Set-up of central gas supplies for emergency treatment facilities

Recommendations for setting up central medical gas supply systems in different scenarios and facilities

Dräger

The current Covid-19 pandemic creates urgent demand for additional intensive care and ventilation facilities. Besides obvious requirements like ventilators and patient beds, the necessary medical infrastructure needs consideration as well. In this paper we would like to discuss different aspects of medical gas supply for short-term capacity enhancements for the treatment of Covid-19 patients.

SUMMARY

When setting up emergency Covid-19 treatment areas, oxygen and medical air supply are crucial. Depending on the building context, different options are feasible. As life of patients depend on the system, also in emergency situations basic design principles need to be followed.

MEDICAL BACKGROUND

The range of medical treatment requirements for patients suffering Covid-19 is broad and ranges from no or mild symptoms up to critically ill and fatal. In this paper we focus on areas for critically ill Covid-19 patients who require hospitalization.
Roughly three major treatment options should be differentiated when discussing medical gas requirements. From the lowest to the highest intensity these are:

1. Low flow oxygen therapy (e.g. oxygen nasal cannula)
2. High flow oxygen therapy
3. Mechanical ventilation (incl. NIV)

Table 1 gives an overview of technical details resulting from the different therapies.

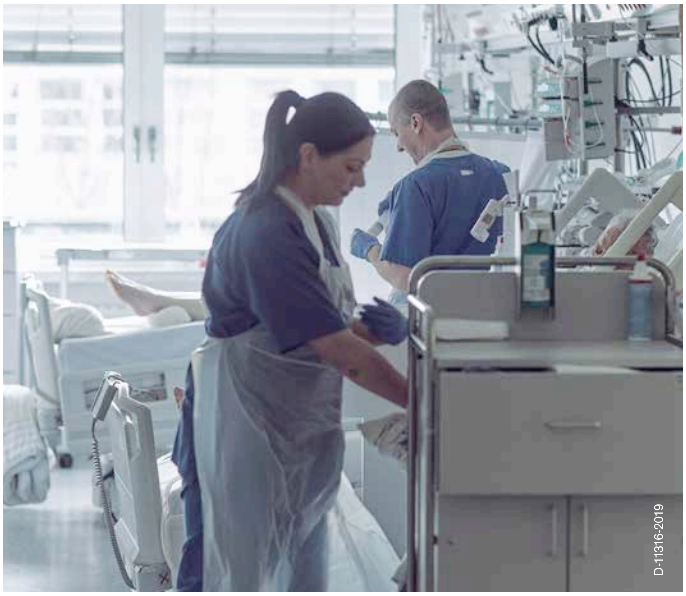
Therapy	Gases required	Peak Flow / Minute Volume in l/min per patient	% of O_2 in gas supplied	Avr. daily demand
O_2 low flow	O_2	Ø 6-10, max. ~15	100%	O_2: ~14m³
O_2 high flow	O_2 and Air	Ø 40-60, max. ~85	0-100% Ø ~50%	O_2: >40m³ Air: >40m³
Mechanical Ventilation	O_2 and Air	Ø 10-12, max. ~20	0-100% Ø ~60-80%	O_2: ~8m³ Air: ~10m³

Table 1

STANDARD ICU SETUP

In a normal ICU setting, all bed places are equipped with oxygen, medical air and vacuum, typically with a minimum of two outlets per gas type. Of course, this is also the preferred setup for the treatment of Covid-19. However, to quickly expand capacities, a focus on the provision of oxygen and medical air is advisable, as these two are mandatory for the required ventilation therapy.

If the ventilator used possesses an integrated compressor and thus provides its own medical air, all focus can be put on oxygen, medical air is less crucial. However, it is still advisable to have medical air available in case other types of ventilators are deployed. Furthermore, medical air can be used for driving ejectors for the provision of suction (vacuum) and for applying high-flow oxygen therapy for less critical patients to free up ventilation resources.



CAPACITY INCREASE SCENARIOS

There is a broad range of potential ways to increase capacities. Among scenarios often discussed are the following:

1. Upgrade of normal ward areas
2. Creation of new areas inside an existing health care facility
3. Creation of new ad hoc facilities independent of existing hospitals (e.g. hotels, nursing homes, gyms, exhibition halls)

SCENARIO 1: UPGRADE OF NORMAL WARD AREAS FOR HIGH ACUITY PATIENTS

In this scenario all necessary equipment including infusion pumps and ventilators are brought into a normal ward room. Each bed should already have at least one oxygen and one medical air gas outlet. In some countries normal ward areas are equipped with O_2 and vacuum instead. In this case, either medical air must be added or ventilators with integrated compressors must be used.

The big advantage of this approach is the close connection to existing hospital infrastructure which can help significantly to deal with the challenges of mass patient inrush.

