**INTERNATIONAL ASSOCIATION OF PLUMBING AND MECHANICAL OFFICIALS**

**UNIFORM EVALUATION SERVICES**

**EVALUATION CRITERIA FOR**

 **Evaluation of Equivalency of Corrugated Medical Tubing to the Requirements for Medical Gas Tube in Chapter 13 of the Uniform Plumbing Code (UPC)**

**EC 044-2020**

**(Proposed September 2020)**

1. **INTRODUCTION**
	1. **Purpose:** This Evaluation Criteria establishes the requirements for Corrugated Medical Tubing (CMT) relative to the Requirements for Medical Gas Tube found in Chapter 13 of the Uniform Plumbing Code (UPC) to be recognized in an evaluation report issued by an Model Code Evaluation service agency, recognized as conforming with ISO/IEC 17065, under the Uniform Plumbing Code® (UPC ).

 This Evaluation Criteria provides requirements for the evaluation of Corrugated Medical Tubing to supplement the requirements provided in Chapter 13 of the 2018 UPC.

**1.2 Scope:** The provisions of this document shall provide a basis for an objective, performance-based comparison between established medical gas installation practices, materials and operational functionality and emerging corrugated tubing technology, alternative assembly methods and/or different materials. The evaluation is founded on a framework consisting of a general engineering assessment of the considered products, a review of accepted industry practices, knowledge of tubing technologies, and the evaluation of existing and new testing requirements for medical gas tube products. The testing requirements contained herein are based on the stated performance for medical gas tube stipulated within Chapter 13 of the UPC, the typical performance of copper tube for general applications, and other accepted industry standards for medical gas systems.

The evaluation report shall include the installation, maintenance, testing, and performance of the following:

1. Nonflammable medical gas systems with operating pressure below a gauge pressure of 300 psi (2068.4 KPa)
2. Vacuum systems in health care facilities
3. Waste anesthetic gas disposal (WAGD) systems – NFPA 99-2018 or -2015 provides testing requirements.
	1. **Definitions:** For terms not defined in this section, applicable codes, or referenced standards shall have the ordinary accepted definition for the context for which they are intended.
4. **REFERENCED STANDARDS**

Standards shall be applied consistent with the specific edition of the code(s) for which the Evaluation Report is prepared unless otherwise approved by UES.

# International Association of Plumbing Mechanical Officials

* IAPMO/ANSI-UPC-1-2018 edition of the Uniform Plumbing Code
	1. National Fire Protection Association
* NFPA 99-2018 Health Care Facilities Code
* NFPA 99-2015 Health Care Facilities Code
	1. State of California

California Code of Regulations: Title 24, Part 5 – California Plumbing Code - 2019

 **2.4** Underwriters Laboratories

* UL 1365 Issue 7: Outline of Investigation for Corrugated Medical Tubing (CMT) Systems; August 2020 by UL, LLC
	1. International Standards Organization / International Electrical Commission
* ISO/IEC 17065-12 Conformity assessment -- Requirements for bodies certifying products, processes and services
* ISO/IEC 17011-17: Conformity assessment – Requirements for accreditation bodies accrediting conformity assessment
	1. American Society of Sanitary Engineers
* ASSE 6010 Medical Gas Installer Course
	1. ASTM International
		+ ASTM B819-19 Standard Specification for Seamless Copper Tube for Medical Gas Systems
		+ ASTM B88 -03 Standard Specification for Seamless Copper Water Tube
		+ AST B280 -20 Standard Specification for Seamless Copper Tube for Air Conditioning and Refrigeration Field Service
		+ ASTM B103-19 Standard Specification for Phosphor Bronze Plate, Sheet, Strip, and Rolled Bar

**3.0 BASIC INFORMATION**

* 1. **Description:** The following information and data shall be submitted for review and evaluation for recognition of Corrugated Medical Tubing (CMT) to the Requirements for Medical Gas Tube in Chapter 13 of the Uniform Plumbing Code (UPC) in an evaluation report:
		+ 1. **Product Description:** CMT is corrugated copper alloy tubing supplied with an external plastic jacket. The CMT fittings are fully metallic construction and are field\*installed to the tube through an irreversible, axially swaged process.
			2. **Installation Instructions:** Installations shall be in accordance with the manufacturer’s installation instructions, its installer training program and in compliance with ASSE 6010 certification or state equivalent.
			3. **Packaging and Identification:** Packaging labels for the system shall include the manufacturer or a registered trademark, model or name of the product, size and applicable certification body logo and evaluation report number.

