Appendix A
Detailed Statistical Analysis Results

A. Statistical Analysis Results

In this appendix we detail the results of the statistical analyses. The major sections and their corresponding topics are:

A.1- The effect of temperature and humidity on response time
A.2- The effect of temperature and humidity on recovery time
A.3- The effect of temperature and humidity on accuracy
A.4- The effect of temperature and humidity on repeatability
A.5- The effect of temperature and humidity on instrument response
A.6- The effect of interferents on instrument performance in the presence of an agent
A.7- Instrument sensitivity to interferents alone
A.8- The effect of fluctuation in agent concentration on instrument performance

A.1 Response Time

The ANOVA analyses of response time are contained in the following sections (see Chapter 5 for more details on the ANOVA procedure used). It should be noted that, in all cases, the log response time was modeled. The geometric means of results from the ANOVA models were then used to put the findings back into the original scale (as opposed to the log scale).

A.1.1 Effect of Temperature on Response Time

The tests used to assess the effect of temperature on instrument performance in the presence of GB are identified in Table A-1. There were 6 runs at low temperature, and 5 at medium and high temperature.

Table A-1. IDs of Tests included in the Agent Testing of the Effect of Temperature on M90-D1-C Performance

GB-01	GB-05	GB-07

Temperature had an effect on performance. At the high temperature level, the M90-D1-C had no response. At low and room temperature, there was a response, with the M90-D1-C taking significantly longer (p-value of 0.04) to respond at room temperature. The modeled response time at the low temperature setting was about 5 seconds; that at room temperature was about 9 seconds.

A.1.2 Effect of Humidity on Response Time

The tests used to assess the effect of humidity on instrument performance in the presence of GB are identified in Table A-2. There were 5 runs at each humidity level.

Table A-2. IDs of Tests included in the Agent Testing of the Effect of Humidity on M90-D1-C Performance

GB-01	GB-03	GB-04

There was evidence that humidity has an effect on M90-D1-C response time (p-value<0.01). The modeled response times of the M90-D1-C as a function of humidity level are presented in Figure A-1. The M90-D1-C appeared to respond more quickly in high humidity.

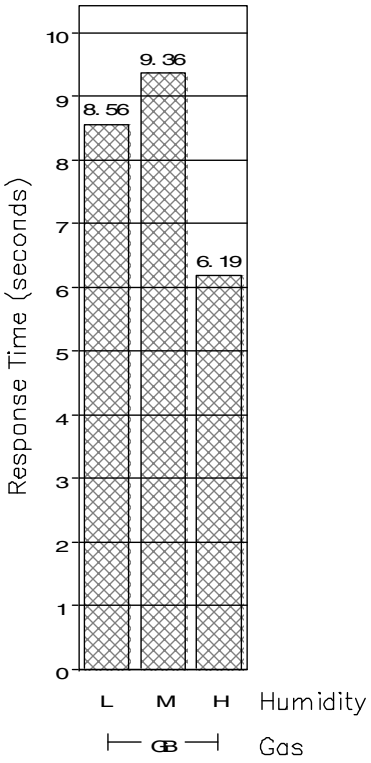

Figure A-1. Modeled geometric mean of response time by humidity level.

A.1.3 Summary of the Response Time Analysis

Both variation in temperature and humidity appear to affect M90-D1-C response time. No response times were measured at high temperature and normal (50%) RH because the instrument had no response at high temperature. Response time appeared to be higher at room temperature than at low temperature. Response time appeared to be lower at high humidity than it was at low or medium humidity.

A.2 Recovery Time

In both the temperature and humidity tests of recovery time, we observed recovery times in excess of 600 seconds. The recovery time for all runs at low temperature and medium humidity exceeded the 600 second threshold. The recovery for all runs at room temperature and high

humidity also exceeded the 600 second threshold. Thus, for both low temperature and high humidity, there were no uncensored recovery times. The best estimate for recovery time at low temperature or high humidity is a number in excess of 600 seconds.

