
Air



Letterpress / Offset Lithographic Industry Condenser / ESP

Emission Test Report Lehigh Steck-Warlick Dallas, Texas



° EMISSION TEST REPORT °

METHOD DEVELOPMENT AND TESTING FOR
LETTERPRESS/OFFSET LITHOGRAPHIC INDUSTRY
Lehigh Steck-Warlick Company
Dallas, Texas
ESED 80/48

by

PEDCo Environmental, Inc.
11499 Chester Road
Cincinnati, Ohio 45246

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SECTION 1

INTRODUCTION

During the week of March 23, 1981, personnel from PEDCo Environmental, Inc., conducted emission tests at the offset lithographic printing plant of Lehigh Steck-Warlick Company in Dallas, Texas. Tests were conducted to determine the efficiency of a condenser/electrostatic precipitator (ESP) control system used to control hydrocarbon emissions from the press dryer.

Hydrocarbon sampling was conducted by means of an Environmental Protection Agency (EPA) Method 5 sample train with a tee at the back of the heated filter from which a Method 25 sample was extracted. Samples were collected isokinetically, and Methods 5 and 25 sampling procedures were followed in the operation of the separate portions of the sample train. This procedure was used in order to limit bias that could result from any aerosol or particulate matter present in the gas streams.

During the testing, process data were monitored and several process samples were collected. Process samples included fountain solutions analyzed for percent isopropanol, process ink analyzed for density and percent volatile content, and printed signatures analyzed for the quantity of ink solvent remaining in the finished product.

During this week, numerous problems were encountered in the press operation. Testing was conducted on only two days, and both tests were run with the press at a lower than normal operating speed. Press speeds during the two tests were 259 and 305 m/min (850 and 1000 ft/min). Normal operating speed ranges from 427 to 488 m/min (1400 and 1600 ft/min).

Because these tests were run at lower than normal press speeds, the data are not representative and cannot be used to set standards for the industry. While the EPA test was in progress, a similar test was conducted by Pollution Control Science, Inc. (PCS). This effort was sponsored by the Sun Chemical Corporation and the Graphic Arts Technical Foundation and consisted of filtered Method 25 samples taken from a single point in the inlet and outlet ducts. The samples were taken at the beginning and end of the EPA runs, which means that there is no corresponding PCS data for the middle portion of the EPA test.

The following individuals were present to observe the sampling program:

- Mr. Frank Clay - EMB Task Manager
- Mr. Theodore Michaelis - Engineering Science Process Officer
- Mr. J.D. Boehlert - Sun Chemical Corporation
- Mr. J.L. Zburovsky - Sun Chemical Corporation

These data will be evaluated for use in a Control Techniques Guideline document for the letterpress/offset lithographic printing industry.

SECTION 2

SUMMARY OF RESULTS

2.1 EMISSION TEST RESULTS

Gas Stream Flow Rate and Composition

Table 2-1 lists gas stream temperatures and flow rates that were measured by EPA Methods 1* and 2* prior to particulate sampling. Gas stream temperatures at the inlet test site averaged 150°C (302°F) and 161°C (322°F) during the first two days. After these measurements were taken, it was discovered that a damper controlling the amount of dilution air added to the dryer discharge had been inadvertantly left closed. Plant personnel corrected the problem, and in subsequent velocity traverses the recorded inlet temperatures were 73°C (163°F) and 86°C (186°F). The outlet gas temperature dropped from 42°C (107°F) on the first day to 30°C (86°F) and 32°C (90°F) on the following days. This temperature drop was due to adjustments made on the control system by a representative of United Air Specialists, who was on hand to inspect the condenser/ESP operation.

Gas flow rates were adjusted to standard conditions based on the assumed moisture contents indicated in Table 2-1.

* Federal Register, Vol. 42, No. 160, August 18, 1977.

TABLE 2-1. VELOCITY TRAVERSE DATA

Date, 1981	Time, 24-h	Gas stream temperature				Gas stream flow rate standard conditions ^a			
		Inlet		Outlet		Inlet		Outlet	
		°C	°F	°C	°F	dscmh	dscfh	dscmh	dscfh
3/24	1035	150	302	42	107	7,000	247,200	10,433	368,460
3/25	0730	161	322	30	86	6,826	241,080	9,778	345,300
3/26	1400	73	163	32	90	9,664	341,280	12,550	443,220
3/28	0830	86	186	32	89	9,893	349,380	12,441	439,380

^aStandard conditions: 760 mm Hg, 20°C (29.92 in. Hg, 68°F), adjusted to dry basis with the following assumed moisture contents:
 3/24, 25/81: Inlet, 3.5%; Outlet, 3.0%; 3/26/81: Inlet, 3.0%; Outlet 3.0%;
 3/28/81: Inlet, 3.0%; Outlet, 1.5%.

Table 2-2 lists the gas stream flow rate and composition measured during the particulate and hydrocarbon sampling. At the inlet site, the flow rate was measured at 10,275 dry standard cubic meters per hour (dscmh) (362,839 dscfh) during Test 1 and 10,296 dscmh during Test 2. Gas temperatures were 73° and 81°C (163° and 178°F), respectively. Orsat analysis at the inlet site showed 0.4 percent carbon dioxide and 20 percent oxygen. At the outlet site, the flow rate was measured at 12,999 dscmh (459,065 dscfh) for Test 1 and 11,751 dscmh (414,984 dscfh) for Test 2. Outlet temperatures were 32° and 34°C (89° and 93°F) for the two tests. Orsat analysis showed 0.2 percent carbon dioxide at the outlet site. The difference between the inlet and outlet flow rates is due to air leakage around the fan which was located after the ESP and before the outlet sampling location. Some leaks were sealed for the second test.

All calculations for hydrocarbon and particulate emission rates were based on flows measured during the test. These data are presented in Table 2-2.

Hydrocarbon Emissions from Method 25 Analysis

Each test at the inlet and outlet of the condenser/ESP consisted of three separate particulate traverses. During each traverse, a Method 25* sample was collected from the back of the Method 5** filter for hydrocarbon analysis. Table 2-3 summarizes the data from the Method 25 sampling.

* Federal Register, Vol. 45, No. 194, October 3, 1980.

** Federal Register, Vol. 42, No. 160, August 18, 1977.

TABLE 2-2. GAS STREAM CONDITIONS MEASURED DURING PARTICULATE AND HYDROCARBON TESTS

Test No.	Sample location	Gas stream temperature		Gas absolute pressure		Actual flow rate ^a		Flow rate at standard conditions ^b		Composition,		
		°C	°F	mm Hg	in. Hg	acmh	acfh	dscmh	dscfh	% H ₂ O	% O ₂	% CO ₂
LWI-51	Inlet	73	163	756.8	29.80	12,402	437,987	10,275	362,839	1.89	20.0	0.4
LW0-51	Outlet	32	89	762.1	30.01	13,694	483,606	12,999	459,065	1.51	20.2	0.2
LWI-52	Inlet	81	178	750.9	29.56	12,967	457,911	10,296	363,589	2.90	20.0	0.4
LW0-52	Outlet	34	93	755.7	29.75	12,660	447,072	11,751	414,984	2.23	20.2	0.2

^aActual flow rate at stack temperature and pressure.

