Experimental Installation used for Preparation of Breathing Mixtures Needed for Professional Diving

Simona Rus¹, Mircea Degeratu², Felicia Alboiu², Livia Nica-Rus³ and Edith-Hilde Kaiter⁴

¹ Diving Centre, Constanța, Romania
² Technical University of Civil Engineering of Bucharest, Romania,
³ “Ion Mincu” University of Architecture and Urban Planning, Bucharest, Romania,
⁴ “Mircea cel Bătrân” Naval Academy Constanța, Romania,
⁵ Author to whom any correspondence should be addressed, e-mail adress: simona_elena_rus@yahoo.com

Abstract: Starting from the mathematical modelling of the gas dynamics processes and, of course, from the needs of the Diving Center, several schemes of experimental installations were developed. These schemes are used for the preparation of binary or ternary gas mixtures, specific: for autonomous professional diving, for the system diving, respectively for those simulated or real which are performed in the hyperbaric chambers of the Diving Center or in the diving turrets.

The principle of preparing breathing gas mixtures in the experimental installation ensures that an invariable flow rate (with the pressure of the gaseous mixture from a pressurized cylinder) is injected (constant mass flow) while ensuring the permanent control of this flow.

The installation delivers an invariable gas mixture flow regardless of the gas pressure value inside the storage cylinder.

Depending on the number of components from which the binary or ternary breathable mixture is to be prepared, the design of the plant has been structured in two parts or in the case of a more complex ternary structure of the gaseous mixture, the plant has three distribution-injection lines active. Each of these lines independently carries the three pure component gases used to continuously produce the required respiratory mixture.

Finally, the tests of the gas-dynamical processes related to the plant were presented very succinctly, following a comprehensive testing and evaluation plan in the summer of last year.

1. Mathematical Modelling of Hyperbaric Processes with Binary and Ternary Gas Mixtures

At present, leading and following-up the hyperbaric processes, related to system simulated or real diving, are activities performed by the team of hyperbaric engineers who secure the surface. Helped by special equipment and control panels (see Figure 1), they monitor the evolution of parameters (working depths and the time spent there, pressures, ambient temperature, diving chamber humidity – in case of simulated dives, application of treatments, or simply when making decompressions after a forced output from the working depth, purity of the gas used for breathing mixtures, etc.) during compression and decompression, processes that are absolutely necessary for the human body to adapt to the pressure exerted by the underwater environment on the diver’s body.

The surface team consists of: engineers, physicians and nurses specialised in hyperbaric medicine who intervene in case medical problems appear to the divers during compression and decompression, chamber technicians, pressure chambers operators who perform, according to procedures, the manoeuvres specific to these hyperbaric processes from the control panels (Fig. 1).
From the experience of approximately 50 years of unit and saturation diving performed in the unit, there has been a need for automatic carrying out and following up the processes specific to these system dives in order to eliminate any human mistakes. As a consequence, a new hyperbaric system will be installed in the Hyperbaric Laboratory of the Diving Center in the years to come.

Under this research-development program, there has been an attempt to develop extremely complex theoretical models regarding the mathematical simulation of hyperbaric pressurization and decompression processes related to unitary and saturation system diving. These models refer to both the compression phase of divers within the chambers pertain to hyperbaric systems containing helium-oxygen binary mixtures (HELIOX) and helium-nitrogen-oxygen ternary mixtures (TRIMIX) depending on the type and depth of immersion within the system, as well as while coming back to the surface.

Modelling the hyperbaric compression and decompression processes aims at determining the volumetric and mass participations, the partial pressures and the masses of each gaseous component in the gas mixtures used by divers for breathing in every moment of the hyperbaric process. Gas masses resulting from models of hyperbaric processes within diving systems will be useful in properly sizing the gas stores, which have to be prepared for each type of diving system. The results of the theoretical model were compared with the data obtained in the hyperbaric processes carried out at certain dives in the chambers belonging to the Hyperbaric Laboratory (Fig. 2) of the Diving Center in order to validate the theoretical models obtained by means of mathematical simulation of the of gas dynamics and thermohydraulics phenomena specific to these hyperbaric processes.

