MANUAL OF RECOMMENDED PRACTICE FOR

Medical Gas Resiliency

IAPMO Manual 2-2023

PUBLISHED BY THE IAPMO GROUP

The International Association of Plumbing and Mechanical Officials

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Published by
International Association of Plumbing and Mechanical Officials (IAPMO)
4755 East Philadelphia Street, Ontario, California, 91761, USA
1-800-854-2766 • 1-909-472-4100

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Printed in the United States of America

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Foreword and Purpose

In the face of unprecedented challenges and lessons learned from the global COVID-19 pandemic, the importance of resilient medical gas systems has come to the forefront of healthcare planning and design. Recognizing the need for comprehensive guidance in this critical area, we are proud to present the Manual of Recommended Practices for Medical Gas Resiliency. This manual integrates the expertise and insights from two guidance practices, each with its own distinct scope and purpose, to provide a comprehensive approach to ensuring the availability and effectiveness of medical gases in healthcare facilities.

By combining the insights from these two chapters, this Manual of Recommended Practices for Medical Gas Resiliency equips healthcare professionals, engineers, architects, and facility managers with the necessary tools to enhance the resilience and reliability of medical gas systems. We believe that by implementing the recommended practices outlined in this manual, healthcare facilities can confidently prepare for and navigate the challenges of future pandemics and other unforeseen circumstances, ensuring the continuous availability of critical medical gases to support patient care and safety.

Disclaimer

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Manual of Recommended Practice for

Medical Gas Resiliency

Scope

1.1 Intro to Operating Medical Air and Oxygen Systems with Non-standard Pressures.
COVID-19 served as a wake-up call, revealing the limitations of conventional medical gas systems in meeting the demands associated with respiratory pandemics. In response to this urgent need for improved resiliency, the IAPMO Medical Gas Resiliency Group was formed, comprising medical gas industry and design professionals dedicated to offering guidance on designing systems that can effectively respond to and overcome future crises.

This chapter provides essential guidance on designing medical oxygen and medical air systems with higher pipeline pressures than traditionally employed. It addresses the practical implementation of elevated pressure capabilities, which proved instrumental during the COVID-19 pandemic in managing crisis-level caseloads. By equipping medical gas systems with the capacity to operate under elevated pressures, healthcare facilities can enhance their ability to respond to surges in demand, ensuring the continuous and reliable delivery of critical gases.

1.2 Intro to the Use of Concentrator Plant with Centrally Piped Medical Oxygen Systems.
Oxygen concentrator plants have long been recognized as a viable option for central supply systems in health-care facilities worldwide. However, the global impact of the COVID-19 pandemic exposed certain issues related to oxygen supply that were previously underestimated or overlooked. In response to these challenges, this chapter aims to provide assistance to healthcare facilities in managing the valuable lessons learned from recent experiences around the world.

This chapter offers comprehensive guidance and considerations for the utilization of oxygen concentrators in various configurations within centrally piped medical oxygen systems. While detailed in nature, it is essential to consult local codes and standards, including applicable pharmacopeia requirements, as well as seek consent from the facility's clinical teams and adhere to good engineering practices. This guide does not provide absolute or exhaustive means and methods but serves as a valuable resource for facilities to consider and navigate the complexities associated with incorporating oxygen concentrators, ensuring compliance with pharmacopeia requirements, and aligning with the capabilities, limitations, and policies of the facility's clinical operations department.

Reference Publications

National Fire Protection Association (NFPA)
NFPA 99, Healthcare Facilities Code – 2021

International Association of Plumbing and Mechanical Officials (IAPMO)
IAPMO/ANSI UPC-1 Uniform Plumbing Code - 2024

American Society of Plumbing Engineers (ASPE)
Plumbing Engineering Design Handbook Volume 3

Beacon Medaes Medical Gas
Medical Gas Design Guide

Crane Fluid Handling
2009 Edition of Technical Paper No. 410

Amico Medical Gas
Medical Gas Design Guide

WHO Oxygen 93 Pharmacopia Working document
QAS/20.867/Rev 6 – May 2022 for publication in the 11th Edition of Ph. Int.

Definitions and Abbreviations

Accepted Engineering Practice. That which conforms to technical or scientific-based principles, tests, or standards that are accepted by the engineering profession.

Central Supply System. The entirety of the components comprising the oxygen source on the source side of the Source Valve. Required components for various configurations of Central Supply Systems are detailed in the Medical Gas Standards

Ceramic Ion transfer Membrane (MCOG). MCOG systems disassociate O2 into oxygen ions, transfer those ions across a selective membrane, and return them to O2. The nature of the process is such that these concentrators produce essentially 100% oxygen. MCOG systems were under development at the time of writing, and may become commercially available during the life of this Guidance.

Concentrator. The device which actually performs the separation of oxygen from air typically using a zeolite molecular sieve and one of: Pressure Swing Adsorbtion (PSA), Vacuum Swing Adsorbtion (VSA), or Pressure-Vacuum Swing Adsorbtion (PVSA) (see Annex) However, the definition is not technology restrictive and any device which can produce the concentration and purity required by the pharmacopeia might be included.

Concentrator Plant. A source of supply, based on concentrator technology, connected to a piped oxygen distribution network in a medical facility. Depending on context, this may be a full Concentrator based Central Supply System or a single Concentrator based Supply Source.

Main. The principal artery of a system of continuous piping to which branches may be connected.

Medical Gas Standards. Depending on the locality(ies) in which the User is based, the standard(s) in use may vary (see the reference standards list) and may involve standards other than the medical gas systems technical standard. The locally relevant standards should be consulted when using this Guidance.

Pressure. The normal force exerted by a homogeneous liquid or gas, per unit of area, on the wall of the container.

Pressure-Vacuum Swing Adsorbtion (VPSA). VPSA systems apply pressurized gas to the separation process and also apply a vacuum to the purge gas. VPSA systems, like one of the portable oxygen concentrators, are among the most efficient systems measured on customary industry indices, such as recovery (product gas out/product gas in) and productivity (product gas out/mass of sieve material). Generally, higher recovery leads to a smaller compressor, blower, or other compressed gas or vacuum source and lower power consumption. Higher productivity leads to smaller sieve beds.

Pressure Swing Adsorbtion (PSA). A technique used to separate some gas species from a mixture of gases (typically air) under pressure according to the species' molecular characteristics and affinity for an adsorbent material. It operates at near-ambient temperature and significantly differs from the cryogenic distillation commonly used to separate gases. Selective adsorbent materials (e.g., zeolites, (aka molecular sieves), activated carbon, etc.) are used as trapping material, preferentially adsorbing the target gas species at high pressure. The process then swings to low pressure to desorb the adsorbed gas.

Supply Source. A collection of components necessary to control, monitor and supply oxygen, whether from a liquid container, cylinder(s) or cylinder header(s) or a concentrator. Required components are detailed in the Medical Gas Standards.

Source Valve. The control valve on the patient side of all components of the Central Supply System which shuts off flow from the Central Supply System to the distribution piping.

Terminal. The attachment point and valve, located on the wall, ceiling or other device where the user will connect their clinical equipment and access the oxygen supply. Terminals are always gas specific to prevent misconnection. The keying systems are detailed in the Medical Gas Standards.

User. A trained medical professional capable of administering medical gases to a patient, assessing the condition of that patient, and adjusting the administration of the gases in response.

Vacuum Swing Adsorbtion (VSA). Segregates certain gases from a gaseous mixture at near ambient pressure; the process then swings to a vacuum to regenerate the adsorbent material. VSA differs from other PSA techniques because it operates at near-ambient temperatures and pressures. VSA typically draws the gas through the separation process with a vacuum. For oxygen and nitrogen VSA systems, the vacuum is typically generated by a blower.

Guidance for Operating Medical Air and Oxygen Systems with Nonstandard Pressures

101.0 Scope. This document will serve as a guide in assessing medical gas flow rates associated with varying pressures. Since the pandemic, the medical gas piping systems were stretched to their limits resulting in insufficient flow rates and pressures at patient outlets, due in part to undersized lines for elevated flow rates. The pandemic required facilities to alter their medical gas pressures for medical air and oxygen. This document will assist you in evaluating the medical gas systems and flow rates for temporary operations at elevated pressures.

For existing systems, this document provides guidance on how to determine the limitations of the line pressure increase and estimating the performance improvements using the pressure loss charts provided or by developing new charts. This document looks to provide additional concepts in using pressure regulators (refer to 2021 NFPA 99 5.1.3.5.7 in regard to multiple pressure requirements). Pressure regulators help to provide higher pressures in areas needing elevated pressure due to increased demand without having to increase pressure everywhere.

101.1 Scope Limitations. What this document is meant to be is a guide in performing medical gas assessments on existing medical gas systems and development of new medical gas systems that operate at pressures outside of what has been standard in the past.

IAPMO has developed this medical gas design guide as it relates to pressures related to oxygen and medical air systems. This document is establishing uniform pressure loss concepts for oxygen and medical air systems. and a framework for designers to consistently review design documents and assess existing and new oxygen and medical air piping systems.

This design guide provides guidelines and criteria for designers to consider in sizing medical gas piping using pressures beyond the typical 55 psi and preparing medical gas documents. This document clarifies new engineering concepts in best practices in providing oxygen and medical air piping systems that can handle high pressures and flow rates with existing pipes and to assist in reviewing sizing of piping to be able to handle increased flow rates at non-standard pressures.

This design guide identifies requirements and recommended design standards for ensuring safe and reliable oxygen and medical air pipe sizes at non-standard delivery pressures. Where this design guide doesn’t restate a regulatory requirement, it reflects best practices on what constitutes the basis for designing a safe, reliable, and sustainable oxygen and medical air piping system. While establishing these standards, we attempted to balance the reduction of risk against the added cost to provide that reduced risk and the capacity of oxygen and medical air piping systems to handle anticipated flow rates at varying pressures.

We also strive to share our collective experience to promote construction and operation of appropriate, safe and reliable oxygen and medical air piping systems. The goal is to assist the design engineer and designers build a project that will be safe and reliable now and into the future. We do this by asking questions, exploring risk versus available resources in the design phase, and helping oxygen and medical air piping system owners and design engineers identify potential consequences of operational failure.

Design engineers need to know what we think are appropriate design standards, but they also need flexibility to approach the unique design circumstances they face. We encourage design engineers to consider various alternatives and options, as long as the selected approach does not conflict with regulation. If the designer’s selected approach differs from these guidelines, we expect the design engineer to justify their design decisions.

101.2 Background.

101.2.1 Healthcare Facility Pandemic Reactions. The COVID pandemic can be seen to have three phases with regards to the reactions from facilities management. In the first phase, the medical people believed that intubation ventilation would be necessary for every patient. That would have impacted medical air, vacuum and oxygen demand as well as requiring space that facilities did not have. In this time, the unlikeliest of companies prepared to manufacture ventilators, convention centers were configured as COVID wards, and other preparations were made to support that worst case assumption.

In the second phase, it was discovered that intubation was the wrong approach clinically, and instead a variety of techniques based on CPAP and BIPAP practices proved to be more effective. These were almost entirely oxygen based, with little to no impact on other systems. However, they demanded quantities of oxygen which were inconceivable in the past. The impact on facilities managers was dramatic, as they had to discover ways to obtain, vaporize and convey through the piping massive quantities of oxygen into parts of their facilities which had never been designed to handle these flows.

In the developed world, gas suppliers responded well, and there was relatively little concern over obtaining the liquid or gas itself.

The Vaporizers: Keeping the vaporizers ice free and therefore able to convert the liquid to gas was a widespread and major challenge.

The Piping: The pipes in the building were never sized with this kind of flow rate in mind, and therefore facilities found that they struggled to maintain pressures at peak flows.

We are now in the third phase. COVID is endemic, and we must all expect to contract the disease at some time and possibly repeatedly. But vaccination has reduced the severity of the disease for most who contract it, and therefore the number of patients requiring the heroic respiratory support which was so challenging during the first two phases is much reduced.

Another issue to be aware of, is with ventilators and the effects of lower oxygen pressure compared to the medical air pressure being used on the ventilator. If the oxygen pressure falls below a certain pressure compared to the medical air, the patient may go into low O2 stats alarm and the ventilator will start to use medical air or room air to compensate which will cause patient to go into alarm.

So the crisis may be past, but the question now becomes how to ensure we are not unprepared for surges and conceivably by the next pandemic? In large, that question is outside the scope of this document, but one tool used successfully during the worst of the pandemic and which will always be worth understanding is the simple expedient of raising the pressure at the source. More pressure, more flow though the same piping. While there are issues with doing this and limits on how far one can take it, it proved to be a way to overcome some of the limitations of existing piping for facilities where the piping was otherwise inadequate.

As designers and medical professionals consider what flow rates they want to use in designing their systems, this document provides the tool necessary for implementing those designs. In addition, it provides the data for standard pressures and for somewhat elevated pressures should that be needed in determining what might be possible in the event of unexpected demand.

101.3 Implementation Guidance for Elevated Line Pressures.

101.3.1 Existing System Considerations. Increasing the supply pressure can have a significant impact on system capacity. There are two components to this performance improvement. First, the available pressure loss within the system increases by the difference in supply pressure. For example, increasing the supply pressure from 55 to 65 psi changes the available pressure loss from 5 psi (standard design of 10% loss) to 15 psi. Also, the fluid density is increased, which reduces the average velocity providing a 5% to 10% improvement (reduction in pressure loss). In combination, increasing an oxygen or medical air source supply from 55 to 65 psi can theoretically result in a capacity increase of up to 70% while still maintaining 50 psi at the most remote outlet. Likewise, increasing from 55 to 75 psi can theoretically result in a capacity increase of up to 220%. However, the full increase may not be realized due to other factors such as limitations at the cryogenic fluid central supply system (for example, the capacity of the line pressure reducing valve or vaporizer limitations), relief valve setpoint or other mechanical device choke-points.

There are a number of system design considerations and patient risk issues that will limit the ability to safely operate the system at a higher-than-standard operating pressure.

Clinical staff, respiratory equipment manufacturers as well as the Responsible Facility Authority, facilities engineers etc. must be integrally involved in the evaluation and decision-making process. Considerations include:

A. NFPA 99-2021 Table 5.1.11 indicates the standard operating pressure for Medical Air and Oxygen at 50-55 psig. Code allows for establishment of a higher operating pressure if all design considerations are addressed. However, most application of this guide (to increase line pressure) would occur in systems originally designed to operate at standard operating pressure. Therefore, several system parameters would need to be evaluated before establishing a higher operating pressure including but not limited to relief valve settings, alarm set-points, pressure testing, medical equipment, flow meter calibration etc.

B. Piping is initially subjected to a 150 psi (minimum) initial pressure test (NFPA 99-2021 paragraph 5.1.12.2.3) which establishes the maximum operating pressure for the piping (e.g. a 150 psi initial pressure test establishes a maximum operating pressure of 100 psi). This test is performed after the installation of rough-in assemblies but prior to the installation of station outlet/inlet valve bodies and faceplates etc. The complete piping system (with all outlet/inlet valve bodies, faceplates etc.) is only subject to a pressure test of 20% above operating pressure (e.g. 66 psi for a 55 psi system) per NFPA 99-2021 para 5.1.12.2.6 for the Installers Standing Pressure Test. This test pressure may be interpreted as the maximum allowable working pressure (MAWP) although code does not clearly define it as such. This test pressure or MAWP establishes a practical limit on system pressure increase without needing to retest the piping system.

C. Medical Air compressors are required by NFPA 99-2021 para 5.1.3.6.3.2 to include a pressure relief valve set at 50% above the line pressure (e.g. 75 psi for standard system pressure). Medical air equipment dewpoint monitor, control and alarm accuracy may be impacted by the higher supply pressure as these devices are calibrated at the standard 50-55 psi line pressure.

D. Line pressure regulators are required by NFPA 99 to be in an N+1 configuration with each sized for 100% of the peak calculated demand (per NFPA 99-2021 para 5.1.3.5.5) at the operating pressure. Therefore, depending on the nominal manifold selection, there may not be spare capacity in any single line pressure regulator to achieve a higher flow at a higher line pressure. A temporary increase in capacity may be obtained by activating both line pressure regulators simultaneously. Use of this approach should be carefully sized and not utilized for normal operation as the 100% redundancy requirement may no longer be met. While opening the second line pressure regulator may be a temporary emergency option a better approach would be to provide a third regulator that could be opened in the event additional capacity is needed.

E. Alarms are required to activate at 20% above normal operating pressure (e.g. 66 psi for a 55 psi system). These will most likely need to be adjusted for the temporary operating condition in order to maintain the safety device. However, many are factory set and cannot be adjusted.

F. Component ratings throughout the system must be evaluated for limiting ratings (e.g. demand checks, gauges, sensors, boom hoses, manufactured assemblies etc.). Some devices have minimum ratings established by code and others by the manufacturer. For example, minimum burst pressure for hoses and flexible connections is 1000 psi per NFPA 99. Manufacturer component ratings vary but some examples include: Amico inlets/outlet complete with latch-valve assembly are rated at a maximum operating pressure of 100 psi except for Nitrogen/Instrument Air DISS assemblies which are rated at 200 psi.

G. Medical equipment ratings. Assess operational limitations on medical equipment utilized. Examples include: Thorpe tube flowmeters (rotameters) are typically calibrated at an operating pressure of 50 psig. Higher pressures will result in meter error, inaccurate dosing or possible shutdown of the medical devices served. Manufacturers also produce flow meters calibrated for 60 psi however a system temporarily operating at a line pressure of 65 psi may have outlets seeing anywhere from 65psi (nearest outlet to the source) to 50 psi (most remote outlet) under an emergency demand scenario. This would result in uncertainty of the gas delivery with potential patient risk. This patient risk must be carefully considered.Respiratory equipment which blends medical gases is designed and calibrated around use of standard design pressures. Non-standard pressures or unequal supply pressures could impact the dosing mixture, cause bleed-through or cause a safety shut-down of the equipment. Clinical input including a comprehensive evaluation of all respiratory equipment in use is critical in such decisions.

H. Labelling requirements for nonstandard system pressures include special labelling of alarm panels (NFPA 99-2021 para 5.1.11.4), valving (NFPA 99-2021 para 5.1.11.2), and outlets (NFPA 99-2021 para 5.1.11.3) etc.

101.4 Foundational Equations and Assumptions. The following pressure loss charts were developed utilizing the Darcy-Weisbach formula in combination with the Moody Diagrams. The Moody Diagram provides a method to obtain the friction factor as a function of the Reynolds number without the need for iterative calculations. The Moody Diagram was curve-fit to a set of equations in order to easily calculate each point. The output data in the pressure loss charts is almost exclusively in the turbulent flow region ensuring accurate results except for limited values at the top of each column (representing the lowest velocities) that enter the critical flow regime (Reynolds numbers below 4000). However, the pressure drop per 100ft for these entries is extremely low (0.02 psi/100 ft or less) which makes the impact of the inaccuracy insignificant in the overall calculation (typically 5 psi total pressure loss).

All calculations are based on a uniform definition of Standard Temperature and Pressure (68 Deg F and 14.7 psia respectively). Pipe dimensions are based on ASTM B819 Type L copper with a surface roughness (ε) = 0.000005. Gas properties are applied to each table (specific gravity of air is 1.0 and specific gravity of oxygen is 1.1)

Table values are limited to a pressure drop of 10% of the supply pressure (gauge pressure) or less. This is based on the published limitation of Darcy-Weisbach. For example, the 65 psig Oxygen chart cuts off any pressure drop values that exceed 6.5 psi.

101.5 Developing Charts. There are several industry standard pressure loss charts available for standard system pressures and pipe sizes, however, most do not provide the calculation assumption in order to validate or to extrapolate for other conditions. Also, most sources only provide data for Type L copper which may not address all field conditions as some jurisdictions mandate Type K copper which has a reduced internal diameter. This reduced internal diameter can have a significant impact on the pressure drop for smaller pipe sizes if not considered in the design. For example, if Type L copper charts are inadvertently used, the pressure drop error introduced for pipe sizes in the range of ½ inch to 1-½ inch can be 25% or more. The pressure drop error gradually reduces as the pipe sizes get larger (e.g. less than 10% error for sizes over 2 inch) and insignificant for 6-inch pipe.

If there is a need to create additional tables or calculations, the Darcy-Weisbach equations represent the most accurate engineering approach. The Darcy-Weisbach equation is empirically based. However, it can be difficult to utilize due to the potential need to iterate to get the friction factor. Alternatives such as the Moody diagram or Colebrook equations can avoid the need for iteration.

101.6 Pressure Loss Charts for Oxygen and Medical Air at Selected Source Pressures.

101.6.1 Medical Air and Oxygen Pressure Loss Charts for Type L Copper. ***(See page 9)***

101.6.2 Medical Air and Oxygen Pressure Loss Charts for Type K Copper. ***(See page 27)***

101.6.1 Medical Air and Oxygen Pressure Loss Charts for Type L Copper.

Medical Air (55 psig) Piping Pressure Loss Data (PSI/100ft)

		PIPE SIZE (ASTM B819 Type L Copper Tube)				
	IP Nominal	1/2"	3/4"	1"	1-1/4"	1-1/2"
	IP Inner Diameter (in)	0.54	0.78	1.02	1.26	1.50
	SI Nominal	DN15	DN20	DN25	DN32	DN40
	SI Inner Diameter (mm)	13.8	19.9	26.0	32.1	38.1
FLOW RATE						
Standard LPM	Standard CFM					
10	0.35	0.00	0.00	0.00	0.00	0.00
20	0.71	0.01	0.00	0.00	0.00	0.00
30	1.06	0.02	0.00	0.00	0.00	0.00
40	1.41	0.03	0.01	0.00	0.00	0.00
50	1.77	0.05	0.01	0.00	0.00	0.00
60	2.12	0.06	0.01	0.00	0.00	0.00
70	2.47	0.08	0.01	0.00	0.00	0.00
80	2.83	0.11	0.02	0.01	0.00	0.00
90	3.18	0.13	0.02	0.01	0.00	0.00
100	3.53	0.16	0.03	0.01	0.00	0.00
120	4.24	0.21	0.04	0.01	0.00	0.00
140	4.94	0.28	0.05	0.01	0.01	0.00
160	5.65	0.36	0.06	0.02	0.01	0.00
180	6.36	0.44	0.08	0.02	0.01	0.00
200	7.06	0.53	0.09	0.03	0.01	0.00
220	7.77	0.62	0.11	0.03	0.01	0.01
240	8.48	0.73	0.13	0.04	0.01	0.01
260	9.18	0.84	0.14	0.04	0.02	0.01
280	9.89	0.96	0.16	0.05	0.02	0.01
300	10.6	1.08	0.19	0.05	0.02	0.01
350	12.4	1.42	0.24	0.07	0.03	0.01
400	14.1	1.81	0.31	0.09	0.03	0.01
450	15.9	2.24	0.38	0.11	0.04	0.02
500	17.7	2.71	0.46	0.13	0.05	0.02
550	19.4	3.22	0.54	0.15	0.06	0.02
600	21.2	3.77	0.63	0.18	0.06	0.03
650	23.0	4.36	0.73	0.20	0.07	0.03
700	24.7	4.99	0.83	0.23	0.08	0.04
750	26.5		0.94	0.26	0.10	0.04
800	28.3		1.06	0.29	0.11	0.05
850	30.0		1.18	0.33	0.12	0.05
900	31.8		1.30	0.36	0.13	0.06
950	33.5		1.44	0.40	0.15	0.06
1000	35.3		1.58	0.44	0.16	0.07
1100	38.8		1.87	0.52	0.19	0.08
1200	42.4		2.19	0.61	0.22	0.10
1300	45.9		2.53	0.70	0.25	0.11
1400	49.4		2.90	0.80	0.29	0.13
1500	53.0		3.29	0.91	0.33	0.14
1600	56.5		3.70	1.02	0.36	0.16
1700	60.0		4.13	1.14	0.41	0.18
1800	63.6		4.59	1.26	0.45	0.20
1900	67.1		5.07	1.39	0.50	0.22
2000	70.6			1.53	0.54	0.24
2250	79.5			1.90	0.67	0.30
2500	88.3			2.30	0.81	0.36

Notes:
1. Standard conditions are 68F, 14.7 psia
2. Actual conditions are 68F and the pressure indicated
3. Values stop where pressure drop exceeds 10% of inlet pressure per limits of Darcy-Wiesbach.

