GAS AND PARTICULATE REMOVAL BY XCAPER CIVILIAN AND PROFESSIONAL MASK FILTERS

Prepared for:

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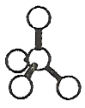
August 2007



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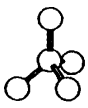

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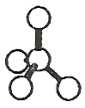

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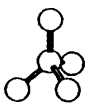

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I. Introduction

This is a report of the tests carried out on the XCAPER Civilian and Professional filters at the RNK Environmental, Inc. laboratory in Erlanger, Ky. from February to August 2007 for both gas and particulate removal. This testing was conducted to support the XCAPER application for certification of their filters under the European Union standards program. The tests were carried out in a specially designed Plexiglas "glove box" chamber with a breathing human head simulator. In conducting the testing the EN403 test protocol was modified slightly to accommodate the vapor liquid extraction and dynamic filter media technology of the XCAPER filters. Figure A presents a schematic of the test apparatus used in this testing.

The test gases and concentrations in EN403 were used to challenge the XCAPER mask filters. The gases separately tested were carbon monoxide (CO), acrolein (C_3H_4O), hydrogen cyanide (HCN) and hydrogen chloride (HCl) along with particulates suspended in nitrogen (N_2). Each gas concentration and particulate concentration was certified by its supplier and confirmed by RNK Environmental, Inc. personnel. Figure B is a picture of the actual test apparatus used and shows a probe placed in the glove box to monitor the challenge gas concentration near the human head simulator.

II. Specific Objectives

1. To test the removal of carbon monoxide from ambient air by the filters.

2. To test the removal of acrolein from ambient air by the filters.

3. To test the removal of hydrogen cyanide from ambient air by the filters.

4. To test the removal of hydrogen chloride from ambient air by the filters.

5. To test the removal of particulates from ambient air by the filters.

6. To conduct tests 15 minutes in duration.

7. To simulate real world breathing and conditions.

8. To develop a test protocol for dynamic media vapor liquid extraction filter technologies.

9. To test the filters using air pollutant concentrations of: 30 x 10^9 particles per cubic meter for particulates, 10 ppm acrolein, 100 ppm acrolein, 2,500 ppm carbon monoxide, 400 ppm for hydrogen cyanide, and 1,000 ppm for hydrogen chloride.

Figure A. Test Apparatus Schematic (Not-to-Scale)

