

COURSE OUTLINE

INTRODUCTION

Topics	Notes
1. Course Objectives: <ul style="list-style-type: none">• Explain the NFPA 99-2021, NFPA Installation Handbook-2021, and ASSE 6000-2021• The written test• The brazing test	
2. Medical Gases and Support Gases: <ul style="list-style-type: none">• Oxygen – given to patients only by a doctor’s prescription – usually mixed with other gases after the outlet and before patient use• Medical air – given to patients as breathable air• Nitrous oxide – capable of inducing the first stages of anesthesia when inhaled• Nitrogen NF and instrument air – used to run surgical tools and equipment• Vacuum – used on the patient to remove excess fluids during surgery and recovery• WAGD – system that removes excess nitrous oxide from treatment area	
3. Medical Gas and Support Gas Pressures: <ul style="list-style-type: none">• Oxygen, nitrous oxide, and medical air• Nitrogen and instrument air• Medical-surgical vacuum	
4. Valve Specifications for Positive Pressure Systems: <ul style="list-style-type: none">• Must be a quarter-turn valve• Must be a full-port valve• Three-piece construction with brazed extensions• A gauge port required downstream of a zone valve• Must be cleaned for oxygen service, and made of brass, bronze, or stainless steel	
5. Shutoff Valve Requirements: <ul style="list-style-type: none">• Source valve – located at the source equipment, in the same room as the source equipment• Main valve – located just inside the facility being served	

- Riser valve – located on the riser, adjacent to the main line
- Service valve – located on the lateral branch piping off a riser or main
- Zone valve – all outlet/inlets shall be supplied through a zone valve

6. Master, Area, and Local Alarms:

- Master alarm – monitors the operation and condition of the source of supply, the reserve, and the pressure in the main lines.
 - The minimum number of master alarm locations is two.
 - One of the locations must be manned while the facility is in operation.
 - A computer can be used to substitute for one of the master alarms.
 - The alarm shall have a visual and audible signal.
 - The audible indication may be silenced; reinitiation of the audible signal if another alarm condition occurs.
- Area alarm – monitors the pressure in the pipelines at anesthetizing locations and other vital life support and critical care areas
 - This alarm shall indicate when line pressure increases or decreases by 20%.
 - This alarm panel must have a digital or analog gauge.
- Local alarm – monitors the function of the medical air compressor system, surgical vacuum pump system, and instrument air system
 - This alarm is located on or in the control panel, within a monitoring device or on a separate alarm panel.

7. Materials Cleaned for Oxygen Service:

- Copper tubing for medical gas systems shall conform with ASTM B819 and be cleaned for oxygen service by the manufacturer. Each length of tube shall be permanently labeled and delivered to the job site, cleaned, plugged, or capped.
- Valves, fittings, and other components shall be cleaned for oxygen service in accordance with CGA pamphlet G-4.1, Cleaning Equipment for Oxygen Service prior to delivery to the job site. Cleaning is not permitted on the job site.

8. Brazing and Installation Requirements:

- Turns, offsets, and other changes in direction in brazed piping shall be made with wrought copper capillary fittings.

- Threaded joints shall be limited to pressure/vacuum gauges, alarm devices, and check valves at the source equipment, and source equipment.
- New or replacement in-line check valves are required in the piping associated with EOSC and the in-building emergency reserves.
- Copper-to-copper joints shall be made using a BCuP series rod.
- Tubes shall be cut with a clean, sharp tubing cutter and allowed to be deburred or rolled smooth.
- Braze joints shall be continuously purged with nitrogen NF to prevent the oxidation of the inside of the tube. Do not remove purge until the joint is cool to the touch.
- Use an oxygen analyzer to detect when all oxygen has been removed from the pipeline below 1% oxygen. It is recommended to leave the pipeline constantly purged.
- Larger systems may consider the use of a liquid nitrogen container for purging and testing. Unit cost of liquid nitrogen is normally less than the rental on many individual cylinders of gaseous nitrogen.