A.2.1 Effect of Temperature on Recovery Time

The data available for the agent analysis of the effect of temperature on recovery time came from the tests identified in Table A-1. There was evidence that temperature had an effect on M90-D1-C recovery (p-value<0.01). As with the response time testing, there was no recovery time associated with the runs at high temperature since there was no instrument response at high temperature. As indicated in the introduction to this section, recovery times with medium humidity at low temperature all exceeded 600 seconds. The average of the 5 observed recovery times associated with room temperature was about 57 seconds, with a standard error of approximately 36 seconds. The magnitude of the mean and standard error was greatly influenced by one outlier. For 4 of the 5 runs at room temperature, instrument response was "low" and recovery took 32 seconds or less. For 1 of the 5 runs at room temperature, instrument response was "medium" and recovery took 199 seconds.

A.2.2 Effect of Humidity on Recovery Time

The data available for the agent analysis of the effect of humidity on recovery time came from the tests identified in Table A-2. There was evidence that humidity had an effect on M90-D1-C recovery time (p-value<0.01). As indicated in the introduction to this section, recovery times at room temperature and high humidity all exceeded 600 seconds. In contrast, the modeled recovery times at low and medium humidity were both approximately 30 seconds.

A.2.3 Summary of the Recovery Time Analysis

As with response time, variation in temperature and humidity appear to affect M90-D1-C recovery time. Recovery time at low temperature with medium humidity appears to exceed 600 seconds. Recovery time at high humidity at room temperature also appears to exceed 600 seconds.

A.3 Accuracy

The following sections present the results of analyses of the accuracy of M90-D1-C response. The M90-D1-C was considered to be "accurate" under a given set of conditions if it:

1. Alarmed in the presence of the agent and
2. Correctly identified the agent

A.3.1 Effects of Temperature and Humidity on Accuracy

Data available for the agent analysis of the effect of temperature on accuracy came from the tests identified in Table A-1. Based on tests conducted at medium humidity (50% RH), there was evidence that temperature had an effect on M90-D1-C accuracy (p-value<0.01). The M90-D1-C

performed with 100% accuracy on all runs at low and room temperature. However, at high temperature/medium humidity it performed with 0% accuracy since it had no response.

Data available for the agent analysis of the effect of humidity on accuracy came from the tests identified in Table A-2. Based on tests at room temperature (22°C), there was no evidence that humidity had an effect on M90-D1-C accuracy. Over the range of 20% to 80% RH, the M90-D1-C performed with perfect accuracy.

A.4 Repeatability

The following sections contain the statistical analyses of the repeatability of M90-D1-C response, response time, and recovery time. Table A-1 provides the IDs of tests used to determine the effect of temperature on repeatability; and Table A-2 provides the IDs of tests used to determine the effect of humidity on repeatability.

A.4.1 Repeatability of Response

Although temperature appears to affect instrument response, there was no evidence that variation in temperature had an effect on the repeatability of the response (p-value of 0.29). Instrument response was consistently high at low temperature. At room temperature, it was low for all but one run. At high temperature, there was consistently no response. There was also no evidence that variation in humidity had an effect on the repeatability of the response (p-value of 0.19). For the low and medium humidity runs, response tended to be low. For the high humidity runs, response was consistently medium.

A.4.2 Repeatability of Response Time

There was no evidence that variation in either temperature or humidity had an effect on the repeatability of response time (p-values of 0.32 and 0.77, respectively).

A.4.3 Repeatability of Recovery Time

There was insufficient data to assess whether variation in temperature had an effect on the repeatability of recovery time. For both low and high temperature, recovery was not observed. For low temperature, recovery consistently exceeded the 600 second threshold. For high, there was no instrument response.

There was sufficient data for some assessment of whether variation in humidity had an effect on the repeatability of recovery time. For high humidity, recovery was not observed since recovery at high humidity consistently exceeded the 600 second threshold. An assessment of the effect of humidity including only the low and medium levels could find no evidence of an humidity effect (p-value of 0.94).

A.4.4 Summary of the Repeatability Analysis

Variation in temperature and humidity appear to have little affect on the repeatability of M90-D1-C performance.

