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Research Triangle Park NC 27711

EMB Report 78-OCM-9

Air

Acrylic Acid and Esters Production

Emission Test Report
Rohm and Haas Company
Deer Park, Texas

EMISSION TEST OF AN ACRYLIC ACID AND ESTER MANUFACTURING PLANT

by

George W. Scheil

FINAL REPORT
August 1980

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For

Emission Measurement Branch
Field Testing Section
U.S. Environmental Protection Agency
Research Triangle Park, North Carolina 27711

Attn: Mr. J. McCarley, Jr.

PREFACE

This work was conducted by Midwest Research Institute under Environmental Protection Agency Contract No. 68-02-2814, Work Assignment No. 16.

The project was supervised by Mr. Doug Fiscus, Head, Field Programs Section. Dr. George Scheil served as field team leader and was assisted in the field by Messrs. Ron Jones, Robert Stultz, Dan Vogel, Jeff Thomas, and Mark Hansen of Midwest Research Institute. Laboratory assistance was provided by Mr. Tom Walker.

Approved for:

MIDWEST RESEARCH INSTITUTE

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SECTION 1

INTRODUCTION

This report presents the results of source testing performed during the period February 8 to March 15, 1979, by Midwest Research Institute (MRI) at the acrylic acid facility of Rohm and Haas Corporation at Deer Park, Texas. The inlet and outlet of a high temperature, short residence time fume combustor were sampled at two different combustor temperatures. The combustor is used to limit emissions of the process off-gases from an acrylic acid plant and a storage tank area. The acrylic acid unit uses partial oxidation of propylene to produce its product.

The vapor streams were analyzed for methane, ethylene, ethane, propane, propylene, acetaldehyde, acrolein, acetone, acrylic acid, methyl-butyl acrylates, and total hydrocarbons by gas chromatography (GC). Duct temperature, flow rate, oxygen, carbon monoxide, carbon dioxide, and aldehydes were also determined by manual sampling of all streams. The fuel gas was analyzed by GC, and NO_x samples were taken at the outlet.

The results of these tests are to be used as reference data for establishing performance standards of organic fume combustors.

SECTION 2

SUMMARY AND DISCUSSION OF RESULTS

The GC analysis results are shown in Tables 1 through 19. The first 18 tables show results for each component observed, from methane to butyl acrylate, at the inlet and outlet to the incinerator. Table 19 shows the sum of all components. All actual measurements were made as parts per million (ppm) of propane (by volume) with the other units reported derived from the propane equivalent response. The tables include any contribution from the portion of each sample which condensed in the sampling train trap. Only acetaldehyde and acetone were found in the condensate. All results were measured by digital integration. Data for propylene, acrolein, and two unknown compounds (Tables 5, 10, and 11) were obtained, considered confidential by Rohm and Haas, and were removed from the final report and stored in the EPA Emissions Standards and Engineering Division's (ESED) files.

The incinerator combustion temperature for the first four runs was at normal combustion temperature. Runs 5 through 8 were made at an elevated incinerator temperature. During Run 5 the combustion conditions were not optimized--apparently insufficient oxygen was present for proper combustion. Run 9 was completed during the firing of liquid wastes to the incinerator, again at high temperature. The higher temperature runs caused many of the compounds heavier than propane to drop below the detection limits. No single number can be assigned as a detection limit due to the wide range of attenuations used, nearby obscuring peaks, and baseline noise variations. The detection limit ranges from about 10 ppb to 10 ppm, generally increasing during the chromatogram, and especially near large peaks. Several of the minor peaks were difficult to measure. However, the compounds of interest, methane, ethane, ethylene, propane, propylene, acetaldehyde, acetone, acrolein, and acrylic acid, dominate the chromatograms (see Figures 1 through 3 for examples). The suction vent and process off gas chromatograms (Figures 1 and 2) are in the ESED files. Acetic acid was never detected in any sample. Methyl, ethyl, propyl, and butyl acrylates were observed in large quantities in the suction vent. Several minor peaks were found, some of which have probable identifications.

