and can be easily deployed and operated outside hospitals, in temporary emergency camps and halls - emphasized by Dr. Miklós Kozlovsky, research and development engineer, head of the project.

The COVID-19 epidemic which was declared a pandemic by the WHO in early March 2020, has already claimed the life of many people worldwide and their number is exponentially increasing day by day. One of the key elements to treating patients with acute respiratory problems is continuous ventilation. Unfortunately, many of the victims didn't receive adequate level of care due to the lack of medical ventilators.

Concurrently with the announcement of the pandemic, Dr. Kozlovsky envisaged a ventilator: it's most important feature being the ability to be used by several patients simultaneously, i.e. one machine can ventilate more than one person at a time.

Explaining the technical solutions of the MassVentil Project the research-development engineer emphasized that the main benefit of the concept is that while the currently used ventilators can only supply one person at a time, the MassVentil system can ventilate more persons. It consists of two main parts: a central gas transport system and smaller patient-specific ventilators. The central inhalation and exhalation gas management allows more patients to be ventilated at the same time, thereby saving more lives.



MassVentil project – Dr. Galambos

Overview of the mass ventilator system concept



Dr. Kozlovsky, Miklos

“The system also protects the healthcare professionals by transporting the contaminated exhaled air from the common hospital space, unlike currently used ventilators.” - explains the expert, as doctors and nurses are exposed to a high level of pathogen agents in the air of the ward. The new equipment removes and filters exhaled contaminated air from the common space, significantly reducing the risk of infection of the healthcare staff.

Dr. Kozlovsky highlights an important factor in connection with setting up temporary emergency hospitals or care facilities. Most equipment

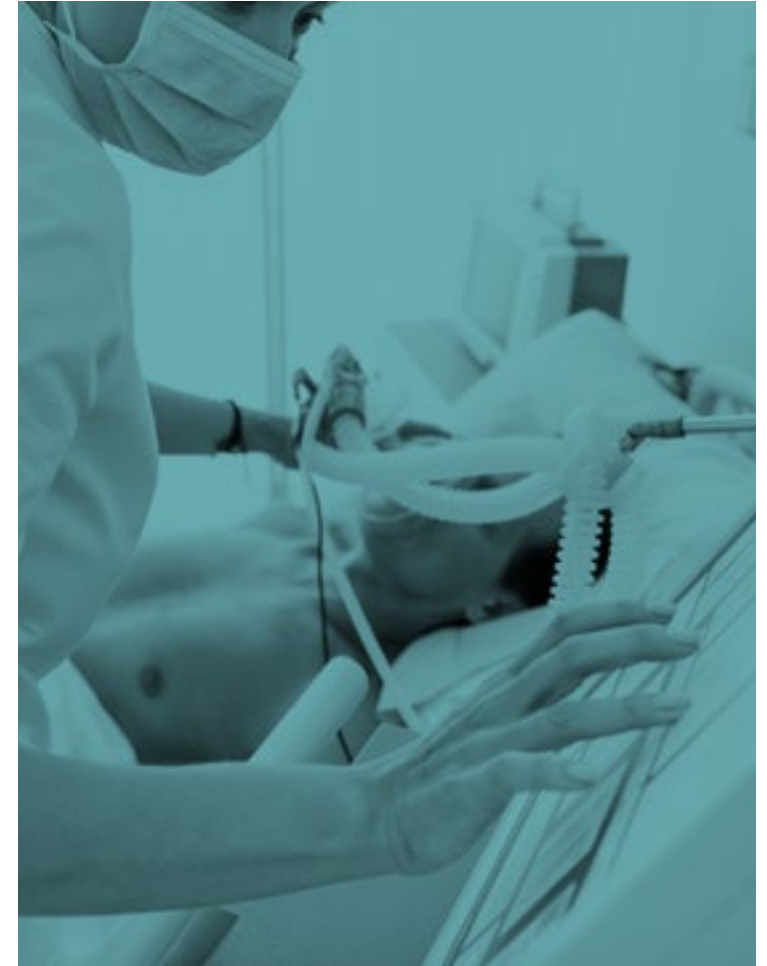
cannot be used without hospital infrastructure, such as wall-mounted air/gas technology or continuous power supply. The MassVentil System can be installed outside healthcare facilities, without advanced hospital infrastructure, even in emergency camp environment. The system is able to ventilate hundreds of people at the same time. “The MassVentil Project could save the lives of thousands worldwide during times of pandemic causing acute respiratory problems, like the current COVID-19” - adds Dr. Kozlovsky.