^bFlow rate adjusted to standard conditions: 760 mm Hg, 20°C (29.92 in. Hg, 68°F); dry basis.

TABLE 2-3. METHOD 25 DATA SUMMARY ^a

Test No.	Hydrocarbon concentration as CH ₄ , ^b ppm		Hydrocarbon mass flow rate as CH ₄ ^c				Control ^d efficiency, %
	Inlet	Outlet	Inlet		Outlet		
			kg/h	lb/h	kg/h	lb/h	
LW-1-1	630	475	4.31	9.50	4.11	9.06	4.6
LW-1-2	902	657	6.17	13.60	5.68	12.52	7.9
LW-1-3	653	755	4.47	9.85	6.53	14.40	
Average	728	629	4.98	10.98	5.44	11.99	
LW-2-1	1319	350	9.04	19.93	2.74	6.04	69.7
LW-2-2	1897	569	13.00	28.66	4.45	9.81	65.8
LW-2-3	1104	600	7.57	16.69	4.69	10.34	38.0
Average	1440	506	9.87	21.76	3.96	8.73	59.9
LW-A ^e	1739	827	11.92	26.28	6.47	14.26	45.7

^a Press speed was less than normal and data should not be used for standard setting.

^b Parts per million by volume measured as methane.

^c Based on dry standard gas flow rates measured during the test period (see Table 2-2) and on the molecular weight of methane: 16 g/g-mole (16 lb/lb-mole)

^d Control efficiency is based on mass emission rates $\frac{\text{kg}_{\text{in}} - \text{kg}_{\text{out}}}{\text{kg}_{\text{in}}} \times 100$.

^e LW-A run as standard Method 25 (single point, constant sampling rate) simultaneous with inlet and outlet runs LW-2-3.

During Test 1, hydrocarbon concentrations at the inlet test site were measured at 630, 902, and 653 ppm as methane with an average concentration of 728 ppm as methane. The equivalent hydrocarbon mass flow rates to the condensers were 4.31, 6.17, and 4.47 kg/h (9.50, 13.60, and 9.8 lb/h) with an average value of 4.98 kg/h (10.98 lb/h).

At the outlet site, Test 1 concentrations were 475, 657, and 755 ppm as methane. The outlet emission rates were 4.11, 5.68, and 6.53 kg/h (9.06, 12.52, 14.40 lb/h) with an average value of 5.44 kg/h (11.99 lb/h).

Based on mass emission rates, the control efficiencies indicated by the results are 4.6 and 7.9 percent for the first and second samples and negative efficiency for the third sample and the average. The press was operating at the rate of 259 m/min (850 ft/min) through most of the test period.

During Test 2, the press speed was 305 m/min (1000 ft/min) and the measured inlet hydrocarbon concentrations were 1319, 1897, and 1104 ppm for an average of 1440 ppm as methane. The average value of 1440 ppm corresponds to a hydrocarbon mass flow of 9.87 kg/h (21.76 lb/h) as methane.

At the outlet, the measured concentrations were 350, 569, and 600 ppm as methane with an average concentration of 506 ppm. The average mass emission rate was 3.96 kg/h (8.73 lb/h).

Based on the average inlet and outlet mass emission rates, the average control efficiency for Test 2 was 59.9 percent. The control efficiencies for Samples 1, 2, and 3 were 69.7, 65.8, and

38.0 percent, respectively. Press speeds during both tests were lower than normal.

Test LW-A consisted of standard Method 25 samples collected simultaneously with the third inlet and outlet samples in Test 2. These samples were collected at a single point in the inlet and outlet stacks using a constant sampling rate of 85 ml/min. No particulate filters were used at either site. The hydrocarbon concentrations measured with standard Method 25 procedures were 1739 ppm at the inlet to the condensers and 827 ppm at the outlet of the ESP. The control efficiency at 45.7 percent was higher than the 38 percent measured with Sample LW-2-3, which was taken from the back of the Method 5 filter.

If the values of the first test were to be consistent with the values of the second test, the inlet concentrations of the first test should be multiplied by a factor of 2. The data, however, have been checked and rechecked and samples were re-analyzed to check results. The initial values remain unchanged.

The procedure of collecting Method 25 samples from the back of a Method 5 filter is an innovation. Data on the precision and accuracy expected from this sampling procedure has not yet been compiled and published by the EPA. In reviewing the data in Table 2-3, it appears that the variance in the measured concentrations for both tests is about +20 percent. This variance may be partly due to the variance in actual stack conditions and partly due to the inherent precision of the test procedure. Thus, the negative efficiency indicated by the data in Test 1 is

probably more a reflection of the precision of the test method than the actual operating conditions. The actual efficiency is probably low but positive. Based on the variance in the data, the true efficiency could be as high as 10 to 15 percent or as low as the 5 percent indicated by Tests LW-1-1 and LW-1-2. The data from Test 2 show about the same variance as measured efficiency ranges from 69.7 percent to a low of 38.0 percent.

Appendix B contains field data sheets for the velocity traverses and Method 25 sampling. Appendix C contains all laboratory results. Appendix D contains a complete description of the sampling and analytical procedures.

Isopropanol Content

Isopropanol is used as a roll wetting agent in the press fountain solutions and as a general solvent for cleaning around the press. To determine the amount of isopropanol vented in the press dryer discharge, samples were collected at each site and analyzed for isopropanol content. Table 2-4 gives the results of these analyses.

During each particulate test, an evacuated stainless steel tank was used to collect the samples. A stainless steel probe line with an outside diameter (O.D.) of 0.635 cm was used. A needle valve was placed between the tank and the probe line to control sample flow rate. In analyzing these samples, several light hydrocarbon peaks were included in the total isopropanol content (see Section 4.4). This was based on the assumption that the light hydrocarbons present resulted from chemical reactions of the isopropanol in the dryer.

TABLE 2-4. ISOPROPANOL CONTENT OF THE EMISSION STREAM

Test No.	Isopropanol concentration		Equivalent concentration as methane,		Percent of total hydrocarbon ^a		Isopropanol emission rate ^b			
	Inlet, ppm ^c	Outlet, ppm ^c	Inlet, ppm ^d	Outlet, ppm ^d	Inlet, %	Outlet, %	Inlet		Outlet	
							kg/h	lb/h	kg/h	lb/h
LW-1	88	24	264	72	36.3	11.4	2.25	4.98	0.78	1.72
LW-2	117	86	351	258	24.4	51.0	3.01	6.64	2.53	5.58

^aThe isopropanol concentration as methane compared with the average total hydrocarbon concentration as methane (see Table 2-3) for the corresponding test number.

^bBased on dry standard flow rate measured during the test and on the molecular weight of isopropanol: 60.09 g/g-mole.

^cParts per million by volume as isopropanol.

^dBasis: 3 moles of methane formed per mole of isopropanol.

