ORGANIC VAPOR MONITOR WITH BACKUP SECTION #3520

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Introduction

The 3M Brand Organic Vapor Monitor #3520 with backup section is a diffusionally controlled sampling device designed to measure time-weighted-average concentration of potentially hazardous organic vapors in the environment. The sample is equipped with a backup section which collects contaminants when the capacity of the primary adsorbent has been exceeded. The monitor consists of two layers of adsorbent medium separated by a small space containing a placid air layer within the monitor. The amount of contaminant collected by the primary adsorbent layer is determined by sampling time and contaminant concentration in the environment. For a specific contaminant, the secondary adsorbent begins to collect contaminant by diffusion when the capacity of the primary adsorbent is exceeded for that particular contaminant. The capacity can be exceeded when sampling contaminant mixtures, contaminants at high concentrations, as well as contaminants for which activated carbon has a low capacity. By comparing the weight collected on each of the adsorbents (primary and secondary), the validity of the sample collected by the monitor can be determined. If the sample is determined to be valid, then the weight of contaminant on the primary and secondary adsorbent is used to calculate the time-weighted-average concentration of the contaminant in the environment during the sampling period.

Principle of the Method

The 3M Brand Organic Vapor Monitor #3520 with the backup section is a personal sampler to be worn near the breathing zone of the worker. The sampler collects contaminants from the ambient atmosphere by diffusion onto the primary adsorbent where it is collected. The weight collection rate is a linear function of the exposure (product of the concentration and time). As the primary adsorbent collects contaminant, the collection rate will eventually deviate from the linear relationship. The adsorbent's capacity for the contaminant is defined as the weight adsorbed when the above deviation occurs. When the capacity of the primary adsorbent is reached with the 3520 Organic Vapor Monitor, the contaminant then diffuses to the secondary adsorbent in the backup section. Because of the geometric dimensions, the sampling rate of the contaminant onto the secondary adsorbent is 45% of the sampling rate onto the primary adsorbent.

Upon analysis of each adsorbent, the validity of the sample can be determined. Because the mass of activated carbon in the primary adsorbent is equivalent to the mass of activated carbon in the secondary adsorbent, the contaminant capacity on each should be equivalent. But in order to assure a valid sample under all sampling conditions, the ratio of the contaminant weight (W_s) on the secondary adsorbent to the contaminant weight (W_p) on the primary adsorbent must meet the following criteria.

$$\frac{W_s}{W_p} \leqslant .50$$

When sampling an environment containing multiple contaminants with the 3520 Organic Vapor Monitor, the above criteria can be used to determine the sample validity of each contaminant. Therefore, for those contaminants which fulfill the above criteria, the weight (W_p) on the primary adsorbent and the weight (W_s) on the secondary adsorbent can be used to accurately determine the time-weighted-average concentration.

The weight corrected for the blank of each contaminant on the primary and secondary adsorbent (W_p and W_s) can be used to calculate the time-weighted-average concentration according to the following equation:

$$C\ (mg/m^3) = \frac{W_p}{K_p \times t} + \frac{W_s}{K_s \times t}$$

W_p - corrected weight collected on the primary adsorbent

W_s - corrected weight collected on the secondary adsorbent

K_p - sampling rate of the contaminant onto the primary adsorbent

K_s - sampling rate of the contaminant onto the secondary adsorbent

t - length of sampling period

The above equation can be simplified to the following:

$$C\ (mg/m^3) = \frac{W_p + kW_s}{K_p \times t}$$

where,

k - A constant determined by the ratio K_p/K_s. For all contaminants, this ratio has been determined to be a constant value of 2.2.

With this simplification, the time-weighted-average concentration of the contaminant in the environment can be calculated from the corrected weight collected by the primary and secondary adsorbent, the length of the sampling period and contaminant sampling rate onto the primary adsorbent.

The geometric dimensions (area and length) of the primary diffusional chamber for the 3520 Organic Vapor Monitor with the backup section are the same as the dimensions of the diffusional chamber for the 3500 Organic Vapor Monitor. Therefore, the sampling rates (K_p) for contaminants onto the primary adsorbent of the 3520 Organic Vapor Monitor are the same as those tabulated in the Sampling and Analysis Guide for the 3500 Organic Vapor Monitor.

As the diffusional capacity of the primary adsorbent is reached with the 3520 Organic Vapor Monitor and the secondary adsorbent starts to collect contaminant, it is merely an indication that for the primary adsorbent, the weight collection rate is no longer a linear function of the exposure. Although the diffusional capacity for the primary adsorbent may be reached during sampling, the adsorbent will continue to collect contaminant even though the weight collection rate deviates from the linear relationship. As will be shown later, the weight (W_p) collected on the primary adsorbent even though in excess of the defined capacity can be combined with the weight (W_s) collected on the secondary adsorbent to give an accurate determination of the time-weighted-average concentration in the sampled environment. These weights (W_p and W_s) can be combined according to the above expression as long as the ratio W_s/W_p complies with the above criteria. Therefore, the 3520 Organic Vapor with the backup section increases the effective sampling capacity by a factor of at least four over the 3500 Organic Vapor Monitor capacity. This allows the recommended sampling periods tabulated in the Sampling Guide for the 3500 Organic Vapor monitor to be increased by at least four times when sampling with the 3520 Organic Vapor Monitor.

To insure proper operation of the secondary section according to the given criteria, immediately separate the primary and secondary sections after sampling is terminated. Conclusion of sampling occurs when the white face of the monitor and the retaining ring are removed and the closure cap is snapped in place. Next, the primary and secondary sections are separated. The brown cap is snapped into place on the bottom of the primary section and the other closure cap is snapped on the secondary section. The two ports in the cap are firmly closed with the attached plugs. The improtance of these final steps should be emphasized since environmental sampling continues until the bottom brown cup and the closure are on with all ports closed.

Documentation of Sampling Performance

The 3M Brand Organic Vapor Monitor #3520 with the backup section is a diffusional sampling device which allows the industrial hygienist to determine sample validity. It is very valuable to assure sample validity when sampling an environment with a mixture of contaminants as well as contaminants at high concentrations. Besides assuring sample validity when sampling contaminants such as acetone, methylene chloride, vinyl chloride, etc. for which the activated carbon has a low capacity, the #3520 Organic Vapor Monitor also extends the effective sampling capacity and enables the recommended sampling periods to be increased. The following table is a list of eight commonly sampled contaminants which not only have high Permissible Exposure Level (PEL's) but also have limited capacity for activated carbon. From the table, it can be observed that the recommended sampling times can be extended in most instances to allow full work shift sampling.

TABLE I

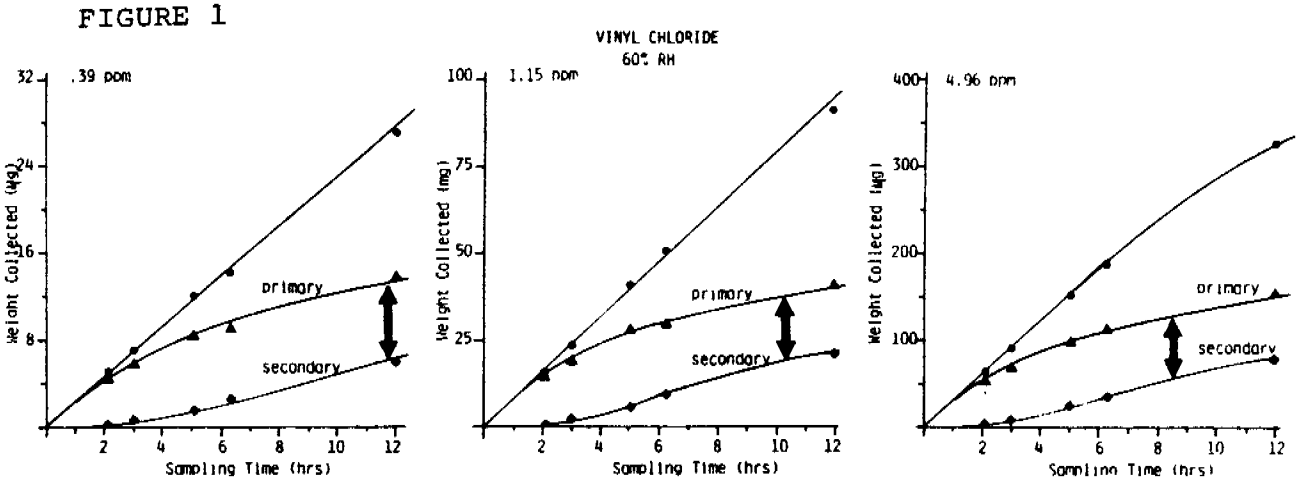
	OSHA PEL (ppm)	Sampling Rate $\left(\frac{\text{Micrograms}}{\text{ppm-hrs}}\right)$	Primary Adsorbent Capacity (mg)	Recommended Sampling Period for 3520 OVM (hours) Concentration x PEL .1X	.5X	1X	3X
Acetone	1,000	5.71	3	8	4	2	1
Ethyl acetate	400	7.45	10	8	8	8	5
Ethyl ether	400	6.68	.4	6	1	.6	.2
Methyl acetate	200	6.72	2	8	8	6	2
Methyl chloroform	350	10.09	12	8	8	8	5
Methyl chloride	500	7.91	2	8	4	2	1
Pentane	1,000	5.56	7	8	8	5	2
Vinyl chloride	1	6.22	.04	8	8	8	8