Based on relevant standards and expected use (simultaneity factor), a newly designed ward area is planned with a significantly lower peak flow for oxygen and medical air compared to an ICU. When these normal ward rooms are used as intensive care units, the system might not be able to provide enough flow, resulting in pipeline pressure drops. Depending on the actual flow and pressure, the ventilators could alarm or even stop working. Normal pipeline pressures are 4-5 bar, the minimum required pressure for ventilators is typically 3-3.5 bar.

If a normal ward is re-dedicated for intensive care, the existing pipeline system and central plant capacity should be checked to make sure that future demands are met. Ideally the check is performed both by re-calculating existing pipeline plans and plant designs and by on-site testing with flow capacity and pressure tests.

If the system is not providing enough capacity, the solution depends on identifying the bottle neck. For example, if the pipeline system lacks capacity on the last meters, an additional supply from the main raiser to the area in focus could be a solution. On the other hand, if the plant is too small, either additional cylinder manifolds or compressor systems in the basement or smaller decentralized sources of supply could be the solution. To ensure proper interaction with the existing system, a close co-operation with the manufacturer of the original installation is recommended.

SCENARIO 2: CREATION OF NEW AREAS INSIDE EXISTING HEALTH CARE FACILITIES

Available areas inside a hospital, which are empty or at least not used for medical purposes so far, can be prepared to allow treatment of additional patients.

If central plants for oxygen and medical air with sufficient capacity are available, and main (raiser) pipelines are accessible, the new area should preferably be connected to the existing system. It is important that both the supply line from the existing system and the newly added pipeline system are appropriately sized.

If the central plants are either not accessible or have insufficient capacity, an additional local (decentralized) supply for air and oxygen is needed. This can be sized purely for the supply of the new area. To keep installation effort low, the plant should be located close to the new area if possible. However, general requirements for plant rooms should be considered. If cylinders or cylinder bundles are used, the room must be easily accessible to ensure smooth logistics. If a compressor station is planned, cooling and fresh air demand as well as electrical supply need consideration. Compressors are normally operated with 3-phase 380-400V electrical supply. For safety reasons, compressors and oxygen manifolds must not be installed in the same room.

SCENARIO 3: CREATION OF NEW AD HOC FACILITIES

In this setting, neither central plants or pipeline systems are existent. Everything must be set-up from scratch. In many cases, this scenario applies for larger installations with up to several hundred bed places. The whole system must be designed accordingly, both to match the resulting gas demand and to fulfill the safety requirements if several dozens or hundreds of patients rely on the gas supply. Failure of the gas supply system with so many patients depending on oxygen and ventilation cannot be compensated and could consequently result in patients suffering permanent or even fatal injuries.

CALCULATION REFERENCES

For appropriate dimensioning of a medical gas supply, both the peak flow as well as the total consumption (daily or hourly) need to be considered. The required peak flow determines the pipeline dimensioning, especially the diameters and the required volume flow rate of the plants. The hourly or daily consumption is the key input for selecting the size of cylinder manifolds (number of cylinders) and liquid oxygen tanks. As mentioned in scenario 1, normally gas supply systems are calculated based on certain simultaneity factors to reflect the average usage of the system. For Covid-19 emergency areas, the simultaneity factor should be left out (or considered as being 1) as the expected occupancy is very high.

PEAK FLOW

As the simultaneity factor should be assumed as being 1, the system peak flow is equivalent to the expected average flow per bed place multiplied with the number of bed places. Indications for the flow demand of different therapies can be found in table 1. The project specific figures should be determined together with the medical staff in charge and with consideration of the technical data of the devices planned for the area.

It is important to base the calculation on bed places and not on gas outlets or medical supply units. Providing one bed place with two oxygen outlets is advisable but will not double the gas demand as still only one patient will be ventilated. On the other hand, if a medical supply unit is supposed to cater for two patients, demand will be doubled.

PIPELINE DIMENSIONING

The expected peak flow and the overall length of the pipeline system are the key determinants of the required pipeline diameter. General statements can hardly be made. It is mandatory, that experts, either from the Medical Gas Pipeline System manufacturer or specialized planners or consultants are involved in the design and calculation of the system. As a rough indication, table 2 provides some base figures on minimum diameters for pipeline length of up to 35 m.

Calculated flow	Pipeline diameter
<400 l/min	15 mm
< 1.300 l/min	22 mm
< 2.200 l/min	28 mm
< 4.500 l/min	35 mm

Table 2

It is important, that the overall pressure drop of the whole system from the sources of supply to the very last gas outlet is kept below 10%. Therefore, single sections of the pipeline system cannot be designed without consideration of the complete system.

PLANT CAPACITY

Based on the daily or hourly consumption (some indications are given in table 1), the daily consumption should be calculated. With the simultaneity factor set to 1 the daily demand results of the average flow (l/min) multiplied with 60 min/h and 24 h/d divided by 1000 l/m³ to come to m³/day.

