

Characterization of the Vapor Stream at the Lawrence Livermore Dynamic Stripping Site by Differential Ultraviolet Absorption Spectroscopy (DUVAS)

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Characterization of the Vapor Stream at the Lawrence Livermore Dynamic Stripping Site by Differential Ultraviolet Absorption Spectroscopy (DUVAS)

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ABSTRACT

An ultraviolet absorption sensor was used to monitor the composition of the gas stream extractant from wells at the Lawrence Livermore Dynamic Stripping Site. The sensor measured absorption in the spectral region of 217.5 to 300.0 nm, allowing direct detection of benzene and its derivatives (eg. toluene, xylenes, ethylbenzene, etc.). Furthermore, the spectra of these compounds have considerable fine structure that makes the absorption spectrum of each compound unique. Deconvolution of the overlapping absorption spectra of the mixture of aromatic hydrocarbons present in the vapor stream made it possible to determine the concentration of benzene. Relative levels of total aromatic hydrocarbons and of xylenes were also determined. The trends measured by the in-line sensor are in agreement with off-line laboratory analysis methods, and demonstrates the ability to obtain compositional data in real time. Such data may be useful for control or optimization of the extraction process.

INTRODUCTION

Aromatic hydrocarbons are among the most commonly encountered environmental contaminants at Department of Energy (DOE), Department of Defense (DOD), and private sites due to their widespread use as solvents, degreasers, and in fuels. The carcinogenic nature and other health effects associated with aromatic hydrocarbons has resulted in great concern over potential exposure to these compounds, and has led to public demand for the cleanup of contaminated sites. A promising new approach for site cleanup is dynamic stripping. In this process, the ground temperature is raised by a combination of resistive heating and/or steam injection so as to cause volatilization of organic contaminants. The volatilized contaminants and steam are then removed from the soil using a vapor and liquid extraction system.

The quantity of aromatics hydrocarbons and other contaminants removed from the soil is conventionally measured by off-line techniques which require sample collection and analysis. Not only is this approach costly and potentially hazardous, but it cannot provide real time feedback required for optimization and control of the stripping process. Numerous types of instruments have been suggested and deployed for on-line site characterization. The simplest of these instruments are merely a single channel detector which measure concentration by detect absorption at a given wavelength, photoionization, etc.. While these can be sensitive, they are not selective yielding no information about sample composition. On-line gas chromatographs can provide high sensitivity and selectivity, but can not provide real time analysis and are subject to contamination. On-line mass spectrometers can provide sensitive, selective, and real time

analysis. Unfortunately, they can be, depending on the system, moderate to very expensive to purchase and operate, can be difficult to maintain, and can be easily contaminated.

Absorption spectroscopy represents an excellent compromise between overall system cost, sensitivity, selectivity, and system ruggedness. The most spectral information about aromatic hydrocarbons can obtain in the near ultraviolet (UV) or mid infrared (IR). Unlike IR, near UV spectroscopy can be performed in the presence of large concentrations of water with minimal interferences. Even though ultraviolet absorption spectroscopy is one of the oldest analytical techniques, it is still one of the most powerful and widely used methods. Absorption is easily measured and most compounds have large molar absorptivities in the ultraviolet. Although the absorption spectra of most organic compounds are too similar to allow compound-specific identification based solely on UV absorption, aromatic hydrocarbons are a notable exception. In the spectral region from 230 to 300 nm, aromatic hydrocarbons have highly unique absorption spectra. Their spectra are sufficiently different to allow the identification of individual aromatic species based on their absorption fingerprints. In addition, most branched and cyclic alkanes are transparent in the near UV (200 to 380 nm), so background interferences from alkanes are minimal {Sadtler, 1979}. Hence, in this spectral region DUVAS can be used as a highly selective aromatic hydrocarbon sensor.

Mixtures of benzene and its derivatives can be analyzed by deconvolution of their combined spectra. Numerous methods have been developed to deconvolute overlapping spectra {Erickson, et.al., 1992}. One of the oldest approaches is based on derivative spectroscopy. In

this approach, peak intensity and location are determined from the first-, second-, or higher-order derivative of the spectra. This approach has been shown to minimize the magnitude of errors due to overlapping peaks {Hawthorne, et.al.,1984}. With the availability of more powerful computers, higher accuracy and greater speed can be achieved using multivariate methods. These methods range from simple classical summation methods to complex digital filtering and nonlinear calculations {Erickson, et.al., 1992}.

In this work, a differential ultraviolet absorption spectroscopy (DUVAS) sensor was evaluated as a potential on-line, real time analyses device. In order to obtain continuous monitoring of gas stream extractant from the wells at the dynamic stripping site, the DUVAS system was installed on the gas stream from the extraction wells. A small portion of the gas stream was diverted through the sensor. Absorption spectra were collected every thirty minutes over a period of five weeks. From these absorption spectra the concentration of benzene was determined and relative measurements were made for total aromatics, m/p-xylene, and o-xylene using simple classical summation calculations.

EXPERIMENTAL

A schematic diagram of the instrumentation used to monitor the gas stream is shown in Figure 1. The system is based on the measurement of the absorption of the vapor stream in a flow-thru gas cell (Figure 2). A small fraction of the flow in the main gas extraction-line was diverted through the DUVAS cell. The cell was located between the flat-plate heat exchanger and the external knock-out tank of the internal combustion engine (ICE). The quantity of gas flowing through the cell was determined by the pressure drop across the sampling ports. The inlet and outlet sampling ports were located approximately 1.5 m apart, and a ninety degree elbow was located between the ports. The pressure drop across the ports was approximately 74 Pa. The cell was connected to the ports by 9.5-mm I.D. vacuum tubing. The main extraction line onto which the cell was mounted was operated at a vacuum of approximately 10 kPa below atmosphere.

The cell was constructed from commercially available 19-mm O.D. pipe fittings. Quartz windows were held in place at each end of the cell using face seal fittings (Park Fluid Connectors, Huntsville, AL) giving an optical path of 30 cm. The detector used was a 1-cm diameter, UV sensitive photodiode which was packaged with an current to voltage operational amplifier (HUV-4000B, $R_f=200\text{ M}\Omega$, EG&E Judson, Montgomeryville, PA). The output of the photodiode assembly was isolated from the other electronics and amplified by a factor of ten using a second operational amplifier configured as a voltage follower. The photodiode and associated electronics were enclosed in an aluminum housing attached directly to the weld gland

of the face seal fitting. Light was transmitted to the cell by a high OH 600- μm diameter fused silica optical fiber (Polymicro Technologies, Phoenix, AZ). A single 12.7-mm diameter ($f/2$) lens was used to collimate the light emitted from the fiber. The optical fiber and lens were held in place using custom components. The collimated light was directed through the cell and onto the active surface of the photodiode. The cell was remotely located from the rest of the instrumentation by a 25-m optical fiber and photodiode electrical connection.

A 30-W deuterium lamp (L2196, Hamamatsu, Bridgewater, NJ) was used as the source. Light from the lamp was collimated and focused on the entrance slit of a 0.3-m monochromator (HR320 with a 2400 groove/mm, 250-nm blazed grating, Instrument SA, Inc., Edison, NJ) by a dual lens aperture matching system. Slit widths of 50 μm were used throughout the demonstration. The light transmitted through the monochromator was launched into the fiber using a second dual lens configuration. The light beam was modulated at 200 Hz using a mechanical chopper (Model 230, Ithaco, Ithaca, NY) located prior to the fiber coupling optics. A lock-in amplifier (Model 3921, Ithaco, Ithaca, NY) was used to demodulate the chopped signal measured at the photodiode. The output voltage of the lock-in amplifier was converted to frequency by a function generator (FG-500, Tektronix, Beaverton, OR) and was digitized using a frequency counter (SpectraLink IFCNT signal acquisition module with Prism Software, Instruments SA, Edison, NJ). The linearity of the measured absorbance was verified up to 1.25 A.U. (absorbance units) using optical neutral density filters placed in the optical path.

To obtain a spectrum, the monochromator was scanned from 217.5 to 300.0 nm in 0.1-

nm steps, acquiring data for 0.2 s at each step. A complete scan required approximately 5 minutes, and spectra were collected every thirty minutes. Since only a single channel was used, it was periodically necessary to purge the cell with air in order to obtain a reference spectrum. This was accomplished using timer controlled solenoid valves on the sampling lines. The cell was purged every four hours for a period of one hour. The absorption spectra were obtained by taking the negative log of the ratio of the sample, S , and reference, R , spectra according to Equation (1):

$$A = -\log\left(\frac{S}{R}\right) \quad (1)$$

Figures 3 and 4 show representative reference and sample spectra and the resulting absorption spectrum.

To calibrate the system, calibration gases were generated by injection of a known amount of compound into a calibrated flow of air {Woodfin, 1984}. A syringe pump was used to inject the compound of interest, and a mass flow controller was used to control the flow rate of the air. The gas flow rate was calibrated using a wet-test meter (Model 63126, Precision Scientific, Inc., Chicago, IL). The linearity of the gas generator was independently verified using a flame ionization detector (OVA 128, Foxboro, Norwalk, CT) to determine gas concentration.

RESULTS

To obtain an indication of the relative changes in concentration of the aromatic hydrocarbons, the area of the absorption curve from 234 to 284 nm was integrated. This is a region of common absorption for all aromatic species present. Figure 5 shows the variation of the integrated area averaged over a period of 24 hours plotted against time of site operation. Several interesting trends are observed in the data. The rate of aromatic hydrocarbon removal decreased when steam injection was initiated, and the amount of aromatics extracted continued to decrease while steam injection continued. It has been suggested that this is caused by the increase in well pressure due to the presences of steam. Immediately after the stop of steam injection, the concentration of extracted hydrocarbons present in the vapor stream rapidly increased. Peak concentrations were reached approximately 23 and 13 hours after the steam injection was stopped on 6/21 and 7/1, respectively (Table 1).

The data also show significant diurnal fluctuations in the absorption of total aromatics as determined by total peak area (Figure 6). The periodic fluctuations in the data correspond exactly with the fluctuations recorded in temperature, pressure, and flow of the vapor extraction-line. If ideal gas behavior of the system is considered, the quantity of gas present in the cell can be approximated by Equation (2),

$$\frac{n}{V} = \frac{P}{RT} \quad (2)$$

where p , V , n , R , and T are pressure (kPa), volume (m^3), moles, gas constant ($\text{kPa}\cdot\text{m}^3/\text{K}$), and gas temperature (K), respectively. Since the volume of the cell is constant, any changes in temperature or pressure will result in a change in the amount (n) of gas present in the cell. Increasing vapor temperature or decreasing pressure at a given rate of extraction will decrease the measured absorption due to the proportional decrease in number of moles of gas per unit volume present in the cell. However, when calculations made using the applied vacuum and post condenser temperatures, the expected change in absorption is opposite of the observed results. This may be due to differences in the cell conditions and compared to those at the location of the temperature and pressure sensors. A more likely explanation is that increases in the system temperature causes an increase the vapor pressure of the hydrocarbons, possibly due to reduced condensation at the walls of the extraction system. This would explain the increase in absorption observed in the cell. Unfortunately, it is not possible to calculate expected changes since the system is not at equilibrium.

Relative concentration of m/p-xylene and o-xylene were determined from the peak intensity at 272 and 274 nm, respectively. At these wavelengths, the xylenes have characteristic absorption bands. While there is significant spectral overlap for the aromatic hydrocarbons at these wavelengths, this data should indicate general trends in the extracted concentration of these compounds. Figure 7 shows the variation of relative xylene concentration with time.