Medical Air (55 psig) Piping Pressure Loss Data (PSI/100ft)

		PIPE SIZE (ASTM B819 Type L Copper Tube)				
	IP Nominal	**1"**	**1-1/4"**	**1-1/2"**	**2"**	**2-1/2"**
	IP Inner Diameter (in)	1.02	1.26	1.50	1.98	2.46
	SI Nominal	**DN25**	**DN32**	**DN40**	**DN50**	**DN65**
	SI Inner Diameter (mm)	26.0	32.1	38.1	50.4	62.6
FLOW RATE						
Standard LPM	**Standard CFM**					
500	17.7	0.13	0.05	0.02	0.01	0.00
550	19.4	0.15	0.06	0.02	0.01	0.00
600	21.2	0.18	0.06	0.03	0.01	0.00
650	23.0	0.20	0.07	0.03	0.01	0.00
700	24.7	0.23	0.08	0.04	0.01	0.00
750	26.5	0.26	0.10	0.04	0.01	0.00
800	28.3	0.29	0.11	0.05	0.01	0.00
850	30.0	0.33	0.12	0.05	0.01	0.01
900	31.8	0.36	0.13	0.06	0.02	0.01
950	33.5	0.40	0.15	0.06	0.02	0.01
1000	35.3	0.44	0.16	0.07	0.02	0.01
1100	38.8	0.52	0.19	0.08	0.02	0.01
1200	42.4	0.61	0.22	0.10	0.03	0.01
1300	45.9	0.70	0.25	0.11	0.03	0.01
1400	49.4	0.80	0.29	0.13	0.03	0.01
1500	53.0	0.91	0.33	0.14	0.04	0.01
1600	56.5	1.02	0.36	0.16	0.04	0.02
1700	60.0	1.14	0.41	0.18	0.05	0.02
1800	63.6	1.26	0.45	0.20	0.05	0.02
1900	67.1	1.39	0.50	0.22	0.06	0.02
2000	70.6	1.53	0.54	0.24	0.06	0.02
2250	79.5	1.90	0.67	0.30	0.08	0.03
2500	88.3	2.30	0.81	0.36	0.09	0.03
2750	97.1	2.74	0.96	0.42	0.11	0.04
3000	105.9	3.22	1.13	0.49	0.13	0.05
3250	114.8	3.73	1.30	0.57	0.15	0.05
3500	123.6	4.28	1.49	0.65	0.17	0.06
3750	132.4	4.86	1.69	0.74	0.19	0.07
4000	141.3	5.48	1.90	0.83	0.22	0.08
4250	150.1		2.12	0.93	0.24	0.09
4500	158.9		2.35	1.03	0.27	0.09
4750	167.7		2.59	1.13	0.30	0.10
5000	176.6		2.85	1.25	0.32	0.11
5500	194.2		3.39	1.48	0.38	0.14
6000	211.9		3.98	1.74	0.45	0.16
6500	229.5		4.61	2.01	0.52	0.18
7000	247.2		5.29	2.31	0.60	0.21
7500	264.9			2.62	0.68	0.24
8000	282.5			2.95	0.76	0.27
8500	300.2			3.30	0.85	0.30
9000	317.8			3.67	0.95	0.33
9500	335.5			4.05	1.04	0.37
10000	353.1			4.46	1.15	0.40
10500	370.8			4.88	1.26	0.44

Notes:
1. Standard conditions are 68F, 14.7 psia
2. Actual conditions are 68F and the pressure indicated
3. Values stop where pressure drop exceeds 10% of inlet pressure per limits of Darcy-Wiesbach.

Medical Air (55 psig) Piping Pressure Loss Data (PSI/100ft)

		PIPE SIZE (ASTM B819 Type L Copper Tube)				
	IP Nominal	2"	2-1/2"	3"	4"	6"
	IP Inner Diameter (in)	1.98	2.46	2.94	3.90	5.85
	SI Nominal	DN50	DN65	DN80	DN100	DN150
	SI Inner Diameter (mm)	50.4	62.6	74.8	99.0	148.5
FLOW RATE						
Standard LPM	Standard CFM					
4000	141.3	0.22	0.08	0.03	0.01	0.00
4250	150.1	0.24	0.09	0.04	0.01	0.00
4500	158.9	0.27	0.09	0.04	0.01	0.00
4750	167.7	0.30	0.10	0.04	0.01	0.00
5000	176.6	0.32	0.11	0.05	0.01	0.00
5500	194.2	0.38	0.14	0.06	0.02	0.00
6000	211.9	0.45	0.16	0.07	0.02	0.00
6500	229.5	0.52	0.18	0.08	0.02	0.00
7000	247.2	0.60	0.21	0.09	0.02	0.00
7500	264.9	0.68	0.24	0.10	0.03	0.00
8000	282.5	0.76	0.27	0.11	0.03	0.00
8500	300.2	0.85	0.30	0.13	0.03	0.00
9000	317.8	0.95	0.33	0.14	0.04	0.01
9500	335.5	1.04	0.37	0.16	0.04	0.01
10000	353.1	1.15	0.40	0.17	0.04	0.01
10500	370.8	1.26	0.44	0.19	0.05	0.01
11000	388.5	1.37	0.48	0.20	0.05	0.01
11500	406.1	1.49	0.52	0.22	0.06	0.01
12000	423.8	1.61	0.56	0.24	0.06	0.01
13000	459.1	1.86	0.65	0.28	0.07	0.01
14000	494.4	2.14	0.75	0.32	0.08	0.01
15000	529.7	2.43	0.85	0.36	0.09	0.01
16000	565.0	2.74	0.96	0.40	0.10	0.01
17000	600.3	3.07	1.07	0.45	0.12	0.02
18000	635.7	3.42	1.19	0.50	0.13	0.02
19000	671.0	3.78	1.32	0.55	0.14	0.02
20000	706.3	4.17	1.45	0.61	0.16	0.02
21000	741.6	4.56	1.59	0.67	0.17	0.02
22000	776.9	4.98	1.73	0.73	0.19	0.03
23000	812.2	5.42	1.88	0.79	0.20	0.03
24000	847.6		2.04	0.86	0.22	0.03
25000	882.9		2.20	0.92	0.24	0.03
26000	918.2		2.37	0.99	0.25	0.04
27000	953.5		2.54	1.07	0.27	0.04
28000	988.8		2.72	1.14	0.29	0.04
29000	1024.1		2.91	1.22	0.31	0.04
30000	1059.4		3.10	1.30	0.33	0.05
35000	1236.0		4.15	1.74	0.44	0.06
40000	1412.6		5.34	2.23	0.57	0.08
45000	1589.2			2.79	0.71	0.10
50000	1765.7			3.41	0.87	0.12
55000	1942.3			4.09	1.04	0.14
60000	2118.9			4.82	1.22	0.17
65000	2295.5				1.42	0.20

Notes:
1. Standard conditions are 68F, 14.7 psia
2. Actual conditions are 68F and the pressure indicated
3. Values stop where pressure drop exceeds 10% of inlet pressure per limits of Darcy-Wiesbach.

Medical Air (65 psig) Piping Pressure Loss Data (PSI/100ft)

		PIPE SIZE (ASTM B819 Type L Copper Tube)				
		IP Nominal	**1/2"**	**3/4"**	**1"**	**1-1/4"**	**1-1/2"**
		IP Inner Diameter (in)	0.54	0.78	1.02	1.26	1.50
		SI Nominal	**DN15**	**DN20**	**DN25**	**DN32**	**DN40**
		SI Inner Diameter (mm)	13.8	19.9	26.0	32.1	38.1

FLOW RATE						
Standard LPM	**Standard CFM**					
10	0.35	0.00	0.00	0.00	0.00	0.00
20	0.71	0.01	0.00	0.00	0.00	0.00
30	1.06	0.02	0.00	0.00	0.00	0.00
40	1.41	0.03	0.00	0.00	0.00	0.00
50	1.77	0.04	0.01	0.00	0.00	0.00
60	2.12	0.06	0.01	0.00	0.00	0.00
70	2.47	0.07	0.01	0.00	0.00	0.00
80	2.83	0.09	0.02	0.00	0.00	0.00
90	3.18	0.11	0.02	0.01	0.00	0.00
100	3.53	0.14	0.02	0.01	0.00	0.00
120	4.24	0.19	0.03	0.01	0.00	0.00
140	4.94	0.25	0.04	0.01	0.00	0.00
160	5.65	0.31	0.05	0.02	0.01	0.00
180	6.36	0.38	0.07	0.02	0.01	0.00
200	7.06	0.46	0.08	0.02	0.01	0.00
220	7.77	0.54	0.09	0.03	0.01	0.00
240	8.48	0.64	0.11	0.03	0.01	0.01
260	9.18	0.73	0.13	0.04	0.01	0.01
280	9.89	0.84	0.14	0.04	0.02	0.01
300	10.6	0.95	0.16	0.05	0.02	0.01
350	12.4	1.25	0.21	0.06	0.02	0.01
400	14.1	1.58	0.27	0.08	0.03	0.01
450	15.9	1.96	0.33	0.09	0.03	0.02
500	17.7	2.37	0.40	0.11	0.04	0.02
550	19.4	2.81	0.47	0.13	0.05	0.02
600	21.2	3.29	0.55	0.15	0.06	0.03
650	23.0	3.81	0.64	0.18	0.07	0.03
700	24.7	4.36	0.73	0.20	0.07	0.03
750	26.5	4.95	0.82	0.23	0.08	0.04
800	28.3	5.57	0.92	0.26	0.09	0.04
850	30.0	6.22	1.03	0.29	0.10	0.05
900	31.8		1.14	0.32	0.12	0.05
950	33.5		1.26	0.35	0.13	0.06
1000	35.3		1.38	0.38	0.14	0.06
1100	38.8		1.64	0.45	0.16	0.07
1200	42.4		1.92	0.53	0.19	0.08
1300	45.9		2.22	0.61	0.22	0.10
1400	49.4		2.54	0.70	0.25	0.11
1500	53.0		2.88	0.79	0.28	0.13
1600	56.5		3.23	0.89	0.32	0.14
1700	60.0		3.61	1.00	0.36	0.16
1800	63.6		4.01	1.10	0.39	0.17
1900	67.1		4.43	1.22	0.43	0.19
2000	70.6		4.87	1.34	0.47	0.21
2250	79.5		6.04	1.66	0.59	0.26
2500	88.3			2.01	0.71	0.31

Notes:
1. Standard conditions are 68F, 14.7 psia
2. Actual conditions are 68F and the pressure indicated
3. Values stop where pressure drop exceeds 10% of inlet pressure per limits of Darcy-Wiesbach.

Medical Air (65 psig) Piping Pressure Loss Data (PSI/100ft)

	PIPE SIZE (ASTM B819 Type L Copper Tube)					
	IP Nominal	**1"**	**1-1/4"**	**1-1/2"**	**2"**	**2-1/2"**
	IP Inner Diameter (in)	1.02	1.26	1.50	1.98	2.46
	SI Nominal	**DN25**	**DN32**	**DN40**	**DN50**	**DN65**
	SI Inner Diameter (mm)	26.0	32.1	38.1	50.4	62.6
FLOW RATE						
Standard LPM	**Standard CFM**					
500	17.7	0.11	0.04	0.02	0.00	0.00
550	19.4	0.13	0.05	0.02	0.01	0.00
600	21.2	0.15	0.06	0.03	0.01	0.00
650	23.0	0.18	0.07	0.03	0.01	0.00
700	24.7	0.20	0.07	0.03	0.01	0.00
750	26.5	0.23	0.08	0.04	0.01	0.00
800	28.3	0.26	0.09	0.04	0.01	0.00
850	30.0	0.29	0.10	0.05	0.01	0.00
900	31.8	0.32	0.12	0.05	0.01	0.00
950	33.5	0.35	0.13	0.06	0.01	0.01
1000	35.3	0.38	0.14	0.06	0.02	0.01
1100	38.8	0.45	0.16	0.07	0.02	0.01
1200	42.4	0.53	0.19	0.08	0.02	0.01
1300	45.9	0.61	0.22	0.10	0.03	0.01
1400	49.4	0.70	0.25	0.11	0.03	0.01
1500	53.0	0.79	0.28	0.13	0.03	0.01
1600	56.5	0.89	0.32	0.14	0.04	0.01
1700	60.0	1.00	0.36	0.16	0.04	0.01
1800	63.6	1.10	0.39	0.17	0.05	0.02
1900	67.1	1.22	0.43	0.19	0.05	0.02
2000	70.6	1.34	0.47	0.21	0.06	0.02
2250	79.5	1.66	0.59	0.26	0.07	0.02
2500	88.3	2.01	0.71	0.31	0.08	0.03
2750	97.1	2.40	0.84	0.37	0.10	0.03
3000	105.9	2.81	0.98	0.43	0.11	0.04
3250	114.8	3.26	1.14	0.50	0.13	0.05
3500	123.6	3.74	1.30	0.57	0.15	0.05
3750	132.4	4.25	1.47	0.65	0.17	0.06
4000	141.3	4.79	1.66	0.73	0.19	0.07
4250	150.1	5.36	1.85	0.81	0.21	0.07
4500	158.9	5.96	2.05	0.90	0.23	0.08
4750	167.7		2.27	0.99	0.26	0.09
5000	176.6		2.49	1.09	0.28	0.10
5500	194.2		2.97	1.30	0.34	0.12
6000	211.9		3.48	1.52	0.39	0.14
6500	229.5		4.03	1.76	0.46	0.16
7000	247.2		4.63	2.02	0.52	0.18
7500	264.9		5.25	2.29	0.59	0.21
8000	282.5		5.92	2.58	0.67	0.23
8500	300.2			2.89	0.74	0.26
9000	317.8			3.21	0.83	0.29
9500	335.5			3.55	0.91	0.32
10000	353.1			3.90	1.00	0.35
10500	370.8			4.27	1.10	0.38

Notes:
1. Standard conditions are 68F, 14.7 psia
2. Actual conditions are 68F and the pressure indicated
3. Values stop where pressure drop exceeds 10% of inlet pressure per limits of Darcy-Wiesbach.

Medical Air (65 psig) Piping Pressure Loss Data (PSI/100ft)

		PIPE SIZE (ASTM B819 Type L Copper Tube)				
	IP Nominal	2"	2-1/2"	3"	4"	6"
	IP Inner Diameter (in)	1.98	2.46	2.94	3.90	5.85
	SI Nominal	DN50	DN65	DN80	DN100	DN150
	SI Inner Diameter (mm)	50.4	62.6	74.8	99.0	148.5
FLOW RATE						
Standard LPM	Standard CFM					
4000	141.3	0.19	0.07	0.03	0.01	0.00
4250	150.1	0.21	0.07	0.03	0.01	0.00
4500	158.9	0.23	0.08	0.04	0.01	0.00
4750	167.7	0.26	0.09	0.04	0.01	0.00
5000	176.6	0.28	0.10	0.04	0.01	0.00
5500	194.2	0.34	0.12	0.05	0.01	0.00
6000	211.9	0.39	0.14	0.06	0.02	0.00
6500	229.5	0.46	0.16	0.07	0.02	0.00
7000	247.2	0.52	0.18	0.08	0.02	0.00
7500	264.9	0.59	0.21	0.09	0.02	0.00
8000	282.5	0.67	0.23	0.10	0.03	0.00
8500	300.2	0.74	0.26	0.11	0.03	0.00
9000	317.8	0.83	0.29	0.12	0.03	0.00
9500	335.5	0.91	0.32	0.14	0.04	0.01
10000	353.1	1.00	0.35	0.15	0.04	0.01
10500	370.8	1.10	0.38	0.16	0.04	0.01
11000	388.5	1.20	0.42	0.18	0.05	0.01
11500	406.1	1.30	0.45	0.19	0.05	0.01
12000	423.8	1.41	0.49	0.21	0.05	0.01
13000	459.1	1.63	0.57	0.24	0.06	0.01
14000	494.4	1.87	0.65	0.28	0.07	0.01
15000	529.7	2.13	0.74	0.31	0.08	0.01
16000	565.0	2.40	0.84	0.35	0.09	0.01
17000	600.3	2.69	0.94	0.39	0.10	0.01
18000	635.7	2.99	1.04	0.44	0.11	0.02
19000	671.0	3.31	1.15	0.48	0.12	0.02
20000	706.3	3.64	1.27	0.53	0.14	0.02
21000	741.6	3.99	1.39	0.58	0.15	0.02
22000	776.9	4.36	1.51	0.64	0.16	0.02
23000	812.2	4.74	1.65	0.69	0.18	0.02
24000	847.6	5.13	1.78	0.75	0.19	0.03
25000	882.9	5.54	1.92	0.81	0.21	0.03
26000	918.2	5.97	2.07	0.87	0.22	0.03
27000	953.5	6.41	2.22	0.93	0.24	0.03
28000	988.8		2.38	1.00	0.26	0.04
29000	1024.1		2.54	1.07	0.27	0.04
30000	1059.4		2.71	1.14	0.29	0.04
35000	1236.0		3.63	1.52	0.39	0.05
40000	1412.6		4.67	1.95	0.50	0.07
45000	1589.2		5.84	2.44	0.62	0.09
50000	1765.7			2.98	0.76	0.10
55000	1942.3			3.57	0.91	0.13
60000	2118.9			4.22	1.07	0.15
65000	2295.5			4.91	1.24	0.17

Notes:
1. Standard conditions are 68F, 14.7 psia
2. Actual conditions are 68F and the pressure indicated
3. Values stop where pressure drop exceeds 10% of inlet pressure per limits of Darcy-Wiesbach.

Medical Air (75 psig) Piping Pressure Loss Data (PSI/100ft)

FLOW RATE		PIPE SIZE (ASTM B819 Type L Copper Tube)				
	IP Nominal	1/2"	3/4"	1"	1-1/4"	1-1/2"
	IP Inner Diameter (in)	0.54	0.78	1.02	1.26	1.50
	SI Nominal	DN15	DN20	DN25	DN32	DN40
	SI Inner Diameter (mm)	13.8	19.9	26.0	32.1	38.1
Standard LPM	Standard CFM					
10	0.35	0.00	0.00	0.00	0.00	0.00
20	0.71	0.01	0.00	0.00	0.00	0.00
30	1.06	0.01	0.00	0.00	0.00	0.00
40	1.41	0.02	0.00	0.00	0.00	0.00
50	1.77	0.04	0.01	0.00	0.00	0.00
60	2.12	0.05	0.01	0.00	0.00	0.00
70	2.47	0.06	0.01	0.00	0.00	0.00
80	2.83	0.08	0.01	0.00	0.00	0.00
90	3.18	0.10	0.02	0.01	0.00	0.00
100	3.53	0.12	0.02	0.01	0.00	0.00
120	4.24	0.17	0.03	0.01	0.00	0.00
140	4.94	0.22	0.04	0.01	0.00	0.00
160	5.65	0.28	0.05	0.01	0.01	0.00
180	6.36	0.34	0.06	0.02	0.01	0.00
200	7.06	0.41	0.07	0.02	0.01	0.00
220	7.77	0.48	0.08	0.02	0.01	0.00
240	8.48	0.56	0.10	0.03	0.01	0.00
260	9.18	0.65	0.11	0.03	0.01	0.01
280	9.89	0.74	0.13	0.04	0.01	0.01
300	10.6	0.84	0.14	0.04	0.02	0.01
350	12.4	1.11	0.19	0.05	0.02	0.01
400	14.1	1.41	0.24	0.07	0.02	0.01
450	15.9	1.74	0.29	0.08	0.03	0.01
500	17.7	2.10	0.35	0.10	0.04	0.02
550	19.4	2.50	0.42	0.12	0.04	0.02
600	21.2	2.93	0.49	0.14	0.05	0.02
650	23.0	3.39	0.57	0.16	0.06	0.03
700	24.7	3.88	0.65	0.18	0.07	0.03
750	26.5	4.40	0.73	0.20	0.07	0.03
800	28.3	4.95	0.82	0.23	0.08	0.04
850	30.0	5.53	0.91	0.25	0.09	0.04
900	31.8	6.14	1.01	0.28	0.10	0.05
950	33.5	6.78	1.12	0.31	0.11	0.05
1000	35.3	7.45	1.23	0.34	0.12	0.05
1100	38.8		1.46	0.40	0.15	0.06
1200	42.4		1.70	0.47	0.17	0.08
1300	45.9		1.97	0.54	0.20	0.09
1400	49.4		2.25	0.62	0.22	0.10
1500	53.0		2.55	0.70	0.25	0.11
1600	56.5		2.87	0.79	0.28	0.13
1700	60.0		3.21	0.88	0.32	0.14
1800	63.6		3.56	0.98	0.35	0.15
1900	67.1		3.94	1.08	0.38	0.17
2000	70.6		4.32	1.19	0.42	0.19
2250	79.5		5.37	1.47	0.52	0.23
2500	88.3		6.52	1.79	0.63	0.28

Notes:
1. Standard conditions are 68F, 14.7 psia
2. Actual conditions are 68F and the pressure indicated
3. Values stop where pressure drop exceeds 10% of inlet pressure per limits of Darcy-Wiesbach.

