VITAL DESIGN

*How **engineers** can **help doctors** save lives with properly functioning **medical gas** and **vacuum systems***

by Donald Keith, CPD, MSS

In the past year, healthcare has been a hot political topic—how much we pay, what we get for that price, and what insurance provides. However, in the actual practice of healthcare, no matter what you pay, who pays, or what type of insurance you have, a hospital must render accessible and adequate attention to all who enter its doors. Thus, the real concern is whether a hospital is capable of providing the required service. Do the doctors have the necessary skills, equipment, and medical gas and vacuum systems readily available?

Engineers and architects can enhance doctors' skills and abilities by providing suitable designs for the required medical gas systems and services, which are a major necessity in any hospital or healthcare facility. These services are administered to patients by a doctor's prescription. Hospital medical gases are prescription drugs governed under the guidance of the U.S. Food and Drug Administration (FDA). However, the FDA does not provide guidance for the design of medical gas systems. This falls under the jurisdiction of

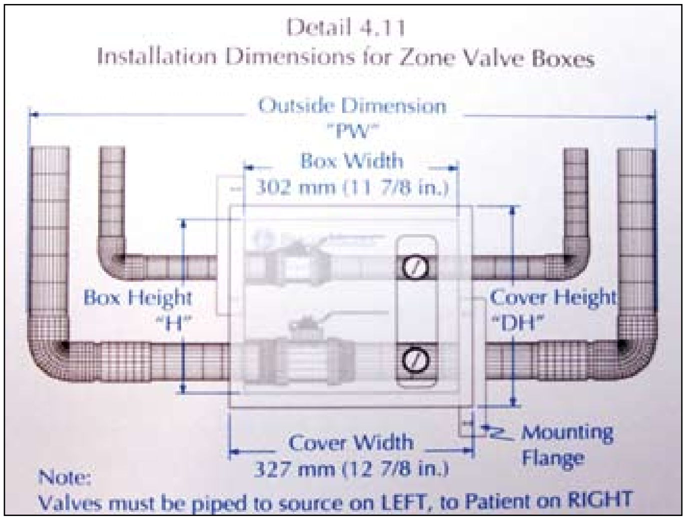


Figure 1 Zone valve box *Source:* BeaconMedaes

National Fire Protection Association (NFPA) standards. The NFPA standards, your experience, and asking doctors the right questions before design are essential to the provision of properly designed medical gas and vacuum systems.

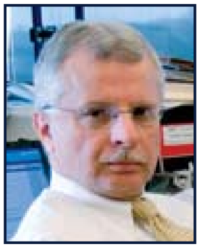
Most medical system sizing information used by design engineers and expressed herein is derived from *Guidelines for Design and Construction of Healthcare Facilities* by the American Institute of Architects (AIA), *Facility Piping Systems Handbook* by Michael

From this information, the daily flow can be calculated, and from the treatment time the sizing of the tanks can be achieved. The tanks are typically ASME 316L stainless steel design vessels. All electrically powered equipment should be provided with standby power. All equipment and controls should be arranged to allow for service without interruption of the collection and treatment of the waste. (There are a number of other specific design considerations for the effluent decontamination equipment to consider, but they are too numerous for this article to address.)

One important aspect of monitoring the effluent decontamination system is that it is necessary to record all operational parameters to validate the decontamination of the waste. All systems utilize a microprocessor-based control panel, which typically is interconnected to the building automation system (BAS). The effluent decontamination system can be configured to record any specific parameters and alarms and can output this information to the BAS system. Per the BMBL, decontamination of all liquid wastes must be documented, the process must be validated physically and biologically, and the biological validation must be performed annually or more often if required by institutional policy. Records must be maintained and be available for inspection by any regulatory agencies (federal, state, or local) that may request them.

KNOWLEDGE IS CRUCIAL

We hope it is clear that understanding of how the facility operates is critical for the design and sizing of systems for high containment. Do not attempt to design systems without a thorough discussion with the owner regarding the limitations of the design of the systems. It may help to conduct a hazardous operations assessment of these systems to review any potential maintenance or safety issues and make sure they are evaluated and addressed during the design. PSD



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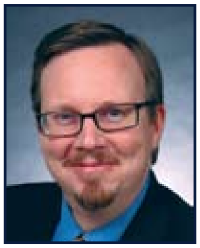

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Table 5 Medical vacuum pipe (vertical) main service line sizing

Start	End	Run, ft	Flow, lpm	Actual scfm	Pipe Size, in.	Loss/100	Loss	Running Subtotal
A	B	12	765	27	1½	0.197	0.02364	0.02364
B	C	12	1,530	54	2	0.183	0.02196	0.0456
C	D	12	2,295	81	2	0.354	0.04248	0.08808
D	E	12	3,060	108	2½	0.210	0.0252	0.11328
E	F	12	3,825	135	2½	0.318	0.03816	0.15144
F	G	175	4,590	162	2½	0.430	0.7525	0.90394

gested sizing system. All are based on AIA guidelines, as well as NFPA 99, 99C, 50, and 101.