An much more accurate approach was used to determined benzene concentration. Benzene exhibits a sharp absorption peak at 243 nm. In the wavelength region of 230 to 250

nm, the other aromatic hydrocarbons present in the mixture (as indicated by gas chromatography/mass spectral (GC/MS) analysis) show only broad background absorption. It can be safely assumed that the total absorption, A_T , at any wavelength in the spectrum is the linear summation of the absorption of the individual components, $A_1, A_2, A_3, \dots, A_n$ (Equation (3)).

$$A_T = \sum_{i=1}^n A_i \quad (3)$$

Based on this assumption the peak observed at 243 nm can be attributed to benzene absorption superimposed on the broad background absorption of the other aromatic hydrocarbons. By approximating this background contribution using a second-order polynomial, it was possible to calculate the absorption contribution due to benzene. This approach is graphically represented in Figure 8.

From the measured peak height and the calibration of the system, the concentration of benzene was calculated. The concentration of benzene as measured by both DUVAS and off-line GC versus time is shown in Figure 9. From hour 360 to 925, the qualitative trends are in excellent agreement with the results obtained by the analytical laboratory. Note, however, that the absolute concentrations measured by DUVAS are approximately a factor of 2 less than those measured by the analytical laboratory. This may be due to the uncertainty associated with the pressure and temperature of the cell. Another possible cause may be due to the fact that it was necessary for the instrument to be calibrated after it was returned to Oak Ridge National Laboratory. This required complete disassembly and reassembly between the on-site

measurements and the calibration. This could possibly result in a systematic error in the calibration of instrument, but would not affect relative performance of the instrument throughout the course of the demonstration. The results are further complicated by the fact that the data from hours 925 to 1130 are in good agreement with the laboratory results in both concentration and temporal trends. No changes were made to the DUVAS system during this time, and the differences can not presently be explained based on the changes in the DUVAS system alone.

One of the main advantages of on-line DUVAS is that the sampling frequency is much greater than can be practically achieved with off line sampling methods (GC and FID) due to cost and time required for each analysis. The analytical laboratory samples were taken only once or twice a day, thus the analytical results represent only a small fraction of time when compared to the overall time of the demonstration. Because of the limited number of samples, laboratory analysis are incapable of detecting short term fluctuations in sample concentrations which may be important indicators of various processes occurring during the dynamic stripping operation. The fluctuations in the aromatic concentration with temperature is an example of the power of on-line measurements over off-line techniques (Figure 6). Off line sampling also can not detect transient spikes in concentration which may indicate system malfunctions or other rapid variations in the extraction process. Figure 10 shows spikes observed in the measured benzene absorbance. Examination of the absorption spectra shows that these spikes are not due noise in the measurement process. One of the spikes can be attributed to ICE failure which occurred at 800 hours. The other spikes are probably due to rapid changes in the temperature and pressure of the main vapor line.

DISCUSSION

The DUVAS instrumentation used in this integrated demonstration at the Lawrence Livermore dynamic stripping site represents a significant improvement over instruments deployed in two earlier tests conducted in 1992. One the most significant changes made in the system was the implementation of modulation signal processing. Previous versions of DUVAS relied on DC signal carriers. With a DC type of carrier, it is nearly impossible to reject environmental noise such as background electrical interferences and fluctuations in background lighting. The modulated signal processing was made possible through the use of lock-in detection. This type of detection can discriminate extremely weak signals from large background noise {Horowitz and Hill}. With the use of this method, no significant background noise was observed, even from significant diurnal changes in ambient lighting associated with 24-hour operation of the system.

As a result of these improvements in signal-to-noise performance, it was possible to dramatically improve the spectral resolution of the system without loss of sensitivity. The previous versions of DUVAS employed a 0.1-m focal length monochromator as the wavelength dispersive element. While this type of monochromator is compact and can have high light transmission efficiency, the gain in size and light throughput do not justify the sacrifice in resolution. In this study, a 0.3-m monochromator was used, resulting in dramatic improvements in resolution from >1 nm to approximately 0.06 nm. The higher resolution is crucial for successful deconvolution of the spectra of benzene and its derivatives. The linearity of

absorption would have been limited by a lower resolution instrument since the spectral bandpass of the monochromator can lead to polychromatic nonlinearity when the spectral bandpass of the monochromator is greater than 1/10 of the absorption band width {Ingel and Crouch, 1988}. It would not have been possible to determine the concentration of benzene with the lower resolution system.

Additional enhancements in the system were also made. The optics were redesigned to improve collection efficiencies of light from the deuterium lamp and coupling efficiency with the optical fiber. Data collection was fully automated allowing the system to operate unattended for periods of 24 hours.

Future Enhancements to DUVAS. To fully exploit the potential of the DUVAS approach, several instrumental enhancements are needed to increase deployment flexibility, analytical sensitivity, and extent of system automation. A modular configuration is needed to allow rapid incorporation of these enhancements into a complete system, and more importantly to allow easy user configuration of the system for the specialized requirements of site-specific applications. Overall system performance would then be optimized by making necessary modifications to individual modules. The overriding concerns in this effort must be on system ruggedness, flexibility, and ease of use. The modular approach has the added benefit of simplifying and speeding system repair by the end user, since in the event of failure of a particular module, it will be easily replaced with a working module.

Cell designs developed for future work will be optimized for both liquid and vapor-phase samples. Universal cells would maximize adaptability for applications requiring monitoring of various liquid and gaseous materials. Specific issues to be resolved include optimization of optical geometries, source and detector placement, cell path length, and sample conductance. These cells could be designed for easy conversion between point monitoring and remote monitoring configurations (via a fiberoptic interface).

The analytical sensitivity of the present DUVAS system was limited primarily by detector noise. One approach for reducing this limitation is replacement of the continuous-wave optical source of the initial DUVAS with a pulsed source. This would increase UV radiation transmitted to the detector, and thereby increase the signal to a level above the inherent noise level of the detector. A second approach would be to use an array detector. The multiplex advantage of this type of detector allows one to obtain spectra very quickly (ie, in a second or less) at very high signal-to-noise ratios.

The most important change to be implemented for the end user of the next version of DUVAS is new control and data processing software. Instrument control and data processing will be simplified through the development of new software which will automate routine operation of the device. This will reduce operator training requirements and allow long-term, unattended monitoring of on-going processes.

CONCLUSIONS

The utility of the DUVAS sensor has been clearly demonstrated through successful deployment and continuous operation at the Livermore site for a period of five weeks. The work presented here documents completion of fiscal year 1993 milestone number 2, "Monitoring of Dynamic Stripping" in the DUVAS Demonstration TTP, Number OR1-0-11-01. While the magnitude of concentrations do not agree between the DUVAS and laboratory analyses, the results do show the utility of using on-line measurements to reduce the number samples required to characterize the extraction gas stream. The on-line results could be used to extrapolate between the laboratory measurements to show trends which occurred between samples and more importantly could provide real time feedback for control of extraction.

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3-417

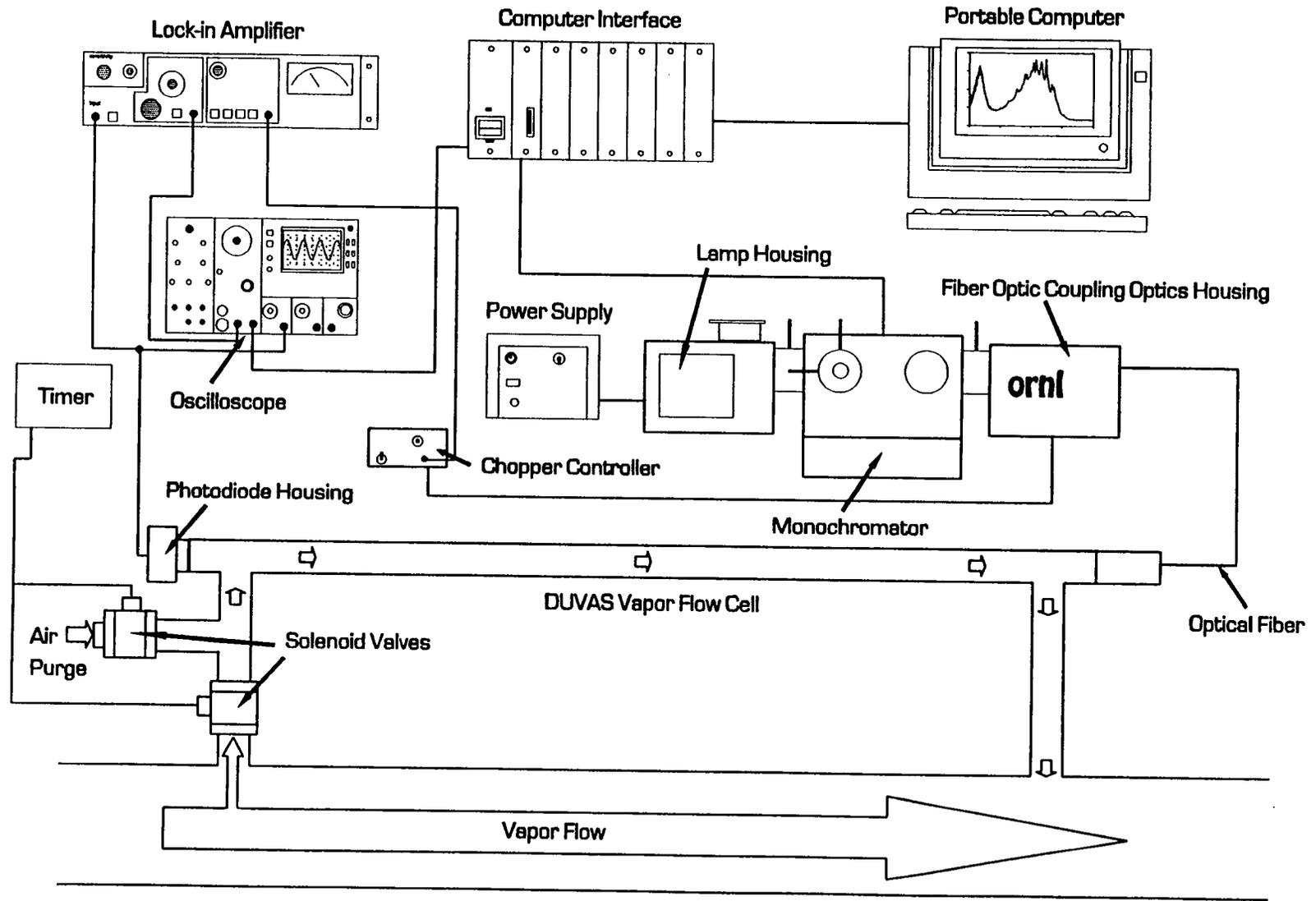


Fig. 1

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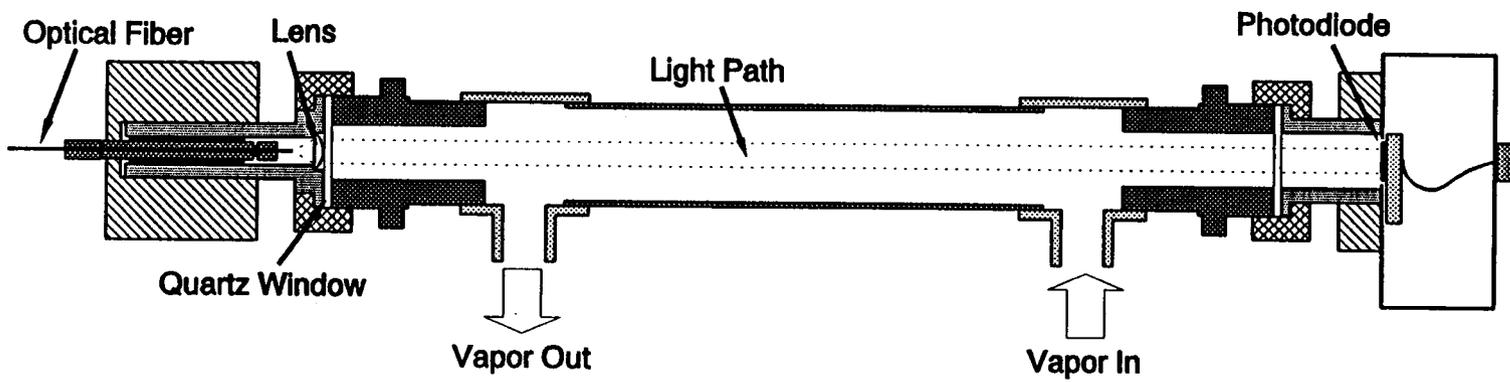