At the inlet site, isopropanol concentrations were 88 and 117 ppm as isopropanol. For comparison to the Method 25 data, the equivalent concentrations if measured as methane would be 264 and 351 ppm. Thus the alcohol content was 36.3 percent of the total hydrocarbon concentration measured with Method 25 for Test 1 and 24.4 percent for Test 2. Based on the molecular weight of isopropanol (60.09 g/g-mole), mass flow rates were 2.26 kg/h (4.98 lb/h) for Test 1 and 3.01 kg/h (6.64 lb/h) for Test 2.

At the outlet site, isopropanol concentrations were 24 ppm and 86 ppm as isopropanol. The equivalent concentrations as methane would be 72 and 258 ppm. The mass emission rates of isopropanol were 0.78 kg/h (1.72 lb/h) in Test 1 and 2.53 kg/h (5.58 lb/h) for Test 2.

During Test 1 at the outlet site, the needle valve in the sample train became partially plugged, thus reducing the sampling rate. Although the total sample volume was about the same as the other samples, the plugged valve and reduced sample rate may have affected the amount of isopropanol collected. This may account for the lower than expected value of isopropanol found in this test (24 ppm).

Isopropanol would reduce the control efficiency of the control system operation because isopropanol has a much lower boiling point than the ink solvent and would therefore be less condensable at the condenser operating temperature. In the second test where the measured efficiency was positive, the control efficiency would change from 59.9 percent, based on

average total hydrocarbon content, to 74.0 percent, if the alcohol content were subtracted from the total hydrocarbon at the inlet and outlet. In Test 2 the hydrocarbon emission rates corrected by subtracting the isopropanol content would be 7.43 kg/h (16.38 lb/h) at the inlet and 1.93 kg/h (4.26 lb/h) at the outlet.

Method 5 Data Summary

Table 2-5 summarizes the data obtained from the Method 5 sampling train. In all cases, the amount of material collected was extremely low. Method 5 filters were used through both tests. At the inlet site, the total filter catch was only 0.8 mg in 7.42 standard cubic meters sampled (262.030 scf). At the outlet site, the filter catch was zero in 6.535 scm (230.768 scf). Condensible organic material ranged from 11.9 mg for Test 1 to 43.7 mg for Test 2 at the inlet. At the outlet site, the condensible organic catches were 22.5 mg Test 1 and 8.7 mg in Test 2. Impinger contents were recovered after each test.

In no case was there sufficient material to ensure an accurate recovery and weighing. Therefore, the only conclusion indicated by the Method 5 data is that the particulate and aerosol content of the gas stream was negligible.

Data in Table 2-5 do not include particulate catch from the toluene rinse of the front-half glassware and probe. These rinses were shipped to the Emission Measurement Branch laboratory for analysis. No particulate could be observed by visual inspection of the rinses.

TABLE 2-5. METHOD 5 DATA SUMMARY

Test date, 1981	Test No.	Sample location	Filterable ^a particulate		Condensible organics		Condensible inorganics	
			kg/h	lb/h	kg/h	lb/h	kg/h	lb/h
3/26	LWI-5-1	Inlet	0.001	0.002	0.033	0.073	0.009	0.020
3/26	LWO-5-1	Outlet	0.000	0.000	0.086	0.189	0.006	0.013
3/28	LWI-5-2	Inlet	0.001	0.002	0.120	0.265	0.013	0.029
3/28	LWO-5-2	Outlet	0.000	0.000	0.033	0.072	0.006	0.013

^aDoes not include toluene rinse of front-half glassware and probe.

All Method 5 field data are presented in Appendix B of this report. Values in Table 2-5 were calculated without including the Method 25 sample volumes. These sample volumes ranged from 3 to 4 liters per sample and thus had a negligible effect on the Method 5 calculations. For comparison, calculations were made onsite using the Method 25 sample volumes. These calculations are shown in Appendix B with the field data sheets. Method 5 computer calculations are shown in Appendix A of this report. Laboratory data are presented in Appendix C. A complete description of the sampling and analytical procedures is shown in Appendix D.

2.2 PROCESS DATA

During each test, the process operation was carefully monitored, and operating parameters were recorded every 10 minutes. In addition, an attempt was made to measure the volume of ink dispensed, the quantity of isopropanol used, and the amount of ink solvent and water recovered from the condenser drain.

Table 2-6 summarizes the press operation during the test periods. Press speed during both tests was slower than normal because of problems with the press operation. Test 1 press speed averaged 261 m/min (856 ft/min). During Test 2, the press speed was constant at 305 m/min (1000 ft/min). Normal press speed ranges from 427 to 488 m/min (1400 to 1600 ft/min). Some downtime occurred during each test. Testing was stopped whenever the press went down and resumed only when the press was back on line at full operating speed. Appendix B contains a complete list of downtime and causes along with the field data sheets.

TABLE 2-6. PRESS OPERATION SUMMARY FOR THE LEHIGH STECK-WARLICK COMPANY

Test No.	Date, 1981	Measurement period, 24-h time	Downtime during measurement, min.	Total operating time, min.	Signature count, signatures/minutes recorded	Press speed summary		
						Time period	m/min	ft/min
LW-1	3/26	1500 - 2010	40	270	96,000/245	1500 - 1520	262	860
						1520 - 1545	290	950
						1545 - 2010	259	850
LW-2	3/28	0845 - 1745	141	399	106,820/413	0845 - 1745	305	1000

Table 2-7 lists the average values of the press operating parameters monitored during the testing. Data were recorded every 10 minutes during the test, but no significant variations were observed. Appendix B presents a complete data list along with field data.

During each test, the ambient relative humidity was measured in the press room with a sling psycrometer. In Test 1, the relative humidity averaged 56 percent at 24°C (76°F). In Test 2, the relative humidity was 60 percent at 26°C (79°F).

At the test site, the condenser cooling fluid temperature, the air temperature at the outlet of the final condenser, and the ambient temperature and relative humidity were recorded every 10 minutes during the test. Table 2-8 lists the average values of these parameters for each test. Cooling fluid temperatures were steady for both tests with a variance of only $\pm 1^{\circ}\text{F}$ through the entire test period. The air temperature was also constant, varying $\pm 1^{\circ}\text{C}$.

Process Ink

Process ink is pumped to the press by means of a piston-type displacement pump. The piston covers the cross-sectional area of the ink drum, and ink is forced out of the exit line as the piston is moved into the barrel. The displacement of the pump and the cross-sectional area of the ink drum were measured to determine the volume of ink used during the test periods. Samples of each ink color used were obtained from the supplier, Sun Chemical Corporation, and analyzed to determine the density and the percent volatile content.

TABLE 2-7. PRESS PROCESS DATA SUMMARY^a

Test No.	Date 1981	Web speed		Web temperature		Dryer temperature		Chill roll water					
								Temperature				Flow rate, m ³ /min	
								Inlet		Outlet			
		m/min	ft/min	°C	°F	°C	°F	°C	°F				
LW-1	3/26	261	856	121	249	131	269	17	62	18	64	0.202	
LW-2	3/28	305	1000	103	218	148	298	17	63	19	67	0.204	

^aAverage values reported here. Complete data log is in Appendix B.

