

COMPARISON OF DIFFUSIONAL ORGANIC VAPOR MONITORS WITH CHARCOAL  
TUBES FOR SAMPLING LABORATORY CHALLENGES TO CONTAMINANT MIXTURES.

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ABSTRACT

Because most industrial environments contain numerous contaminants, a laboratory evaluation compared performance of diffusional organic vapor monitors to charcoal tubes when sampling mixtures of known concentrations. The challenges consisted of a binary mixture of toluene and methyl ethyl ketone and a tertiary mixture of benzene, toluene and xylene. Unleaded gasoline and unleaded gasoline containing various alcohols, e.g. ethanol, methanol and t-butyl alcohol were the complex mixtures used in the evaluation. The results of each sampling technique are correlated with the challenges of known concentrations.

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INTRODUCTION

Diffusional sampling devices such as the 3M Organic Vapor Monitor (OVM) offer many advantages for measuring concentration levels of industrial contaminants because they are lightweight, require no power, pump or tubing and are not likely to impede the work activity of the user.

Because these sampling devices could replace the conventional pump and charcoal tubes for sampling the industrial environment, this evaluation compared the precision and accuracy of the charcoal tubes to the 3M-Organic Vapor Monitors. A selected set of simple and complex mixtures were used to generate air concentrations normally found in the industrial environment. This evaluation consisted entirely of sampling laboratory generated air concentrations of the contaminant mixtures. Evaluating the precision and accuracy of these two sampling techniques is in keeping with the NIOSH Standards Completion Program where the precision and accuracy of the charcoal tubes were validated by sampling known air concentrations of organic vapor contaminant from a laboratory generation system.

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# PROCEDURE

To evaluate and compare the sampling performance of charcoal tubes to the 3M Organic Vapor Monitors, known air concentrations were generated for simple and complex mixture in a laboratory generator-dilution system. This system as illustrated in Figure 1, consists of a calibrated dry air gas meter, a syringe device mechanism to deliver the liquid contaminant mixture to a heated manifold, and a device to hold eighteen (18) charcoal tubes or monitors. The air concentration can be determined by measuring the initial and final weight of the syringe containing the liquid contaminant and measuring the total air volume during a sampling period of known time.

The evaluation consisted of two parts; Part I - Comparison of Charcoal Tubes to 3M - Organic Vapor Monitor (OVM) when Sampling Contaminant Mixtures at Constant Concentrations, and Part II - Comparison of Charcoal Tubes to 3M - Organic Vapor Monitor (OVM) when Sampling Contaminant Mixtures at Variable Concentrations. In Part I, mixtures and desired concentrations used for the comparison are tabulated in Table I. In this part of the evaluation, three (3) charcoal tubes and three (3) 3M - Organic Vapor Monitors samples were collected at intervals of one (1), two (2), three (3), five (5), six (6) and seven (7) hours. For each mixture, the thirty six (36) samples (18 - charcoal tubes and 18 - 3M Organic Vapor monitors) were collected during an eight hour sampling period. The time-weighted-average

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concentration during the eight hour period was determined by measuring the total air volume and the weight of the liquid contaminant mixture delivered to the heated air manifold measuring the syringe/liquid contaminant weight at the beginning and at the end of the sampling period. Eighteen (18) samples could be collected simultaneously, therefore, the following sampling profile allowed the thirty six (36) samples to be collected in an eight hour period. The one hour samples were followed by the seven hour samples, the two hour samples followed by the six hour samples, and the three hour samples followed by the five hour samples. In order to compare the results with the known time-weighted-average concentration for the eight hour period as determined by mass balance of the air flow and liquid contaminant flow to the heated manifold, the results of the following data sets must be combined. The results of one hour samples combined with the seven hour samples, the two hour samples combined with the six hour samples and the three hour samples combined with the five hour samples. Although the results of the above sample sets had to be combined to compare them to the time-weighted-average concentration determined by mass balance of the laboratory generation system, a comparison of the charcoal tube results can be compared to the 3M-Organic Vapor Monitor results for each of sampling intervals.

In Part II, the mixtures and desired concentrations sampled for the evaluation are tabulated in Table II. The evaluations in Part II are divided into exposure profile A where a contaminant mixture is sampled for one hour followed by sampling air with a zero concentration of the contaminant mixture for one hour.

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This sequence was repeated four times. In exposure profile B, a contaminant mixture is sampled for one hour, then air with a zero concentration of the contaminant mixture is sampled for three hours. This sequence was repeated. In both profiles, the total sampling period was eight hours with the difference being in profile A, where the contaminant mixture concentration is sampled for four hours while in profile B, the contaminant mixture concentration is sampled for only two hours.

In this part of the evaluation, the variable concentrations were sampled to evaluate if any sample loss occurs during the sampling period when the contaminant mixture concentration was zero.

#### ANALYTICAL PROCEDURES

After sample collection, the 3M-Organic Vapor Monitor and the charcoal tubes were capped and stored at ambient temperatures. The recovery coefficients were determined for the 3M-Organic Vapor Monitor according to the recommended procedure. The recovery coefficient for the charcoal tubes were also determined by spiking the liquid mixture on a filter paper and allowing the charcoal to collect the organic vapors. After desorbing the samples with carbon disulfide, the analysis was performed using a Hewlett Packard (5840A) gas chromatograph equipped with a flame ionization detector. For the gasoline samples, the total integrated area was used to determine the sample weight.

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For the charcoal tubes, the sampling rates were determined by calibration of critical orifices which ranged from 30-45 cubic centimeters per minute. For the 3M-Organic Vapor Monitor, the sampling rates for gasoline and naphtha were determined in separate experiments by measuring the weight collection rate from a challenge of known concentration. The sampling rates and recovery coefficients are tabulated in Table III.

#### RESULTS AND DISCUSSION

##### Part I - COMPARISON OF CHARCOAL TUBES TO 3M - ORGANIC VAPOR MONITOR (OVH) WHEN SAMPLING CONTAMINANT MIXTURES AT CONSTANT CONCENTRATIONS.

The results of sampling a toluene/methyl ethyl ketone mixture are summarized and tabulated in Table IV. For toluene, there is excellent correlation of the results of charcoal tube samples and the 3M - Organic Vapor Monitor samples for each of the sampling intervals. The time-weighted-average concentrations as determined by the combined results of each sample set (18 samples) was  $186 \text{ mg/m}^3$  measured by the 3M - Organic Vapor Monitor and  $176 \text{ mg/m}^3$  measured by the charcoal tubes. When compared to the concentration as determined by the mass balance of the generation system, these results are 97% and 92% of the concentration for 3M - Organic Vapor Monitor and charcoal tubes respectively.

For methyl ethyl ketone, the results of the charcoal tubes are very low and compare poorly with those of the 3M - Organic Vapor monitor. For the 3M - Organic Vapor Monitor, the time-weighted-average

concentration determined by the combined sample set (18) was 144 mg/m<sup>3</sup>. This is 104% of the concentration determined by mass balance of the generation system. For the charcoal tubes, the time-weighted-average concentration determined by the combined sample set (18) was 50 mg/m<sup>3</sup> or 36% of the concentration determined by mass balance of the generation system. These charcoal tubes were not overloaded, in fact, no methyl ethyl ketone was found in the back section of the charcoal tubes.

In Table V, the results of sampling a benzene/toluene/xylene mixture are summarized and tabulated. For each of the contaminants in the mixture, there is excellent correlation of the charcoal tube with the 3M-Organic Vapor Monitor at all sampling intervals. The total time-weighted-average concentration determined by combining the eighteen (18) samples collected by each technique enables an assessment of the accuracy by comparison with the concentration determined by mass balance of generation system. For benzene, the results are 91% and 97% for the 3M - Organic Vapor Monitor and charcoal tubes respectively when comparing to the mass balance concentration. For toluene, the results are 90% and 95% and for xylene the results are 87% and 91% for the 3M - Organic Vapor Monitor and charcoal tubes respectively for each data set.

In Table VI, the results of sampling a complex mixture, VM & P Naphtha, are summarized and tabulated. There is excellent correlation of the charcoal tubes with the 3M - Organic Vapor Monitor at each of the sampling intervals. The accuracy is also excellent as determined by

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comparing the time-weighted-average concentration determined by the mass balance of the generation system. When combining all eighteen (18) samples collected by one technique, the accuracy is 95% and 97% for the 3M - Organic Vapor Monitor and charcoal tubes respectively.

Unleaded gasoline was sampled at two concentrations, 42 mg/m<sup>3</sup> and 96 mg/m<sup>3</sup>. These results are summarized and tabulated in Tables VII and VIII. Again, the correlation of the two sampling techniques is excellent. The accuracy as determined by comparing the time-weighted-average of the eighteen (18) samples collected by each technique and the concentration as determined by the mass balance of the generation system was at, the low concentration (42 mg/m<sup>3</sup>), 91% and 95% and, at the high concentration (96 mg/m<sup>3</sup>), 97% and 101% for the 3M - Organic Vapor Monitor and the charcoal tubes respectively in each of the evaluations.

Unleaded gasoline blended with ethanol and unleaded gasoline blended with methanol and tert-butyl alcohol were also sampled as complex mixtures. The results are summarized and tabulated in Tables IX and X. Again, the correlation of the two sampling techniques is excellent. In gasoline/ethanol, the accuracy was 101% and 103% for the 3M - Organic Vapor monitor and the charcoal tubes. For the gasoline/methanol/TBA, the accuracy was 96% and 103% for the 3M - Organic Vapor Monitor and the charcoal tubes. The accuracy of each sampling technique is again compared to the concentration determined by the mass balance of the generation system.

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Part II - COMPARISON OF CHARCOAL TUBES TO 3M - ORGANIC VAPOR MONITOR (OVH) WHEN SAMPLING CONTAMINANT MIXTURES AT VARIABLE CONCENTRATIONS.

For this part of the evaluation, the variable concentrations were generated in two ways. The results are summarized and tabulated in Table XI for samples collected when sampling a high concentration of the contaminant mixture on one hour followed by sampling a zero concentration for three hours. This sequence was repeated so that the samples collected the high concentration for a two hour period. For the six simple and complex mixtures listed in Table II, it can be observed that the sample collected with the charcoal tubes have excellent correlation with those collected with the 3M - Organic Vapor Monitor with the exception of methyl ethyl ketone in the toluene/methyl ketone mixture. It can be noted that the charcoal tubes greatly underestimates the methyl ethyl ketone concentration. Besides the excellent correlation between the two sampling techniques, both techniques also have acceptable accuracy when comparing the concentration measured by the 3M - Organic Vapor Monitor and the charcoal tubes to the concentration determined from the mass balance of the generation system.