Fig. 2

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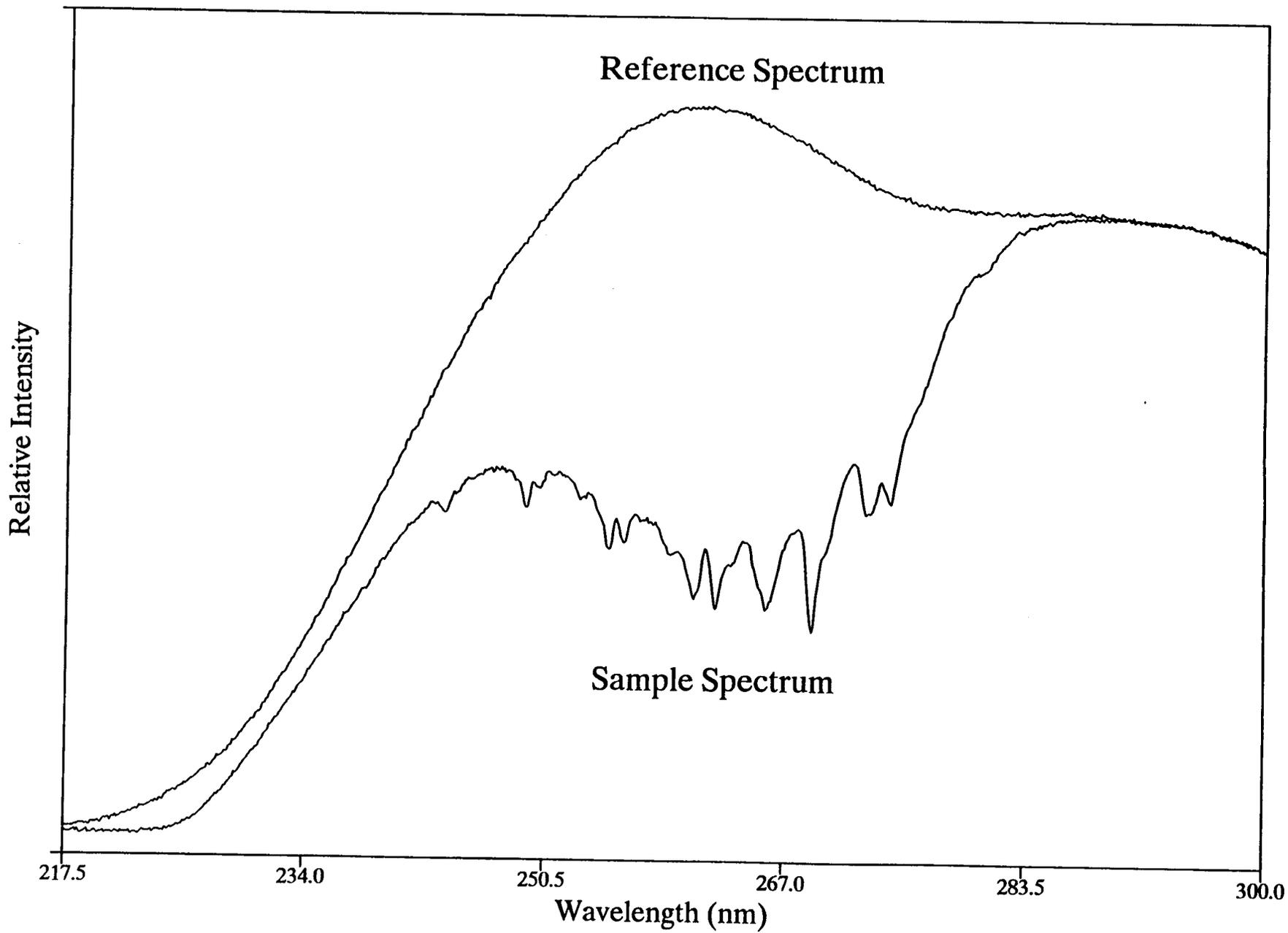