To document the increase in effective sampling capacity, a number of contaminants from the above table were selected to be evaluated by sampling a laboratory challenge of known concentration. In Figure 1, vinyl chloride was sampled at three concentrations (.39, 1.15 and 4.96 ppm) at a relative humidity of 60%. The double arrow between the primary and secondary curve indicates where the ratio W_s/W_p is equal to .50. Therefore, it is the point beyond which the sample would be considered to be invalid. The response line of the 3520 was obtained from the combined weight (W_c) of the weight (W_p) on the primary adsorbent and the weight (W_s) on the secondary adsorbent according to the following equation.

$$W_c = W_p + 2.2\ W_s$$

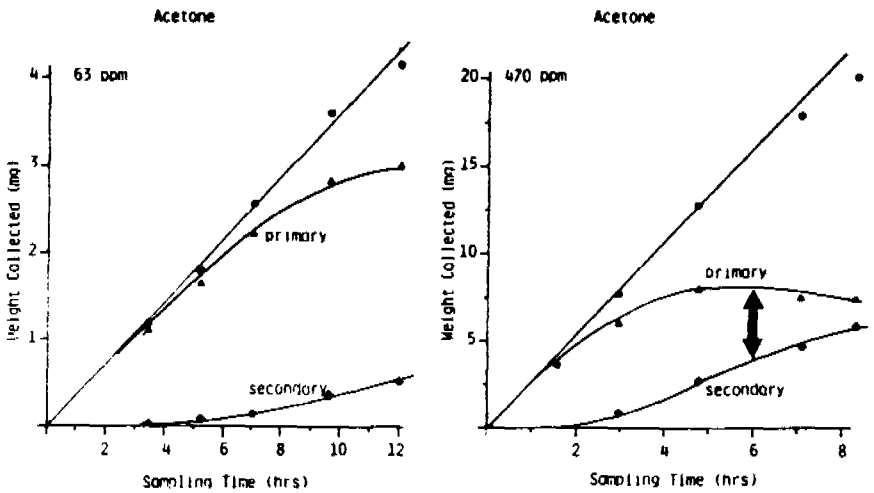
It can be observed that the response of the 3520 as measured by the combined weight (W_c) is linear beyond the point of the double arrow and also that the sampling time at all concentrations can be in excess of eight hours.

FIGURE 1



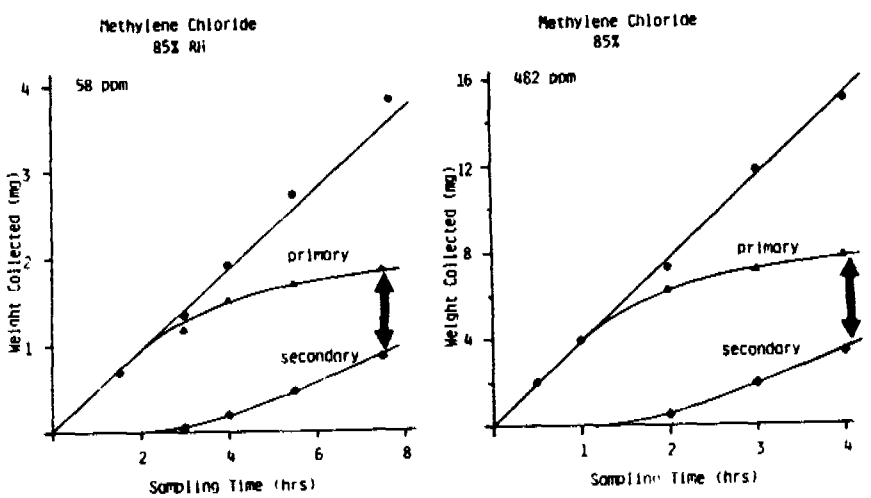
In Figure 2, acetone was sampled from known challenges of 63 and 470 ppm. At the lower concentration it can be observed that a valid sample was collected through the entire 12 hour sampling period while at the higher concentration after six hours of sampling the sample was invalid. Although, it should be pointed out that after eight hours, the response of the 3520 OVM as measured by the combined weight (W_c) deviated only slightly from the expected linear response.

FIGURE 2



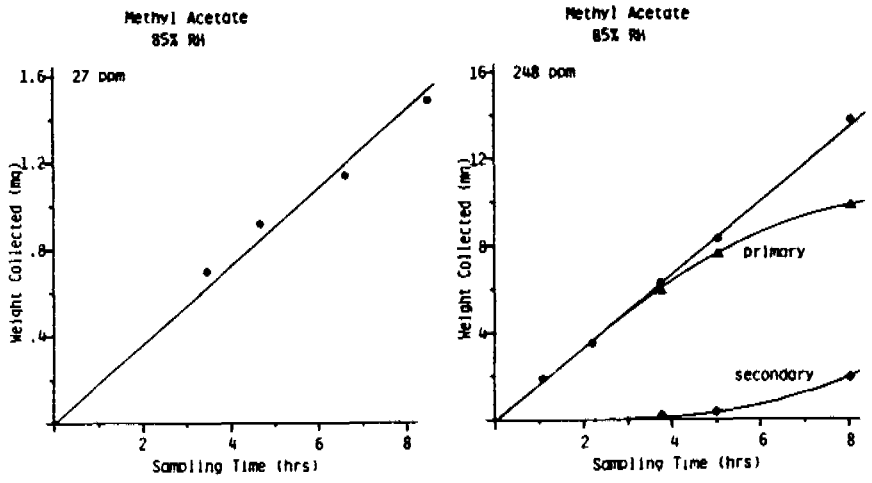
In Figure 3, methylene chloride was sampled from known challenges of 58 and 482 ppm at a relative humidity of 85%. Again, the double arrow indicates the point beyond which an invalid sample would be collected as determined by the above criteria of weight ratio. As expected the response of the 3520 OVM as measured by the combined weight (W_c) gives the expected linear relationship between weight and the sampling time at known constant challenges.

FIGURE 3



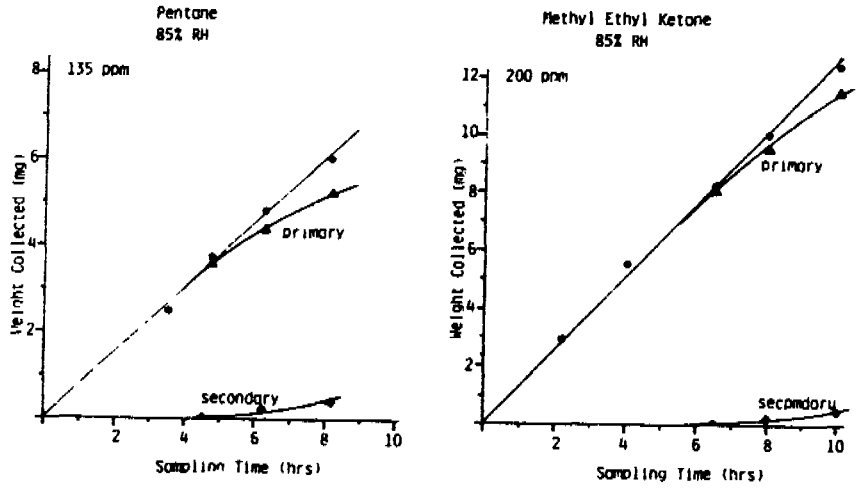
In Figure 4, methyl acetate was sampled from known challenges of 27 and 248 ppm. From the results it can be observed that at both challenges a valid sample was collected through the eight hour sample periods.