In Table XII, the results are summarized and tabulated for samples collected when sampling a high concentration for one hour followed by sampling zero concentration for one hour and a repeat of this sequence four times. With the exception of the charcoal tube estimation of the methyl ethyl ketone concentration in the toluene/methyl ethyl ketone mixture, all the results tabulated in Table XII indicate again the excellent correlation of the charcoal tubes

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results with the 3M - Organic Vapor monitor results of measuring the concentration of the six simple and complex mixtures. Both techniques also have acceptable accuracy as determined by comparing the concentrations measured by the 3M - Organic Vapor Monitor and the charcoal tubes with the concentration determined by the mass balance of the generation system.

### Conclusions

From these laboratory evaluations, the 3M - Organic Vapor Monitor was able to sample and determine the concentration of a representative set of simple and complex mixtures with excellent precision and accuracy. The charcoal tubes also measured the same mixtures with excellent precision and accuracy with the exception of methyl ethyl ketone in the toluene/methyl ethyl ketone mixture.

TABLE I - Simple and Complex Mixtures Generated for Part I  
of the Evaluation.

| Mixture |                             | Concentrations<br>(mg/m <sup>3</sup> ) | (ppm) |
|---------|-----------------------------|----------------------------------------|-------|
| I-1     | Toluene/Methyl Ethyl Ketone | 147/147                                | 50/50 |
| I-2     | Benzene/Toluene/Xylene      | 3/15/22                                | 1/5/5 |
| I-3     | Naphtha (VM & P)            | 204                                    | 50    |
| I-4     | Gasoline (unleaded)         | 49                                     | 10    |
| I-5     | Gasoline (unleaded)         | 123                                    | 25    |
| I-6     | Gasoline/Ethanol            | 123                                    | 25    |
| I-7     | Gasoline/Methanol/TBA       | 123                                    | 25    |

TABLE II - Simple and Complex Mixtures Generated for Part II  
of the Evaluation.

| Mixture |                             | Concentration<br>(mg/m <sup>3</sup> ) | (ppm)    |
|---------|-----------------------------|---------------------------------------|----------|
| II-1    | Toluene/Methyl Ethyl Ketone | 147/147                               | 50/50    |
| II-2    | Benzene/Toluene/Xylene      | 30/150/220                            | 10/50/50 |
| II-3    | Naphtha (VM & P)            | 204                                   | 50       |
| II-4    | Gasoline (unleaded)         | 1230                                  | 250      |
| II-5    | Gasoline (Ethanol)          | 1230                                  | 250      |
| II-6    | Gasoline/Methanol/TBA       | 1230                                  | 250      |

TABLE III - Sample Rates and Recovery Coefficients

| Compound            | Sampling Rate<br>3M-OVM<br>(cc/min.) | Recovery Coefficient |               |
|---------------------|--------------------------------------|----------------------|---------------|
|                     |                                      | 3M-OVM               | Charcoal Tube |
| Benzene             | 35.5 ± .6                            | 1.02                 | 1.02          |
| Xylene              | 27.3 ± .5                            | 1.07                 | .99           |
| Toluene             | 31.4 ± .6                            | 1.05                 | 1.01          |
| Methyl Ethyl Ketone | 36.3 ± .9                            | 1.00                 | .86           |
| Naphtha             | 33.2 ± .7                            | 1.04                 | .99           |
| Gasoline            | 31.0 ± .6                            | 1.05                 | .99           |

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TABLE IV - Toluene/Methyl Ethyl Ketone

| Length of Sampling Period (min.)                     | Sample Type and Number of Samples | Measured Concentration (mg/m <sup>3</sup> ) |                        |
|------------------------------------------------------|-----------------------------------|---------------------------------------------|------------------------|
|                                                      |                                   | Toluene                                     | Methyl Ethyl Ketone    |
| 60<br>(0-60)                                         | 3M-OVM (3)<br>CT (3)              | 198 ± 6<br>182 ± 6                          | 137 ± 1<br>34 ± 11     |
| 500<br>(60-560)                                      | 3M-OVM (3)<br>CT (3)              | 186 ± 4<br>176 ± 5                          | 153 ± 6<br>61 ± 4      |
| Time-Weighted - Average Concentration                | 3M-OVM (6)<br>CT (6)              | 187 (98%)<br>177 (92%)                      | 151 (109%)<br>58 (42%) |
| 120<br>(0-120)                                       | 3M-OVM (3)<br>CT (3)              | 202 ± 6<br>162 ± 14                         | 140 ± 6<br>30 ± 3      |
| 440<br>(120-560)                                     | 3M-OVM (3)<br>CT (3)              | 182 ± 2<br>182 ± 5                          | 140 ± 4<br>53 ± 4      |
| Time-Weighted - Average Concentration                | 3M-OVM (6)<br>CT (6)              | 186 (97%)<br>170 (93%)                      | 140 (101%)<br>48 (35%) |
| 180<br>(0-180)                                       | 3M-OVM (3)<br>CT (3)              | 189 ± 2<br>168 ± 13                         | 132 ± 4<br>37 ± 3      |
| 380<br>(180-560)                                     | 3M-OVM (3)<br>CT (3)              | 183 ± 2<br>176 ± 4                          | 147 ± 9<br>49 ± 6      |
| Time-Weighted - Average Concentration                | 3M-OVM (6)<br>CT (6)              | 184 (96%)<br>173 (90%)                      | 142 (102%)<br>45 (32%) |
| Total                                                |                                   |                                             |                        |
| Time-Weighted - Average Concentration                | 3M-OVM (18)<br>CT (18)            | 186 (97%)<br>176 (92%)                      | 144 (104%)<br>50 (36%) |
| Concentration from Mass Balance of Generation System |                                   | 192<br>(51/ppm)                             | 139<br>(47 ppm)        |

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TABLE V - Benzene/Toluene/Xylene

| Length of<br>Sampling Period<br>(min.)                     | Sample Type<br>and<br>Number of Samples | Measured Concentration<br>( $\mu\text{g}/\text{m}^3$ ) |                 |                 |
|------------------------------------------------------------|-----------------------------------------|--------------------------------------------------------|-----------------|-----------------|
|                                                            |                                         | Benzene                                                | Toluene         | Xylene          |
| 60<br>(0-60)                                               | 3M-OVM (3)                              | 12 $\pm$ 1                                             | 53 $\pm$ 1      | 53 $\pm$ 1      |
|                                                            | CT (3)                                  | 12 $\pm$ 1                                             | 63 $\pm$ 11     | 62 $\pm$ 10     |
| 435<br>(60-495)                                            | 3M-OVM (3)                              | 5.0 $\pm$ .2                                           | 23 $\pm$ 1      | 25 $\pm$ 1      |
|                                                            | 3M-OVM (3)                              | 5.4 $\pm$ 1                                            | 25 $\pm$ 2      | 26 $\pm$ 2      |
| Time-Weighted -<br>Average Concentration                   | 3M-OVM (6)                              | 5.9 (96%)                                              | 27 (93%)        | 28 (93%)        |
|                                                            | CT (6)                                  | 6.2 (102%)                                             | 30 (103%)       | 30 (100%)       |
| 125<br>1-125)                                              | 3M-OVM (3)                              | 7.3 $\pm$ .2                                           | 37 $\pm$ 1      | 34 $\pm$ 1      |
|                                                            | CT (3)                                  | 9.1 $\pm$ 2                                            | 42 $\pm$ 8      | 42 $\pm$ 8      |
| 370<br>(125-495)                                           | 3M-OVM (3)                              | 4.6 $\pm$ .3                                           | 22 $\pm$ 2      | 22 $\pm$ 2      |
|                                                            | CT (6)                                  | 4.7 $\pm$ 1                                            | 21 $\pm$ 2      | 21 $\pm$ 2      |
| Time-Weighted-<br>Average Concentration                    | 3M-OVM (6)                              | 5.3 (87%)                                              | 26 (90%)        | 25 (83%)        |
|                                                            | CT (6)                                  | 5.8 (95%)                                              | 25 (90%)        | 26 (87%)        |
| 180<br>(0-180)                                             | 3M-OVM (3)                              | 6.7 $\pm$ .1                                           | 31 $\pm$ 1      | 31 $\pm$ 1      |
|                                                            | CT (3)                                  | 7.2 $\pm$ 1                                            | 33 $\pm$ 5      | 32 $\pm$ 5      |
| 315<br>(180-495)                                           | 3M-OVM (3)                              | 4.6 $\pm$ .2                                           | 22 $\pm$ 1      | 22 $\pm$ 1      |
|                                                            | CT (3)                                  | 4.9 $\pm$ 1                                            | 23 $\pm$ 2      | 23 $\pm$ 2      |
| Time-Weighted-<br>Average Concentration                    | 3M-OVM (6)                              | 5.4 (89%)                                              | 25 (86%)        | 25 (83%)        |
|                                                            | CT (6)                                  | 5.7 (93%)                                              | 27 (93%)        | 26 (91%)        |
| Total<br>Time-Weighted-<br>Average Concentration           | 3M-OVM (18)                             | 5.5 (91%)                                              | 26 (90%)        | 26 (87%)        |
|                                                            | CT (18)                                 | 5.9 (97%)                                              | 28 (95%)        | 27 (91%)        |
| Concentration from<br>Mass Balance of<br>Generation System |                                         | 6.1<br>(1.9ppm)                                        | 29<br>(7.7 ppm) | 30<br>(6.9 ppm) |

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TABLE VI - Naphtha (VM & P) 236 mg/m<sup>3</sup> (58 ppm)

| Length of<br>Sampling Period<br>(min.)                     | Sample Type<br>and<br>Number of Samples | Measured Concentration<br>(mg/m <sup>3</sup> ) |
|------------------------------------------------------------|-----------------------------------------|------------------------------------------------|
|                                                            |                                         | Naphtha (VM & P)                               |
| 60<br>(0-60)                                               | 3M-OVM (3)<br>CT (3)                    | 219 ± 2<br>191 ± 33                            |
| 420<br>(60-480)                                            | 3M-OVM (3)<br>CT (3)                    | 247 ± 4<br>251 ± 5                             |
| Time-Weighted -<br>Average Concentration                   | 3M-OVM (6)<br>CT (6)                    | 243 (103%)<br>243 (103%)                       |
| 120<br>(0-120)                                             | 3M-OVM (3)<br>CT (3)                    | 284 ± 10<br>289 ± 20                           |
| 360<br>(120-480)                                           | 3M-OVM (3)<br>CT (3)                    | 181 ± 5<br>190 ± 5                             |
| Time-Weighted-<br>Average Concentration                    | 3M-OVM (6)<br>CT (6)                    | 207 (88%)<br>214 (91%)                         |
| 180<br>(0-180)                                             | 3M-OVM (3)<br>CT (3)                    | 291 ± 3<br>289 ± 12                            |
| 300<br>(180-480)                                           | 3M-OVM (3)<br>CT (3)                    | 189 ± 7<br>190 ± 10                            |
| Time-Weighted-<br>Average Concentration                    | 3M-OVM (6)<br>CT (6)                    | 225 (95%)<br>244 (103%)                        |
| Total<br>Time-Weighted-<br>Average Concentration           | 3M-OVM (18)<br>CT (18)                  | 225 (95%)<br>228 (97%)                         |
| Concentration from<br>Mass Balance of<br>Generation System |                                         | 236<br>(58 ppm)                                |

