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EVALUATION OF U-TUBE UNDERGROUND TANK SYSTEMS FOR SOIL VAPOR TESTING

Suffolk County, New York

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REPORT

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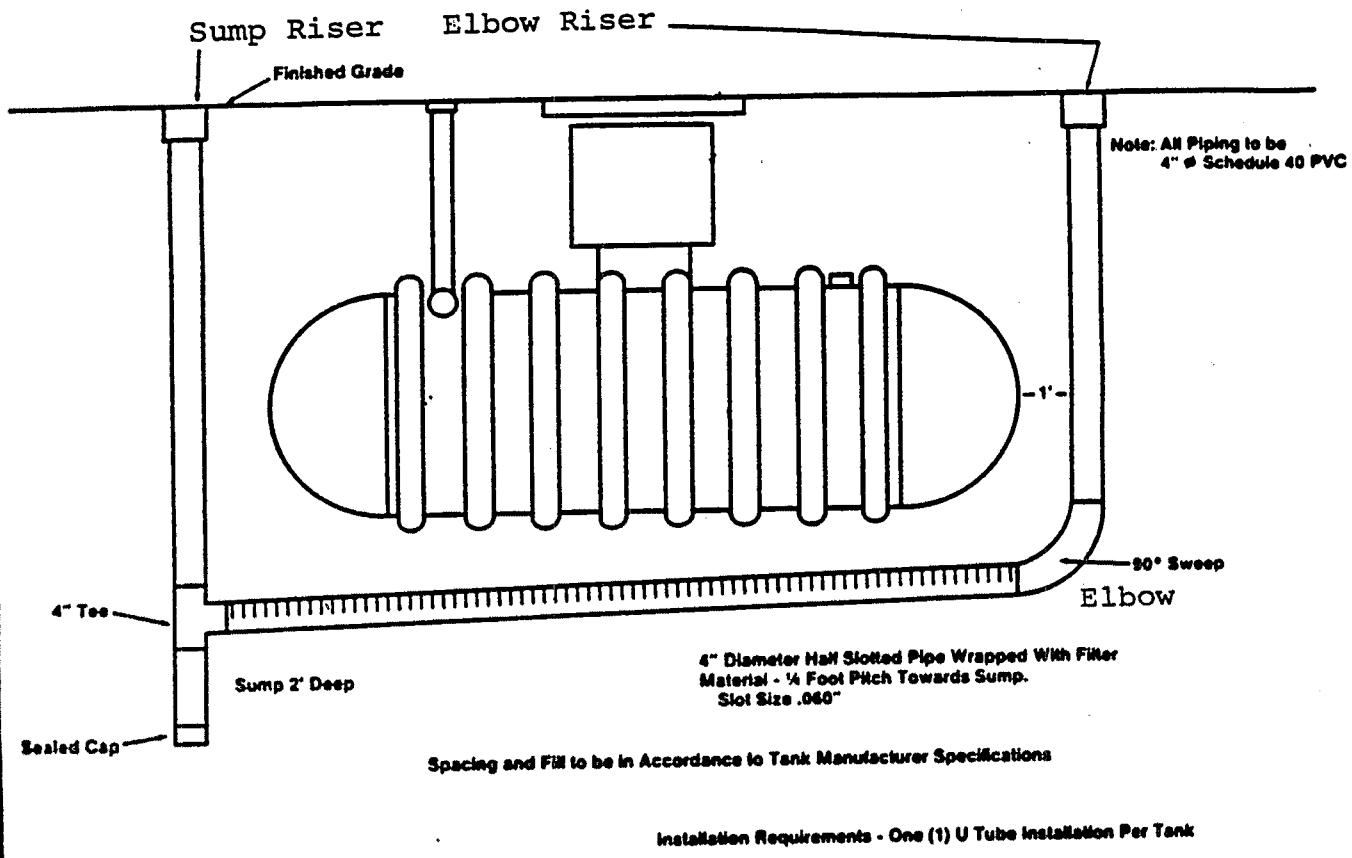
SECTION 1
INTRODUCTION

This report is a summary and evaluation of the methodology and results of background soil vapor concentrations measured in underground storage tank (UST) U-tube vapor monitoring devices. Kaman Tempo performed this study under subcontract to Midwest Research Institute as a contribution to the EPA UST Federal Guidelines and Regulations.

The study was conducted in Suffolk County, New York, where a large number of UST sites with U-tubes have been installed under tight County regulatory control. The County regulation most relevant to this study is the tank registration program which provides an identification number, historical use data, and construction records for each tank.

U-tubes, originally intended for leak detection by liquid interception rather than vapor monitoring, have been installed beneath hundreds of UST's since 1980. A schematic U-tube construction diagram is presented in Figure 1-1. The U-tubes consist of an inclined PVC pipe with perforations only in the upper half placed lengthwise beneath the tank. The up-slope end of the perforated pipe is connected by a 90° elbow to a vertical riser pipe. The lower end is connected by a tee to a sump and riser pipe. All parts are generally of Schedule 40 4-inch PVC. Risers are generally 10 feet long and inclined sections average 25 feet in length.

The dual purpose of the study was to develop a method for soil background measurements using U-tubes and to collect a background concentration database for the study area. In developing the testing method, the usefulness, style and quality of U-tube installations were also evaluated. The motivating objective for the soil vapor concentration background database is the regulatory need to assign a threshold concentration alarm level for automatic vapor monitoring systems and periodic manual monitoring programs.

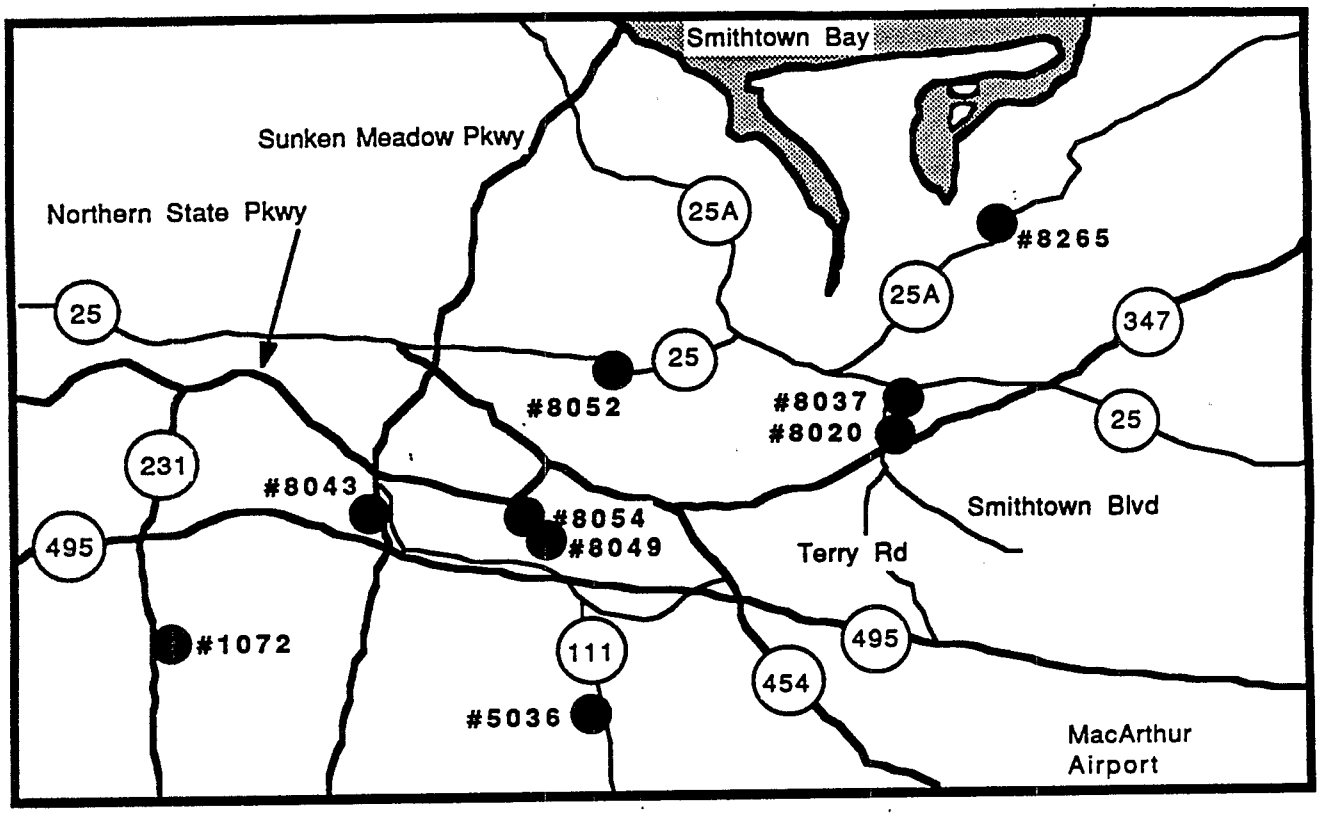


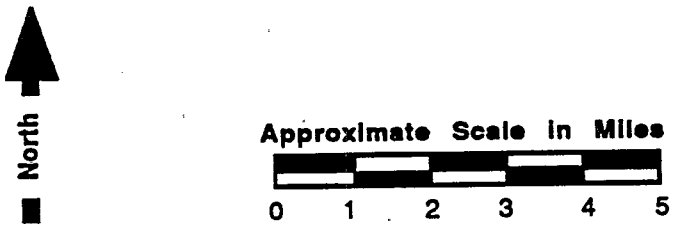
From: R.A. Scheinfeld, 1985, Eastern Regional Groundwater Conference of the National Water Well Association

Figure 1-1. Schematic Diagram of U-Tube Monitoring System for Underground Storage Tanks.

All the sites were selected directly from the tank registry with the aid of additional information provided by County Health Department officials. Several site criteria were considered in the selection process. For logistic reasons all sites were selected within a five mile radius. An attempt was made to select sites with a variety of tank products, tank construction materials, site leak histories, depth-to-groundwater, and site ages. The selected locations are presented in Figure 1-2.

Kaman Tempo would like to thank Mr. James Pim and staff of Suffolk County Department of Health Services, Bureau of Hazardous Materials, for their cooperation and assistance in conducting this study.





EXPLANATION

#8265 ● Location of underground Storage Tank Site Showing Identification Number

Figure 1-2. Location Map of Underground Storage Tank Sites.

SECTION 2
INVESTIGATIVE METHODS

2.1 DESCRIPTION OF SITES

Twenty U-tubes at nine sites were visited during the week of July 20, 1987. The characteristics of each site and tank are summarized in Table 2-1. Each U-tube and corresponding underground tank is identified in the table by a Suffolk County tank tax identification number followed by a number designating the chronological order of testing at a particular site. The three sites having a suspected or known history of leaks (5036, 8020 and 8037) according to Suffolk County officials are designated by bold face identification numbers.