TABLE 2-8. CONTROL EQUIPMENT OPERATION

Test No.	Date, 1981	Ambient conditions			Condenser cooling fluid temperature				Air temperature at the outlet of the final condenser	
		Temperature		% relative humidity	Inlet		Outlet			
		°C	°F		°C	°F	°C	°F	°C	°F
LW-1	3/26	23	73	49	28	82	44	111	34	93
LW-2	3/28	21	69	77	29	84	46	115	34	93

Table 2-9 lists the ink usage for each test. The mass of ink used was determined based on the average ink density for all four colors, 0.985 kg/liter (8.219 lb/gal). Density and volatile content data are listed in Table 2-10. Ink density varied from 0.974 kg/liter for the yellow and black inks to 1.010 kg/liter for the blue ink. This amounts to a variance of only +2.5 percent from the mean value. The average density of the four ink colors and the total volume of the four ink colors dispensed were used to compile the data in Table 2-9.

For Test 1, the amount of ink dispensed was 95.04 liters (25.11 gal), which is equivalent to 93.61 kg (206.38 lb). A total of 274 minutes of press operating time was recorded for the measurement period. The rate of ink usage was 0.39 kg/min (0.75 lb/min). In Test 2, 152.99 liters (40.39 gal) of ink were dispensed in 405 minutes of operating time. The ink usage rate for Test 2 was 0.37 kg/min (0.82 lb/min).

Volatile content of the ink was determined by means of Procedure B of ASTM Method D-2367. In this procedure, the ink is dispersed in solvent and heated for 1 hour at 110°C to drive off volatile material. The sample is weighed before and after the heating period to determine the percent volatile content gravimetrically. Because this method may not be applicable for all types of coatings, samples were also heated through extended periods of 3, 4, 5, 6, and 24 hours to determine the relationship of heating time to the measured volatile content. These data are included in Table 2-10. Figure 2-1 is a graphical representation of this same data.

TABLE 2-9. INK USAGE AT THE LEHIGH STECK-WARLICK COMPANY

Test No.	Date, 1981	Total ink usage, all colors						
		Volume		Mass ^a		Total operating time, ^b min	Usage rate	
		liter	gal	kg	lb		kg/min	lb/min
LW-1	3/26	95.04	25.11	93.61	206.38	274	0.34	0.75
LW-2	3/28	152.89	40.39	150.60	332.01	405	0.37	0.82

^aBased on average ink density of 0.985 kg/liter (8.219 lb/gal).

^bTotal operating time = (measurement time period) - (downtime in period).

TABLE 2-10. INK DENSITY AND PERCENT VOLATILE CONTENT

Ink color	Blue	Black	Red	Yellow	Average all colors
Density, kg/liter	1.010	0.974	0.980	0.974	0.985
lb/gal	8.428	8.127	8.178	8.127	8.219
% Volatiles ^a					
1 h at 110°C	18.77	19.48	27.36	27.84	23.36
3 h at 110°C	31.00	21.85	34.60	34.30	30.44
4 h at 110°C	31.60	23.65	35.35	35.30	31.48
5 h at 110°C	31.90	25.05	35.80	36.00	32.19
6 h at 110°C	31.95	26.05	36.00	36.55	32.64
24 h at 110°C	32.55	32.05	37.35	38.75	35.18

^aPercent volatile content by weight determined by Procedure B of ASTM Method D-2369-81, which calls for a heating period of 1 hour at 110°C. To determine relationship between heating time and measured volatile content, samples were also heated through 3-, 4-, 5-, 6-, and 24-hour periods.

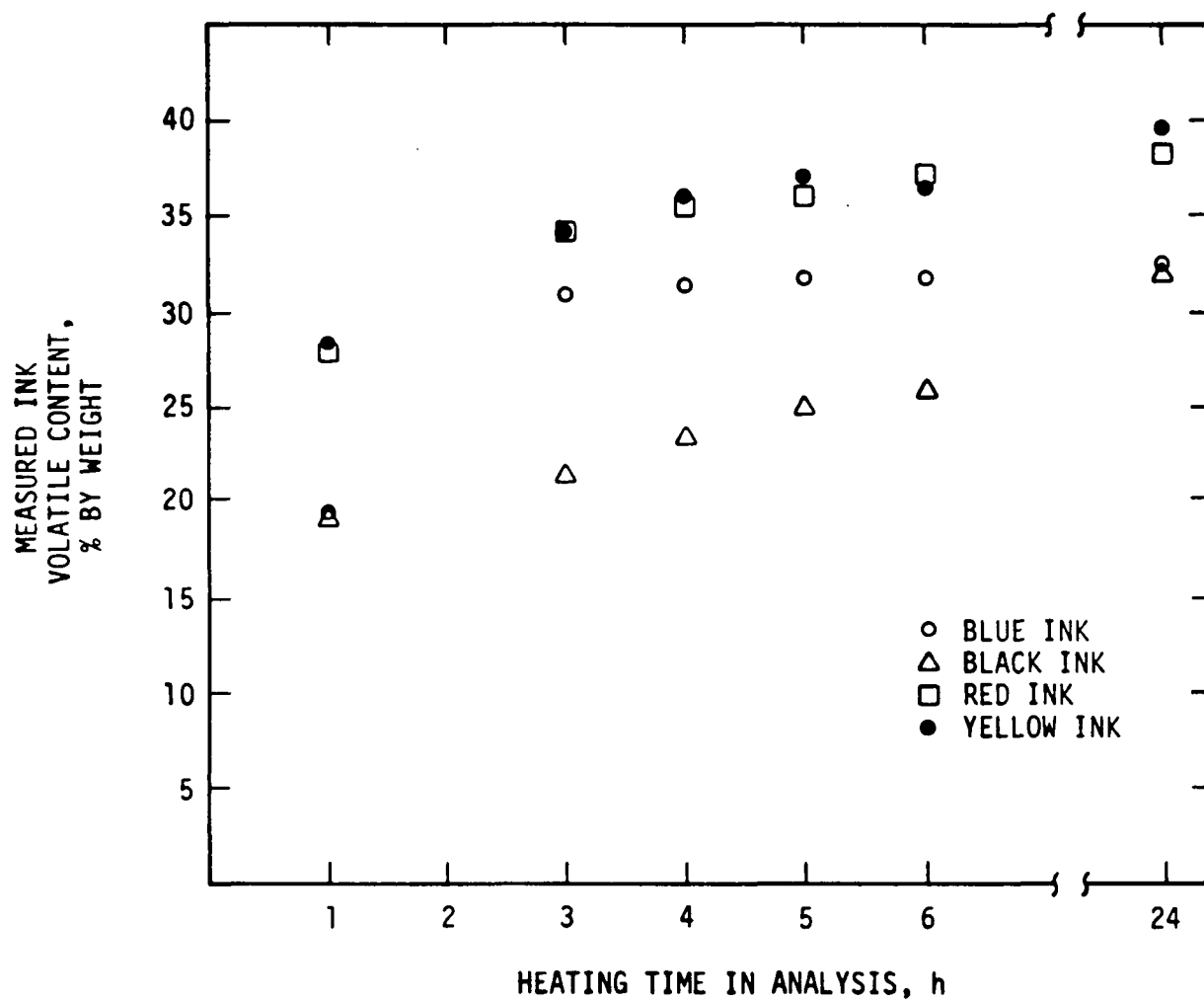


Figure 2-1. Relationship between measured ink volatile content and heating time in analysis.