Notes

UNIT 1—ADMINISTRATION, PUBLICATIONS, DEFINITIONS, AND FUNDAMENTALS

	Topics	Notes
1.3	Applications	
1.3.4	Patient care spaces	
2.2	NFPA publications	
2.3.5	ASSE publications	
2.3.10	CGA publications	
2.3.18	USP publications	
	Chapter 3 definitions	
	Chapter 4 fundamentals	
4.2	Risk Assessment	
	Exercise: Worksheet 1	

UNIT 2—CATEGORY 1: PIPED GAS AND VACUUM SYSTEMS

Topics	Notes
Review Worksheet 1	
Piped Gas and Vacuum Systems: Central Supply Systems	
5.1.2 Hazards Associated with Gas and Vacuum Systems:	
<ul style="list-style-type: none">• Fire and explosion hazards	
5.1.3 Central Supply Locations:	
<ul style="list-style-type: none">• Manifold and bulk systems are allowed together outdoors.• Outdoor enclosures for medical gas sources now must have two egress gates.• Manifold systems and in-building emergency reserves and instrument air standby headers are allowed together indoors.• Nitrous oxide and carbon dioxide cylinders or containers shall be prevented from reaching minus 20°F or greater than 125°F.• Compressors and vacuum pump are allowed together indoors.	
5.1.3.3.3 Ventilation HVAC Chapter 9 Indoor Locations:	
<ul style="list-style-type: none">• Natural 9.3.7.5.2• Mechanical 9.3.7.5.3	
5.1.3.3.3.4 Ventilation Outdoor Locations:	
<ul style="list-style-type: none">• Protected openings• Shared wall	
5.1.3.5 Central Supply Systems:	
<ul style="list-style-type: none">• Gas cylinder manifold• Cryogenic liquid container manifold• Bulk cryogenic liquid system• Medical air compressor• Medical–surgical vacuum• WAGD vacuum• Instrument air system	
5.1.3 Final Line Pressure Regulator	
5.1.3.5.6 Relief Valves:	
<ul style="list-style-type: none">• Brass, bronze, or stainless steel construction• Vented to the outside, except air systems	
5.1.3.5.9 Headers:	
<ul style="list-style-type: none">• Cylinder leads must comply with CGA V-1.• Each header must have a filter, header shutoff, header pressure indicator, and check valve.	

- Oxygen cylinder header must have a check valve in the lead connection.
- Cryogenic liquid container header must have a relief valve.

Notes

5.1.3.5.10 Manifolds for Gas Cylinders:

- Two equal headers, each with an average day's supply, but not fewer than two connections
- Automatic changeover
- Two equal headers, each with an average day's supply, but not fewer than two connections
- A reserve header with an average day's supply, but not fewer than three connections
- Automatic changeover to the three headers

5.1.3.5.11 Manifolds for Cryogenic Liquid Containers:

- Two equal headers, each with an average day's supply
- A reserve header, with an average day's supply, but not fewer than three compressed gas cylinder connections
- Automatic changeover to the three headers

5.1.3.5.12 Cryogenic Fluid Central Supply Systems:

- Systems compliant with NFPA 55
- One or more main supply vessels
- A reserve supply sized for greater than an average day's supply
- Reserve supply can be either another cryogenic liquid vessel or compressed gas cylinders
- Automatic changeover

5.1.3 Emergency Oxygen Supply Connection (EOSC):

- Required when the bulk liquid supply is remote
- Located on the exterior of the building being served and physically protected

5.1.3 In-Building Emergency Reserves

Exercise: Worksheet 2

UNIT 3—CATEGORY 1: MEDICAL AIR SUPPLY SYSTEMS

Topics	Notes
Review Worksheet 2	

5.1.3.6.1 Quality of Medical Air:

- Be supplied from cylinders, bulk containers, and medical air compressor sources

- Meet USP medical air requirements
- Have no detectable liquid hydrocarbons
- Have less than 25 ppm gaseous hydrocarbons
- Have equal to or less than 5 mg/m³ of particulates sized 1 micron or larger in the air