All the tanks tested contained petroleum fuel products including gasoline, diesel, and kerosene as well as heating, lubrication, and waste oil. Diesel was the only product believed to have leaked from visited on-site tanks; however, measurements were made at Site 8043 of trichloroethylene (TCE) from a groundwater contamination plume having an off-site source according to Suffolk County officials. Groundwater concentrations of TCE in the area are reportedly on the order of several thousand micrograms per liter (ppb).

Groundwater depths ranged from 27 to 161 feet below ground surface and are bimodally distributed between levels shallower and deeper than 50 feet.

Based upon the number of years that underground storage tanks have been present, the sites ranged from 7 to 75 years in age. Because the first U-tubes were installed in Suffolk County in 1980, the tanks tested were no more than 7 years of age. Tank types were either fiberglass or STIP-3 cathodically protected. No plain steel or buff-hide tanks were available for testing. Two of the sites were greater than 600 feet distant from any other underground storage tank, contained only one tank, and therefore are designated as "isolated" sites.

Table 2-1. Summary of Site Characteristics.

U-Tube# (1)	Address	Product In Tank (2)	Products on Site	Leaks on Record	Depth to Ground-water(3)	Depth to Ground-water(4)	Site Age (yrs)	Date Old tanks Installed	Date New Tanks Installed	Tank Type	Isolated Tank?
1072	Deer park & Claremont(NE cor)	SU	G,W	N	27.0	shallow	15	1972	1981	Fiber	N
5036-1*	Islip & Blacker(NW cor)	D	G,D,K	D,'86	39.5	shallow	25	1962	1983	Fiber	N
5036-2*		SU								Fiber	N
5036-3*		R								Fiber	N
8020-1*	347 + Terry(NW cor)	D	G,D	Suspected	20.0	shallow	27	1960	1984	Fiber	N
8020-2*		U								Fiber	N
8020-3*		U								Fiber	N
8020-4*		SU								Fiber	N
8020-5*		R								Fiber	N
8037-1*	25 +Terry(SE cor)	U	G,H,W	Y	20.9	shallow	28	1959	1984	STIP 3	N
8037-2*		SU								STIP 3	N
8037-3*		R								STIP 3	N
8043-1	Crooked Hill+495+Vanderbilt+	D	G,D,H,L,W	Offsite TCE	92.0	deep	7	1980	1980	Fiber	N
8043-2	Sagtikos Pkwy	R		(5)						Fiber	N
8049	Commerce Dr+Adams Ave	D	D	N	110.0	deep	7	1980	1980	STIP 3	Y
8052-1	Plymouth Blvd+25(NW cor)	U	G,H,W	N	35.0	shallow	15	1972	1981	Fiber	N
8052-2		SU								Fiber	N
8052-3		R								Fiber	N
8054	Oser Ave+Pkwy Dr S. Serv. Rd	U	U	N	161.0	deep	7	1980	1980	STIP 3	Y
8265	25A+Thompson Hill Rd(NW cor)	U	G,D,W	N	112.0	deep	75	1912	1985	Fiber	N

(1) Known or suspected leak sites denoted by asterisk

(2) Key: G=Gasoline
R=Regular
U=Unleaded
SU=Super Unleaded
D=Diesel
K=Kerosene
H=Heating Oil
L=Lube Oil
W=Waste Oil

(3) Depth to groundwater in feet below land surface.

(4) Groundwater deeper than 50 feet is designated as "deep".

(5) Suffolk County Officials report offsite release of trichloroethylene (TCE) to groundwater in vicinity of site 8043.

2.2 TESTING METHODS

Background total hydrocarbon concentrations were measured in the U-tubes by three methods. In order of performance these methods include a top-of-casing measurement, downhole measurement, and time-domain concentration measurement while pumping at a high discharge rate. The primary analytical equipment used was a Photovac Model 10S30 dual-column gas chromatograph. For comparative evaluation of the instruments themselves, a Photovac TIP and HNu Model PI-101 were also used in each method. The chromatograph was not used for the top of casing measurement.

The construction characteristics of the U-tube and pumping times and volumes for each U-tube are presented in Table 2-2. The style and quality of installations varied, including one site with water-flooded 2-inch diameter steel risers (#1072), two uncapped risers and one riser (#8037-1 and #8037-2) constructed of perforated casing (#8052-3).

Downhole Background Measurement Method

The procedures for downhole measurement of background soil vapor concentrations in U-tubes developed during the study are detailed below.

Field equipment included the following:

- Mechanical Packer (plumber's 4-inch wing-nut test plug)
- 1-cfm vacuum pump
- 1-liter tedlar sampling bag
- 30-foot teflon 1/8" O.D. tubing
- Swagelok fittings to reduce pump intake to 1/8" O.D. tubing
- 25-foot plumber's snake
- Photovac Model 10S30 gas chromatograph, Photovac Model TIP-I and HNu Model PI-101 photoionization detectors
- Calibrant gas (57 ppm isobutylene and 200 ppb BTX)
- Centralizer
- Powerful flashlight
- Mirror

Table 2-2. U-Tube Characteristics and Test Parameters.

U-Tube# (1)	U Tube Top Size (inches)	U Tube Capped	Perforations to Surface	U Tube Flooded	Incline Length (ft)	Riser Length (ft)	Casing Volumes Pumped (2)	Minutes Pumped
1072	2	Y	N	Y	-	-	9	30
5036-1*	4	N	N	N	20	9	9	30
5036-2*	4	N	N	N	20	10	9	30
5036-3*	4	Y	N	N	20	9	0	0
8020-1*	4	Y	N	N	21	8	3	10
8020-2*	4	Y	N	N	32	10	0	0
8020-3*	4	Y	N	N	16	8	0	0
8020-4*	4	Y	N	N	32	8	0	0
8020-5*	4	Y	N	N	32	8	0	0
8037-1*	4	N	N	N	18	9	0	0
8037-2*	4	N	N	N	18	7	0	0
8037-3*	4	Y	N	N	18	7	0	0
8043-1	4	Y	N	N	0	29	12	30
8043-2	4	Y	N	N	0	29	12	30
8049	4	Y	N	N	20	10	11	30
8052-1	4	Y	N	N	26	16	6	30
8052-2	4	Y	N	N	26	12	7	30
8052-3	4	Y	Y	N	26	12	7	30
8054	4	Y	N	N	16	10	6	20
8265	4	Y	N	N	25	11	8	31

(1) Known or suspected leak sites denoted by asterisk.

(2) One casing volume is equal to 2.5 to 5 cubic feet depending on length of casing.

Equipment Preparation:

The background measurements were made downhole through 1/8" tubing. This size was required to minimize the interval volume and concomitant flushing times between sites. To prevent the tubing from snarling inside the U-tube, the tubing was taped to the plumber's snake at 1 or 2 foot intervals. A centralizer was attached to the end of the snake 1 to 2 centimeters above the tubing inlet. The purpose of the centralizer was to lift the tubing intake off the bottom of the U-tube where several millimeters of condensation were frequently encountered.

Testing Procedure:

The elbow and sump risers (Figure 1-2) were visually identified with the aid of a flashlight or mirror. To reduce vapor advection and resulting dilution by surface air, both risers were never left uncapped at the same time. The risers were also visually inspected for flooded conditions. The top of the sump riser was firmly sealed with a mechanical packer. If the risers were not flooded, the snake was passed down the elbow riser to the mid-point of the inclined section of the U-tube (usually 16 to 20 feet above snake length). The tubing intake was thus positioned directly below the center of the tank. For comparison, measurements were also taken with the intake positioned at the elbow at sites 8020 (suspected leak site) and 8037 (known leak site). The riser opening was immediately recapped to prevent dilution by surface air.

The pump's intake and discharge ports were then connected to the 1/8-inch tubing and to a 1-liter tedlar gas sampling bag, respectively. The pump was not able to discharge at its rated capacity due to the restriction of the small diameter tubing. When approximately ½ liter of gas was collected, the bag was disconnected and the pump was switched off. The bag was then connected alternately to a calibrated TIP-I and HNu PI-101 and concentrations recorded in ppm. The bag and tubing were flushed with ambient air between measurements, testing with the TIP-I for cross-contamination.

Syringe samples were taken from a septum tee mounted upstream of the pump intake and injected into the 10S30 chromatograph. The chromatograph was used in the following configuration:

- flow rate - 10 milliliters per minute
- back-flush switching time at 50 seconds
- four-foot CSP-20M analytical column
- five minute analysis time

The detection limit for aromatic fuel components in this mode is approximately 1 ppm. Injection volumes were varied between 0.01 to 1.0 ml depending on concentration indicated by the TIP. To avoid overloading the 10S30 detector and column, smaller injections were used when the TIP indicated high concentrations.

For five of the seven sites with multiple U-tubes, as many U-tubes were tested as time allowed. After removing the snake from each elbow riser, the riser cap was carefully replaced to avoid downhole contamination or vapor dilution.

Time Domain Background Measurement Method

Immediately following the downhole measurement, the 1/8" tubing was removed and disconnected from the pump. The opposite end of the U-tube remained sealed. The elbow riser was quickly fitted with a second mechanical packer having a ¼-inch hose-barb which was connected to the 1 cfm pump by a ¼-inch I.D. Tygon vacuum hose. A septum tee was installed near to the test plug. The entire U-tube could be pumped, thus drawing soil gas through the inclined perforated section, while periodic samples for the 10S30 were obtained with a syringe from the septum tee. The pump was briefly switched off for each syringe sample to avoid negative pressures in the syringe barrel.

The pump discharge was continuously measured with the TIP and HNu. The flow to the TIP and HNu was reduced to an instrument-compatible rate by means of a 5-port manifold. The pumping rate was monitored with a Gilmont floating-ball type gauge. Due to the U-tubes' very large diameter, the pump was able

to pump without restriction at its rated capacity of approximately 1 cfm (30 liters per minute).

Instrument Calibration Procedure

The 10S30, TIP and HNu were calibrated to a 57 ppm isobutylene standard on a daily basis. All concentrations in this report are given as ppm isobutylene.

First, the instruments were zeroed with ultra pure air from the same cylinder used for 10S30 carrier gas. A tedlar gas sample bag was then filled with isobutylene standard gas. The TIP and HNu were then alternately calibrated to the isobutylene and rezeroed twice. A check for syringe background contamination was run for the 10S30 prior to isobutylene standardization.

A 200 ppb benzene/toluene/xylene (BTX) gas standard was provided by Suffolk County to aid the interpretation of chromatographic fuel product signatures. The BTX standard was also used to calculate the 10S30 detector sensitivity for isobutylene relative to benzene, toluene and xylenes. The ratios of concentrations (sensitivity coefficients) reported as isobutylene to concentrations of the actual compounds are listed below.

Benzene	0.94
Toluene	1.07
Xylenes	0.36

These values indicate that although benzene and toluene are reported within 6% of their true concentrations, because of the 10S30's low sensitivity to xylene, reported concentrations of xylene are much lower than their true values. A true xylene value can be obtained by dividing the reported value by a 0.36 sensitivity coefficient. Xylene was encountered in only a few of the U-Tubes in this study and therefore this problem was insignificant.