The Hungarian-led project involves international professionals, teachers and students from several universities around the world, who also contribute their expertise to the success of the development.

Mission of the MassVentil Project

We are designing a mass ventilator system, that can ventilate 5, 10, 50 or even more people simultaneously, protect healthcare workers, and can be operated outside of hospitals including temporary emergency camps.

The mission of the MassVentil project team is to develop a working prototype for a modular mass ventilator system, which, under critical circumstances, can be used to simultaneously ventilate a large number of coronavirus patients in critical condition. Plans and results are available for free for those who wish to use it during the COVID-19 outbreak.



The Most Important Benefits of the MassVentil Concept:

(1) Equipments currently in use are capable of supplying only one person, and each patient must be provided with a separate ventilator, so the available quantity may soon run out. Our MassVentil solution consists of a central duct system and personal ventilator modules for the individual patients. The central inhalation and exhalation duct system supplies air to and collects gases from all the personal ventilator modules for ventilating more patients at the same time, thereby saving more lives.

(2) Like any other medical ventilators, our mass ventilator system supports personalized patient ventilation. Medical professionals can adjust all important parameters individually (such as oxygen concentration, pressure, respiration rate, PEEP) at each patient according to the treatment strategy.

(3) Exhaled infectious air exits into the common hospital airspace by the respiratory equipment currently in use, whereby doctors and nurses are at increased risk due to working in air contaminated with high concentrations of viruses. In our MassVentil concept, the medical ventilator removes (and filters) exhaled infectious air from the common airspace, significantly reducing the risk of infection for nursing staff, to provide safer working conditions.

(4) An important factor to consider when setting up mass health camps is, which equipment can be used without hospital infrastructure in places where there are no drainage pipes in the wall and power distribution is limited to each camp bed. The mass medical ventilator, that we are designing within the framework of the MassVentil project, is to be employed ad-hoc in an out-of-hospital environment without the need for advanced hospital infrastructure.

With some of these devices, hundreds of people could be ventilated at the same time in an emergency camp environment. Thousands of people in camps around the world could be saved: patients, doctors, nurses.



Chapter II.

Technical details

Technical Description of the MassVentil System

Background

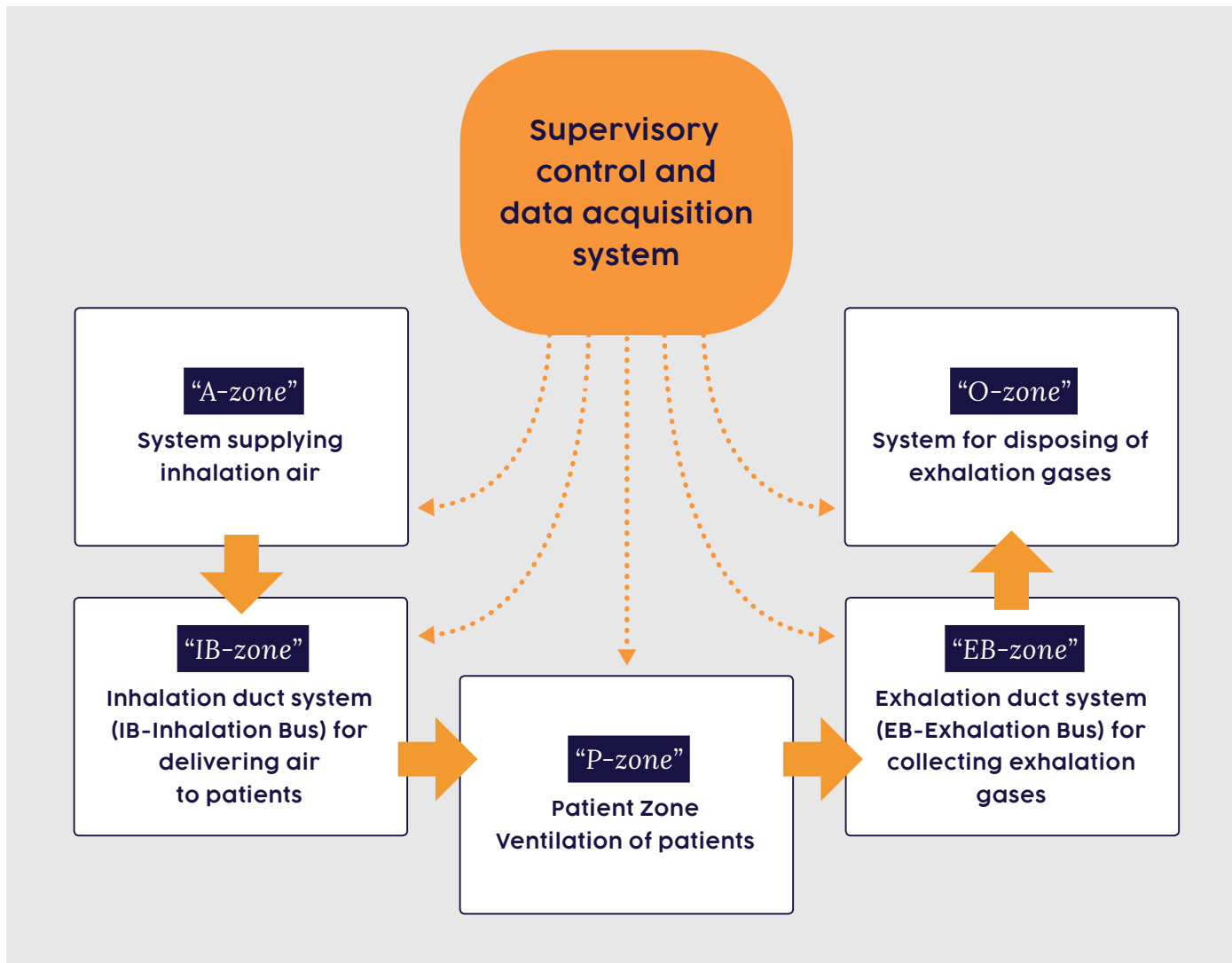
Effective management of epidemics that cause acute respiratory distress (ARDS) such as COVID-19, SARS, or MERS, can only be defeated with vast amount of medical devices and effective medical care. The treatment process of acute respiratory problems involves continuous patient ventilation. Current medical practice implements ventilation with dedicated respiratory devices.