FIGURE 4



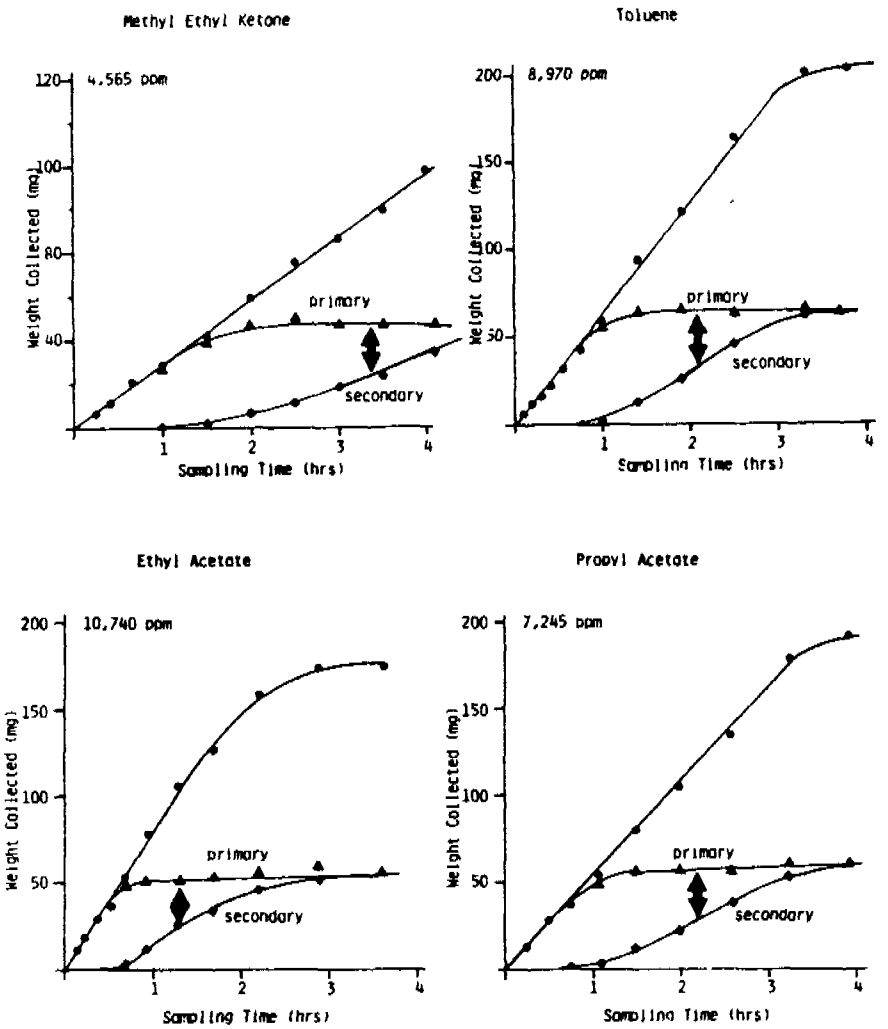
In Figure 5, pentane and methyl ethyl ketone were sampled from challenges at concentrations of 135 and 200 ppm respectively. In both cases very little sample was collected by the secondary adsorbent during the sampling periods.

FIGURE 5



As was pointed out earlier, the 3520 OVM is also able to determine sample validity when sampling at very high concentrations. In Figure 6, MEK, toluene, ethyl acetate and propyl acetate were sampled from challenges where the known concentrations were very high. The double arrow again indicates the point beyond which the sample should be considered to be invalid. The response of the 3520 OVM as measured by the combined weight (W_c) is linear even past the double arrow.

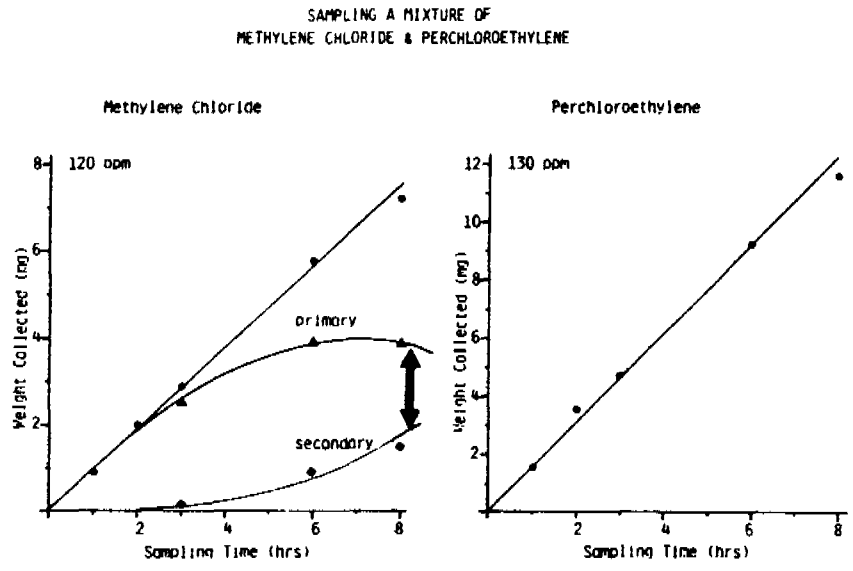
FIGURE 6



From the above results where the 3520 OVM sampled known challenges of a single contaminant, it has been shown that sample validity can be determined from a realistic criteria defined by the ratio of the weight collected on the secondary adsorbent to the weight collected on the primary adsorbent. It also has been shown that the effective capacity of the sampling device is greater than four times the capacity for a sampling device containing only a single adsorbent. This increased effective capacity allows longer sampling periods when sampling contaminants with a low capacity on activated carbon.

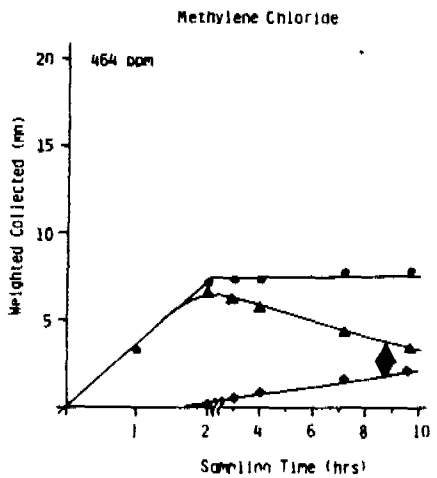
As was indicated above, the 3520 OVM is also very valuable to determine sample validity when sampling environments containing more than one contaminant. First the performance of the 3520 OVM was documented by sampling known charges of a two component mixture. In Figure 7, a mixture of methylene chloride and perchloroethylene at concentrations of 120 and 130 ppm respectively was sampled. As expected, the methylene chloride, for which the activated carbon has a low capacity, was collected on both the primary and secondary adsorbent. The perchloroethylene was collected only on the primary adsorbent of the 3520 OVM. The double arrow again indicates the point where the ratio W_s/W_p is equal to .50.

FIGURE 7



In Figure 8, methylene chloride was sampled from a 464 ppm challenge for two hours. This was followed by a challenge containing a zero concentration of methylene chloride. It is evident that the primary adsorbent collected methylene chloride in excess of its capacity. Although the primary adsorbent lost methylene chloride during this period, the secondary adsorbent collected the appropriate amount from the primary adsorbent. The response of the 3520 as measured by the combined weight gave an accurate measure of the concentration sampled.

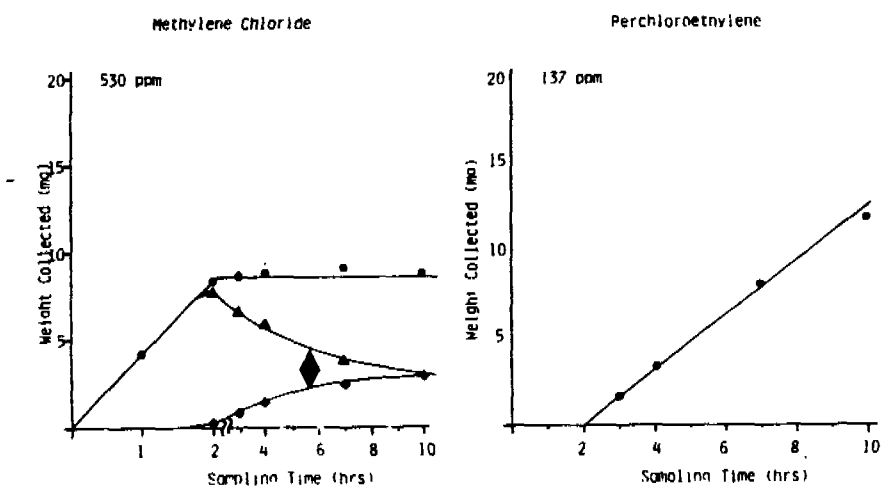
FIGURE 8



In Figure 9, methylene chloride was again collected in excess of the capacity of the primary adsorbent. After the methylene chloride was sampled during the first two hours, a challenge of perchloroethylene was sampled for eight hours. During this period, the methylene chloride was displaced from the primary adsorbent. Again the response of the 3520 as measured by the combined weight gave an accurate measure of the concentration sampled for each of the contaminant.