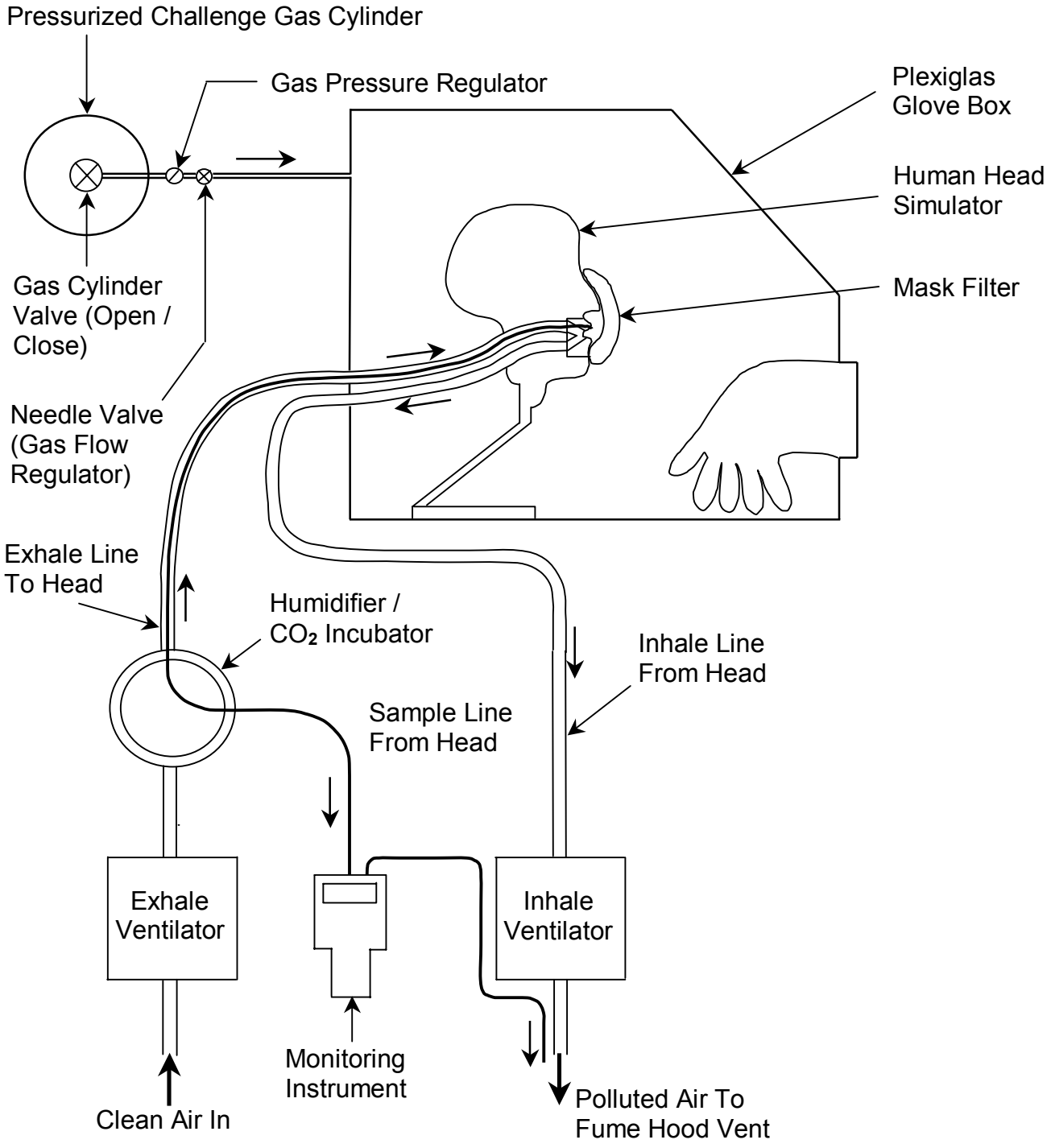

Figure B. Filter Mask For Testing Mounted On Human Head Simulator In Glove Box

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III. Results

Four types of filters were tested. For each filter and each challenge gas two tests were conducted. All of the filters provided high degrees of removal over the 15-minute test period. Table A below presents a summary of the mean percent removals of all of the gases and particulates for each mask filter type tested.

IV. Brief Discussion

The test protocol used in these studies was modified from EN403 standards to support testing of dynamic media vapor liquid extraction filters. Test procedures were designed to simulate human respiration.

Each of the masks tested was easy to mount on the simulated human head. Each of the types of mask filters used performed well over the entire 15-minute test period. Removals of gas were excellent for the 15-minute test period. Removals for particulates were near 100% for the 15-minute test period.

V. Summary

Each of the four filters tested removed large quantities of the target gas concentrations of 100 ppm acrolein, 400 ppm hydrogen cyanide, 1,000 ppm hydrogen chloride and 2,500 ppm carbon monoxide. Removal of 0.3 μm diameter particles at a concentration of 30 x 10^9 particles per cubic meter approached 100% for the 15-minute test period for each of the filters tested. Table A below presents a summary of the mean percent removals of all of the gases and particulates for each mask filter type tested. The results indicate the filters are useful in situations where these chemicals are introduced into the ambient air either accidentally such as in a fire setting or intentionally such as in a terrorist attack.

Table A. Mean Percent Removals For All Tests

Challenge / Mask Type	Particulates 30 x 10^9 / m^3	Acrolein 10 ppm	Acrolein 100 ppm	CO 2,500 ppm	HCN 400 ppm	HCl 1,000 ppm
Civilian 14/24	96.4%	97.5%	95.0%	90.4%	97.9%	99.7%
Civilian 17/30	99.6%	98.0%	96.2%	91.6%	97.7%	99.9%
Prof. 3.5 Mock Int.	98.8%	99.1%	96.2%	92.0%	97.9%	99.9%
Prof. 14/24	98.5%	98.9%	95.2%	91.2%	97.7%	99.6%

1. Introduction

This is a report of the tests carried out on the XCAPER Civilian and Professional filters at the RNK Environmental, Inc. laboratory in Erlanger, Ky. from February to August 2007 for both gas and particulate removal. This testing was conducted to support the XCAPER application for certification of their masks under the European Union standards program. The tests were carried out to simulate high breathing rates under stressful conditions in a specially designed Plexiglas "glove box" chamber with a breathing human head simulator. In conducting the testing the EN403 test protocol was modified slightly to accommodate the vapor liquid extraction and dynamic filter media technology of the XCAPER mask filters. Figure 1 presents a schematic diagram of the test apparatus used in this testing.

The challenge gases and concentrations in EN403 were used because there was no specific protocol for this type of mask. The gases separately tested were carbon monoxide (CO), acrolein (C_3H_4O), hydrogen cyanide (HCN) and hydrogen chloride (HCl) along with particulates suspended in nitrogen (N_2). Each gas concentration and particulate concentration was certified by its supplier and confirmed by RNK Environmental, Inc. staff.