The probable reason for negative destruction efficiencies for several light components is generation by pyrolysis from other components. For instance, the primary pyrolysis products of acrolein are carbon monoxide and ethylene. Except for methane and, to a much lesser extent, ethane and propane, the fuel gas cannot contribute hydrocarbons to the outlet samples.

TABLE 1. GAS CHROMATOGRAPHY ANALYSES FOR METHANE

	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9
Suction vent								
ppm as Propane	0.70	0.65	0.72	1.54	1.27	0.74	0.45	0.97
ppm as Methane	1.94	1.81	2.0	4.28	3.53	2 06	1.25	2.69
ppm as Carbon	1.94	1.81	2.0	4.28	3.53	2.06	1.25	2.69
G/M^3 as Methane a/	1.29×10^{-3}	1.20×10^{-3}	1.33×10^{-3}	2.84×10^{-3}	2.34×10^{-3}	1.36×10^{-3}	8.30×10^{-4}	1.79×10^{-3}
G/M^3 as Carbon a/	9.68×10^{-4}	8.99×10^{-4}	9.96×10^{-4}	2.13×10^{-3}	1.76×10^{-3}	1.02×10^{-3}	6.22×10^{-4}	1.34×10^{-3}
G/sec as Methane	7.59×10^{-3}	7.06×10^{-3}	7.79×10^{-3}	0.02	0.01	8.02×10^{-3}	5.01×10^{-3}	0.01
G/sec as Carbon	5.69×10^{-3}	5.30×10^{-3}	5.85×10^{-3}	0.01	0.01	6.02×10^{-3}	3.76×10^{-3}	8.04×10^{-3}
lb/ft^3 as Methane a/	8.05×10^{-8}	7.48×10^{-8}	8.28×10^{-8}	1.77×10^{-7}	1.46×10^{-7}	8.51×10^{-8}	5.18×10^{-8}	1.12×10^{-7}
lb/ft^3 as Carbon a/	6.04×10^{-8}	5.61×10^{-8}	6.21×10^{-8}	1.33×10^{-7}	1.10×10^{-7}	6.38×10^{-8}	3.88×10^{-8}	8.37×10^{-8}
lb/hr as Methane	0.06	0.06	0.06	0.13	0.11	0.06	0.04	0.08
lb/hr as Carbon	0.05	0.04	0.05	0.10	0.08	0.05	0.03	0.06
Process off-gas								
ppm as Propane	46.5	44.0	45.5	68.0	50.0	41.0	52.0	54.0
ppm as Methane	129.0	122.0	126.0	189.0	139.0	114.0	144.0	150.0
ppm as Carbon	129.0	122.0	126.0	189.0	139.0	114.0	144.0	150.0
G/M^3 as Methane a/	0.09	0.08	0.08	0.13	0.09	0.08	0.10	0.10
G/M^3 as Carbon a/	0.06	0.06	0.06	0.09	0.07	0.06	0.07	0.07
G/sec as Methane	1.75	1.53	1.61	2.35	1.71	1.40	1.78	1.81
G/sec as Carbon	1.32	1.14	1.21	1.76	1.28	1.05	1.33	1.36
lb/ft^3 as Methane a/	5.35×10^{-6}	5.06×10^{-6}	5.23×10^{-6}	7.82×10^{-6}	5.75×10^{-6}	4.72×10^{-6}	5.98×10^{-6}	6.21×10^{-6}
lb/ft^3 as Carbon a/	4.01×10^{-6}	3.80×10^{-6}	3.93×10^{-6}	5.87×10^{-6}	4.31×10^{-6}	3.54×10^{-6}	4.49×10^{-6}	4.66×10^{-6}
lb/hr as Methane	13.91	12.10	12.74	18.63	13.56	11.09	14.08	14.39
lb/hr as Carbon	10.43	9.08	9.56	13.98	10.12	8.31	10.56	10.79
Outlet								
ppm as Propane	87.0	79.0	53.0	30.0	10.6	8.4	10.0	2.0
ppm as Methane	240.0	219.0	149.0	83.0	29.0	23.0	28.0	5.5
ppm as Carbon	240.0	219.0	149.0	83.0	29.0	23.0	28.0	5.5
G/M^3 as Methane a/	0.17	0.147	0.092	0.06	0.02	0.02	0.02	3.69×10^{-3}
G/M^3 as Carbon a/	0.12	0.11	0.074	0.04	0.01	0.01	0.01	2.77×10^{-3}
G/sec as Methane	6.2	5.6	3.8	1.85	0.73	0.58	0.67	0.14
G/sec as Carbon	4.7	4.2	2.8	1.39	0.55	0.44	0.50	0.10
lb/ft^3 as Methane a/	1.00×10^{-5}	9.1×10^{-6}	6.1×10^{-6}	3.45×10^{-6}	1.22×10^{-6}	9.66×10^{-7}	1.15×10^{-6}	2.30×10^{-7}
lb/ft^3 as Carbon a/	7.5×10^{-6}	6.8×10^{-6}	4.6×10^{-6}	2.59×10^{-6}	9.14×10^{-7}	7.25×10^{-7}	8.63×10^{-7}	1.73×10^{-7}
lb/hr as Methane	49.0	45.0	30.0	14.70	5.81	4.61	5.34	1.10
lb/hr as Carbon	37.0	33.0	23.0	11.02	4.36	3.45	4.00	0.82
% Efficiency	b/	b/	b/	22.0	57.0	59.0	62.0	92.4