**3.2 Test Reports:** Where the evaluation service agency is unable to perform one or more of the prescribed evaluation tests included in Section 5.0 of this document, then the agency shall permit the manufacturer to obtain these test results from an accredited, third-party testing laboratory qualified in accordance with Section 3.3 of this document. Test reports issued by the testing laboratory shall be recognized as an equal part of the overall evaluation as permitted in Section 7.0 of this document.

**3.3 Testing Laboratories:** Laboratories shall be accredited as complying with ISO/IEC Standard 17025 for the testing conducted and reported (i.e. the laboratory’s scope of accreditation shall include the tests submitted as supporting data). The laboratory’s accreditation shall be issued by an accreditation body conforming to ISO/IEC 17011 and that is a signatory of the International Laboratory Accreditation Cooperation (ILAC) Mutual Recognition Arrangement (MRA).

* 1. **Product Sampling:** The test specimens shall be sampled or verified by an accredited inspection agency or testing laboratory. The sampled product shall be representative of the production ongoing after the sampling has taken place. The product specifications shall be within the tolerance limits reported in the quality documentation and the relevant standards.
1. **TESTING AND PERFORMANCE REQUIREMENTS**

**Basis for Comparisons: S**tandard tubes for medical gas systems shall be hard-drawn seamless copper complying with ASTM B819 Type L or Type K for operating pressures exceeding 185 psi (1275 kPa). Standard tubes for medical vacuum systems and WAGD (Waste Anestetic Gas Disposal) systems shall be constructed from hard-drawn copper in accordance with ASTM B88 (Type K, L or M); ASTM B280 (ACR tube); or ASTM B819 (Type K or L). Standard joints for medical gas systems, vacuum systems and WAGD systems shall be constructed of hard-drawn seamless copper or stainless steel tubing utilizing one of the following joining methods:

* Brazing
* Welding
* Memory metal fitting
* Axially swaged
* Threaded

Corrugated medical tubing (CMT) and fittings are by their very nature different than the standard tube (described above) used in medical gas and vacuum service. CMT is fabricated from copper alloy strip (complying with ASTM B103), which is rolled, continuously seam-welded, and corrugated. CMT shall comply with the CGA G4.1 cleanliness requirement. CMT is supplied with an external plastic jacket. The CMT fittings shall be fully metallic construction of yellow brass (copper alloy number CA360) and shall be CGA G4.1 compliant. The fittings shall be attached to the tube through an irreversible, axially swaged process. However, the nature of determining equivalency goes beyond the limits of side-by-side material and component design comparisons.

There are also requirements that the installed systems operate at the same level of performance including pre-operational pressure and flow testing, as well as post-operational purity and particulate testing. Therefore, a series of comparative component and system level tests have been developed and included to permit the complete assessment and comparison of all critical performance requirements.

Component tests, testing methods and acceptance criteria (included in the UL 1365 document) are included in Section 5.1 for the following design areas:

* External Leakage Test
* Hydrostatic-Strength Test
* Impact Test
* Axial Tension Test
* Torsion Test
* Temperature Test
* Flame Test
* Compression Test
* Bending Test
* Electrical Resistance Test
* Mechanical Tube Fitting Performance

Comparative testing between CMT and copper tube at the operational system-level including , testing methods and acceptance criteria (from NFPA 99 document and UPC Ch 13) are included in Section 5.2 for the following design areas:

* Piping Purge Test
* Piping Particulate Test
* Piping Purity Test

**5.0 Evaluation Testing**

Representative samples of each size and specific construction of the CMT shall be subjected to the tests described in these requirements. CMT systems are to be tested on the following basis consistent with the intended use of the product and Table 5.0:

a) Size or diameter;

b) Minimum radius of bend (per manufacturer’s instructions); and

c) Maximum rated pressure (per manufacturer’s instructions).