A.5. Response

A Jonckheere-Terpstra test was used to assess the effect of temperature on M90-D1-C response (see Chapter 5 for more details). The IDs of tests used in the analyses of instrument response are included in Tables A-1 and A-2.

A.5.1 Effect of Temperature on Response

There was evidence that temperature has an effect on instrument response (p-value <0.01) at medium humidity (50% RH). The observed responses of the M90-D1-C to the temperature challenges are summarized in Figure A-2. The M90-D1-C responded with a High reading to all six runs at low temperature. As temperature increased, the level of response decreased. At high temperature/50% RH, there was no response.

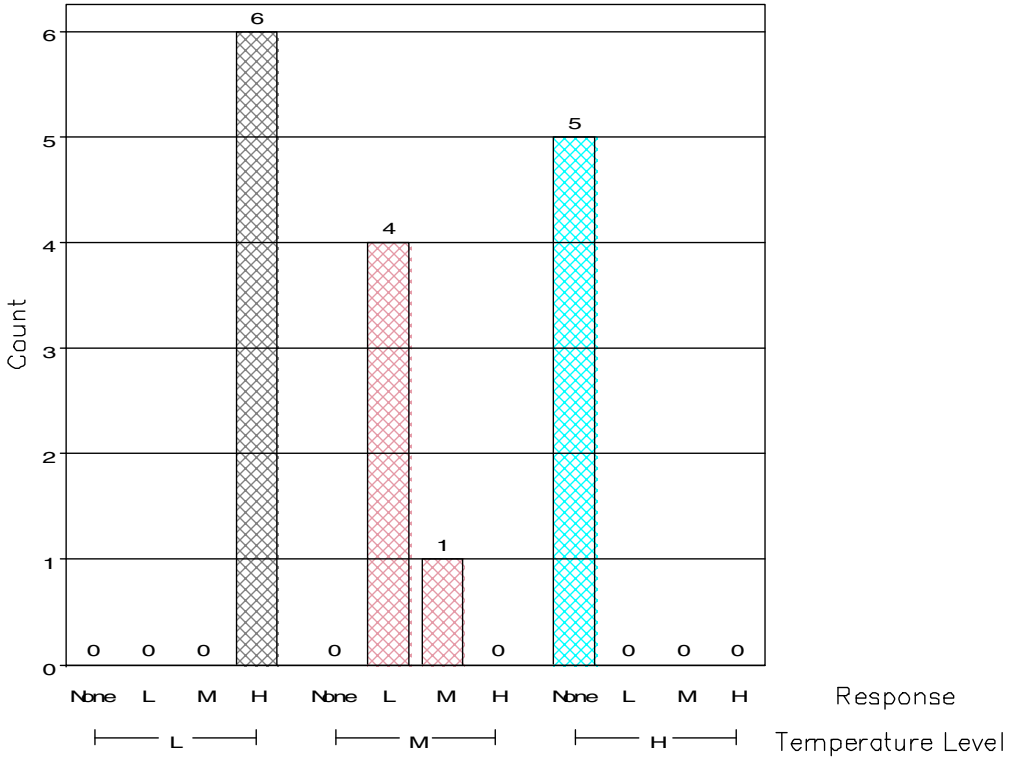

Figure A-2. Observed response by temperature level.

A.5.2 Effect of Humidity on Response

There was insufficient evidence that humidity had an effect on instrument response (p-value=0.12). Over the range of humidity conditions, the M90-D1-C registered either a low or medium response. All five of the runs at high humidity registered medium.

A.5.3 Summary of the Response Analysis

Variation in temperature appears to effect M90-D1-C response with constant humidity of 50% RH. At high temperature, the instrument provided no response. Humidity at room temperature does not appear to affect M90-D1-C response.