The tests carried out in the new glove box apparatus involved several changes in methodology from previous mask filter testing conducted for XCAPER Industries, LLC by RNK Environmental, Inc. In the previous mask filter testing, gases were forced through the mask filters rather than drawn through the mask filters. A stainless steel testing chamber was used in the previous testing whereas in the current work a specially designed Plexiglas glove box testing chamber was used. Figure 2 presents a picture of the glove box showing an XCAPER mask filter mounted on the human head simulator. Percent removals from the current testing were similar to those obtained in previous testing when the challenge gases are at the same concentrations.

The breathing rate used in earlier testing of 38 l/min was reduced to 30 l/min in accordance with EN403. The breathing volume was one liter. Figure 3 presents a picture of the test apparatus setup showing the glove box, human head simulator, and the hospital ventilators used. Monitoring methodologies remained the same between the previous and current testing and were consistent with EN403. Figure 4 presents a picture of the monitoring instrument being connected to the sample line in preparation for testing.

The EN403 standard does not currently support the dynamic media vapor liquid extraction technology used in the XCAPER mask filters. The XCAPER filter media is designed to shift within the filter during use in response to the wearer's body and facial movement. This continuously renews the microscopic surface layer of gas absorbing gel. This occurs several times per minute during actual use. To simulate this effect during testing a number of mechanical means were considered. None were judged to adequately simulate the media shifting effect. Ultimately the most effective and simplest means of simulating media shifting during testing was a light manual massage of the filter conducted at one-minute intervals. Figure 5 is a picture showing a mask filter being massaged during active testing.

2. Specific Objectives

1. To test the removal of 2,500 ppm carbon monoxide (CO) from ambient air by the filters.

2. To test the removal of 400 ppm hydrogen cyanide (HCN) from ambient air by the filters.

3. To test the removal of 10 ppm acrolein (C_3H_4O) from ambient air by the filters.

4. To test the removal of 100 ppm acrolein (C_3H_4O) from ambient air by the filters.

5. To test the removal of 1,000 ppm hydrogen chloride (HCl) from ambient air by the filters.

6. To test the removal of particulates at a concentration of 30×10^9 particles per cubic meter from ambient air.

7. To conduct two tests 15 minutes in duration for each filter against each challenge gas.

8. To simulate human respiration during testing.

9. To develop a test protocol for dynamic media vapor liquid extraction filter technologies.

3. Test Apparatus

1. A Plexiglas glove box test chamber.

2. A molded rubber human head simulator mounted on a metal pedestal.

3. A human breathing simulation system connected to the human head simulator with breathing tubes and consisting of: a) on the inhale side of a hospital breathing vent and b) on the exhale side a hospital breathing vent and a humidifier / CO_2 incubator.

4. A challenge gas delivery system consisting of: a.) a pressurized cylinder containing the certified challenge gas and equipped with an open/close valve; b) a gas pressure regulator; c) a needle valve for regulating the flow of the challenge gas to the test chamber; and d) a challenge gas supply line leading to the test chamber.

5. A filtered gas sample line attached to the breathing zone of the human head simulator.

6. A monitoring instrument to analyze the concentration of the challenge gas behind the mask filter.

Figure 1. Test Apparatus Schematic Diagram (Not-to-Scale)