During diving the following processes take place:

- exposure of the human body to external pressure, during which the man breathes a gaseous mixture at a pressure corresponding to the depth of immersion. Inert gas (in the case of binary mixtures) or...
inert gases (in the case of ternary mixtures) within the composition of the respiratory mixture are transported to the body’s biomass and dissolve in the tissues;

-return to atmospheric pressure (decompression), during which the gas or inert gases dissolved in tissues during exposure to pressure are eliminated. Disposal must take place in such a way that no dangerous gas bubbles are formed.

The exposure to pressure of the diver can be short-lived (unitary) and long-lasting (diving in saturation). Depending on the duration of exposure to pressure, body tissues absorb a certain quantity or are saturated with the gas or inert gases of the respiratory composition. The pressure exposures of the diver are carried out in the first two stages of a dive, namely in the stage of descent to the working depth (compression) and in the stage of actual work in the underwater yard (staying at work level).

In order to calculate the return to atmospheric pressure (decompression), which consists of setting the pressure reduction rates (climb to the surface of the water), the depth corresponding to the decompression stages, as well as the residence time at these levels, it is necessary to know the gas pressure or of inert gases dissolved in the tissues of the body during exposure to pressure. For operational reasons, the diver must return to atmospheric pressure in any situation related to sea condition and water temperature, in a very short time as possible and with minimum risks of accidents.

It is noteworthy that the time to return to the surface after a dive of 100 minutes, 30 meters deep, where the breathing mixture is a natural one (respectively: unitary diving with air) is 88.4 minutes, in dives where “NITROX” respiratory gas mix was used, the total decompression time is 45.6 minutes for NITROX with 30% O₂, 20.8 minutes for NITROX with 40% O₂, and 2.8 minutes for NITROX with 50% O₂.

It is noted that the decompression time decreases greatly as the gaseous mixture used has a higher oxygen concentration. It is easy to understand that diving performance increases with the use of gaseous mixtures with a higher oxygen concentration. When using “NITROX” binary gaseous mixtures for unitary diving, a depth of 54 meters must not be exceeded.

2. Description of Experimental Installation for the Continuous Preparation of Breathing Mixtures

This hereby chapter deals with scheme of the experimental installation (EI) for the preparation of binary or ternary gas mixtures, specific to independent professional diving, to the ones in the system for simulated or real dives performed in the hyperbaric chambers of the Diving Center or by means of diving turrets and, the scheme of the parameters of the constituent gases and the breathing gas mixture: “NITROX”, “HELIOX”, “TRIMIX” along the preparation EI, in continuous flow, of the synthetic, respiratory gas mixtures.

The installation for the preparation of breathable mixtures can be made in two distinct modes, namely: in the mode intended for autonomous diving appliances and, in the mode in which breathing mixtures, necessary for feeding pressurized enclosures - of the hyperbaric chambers type, or for diving missions which require supplying the divers from the surface, are provided.

It should be noted the fact that the most complex mode of the experimental installation is still under consideration, where both binary mixtures and ternary mixtures can be prepared.
For both modes, the most complex construction installation consists of three distinct distribution-injection lines for the component gases that make up the gaseous mixture.

The experimental installation was designed for the immediate (on-site) manufacture of any breathing gas mixtures specific to the diving professional processes, regardless of the ratios between the components and the pure gases from which they are formed.

The experimental installation falls into the category of those intended for continuous preparation of breathing, synthetic, binary or ternary gas mixtures used in professional, utility or military diving. The desired mixture is made by combining pure gases stored in separate pressurised cylinder.

The principle of achieving gaseous mixtures in this plant consists of providing and controlling the flow rates by carrying out a constant mastic flow injection system. This assures the injection of an invariable flow with the pressure of the gaseous mixture from a pressurized enclosure (constant mass flow) while ensuring the possibility of permanent control of this flow.

The EI thus delivers an invariable flow of gaseous mixture, regardless of the value of the gas pressure inside the storage enclosure (gas cylinders). There is also the possibility of constant injection control.

The experimental installation could be adapted for both underwater breathing apparatuses and chamber supply.

Depending on the number of components from which the respiratory mixture is to be prepared, namely binary (HELIOX or NITROX) or ternary mixture (TRIMIX type), the installation consists of two or three active distribution-injection lines.