SECTION 3
RESULTS

3.1 DISCUSSION OF TOTAL CONCENTRATION

The total petroleum hydrocarbon concentration measured in 20 U-tubes are summarized in Table 3-1. The known or suspected leak sites, denoted by asterisks, clearly show the highest concentrations. Concentrations ranged from below the detection limit to greater than 2200 ppm as isobutylene.

The complete pumping concentration data are presented in Appendix B, showing the calculated concentration for each compound and sum total concentration of all compounds detected. The maximum value from Appendix B for each U-tube appears in Table 3-1. No TIP data were available for sites 1072, 5036 and 8265 because of low instrument battery conditions. No downhole data are available for site 1072 because of flooded conditions and the inability to identify the elbow riser in the 2-inch diameter tubing.

In general, the mid-point downhole TIP reading approximates the TIP pumping maximum reading; however, the 10S30 downhole readings are generally 20 percent lower than the 10S30 pumping maximum readings.

Top-of-casing readings prove to be poor indicators of true soil conditions as they were greatly influenced by wind conditions. For example, very small top-of-casing readings and very large pumping and downhole readings were obtained at U-tubes 5036-1 and 8020-1. It is significant that both of these U-tubes are at known leak sites.

The patterns of variation which concentration followed with time during pumping appear to be dependent on the general concentration level for the U-Tube being measured. At high concentration values, the concentration level stabilizes somewhat at approximately 10 minutes (approximately 3 times the internal volume of the U-tube) (see Figure 3-1). For sites with moderate and low concentrations, no apparent plateau was reached after 30 minutes of pumping (see Figure 3-2 and 3-3).

Table 3-1. Summary of Background Concentration in U-Tubes.

U-Tube# (1)	10S30 Midpoint (ppm)	TIP Midpoint (ppm)	HNu Midpoint (ppm)	10S30 Elbow (ppm)	TIP Elbow (ppm)	HNu Elbow (ppm)	10S30 Max (ppm)(5)	TIP Max (ppm)	HNu Max (ppm)	TIP Top of Casing (ppm)	HNU Top of Casing (ppm)
1072	- (2)	-	-	-	-	-	222	-	112	-	1
5036-1*	373.00	-	-	-	-	-	692	-	142	-	1
5036-2*	645	-	50	-	-	-	>2201	-	49	-	50
5036-3*	123	-	-	-	-	-	OFFSCALE	-	-	-	40
8020-1*	758	1142	210	547	927	200	1180	1300	150	84	70
8020-2*	730	1237	190	599	855	200	-	-	-	130	15
8020-3*	513	840	165	445	623	172	-	-	-	270	40
8020-4*	365	424	155	222	311	150	-	-	-	14.5	9.5
8020-5*	245	222	140	10.8	180	100	-	-	-	140	13.6
8037-1*	-	-	-	OFFSCALE	1274	0	-	-	-	1200	11
8037-2*	-	-	-	OFFSCALE	1136	0	-	-	-	126	65
8037-3*	-	-	-	-	1050	0	-	-	-	696	8
8043-1(3)	11.9	26	12.6	-	-	-	17.7	15	14.2	8.5	8.8
8043-2(3)	6.8	14.2	11.1	-	-	-	11.3	9.3	8.7	0	1
8049	0	7.9	3.3	-	-	-	1.3	7.6	4.5	7.5	4
8052-1	31.09	-	-	-	-	-	67.4	56.7	35	6.5	4
8052-2	0(4)	-	-	-	-	-	80.3	35	32	2	0
8052-3	0	-	-	-	-	-	0	2.7	1.3	6.6	0
8054	0	-	-	-	-	-	0.52	1.6	1.5	0	0
8265	3.44	-	0	-	-	-	5.88	-	6.5	-	0

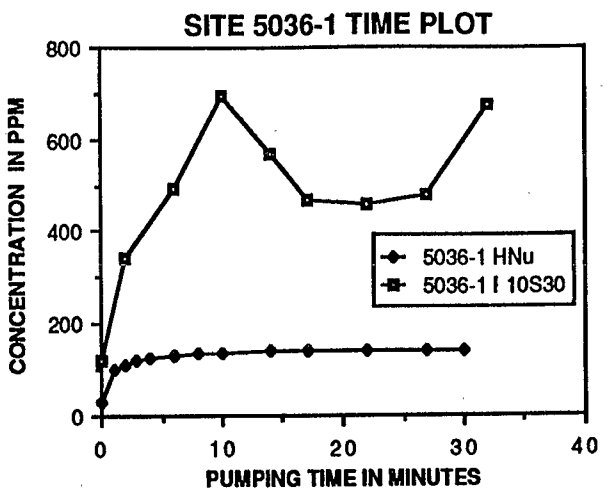
(1) Known or suspected leak sites in boldface.

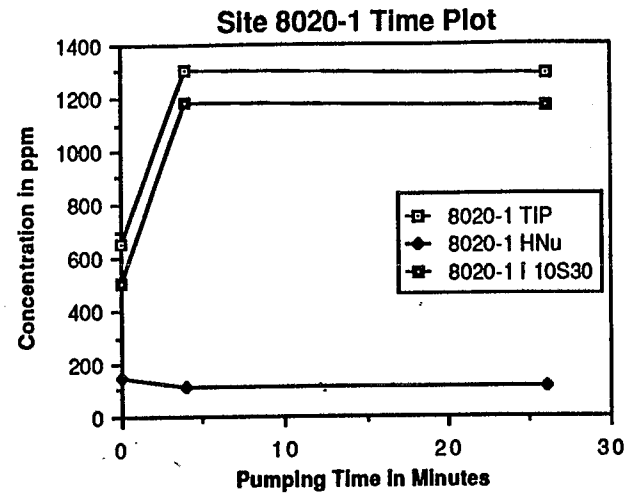
(2) Blank spaces indicate measurement not taken.

(3) Suffolk County officials report offsite release of TCE to groundwater in vicinity of site 8043. Concentrations measured in 4" PVC vapor wells.

(4) Injection volume too small = .02 ml. Detection limit approximately 10 ppm.

(5) Maximum readings for Photovac 10S30, Photovac TIP and HNu measured while pumping continuously at 1 cfm. See Appendix B for list of all concentrations measured during pumping.





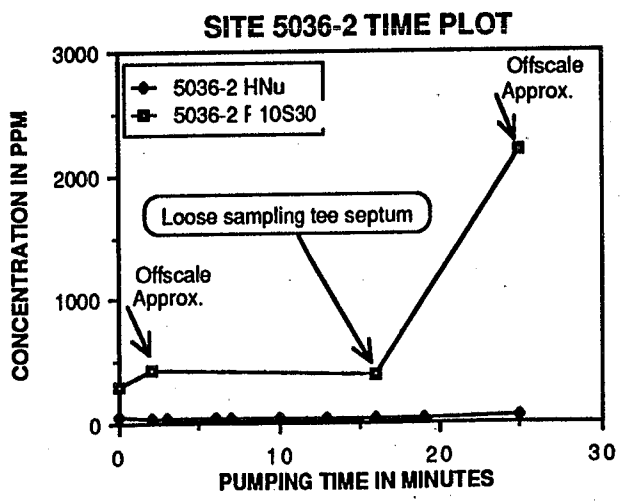
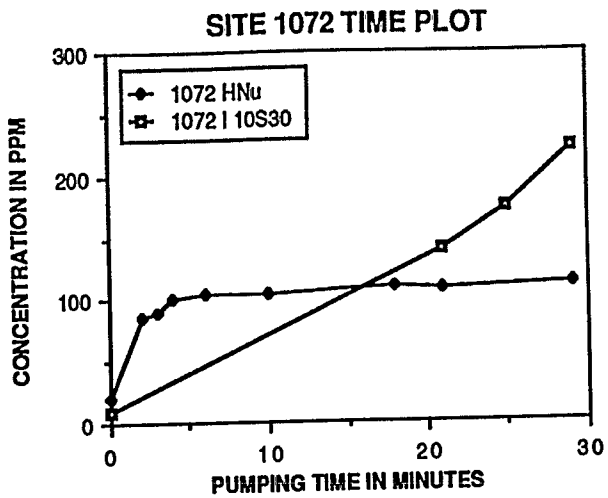
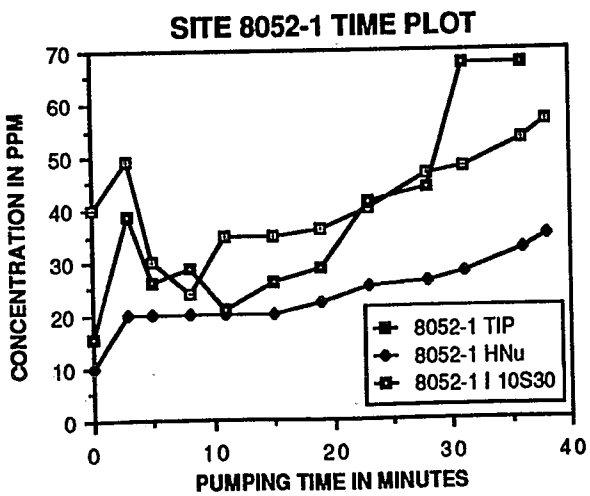
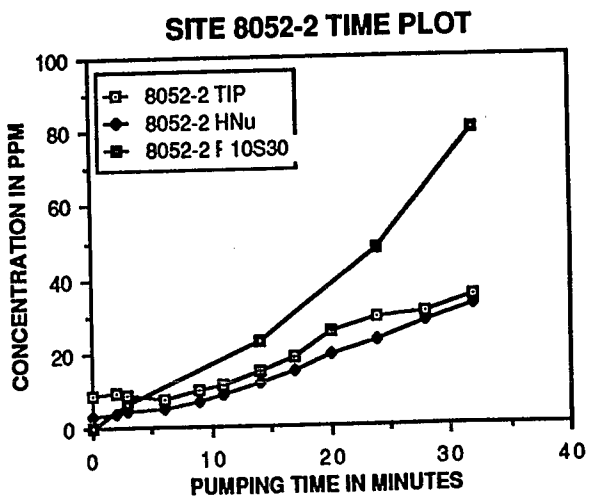


Figure 3-1. Pumping Time Versus Concentration Plots for Known or Suspected Leak Sites.







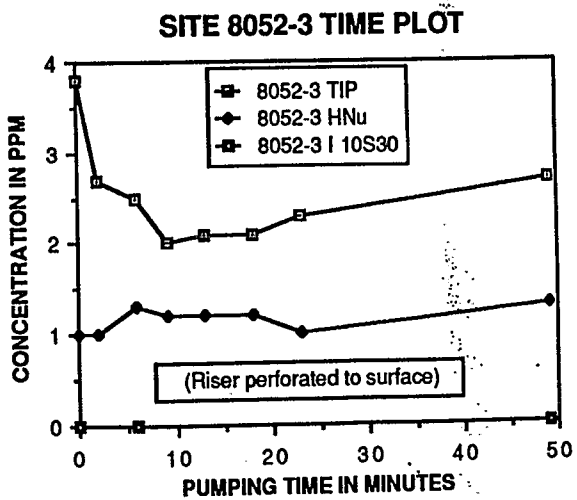


Figure 3-2. Pumping Time Versus Concentration Plots for Non-Leak Sites with Moderate Soil-Gas Background Concentrations.