A pandemic outbreak poses many problems in terms of hardware (medical ventilators) quantity, capacity, manageability, and installation.

Concept

During mass respiration in our mass ventilator concept, patients are connected to a modular or monolithically designed centralized ventilator system. In our concept the system can be designed and installed in a pre-built or ad hoc manner (in medical/ non-medical facilities such as wards, sports grounds, gyms, etc.).

The mass ventilator system is designed for the combined management of inhalation and exhalation gases (production, temperature/ humidity/ pressure adjustment, filtration, etc.). During inhalation and exhalation, the air is filtered in both directions in one or more steps.



The management of respiratory gases (filtration, temperature control, humidity control, pressure control, safety control, etc.) is carried out in a distributed manner under centralized control in multiple locations within the mass ventilator system.

Fig. 1.: MassVentil project – Dr. Kozlovsky
 Overview of the structure of the mass ventilator system concept

Our MassVentil concept is not based on a single patient ventilator concept. Due to the modularity of the system, new patients can be integrated into the system up to the system's maximum capacity. The maximum capacity of the system is mainly determined by the capacity of the motors used in the inhalation and exhalation system (important parameters: the amount and minimum pressure of the air supplied and size restrictions due to the environment).

The inhalation air generator system (A-zone) can receive air from different sources.

These can be buffer bottles (for both air and oxygen), hospital pre-installed aeration tubing, or dedicated ventilator or compressor based air supply systems. The combination or multiplication of different types of air-generating systems increases the capacity and robustness of the ventilator system (thereby increasing similar parameters of the entire mass-airway system).

In the present example, a mass ventilator system comprising a fan motor air supply system is shown.