The measured volatile content increases steadily with increased heating time. Even after 6 hours at 110°C, measured volatile content had not reached a steady level as indicated by the samples heated for 24 hours.

Laboratory data for the ink samples are shown in Appendix C.

Residual Solvent Content in Printed Product

Samples of the printed signatures were collected during each test and analyzed for residual solvent content. The paper samples were extracted with pentane by means of a soxhlet extraction apparatus, and the extracts were analyzed for ink solvent content by gas chromatography (GC). Samples of the ink solvent were used to identify the solvent peaks from the extract. Unprinted paper was extracted as a blank to identify and eliminate from consideration those peaks resulting from extractables in the paper.

Signature samples were collected at the beginning, middle, and end of each test run. Each sample consisted of about 25 signatures. At the PEDCo laboratory, the top and bottom portions of this sample were discarded. At least one whole signature from the center of the sample pack was then shredded and loosely packed in a soxhlet apparatus. No attempt was made to evaluate the percent ink coverage on the signature nor to separate the lightly covered areas from the more heavily covered areas.

Soxhlet extraction data are summarized in Table 2-11. Samples from Test 1 averaged 0.30 mg of solvent per gram of paper. In Test 2, the samples average 0.20 mg of solvent per gram of paper.

The paper used on both test days was Champion paper product weighing 60 lb/ream. A ream of paper is defined as 500 sheets measuring 25 by 38 in. Thus, the weight of the paper is 1.26×10^{-4} lb/in.² During Test 1, 96,000 signatures were run in 245 operating minutes. Each signature is 42 in. wide by 45.669 in. long or 1918.10 in.² Thus, in Test 1, 5682 lb of paper per hour were run through the press. Based on the average solvent content from Table 2-11, 1.70 lb/h of ink solvent was retained in the printed product. The measured ink usage rate for Test 1 was 0.75 lb/min or 45.00 lb/h. Assuming that 30 percent of the ink weight is solvent, 13.5 lb/h of ink solvent was applied to the paper. Therefore, about 12.6 percent of ink solvent applied remained in the printed product after the press dryer unit.

In Test 2, 106,820 signatures were run in 413 operating minutes for a rate of 3751 lb/h of paper run. Based on the extraction data, therefore, 0.75 lb/h of solvent was retained in the printed product. The ink usage rate for Test 2 was 0.82 lb/min or 49.20 lb/h. If the ink contains 30 percent solvent, 14.76 lb/h of solvent was applied to the paper. Thus, 5.1 percent of the solvent applied remained in the printed product.

TABLE 2-11. RESIDUAL SOLVENT CONTENT OF PRINTED SIGNATURES

Sample I.D.	Weight of paper extracted, g	Solvent content	
		mg solvent/ g paper	lb solvent/ lb paper
Test 1 ^a			
No. 1, top line	36.69	0.38	3.8×10^{-4}
No. 1, bottom line	35.26	0.40	4.0×10^{-4}
No. 2, top line	35.62	0.24	2.4×10^{-4}
No. 2, bottom line	37.63	0.37	3.7×10^{-4}
No. 3, top line	35.42	0.21	2.1×10^{-4}
No. 3, bottom line	38.99	0.23	2.3×10^{-4}
No. 4, top line	40.92	0.27	2.7×10^{-4}
No. 4, bottom line	42.03	0.29	2.9×10^{-4}
Average Test 1	37.82	0.30	3.0×10^{-4}
Test 2			
No. 1	40.31	0.19	1.9×10^{-4}
No. 2	39.90	0.21	2.1×10^{-4}
No. 3	36.92	0.21	2.1×10^{-4}
Average Test 2	39.04	0.20	2.0×10^{-4}

^aSignatures from the Test 1 product were split after printing into two product lines. Thus, top line and bottom line samples are of the same signature. Product in Test 2 was not split.

Laboratory data from the study are presented in Appendix C. A description of the sampling and analytical procedure is contained in Appendix D.

Fountain Solutions

During the tests, samples of the fountain solutions were collected to check the concentration of isopropanol. In addition, attempts were made to measure the amount of isopropanol used per test.

Isopropanol concentration was measured by determining the specific gravity of the solutions using a hydrometer. In Test 1, fountain solution concentrations ranged from 6.7 to 10.0 percent isopropanol with an average value for the four solutions of 8.2 percent. The makeup alcohol was 96.9 percent isopropanol. In Test 2, the fountain solution concentrations ranged from 6.2 to 10.9 percent isopropanol with an average value of 8.2 percent. Makeup alcohol for Test 2 was 96.4 percent isopropanol.

All four fountain solution temperatures were checked every 1/2 hour through a 4-hour period during Test 1. Temperatures of the fountain solution ranged from 14° to 17°C (58° to 63°F) with an overall average temperature of 16°C (60°F). Alcohol use was determined by measuring the liquid level in the makeup containers at various times during Test 1. This proved impractical, however, because the makeup containers were frequently refilled, often before the data clerk could take readings. As a result, only one valid measurement was recorded for one 71-minute period. Based on this measurement, 1.49 liters of 96.9 percent

isopropanol were used in 71 minutes. This corresponds to a usage rate of 16.5 g/min (0.036 lb/min).

During Test 2, the press operators were instructed to fill several 5-gal containers with makeup alcohol and then to use these containers to refill fountain solution containers. Thus, alcohol use was measured by weighing the full 5-gal containers at the start of the day, and as they were emptied. The alcohol in these containers, however, was also occasionally used for general cleaning around the press. Thus, this measurement does not yield an accurate indication of the amount of isopropanol delivered to the fountain solutions. Based on this measurement, a total of 185.36 lb of isopropanol was used in 359 operating minutes. Thus, the usage rate for isopropanol was 0.516 lb/min or 234.3 g/min.

Material Recovered from the Condenser Drain

To measure the material collected in the condensers, a decanter system was set up on the condenser drain line. The decanter consisted of a large drum with outlet taps at the top and bottom of the drum. Ink solvent was collected off of the top drain and condensed water from the bottom of the drum. Solvent and water were collected in tared buckets and weighed to determine the quantity condensed.

In Test 1, a total of 25.91 lb of ink solvent was collected in 319 operating minutes. A total of 5.38 lb of water was collected in the same 319-minute period. Thus, 4.87 lb/h of ink solvent and 1.01 lb/h of water were condensed. In Test 2, 47.40

1b of ink solvent and 0.89 lb of water were recovered in 400 operating minutes. The rates of condensation were, therefore, 7.11 lb/h for solvent and 0.13 lb/h for water.

The Method 25 data for Test 2 indicates that 13.03 lb/h of ink solvent were condensed.

SECTION 3

PROCESS DESCRIPTION

Testing was conducted on Press No. 64 at the Lehigh Steck-Warlick Company in Dallas, Texas. Press No. 64 is a Toshiba model four-color printing press with a TEC Systems Series 80 dryer unit. Vapors exhausted from the dryer are vented along with dilution air to a control system consisting of five water-cooled condensers in series followed by an ESP with two collectors.