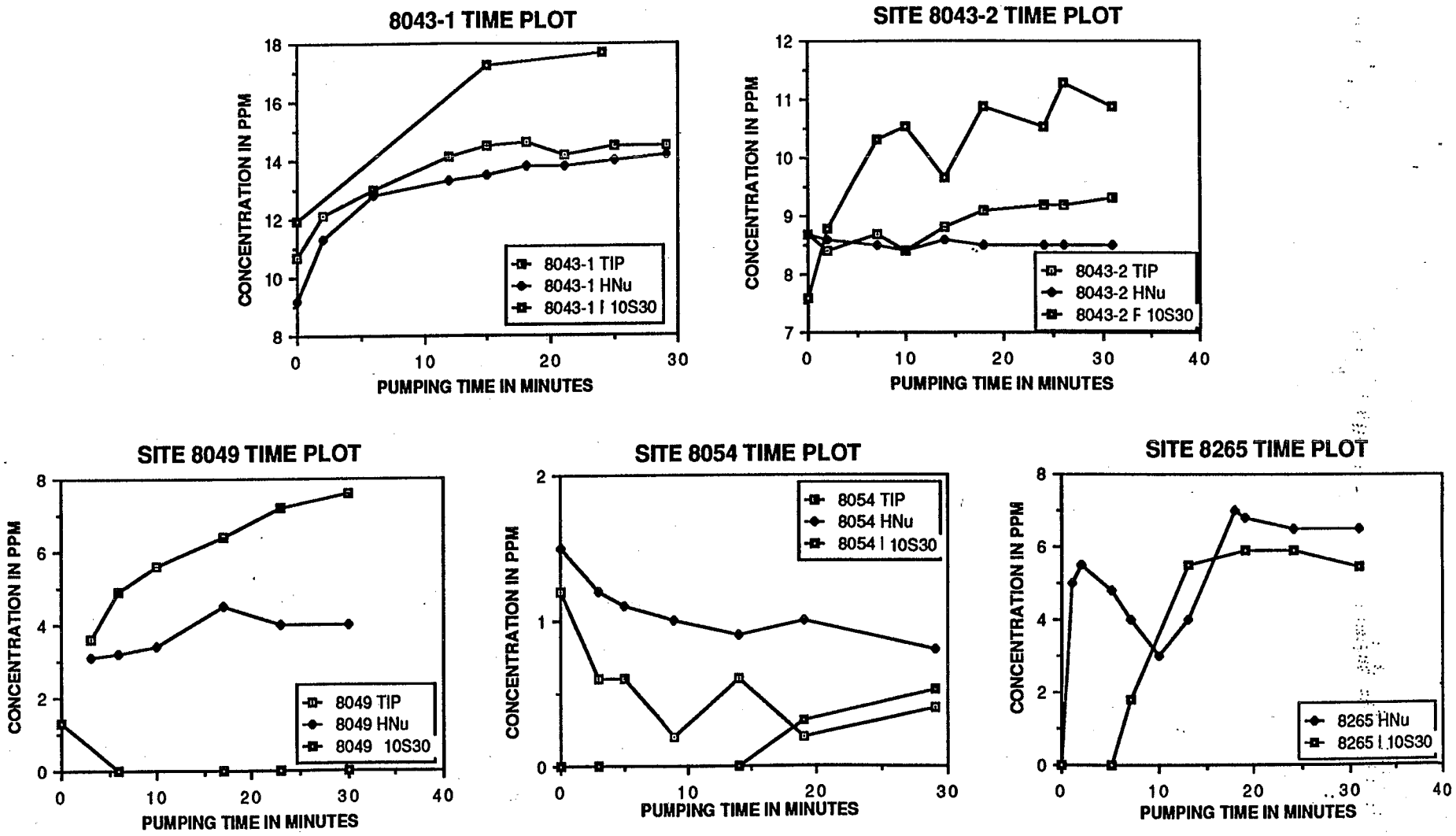


Figure 3-3. Pumping Time Versus Concentration Plots for Non-Leak Sites with Low Soil-Gas Background Concentrations.

At low concentrations, measurements from the three instruments are in fair agreement (see Figure 3-3). However, the HNu did not perform linearally with the other instruments above approximately 50 ppm. Figure 3-4 illustrates the linear agreement of 10S30 and TIP measurements and the non-linearity between the HNu data and with TIP data above the 50 ppm concentration level.

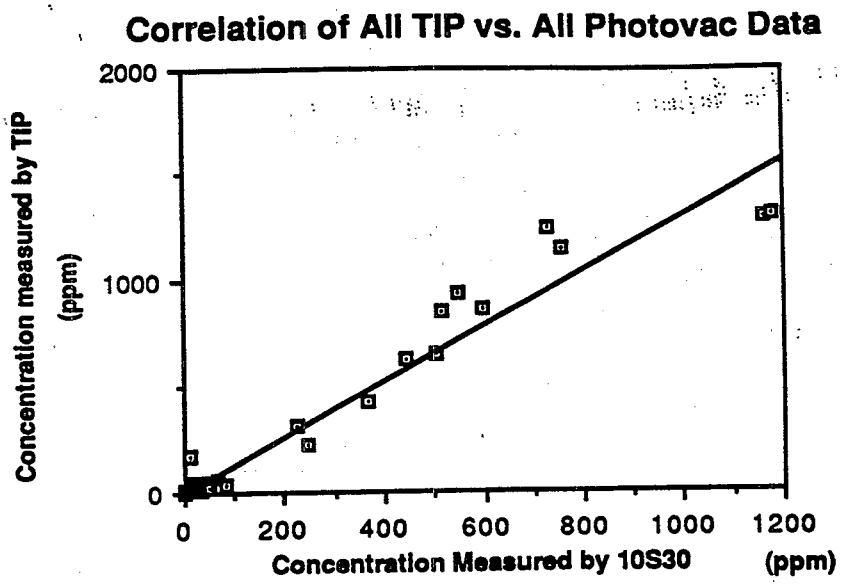
A correlation is suggested between depth-to-groundwater and concentration. Figure 3-5A shows the distribution of groundwater levels as well as highest concentration measured at each site. Note the break in distribution at about 50 feet below land surface. Among non-leak sites, a fairly good correlation is observed between total concentration and depth-to-groundwater, with concentration exponentially decreasing with depth-to-groundwater. The fact that all leak sites were located in shallow groundwater areas is purely coincidental, therefore leak sites are not plotted in Figure 3-5B.

The time that a site has been in service for underground fuel product storage (site age) did not correlate with background soil vapor concentration as well as depth-to-groundwater (see Figure 3-6). However, if the 75 year point is removed from the dataset, a general upward direct correlation is observed. This trend may be ascribed to such factors as small unreported overflows during delivery and dispensing which could cause a slow accumulation of product in the soil.

The distribution of soil-gas concentration at sites with multiple tanks and U-Tubes can help identify leaking tanks. For example, a leak was suspected at Site 8020 where five tanks (8020-1 through 8020-5) have been placed side by side with their centers spaced ten feet apart. Concentration drops steadily with distance from 758 ppm at 8020-1 to 245 ppm at 8020-5. A former or existing leak at 8020-1 is clearly indicated by this distribution, assuming that concentration does not continue to increase away from the tank cluster. A leak was verified at this site by the county.

3.2 VARIATION IN CHEMICAL COMPOSITION

The unique chemical compositions of fuel products are identifiable by their chromatographic signatures which are defined by characteristic peak shapes, relative peak areas, and retention times for each chemical component.



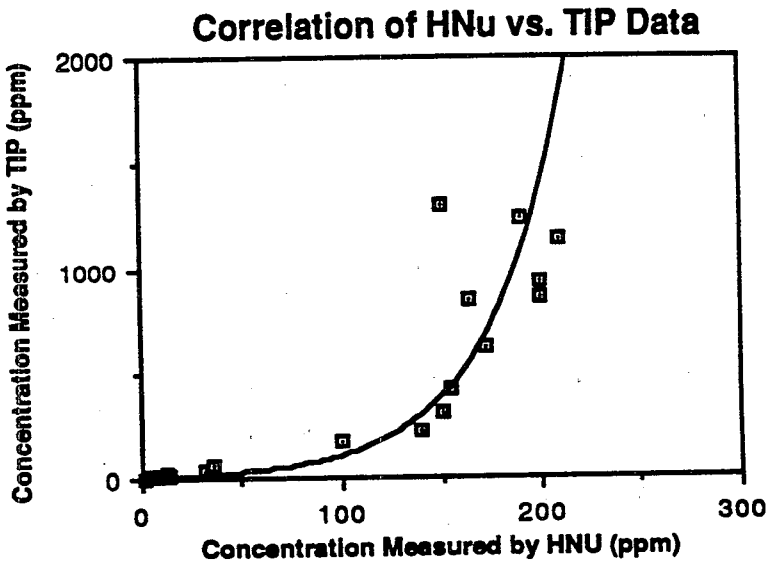
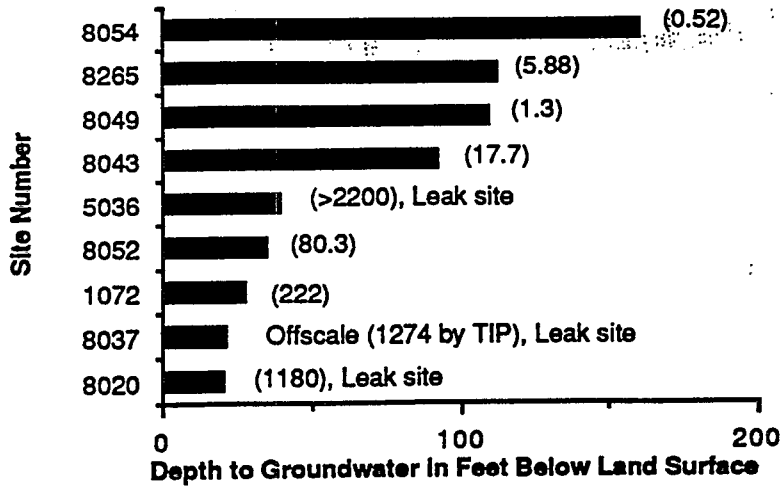


Figure 3-4. Scattergrams comparing performance of Photovac 10S30 TIP and HNu.

a. Note good linear fit of TIP and 10S30 data. (Top-of-casing readings removed.)

b. Note exponential correlation of TIP and HNu data. (Top-of-casing and outlying zero HNu readings removed).

a)



b)

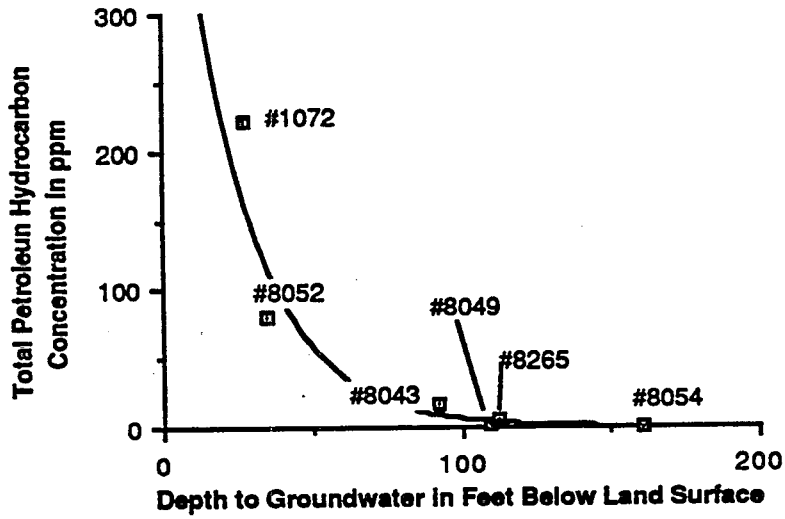


Figure 3-5. Depth to Groundwater and Soil-Gas Concentration at U-Tube Sites:

a. Depth to Groundwater for All Sites Showing Maximum Soil-Gas Concentration Measured by 10S30 in Parentheses.

b. Depth to Groundwater Versus Soil-Gas Concentration at Non-Leak Sites.