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TABLE VII - Gasoline (Unloaded) (42 mg/m<sup>3</sup>)

| Length of<br>Sampling Period<br>(min.)                      | Sample Type<br>and<br>Number of Samples | Measured Concentration<br>(mg/m <sup>3</sup> ) |          |
|-------------------------------------------------------------|-----------------------------------------|------------------------------------------------|----------|
|                                                             |                                         | Gasoline (Unloaded)                            |          |
| 60<br>(0-60)                                                | 3M-OVM (3)                              | 52 ± 2                                         |          |
|                                                             | CT (3)                                  | 54 ± 9                                         |          |
| 375<br>(60-435)                                             | 3M-OVM (3)                              | 37 ± 2                                         |          |
|                                                             | CT (3)                                  | 39 ± 1                                         |          |
| Time-Weighted -<br>Average Concentration                    |                                         | 3M-OVM (6)                                     | 39 (93%) |
|                                                             |                                         | CT (6)                                         | 41 (90%) |
| 120<br>(0-120)                                              | 3M-OVM (3)                              | 44 ± 1                                         |          |
|                                                             | CT (3)                                  | 47 ± 10                                        |          |
| 315<br>(0-435)                                              | 3M-OVM (3)                              | 37 ± 1                                         |          |
|                                                             | CT (3)                                  | 36 ± 2                                         |          |
| Time-Weighted-<br>Average Concentration                     |                                         | 3M-OVM (6)                                     | 38 (91%) |
|                                                             |                                         | CT (6)                                         | 30 (93%) |
| 180<br>(0-180)                                              | 3M-OVM (3)                              | 42 ± 1                                         |          |
|                                                             | CT (3)                                  | 44 ± 1                                         |          |
| 255<br>(180-435)                                            | 3M-OVM (3)                              | 36 ± 1                                         |          |
|                                                             | CT (3)                                  | 30 ± 1                                         |          |
| Time-Weighted-<br>Average Concentration                     |                                         | 3M-OVM (6)                                     | 38 (91%) |
|                                                             |                                         | CT (6)                                         | 40 (95%) |
| Total                                                       |                                         |                                                |          |
| Time-Weighted-<br>Average Concentration                     |                                         | 3M-OVM (18)                                    | 38 (91%) |
|                                                             |                                         | CT (18)                                        | 40 (95%) |
| Concentration from<br>Mass Balance of<br>Ventilation System |                                         | 42<br>(0.5 ppm)                                |          |

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TABLE VIII - Gasoline (Unleaded) (96 m/m<sup>3</sup>)

| Length of<br>Sampling Period<br>(min.)                     | Sample Type<br>and<br>Number of Samples | Measured Concentration<br>(mg/m <sup>3</sup> ) |  |
|------------------------------------------------------------|-----------------------------------------|------------------------------------------------|--|
|                                                            |                                         | Gasoline (Unleaded)                            |  |
| 60<br>(0-60)                                               | 3M-OVM (3)                              | 93 ± 7                                         |  |
|                                                            | CT (3)                                  | 87 ± 3                                         |  |
| 420<br>(60-480)                                            | 3M-OVM (3)                              | 92 ± 3                                         |  |
|                                                            | CT (3)                                  | 95 ± 5                                         |  |
| Time-Weighted -<br>Average Concentration                   | 3M-OVM (6)                              | 92 (96%)                                       |  |
|                                                            | CT (6)                                  | 94 (98%)                                       |  |
| 120<br>(0-120)                                             | 3M-OVM (3)                              | 93 ± 3                                         |  |
|                                                            | CT (3)                                  | 95 ± 7                                         |  |
| 360<br>(120-480)                                           | 3M-OVM (3)                              | 91 ± 4                                         |  |
|                                                            | CT (3)                                  | 96 ± 4                                         |  |
| Time-Weighted-<br>Average Concentration                    | 3M-OVM (6)                              | 91 (95%)                                       |  |
|                                                            | CT (6)                                  | 96 (100%)                                      |  |
| 175<br>(0-175)                                             | 3M-OVM (3)                              | 93 ± 1                                         |  |
|                                                            | CT (3)                                  | 99 ± 3                                         |  |
| 305<br>(175-480)                                           | 3M-OVM (3)                              | 96 ± 5                                         |  |
|                                                            | CT (3)                                  | 103 ± 3                                        |  |
| Time-Weighted-<br>Average Concentration                    | 3M-OVM (6)                              | 92 (96%)                                       |  |
|                                                            | CT (6)                                  | 102 (106%)                                     |  |
| Total<br>Time-Weighted-<br>Average Concentration           | 3M-OVM (18)                             | 93 (97%)                                       |  |
|                                                            | CT (18)                                 | 97 (101%)                                      |  |
| Concentration from<br>Mass Balance of<br>Generation System |                                         | 96<br>(19.5 ppm)                               |  |

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TABLE IX - Gasoline (Ethanol) (125  $\mu\text{g}/\text{m}^3$ )

| Length of<br>Sampling Period<br>(min.)                    | Sample Type<br>and<br>Number of Samples | Measured Concentration<br>( $\mu\text{g}/\text{m}^3$ ) |            |
|-----------------------------------------------------------|-----------------------------------------|--------------------------------------------------------|------------|
|                                                           |                                         | Gasoline (Ethanol)                                     |            |
| 60<br>(0-60)                                              | 3M-OVM (3)                              | 106 $\pm$ 5                                            |            |
|                                                           | CT (3)                                  | 114 $\pm$ 15                                           |            |
| 420<br>(60-480)                                           | 3M-OVM (3)                              | 130 $\pm$ 4                                            |            |
|                                                           | CT (3)                                  | 133 $\pm$ 8                                            |            |
| Time-Weighted -<br>Average Concentration                  |                                         | 3M-OVM (6)                                             | 127 (102%) |
|                                                           |                                         | CT (6)                                                 | 131 (105%) |
| 120<br>(0-120)                                            | 3M-OVM (3)                              | 113 $\pm$ 3                                            |            |
|                                                           | CT (3)                                  | 114 $\pm$ 5                                            |            |
| 360<br>(120-480)                                          | 3M-OVM (3)                              | 129 $\pm$ 7                                            |            |
|                                                           | CT (3)                                  | 129 $\pm$ 16                                           |            |
| Time-Weighted -<br>Average Concentration                  |                                         | 3M-OVM (6)                                             | 125 (100%) |
|                                                           |                                         | CT (6)                                                 | 125 (100%) |
| 180<br>(0-180)                                            | 3M-OVM (3)                              | 113 $\pm$ 5                                            |            |
|                                                           | CT (3)                                  | 116 $\pm$ 2                                            |            |
| 300<br>(180-480)                                          | 3M-OVM (3)                              | 134 $\pm$ 3                                            |            |
|                                                           | CT (3)                                  | 139 $\pm$ 5                                            |            |
| Time-Weighted -<br>Average Concentration                  |                                         | 3M-OVM (6)                                             | 126 (101%) |
|                                                           |                                         | CT (6)                                                 | 130 (104%) |
| Total<br>Time-Weighted -<br>Average Concentration         |                                         | 3M-OVM (18)                                            | 126 (101%) |
|                                                           |                                         | CT (18)                                                | 129 (103%) |
| Concentration from<br>Mass Balance of<br>Iteration System |                                         | 125<br>(25.4 ppm)                                      |            |

3M 008996

TABLE X - Gasoline (Methanol/TBA)

| Length of<br>Sampling Period<br>(min.)                     | Sample Type<br>and<br>Number of Samples | Measured Concentration  |                         |
|------------------------------------------------------------|-----------------------------------------|-------------------------|-------------------------|
|                                                            |                                         | (mg/m <sup>3</sup> )    | Gasoline (Methanol/TBA) |
| 60<br>(0-60)                                               | 3M-OVM (3)<br>CT (3)                    | 94 ± 1<br>86 ± 10       |                         |
| 420<br>(60-480)                                            | 3M-OVM (3)<br>CT (3)                    | 112 ± 2<br>124 ± 4      |                         |
| Time-Weighted -<br>Average Concentration                   | 3M-OVM (6)<br>CT (6)                    | 110 (97%)<br>119 (105%) |                         |
| 120<br>(0-120)                                             | 3M-OVM (3)<br>CT (3)                    | 102 ± 3<br>101 ± 2      |                         |
| 360<br>(120-480)                                           | 3M-OVM (3)<br>CT (3)                    | 108 ± 5<br>119 ± 1      |                         |
| Time-Weighted-<br>Average Concentration                    | 3M-OVM (6)<br>CT (6)                    | 107 (95%)<br>115 (102%) |                         |
| 180<br>(0-180)                                             | 3M-OVM (3)<br>CT (3)                    | 102 ± 4<br>103 ± 6      |                         |
| 300<br>(120-480)                                           | 3M-OVM (3)<br>CT (3)                    | 116 ± 2<br>122 ± 4      |                         |
| Time-Weighted-<br>Average Concentration                    | 3M-OVM (6)<br>CT (6)                    | 111 (98%)<br>115 (102%) |                         |
| Total                                                      |                                         |                         |                         |
| Time-Weighted-<br>Average Concentration                    | 3M-OVM (18)<br>CT (18)                  | 109 (96%)<br>116 (103%) |                         |
| Concentration from<br>Mass Balance of<br>Generation System |                                         | 113<br>(22.9 ppm)       |                         |