**NOTE:** The N, H and O indices refer to nitrogen, helium and oxygen, respectively.

---

**Fig. 4 - Structure of the EI injection system for the preparation of respiratory mixtures**

**LEGEND:** B – gas cylinder, M1 – high pressure gauge/manometer, R1 – gas cylinder valve, RP – low and medium pressure reducer, M2,3,4 – low pressure gauges/manometers, R2 needle valve for fine gas regulation on IE branches, R3,4,5 – ball valves, BC – control block, Bi - mass injection block, Rt - rotameter GR-065GK, Ss – uni-directional valve, Fi – filter, Cam – room in which the breathing gas mixture is achieved from pure components, Ssg – safety valve, FAm – filter element for respiratory mix, REV – ball valve, CRp – fast coupler.

In the final part of the installation, after the mixing chamber (Cam), in which the pure gases injected in the desired proportion and pressure of the binary or ternary synthesis mixture – to isolate the installation from the potential consumer, a ball valve for separation (RS) has been added to the
cylinder vave. Connection of any type of apparatus and mixer to the EI is made by means of the quick coupler with which the experimental installation (EI) has been provided. EI emptying is done with the help of a vave.

Fig. 5 - Parameters of the constituent gases, nitrogen (Ni), helium (He), oxygen (Ox) and of the gas mixture “NITROX”, “HELIOX” and “TRIMIX” along the preparation EI, in continuous flow, of the synthetic, respiratory, binary and ternary gas mixtures

In order to mix the three gases helium, nitrogen and oxygen and to form a ternary respiratory mixture, the plant is made up of three distinct lines (see Figures 4 and 6). Each of these is carried independently of the gas contained in the cylinders (see Figure 6, a)) used to form the mixture.

The IE constructive structure of Figure 6, intended for the continuous preparation of gas mixtures is illustrated by the scheme of Figure 4. It consists of two separate lines for the distribution and injection of inert gases (which do not support combustion or life) and from a line through which oxygen circulates.

Each of the lines is dedicated to a single component that forms the mixture. The helium installation is powered by opening the HR1 valve (see fig. 4). The gas delivery pressure is checked by reading the value indicated by the high pressure gauge/manometer HM1. This pressure gauge indicates the inlet pressure and the next manometer HM2 indicates the outlet pressure from the reducer, the initial pressure, respectively, that will enter the IE branch. Downstream of the needle valve for fine gas pressure regulation on IE branches, there is a HRP ungoverned pressure reducer. Its role is to change the pressure value from high pressure values to medium pressure values. It is part of the reduction gear mounted on each pure gas cylinder.

Gas pressure monitoring after changing the pressure stage is done by means of HBc control block (see fig. 7 (a) and fig. 4), which is connected to the HM2 and HM3 manometers, which actually act as a differential pressure gauge/manometer. The last element in the helium line is the HBi mass injection unit.

The nitrogen line consists of elements similar to those of the helium line. Thus, the pressure at which the nitrogen is stored in the NB cylinder, and which represents the supply or inlet pressure, is checked by means of the NM1 high pressure gauge. The shift from the high pressure to medium values is provided by the NRP pressure reducer and the assembly of the NBc control block and the NM2 and NM3 differential pressure gauge positioned downstream and upstream of NBc make it easier to check these pressure values. Nitrogen supply at constant flow rate of the mixing chamber CA is provided by the NBi mass injection unit.

The Oxygen Injection Circuit consists of an ungoverned ORP pressure reducer having as reference the atmospheric pressure. The role of the regulator is to reduce the pressure from the existing high pressure in the OB gas tank to the medium pressure required to supply the mass injection unit and the BIMC control. In order to check the pressure value, manometers have been installed both at the outlet of the storage gas cylinder and in the supply section of a circuit and upstream of the OBi. The first of these is a large pressure gauge OM1 and the second OM2 is associated with the of the ORP pressure.
reducer, the next OM3 of the control block OBc, located between the pressure reducer (mounted on
the cylinder) and the Obi mass injector block, situated before the rotometer.
To measure the flow of pure gas circulating on each branch of the experimental plant, the following
rotameters are used: Ort, NRt, HRt. The rotameters (see Figure 6, d) are flowmeters designed to
continuously control the flow of fluid, which passes through pressurized experimental installations.
Since oxygen (O2), nitrogen (N2) and helium (He) are conveyed through the three branches (lines) of
the system, these devices were chosen to measure gas flows according to the initial required data.
Their installation on each branch has been proposed to be carried out as shown in figure 4 so that they
can be bridged if necessary.
In each branch there are direction valves that allow the circulation of pure gases in one direction (not
allowing entrance to the lines of the gaseous mixture in the CAm) and filters that contain fine webs
that cause gas breakage with the purpose of facilitate mixing.
All three lines converge to the mixing chamber where proper preparation of “TRIMIX” type
respiratory, synthetic, ternary mixture takes place.
The three gases are stored separately in the gas cylinders (see Figure 6, a)) at high pressure \( p_B \),
occupying the volume \( V_B \), at temperature \( T_B \) and having the usable quantity of \( C_U \) gas. These values
change along the three lines.
Helium is injected into the plant at the flow rate \( Q_{He} \), value that is kept constant along the line. As
regards the temperature of the gas storage \( T_B, He \), and the temperature it has along the circuit, absolute
temperatures, there are no notable differences. After the supply section the value of this physical
quantity can be considered constant, \( T_{in,He} \).