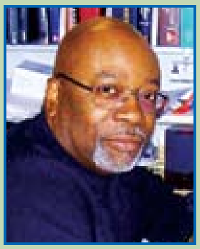
The vacuum sizing chart assumes a source pressure of 19 in. Hg and an ambient temperature of approximately 68°F. The engineer's starting point is the most remote outlet.

In Figure 4, the first outlet is served by the segment of pipe marked A – B. Segment A – B supplies 1.5 liters per minute (lpm). Per the chart, you can interpolate the lpm to achieve 42.5 actual lpm at a loss per 100 feet, which equals 0.01178 loss (38 feet x 0.031/100) in this segment of piping. Continue the pipe loss procedure per segment as indicated. Table 4 provides the pipe size based on the pressure loss of each pipe segment. Place each segment and pipe size as arranged in the vacuum sizing chart (Table 5).

Once all segment losses have been tabulated, you must verify that the total does not exceed the maximum allowed 4 psi for vacuum systems (5 psi for other systems). The calculations above indicate a total system pressure loss of 1.15 psi (0.24477 + 0.90394). This tells us that the system is well within the maximum loss limit. In the future, adding additional vacuum load to this piping system will be possible without replacing the piping.

If the total had exceeded the maximum 4-psi allowed system loss, a reevaluation of the entire vacuum system or individual line segment losses would be needed to determine how to lower the pressure losses.

This procedure is similar for medical air, oxygen, and other medical gas piping systems. What makes the sizing different is their assigned value for rooms, beds, or procedures. Each gas and vacuum outlet has an assigned cubic foot per minute (cfm) or liter per minute (lpm) value. Be sure in your design to follow the lpm designation. Standard cubic feet per minute (scfm) is the cfm prior to the source pump. Actual cubic feet per minute (acfm) is the actual cfm after the source pump. Confusing these designations can cause design sizing errors. Remember to always follow any design methods with the guidance of an experienced medical design professional. PSD



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Frankel, *Plumbing Engineering Design Handbooks* by the American Society of Plumbing Engineers (ASPE), and *Practical Plumbing Design Guide* by James C. Church. Manufacturers such as Allied Medical and BeaconMedaes provide cookbook concepts and compilations of sizing and system design based on their employees' experience. These references are based on the following NFPA standards: 50: *Standard for Bulk Oxygen Systems at Consumer Sites,* 99: *Standard for Healthcare Facilities*, 99C: *Standard on Gas and Vacuum Systems,* and 101: *Life Safety Code*.

A multitude of studies, design guides, and handbooks are available, but you should keep in mind that none of these studies, standards, and guides can be used without the doctors', nurses', and/or user groups' guidance, especially for the specialty requirements of clinics, operating and special procedure rooms, hospital laboratories, and other specialty departments.

The length limitations of this article preclude a full description of all medical gas piping systems, so the systems discussed will be abbreviated and limited to medical air, oxygen, and vacuum.

FACILITY DESIGN LEVEL

NFPA 99 requires medical gas and vacuum systems for hospitals and healthcare facilities to be designed adhering to one of three levels. Hospitals typically fall under Level 1. Levels 2 and 3 govern clinical, dental, and laboratory-type facilities or departments.

Hospitals are to be designed per the Level 1 rating based on the following criteria:

- Level 1 Medical Piped Gas Systems: These are systems serving occupancies where interruption of the piped medical gas and vacuum system would place the patient in imminent danger of morbidity or mortality.
- Level 1 Vacuum System: This is a system consisting of central vacuum-producing equipment with pressure and operating controls, shutoff valves, alarm warning systems, gauges, and a network of piping extended to and terminating with suitable inlets at locations where patient suction could be required.