Typical gas cylinders for hospital use (non-mobile) are 50l filled with either 200 bar or 150 bar. As the gases under consideration are roughly ideal gases, the resulting capacity per cylinder equals 10m³ at 200 bar and 7.5 m³ at 150 bar.

For 10 bed places with artificial ventilation around 50m³/d for oxygen and 120 m³/d for medical air can be expected. If the system in place has 2 x 6 cylinders per gas, the capacity per cylinder side at 200bar is 60m². Consequently, for oxygen one cylinder change per day and for medical air up to three per day (i.e. every 8 hours) should be expected. Figure 1 shows a 2 x 6 automatic cylinder manifold.

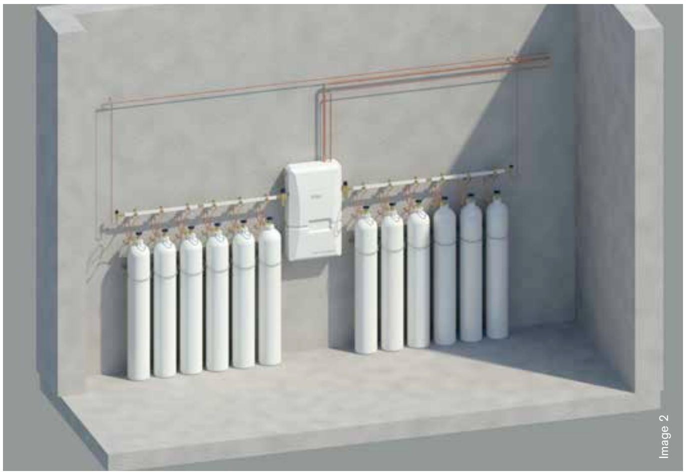


Figure 1

For bigger installations liquid oxygen tanks (also referred to LOX or VIE) are the preferred solution for the primary oxygen supply and a cylinder manifold can serve as backup. For medical air a compressor station with appropriate air dryers and filters should

SINGLE STAND-ALONE CYLINDERS

The use of stand-alone cylinders with cylinder pressure regulators is generally not advisable. These set-ups are for short-term bridging situations for transport, during maintenance work or as back-ups. On the one side mobile cylinders provide only a very limited capacity. For example, 20 l oxygen and medical air cylinders with 200 bar provide a capacity of 2 x 4 m³.

Based on the figures from table 1, this would provide an average use time of 7h per cylinder for low flow O2 therapy and for ventilation 12h for oxygen and 9,5h for medical air. With 25 patients with oxygen therapy the total amount of oxygen cylinder changes per day is 85, with 25 patients on artificial ventilation it is approximately 50 for oxygen and 63 for medical air, totaling up to 113. All cylinders will empty unsynchronized at different times.

Most cylinder pressure reducers do not alarm actively when the cylinder content is running low, therefore staff have to continuously, visually monitor the gauges for all patients in an already stressful and challenging environment. Once the cylinder is empty immediate replacement is required. As there is no automatic switch-over, there will always be a short interruption. If staff are trained and available and a full cylinder ready for connection, the interruption can be short. Else patients will suffer from prolonged oxygen or ventilation deficiency which would impose a high risk to critically ill patients.

OXYGEN GENERATORS

In case oxygen either in cylinders or as liquid oxygens is difficult to obtain, oxygen generator plants are a possible option. Some points should be discussed when considering oxygen generators. Firstly, they are often not readily available and entail relatively large plant installations with significant delivery times. To generate 1 m³ oxygen, the feeding air plants must provide >5 m³ compressed air. This results in huge compressor stations with additional installation effort and demand for space and electrical energy, and this in addition to the actual medical air consumption. Commercially available oxygen generators provide O_2 with 93% purity, while normal medical oxygen has a purity of 99,9%. Many medical devices are not approved for use with 93% oxygen. When used in low or high flow oxygen therapy, this difference can be compensated, even though this might constitute an off-label use*. For ventilators the situation is more challenging, as the calibration feature of most ventilators does not function correctly with 93% oxygen, resulting in a significant off-set between oxygen concentrations set at the ventilator and those achieved.

DISCLAIMER

Medical Gas Pipeline Systems are critical hospital infrastructure. Life and well-being of patients depend on the continuous availability of medical gases. In many countries MGPS are considered medical devices. Planning, installation and testing of such systems requires expert knowledge and appropriate quality management and certification. This paper is supposed to provide basic general information. It does not replace project specific expert planning and consultation.

All technical data provided in this document, like flow and consumption data, are for illustration purpose only. For specific projects, all data must be checked with the situation on-site and with the equipment and therapies planned for use.

*Off-label use: product is not used according to the official instruction for use.

CORPORATE HEADQUARTERS
Drägerwerk AG & Co. KGaA
Moislinger Allee 53–55
23558 Lübeck, Germany

www.draeger.com

PDF-10354 | 20.04-1