3. Operation Description of the Control Block (BC) and Mass Injection Block (BIM)
Both blocks, namely the BC control block and the BIM mass injection block, have their nozzles as
main elements. The first of these is a cylindrical micro-nozzle designed to operate in a non-critical
(subsonic) mode, and the second is a convergent-divergent micro-nozzle, working in the minimal section in critical (sonic) mode - (Figure 7 (a) and (b)).

Fig. 7 - BIM and BC nozzles

(a) – (non-critical) cylindrical subsonic nozzle and the associated physical sizes;
(b) – (critical) convergent divergent sonic nozzle and related physical magnitudes;
(c) – graphical representation of the mass flow variation $q_m$ corresponding to the non-critical cylindrical nozzle;
(d) – graphical representation of the mass flow variation $q_m$ corresponding to the convergent-divergent nozzle operating in critical mode.

The role of the two blocks is different. The control block BC is designed to measure, by means of a differential pressure gauge, the pressure difference $\Delta p$ between the upstream existing pressure $p_0 + \Delta p$ of the cylindrical micro-nozzle and the downstream pressure $p_0$. Thus, via the cylindrical micro-nozzle provided within the BC control block, measurement and control of the flow provided through the gas-distributing line-injection of the respiratory mixture is ensured. In the subsonic field, the pressure drop $\Delta p$ made by this element is dependent on the injected mass flow.

By means of the BIM mass injection block, due to the presence of the convergent-divergent nozzle in which the minimum section flow occurs in the critical (sonic) mode, it is ensured in a continuous motion mode the delivery of a constant helium mass flow to the experimental plant mixing box.

For the critical operation of the nozzle in the BIM structure, the value $p_0$ of the minimum supply pressure of this element must be determined.

\[
\frac{p_e}{p_o} = \frac{p_{cr}}{p_o} = \left( \frac{2}{k + 1} \right) \frac{k}{k - 1}
\]

from which it follows:

\[
p_{o, min} = \frac{p_{cr}}{\frac{2}{k + 1}}
\]

In which:

- $p_e$ – the pressure downstream of the nozzle from BIM [N/m$^2$ abs.];
- $p_0$ – BIM supply pressure [N/m$^2$ abs.];
- $p_{cr}$ – the pressure at which the nozzle operates in critical condition, - value corresponding to the minimum section [N/m$^2$ abs.];
- $p_0^{min}$ – the minimum supply pressure to achieve critical performance [N/m$^2$ abs.];
- $k$ – the adiabatic exponent of the gas that transits the nozzle [-].
4. Testing the Experimental Installation

Regarding the installation designed for the autonomous diving mode, Figure 4, the line for the inert-gas helium has as a first element the storage gas cylinder, provided with the valve, through which the gas intake is made in the circuit.

Check the pressure value at which the gas is delivered with the high-pressure gauge/manometer.

To reduce the pressure from the existing high pressure in the gas cylinder battery, a non-governed pressure regulator has been provided at the medium pressure level with reference to atmospheric pressure.

The correct operation of the line is verified by means of the control block BC, which has as main element a micro-nozzle operating in the subsonic field. The differential pressure across the fluid through this element is tracked through the differential pressure gauge. In order to deliver a constant mass flow to the mixing chamber (CA), the line provided with a mass injection unit BIM equipped with a convergent-divergent critical nozzle that operates in the critical (sonic) range.