3M 008997

Fig XI - Variable Challenge Concentrations According to Profile A

| Mixture Sampled                         | Length of Sampling Period (min.) | Concentration from Mass Balance of Generation System (mg/m <sup>3</sup> ) | Sample Type and Number of Samples        | Measured Concentration (mg/m <sup>3</sup> ) |
|-----------------------------------------|----------------------------------|---------------------------------------------------------------------------|------------------------------------------|---------------------------------------------|
| II-1 Toluene/<br>Methyl Ethyl<br>Ketone | 120                              | 228                                                                       | <u>Toluene</u><br>3M-OVM (4)             | 231 ± 3 (101%)                              |
|                                         |                                  |                                                                           | CT (4)                                   | 217 ± 10 (95%)                              |
|                                         |                                  | 178                                                                       | <u>Methyl Ethyl Ketone</u><br>3M-OVM (4) | 144 ± 11 (81%)                              |
|                                         |                                  |                                                                           | CT (4)                                   | 48 ± 1 (27%)                                |
|                                         |                                  |                                                                           |                                          |                                             |
|                                         |                                  |                                                                           |                                          |                                             |
| II-2 Benzene/<br>Toluene/<br>Xylene     | 120                              | 47                                                                        | <u>Benzene</u><br>3M-OVM (4)             | 45 ± 1 (96%)                                |
|                                         |                                  |                                                                           | CT (4)                                   | 44 ± 1 (94%)                                |
|                                         |                                  | 222                                                                       | <u>Toluene</u><br>3M-OVM (4)             | 207 ± 6 (93%)                               |
|                                         |                                  |                                                                           | CT (4)                                   | 217 ± 4 (98%)                               |
|                                         |                                  | 227                                                                       | <u>Xylene</u><br>3M-OVM (4)              | 222 ± 7 (98%)                               |
|                                         |                                  |                                                                           | CT (4)                                   | 224 ± 4 (99%)                               |
| II-3 Naphtha                            | 155                              | 212                                                                       | 3M-OVM (9)                               | 214 ± 5 (101%)                              |
|                                         |                                  |                                                                           | CT (9)                                   | 228 ± 11 (108%)                             |
| II-4 Gasoline<br>(unleaded)             | 120                              | 1,000                                                                     | 3M-OVM (4)                               | 957 ± 38 (96%)                              |
|                                         |                                  |                                                                           | CT (9)                                   | 979 ± 14 (98%)                              |
| II-5 Gasoline/<br>Ethanol               | 120                              | 1,011                                                                     | 3M-OVM (4)                               | 1065 ± 61 (105%)                            |
|                                         |                                  |                                                                           | CT (4)                                   | 1197 ± 38 (118%)                            |
| II-6 Gasoline/<br>Methanol/<br>TBA      | 120                              | 1,011                                                                     | 3M-OVM (4)                               | 981 ± 48 (97%)                              |
|                                         |                                  |                                                                           | CT (4)                                   | 982 ± 53 (97%)                              |

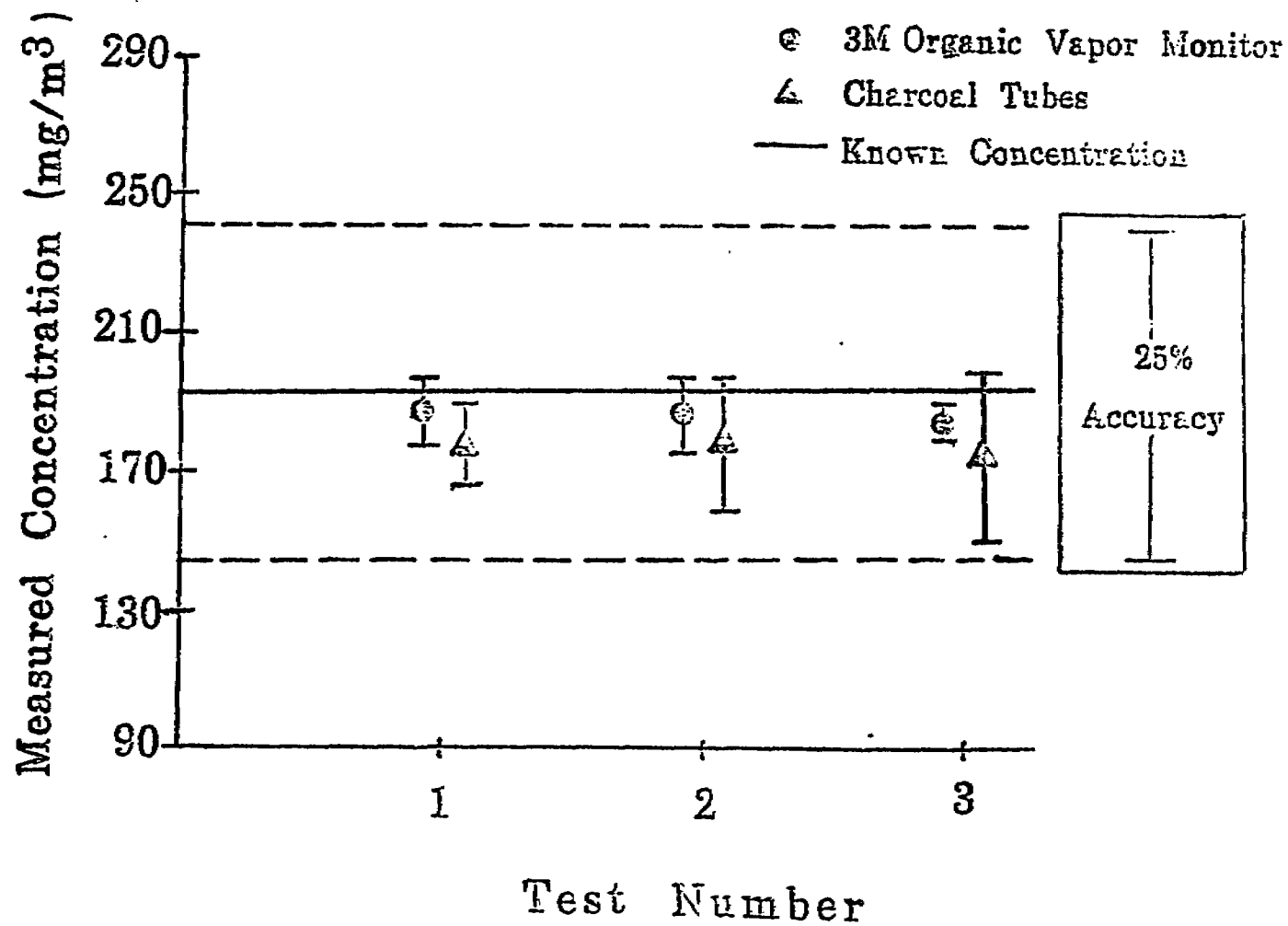
3M 008998

Table XII - Variable Challenge Concentrations According to Profile B

| Mixture Sampled                        | Length of Sampling Period (min.) | Concentration from Mass Balance of Generation System (mg/m <sup>3</sup> ) | Sample Type and Number of Samples        | Measured Concentration (mg/m <sup>3</sup> ) |
|----------------------------------------|----------------------------------|---------------------------------------------------------------------------|------------------------------------------|---------------------------------------------|
| I-1 Toluene/<br>Methyl Ethyl<br>Ketone | 240                              | 206                                                                       | <u>Toluene</u><br>3M-OVM (4)             | 226 ± 3 (110%)                              |
|                                        |                                  |                                                                           | CT (4)                                   | 226 ± 6 (110%)                              |
|                                        |                                  | 161                                                                       | <u>Methyl Ethyl Ketone</u><br>3M-OVM (4) | 155 ± 10 (96%)                              |
|                                        |                                  |                                                                           | CT (4)                                   | 67 ± 3 (42%)                                |
|                                        |                                  |                                                                           |                                          |                                             |
|                                        |                                  |                                                                           |                                          |                                             |
| I-2 Benzene/<br>Toluene/<br>Xylene     | 240                              | 47                                                                        | <u>Benzene</u><br>3M-OVM (4)             | 46 ± 3 (97%)                                |
|                                        |                                  |                                                                           | CT (4)                                   | 43 ± 2 (92%)                                |
|                                        |                                  | 223                                                                       | <u>Toluene</u><br>3M-OVM (4)             | 211 ± 15 (95%)                              |
|                                        |                                  |                                                                           | CT (4)                                   | 203 ± 8 (95%)                               |
|                                        |                                  | 228                                                                       | <u>Xylene</u><br>3M-OVM (4)              | 227 ± 30 (100%)                             |
|                                        |                                  |                                                                           | CT (4)                                   | 209 ± 9 (92%)                               |
|                                        |                                  |                                                                           |                                          |                                             |
|                                        |                                  |                                                                           |                                          |                                             |
| I-3 Naphtha                            | 240                              | 176                                                                       | 3M-OVM (4)                               | 176 ± 4 (100%)                              |
|                                        |                                  |                                                                           | CT (4)                                   | 183 ± 13 (103%)                             |
| I-4 Gasoline<br>(unleaded)             | 240                              | 906                                                                       | 3M-OVM (4)                               | 807 ± 32 (89%)                              |
|                                        |                                  |                                                                           | CT (4)                                   | 890 ± 30 (98%)                              |
| I-5 Gasoline/<br>Ethanol               | 240                              | 897                                                                       | 3M-OVM (4)                               | 933 ± 32 (104%)                             |
|                                        |                                  |                                                                           | CT (4)                                   | 1003 ± 70 (112%)                            |
| I-6 Gasoline/<br>Methanol/<br>TBA      | 240                              | 888                                                                       | 3M-OVM (4)                               | 830 ± 41 (93%)                              |
|                                        |                                  |                                                                           | CT (4)                                   | 772 ± 73 (87%)                              |