WHERE TO START

The starting point in the design of medical gas systems is to determine the medical gas and vacuum outlet requirements, specifically what outlets and how many are required for

Table 1 Minimum station outlets for oxygen, vacuum, and medical air systems[1]

Location	Oxygen	Vacuum	Medical Air
Patient rooms (medical and surgical)	1/bed	1/bed	—
Examination/treatment (medical, surgical, and postpartum care)	1/room	1/room	—
Airborne infection isolation/protective environment rooms	1/bed	1/bed	—
Seclusion room (medical, surgical, and postpartum)	1/bed	1/bed	—
Intermediate care	2/bed	2/bed	1/bed
Critical care (general)	3/bed	3/bed	1/bed
Airborne infection isolation	3/bed	3/bed	1/bed
Coronary critical care	3/bed	2/bed	1/bed
Pediatric critical care	3/bed	3/bed	1/bed
Newborn intensive care	3/bassinet	3/bassinet	3/bassinet
Newborn nursery (full-term)	1/4 bassinets[2]	1/4 bassinets[2]	1/4 bassinets[2]
Pediatric nursery	1/bassinet	1/bassinet	1/bassinet
Pediatric and adolescent	1/bed	1/bed	1/bed
Psychiatric patient rooms	—	—	—
Seclusion treatment room	—	—	—
General operating room	2/room	3/room	—
Cardio, ortho, neurological	2/room	3/room	—
Orthopedic surgery	2/room	3/room	—
Surgical cysto and endo	1/room	3/room	—
Post-anesthesia care unit	1/bed	3/bed	1/bed
Phase II recovery[3]	1/bed	3/bed	—
Anesthesia workroom	1/workstation	—	1/workstation
Postpartum bedroom	1/bed	1/bed	—
Labor room	1/room	1/room	1/room
Cesarean/delivery room	2/room	3/room	1/room
Infant resuscitation space[4]	1/bassinet	1/bassinet	1/bassinet
OB recovery room	1/bed	3/bed	1/room
Labor/delivery/recovery (LDR)	1/bed	1/bed	—
Labor/delivery/recovery/postpartum (LDRP)	1/bed	1/bed	—
Initial emergency management	1/bed	1/bed	—
Triage area (definitive emergency care)	1/station	1/station	—
Definitive emergency care exam/treatment rooms	1/bed	1/bed	1/bed
Definitive emergency care observation unit	1/bed	1/bed	—
Trauma/cardiac room(s)	2/bed	3/bed	1/bed
Orthopedic and cast room	1/room	1/room	—
MRI	1/room	1/room	1/room
Cardiac catheterization lab	2/bed	2/bed	2/bed
Autopsy room	—	1/workstation	—

[1]For any area or room not described, the facility clinical staff shall determine outlet requirements after consultation with the authority having jurisdiction.
[2]Four bassinets may share one outlet that is accessible to each bassinet.
[3]If the Phase II recovery area is a separate area from the PACU, only one vacuum per bed or station shall be required.
[4]When infant resuscitation takes place in rooms such as cesarean section/delivery or LDRP, then the infant resuscitation services must be provided in that room in addition to the minimum services required for the mother.