The printing rolls on the Toshiba press are 106.68 cm (42 in.) in diameter with a 116-cm (45.669-in.) cutoff. Normal printing speed ranges from 427 to 488 m/min (1400 to 1600 ft/min). The press is designed for maximum operating speed of 549 m/min (1800 ft/min).

The inks used in this printing operation are formulated with a solvent base that consists primarily of C-10 to C-16 straight chain, saturated hydrocarbons. Based on solvent vapor pressure data, it was estimated that the exhaust air from the dryer could contain up to 3000 ppm hydrocarbon vapor at a dryer temperature of 132°C (270°F).

The other source of hydrocarbon emissions from the press operation is the isopropanol used as a wetting agent in the fountain solution. Samples of the four fountain solutions were

collected during the test. The isopropanol concentration in these samples ranged from 8 to 11 percent by volume. Pure isopropanol (~97 percent) is used to make up the alcohol content of the fountain solutions and is also used for cleaning the printing rolls and other equipment around the press. Press rolls are cleaned periodically during the day, and some of the vapors from the isopropanol used for cleaning are also drawn through the press dryer.

The TEC Series 80 dryer normally operates in the temperature range of 121° to 127°C (250° to 260°F). This is somewhat lower than the temperature used in most press dryers, but the dryer is longer than most units and thus provides more drying area. This arrangement is employed by the plant to lower the chance of damaging the paper or print quality through overheating, to provide more even drying, and to conserve energy by lowering the heat input to the dryer and reducing the amount of cooling required in the chill rolls. During testing, the dryer temperature was measured at 131°C (268°F) for the first test and 148°C (298°F) for the second.

The emission control system consists of five condenser units in series followed by a Smog Hog^R ESP with two collectors. Most of the control equipment was supplied by United Air Specialists, Inc.

A 50/50 mixture of ethylene glycol and water is used as the cooling fluid in the condenser system. The glycol-water mix enters the condenser system at the fourth condenser then flows

through the fifth, third, second, and first condensers in series. During testing, the inlet temperature of the cooling fluid averaged 28°C (83°F), and the outlet temperature after the first condenser averaged 45°C (113°F). These temperatures were read from thermometers installed on the inlet and outlet lines by plant personnel. Cooling fluid flow rate is approximately 132 liters/min. (35 gal/min).

Hot cooling fluid from the condensers is directed to a heat exchanger near the press where the heat of the fluid is used to preheat dryer blower air. Because the dryer preheater and the condensers at the control system are part of the same heat exchange system, temperatures at the condenser are not variable. Experiments conducted by Lehigh Steck-Warlick personnel have shown that varying condenser temperatures more than $\pm 10^{\circ}\text{F}$ results in fouling and plugging of the condenser coils and reduced operating efficiency in the ESP. All testing was conducted under normal operating temperatures.

SECTION 4

SAMPLING AND ANALYTICAL PROCEDURES

Tests were conducted at the inlet and outlet of the condenser/ESP to determine the hydrocarbon concentrations at each site and the control efficiency achieved by the condenser/ESP system. Because a potential existed for aerosol formation in the inlet duct, samples were collected isokinetically by means of the EPA Method 5* sampling procedure. A Method 25** sample was collected from the backside of the Method 5 filter and analyzed for total nonmethane organic content. In addition to the emission test, samples of the process ink, printed product, and isopropanol fountain solutions were collected for analysis. The following report sections describe the sampling and analytical procedures used in this test.

4.1 DESCRIPTION OF SAMPLE LOCATIONS

The inlet test site consisted of an insulated 15 by 24 in. rectangular duct. Approximately 2-1/2 duct diameters of undisturbed flow were downstream from the sample location and about 1/2 diameter upstream. A total of 25 sample points were used in each traverse. Five ports were installed in the duct to provide

* Federal Register, Vol. 42, No. 160, August 18, 1977.

** Federal Register, Vol. 45, No. 194, October 3, 1980.

a 5 by 5 sample point matrix. Based on the procedures of Method 1*, a 6 by 6 sample point matrix should have been used to provide 36 traverse points. Studies by Fluidyne, Entropy Environmentalists, Inc., and others indicate that the number of points sampled to obtain representative data may be less than those presently specified in Method 1.^{1,2,3} The Method 25 sampling time is also limited by the size of the sample tank to less than 1 hour. Thus, to accommodate the Method 25 sample, the number of sample points were reduced to 25, and each sample point was sampled for 2 minutes for a total test time of 50 minutes. Figure 4-1 is a diagram of the inlet test site.

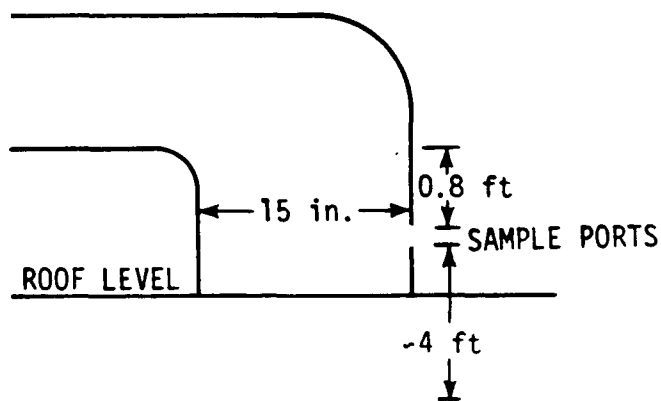
The rectangular duct at the outlet test site was 20 by 24 in. The sample location selected was 4 duct diameters from the nearest downstream flow disturbance and 1 duct diameter from the nearest upstream flow disturbance. Four sample ports were installed. Traverse points were laid out in a 4 by 5 matrix to provide a total of 20 traverse points. Figure 4-2 is a diagram of the test site and traverse point locations. Again, the number of traverse points selected was based on the total test time allowed by the Method 25 sample train and the rationale presented above. Each traverse point was sampled for 2-1/2 minutes for a total test time of 50 minutes.

* Federal Register, Vol. 42, No. 160, August 18, 1977.

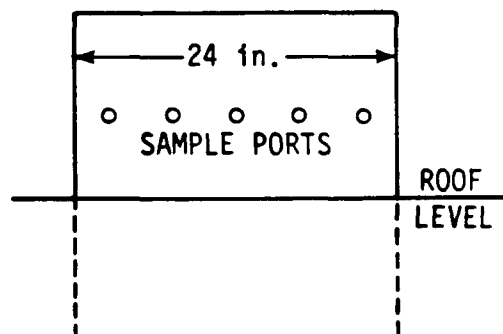
¹ H.A. Hanson, R.J. Davini, J.K. Morgan, A.A. Iverson. Fluidyne. Particulate Sampling Strategies for Large Power Plants Including Nonuniform Flow. EPA-600/2-76-170, June 1976.

² Traverse Point Study. June 1977. Entropy Environmentalists, Inc., P.O. Box 12291, Research Triangle Park, North Carolina 27709. 18 p.