Medical Air (75 psig) Piping Pressure Loss Data (PSI/100ft)

		PIPE SIZE (ASTM B819 Type L Copper Tube)				
	IP Nominal	1"	1-1/4"	1-1/2"	2"	2-1/2"
	IP Inner Diameter (in)	1.02	1.26	1.50	1.98	2.46
	SI Nominal	DN25	DN32	DN40	DN50	DN65
	SI Inner Diameter (mm)	26.0	32.1	38.1	50.4	62.6
FLOW RATE						
Standard LPM	Standard CFM					
500	17.7	0.10	0.04	0.02	0.00	0.00
550	19.4	0.12	0.04	0.02	0.01	0.00
600	21.2	0.14	0.05	0.02	0.01	0.00
650	23.0	0.16	0.06	0.03	0.01	0.00
700	24.7	0.18	0.07	0.03	0.01	0.00
750	26.5	0.20	0.07	0.03	0.01	0.00
800	28.3	0.23	0.08	0.04	0.01	0.00
850	30.0	0.25	0.09	0.04	0.01	0.00
900	31.8	0.28	0.10	0.05	0.01	0.00
950	33.5	0.31	0.11	0.05	0.01	0.00
1000	35.3	0.34	0.12	0.05	0.01	0.01
1100	38.8	0.40	0.15	0.06	0.02	0.01
1200	42.4	0.47	0.17	0.08	0.02	0.01
1300	45.9	0.54	0.20	0.09	0.02	0.01
1400	49.4	0.62	0.22	0.10	0.03	0.01
1500	53.0	0.70	0.25	0.11	0.03	0.01
1600	56.5	0.79	0.28	0.13	0.03	0.01
1700	60.0	0.88	0.32	0.14	0.04	0.01
1800	63.6	0.98	0.35	0.15	0.04	0.01
1900	67.1	1.08	0.38	0.17	0.04	0.02
2000	70.6	1.19	0.42	0.19	0.05	0.02
2250	79.5	1.47	0.52	0.23	0.06	0.02
2500	88.3	1.79	0.63	0.28	0.07	0.03
2750	97.1	2.13	0.75	0.33	0.09	0.03
3000	105.9	2.50	0.87	0.38	0.10	0.04
3250	114.8	2.90	1.01	0.44	0.12	0.04
3500	123.6	3.32	1.16	0.51	0.13	0.05
3750	132.4	3.78	1.31	0.57	0.15	0.05
4000	141.3	4.26	1.47	0.65	0.17	0.06
4250	150.1	4.76	1.64	0.72	0.19	0.07
4500	158.9	5.30	1.83	0.80	0.21	0.07
4750	167.7	5.86	2.02	0.88	0.23	0.08
5000	176.6	6.45	2.21	0.97	0.25	0.09
5500	194.2		2.64	1.15	0.30	0.11
6000	211.9		3.09	1.35	0.35	0.12
6500	229.5		3.58	1.56	0.41	0.14
7000	247.2		4.11	1.79	0.46	0.16
7500	264.9		4.67	2.03	0.53	0.18
8000	282.5		5.26	2.29	0.59	0.21
8500	300.2		5.89	2.56	0.66	0.23
9000	317.8		6.55	2.85	0.73	0.26
9500	335.5		7.24	3.15	0.81	0.28
10000	353.1			3.46	0.89	0.31
10500	370.8			3.79	0.98	0.34

Notes:
1. Standard conditions are 68F, 14.7 psia
2. Actual conditions are 68F and the pressure indicated
3. Values stop where pressure drop exceeds 10% of inlet pressure per limits of Darcy-Wiesbach.

Medical Air (75 psig) Piping Pressure Loss Data (PSI/100ft)

	PIPE SIZE (ASTM B819 Type L Copper Tube)					
	IP Nominal	2"	2-1/2"	3"	4"	6"
	IP Inner Diameter (in)	1.98	2.46	2.94	3.90	5.85
	SI Nominal	DN50	DN65	DN80	DN100	DN150
	SI Inner Diameter (mm)	50.4	62.6	74.8	99.0	148.5
FLOW RATE						
Standard LPM	Standard CFM					
4000	141.3	0.17	0.06	0.03	0.01	0.00
4250	150.1	0.19	0.07	0.03	0.01	0.00
4500	158.9	0.21	0.07	0.03	0.01	0.00
4750	167.7	0.23	0.08	0.03	0.01	0.00
5000	176.6	0.25	0.09	0.04	0.01	0.00
5500	194.2	0.30	0.11	0.04	0.01	0.00
6000	211.9	0.35	0.12	0.05	0.01	0.00
6500	229.5	0.41	0.14	0.06	0.02	0.00
7000	247.2	0.46	0.16	0.07	0.02	0.00
7500	264.9	0.53	0.18	0.08	0.02	0.00
8000	282.5	0.59	0.21	0.09	0.02	0.00
8500	300.2	0.66	0.23	0.10	0.03	0.00
9000	317.8	0.73	0.26	0.11	0.03	0.00
9500	335.5	0.81	0.28	0.12	0.03	0.00
10000	353.1	0.89	0.31	0.13	0.03	0.00
10500	370.8	0.98	0.34	0.14	0.04	0.01
11000	388.5	1.06	0.37	0.16	0.04	0.01
11500	406.1	1.15	0.40	0.17	0.04	0.01
12000	423.8	1.25	0.44	0.18	0.05	0.01
13000	459.1	1.45	0.51	0.21	0.06	0.01
14000	494.4	1.66	0.58	0.25	0.06	0.01
15000	529.7	1.89	0.66	0.28	0.07	0.01
16000	565.0	2.13	0.74	0.31	0.08	0.01
17000	600.3	2.39	0.83	0.35	0.09	0.01
18000	635.7	2.66	0.93	0.39	0.10	0.01
19000	671.0	2.94	1.02	0.43	0.11	0.02
20000	706.3	3.24	1.13	0.47	0.12	0.02
21000	741.6	3.55	1.23	0.52	0.13	0.02
22000	776.9	3.87	1.35	0.57	0.15	0.02
23000	812.2	4.21	1.46	0.61	0.16	0.02
24000	847.6	4.56	1.58	0.67	0.17	0.02
25000	882.9	4.92	1.71	0.72	0.18	0.03
26000	918.2	5.30	1.84	0.77	0.20	0.03
27000	953.5	5.69	1.98	0.83	0.21	0.03
28000	988.8	6.10	2.12	0.89	0.23	0.03
29000	1024.1	6.52	2.26	0.95	0.24	0.03
30000	1059.4	6.95	2.41	1.01	0.26	0.04
35000	1236.0		3.22	1.35	0.34	0.05
40000	1412.6		4.15	1.74	0.44	0.06
45000	1589.2		5.19	2.17	0.55	0.08
50000	1765.7		6.34	2.65	0.67	0.09
55000	1942.3			3.17	0.80	0.11
60000	2118.9			3.75	0.95	0.13
65000	2295.5			4.36	1.10	0.15

Notes:
1. Standard conditions are 68F, 14.7 psia
2. Actual conditions are 68F and the pressure indicated
3. Values stop where pressure drop exceeds 10% of inlet pressure per limits of Darcy-Wiesbach.

Oxygen (55 psig) Piping Pressure Loss Data (PSI/100ft)

		PIPE SIZE (ASTM B819 Type L Copper Tube)				
	IP Nominal	1/2"	3/4"	1"	1-1/4"	1-1/2"
	IP Inner Diameter (in)	0.54	0.78	1.02	1.26	1.50
	SI Nominal	DN15	DN20	DN25	DN32	DN40
	SI Inner Diameter (mm)	13.8	19.9	26.0	32.1	38.1
FLOW RATE						
Standard LPM	Standard CFM					
10	0.35	0.00	0.00	0.00	0.00	0.00
20	0.71	0.01	0.00	0.00	0.00	0.00
30	1.06	0.02	0.00	0.00	0.00	0.00
40	1.41	0.03	0.01	0.00	0.00	0.00
50	1.77	0.05	0.01	0.00	0.00	0.00
60	2.12	0.07	0.01	0.00	0.00	0.00
70	2.47	0.09	0.02	0.00	0.00	0.00
80	2.83	0.12	0.02	0.01	0.00	0.00
90	3.18	0.14	0.03	0.01	0.00	0.00
100	3.53	0.17	0.03	0.01	0.00	0.00
120	4.24	0.24	0.04	0.01	0.00	0.00
140	4.94	0.31	0.05	0.02	0.01	0.00
160	5.65	0.39	0.07	0.02	0.01	0.00
180	6.36	0.48	0.08	0.02	0.01	0.00
200	7.06	0.58	0.10	0.03	0.01	0.00
220	7.77	0.69	0.12	0.03	0.01	0.01
240	8.48	0.80	0.14	0.04	0.01	0.01
260	9.18	0.93	0.16	0.04	0.02	0.01
280	9.89	1.06	0.18	0.05	0.02	0.01
300	10.6	1.20	0.21	0.06	0.02	0.01
350	12.4	1.58	0.27	0.08	0.03	0.01
400	14.1	2.00	0.34	0.10	0.04	0.02
450	15.9	2.48	0.42	0.12	0.04	0.02
500	17.7	2.99	0.51	0.14	0.05	0.02
550	19.4	3.56	0.60	0.17	0.06	0.03
600	21.2	4.17	0.70	0.19	0.07	0.03
650	23.0	4.82	0.81	0.22	0.08	0.04
700	24.7		0.92	0.26	0.09	0.04
750	26.5		1.04	0.29	0.11	0.05
800	28.3		1.17	0.32	0.12	0.05
850	30.0		1.30	0.36	0.13	0.06
900	31.8		1.44	0.40	0.15	0.06
950	33.5		1.59	0.44	0.16	0.07
1000	35.3		1.74	0.48	0.18	0.08
1100	38.8		2.07	0.57	0.21	0.09
1200	42.4		2.43	0.67	0.24	0.11
1300	45.9		2.80	0.78	0.28	0.12
1400	49.4		3.21	0.89	0.32	0.14
1500	53.0		3.64	1.00	0.36	0.16
1600	56.5		4.09	1.13	0.40	0.18
1700	60.0		4.57	1.26	0.45	0.20
1800	63.6		5.08	1.40	0.50	0.22
1900	67.1			1.54	0.55	0.24
2000	70.6			1.69	0.60	0.26
2250	79.5			2.10	0.74	0.33
2500	88.3			2.55	0.90	0.39

Notes:

1. Standard conditions are 68F, 14.7 psia
2. Actual conditions are 68F and the pressure indicated
3. Values stop where pressure drop exceeds 10% of inlet pressure per limits of Darcy-Wiesbach.

Oxygen (55 psig) Piping Pressure Loss Data (PSI/100ft)

FLOW RATE		PIPE SIZE (ASTM B819 Type L Copper Tube)				
		IP Nominal	**1"**	**1-1/4"**	**1-1/2"**	**2"**
		IP Inner Diameter (in)	1.02	1.26	1.50	1.98
		SI Nominal	**DN25**	**DN32**	**DN40**	**DN50**
		SI Inner Diameter (mm)	26.0	32.1	38.1	50.4

Standard LPM	Standard CFM	1" (DN25, 1.02 in, 26.0 mm)	1-1/4" (DN32, 1.26 in, 32.1 mm)	1-1/2" (DN40, 1.50 in, 38.1 mm)	2" (DN50, 1.98 in, 50.4 mm)	2-1/2" (DN65, 2.46 in, 62.6 mm)
500	17.7	0.14	0.05	0.02	0.01	0.00
550	19.4	0.17	0.06	0.03	0.01	0.00
600	21.2	0.19	0.07	0.03	0.01	0.00
650	23.0	0.22	0.08	0.04	0.01	0.00
700	24.7	0.26	0.09	0.04	0.01	0.00
750	26.5	0.29	0.11	0.05	0.01	0.00
800	28.3	0.32	0.12	0.05	0.01	0.00
850	30.0	0.36	0.13	0.06	0.02	0.01
900	31.8	0.40	0.15	0.06	0.02	0.01
950	33.5	0.44	0.16	0.07	0.02	0.01
1000	35.3	0.48	0.18	0.08	0.02	0.01
1100	38.8	0.57	0.21	0.09	0.02	0.01
1200	42.4	0.67	0.24	0.11	0.03	0.01
1300	45.9	0.78	0.28	0.12	0.03	0.01
1400	49.4	0.89	0.32	0.14	0.04	0.01
1500	53.0	1.00	0.36	0.16	0.04	0.01
1600	56.5	1.13	0.40	0.18	0.05	0.02
1700	60.0	1.26	0.45	0.20	0.05	0.02
1800	63.6	1.40	0.50	0.22	0.06	0.02
1900	67.1	1.54	0.55	0.24	0.06	0.02
2000	70.6	1.69	0.60	0.26	0.07	0.02
2250	79.5	2.10	0.74	0.33	0.09	0.03
2500	88.3	2.55	0.90	0.39	0.10	0.04
2750	97.1	3.03	1.06	0.47	0.12	0.04
3000	105.9	3.56	1.24	0.55	0.14	0.05
3250	114.8	4.12	1.44	0.63	0.17	0.06
3500	123.6	4.73	1.65	0.72	0.19	0.07
3750	132.4	5.37	1.86	0.82	0.21	0.08
4000	141.3		2.10	0.92	0.24	0.08
4250	150.1		2.34	1.03	0.27	0.09
4500	158.9		2.60	1.14	0.30	0.10
4750	167.7		2.87	1.26	0.33	0.12
5000	176.6		3.15	1.38	0.36	0.13
5500	194.2		3.75	1.64	0.43	0.15
6000	211.9		4.40	1.92	0.50	0.18
6500	229.5		5.10	2.23	0.58	0.20
7000	247.2			2.55	0.66	0.23
7500	264.9			2.90	0.75	0.26
8000	282.5			3.26	0.84	0.30
8500	300.2			3.65	0.94	0.33
9000	317.8			4.06	1.05	0.37
9500	335.5			4.48	1.16	0.41
10000	353.1			4.93	1.27	0.44
10500	370.8			5.40	1.39	0.49

Notes:
1. Standard conditions are 68F, 14.7 psia
2. Actual conditions are 68F and the pressure indicated
3. Values stop where pressure drop exceeds 10% of inlet pressure per limits of Darcy-Wiesbach.

Type L — O 55 (2" - 6")

Oxygen (55 psig) Piping Pressure Loss Data (PSI/100ft)

		PIPE SIZE (ASTM B819 Type L Copper Tube)				
	IP Nominal	2"	2-1/2"	3"	4"	6"
	IP Inner Diameter (in)	1.98	2.46	2.94	3.90	5.85
	SI Nominal	DN50	DN65	DN80	DN100	DN150
	SI Inner Diameter (mm)	50.4	62.6	74.8	99.0	148.5
FLOW RATE						
Standard LPM	Standard CFM					
4000	141.3	0.24	0.08	0.04	0.01	0.00
4250	150.1	0.27	0.09	0.04	0.01	0.00
4500	158.9	0.30	0.10	0.04	0.01	0.00
4750	167.7	0.33	0.12	0.05	0.01	0.00
5000	176.6	0.36	0.13	0.05	0.01	0.00
5500	194.2	0.43	0.15	0.06	0.02	0.00
6000	211.9	0.50	0.18	0.07	0.02	0.00
6500	229.5	0.58	0.20	0.09	0.02	0.00
7000	247.2	0.66	0.23	0.10	0.03	0.00
7500	264.9	0.75	0.26	0.11	0.03	0.00
8000	282.5	0.84	0.30	0.13	0.03	0.00
8500	300.2	0.94	0.33	0.14	0.04	0.01
9000	317.8	1.05	0.37	0.16	0.04	0.01
9500	335.5	1.16	0.41	0.17	0.04	0.01
10000	353.1	1.27	0.44	0.19	0.05	0.01
10500	370.8	1.39	0.49	0.21	0.05	0.01
11000	388.5	1.51	0.53	0.22	0.06	0.01
11500	406.1	1.64	0.58	0.24	0.06	0.01
12000	423.8	1.78	0.62	0.26	0.07	0.01
13000	459.1	2.06	0.72	0.30	0.08	0.01
14000	494.4	2.37	0.83	0.35	0.09	0.01
15000	529.7	2.69	0.94	0.40	0.10	0.01
16000	565.0	3.03	1.06	0.45	0.11	0.02
17000	600.3	3.40	1.18	0.50	0.13	0.02
18000	635.7	3.78	1.32	0.55	0.14	0.02
19000	671.0	4.18	1.46	0.61	0.16	0.02
20000	706.3	4.61	1.60	0.67	0.17	0.02
21000	741.6	5.05	1.76	0.74	0.19	0.03
22000	776.9		1.92	0.81	0.21	0.03
23000	812.2		2.08	0.87	0.22	0.03
24000	847.6		2.25	0.95	0.24	0.03
25000	882.9		2.43	1.02	0.26	0.04
26000	918.2		2.62	1.10	0.28	0.04
27000	953.5		2.81	1.18	0.30	0.04
28000	988.8		3.01	1.26	0.32	0.05
29000	1024.1		3.22	1.35	0.34	0.05
30000	1059.4		3.43	1.44	0.37	0.05
35000	1236.0		4.58	1.92	0.49	0.07
40000	1412.6			2.47	0.63	0.09
45000	1589.2			3.09	0.78	0.11
50000	1765.7			3.77	0.96	0.13
55000	1942.3			4.52	1.15	0.16
60000	2118.9			5.33	1.35	0.19
65000	2295.5				1.57	0.22

Notes:
1. Standard conditions are 68F, 14.7 psia
2. Actual conditions are 68F and the pressure indicated
3. Values stop where pressure drop exceeds 10% of inlet pressure per limits of Darcy-Wiesbach.

Oxygen (65 psig) Piping Pressure Loss Data (PSI/100ft)

		PIPE SIZE (ASTM B819 Type L Copper Tube)				
	IP Nominal	1/2"	3/4"	1"	1-1/4"	1-1/2"
	IP Inner Diameter (in)	0.54	0.78	1.02	1.26	1.50
	SI Nominal	DN15	DN20	DN25	DN32	DN40
	SI Inner Diameter (mm)	13.8	19.9	26.0	32.1	38.1
FLOW RATE						
Standard LPM	Standard CFM					
10	0.35	0.00	0.00	0.00	0.00	0.00
20	0.71	0.01	0.00	0.00	0.00	0.00
30	1.06	0.02	0.00	0.00	0.00	0.00
40	1.41	0.03	0.01	0.00	0.00	0.00
50	1.77	0.05	0.01	0.00	0.00	0.00
60	2.12	0.06	0.01	0.00	0.00	0.00
70	2.47	0.08	0.01	0.00	0.00	0.00
80	2.83	0.10	0.02	0.01	0.00	0.00
90	3.18	0.13	0.02	0.01	0.00	0.00
100	3.53	0.15	0.03	0.01	0.00	0.00
120	4.24	0.21	0.04	0.01	0.00	0.00
140	4.94	0.27	0.05	0.01	0.00	0.00
160	5.65	0.34	0.06	0.02	0.01	0.00
180	6.36	0.42	0.07	0.02	0.01	0.00
200	7.06	0.51	0.09	0.02	0.01	0.00
220	7.77	0.60	0.10	0.03	0.01	0.00
240	8.48	0.70	0.12	0.03	0.01	0.01
260	9.18	0.81	0.14	0.04	0.01	0.01
280	9.89	0.93	0.16	0.04	0.02	0.01
300	10.6	1.05	0.18	0.05	0.02	0.01
350	12.4	1.38	0.24	0.07	0.02	0.01
400	14.1	1.75	0.30	0.08	0.03	0.01
450	15.9	2.17	0.37	0.10	0.04	0.02
500	17.7	2.62	0.44	0.12	0.05	0.02
550	19.4	3.11	0.52	0.15	0.05	0.02
600	21.2	3.64	0.61	0.17	0.06	0.03
650	23.0	4.22	0.70	0.20	0.07	0.03
700	24.7	4.83	0.80	0.22	0.08	0.04
750	26.5	5.47	0.91	0.25	0.09	0.04
800	28.3	6.16	1.02	0.28	0.10	0.05
850	30.0		1.14	0.32	0.12	0.05
900	31.8		1.26	0.35	0.13	0.06
950	33.5		1.39	0.39	0.14	0.06
1000	35.3		1.53	0.42	0.15	0.07
1100	38.8		1.81	0.50	0.18	0.08
1200	42.4		2.12	0.59	0.21	0.09
1300	45.9		2.45	0.68	0.24	0.11
1400	49.4		2.81	0.77	0.28	0.12
1500	53.0		3.18	0.88	0.31	0.14
1600	56.5		3.58	0.99	0.35	0.16
1700	60.0		4.00	1.10	0.39	0.17
1800	63.6		4.44	1.22	0.44	0.19
1900	67.1		4.90	1.35	0.48	0.21
2000	70.6		5.38	1.48	0.53	0.23
2250	79.5			1.84	0.65	0.29
2500	88.3			2.23	0.78	0.34

Notes:
1. Standard conditions are 68F, 14.7 psia
2. Actual conditions are 68F and the pressure indicated
3. Values stop where pressure drop exceeds 10% of inlet pressure per limits of Darcy-Wiesbach.

Oxygen (65 psig) Piping Pressure Loss Data (PSI/100ft)

		PIPE SIZE (ASTM B819 Type L Copper Tube)				
	IP Nominal	1"	1-1/4"	1-1/2"	2"	2-1/2"
	IP Inner Diameter (in)	1.02	1.26	1.50	1.98	2.46
	SI Nominal	DN25	DN32	DN40	DN50	DN65
	SI Inner Diameter (mm)	26.0	32.1	38.1	50.4	62.6
FLOW RATE						
Standard LPM	Standard CFM					
500	17.7	0.12	0.05	0.02	0.01	0.00
550	19.4	0.15	0.05	0.02	0.01	0.00
600	21.2	0.17	0.06	0.03	0.01	0.00
650	23.0	0.20	0.07	0.03	0.01	0.00
700	24.7	0.22	0.08	0.04	0.01	0.00
750	26.5	0.25	0.09	0.04	0.01	0.00
800	28.3	0.28	0.10	0.05	0.01	0.00
850	30.0	0.32	0.12	0.05	0.01	0.00
900	31.8	0.35	0.13	0.06	0.01	0.01
950	33.5	0.39	0.14	0.06	0.02	0.01
1000	35.3	0.42	0.15	0.07	0.02	0.01
1100	38.8	0.50	0.18	0.08	0.02	0.01
1200	42.4	0.59	0.21	0.09	0.02	0.01
1300	45.9	0.68	0.24	0.11	0.03	0.01
1400	49.4	0.77	0.28	0.12	0.03	0.01
1500	53.0	0.88	0.31	0.14	0.04	0.01
1600	56.5	0.99	0.35	0.16	0.04	0.01
1700	60.0	1.10	0.39	0.17	0.05	0.02
1800	63.6	1.22	0.44	0.19	0.05	0.02
1900	67.1	1.35	0.48	0.21	0.06	0.02
2000	70.6	1.48	0.53	0.23	0.06	0.02
2250	79.5	1.84	0.65	0.29	0.07	0.03
2500	88.3	2.23	0.78	0.34	0.09	0.03
2750	97.1	2.65	0.93	0.41	0.11	0.04
3000	105.9	3.11	1.09	0.48	0.13	0.04
3250	114.8	3.61	1.26	0.55	0.14	0.05
3500	123.6	4.14	1.44	0.63	0.16	0.06
3750	132.4	4.70	1.63	0.71	0.19	0.07
4000	141.3	5.30	1.83	0.80	0.21	0.07
4250	150.1	5.93	2.05	0.90	0.23	0.08
4500	158.9		2.27	0.99	0.26	0.09
4750	167.7		2.51	1.10	0.29	0.10
5000	176.6		2.76	1.21	0.31	0.11
5500	194.2		3.28	1.43	0.37	0.13
6000	211.9		3.85	1.68	0.44	0.15
6500	229.5		4.46	1.95	0.50	0.18
7000	247.2		5.12	2.23	0.58	0.20
7500	264.9		5.81	2.53	0.65	0.23
8000	282.5			2.85	0.74	0.26
8500	300.2			3.19	0.82	0.29
9000	317.8			3.55	0.91	0.32
9500	335.5			3.92	1.01	0.35
10000	353.1			4.31	1.11	0.39
10500	370.8			4.72	1.22	0.43

Notes:
1. Standard conditions are 68F, 14.7 psia
2. Actual conditions are 68F and the pressure indicated
3. Values stop where pressure drop exceeds 10% of inlet pressure per limits of Darcy-Wiesbach.