Fig. 3

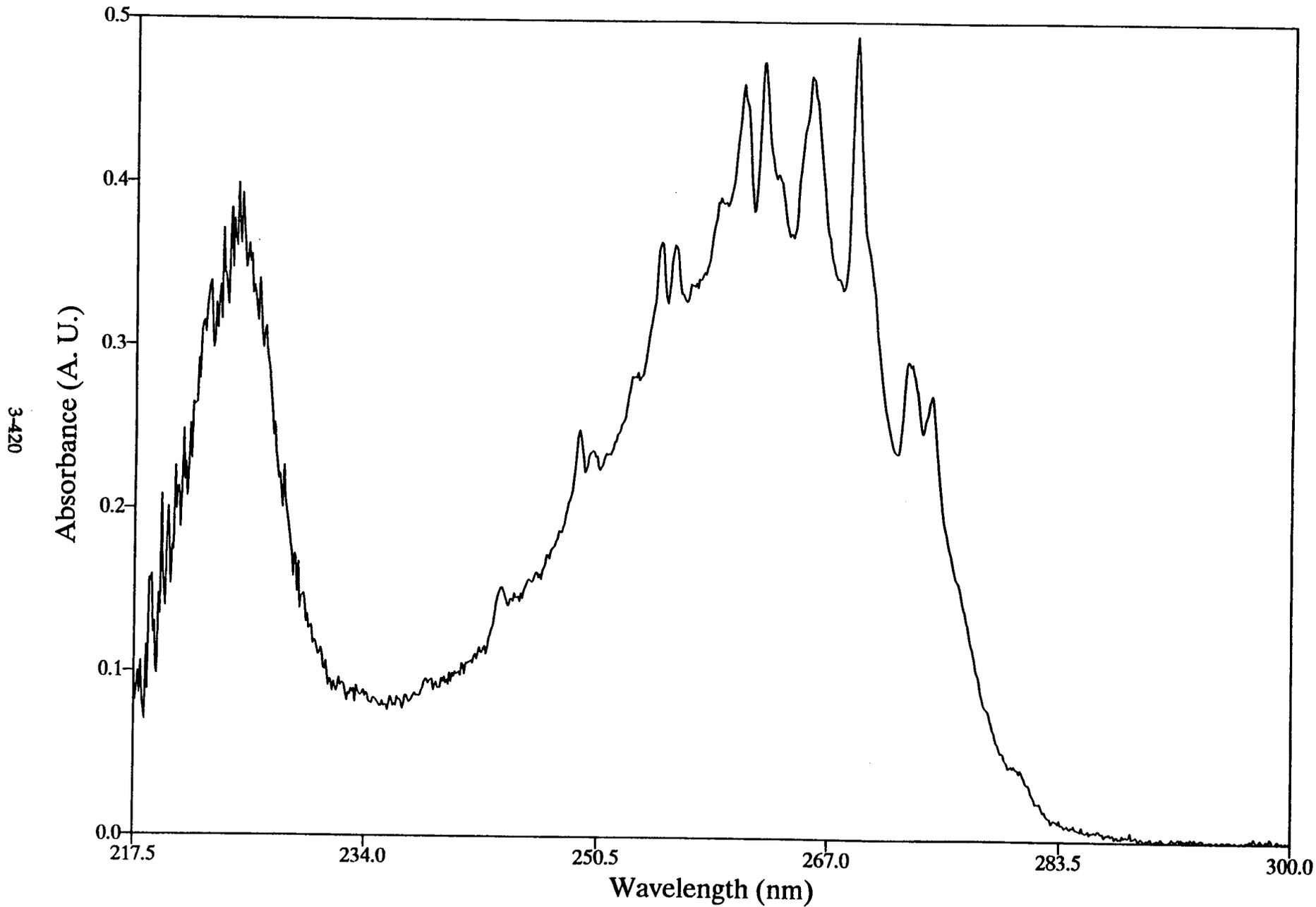


Fig. 4

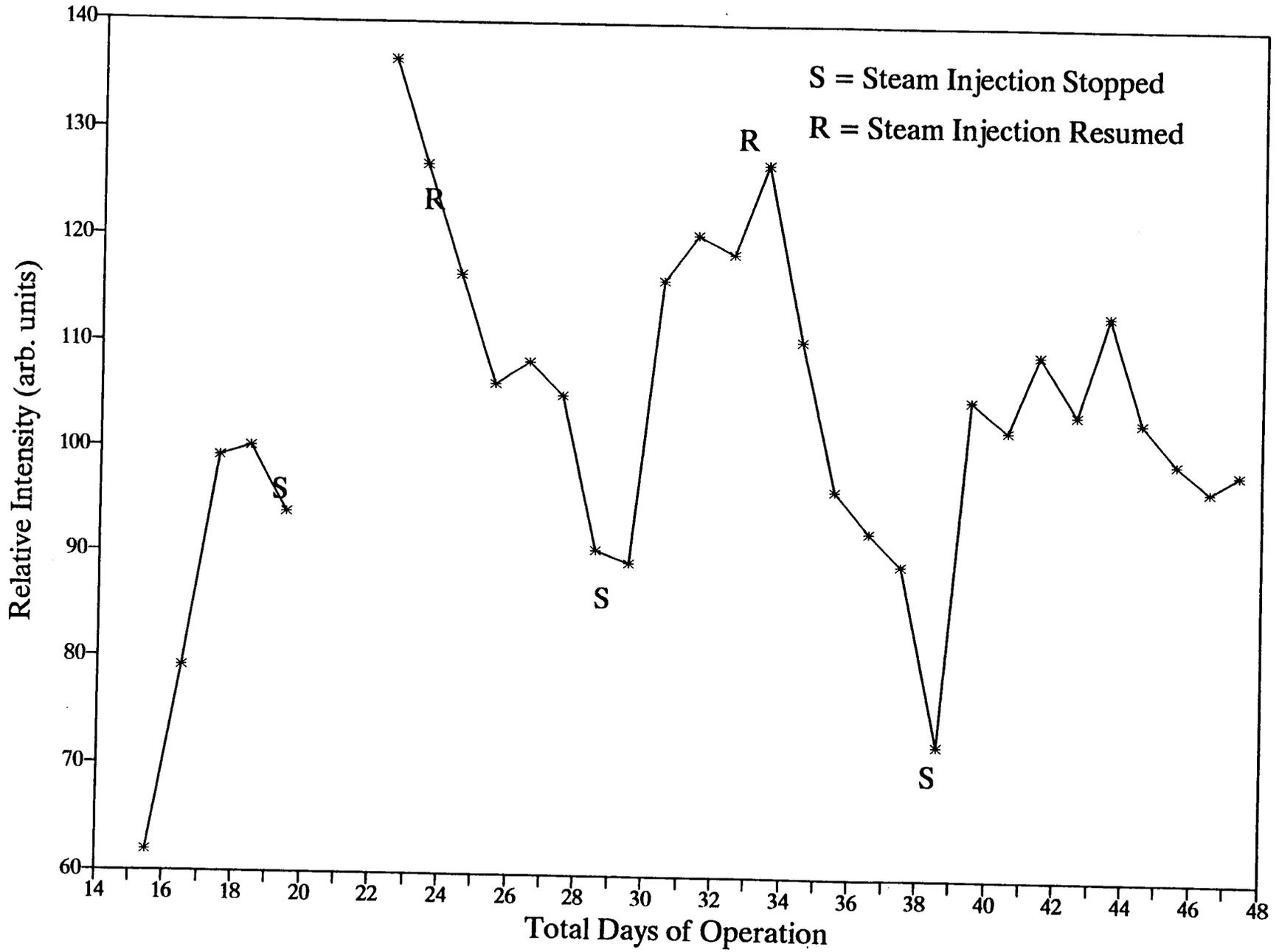


Fig. 5

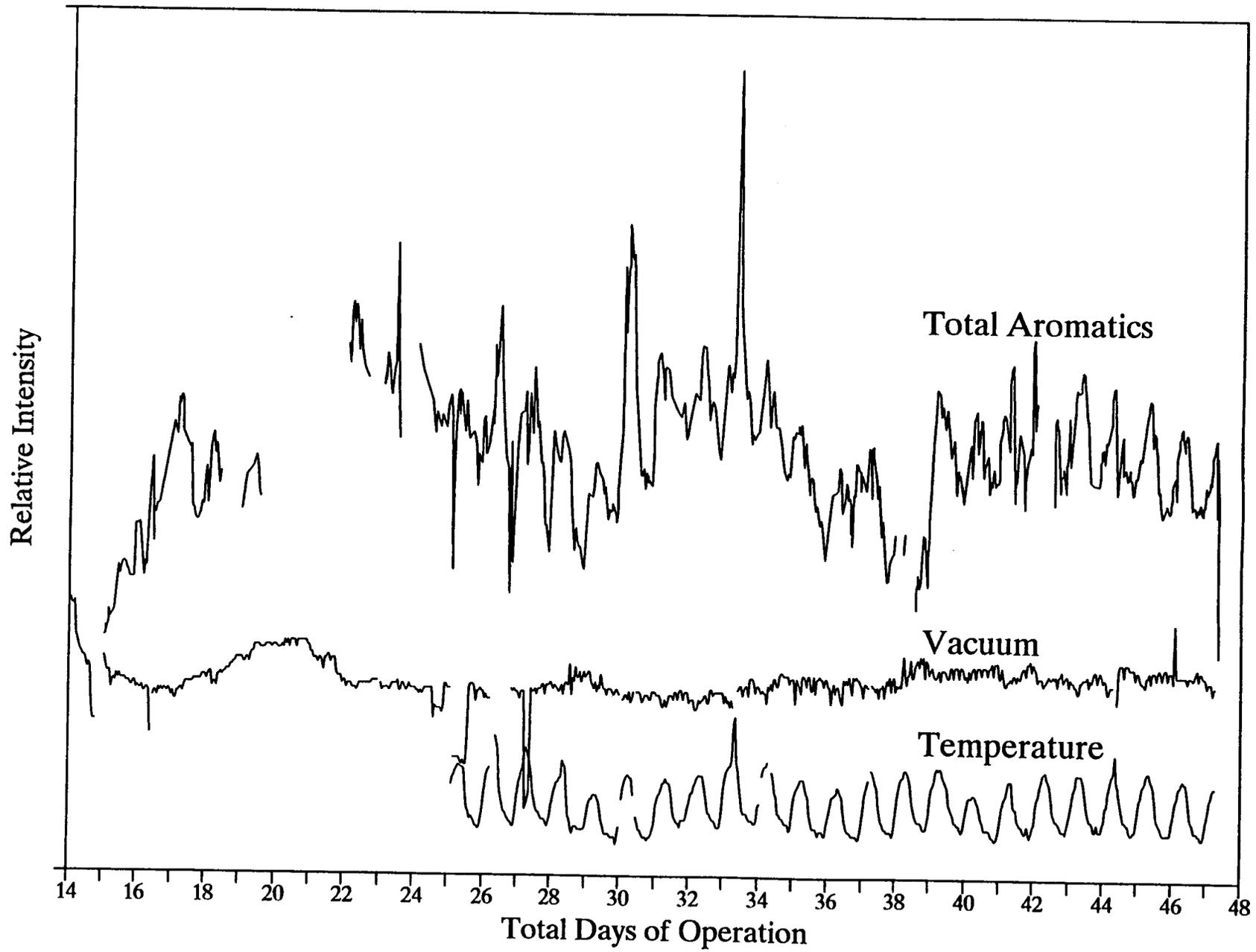


Fig. 6

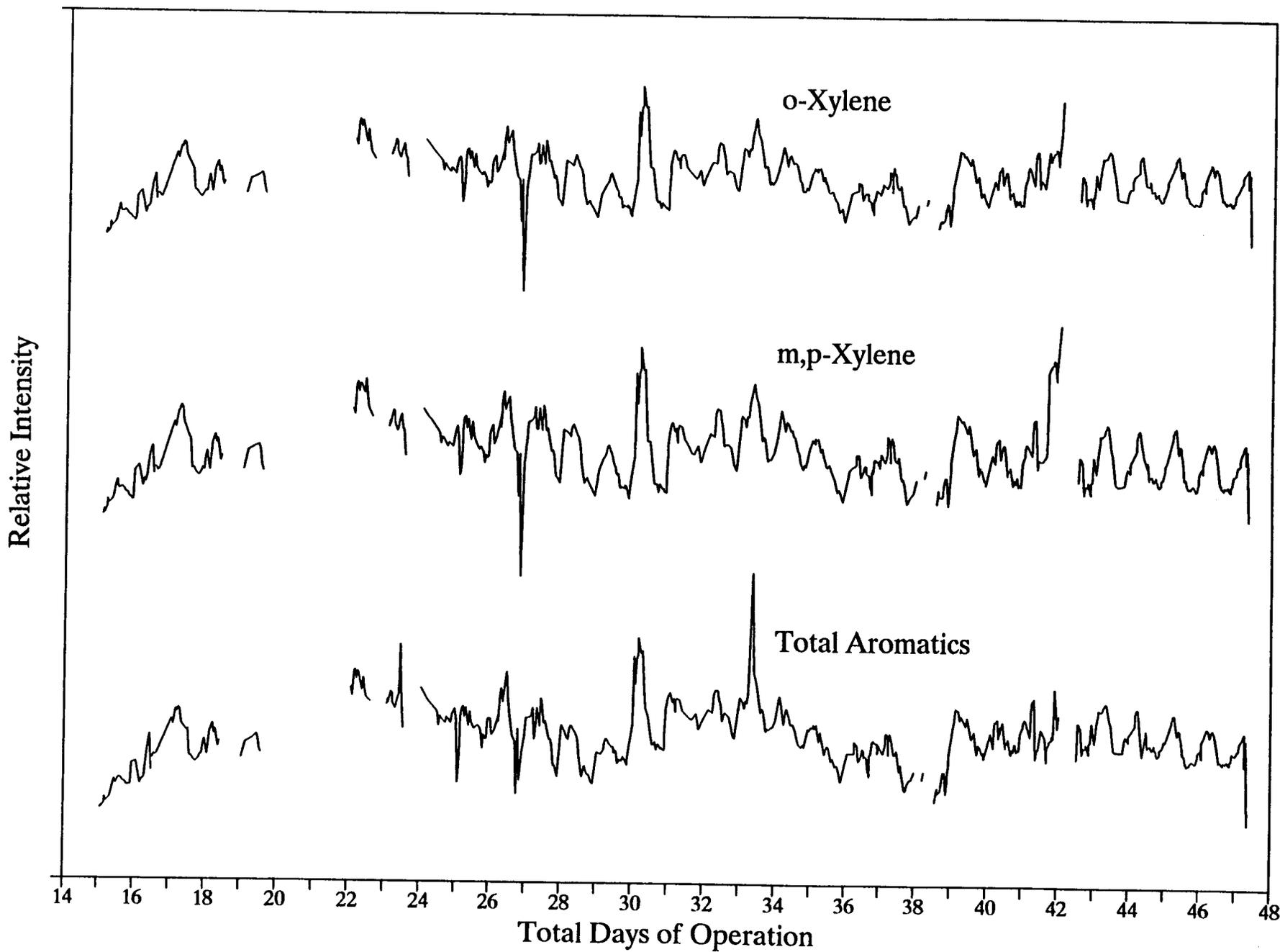


Fig. 7

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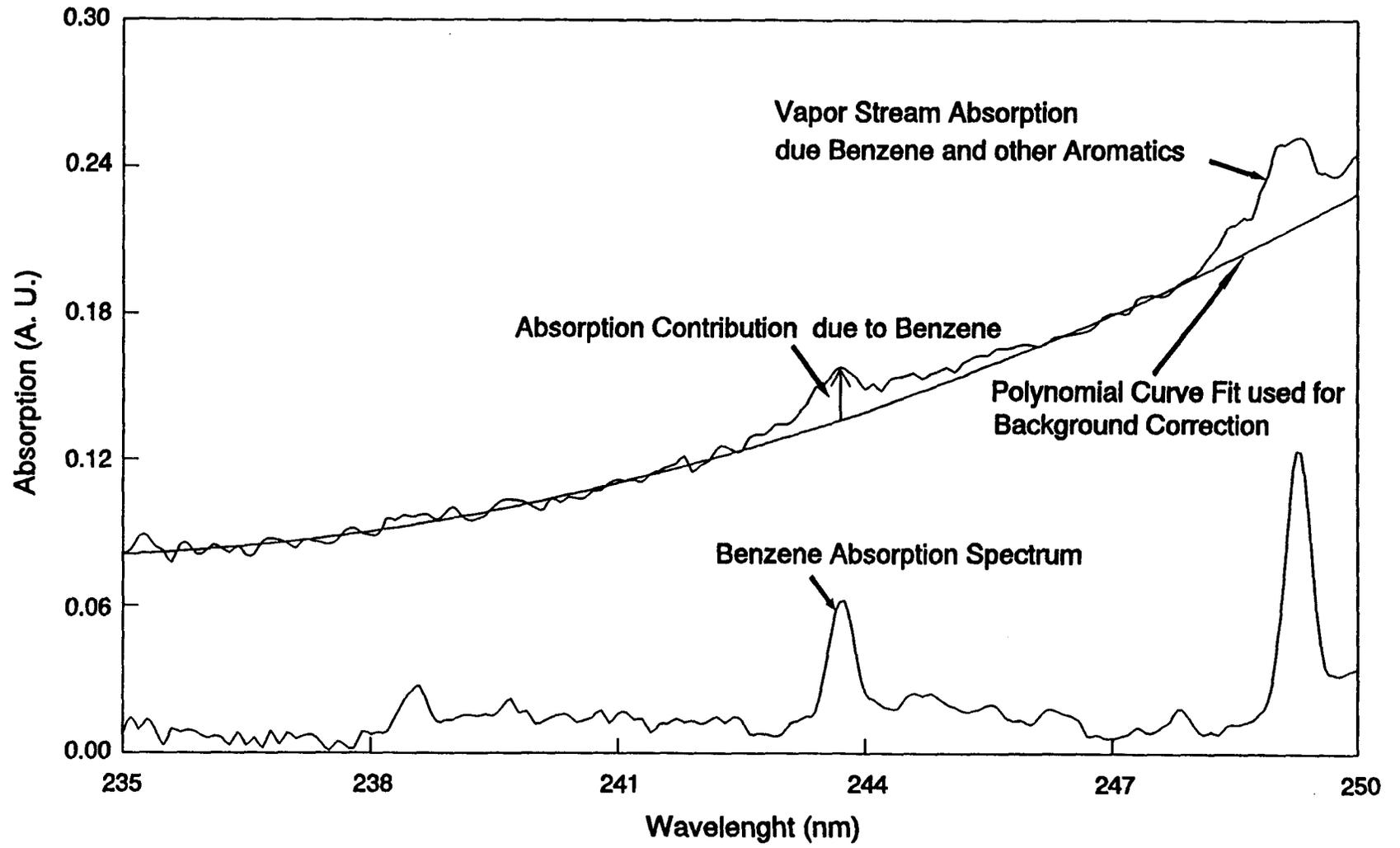