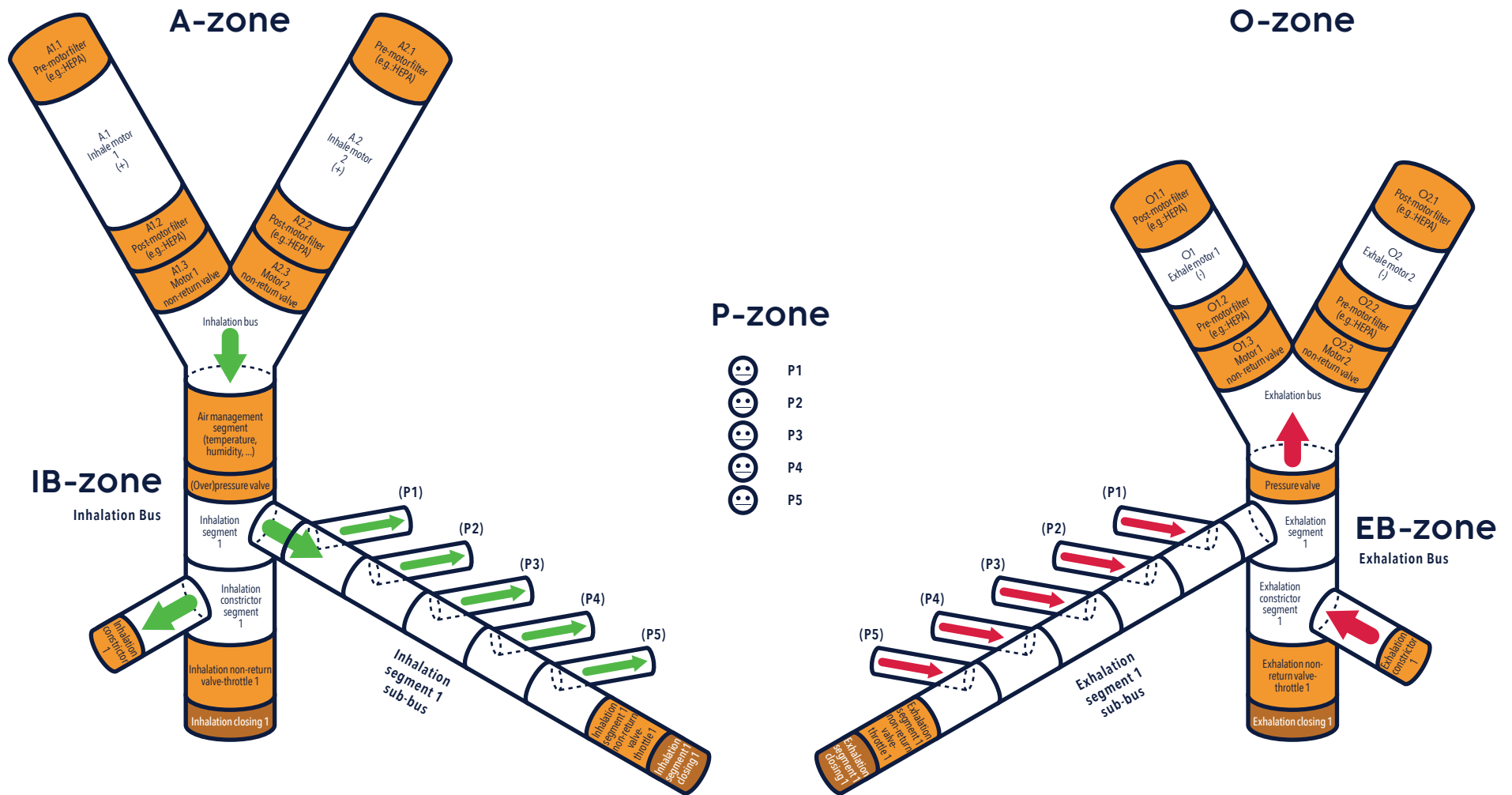


Fig. 2: MassVentil project – Dr. Kozlowszky

Example for the implementation of the mass ventilator system (one single segment with 5 patients)

In this example, the flow of air for inhalation and exhalation is provided by separate ventilators (electrical). Power supply to the fans is provided with adequate redundancy and preferably uninterruptible power supply. The pressure ratios of inhalation and exhalation gases are defined and maintained so that no backflow or gas mixing occurs in the system.

On the inspiratory side (IB-zone), an excess pressure of at least 80 mbar is required. Both the inhalation air supply system and exhalation air dispensing system are

redundant in order to remain operational in case of hardware problems and to be able to perform maintenance work (e.g. replacement of filters). A minimum of two fans per inhalation and exhalation site is required to achieve adequate redundancy.

Fans must be fitted with filter(s) to exclude contaminants and pathogens (e.g.: COVID-19 virus) of different sizes. It is also advisable to install filter(s) after the fan to prevent any contamination that may occur during replacement of the external filter(s) or engine

operation. As the filters become dirty, their resistance increases, and the increased pressure difference must be monitored by a pressure gauge to avoid exceeding the performance of the aeration system (fan), in which case the operating point is shifted to an undesirable range.