**Table 5.0**

**CMT System**

|  |  |  |
| --- | --- | --- |
| Size (in.) | OAL (in.) hydrostatic vibration, torsion tests (5.1.11) | Torsional stress (in-lb) |
| ⅜ | 14 | 150 |
| ½ | 17 | 150 |
| ⅝ | 19 | 175 |
| ¾ | 21 | 200 |
| 1 | 26 | 250 |
| 1 ¼ | 31 | 300 |
|  1 ½ | 36 | 350 |
| 2 | 45 | 450 |

For tests requiring pressure, a calibrated pressure-indicating device shall be mounted to indicate pressures developed within the vessel and/or test specimen. The pressure-indicating device shall comply with one of the following:

a) An analog gauge having a pressure range of at least 150 percent of the anticipated maximum working pressure;

b) A digital pressure transducer, or other digital gauge, that is calibrated over a range of pressure that includes the test pressure; or

c) Other device that is equivalent to the devices in (a) or (b).

* 1. **Component Testing**
		1. **External Leakage Test**

**Acceptance Criteria:**

A CMT system shall not leak when tested as described in the following Test Method.

**Test Method:**

Three samples of the largest and the smallest diameter and one in between, not less than 3 feet (914 mm) in length, shall be installed with fittings on both ends: one end plugged and the other end connected to a pneumatic system capable of supplying clean, dry air at the specified test pressure and to a flow-measuring device capable of accurately indicating any leakage or pressure loss. The pressure shall be slowly increased to 1.5 times rated pressure and maintained at that pressure for at least 5 minutes, after which the pressure loss or leakage (if any) shall be determined. Pressure loss shall be determined by any decrease in test pressure based on a visual observation of the pressure-indicating device over a 5-minute observation period. Leakage may also be determined by the observation of air bubbles when the test sample has been completely immersed in a water bath. The leakage acceptance criteria is an average of no more than three observed air bubbles per minute over a 5 minute observation period.

Testing for leakage in the field shall be performed in accordance with the prevailing code as determined by a loss of pressure on the pressure-indicating device.

* + 1. **Hydrostatic-Strength Test**

**Acceptance Criteria:**

A CMT medical tubing system shall not leak nor rupture when tested as described in the following Test Method.

**Test Method:**

One sample of each diameter per Table 5.0 having a minimum length of 24 inches (610 mm) with f5ttings mounted on both ends shall be used in this test. The sample shall be installed in a straight line, with one end attached to the pressure source and other end plugged and free. Each sample shall be filled with water so as to exclude all air.

The pressure shall be uniformly raised to 1.5 times rated pressure and maintained at that pressure for at least 1 minute. The tubing shall then be bent with a radius of curvature as specified by the manufacturer as the minimum bend radius, and the pressure maintained for one additional minute.

With the tubing maintained in the bent position, the pressure is then to be increased to 3.5 times maximum rated pressure for at least 5 minute after which the pressure loss or leakage (if any) shall be determined in accordance with the procedure prescribed in Section 5.1.1.

* + 1. **Impact Test**

**Acceptance Criteria:**

Each CMT medical tubing sample shall withstand an impact of 30 ft-lb (40.67 N·m), using a steel ball falling through a vertical guide tube. The External Leakage Test (as determined in accordance with Section 5.1.1) shall be conducted before and after each test as described below:

**Test Method:**

The 30 ft-lb (40.64 N.m) impact shall be conducted using a 9 to 10 lb. (4.08 to 4.54 kg) steel ball. Two completed assemblies consisting of a 2-foot-long (610 mm) section of tubing with fittings at each end shall be assembled in accordance with the manufacture’s installation instructions.

A V-block steel holder shall be used to support the tubing for the impact test. The sides of the “V” shall be of sufficient length to support the tubing below the top edges of the “V.” The V-block and the impacted samples shall be supported on a hard, flat surface.

One assembly shall be impacted such that the striking nose of the falling weight will strike at the center of the specimen.

One assembly shall be impacted such that the striking nose of the falling weight will strike at the centerline of contact between the striking weight and the longitudinal center of the fitting.

* + 1. **Axial Tension Test**

**Acceptance Criteria:**

The CMT medical tubing system shall withstand the applied axial tension without external leakage (as determined in accordance with Section 5.1.1), before and after each test as described in the following Test Method.