Oxygen (65 psig) Piping Pressure Loss Data (PSI/100ft)

		PIPE SIZE (ASTM B819 Type L Copper Tube)				
	IP Nominal	2"	2-1/2"	3"	4"	6"
	IP Inner Diameter (in)	1.98	2.46	2.94	3.90	5.85
	SI Nominal	DN50	DN65	DN80	DN100	DN150
	SI Inner Diameter (mm)	50.4	62.6	74.8	99.0	148.5
FLOW RATE						
Standard LPM	Standard CFM					
4000	141.3	0.21	0.07	0.03	0.01	0.00
4250	150.1	0.23	0.08	0.04	0.01	0.00
4500	158.9	0.26	0.09	0.04	0.01	0.00
4750	167.7	0.29	0.10	0.04	0.01	0.00
5000	176.6	0.31	0.11	0.05	0.01	0.00
5500	194.2	0.37	0.13	0.06	0.01	0.00
6000	211.9	0.44	0.15	0.07	0.02	0.00
6500	229.5	0.50	0.18	0.08	0.02	0.00
7000	247.2	0.58	0.20	0.09	0.02	0.00
7500	264.9	0.65	0.23	0.10	0.03	0.00
8000	282.5	0.74	0.26	0.11	0.03	0.00
8500	300.2	0.82	0.29	0.12	0.03	0.00
9000	317.8	0.91	0.32	0.14	0.04	0.01
9500	335.5	1.01	0.35	0.15	0.04	0.01
10000	353.1	1.11	0.39	0.16	0.04	0.01
10500	370.8	1.22	0.43	0.18	0.05	0.01
11000	388.5	1.32	0.46	0.20	0.05	0.01
11500	406.1	1.44	0.50	0.21	0.06	0.01
12000	423.8	1.56	0.54	0.23	0.06	0.01
13000	459.1	1.80	0.63	0.27	0.07	0.01
14000	494.4	2.07	0.72	0.31	0.08	0.01
15000	529.7	2.35	0.82	0.35	0.09	0.01
16000	565.0	2.65	0.93	0.39	0.10	0.01
17000	600.3	2.97	1.04	0.44	0.11	0.02
18000	635.7	3.31	1.15	0.49	0.12	0.02
19000	671.0	3.66	1.27	0.54	0.14	0.02
20000	706.3	4.03	1.40	0.59	0.15	0.02
21000	741.6	4.41	1.54	0.65	0.17	0.02
22000	776.9	4.82	1.67	0.70	0.18	0.03
23000	812.2	5.24	1.82	0.77	0.20	0.03
24000	847.6	5.67	1.97	0.83	0.21	0.03
25000	882.9	6.13	2.13	0.89	0.23	0.03
26000	918.2		2.29	0.96	0.25	0.03
27000	953.5		2.46	1.03	0.26	0.04
28000	988.8		2.63	1.10	0.28	0.04
29000	1024.1		2.81	1.18	0.30	0.04
30000	1059.4		3.00	1.26	0.32	0.04
35000	1236.0		4.01	1.68	0.43	0.06
40000	1412.6		5.16	2.16	0.55	0.08
45000	1589.2		6.46	2.70	0.69	0.10
50000	1765.7			3.30	0.84	0.12
55000	1942.3			3.95	1.00	0.14
60000	2118.9			4.66	1.18	0.16
65000	2295.5			5.43	1.37	0.19

Notes:
1. Standard conditions are 68F, 14.7 psia
2. Actual conditions are 68F and the pressure indicated
3. Values stop where pressure drop exceeds 10% of inlet pressure per limits of Darcy-Wiesbach.

Oxygen (75 psig) Piping Pressure Loss Data (PSI/100ft)

		PIPE SIZE (ASTM B819 Type L Copper Tube)				
	IP Nominal	1/2"	3/4"	1"	1-1/4"	1-1/2"
	IP Inner Diameter (in)	0.54	0.78	1.02	1.26	1.50
	SI Nominal	DN15	DN20	DN25	DN32	DN40
	SI Inner Diameter (mm)	13.8	19.9	26.0	32.1	38.1
FLOW RATE						
Standard LPM	Standard CFM					
10	0.35	0.00	0.00	0.00	0.00	0.00
20	0.71	0.01	0.00	0.00	0.00	0.00
30	1.06	0.02	0.00	0.00	0.00	0.00
40	1.41	0.03	0.00	0.00	0.00	0.00
50	1.77	0.04	0.01	0.00	0.00	0.00
60	2.12	0.05	0.01	0.00	0.00	0.00
70	2.47	0.07	0.01	0.00	0.00	0.00
80	2.83	0.09	0.02	0.00	0.00	0.00
90	3.18	0.11	0.02	0.01	0.00	0.00
100	3.53	0.13	0.02	0.01	0.00	0.00
120	4.24	0.18	0.03	0.01	0.00	0.00
140	4.94	0.24	0.04	0.01	0.00	0.00
160	5.65	0.31	0.05	0.02	0.01	0.00
180	6.36	0.38	0.07	0.02	0.01	0.00
200	7.06	0.45	0.08	0.02	0.01	0.00
220	7.77	0.54	0.09	0.03	0.01	0.00
240	8.48	0.63	0.11	0.03	0.01	0.01
260	9.18	0.72	0.12	0.03	0.01	0.01
280	9.89	0.82	0.14	0.04	0.01	0.01
300	10.6	0.93	0.16	0.04	0.02	0.01
350	12.4	1.22	0.21	0.06	0.02	0.01
400	14.1	1.56	0.26	0.07	0.03	0.01
450	15.9	1.92	0.33	0.09	0.03	0.01
500	17.7	2.33	0.39	0.11	0.04	0.02
550	19.4	2.77	0.47	0.13	0.05	0.02
600	21.2	3.24	0.54	0.15	0.06	0.02
650	23.0	3.75	0.63	0.17	0.06	0.03
700	24.7	4.29	0.71	0.20	0.07	0.03
750	26.5	4.86	0.81	0.23	0.08	0.04
800	28.3	5.47	0.91	0.25	0.09	0.04
850	30.0	6.12	1.01	0.28	0.10	0.05
900	31.8	6.79	1.12	0.31	0.11	0.05
950	33.5		1.24	0.34	0.12	0.06
1000	35.3		1.36	0.38	0.14	0.06
1100	38.8		1.61	0.45	0.16	0.07
1200	42.4		1.88	0.52	0.19	0.08
1300	45.9		2.18	0.60	0.22	0.10
1400	49.4		2.49	0.69	0.25	0.11
1500	53.0		2.83	0.78	0.28	0.12
1600	56.5		3.18	0.88	0.31	0.14
1700	60.0		3.55	0.98	0.35	0.15
1800	63.6		3.94	1.09	0.39	0.17
1900	67.1		4.35	1.20	0.43	0.19
2000	70.6		4.78	1.32	0.47	0.21
2250	79.5		5.94	1.63	0.58	0.25
2500	88.3		7.21	1.98	0.70	0.31

Notes:
1. Standard conditions are 68F, 14.7 psia
2. Actual conditions are 68F and the pressure indicated
3. Values stop where pressure drop exceeds 10% of inlet pressure per limits of Darcy-Wiesbach.

Oxygen (75 psig) Piping Pressure Loss Data (PSI/100ft)

		PIPE SIZE (ASTM B819 Type L Copper Tube)				
	IP Nominal	1"	1-1/4"	1-1/2"	2"	2-1/2"
	IP Inner Diameter (in)	1.02	1.26	1.50	1.98	2.46
	SI Nominal	DN25	DN32	DN40	DN50	DN65
	SI Inner Diameter (mm)	26.0	32.1	38.1	50.4	62.6
FLOW RATE						
Standard LPM	Standard CFM					
500	17.7	0.11	0.04	0.02	0.00	0.00
550	19.4	0.13	0.05	0.02	0.01	0.00
600	21.2	0.15	0.06	0.02	0.01	0.00
650	23.0	0.17	0.06	0.03	0.01	0.00
700	24.7	0.20	0.07	0.03	0.01	0.00
750	26.5	0.23	0.08	0.04	0.01	0.00
800	28.3	0.25	0.09	0.04	0.01	0.00
850	30.0	0.28	0.10	0.05	0.01	0.00
900	31.8	0.31	0.11	0.05	0.01	0.00
950	33.5	0.34	0.12	0.06	0.01	0.01
1000	35.3	0.38	0.14	0.06	0.02	0.01
1100	38.8	0.45	0.16	0.07	0.02	0.01
1200	42.4	0.52	0.19	0.08	0.02	0.01
1300	45.9	0.60	0.22	0.10	0.03	0.01
1400	49.4	0.69	0.25	0.11	0.03	0.01
1500	53.0	0.78	0.28	0.12	0.03	0.01
1600	56.5	0.88	0.31	0.14	0.04	0.01
1700	60.0	0.98	0.35	0.15	0.04	0.01
1800	63.6	1.09	0.39	0.17	0.04	0.02
1900	67.1	1.20	0.43	0.19	0.05	0.02
2000	70.6	1.32	0.47	0.21	0.05	0.02
2250	79.5	1.63	0.58	0.25	0.07	0.02
2500	88.3	1.98	0.70	0.31	0.08	0.03
2750	97.1	2.36	0.83	0.36	0.10	0.03
3000	105.9	2.77	0.97	0.42	0.11	0.04
3250	114.8	3.21	1.12	0.49	0.13	0.05
3500	123.6	3.68	1.28	0.56	0.15	0.05
3750	132.4	4.18	1.45	0.64	0.17	0.06
4000	141.3	4.71	1.63	0.71	0.19	0.07
4250	150.1	5.27	1.82	0.80	0.21	0.07
4500	158.9	5.86	2.02	0.88	0.23	0.08
4750	167.7	6.48	2.23	0.98	0.25	0.09
5000	176.6	7.13	2.45	1.07	0.28	0.10
5500	194.2		2.92	1.27	0.33	0.12
6000	211.9		3.42	1.49	0.39	0.14
6500	229.5		3.97	1.73	0.45	0.16
7000	247.2		4.55	1.98	0.51	0.18
7500	264.9		5.16	2.25	0.58	0.20
8000	282.5		5.82	2.54	0.65	0.23
8500	300.2		6.51	2.84	0.73	0.26
9000	317.8		7.24	3.15	0.81	0.29
9500	335.5			3.48	0.90	0.31
10000	353.1			3.83	0.99	0.35
10500	370.8			4.20	1.08	0.38

Notes:
1. Standard conditions are 68F, 14.7 psia
2. Actual conditions are 68F and the pressure indicated
3. Values stop where pressure drop exceeds 10% of inlet pressure per limits of Darcy-Wiesbach.

Type L — O 75 (2" - 6")

Oxygen (75 psig) Piping Pressure Loss Data (PSI/100ft)

		PIPE SIZE (ASTM B819 Type L Copper Tube)				
	IP Nominal	2"	2-1/2"	3"	4"	6"
	IP Inner Diameter (in)	1.98	2.46	2.94	3.90	5.85
	SI Nominal	DN50	DN65	DN80	DN100	DN150
	SI Inner Diameter (mm)	50.4	62.6	74.8	99.0	148.5
FLOW RATE						
Standard LPM	Standard CFM					
4000	141.3	0.19	0.07	0.03	0.01	0.00
4250	150.1	0.21	0.07	0.03	0.01	0.00
4500	158.9	0.23	0.08	0.03	0.01	0.00
4750	167.7	0.25	0.09	0.04	0.01	0.00
5000	176.6	0.28	0.10	0.04	0.01	0.00
5500	194.2	0.33	0.12	0.05	0.01	0.00
6000	211.9	0.39	0.14	0.06	0.02	0.00
6500	229.5	0.45	0.16	0.07	0.02	0.00
7000	247.2	0.51	0.18	0.08	0.02	0.00
7500	264.9	0.58	0.20	0.09	0.02	0.00
8000	282.5	0.65	0.23	0.10	0.03	0.00
8500	300.2	0.73	0.26	0.11	0.03	0.00
9000	317.8	0.81	0.29	0.12	0.03	0.00
9500	335.5	0.90	0.31	0.13	0.03	0.00
10000	353.1	0.99	0.35	0.15	0.04	0.01
10500	370.8	1.08	0.38	0.16	0.04	0.01
11000	388.5	1.18	0.41	0.17	0.05	0.01
11500	406.1	1.28	0.45	0.19	0.05	0.01
12000	423.8	1.38	0.48	0.20	0.05	0.01
13000	459.1	1.60	0.56	0.24	0.06	0.01
14000	494.4	1.84	0.64	0.27	0.07	0.01
15000	529.7	2.09	0.73	0.31	0.08	0.01
16000	565.0	2.36	0.82	0.35	0.09	0.01
17000	600.3	2.64	0.92	0.39	0.10	0.01
18000	635.7	2.94	1.02	0.43	0.11	0.02
19000	671.0	3.25	1.13	0.48	0.12	0.02
20000	706.3	3.58	1.25	0.52	0.13	0.02
21000	741.6	3.92	1.36	0.57	0.15	0.02
22000	776.9	4.28	1.49	0.63	0.16	0.02
23000	812.2	4.65	1.62	0.68	0.17	0.02
24000	847.6	5.04	1.75	0.74	0.19	0.03
25000	882.9	5.45	1.89	0.79	0.20	0.03
26000	918.2	5.86	2.03	0.85	0.22	0.03
27000	953.5	6.30	2.18	0.92	0.23	0.03
28000	988.8	6.74	2.34	0.98	0.25	0.04
29000	1024.1	7.21	2.50	1.05	0.27	0.04
30000	1059.4		2.66	1.12	0.29	0.04
35000	1236.0		3.56	1.49	0.38	0.05
40000	1412.6		4.59	1.92	0.49	0.07
45000	1589.2		5.74	2.40	0.61	0.08
50000	1765.7		7.01	2.93	0.74	0.10
55000	1942.3			3.51	0.89	0.12
60000	2118.9			4.14	1.05	0.14
65000	2295.5			4.82	1.22	0.17

Notes:
1. Standard conditions are 68F, 14.7 psia
2. Actual conditions are 68F and the pressure indicated
3. Values stop where pressure drop exceeds 10% of inlet pressure per limits of Darcy-Wiesbach.

101.6.1 Medical Air and Oxygen Pressure Loss Charts for Type K Copper.

Medical Air (55 psig) Piping Pressure Loss Data (PSI/100ft)

		PIPE SIZE (ASTM B819 Type K Copper Tube)				
	IP Nominal	1/2"	3/4"	1"	1-1/4"	1-1/2"
	IP Inner Diameter (in)	0.53	0.75	1.00	1.24	1.48
	SI Nominal	DN15	DN20	DN25	DN32	DN40
	SI Inner Diameter (mm)	13.4	19.0	25.3	31.6	37.6
FLOW RATE						
Standard LPM	Standard CFM					
10	0.35	0.00	0.00	0.00	0.00	0.00
20	0.71	0.01	0.00	0.00	0.00	0.00
30	1.06	0.02	0.00	0.00	0.00	0.00
40	1.41	0.04	0.01	0.00	0.00	0.00
50	1.77	0.05	0.01	0.00	0.00	0.00
60	2.12	0.07	0.01	0.00	0.00	0.00
70	2.47	0.10	0.02	0.00	0.00	0.00
80	2.83	0.12	0.02	0.01	0.00	0.00
90	3.18	0.15	0.03	0.01	0.00	0.00
100	3.53	0.18	0.03	0.01	0.00	0.00
120	4.24	0.25	0.05	0.01	0.00	0.00
140	4.94	0.32	0.06	0.02	0.01	0.00
160	5.65	0.41	0.08	0.02	0.01	0.00
180	6.36	0.50	0.09	0.02	0.01	0.00
200	7.06	0.61	0.11	0.03	0.01	0.00
220	7.77	0.72	0.13	0.03	0.01	0.01
240	8.48	0.84	0.16	0.04	0.01	0.01
260	9.18	0.96	0.18	0.05	0.02	0.01
280	9.89	1.10	0.20	0.05	0.02	0.01
300	10.6	1.24	0.23	0.06	0.02	0.01
350	12.4	1.64	0.30	0.08	0.03	0.01
400	14.1	2.08	0.38	0.10	0.03	0.02
450	15.9	2.58	0.47	0.12	0.04	0.02
500	17.7	3.12	0.57	0.15	0.05	0.02
550	19.4	3.71	0.67	0.17	0.06	0.03
600	21.2	4.34	0.79	0.20	0.07	0.03
650	23.0	5.02	0.91	0.23	0.08	0.04
700	24.7		1.04	0.26	0.09	0.04
750	26.5		1.17	0.30	0.10	0.05
800	28.3		1.32	0.33	0.12	0.05
850	30.0		1.47	0.37	0.13	0.06
900	31.8		1.63	0.41	0.14	0.06
950	33.5		1.80	0.45	0.16	0.07
1000	35.3		1.97	0.50	0.17	0.07
1100	38.8		2.34	0.59	0.20	0.09
1200	42.4		2.74	0.69	0.24	0.10
1300	45.9		3.17	0.80	0.27	0.12
1400	49.4		3.62	0.91	0.31	0.14
1500	53.0		4.11	1.03	0.35	0.15
1600	56.5		4.62	1.16	0.39	0.17
1700	60.0		5.17	1.30	0.44	0.19
1800	63.6			1.44	0.48	0.21
1900	67.1			1.59	0.53	0.23
2000	70.6			1.75	0.59	0.25
2250	79.5			2.16	0.72	0.31
2500	88.3			2.63	0.87	0.38

Notes:

1. Standard conditions are 68F, 14.7 psia
2. Actual conditions are 68F and the pressure indicated
3. Values stop where pressure drop exceeds 10% of inlet pressure per limits of Darcy-Wiesbach.

Medical Air (55 psig) Piping Pressure Loss Data (PSI/100ft)

		PIPE SIZE (ASTM B819 Type K Copper Tube)				
	IP Nominal	1"	1-1/4"	1-1/2"	2"	2-1/2"
	IP Inner Diameter (in)	1.00	1.24	1.48	1.96	2.44
	SI Nominal	DN25	DN32	DN40	DN50	DN65
	SI Inner Diameter (mm)	25.3	31.6	37.6	49.8	61.9
FLOW RATE						
Standard LPM	Standard CFM					
500	17.7	0.15	0.05	0.02	0.01	0.00
550	19.4	0.17	0.06	0.03	0.01	0.00
600	21.2	0.20	0.07	0.03	0.01	0.00
650	23.0	0.23	0.08	0.04	0.01	0.00
700	24.7	0.26	0.09	0.04	0.01	0.00
750	26.5	0.30	0.10	0.05	0.01	0.00
800	28.3	0.33	0.12	0.05	0.01	0.00
850	30.0	0.37	0.13	0.06	0.01	0.01
900	31.8	0.41	0.14	0.06	0.02	0.01
950	33.5	0.45	0.16	0.07	0.02	0.01
1000	35.3	0.50	0.17	0.07	0.02	0.01
1100	38.8	0.59	0.20	0.09	0.02	0.01
1200	42.4	0.69	0.24	0.10	0.03	0.01
1300	45.9	0.80	0.27	0.12	0.03	0.01
1400	49.4	0.91	0.31	0.14	0.04	0.01
1500	53.0	1.03	0.35	0.15	0.04	0.01
1600	56.5	1.16	0.39	0.17	0.04	0.02
1700	60.0	1.30	0.44	0.19	0.05	0.02
1800	63.6	1.44	0.48	0.21	0.06	0.02
1900	67.1	1.59	0.53	0.23	0.06	0.02
2000	70.6	1.75	0.59	0.25	0.07	0.02
2250	79.5	2.16	0.72	0.31	0.08	0.03
2500	88.3	2.63	0.87	0.38	0.10	0.04
2750	97.1	3.13	1.04	0.45	0.12	0.04
3000	105.9	3.67	1.21	0.53	0.14	0.05
3250	114.8	4.26	1.40	0.61	0.16	0.06
3500	123.6	4.88	1.60	0.69	0.18	0.06
3750	132.4		1.82	0.79	0.20	0.07
4000	141.3		2.04	0.88	0.23	0.08
4250	150.1		2.28	0.99	0.26	0.09
4500	158.9		2.53	1.10	0.28	0.10
4750	167.7		2.80	1.21	0.31	0.11
5000	176.6		3.07	1.33	0.34	0.12
5500	194.2		3.66	1.58	0.41	0.14
6000	211.9		4.29	1.85	0.48	0.17
6500	229.5		4.98	2.15	0.55	0.19
7000	247.2			2.46	0.63	0.22
7500	264.9			2.79	0.72	0.25
8000	282.5			3.14	0.81	0.28
8500	300.2			3.52	0.90	0.32
9000	317.8			3.91	1.00	0.35
9500	335.5			4.32	1.11	0.39
10000	353.1			4.75	1.22	0.43
10500	370.8			5.20	1.33	0.47

Notes:
1. Standard conditions are 68F, 14.7 psia
2. Actual conditions are 68F and the pressure indicated
3. Values stop where pressure drop exceeds 10% of inlet pressure per limits of Darcy-Wiesbach.