The heat generated by the continuous operation of the fan should be monitored continuously to avoid overheating.

Each fan is connected to the duct system via non-return valves (IB-zone and EB-zone). The duct system pressure can

be set to the desired value by means of adjustable valves located at the end of the inhalation and exhalation ducts (the main ducts). The flow rate should be continuously measured in the main duct to ensure that it is sufficient for patients connected to the system. Parameters to be measured in the duct system are as follows:

- ~ air temperature
- ~ flow
- ~ pressure loss on filters
- ~ bus pressure
- ~ air humidity
- ~ concentration of gases in the air
- ~ system integrity

Both main ducts must be equipped with a mechanical pressure limiter (or even more) to prevent undesired operation. The inhalation duct may also optionally include an air management segment that measures and controls various important air parameters (temperature, heating-cooling, humidity, etc.). This segment is optional because parameters can be managed in other locations (e.g. in the patient P-zone). The inhalation and exhalation duct systems must be protected against static electricity with appropriate ESD protection by grounding the tubing.

Exhaled air is also transported via a centralized duct system, thus reducing the potential risk of infection for those working in the area. The exhaled air is contagious and for this reason the exhalation ducts must be appropriately marked and painted.

In the exhaled air transporting system, there is depression up to the pressure side of the fan, the pressure can be adjusted with a valve at the end of the exhalation duct and should be about 40-80 mbar lower than the outside air pressure. Due to the lower than

atmospheric pressure, the pathogens cannot escape. The pressure side of the fan must be designed in such a way that the air can escape only after appropriate filtering.

The duct systems have to be connected to the devices of the patients via a separate shut-off device, so that new patients can be integrated into the system without any interruption in the whole system. A shut-off fitting must be provided at the end of the main ducts for the purpose of scalability.

Integration, Ventilation, and Removal of Individuals from the System

Patients receive air based on their personalized ventilation parameters (pressure, respiratory rate, volume, etc.). An intelligent metering-controlling-mixing-air management system near the patient is responsible for personalized patient ventilation. Due to the modularity of the system, new patients can be integrated into the system without having to stop ventilating already connected patients.