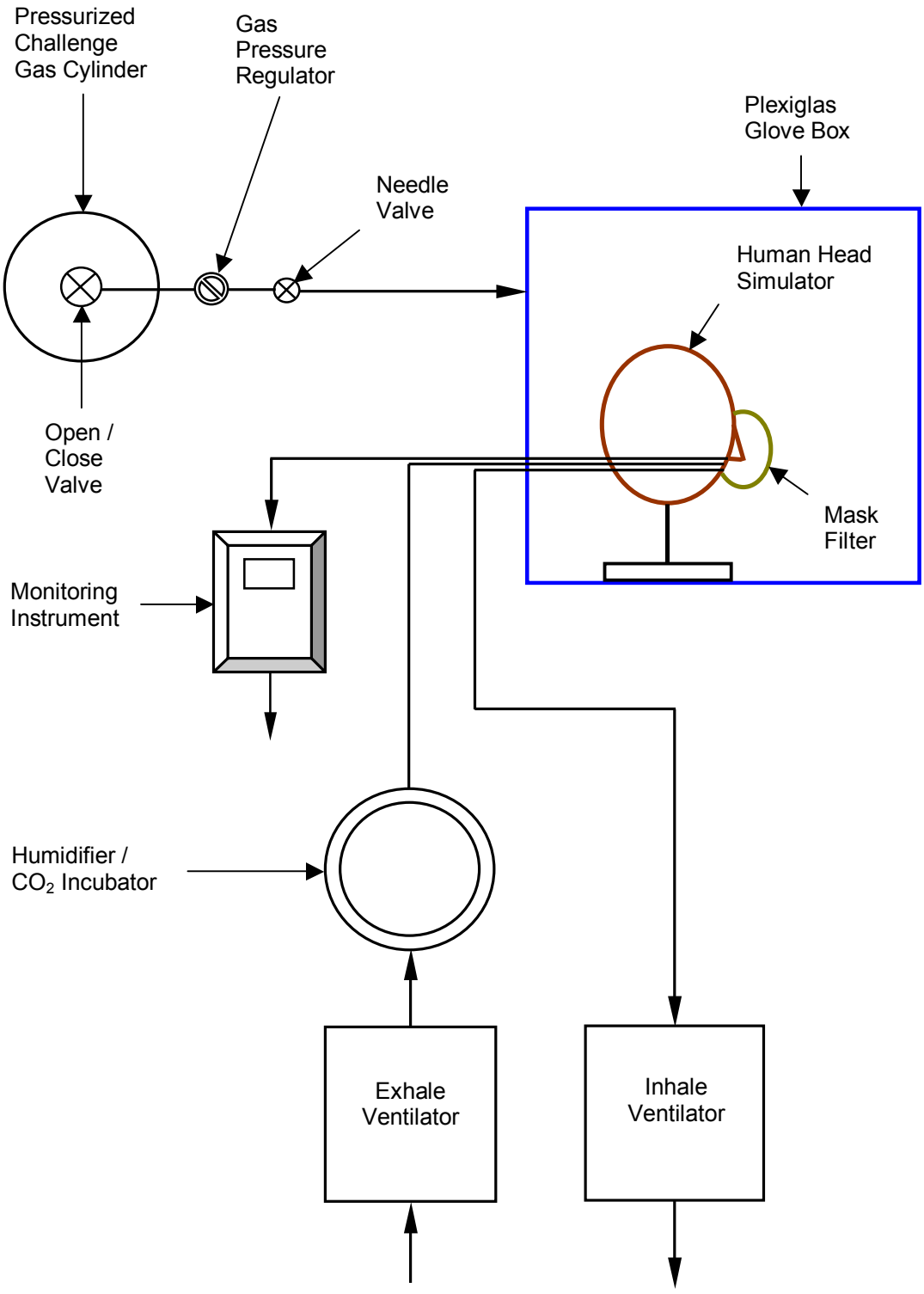

Figure 2. Mask Mounted on Human Head Simulator Inside Plexiglas Glove Box

Figure 3. Test Apparatus Setup With Head, Glove Box, and Hospital Ventilators

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Figure 4. Preparing For Testing By Connecting Monitoring Instrument to Sampling Line

Figure 5. Massaging Mask Filter During Active Test

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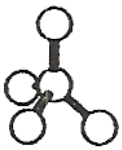
XCAPER Mask Filter Testing Project

Glove Box Chamber Test Procedure for Gases

1. Mount filter to be tested on head. Record number of filter.
2. Turn on exhale CO_2 incubator and heater for humidity (10 minutes).
3. Turn on monitoring instrument and calibrate.
4. Ensure mask is secure on head.
5. Check all tubing for leaks.
6. Turn on gas at cylinder.
7. Adjust pressure to 10 psi.
8. Fill glove box chamber with gas.
9. Start test when glove box chamber reaches target gas concentration.
10. Read temperature and humidity in chamber.
11. Monitor challenge gas flow throughout test and adjust as needed.
12. Inhale vent on = start of test = time zero.
13. Exhale vent on 1 second later.
14. Read monitoring instrument for target gas at 1-minute intervals. See data sheet after mask has cleared.
15. Massage mask at 1-minute intervals to simulate wearer-filter interactions.
16. Carry out test for 15 minutes.
17. Shut off gas to chamber.
18. Shut off instruments.
19. Ensure all data are collected and recorded on data sheet.
20. Sign data sheet.
21. Leave hood fans on until chamber is cleared.



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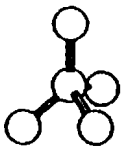

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XCAPER Mask Filter Testing Project

Glove Box Chamber Test Procedure for Particulates

1. Mount filter to be tested on head. Record number of filter.
2. Turn on exhale CO_2 incubator and heater for humidity (10 minutes)
3. Turn on monitoring instrument and calibrate background.
4. Ensure mask is secure on head.
5. Charge the particle reservoir chamber with particle to achieve the desired concentration of 30×10^9 particles per cubic meter
6. Start flow from the particle reservoir chamber to the glove box chamber.
7. Start test when glove box chamber reaches target particle concentration.
8. Read temperature and humidity in chamber.
9. Monitor particle flow throughout test and adjust as needed.
10. Inhale vent on = start of test = time zero.
11. Exhale vent on 1 second later.
12. Read instrument for particles/cm^3 at 1-minute intervals. See data sheet.
13. Massage mask at 1-minute intervals to simulate wearer-filter interactions.
14. Carry out test for 15 minutes.
15. Shut off feed from particle reservoir chamber to glove box chamber.
16. Shut off exhale vent.
17. Shut off instruments.
18. Ensure all data are collected and recorded on data sheet.
19. Sign data sheet.
20. Leave hood fans on until chamber is cleared.

