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**Instruction Manual for Installation,
Operation, and Maintenance of the
Q-250 LLNL Filter-Life Tester**

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Instruction Manual for Installation, Operation, and Maintenance of the Q-250 LLNL Filter-Life Tester

1.0 Scope

This manual describes the installation, operation, and maintenance of the LLNL filter-life tester Q-250. This apparatus is designed to determine the gas life of a variety of chemical filters, such as M10-A1, M11, M13-A2, C2, and similar filters. The LLNL filter-life tester can generate isopropylmethylphosphonofluoridate (GB) or dimethylmethylphosphonate (DMMP) vapors in air at flow rates of up to 50 lpm. These filters and their specifications are listed in Appendix A. *CAUTION: Personnel performing operations with this tester must be completely familiar with the contents of this manual, knowledgeable in system operation, and knowledgeable of materials used in operation of the LLNL filter-life tester.*

2.0 Outline of Method

Filter-life tests using destructive gas are performed by challenging a protective filter with a test gas. The filter under test is acceptable if the concentration of the test gas downstream of the filter does not exceed the "break" level within a specified time. The required challenge concentration of the test agent/simulant is obtained by heating and vaporizing the liquid test chemical into an air stream to obtain the required concentration at a specified flowrate. The concentration of challenge agent/simulant is measured upstream and downstream of the test filter. When the apparatus is generating the challenge stream at the specified test conditions, the challenge stream is drawn through the test filter until the "break" concentration is measured by the downstream analyzer.

3.0 Applicable Documents

3.1 Government Documents

The current issue of the following documents form a part of this manual. Additional documents that apply to the filters to be tested are provided in Appendix A. Appendix B is a bibliography of useful documents. Document 136-300-128 is the manual for the previous version of the Q250.

3.1.1 *Specification.* MILITARY MIL-C-10758 - Chemical Agent, GB

3.1.2 *Drawings.* Drawings 136-41-5151 through 136-41-5181

3.2 Other Publications

The operation manuals for the following commercial components should be used in conjunction with this manual.

3.2.1 *Upstream Detector.* A Beckman 400A Hydrocarbon Analyzer is an acceptable upstream analyzer (available from Beckman Industrial). Other methods of upstream vapor concentration analysis, such as wet chemistry, are also acceptable.

3.2.2 **Downstream Detector.** A Meloy SA 160-2 is an acceptable downstream analyzer (available from Columbia Scientific Industries Corp.).

3.2.3 **Chart Recorders.** One double-pen chart recorder is required to monitor the upstream and downstream analyzers. A Hewlett-Packard Model 7132A recorder is acceptable for this task.

4.0 Utilities and Facilities

4.1 Utilities

4.1.1 **Vacuum Supply.** A vacuum supply of approximately 25 in. of mercury is required.

4.1.2 **Air Supply.** A clean, bone-dry, compressed-air supply of at least 50 psig is required. This will serve as both the zero gas to the upstream gas analyzer and the air supply to the vapor generator.

4.1.3 **Electrical Power.** Single phase, 60-Hz, 120-V AC capable of delivering 15 A.

4.1.4 **Water Supply.** If a water bath is to be used to heat the vapor generator, a large supply of distilled or deionized water shall be available.

4.2 Facilities

4.2.1 **Temperature-Controlled Room.** A temperature-controlled room (70–80°F) with a minimum working area of approximately 100 ft² is required. The room shall be well lighted and relatively free from dust and dirt.

4.2.2 **Primary Ventilation Hood.** The vapor generator assembly and the test chamber assembly of the apparatus must be located in a ventilated hood at least 60 in. wide and 24 in. deep. The laboratory hood will be designed to insure that the permissible exposure limits (PEL) for the materials used in this tester are not exceeded. Portions of the equipment that may contain toxic materials will be kept at least 20 cm inside the hood face. The laboratory hood will discharge into an exhaust ventilating system capable of removing toxic materials that could be harmful to unprotected personnel in surrounding areas.

4.2.3 **Secondary Ventilation Hood.** The gas analyzers will be vented to a ventilation hood with a suitable exhaust system.

5.0 Reagents and Materials

5.1 Chemicals and Water

Unless otherwise specified, ACS grade chemicals and distilled or deionized water shall be used when testing.

5.2 GB

The GB used for testing shall conform to specification MIL-C-10758 except the purity shall be 96 percent minimum.

5.3 DMMP

The DMMP used for testing shall have a purity of 96 percent minimum. If the required vapor concentration of the DMMP at the filter is 4.0 mg DMMP per liter of air and the density of DMMP is about 1.1547 g/ml at 20°C, then at an air flow of 50 lpm, this translates into a DMMP consumption rate of 0.00288 ml DMMP per second or about 10 ml DMMP per hour. For more properties of DMMP, see Appendix C. Appendix D is a Material Safety Data Sheet (MSDS) for DMMP. DMMP may be purchased from a variety of chemical companies, such as Aldrich Chemical Co., Mobile Chemical Co., or Virginia Chemical, Inc.

5.4 Methane Span Gas

A compressed gas mixture of about 1000 ppm methane (CH₄) in air is required as a sensitivity reference for the upstream detector.

5.5 Hydrogen Gas

A cylinder of compressed hydrogen (H₂) having a suitable pressure regulating valve to reduce the pressure to approximately 30 psig is required. The hydrogen gas is used as a fuel for both the upstream and downstream gas analyzers.

5.6 Filters

A supply of appropriately conditioned M13-A2 control filters is needed to perform the control tests, establish control limits, and verify correct operation of the apparatus.

6.0 Apparatus

6.1 General Description of Components

The LLNL 50-lpm filter-life tester is manufactured in accordance with the drawings and specifications listed on Drawing 136-41-51551 through 136-41-5181. The apparatus consists of four major assemblies: control box, vapor generator, test chamber, and chemical instrumentation. A listing of all the major components is found in Appendix E. Figures 3-12 show the LLNL filter-life tester with callouts identifying all major parts listed in Appendix E and described below in sections 6.2-6.5. The interfunctional relationship of the components is described in section 8.

6.1.1 Control Box Assembly. The control box assembly consists of the control box and associated cables and power cord. Located just outside of chemical hood housing the vapor generator and test chamber, the control box allows remote operation of the LLNL filter-life tester. A 12-ft cable connects the control box to the front of the vapor generator assembly.

6.1.2 Vapor Generation Assembly. Located in a chemical hood, the vapor generation assembly consists of a nebulizer to generate vapor, a vapor mixer, and a variety of regulators and several solenoid valves.

6.1.3 Test Chamber Assembly. Attached to the vapor generation assembly, the test chamber assembly must also be located in a chemical hood. The test chamber assembly consists of the filter test chamber and various filters and flowmeters.

6.1.4 Chemical Instrumentation. The chemical instrumentation consists of two gas analyzers and a two-pen chart recorder.

6.2 Control Box (1)

- 6.2.1 Main Power On Switch (2).** Located at the back of the control box, this switch controls the power to the control box.
- 6.2.2 Power Indicator Light (3).** Located on the front of the control box, this light indicates when power is available to the control box.
- 6.2.3 System Power Off Button (4).** This switch controls the power to the solenoid valves on the LLNL filter-life tester. It must be pulled out to power the vapor generator.
- 6.2.4 Vapor Generator Mode Buttons (5, 7, 9, 11).** These buttons control airflow through the LLNL filter-life tester.
- 6.2.5 Vapor Generator Mode Lights (6, 8, 10, 12).** These lights indicate the state of the LLNL filter-life tester.
- 6.2.6 Upstream Analyzer Mode Switch (13).** This switch controls flow to the upstream analyzer.
- 6.2.7 Downstream Analyzer Mode Switch (14).** This switch controls flow to the downstream analyzer.
- 6.2.8 Thermocouple Indicator (15).** This type J (iron-constantan) thermocouple indicator displays the bulk temperature (°C) of the fluid in the vapor generator.
- 6.2.9 Machine Timer (16).** The machine timer displays the running time of the LLNL filter-life tester. The machine clock runs whenever the LLNL filter-life tester is in the PURGE, GENERATE, or TEST mode.
- 6.2.10 Test Timer (17).** The test timer displays the elapsed time of an individual test. The test timer runs anytime the downstream analyzer mode switch is in the SAMPLE mode.
- 6.2.11 Control Box Cable (18).** This 12-ft cable connects to the front of the vapor generation assembly. This cable supplies power and allows control of the solenoid valves. A type J thermocouple wire is also attached to the control box cable.

6.3 Vapor Generator Assembly (19)

- 6.3.1 Upstream Analyzer Air supply Regulator (20).** This regulator controls the air supply to the upstream gas analyzer.
- 6.3.2 Main Air Pressure Shutoff Solenoid Valve (21) (SV1).** This valve controls air flow to the LLNL filter-life tester.
- 6.3.3 Dilution Flow Regulator (22).** This regulator controls air pressure to the mixer/condenser.
- 6.3.4 Nebulizer Flow Regulator (23).** This regulator controls air pressure to the nebulizer.
- 6.3.5 Dilution Flow Solenoid Valve (24) (SV2).** This valve controls air flow to the mixer/condenser; it is normally closed.
- 6.3.6 Nebulizer Inlet Flow Solenoid Valve (25) (SV3).** This valve controls air flow to the nebulizer; it is normally closed.