Fig. 8

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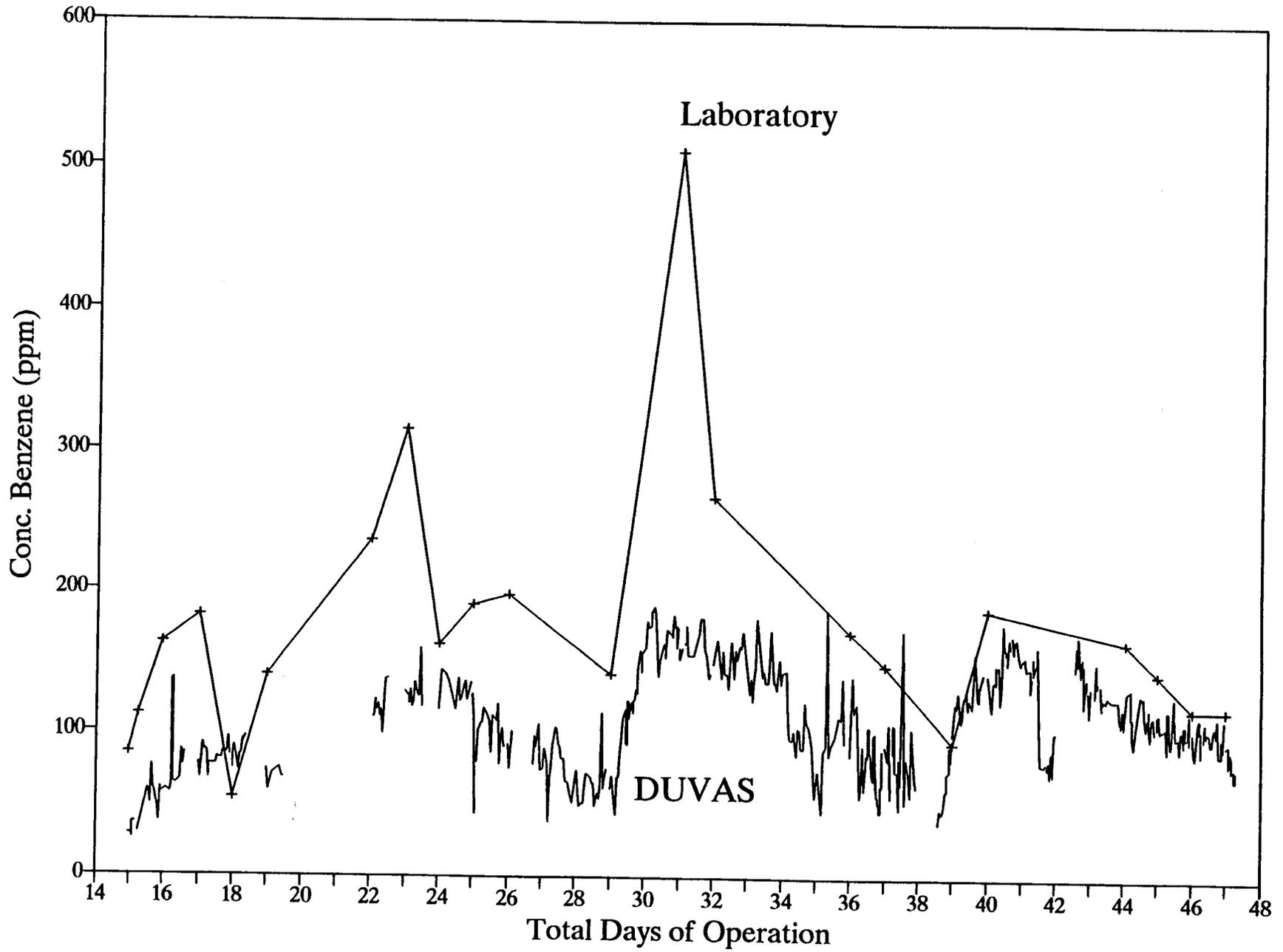


Fig. 9

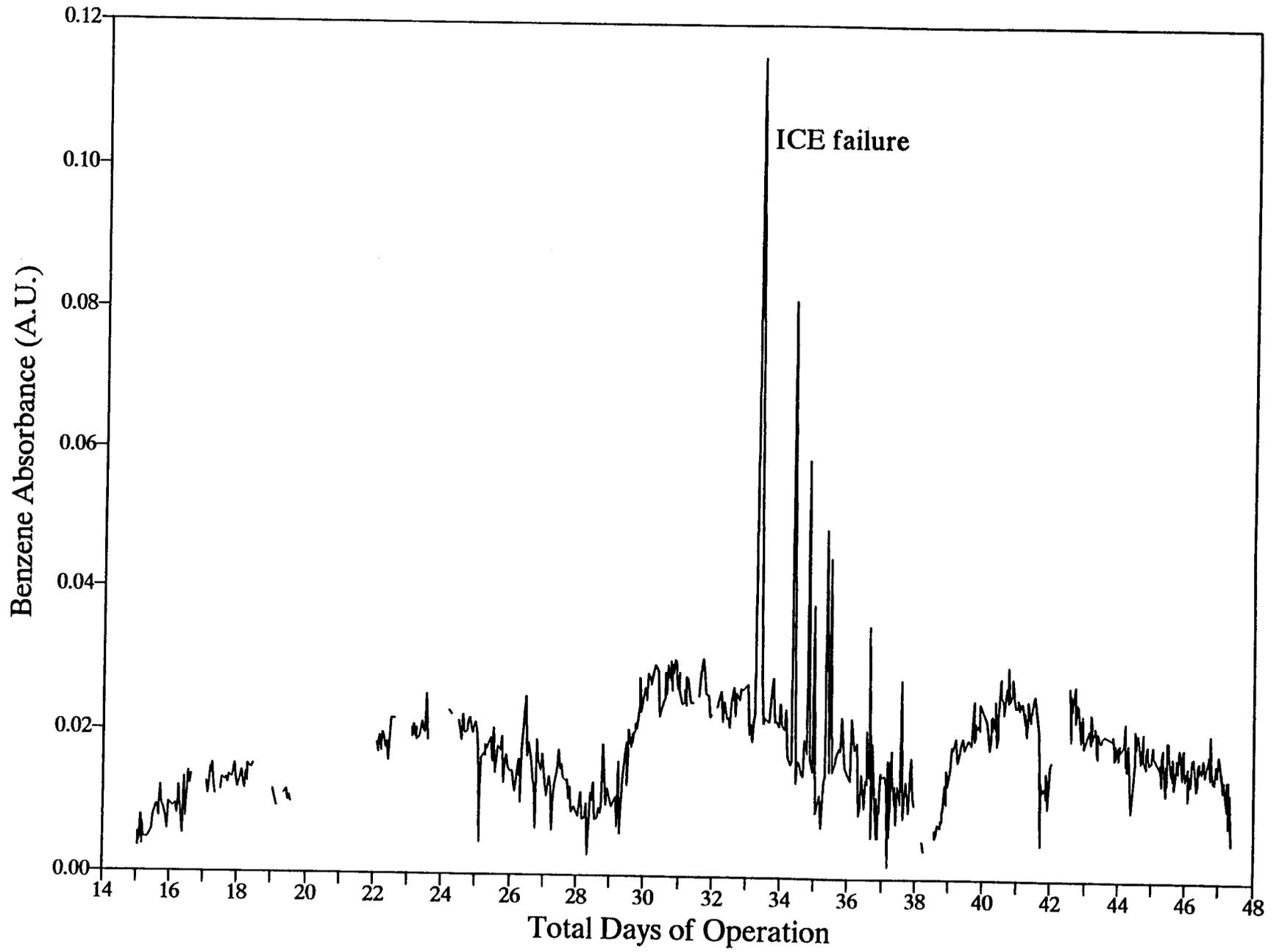


Fig. 10

Table 1. DUVAS Results from Second Steam Pass

Total Run Hours	Total Run Days	Relative Total Aromatics Conc.	Relative m/p-Xylene Conc.	Relative o-Xylene Conc.	Benzene Conc. (ppm)
361.50	15.06	48.2	2.96	2.61	28
361.75	15.07	48.9	3.05	2.67	28
362.00	15.08	50.8	3.22	2.80	26
362.25	15.09	49.2	3.06	2.67	26
364.00	15.17	52.1	3.31	2.85	36
364.50	15.19	55.7	3.58	3.09	37
365.00	15.21	53.4	3.44	2.96	37
368.00	15.33	55.6	3.63	3.12	29
370.75	15.45	68.5	4.37	3.83	38
371.75	15.49	65.7	4.04	3.56	51
372.75	15.53	68.0	4.03	3.55	54
373.75	15.57	69.4	4.11	3.59	59
374.75	15.61	69.6	4.11	3.60	58
375.75	15.66	69.3	4.03	3.54	49
376.75	15.70	67.6	3.94	3.43	76
377.75	15.74	66.9	3.85	3.37	59
378.75	15.78	64.9	3.70	3.30	57
379.75	15.82	65.2	3.71	3.26	52
380.75	15.86	64.9	3.60	3.19	47
381.75	15.91	65.0	3.59	3.27	37
382.75	15.95	80.5	4.79	4.17	61
385.75	16.07	80.7	5.01	4.40	57
388.50	16.19	65.3	4.17	3.52	60
389.50	16.23	68.7	4.45	3.74	58
389.75	16.24	69.5	4.46	3.80	64
390.25	16.26	68.2	4.35	3.71	137
390.75	16.28	70.9	4.55	3.86	137
393.00	16.38	88.4	5.45	4.69	64
394.50	16.44	99.9	5.82	5.11	63
395.50	16.48	75.6	4.70	4.07	65
396.50	16.52	83.9	4.93	4.31	67
397.50	16.56	86.4	4.89	4.29	88
398.50	16.60	86.2	4.80	4.16	76
399.50	16.65	87.2	4.83	4.20	85

Table 1. DUVAS Results from Second Steam Pass

Total Run Hours	Total Run Days	Relative Total Aromatics Conc.	Relative m/p-Xylene Conc.	Relative o-Xylene Conc.	Benzene Conc. (ppm)
409.75	17.07	110.5	6.80	5.99	79
411.00	17.13	106.5	6.59	5.76	68
412.75	17.20	117.3	7.29	6.28	92
413.25	17.22	115.9	7.24	6.23	87
413.75	17.24	117.2	7.37	6.34	87
414.25	17.26	118.2	7.48	6.42	87
415.00	17.29	116.7	7.40	6.36	87
415.75	17.32	108.1	6.80	5.88	68
420.00	17.50	102.8	6.21	5.42	78
421.00	17.54	103.6	6.12	5.33	78
422.00	17.58	85.4	4.92	4.46	83
423.00	17.63	85.6	4.93	4.46	81
424.00	17.67	82.8	4.72	4.27	81
425.00	17.71	81.9	4.65	4.21	81
426.00	17.75	82.0	4.62	4.21	86
428.00	17.83	84.2	4.78	4.36	85
429.00	17.88	87.2	4.96	4.49	85
430.00	17.92	86.4	4.83	4.42	96
431.00	17.96	93.7	5.35	4.86	83
432.00	18.00	97.6	5.65	5.11	75
433.50	18.06	86.7	4.83	4.41	84
435.25	18.14	103.1	5.99	5.34	90
436.25	18.18	105.3	6.13	5.49	80
437.25	18.22	107.6	6.32	5.63	74
438.00	18.25	101.3	5.99	5.22	84
438.50	18.27	103.7	6.14	5.38	84
439.00	18.29	103.8	6.15	5.40	95
439.25	18.30	104.0	6.11	5.39	95
441.25	18.39	92.7	5.25	4.69	93
442.25	18.43	96.1	5.48	4.87	97
457.00	19.04	85.0	4.88	4.38	75
460.00	19.17	95.1	5.67	5.00	59
464.50	19.35	97.9	5.84	5.11	71
467.00	19.46	100.9	5.93	5.22	75