5.1.3.6.3 Medical Air Compressor Sources:

- Location – dedicated mechanical room
- Multiple compressors – 2 minimum
- Receiver – corrosion resistant; complies with ASME Section VIII; has a relief valve, manual and automatic drain, sight glass, and pressure indicator
- Aftercoolers – where required, be provided with individual condensate traps
- Dryers – provide air that is below the frost point (32°F)
- Filters – be rated for a minimum of 98% efficiency at 1 micron
- Regulators – be equipped with a pressure indicator
- Local alarm – backup or lag in use; high water sensors and high temperature sensors (when required)
- Piping arrangement and redundancies
- Electrical power and control – automatic activation of backup compressor, dedicated disconnect switch, motor starting device, and overload protection
- Intake – outside, 20 ft off the ground, 10 ft from doors, windows or other openings in the building and 25 ft from any vents, exhausts, fuel storage vents, plumbing, vacuum vents, and WAGD discharges; areas that can collect vehicular exhausts or noxious fumes.
- Alternate intake shall be available 24 hours-per-day, 7 days-per-week basis.

5.1.3.6.3.12 Operating Alarms and Local Signals

5.1.3.5.3.13 Medical Air Quality Monitoring

5.1.3.6.3.14 Category 1 Medical Air Proportioning Systems:

- General: Reconstituted from oxygen USP and nitrogen NF
- Approved by the FDA
- Location NFPA 99 per 5.1.3.3, also NFPA 55
- Required Components
- Warning systems

Exercise: Worksheet 3

UNIT 4—MEDICAL SURGICAL VACUUM AND WAGD SUPPLY SYSTEMS

Topics	Notes
Review Worksheet 3	
5.1.3.7 Medical–Surgical Vacuum and WAGD Supply Systems	
5.1.3.7.1.1 Medical–Surgical Sources:	
<ul style="list-style-type: none"> • Location – dedicated mechanical room • Multiple pumps – 2 minimum • Receiver – complies with ASME Section VIII • Local alarm – backup or lag in use • Piping arrangement and redundancies • Electrical power and control • Exhaust – outside • Operating alarms 	
5.1.3.8 Waste Anesthetic Gas Disposal WAGD:	
<ul style="list-style-type: none"> • Source • Types of producers • WAGD to vacuum connections • Local alarm – backup or lag in use • Electrical power and control • Exhaust – outside, 10 ft from any openings 	
5.1.3.9.1 Oxygen Concentrator Supply System:	
Exercise: Worksheet 4	

UNIT 5—VALVES

Topics	Notes
Review Worksheet 4	
5.1.4 Valves:	
<ul style="list-style-type: none"> • Accessibility • Valve types • Source valve • Main valve • Riser valve • Service valve • Zone valve • In-line • Future valves • In-line check valves 	
Exercise: Worksheet 5	

**UNIT 6—STATION OUTLET/INLETS, MANUFACTURED ASSEMBLIES AND
MEDICAL GAS RAILS, AND PRESSURE AND VACUUM INDICATORS**

Topics	Notes
Review Worksheet 5	
5.1.5 Station Outlet/Inlets:	
<ul style="list-style-type: none"> • Gas-specific • Primary and secondary valves • Identified/labeled • D.I.S.S. • Components • Factory installed tubes • 1. Outlets – Factory installed tubes • 2. Inlets – Factory installed tubes • Nonstandard operating pressures • WAGD inlets 	
5.1.6 & 5.1.7. Manufactured Assemblies and Medical Gas Rails:	
<ul style="list-style-type: none"> • Pretested • Flexible hose and connectors • Pipeline connections • MGR installation requirements • MGR locations • MGR pipeline connections 	
5.1.8 Pressure and Vacuum Indicators:	
<ul style="list-style-type: none"> • Scale range for analog indicators • Scale range for digital indicators • Scale range for vacuum indicators • Scale range for testing shall be 1% full scale or better at the point of reading • Location • Require gas-specific demand check fitting 	
Exercise: Worksheet 6	

UNIT 7— CATEGORY 1: WARNING SYSTEMS

Topics	Notes
Review Worksheet 6	
Category 1: Warning Systems	
5.1.9 General Requirements:	
<ul style="list-style-type: none"> • Separate visual and audible indications • Cancelable audible indication • Sound of 80 dBA at 3 ft • Means to indicate lamp or LED failure 	