Source: Guidelines for Design and Construction of Healthcare Facilities

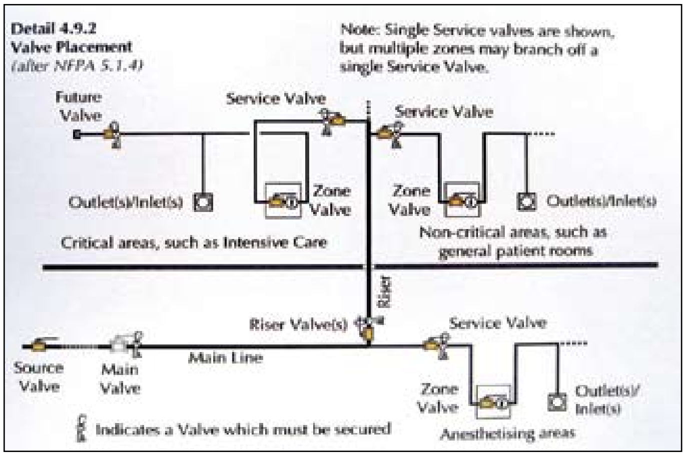

Figure 2 Valve placement *Source:* NFPA 99C

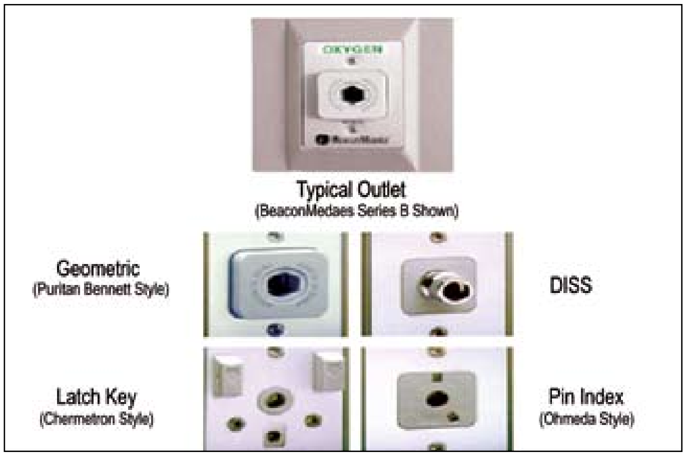

Figure 3 Medical gas and vacuum outlets *Source:* BeaconMedaes

a specific department or room under design. In any department, the lead doctor and/or the user group can provide the number and location of the medical outlets required. *Guidelines for Design and Construction of Healthcare Facilities* provides a table outlining the minimum station outlets for oxygen, vacuum, and medical air systems in hospitals (see Table 1). This table does not include all possible medical gas and vacuum outlets used in a modern facility. Other medical outlets include nitrous oxide, nitrogen, carbon dioxide, instrument air, and WAGD (waste anesthesia gas disposal). The *BeaconMedaes Medical Gas Design Guide* includes these additional medical gas outlet requirements.

ZONE VALVE BOXES

Once the medical gas outlets have been located, zone valve boxes should be placed as required (see Figure 1). Every outlet in the hospital must be controlled by a zone valve box, which can be located per floor, area, or wing of the facility. Critical care units (areas where anesthesia is administered) must have their own individual control valves. Valves must be located outside the critical area and within the path of exit. If a person is standing next to the control valve and is within the same space occupied by the outlet, then the valve is not placed in an acceptable location.

SOURCE

Medical gas and vacuum outlets are the beginning of the piping system. The zone control valves are intermediate in the system, and the end point is the source of the medical gas and vacuum. Medical air, vacuum, and WAGD systems are the only on-site manufactured mediums. All others are provided by a tank manifold system. At this point, there is a coordination issue between the architect, facility engineer, and design engineer regarding the appropriate location of the source mediums. The desired location of the source mediums completes the piping destinations of the medical gas and vacuum systems. Now the routing of the pipe can begin.

PIPE AND PIPE ROUTING

Pipe routing is basically a "connect the dot" exercise. Piping starts at the medical gas outlets, runs through the zone control box, and ends at the source point. Piping should be run as straight and true as possible. Special consideration must be given to avoid unnecessary turns required by duct locations or other obstructions. Keep in mind that all turns in the piping require fittings, and fittings add length to the total piping system. Access fittings also produce higher pressure loss, which must be overcome by the medical gas and vacuum source unit.

The ideal mounting for vacuum piping would include sloping. Sloping of vacuum piping away from the patient is desirable to keep the outlet free of moisture. This slope may not always be attainable, but the designer should keep fluid drainage in mind. The designer also should make sure sags in medical gas and vacuum piping are eliminated.

Care should be taken to minimize penetrations of smoke partitions because these require fireproof sealing.

VALVES

After all piping is run satisfactorily, the medical gas outlet placements are approved, the zone valves are properly placed, and the medical gas and vacuum source equipment locations are set, the designer should evaluate the system for the placement of service valves, source valves, and main line valves (see Figure 2). Service valves shall be placed at the beginning of every system riser adjacent to the main line. This valve is one of the most confusing and draws the most adverse review comments of the system. NFPA 99 does not allow two valves in the same line. Should one valve be operated in adverse position of the other, a catastrophic condition may occur.

NFPA provides requirements for service valves when used. Service valves shall be located according to any one of the following:

- Behind a locked access door
- Locked in the open position above a ceiling
- Locked open in a secure area

A source valve must be provided at the source of the medical gas service in the immediate location of the tank or source equipment. Appropriate labeling must be provided.

The main line valve shall be located on the facility side of the source valve inside the building. The valve shall be placed in a secure area accessible only to the facility engineers.

AREA ALARM

Area alarm panels shall be provided to monitor all medical gas, medical and surgical vacuum, and piped WAGD systems supplying anesthetizing locations and other vital life support and critical areas. Area alarms shall be placed primarily at the nurses' station. However, any area that is under surveillance is acceptable.