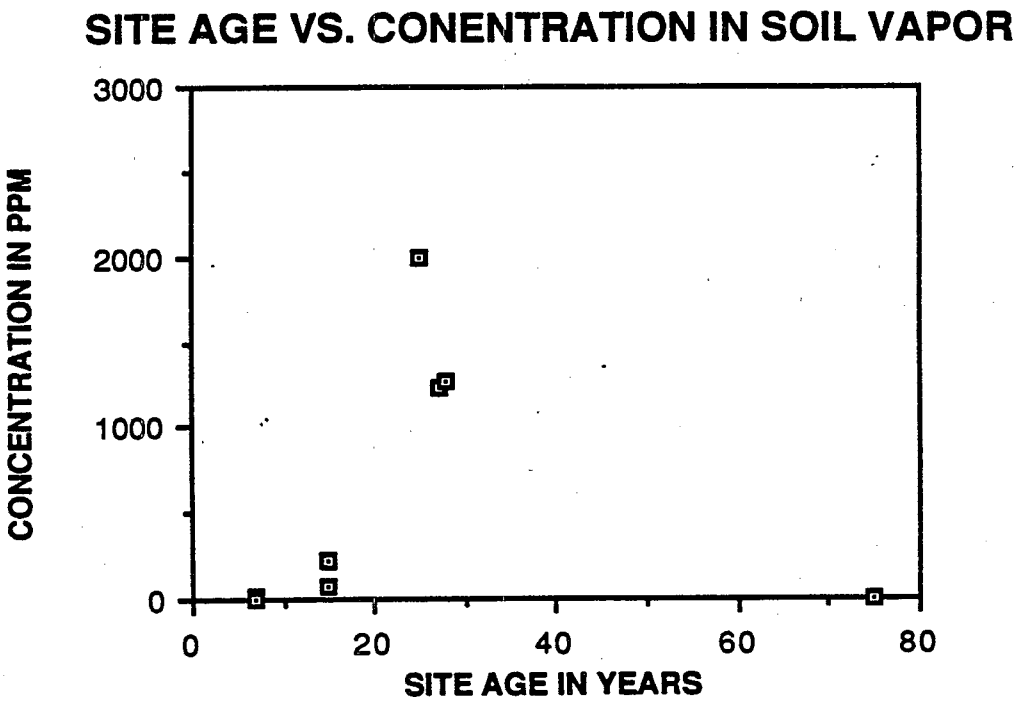
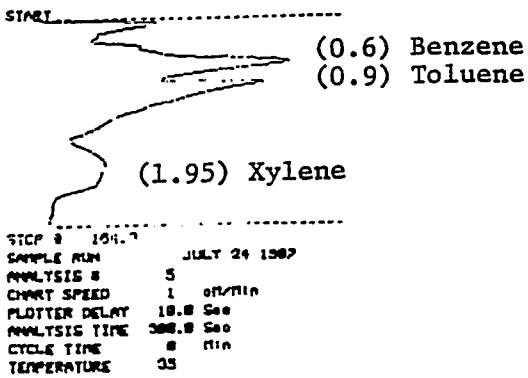
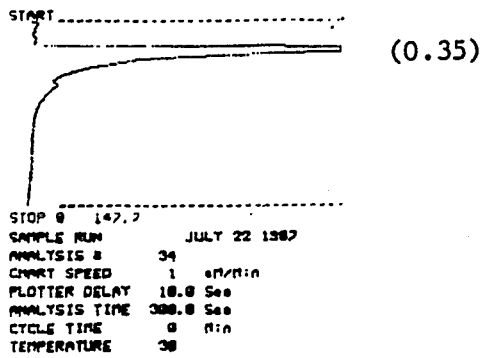


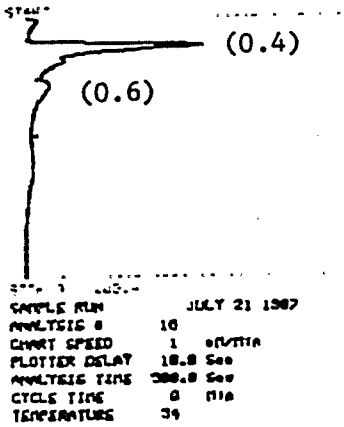
Figure 3-6. Site Age Versus Soil Gas Background Concentration Scattergram.



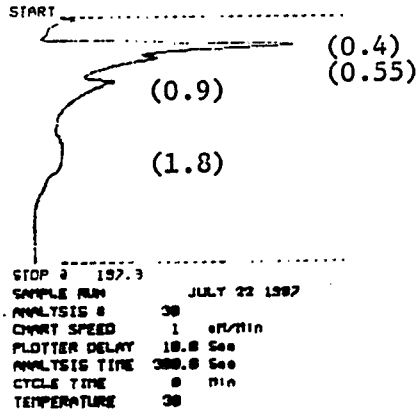
A. BTX Standard



B. Site: 8052
Unleaded



C. Site: 1072
Super Unleaded



D. Site: 8052
Regular

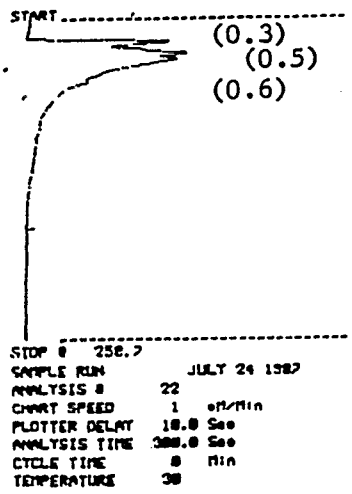
Figure 3-7. Chromatograms of fuel products: peak retention time in minutes in parentheses. Samples B, C, and D obtained from fill pipes of actual fuel tanks.

The chromatographic signatures of the soil-gas samples from U-Tubes varied significantly with site location, different U-Tubes within particular sites, and pumping time.

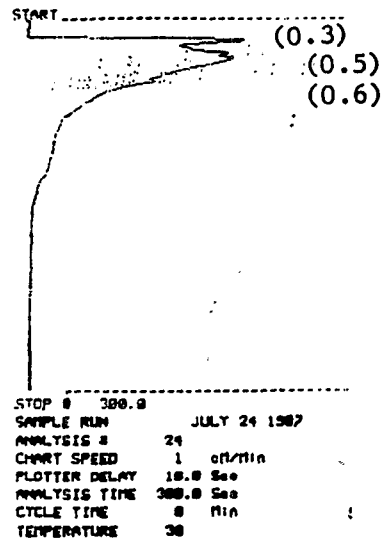
Chromatograms of vapor samples obtained from the fill pipes of underground storage tanks containing unleaded, super unleaded and regular fuel are compared to the signature of a benzene/toluene/xylene standard in Figure 3-7. Concentrations of benzene, toluene, and xylene in the standard (Chromatogram A) are nearly equal, however, it appears by comparison with Chromatograms B, C, and D that actual fuel products contain low levels of toluene and xylene relative to benzene. These observations are consistent with previous site work at refineries performed by Kaman.

Considerable variation in chemical composition of soil-gas is observable for the same product measured at different pumping times and different locations in soil-gas (see Figure 3-8). The only product known to have leaked at Site 8020 was diesel, however, Chromatograms E and F represent a noticeable variation in samples from the same U-tube taken 10 minutes apart. Three casing volumes were purged during this period. Note the increase in peak height of the first peak with increasing pumping time. Chromatograms G and H depict variations in relative peak heights at two separate diesel spill sites.

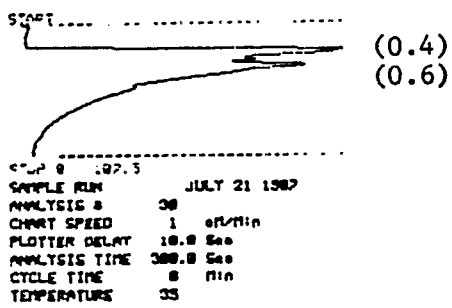
Variations in the composition of soil gas are also observed in non-leak sites with very low background concentrations (see Figure 3-9). Chromatograms I and J, obtained beneath two different tanks at the same site demonstrate differences in relative concentrations (peak heights) of the same three compounds. Chromatogram K, representing a soil gas sample taken above a known TCE groundwater plume with an off-site source, depicts a second peak shape and retention time that contrasts with the petroleum product background signatures of Chromatograms I and J. TCE coelutes with other compounds in the second peak causing the unusual peak shape in Chromatogram K.