Note: All compounds were measured as ppm of propane. Other units shown are derived from the propane response.

Note: Retention index = 100

a/ Dry standard conditions.

b/ Negative efficiency.

TABLE 2. GAS CHROMATOGRAPHY ANALYSES FOR ETHYLENE

	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9
Suction Vent								
ppm as Propane	0.97	1.31	1.49	1.21	1.03	1.00	1.3	1.4
ppm as Ethylene	1.47	1.98	2.25	1.83	1.56	1.51	1.9	2.0
ppm as Carbon	2.93	3.96	4.50	3.66	3.11	3.02	3.8	4.1
g/m^3 a/ as Ethylene	1.70×10^{-3}	2.30×10^{-3}	2.62×10^{-3}	2.2×10^{-3}	1.81×10^{-3}	1.76×10^{-3}	2.2×10^{-3}	2.4×10^{-3}
g/m^3 a/ as Carbon	1.46×10^{-3}	1.97×10^{-3}	2.24×10^{-3}	1.82×10^{-3}	1.55×10^{-3}	1.50×10^{-3}	1.9×10^{-3}	2.0×10^{-3}
g/sec as Ethylene	0.0100	0.0135	0.0154	0.0124	0.0106	0.0103	0.013	0.0142
g/sec as Carbon	8.6×10^{-3}	0.0116	0.0132	0.0107	9.05×10^{-3}	8.85×10^{-3}	0.011	0.0122
lb/ft^3 a/ as Ethylene	1.06×10^{-7}	1.43×10^{-7}	1.63×10^{-7}	1.32×10^{-7}	1.13×10^{-7}	1.09×10^{-7}	1.38×10^{-7}	1.5×10^{-7}
lb/ft^3 a/ as Carbon	9.1×10^{-8}	1.23×10^{-7}	1.40×10^{-7}	1.14×10^{-7}	9.67×10^{-8}	9.38×10^{-7}	1.18×10^{-7}	1.3×10^{-7}
lb/hr as Ethylene	0.0794	0.107	0.122	0.0985	0.0837	0.106	0.11	0.11
lb/hr as Carbon	0.0681	0.0921	0.104	0.0845	0.0718	0.0908	0.091	0.0965
Process Off-Gas								
ppm as Propane	108	100	102	96	104	100	97	99
ppm as Ethylene	163	151	154	145	157	151	147	150
ppm as Carbon	326	302	308	290	314	302	293	299
g/m^3 a/ as Ethylene	0.190	0.176	0.179	0.169	0.183	0.176	0.170	0.174
g/m^3 a/ as Carbon	0.163	0.150	0.153	0.144	0.156	0.150	0.146	0.149
g/sec as Ethylene	3.88	3.30	3.43	3.16	3.38	3.25	3.15	3.17
g/sec as Carbon	3.32	2.83	2.94	2.71	2.90	2.78	2.70	2.71
lb/ft^3 a/ as Ethylene	1.18×10^{-5}	1.09×10^{-5}	1.12×10^{-5}	1.05×10^{-5}	1.14×10^{-5}	1.09×10^{-5}	1.06×10^{-5}	1.08×10^{-5}
lb/ft^3 a/ as Carbon	1.01×10^{-5}	9.38×10^{-6}	9.57×10^{-6}	9.01×10^{-6}	9.76×10^{-6}	9.38×10^{-6}	9.10×10^{-6}	9.29×10^{-6}
lb/hr as Ethylene	30.7	26.2	27.2	25.0	26.8	25.7	25.0	25.1