A.6 Interference Effects

The M90-D1-C response, response time, and recovery time were tested at room temperature and medium humidity with each of the following interferents:

1. Latex paint fumes
2. Floor cleaner vapors
3. Air freshener vapors
4. Gasoline engine exhaust hydrocarbons
5. DEAE

Performance in the presence of GB without interferent served as a control for the interferent results. The following sections summarize the statistical analyses of the effect of interferents. The IDs of tests included in the analysis in Table A-3. There were 5 runs with each interferent and 5 runs associated with the control.

Table A-3. IDs of Tests included in the Agent Testing of the Effect of Interferents on Performance

GB-01	GB-09	GB-10	GB-11	GB-12	GB-13

A.6.1 Effect of Interferent on Response

Interferents did not appear to have a statistically significant effect on the response of the M90-D1-C (p-value=0.38). The response tended to be low under all of the conditions.

A.6.2 Effects of Interferent on Response and Recovery Time

Analyses of the effects of interferents on response and recovery time were performed on the log time scale. Interferents did appear to have a statistically significant effect on the response time of the M90-D1-C (p-value<0.01). Figure A-3 contains the modeled geometric means of the response times without and with interferent. Floor cleaner and paint appeared to increase response time.

In contrast, interferents did not have a statistically significant effect on the recovery time of the M90-D1-C (p-value=0.61). However, there was a great deal of variability in the data, limiting the power of the test. Figure A-4 provides a plot of observed recovery times by interferent. As the figure illustrates, while most recovery times were under 100 seconds, within each condition is a recovery time in excess of 100 seconds. Runs with DEAE included two recovery times in excess of 300 seconds.

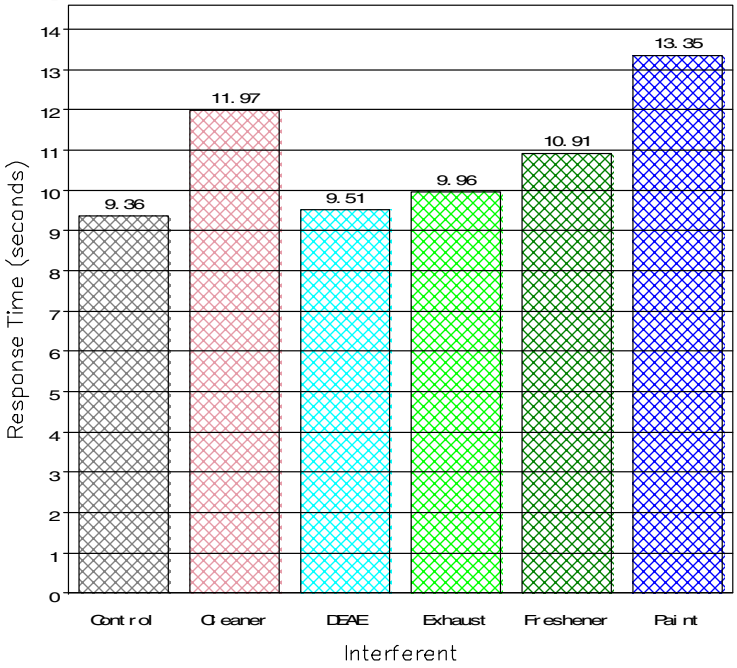

Figure A-3. Modeled geometric mean of response time by interferent.

A.6.3 Summary of the Interferent Analysis

Presence of interferents appears to have an effect on M90-D1-C response time. There was a great deal of variability in the recovery time data, both with and without interferents. No statistically significant relationship between interferent and recovery time could be detected.