Alarm panels shall be set to alarm when pressures rises or drops 20 percent from required pressure settings. The sensor for area alarms in vital life support areas shall be located on the patient side of the zone valve box. Sensors in areas for anesthetizing gas delivery shall be installed on either the source or patient side of the individual room zone box assembly. Note: Sensors shall not be placed in a position that would impede their operation, particularly by valve locations.

Table 2 Allowance for friction loss in fittings as equivalent lengths

Fitting Size, inches (mm)	Ells, feet (meters)		Tees, feet (meters)		Couplings, feet (meters)
	90	45	Side	Run	
½ (13)	0.5 (0.2)	0.3 (0.1)	0.75 (0.2)	0.15 (0.05)	0.15 (0.05)
¾ (19)	1.25 (0.4)	0.75 (0.2)	2 (0.6)	0.4 (0.12)	0.4 (0.12)
1 (25)	1.5 (0.5)	1 (0.3)	2.5 (0.8)	0.45 (0.14)	0.45 (0.14)
1.25 (32)	2 (0.6)	1.2 (0.4)	3 (0.9)	0.6 (0.18)	0.6 (0.18)
1.5 (38)	2.5 (0.8)	1.5 (0.5)	3.5 (1.1)	0.8 (0.24)	0.8 (0.24)
2 (51)	3.5 (1.1)	2 (0.6)	5 (1.5)	1 (0.3)	1 (0.3)
2.5 (64)	4 (1.2)	2.5 (0.8)	6 (1.8)	1.3 (0.4)	1.3 (0.4)
3 (76)	5 (1.5)	3 (0.9)	7.5 (2.3)	1.5 (0.46)	1.5 (0.46)
3.5 (89)	6 (1.8)	3.5 (1.1)	9 (2.7)	1.8 (0.55)	1.8 (0.55)
4 (102)	7 (2.1)	4 (1.2)	10.5 (3.2)	2 (0.61)	2 (0.61)
5 (127)	9 (2.7)	5 (1.5)	13 (4)	2.5 (0.76)	2.5 (0.76)
6 (152)	10 (3)	6 (1.8)	15 (4.6)	3 (0.91)	3 (0.91)

Allowances are for standard copper sweat and braze fittings. For threaded fittings, double the allowances shown.
Table after *Copper Tube Handbook*, Copper Development Association

MASTER ALARM

Master alarms monitor the facility's medical gas and vacuum source and pressure operation. The facility shall be provided with at least two master alarm panels. Both shall be continuously monitored by on-site personnel. The primary panel shall be placed in the facility's engineering office. The second panel can be placed in the emergency department, security office, or any continuously monitored area. The second location also can be a centralized computer system or building maintenance system when specific requirements are met.

MEDICAL GAS OUTLETS

Medical gas outlets come in a variety of different outlet connections, and here is where the hospital facility engineer is your best guide because he will know what type of outlets the hospital will use or has used. Per NFPA 99, all outlets shall be gas specific, regardless of if the outlet/inlet for medical gas or vacuum is threaded or a non-interchangeable quick coupler. A confusing or questionable point is that in some hospitals, the vacuum and WAGD systems at times are a shared vacuum source. Regardless of the source, the vacuum and WAGD outlets must be non-interchangeable.

In addition to the typical outlet, medical gas and vacuum outlets come in the following styles (see Figure 3):

- Latch
- Geometric
- Pin index
- DISS (Diameter Index Safety System)

An important and specific DISS outlet is a quick-coupling disconnect, which is required in all operating rooms. Providing DISS outlets throughout the hospital helps minimize confusion for equipment connections, but doing so is a choice, not a requirement. Again, it is up to the design engineer and the facility engineer to determine what outlets are to be used throughout the hospital. However, if equipment does not match the wall or column connections properly, this can lead to severe consequences. Adapters can be used for non-matching outlets, but they not expedient when quick action is needed. Therefore, discuss and verify with the facility engineer the medical outlet system type requirements prior to design.

CONSIDERATIONS FOR SYSTEM SOURCE SIZING

A hospital's major gas use includes medical air, oxygen, and vacuum outlets. Operating rooms usually include nitrogen, nitrous oxide, and carbon dioxide. Something not usually known is that medical gases are rarely, if ever, used in patient and examination rooms, but that is not to say that outlets can or should be eliminated in these areas. Exceptions and emergencies always occur. However, the medical gas system usually is oversized in a hospital when the additional loads for these outlets are included.

