

Additional Ventilators May Pose a Risk to Hospital Gas Supply Systems

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COVID-19 Epidemic Concerns

- Increased usage of mechanical ventilators
 - Increased usage of current inventory
 - Rapid increase in new ventilator purchases
- The limiting factor may not be the number of ventilators but the medical gas supply to operate them

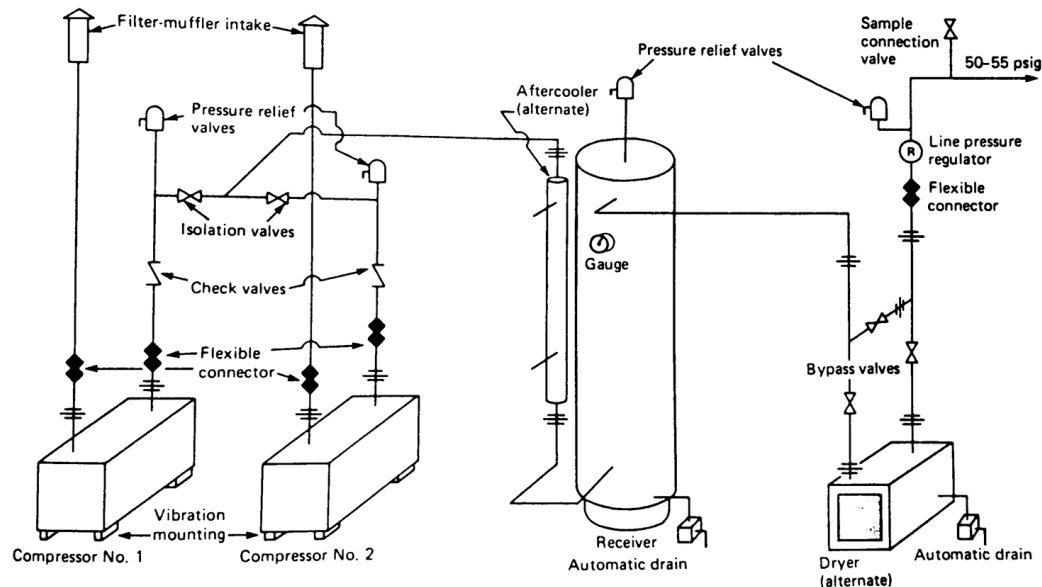
Facilities Design Concepts

- Medical oxygen is stored in liquid form
 - Limitations in flow due to plumbing resistance
 - Limitations in rate of usage due to icing on evaporation coils



Facilities Design Concepts

- Air is supplied by huge air compressors with dryers to remove water vapor
 - Failure of dryers will lead to water in piping system that can damage ventilators





Facilities Design Concepts

- No set design procedure of medical gas sizing
- Surge tolerances built into systems may not match actual surge due to increased ventilator usage
 - Oxygen usage by other delivery systems must be considered (O_2 , masks, cannula, high flow systems)
- Clinicians need a way to communicate with engineers to determine gas flow capacity in each location where ventilators are or will be used



Medical Gas Calculator – Inputs

- Calculator built as an Excel file (download from AARC website)
- <https://www.aarc.org/additional-ventilators-may-pose-risk-to-hospital-gas-systems/>
- Runs on any computer that runs Microsoft Excel
- Simple numerical inputs from clinical planners

Medical Gas Calculator – Inputs

- Atmospheric temperature and pressure
- Ventilator minute ventilation
- FiO_2
 - Assumes ventilator does not have a blower
- Predicted peak ventilator census
- Estimated duration of ventilation

CRITICAL ASSUMPTIONS	High	Median	Low
Daily Ventilator Census (vents)	800	500	100
Duration of Ventilation (d)	14	12	10
Total vent-days	11,200	6,000	1,000
Capacity of Oxygen H-Tanks (L/tank)	7,080		
Capacity of Air H-Tanks (L/tank)	7,080		

Medical Gas Calculator - Outputs

- Outputs relevant to clinicians and engineers
 - Adjustable reporting units
 - Cubic meters (Liters) per minute
 - Cubic feet per hour
- Oxygen and Air Consumption Rate
 - Per minute, hour, day

RESULTS for PIPING SYSTEMS (STPD)	High	Median	Low
Oxygen Consumption Rate (per min)	280	56	4
Oxygen Consumption Rate (per hr)	16,806	3,388	211
Oxygen Consumption Rate (per day)	403,335	81,305	5,052
Air Consumption Rate (per min)	0	58	11
Air Consumption Rate (per hour)	0	3,475	665
Air Consumption Rate (per day)	0	83,390	15,955



Medical Gas Calculator - Outputs

- Total Gas Consumption Duration of Ventilation
 - Oxygen and air tanks required if no piped oxygen

RESULTS for TANK SYSTEMS (STPD)			
	High	Median	Low
Required Oxygen H-Tanks per Day (tanks per day)	57	11	1
Required Oxygen H-Tanks per Population Duration of Ventilation (total tanks)	798	138	7
Required Air H-Tanks per Day (tanks per day)	0	12	2
Required Air H-Tanks per Population Duration of Ventilation (total tanks)	0	141	23



Practical Suggestions

1. Consider testing location gas capacity by placing running ventilators with test lungs
2. Turn off oxygen to manual resuscitators until used
3. Close zone valves to empty units
4. Use minimal FiO_2 for adequate oxygenation
5. Reduce use of high flow nasal cannula for oxygen delivery

Practical Equations

- Oxygen use by ventilator
 - Add bias flow if present

$$O_2(L/min) = [tidal\ volume\ (L) \times respiratory\ rate\ (bpm)] \times \frac{FiO_2 - 0.21}{0.79}$$

$$O_2(L/min) = [tidal\ volume\ (L) \times respiratory\ rate\ (bpm)] \times \frac{FiO_2 - 0.21}{0.79} \\ + bias\ flow\ (lpm) \times \frac{FiO_2 - 0.21}{0.79}$$



Take-Home Messages

- Accurate prediction of medical gas consumption during extreme surges requires a combination of both clinical and engineering information
- The limiting factor for COVID-19 ventilation surge may not be the available ventilators
- Medical oxygen and air supply systems may not be able to handle the increased usage



Take-Home Messages

- A calculator is available to make accurate estimates useful to engineers based on relevant ventilator usage data from clinical experience
- Other practical actions should be taken to assure adequate oxygen supplies