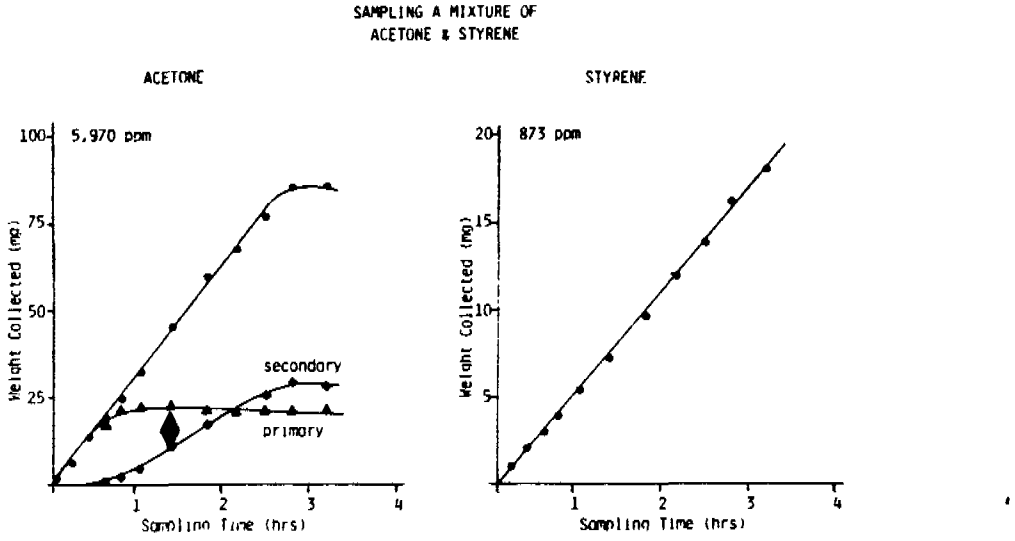
FIGURE 9

SEQUENTIAL SAMPLING OF
METHYLENE CHLORIDE ON PERCHLORDETHYLENE



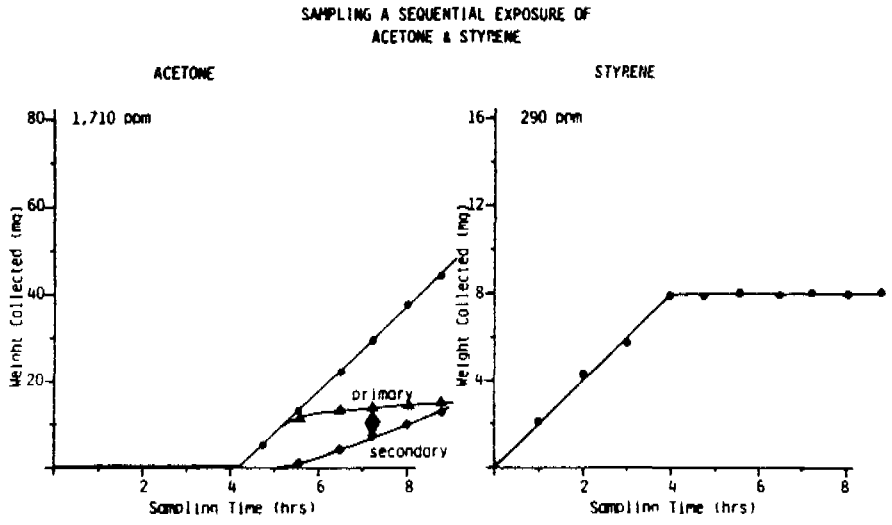
A mixture of acetone and styrene is often found in many industrial environments. In Figure 10, these two contaminants were sampled from laboratory challenges of 5970 and 873 ppm respectively. These were certainly very high concentrations, but valid samples were collected even in excess of the limit imposed by the validity criteria. It is interesting to point out that the secondary adsorbent collected more acetone than the primary adsorbent. This occurred because part of the capacity of the primary adsorbent was used by the adsorbed styrene.

FIGURE 10



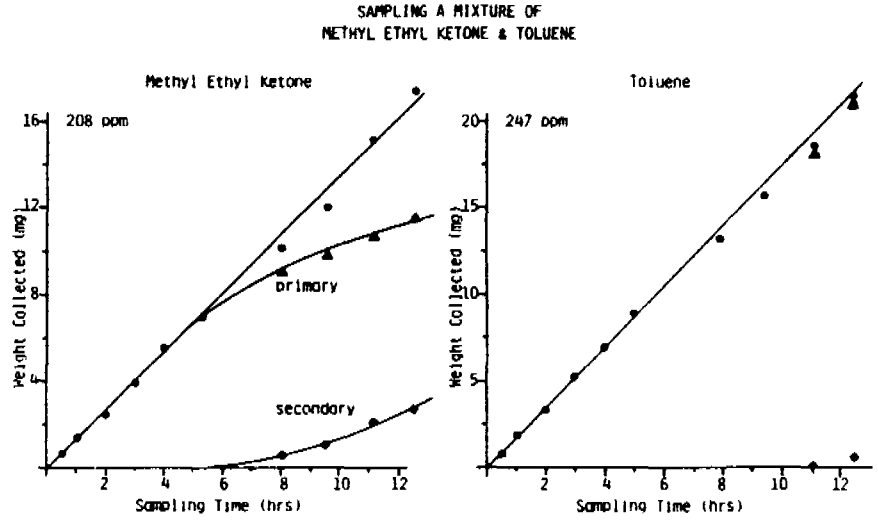
In Figure 11, instead of sampling acetone and styrene simultaneously from a mixture, the 3520 OVM was used to sequentially sample a known challenge of styrene for four hours then a known challenge of acetone for five hours. With styrene, the sample was valid because no contaminant was ever collected on the secondary adsorbent. For acetone, the sample would have been judged to be valid through seven hours of sampling by comparing the ration of W_s/W_p, but it is interesting that the 3520 OVM gave a linear response during the entire nine hour sampling period.

FIGURE 11



Methyl ethyl ketone and toluene is another mixture often found in the industrial environment. In Figure 12, valid samples were collected through 12.5 hours when a known challenge of 208 and 247 ppm respectively

FIGURE 12



In Figure 13, the same mixture was sampled from a challenge with even higher concentrations of both methyl ethyl ketone and toluene. The response of the 3520 as measured by the combined weight (W_c) is again linear even past where the weight ratio criteria has been exceed.
When sampling the high concentration of this mixture, it can be observed that methyl ethyl ketone was displaced from the primary adsorbent by the toluene during latter portion of the sampling. This is evident by observing that the methyl ethyl ketone weight collected on the primary adsorbent decreases after one hour of sampling while the weight on the secondary continues to increase. Even though the displacement occurred, the combined weight as determined according to the above equation from the weight collected by the primary and secondary still gives the expected linear response as a function of sampling time.

FIGURE 13

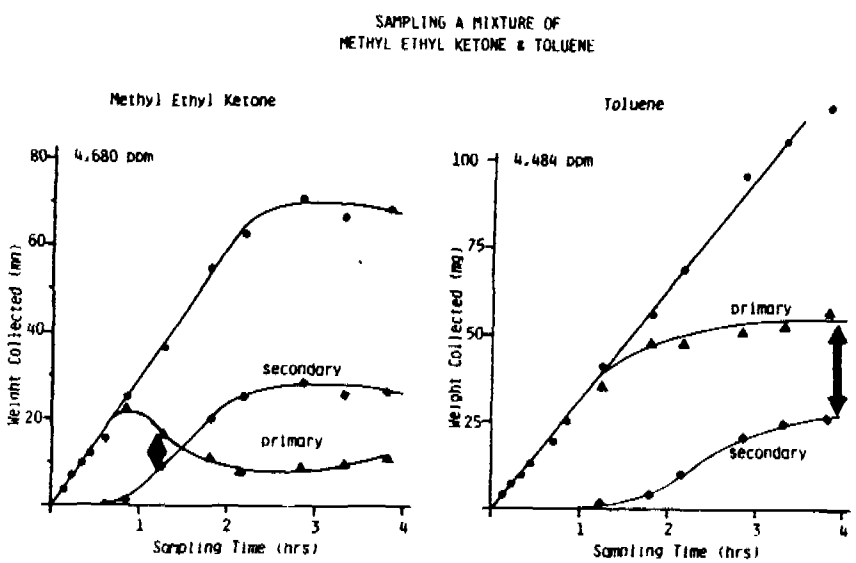
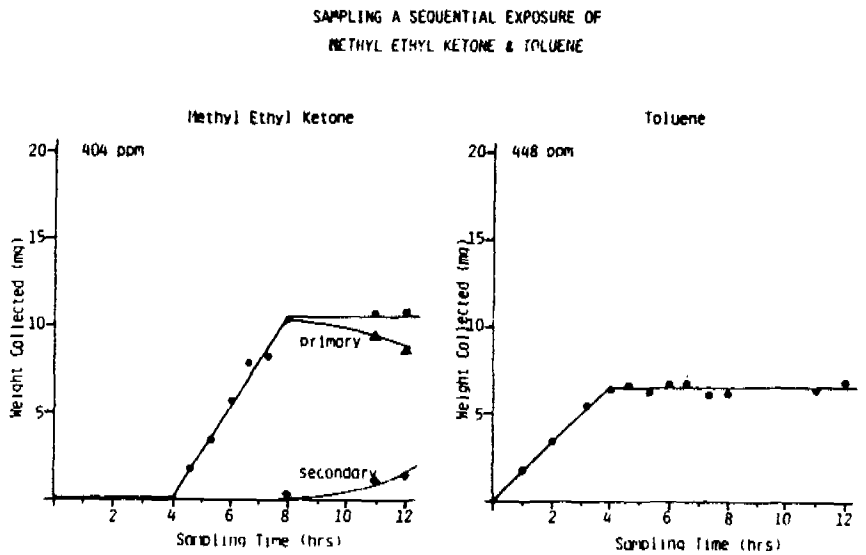