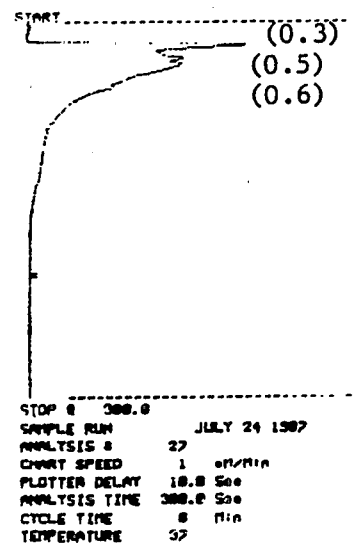
E. Site: 8020-1



F. Site: 8020-1

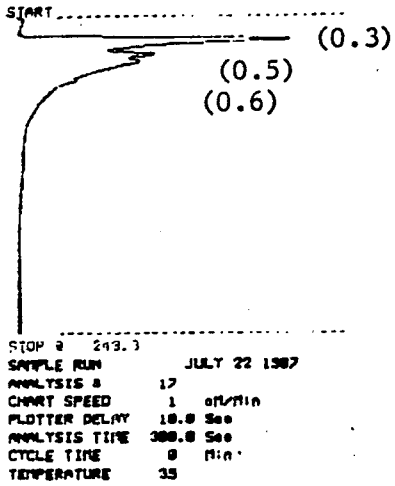


G. Site: 5036

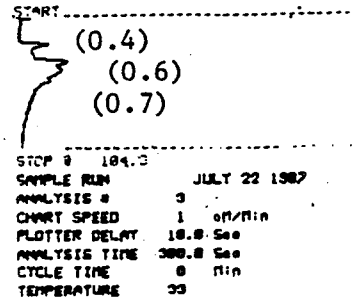


H. Site: 8020-2

Figure 3-8. Variation in Soil Gas Chromatographic signatures at known or suspected diesel leak sites: Chromatograms E and F represent samples from the same U-tubes taken ten minutes apart during pumping. Three casing volumes were purged during this period. Note the increase in relative peak height of the first peak with pumping time. Chromatograms G and H depict variations in relative peak heights at two separate spill sites.

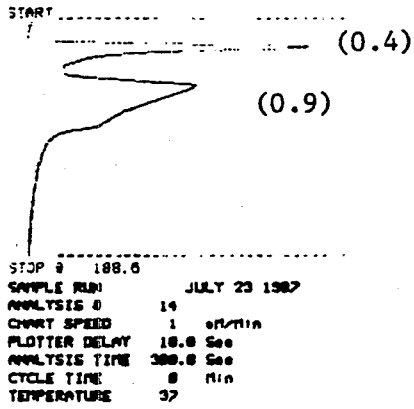


I. Site: 8052-2



J. 8052-1

Note changes in relative peak heights.



K. Site: 8043-1
Offsite TCE

Figure 3-9. Variation in Soil Gas Chromatographic Signatures at non-leak sites. Chromatograms I and J, obtained beneath two different tanks at the same site, demonstrate differences in relative concentrations (peak heights) of the same three components. Chromatogram K, representing a soil gas sample taken above a known TCE groundwater plume with an offsite source depicts a peak shape and retention time that contrasts with the petroleum product background signatures of Chromatograms I and J.

SECTION 4
CONCLUSIONS AND RECOMMENDATIONS

4.1 BACKGROUND CONCENTRATION

1. Soil vapor concentrations at sites with leak histories exceeded 122 ppm. However, measurements for this study were taken months after the leaks had occurred. The 122 ppm measurement was taken in a U-tube that was approximately 50 feet distant from the location of the former leaking tank. Measurements taken closer to tanks with more recent known leak histories had off-scale readings exceeding 2000 ppm. The concentrations may have been on the order of 10,000 ppm, had equipment capable of such measurements been used. Therefore, Kaman Tempo feels that an alarm level much greater than 500 ppm may be acceptable for detecting leaks as they occur. The actual alarm level could be set lower for sites with lower background vapor concentrations.

2. Background concentrations appear to be an order of magnitude higher in areas of shallow groundwater.

3. Background concentrations are often influenced by non-leak events and conditions, e.g. off-site TCE spill that resulted in a groundwater contaminant plume at Site 8043.

4. The chromatographic signatures of the soil-gas samples from U-Tubes varied significantly with site location, different U-Tubes within particular sites, and pumping time. Therefore, care should be used in determining which tank at a site is leaking based on chemical composition alone. Each tank should be monitored separately and leaks identified on the basis of concentration level.

5. Older sites (sites that have been in service for underground fuel storage for many years) generally have higher background concentrations than do younger sites.

6. Isolated sites (sites greater than 600 feet distant from other tank sites) had the lowest background concentrations of those measured (Table 4-1). The alarm level could be set at a lower level at such sites than for non-isolated sites.

7. Background concentration level appears to be independent of tank construction material.

4.2 METHODOLOGY

1. U-tubes can be used effectively to monitor the concentration of fuel product components in soil-gas in granular underground storage tank backfill.

2. Elevated concentrations measured in U-tubes can indicate the occurrence of tank leaks.

3. The most accurate representative background concentrations are obtained by pumping a minimum of nine casing volumes (30 minutes at 1 cfm) from the U-tubes (accuracy is based on stabilization of concentration with time). However, this method is time intensive.

4. Many U-tubes can rapidly be measured in one day by the downhole method to yield concentrations within 20 percent of the concentrations measured by the pumping method. This accuracy should be sufficient for leak detection purposes.

5. The top-of-casing method does not provide reproducible or representative information and should not be used in a formal monitoring program.

6. Concentrations measured with the HNu PID-101 do not correlate linearly with those measured by the Photovac 10S30 or TIP (based on comparison of data from a single instrument of each model).

Table 4-1. Isolated sites show the lowest background concentrations.

U-Tube# (1)	Isolated Tank?	10S30 Midpoint (ppm)	TIP Midpoint (ppm)
1072	N	- (2)	-
5036-1*	N	373.00	-
5036-2*	N	645	-
5036-3*	N	123	-
8020-1*	N	758	1142
8020-2*	N	730	1237
8020-3*	N	513	840
8020-4*	N	365	424
8020-5*	N	245	222
8037-1*	N	-	-
8037-2*	N	-	-
8037-3*	N	-	-
8043-1	N	11.9	26
8043-2	N	6.8	14.2
8049	Y	0	7.9
8052-1	N	31.09	-
8052-2	N	0(4)	-
8052-3	N	0	-
8054	Y	0	-
8265	N	3.44	-

(1) Known or suspected leak sites in boldface.

(2) Blank spaces indicate measurement not taken.

4.3 CONSTRUCTION DESIGN AND INSTALLATION QUALITY

1. Inconsistent U-Tube construction design and installation quality were observed in this study resulting in erratic monitoring conditions. Riser caps must provide a good atmospheric seal and should be installed sufficiently below grade to allow clearance with the monument lid. Risers must be constructed of non-perforated casing.

2. Design considerations should include locking caps and surface seals to prevent tampering or inadvertent contamination by surface spills.

3. Smaller diameter pipe and elimination of the sump riser would obviate the long pumping times or large pumping rates needed for monitoring of 4-inch casing.

4. Because high background concentrations can persist in soil gas for longer than two years after a leak, e.g. Site 5036, a monitoring system cannot function properly unless all contaminated soil is excavated before reinstalling tanks at a leak site.

APPENDIX A

CALCULATION OF RELATIVE DETECTOR SENSITIVITIES FOR ISOBUTYLENE, BENZENE, TOLUENE, AND XYLENE

Appendix A. Calculation of Relative Detector Sensitivities for Isobutylene, Benzene, Toluene and Xylene.

Date: 7/24/87

Isobutylene STD Conc. (ppm) =	57
Isobutylene STD inj. vol.(ml) =	0.02
Isobutylene STD Gain =	2
Isobutylene STD Area (sqmm) =	20

K= 0.114

Where K = (STD Conc. * STD inj volume * STD Gain) / STD Area

Conc. of Sample = (K * A)/ (V * G)

Where A,V and G are sample Area, Volume, and Gain, respectively.

Compound	Actual Concentration (ppm)	Injection Volume (ml)	Gain	Peak Elution Time (min)	Peak Area (sqmm)	Concentration Computed as Isobutylene
Benzene	0.224	0.7	50	6	65	0.21
Toluene	0.214	0.7	50	9	70.5	0.23
Xylenes	0.223	0.7	50	19.5	25	0.08

Relative sensitivity*	Compound
0.94	**Benzene**
1.07	**Toluene**
0.36	**Xylenes**

Note:

Actual concentrations of BTX were 224,214, and 223 ppb.

Benzene and toluene have early identical detector sensitivities as isobutylene.

Xylene detector sensitivity is much lower.

* (Concentration as isobutylene)/(Concentration as BTX)

APPENDIX B

CALCULATIONS OF CONCENTRATIONS FROM PHOTOVAC 10S30 PEAK AREAS

Appendix B.. Calculation of Concentrations from Photovac 10S30 Peak Areas.

U-Tube 1072
Product SU
Date 7/21/87

Isobutylene STD Conc. (ppm) = 57
STD inj. vol.(ml) = 0.02
STD Gain = 2
STD Area (sqmm) = 24

K= 0.095
Where K = (STD Conc. * STD inj volume * STD Gain) / STD Area

Conc. of Sample = (K * A)/ (V*G)
Where A,V and G are sample Area, Volume, and Gain, respectively.

INJ Vol (ml)	Gain	Peak 1 Elut. t (min)	Peak 1 Area (sqmm)	Peak 1 Concentration	Peak 2 Elut. t (min)	Peak 2 Area (sqmm)	Peak 2 Concentration	Peak 3 Elut. t (min)	Peak 3 Area (sqmm)	Peak 3 Concentration	Total Concentration	Measuring Point/ Elapsed Time
not run							-			-	-	midpoint
1.00	2	4	189	8.98			0.00			0.00	8.98	0
1.00	2	3.5	384	18.24			0.00	20	40	1.90	off scale	16
0.02	2	3.5	34	80.75	6	22	52.25	20	2.5	5.94	138.94	21
0.02	2	3.5	40	95.00	6	28	66.50	20	5	11.88	173.38	25
0.02	2	3.5	41	97.38	6	48	114.00	20	4.5	10.69	222.06	29

Appendix B. Calculation of Concentrations from Photovac 10S30 Peak Areas.

U-Tube 5036-1
Product D
Date 7/21/87

Isobutylene STD Conc. (ppm) = 57
STD inj. vol.(ml) = 0.02
STD Gain = 2
STD Area (sqmm) = 29

K= 0.07862068
Where K = (STD Conc. * STD inj volume * STD Gain) / STD Area

Conc. of Sample = (K * A)/ (V*G)
Where A,V and G are sample Area, Volume, and Gain, respectively.

INJ Vol (ml)	Gain	Peak 1 Elut. t (min)	Area (sqmm)	Concentration	Peak 2 Elut. t (min)	Area (sqmm)	Concentration	Peak 3 Elut. t (min)	Area (sqmm)	Concentration	Total Concentration	Measuring Point/ Elapsed Time Midpoint
0.02	2	4	55	108.10	5	35	68.79	6	100	196.55	373.45	0
0.02	2	3.5	17	33.41	5	7	13.76	6	38	74.69	121.86	2
0.02	2	3.5	68	133.66	5	27	53.07	6	80	157.24	343.97	6
0.02	2	3.5	71	139.55	5	61	119.90	6	120	235.86	495.31	10
0.01	2	3.5	50	196.55	5	24	94.34	6	102	400.97	691.86	14
0.01	2	3.5	32	125.79	5	17	66.83	6	96	377.38	570.00	17
0.01	2	3.5	30	117.93	5	17	66.83	6	72	283.03	467.79	22
0.01	2	3.5	47	184.76	5	18	70.76	6	52	204.41	459.93	27
0.01	2	3.5	42	165.10	5	15	58.97	6	65	255.52	479.59	32
0.01	2	3.5	51	200.48	5	22	86.48	6	99	389.17	676.14	

Appendix B. Calculation of Concentrations from Photovac 10S30 Peak Areas.