Medical Air (55 psig) Piping Pressure Loss Data (PSI/100ft)

		PIPE SIZE (ASTM B819 Type K Copper Tube)				
	IP Nominal	2"	2-1/2"	3"	4"	6"
	IP Inner Diameter (in)	1.96	2.44	2.91	3.87	5.76
	SI Nominal	DN50	DN65	DN80	DN100	DN150
	SI Inner Diameter (mm)	49.8	61.9	73.9	98.2	146.2
FLOW RATE						
Standard LPM	Standard CFM					
4000	141.3	0.23	0.08	0.03	0.01	0.00
4250	150.1	0.26	0.09	0.04	0.01	0.00
4500	158.9	0.28	0.10	0.04	0.01	0.00
4750	167.7	0.31	0.11	0.05	0.01	0.00
5000	176.6	0.34	0.12	0.05	0.01	0.00
5500	194.2	0.41	0.14	0.06	0.02	0.00
6000	211.9	0.48	0.17	0.07	0.02	0.00
6500	229.5	0.55	0.19	0.08	0.02	0.00
7000	247.2	0.63	0.22	0.09	0.02	0.00
7500	264.9	0.72	0.25	0.11	0.03	0.00
8000	282.5	0.81	0.28	0.12	0.03	0.00
8500	300.2	0.90	0.32	0.13	0.03	0.01
9000	317.8	1.00	0.35	0.15	0.04	0.01
9500	335.5	1.11	0.39	0.16	0.04	0.01
10000	353.1	1.22	0.43	0.18	0.05	0.01
10500	370.8	1.33	0.47	0.20	0.05	0.01
11000	388.5	1.45	0.51	0.22	0.05	0.01
11500	406.1	1.57	0.55	0.23	0.06	0.01
12000	423.8	1.70	0.59	0.25	0.06	0.01
13000	459.1	1.98	0.69	0.29	0.07	0.01
14000	494.4	2.27	0.79	0.34	0.08	0.01
15000	529.7	2.58	0.90	0.38	0.10	0.01
16000	565.0	2.91	1.01	0.43	0.11	0.02
17000	600.3	3.26	1.13	0.48	0.12	0.02
18000	635.7	3.62	1.26	0.53	0.13	0.02
19000	671.0	4.01	1.39	0.59	0.15	0.02
20000	706.3	4.42	1.53	0.65	0.16	0.02
21000	741.6	4.84	1.68	0.71	0.18	0.03
22000	776.9	5.28	1.83	0.77	0.19	0.03
23000	812.2		1.99	0.84	0.21	0.03
24000	847.6		2.16	0.91	0.23	0.03
25000	882.9		2.33	0.98	0.25	0.04
26000	918.2		2.51	1.06	0.26	0.04
27000	953.5		2.69	1.13	0.28	0.04
28000	988.8		2.88	1.21	0.30	0.04
29000	1024.1		3.08	1.30	0.32	0.05
30000	1059.4		3.28	1.38	0.35	0.05
35000	1236.0		4.39	1.85	0.46	0.07
40000	1412.6			2.38	0.59	0.09
45000	1589.2			2.97	0.74	0.11
50000	1765.7			3.63	0.90	0.13
55000	1942.3			4.35	1.08	0.15
60000	2118.9			5.13	1.27	0.18
65000	2295.5				1.48	0.21

Notes:
1. Standard conditions are 68F, 14.7 psia
2. Actual conditions are 68F and the pressure indicated
3. Values stop where pressure drop exceeds 10% of inlet pressure per limits of Darcy-Wiesbach.

Medical Air (65 psig) Piping Pressure Loss Data (PSI/100ft)

		PIPE SIZE (ASTM B819 Type K Copper Tube)					
		IP Nominal	1/2"	3/4"	1"	1-1/4"	1-1/2"
		IP Inner Diameter (in)	0.53	0.75	1.00	1.24	1.48
		SI Nominal	DN15	DN20	DN25	DN32	DN40
		SI Inner Diameter (mm)	13.4	19.0	25.3	31.6	37.6
FLOW RATE							
Standard LPM	Standard CFM						
10	0.35		0.00	0.00	0.00	0.00	0.00
20	0.71		0.01	0.00	0.00	0.00	0.00
30	1.06		0.02	0.00	0.00	0.00	0.00
40	1.41		0.03	0.01	0.00	0.00	0.00
50	1.77		0.05	0.01	0.00	0.00	0.00
60	2.12		0.06	0.01	0.00	0.00	0.00
70	2.47		0.08	0.02	0.00	0.00	0.00
80	2.83		0.11	0.02	0.01	0.00	0.00
90	3.18		0.13	0.02	0.01	0.00	0.00
100	3.53		0.16	0.03	0.01	0.00	0.00
120	4.24		0.22	0.04	0.01	0.00	0.00
140	4.94		0.28	0.05	0.01	0.00	0.00
160	5.65		0.36	0.07	0.02	0.01	0.00
180	6.36		0.44	0.08	0.02	0.01	0.00
200	7.06		0.53	0.10	0.03	0.01	0.00
220	7.77		0.63	0.12	0.03	0.01	0.00
240	8.48		0.73	0.14	0.04	0.01	0.01
260	9.18		0.84	0.16	0.04	0.01	0.01
280	9.89		0.96	0.18	0.05	0.02	0.01
300	10.6		1.09	0.20	0.05	0.02	0.01
350	12.4		1.43	0.27	0.07	0.02	0.01
400	14.1		1.82	0.34	0.09	0.03	0.01
450	15.9		2.25	0.41	0.11	0.04	0.02
500	17.7		2.73	0.50	0.13	0.04	0.02
550	19.4		3.24	0.59	0.15	0.05	0.02
600	21.2		3.80	0.69	0.18	0.06	0.03
650	23.0		4.39	0.79	0.20	0.07	0.03
700	24.7		5.03	0.91	0.23	0.08	0.04
750	26.5		5.70	1.03	0.26	0.09	0.04
800	28.3		6.42	1.15	0.29	0.10	0.04
850	30.0			1.29	0.33	0.11	0.05
900	31.8			1.42	0.36	0.12	0.05
950	33.5			1.57	0.40	0.14	0.06
1000	35.3			1.72	0.44	0.15	0.07
1100	38.8			2.05	0.52	0.18	0.08
1200	42.4			2.40	0.60	0.21	0.09
1300	45.9			2.77	0.70	0.24	0.10
1400	49.4			3.17	0.80	0.27	0.12
1500	53.0			3.59	0.90	0.31	0.13
1600	56.5			4.04	1.02	0.34	0.15
1700	60.0			4.52	1.14	0.38	0.17
1800	63.6			5.02	1.26	0.42	0.18
1900	67.1			5.54	1.39	0.47	0.20
2000	70.6			6.09	1.53	0.51	0.22
2250	79.5				1.89	0.63	0.27
2500	88.3				2.30	0.76	0.33

Notes:
1. Standard conditions are 68F, 14.7 psia
2. Actual conditions are 68F and the pressure indicated
3. Values stop where pressure drop exceeds 10% of inlet pressure per limits of Darcy-Wiesbach.

Medical Air (65 psig) Piping Pressure Loss Data (PSI/100ft)

		PIPE SIZE (ASTM B819 Type K Copper Tube)				
	IP Nominal	1"	1-1/4"	1-1/2"	2"	2-1/2"
	IP Inner Diameter (in)	1.00	1.24	1.48	1.96	2.44
	SI Nominal	DN25	DN32	DN40	DN50	DN65
	SI Inner Diameter (mm)	25.3	31.6	37.6	49.8	61.9
FLOW RATE						
Standard LPM	Standard CFM					
500	17.7	0.13	0.04	0.02	0.01	0.00
550	19.4	0.15	0.05	0.02	0.01	0.00
600	21.2	0.18	0.06	0.03	0.01	0.00
650	23.0	0.20	0.07	0.03	0.01	0.00
700	24.7	0.23	0.08	0.04	0.01	0.00
750	26.5	0.26	0.09	0.04	0.01	0.00
800	28.3	0.29	0.10	0.04	0.01	0.00
850	30.0	0.33	0.11	0.05	0.01	0.00
900	31.8	0.36	0.12	0.05	0.01	0.01
950	33.5	0.40	0.14	0.06	0.02	0.01
1000	35.3	0.44	0.15	0.07	0.02	0.01
1100	38.8	0.52	0.18	0.08	0.02	0.01
1200	42.4	0.60	0.21	0.09	0.02	0.01
1300	45.9	0.70	0.24	0.10	0.03	0.01
1400	49.4	0.80	0.27	0.12	0.03	0.01
1500	53.0	0.90	0.31	0.13	0.04	0.01
1600	56.5	1.02	0.34	0.15	0.04	0.01
1700	60.0	1.14	0.38	0.17	0.04	0.02
1800	63.6	1.26	0.42	0.18	0.05	0.02
1900	67.1	1.39	0.47	0.20	0.05	0.02
2000	70.6	1.53	0.51	0.22	0.06	0.02
2250	79.5	1.89	0.63	0.27	0.07	0.03
2500	88.3	2.30	0.76	0.33	0.09	0.03
2750	97.1	2.74	0.91	0.39	0.10	0.04
3000	105.9	3.21	1.06	0.46	0.12	0.04
3250	114.8	3.72	1.23	0.53	0.14	0.05
3500	123.6	4.27	1.40	0.61	0.16	0.06
3750	132.4	4.85	1.59	0.69	0.18	0.06
4000	141.3	5.47	1.79	0.77	0.20	0.07
4250	150.1	6.12	2.00	0.86	0.22	0.08
4500	158.9		2.22	0.96	0.25	0.09
4750	167.7		2.45	1.06	0.27	0.10
5000	176.6		2.69	1.16	0.30	0.11
5500	194.2		3.20	1.38	0.36	0.13
6000	211.9		3.76	1.62	0.42	0.15
6500	229.5		4.35	1.88	0.48	0.17
7000	247.2		4.99	2.15	0.55	0.19
7500	264.9		5.67	2.44	0.63	0.22
8000	282.5		6.39	2.75	0.71	0.25
8500	300.2			3.08	0.79	0.28
9000	317.8			3.42	0.88	0.31
9500	335.5			3.78	0.97	0.34
10000	353.1			4.16	1.06	0.37
10500	370.8			4.55	1.16	0.41

Notes:
1. Standard conditions are 68F, 14.7 psia
2. Actual conditions are 68F and the pressure indicated
3. Values stop where pressure drop exceeds 10% of inlet pressure per limits of Darcy-Wiesbach.

Type K — MA 65 (2" - 6")

Medical Air (65 psig) Piping Pressure Loss Data (PSI/100ft)

		PIPE SIZE (ASTM B819 Type K Copper Tube)				
	IP Nominal	2"	2-1/2"	3"	4"	6"
	IP Inner Diameter (in)	1.96	2.44	2.91	3.87	5.76
	SI Nominal	DN50	DN65	DN80	DN100	DN150
	SI Inner Diameter (mm)	49.8	61.9	73.9	98.2	146.2
FLOW RATE						
Standard LPM	Standard CFM					
4000	141.3	0.20	0.07	0.03	0.01	0.00
4250	150.1	0.22	0.08	0.03	0.01	0.00
4500	158.9	0.25	0.09	0.04	0.01	0.00
4750	167.7	0.27	0.10	0.04	0.01	0.00
5000	176.6	0.30	0.11	0.05	0.01	0.00
5500	194.2	0.36	0.13	0.05	0.01	0.00
6000	211.9	0.42	0.15	0.06	0.02	0.00
6500	229.5	0.48	0.17	0.07	0.02	0.00
7000	247.2	0.55	0.19	0.08	0.02	0.00
7500	264.9	0.63	0.22	0.09	0.02	0.00
8000	282.5	0.71	0.25	0.11	0.03	0.00
8500	300.2	0.79	0.28	0.12	0.03	0.00
9000	317.8	0.88	0.31	0.13	0.03	0.00
9500	335.5	0.97	0.34	0.14	0.04	0.01
10000	353.1	1.06	0.37	0.16	0.04	0.01
10500	370.8	1.16	0.41	0.17	0.04	0.01
11000	388.5	1.27	0.44	0.19	0.05	0.01
11500	406.1	1.38	0.48	0.20	0.05	0.01
12000	423.8	1.49	0.52	0.22	0.06	0.01
13000	459.1	1.73	0.60	0.26	0.06	0.01
14000	494.4	1.98	0.69	0.29	0.07	0.01
15000	529.7	2.26	0.79	0.33	0.08	0.01
16000	565.0	2.54	0.89	0.38	0.09	0.01
17000	600.3	2.85	0.99	0.42	0.11	0.02
18000	635.7	3.17	1.10	0.47	0.12	0.02
19000	671.0	3.51	1.22	0.52	0.13	0.02
20000	706.3	3.86	1.34	0.57	0.14	0.02
21000	741.6	4.23	1.47	0.62	0.16	0.02
22000	776.9	4.62	1.60	0.68	0.17	0.02
23000	812.2	5.02	1.74	0.74	0.18	0.03
24000	847.6	5.44	1.89	0.80	0.20	0.03
25000	882.9	5.88	2.04	0.86	0.22	0.03
26000	918.2	6.33	2.19	0.92	0.23	0.03
27000	953.5		2.35	0.99	0.25	0.04
28000	988.8		2.52	1.06	0.27	0.04
29000	1024.1		2.69	1.13	0.28	0.04
30000	1059.4		2.87	1.21	0.30	0.04
35000	1236.0		3.84	1.62	0.40	0.06
40000	1412.6		4.94	2.08	0.52	0.07
45000	1589.2		6.18	2.60	0.65	0.09
50000	1765.7			3.17	0.79	0.11
55000	1942.3			3.80	0.94	0.14
60000	2118.9			4.49	1.11	0.16
65000	2295.5			5.23	1.29	0.18

Notes:
1. Standard conditions are 68F, 14.7 psia
2. Actual conditions are 68F and the pressure indicated
3. Values stop where pressure drop exceeds 10% of inlet pressure per limits of Darcy-Wiesbach.

Medical Air (75 psig) Piping Pressure Loss Data (PSI/100ft)

		PIPE SIZE (ASTM B819 Type K Copper Tube)				
	IP Nominal	1/2"	3/4"	1"	1-1/4"	1-1/2"
	IP Inner Diameter (in)	0.53	0.75	1.00	1.24	1.48
	SI Nominal	DN15	DN20	DN25	DN32	DN40
	SI Inner Diameter (mm)	13.4	19.0	25.3	31.6	37.6
FLOW RATE						
Standard LPM	Standard CFM					
10	0.35	0.00	0.00	0.00	0.00	0.00
20	0.71	0.01	0.00	0.00	0.00	0.00
30	1.06	0.02	0.00	0.00	0.00	0.00
40	1.41	0.03	0.01	0.00	0.00	0.00
50	1.77	0.04	0.01	0.00	0.00	0.00
60	2.12	0.06	0.01	0.00	0.00	0.00
70	2.47	0.07	0.01	0.00	0.00	0.00
80	2.83	0.09	0.02	0.00	0.00	0.00
90	3.18	0.12	0.02	0.01	0.00	0.00
100	3.53	0.14	0.03	0.01	0.00	0.00
120	4.24	0.19	0.04	0.01	0.00	0.00
140	4.94	0.25	0.05	0.01	0.00	0.00
160	5.65	0.32	0.06	0.02	0.01	0.00
180	6.36	0.39	0.07	0.02	0.01	0.00
200	7.06	0.47	0.09	0.02	0.01	0.00
220	7.77	0.56	0.10	0.03	0.01	0.00
240	8.48	0.65	0.12	0.03	0.01	0.00
260	9.18	0.75	0.14	0.04	0.01	0.01
280	9.89	0.86	0.16	0.04	0.01	0.01
300	10.6	0.97	0.18	0.05	0.02	0.01
350	12.4	1.27	0.24	0.06	0.02	0.01
400	14.1	1.62	0.30	0.08	0.03	0.01
450	15.9	2.00	0.37	0.09	0.03	0.01
500	17.7	2.42	0.44	0.11	0.04	0.02
550	19.4	2.88	0.52	0.13	0.05	0.02
600	21.2	3.37	0.61	0.16	0.05	0.02
650	23.0	3.90	0.71	0.18	0.06	0.03
700	24.7	4.47	0.81	0.20	0.07	0.03
750	26.5	5.07	0.91	0.23	0.08	0.04
800	28.3	5.70	1.02	0.26	0.09	0.04
850	30.0	6.37	1.14	0.29	0.10	0.04
900	31.8	7.08	1.27	0.32	0.11	0.05
950	33.5		1.39	0.35	0.12	0.05
1000	35.3		1.53	0.39	0.13	0.06
1100	38.8		1.82	0.46	0.16	0.07
1200	42.4		2.13	0.54	0.18	0.08
1300	45.9		2.46	0.62	0.21	0.09
1400	49.4		2.82	0.71	0.24	0.11
1500	53.0		3.19	0.80	0.27	0.12
1600	56.5		3.59	0.90	0.31	0.13
1700	60.0		4.01	1.01	0.34	0.15
1800	63.6		4.46	1.12	0.38	0.16
1900	67.1		4.92	1.23	0.41	0.18
2000	70.6		5.41	1.36	0.45	0.20
2250	79.5		6.72	1.68	0.56	0.24
2500	88.3			2.04	0.68	0.29

Notes:
1. Standard conditions are 68F, 14.7 psia
2. Actual conditions are 68F and the pressure indicated
3. Values stop where pressure drop exceeds 10% of inlet pressure per limits of Darcy-Wiesbach.

Medical Air (75 psig) Piping Pressure Loss Data (PSI/100ft)

		PIPE SIZE (ASTM B819 Type K Copper Tube)				
	IP Nominal	1"	1-1/4"	1-1/2"	2"	2-1/2"
	IP Inner Diameter (in)	1.00	1.24	1.48	1.96	2.44
	SI Nominal	DN25	DN32	DN40	DN50	DN65
	SI Inner Diameter (mm)	25.3	31.6	37.6	49.8	61.9
FLOW RATE						
Standard LPM	Standard CFM					
500	17.7	0.11	0.04	0.02	0.00	0.00
550	19.4	0.13	0.05	0.02	0.01	0.00
600	21.2	0.16	0.05	0.02	0.01	0.00
650	23.0	0.18	0.06	0.03	0.01	0.00
700	24.7	0.20	0.07	0.03	0.01	0.00
750	26.5	0.23	0.08	0.04	0.01	0.00
800	28.3	0.26	0.09	0.04	0.01	0.00
850	30.0	0.29	0.10	0.04	0.01	0.00
900	31.8	0.32	0.11	0.05	0.01	0.00
950	33.5	0.35	0.12	0.05	0.01	0.00
1000	35.3	0.39	0.13	0.06	0.02	0.01
1100	38.8	0.46	0.16	0.07	0.02	0.01
1200	42.4	0.54	0.18	0.08	0.02	0.01
1300	45.9	0.62	0.21	0.09	0.02	0.01
1400	49.4	0.71	0.24	0.11	0.03	0.01
1500	53.0	0.80	0.27	0.12	0.03	0.01
1600	56.5	0.90	0.31	0.13	0.03	0.01
1700	60.0	1.01	0.34	0.15	0.04	0.01
1800	63.6	1.12	0.38	0.16	0.04	0.02
1900	67.1	1.23	0.41	0.18	0.05	0.02
2000	70.6	1.36	0.45	0.20	0.05	0.02
2250	79.5	1.68	0.56	0.24	0.06	0.02
2500	88.3	2.04	0.68	0.29	0.08	0.03
2750	97.1	2.43	0.81	0.35	0.09	0.03
3000	105.9	2.85	0.94	0.41	0.11	0.04
3250	114.8	3.31	1.09	0.47	0.12	0.04
3500	123.6	3.79	1.25	0.54	0.14	0.05
3750	132.4	4.31	1.41	0.61	0.16	0.06
4000	141.3	4.86	1.59	0.69	0.18	0.06
4250	150.1	5.44	1.77	0.77	0.20	0.07
4500	158.9	6.05	1.97	0.85	0.22	0.08
4750	167.7	6.69	2.17	0.94	0.24	0.09
5000	176.6	7.36	2.39	1.03	0.27	0.09
5500	194.2		2.84	1.23	0.32	0.11
6000	211.9		3.34	1.44	0.37	0.13
6500	229.5		3.87	1.67	0.43	0.15
7000	247.2		4.43	1.91	0.49	0.17
7500	264.9		5.04	2.17	0.56	0.20
8000	282.5		5.68	2.44	0.63	0.22
8500	300.2		6.36	2.73	0.70	0.25
9000	317.8		7.07	3.04	0.78	0.27
9500	335.5			3.36	0.86	0.30
10000	353.1			3.69	0.95	0.33
10500	370.8			4.04	1.03	0.36

Notes:
1. Standard conditions are 68F, 14.7 psia
2. Actual conditions are 68F and the pressure indicated
3. Values stop where pressure drop exceeds 10% of inlet pressure per limits of Darcy-Wiesbach.

Medical Air (75 psig) Piping Pressure Loss Data (PSI/100ft)

	PIPE SIZE (ASTM B819 Type K Copper Tube)					
	IP Nominal	2"	2-1/2"	3"	4"	6"
	IP Inner Diameter (in)	1.96	2.44	2.91	3.87	5.76
	SI Nominal	DN50	DN65	DN80	DN100	DN150
	SI Inner Diameter (mm)	49.8	61.9	73.9	98.2	146.2
FLOW RATE						
Standard LPM	Standard CFM					
4000	141.3	0.18	0.06	0.03	0.01	0.00
4250	150.1	0.20	0.07	0.03	0.01	0.00
4500	158.9	0.22	0.08	0.03	0.01	0.00
4750	167.7	0.24	0.09	0.04	0.01	0.00
5000	176.6	0.27	0.09	0.04	0.01	0.00
5500	194.2	0.32	0.11	0.05	0.01	0.00
6000	211.9	0.37	0.13	0.06	0.01	0.00
6500	229.5	0.43	0.15	0.06	0.02	0.00
7000	247.2	0.49	0.17	0.07	0.02	0.00
7500	264.9	0.56	0.20	0.08	0.02	0.00
8000	282.5	0.63	0.22	0.09	0.02	0.00
8500	300.2	0.70	0.25	0.10	0.03	0.00
9000	317.8	0.78	0.27	0.12	0.03	0.00
9500	335.5	0.86	0.30	0.13	0.03	0.00
10000	353.1	0.95	0.33	0.14	0.04	0.01
10500	370.8	1.03	0.36	0.15	0.04	0.01
11000	388.5	1.13	0.39	0.17	0.04	0.01
11500	406.1	1.22	0.43	0.18	0.05	0.01
12000	423.8	1.32	0.46	0.20	0.05	0.01
13000	459.1	1.54	0.54	0.23	0.06	0.01
14000	494.4	1.76	0.61	0.26	0.07	0.01
15000	529.7	2.00	0.70	0.30	0.07	0.01
16000	565.0	2.26	0.79	0.33	0.08	0.01
17000	600.3	2.53	0.88	0.37	0.09	0.01
18000	635.7	2.82	0.98	0.41	0.10	0.02
19000	671.0	3.12	1.08	0.46	0.12	0.02
20000	706.3	3.43	1.19	0.50	0.13	0.02
21000	741.6	3.76	1.30	0.55	0.14	0.02
22000	776.9	4.10	1.42	0.60	0.15	0.02
23000	812.2	4.46	1.55	0.65	0.16	0.02
24000	847.6	4.83	1.68	0.71	0.18	0.03
25000	882.9	5.22	1.81	0.76	0.19	0.03
26000	918.2	5.62	1.95	0.82	0.21	0.03
27000	953.5	6.04	2.09	0.88	0.22	0.03
28000	988.8	6.47	2.24	0.94	0.24	0.03
29000	1024.1	6.91	2.39	1.01	0.25	0.04
30000	1059.4	7.37	2.55	1.07	0.27	0.04
35000	1236.0		3.41	1.44	0.36	0.05
40000	1412.6		4.39	1.85	0.46	0.07
45000	1589.2		5.49	2.31	0.57	0.08
50000	1765.7		6.71	2.82	0.70	0.10
55000	1942.3			3.38	0.84	0.12
60000	2118.9			3.99	0.99	0.14
65000	2295.5			4.64	1.15	0.16

Notes:
1. Standard conditions are 68F, 14.7 psia
2. Actual conditions are 68F and the pressure indicated
3. Values stop where pressure drop exceeds 10% of inlet pressure per limits of Darcy-Wiesbach.