- 6.3.7 *Dilution Flow Check Valve (26)*. This check valve prevents back flow of agent/simulant into the dilution regulator.
- 6.3.8 *Nebulizer Flow Check Valve (27)*. This check valve prevents back flow of agent/simulant into the nebulizer regulator.
- 6.3.9 *Liquid Trap (28)*. This traps and holds up to 200 ml of liquid agent/simulant if the nebulizer is overfilled and any back-pressure occurs.
- 6.3.10 *Liquid Trap Drain Valve (29)*. This valve allows the liquid trap to be drained, if it fills with agent/simulant.
- 6.3.11 *Nebulizer Quick-Connect (30)*. This allows easy removal of the nebulizer from the apparatus for refill and cleaning.
- 6.3.12 *Nebulizer (31)*. This stainless steel cylinder holds up to 150 ml of liquid agent/simulant. Air entering the side of the nebulizer through a small hole (#60 drill size) nebulizes the liquid agent/simulant and exits at the top of the nebulizer. The nebulizer is removeable and refillable.
- 6.3.13 *Nebulizer Refill Tap (32)*. The nebulizer may be refilled through this port with agent/simulant after a test. It is normally capped.
- 6.3.14 *Nebulizer Thermocouple (33)*. This type J iron-constantan thermocouple monitors the bulk liquid agent/simulant temperature. It is connected to a thermocouple indicator on the control box.
- 6.3.15 *Nebulizer Heating Tape (34)*. The liquid agent/simulant in the nebulizer is heated to raise its vapor pressure and aid vaporization. This is done by a heating tape approximately 2 ft long and 1 in. wide. A BriskHeat Corp. Model BMC481301 120-V AC, 208-W, 1.73-amp heat tape is typically used. It is covered with braided fiberglass and has a maximum exposure temperature of 900°F. The heating tape is wrapped around the base of the nebulizer and receives its power from a variable transformer.
- 6.3.16 *Nebulizer Flow Outlet Solenoid Valve (35) (SV4)*. This valve controls airflow to the nebulizer; it is normally closed. Valves SV3 and SV4 both open to allow flow through the nebulizer.
- 6.3.17 *Mixer/Condenser (36)*. This stainless steel cylinder combines the warm vapor-rich nebulizer flow with the cool dilution flow. Two baffles in the mixer aid mixing. In the mixer, the sample is cooled. This allows maximum agent/simulant concentrations at minimum air flow rates.
- 6.3.18 *Column (37)*. This vertically orientated, stainless steel tubing provides additional cooling. Agent/simulant may condense in this vertical column and drain down to the mixer and nebulizer.
- 6.3.19 *Column Drain Valve (38)*. Located at the bottom of the downcoming tubing of the column, this valve allows drainage of any agent/simulant that may condense in this part of the column. It is normally capped.
- 6.3.20 *Upstream Sample Port (39)*. This opening can be used to sample the upstream vapor concentration for the calibration of the upstream gas analyzer. Calibration of the upstream analyzer for DMMP is usually done by collecting upstream vapor in a activated charcoal tube. The weight collected, volumetric flowrate, and collection time determine the upstream vapor concentration.

It is normally capped. It may also be used to collect a sample of the sample stream for chemical analysis in place of using the upstream analyzer.

- 6.3.21 **Calibration Flowmeter (40).** This flowmeter measures the sample flow rate during charcoal tube calibration of the upstream gas analyzer or during challenge stream sample collection.
- 6.3.22 **Upstream Analyzer Calibration Flow Solenoid Valve (41) (SV7).** This valve controls the calibration gas flow to the upstream gas analyzer. Either span gas (1000 ppm) or zero gas is directed to the upstream analyzer.
- 6.3.23 **Upstream Analyzer Sample Flow Solenoid Valve (42) (SV8).** This valve controls the sample flow to the upstream gas analyzer.
- 6.4 **Test Chamber Assembly (43)**
 - 6.4.1 **Test Chamber Purge Flow Filter (44).** This M10-A1 filter cleans the air pulled into the test chamber line whenever the apparatus is not in TEST mode.
 - 6.4.2 **Test Chamber Purge Flow Solenoid Valve (45) (SV6).** This valve controls the flow of air into the test chamber line.
 - 6.4.3 **Test Chamber Sample Flow Solenoid Valve (46) (SV5).** This valve controls the flow of air into the test chamber line.
 - 6.4.4 **M13 Test Chamber (47).** This stainless steel chamber holds M13-A2 filters properly in place during testing. There are two different test chambers used on the LLNL filter-life tester: the M13 test chamber and the M10 test chamber.
 - 6.4.5 **M10, M11, and C2 Test Chamber (48).** This cylindrical stainless steel chamber has fittings that adapt it to be used with three different filters. The M10-A1, M11, and C2 filters can be tested in this chamber.
 - 6.4.6 **Flexible Line (49).** The flexible stainless steel line allows easy access to the test chamber for filter change out.
 - 6.4.7 **Downstream Analyzer Purge Filter (50).** This M10-A1 filter cleans the air pulled into the downstream gas analyzer when the downstream analyzer mode switch is in the STANDBY mode.
 - 6.4.8 **Downstream Analyzer Pressure Reducing Valve (51).** This valve allows adjustment of the pressure in the downstream sample line, so that there are no pressure fluctuations during sampling to cause flame-out of the downstream analyzer.
 - 6.4.9 **Downstream Analyzer Sample Flow Solenoid Valve (52) (SV9).** This valve controls the sample flow to the downstream gas analyzer.
 - 6.4.10 **Downstream Analyzer Pressure Gauge (53).** This gauge allows monitoring of the pressure in the downstream sample line.
 - 6.4.11 **Test Chamber Flow Scrubbing Filter (54).** The test chamber flow scrubbing filter is an M18 gas filter and removes all agent/simulant from the sample stream. This large filter prevents agent/simulant contamination of the vacuum system and is located on the stand behind the flowmeter mounting.

- 6.4.12 *Sample Flow Scrubbing Filter (55)*. The sample flow scrubbing filter is an M18 gas filter and removes all agent/simulant from the sample stream. This large white filter prevents agent/simulant contamination of the exhaust system and is located on the stand behind the flowmeter mounting.
- 6.4.13 *Test Chamber Line Flowmeter (56)*. This flowmeter controls and monitors the air flow through the test chamber.
- 6.4.14 *Sample Line Flowmeter (57)*. This flowmeter controls and monitors the sample flow through the LLNL filter-life tester.
- 6.5 **Chemical Instrumentation Assembly (58)**
- 6.5.1 *Upstream Analyzer (59)*. The upstream monitor is a commercial flame-ionization detector (400A Hydrocarbon Analyzer manufactured by Beckman Industrial of La Habra, California). Other suitable analyzers may also be found.
- 6.5.2 *Downstream Analyzer (60)*. The downstream monitor is a commercial flame photometric detector (FPD) sulfur analyzer modified to detect phosphorous. The modification is accomplished by incorporating a 526-m interference filter. The Meloy model SA160-2 (HYFED) sulfur analyzer is manufactured by Columbia Scientific Industries Corp., of Austin, Texas. Other suitable analyzers may also be found.
- 6.5.3 *Strip Chart Recorders (61)*. A strip chart recorder makes a record of the output of the upstream and the downstream detectors.

7.0 Installation and Calibration

7.1 Installation

1. Locate the apparatus in a well-ventilated laboratory hood. All portions of the equipment and vapor generator must be kept at least 20 cm (about 8 in.) inside the hood face.
2. Plug the main power cord at the back of the control box into a 120-V AC, 15-amp power source.
3. Connect the type J thermocouple line to the back of the control box.
4. Connect the control cable to the back of the control box and to the front of the vapor generator assembly. Make sure that the cable to the test chamber assembly is plugged into the back of the generator assembly. This cable has an interlock in it; if it isn't connected properly, no power comes to the LLNL filter-life tester.
5. Connect the vacuum supply to the back side of the test chamber assembly.
6. Connect the air supply to the back of the generator assembly. This air supply should be regulated to 50 psig (± 2 psig). The humidity of air being provided must not exceed 15 percent relative humidity.
7. Connect the span gas (about 1000 ppm methane) to the bulkhead fitting at the back of the generator assembly. The upstream analyzer should be allowed to warm up sufficiently before testing. *NOTE: The upstream gas analyzer may require up to 4 hr to warm up and stabilize after prolonged shutdown.*

8. Wrap heating tape (~2 ft in length and 1 in. wide) around the bottom of the nebulizer and plug the heating tape into a variable transformer. *NOTE: The nebulizer may also be heated with a water bath.*

7.2 Checks and Adjustments

7.2.1 Initial Leak Check

1. Install the filter to be tested in the test chamber.
2. Leak check the test chamber. This procedure should be completed prior to beginning each day's testing.
3. Remove the test chamber purge flow filter (M10-A1) from the purge inlet. Use a rubber stopper (size 00) to plug the purge inlet.
4. With the vacuum on, the test chamber flowmeter must read zero. A high reading on the flowmeter indicates that a leak is present. Gaskets, pipe fittings, and welds should then be inspected for the source of the leak.
5. If no leaks exist, remove the rubber stopper and replace the test chamber purge flow filter (M10-A1) onto the purge inlet.

7.2.2 Adjustment

1. Adjust the test chamber flowmeter to a reading of about 120 percent (about 50 lpm for DMMP testing). This is a preliminary adjustment. To adjust the test chamber flow, the vacuum supply must be on. *NOTE: The flowmeters can be adjusted to the proper values, if the test flows are known. The test chamber flow is adjusted to the specified flow rate for the item to be tested.*
2. Insure that dilution regulator at the front of the generator assembly is closed (full counterclockwise).
3. Insure that nebulizer regulator at the front of the generator assembly is closed (full counterclockwise).
4. Adjust the plant air supply pressure regulator to 50 ± 2 psig.
5. Turn on main power switch at the back of the control box. The green indicator light at the front of the control box will light.
6. Pull the large red SYSTEM POWER OFF button on the front of the control box out.
7. Push the STANDBY mode button; the yellow light beneath it should come on. The four mode buttons must be pressed in order when progressing toward vapor generation. From the STANDBY mode, you must press the PURGE button before you can get to the GENERATE and TEST modes. This is not true in the reverse (from the TEST mode, you can go immediately to the PURGE mode by pressing the PURGE button). Also, from the TEST mode, you can immediately shut off everything by pressing the main power off button.
8. Adjust the dilution regulator to about 10 psig.
9. Adjust the nebulizer regulator to about 30 psig.
10. Push the PURGE mode button.
11. Adjust the sample flowmeter to a reading of about 140 percent (about 55 lpm for DMMP testing). This is a preliminary adjustment. The sample flow should be approximately 10 percent greater than the required test chamber flow to insure that air is not drawn into the sample line through the sample line exhaust.