**Test Method:**

Test samples consisting of each size of tubing and each type of fitting installed on each end of the sample shall be assembled in accordance with the manufacturer’s installation instructions. The sample length shall be based on a minimum length over internal diameter ratio (L/D) of 6 but shall be at least 6 inches (152 mm) long.

One end of the assembly shall be securely attached to a fixed hose to which a hydrostatic supply system and pressure indicating device is connected. The assembly shall be pressurized to its maximum operating pressure. The other end of the sample shall be securely attached in a similar manner to a closed hose connected to a mechanical means capable of applying a constant pulling force of 800 lb/in (140 N/mm) of nominal inside tube diameter.

The required tensile load shall be applied at a rate smooth and continuous, and then maintained for at least 5 minutes. The tubing assembly is removed from the test apparatus and the external leakage test shall be performed in accordance with the Section 5.1.1.

* + 1. **Torsion Test**

**Acceptance Criteria:**

The medical tubing system shall withstand without rupture or leakage the maximum torsion stresses specified in Table 5.0. The External Leakage Test, as described in Section 5.1.1, shall be performed before and after each test as described in the following Test Method.

**Test Method:**

One CMT medical tubing sample of each size with fittings attached at each end and not less than 24 inches (610 mm) in length shall be tested. One end shall be firmly secured, and the other end shall be anchored in a straight line such that it can be rotated. A torsional stress shall be applied to the rotatable end, and gradually increased until attaining the stress indicated in Table 5.0.

The stress shall then be removed, and the sample shall be subjected to the external leakage test in accordance with Section 5.1.1.

* + 1. **Temperature Test**

**Acceptance Criteria:**

The medical tubing fitting shall withstand a temperature of 1000°F (538 °C) for 30 minutes, without leaking in excess of 6.0 ft3 (0.17 m3) of air per hour. The External Leakage Test, as described in Section 5.1.1, shall be conducted before each sample is tested as described in the following Test Method.

**Test Method:**

Test samples consisting of tubing without the jacket with one of each type of fitting shall be assembled in accordance with the manufacturer’s installation instructions. The test fitting end of the assembly shall be sealed and the other end of the assembly shall be connected to a pneumatic system capable of supplying clean dry air at the specified test pressure, and to a flow-measuring device capable of accurately measuring the allowable leakage rate. The flow-measuring device shall be located between the air supply and the inlet of the tubing assembly. A thermocouple shall be firmly attached to one fitting to monitor its temperature.

The assembly shall be placed in a preheated 1000°F (538°C) test oven. The sample shall be arranged so that the inlet end of the tubing assembly extends through an opening in the oven wall and connects to the air supply system.

Air is admitted to the system and maintained at a minimum pressure of 55 PSI (379 kPa) throughout the test, unless a leak is indicated by a drop in pressure. In this event, the test shall be discontinued.

When the temperature of the fitting reaches 990°F (532°C), the oven shall be adjusted as necessary so that the fitting temperature is maintained at 990°F to 1010°F (532°C to 543°C) for at least 30 minutes. During this period, any leakage indicated by the flow-measuring device shall not exceed 6.0 ft3 per hour when corrected to standard conditions of 30 in Hg (101.59 kPa) column pressure and 60°F (15.5 C). Leakage exceeding this rate shall terminate the test.

* + 1. **Flame Test**

**Acceptance Criteria:**

The medical tubing system, without jacket, shall not leak or show evidence of damage after being subjected to the flame test as described in the following Test Method. The External Leakage Test as described in Section 5.1.1, shall be conducted before and after each test.

**Test Method:**

One medical tubing sample of each diameter and at least 12 inches (305 mm) long between couplings shall be assembled in accordance with the manufacturer’s installation instructions. A lineal section of 6 inches (152 mm) shall be suspended horizontally at a vertical distance of 3 inches (76.2 mm) above and parallel to a strip pipe gas burner.

The burner shall to be constructed of ¾inch Schedule 40 iron pipe (Standard for Welded and Seamless Wrought Steel Pipe, ANSI/ASME B36.10M) having a straight line of 1/16 inch (1.6 mm) drilled ports, on ½inch (12.7 mm) centers, located along the top for a distance of 8 inches (203 mm). A gas pressure equal to 1-inch (25.4 mm) water column shall be maintained inside the pipe when gas equivalent to natural gas having approximately 1,000 Btu per cubic foot (37.3 MJ/m3) is utilized.