Table 1. DUVAS Results from Second Steam Pass

Total Run Hours	Total Run Days	Relative Total Aromatics Conc.	Relative m/p-Xylene Conc.	Relative o-Xylene Conc.	Benzene Conc. (ppm)
468.00	19.50	98.5	5.68	5.02	68
469.00	19.54	91.1	5.05	4.59	68
470.00	19.58	88.9	4.82	4.36	62
530.00	22.08	133.7	7.42	6.62	121
531.00	22.13	128.4	7.18	6.41	111
531.50	22.15	140.7	8.05	7.10	111
532.00	22.17	142.8	8.22	7.25	123
533.00	22.21	146.4	8.49	7.46	117
534.00	22.25	139.8	8.09	7.11	116
535.00	22.29	145.4	8.44	7.41	121
536.00	22.33	140.9	8.40	7.07	111
537.00	22.38	132.2	8.03	6.52	117
538.00	22.42	140.6	8.59	7.03	99
539.00	22.46	132.0	7.95	6.49	119
540.00	22.50	127.1	7.45	6.12	137
543.00	22.63	123.9	7.08	5.79	138
554.50	23.10	121.9	6.68	6.01	129
555.00	23.13	125.9	6.98	6.26	126
555.50	23.15	123.4	6.81	6.12	126
556.50	23.19	131.2	7.39	6.63	121
557.50	23.23	129.0	7.25	6.49	130
558.00	23.25	123.5	6.87	6.13	119
559.50	23.31	119.1	6.52	5.85	121
561.50	23.40	126.9	7.06	6.29	136
562.50	23.44	128.9	7.20	6.42	126
563.50	23.48	163.4	6.62	5.95	125
564.50	23.52	121.8	6.51	5.83	159
565.50	23.56	106.4	5.50	5.07	118
577.50	24.06	133.7	7.42	6.62	116
581.00	24.21	126.7	7.08	6.31	144
582.50	24.27	124.2	6.99	6.17	141

Table 1. DUVAS Results from Second Steam Pass

Total Run Hours	Total Run Days	Relative Total Aromatics Conc.	Relative m/p-Xylene Conc.	Relative o-Xylene Conc.	Benzene Conc. (ppm)
588.00	24.50	117.4	6.45	5.74	136
589.50	24.56	107.9	6.01	5.35	117
590.50	24.60	114.3	6.29	5.63	139
591.50	24.65	112.7	6.23	5.55	123
593.50	24.73	109.6	5.92	5.30	124
594.50	24.77	113.1	6.09	5.46	134
595.50	24.81	112.3	6.05	5.40	136
597.50	24.90	109.6	5.89	5.27	124
598.50	24.94	115.8	6.23	5.61	132
599.50	24.98	117.6	6.50	5.89	135
600.50	25.02	119.3	6.75	5.95	128
601.75	25.07	112.0	6.30	5.61	111
602.75	25.11	68.2	4.71	4.05	28
603.00	25.13	80.6	5.02	4.39	60
604.00	25.17	104.5	5.92	5.24	79
604.25	25.18	112.8	6.55	5.76	102
605.25	25.22	119.6	7.08	6.19	105
606.25	25.26	120.8	7.17	6.26	107
606.75	25.28	113.3	6.62	5.80	108
608.00	25.33	119.8	7.04	6.14	109
610.00	25.42	108.2	6.18	5.47	117
611.00	25.46	117.5	6.92	6.05	111
612.00	25.50	110.0	6.35	5.55	108
613.00	25.54	106.1	6.00	5.28	87
615.00	25.63	107.8	5.81	5.21	112
616.00	25.67	108.1	5.94	5.32	110
617.00	25.71	106.7	5.82	5.22	108
618.00	25.75	104.0	5.71	5.10	120
619.00	25.79	92.5	5.25	4.67	78
620.00	25.83	101.8	5.59	4.97	96
621.00	25.88	99.5	5.46	4.87	103
622.00	25.92	99.3	5.53	4.91	91
623.00	25.96	112.2	6.50	5.75	91
624.50	26.02	112.9	6.79	5.96	91
625.50	26.06	101.6	6.04	5.32	93

Table 1. DUVAS Results from Second Steam Pass

Total Run Hours	Total Run Days	Relative Total Aromatics Conc.	Relative m/p-Xylene Conc.	Relative o-Xylene Conc.	Benzene Conc. (ppm)
627.25	26.14	104.5	6.34	5.52	75
630.00	26.25	115.0	7.09	6.14	102
630.50	26.27	110.2	6.68	5.82	96
630.75	26.28	127.2	7.82	6.74	87
631.00	26.29	127.1	7.64	6.66	96
631.50	26.31	133.7	8.19	7.15	62
632.50	26.35	124.4	7.42	6.49	109
635.25	26.47	145.5	7.92	6.98	156
636.25	26.51	124.8	7.10	6.22	104
637.25	26.55	115.2	6.70	5.89	116
639.25	26.64	100.8	5.80	5.14	100
640.25	26.68	99.2	5.72	5.06	82
641.25	26.72	97.6	5.63	4.97	79
642.25	26.76	61.1	3.90	3.30	41
643.25	26.80	105.6	5.65	5.05	119
644.25	26.84	70.0	0.64	0.46	98
646.25	26.93	90.2	5.19	4.69	90
647.25	26.97	102.3	6.18	5.48	106
649.00	27.04	113.8	6.95	6.03	75
650.00	27.08	114.0	6.98	6.06	75
652.00	27.17	114.7	7.10	6.15	89
653.00	27.21	120.4	7.52	6.48	80
654.00	27.25	98.7	6.67	5.66	39
655.00	27.29	106.0	6.66	5.72	69
656.00	27.33	120.1	7.49	6.44	77
658.00	27.42	107.7	6.59	5.64	93
659.00	27.46	127.4	7.63	6.61	104
660.00	27.50	119.9	7.32	6.34	103
661.00	27.54	109.7	6.59	5.75	92
662.00	27.58	111.6	6.68	5.81	91
664.00	27.67	99.1	5.73	5.08	83
665.00	27.71	99.5	5.81	5.20	82
666.00	27.75	94.3	5.54	4.92	66
667.00	27.79	81.1	4.72	4.22	66
668.00	27.83	81.2	4.65	4.17	65

Table 1. DUVAS Results from Second Steam Pass

Total Run Hours	Total Run Days	Relative Total Aromatics Conc.	Relative m/p-Xylene Conc.	Relative o-Xylene Conc.	Benzene Conc. (ppm)
670.00	27.92	73.5	4.44	3.95	60
673.00	28.04	108.6	6.63	5.81	51
675.00	28.13	103.4	6.52	5.68	74
676.00	28.17	100.2	6.46	5.65	50
677.00	28.21	99.6	6.39	5.56	52
678.00	28.25	106.4	6.75	5.90	52
679.00	28.29	108.7	6.90	6.02	65
682.00	28.42	104.3	6.42	5.55	72
683.00	28.46	102.4	6.32	5.47	70
684.00	28.50	99.4	6.02	5.22	65
685.00	28.54	87.1	5.21	4.59	66
687.00	28.63	73.6	4.43	4.02	50
688.00	28.67	80.6	4.65	4.19	58
689.00	28.71	76.9	4.49	4.03	54
690.00	28.75	75.2	4.41	3.96	64
691.00	28.79	75.1	4.30	3.84	114
693.00	28.88	69.5	4.05	3.61	61
694.00	28.92	68.3	3.93	3.52	75
697.00	29.04	90.5	5.03	4.48	61
700.00	29.17	89.5	5.48	4.81	71
701.00	29.21	92.3	5.62	4.95	44
702.25	29.26	99.0	5.93	5.21	69
703.00	29.29	99.7	6.00	5.29	70
704.75	29.36	96.1	5.69	4.99	87
707.00	29.46	94.5	5.18	4.65	111
707.50	29.48	94.6	5.08	4.58	117
708.00	29.50	90.2	4.91	4.41	93
708.50	29.52	90.4	4.77	4.31	92
709.00	29.54	92.6	4.85	4.37	123
709.50	29.56	91.5	4.85	4.36	122
711.00	29.63	82.8	4.25	3.91	110
711.50	29.65	84.9	4.29	3.93	122
712.00	29.67	85.8	4.34	3.99	114
713.00	29.71	85.2	4.29	3.95	123
713.50	29.73	85.7	4.28	3.97	123

Table 1. DUVAS Results from Second Steam Pass

Total Run Hours	Total Run Days	Relative Total Aromatics Conc.	Relative m/p-Xylene Conc.	Relative o-Xylene Conc.	Benzene Conc. (ppm)
714.00	29.75	87.4	4.39	4.03	131
714.50	29.77	85.4	4.20	3.90	132
715.00	29.79	86.8	4.32	3.98	128
716.50	29.85	83.6	3.97	3.69	144
717.00	29.88	82.3	3.83	3.55	159
717.50	29.90	85.2	4.01	3.71	152
718.00	29.92	92.2	4.47	4.03	144
720.50	30.02	108.7	5.55	5.07	156
722.00	30.08	157.0	8.98	7.84	160
722.50	30.10	137.9	7.72	6.85	179
724.00	30.17	155.7	8.95	7.99	175
724.50	30.19	157.5	9.10	8.09	175
725.00	30.21	169.2	10.01	8.87	176
726.75	30.28	159.1	9.05	8.00	185
727.75	30.32	160.9	9.13	8.07	189
729.50	30.40	121.4	6.18	5.56	183
731.00	30.46	115.9	6.22	5.55	140
734.00	30.58	96.0	4.47	4.18	151
734.50	30.60	95.9	4.45	4.14	163
735.00	30.63	96.7	4.47	4.16	163
735.50	30.65	98.1	4.47	4.17	154
737.00	30.71	92.2	4.13	3.89	173
737.50	30.73	96.5	4.45	4.12	174
738.00	30.75	96.0	4.34	4.04	171
738.50	30.77	95.6	4.32	4.05	171
739.00	30.79	93.7	4.21	3.93	170
739.50	30.81	94.4	4.24	3.97	157
740.00	30.83	94.3	4.26	3.97	168
740.50	30.85	93.3	4.19	3.92	172
742.00	30.92	92.7	4.10	3.87	184
742.50	30.94	101.9	4.72	4.40	175
743.00	30.96	116.2	5.70	5.28	177
743.50	30.98	121.2	6.16	5.66	160
744.00	31.00	125.8	6.47	5.94	176
744.50	31.02	129.5	6.85	6.28	161