Figure 14 is another example of sequentially sampling a known challenge. Toluene was sampled for four hours with all the contaminant collected only on the primary adsorbent. Methyl ethyl ketone was sampled for the following four hours and all of the contaminant was collected on the primary adsorbent. During the next four hours, the sampling devices were exposed to air with a zero challenge of each contaminant. It is evident that some methyl ethyl ketone was lost by the primary adsorbent during this period, but with the secondary adsorbent present, the 3520 response as measured by the combined weight accurately indicated the weight collected during the sampling of the known challenge.

FIGURE 14



In the next set of laboratory evaluations to document the performance of the 3520 OVM, challenges of three sets of contaminant mixtures were sampled. The mixtures consisted of a group of ketone, a group of esters and a group of halogenated compounds. In Figure 15, 16, and 17, the mixture consisted of acetone, methyl ketone and methyl isobutyl ketone. Three sets of challenges each with increased concentration of the contaminants were sampled. These ketones were selected because of the capacity range activated carbon has for these contaminants. It should be indicated that sample validity can be judged for each contaminant independent of the response of the 3520 for the other contaminants present in the challenge being sampled.

FIGURE 15

SAMPLING A MIXTURE OF
THREE KETONES AT 85% RH

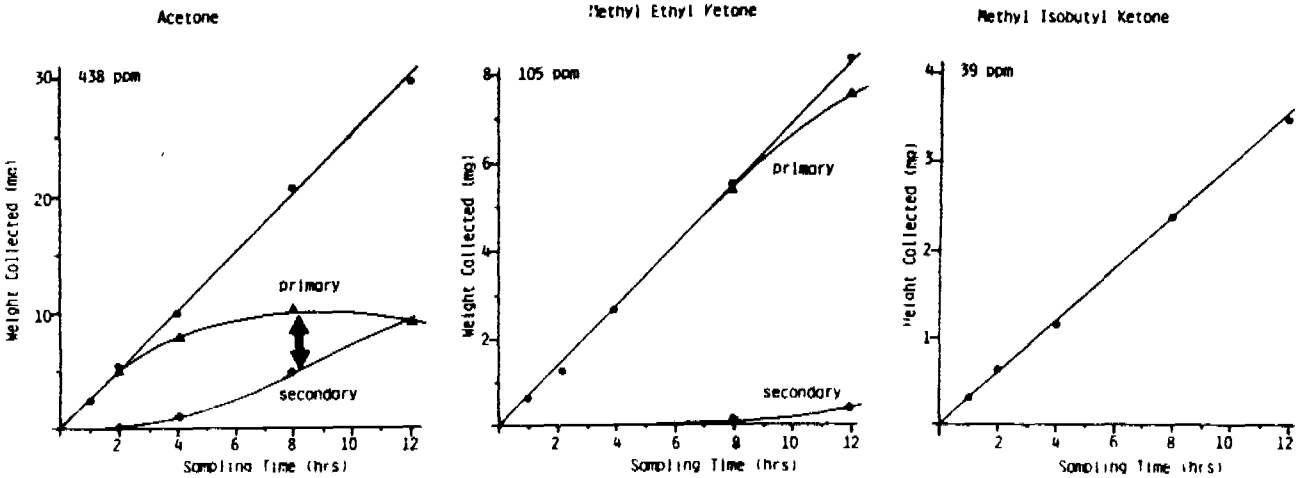


FIGURE 16

SAMPLING A MIXTURE OF
THREE KETONES AT 85% RH

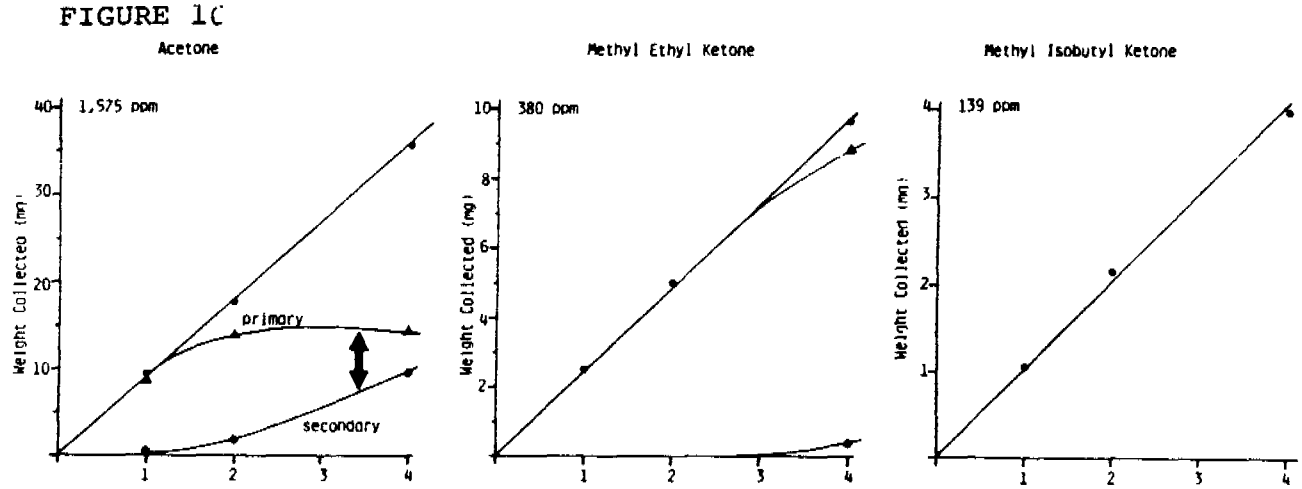
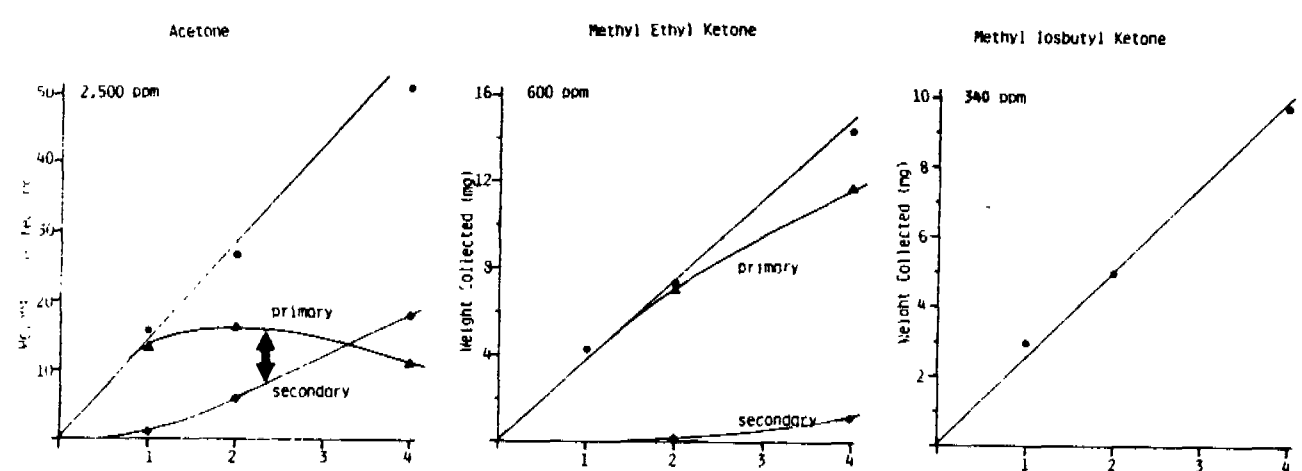