lb/hr as Carbon	26.4	22.4	23.3	21.5	23.0	22.1	21.4	21.5
Outlet								
ppm as Propane	369	342	346	114	34.7	26.3	32	9.1
ppm as Ethylene	558	517	523	172	52.4	39.7	48.4	13.8
ppm as Carbon	1,116	1,030	1,050	345	105	79.5	96.7	27.5
g/m^3 a/ as Ethylene	0.649	0.602	0.607	0.200	0.0609	0.0462	0.0562	0.0160
g/m^3 a/ as Carbon	0.556	0.515	0.501	0.172	0.0522	0.0396	0.0481	0.0137
g/sec as Ethylene	25.2	23.2	23.4	6.70	2.28	1.73	2.05	0.601
g/sec as Carbon	21.6	19.9	20.1	5.75	1.96	1.48	1.76	0.515
lb/ft^3 a/ as Ethylene	4.04×10^{-5}	3.75×10^{-5}	3.79×10^{-5}	1.25×10^{-5}	3.80×10^{-6}	2.88×10^{-6}	3.50×10^{-6}	9.96×10^{-7}
lb/ft^3 a/ as Carbon	3.41×10^{-5}	3.22×10^{-5}	3.24×10^{-5}	1.07×10^{-5}	3.26×10^{-6}	2.47×10^{-6}	3.00×10^{-6}	8.54×10^{-7}
lb/hr as Ethylene	199	183	186	53.2	18.1	13.7	16.3	4.76
lb/hr as Carbon	170	157	159	45.6	15.5	11.8	13.9	4.08
% Efficiency	b/	b/	b/	b/	33	47	35	81

Note: All compounds were originally measured as ppm of propane. Other units shown are derived from the propane response.

Retention Index = 185

a/ Dry standard conditions.

b/ Negative efficiency.

TABLE 3. GAS CHROMATOGRAPHY ANALYSES FOR ACETYLENE

	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9
Outlet								
ppm as Propane	9.9	12.1	8.5	5.8		0.90		
ppm as Acetylene	15.4	18.8	13.2	9.0		1.4		
ppm as Carbon	30.7	37.7	26.3	18.0		2.8		
G/M^3 as Acetylene[a/]	0.0166	0.0204	0.0143	9.7×10^{-3}		1.5×10^{-3}		
G/M^3 as Carbon[a/]	0.0152	0.0188	0.0131	$9.0 < 10^{-3}$		1.4×10^{-3}		
G/sec as Acetylene	0.64	0.79	0.55	0.33		0.057		
G/sec as Carbon	0.59	0.72	0.50	0.30		0.052		
lb/ft^3 as Acetylene[a/]	10.3×10^{-6}	1.27×10^{-6}	8.8×10^{-7}	6.1×10^{-7}		9.4×10^{-8}		
lb/ft^3 as Carbon[a/]	9.6×10^{-7}	1.18×10^{-6}	8.1×10^{-7}	5.6×10^{-7}		8.7×10^{-8}		
lb/hr as Acetylene	5.0	6.3	4.4	2.6		0.45		
lb/hr as Carbon	4.7	5.7	4.0	2.4		0.41		

None Detected at Suction Vent or Process Off-Gas

Note: All compounds were originally measured as ppm of propane. Other units shown are derived from the propane response.