Table 1. DUVAS Results from Second Steam Pass

Total Run Hours	Total Run Days	Relative Total Aromatics Conc.	Relative m/p-Xylene Conc.	Relative o-Xylene Conc.	Benzene Conc. (ppm)
746.00	31.08	131.9	6.98	6.26	152
748.00	31.17	125.5	6.58	5.89	160
748.29	31.18	127.5	6.74	6.01	166
748.57	31.19	126.3	6.66	5.93	164
749.14	31.21	118.4	6.13	5.52	163
749.43	31.23	126.5	6.63	5.94	164
750.50	31.27	127.8	6.88	6.10	176
752.00	31.33	127.1	6.84	6.10	155
754.00	31.42	119.1	6.28	5.60	155
758.00	31.58	115.5	5.89	5.32	156
759.00	31.63	114.6	5.76	5.23	171
761.00	31.71	113.4	5.66	5.11	181
762.00	31.75	114.9	5.80	5.22	181
763.00	31.79	117.6	6.02	5.45	158
765.00	31.88	106.8	5.35	4.87	157
766.00	31.92	108.3	5.53	5.01	139
767.00	31.96	111.8	5.75	5.22	142
771.50	32.15	120.5	6.53	5.84	150
774.50	32.27	118.3	6.44	5.77	166
775.50	32.31	130.9	7.36	6.46	139
776.50	32.35	134.0	7.52	6.59	158
778.00	32.42	133.6	7.47	6.56	143
779.25	32.47	126.8	7.03	6.19	142
780.25	32.51	123.9	6.71	5.96	132
781.25	32.55	112.5	6.00	5.29	150
783.25	32.64	118.0	6.08	5.50	165
784.25	32.68	117.2	6.07	5.44	139
785.25	32.72	115.2	5.98	5.35	159
787.25	32.80	106.9	5.30	4.88	153
788.25	32.84	102.4	5.11	4.72	162
789.25	32.89	100.8	5.01	4.63	160
793.50	33.06	128.6	7.24	6.41	172
794.50	33.10	125.7	7.14	6.31	128
795.50	33.15	120.8	6.80	6.03	139

Table 1. DUVAS Results from Second Steam Pass

Total Run Hours	Total Run Days	Relative Total Aromatics Conc.	Relative m/p-Xylene Conc.	Relative o-Xylene Conc.	Benzene Conc. (ppm)
796.50	33.19	126.7	7.26	6.38	123
797.50	33.23	124.8	7.21	6.32	141
798.50	33.27	132.9	7.78	6.76	147
801.50	33.40	213.9	8.58	7.65	
802.75	33.45	146.6	8.10	7.07	181
803.75	33.49	138.1	7.71	6.73	140
804.75	33.53	132.2	7.25	6.38	144
806.75	33.61	118.7	6.22	5.57	137
807.75	33.66	121.0	6.39	5.64	136
808.75	33.70	119.2	6.32	5.66	152
810.75	33.78	105.6	5.42	4.90	174
811.75	33.82	108.2	5.53	5.00	136
812.75	33.86	106.6	5.44	4.92	137
814.75	33.95	108.9	5.67	5.10	131
815.75	33.99	108.8	5.81	5.24	152
816.75	34.03	113.4	6.32	5.67	135
819.00	34.13	125.1	7.03	6.13	144
820.00	34.17	130.3	7.50	6.43	144
821.00	34.21	125.4	7.29	6.25	111
823.00	34.29	110.4	6.62	5.63	98
824.00	34.33	117.6	7.05	6.06	97
825.00	34.38	121.2	6.97	6.08	
826.50	34.44	115.2	6.63	5.76	102
827.00	34.46	110.5	6.68	5.81	86
828.00	34.50	110.3	6.40	5.73	104
829.00	34.54	110.3	6.41	5.71	103
831.00	34.63	105.0	5.85	5.11	90
832.00	34.67	100.4	5.76	5.04	90
833.00	34.71	97.5	5.34	4.66	122
835.00	34.79	95.1	5.07	4.65	108
836.00	34.83	97.2	5.27	4.80	
837.00	34.88	95.8	5.18	4.71	104
839.00	34.96	108.1	5.99	5.38	92
840.00	35.00	107.1	6.10	5.44	
841.00	35.04	109.1	6.28	5.60	57

Table 1. DUVAS Results from Second Steam Pass

Total Run Hours	Total Run Days	Relative Total Aromatics Conc.	Relative m/p-Xylene Conc.	Relative o-Xylene Conc.	Benzene Conc. (ppm)
843.00	35.13	108.8	6.12	5.45	
843.50	35.15	111.0	6.33	5.60	
844.00	35.17	108.2	6.32	5.56	75
845.00	35.21	111.1	6.38	5.61	45
847.00	35.29	98.9	5.79	5.08	88
848.00	35.33	105.7	5.98	5.27	92
848.50	35.35	99.6	5.59	4.96	187
849.00	35.38	100.9	5.70	5.07	
850.50	35.44	90.9	5.17	4.64	85
851.00	35.46	94.0	5.19	4.60	94
852.00	35.50	96.0	5.28	4.64	
853.00	35.54	95.4	5.11	4.62	93
855.00	35.63	86.1	4.81	4.28	99
856.00	35.67	87.4	4.66	4.25	106
858.00	35.75	81.7	4.15	3.80	113
859.00	35.79	83.3	4.27	3.82	111
860.00	35.83	81.0	4.18	3.93	139
862.00	35.92	71.8	3.79	3.40	94
865.50	36.06	87.4	4.81	4.33	85
866.50	36.10	91.1	5.08	4.57	140
868.25	36.18	91.4	5.20	4.62	115
870.75	36.28	91.9	5.28	4.69	121
871.25	36.30	99.0	5.70	5.05	56
872.75	36.36	97.5	5.70	4.99	63
874.00	36.42	85.3	4.79	4.28	92
875.75	36.49	89.2	4.98	4.55	62
876.25	36.51	93.4	5.26	4.57	86
876.75	36.53	94.1	5.23	4.57	85
877.25	36.55	92.2	5.25	4.57	106
877.75	36.57	89.0	4.95	4.30	105
878.75	36.61	90.1	4.88	4.31	89
879.25	36.64	88.6	4.89	4.27	86
879.75	36.66	79.5	4.33	3.90	
880.25	36.68	87.7	4.79	4.15	70
880.75	36.70	75.7	4.10	3.71	69

Table 1. DUVAS Results from Second Steam Pass

Total Run Hours	Total Run Days	Relative Total Aromatics Conc.	Relative m/p-Xylene Conc.	Relative o-Xylene Conc.	Benzene Conc. (ppm)
881.25	36.72	90.6	4.95	4.32	100
881.75	36.74	90.9	5.11	4.41	102
882.25	36.76	90.3	4.94	4.29	87
883.25	36.80	99.6	5.51	4.69	57
883.75	36.82	100.1	5.50	4.68	58
884.25	36.84	99.6	5.46	4.65	53
884.75	36.86	99.3	5.48	4.64	52
885.25	36.89	98.1	5.38	4.58	47
885.75	36.91	97.9	5.29	4.54	47
886.25	36.93	98.0	5.52	4.72	64
886.75	36.95	92.0	5.18	4.62	65
887.25	36.97	96.8	5.62	4.90	90
887.75	36.99	96.7	5.74	4.98	86
890.25	37.09	92.0	5.38	4.78	
891.75	37.16	98.0	5.84	5.07	93
892.25	37.18	104.6	6.49	5.45	83
892.75	37.20	104.7	6.24	5.38	108
893.25	37.22	103.9	6.28	5.35	56
893.75	37.24	102.9	6.24	5.41	37
894.00	37.25	90.1	5.39	4.61	82
894.33	37.26	98.6	6.04	5.30	107
894.66	37.28	104.4	6.40	5.62	87
895.33	37.31	104.9	6.34	5.44	107
895.66	37.32	102.1	6.28	5.40	106
897.25	37.39	96.7	5.58	4.95	75
897.75	37.41	90.9	5.48	4.78	75
898.25	37.43	90.2	5.39	4.75	49
899.25	37.47	93.8	5.62	4.93	83
901.25	37.55	78.9	4.65	4.06	65
902.25	37.59	83.4	4.75	4.15	173
903.25	37.64	75.9	4.51	3.91	52
905.25	37.72	65.4	3.71	3.34	84
906.25	37.76	65.8	3.84	3.42	71
907.25	37.80	70.7	3.96	3.56	57
909.25	37.89	73.4	4.10	3.65	104

Table 1. DUVAS Results from Second Steam Pass

Total Run Hours	Total Run Days	Relative Total Aromatics Conc.	Relative m/p-Xylene Conc.	Relative o-Xylene Conc.	Benzene Conc. (ppm)
910.25	37.93	73.7	4.14	3.64	71
911.25	37.97	79.2	4.68	4.14	64
917.25	38.22	73.8	4.77	4.11	29
917.75	38.24	79.4	5.09	4.38	30
925.75	38.57	57.5	3.72	3.18	43
926.25	38.59	64.0	4.27	3.47	38
926.75	38.61	64.7	3.97	3.40	38
927.25	38.64	67.6	4.05	3.50	
927.75	38.66	63.8	3.97	3.42	48
929.25	38.72	65.2	3.99	3.52	46
929.75	38.74	72.9	4.57	3.96	46
930.25	38.76	73.5	4.50	3.85	52
930.75	38.78	79.4	4.80	4.16	51
931.25	38.80	75.7	4.54	3.91	61
931.75	38.82	78.7	4.79	4.10	61
933.25	38.89	64.1	3.67	3.29	74
933.75	38.91	73.1	4.23	3.76	75
934.25	38.93	77.5	4.33	3.88	92
934.75	38.95	83.4	4.96	4.38	93
935.25	38.97	90.5	5.43	4.79	83
937.50	39.06	108.4	6.51	5.65	100
938.50	39.10	113.6	6.78	5.88	122
939.50	39.15	121.9	7.35	6.34	119
941.50	39.23	120.9	7.23	6.26	131
942.50	39.27	114.2	7.07	6.07	109
943.50	39.31	117.0	7.16	6.16	113
945.50	39.40	110.5	6.63	5.74	127
946.50	39.44	116.4	6.97	6.05	130
947.50	39.48	111.6	6.61	5.74	118
949.50	39.56	102.1	5.76	5.11	125
951.50	39.65	106.9	6.05	5.29	120
953.50	39.73	91.3	4.87	4.47	158
954.00	39.75	98.3	5.24	4.63	125

Table 1. DUVAS Results from Second Steam Pass

Total Run Hours	Total Run Days	Relative Total Aromatics Conc.	Relative m/p-Xylene Conc.	Relative o-Xylene Conc.	Benzene Conc. (ppm)
954.50	39.77	95.8	5.07	4.54	124
955.00	39.79	97.1	5.14	4.61	136
955.50	39.81	97.0	5.11	4.58	135
957.00	39.88	91.5	4.68	4.19	136
957.50	39.90	93.7	4.68	4.21	143
958.00	39.92	88.9	4.50	4.09	143
963.00	40.13	105.9	5.73	5.14	143
964.50	40.19	96.4	5.42	4.78	117
965.50	40.23	113.5	6.27	5.54	137
966.00	40.25	114.0	6.36	5.58	138
966.50	40.27	113.7	6.24	5.55	136
967.00	40.29	115.9	6.44	5.68	149
968.50	40.35	103.4	5.58	4.94	148
969.00	40.38	110.4	5.99	5.31	149
969.50	40.40	105.5	5.84	5.17	122
970.00	40.42	111.1	6.16	5.47	122
970.50	40.44	113.5	6.16	5.50	138
971.00	40.46	113.0	6.16	5.42	137
972.50	40.52	96.3	4.90	4.43	178
973.00	40.54	100.5	5.13	4.65	161
973.50	40.56	99.5	5.07	4.58	160
974.00	40.58	100.5	5.07	4.60	157
974.50	40.60	100.8	5.14	4.59	155
975.00	40.63	102.4	5.26	4.70	151
976.50	40.69	91.6	4.49	4.12	169
977.00	40.71	95.3	4.71	4.33	161
977.50	40.73	95.0	4.66	4.26	150
978.00	40.75	93.8	4.56	4.18	170
978.50	40.77	95.0	4.57	4.17	158
979.00	40.79	98.9	4.84	4.38	158
980.50	40.85	93.8	4.46	4.14	168
981.00	40.88	94.8	4.52	4.19	168
981.50	40.90	95.0	4.54	4.18	160
982.00	40.92	94.6	4.45	4.15	160