The flame resulting from this apparatus shall burn under at least 6 inches (152 mm) of the exposed length of tubing sample and under one coupling or union at one end. The tubing sample shall be exposed to the flame for 5 minutes.

At the end of the flame exposure, the sample shall be allowed to cool to room temperature and shall then to be subjected to the external leakage test in accordance with Section 5.1.1.

* + 1. **Compression Test**

**Acceptance Criteria:**

The medical tubing system shall withstand the effects of an external load of 1,000 pounds (454 kg) applied over a distance of 1 inch (25.4 mm) along the length of the tubing at three equally spaced locations, and not leak when subjected to a pressure 1.5 times the maximum operating pressure.

**Test Method**

One 18-inch (457 mm) sample of each diameter shall be tested. A hydrostatic pressure of 25 psig (172.4 kPa) shall be maintained within the sample when under test.

With the sample supported uniformly along its length, a load of 1,000 pounds (454 kg) shall be successively applied by a flat metal surface over a distance of 1 inch (25.4 mm) along the length of the tube at three equally spaced locations.

The applied load at each location shall be maintained for at least 1 minute.

After the three loadings are completed, the sample shall be subjected to a hydrostatic pressure of 1.5 times maximum rated pressure for at least 1 minute after which the pressure loss or leakage (if any) shall be determined in accordance with the procedure described in Section 5.1.1.

* + 1. **Bending Test**

**Acceptance Criteria:**

The medical tubing system shall withstand the effects of repeated cycles of abnormal bending. The External Leakage Test described in Section 5.1.1, shall be conducted before and after each sample is tested as described in the following Test Method.

**Test Method:**

Two samples of each diameter shall have a length based on a minimum length over internal diameter ratio (L/D) of 24, but shall be at least 2 ft (610 mm) long. Each sample shall be supported uniformly along its length as on a table.

One sample shall be successively bent to a 90-degree arc having a bend radius of 60 percent of the minimum radius specified in the manufacturer’s installation instructions. The other sample shall be successively bent to a 90-degree arc having a bend radius of 30 percent of the minimum radius specified in the manufacturer’s installation instructions. The bending at each of the two radii shall be repeated 10 times, after which the pressure loss or leakage (if any) shall be determined in accordance with the procedure described in Section 5.1.1.

* + 1. **Electrical Resistance Test**

**Acceptance Criteria:**

An assembly of medical tubing and fittings shall not have an electrical resistance that exceeds the values given in Table 5.1.10, Maximum Electrical Resistance when tested in accordance with the following Test Method.

**Table 5.1.10**

**Maximum Electrical Resistance**

|  |  |
| --- | --- |
| **Nominal size of pipe (in.)** | **Resistance (**Ω**/ft.)** |
|  ⅜ | 0.180 |  |
| ½ | 0.150  |  |
|  ⅝ | 0.130 |  |
|  ¾ | 0.120 |  |
| 1 | 0.120 |  |
|  1 ¼ | 0.100 |  |
|  1 ½ | 0.090 |   |
| 2 | 0.090 | 2 |

**Test Method:**

A straight length of medical tubing (with external jacket) shall be placed on a flat, horizontal, noncombustible, electrically nonconductive table. A test segment of each tubing size shall be used and shall be 6 ft (1,830 mm) long. Fitting connection to the tubing shall be made and installed at each end of the tubing in accordance with the manufacturer’s instructions. A single, conductor (no smaller than 6 AWG) of sufficient length shall be secured (by an appropriate means as determined by the testing agency) to each end fitting and to an alternating-current supply with a no-load voltage not to exceed 12 V.

A current of 25 A shall be passed between the end fittings of the test assembly by starting with an impressed potential of 0.0 volts AC and gradually increasing the voltage until 25 ampere current is attained. The test specimen shall not be moved or otherwise manipulated during any part of this test. The voltage drop between the end fittings shall be measured. The resistance shall be calculated from the measured voltage drop and the current in accordance with the following equation and compared against the acceptance value listed in Table 5.1.10, Maximum Electrical Resistance.