The others distribution lines have a similar structure to the previously described line, the differences consisting of the type of pure gas which is conveyed and the values of the characteristic sizes, which may require devices and components that operate at different intervals. The line B used for distributing and injecting of the second inert gas, in the present case nitrogen, is comprised of the gas storage cylinder, the intake cock, the high pressure gauge/manometer, the unmanned pressure regulator with reference to atmospheric pressure (NM1 or HM1), the control unit (BC) to which the differential pressure gauge/manometer is added and the mass injection unit (BIM). In case of line C intended for oxygen distribution and injection, the gas inlet from the storage gas cylinder into the circuit is made by opening the oxygen valve. The pressure at which the gas is delivered is checked by means of the high pressure oxygen gauge/oxygen manometer preceding the unmanned pressure oxygen reducer with reference to the atmospheric pressure.

As with the other two lines, the correct operation of the oxygen line is checked by means of the differential control unit - differential oxygen pressure gauge/oxygen manometer.

The proper formation of the binary or ternary mixtures is realised in the mixing chamber (CA). Hence, by adjusting the tap, the mixture formed is delivered to a respiratory bag which takes over the variations in volume and pressure resulting from breathing, to reduce the internal gas pressure to the hydrostatic pressure corresponding to the depth of immersion, as well as to ensure that gas is stored at the desired breathing parameters.

From the respiratory bag the mixture is distributed to the consumer in the amount and pressure required by the circuit. The gas exhaled by the diver is theoretically a mixture of oxygen and carbon dioxide, and the purge cartridge is provided on the exhalation circuit for retaining the latter. It provides for the retention of carbon dioxide in the respiratory mixture. As with the decrease in the depth of dive (when the diver returns to the surface) a gas surplus appears in the respiratory bag, an outlet valve is provided which ensures the evacuation of this surplus.

In its non-measurable version, the device designed for the preparation of dry air mixtures, such as hyperbaric complexes within the Diving Center, on diving or offshore vessels, consists of three distinct lines for the distribution and injection of the mixture’s gaseous components. Lines (N) and (H) correspond to inert gases used for the continuous preparation of synthetic gas mixtures and line (O) of oxygen. In the case of preparing a binary gaseous mixture, line (N) or line (H) will be active in conjunction with line (O) of O₂, and all three lines will be used for the production of ternary mixtures ("TRIMIX" type).
5. Final Conclusions

The experimental installation for the preparation of binary and ternary gaseous mixtures in continuous flow is the basis for the design and production of the following types of installations used in hyperbaric technologies: installation for the continuous preparation and delivery of breathing mixtures for divers by working with surface supply, a device for the continuous preparation and delivery of air mixtures intended for the supply of hyperbaric chambers (for which a suppressor has to be added), installation for the continuous preparation and delivery of breathing gas mixtures for filling the diver’s bottles (for which a suppressor must be added) and, installation for the continuous preparation and delivery of binary breathing gas mixtures of the underwater breathing apparatus in the semi-dry circuit with the local preparation of the binary mixture (“NITROX” or “HELIOX”).

Remarks that the experimental installation for preparation of continuous binary and ternary breathing gaseous mixtures prepared and tested in the Hyperbaric Laboratory has had the role of experimentally validating the theoretical calculations and showing that the underlying principle of such installations is correctly carried out and valid and, the four types of installations, shown above and, having as a principle the experimental installation will have to be designed and built to the specific thermodynamic dimensions and parameters of each of the four types of installations.

Important features of the installation:

- EI can prepare and deliver binary or ternary streams in continuous flow with the desired proportion of components and at different mass flow rates;
- EI may, by performing simple manoeuvres to modify the supply pressures of the mass injection nozzles, with a mass flow blocked on the lines of the gaseous components, change both the composition and the mass flow rate of the respiratory mixture delivered to the consumer;
- The dimensions of the mass injection nozzles and their supply pressures can thus be chosen and adjusted so that the mass flow rates of the components should remain constant and independent of the consumer pressure, fact that ensures a mass flow rate of the constant mixture and the concentrations of the constant mixture components, to the desired values.