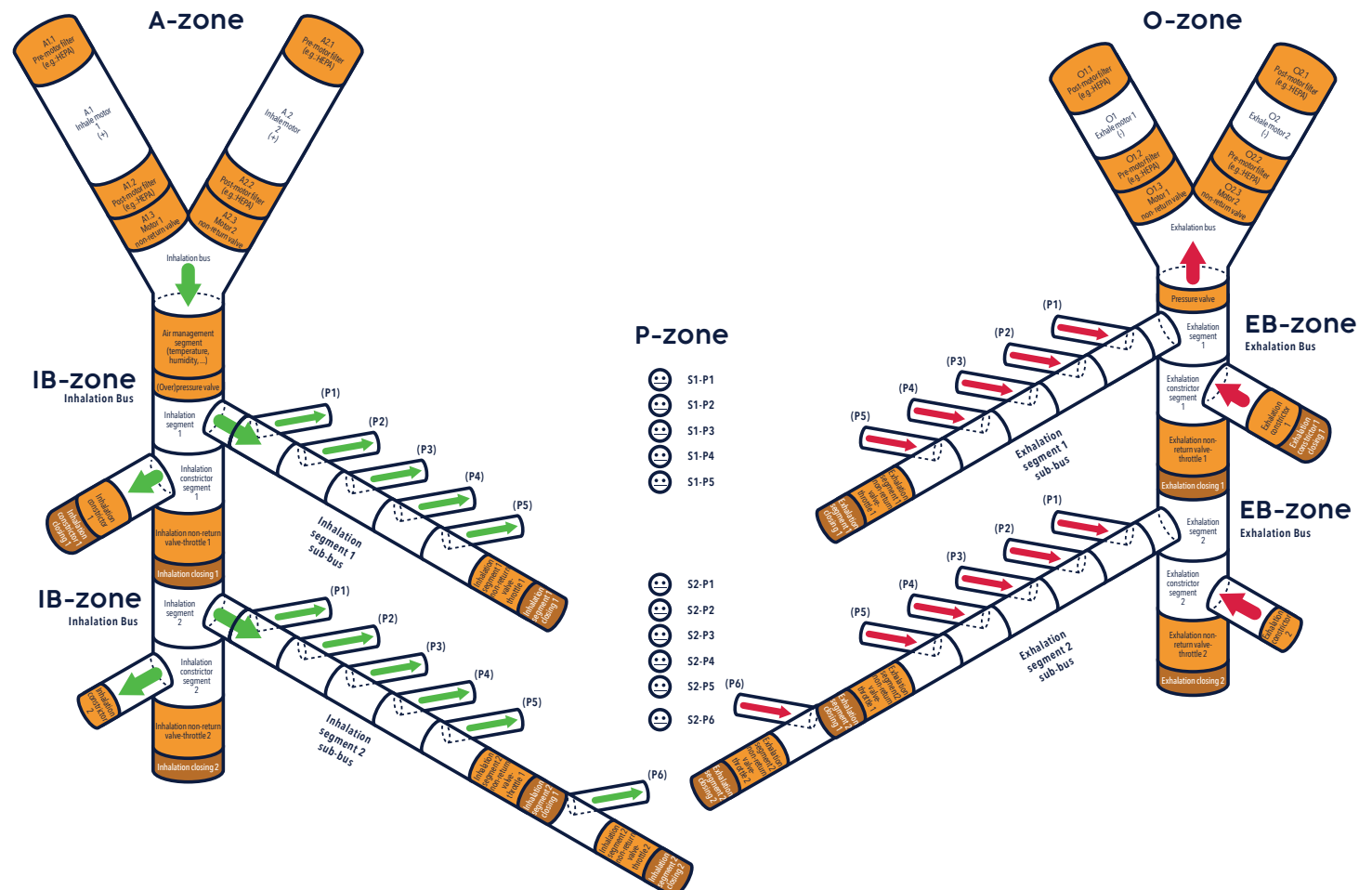


Fig. 3.: MassVentil project – Dr. Kozlowszky
 Example of the mass-ventilator system with additional segments

One or more patients may be connected in each segment at a time. Patients in one segment can be individually integrated into the system or removed from the system at any time independently of the other patients. Connection and disconnection of a given patient module is accomplished by patient level control. The patient is connected to a sub-duct of a particular segment via a three-passage control valve.

The valve body is designed so, that by rotating the valve we start from maximum inflow and end at maximum

outflow status. Thanks to this, the patient side pressure can be gently controlled. By varying the flow cross sections of the valve's pressurized passage (connected to the inhalation duct segment) and the depressurised passage (connected to the exhalation duct segment), the desired pressure and flow rate are produced in the third passage leading to a patient tube or mask. The control of air pressure and flow can be achieved by active or passive control loops. Thanks to the model-based calibration, in addition to complex mechanisms, even a simpler

(but efficient) control loop can be created and pressure and flow control can be achieved with a simple stepped motor position control.

In the P-zone, the system provides several options for adjusting the O₂ concentration of each patient: oxygen delivery can be achieved by concentration-based or even time-based control. It is difficult to obtain relatively expensive and accurate O₂ sensors for use in concentration-based control and to replace them continuously (periodically) in an epidemic situation.

With time-based control, the accuracy is lower, but still suitable for operation. The constant amount of gas delivered per unit time by a mechanical O₂ flow control valve is delivered to the patient by controlling the solenoid valve at suitable time periods.

Thanks to the mechanical flow controller, the amount of O₂ introduced does not depend on the difference in pressure in the O₂ supply system and in the P-zone, it depends only on the time period of delivery. In flow control mode, a predetermined amount of ambient air is supplied so that the required O₂ can be calculated accurately. In pressure control mode, depending on the patient's condition and parameters (which may change over time), different amounts of ambient air can be injected, so that the required additional O₂ concentration (the difference between two

cycles) is calculated using the O₂ quantity of the previous breathing cycle.