12. Push the GENERATE mode button. Check the sample flowmeter for the appropriate flow rate, and adjust it if necessary. *NOTE: The generator should not have agent/simulant in it for this preliminary adjustment.*
13. Set the transformer (approximately 40 percent of output) to maintain the appropriate temperature of the agent/simulant in the nebulizer as indicated by the thermocouple. Because the temperature is set with no flow through the nebulizer, the temperature in the nebulizer will go down when flow starts through the nebulizer. The appropriate temperature for GB with air flowing through the analyzer is $32 \pm 1^\circ\text{C}$ (about 90°F), or as required to obtain and maintain the required concentration.

For DMMP, the appropriate bulk temperature is $37 \pm 1^\circ\text{C}$ (about 100°F), or as required to obtain and maintain the required concentration. *NOTE: DMMP boils at 181°C (about 358°F); for DMMP, do not exceed 69°C (about 156°F).*
14. Put the downstream analyzer in SAMPLE mode. Adjust the downstream analyzer pressure reducing valve so that the pressure in the downstream analyzer sample line is about 3 in. Hg. Push the TEST mode button. If flame-out occurs, close the valve down further and start over. *NOTE: The downstream analyzer will not relight from this state.*
15. Check the test chamber flowmeter for the appropriate flow rate (about 50 lpm for DMMP testing) and adjust if necessary. *NOTE: The LLNL filter-life tester does not go into TEST mode unless the downstream analyzer is in SAMPLE mode.*

7.3 Calibration of Instruments

- 7.3.1 **Test Chamber Flowmeter.** The test chamber flowmeter is calibrated with a dry gas meter. A complete calibration of the test chamber flowmeter is not required. The reading that corresponds to the desired flow rate for a test is established by calibration with a dry gas meter. To calibrate the test chamber flowmeter, press both the STANDBY mode button and the system power button OFF. Remove the test chamber purge filter. Connect the calibrated flow measuring device to the purge inlet line. Ensure the vacuum system is on and connected. Adjust the test chamber flowmeter control valve so that the calibrated flow device reads the flow rate specified for the test. The corresponding reading of the test chamber flowmeter is then used for testing at the established flow rate.
- 7.3.2 **Sample Flowmeter.** The sample flowmeter will be calibrated with the system in the PURGE mode. Attach a calibrated dry gas test meter to the outlet of the flowmeter to make the necessary measurements.
- 7.3.3 **Calibration Flowmeter.** The calibration flowmeter will be calibrated by attaching a calibrated dry gas test meter to the inlet of the flowmeter.
- 7.3.4 **Thermocouple Meter (Type J iron-constantan).** The thermocouple meter need not be calibrated because accurate measurement of the temperature is not required. Consistent readings, however are necessary.
- 7.3.5 **Upstream Gas Analyzer (Microcarbon Analyzer).** The upstream analyzer must warm up and stabilize after prolonged shutdown. This may take up to 4 hr. The upstream gas analyzer for DMMP can be calibrated with a large (~5 g) charcoal tube. Attach a tared charcoal tube to the calibration port and to the calibration flowmeter. With the LLNL filter-life tester in the GENERATE mode, open the calibration port sample valve and collect DMMP on the charcoal tube. Record the collection flowrate and the time of collection, then measure the final weight of the charcoal tube. This process can be repeated many times to generate an empirical calibration curve. A large charcoal tube will collect about 200 mg of DMMP; this means about

1 hr of collection at a sample concentration of approximately 4 mg DMMP per liter and a sampling flowrate of 0.5 lpm. An analytical balance capable of measuring to ± 1 mg is necessary. Depending on the accuracy of the balance, sampling can be done at 5- to 10-min intervals. If another type of upstream analysis is used, an appropriate calibration procedure must be instituted.

- 7.3.6 **Downstream Gas Analyzer (Phosphorus Detector).** The downstream analyzer must warm up and stabilize after prolonged shutdown. The downstream gas analyzer can be calibrated according to the manufacturer's instructions.

7.4 Use of Control Filters

- 7.4.1 **Purpose.** The purpose of the M13-A2 control filters is to provide a check on satisfactory operation of the test system. To insure a maximum degree of reliability in the gas life data, the use of control filters will be required. A control filter test will be done daily. M13-A2 filters have a breakthrough time of approximately 1 hr.

- 7.4.2 **Method.** The American Society for Testing Materials's (ASTM) *STP 15D Manual on Presentation of Data and Control Chart Analysis* details a method of constructing a control chart. Specific instructions for constructing a control chart using the mean and standard deviation are on pp. 86-90 of the ASTM manual, available from the ASTM (see also pp. 65-67).

- 7.4.3 **Storage.** The control filters will be a designated lot of the M13-A2 filters. Upon inspection and acceptance of the control lot, the packaged filters will be placed in a cold storage chamber capable of maintaining a temperature of 32-38°F (0-4°C). Cold storage minimizes possible aging and deterioration of the control filters. Filters that are hermetically sealed in cans need not be placed in cold storage.

- 7.4.4 **Establishing Control Limits.** A sample size of 10 M13-A2 filters will be tested on the test apparatus to establish control values. The testing procedures defined in this manual for the test agent will be followed. The control filters must be tested at the same conditions as those required for the test filters. Calculate the mean ($\bar{X}$) and standard deviation (s) for each test apparatus using the data of 10 control filters. Determine $\bar{X} \pm 2s$ and $\bar{X} \pm 3s$ for the test apparatus. A control chart with the limits $\bar{X} \pm 2s$ and $\bar{X} \pm 3s$ will be prepared.

- 7.4.5 **Procedure.** The following procedure describes the use of control filters:

1. Remove the required control filters from cold storage. The control filters must be temperature-equilibrated in the test laboratory for a minimum of 8 hr prior to testing. To allow sufficient time for the control items to reach room temperature, they should be removed from cold storage at the end of the working day prior to the day of testing (not to exceed 120 hr)
2. Inspect the control filter packaging for tears and openings and record any defects.
3. Number the packaging of each control filter for identification.
4. Just prior to testing, remove the control filter from the sealed bag and mark it with the number placed on the packaging for identification.
5. Inspect the control filter for defects and record those noted.
6. A control filter will be run at the start of the day on each test chamber of each apparatus to be used for testing. The data obtained from the control item gas life test will be recorded to the nearest one-tenth of a minute and plotted in the order of testing on the control chart set-up for the test chamber in question. When the performance of the control item falls within the established $\bar{X} \pm 2s$, the apparatus is considered satisfactory for use. If the performance

is between $X \pm 2s$ and $X \pm 3s$, troubleshoot the apparatus in accordance with procedures listed in Appendix F, note corrective action taken in the log book for the apparatus, and proceed with normal testing. If the performance is outside the $X \pm 3s$ control limits, troubleshoot the apparatus in accordance with procedures listed in Appendix F, make any appropriate corrections, and run a second control filter. If the second control filter fall outside the $X \pm 3s$ control limit, the equipment and procedures should be thoroughly checked for deficiencies. If no obvious solution is found, shut down the tester in accordance with section 8.4 of this manual. Contact the government agency listed on the title page of this manual for further disposition of the test apparatus.

7. Test data on every control item will be recorded, without exception, including control items discarded after being removed from cold storage and not used.

8.0 Operation

8.1 Overview

The LLNL filter-life tester is designed to evaluate the breakthrough time of a variety of chemical filters. These filters are mounted in a test chamber and exposed to a high concentration of chemical. The required challenge concentration of the test agent/simulant is obtained by heating and vaporizing liquid test chemical into an air stream to obtain the required concentration at a specified flowrate. The concentration of challenge agent/simulant is measured upstream and downstream of the test filter. When the apparatus is generating the challenge stream at the specified test conditions, the challenge stream is drawn through the test filter until a "break" concentration is measured by a downstream gas analyzer.

- 8.1.1 **Solenoid Control Valves.** Nine solenoid valves control the flow of air through the tester. The general location of the solenoid valves can be seen in Fig. 1, a schematic of the LLNL filter-life tester. The operating states of the solenoid valves are listed in Appendix G. Six of these valves are controlled by the mode buttons on the front of the control box. The other three are controlled by the analyzer switches, also on the control box. Pushing the STANDBY mode button puts the solenoid valve in the STANDBY configuration.. These four buttons must be pressed in order when progressing toward vapor generation. From STANDBY, you must press the PURGE mode button before you can get to the GENERATE mode. This is not true in the reverse; from the TEST mode, you can go immediately to PURGE mode by pressing the PURGE mode button.
- 8.1.2 **Sample Flow.** Plant air enters the LLNL filter-life tester and is split, with a portion being directed to the nebulizer and a portion directed to the mixer/condenser. The portion directed to the mixer/condenser is called the dilution stream or dilution flow. The portion directed to the nebulizer is called the nebulizer flow. At the mixer/condenser these two airflows are recombined into the sample flow. The sample flow then travels to either the exhaust scrubbing filter or the test chamber.
- 8.1.3 **Nebulizer.** This stainless steel cylinder holds up to 150 ml of liquid agent/simulant. The nebulizer vaporizes the required quantity of agent/simulant (up to ~4 mg DMMP per liter of air) by forcing air over the surface of the liquid agent/simulant. Air entering the side of the nebulizer through a small hole (#60 drill size) atomizes the liquid agent/simulant and exits at the top of the nebulizer. Heating tape wrapped around the bottom of the nebulizer maintains the proper liquid temperature. The vapor generated is at a concentration well above the required concentration and at a temperature above the ambient temperature. Airflow through the nebulizer is controlled by solenoid valves located upstream and downstream of the nebulizer. The solenoid valves are opened and closed by means of switches located on the control box.