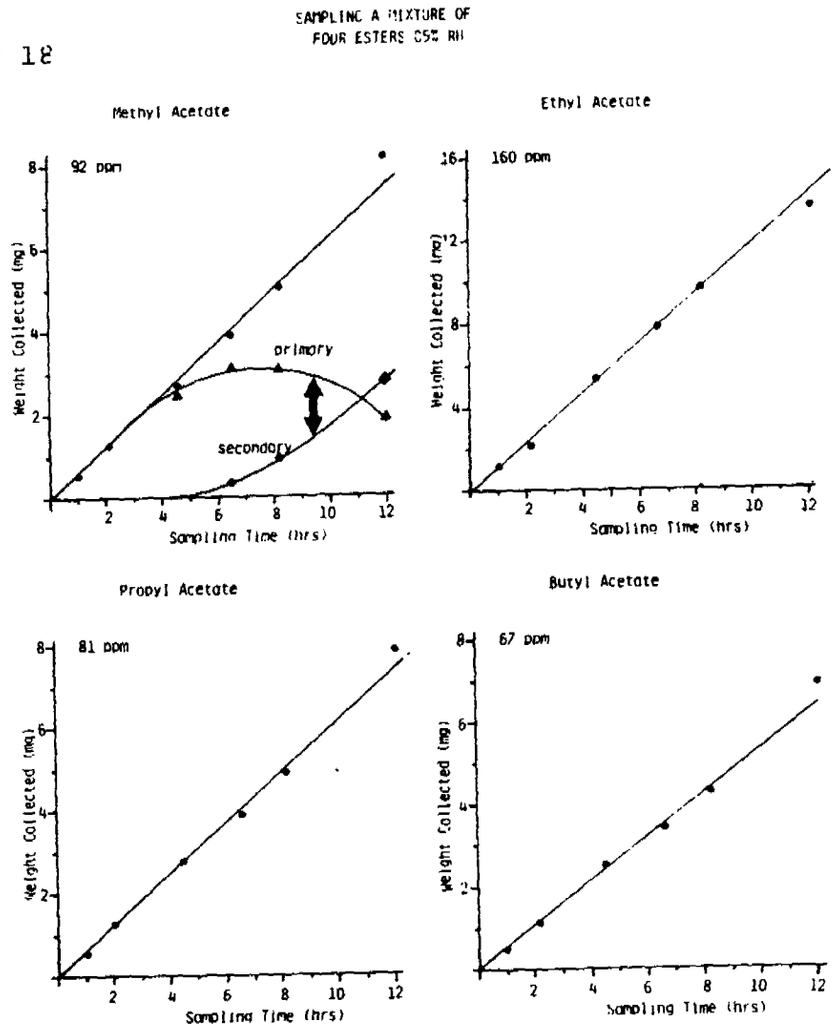
FIGURE 17

SAMPLING A MIXTURE OF
THREE KETONES AT 85% RH



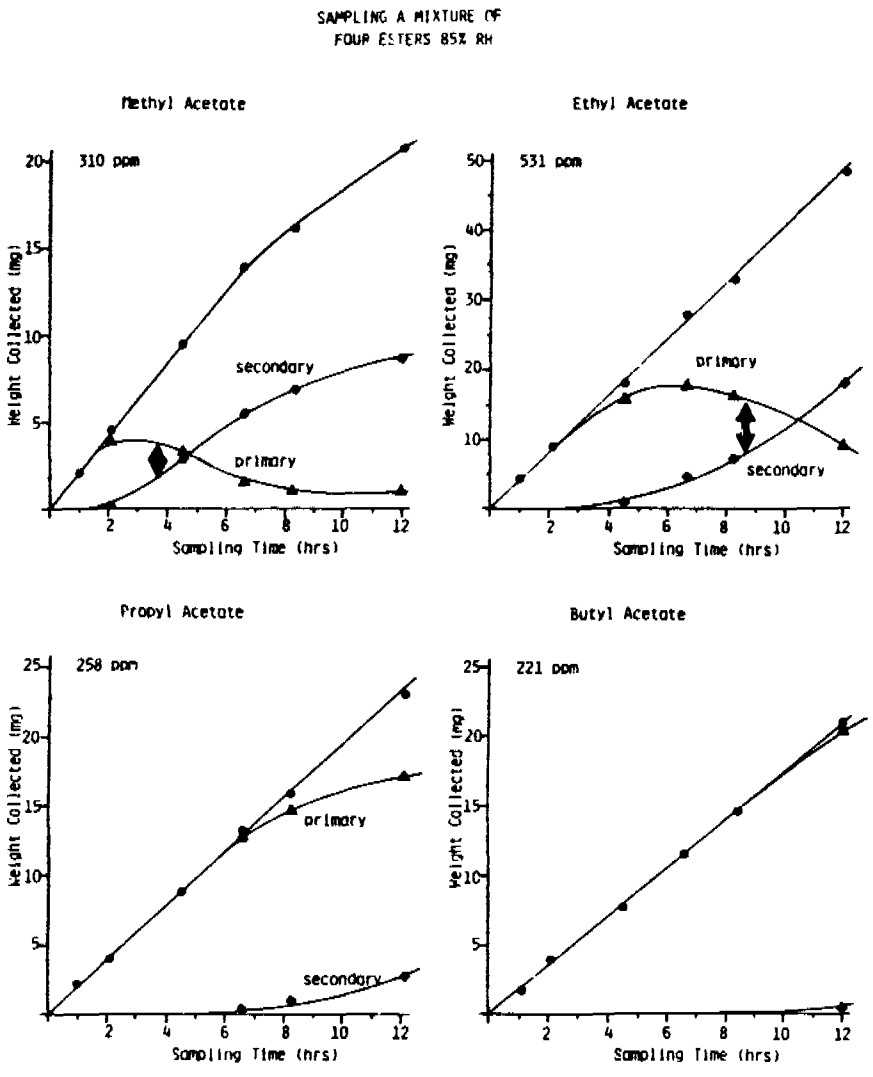
The next mixture consisted of a group of esters again selected because of the capacity range the activated carbon has for these four contaminants. In Figure 18, at the lowest challenge concentration, only methyl acetate was collected on the secondary adsorbent and the samples were valid for all contaminants for at least a nine hour sampling period.

FIGURE 18



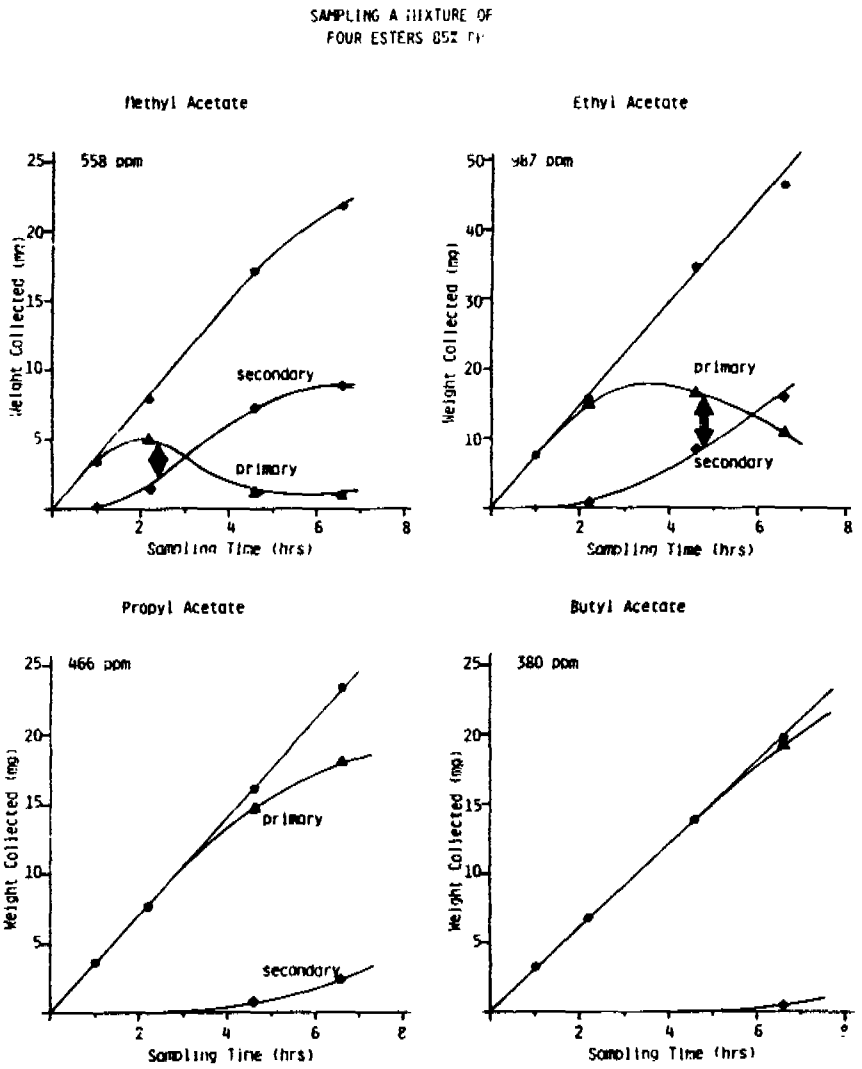
In Figure 19, with the same esters at higher concentrations, the secondary adsorbent collected even butyl acetate after 12 hours of sampling. It is important to indicate again that the 3520 response as measured by the linear response of the combined weight was excellent even past the point of the double arrows.