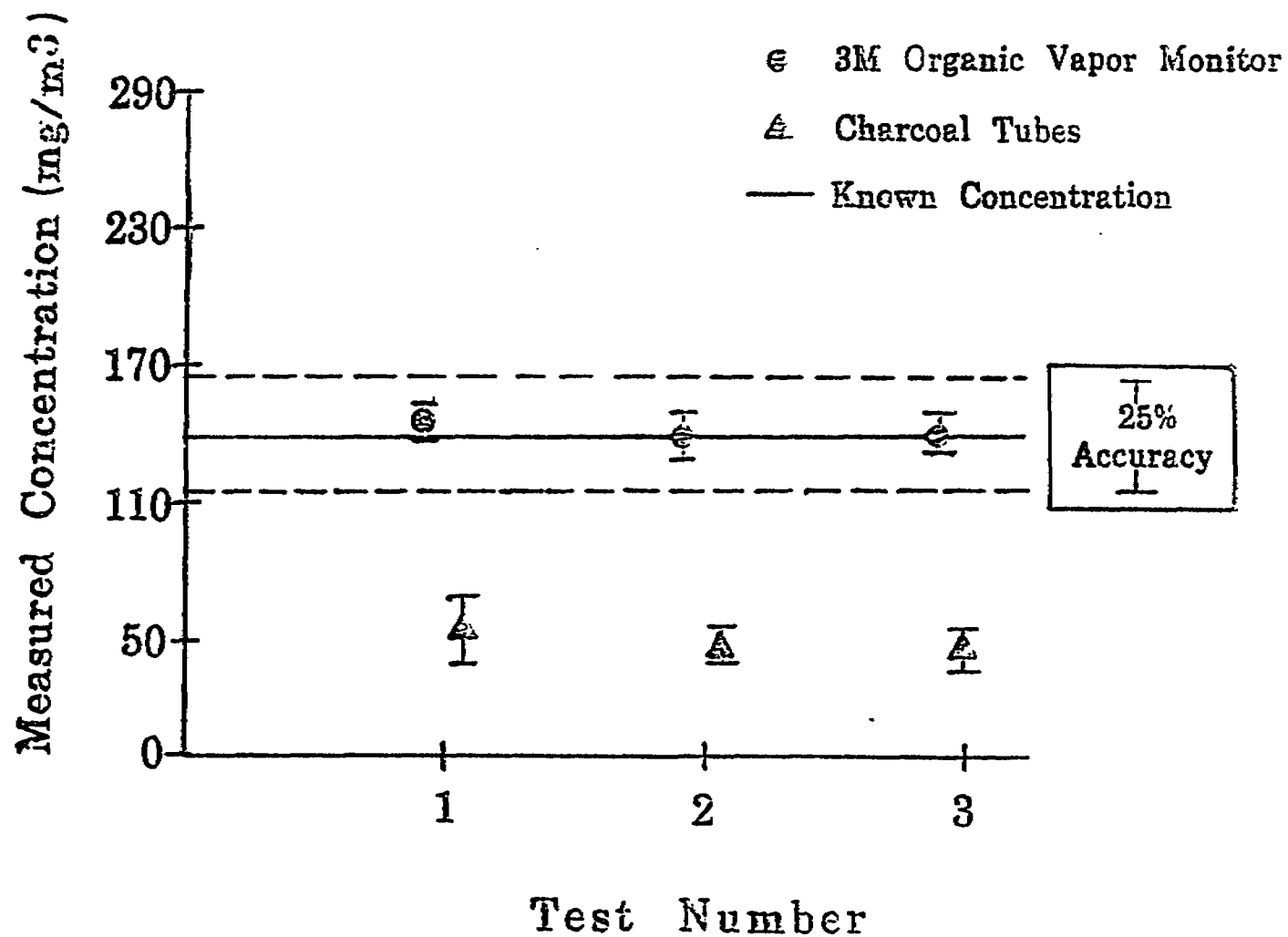
3M 008999

# TOLUENE



000600 ME

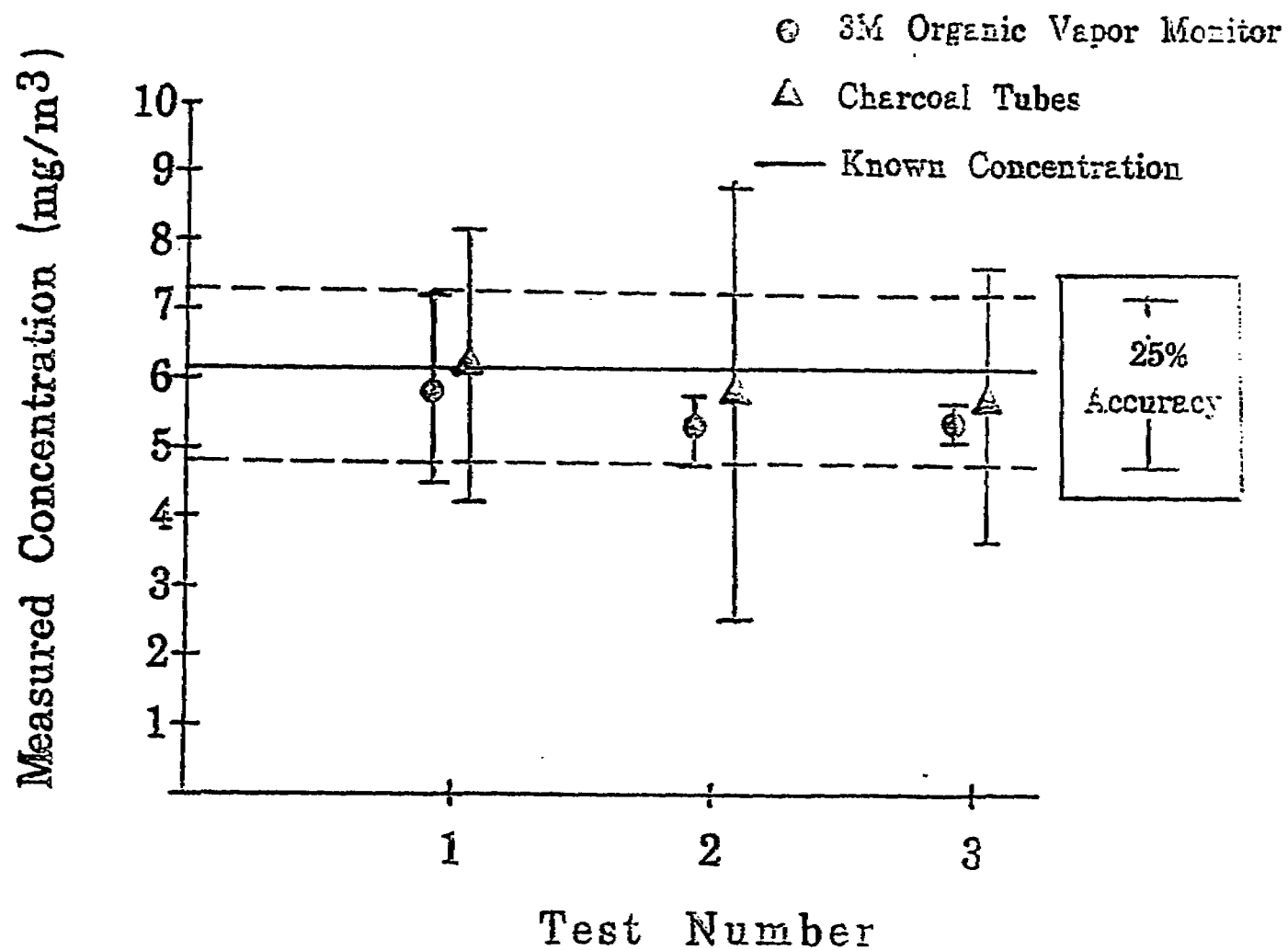
# METHYL ETHYL KETONE



3M 009001