- 8.1.4 **Nebulizer Thermocouple.** A type J (iron-constantan) thermocouple is located on the top of the nebulizer. The thermocouple junction is positioned to monitor the bulk liquid temperature of the challenge agent/simulant in the bottom of the nebulizer.
- 8.1.5 **Mixer/Condenser.** The mixer/condenser combines the saturated nebulizer flow with a dilution air flow to form the sample flow. This cools the sample flow to room temperature. Agent/simulant may condense out of the vapor phase in the mixer/condenser. The sample flow exits the mixer/condenser and is directed by a solenoid valve to either the exhaust scrubbing filter or the test chamber. Additional condensation may take place in the vertical column above and downstream of the mixer/condenser.
- 8.1.6 **Upstream Analyzer Sample Flow Solenoid Valves (SV7 and SV8).** The upstream calibration flow control valve (SV7) and the upstream analyzer sample flow solenoid valve (SV8) are small 3-way valves located at the back of the vapor generator assembly. These two valves are controlled by the upstream analyzer mode switch located on the front of the control box. The upstream sample line transports sample flow from the upstream analyzer sample flow control valve to the upstream detector. When the upstream analyzer mode switch is in the STANDBY mode these valves direct clean air to the upstream analyzer. In the SPAN mode, the valves direct span gas (~1000 ppm) to the upstream analyzer. In the SAMPLE mode, the valves direct a portion of the sample flow before the test chamber to the upstream gas analyzer.
- 8.1.7 **Test Chambers.** Two interchangeable test chambers are used, one for the M13-A2 control filters and one for the M10-A1, M11, and C2 canisters. After passing through the test chamber, the test flow is sampled for downstream concentration. The test flow is next purified by the test chamber scrubbing filter and then passes to the test chamber flowmeter.
- 8.1.8 **Downstream Analyzer Sample Flow Solenoid Valve (SV9).** The downstream analyzer sample-flow solenoid valve is a small 3-way valve located in the middle of the test chamber assembly. This valve directs either purge air or sample to the downstream analyzer via the downstream sample line. When the downstream analyzer-mode switch on the control box indicates STANDBY, air is pulled through the downstream analyzer purge filter and through the downstream analyzer sample-flow solenoid valve. When the downstream analyzer-mode switch indicates SAMPLE, the flow downstream of the test chamber is direct through downstream analyzer sample-flow solenoid valve to the downstream analyzer.
- 8.1.9 **Chemical Instrumentation.** The chemical instrumentation includes the upstream analyzer, downstream analyzer, and recorder for each analyzer. Each of these components is a self-sufficient, unmodified commercial item.

8.2 General Starting Procedure

1. Perform the start-up procedure and calibrations described in section 7.0; Appendix H is an operational checklist. The normal operating temperature range of the LLNL filter-life tester is 20–25°C.
2. Install the filter to be tested in the appropriate test chamber, and connect the test chamber to the filter-life tester.
3. Perform a leak test as described in section 7.2.1.
4. Flip up the power switch on the back of the control box. Pull out the SYSTEM POWER button on the left front of the control box.
5. Turn on, calibrate, and zero the upstream and downstream gas analyzers. Ensure that the analyzer gas flows have been properly set and the analyzer burners are lighted.

6. Close the dilution and nebulizer flow regulators (turn counterclockwise to close).
7. Determine if the nebulizer is full of agent/simulant. If not, fill nebulizer with the appropriate amount of agent/simulant. Tighten and seal the nebulizer.
8. Ensure that the refill port on the nebulizer is closed.
9. Turn on power to the nebulizer heating tape (~40 percent) and adjust to the desired liquid temperature. *NOTE: Without flow through the nebulizer, the temperature will rise higher than required for the test. This is acceptable. It will immediately cool when flow is started. It is possible to "dead start" the system without preheating the nebulizer.*
10. Adjust the main air supply regulator until a pressure of 50 ± 2 psig, as indicated on the gauge
11. Turn on the the vacuum supply.
12. Install the filter to be tested in the appropriate test chamber. Care must be taken to insure that the item being tested is securely mounted in the test chamber. A leak around the test chamber-filter interface will produce a false break and possibly contaminate the downstream detector. Make sure that the flexible hose is connected and the clamps are attached to the inlet and exit of the test chamber.
13. Leak check the test chamber sample line as described in section 7.2.1.
14. Disconnect the inlet to the test chamber from the apparatus. Connect a dry gas meter to the inlet of the test chamber. Adjust the test chamber flow to the prescribed flowrate as indicated by the dry gas meter. Reconnect the test chamber to the apparatus.
15. Turn the main power switch on the back of the control box to ON. A green light at the front will come on. If the control box is getting power and all the electrical connection are properly attached. The thermocouple indicator will also come on. *NOTE: If any of the electrical connectors are loose, the control box will not energize.*
16. Insure that column drain valve is closed and capped. Insure that the upstream sampling port is closed.
17. Push the STANDBY mode button; the yellow STANDBY light will come on. This will open the main air pressure shutoff valve (SV1) and bring pressure to the nebulizer and dilution flow regulators.
18. Push the PURGE mode button. This puts you in the PURGE mode and allows air to go through the dilution flow regulator.
19. Adjust the dilution flow regulator at the front of the generator assembly until the appropriate flowrate is indicated on the sample line flowmeter. This is approximately 10 percent greater than the test chamber flowrate. *NOTE: This is not the operating flowrate setting. This is only to check the apparatus for any major leaks or loose connections.*
20. Check the ambient temperature, to see if it is within the specified limits (20–25°C).

8.3 Generating Vapor and Testing Procedure

1. Press the GENERATE mode button on the control box.
2. Adjust the dilution and nebulizer regulators at the front of the generator assembly until the appropriate sample concentration is obtained at the appropriate flowrate. The sample flowrate must be approximately 10 percent greater than the prescribed test chamber flowrate. For example, if the required test chamber flowrate is 50 lpm, then the sample line flowmeter should indicate at least 55 lpm.

3. Ensure that the temperature of agent/simulant in the nebulizer is within appropriate limits (~37°C for DMMP).
4. Monitor the challenge concentration by placing the upstream analyzer-mode switch on the control box in the SAMPLE position and observe the reading on the upstream detector. The response may take a several minutes. Adjust the dilution and nebulizer regulators until the appropriate concentration is indicated. After the reading, return the upstream analyzer mode switch to STANDBY. *NOTE: Prolonged sampling of the upstream concentration will foul the upstream detector.*
NOTE: The concentration may also be controlled by increasing or decreasing the bulk liquid temperature in the nebulizer. Increasing the power to the heating tape increases the agent/simulant concentration.
5. Switch the downstream analyzer switch to SAMPLE, and press the TEST mode button on the control box. At this time the challenge stream will begin to pass through the test filter, and the test timer will operate. Readjust the test chamber flowmeter control valve, if necessary, to the required flowrate. *NOTE: If the downstream analyzer switch is not in the SAMPLE mode, the LLNL filter-life tester will not go into TEST mode.*
6. At intervals throughout the test, ensure that the specified test flow rate through the test chamber (50 lpm) and challenge concentration (~4 mg DMMP per liter air) are maintained. The upstream challenge concentration should not be sampled continuously as fouling of the upstream detector can occur. Sample for periods of several minutes spaced at least 10 min apart. Adjust the generator and air flows, as required, to maintain the proper flow and concentration.
7. The downstream sample from the test chamber should drive the recorder pen toward a stable baseline. This must be checked immediately.
8. If the recorder pen is driven up scale, leakage should be suspected. In this instance, press either the PURGE or STANDBY mode buttons and investigate the cause of the leak.
9. During the course of testing, the response of the downstream detector may not return to the baseline of the previous test. If the new baseline is a stable signal, adjustment of the signal with the buckout or zero control on the downstream detector to a new baseline is permissible. If the baseline drifts downward, this is an indication of contamination still in the lines from the previous test. If the baseline drifts below zero, upward adjustment with the buckout or zero control must be made.
10. Anytime changes in the buckout or zero are made, an appropriate notation of these changes must be made on the recorder chart paper.
11. Any significant *premature* increase in downstream detector response from the baseline should be suspected as resulting from a poorly seated filter or a malfunction in detector or recorder operation. The test should be interrupted while the cause of the baseline drift is determined. If the cause of the drift can be determined, the deficiency will be corrected and the test will be restarted. If no cause for the drift can be determined, the test will be restarted, without downward adjustment of downstream detector response, and will continue until the normal breakpoint is reached. The breaktime in either case is the total time the item is under test. (Do not include time during which the test was interrupted.)
12. In normal operation, the baseline appears as a straight line with some background electronic noise. Generally, this noise should cause deviations of about one to two divisions on the chart paper. There will be occasions when this noise will be greater or less, and if the noise remains high, such as three or four divisions on the chart paper, and persists for several days, then steps should be taken to correct the problem. The manual for the

downstream detector has a trouble-locating procedure that includes corrections for noisy operation as well as corrections for other problems that may arise.