Notes

- Labeling
- Reinitiation of audible signal
- Electrical power
- Wiring shall be supervised or protected as required by NFPA 70
- Alarms switches/sensors installed so as to be removable
- Automatic restart

5.1.9.2 Master Alarm:

- Monitors operation and condition of main source
- Monitors operation and condition of reserve source
- Monitors pressure in the main line
- Two panels and two locations
- Computer substituted for one panel
- Changeover from primary to supply to secondary supply
- Bulk liquid main supply low
- Changeover to reserve
- Reserve low
- Liquid reserve low pressure
- Main line pressure
- Main line vacuum low
- Local alarm indication
- Medical air dew point high
- Instrument air dew point high
- WAGD low

5.1.9.2 Master Alarms by Computer Systems:

- Mechanical and electrical characteristics
- Continuously uninterrupted
- Provide remote signaling
- Wiring of computer to sensors
- Operating programs

5.1.9.4 Area Alarm:

- Monitors pipeline pressure in anesthetizing locations and other vital life support and critical care areas
- Location of alarms panels
- Positive pressure systems
- Medical–surgical vacuum system
- Alarm sensors locations

5.1.9.5 Local Alarms:

- Monitors air compressors and vacuum pumps
- Alarm location
- More than one equipment room
- Backup or lag compressor

- High carbon monoxide
- Medical air dew point
- Backup or lag vacuum pump
- Backup or lag WAGD pump
- Instrument air dew point
- High water in receiver
- High water in separator
- High air temperature
- Proportioning systems pressure in operation

Notes**Exercise: Worksheet 7**

UNIT 8—CATEGORY 1: DISTRIBUTION

Topics	Notes
Review Worksheet 7	
5.1.10 Category 1 Distribution	
5.1.10.1 Piping Materials for Positive Pressure Systems:	
<ul style="list-style-type: none"> • Cleaned for oxygen service by the manufacturer • Tubes to be plugged or capped • Delivered, sealed, and labeled • Hard-drawn seamless copper ASTM B-819 • Tube identified by “OXY,” “MED,” “OXY/ACR,” “ACR/MED” • Documentation for all piping materials 	
5.1.10.2 Piping Materials for Vacuum Systems:	
<ul style="list-style-type: none"> • Hard-drawn seamless copper ASTM B88, B280, or B819 • Stainless steel tube permitted • Identification of piping required when installed with medical gas tubing • WAGD under 5 in. Hg/V permitted to use non-corroding tubing or ductwork 	
5.1.10 Joints:	
<ul style="list-style-type: none"> • Required for turns, offsets, and other changes in direction • Wrought copper capillary per ASME B16.22 or ASME B16.50 • Cast copper fitting not allowed • Tee drill allowed for vacuum systems • Threaded joints • Brazed • Welded • Memory metal • Axially swaged 	

Notes

5.1.10.4 Brazed Joints:

- Brazing alloy that melts in excess of 1000° F shall be used.
- Tube joints shall be socket type; fully inserted.
- Copper-to-copper joints shall be brazed using BCuP series.
- Dissimilar metals use bag with flux.
- Brazed joints shall be continuously purged with nitrogen NF.
- Tube ends shall be cut with sharp, clean tubing cutters.
- After being cut, end shall be rolled smooth or deburred.
- Clean outside of tube with nonshedding abrasive pads.
- Wipe clean with lint-free white cloth.
- Visually examine tube internally.
- Braze joints within 8 hours.

5.1.10.4.7 Inspection of Brazed Joints:

- Clean joint with water and a wire brush.
- Visually inspect after cleaning the outside surfaces.
- Joints that are defected are permitted to be repaired.
- No joint shall be reheated more than once.
- Melted or cracked tubes or components must be replaced.