FIGURE 19



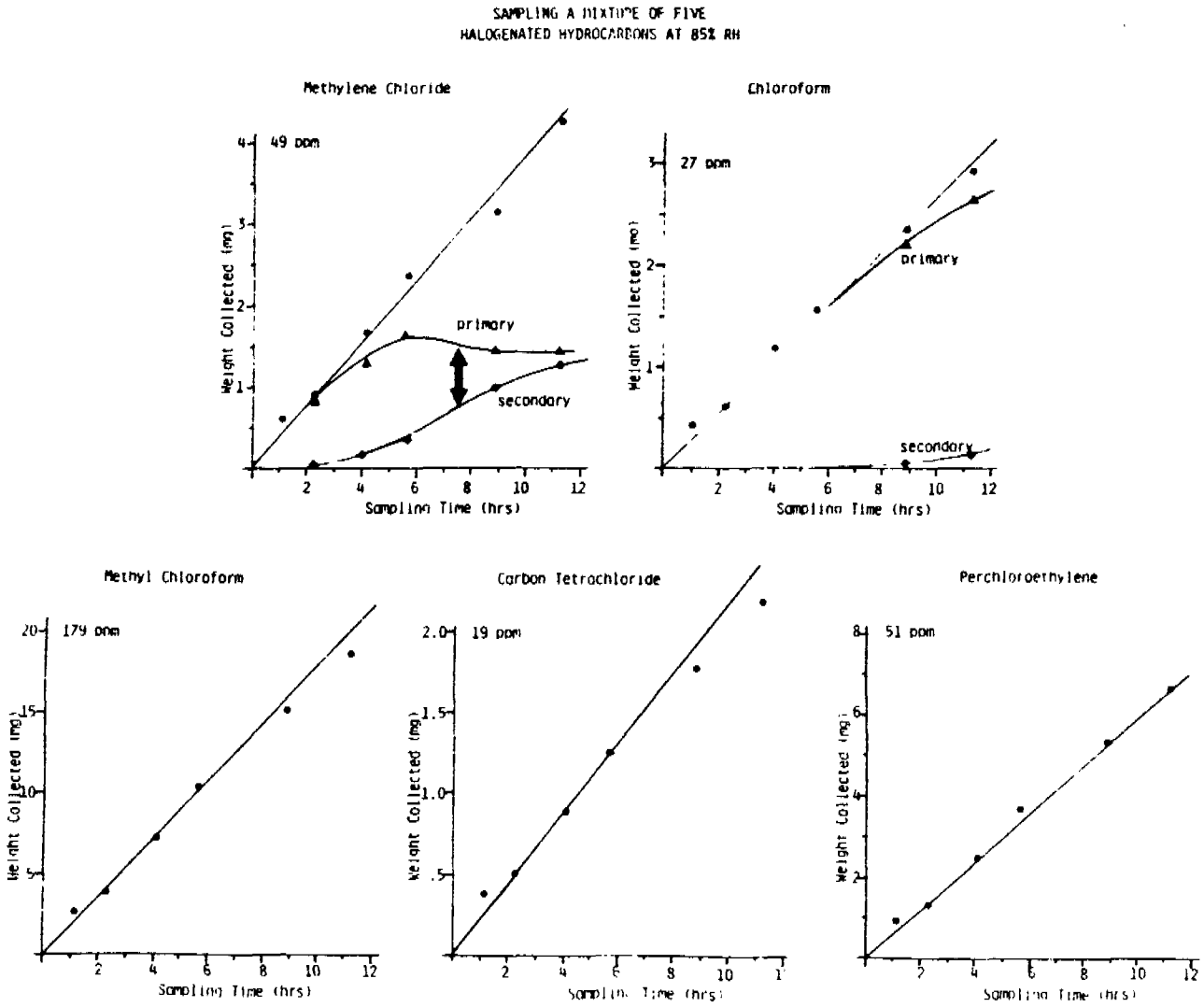
In the above figure as well as in Figure 20, where the same contaminants are sampled even at higher concentration, the displacement of methyl acetate and ethyl acetate from the primary adsorbent occurred during the latter part of the sampling period. But because of the secondary adsorbent, the combined weight gave the expected linear response even past the point where the samples were determined to be valid.

FIGURE 20



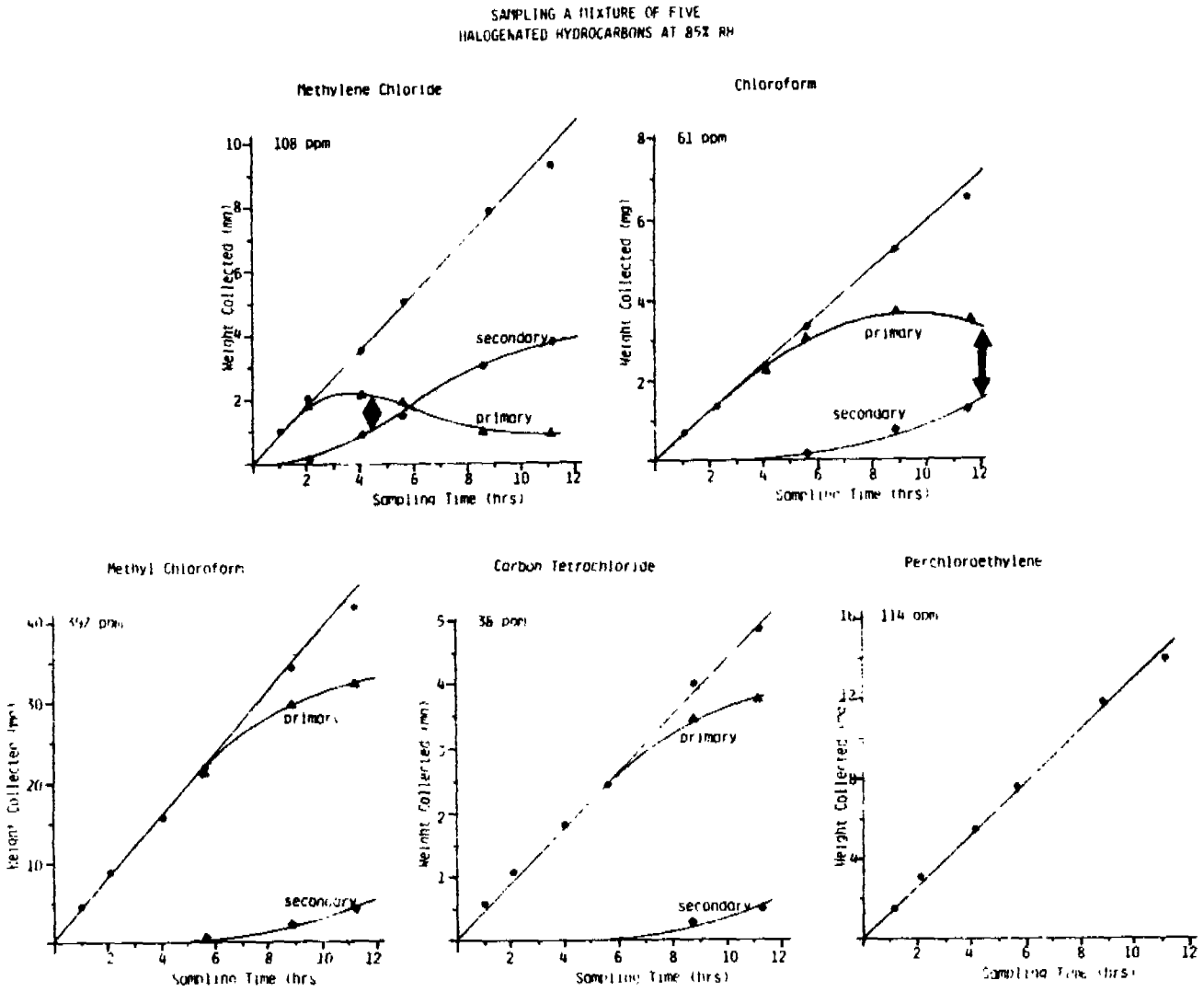
In the next three figures, the 3520 sampled known challenges of a mixture consisting of five halogenated hydrocarbons. In Figure 21, valid samples were collected for twelve hours for all of the contaminants except for methylene chloride. For methylene chloride, the sample was valid for a seven hour sampling period when judged by the weight ratio of the contaminant collected on the secondary and primary adsorbent.