R = E/I

Where:

E = volts

I = amperes

R = ohms

* + 1. **Mechanical Tube Fitting Performance**

**Test Criteria:**

Medical tubing system connections shall withstand vibration, tension and torque without loosening and without developing leakage when tested as described in the following Test Method.

**Test Method:**

The following test procedures shall be applied to each type, material, and nominal size of mechanical tube fitting. New, unused samples of tubing and fittings shall be used for each test.

A length of tubing as specified in Table 5.0, OAL (in) Hydrostatic, Vibration, Torsion Tests, shall be assembled to fittings at each end in accordance with the manufacturer’s installation instructions. The assembly shall be mounted in a test apparatus as shown in Figure 5.1.11, Test apparatus for the vibration, tension and torque test. One end shall be sealed gas-tight and the other end connected to a hydrostatic system supplying the specified test pressure. The assembly shall be hydrostatically pressurized and maintained at the maximum rated operating pressure throughout the test. Any leaks in the test apparatus or in the connections to the test apparatus shall be eliminated prior to beginning the test.

**Figure 5.1.11**

**Test apparatus for the vibration, tension, and torque test**



The tubing assembly shall be loaded in tension with an axial load equal to 200 lb (890 N) per inch of nominal internal tubing diameter. The assembly shall also be loaded with a clockwise radial torque, applied at opposite ends of the tubing, as required to produce and maintain a 10-degree (0.17 rad) displacement between the at-rest positions of the two ends of the tubing assembly. During application of the radial torque, means shall be provided to prevent rotation of pipe threads at the connections of the tubing assembly to the test apparatus.

The vibration device shall be adjusted to produce a vibration amplitude of 0.125 in (3.2 mm) at a frequency of 1000 cycles per minute. The amplitude is defined as the maximum displacement of sinusoidal motion from position of rest or one-half the total displacement of the tube fitting.

The vibration device shall be placed in operation and continued for 55 minutes, followed by an off period of five minutes. The vibration cycle of 55 minutes on and 5 minutes off shall then be repeated continuously for a total test period of 30 consecutive hours. During this test period, the test pressure, tensile load, and torque load shall be applied continuously. The hydrostatic pressure shall be monitored continuously throughout the test and shall indicate no loss of pressure.

The test shall be repeated three more times with a new test sample each time, but with the test modified as stated below:

* The test shall be repeated as stated above except with the tensile load removed.
* The test shall be repeated as stated above except with the radial torque applied in a counterclockwise direction.
* The test shall be repeated as stated above except with the tensile load removed and the radial torque applied in a counter-clockwise direction.

**5.2 System Testing**

**5.2.1 Mock-up Assembly:**

Two identical simulated medical gas systems shall be constructed to replicate a typical hospital piping system including several bends, changes in elevation and direction, and outlets. One complete system shall be built for copper medical tube and one for CMT. The total length of the tube in each system shall be identical, and shall not be less than 30-ft with no less than five 90-deg bends, and at least 10-ft in elevation change (up and down) and one outlet. Figure 5.2.1 is an example of a piping system configuration meeting the design criteria specified within this section. Each system shall be assembled by an ASSE 6010 qualified installer. Each system shall be subjected to a nitrogen purge in accordance with standard industry practices and the requirements of Chapter 13 UPC and NFPA-99 (whichever is more stringent).

**Figure 5.2.1**

**Sample Piping System Configuration**



The evaluation testing shall be performed by an ASSE 6020 Inspector or ASSE 6030 Verifier.

**5.2.2 Acceptance Criteria**

Determining the acceptable physical measurement of performance for these types of tests is difficult as it may depend on a subjective assessment (smell test), and/or measurements that are dependent on the physical length and orientation of the piping system. The equivalency of one tubing materials over another shall be based on a direct comparison of the outcomes from the following test methods, and shall be considered equivalent when the outcomes are the same or within the standard deviation permitted by the test.

**5.2.3 Piping Purge Test Method**

The piping purge evaluation shall be conducted in accordance with NFPA 99 Section 5.1.12.4.6 and Figure 5.2.1. In order to provide a valid comparison between CMT and copper tubing, both apparatuses shall be tested simultaneously to ensure they receive equal flow and pressure of the purging and test gas. Nitrogen NF shall be piped to the inlet fittings of both test apparatus utilizing equal lengths and sizes of piping to ensure each apparatus is supplied with equal volumes and pressures during blowdown and purge testing.