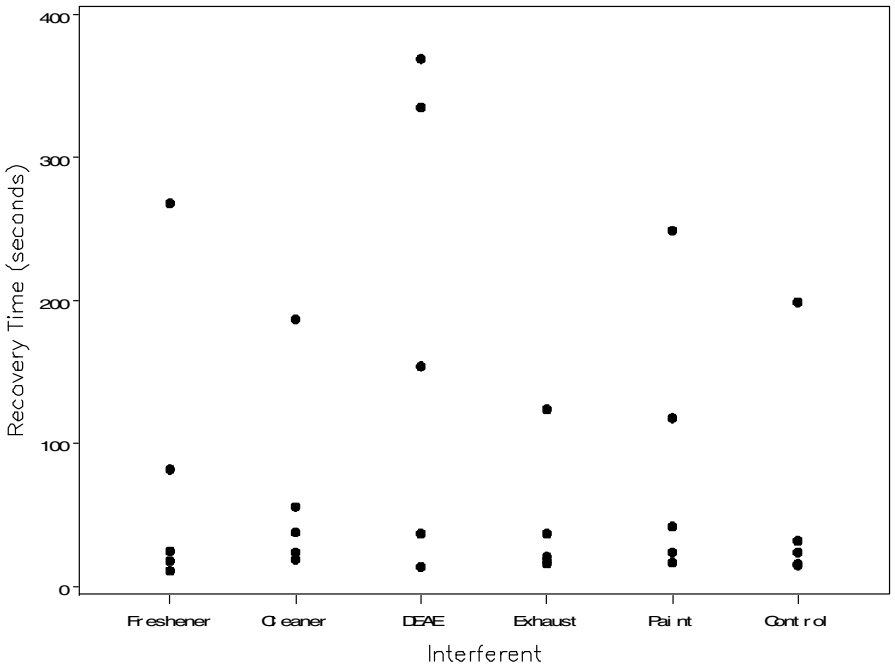

Figure A-4. Distribution of observed recovery times by interferent.

A.7 Analysis of False Positives

The M90-D1-C response was tested without GB but with interferents. Testing was at room temperature and medium humidity. The interferents were:

1. Latex paint fumes
2. Ammonia floor cleaner vapors
3. Air freshener vapors
4. Gasoline engine exhaust hydrocarbons
5. DEAE

For air freshener and gasoline exhaust hydrocarbons, there were 3 runs. For the other three interferents, there were five runs.

A false-positive was defined as any M90-D1-C response. The number of false positive readings was recorded, and a Clopper-Pearson 95% confidence interval was constructed for the proportion of false positives in the presence of interferents.

The M90-D1-C performed perfectly during the false positive testing of air freshener and gasoline exhaust hydrocarbons. It gave no response to these interferents. On the other hand, it consistently responded to ammonia cleaner vapors and latex paint fumes. In one of the five DEAE challenges, there was an instrument response. Overall, the instrument responded to 11 of the 21 runs. An estimate of the chance of a false positive in the presence of an interferent is 52% with a confidence bound of (30%,74%).

A.8 Effect of Alternating Concentration on Response

The tests used to assess the effect of alternating agent concentration on M90-D1-C performance are identified in Table A-4. Six cycles of alternating concentration were conducted, three with high concentration preceding low, and three with low preceding high. The high concentration challenge for GB was 4 IDLH; the low was 0.5 IDLH. Tests were conducted at room temperature and medium humidity.

Table A-4. IDs of Tests included in the Agent Testing of the Effect of Alternating Concentration

GB-01	GB-06

A.8.1 Effect of Order on Response

One of the purposes of alternating testing is to assess whether instrument response to a given concentration is affected by initial exposure to an alternate concentration. The effect of an initial alternate concentration was investigated using a Cochran-Mantel-Hansel statistic (see Chapter 5 for more details). There was no evidence that M90-D1-C response to a given concentration is affected by a preceding alternate concentration (p-value=0.96). The response to GB at both high and low concentration tended to be Low whether or not the challenge was preceded by an alternate concentration.

A.8.2 Instrument Sensitivity to Alternating Concentrations

When challenged by a high concentration after being challenged by a low, the level of instrument response might be expected to increase. Similarly, when challenged by a low concentration after being challenged by a high, the level of response might be expected to decrease. Another purpose of alternating-concentration testing is to assess whether this expectation is realized. For the assessment, the proportion of tests exhibiting the expected behavior is recorded.

M90-D1-C response to both high and low concentrations tended to be Low regardless of their order. Based on these results at 4 × IDLH and 0.5 × IDLH, a best estimate of the chance that the instrument will exhibit alternating response levels that correspond to alternating concentration levels is 0 % with a 95% confidence interval of (0%, 46%).