Table 1. DUVAS Results from Second Steam Pass

Total Run Hours	Total Run Days	Relative Total Aromatics Conc.	Relative m/p-Xylene Conc.	Relative o-Xylene Conc.	Benzene Conc. (ppm)
982.50	40.94	95.8	4.52	4.20	154
983.00	40.96	106.8	5.40	4.96	151
984.50	41.02	110.7	5.74	5.30	152
985.00	41.04	113.6	6.04	5.54	154
985.50	41.06	114.7	6.13	5.64	145
986.00	41.08	115.1	6.17	5.68	155
986.50	41.10	114.0	6.12	5.62	155
989.50	41.23	104.3	5.72	4.97	146
990.00	41.25	125.6	7.00	6.15	148
990.50	41.27	127.0	7.11	6.23	131
991.00	41.29	128.6	7.18	6.34	142
991.50	41.31	127.8	7.10	6.18	141
992.00	41.33	129.5	7.19	6.31	156
993.50	41.40	89.0	5.17	4.85	143
994.00	41.42	95.6	5.58	5.19	150
994.50	41.44	95.8	5.58	5.16	149
995.00	41.46	95.0	5.52	5.12	153
997.00	41.54	109.2	5.49	4.84	162
1000.00	41.67	103.3	5.78	6.33	80
1000.50	41.69	87.2	8.34	5.97	80
1001.00	41.71	95.1	9.07	5.90	82
1001.50	41.73	97.9	9.31	6.15	75
1002.00	41.75	98.8	9.31	6.21	79
1002.50	41.77	101.3	9.41	6.29	78
1004.00	41.83	102.4	9.48	6.30	82
1004.50	41.85	105.4	9.65	6.43	72
1005.00	41.88	105.3	9.59	6.39	88
1005.50	41.90	103.5	9.46	6.30	81
1006.00	41.92	133.2	8.76	5.78	72
1006.50	41.94	136.9	9.13	6.10	79
1008.00	42.00	110.2	10.42	7.06	103
1008.50	42.02	118.4	11.07	8.41	103
1021.00	42.54	88.5	4.64	4.37	162
1021.50	42.56	112.6	5.63	5.27	148

Table 1. DUVAS Results from Second Steam Pass

Total Run Hours	Total Run Days	Relative Total Aromatics Conc.	Relative m/p-Xylene Conc.	Relative o-Xylene Conc.	Benzene Conc. (ppm)
1022.00	42.58	114.0	5.71	5.35	147
1022.50	42.60	112.6	5.62	5.29	164
1023.00	42.63	110.4	5.49	5.17	152
1023.50	42.65	111.2	5.52	5.19	151
1025.00	42.71	92.1	4.18	4.16	170
1025.50	42.73	97.2	4.52	4.47	142
1026.00	42.75	97.3	4.49	4.44	142
1026.50	42.77	96.8	4.51	4.45	155
1027.00	42.79	97.0	4.47	4.41	151
1027.50	42.81	99.0	4.65	4.54	150
1029.00	42.88	92.1	4.14	4.09	120
1029.50	42.90	100.5	4.64	4.50	140
1030.00	42.92	101.3	4.70	4.55	133
1030.50	42.94	100.5	4.66	4.52	144
1031.00	42.96	111.8	5.44	5.20	132
1031.50	42.98	114.0	5.67	5.41	117
1032.75	43.03	100.2	5.02	4.89	114
1035.00	43.13	115.6	6.03	5.68	135
1035.50	43.15	119.2	6.36	5.91	132
1036.00	43.17	122.7	6.57	6.10	129
1036.50	43.19	121.7	6.53	6.06	151
1037.00	43.21	121.9	6.57	6.11	135
1037.50	43.23	121.6	6.57	6.08	136
1039.00	43.29	122.2	6.64	6.10	139
1039.50	43.31	124.8	6.86	6.27	143
1040.00	43.33	126.6	6.99	6.39	136
1040.50	43.35	127.4	7.04	6.41	120
1041.00	43.38	127.0	6.95	6.35	124
1041.50	43.40	126.2	6.95	6.31	124
1043.00	43.46	115.7	6.04	5.62	126
1043.50	43.48	115.4	6.01	5.59	125
1044.00	43.50	112.5	5.76	5.37	127
1044.50	43.52	113.8	5.80	5.43	126
1046.00	43.58	95.4	4.62	4.47	128
1048.00	43.67	94.6	4.50	4.38	126

Table 1. DUVAS Results from Second Steam Pass

Total Run Hours	Total Run Days	Relative Total Aromatics Conc.	Relative m/p-Xylene Conc.	Relative o-Xylene Conc.	Benzene Conc. (ppm)
1052.00	43.83	94.2	4.54	4.37	125
1052.50	43.85	96.7	4.69	4.48	125
1053.00	43.88	101.3	4.94	4.67	111
1053.50	43.90	101.8	4.99	4.68	100
1054.00	43.92	104.8	5.20	4.88	113
1054.50	43.94	104.9	5.22	4.84	107
1056.00	44.00	101.0	5.06	4.83	119
1056.50	44.02	105.7	5.40	5.17	106
1057.00	44.04	107.2	5.56	5.30	121
1057.50	44.06	106.8	5.58	5.34	116
1060.50	44.19	112.4	6.02	5.54	131
1061.00	44.21	119.9	6.61	6.04	133
1061.50	44.23	122.2	6.66	6.11	113
1062.00	44.25	122.7	6.78	6.16	114
1062.50	44.27	123.3	6.80	6.20	101
1063.00	44.29	122.9	6.81	6.21	94
1065.00	44.38	91.8	5.75	5.02	92
1068.00	44.50	105.5	5.24	4.97	108
1068.50	44.52	108.7	5.54	5.21	129
1069.00	44.54	97.7	4.79	4.72	128
1069.50	44.56	99.0	4.96	4.78	127
1070.00	44.58	98.1	4.91	4.74	128
1070.50	44.60	99.2	4.98	4.79	126
1072.00	44.67	96.0	4.71	4.53	111
1072.50	44.69	96.3	4.81	4.61	106
1073.00	44.71	97.0	4.74	4.56	113
1073.50	44.73	99.1	4.92	4.69	101
1074.00	44.75	96.1	4.79	4.56	120
1074.50	44.77	96.1	4.72	4.48	107
1076.00	44.83	91.7	4.50	4.36	99
1076.50	44.85	92.0	4.50	4.33	113
1077.00	44.88	93.8	4.62	4.43	114
1077.50	44.90	96.7	4.77	4.57	114
1078.00	44.92	96.8	4.80	4.59	104
1078.50	44.94	96.6	4.79	4.63	103

Table 1. DUVAS Results from Second Steam Pass

Total Run Hours	Total Run Days	Relative Total Aromatics Conc.	Relative m/p-Xylene Conc.	Relative o-Xylene Conc.	Benzene Conc. (ppm)
1080.00	45.00	99.8	5.16	4.98	106
1080.50	45.02	102.5	5.38	5.17	115
1081.00	45.04	102.0	5.47	5.23	117
1081.50	45.06	101.6	5.43	5.26	112
1085.50	45.23	114.4	6.51	5.86	105
1086.00	45.25	116.2	6.72	6.03	106
1086.50	45.27	117.6	6.80	6.11	89
1087.00	45.29	119.5	6.90	6.17	118
1087.50	45.31	119.7	6.85	6.13	128
1088.00	45.33	118.7	6.91	6.19	118
1089.50	45.40	105.8	5.88	5.38	93
1090.00	45.42	109.0	6.13	5.59	94
1090.50	45.44	109.9	6.16	5.63	109
1091.00	45.46	108.8	6.11	5.59	109
1091.50	45.48	106.1	5.84	5.35	127
1092.00	45.50	102.9	5.62	5.18	115
1093.50	45.56	92.6	4.77	4.56	99
1094.00	45.58	92.8	4.83	4.58	99
1094.50	45.60	92.9	4.82	4.57	100
1095.00	45.63	86.9	4.53	4.34	100
1095.50	45.65	87.7	4.56	4.34	90
1096.00	45.67	85.0	4.44	4.33	90
1097.50	45.73	86.1	4.43	4.23	104
1098.00	45.75	86.9	4.48	4.27	104
1098.50	45.77	87.2	4.47	4.25	95
1099.00	45.79	87.9	4.54	4.29	108
1099.50	45.81	88.6	4.57	4.30	108
1101.50	45.90	86.4	4.35	4.22	100
1102.00	45.92	87.3	4.40	4.25	100
1102.50	45.94	88.8	4.48	4.33	116
1103.00	45.96	91.2	4.67	4.49	96
1103.50	45.98	94.7	5.00	4.80	89
1105.50	46.06	96.8	5.28	5.00	103
1106.00	46.08	90.4	5.07	4.73	88
1106.50	46.10	102.0	5.46	5.22	85

Table 1. DUVAS Results from Second Steam Pass

Total Run Hours	Total Run Days	Relative Total Aromatics Conc.	Relative m/p-Xylene Conc.	Relative o-Xylene Conc.	Benzene Conc. (ppm)
1108.00	46.17	106.4	5.89	5.54	86
1108.50	46.19	108.5	6.07	5.66	109
1109.00	46.21	108.8	6.15	5.72	110
1109.50	46.23	110.4	6.25	5.77	113
1110.00	46.25	111.1	6.32	5.85	105
1110.50	46.27	109.6	6.17	5.73	105
1112.00	46.33	104.8	5.95	5.42	87
1112.50	46.35	107.7	6.09	5.58	87
1113.00	46.38	109.2	6.27	5.71	98
1113.50	46.40	109.5	6.29	5.71	110
1114.00	46.42	108.8	6.23	5.66	102
1114.50	46.44	107.6	6.15	5.60	101
1116.00	46.50	96.3	5.18	4.83	104
1117.00	46.54	88.7	4.64	4.49	103
1117.50	46.56	87.6	4.60	4.41	96
1118.00	46.58	88.3	4.62	4.44	96
1118.50	46.60	88.2	4.51	4.40	95
1120.00	46.67	86.0	4.41	4.26	104
1120.50	46.69	87.5	4.52	4.34	107
1121.00	46.71	87.8	4.49	4.31	101
1121.50	46.73	86.7	4.46	4.30	101
1122.00	46.75	88.0	4.50	4.34	113
1122.50	46.77	89.1	4.55	4.35	112
1124.00	46.83	86.4	4.41	4.21	87
1124.50	46.85	85.9	4.35	4.17	87
1125.00	46.88	88.4	4.54	4.30	87
1125.50	46.90	88.9	4.59	4.35	99
1126.00	46.92	88.3	4.53	4.29	99
1126.50	46.94	94.0	4.92	4.62	92
1128.00	47.00	92.2	5.02	4.81	112
1129.50	47.06	94.8	5.32	4.98	94
1130.00	47.08	96.0	5.40	5.09	95
1130.50	47.10	95.1	5.34	5.08	80
1131.00	47.13	96.6	5.43	5.14	90
1131.50	47.15	99.8	5.68	5.35	90

Table 1. DUVAS Results from Second Steam Pass

Total Run Hours	Total Run Days	Relative Total Aromatics Conc.	Relative m/p-Xylene Conc.	Relative o-Xylene Conc.	Benzene Conc. (ppm)
1132.00	47.17	102.3	5.84	5.48	88
1133.50	47.23	105.4	6.15	5.59	78
1134.00	47.25	105.8	6.21	5.64	78
1134.50	47.27	108.0	6.26	5.69	71
1135.00	47.29	85.3	5.49	4.90	71
1135.50	47.31	95.5	5.74	5.19	78
1136.00	47.33	102.9	6.03	5.46	79
1136.50	47.35	44.6	3.16	2.63	33