³ P.G.W. Hawksley, S. Badzioch, and J.H. Blackett. Measurement of Solids in Flue Gases. The British Coal Utilization Research Association. Leatherhead, Surrey, England, 1961.

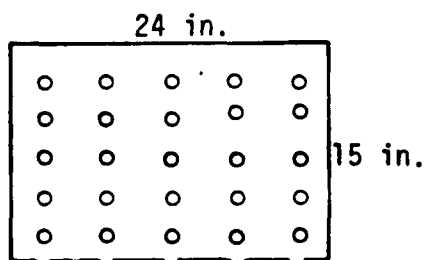


DRYER DISCHARGE
SIDE VIEW



DRYER DISCHARGE
FRONT VIEW

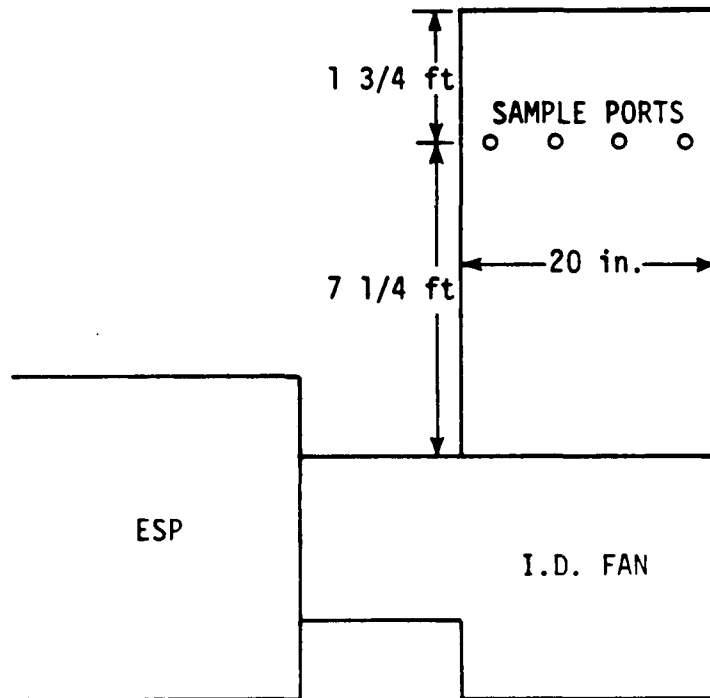
TRAVERSE POINT LOCATION



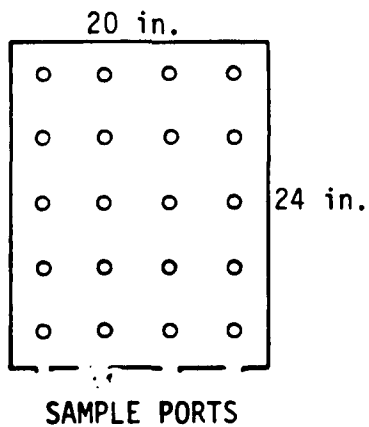
SAMPLE PORTS

TRAVERSE POINT NO.	LOCATION IN DUCT, INCHES
1	2.0
2	5.0
3	8.0
4	11.0
5	14.0

Figure 4-1. Inlet test site and traverse point locations.



TRAVERSE POINT LOCATION



TRAVERSE POINT NO.	LOCATION IN DUCT, INCHES
1	2 5/8
2	7 3/8
3	12 1/4
4	17
5	21 3/4

Figure 4-2. Outlet test site and traverse point locations.

4.2 GAS STREAM FLOW RATE, TEMPERATURE, AND COMPOSITION

Gas stream flow rate and temperature were measured before each test using the procedures described in EPA Method 2*. During each particulate test, an integrated bag sample was collected and analyzed by orsat analysis to determine the oxygen and carbon dioxide content. Method 3* sampling and analytical procedures were used.

Gas stream velocities were measured with an S-type pitot tube and an inclined draft gauge manometer. Temperatures were measured with a calibrated thermocouple and digital potentiometer.

Calculations and results for velocity traverses are shown in Appendix A. Equipment calibration procedures and results are presented in Appendix E.

4.3 PARTICULATE AND HYDROCARBON EMISSION TESTS

Hydrocarbon and particulate sampling were conducted simultaneously by means of a method that combined Methods 5* and 25**. In conducting these tests, the gas stream was sampled isokinetically using the standard Method 5 procedures described in the Federal Register*. The Method 25 sample was extracted from a tee at the back of the Method 5 filter. A shutoff valve was placed between the Method 5 and 25 sample trains to enable the operator to leak check each section separately.

For each test, three complete particulate traverses were made. A Method 25 sample was extracted during each traverse.

* Federal Register, Vol. 42, No. 160, August 18, 1977.

** Federal Register, Vol. 45, No. 194, October 3, 1980.

Method 5 impinger contents were recovered after the third traverse and analyzed for organic and inorganic condensibles with ether-chloroform extraction. Impingers were rinsed first with distilled water, then with acetone to ensure complete recovery of the condensed organics. The Method 5 filters and probe rinses were not recovered until both tests were completed.

The following leak check procedures were used in conducting the sampling:

1. Prior to each traverse, the Methods 5 and 25 sampling trains were leak checked separately before they were connected. The pretest leak check of the combined system was conducted with the shutoff valve to the Method 25 sample tank closed. This was necessary to prevent loss of tank vacuum prior to sampling.
2. The posttest leak check was conducted with the shutoff valve between the Method 25 condensate trap and the Method 5 filter closed. This procedure was necessary to prevent loss of material collected in the condensate trap. Methods 5 and 25 sample trains were thus leak checked separately after each traverse.

For analysis, the Method 5 filters were desiccated to a constant weight and then weighed on an analytical balance to within 0.1 mg. The probe and front half of the filter holder were rinsed with toluene after completion of the testing.

Toluene rinses were shipped to the Emission Measurement Branch laboratory for analysis. The impinger contents were rinsed with distilled water and acetone. The distilled water rinse and the impinger contents were analyzed for organic and inorganic condensibles by ether-chloroform extraction. After separation, the organic and inorganic fractions were dried, desiccated to a constant weight, and weighed on an analytical

balance. The acetone rinse was treated in the same manner as the ether-chloroform extract. The condensible material from the acetone rinse was added to the catch from the ether-chloroform extract to determine the total organic condensibles.

Method 25 samples were collected by drawing the sample gas from the back of the Method 5 filter through a dry-ice condensate trap by means of an evacuated sample tank. A constant sampling rate of 85 ml/min was maintained throughout the test.

The sample tanks were analyzed by injecting the contents into an analyzer that separates the nonmethane organics from CO, CH₄, and CO₂; oxidizes organic compounds to CO₂; reduces the CO₂ to methane; and measures the resulting methane with a flame ionization detector (FID). Condensate is recovered by completely oxidizing the trap contents, then reducing the CO₂ to methane for measurement with the FID. The total nonmethane organic content is the sum of the trap and tanks fractions.

A complete description of the sampling and analytical procedures is contained in Appendix D. Calculations including gas velocity data are shown in Appendix A. Field and laboratory data sheets are presented in Appendices B and C, respectively. Equipment calibration procedures and results are shown in Appendix E.