NFPA requires an additional 25 percent increase in the calculated load for future medical system expansion. The major areas that actually govern the size of the gas systems are as follows:

- Operating rooms (major and minor invasive procedures)
- Intensive care units
- Natal intensive care units
- Pediatric intensive care units
- Ventilator systems (total units)
- Birthing or labor and delivery rooms

What about the emergency room? If you've ever been in an emergency room, you might have noticed that no one was connected to wall outlets because an emergency room is basically a triage center. It is a clearinghouse for the ultimate destination of a patient. An emergency patient with major wounds may need oxygen during the stabilization process, but ultimately they will be moved to an operating room or the ICU. The six areas listed above define the required gas and vacuum source and pipe size.

SYSTEM SIZING

At this point in the design, all outlets, valves, alarm panels, master alarms, pipe routing, and fittings should be determined. The only thing left is sizing. As stated previously, there is no single set design procedure for medical system gas sizing, and the various medical gas system companies have their own methods. Some start their design procedure from the source, and others from the outlet. However, the principle of all design procedures is the required pressures at the outlet: source pressure, the medium's velocity, and the allowable pressure loss per 100 feet of piping length. When calculating the developed pipe lengths, remember to include fitting equivalent lengths of run (see Table 2). If these are left out, the pressure loss calculations will be adversely affected.

The NFPA's minimum pipe sizes to start the design are as follows:

- Pressurized gas piping shall not be smaller than ½ inch inside diameter (ID) and ⅝ inch outside diameter (OD).

Table 3 Medical vacuum (horizontal) pipe sizing

Start	End	Run, ft	Flow, scfm	Flow, lpm	Pipe Size, in.	Loss/100	Loss	Running Subtotal
A	B	38	1.5	42.5	¾	0.031	0.01178	0.01178
B	C	18	4.5	127.5	¾	0.198	0.03564	0.04742
C	D	12	6	170	1	0.091	0.01092	0.05834
D	E	18	7.5	212.5	1	0.134	0.02412	0.08246
E	F	12	9	255	1	0.182	0.02184	0.1043
F	G	18	10.5	297.4	1¼	0.238	0.04284	0.14714
G	1	7	12	340	1¼	0.111	0.00777	0.15491
H	I	38	1.5	42.5	¾	0.031	0.01178	0.01178
I	J	12	4.5	127.5	¾	0.198	0.02376	0.19045
J	K	18	6	170	1	0.091	0.01638	0.20683
K	L	12	7.5	212.5	1	0.134	0.01608	0.22291
L	M	18	9	255	1	0.182	0.03276	0.20825
M	N	12	10.5	297.4	1¼	0.238	0.02856	0.23681
N	O	18	12	340	1¼	0.111	0.01998	0.22175
O	P	12	13.5	382.5	1¼	0.134	0.01608	0.23783
P	1	4	15	425	1¼	0.163	0.00652	0.25567
1	END	123	27	765	1.5	0.199	0.24477	0.24477

Source: BeaconMedaes

- Vacuum, high vacuum, and WAGD piping shall be no smaller than ¾ inch ID and ⅞ inch OD.
- Runouts to alarm panels and connecting tubes for gauges and alarm devices shall be no smaller than ¼ inch ID and ⅜ inch OD.

Medical Air

The medical air source should be provided with oil-less rotary compressors, receivers, dryers, filters, and constant-pressure valves to deliver dry, clean, oil-free air at 55 pounds per square inch (psi). A 5-psi maximum pressure drop is allowed throughout the total piping system, providing 50 psi at the outlets.

Oxygen

Oxygen is delivered from a tank, typically placed on the exterior of the hospital with a smaller manifold system located in a segregated room inside as a reserve or backup system. Included in this piping system is an emergency connection panel. This panel is placed at the exterior wall of the hospital's storage bottle room or in an area that is vehicle (tanker truck) accessible. Should the main oxygen tank and/or reserve bottles fail, connection to a tanker truck can provide a temporary supply. The pipe size is based on a maximum friction loss rate of 1 psi per 100 feet, with a maximum 5-psi loss throughout the full system. Include in the pipe lengths all equivalent lengths produced by fittings, valves, etc.

Medical Vacuum

The medical vacuum source should provide 19 inches of mercury (in. Hg) suction. Piping should be sized to allow no more than a 4-in. Hg loss throughout the entire piping system. The maximum velocity in any system shall not exceed 5,000 feet per minute. The maximum length shall include all equivalent lengths produced by fittings, valves, etc.