Oxygen (55 psig) Piping Pressure Loss Data (PSI/100ft)

		PIPE SIZE (ASTM B819 Type K Copper Tube)				
	IP Nominal	1/2"	3/4"	1"	1-1/4"	1-1/2"
	IP Inner Diameter (in)	0.53	0.75	1.00	1.24	1.48
	SI Nominal	DN15	DN20	DN25	DN32	DN40
	SI Inner Diameter (mm)	13.4	19.0	25.3	31.6	37.6
FLOW RATE						
Standard LPM	Standard CFM					
10	0.35	0.00	0.00	0.00	0.00	0.00
20	0.71	0.01	0.00	0.00	0.00	0.00
30	1.06	0.02	0.00	0.00	0.00	0.00
40	1.41	0.04	0.01	0.00	0.00	0.00
50	1.77	0.06	0.01	0.00	0.00	0.00
60	2.12	0.08	0.02	0.00	0.00	0.00
70	2.47	0.11	0.02	0.01	0.00	0.00
80	2.83	0.13	0.03	0.01	0.00	0.00
90	3.18	0.16	0.03	0.01	0.00	0.00
100	3.53	0.20	0.04	0.01	0.00	0.00
120	4.24	0.27	0.05	0.01	0.00	0.00
140	4.94	0.36	0.07	0.02	0.01	0.00
160	5.65	0.45	0.09	0.02	0.01	0.00
180	6.36	0.56	0.10	0.03	0.01	0.00
200	7.06	0.67	0.13	0.03	0.01	0.00
220	7.77	0.79	0.15	0.04	0.01	0.01
240	8.48	0.93	0.17	0.04	0.02	0.01
260	9.18	1.07	0.20	0.05	0.02	0.01
280	9.89	1.22	0.23	0.06	0.02	0.01
300	10.6	1.38	0.26	0.07	0.02	0.01
350	12.4	1.81	0.34	0.09	0.03	0.01
400	14.1	2.31	0.42	0.11	0.04	0.02
450	15.9	2.85	0.52	0.13	0.05	0.02
500	17.7	3.45	0.63	0.16	0.06	0.02
550	19.4	4.10	0.75	0.19	0.07	0.03
600	21.2	4.80	0.87	0.22	0.08	0.03
650	23.0		1.01	0.26	0.09	0.04
700	24.7		1.15	0.29	0.10	0.04
750	26.5		1.30	0.33	0.11	0.05
800	28.3		1.46	0.37	0.13	0.06
850	30.0		1.63	0.41	0.14	0.06
900	31.8		1.80	0.46	0.16	0.07
950	33.5		1.99	0.50	0.17	0.08
1000	35.3		2.18	0.55	0.19	0.08
1100	38.8		2.59	0.65	0.22	0.10
1200	42.4		3.03	0.77	0.26	0.11
1300	45.9		3.50	0.88	0.30	0.13
1400	49.4		4.01	1.01	0.34	0.15
1500	53.0		4.55	1.14	0.39	0.17
1600	56.5		5.12	1.29	0.44	0.19
1700	60.0			1.44	0.48	0.21
1800	63.6			1.59	0.54	0.23
1900	67.1			1.76	0.59	0.26
2000	70.6			1.93	0.65	0.28
2250	79.5			2.39	0.80	0.35
2500	88.3			2.90	0.97	0.42

Notes:
1. Standard conditions are 68F, 14.7 psia
2. Actual conditions are 68F and the pressure indicated
3. Values stop where pressure drop exceeds 10% of inlet pressure per limits of Darcy-Wiesbach.

Oxygen (55 psig) Piping Pressure Loss Data (PSI/100ft)

		PIPE SIZE (ASTM B819 Type K Copper Tube)				
	IP Nominal	1"	1-1/4"	1-1/2"	2"	2-1/2"
	IP Inner Diameter (in)	1.00	1.24	1.48	1.96	2.44
	SI Nominal	DN25	DN32	DN40	DN50	DN65
	SI Inner Diameter (mm)	25.3	31.6	37.6	49.8	61.9
FLOW RATE						
Standard LPM	Standard CFM					
500	17.7	0.16	0.06	0.02	0.01	0.00
550	19.4	0.19	0.07	0.03	0.01	0.00
600	21.2	0.22	0.08	0.03	0.01	0.00
650	23.0	0.26	0.09	0.04	0.01	0.00
700	24.7	0.29	0.10	0.04	0.01	0.00
750	26.5	0.33	0.11	0.05	0.01	0.00
800	28.3	0.37	0.13	0.06	0.01	0.01
850	30.0	0.41	0.14	0.06	0.02	0.01
900	31.8	0.46	0.16	0.07	0.02	0.01
950	33.5	0.50	0.17	0.08	0.02	0.01
1000	35.3	0.55	0.19	0.08	0.02	0.01
1100	38.8	0.65	0.22	0.10	0.03	0.01
1200	42.4	0.77	0.26	0.11	0.03	0.01
1300	45.9	0.88	0.30	0.13	0.03	0.01
1400	49.4	1.01	0.34	0.15	0.04	0.01
1500	53.0	1.14	0.39	0.17	0.04	0.02
1600	56.5	1.29	0.44	0.19	0.05	0.02
1700	60.0	1.44	0.48	0.21	0.06	0.02
1800	63.6	1.59	0.54	0.23	0.06	0.02
1900	67.1	1.76	0.59	0.26	0.07	0.02
2000	70.6	1.93	0.65	0.28	0.07	0.03
2250	79.5	2.39	0.80	0.35	0.09	0.03
2500	88.3	2.90	0.97	0.42	0.11	0.04
2750	97.1	3.46	1.15	0.50	0.13	0.05
3000	105.9	4.06	1.34	0.58	0.15	0.05
3250	114.8	4.71	1.55	0.67	0.17	0.06
3500	123.6	5.40	1.77	0.77	0.20	0.07
3750	132.4		2.01	0.87	0.23	0.08
4000	141.3		2.26	0.98	0.25	0.09
4250	150.1		2.53	1.09	0.28	0.10
4500	158.9		2.80	1.21	0.31	0.11
4750	167.7		3.09	1.34	0.35	0.12
5000	176.6		3.40	1.47	0.38	0.13
5500	194.2		4.05	1.75	0.45	0.16
6000	211.9		4.75	2.05	0.53	0.19
6500	229.5			2.37	0.61	0.21
7000	247.2			2.72	0.70	0.25
7500	264.9			3.09	0.79	0.28
8000	282.5			3.48	0.89	0.31
8500	300.2			3.89	1.00	0.35
9000	317.8			4.32	1.11	0.39
9500	335.5			4.78	1.22	0.43
10000	353.1			5.26	1.35	0.47
10500	370.8				1.47	0.51

Notes:
1. Standard conditions are 68F, 14.7 psia
2. Actual conditions are 68F and the pressure indicated
3. Values stop where pressure drop exceeds 10% of inlet pressure per limits of Darcy-Wiesbach.

Oxygen (55 psig) Piping Pressure Loss Data (PSI/100ft)

	PIPE SIZE (ASTM B819 Type K Copper Tube)					
	IP Nominal	2"	2-1/2"	3"	4"	6"
	IP Inner Diameter (in)	1.96	2.44	2.91	3.87	5.76
	SI Nominal	DN50	DN65	DN80	DN100	DN150
	SI Inner Diameter (mm)	49.8	61.9	73.9	98.2	146.2
FLOW RATE						
Standard LPM	Standard CFM					
4000	141.3	0.25	0.09	0.04	0.01	0.00
4250	150.1	0.28	0.10	0.04	0.01	0.00
4500	158.9	0.31	0.11	0.05	0.01	0.00
4750	167.7	0.35	0.12	0.05	0.01	0.00
5000	176.6	0.38	0.13	0.06	0.01	0.00
5500	194.2	0.45	0.16	0.07	0.02	0.00
6000	211.9	0.53	0.19	0.08	0.02	0.00
6500	229.5	0.61	0.21	0.09	0.02	0.00
7000	247.2	0.70	0.25	0.10	0.03	0.00
7500	264.9	0.79	0.28	0.12	0.03	0.00
8000	282.5	0.89	0.31	0.13	0.03	0.01
8500	300.2	1.00	0.35	0.15	0.04	0.01
9000	317.8	1.11	0.39	0.17	0.04	0.01
9500	335.5	1.22	0.43	0.18	0.05	0.01
10000	353.1	1.35	0.47	0.20	0.05	0.01
10500	370.8	1.47	0.51	0.22	0.06	0.01
11000	388.5	1.60	0.56	0.24	0.06	0.01
11500	406.1	1.74	0.61	0.26	0.07	0.01
12000	423.8	1.88	0.66	0.28	0.07	0.01
13000	459.1	2.19	0.76	0.32	0.08	0.01
14000	494.4	2.51	0.87	0.37	0.09	0.01
15000	529.7	2.85	0.99	0.42	0.11	0.02
16000	565.0	3.22	1.12	0.47	0.12	0.02
17000	600.3	3.60	1.25	0.53	0.13	0.02
18000	635.7	4.01	1.39	0.59	0.15	0.02
19000	671.0	4.44	1.54	0.65	0.16	0.02
20000	706.3	4.88	1.70	0.72	0.18	0.03
21000	741.6	5.35	1.86	0.79	0.20	0.03
22000	776.9		2.03	0.86	0.21	0.03
23000	812.2		2.20	0.93	0.23	0.03
24000	847.6		2.38	1.01	0.25	0.04
25000	882.9		2.57	1.09	0.27	0.04
26000	918.2		2.77	1.17	0.29	0.04
27000	953.5		2.97	1.26	0.31	0.05
28000	988.8		3.18	1.34	0.34	0.05
29000	1024.1		3.40	1.43	0.36	0.05
30000	1059.4		3.63	1.53	0.38	0.06
35000	1236.0		4.85	2.04	0.51	0.07
40000	1412.6			2.63	0.65	0.09
45000	1589.2			3.28	0.82	0.12
50000	1765.7			4.01	1.00	0.14
55000	1942.3			4.81	1.19	0.17
60000	2118.9				1.40	0.20
65000	2295.5				1.63	0.23

Notes:
1. Standard conditions are 68F, 14.7 psia
2. Actual conditions are 68F and the pressure indicated
3. Values stop where pressure drop exceeds 10% of inlet pressure per limits of Darcy-Wiesbach.

Oxygen (65 psig) Piping Pressure Loss Data (PSI/100ft)

FLOW RATE		PIPE SIZE (ASTM B819 Type K Copper Tube)				
	IP Nominal	1/2"	3/4"	1"	1-1/4"	1-1/2"
	IP Inner Diameter (in)	0.53	0.75	1.00	1.24	1.48
	SI Nominal	DN15	DN20	DN25	DN32	DN40
	SI Inner Diameter (mm)	13.4	19.0	25.3	31.6	37.6
Standard LPM	Standard CFM					
10	0.35	0.00	0.00	0.00	0.00	0.00
20	0.71	0.01	0.00	0.00	0.00	0.00
30	1.06	0.02	0.00	0.00	0.00	0.00
40	1.41	0.04	0.01	0.00	0.00	0.00
50	1.77	0.05	0.01	0.00	0.00	0.00
60	2.12	0.07	0.01	0.00	0.00	0.00
70	2.47	0.09	0.02	0.00	0.00	0.00
80	2.83	0.12	0.02	0.01	0.00	0.00
90	3.18	0.14	0.03	0.01	0.00	0.00
100	3.53	0.17	0.03	0.01	0.00	0.00
120	4.24	0.24	0.05	0.01	0.00	0.00
140	4.94	0.31	0.06	0.02	0.01	0.00
160	5.65	0.40	0.07	0.02	0.01	0.00
180	6.36	0.49	0.09	0.02	0.01	0.00
200	7.06	0.59	0.11	0.03	0.01	0.00
220	7.77	0.69	0.13	0.03	0.01	0.01
240	8.48	0.81	0.15	0.04	0.01	0.01
260	9.18	0.93	0.17	0.04	0.02	0.01
280	9.89	1.07	0.20	0.05	0.02	0.01
300	10.6	1.20	0.22	0.06	0.02	0.01
350	12.4	1.59	0.29	0.08	0.03	0.01
400	14.1	2.02	0.37	0.10	0.03	0.01
450	15.9	2.49	0.46	0.12	0.04	0.02
500	17.7	3.02	0.55	0.14	0.05	0.02
550	19.4	3.59	0.65	0.17	0.06	0.03
600	21.2	4.20	0.76	0.19	0.07	0.03
650	23.0	4.86	0.88	0.22	0.08	0.03
700	24.7	5.56	1.00	0.26	0.09	0.04
750	26.5	6.31	1.14	0.29	0.10	0.04
800	28.3		1.28	0.32	0.11	0.05
850	30.0		1.42	0.36	0.12	0.05
900	31.8		1.58	0.40	0.14	0.06
950	33.5		1.74	0.44	0.15	0.07
1000	35.3		1.91	0.48	0.17	0.07
1100	38.8		2.26	0.57	0.20	0.09
1200	42.4		2.65	0.67	0.23	0.10
1300	45.9		3.06	0.77	0.26	0.11
1400	49.4		3.51	0.88	0.30	0.13
1500	53.0		3.98	1.00	0.34	0.15
1600	56.5		4.47	1.13	0.38	0.17
1700	60.0		5.00	1.26	0.42	0.18
1800	63.6		5.55	1.39	0.47	0.20
1900	67.1		6.13	1.54	0.52	0.23
2000	70.6			1.69	0.57	0.25
2250	79.5			2.09	0.70	0.30
2500	88.3			2.54	0.85	0.37

Notes:
1. Standard conditions are 68F, 14.7 psia
2. Actual conditions are 68F and the pressure indicated
3. Values stop where pressure drop exceeds 10% of inlet pressure per limits of Darcy-Wiesbach.

Oxygen (65 psig) Piping Pressure Loss Data (PSI/100ft)

		PIPE SIZE (ASTM B819 Type K Copper Tube)				
	IP Nominal	1"	1-1/4"	1-1/2"	2"	2-1/2"
	IP Inner Diameter (in)	1.00	1.24	1.48	1.96	2.44
	SI Nominal	DN25	DN32	DN40	DN50	DN65
	SI Inner Diameter (mm)	25.3	31.6	37.6	49.8	61.9
FLOW RATE						
Standard LPM	Standard CFM					
500	17.7	0.14	0.05	0.02	0.01	0.00
550	19.4	0.17	0.06	0.03	0.01	0.00
600	21.2	0.19	0.07	0.03	0.01	0.00
650	23.0	0.22	0.08	0.03	0.01	0.00
700	24.7	0.26	0.09	0.04	0.01	0.00
750	26.5	0.29	0.10	0.04	0.01	0.00
800	28.3	0.32	0.11	0.05	0.01	0.00
850	30.0	0.36	0.12	0.05	0.01	0.01
900	31.8	0.40	0.14	0.06	0.02	0.01
950	33.5	0.44	0.15	0.07	0.02	0.01
1000	35.3	0.48	0.17	0.07	0.02	0.01
1100	38.8	0.57	0.20	0.09	0.02	0.01
1200	42.4	0.67	0.23	0.10	0.03	0.01
1300	45.9	0.77	0.26	0.11	0.03	0.01
1400	49.4	0.88	0.30	0.13	0.03	0.01
1500	53.0	1.00	0.34	0.15	0.04	0.01
1600	56.5	1.13	0.38	0.17	0.04	0.02
1700	60.0	1.26	0.42	0.18	0.05	0.02
1800	63.6	1.39	0.47	0.20	0.05	0.02
1900	67.1	1.54	0.52	0.23	0.06	0.02
2000	70.6	1.69	0.57	0.25	0.06	0.02
2250	79.5	2.09	0.70	0.30	0.08	0.03
2500	88.3	2.54	0.85	0.37	0.10	0.03
2750	97.1	3.03	1.00	0.44	0.11	0.04
3000	105.9	3.55	1.17	0.51	0.13	0.05
3250	114.8	4.12	1.36	0.59	0.15	0.05
3500	123.6	4.72	1.55	0.67	0.17	0.06
3750	132.4	5.37	1.76	0.76	0.20	0.07
4000	141.3	6.05	1.98	0.86	0.22	0.08
4250	150.1		2.21	0.96	0.25	0.09
4500	158.9		2.45	1.06	0.27	0.10
4750	167.7		2.71	1.17	0.30	0.11
5000	176.6		2.97	1.28	0.33	0.12
5500	194.2		3.54	1.53	0.39	0.14
6000	211.9		4.15	1.79	0.46	0.16
6500	229.5		4.82	2.08	0.53	0.19
7000	247.2		5.52	2.38	0.61	0.21
7500	264.9		6.27	2.70	0.69	0.24
8000	282.5			3.04	0.78	0.27
8500	300.2			3.40	0.87	0.31
9000	317.8			3.78	0.97	0.34
9500	335.5			4.18	1.07	0.37
10000	353.1			4.60	1.18	0.41
10500	370.8			5.03	1.29	0.45

Notes:
1. Standard conditions are 68F, 14.7 psia
2. Actual conditions are 68F and the pressure indicated
3. Values stop where pressure drop exceeds 10% of inlet pressure per limits of Darcy-Wiesbach.

Oxygen (65 psig) Piping Pressure Loss Data (PSI/100ft)

FLOW RATE		PIPE SIZE (ASTM B819 Type K Copper Tube)				
	IP Nominal	2"	2-1/2"	3"	4"	6"
	IP Inner Diameter (in)	1.96	2.44	2.91	3.87	5.76
	SI Nominal	DN50	DN65	DN80	DN100	DN150
	SI Inner Diameter (mm)	49.8	61.9	73.9	98.2	146.2
Standard LPM	**Standard CFM**					
4000	141.3	0.22	0.08	0.03	0.01	0.00
4250	150.1	0.25	0.09	0.04	0.01	0.00
4500	158.9	0.27	0.10	0.04	0.01	0.00
4750	167.7	0.30	0.11	0.05	0.01	0.00
5000	176.6	0.33	0.12	0.05	0.01	0.00
5500	194.2	0.39	0.14	0.06	0.02	0.00
6000	211.9	0.46	0.16	0.07	0.02	0.00
6500	229.5	0.53	0.19	0.08	0.02	0.00
7000	247.2	0.61	0.21	0.09	0.02	0.00
7500	264.9	0.69	0.24	0.10	0.03	0.00
8000	282.5	0.78	0.27	0.12	0.03	0.00
8500	300.2	0.87	0.31	0.13	0.03	0.00
9000	317.8	0.97	0.34	0.14	0.04	0.01
9500	335.5	1.07	0.37	0.16	0.04	0.01
10000	353.1	1.18	0.41	0.18	0.04	0.01
10500	370.8	1.29	0.45	0.19	0.05	0.01
11000	388.5	1.40	0.49	0.21	0.05	0.01
11500	406.1	1.52	0.53	0.23	0.06	0.01
12000	423.8	1.65	0.58	0.24	0.06	0.01
13000	459.1	1.91	0.67	0.28	0.07	0.01
14000	494.4	2.19	0.76	0.32	0.08	0.01
15000	529.7	2.49	0.87	0.37	0.09	0.01
16000	565.0	2.81	0.98	0.41	0.10	0.02
17000	600.3	3.15	1.10	0.46	0.12	0.02
18000	635.7	3.51	1.22	0.52	0.13	0.02
19000	671.0	3.88	1.35	0.57	0.14	0.02
20000	706.3	4.27	1.48	0.63	0.16	0.02
21000	741.6	4.68	1.62	0.69	0.17	0.03
22000	776.9	5.11	1.77	0.75	0.19	0.03
23000	812.2	5.55	1.93	0.81	0.20	0.03
24000	847.6	6.02	2.09	0.88	0.22	0.03
25000	882.9	6.50	2.25	0.95	0.24	0.03
26000	918.2		2.42	1.02	0.26	0.04
27000	953.5		2.60	1.10	0.27	0.04
28000	988.8		2.79	1.17	0.29	0.04
29000	1024.1		2.98	1.25	0.31	0.05
30000	1059.4		3.17	1.34	0.33	0.05
35000	1236.0		4.24	1.79	0.45	0.06
40000	1412.6		5.46	2.30	0.57	0.08
45000	1589.2			2.87	0.71	0.10
50000	1765.7			3.51	0.87	0.12
55000	1942.3			4.20	1.04	0.15
60000	2118.9			4.96	1.23	0.18
65000	2295.5			5.78	1.43	0.20

Notes:
1. Standard conditions are 68F, 14.7 psia
2. Actual conditions are 68F and the pressure indicated
3. Values stop where pressure drop exceeds 10% of inlet pressure per limits of Darcy-Wiesbach.

Oxygen (75 psig) Piping Pressure Loss Data (PSI/100ft)

		PIPE SIZE (ASTM B819 Type K Copper Tube)				
	IP Nominal	1/2"	3/4"	1"	1-1/4"	1-1/2"
	IP Inner Diameter (in)	0.53	0.75	1.00	1.24	1.48
	SI Nominal	DN15	DN20	DN25	DN32	DN40
	SI Inner Diameter (mm)	13.4	19.0	25.3	31.6	37.6
FLOW RATE						
Standard LPM	Standard CFM					
10	0.35	0.00	0.00	0.00	0.00	0.00
20	0.71	0.01	0.00	0.00	0.00	0.00
30	1.06	0.02	0.00	0.00	0.00	0.00
40	1.41	0.03	0.01	0.00	0.00	0.00
50	1.77	0.05	0.01	0.00	0.00	0.00
60	2.12	0.06	0.01	0.00	0.00	0.00
70	2.47	0.08	0.02	0.00	0.00	0.00
80	2.83	0.10	0.02	0.01	0.00	0.00
90	3.18	0.13	0.02	0.01	0.00	0.00
100	3.53	0.15	0.03	0.01	0.00	0.00
120	4.24	0.21	0.04	0.01	0.00	0.00
140	4.94	0.28	0.05	0.01	0.00	0.00
160	5.65	0.35	0.07	0.02	0.01	0.00
180	6.36	0.43	0.08	0.02	0.01	0.00
200	7.06	0.52	0.10	0.03	0.01	0.00
220	7.77	0.62	0.12	0.03	0.01	0.00
240	8.48	0.72	0.13	0.03	0.01	0.01
260	9.18	0.83	0.15	0.04	0.01	0.01
280	9.89	0.95	0.18	0.05	0.02	0.01
300	10.6	1.07	0.20	0.05	0.02	0.01
350	12.4	1.41	0.26	0.07	0.02	0.01
400	14.1	1.79	0.33	0.08	0.03	0.01
450	15.9	2.22	0.41	0.10	0.04	0.02
500	17.7	2.68	0.49	0.13	0.04	0.02
550	19.4	3.19	0.58	0.15	0.05	0.02
600	21.2	3.73	0.68	0.17	0.06	0.03
650	23.0	4.32	0.78	0.20	0.07	0.03
700	24.7	4.94	0.89	0.23	0.08	0.03
750	26.5	5.61	1.01	0.26	0.09	0.04
800	28.3	6.31	1.13	0.29	0.10	0.04
850	30.0	7.05	1.26	0.32	0.11	0.05
900	31.8		1.40	0.35	0.12	0.05
950	33.5		1.54	0.39	0.13	0.06
1000	35.3		1.69	0.43	0.15	0.06
1100	38.8		2.01	0.51	0.17	0.08
1200	42.4		2.35	0.59	0.20	0.09
1300	45.9		2.72	0.69	0.23	0.10
1400	49.4		3.12	0.79	0.27	0.12
1500	53.0		3.53	0.89	0.30	0.13
1600	56.5		3.98	1.00	0.34	0.15
1700	60.0		4.44	1.12	0.38	0.16
1800	63.6		4.93	1.24	0.42	0.18
1900	67.1		5.45	1.37	0.46	0.20
2000	70.6		5.98	1.50	0.50	0.22
2250	79.5		7.43	1.86	0.62	0.27
2500	88.3			2.26	0.75	0.33

Notes:
1. Standard conditions are 68F, 14.7 psia
2. Actual conditions are 68F and the pressure indicated
3. Values stop where pressure drop exceeds 10% of inlet pressure per limits of Darcy-Wiesbach.