13. The downstream concentration is determined by reading the percent response of the recorder for the downstream detector and checking that response against the calibration curve. The calibration curve for the detector showing percent response versus concentration in micrograms per liter (mg/l) will be furnished with the test apparatus. If the operator misses the breakpoint and does not record the exact time at which the break concentration was attained, the break time will be determined from the recorder chart. *CAUTION: The downstream detector response should be checked periodically during testing to make certain the flame in the block has not been extinguished. Anytime the background noise has disappeared and the recorder pen plots a perfectly straight line, a flame out is suspected. A slight change in the air or hydrogen flowmeter settings will bring an immediate response on the recorder pen indicating that the flame is lighted. If the flame is out, relight it using the standard procedure outlined in the detector manual. If the breakpoint concentration have been exceeded while the flame was extinguished, the test is invalid and must be repeated. If the breakpoint was not exceeded while the flame was extinguished, the test is valid.*
14. During the test, the downstream concentration is monitored continually. The test continues until the downstream detector begins a gradual, steady rise up scale (~1 hr for the M13-A2 control filters). Once the downstream detector indicates the test agent/simulant concentration specified in the applicable document listed in Appendix A, press the PURGE mode button. A record of the total test time is made. Record the total test time in the appropriate data sheet or logbook. If a strip chart recorder with a cut out switch is used, the tester can be modified to automatically switch to PURGE when the downstream concentration reaches the prescribed set limit. *CAUTION: Do not saturate the downstream detector with test agent/simulant. A long period of out-gassing will be necessary if the detector is exposed to high concentrations of test chemicals.*
15. When the test is over, push the GENERATE mode button. Appendix I lists typical test times for various filters.
16. After a suitable time to vent, open the test chamber and remove the test filter.
17. Return to step 6 in section 8.2 to install a new test filter and continue testing.

8.4 Shutdown Procedure

Three shutdown procedures are outlined. The first covers emergency shutdown procedures to be used when time does not permit routine daily shutdown. This procedure is to be used only to isolate the test agent/simulant until the emergency is over. The second covers routine daily shutdown, and the third procedure covers complete shutdown and preparation for disassembly.

- 8.4.1 **Decontamination.** The equipment shall be decontaminated and certified free of contamination in accordance with the policies and procedures prescribed by the Department of Defense Explosive Safety Board (DDESB), the U.S. Army Material Command (AMC), and the locally approved Standard Operating Procedures (SOPs) prior to being removed from the laboratory hood and placed into storage.

8.4.2 Emergency Shutdown

1. Operate the SYSTEM POWER OFF switch on the front of the control box by pressing it in.
2. Turn off the power switch in the back of the control box.

8.4.3 Daily Shutdown

1. Press the PURGE mode button. The system should be purged sufficient time to remove residual agent/simulant minutes. This will purge the sample line and remove any residual challenge concentrations that may exist in the sample line. *NOTE: This will not purge the nebulizer. The system must be in GENERATE mode to completely purge the generator of challenge agent/simulant.*
2. Operate the SYSTEM POWER OFF switch on the front of the control box by pressing it in.
3. Turn off the power to the control box by flipping the power switch on the back of the control box.
4. Turn off the power to the nebulizer heating tape or water bath heater.
5. Turn off the power switches on the gas analyzers and chart recorders.
6. Open drain valve and collect excess any excess condensate.
7. Close off the main air supply valve on the hood.
8. Close off the vacuum supply valve on the hood.
9. Remove nebulizer and decontaminate/clean it, if required by a regulation or SOP.

8.4.4 Complete Shutdown

1. Perform steps listed under daily shut down.
2. Close off all gas supplies to the upstream and downstream detectors and turn them OFF. *NOTE: The analyzers will now require time to stabilize upon restart.*
3. Unplug all power cords from the power outlets.
4. Close off the air supply and disconnect the air supply line from the back of the vapor generation assembly. Disconnect the upstream analyzer span gas line at the back of the vapor generation assembly.
5. Disconnect the vacuum supply. Disconnect and remove the upstream and downstream gas analysis sample lines.
6. Disconnect and remove the heating tape from around the nebulizer (or drain the water from the nebulizer bath).
7. If the tester is to be removed from the laboratory hood, disconnect the electrical connections from the vapor generator assembly and the test chamber assembly, such that the control box and the chemical instrumentation can be removed independently. You may disconnect the vapor generation assembly from the test chamber assembly if necessary.

9.0 Safety

- When the test apparatus is used by contractors, the safety requirements form a part of the contract provisions.
- When the test apparatus is used by government laboratories, the safety procedures applicable to chemical agents, as cited in DDESB, AMC, and local safety regulations shall be followed as a guide for establishing safe work methods.
- Detailed operating procedures should be developed to supplement this manual.

- A copy of this manual shall be kept near the apparatus.
- Physical property information about DMMP is in Appendix C.
- A MSDS for DMMP can be found in Appendix D.
- Material compatibility information for GB and DMMP can be found in Appendix J.

10.0 Maintenance

10.1 Concepts

General maintenance concepts appear first, followed by a detailed component-by-component list of repair or replacement frequencies and procedures. A description of statistical control for the LLNL filter-life tester operation leads to a troubleshooting and repair guide. This section describes minimum maintenance procedures required and tests that must be used by the operator. A sample maintenance log sheet can be found in Appendix K. The periodic replacement schedule for components is summarized in Appendix L. *CAUTION: All components of this tester will be considered contaminated with the test materials used unless otherwise certified to be free of contamination by personnel knowledgeable in chemical decontamination.*

CAUTION: Personnel performing maintenance on the LLNL filter-life tester must be completely familiar with the contents of this manual and knowledgeable in system operation and of materials used in tester operation.

Maintaining safe and reliable performance of the LLNL filter-life tester requires following prescribed routine shutdown and purge procedures to minimize contact between the agent/simulant and degradable materials. Periodic repair and replacement of components are necessary preventive measures. Appendix M is listing of the frequently replaced parts on the LLNL filter-life tester. Appendix N is a listing of the fittings for the LLNL filter-life tester. Appendix O is a listing of the electronic parts required to assemble the control box.

10.1.1 Materials Compatibility. Qualitative materials compatibility for DMMP and GB appear in Appendix J. These should be used to specify appropriate elastomer and seal materials for the components in the LLNL filter-life tester that require them. Appendices M and N list the appropriate replacement parts. DMMP compatibility information was provided by the MRC Division of Chamberlain Mfg. Corp.. GB compatibility data were obtained from Dr. James Baker. These references are listed in Appendix B.

10.1.2 Machine Clock. The machine clock runs whenever the LLNL filter-life tester is in the PURGE, GENERATE or TEST mode. This elapse time is to be used to determine when parts are to be replaced.

10.2 Statistical Control

10.2.1 Method. For statistical evaluation of control filter test results and actions to be taken in the event of large deviations, see section 7.4 for a description of the statistical control methods and procedures.

10.2.2 Troubleshooting. Actions to be taken as a result of deviations from the expected lives for control items are listed in Appendix F. Take priority one actions when the life of a control falls outside

the two standard deviation limit. Take priority two actions when the lives of two successive controls fall outside the three standard deviation limit.

10.2.3 Procedures. Procedures for routine shutdown are found in section 8.4. Procedures for statistical evaluation of control filter test results are found in section 7.4. The periodic replacement schedule for components is summarized in Appendix L. In order to accumulate reliability data, a sample maintenance log sheet has been included in this document in Appendix K. Repairs, replacements, and component failures should be noted on this log sheet at the time the work is performed.

10.2.4 Sample Maintenance Log. Appendix K is a sample maintenance log sheet. All changes and work performed on the filter life tester should be recorded on this log sheet.

10.3 Component Replacement

Two types of filters are found on the LLNL filter-life tester: Standard M10-A1 and M18 canister filters.

10.3.1 M10-A1 Filter

Replace the M10-A1 filter every 2000 hr of operation, or immediately if contaminated.

1. The LLNL filter-life tester must be shut down and purged according to section 8.4.
2. Disconnect the M10-A1 filter from the rubber stopper and stainless steel tube.
3. Decontaminate and discard old filter in accordance with approved disposal procedures.
4. Look at the stopper carefully. If there are cracks or swelling, so much so that it cannot be used, replace it with a new one.
5. Connect the new M10-A1 filter to the stopper and mount on filter tester.
6. Record the replacement in the maintenance log.

10.3.2 M18 Filter

Replace the sample line scrubbing filter every 8 hr of operation. Replace the test chamber line scrubbing filter every 1000 hr of operation, or immediately if contaminated.

1. The LLNL filter-life tester must be shut down and purged according to paragraph 8.4 in this manual.
2. Loosen the 1/2-in. Swagelok tube fitting at the top of the M18 filter.
3. Loosen all four hose clamps from around the black, 1-in.-inside-diameter (ID) rubber tubing that forms the seal between the filter and the stainless steel fitting at the top and bottom of the filter housing.
4. Remove stainless steel fitting and rubber tubing from the top and bottom of the M18 filter. Remove the filter.
5. Decontaminate and discard the used filter in accordance with approved disposal procedures.
6. Install a new M18 filter and replace the rubber tubing at the top and bottom of the filter. Be careful not to collapse the metal tubing at the end of the M18 filter housing when installing the stainless steel fittings.

7. Tighten the hose clamps around the top and bottom fittings and the rubber hose to seal the filter housing.
8. Connect and tighten the 1/2-in. Swagelok fittings.
9. Record the replacement in the maintenance log.

10.3.3 Solenoid Valves

Replace the solenoid valves when the device does not function correctly, or every 2000 hr.

1. Shut down and purge the LLNL filter-life tester according to section 8.4.
2. Loosen the fittings and remove the solenoid valve.
3. Decontaminate and discard the used valves in accordance with regulations.
4. Replace with like unit (see Appendix M for part numbers).
5. Record these repairs in the maintenance log.

10.3.4 Check Valves

The check valves should be replaced after 2000 hr of operation, or immediately if failure is observed.

1. Shut down the LLNL filter-life tester according to section 8.4.
2. Loosen fittings and remove check valve.
3. Decontaminate and discard the used valve in accordance with applicable disposal procedures.
4. Install new check valve (see Appendix M for part numbers).
5. Record repairs in maintenance log.

10.3.5 Flowmeters

Replace when device does not function correctly.

1. Shut down and purge the LLNL filter-life tester according to section 8.4.
2. Loosen the fittings and remove the flowmeter.
3. Decontaminate and discard the used flowmeter in accordance with regulations.
4. Replace it with a like unit (see Appendix M for part numbers).
5. Record these repairs in the maintenance log.