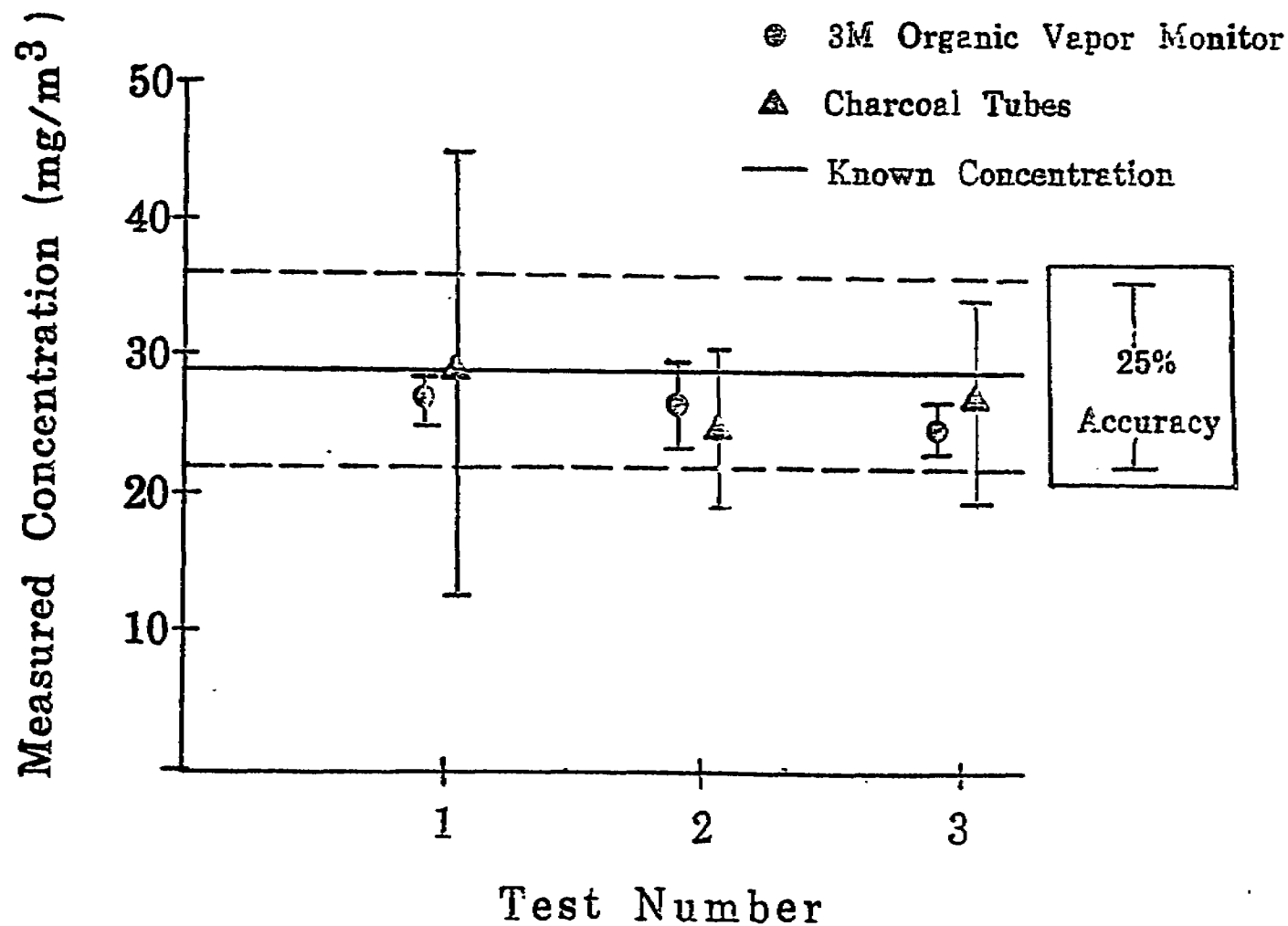
3M 009002

# BENZENE

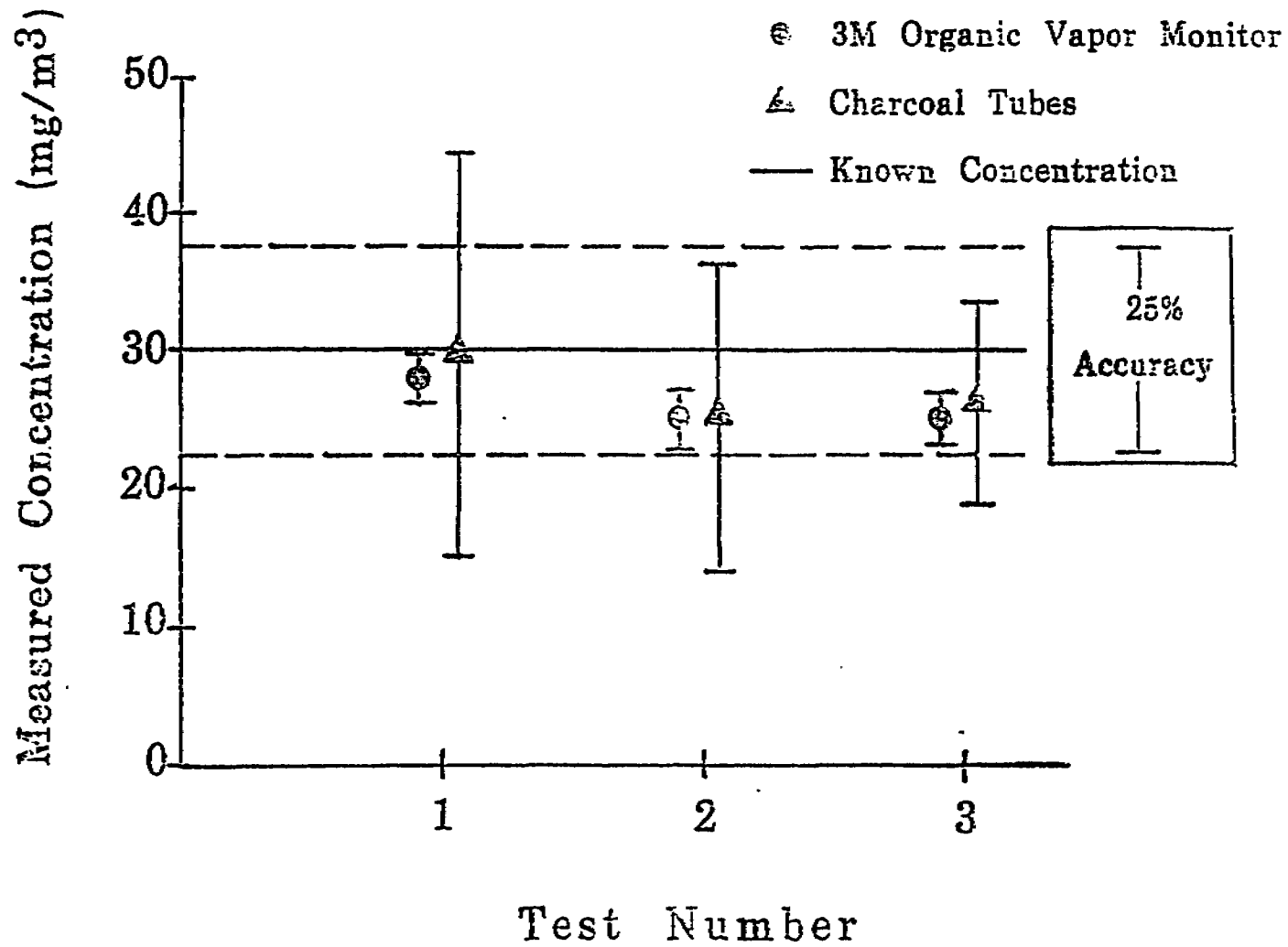


3M 009003

# TOLUENE



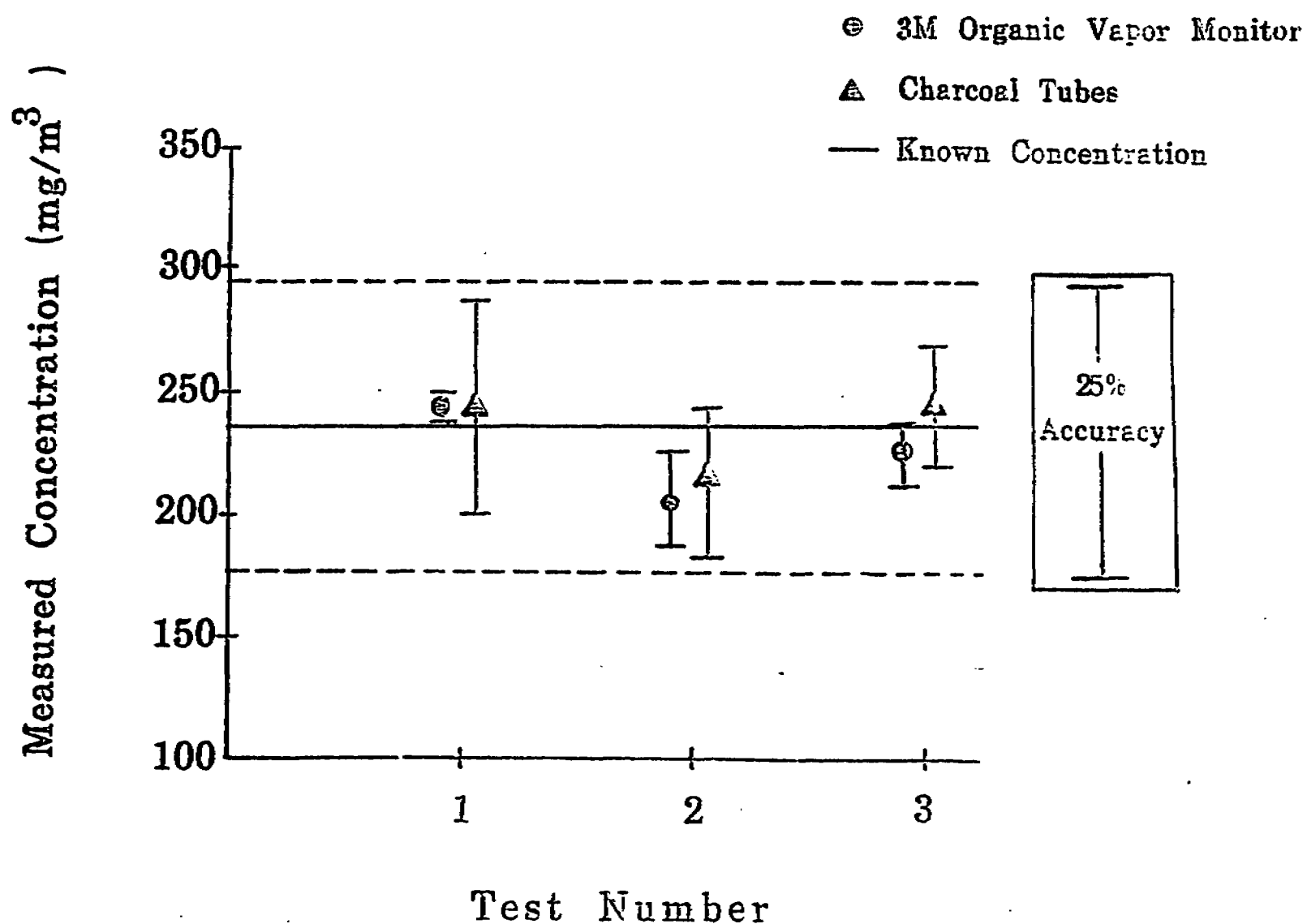