4. Results

Table 1. contains a listing of the particular XCAPER mask filters that were tested in this current work effort.

Table 1. Types of Mask Filters Tested

Mask Type	Filter Composition
Civilian	14 oz. Beads 24 g. Gel
Civilian	17 oz. Beads 30 g. Gel
Professional	3.5 g. mock interlock 14 oz. Beads 24 g. Gel
Professional	14 oz. Beads 24 g. Gel

At least two 15-minute runs were made on each mask filter with the concentration recorded after each minute of breathing exposure. Either 38 liters or 30 liters of the gas contaminants were passed through the masks between readings that were recorded after the start of each test. All of the mask filters generally provided a high degree of removal of the contaminants tested. Mean percent removals for all contaminants were above 90 percent and are discussed in more detail as follows.

Table 2. presents the percent removal results for each of the mask types for 10 ppm (+/- 10%) acrolein. Actual acrolein concentrations in the challenge gas were between 10.8 and 11.0 ppm. The data are based upon an assumed challenge gas concentration of 10 ppm. The Civilian 14/24 mask exhibited removals of 96.2 percent and 98.7 percent when challenged with 10 ppm acrolein.

The Civilian 17/30 mask exhibited removals of 98.2 percent and 97.8 percent when challenged with 10 ppm acrolein. These results indicate that this type of mask provides a high degree of protection against acrolein at concentrations well above those found in residential or office fires.

The Professional 3.5 Mock Interlock/14/24 mask exhibited removals of 99.3 percent and 98.8 percent when challenged with 10 ppm acrolein. These results indicate that this type of mask provides a high degree of protection against acrolein at concentrations well above those found in residential or office fires.

The Professional 14/24 mask exhibited removals of 98.0 percent and 99.7 percent when challenged with 10 ppm acrolein. These results indicate that this type of mask provides a high degree of protection against acrolein at concentrations well above those found in residential or office fires.

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XCAPER Industries, LLC
Summary of July 2007 Filter Testing
Acrolein – 10 ppm

Date	Mask Type	Composition	Test Time (minutes)	Mean % Removal
7/16/07	Civilian	14 oz Beads 24 g Gel	15	96.2
7/17/07	Civilian	14 oz Beads 24 g Gel	15	98.7
7/16/07	Professional	3.5 oz Mock Intlk. 14 oz Beads 24 g Gel	15	99.3
7/17/07	Professional	3.5 oz Mock Intlk. 14 oz Beads 24 g Gel	15	98.8
7/16/07	Civilian	17 oz Beads 30 g Gel	15	98.2
7/24/07	Civilian	17 oz Beads 30 g Gel	15	97.8
7/17/07	Professional	14 oz Beads 24 g Gel	15	98.0
7/25/07	Professional	14 oz Beads 24 g Gel	15	99.7

Table 2. Mean Percent Removals for 10 ppm Acrolein

Table 3. presents the percent removal results for each of the mask types for 100 ppm (+/- 10%) acrolein. Actual acrolein concentrations in the challenge gas were between 100 and 102 ppm. The data are based upon an assumed challenge gas concentration of 100 ppm. The Civilian 14/24 mask exhibited removals of 95.1 percent, 94.9 percent. These results indicate that this type of mask provides a high degree of protection even at a challenge gas concentration of 100 ppm acrolein.

The Civilian 17/30 mask exhibited removals of 97.3 percent and 95.1 percent when challenged with 100 ppm acrolein. These results indicate that this type of mask provides a high degree of protection at a challenge gas concentration of 100 ppm acrolein.

The Professional 3.5 Mock Interlock/14/24 mask exhibited removals of 96.4 percent and 95.9 percent when challenged with 100 ppm acrolein. These results indicate that this type of mask provides a high degree of protection even at a challenge gas concentration of 100 ppm acrolein.

The Professional 14/24 mask exhibited removals of 95.5 percent and 94.9 percent when challenged with 100 ppm acrolein. These results indicate that this type of mask provides a high degree of protection even at a challenge gas concentration of 100 ppm acrolein.