10.3.6 Pressure Regulators

Replace the pressure regulator when the device does not function correctly.

1. Shut down and purge the LLNL filter-life tester according to section 8.4.
2. Loosen the fittings and remove the pressure regulator.
3. Decontaminate and discard the used regulator in accordance with regulations.

4. Replace it with a like unit (see Appendix M for part numbers).
5. Record these repairs in the maintenance log.

10.3.7 *Pressure Gauges*

Replace the pressure gauge when the device does not function correctly.

1. Shut down and purge the LLNL filter-life tester in accordance with section 8.4.
2. Loosen the fittings and remove the pressure gauge.
3. Decontaminate and discard the gauge in accordance with regulations.
4. Replace the defective parts with like items (see Appendix M for part numbers).
5. Record these repairs in the maintenance log.

10.3.8 *Fittings, Gaskets, and Tubing*

Inspect the fittings, gaskets, and tubing for obvious cracks, breaks, bulges, or holes every 40 hr of operation. Replace them as needed.

1. Shut down and purge the LLNL filter-life tester in accordance with section 8.4 .
2. Loosen and remove the fittings, gaskets, or tubing.
3. Decontaminate and discard the fittings, gaskets, or tubing in accordance with regulations.
4. Replace defective parts with like items (see Appendix N for part numbers).
5. Record these repairs in the maintenance log.

Appendix A
Components and Operational Requirements
of LLNL Filter-Life Tester

RESPIRATOR		FILTER			TEST CHAMBER	
Component ID	Specification No.	Component ID	Specification Drawing No.	Assembly Drawing No.	Assembly Drawing No.	Specific Drawing No.
Mask, M17-A1	MIL-M-51282	Filter Element Set, M13-A1	EA-F-1089 SB 740-94-5 (Appendix K)	D5-3-917	E136-41-3500	136-41-870
Mask, M17-A2	MIL-M-51495	Filter Element Set, M13-A2	EA-F-1091 SB 740-94-5 (Appendix K)	D5-3-1000	E136-41-3500	136-41-870
Mask, M25-A1	MIL-M-51178	Canister, M10-A1	MIL-C-13864	D5-3-547	E136-41-3500	136-41-890-1
Mask, M9-A1	MIL-M-12296	Canister, M11	MIL-C-10116	D5-3-588	E136-41-3500	136-41-890-2
Mask, ND Mark V	MIL-M-17522	Canister, ND-C1	MIL-C-24314A	S7702-F 1434408	E136-41-3500	136-41-890-3
Mask, M-40	MIL-M-?	Canister, C2	EA-C-1322	D5-3-1500	E136-41-3500	136-41-890-4
Mask, M-42	MIL-M-?	Canister, C2	EA-C-1322	D5-3-1500	E136-41-3500	136-41-890-4
Mask, M-43	MIL-M-?	Canister, C2	EA-C-1322	D5-3-1500	E136-41-3500	136-41-890-4

Appendix B

Bibliography

1. *Environmental Hazards of Chemical Agent Simulants*, Bennent S.R. et al., CRDC-TR-84055, August 1984.
2. *Instruction Manual for the Installation, Operation and Maintenance of the Fifty Liter per Minute Filter Life Tester 250*, 136-300-328, Aberdeen proving ground, Maryland, May 1985.
3. *Evaluation of Dimethyl Methylphosphate and Exo-tetrahydrodi-(cyclopentadiene) in a Battery of in Vitro Short-Term Aassays* (Arthur D. Little, Inc., Cambridge, MA, 1983).
4. *Development of Candidate Chemical Simulant List: the Evaluation of Candidate Chemical Simulants Which May be Used in Chemically Hazardous Operations* (Arthur D. Little, Inc., Cambridge, MA, 1982).
5. *Vapor Pressures of Pure Substances*, Boublik T. et al. (Elsevier Scientific Publishing Co., New York, NY, 1973).
6. *Handbook of Chemical Property Estimate Methods*, Lyman et al. (McGraw-Hill, New York, NY, 1982).
7. *Manual on Presentation of Data and Control Chart Analysis*, 6th ed. (Philadelphia, PA, 1990).
8. *Merck Index: an Encyclopedia of Chemicals, Drugs and Biologicals*, Susan Budavari, Ed., 12th ed. (Merck & Co. Rahway, NJ, 1989).

Appendix C

Properties of Challenge Agents/Simulants

Properties of GB (Sarin)

Chemical Formula $(\text{CH}_3)_2\text{CHOP}(\text{O})\text{FCH}_3$

Molecular weight = 140.09

Specific gravity = 1.1 H_2O at 20°C

Melting point = -57°C

Hydrolyzed by water

Boiling point = 147°C at 760 mm

Boiling point = 56°C at 16 mm

Properties of DMMP

Chemical Formula $(\text{CH}_3\text{O})_2\text{P}(\text{O})\text{CH}_3$

Molecular weight = 124.09

Specific gravity = 1.145 H_2O at 20°C

Vapor specific gravity = 4.3 (calculated)

Vapor Pressure = 0.87 mm Hg at 25°C (calculated)

Volatility = 4100 mg/m^3

Completely soluble in water

Viscosity = 1.81 centistokes at 25°C

Melting point $< -50^\circ\text{C}$

Boiling point = 181°C

Flash point = 104.4°C (closed cup)

Appendix D

MSDS for DMMP

DMMP Material Safety Data Sheet Aldrich Chemical Co.
P.O.Box 355,
Milwaukee, WI 53201
(414) 273-3850

Identification

Name: Dimethyl Methylphosphonate, 97%
Product Number: D16910-2
CAS Number: 756-79-6
Molecular Formula: C₃H₉O₃P
Synonyms: Dimethyl methylphosphonate, DMMP, methanephosphonic acid dimethyl ester, NCI-C54762, methyl phosphonic acid dimethyl ester

Toxicity Hazards

RTECS Number: SZ9120000 Phosponic acid, methyl-, dimethyl ester
Reviews/Standards: EPA TSCA chemical inventory, 1986
EPA TSCA test submission (TSCATS) data base, June 1986
NTP carcinogenesis studies (gavage); some evidence: rat NTPTR NTP-TR-323,87
NTP carcinogenesis studies (gavage); inadequate evidence: mouse NTPTR NTP-TR-323,87 meets criteria for proposed OSHA medical records rule
FEREAC 47,30420,82

Only selected registry of toxic effects of chemical substances (RTECS) data is presented here. See actual entry in RTECS for complete information.

Health Hazard Data

Acute Effects

Maybe harmful by inhalation, ingestion, or skin absorption.
Vapor or mist is irritating to the eyes, mucous membranes, and upper respiratory tract.
Causes skin irritation.
Exposure can cause nausea, headache, and vomiting.
To the best of our knowledge, the chemical, physical, and toxicological properties have not been thoroughly investigated.

First Aid

In case of contact, immediately flush eyes with copious amounts of water for at least 15 minutes.
In case of contact, immediately wash skin with soap and copious amounts of water.
If inhaled, remove to fresh air. If not breathing give artificial respiration. If breath is difficult, give oxygen.
Call physician.
Wash contaminated clothing before reuse.

Physical Data

Boiling point: 181°C
Specific gravity: 1.145 H₂O at 20°C
Vapor pressure: <0.1 mm Hg at 20°C

Fire and Explosion Data

Flash point: 156°F (69°C)
Extinguishing media: Water spray, carbon dioxide, dry chemical powder, alcohol, or polymer foam.

Special fire fighting procedures: Wear self-contained breathing apparatus and protective clothing to prevent contact with skin and eyes.

Unusual fire and explosion hazards: Emits toxic fumes under fire conditions. Vapor may travel considerable distance to source of ignition and flash back.

Reactivity Data

Incompatibilities: Strong oxidizing agents, strong bases.

Hazardous combustion or decomposition products: Toxic fumes of carbon monoxide or carbon dioxide. Thermal decomposition may produce toxic fumes of phosphorus oxides and/or phosphine.

Spill or Leak Procedures

Steps to be taken if material is released or spilled: Wear self-contained breathing apparatus, rubber boots and heavy rubber gloves. Cover with dry lime or soda ash (NaCO₃), pick up, keep in a closed container, and hold for waste disposal.

Ventilate area, and wash spill site after material pickup is complete.

Waste disposal method: This material may be burned in a chemical incinerator equipped with an afterburner and scrubber. Observe all federal, state, and local laws.

Precautions for Handling and Storage

Chemical safety goggles
Rubber gloves
NIOSH/MSHA-approved respirator
Safety shower and eye bath
Mechanical exhaust required
Avoid contact and inhalation
Do not get in eyes or on skin or clothing
Wash thoroughly after handling
Irritant
Keep tightly closed
Keep away from heat and open flame
Stench
Store in cool place