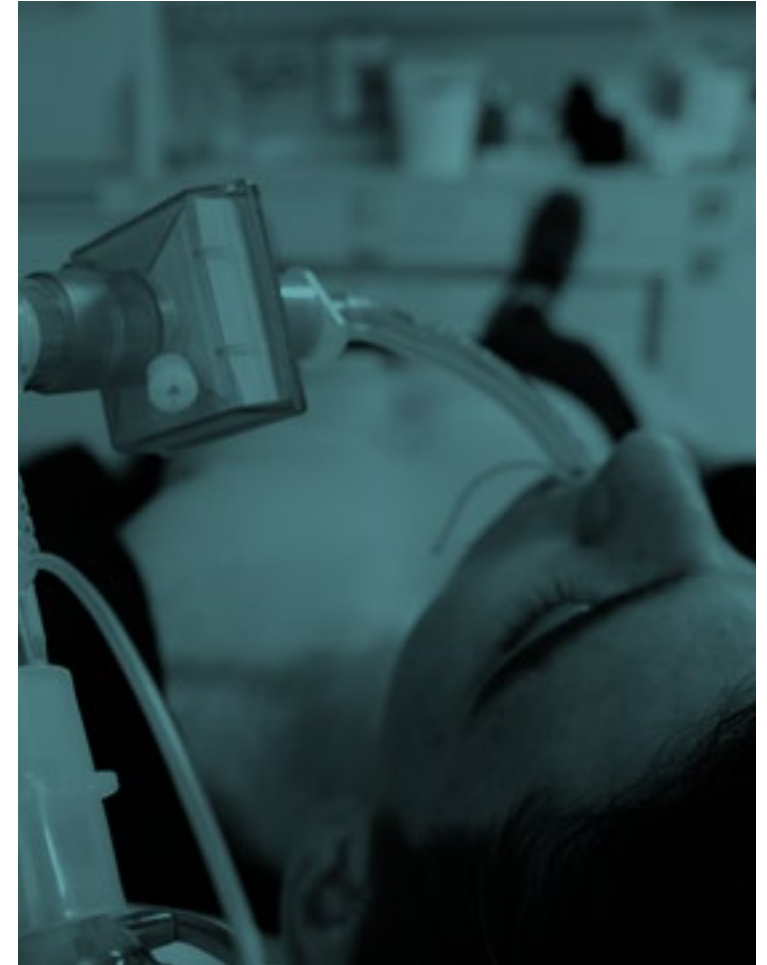
The temperature and humidity of the air supplied to the patient can be controlled both in IB-zone and P-zone.

In the P-zone humidity and temperature control is easier, thus it is possible to set the desired values in the vicinity of the patient's mouth by passive (e.g. HME – Heat and Moisture Exchangers) or active solutions (e.g. HME Booster).

Free Breathing Function

Due to the design of the system, the P-zone is not completely blocked from either the IB-zone or the EB-zone, allowing the patient to breathe freely. In addition the operation is synchronized with the patient's respiratory cycle: if the patient is breathing at a different rate the system will still provide the required amount of air. The excess air that the patient produces or requests during inhalation or exhalation is transported by the sub-ducts.

By setting the inhalation pressure of the patient in the P-zone close to atmospheric pressure, the breathing of a patient with spontaneous breathing can be facilitated. Patient-induced pressure (during exhalation) and depression (during inhalation) can be reduced and increased to atmospheric pressure that allows the patient to exchange air freely and more easily.



Unified Monitoring of Patients

The mass ventilator system and all ventilated patients are monitored by a secure, SCADA like unified monitoring system. Measurement data, derivative values and statistics are transmitted to the local (or central) server(s) over a wireless network using an appropriately encrypted (authenticated) communication channel. Because mass ventilation is theoretically feasible for large number of patients over relatively large areas, it may be necessary to use active wireless devices to bridge distances. Wireless

Access Points (APs) can be integrated into the system to extend the coverage of the communication network.

The monitoring system shows different parts of the ventilator system and only those monitored parameters which are authorised for the personnel accessing the data based on the authentication and security settings. The monitoring system provides data transmission between the personal ventilator modules and the software monitoring, as well as to HISs (Hospital

Information System) and advanced epidemiological monitoring systems.

The main measuring points of the system are located as shown on Fig. 4.