EXAMPLE PROJECT

Following is an example of a hospital vacuum system (see Figure 4) based on the BeaconMedaes sizing chart (see Table 3). Other manufacturers also have a sug-

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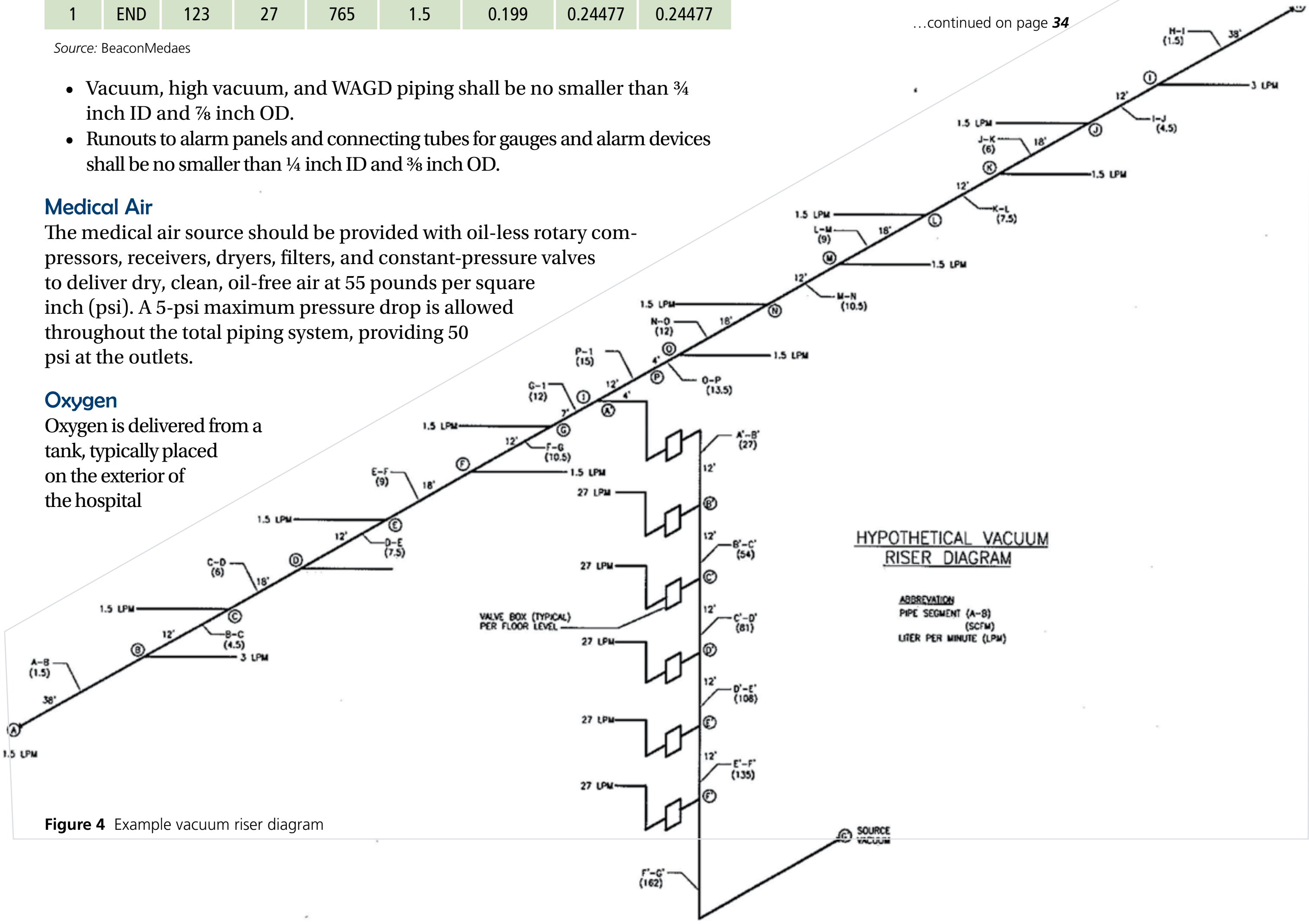