4.4 GAS STREAM ISOPROPANOL CONTENT

During each test period, gas samples were collected and analyzed for isopropanol content. Samples were collected in evacuated stainless steel tanks using an 0.635-cm O.D. stainless

steel probe line. A stainless steel needle valve was placed between the tank and probe line to control the sampling rate.

In the laboratory, the sample tanks were pressurized with nitrogen, and the contents were injected into a gas chromatograph with an FID for analysis. Calibration standards of isopropanol in air were made by injecting known quantities of isopropanol into stainless steel tanks similar to those used for sampling.

A precolumn packed with 10 percent methyl silicone oil was used to prevent the heavy molecular weight ink solvent from bleeding into the separation column and FID. Thus, only the alcohol and light hydrocarbon fractions were quantified with the FID.

In calculating the isopropanol concentrations, peaks resulting from all light hydrocarbons were summed. In the press dryer, some chemical reactions may occur with the isopropanol. Thus, it was assumed that all light hydrocarbons observed were the result of the isopropanol reactions and therefore should be included with the measured isopropanol. Appendix C of this report contains all laboratory data and example chromatograms to show those peaks which were summed.

Field data for the isopropanol sampling are shown in Appendix B. Calculations and results are presented in Appendix A.

4.5 PROCESS SAMPLE ANALYSIS

Printed Signatures

During the testing at the Lehigh Steck-Warlick Company, signature samples were collected and analyzed for residual ink

solvent content by means of a soxhlet extraction procedure suggested by a GATF laboratory study. Signature samples were collected at the beginning, middle, and end of each test run. Each sample consisted of about 25 signatures. Signature samples were wrapped in oil-free aluminum foil to prevent solvent loss during shipment to the PEDCo laboratory. Unprinted paper samples were collected and shipped in the same manner; extracted, and analyzed as blanks.

At the PEDCo laboratory, the top and bottom portions of each sample pack were discarded. At least one whole signature (about 30 to 40 g of paper) from the center of the sample pack was then shredded and loosely packed in a soxhlet apparatus. No attempt was made to evaluate the percent ink coverage on the signature, and no attempt was made to separate lightly covered areas of the signature from the more heavily covered areas.

The material was then subjected to a four hour soxhlet extraction using nanograde pentane. Approximately 350 ml of pentane were used for each extraction. After extraction, the pentane extract was concentrated by evaporating the pentane at room temperature. The concentration step reduced the volume of pentane extract to about 10 ml. Unprinted paper was extracted by the same procedure.

Extracts were analyzed with a gas chromatograph and flame ionization detector (FID). The FID was calibrated with standards of ink solvent in pentane. Extracts from paper blanks were analyzed to located and eliminate from consideration those GC

peaks which were attributable to the extractable content of the paper itself. Signature extracts were then analyzed, and the ink solvent content was quantified by comparison to the FID response of the solvent calibration standards.

The instrument used for analysis was a Perkin-Elmer 990 gas chromatograph with a flame ionization detector. The following GC conditions were used:

Column: 4 ft x 1/8 in. O.D. nickel, packed with 3% SP2100
on 100/120 mesh supelcoport

Temperatures: Injection port: 350°C

Manifold: 350°C

Column: Ambient, hold 3 minutes then program
to 325°C at 12°C/min

Carrier gas: Nitrogen at 30 cc/min

Process Ink Samples

Samples of the process ink were obtained from the manufacturer, the Sun Chemical Corporation, and analyzed for density and percent volatile content by means of the procedures specified in Reference Method 24*. These procedures are ASTM Method D-1475-60 for density and D-2369-81 for percent volatiles. The procedure for percent volatiles involves heating the sample for 1 hour at 110°C. In addition, samples were also analyzed by means of an alternate procedure suggested by printing industry representatives in which the samples were heated for 3 hours at 110°C. To determine the relationship between heating time and the measured percent volatiles, samples were also analyzed by heating for 4-, 5-, and 6-hour periods. Percent volatile content appears to level off after 5 hours of heating.

* Federal Register, Vol. 45, No. 194, October 3, 1980.

All results are included in this report. Laboratory data are shown in Appendix C.

Fountain Solutions

During each test, samples of the fountain solutions, recirculating barrel contents, and makeup alcohol were collected to determine the percent isopropanol in each. The isopropanol content in each was determined by specific gravity measurements taken with a hydrometer. Laboratory results are presented in Appendix C.

SECTION 5

QUALITY ASSURANCE

Quality assurance is an important facet of stack sampling because the end goal of testing is to produce representative emission results. Quality assurance guidelines provide detailed procedures and actions necessary for defining and producing acceptable data. Three documents were used in this test program to provide the required guidance to help ensure the collection of acceptable data and to define data quality that is unacceptable. These documents were the EPA Quality Assurance Handbook Volume III (EPA-600/4-77-8276), the draft PEDCo Environmental Emission Test Quality Assurance Plan, and the PEDCo Environmental Laboratory Quality Assurance Plan. The last two documents are PEDCo's general guideline manuals that define the company's standard operating procedures followed by the emission testing and laboratory groups.

More details on the Quality Assurance procedures are provided in Appendix F. Included in Appendix F are details on quality assurance objectives, data reduction procedures, quality control checks, performance and system audits, preventative maintenance, precision, accuracy, completeness, corrective actions, and quality assurance reports to management.

Routine standard reference method quality control procedures were followed throughout this test program. Included in the standard procedures are the following:

- ° Calibration of field sampling equipment. Calibration procedures and results are described in detail in Appendix E. All equipment used met established EPA requirements.
- ° Train configuration and calculation checks. Calculations from preliminary data were checked on site by the EPA Task Manager. This procedure verified that isokinetic sampling rates and gas flow rate and moisture data were acceptable before further testing was conducted. Onsite calculation sheets are included with field data in Appendix B.
- ° Onsite quality assurance checks such as sample train, pitot tube, and orsat line leak checks. In addition to standard procedures, PEDCo performed the following checks during this test. Dry gas meter calibrations were checked on site by means of EPA calibrated critical orifice No. 174. One meter was found to be 13.3 percent off the expected volume and was not used for any testing. The two meters that were used for the testing were 2.5 and 4.6 percent off the expected volume through the critical orifice. Acceptable limits for this calibration check are ± 5 percent of the expected volume. Data sheets for the field meter box checks are in Appendix B with the field data.

Thermocouples were checked on site against a mercury-in-glass thermometer on each day of testing. All thermocouples were within 1.5 percent of the absolute temperature indicated by the reference thermometer.

- ° Use of designated sampling equipment and analytical reagents. Sampling equipment is described in Appendix D. Blank analytical data for the reagents used in sampling are shown along with the laboratory results in Appendix C.
- ° Lab analysis procedures.
- ° Internal and external audits to ensure accuracy in sampling and analysis.

Sampling equipment, reagents, and analytical procedures for this test follow and meet all guidelines established for Methods 5* and 25**.

* Federal Register, Vol. 42, No. 160, August 18, 1977.

** Federal Register, Vol. 45, No. 194, October 3, 1980.