Oxygen (75 psig) Piping Pressure Loss Data (PSI/100ft)

		PIPE SIZE (ASTM B819 Type K Copper Tube)				
	IP Nominal	1"	1-1/4"	1-1/2"	2"	2-1/2"
	IP Inner Diameter (in)	1.00	1.24	1.48	1.96	2.44
	SI Nominal	DN25	DN32	DN40	DN50	DN65
	SI Inner Diameter (mm)	25.3	31.6	37.6	49.8	61.9
FLOW RATE						
Standard LPM	Standard CFM					
500	17.7	0.13	0.04	0.02	0.01	0.00
550	19.4	0.15	0.05	0.02	0.01	0.00
600	21.2	0.17	0.06	0.03	0.01	0.00
650	23.0	0.20	0.07	0.03	0.01	0.00
700	24.7	0.23	0.08	0.03	0.01	0.00
750	26.5	0.26	0.09	0.04	0.01	0.00
800	28.3	0.29	0.10	0.04	0.01	0.00
850	30.0	0.32	0.11	0.05	0.01	0.00
900	31.8	0.35	0.12	0.05	0.01	0.01
950	33.5	0.39	0.13	0.06	0.02	0.01
1000	35.3	0.43	0.15	0.06	0.02	0.01
1100	38.8	0.51	0.17	0.08	0.02	0.01
1200	42.4	0.59	0.20	0.09	0.02	0.01
1300	45.9	0.69	0.23	0.10	0.03	0.01
1400	49.4	0.79	0.27	0.12	0.03	0.01
1500	53.0	0.89	0.30	0.13	0.03	0.01
1600	56.5	1.00	0.34	0.15	0.04	0.01
1700	60.0	1.12	0.38	0.16	0.04	0.02
1800	63.6	1.24	0.42	0.18	0.05	0.02
1900	67.1	1.37	0.46	0.20	0.05	0.02
2000	70.6	1.50	0.50	0.22	0.06	0.02
2250	79.5	1.86	0.62	0.27	0.07	0.03
2500	88.3	2.26	0.75	0.33	0.09	0.03
2750	97.1	2.69	0.89	0.39	0.10	0.04
3000	105.9	3.16	1.04	0.45	0.12	0.04
3250	114.8	3.66	1.21	0.52	0.14	0.05
3500	123.6	4.20	1.38	0.60	0.16	0.05
3750	132.4	4.77	1.56	0.68	0.18	0.06
4000	141.3	5.37	1.76	0.76	0.20	0.07
4250	150.1	6.02	1.96	0.85	0.22	0.08
4500	158.9	6.69	2.18	0.94	0.24	0.09
4750	167.7	7.40	2.40	1.04	0.27	0.09
5000	176.6		2.64	1.14	0.29	0.10
5500	194.2		3.15	1.36	0.35	0.12
6000	211.9		3.69	1.59	0.41	0.14
6500	229.5		4.28	1.84	0.47	0.17
7000	247.2		4.91	2.11	0.54	0.19
7500	264.9		5.57	2.40	0.62	0.22
8000	282.5		6.28	2.70	0.69	0.24
8500	300.2		7.03	3.02	0.78	0.27
9000	317.8			3.36	0.86	0.30
9500	335.5			3.71	0.95	0.33
10000	353.1			4.09	1.05	0.37
10500	370.8			4.47	1.14	0.40

Notes:
1. Standard conditions are 68F, 14.7 psia
2. Actual conditions are 68F and the pressure indicated
3. Values stop where pressure drop exceeds 10% of inlet pressure per limits of Darcy-Wiesbach.

Oxygen (75 psig) Piping Pressure Loss Data (PSI/100ft)

		PIPE SIZE (ASTM B819 Type K Copper Tube)				
	IP Nominal	2"	2-1/2"	3"	4"	6"
	IP Inner Diameter (in)	1.96	2.44	2.91	3.87	5.76
	SI Nominal	DN50	DN65	DN80	DN100	DN150
	SI Inner Diameter (mm)	49.8	61.9	73.9	98.2	146.2
FLOW RATE						
Standard LPM	Standard CFM					
4000	141.3	0.20	0.07	0.03	0.01	0.00
4250	150.1	0.22	0.08	0.03	0.01	0.00
4500	158.9	0.24	0.09	0.04	0.01	0.00
4750	167.7	0.27	0.09	0.04	0.01	0.00
5000	176.6	0.29	0.10	0.04	0.01	0.00
5500	194.2	0.35	0.12	0.05	0.01	0.00
6000	211.9	0.41	0.14	0.06	0.02	0.00
6500	229.5	0.47	0.17	0.07	0.02	0.00
7000	247.2	0.54	0.19	0.08	0.02	0.00
7500	264.9	0.62	0.22	0.09	0.02	0.00
8000	282.5	0.69	0.24	0.10	0.03	0.00
8500	300.2	0.78	0.27	0.12	0.03	0.00
9000	317.8	0.86	0.30	0.13	0.03	0.00
9500	335.5	0.95	0.33	0.14	0.04	0.01
10000	353.1	1.05	0.37	0.16	0.04	0.01
10500	370.8	1.14	0.40	0.17	0.04	0.01
11000	388.5	1.25	0.44	0.19	0.05	0.01
11500	406.1	1.35	0.47	0.20	0.05	0.01
12000	423.8	1.46	0.51	0.22	0.05	0.01
13000	459.1	1.70	0.59	0.25	0.06	0.01
14000	494.4	1.95	0.68	0.29	0.07	0.01
15000	529.7	2.22	0.77	0.33	0.08	0.01
16000	565.0	2.50	0.87	0.37	0.09	0.01
17000	600.3	2.80	0.97	0.41	0.10	0.02
18000	635.7	3.12	1.08	0.46	0.12	0.02
19000	671.0	3.45	1.20	0.51	0.13	0.02
20000	706.3	3.79	1.32	0.56	0.14	0.02
21000	741.6	4.16	1.44	0.61	0.15	0.02
22000	776.9	4.54	1.57	0.67	0.17	0.02
23000	812.2	4.93	1.71	0.72	0.18	0.03
24000	847.6	5.35	1.85	0.78	0.20	0.03
25000	882.9	5.77	2.00	0.84	0.21	0.03
26000	918.2	6.22	2.15	0.91	0.23	0.03
27000	953.5	6.68	2.31	0.98	0.24	0.04
28000	988.8	7.15	2.47	1.04	0.26	0.04
29000	1024.1		2.64	1.11	0.28	0.04
30000	1059.4		2.82	1.19	0.30	0.04
35000	1236.0		3.77	1.59	0.40	0.06
40000	1412.6		4.85	2.04	0.51	0.07
45000	1589.2		6.07	2.55	0.63	0.09
50000	1765.7		7.42	3.12	0.77	0.11
55000	1942.3			3.73	0.93	0.13
60000	2118.9			4.41	1.09	0.16
65000	2295.5			5.13	1.27	0.18

Notes:
1. Standard conditions are 68F, 14.7 psia
2. Actual conditions are 68F and the pressure indicated
3. Values stop where pressure drop exceeds 10% of inlet pressure per limits of Darcy-Wiesbach.

Guidance for the Use of Concentrator Plant with Centrally Piped Medical Oxygen Systems

102.0 Scope. Oxygen Concentrator Plants have been in medical use for decades. Worldwide they are accepted as a viable option for Central Supply Systems. Rules for their safe application are found in all of the world's major standards, and the requirements for the quality of the product gas are contained in the major pharmacopeia.

The COVID pandemic exposed several issues with oxygen supply worldwide, many of which were previously considered to be problems only of underdevelopment. These problems have been widely detailed elsewhere and need not be reviewed here. This Guidance attempts to provide assistance to facilities attempting to manage the important learnings from recent experience around the world.

This guide was written to provide guidance and considerations for the usage of Oxygen concentrators in various configurations. While detailed in nature, this guide should not be used without first referring to your local codes and standards (including all applicable Pharmacopia requirements), consent from facility's clinical teams as well as following good engineering practices. This guide should also not be considered absolute or exhaustive in means and methods. Considerations should not be limited to devices and configuration but should also consider all applicable Pharmacopia requirements for their location and the capabilities, limitations, and policies of the facility's clinical operations department.

An essential result of that global experience has been to focus attention on concentrator plants as a tool for ensuring oxygen access. In specific:

A. Concentrator plants as primary Central Supply Systems. Detailed in the standards, this solution has long been an option but not one that was widely taken in places with good access to oxygen produced by air separation. COVID made it clear that even where liquid oxygen is plentiful there are situations when oxygen may not be deliverable from those air separation plants in time or in sufficient quantity. Therefore, on site production under the facility's control merits careful consideration.

B. Concentrator plants as supplements to other primary central supply systems. (liquid or cylinder based). This has been contemplated and attempted where facilities already had normally sized and fully functional liquid or cylinder systems in place, but struggled with the capacity of those systems during the crisis. These struggles included (as examples):

1. Inadequate stored volume and therefore high frequency cylinder changes or storage vessel fills.
2. Throughput or an inability of the existing supply to flow sufficient gas into the piping system.
3. Lack of any backup or reserve supply - the entire capacity of the installed Central Supply. System was needed just to keep up, so if any failure should occur the facility would simply be unable to respond.
4. Supply chain disruption or unreliable supply

A Concentrator Plant is a viable way to resolve many of these concerns both by providing additional supply and as a way of having capacity on standby.

C. Concentrator Plants as the primary Central Supply System, supplemented by liquid or cylinder supplies. A properly designed Concentrator Central Supply System is always provided with the capability to employ this strategy with no change to the base installation. As Concentrator Plants have a fixed output, a surge in oxygen requirements as occurred during COVID could easily overwhelm the Concentrator Plant's capacity. Where facilities are able to obtain liquid or cylinder supplies, those can provide a quick and effective way to boost capacity immediately, which can continue through an indefinite time, thereby avoiding the capital investment for additional concentrator plant which may not be usable after the crisis is passed. This strategy was also considered by facilities with some access to cylinders, but who found them to be too expensive, too labor intensive, unreliable, or too subject to supply chain interruption to be used as the primary supply.

Each of these possibilities has advantages and drawbacks. This Guidance is provided to assist in understanding how these may be implemented while ensuring safety both for patients and facilities maintenance personnel working with the systems.

102.1 Terminology. Generally, terms used herein will follow their meaning in common use. For technical terms, we have attempted to use the terminology employed in the Medical Gas Standards. If a term is not defined here, please refer to those standards.

These terms are of specific importance to understanding this Guidance:

Central Supply System: The entirety of the components comprising the oxygen source on the source side of the Source Valve. Required components for various configurations of Central Supply Systems are detailed in the Medical Gas Standards.

Concentrator: The device which actually performs the separation of oxygen from air typically using a zeolite molecular sieve and one of: Pressure Swing Adsorbtion (PSA), Vacuum Swing Adsorbtion (VSA), or Pressure-Vacuum Swing Adsorbtion (PVSA) (see Annex) However, the definition is not technology restrictive and any device which can produce the concentration and purity required by the pharmacopeia might be included.

Concentrator Plant: A source of supply, based on concentrator technology, connected to a piped oxygen distribution network in a medical facility. Depending on context, this may be a full Concentrator based Central Supply System or a single Concentrator based Supply Source.

Medical Gas Standards: Depending on the locality(ies) in which the User is based, the standard(s) in use may vary (see the reference standards list) and may involve standards other than the medical gas systems technical standard. The locally relevant standards should be consulted when using this Guidance.

Supply Source: A collection of components necessary to control, monitor and supply oxygen, whether from a liquid container, cylinder(s) or cylinder header(s) or a concentrator. Required components are detailed in the Medical Gas Standards.

Source Valve: The control valve on the patient side of all components of the Central Supply System which shuts off flow from the Central Supply System to the distribution piping.

Terminal: The attachment point and valve, located on the wall, ceiling or other device where the user will connect their clinical equipment and access the oxygen supply. Terminals are always gas specific to prevent misconnection. The keying systems are detailed in the Medical Gas Standards.

User: A trained medical professional capable of administering medical gases to a patient, assessing the condition of that patient, and adjusting the administration of the gases in response.

Pressure Swing Adsorbtion (PSA): is a technique used to separate some gas species from a mixture of gases (typically air) under pressure according to the species' molecular characteristics and affinity for an adsorbent material. It operates at near-ambient temperature and significantly differs from the cryogenic distillation commonly used to separate gases. Selective adsorbent materials (e.g., zeolites, (aka molecular sieves), activated carbon, etc.) are used as trapping material, preferentially adsorbing the target gas species at high pressure. The process then swings to low pressure to desorb the adsorbed gas.

Vacuum Swing Adsorbtion (VSA): segregates certain gases from a gaseous mixture at near ambient pressure; the process then swings to a vacuum to regenerate the adsorbent material. VSA differs from other PSA techniques because it operates at near-ambient temperatures and pressures. VSA typically draws the gas through the separation process with a vacuum. For oxygen and nitrogen VSA systems, the vacuum is typically generated by a blower.

Pressure-Vacuum Swing Adsorbtion (VPSA): VPSA systems apply pressurized gas to the separation process and also apply a vacuum to the purge gas. VPSA systems, like one of the portable oxygen concentrators, are among the most efficient systems measured on customary industry indices, such as recovery (product gas out/product gas in) and productivity (product gas out/mass of sieve material). Generally, higher recovery leads to a smaller compressor, blower, or other compressed gas or vacuum source and lower power consumption. Higher productivity leads to smaller sieve beds.

Ceramic Ion transfer Membrane (MCOG): MCOG systems disassociate O2 into oxygen ions, transfer those ions across a selective membrane, and return them to O2. The nature of the process is such that these concentrators produce essentially 100% oxygen. MCOG systems were under development at the time of writing, and may become commercially available during the life of this Guidance.

102.2 Applicability. Basics Necessary for Understanding and Applying this Guidance

102.2.1 The Pharmacopeia. The clinical value of Concentrators is recognized in both the U.S. Pharmacopeia and the European Pharmacopeia, and by World Health Organization's International Pharmacopeia.

All include monographs that specifically address zeolite based Concentrator oxygen as "Oxygen 93". The older monograph, "Oxygen" or "Oxygen 99" is designed for oxygen from air separation by liquefaction. The difference results from the fact that the zeolite molecular sieve is also quite effective at concentrating the trace Argon in the air. Argon is nontoxic and inert, and has been shown to present no clinical concerns, but it does reduce the concentration of oxygen in the final product gas.

It is essential to understand that these monographs are production standards, defining the quality of the product as it emerges from the production process (the outlet of the Concentrator Supply Source or the air liquefaction plant). In the pipeline and at the Terminal, the gas administered to the patient is the responsibility of the User. A moments thought, and you will appreciate why this is true - every patient must be dosed as an individual, and therefore the concentration they are given of a specific drug must be the subject of a User's understanding of the clinical need subject to monitoring the patient's condition.

The two monographs are summarized below. In general, Concentrators are designed to meet the production standard for Oxygen 93, air separation will meet Oxygen 99.

Constituent	Oxygen	Oxygen 93
Assay (O2)	≥99%	90-96%
Balance	na	argon (≅ 5%) and nitrogen
	Store in cylinders or pressurized storage tanks.	Produced by molecular sieve process. Store in cylinders or low-pressure tanks.
Odor	none	none
CO2	0.03%	0.03%
CO	0.001%	0.001%
USP is used for this comparison		

Note that the monographs are the same with the exception of the concentration of oxygen in the gas. Therefore, they are not different gases, they are *different concentrations of the same gas*. The analogy would be aspirin 60 mg vs. aspirin 100 mg. Both aspirin, same clinical indications.

There are legal jurisdictions which do not recognize this, and treat these two as if they were entirely separate drugs. The analogy would be aspirin and acetaminophen (paracetamol). Different chemical compounds entirely, different clinical indications. However much separating the two may ignore the clinical realities (ref. Annex on Clinical References), where that pharmacologic limitation exists you may not be able to use much of this guidance because you may not be permitted to mix the two concentrations.

Most relevant to you in this Guidance will be the section entitled *Concentrators as Central Supply Systems* and the Annexes. Everything that follows in this Guidance is based on this essential understanding.

102.3 Clinical Equipment. It is known that some manufacturers of medical equipment (anesthesia workstations, ventilators, etc.) have designed their equipment on the assumption that the oxygen from a wall outlet was 99+% and thus could be used as an internal machine reference. While this has always been a questionable assumption, when zeolite based Concentrator oxygen is used, it naturally becomes entirely invalid. Oxygen concentration from an ordinary zeolite based Concentrators can and will vary during normal operation. While this has been demonstrated to mean little to the patient, it can be of the first importance with the clinical apparatus.

This problem is a limited one, as only some equipment has this problem. It is also obvious from the experiences of many Users that it has not proven much of an obstacle to the use of Concentrators. However, until this is fully addressed by the medical device manufacturers, Users of oxygen 93 must choose their equipment with this in mind and may need to obtain calibration gases with known values to ensure certain clinical apparatus and flowmeters be accurately calibrated. This subject is outside of the scope of this Guidance, but this concern should be noted and the medical staff should always be aware when a Concentrator is used as an oxygen supply.

Otherwise, when Concentrators are employed, the usual guidelines that would be expected of any clinical situation are sufficient. Patient SaO2 (blood saturation) should be monitored and the FiO2 (fraction inspired oxygen) of the inspired gas adjusted as required to titrate the desired SaO2. It is always inappropriate to base any respiratory treatments on FiO2 alone.

102.4 Compliance with Existing Medical Gas Standards. The Medical Gas Standards deal with the basic requirements for any piped medical gas system. These usually deal with essentials such as basic safety and qualifications, sizing, operation both in normal circumstances and in single fault, the cascade from primary to secondary to reserve Supply Source(s) within the Central Supply System, installation requirements, monitoring, maintenance and other concerns. Anyone using this Guidance document should first verify that their current Central Supply System is in compliance with their Medical Gas Standards before considering any of the concepts discussed here.

Much of what we will discuss here will not be found in any Medical Gas Standard, rather it will be covered under the clauses which are intended to allow for alternative methods and technologies (e.g. NFPA 99 2021 clause 1.4, CSA Z 7396-1 2017 Preface and Annex O, ISO 7396-1 2016 clause 4.2). Applying the concepts in this Guidance will require understanding of the rules in your Medical Gas Standards so as to apply these concepts within those rules where possible, and safely in every case.

The reader should understand the alternative methods and technologies allowances in their Medical Gas Standards and also know any procedures needed to obtain any required authorizations under these exceptions from their local regulatory authorities.

Any Concentrator employed in any centrally piped medical gas system must be a *complete* Supply Source as per the relevant technical Medical Gas Standard, including all operating safety elements, installation considerations, location, power supply, monitoring and alarms, etc. (ref. Annex II). This Guidance expects in all cases that only compliant Supply Sources will be employed in implementing any suggestions herein.

It should also be considered that the optimal application of a concentrator system is to maintain continual operation. Increasing and decreasing the output of a concentrator is acceptable but cycling it on and off will not provide optimal performance and may negatively impact the equipment's lifespan. Once a concentrator is cycled off it can take some time when turning it back on to achieve acceptable concentration.

102.5 Common Elements and Control Techniques.

102.5.1 Control Techniques. The most essential starting point for any of the methods discussed herein is how one intends to control the available sources. This includes how and when they will stop and start, how their output (both pressure and volume) will be managed, and the consequences of blending them.

The first essential is to understand the method in use on the Central Supply System to be supplemented. It may be possible to link the Supplementing Supply Source into that control mechanism, but it is more likely to be necessary or desirable to replace the mechanism with another better suited to the new setup.

Three controls techniques can be considered:
1. Pressure control
2. Flow control
3. Concentration control

Details on the basic operating principle for each of these are below:

102.5.1.1 Pressure Control. will set a target pressure and will place regulators in position to ensure that the set pressure is maintained. As the pressure falls (e.g. as one source begins to be overdrawn) the regulators on the supplemental source will open, admitting gas from the supplemental source to the line. (See **Figure 102.5.1.1**)

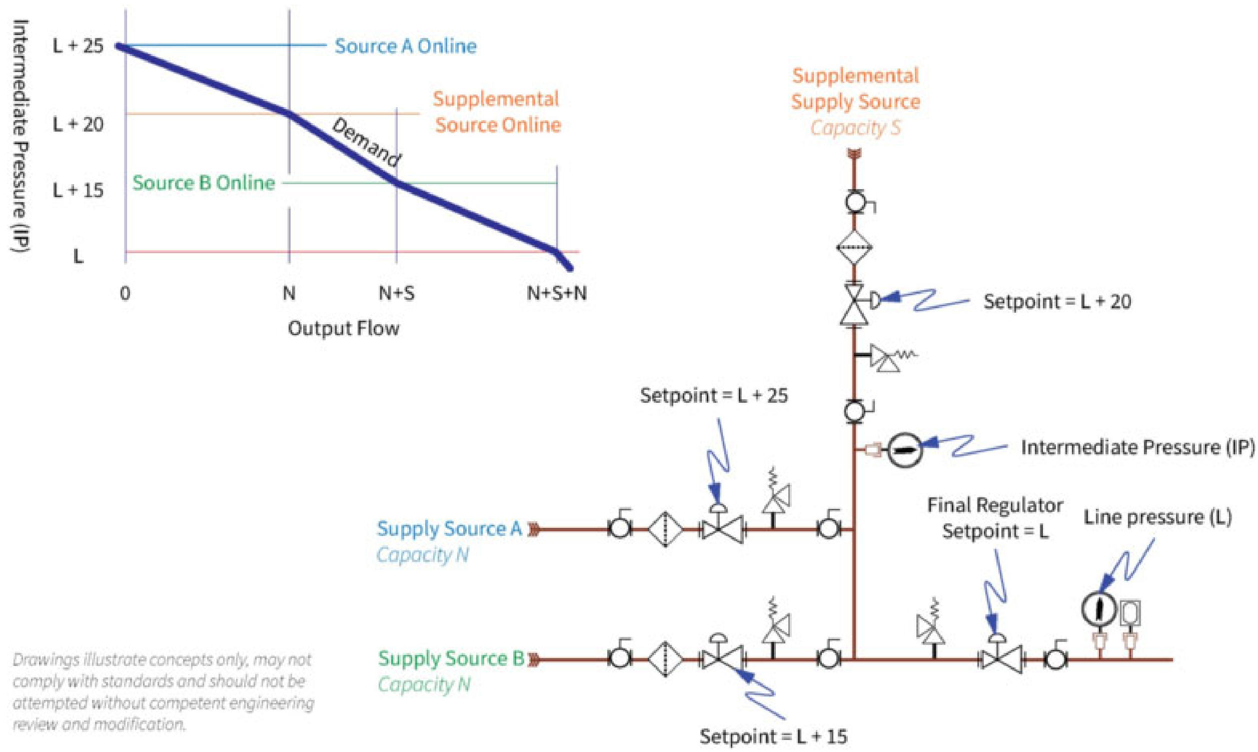


FIGURE 102.5.1.1
PRESSURE CONTROL

In Figure 102.5.1.1 the system pressure is maintained by the Final Line Regulator and the three Supply Sources are controlled by a regulator on each Supply Source controlling against an intermediate pressure (IP). As the system demand increases, the intermediate pressure will fall, so that first source A, then the Supplemental Source, then <u>Source B comes on line to feed the system</u>. The graph shows a two source Central Supply System with Supply Sources A and B being supplemented by a smaller Supplemental Source.