Note: Retention index = 195

a/ Dry standard conditions.

TABLE 4. GAS CHROMATOGRAPHY ANALYSES FOR ETHANE

	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9
<u>Suction Vent</u>		NONE DETECTED AT SUCTION VENT						
<u>Process Off-Gas</u>								
ppm as Propane	35	20.5	24	29	36	23	19	47
ppm as Ethane	52	30.4	35.5	43.0	53.3	34.1	28.1	69.6
ppm as Carbon	104	60.7	71.1	85.9	107	68.1	56.3	139
g/m^{3}a/ as Ethane	0.0645	0.0378	0.0443	0.0535	0.0664	0.0424	0.0350	0.0867
g/m^{3}a/ as Carbon	0.0516	0.0302	0.0354	0.0428	0.0531	0.0340	0.0280	0.0693
g/sec as Ethane	1.32	0.711	0.848	1.00	1.23	0.784	0.649	1.58
g/sec as Carbon	1.06	0.569	0.678	0.802	0.985	0.627	0.519	1.26
lb/ft^{3}a/ as Ethane	4.0×10^{-6}	2.36×10^{-6}	2.76×10^{-6}	3.34	4.14×10^{-6}	2.65×10^{-6}	2.19×10^{-6}	5.41×10^{-6}
lb/ft^{3}a/ as Carbon	3.2×10^{-6}	1.89×10^{-6}	2.21×10^{-6}	2.67	3.31×10^{-6}	2.12×10^{-6}	1.75×10^{-6}	4.32×10^{-6}
lb/hr as Ethane	10.5	5.64	6.72	7.95	9.76	6.22	5.15	12.5
lb/hr as Carbon	8.37	4.51	5.38	6.36	7.81	4.98	4.12	10
<u>Outlet</u>								
ppm as Propane	686	646	703	121	208	13.7	1.2	0.30
ppm as Ethane	1,015	957	1,040	179	308	20.3	1.8	0.44
ppm as Carbon	2,040	1,910	2,080	359	616	40.6	3.6	0.89
g/m^{3}a/ as Ethane	1.265	1.19	1.30	0.223	0.384	0.0253	2.2×10^{-3}	5.5×10^{-4}
g/m^{3}a/ as Carbon	1.011	0.953	1.038	0.179	0.307	0.0202	1.8×10^{-3}	4.4×10^{-4}
g/sec as Ethane	49.1	45.8	49.9	7.48	7.11	0.467	0.0410	0.0101
g/sec as Carbon	39.2	36.6	39.9	5.98	5.69	0.374	0.0328	8.1×10^{-3}
lb/ft^{3}a/ as Ethane	7.89×10^{-5}	7.43×10^{-5}	8.08×10^{-5}	1.39×10^{-5}	2.39×10^{-5}	1.58×10^{-6}	1.38×10^{-7}	3.5×10^{-8}
lb/ft^{3}a/ as Carbon	6.31×10^{-5}	5.94×10^{-5}	6.48×10^{-5}	1.11×10^{-5}	1.91×10^{-5}	1.26×10^{-6}	1.10×10^{-7}	2.8×10^{-8}
lb/hr as Ethane	389	364	396	59.3	56.4	3.70	0.32	0.080
lb/hr as Carbon	312	291	316	47.4	45.1	2.96	0.26	0.064
% Efficiency	b/	b/	b/	b/	b/	41	93.7	99.4

Note: All compounds were originally measured as ppm of propane. Other units shown are derived from the propane response.

Retention Index = 200

a/ Dry standard conditions.

b/ Negative efficiency.