# XYLENE

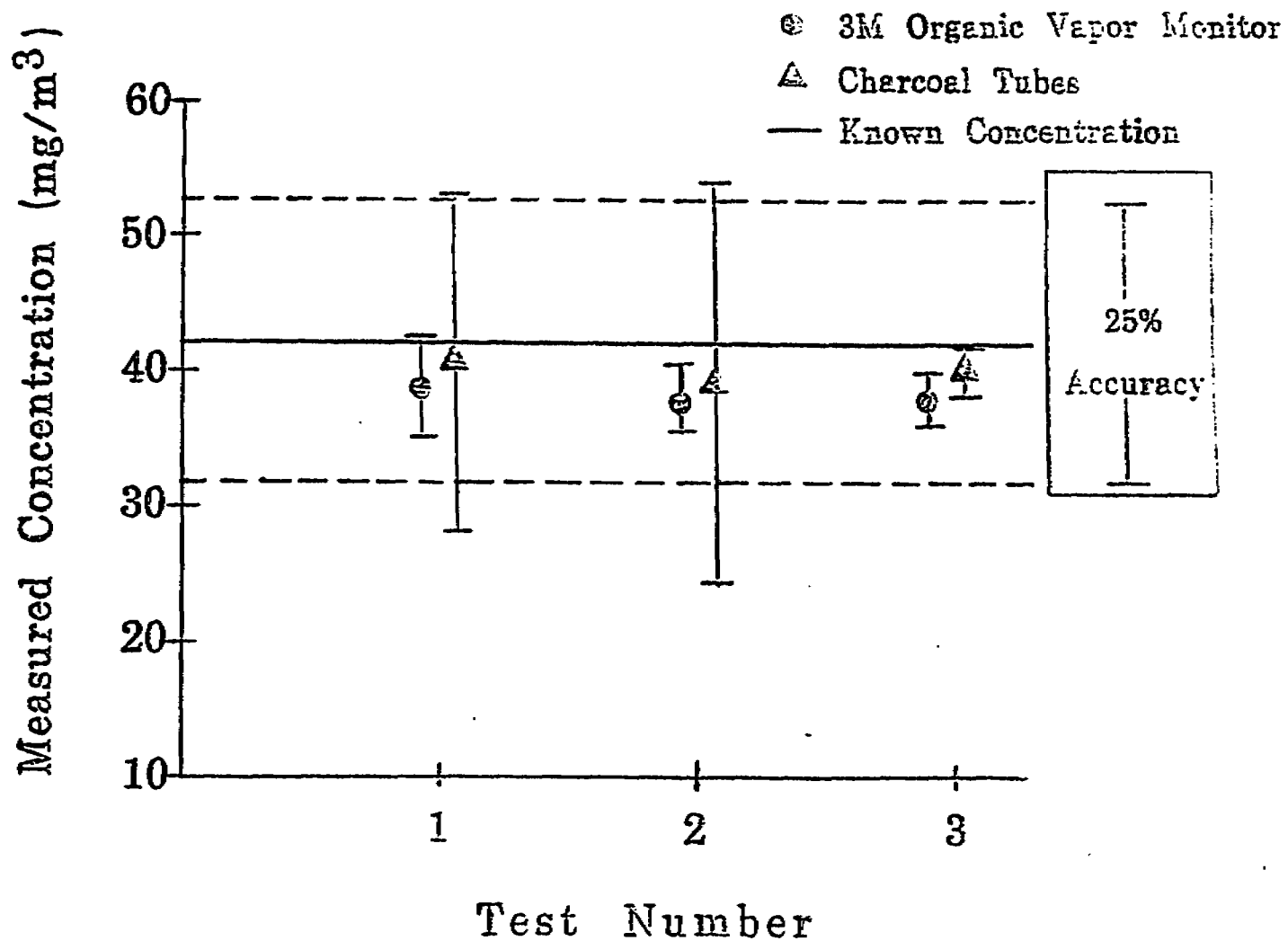


3M 009004

3M 009005

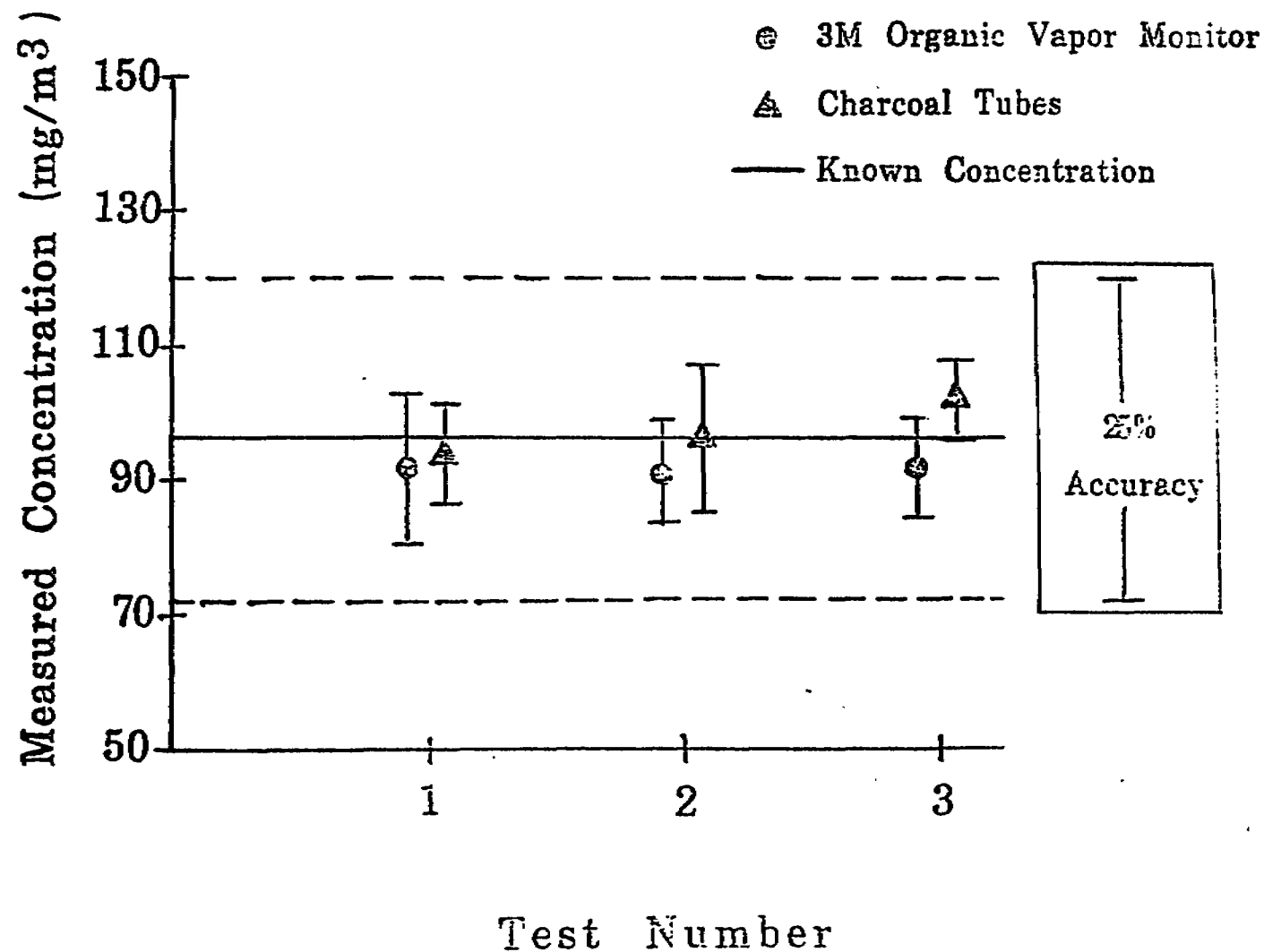
# NAPHTHA (VM & P)