U-Tube 5036-2
Product S
Date 7/21/87

Isobutylene STD Conc. (ppm) = 57
STD inj. vol.(ml) = 0.02
STD Gain = 2
STD Area (sqmm) = 29

K= 0.07862068
Where K = (STD Conc. * STD inj volume * STD Gain) / STD Area

Conc. of Sample = (K * A)/ (V*G)
Where A,V and G are sample Area, Volume, and Gain, respectively.

INJ Vol (ml)	Gain	Peak 1 Elut. t (min)	Peak 1 Area (sqmm)	Peak 1 Concentration	Peak 2 Elut. t (min)	Peak 2 Area (sqmm)	Peak 2 Concentration	Peak 3 Elut. t (min)	Peak 3 Area (sqmm)	Peak 3 Concentration	**Total Concentration**	Measuring Point/ Elapsed Time
0.01	2	4	52	204.41	6	112	440.28			0.00	644.69	midpoint
0.02	2	4	50	98.28	6	105	206.38				304.66	0
0.02	2	4	46	90.41	6	175	343.97			0.00	**434.38**	2
0.01	2	4	50	196.55	6	50	196.55			0.00	393.10	16
0.005	2	*	280	2201.38			0.00			0.00	**2201.38**	25

BOLDFACE TOTAL CONCENTRATIONS ARE APPROXIMATED FROM OFFSCALE PLOTS

Appendix B. Calculation of Concentrations from Photovac 10S30 Peak Areas.

U-Tube 5036-3
Product R
Date 7/21/87

Isobutylene STD Conc. (ppm) = 57
STD inj. vol.(ml) = 0.02
STD Gain = 2
STD Area (sqmm) = 29

K= 0.07862068
Where K = (STD Conc. * STD inj volume * STD Gain) / STD Area

Conc. of Sample = (K * A)/ (V*G)
Where A,V and G are sample Area, Volume, and Gain, respectively.

INJ Vol (ml)	Gain	Peak 1 Elut. t (min)	Peak 1 Area (sqmm)	Peak 1 Concentration	Peak 2 Elut. t (min)	Peak 2 Area (sqmm)	Peak 2 Concentration	Peak 3 Elut. t (min)	Peak 3 Area (sqmm)	Peak 3 Concentration	**Total Concentration**	Measuring Point/
0.10	2	3.5	312	122.65			0.00			0.00	122.65	midpoint

Appendix B. Calculation of Concentrations from Photovac 10S30 Peak Areas.

U-Tube 8020-1
Product D
Date 7/24/87

Isobutylene STD Conc. (ppm) = 57
STD inj. vol.(ml) = 0.02
STD Gain = 2
STD Area (sqmm) = 20

K= 0.114
Where K = (STD Conc. * STD inj volume * STD Gain) / STD Area

Conc. of Sample = (K * A)/ (V*G)
Where A,V and G are sample Area, Volume, and Gain, respectively.

INJ Vol (ml)	Gain	Peak 1 Elut. t (min)	Peak 1 Area (sqmm)	Peak 1 Concentration	Peak 2 Elut. t (min)	Peak 2 Area (sqmm)	Peak 2 Concentration	Peak 3 Elut. t (min)	Peak 3 Area (sqmm)	Peak 3 Concentration	Total Concentration	Measuring Point/ Elapsed Time
0.01	2	3	16	91.20	6	80	456.00			0.00	547.20	Elbow
0.01	2	3	18	102.60	6	115	655.50			0.00	758.10	Midpoint
0.01	2	3	18	102.60	6	70	399.00			0.00	501.60	0
0.01	2	3	49	279.30	6	158	900.60			0.00	1179.90	4
0.01	2	3	42	239.40	6	162	923.40			0.00	1162.80	10

Appendix B. Calculation of Concentrations from Photovac 10S30 Peak Areas.

U-Tube 8020-2
Product U
Date 7/24/87

Isobutylene STD Conc. (ppm) = 57
STD inj. vol.(ml) = 0.02
STD Gain = 2
STD Area (sqmm) = 20

K= 0.114
Where K = (STD Conc. * STD inj volume * STD Gain) / STD Area

Conc. of Sample = (K * A)/ (V*G)
Where A,V and G are sample Area, Volume, and Gain, respectively.

INJ Vol (ml)	Gain	Peak 1 Elut. t (min)	Peak 1 Area (sqmm)	Peak 1 Concentration	Peak 2 Elut. t (min)	Peak 2 Area (sqmm)	Peak 2 Concentration	Peak 3 Elut. t (min)	Peak 3 Area (sqmm)	Peak 3 Concentration	Total Concentration	Measuring Point/
0.01	2	3	17	96.90	6	88	501.60			0.00	598.50	Elbow
0.01	2	3	28	159.60	6	100	570.00			0.00	729.60	Midpoint

Appendix B. - Calculation of Concentrations from Photovac 10S30 Peak Areas.

U-Tube 8020-3
Product U
Date 7/24/87

Isobutylene STD Conc. (ppm) = 57
STD inj. vol.(ml) = 0.02
STD Gain = 2
STD Area (sqmm) = 20

K= 0.114
Where K = (STD Conc. * STD inj volume * STD Gain) / STD Area

Conc. of Sample = (K * A)/ (V*G)
Where A,V and G are sample Area, Volume, and Gain, respectively.

		Peak 1			Peak 2			Peak 3				
INJ Vol (ml)	Gain	Elut. t (min)	Area (sqmm)	Concentration	Elut. t (min)	Area (sqmm)	Concentration	Elut. t (min)	Area (sqmm)	Concentration	**Total Concentration**	Measuring Point/
0.01	2	3	24	136.80	6	54	307.80			0.00	444.60	Elbow
0.01	2	3	30	171.00	6	60	342.00			0.00	513.00	Midpoint

Appendix B. Calculation of Concentrations from Photovac 10S30 Peak Areas.

U-Tube 8020-4
Product SU
Date 7/24/87

Isobutylene STD Conc. (ppm) = 57
STD inj. vol.(ml) = 0.02
STD Gain = 2
STD Area (sqmm) = 20

K= 0.114
Where K = (STD Conc. * STD inj volume * STD Gain) / STD Area

Conc. of Sample = (K * A)/ (V*G)
Where A,V and G are sample Area, Volume, and Gain, respectively.

INJ Vol (ml)	Gain	Peak 1 Elut. t (min)	Peak 1 Area (sqmm)	Peak 1 Concentration	Peak 2 Elut. t (min)	Peak 2 Area (sqmm)	Peak 2 Concentration	Peak 3 Elut. t (min)	Peak 3 Area (sqmm)	Peak 3 Concentration	**Total Concentration**	Measuring Point/ Elapsed Time
0.01	2	3	14	79.80	6	25	142.50			0.00	222.30	Elbow
0.01	2	3	29	165.30	6	35	199.50			0.00	364.80	Midpoint

Appendix B. Calculation of Concentrations from Photovac 10S30 Peak Areas.

U-Tube 8020-5
Product R
Date 7/24/87

Isobutylene STD Conc. (ppm) = 57
STD inj. vol.(ml) = 0.02
STD Gain = 2
STD Area (sqmm) = 20

K= 0.114
Where K = (STD Conc. * STD inj volume * STD Gain) / STD Area

Conc. of Sample = (K * A)/ (V*G)
Where A,V and G are sample Area, Volume, and Gain, respectively.

INJ Vol (ml)	Gain	Peak 1 Elut. t (min)	Peak 1 Area (sqmm)	Peak 1 Concentration	Peak 2 Elut. t (min)	Peak 2 Area (sqmm)	Peak 2 Concentration	Peak 3 Elut. t (min)	Peak 3 Area (sqmm)	Peak 3 Concentration	Total Concentration	Measuring Point/ Elapsed Time
0.10	2	3	5	2.85	6	14	7.98			0.00	10.83	Elbow
0.01	2	3	10	57.00	6	33	188.10			0.00	245.10	Midpoint
0.1	2	3	42	23.94	6	135	76.95			0.00	100.89	Midpoint

Appendix B. Calculation of Concentrations from Photovac 10S30 Peak Areas.

U-Tube 8043-1
Product D
Date 7/23
4" DIA Vapor Well
TCE Spill Offsite

Isobutylene STD Conc. (ppm) = 57
STD inj. vol.(ml) = 0.02
STD Gain = 2
STD Area (sqmm) = 21

K= 0.10857142
Where K = (STD Conc. * STD inj volume * STD Gain) / STD Area

Conc. of Sample = (K * A)/ (V*G)
Where A,V and G are sample Area, Volume, and Gain, respectively.

INJ Vol (ml)	Gain	Peak 1 Elut. t (min)	Peak 1 Area (sqmm)	Peak 1 Concentration	Peak 2 Elut. t (min)	Peak 2 Area (sqmm)	Peak 2 Concentration	Peak 3 Elut. t (min)	Peak 3 Area (sqmm)	Peak 3 Concentration	**Total Concentration**	Measuring Point/ Elapsed Time
0.50	2	4	20	2.17	5	0	0.00	9	90	9.77	11.94	midpoint
0.50	2	4	0	0.00	5	21	2.28	9	28	3.04	5.32	0
0.50	2	4	21	2.28	5	0	0.00	9	105	11.40	13.68	2
0.50	2	4	29	3.15	5	0	0.00	9	123	13.35	16.50	6
0.50	2	4	31	3.37	5	0	0.00	9	117	12.70	16.07	12
0.50	2	4	33	3.58	5	0	0.00	9	126	13.68	17.26	15
0.50	2	4	34	3.69	5	0	0.00	9	123	13.35	17.05	21
0.50	2	4	34	3.69	5	0	0.00	9	129	14.01	17.70	25
0.50	2	4	36	3.91	5	0	0.00	9	126	13.68	17.59	29

Appendix B.- Calculation of Concentrations from Photovac 10S30 Peak Areas.

U-Tube 8043-2
Product R
Date 7/23
4" DIA Vapor Well
TCE Spill Offsite

Isobutylene STD Conc. (ppm) = 57
STD inj. vol.(ml) = 0.02
STD Gain = 2
STD Area (sqmm) = 21

K= 0.10857142
Where K = (STD Conc. * STD inj volume * STD Gain) / STD Area

Conc. of Sample = (K * A)/ (V*G)
Where A,V and G are sample Area, Volume, and Gain, respectively.