5.1.10 Welded Joints for Copper and Stainless Steel Tube:

- GTAW, autogenous orbital welding is permitted.
- Welder shall qualify for each tube size.
- Purge with a mixture of 75% helium and 25% argon.
- Test coupon at start of work day and every 4 hours.
- Stainless steel tube shall be welded using SMAW, GTAW, GMAW.
- Procedures and welders shall be qualified in accordance with ASME Section IX.

5.1.10.6 Memory Metal Fittings**5.1.10.7 Axially Swaged Fittings****5.1.10.8 Threaded Fittings****5.1.10.9 Special Fittings**

5.1.10.10 Prohibited Joints:

- Flared or compression-type connections
- Straight-threaded connections
- The use of pipe-crimping tools
- Removable and nonremovable push-fit connectors

Notes

Exercise: Worksheet 8

UNIT 9—INSTALLATION OF PIPING

Topics	Notes
Review Worksheet 8	
5.1.10.11 Installation of Piping	
5.1.10.11.2 Protection of Piping	
5.1.10.11.3 Location of Piping	
5.1.10.11.4 Pipe Support:	
<ul style="list-style-type: none">• Piping shall be supported from the building structure in accordance with MSS SP-69.• Hangers and supports must comply with MSS SP-58.• Seismically restrained when required.	
5.1.10 Underground Piping Outside of Buildings	
5.1.10 Qualification of Installers:	
<ul style="list-style-type: none">• Installers shall meet the requirements of ASSE/IAPMO/ANSI 6010.• Documentation shall be maintained on the job site.	
5.1.10 Qualification of Brazers:	
<ul style="list-style-type: none">• Brazers shall be qualified in accordance with either ASME Section IX or AWS B2.2.• Brazing qualifications expire after 6 months when a brazer does not braise with the qualified procedure.	
5.1.11.1 Pipe Labeling:	
<ul style="list-style-type: none">• Piping• Shutoff valves• Outlets/inlets• Alarm panels	

Exercise: Worksheet 9

UNIT 10— CATEGORY 1: PERFORMANCE CRITERIA, TESTING AND SUPPORT GASES

Topics	Notes
Review Worksheet 9	
<p>5.1.12.1 General Requirements:</p> <ul style="list-style-type: none"> • Inspection and testing assures the facility that all applicable provisions of NFPA 99 have been adhered to and system integrity has been achieved or maintained. • All systems breached or components that are added or replaced are subject to inspection and testing. • Testing reports shall contain detailed listings of all findings and results. • All documentation shall be maintained on-site. 	
<p>5.1.12.2 Installer–Performed Tests:</p> <ul style="list-style-type: none"> • Installer is to perform required testing prior to system verification. • Test gas shall be nitrogen NF. 	
<p>5.1.12.2.2 Initial Blow Down:</p> <ul style="list-style-type: none"> • Distribution piping to be blown clear • Performed prior to installation of outlet/inlets and other system components 	
<p>5.1.12.2.3 Initial Pressure Test:</p> <ul style="list-style-type: none"> • Test shall be performed after installation of outlet/inlets rough-in assemblies. • Test shall be performed before installation of components that would be damaged by the test pressure. • Test pressure for positive pressure systems shall be 1.5 times working pressure, but not less than 150 psi. • Test pressure for vacuum systems shall not be less than 150 psi. • Pressure maintained until each joint has been examined with soapy water or other equally effective means of leak detection. 	
<p>5.1.12.2.4 Initial Cross-Connection Test:</p> <ul style="list-style-type: none"> • All systems shall be reduced to atmospheric pressure. • Install all faceplates on outlet/inlets. • Charge only one system with nitrogen NF to 50 psi. • Each individual outlet/inlet shall be checked to determine that the system under pressure is 	

the only one dispensing test gas.

- Proper labeling and identification of outlet/inlets are to be confirmed during this test.

Notes

5.1.12.2.5 Initial Piping Purge Test:

- Outlet/inlets are purged to remove any particulates.
- An intermittent high-volume flow is used.
- Purge until no discoloration is produced in a clean white cloth.
- Purge shall start at the closest outlet/inlet to the zone valve and continue to the furthest outlet/inlet in that zone.