1. **Initial Blowdown**

Piping shall be blown clear by means of oil-free dry nitrogen NF after assembly of the piping system.

1. **Piping Purge Test**

Each outlet shall be purged using purge rates of at least 225 Nl/min (8 SCFM) of nitrogen NF. The purging shall be started at the closest outlet to the source of test gas and in the direction of flow to the most distant outlet to the source of test gas.

Each outlet shall be purged with an intermittent high-volume flow (pulse purge) of test gas until the purge produces no discoloration in a clean white cloth.

The number and duration of purging pulses shall be monitored and recorded for each outlet on each test apparatus.

1. **Odor Test**

Flow approximately 10 L/min (2.6 gpm) of nitrogen NF at all outlets.

Deflect a portion of the gas stream toward the nose and sniff.

No pronounced or objectionable odor should be discernible from any positive pressure outlet.

**5.2.4 Piping Particulate Test Method**

The piping particulate evaluation shall be conducted in accordance with NFPA 99 Section 5.1.12.4.7 and Figure 5.2.1. In order to provide a valid comparison between CMT and copper tubing, both apparatuses shall be tested simultaneously to ensure they receive equal flow and pressure of the test gas. Nitrogen NF shall be piped to the inlet fittings of both test apparatus utilizing equal lengths and sizes of piping to ensure each apparatus is supplied with equal volumes and pressures during piping particulate testing.

Pre-weigh a 0.45-micron filter for each outlet to be tested.

Forceps shall be used to handle the filter during testing to avoid introducing any contaminants to the filter from handling.

Flow a minimum of 1,000 L (35 ft3) of dry nitrogen NF through the 0.45-micron filter at a minimum flow rate of 100 Nl/min (3.5 SCFM) though the filters at each outlet.

Each filter shall be weighed and the weights compared to the values obtained before the start of the test.

An increase in the filter weights of more than 0.001g (1 mg) between the before and after weighing’s shall constitute failure of the test.

* + 1. **Piping Purity Test Method**

The piping purity evaluation shall be conducted in accordance with NFPA 99 section 5.1.12.4.8 and Figure 5.2.1 ~~3.2~~.

This test is to be performed using dry nitrogen NF.

Testing shall be conducted at the most remote outlet to the source.

The source gas shall be tested for nonmethane hydrocarbons and halogenated hydrocarbons, and the results recorded.

Attach the source gas to the test apparatus and purge the gas through the most remote outlet from the test gas source.

Analyze and record the nonmethane hydrocarbons and halogenated hydrocarbons in the test gas at the most remote outlet.

The difference between the contaminants recorded before and after completion of the test shall not exceed 5 ppm of total non-methane hydrocarbons and 5 ppm halogenated hydrocarbons.

The moisture concentration of the outlet test shall not exceed 500 ppm or an equivalent pressure dew point of -12°C (10°F) at a gauge pressure of 345 kPa (50 PSI).

Any test results exceeding the limits in contaminants and moisture shall constitute failure of this test.

1. **QUALITY CONTROL**

6.1 Quality documentation complying with the UES Minimum Requirements for Listee’s Quality Assurance System (UES-010) shall be submitted. A complete description shall be provided of the quality management system used in the factory to manufacture the CMT to be used for medical gas applications.

* 1. Inspections of manufacturing facilities are required for this product, by agencies accredited for the required tasks in accordance with ISO/IEC 17020 or ISO/IEC 17065.
1. **7.0 EVALUATION REPORT RECOGNITION**

The agency performing the evaluation can conduct its effort through any combination of the following activities:

* small-scale benchtop evaluations
* full-scale laboratory testing (available in-house or through outside third-party)
* review of test report(s) from recognized and certified, third-party testing laboratories
* technical literature reviews, and
* historical data or expert opinion on similar applications and materials

A final written report shall be prepared that summarizes the results from the agency’s evaluation, all evaluation methods used, and the conclusions drawn regarding the equivalency of the two products for compliance with the requirements of the UPC and Chapter 13 therein.