Table 4. presents the percent removal results for each of the mask types for 1,000 ppm (+/- 10%) hydrogen chloride. Actual hydrogen chloride concentrations in the challenge gas were between 1,000 and 1,020 ppm. The data are based upon an assumed challenge gas concentration of 1,000 ppm. The Civilian 14/24 mask exhibited removals of 99.6 percent and 99.7 percent when challenged with 1,000 ppm hydrogen chloride. These results indicate that this type of mask provides a high degree of protection against the acid gas hydrogen chloride.

The Civilian 17/30 mask exhibited removals of 99.8 percent and 99.9 percent when challenged with 1,000 ppm hydrogen chloride. These results indicate that this type of mask provides a high degree of protection against the acid gas hydrogen chloride.

The Professional 3.5 Mock Interlock/14/24 mask exhibited removals of 99.8 percent and 99.9 percent when challenged with 1,000 ppm hydrogen chloride. These results indicate that this type of mask provides a high degree of protection against the acid gas hydrogen chloride.

The Professional 14/24 mask exhibited removals of 99.5 percent and 99.6 percent when challenged with 1,000 ppm hydrogen chloride. These results indicate that this type of mask provides a high degree of protection against the acid gas hydrogen chloride.

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XCAPER Industries, LLC
Summary of May 2007 Filter Testing
Acrolein – 100 ppm

Date	Mask Type	Composition	Test Time (minutes)	Mean % Removal
5/23/07	Civilian	14 oz Beads 24 g Gel	15	94.9
5/30/07	Civilian	14 oz Beads 24 g Gel	15	95.1
5/25/07	Professional	3.5 oz Mock Intlk. 14 oz Beads 24 g Gel	16	96.4
5/26/07	Professional	3.5 oz Mock Intlk. 14 oz Beads 24 g Gel	15	95.9
5/27/07	Professional	14 oz Beads 24 g Gel	15	95.5
5/27/07	Professional	14 oz Beads 24 g Gel	15	94.9
5/28/07	Civilian	17 oz Beads 30 g Gel	15	97.3
5/28/07	Civilian	17 oz Beads 30 g Gel	15	95.1

Table 3. Mean Percent Removals for 100 ppm Acrolein

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XCAPER Industries, LLC
Summary of June 2007 Filter Testing
Hydrogen Chloride (HCl) – 1,000 ppm

Date	Mask Type	Composition	Test Time (minutes)	Mean % Removal
6/12/07	Civilian	14 oz Beads 24 g Gel	15	99.6
6/12/07	Civilian	14 oz Beads 24 g Gel	15	99.7
6/12/07	Professional	3.5 oz Mock Intlk. 14 oz Beads 24 g Gel	15	99.8
6/13/07	Professional	3.5 oz Mock Intlk. 14 oz Beads 24 g Gel	15	99.9
6/13/07	Professional	14 oz Beads 24 g Gel	15	99.5
6/13/07	Professional	14 oz Beads 24 g Gel	15	99.6
6/14/07	Civilian	17 oz Beads 30 g Gel	15	99.9
6/14/07	Civilian	17 oz Beads 30 g Gel	15	99.8

Table 4. Mean Percent Removals for 1,000 ppm Hydrogen Chloride

Table 5. presents the percent removal results for each of the mask types for 400 ppm (+/- 10%) hydrogen cyanide. Actual hydrogen cyanide concentrations in the challenge gas were between 400 and 408 ppm. The data are based upon an assumed challenge gas concentration of 400 ppm. The Civilian 14/24 mask exhibited removals of 97.8 and 97.9 percent. These results indicate that this type of mask provides a high degree of protection at a challenge gas concentration of 400 ppm hydrogen cyanide.

The Civilian 17/30 mask exhibited removals of 97.6 percent and 97.7 percent when challenged with 400 ppm hydrogen cyanide. These results indicate that this type of mask provides a high degree of protection at a challenge gas concentration of 400 ppm hydrogen cyanide.

The Professional 3.5 Mock Interlock/14/24 mask exhibited removals of 97.8 percent and 97.9 percent when challenged with 400 ppm hydrogen cyanide. These results indicate that this type of mask provides a high degree of protection at a challenge gas concentration of 400 ppm hydrogen cyanide.

The Professional 14/24 mask exhibited removals of 97.7 percent in both tests when challenged with 400 ppm hydrogen cyanide. These results indicate that this type of mask provides a high degree of protection at a challenge gas concentration of 400 ppm hydrogen cyanide.

Table 6. presents the percent removal results for each of the mask types for 2,500 ppm (+/- 10%) carbon monoxide. Actual carbon monoxide concentrations in the challenge gas were between 2,500 and 2,550 ppm. The data are based upon an assumed challenge gas concentration of 2,500 ppm. The Civilian 14/24 mask exhibited removals of 89.5 percent and 91.3 percent when challenged with 2,500 ppm carbon monoxide. These results indicate that this type of mask provides a high degree of protection against carbon monoxide.