Appendix E

Major Parts of LLNL Filter-Life Tester

ID No.	Part Name	Figure Reference	Page Number
1	Control Box	3	42
2	Main Power On Switch	3	42
3	Power Indicator Light	3	42
4	System Power Off Button	3	42
5	STANDBY Mode Button	3	42
6	STANDBY Mode Indicator Light	3	42
7	PURGE Mode Button	3	42
8	PURGE Mode Indicator Light	3	42
9	GENERATE Mode Button	3	42
10	GENERATE Mode Indicator Light	3	42
11	TEST Mode Button	3	42
12	TEST Mode Indicator Light	3	42
13	Upstream Analyzer Mode Switch	3	42
14	Downstream Analyzer Mode Switch	3	42
15	Thermocouple Meter (type J iron-constantan)	3	42
16	Machine Timer	3	42
17	Test Timer	3	42
18	Control Box Cable	4	43
19	Vapor Generator Assembly	4-7	43-46
20	Upstream Analyzer Air Supply Regulator	5,7	43, 46
21	Main Air Pressure Shutoff Solenoid Valve (SV1)	7	46
22	Dilution Flow Regulator	4,6,7	43, 45, 46
23	Nebulizer Flow Regulator	4,6,7	43, 45, 46
24	Dilution Flow Solenoid Valve (SV2)	7	46
25	Nebulizer Inlet Flow Solenoid Valve (SV3)	4, 7	43, 46
26	Dilution Flow Check Valve	5	44
27	Nebulizer Flow Check Valve	4,5,6	43-45
28	Liquid Trap	4-7	43-46
29	Liquid Trap Drain Valve	7	46
30	Nebulizer Quick Connect	4, 6, 7	43, 45, 46
31	Nebulizer	4-7	43-46
32	Nebulizer Refill Tap	4, 6	43, 45
33	Nebulizer Thermocouple (Type J iron-constantan)	4-6	43-45
34	Heating Tape	4, 6	43, 45
35	Nebulizer Outlet Flow Solenoid Valve (SV4)	4, 5, 9	43, 44, 48
36	Mixer/Condenser	4-7, 9	43-46, 48
37	Column	4, 5	43, 44
38	Column Drain Valve with Cap	7	46
39	Upstream Sample Port with Cap	5, 7	44, 46
40	Calibration Flowmeter	4, 6	43, 45
41	Upstream Analyzer Calibration Flow Solenoid Valve (SV7)	4-7	43-46
42	Upstream Analyzer Sample Flow Solenoid Valve (SV8)	5, 7	44, 46

ID No.	Part Name	Figure Reference	Page Number
43	Test Chamber Assembly	4, 5, 8, 9	43, 44, 47, 48
44	Test Chamber Purge Flow Filter	4, 5, 8, 9	43, 44, 47, 48
45	Test Chamber Purge Flow Solenoid Valve (SV6)	5, 9	44, 48
46	Test Chamber Sample Flow Solenoid Valve (SV5)	5, 9	44, 48
47	M13 Test Chamber	4, 8, 9, 10	43, 47, 48, 49
48	M10, M11 and C1 Test Chamber	5, 11	44, 50
49	Flexible Line	4, 8	43, 47
50	Downstream Analyzer Purge Filter	4, 5, 8	43, 44, 47
51	Downstream Analyzer Pressure Reducing Valve	4, 8, 9	43, 47, 48
52	Downstream Analyzer Sample Flow Solenoid Valve (SV9)	4, 8, 9	43, 47, 48
53	Downstream Analyzer Pressure Gauge	4, 8, 9	43, 47, 48
54	Test Chamber Flow Scrubbing Filter	4, 5, 8, 9	43, 44, 47, 48
55	Sample Flow Scrubbing Filter	4, 5, 8, 9	43, 44, 47, 48
56	Test Chamber Line Flowmeter	4, 8	43, 47
57	Sample Line Flowmeter	4, 8	43, 47
58	Chemical Instrumentation Assembly	12	51
59	Upstream Analyzer (Beckman 400A hydrocarbon analyzer)	12	51
60	Downstream Analyzer (Melay SA 160-2 modified sulfur analyzer)	12	51
61	Upstream and Downstream Analyzer Strip Chart Recorder	12	51

Appendix F

Troubleshooting Checklist Based on Control Filter-Life Tester

A. Low Control Filter Life

Possible Cause of Problem	Action to be Taken	Priority*
1. High room temperature	Lower room temperature to specification limits (20–25°C).	1
2. High nebulizer temperature	Lower nebulizer temperature.	1
3. Incorrect settings on upstream analyzer	Check analyzer instruction manual for correct settings	1
4. Improperly seated filter	Test a new control filter	1
5. Hole in control filter	Run another control filter.	1
6. Poor calibration of the upstream analyzer	Recalibrate analyzer.	1
7. High chamber flow	Check accuracy of the test chamber flowmeter.	2
8. Leaky downstream analyzer sample line	Inspect sample line for leaks and perform leak test.	2

B. High Control Filter Life

Possible Cause of Problem	Action to be Taken	Priority*
1. Low sample flow	Adjust sample flow to 10 percent excess of required test flow.	1
2. Low room temperature	Raise room temperature to specification limits (20–25°C).	1
3. Low nebulizer temperature	Raise nebulizer temperature.	1
4. Wrong settings on the upstream analyzer	Check analyzer instruction manual for correct settings.	1
5. Not enough liquid agent/simulant	Add liquid agent/simulant to appropriate level.	1
6. Poor calibration of the upstream analyzer	Recalibrate analyzer.	1
7. Low test chamber flow	Check accuracy of test chamber flowmeter with dry gas meter.	2
8. Leaky test chamber flow line	Inspect test chamber line for leaks and perform leak test.	2
9. Leaky downstream analyzer sample line	Inspect sample line for leaks and perform leak test.	2

*Priority 1 items should be checked whenever a control filter test falls outside the $X \pm 2s$ limit; Priority 2 items should be checked whenever two successive low control filters fall outside the $X \pm 3s$ limit of the test apparatus.

Appendix G **Solenoid Valve Status**

	VALVE NUMBER					
	SV1	SV2	SV3	SV4	SV5	SV6
MAIN POWER SWITCH						
OFF	C	C	C	C	C	O
ON	O	C	C	C	C	C
GENERATOR SWITCH MODE						
STANDBY	O	C	C	C	C	O
PURGE	O	O	C	C	C	O
GENERATE	O	O	O	O	C	O
TEST	O	O	O	O	O	C

	VALVE NUMBER	
	SV7 EPA	SV8 EPA
UPSTREAM ANALYZER MODE		
SPAN GAS	COO	OCO
STANDBY	OCO	OCO
SAMPLE	OCO	COO

	VALVE NUMBER
	SV8 EPA
DOWNSTREAM ANALYZER MODE	
STANDBY	OCO
SAMPLE	COO

Legend: O = Open
 C = Closed
 E = Normally open inlet port
 P = Normally closed inlet port
 A = Normally open exhaust port

Appendix H

Operational Checklist for LLNL Filter-Life Tester

1. Make sure the LLNL filter life tester is assembled properly.
2. Make sure the filter to be tested is installed properly.
3. Make sure the flexible hose to the test chamber outlet is attached to the test chamber properly.
4. Check to see if vacuum supply and air supply is on and connected.
5. Check for leaks in test chamber flow line by removing test chamber flow purge filter and plugging the line. If flow is observed in the test chamber flowmeter; a leak exists.
6. Reattach test chamber flow purge filter.
7. Flip up the power switch on the back of the control box. The green power light at the front of the control box will come on.
8. Pull out the large red MAIN POWER OFF button on the front of the control box.
9. Fully close the dilution flow regulator and the nebulizer flow regulator (turn counterclockwise to close).
10. Check to see that the main air supply regulator is set to 50 psig.
11. Check the sample lines to gas analyzers and make sure calibration gas supply to the gas analyzers is on.
12. Zero both the upstream and downstream gas analyzers.
13. Calibrate upstream analyzer with span gas.
14. Check to see if nebulizer is full before filling with agent/simulant.
15. Fill nebulizer with agent/simulant and close the refill tap.
16. Turn on and adjust power to the nebulizer heating tape.
17. Press the STANDBY mode button. The yellow STANDBY mode light will come on.
18. Press the PURGE button to put the system in PURGE mode.
19. Press the GENERATE mode button to put the system in GENERATE mode.
20. Adjust the flow regulators, so that the sample flowmeter flow is at least 10 percent greater than the required flow.
21. Record initial test information.
22. After at least 15 min, sample the upstream agent/simulant concentration. *NOTE: Do not sample for long periods of time.*
23. If the concentration and flow is correct, press the TEST button to put the system in TEST mode.
24. After the test is over, record the results.
25. Press the GENERATE mode button.
26. If testing is to be continued, wait a few minutes, then remove the old filter, install a new one and go to step 18.
27. If testing is finished, press the PURGE button to put the system in PURGE mode for at least 60 min.
28. After 60 min of purging, press the STANDBY mode button to put the system in STANDBY mode.
29. Perform the appropriate shutdown procedure listed in section 8.4.

Appendix I
Typical Filter Test Durations

Challenge agent/simulant (flowrate)	C2 filter (min)	M10 filter (min)	M11 filter (min)	M13 filter (min)
DMMP (50 lpm)	130-250 min	—	100-130 min	—
GB (32 lpm)	130 min	280 min	—	45 min

Appendix J

Elastomer and Plastic Compatibility Information

GB

Elastomer or Plastic	Compatibility	Type of Failure
Buna-N	Very poor	Swells
Ethylene propylene	Good	—
Silicone rubber	Poor	Swells and dissolves
Teflon	Excellent	—
Viton	Poor	Swells and breaks
Kalrez	?	?

DMMP

Elastomer or Plastic	Compatibility	Type of Failure
Acrylic	Very poor	Decomposes DMMP
Butyl rubber	Fair	Absorbs DMMP
Neoprene rubber	Poor	Absorbs DMMP
Nylon	Fair	Decomposes DMMP
Polycarbonate	Very poor	Absorbs DMMP
Polyethylene	Good	—
Silicone rubber	Poor	Absorbs DMMP
Teflon	Excellent	—
Viton rubber	Very poor	Absorbs DMMP
Kalrez	?	?

Appendix K

Sample Maintenance Log

Date	Operator	Machine Time	Component	Action Taken	Remarks

Appendix L
Periodic Maintenance Schedule for the
LLNL Filter-Life Tester

Component	Interval Replace/Repair	Operating Hours
Purge filters (M10-A1)	Replace	2000**
Sample line scrubbing filter (M18)	Replace	8
Test chamber line scrubbing filter (M18)	Replace	1000**
Solenoid valves	Repair	2000
Check valves	Replace	2000
Flowmeters	Repair	Failure
Pressure regulators	Replace	Failure
Pressure gauge	Replace	Failure
Fittings	Replace	Failure

*Replace component immediately if it fails before the end of the normal service period.