Figure 4 Example vacuum riser diagram

Table 4 Pipe size based on pressure loss

Air Flow: Actual cfm	Air Flow: Actual lpm	Air Flow: scfm 68°F and 29.9 in. HgA	Pressure Drop for Air in in. Hg per 100 Feet of Type L Copper Pipe Under Vacuum at 19 in. HgV Gauge Vacuum at 68°F Temperature: ¾ inch	1 inch	1¼ inch	1½ inch	2 inches	2½ inches	3 inches	4 inches
1	28.32	0.36	0.021							
2	56.63	0.73	0.041							
3	84.95	1.09	0.099							
4	113.27	1.46	0.161							
5	141.58	1.82	0.235	0.067						
6	169.90	2.19	0.320	0.091						
7	198.22	2.55	0.417	0.119						
8	226.53	2.92	0.525	0.149						
9	254.85	3.28	0.642	0.182						
10	283.17	3.65	0.770	0.218	0.081					
11	311.49	4.01	0.908	0.257	0.095					
12	339.80	4.38	1.056	0.299	0.111					
13	368.12	4.74	1.213	0.343	0.127					
14	396.44	5.11	1.380	0.390	0.144					
15	424.75	5.47	1.556	0.439	0.163	0.072				
16	453.07	5.84	1.741	0.491	0.182	0.080				
17	481.39	6.20	1.935	0.546	0.202	0.089				
18	509.70	6.57	2.138	0.603	0.223	0.098				
19	538.02	6.93	2.349	0.662	0.244	0.107				
20	566.34	7.30	2.570	0.724	0.267	0.117				
21	594.65	7.66	2.799	0.788	0.291	0.128				
22	622.97	8.03	3.036	0.855	0.315	0.138				
23	651.29	8.39	3.282	0.924	0.340	0.150				
24	679.60	8.76	3.537	0.995	0.367	0.161				
25	707.92	9.12	3.799	1.068	0.394	0.173				
26	736.24	9.49		1.144	0.421	0.185				
27	764.55	9.85		1.222	0.450	0.197				
28	792.87	10.22		1.302	0.479	0.210				
29	821.19	10.58		1.385	0.510	0.224				
30	849.51	10.95		1.470	0.541	0.237				
31	877.82	11.31		1.557	0.573	0.251				
32	906.14	11.68		1.646	0.605	0.265				
33	934.46	12.08		1.737	0.639	0.280				
34	962.77	12.41		1.831	0.673	0.295				
35	991.09	12.77		1.926	0.708	0.310	0.083			
36	1019.41	13.14		2.024	0.744	0.326	0.088			
37	1047.72	13.50		2.124	0.780	0.342	0.092			
38	1076.04	13.87		2.226	0.818	0.358	0.096			
39	1104.36	14.23		2.330	0.856	0.375	0.101			
40	1132.67	14.60		2.436	0.895	0.392	0.105			
41	1160.99	14.96		2.544	0.934	0.409	0.110			
42	1189.31	15.33		2.655	0.975	0.427	0.115			
43	1217.62	15.69		2.767	1.016	0.445	0.119			
44	1245.94	16.06		2.882	1.058	0.463	0.124			
45	1274.26	16.42		2.998	1.100	0.481	0.129			
46	1302.58	16.79		3.117	1.143	0.500	0.134			
47	1330.89	17.15		3.237	1.188	0.519	0.139			
48	1359.21	17.52		3.360	1.232	0.539	0.145			
49	1387.53	17.88		3.485	1.278	0.559	0.150			
50	1415.84	18.25		3.611	1.324	0.579	0.155			
55	1557.43	20.07			1.566	0.685	0.183			
60	1699.01	21.90			1.826	0.798	0.214	0.076		
65	1840.60	23.72			2.104	0.919	0.246	0.088		
70	1982.18	25.55			2.398	1.047	0.280	0.100		
75	2123.76	27.37			2.710	1.182	0.316	0.113		
80	2265.35	29.20			3.038	1.325	0.316	0.126		
85	2406.93	31.02			3.383	1.475	0.354	0.141		
90	2548.52	32.85			3.745	1.632	0.394	0.155		
95	2690.10	34.67				0.295	0.436	0.171		
100	2831.68	36.50					0.479	0.187		
110	3114.85	40.15						0.221	0.080	
120	3398.02	43.80						0.258	0.095	
130	3681.19	47.45						0.297	0.110	
140	3964.36	51.01						0.338	0.127	
150	4247.53	54.75						0.382	0.145	
160	4530.70	58.40						0.429	0.164	
170	4813.86	62.05						0.477	0.183	
180	5097.03	65.70						0.528	0.204	
190	5380.20	69.35						0.582	0.226	
200	5663.37	73.00						0.637	0.249	0.071
210	5946.54	76.65						0.695	0.272	0.077
220	6229.71	80.30						0.755	0.297	0.084
230	6512.88	83.95						0.817	0.322	0.091
240	6796.04	87.60						0.881	0.349	0.098
250	7079.21	91.25						0.948	0.376	0.105
275	7787.13	100.37						1.123	0.405	0.124