Notations used

- \( p_B \) = pressure from the storage gas cylinder;
- \( T_B \) = absolute temperature;
- \( V_B \) = volume;
- \( C_u \) = the usable amount of gas;
- \( Q_m \) = mass flow;
- \( k \) = the adiabatic gas exponent passing through the measuring nozzle [-],
- \( p_{cr} \) = the pressure at which the nozzle operates in critical condition, corresponding to the minimum section [N/m² abs.];
- \( p_s \) = pressure downstream of the nozzle within the BIM [N/m² abs.];
- \( p_0 \) = the pressure at the storage cylinder outlet, the supply pressure of the BIM [N/m² abs.];
- \( p_0 + \Delta p_{df} \) = medium value of the pressure in the lines of the experimental installation;
- \( p_0^{\text{MIN}} \) = the minimum supply pressure to achieve critical performance [N/m² abs.];
- \( Q_{inj}^{Ni, He, Os, am} \) = the injected mass of the pure gas or the mixture used;
- \( T_0 \) = absolute temperature.

Bibliography

[1] DEGERATU, M., PETRU, A., BEIU, V. – Computer-aided Simulation of Theoretical Processes in Binary and Ternary Mixtures of Hyperbaric Systems Used in Deep Diving. Chemical Abstracts, page 346, 9-Biochem. Methods, vol. 107, Columbus, Ohio, U.S.A., 1986.
[2] DEGERATU, M., PETRU, A., GEORGESCU, Şt., IONIŢĂ, S. – Tehnologii hiperbare pentru scufundări unitare şi în saturaţie. Ed. MATRIX ROM, Bucureşti, 2003.
[3] The National Oceanic and Atmospheric Administration (NOAA), NOAA Diving Manual U.S. Department of Commerce and Best Publishing Company 2011.
[4] ***GHM Messtechnik; Produktinformationen Durchflussmesser GR – 065 GKA 1144K.
Webography

[5] http://www.seasubsea.com/airquality/Air Quality Requirement for Nitrox Blending,
[6] https://doi.org/10.1088/1742-6596/1122/1/012004 (Volintiru, O.N., Scurtu, I.C., Stefănescu, T.M., Modeling and optimization of HVAC system for special ships, Journal of Physics: Conference Series 2018, 1122 (1), art. no. 012004),
[7] https://doi.org/10.1088/1742-6596/1122/1/012034 (Volintiru, O.N., Scurtu, I.C., Stefănescu, T.M., Optimization of the ventilation system for special ships, Journal of Physics: Conference Series 2018, 1122 (1), art. no. 012034).

Acronyms and abbreviations

AmG = gas mixtures;
B = gas cylinder, NB = nitrogen gas cylinder, HB = helium gas cylinder, OB = oxygen gas cylinder;
BC = control block/unit;
BIM = mass injection block;
BIMC = mass injection and control block;
CA = CAM = mixture chamber;
CR = fast coupling;
He = H = Helium/helium line;
EI = experimental installation;
IPA = installation/plant for mixtures’ preparation;
HL = Hyperbaric Laboratory;
MD = differential manometer;
MIP = high pressure manometer;
Ni = N = Nitrogen / nitrogen line;
Ox = O = Oxygen / oxygen line;
RB = cylinder valve;
RBS = ball valve for separation;
RG = drain valve;
RS = spherical valve;
RPN = unmanned pressure reducer;
TED = testing - development assessment;
Ssg = safety valve;
FAm = filter for breathing mixture;
REV = exhaust valve;
CRp = exhaust valve;
NR1 ÷ NR5 = valves/taps on the nitrogen line;
HR1 ÷ HR5 = valves/taps on the helium line;
OR1 ÷ OR5 = valves/taps on the oxygen line;
NM1 ÷ NM4 = manometers on the nitrogen line;
HM1 ÷ HM4 = manometers on the helium line;
OM1 ÷ OM4 = manometers on the oxygen line;
NRP = unmanned pressure reducer (UPR) on the nitrogen line, HRP = UPR on the helium line, ORP = on the oxygen line;
NBc = control block/unit on the nitrogen line, HBc = control block/unit on the helium line, OBc = control block/unit on the oxygen line;
NBI = injection block/unit on the nitrogen line, HBI = injection block/unit on the helium line, OBI = injection block/unit on the oxygen line;
NRT = nitrogen line rotameter, HRt = helium line rotameter, ORt = oxygen line rotameter;
NSS = direction valve on the nitrogen line, HSs = direction valve on the helium line, OSs = direction valve on the oxygen line;
NFI = nitrogen line filter, HFI = helium line filter, OFi = oxygen line filter.