5.1.12.2.6 Standing Pressure Test for Positive Pressure Piping:

- Test shall be conducted after final installation of all components of the distribution piping system.
- Piping shall be subjected to a 24 hour standing pressure test.
- Test gas is nitrogen NF.
- Test pressure shall be 20% above normal system operating pressure.

5.1.12.2.7 Standing Vacuum Test for Vacuum Piping:

- Test conducted after final installation of all components of the distribution piping system
- Piping subjected to a 24 hour standing vacuum test
- Test pressure between 12 in. Hg/V and full vacuum

5.1.12.4 System Verification:

- Verifiers shall meet the requirements of ASSE 6030 Standard.
- Verification test shall be performed after the required installer's testing.
- Verifiers shall perform the following test:
 - Standing pressure test
 - Cross-connection test
 - Valve test
 - Alarm test
 - Piping purge test
 - Piping particulate test
 - Piping purity test
 - Final tie-in test
 - Operational pressure test
 - Medical gas concentration test
 - Medicalair purity test
 - Verify labeling
 - Source equipment verification

Notes

5.1.13 Support Gases:

- Nitrogen and instrument air are not for patient care.
- Support gases are used for powering pneumatic devices.
- The piping purity test and the gas concentration test shall be permitted to be omitted.

5.1.13.3.7 Instrument Air Supply Systems:

- Quality – filtered to 98% efficiency at 0.01 micron; free of liquid and hydrocarbon vapors
- Location – indoors
- Source requirements
- Compressors – capable of not less than 200 psi output pressure
- Standby header – 1 hour normal operation
- Intake – permitted to be taken locally
- Filters and accessories
- Dry to a dew point of –40°F
- Piping arrangement and redundancies
- Alarms
- Electrical power and control

5.1.14 Operations Management**5.2 Category 2 Piped Gas and Vacuum Systems:**

- These systems shall comply with Category 1, except for the following requirements.

5.2.3.5 Category 2 Medical Air Supply Systems:

- Compressors, dryers, aftercoolers, filters, and regulators shall be permitted to be simplex.
- The facility is responsible for their emergency plan for backup.

5.2.3.7 Category 2 Medical–Surgical:

- Vacuum systems shall be permitted to be simplex.
- The facility is responsible for their emergency plan for backup.

5.2.3.8 WAGD:

- WAGD pumps shall be permitted to be simplex.
- The facility is responsible for their emergency plan for backup.

5.2.9 Warning Systems:

- Warning systems shall be permitted to be a single alarm panel.
- The panel shall be located in an area of continuous surveillance.
- Pressure and vacuum switches shall be located at the source equipment with the pressure/vacuum indicators at the panel.

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|----------------|---|--------------|
| 5.2 | Category 2 Piped Gas and Vacuum Systems: | Notes |
| 5.3.3.6 | Category 3: Medical Air Supply Systems: | |
| 5.3.3.7 | Category 2 Medical–Surgical | |
| 5.3.3.8 | WAGD: | |
| 5.3.9 | Warning Systems: | |

Exercise: Worksheet 10

UNIT 11 – DENTAL CHAPTER 15

- | Topics | Notes |
|----------------------------|---|
| Review Worksheet 10 | |
| 15.1 | Applicability: |
| 15.3 | Category 1 Dental Gas and Vacuum: |
| 15.3.2.11 | Support gases |
| 15.3.3.7.2 | Piping for Dental Air and Vacuum |
| 15.4 | Category 2 Dental Gas and Vacuum Systems: |
| 15.4.2 | Medical Gas Systems (Oxygen and Nitrous Oxide). |
| 15.4.2.5 | Medical Gas Source Equipment (Oxygen and Nitrous Oxide). |
| 15.4.2.7 | Station Outlets and Risers (Oxygen and Nitrous Oxide). |
| 15.4.4.2 | Piping for Oxygen and Nitrous Oxide Systems. |
| 15.4.4.3 | Piping for Dental Air Systems. |
| 15.4.4.3.4 | Joints. |
| 15.4.4.4 | Piping for Dental Vacuum Systems and Scavenging Systems. |
| 15.4.7.2 | Required Testing |



Worksheet 11