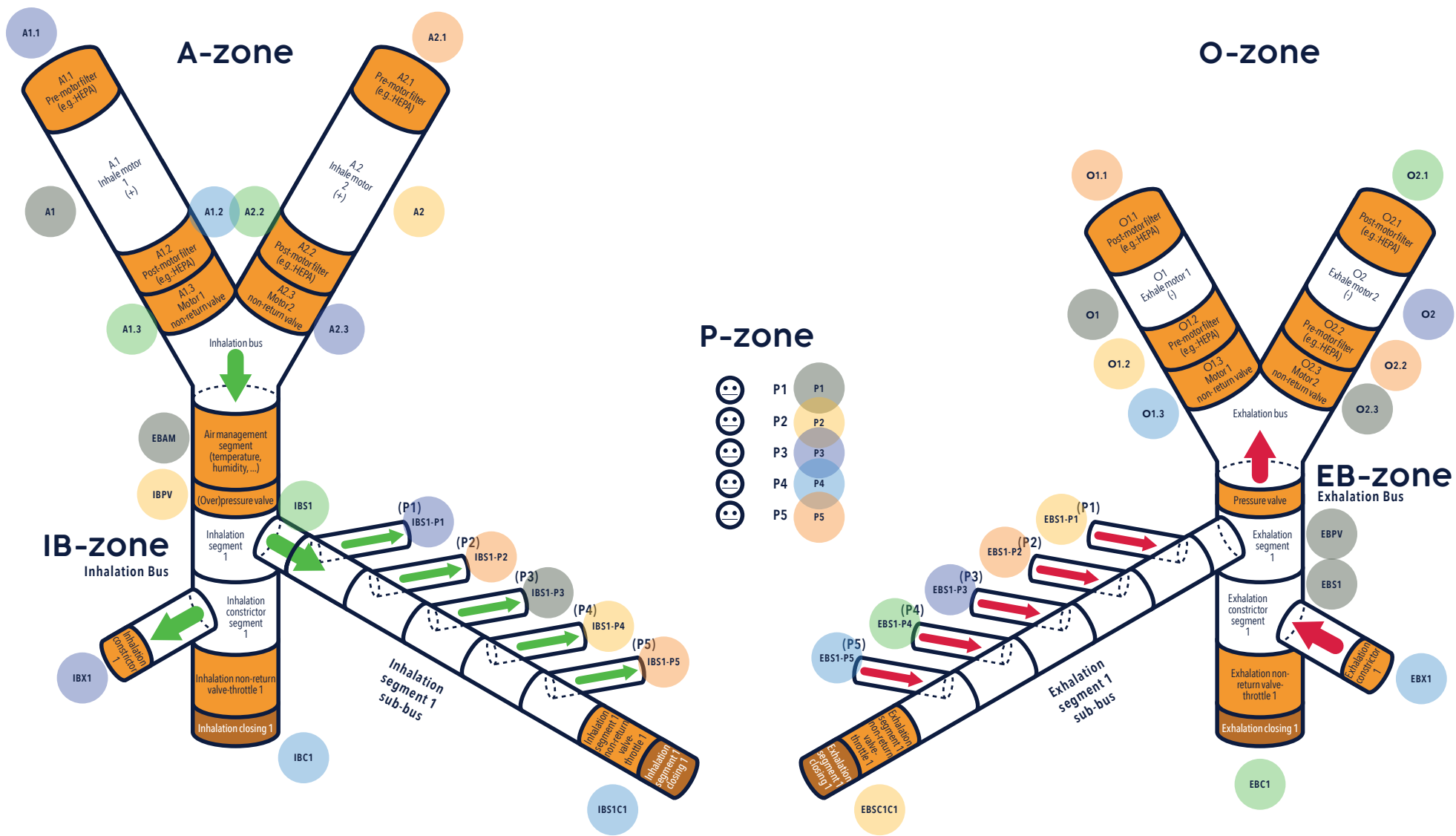


Fig. 4.: MassVentil project- Dr. Kozlovsky
 Important measurement points for the mass ventilator system

Mass Ventilator System Developer Community

As COVID-19 epidemic was spreading fast, Dr. Miklos Kozlovsky, a Hungarian research and development engineer envisaged a new ventilation concept and started to design with his small team a KTG-type mass patient ventilator.

Now, we are an international community: engineers, researchers, inventors, doctors, economists, journalists, physicists, mathematicians, lawyers and university students.

Our members live in different countries and people come from different nationalities. We work in parallel on subtasks and stay connected online.

All community members of the team volunteered to contribute the best of their knowledge to this development. Together, we strongly believe that our intellectual capital and our collective work can be transformed into human lives.



Contact And Further Information

We are looking for...

...maker groups, universities, institutes and manufacturers, who are ready to adapt and build the system for their own country based on the plans and blueprints we share with them.

...medical device companies who are interested in transforming the prototype into a product.

Development community

<https://www.facebook.com/groups/222746815597257>

Website

<http://massventil.org/en/massventil-project>

E-mail

massventil@gmail.com

Facebook

<https://www.facebook.com/massventilproject>

LinkedIn

<https://www.linkedin.com/company/massventil-project>

Twitter

<https://twitter.com/MassVentil>

The MassVentil project