FIGURE 21



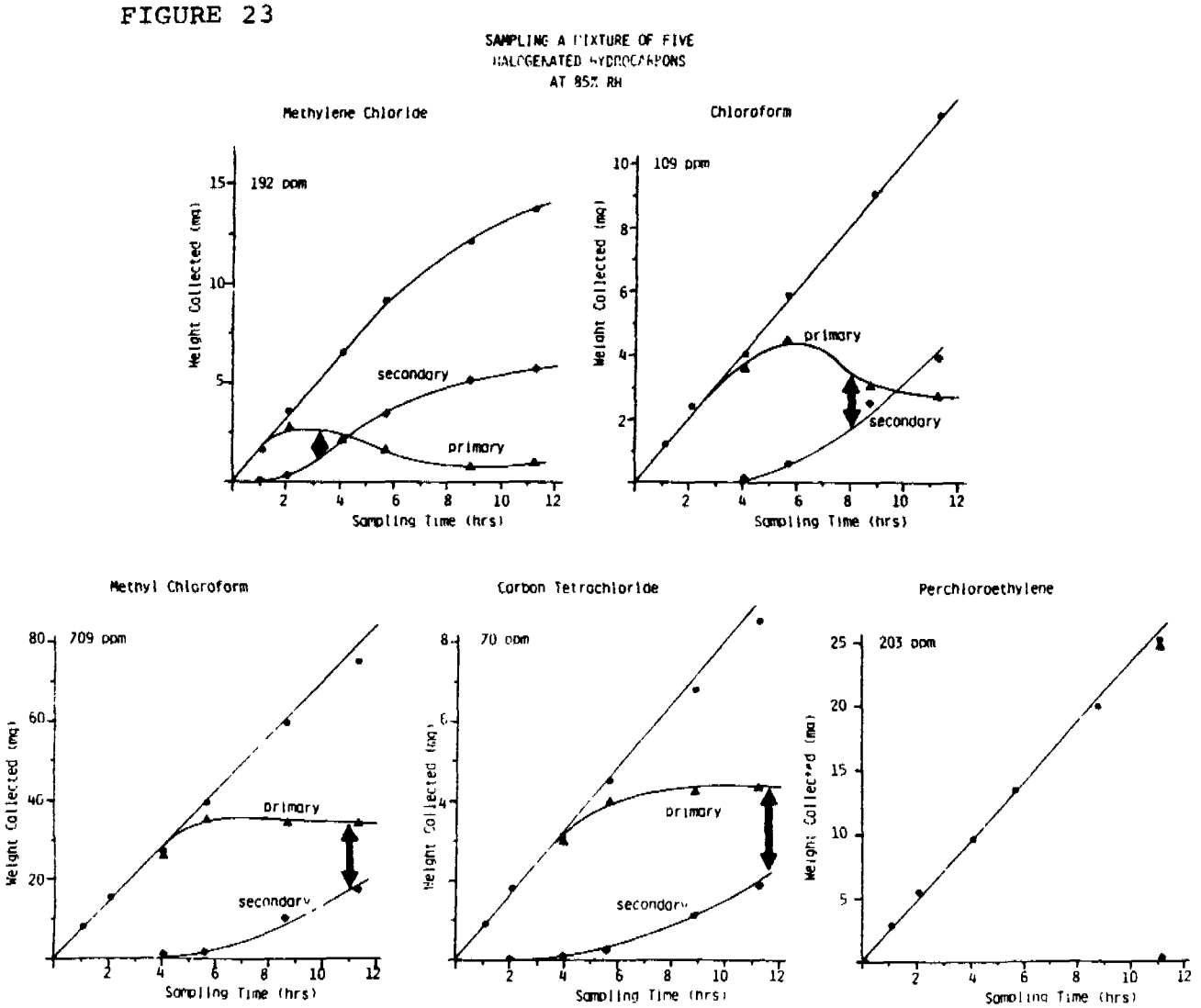
In Figure 22, the same contaminant mixture was sampled at somewhat higher challenge concentrations. Again, the contaminant with the lowest capacity,in this case methylene chloride, was displaced from the primary adsorbent during the latter portion of the sampling period. Even though displacement occurred and sample validity according to the weight ratio criteria was exceeded past a four hour sampling period, it can be observed that all contaminants were sampled accurately for the entire 12 hour sampling period.

FIGURE 22



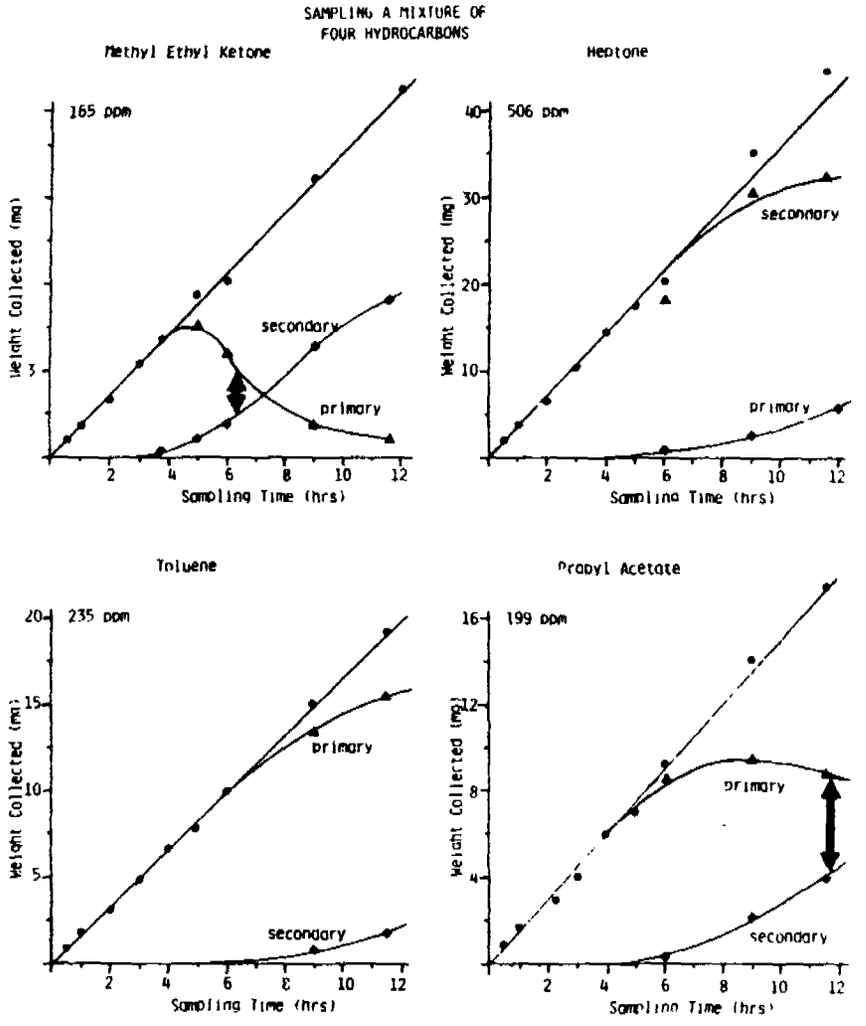
In Figure 23, at even higher concentrations, the weight ratio criteria for validity indicated that for four of the contaminants, the sampling could not be done for a 12 hour period. However, the response of the 3520 OVM as measured by the combined weight gave a linear response over the 12 hour sampling period for all contaminants except for methylene chloride. For methylene chloride, the combined weight deviates from a linear response after six hours of sampling. At this point even the secondary adsorbent is not able to properly sample methylene chloride due to the large amount of the other contaminants also being collected on the secondary adsorbent. It is again important to indicate that even though both the primary and secondary combined were not able to accurately measure the methylene chloride concentration, the sample is valid for the other contaminants even past an eight hour sampling period.

FIGURE 23



The final challenge used to evaluate the 3520 OVM preformance was mixture of contaminants selected from different hydrocarbon families. In Figure 24, it can again be observed that the 3520 response as measured by the combined weight was a linear function of the sampling time. When sampling this mixture, it can be observed that methyl ethyl ketone was displaced from the primary adsorbent. Even with this displacement, the weight ratio criteria indicated a valid sample could be collected for a six hour sampling period and from the linear response of the combined weight a valid sample was actually collected for the entire 12 hour sampling period.

FIGURE 24



In conclusion, the above documentation of the sampling performance of the 3520 Organic Vapor Monitor with the backup section demonstrates the accuracy and validity of the samples collected from known challenges. These challenges consisted of single contaminants for which the activated carbon has limited capacity as well as mixtures with numerous components. The 3520 OVM with the secondary adsorbent has been shown to have increased effective sampling capacity as well as the ability to determine sample validity long before the combined weight deviates from the expected linear response. This assures the industrial hygienist that accurate samples will be collected under any sampling condition when the weight ratio criteria is used to determine sample validity.

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