**Replace component immediately if it is exposed to challenge agent/simulant.

Appendix M

Spare Parts List

Company	Part	Replacement Part Number
1. Mine Safety Appliances Pittsburgh, PA 15230 (800) 672-2222	M10-A1 Filter(4240-00-127-7186) M18 Filter (4240-00-828-3952)	??? (FSCM ???) 5-19-2350 (FSCM 9L087)
2. Automatic Switch Co. Florham Park, NJ 07932 (201) 966-2000	Solenoid valves SV 1, 2, 3, 4, 5 (normally closed) Solenoid valve SV6 (normally open)	8263A325 (FSCM 04845) 8262A153E (FSCM 04845)
3. Skinner Valve Co. New Britain, CT 06051 (203) 827-2300	Solenoid valves SV 7, 8, 9 (small 3-way valve)	B13ADK1150 (FSCM 06769) (specify Teflon O-rings)
4. Circle Seal Controls Anaheim, CA 92801 (714) 774-6110	Check valve (poppet type)	220-TI-288
5. Brooks Instruments Hatfield, PA 19440 (215) 362-3500	Flowmeter Model 1355-V Sho-Rate II "150" (specify Teflon seals) Glass meter tube R-6-15-B Glass meter tube R-2-15-A Glass float Stainless steel float Tantalum float 316 SS 1/4 pipe rear adapter with Teflon seal 316 SS valve assembly with Kalrez seal	S925G313WAA S925C166WAA 345C054WYA 345C067BMA 345G051JNA S014C289BMA S947M124BMA
6. C.A. Norgren Co. Littleton, CO 80120 (303) 794-2611	Pressure regulator Pressure gauge	RO5-200-RNLA 18-013-225
7. Marsh Instr. Co. P.O. Box 1348 Hasting, NE 68902 (402) 463-3390	Pressure gauge	J0046
8. Ashcroft Gauges Stratford, CT 06497 (203) 378-8281	Pressure gauge	1NA240830029
9. BriskHeat Corp. Columbus, OH 43216 (614) 294-3376	Heating tape	Model BMC481301

Company	Part	Replacement Part Number
10. Omega Engineering, Inc. Stamford, CT 06907 (1-800) 622-2378	Type J thermocouple Type J thermocouple connector	TJ36-ICSS-116G-6-BX-OST-M OST-J-MF
11. Ace Glass Louisville, KY 40201 (800) 626-5381	Stainless steel ball joint Stainless steel socket joint	7658-20 7658-22
12. Fischer Scientific Pittsburgh, PA 15219 (412) 562-8300	Stainless steel joint clamp	05-885E
13. Du Pont Company Wilmington, DE 19880 (800) 441-7515	Kalrez O-ring Kalrez O-ring	MIL AS-568A, size 2-214, 0.984-in. ID, 0.139-in. CSD MIL AS-568A, size 2-373, 8.975-in. ID, 0.210-in. CSD

Appendix N

Fittings List

Amount	Item	Part Number
1 ft	1-in.ID black rubber tubing (0.25 wall thickness)	
20 ft	1/8-in. Teflon tubing	
10 ft	1/4-in. polyethylene tubing	
10 ft	1/2-in. polyethylene tubing	
10 ft	1/2-in. stainless steel tubing (0.065 wall thickness)	
8	~4-in.-long hose clamps	
2	3/8-in.-diameter stainless steel pipe (6 in. long)	
3	3/8-in.-diameter stainless steel pipe (4 in. long)	
1	3/8-in.-diameter stainless steel pipe (1.5 in. long)	
10	3/8-in.-diameter stainless steel pipe (1 in. long)	
1	1/4-in.-diameter stainless steel pipe (1 in. long)	
1	1/8-in.-diameter stainless steel pipe (2 in. long)	
1	12-in. long stainless steel flex tubing 1/2 inch O.D. with XBA end adapters (Cajon)	321-8-X-12B2
7	3/8 to 3/8 female pipe 90° ELBOW stainless steel fitting (Cajon)	SS-6-E
2	1/4 to 1/4 female pipe 90° ELBOW stainless steel fitting (Cajon)	SS-4-E
4	3/8 female pipe TEE stainless steel fitting (Cajon)	SS-6-T
2	1/4 female pipe TEE stainless steel fitting (Cajon)	SS-4-T
1	3/8 female pipe CROSS stainless steel fitting (Cajon)	SS-6-CS
2	3/8 male pipe PLUG stainless steel fitting (Cajon)	SS-6-P
1	3/8 male to 1/8 female pipe BUSHING stainless steel fitting (Cajon)	SS-6-RB-2
1	3/8 male to 1/4 female pipe BUSHING stainless steel fitting (Cajon)	SS-6-RB-4
1	3/8 male pipe to 1/8 male pipe REDUCER stainless steel fitting (Cajon)	SS-6-HRN-2
3	3/8 male pipe to 1/4 male pipe REDUCER stainless steel fitting (Cajon)	SS-6-HRN-4
1	1/4 male pipe to 1/8 male pipe REDUCER stainless steel fitting (Cajon)	SS-4-HRN-2
1	1/4 tube SS BULKHEAD UNION stainless steel fitting (Swagelok)	SS-400-11-4
1	1/8 tube SS BULKHEAD UNION stainless steel fitting (Swagelok)	SS-200-11-2
2	1/8 tube to 1/8 male pipe stainless steel fitting (Swagelok)	SS-200-61
4	1/4 tube to 1/4 male pipe stainless steel fitting (Swagelok)	SS-400-61
2	1/4 tube to 1/8 male pipe stainless steel fitting (Swagelok)	SS-400-1-2
3	1/4 tube to 3/8 male pipe stainless steel fitting (Swagelok)	SS-400-1-6
6	1/2 tube to 1/4 male pipe stainless steel fitting (Swagelok)	SS-810-1-4
2	1/2 tube to 3/8 male pipe stainless steel fitting (Swagelok)	SS-810-1-6
1	1/2 tube to 3/8 female pipe stainless steel fitting (Swagelok)	SS-810-7-6

Amount	Item	Part Number
2	1/2 tube to 1/2 tube 90° UNION ELBOW stainless steel fitting (Swagelok)	SS-810-9
2	1/8 tube to 1/8 male pipe 90° ELBOW stainless steel fitting (Swagelok)	SS-200-2-2
3	1/4 tube to 1/8 male pipe 90° ELBOW stainless steel fitting (Swagelok)	SS-400-2-2
3	1/4 tube to 1/4 male pipe 90° ELBOW stainless steel fitting (Swagelok)	SS-400-2-4
1	1/4 tube to 3/8 male pipe 90° ELBOW stainless steel fitting (Swagelok)	SS-400-2-6
2	1/2 tube to 1/2 male pipe 90° ELBOW stainless steel fitting (Swagelok)	SS-810-2-8
2	1/4 tube 1/4 male pipe branch TEE stainless steel fitting (Swagelok)	SS-400-3-4TTM
1	3/8 male pipe VCR body (Cajon)	SS-8-VCR-1-6
1	3/8 female pipe VCR body (Cajon)	SS-8-VCR-7-6
2	3/8 male pipe WVCR connector (Cajon)	SS-8-WVCR-1-6
2	3/8 stainless steel VCR gaskets	SS-8-VCR-2
1	1/4 tube Teflon-sealed Quick-connect stem (Swagelok)	SS-QT2-D-400
1	1/4 pipe Teflon-sealed Quick-connect body (Swagelok)	SS-QT2-B-4PM
2	Toggle Valves (Whitey) 3/8 male pipe ends	SS-1GM6
1	Integral Bonnet Needle Valve (Whitey) 1/8 male pipe ends	SS-ORM2
2	3/8 female pipe CAPS (Cajon)	SS-6-CP
2	VCR Cap (to cap nebulizer when removed)	SS-VCR-CP

Appendix O
Electronic Parts List for Control Box

Amount	Item	Company	Part Number
1	Cabinet	Newark	HC-14103
1	Meter, thermocouple	Analogic	AN25MO2 EM-1-XX-J-C-X
1	Timer, machine	Airpax	K49201-P2
1	Timer, elapse	Kessler-Ellis Products	MTM126/MTM1521
4	Relays	Potter & Brumfield	KRPA -14AG-120
4	Sockets, electrical	Potter & Brumfield	SL-616
1	Circuit breaker	Heinmann	AM1-A3-A
1	AC Connector plug	Switchcraft	EAC-302
1	Terminal block, type J thermocouple	Marlin	1032-6-J
8	Holder, Neon lamp	Dailco	CM10-201-1
5	Lamp, neon, yellow	Dailco	CR04-YCS-N121
5	Lamp, neon, red	Dailco	CR04-RCS-N121
4	Switch, mode	Micro Switch, Inc.	2PB11-T2
1	Switch, pushbutton, emergency stop	Klockner-Moeller	RPV / K01
1	Switch, three position (upstream analyzer)		Mil Spec 35059-21
1	Switch, two position (downstream analyzer)		Mil Spec 35059-23
1	Connector, cable receptical (J2)		Mil Spec 3122E18-11S
1	Connector, interlock receptical (J1)		Mil Spec 3112E8-3S
1	Connector, interlock plug (P1)		Mil Spec 3116E8-3P

Figure 1. Schematic of the LLNL filter-life tester.

Figure 3. Photograph of control box, front view.

Figure 4. Photograph of LLNL filter-life tester, front view.

Figure 5. Photograph of LLNL filter-life tester, rear view.

Figure 6. Detail photograph of vapor generation assembly, front view.

Figure 7. Detail photograph of vapor generation assembly, rear view.

Figure 8. Detail photograph of test chamber assembly, front view.

Figure 9. Detail photograph of test chamber assembly, rear view.

Figure 10. Detail photograph of the M13-A2 filter test chamber.

Figure 11. Detail photograph of the M10-A1, M11, and C2 filter test chamber.

Figure 12. Photograph of the upstream and downstream gas analyzers.

END

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