INJ Vol (ml)	Gain	Peak 1 Elut. t (min)	Peak 1 Area (sqmm)	Peak 1 Concentration	Peak 2 Elut. t (min)	Peak 2 Area (sqmm)	Peak 2 Concentration	Peak 3 Elut. t (min)	Peak 3 Area (sqmm)	Peak 3 Concentration	**Total Concentration**	Measuring Point/ Elapsed Time
0.50	2	4	19	2.06	9	44	4.78			0.00	6.84	midpoint
0.50	2	4	20	2.17	9	50	5.43			0.00	7.60	0
0.50	2	4	21	2.28	9	60	6.51			0.00	8.79	2
0.50	2	4	23	2.50	9	72	7.82			0.00	10.31	7
0.50	2	4	23	2.50	9	74	8.03			0.00	10.53	10
0.50	2	4	21	2.28	9	68	7.38			0.00	9.66	14
0.50	2	4	22	2.39	9	78	8.47			0.00	10.86	18
0.50	2	4	22	2.39	9	75	8.14			0.00	10.53	24
0.50	2	4	24	2.61	9	80	8.69			0.00	11.29	26
0.50	2	4	22	2.39	9	78	8.47			0.00	10.86	31

Appendix B.- Calculation of Concentrations from Photovac 10S30 Peak Areas.

U-Tube 8049
Product D
Date 7/23

Isobutylene STD Conc. (ppm) = 57
STD inj. vol.(ml) = 0.02
STD Gain = 2
STD Area (sqmm) = 21

K= 0.10857142
Where K = (STD Conc. * STD inj volume * STD Gain) / STD Area

Conc. of Sample = (K * A)/ (V*G)
Where A,V and G are sample Area, Volume, and Gain, respectively.

INJ Vol (ml)	Gain	Peak 1 Elut. t (min)	Peak 1 Area (sqmm)	Peak 1 Concentration	Peak 2 Elut. t (min)	Peak 2 Area (sqmm)	Peak 2 Concentration	Peak 3 Elut. t (min)	Peak 3 Area (sqmm)	Peak 3 Concentration	Total Concentration	Measuring Point/ Elapsed Time
0.01	2	4	0	0.00	9	0	0.00			0.00	0.00	midpoint
0.5	2	4	6	0.65	9	6	0.65			0.00	1.30	0
0.5	2	4	0	0.00	9	0	0.00			0.00	0.00	3
0.5	2	4	0	0.00	9	0	0.00			0.00	0.00	6
0.5	2	4	0	0.00	9	0	0.00			0.00	0.00	10
0.5	2	4	0	0.00	9	0	0.00			0.00	0.00	17
0.5	2	4	0	0.00	9	0	0.00			0.00	0.00	23
0.5	2	4	0	0.00	9	0	0.00			0.00	0.00	30

Appendix B.. Calculation of Concentrations from Photovac 10S30 Peak Areas.

U-Tube 8052-1
Product U
Date 7/22

Isobutylene STD Conc. (ppm) = 57
STD inj. vol.(ml) = 0.02
STD Gain = 2
STD Area (sqmm) = 22

K= 0.10363636
Where K = (STD Conc. * STD inj volume * STD Gain) / STD Area

Conc. of Sample = (K * A)/ (V*G)
Where A,V and G are sample Area, Volume, and Gain, respectively.

INJ Vol (ml)	Gain	Peak 1 Elut. t (min)	Peak 1 Area (sqmm)	Peak 1 Concentration	Peak 2 Elut. t (min)	Peak 2 Area (sqmm)	Peak 2 Concentration	Peak 3 Elut. t (min)	Peak 3 Area (sqmm)	Peak 3 Concentration	**Total Concentration**	Measuring Point/ Elapsed Time
0.02	2	4	0	0.00	6	12	31.09			0.00	31.09	midpoint
0.02	2	4	0	0.00	6	6	15.55			0.00	15.55	0
0.02	2	4	0	0.00	6	15	38.86			0.00	38.86	3
0.02	2	4	0	0.00	6	10	25.91			0.00	25.91	5
0.02	2	4	0	0.00	6	11	28.50			0.00	28.50	8
0.02	2	4	0	0.00	6	8	20.73			0.00	20.73	11
0.02	2	4	0	0.00	6	10	25.91			0.00	25.91	15
0.02	2	4	0	0.00	6	11	28.50			0.00	28.50	19
0.02	2	4	1	2.59	6	15	38.86			0.00	41.45	23
0.02	2	4	1	2.59	6	16	41.45			0.00	44.05	28
0.02	2	4	4	10.36	6	22	57.00			0.00	67.36	31
0.02	2	4	4	10.36	6	22	57.00			0.00	67.36	36

Appendix B. Calculation of Concentrations from Photovac 10S30 Peak Areas.

U-Tube 8052-2
Product SU
Date 7/22

Isobutylene STD Conc. (ppm) = 57
STD inj. vol.(ml) = 0.02
STD Gain = 2
STD Area (sqmm) = 22

K= 0.10363636
Where K = (STD Conc. * STD inj volume * STD Gain) / STD Area

Conc. of Sample = (K * A)/ (V*G)
Where A,V and G are sample Area, Volume, and Gain, respectively.

INJ Vol (ml)	Gain	Peak 1 Elut. t (min)	Peak 1 Area (sqmm)	Peak 1 Concentration	Peak 2 Elut. t (min)	Peak 2 Area (sqmm)	Peak 2 Concentration	Peak 3 Elut. t (min)	Peak 3 Area (sqmm)	Peak 3 Concentration	Total Concentration	Measuring Point/ Elapsed Time
0.02	2	4	0	0.00	6	0	0.00			0.00	0.00	midpoint
0.02	2	4	0	0.00	6	0	0.00			0.00	0.00	0
0.10	2	4	1.5	0.78	6	7	3.63			0.00	4.40	2
0.10	2	4	2.5	1.30	6	9	4.66			0.00	5.96	3
0.10	2	4	3	1.55	6	6	3.11			0.00	4.66	6
0.10	2	4	6	3.11	6	14	7.25			0.00	10.36	9
0.10	2	4	8	4.15	6	20	10.36			0.00	14.51	11
0.10	2	4	20	10.36	6	24	12.44			0.00	22.80	14
0.10	2	4	27	13.99	6	33	17.10			0.00	31.09	17
0.10	2	4	29	15.03	6	42	21.76			0.00	36.79	20
0.10	2	4	34	17.62	6	58	30.05			0.00	47.67	24
0.02	2	4	13	33.68	6	14	36.27			0.00	69.95	28
0.02	2	4	16	41.45	6	15	38.86			0.00	80.32	32

Appendix B.- Calculation of Concentrations from Photovac 10S30 Peak Areas.

U-Tube 8052-3
Product R
Date 7/22/87

Isobutylene STD Conc. (ppm) = 57
STD inj. vol.(ml) = 0.02
STD Gain = 2
STD Area (sqmm) = 22

K= 0.10363636
Where K = (STD Conc. * STD inj volume * STD Gain) / STD Area

Conc. of Sample = (K * A)/ (V*G)
Where A,V and G are sample Area, Volume, and Gain, respectively.

INJ Vol (ml)	Gain	Peak 1 Elut. t (min)	Peak 1 Area (sqmm)	Peak 1 Concentration	Peak 2 Elut. t (min)	Peak 2 Area (sqmm)	Peak 2 Concentration	Peak 3 Elut. t (min)	Peak 3 Area (sqmm)	Peak 3 Concentration	Total Concentration	Measuring Point/ Elapsed Time
0.10	2	0	0	0.00	0	0	0.00			0.00	0.00	midpoint
0.10	2	0	0	0.00	0	0	0.00			0.00	0.00	0
0.10	2	0	0	0.00	0	0	0.00			0.00	0.00	2
0.10	2	0	0	0.00	0	0	0.00			0.00	0.00	6
0.10	2	0	0	0.00	0	0	0.00			0.00	0.00	9
0.10	2	0	0	0.00	0	0	0.00			0.00	0.00	13
0.10	2	0	0	0.00	0	0	0.00			0.00	0.00	18
0.10	2	0	0	0.00	0	0	0.00			0.00	0.00	23
0.10	2	0	0	0.00	0	0	0.00			0.00	0.00	49

Appendix B. Calculation of Concentrations from Photovac 10S30 Peak Areas.

U-Tube 8054
Product U
Date 7/22/87

Isobutylene STD Conc. (ppm) = 57
STD inj. vol.(ml) = 0.02
STD Gain = 2
STD Area (sqmm) = 22

K= 0.10363636
Where K = (STD Conc. * STD inj volume * STD Gain) / STD Area

Conc. of Sample = (K * A)/ (V*G)
Where A,V and G are sample Area, Volume, and Gain, respectively.

INJ Vol (ml)	Gain	Peak 1 Elut. t (min)	Peak 1 Area (sqmm)	Peak 1 Concentration	Peak 2 Elut. t (min)	Peak 2 Area (sqmm)	Peak 2 Concentration	Peak 3 Elut. t (min)	Peak 3 Area (sqmm)	Peak 3 Concentration	Total Concentration	Measuring Point/ Elapsed Time
0.10	2	6	0	0.00	9	0	0.00			0.00	0.00	:Elbow
0.10	2	6	0	0.00	9	0	0.00			0.00	0.00	:Midpoint
0.10	2	6	0	0.00	9	0	0.00			0.00	0.00	0
0.10	2	6	0	0.00	9	0	0.00			0.00	0.00	5
0.10	2	6	0	0.00	9	0	0.00			0.00	0.00	9
0.10	2	6	0	0.00	9	0	0.00			0.00	0.00	14
0.10	2	6	0	0.00	9	0	0.00			0.00	0.00	19
1.00	2	6	5	0.26	9	1	0.05			0.00	0.31	20
1.00	2	6	8	0.41	9	2	0.10			0.00	0.52	29

Appendix B. - Calculation of Concentrations from Photovac 10S30 Peak Areas.

U-Tube 8265
Product U
Date 7/20/87

Isobutylene STD Conc. (ppm) = 57
STD inj. vol.(ml) = 0.02
STD Gain = 2
STD Area (sqmm) = 15.7

K= 0.14522292
Where K = (STD Conc. * STD inj volume * STD Gain) / STD Area

Conc. of Sample = (K * A)/ (V*G)
Where A,V and G are sample Area, Volume, and Gain, respectively.

INJ Vol (ml)	Gain	Peak 1 Elut. t (min)	Peak 1 Area (sqmm)	Peak 1 Concentration	Peak 2 Elut. t (min)	Peak 2 Area (sqmm)	Peak 2 Concentration	Peak 3 Elut. t (min)	Peak 3 Area (sqmm)	Peak 3 Concentration	Total Concentration	Measuring Point/ Elapsed Time
1.00	2	4	39.7	2.88	7	7.7	0.56			0.00	3.44	midpoint
0.10	2	4	0	0.00	7	0	0.00			0.00	0.00	0
0.10	2	4	0	0.00	7	0	0.00			0.00	0.00	5
0.10	2	4	2.5	1.82	7	0	0.00			0.00	1.82	7
0.10	2	4	2.5	1.82	7	0	0.00			0.00	1.82	10
0.50	2	4	19	2.76	7	19	2.76			0.00	5.52	13
1.00	2	4	28	2.03	7	53	3.85			0.00	5.88	19
1.00	2	4	31	2.25	7	50	3.63			0.00	5.88	24
1.00	2	4	28	2.03	7	47	3.41			0.00	5.45	31