The Civilian 17/30 mask exhibited removals of 92.9 percent and 90.3 percent when challenged with 2,500 ppm carbon monoxide. These results indicate that this type of mask provides a high degree of protection against carbon monoxide.

The Professional 14/24 mask exhibited removals of 91.2 percent and 91.2 percent when challenged with 2,500 ppm carbon monoxide. These results indicate that this type of mask provides a high degree of protection against carbon monoxide.

The Professional 3.5 Mock Interlock/14/24 mask exhibited a removal of 91.3 percent and 92.7 percent when challenged with 2,500 ppm carbon monoxide. These results indicate that this type of mask provides a high degree of protection against carbon monoxide.

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XCAPER Industries, LLC
Summary of June 2007 Filter Testing
Hydrogen Cyanide (HCN) – 400 ppm

Date	Mask Type	Composition	Test Time (minutes)	Mean % Removal
6/1/07	Civilian	14 oz Beads 24 g Gel	15	97.8
6/2/07	Civilian	14 oz Beads 24 g Gel	15	97.9
6/3/07	Professional	3.5 oz Mock Intlk. 14 oz Beads 24 g Gel	15	97.9
6/4/07	Professional	3.5 oz Mock Intlk. 14 oz Beads 24 g Gel	15	97.8
6/4/07	Professional	14 oz Beads 24 g Gel	15	97.7
6/5/07	Professional	14 oz Beads 24 g Gel	15	97.7
6/5/07	Civilian	17 oz Beads 30 g Gel	15	97.6
6/6/07	Civilian	17 oz Beads 30 g Gel	15	97.7

Table 5. Mean Percent Removals for 400 ppm Hydrogen Cyanide

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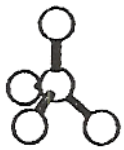
XCAPER Industries, LLC
Summary of April Filter Testing
CO – 2500 ppm

Date	Mask Type	Composition	Test Time (minutes)	Mean % Removal
5/19/07	Civilian	14 oz Beads 24 oz Gel	15	89.5
6/6/07	Civilian	14 oz Beads 24 oz Gel	15	91.3
4/22/07	Civilian	17 oz Beads 30 oz Gel	15	92.9
4/23/07	Civilian	17 oz Beads 30 oz Gel	15	90.3
6/6/07	Professional	3.5 oz Mock Intlk. 14 oz Beads 24 oz Gel	15	91.3
5/15/07	Professional	3.5 oz Mock Intlk. 14 oz Beads 24 oz Gel	15	92.7
6/7/07	Professional	14 oz Beads 24 oz Gel	15	91.2
6/11/07	Professional	14 oz Beads 24 oz Gel	15	91.2

Table 6. Mean Percent Removals for 2,500 ppm Carbon Monoxide



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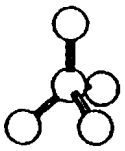

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XCAPER Industries, LLC
Summary of June 2007 Filter Testing
0.3 µm Particles – 30 x 10^9 / m^3

Date	Mask Type	Composition	Test Time (minutes)	Mean % Removal
6/19/07	Civilian	14 oz Beads 24 g Gel	15	93.1
6/19/07	Civilian	14 oz Beads 24 g Gel	15	99.7
6/20/07	Professional	3.5 oz Mock Intlk. 14 oz Beads 24 g Gel	15	97.6
6/20/07	Professional	3.5 oz Mock Intlk. 14 oz Beads 24 g Gel	15	100.0
6/21/07	Professional	14 oz Beads 24 g Gel	15	99.2
6/21/07	Professional	14 oz Beads 24 g Gel	15	97.7
6/22/07	Civilian	17 oz Beads 30 g Gel	15	99.2
6/22/07	Civilian	17 oz Beads 30 g Gel	15	100.0

Table 7. Mean Percent Removals for 0.3 µm Particulates at 30 x 10^9 particles per cubic meter

5. Discussion

Simulation of the human breathing process is impossible to perform with 100% accuracy. At least 17 variables are involved in this breathing process with many of the variables being interdependent. In early testing conducted in 2003 to provide a suitable simulation, an initial protocol was established in which hospital breathing vent pumps were used to push challenge gases through the mask filters placed on a human head simulator. Measurements were made in the nasal area between the mask and the human head simulator on a sample of gas that had passed through filter. In prior testing these measurements were used in determining and reporting percent removals (See previous report by RNK Environmental, Inc.).