GASOLINE (UNLEADED) - 42 mg/m<sup>3</sup>

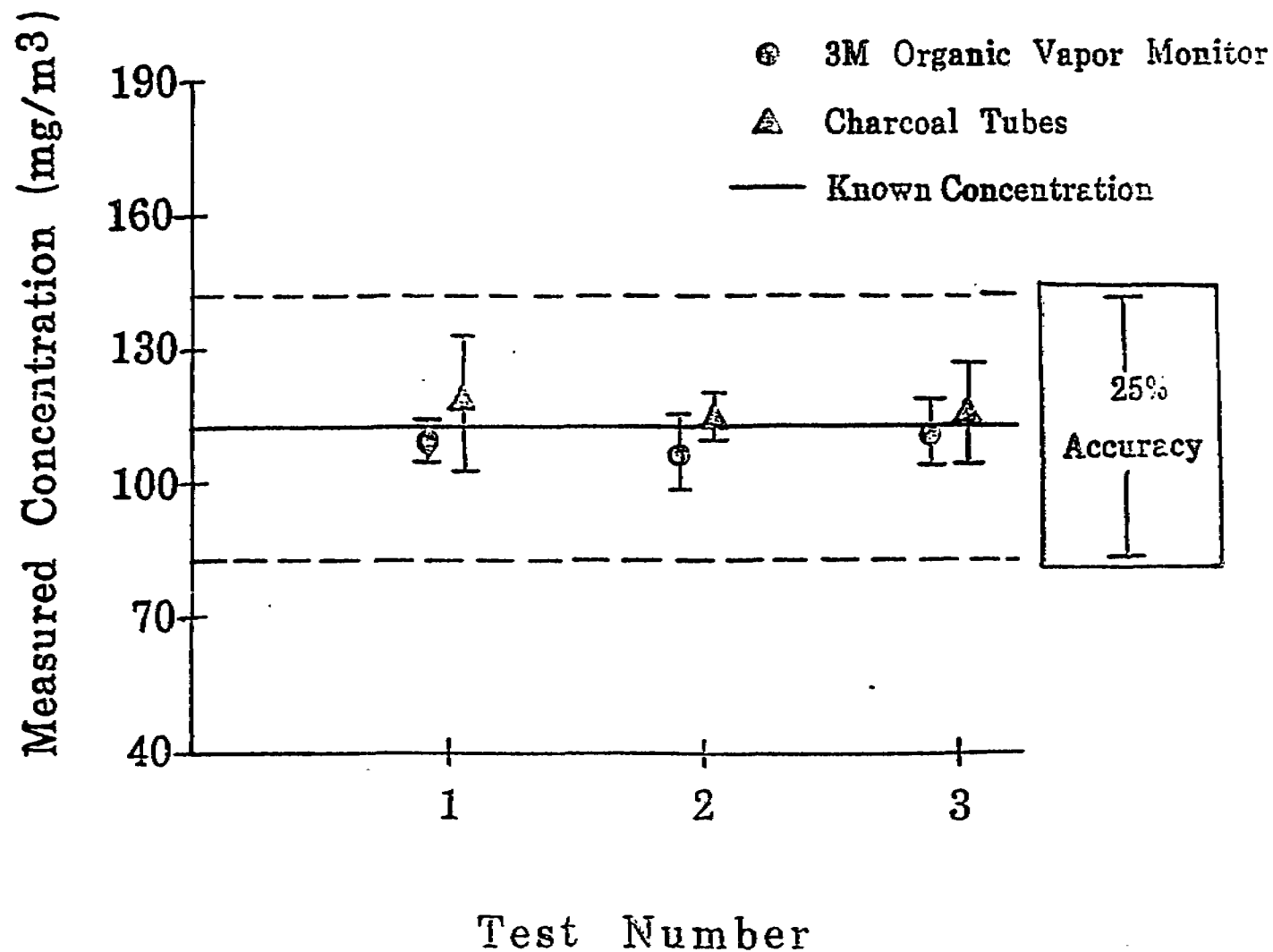
3M 009007

# GASOLINE ( UNLEADED ) - 96 mg/m<sup>3</sup>

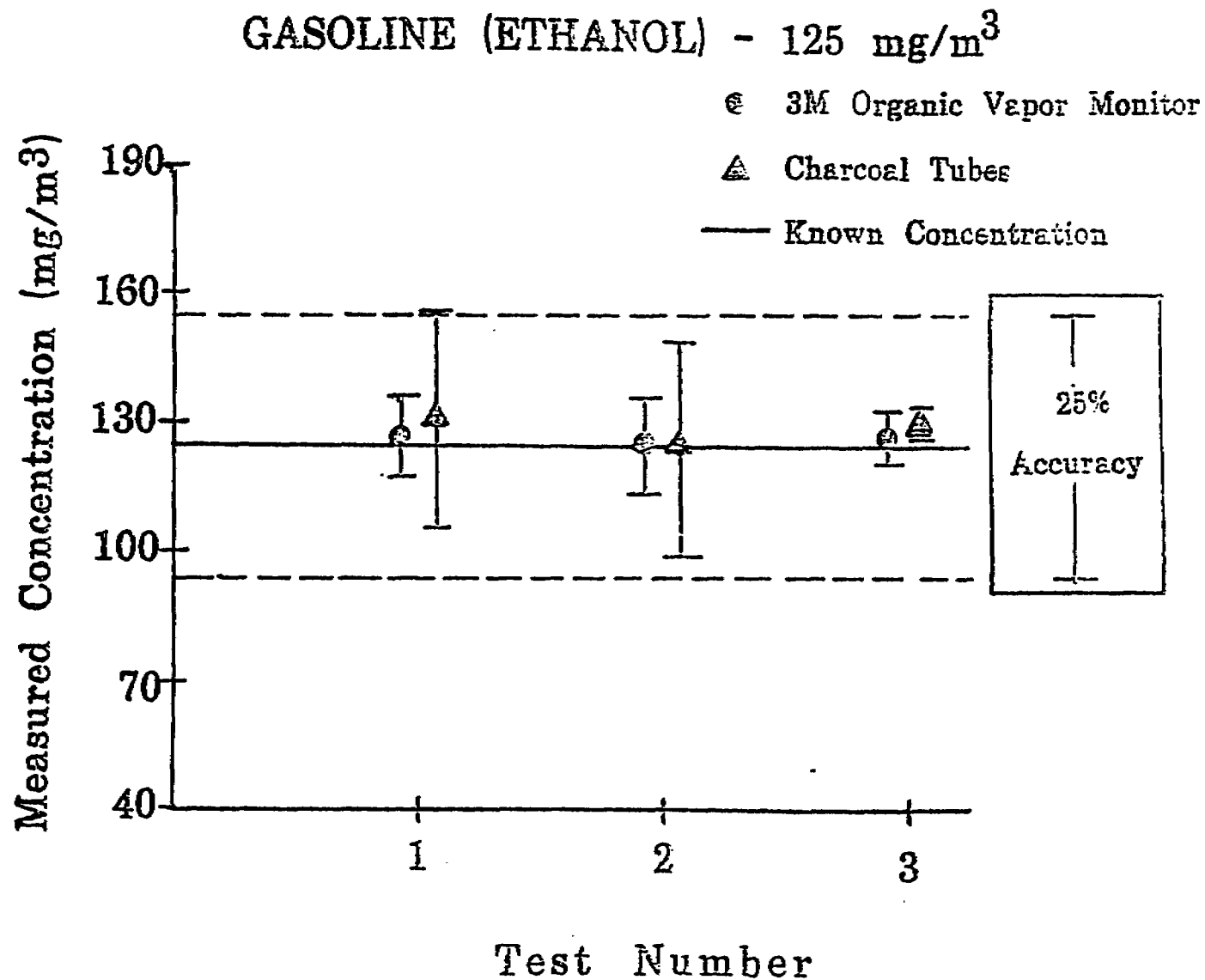


800600 ME  
3M 009008

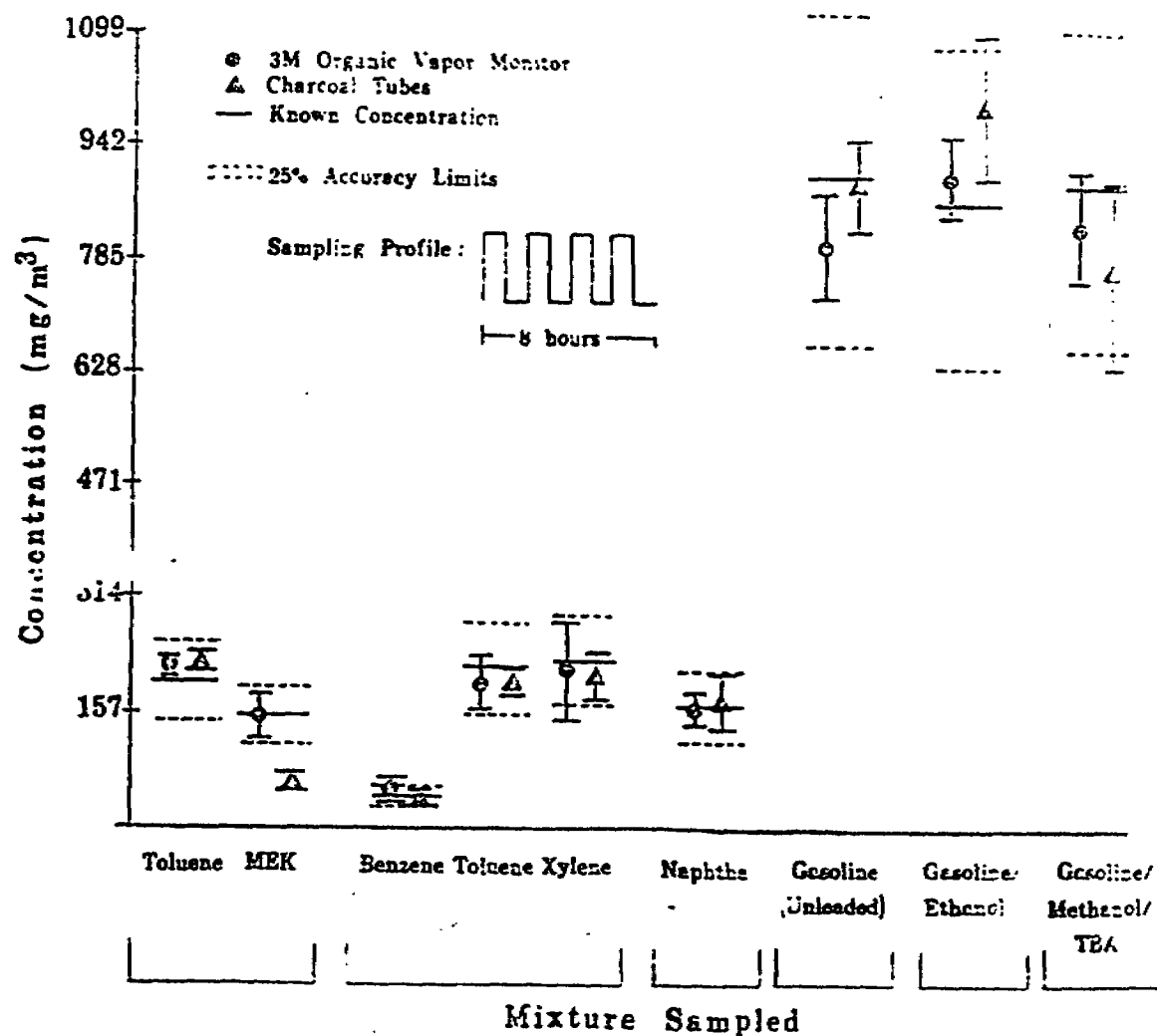
# GASOLINE (METHANOL/TBA)



600600 WE

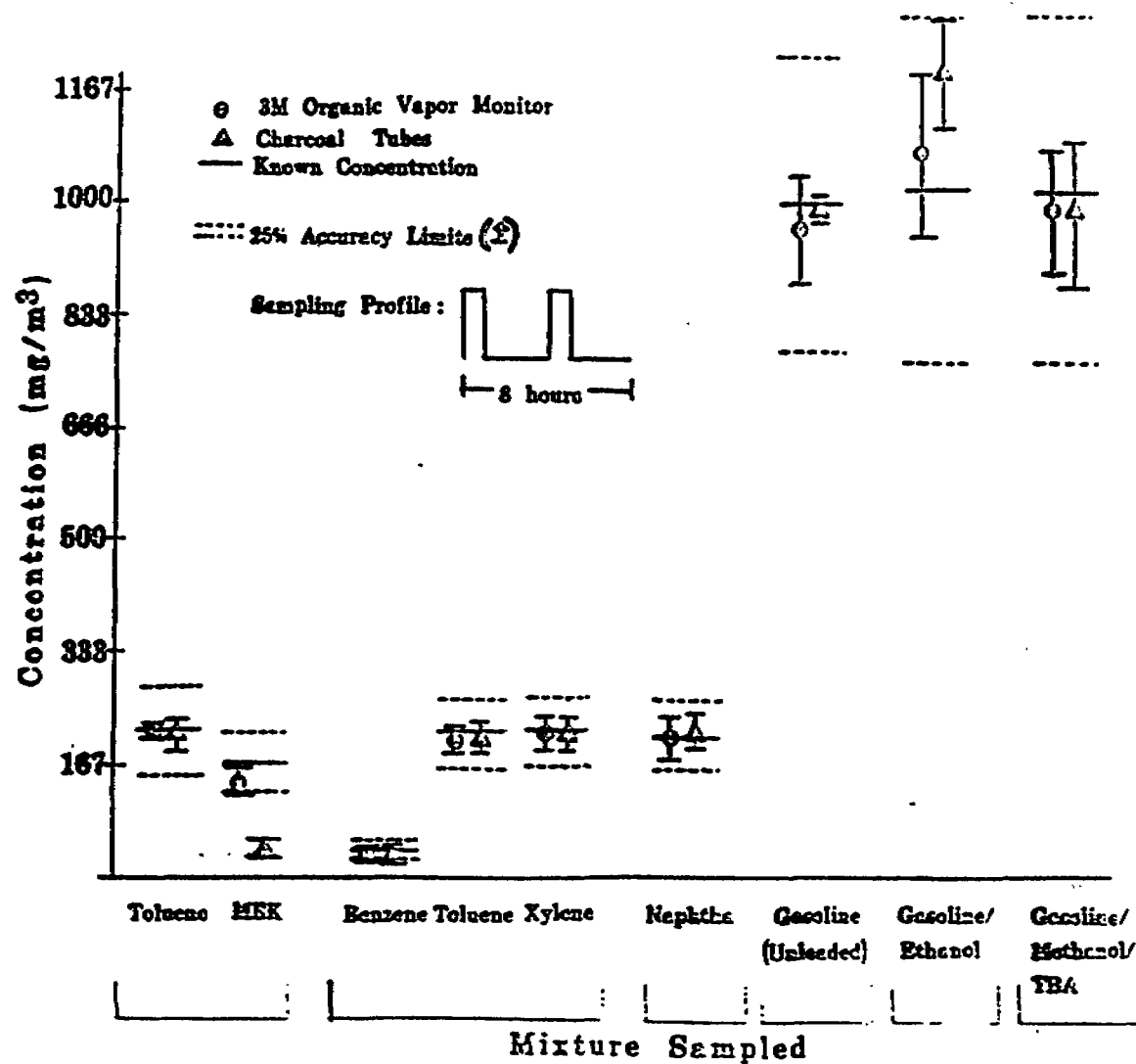


# RESPONSE TO VARIABLE CONCENTRATION



3M 009010

# RESPONSE TO VARIABLE CONCENTRATION



3M 009011