Pressure control in some cases can also be achieved with electronic controls such as variable speed controlled on pressure, or start-stop machines controlled on pressure. In all methods, the basic idea is the same: each source is set at a different output pressure and comes on line when that pressure cannot be maintained by the preceding source(s).

The limitation with pressure control is that it cannot ensure that all sources are used proportionately. This can be problematic with cryogenic liquid sources where the normal evaporation of the liquid must be used or lost and with concentrators which must be operated to maintain readiness. More complex controls will need to be added to this basic scheme to ensure these additional concerns are addressed.

102.5.1.2 Flow Control. is primarily intended to ensure proportionate use of all Supply Sources. The basic principle is to meter the total demand, and then to supply a preset proportion of that demand from each of the available sources. (See **Figure 102.5.1.2**)

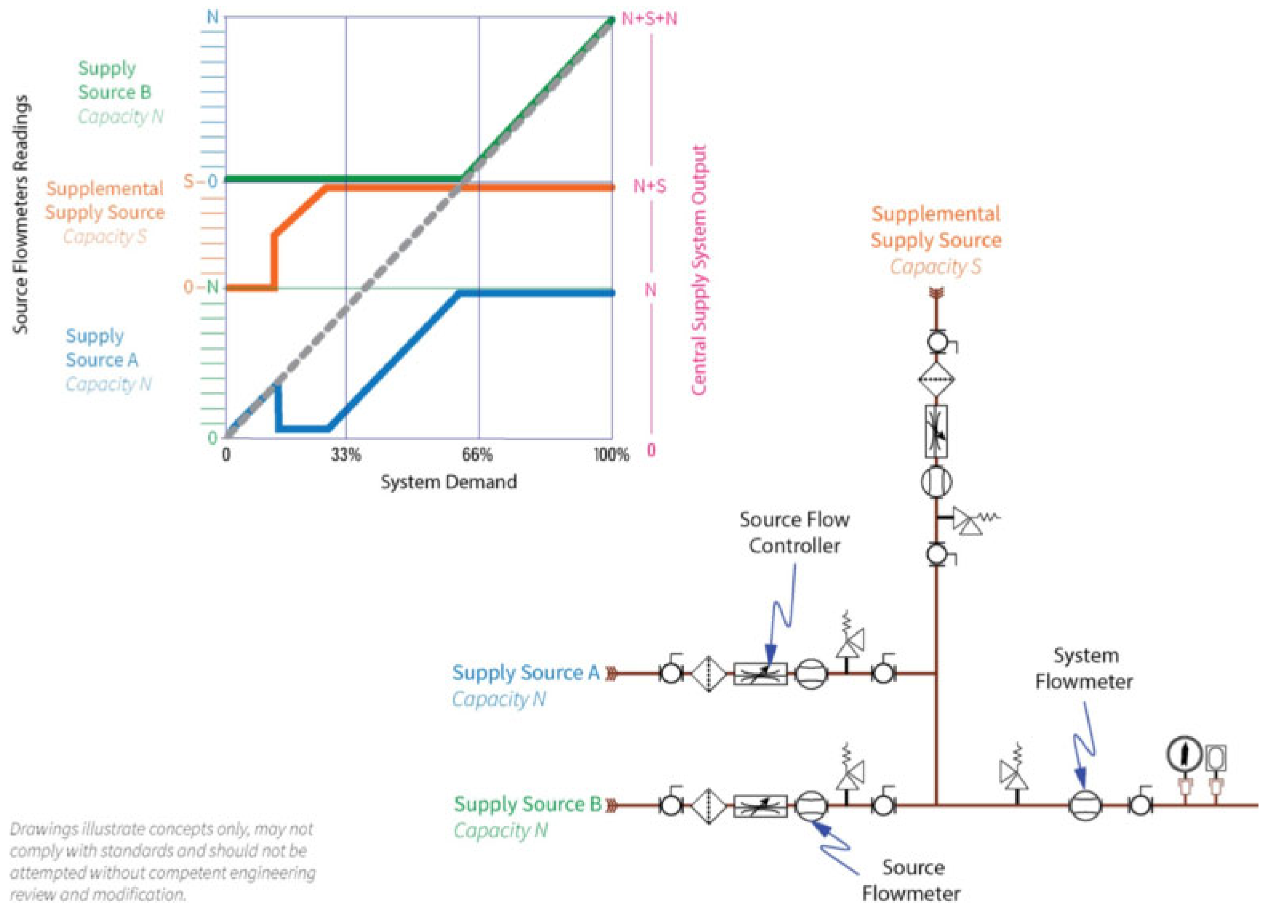


FIGURE 102.5.1.2
FLOW CONTROL

In Figure 102.5.1.2 each Supply Source is fitted with a flow controller and flowmeter, to control the output from that specific Supply Source. The system is also fitted with a flowmeter to monitor the total flow.

As the demand increases on the system overall, each of the Supply Source flow controllers opens to allow a metered portion of the total requirement to flow from that Supply Source into the system. This output is monitored by the flowmeter for that Supply Source. Flow control will allow each source to operate at a level preset by the operator for that demand.

In the example, Supply A is a liquid source, the Supplemental Supply Source is a concentrator and Supply Source B is a cylinder header. At very low flows, the flow controller first activates the Liquid Source (A)_to account for evaporation. Because concentrators do not like to start and stop, the system continues to draw from the Supply Source A until the demand is sufficiently high to operate the concentrator efficiently, at which point it actually reduces the flow from the Liquid Supply Source back to the evaporative rate and ramps up the concentrator in the Supplemental Source. When the Supplemental Source reaches full capacity, the controller begins to any draw additional requirements from Source A. Only when both Source A and the Supplemental Source are at full capacity, does the controller begin to draw from Source B, the cylinder supply.

Across the demand curve, the flow from each Supply Source can thus be tuned to keep all the sources running optimally.

The disadvantage of flow control is that it is complex and adds a number of relatively expensive components to the system. Setup requires expertise in the devices and in the required programming of the computer or PLC which will manage the flow controllers.

102.5.1.3 Concentration Control. is the most complex, but offers all the advantages of flow control while adding the additional benefit of being able to actually increase the total output of the system. Here, the control will be set to manage the flow from each Supply Source as with flow control but with the additional element of control over the final oxygen concentration as well.

Concentrator sources are typically rated at 93 or 95% concentration. However, the pharmacopeial requirements allow for a concentration between 96 and 90%. The volume output increase from the concentrator at lower concentrations can be significant (10% or more). Therefore, running the concentrator at the lowest allowed concentration can improve total gas availability from the overall Central Supply system.

Clinicians also sometimes find that variability of the concentration undesirable, particularly in facilities treating very small neonates. Concentration control offers a way to stabilize that output concentration as well. (See **Figure 102.5.3**)

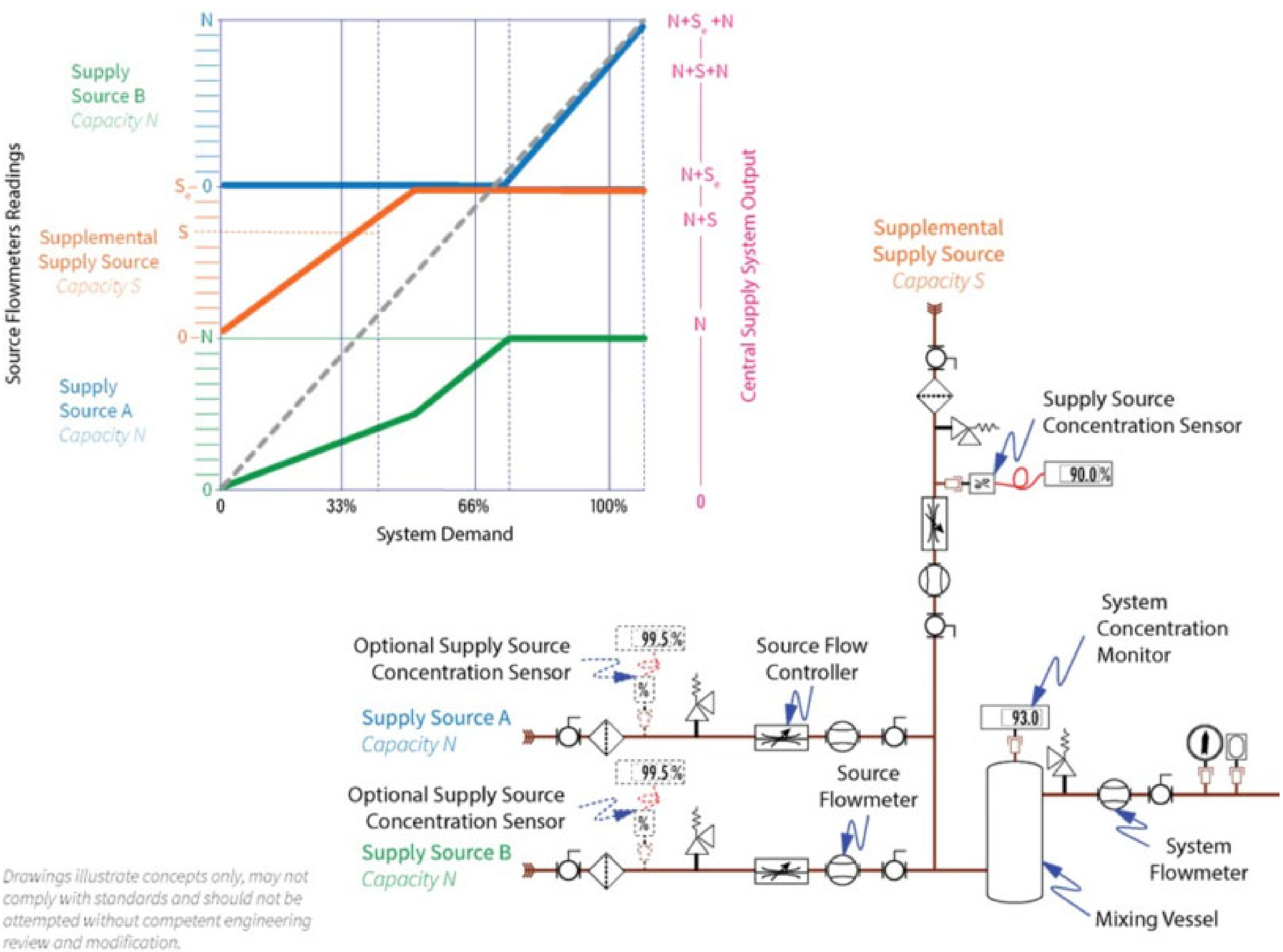


FIGURE 102.5.1.3
CONCENTRATION CONTROL

In Figure 102.5.1.3 the Supplemental (Concentrator) Supply Source is fitted with a flow controller to control the output. This flow controller is driven from the concentration monitor and operated in a manner which will hold the concentration just at 90%, thereby optimizing the output from the Concentrator source.

The other Supply Sources may have concentration monitors, or they may be assumed to be 99%. Their flow controllers will meter a portion of the total requirement to compensate for the lower concentration from the Supplemental Supply Source, or may simply operate as in the Flow Control example above (in the graphic here the various complex effects of the flow control are removed to emphasize only the result of concentration control)

The controls are metering the flow from the sources to ensure the final concentration is maintained at whatever set point the facility has determined. They will draw first from the Supplemental Supply Source, and mix as needed gas from Supply Source A to maintain the flow at the concentration decided. There will come a point in this configuration where the concentration control can no longer operate, and that is of course when the concentrator is producing maximum output. Beyond that point, the concentration will inevitably rise as the additional load is drawn entirely off the other (99% concentration) sources.

Note that all of this is dependent on the concentration chosen. A higher concentration will naturally draw more from the higher concentration source, and less from the low concentration source, greatly changing the shape of the graph, and there are limits to how much the concentration can be "boosted" from a low concentration source.

The disadvantage of concentration control is of course the additional complexity and setup involved. However, many concentrators use concentration control as their standard method to manage the process internal to the concentrator itself.

The example is a basic idea of what concentration control can achieve. It is *possible* to take this further, and actually run the concentrator below 90%, compensating with the high concentration gas from the other sources to produce the desired final concentration. Note that doing that greatly complicates the regulatory problems with the Central Supply System and should not be undertaken without detailed understanding of the operation of the system, close operator supervision, and appropriate regulatory approvals.

The examples above illustrate these control strategies applied by adding a single concentrator supply source as supplement to an existing two source Central Supply System (e.g. NFPA type). They could also be applied in the same manner to a three source Central Supply System (ISO Type). There is also the possibility of using Flow control and / or concentration control to operate multiple supplemental sources, thus achieving additional capacity or load balancing multiple sources to manage very wide swings in demand.

102.6 Configurations and Operations.

102.6.1 Concentrators as standalone Central Supply Systems. The essentials for using Concentrators as Central Supply Systems will be the rules defined by your Medical Gas Standards. There is therefore no need for this Guidance to review this option.

102.6.2 Concentrators Used to Supplement Liquid or Cylinder Based Central Supply Systems. The goal of using a Concentrator to supplement an existing liquid or cylinder based Central Supply system might be:

To increase the total quantity of oxygen available, typically because at peak flows the current source cannot keep up.This is probably the result of exceeding the full capacity of the existing Central Supply System equipment.

To provide a backup source when the current Central Supply System can keep up, but it must draw from the secondary or reserve supply to do so, which leaves the facility no resort in the event of any failure.

This may be on a short to medium term basis, or a permanent installation for emergency preparedness.

A. Configuring a System. First, ensure that your existing Central Supply System is compliant with your Medical Gas Standards.

B. Sizing. The sizing of a concentrator source for use in supplementing an existing Central Supply System will naturally come down to the degree of supplementation required. However, the capacities of the two systems types are typically sized differently. To have a clear understanding of how one will interact with the other, these need to be reconciled.

The primary constraint on a liquid supply or cylinder manifold generally arises from the total volume of gas available in the containers or cylinders. The analogy would be the size of a battery. Sizing is largely an exercise in determining how big to make the "battery" (how many cylinders, how big a liquid container).

In liquid and cylinder sources, before other output problems will generally appear, the number of cylinders being changed or times the liquid container is being refilled is what will come to the operator's attention. As an example, a properly sized manifold with 10 cylinders on a side will typically experience a long-term average draw rate of perhaps 600 liters per hour (lph). Thus, 10 cylinders, one side of the manifold, will be changed once a week, which will take perhaps 10 minutes per cylinder, so the whole exchange will require about an hour and a half's effort. If the draw rate doubles to 1,200 lph, then the same 10 cylinders will now need attention roughly twice a week, or three hours labor weekly.

The output (flow) capability of even a relatively poor manifold is typically well over 20,000 liters per hour, and a good one can flow better than three times this (90-95,000 lph). Therefore, before the manifold's maximum draw rate has even been approached, the manager is going to notice the inconvenience of the extra cylinder changes. By the time the manifold cannot manage the flow, the changing of cylinders will have to be continuous, as a bank of 10 cylinders would last as little as 40 minutes.

By comparison, a concentrator's primary constraint is the output. A concentrator rated for 1,000 lph cannot be expected to produce 1,001 lph. This "hard limit" means that the rated output is all that will be available for supplementation.

C. Operation and Maintenance. Operation and maintenance should be conducted and followed based on the concentrators manufactures requirements.

Disclaimer: Always follow manufacturer's recommendations and adhear to the local authority having jurisdiction.

102.6.3 Liquid or Cylinder Supply Sources Used to Supplement Concentrator Based Central Supply Systems. Concentrators have a defined output, determined by the Medical Gas Standards and the requirement to maintain the pharmacopeia's production quality. It is very possible in a crisis for the draw on the Concentrator to reach this limit. The typical goal of supplementing a Concentrator Central Supply System from liquid or cylinders Supply system would be to increase the total quantity of oxygen available to the distribution pipeline.

The disadvantage of the system is that when there is an emergency demand surge for a large system, it will require large capacity of supplemental source(s). Having a liquid bulk tank system on standby is not practical nor economical, having a large number of cylinders will not be practical either. An emergency oxygen trailer to be connected to EOSC would be a suitable option.

A. Configuring a System. First, ensure that your existing Central Supply System is compliant with your Medical Gas Standards.

B. Sizing. Recommended procedures include the following.

1. Obtain historic onsumption data from the facility and clinical teams. We recommend consumption data collected from 1 to 5 years, including descriptions of any abnormal usage, leading to sudden increase in consumption.
2. Determine required system capacity based on historic peak flow, balanced with cylinder storage
3 Obtain consent with the clinical team of the sizing
4. Provide N+1 units for minimum redundancy. It is highly recommended to provide redundant 2N concentrator systems.
5. Provide separate oxygen cylinder storage room with proper fire rating per code

It is prudent to provide bottle-filling unit, to provide additional buffer/storage as well as for portable O_2 use.

Although it is not a code requirement, it is highly recommended to provide EOSC (Emergency Oxygen Supply Connection) with parking space for emergency oxygen trailer and oxygen fill truck access at building exterior nearby, so the facility has more flexibility to handle sudden O_2 demand surge.

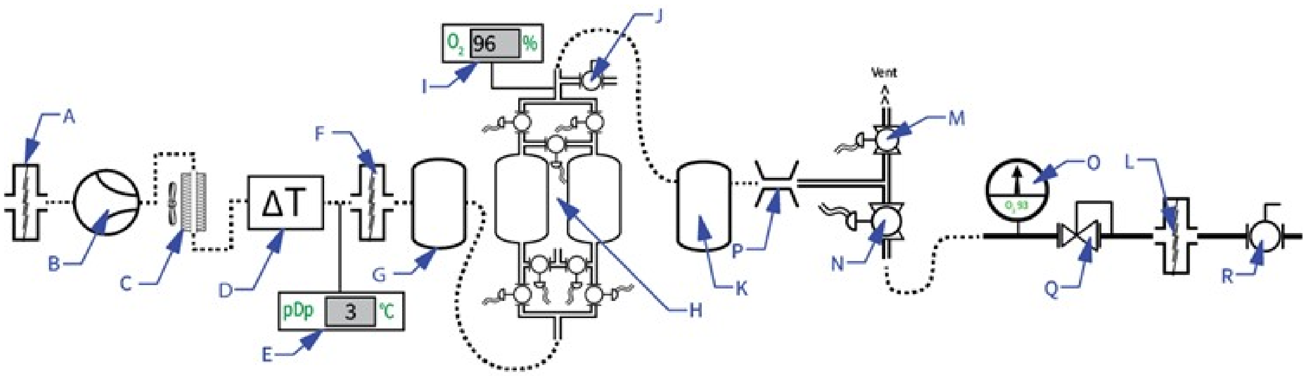
C. Operation and Maintenance. *Regular routine maintenance is critical to maintain the optimal operation condition of the concentrator system*

Disclaimer: Always follow manufacturer's recommendations and adhear to the local authority having jurisdiction.

Annex I

Example Concentrator Supply Source Configurations
Part A: PSA

Part A - Typical Components of a Pressure Swing Adsorption (PSA) Concentrator Supply Source
(Components shown are typical - other arrangements are possible. NFPA 99 2021 used for reference)



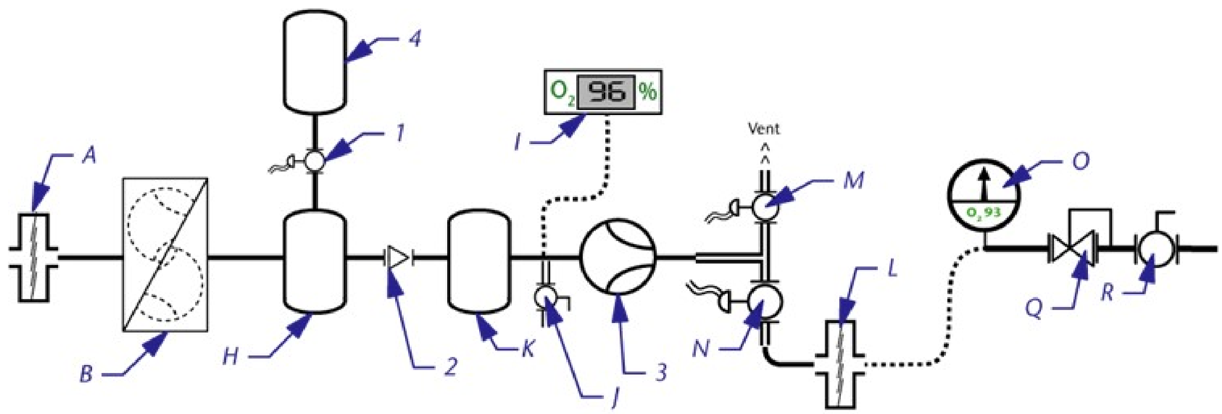
A	Inlet filter	J	Sample and purge port
B	Compressor	K	Oxygen receiver
C	Aftercooler	L	Final filter (0.01 µ)
D	Refrigerated Air dryer	M	Vent valve (optionally automatic)
E	Dew point monitor (optional)	N	Automatic Concentrator isolation valve
F	Filter	O	Pressure gauge
G	Air receiver	P	Flow control (optional)
H	Concentrator	Q	Outlet pressure regulator (optional)
I	Oxygen concentration monitor	R	Manual Supply Source isolation valve

Available Alarm Connections:	
Low Oxygen Concentration (<91%)	Supply Source Disconnected (Valve “N” Closed)

Annex I

Example Concentrator Supply Source Configurations
Part B: VSA

Part B - Typical Components of a Vacuum Swing Adsorbtion (VSA) Concentrator Supply Source
(Components shown are typical - other arrangements are possible. NFPA 99 2021 used for reference)



A	Inlet filter	3	Booster compressor
B	Blower	4	Flush vessel
H	Sieve bed	M	Vent valve (optionally automatic)
I	Oxygen concentration monitor	N	Automatic Concentrator isolation valve
J	Sample and purge port	O	Pressure gauge
K	Oxygen receiver	P	Flow control (optional)
L	Final filter (0.01 µ)	Q	Outlet pressure regulator (optional)
1	Flushing supply valve	R	Manual Supply Source isolation valve
2	Check valve		

Available Alarm Connections:	
Low Oxygen Concentration (<91%)	Supply Source Disconnected (Valve “N” Closed)

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