In the current testing series covered in this report several refinements were made in the testing protocol in accordance with EN403 standards. The human head simulator was placed in a sealed glove box chamber that was filled with the challenge gas to be tested at the desired concentration. One hospital breathing vent was used to pull the challenge gas from the glove box chamber through the mask filter into the nasal area between the mask and the human head simulator while a second hospital breathing vent was to exhale out through the mask one second later. Initial breathing rates of 38 liters per minute established in 2003 were adjusted to 30 liters per minute in accordance with EN403 standards. Gas from the breathing zone between the human head simulator and the mask was sampled continuously with measured concentrations out being recorded at one-minute intervals over the 15-minute test period. Using this refined protocol the current testing of the mask filters was carried out with the same challenge gases as in the 2003 testing but at different concentrations as specified in EN403.

The results using this refined protocol were similar to those obtained using the original protocol but the current test protocol and results are believed to be better and even more indicative of the utility of the filters. This does not mean that this protocol absolutely duplicates human breathing. However, the refined protocol provides a simulation of human breathing sufficient to determine that the mask filters should work well in offering short-term respiratory protection against the gases and particulates used in these tests. It should be noted that the dynamic media in the XCAPER filter mask shifts several times per minute during actual use. Simulated shifting of the media conducted by manually massaging the filter masks at one minute intervals results in slightly lower filtration performance than is experienced during actual use. We are continuing to study other options for more effectively simulating the body and facial movements during testing.

Table 8. below contains the mean results of all of the current testing for percent removal of the gas or particulates at the stated challenge concentration. This table indicates that the masks constructed with the larger amount of beads and gel provide slightly larger percent removals of the challenge gases except for hydrogen cyanide (HCN) where the removals are approximately equal (97.9% vs. 97.7%) regardless of the variations in construction. Furthermore, the table indicates that the 3.5 Mock Interlock construction produced slightly better removals in the professional mask category.

Table 8. Mean Percent Removals For All Tests

Challenge / Mask Type	Particulates 30×10^9 / m^3	Acrolein 10 ppm	Acrolein 100 ppm	CO 2,500 ppm	HCN 400 ppm	HCl 1,000 ppm
Civilian 14/24	96.4%	97.5%	95.0%	90.4%	97.9%	99.7%
Civilian 17/30	99.6%	98.0%	96.2%	91.6%	97.7%	99.9%
Prof. 3.5 Mock Int.	98.8%	99.1%	96.2%	92.0%	97.9%	99.9%
Prof. 14/24	98.5%	98.9%	95.2%	91.2%	97.7%	99.6%

Table 8. above indicates that the mask filters tested should provide a high degree of short-term protection for the wearer in the presence of acid and toxic gases and particulates. This form of respiratory protection is easily placed into service in a short period of time over the nose and mouth by the prospective wearer. With instruction the prospective wearer should be able to don these types of masks in less than 20 seconds.

6. Summary

XCAPER mask filters were tested by challenging them with several toxic and acid gases typically produced by active and smoldering fires. These masks were also challenged with simulated smoke particulates. The masks were mounted on a human head simulator connected to hospital breathing vents in such a manner as to simulate human breathing under high activity and high stress situations. The human head simulator apparatus was mounted inside of a sealed Plexiglas glove box chamber into which the challenge gases were introduced at the desired concentrations. Four specific mask filters of varying construction were challenged with 10 ppm acrolein, 100 ppm acrolein, 400 ppm hydrogen cyanide, 1,000 ppm hydrogen chloride, 2,500 ppm carbon monoxide and 0.3 μm diameter particles suspended in nitrogen at a concentration of 30 x 10^9 particles per cubic meter. Tested in this manner, each of the masks performed well in removing pollutants over the 15-minute test period with percent removals for each filter being in the 90 to 100 percent range. The mask filters were easy to mount on the head simulator and individuals that are provided with a small amount of training should be able to don these masks in less than 20 seconds. Once in place the masks should provide a high degree of short-term respiratory protection against acid and toxic gases and smoke particulates that are typically generated from fires or smoldering fires.

So far removal data have been generated for carbon monoxide, hydrogen chloride, nitrous oxide (2003), nitrogen dioxide (2003), hydrogen cyanide, acrolein, and particulates for various configurations of the XCAPER mask filters during this and previous work conducted by RNK Environmental, Inc. In the current studies both the Professional 3.5 Mock Interlock masks and the new gel used in the construction of all masks tested performed very well. In conducting the current testing the EN403 test protocol was modified slightly to accommodate the vapor liquid extraction and dynamic filter media technology of the XCAPER mask filters. The methodology and protocols used for testing the mask filters as documented in this report are suitable for use by others in testing the XCAPER mask filters. Other physical tests required by EN403 were not conducted by RNK Environmental, Inc.