Table 5 is in the ESED Confidential Data Files

TABLE 6. GAS CHROMATOGRAPHY ANALYSES FOR PROPANE

	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9
Suction Vent								
ppm as Propane	2.7	2.3	1.8	4.0	1.6	2.4	1.1	3.1
ppm as Carbon	8.1	6.9	5.4	12	4.8	7.2	3.3	9.3
g/m3a/ as Propane	4.9×10^{-3}	4.2×10^{-3}	3.3×10^{-3}	7.3×10^{-3}	2.9×10^{-3}	4.4×10^{-3}	2.0×10^{-3}	5.7×10^{-3}
g/m3a/ as Carbon	4.0×10^{-3}	3.4×10^{-3}	2.7×10^{-3}	6.0×10^{-3}	2.4×10^{-3}	3.6×10^{-3}	1.6×10^{-3}	4.6×10^{-3}
g/sec as Propane	0.0290	0.0247	0.0193	0.0427	0.0171	0.0258	0.0121	0.0340
g/sec as Carbon	0.0237	0.0202	0.0158	0.0350	0.0140	0.0211	9.9 x 10	0.0277
lb/ft3a/ as Propane	3.1×10^{-7}	2.6×10^{-7}	2.0×10^{-7}	4.6×10^{-7}	1.8×10^{-7}	2.7×10^{-7}	1.3×10^{-7}	3.5×10^{-7}
lb/ft3a/ as Carbon	2.5×10^{-7}	2.1×10^{-7}	1.7×10^{-7}	3.7×10^{-7}	1.5×10^{-7}	2.2×10^{-7}	1.0×10^{-7}	2.9×10^{-7}
lb/hr as Propane	0.23	0.20	0.15	0.34	0.14	0.20	0.0962	0.27
lb/hr as Carbon	0.19	0.16	0.13	0.28	0.11	0.17	0.787	0.22
Process Off-Gas								
ppm as Propane	3,424	3,131	3,465	3,400	3,328	3,502	3,080	3,468
ppm as Carbon	10,270	9,393	1,040	10,200	9,984	10,510	9,240	10,400
g/m3a/ as Propane	6.251	5.717	6.326	6.207	6.076	6.394	5.623	6.332
g/m3a/ as Carbon	5.115	4.677	5.176	5.079	4.971	5.231	4.601	5.180
g/sec as Propane	127.8	107.5	121.1	116.3	112.6	118.2	104.1	115.4
g/sec as Carbon	104.6	87.97	99.12	95.18	92.17	96.73	85.21	94.39
lb/ft3a/ as Propane	3.899×10^{-4}	3.565×10^{-4}	3.946×10^{-4}	3.872×10^{-4}	3.790×10^{-4}	3.988×10^{-4}	3.507×10^{-4}	3.949×10^{-4}
lb/ft3a/ as Carbon	3.190×10^{-4}	2.917×10^{-4}	3.228×10^{-4}	3.168×10^{-4}	3.101×10^{-4}	3.263×10^{-4}	2.870×10^{-4}	3.231×10^{-4}
lb/hr as Propane	1,014	852.6	960.6	922.4	893.3	937.4	825.8	914.8
lb/hr as Carbon	829.4	697.6	786.0	754.7	730.8	767.0	675.7	748.4
Outlet								
ppm as Propane	267	310	211	48.4	5.7	4.1	2.4	0.72
ppm as Carbon	802	930	633	145.2	15.6	12.3	7.2	2.16
g/m3a/ as Propane	0.488	0.566	0.385	0.0884	9.5 x 10	7.5×10^{-3}	4.4×10^{-3}	1.31×10^{-3}
g/m3a/ as Carbon	0.399	0.463	0.315	0.0723	7.8 x 10	6.1×10^{-3}	3.6×10^{-3}	1.08×10^{-3}
g/sec as Propane	18.9	21.8	14.8	2.96	0.36	0.28	0.16	0.0494
g/sec as Carbon	15.5	17.8	12.1	2.42	0.30	0.23	0.13	0.0404
lb/ft3a/ as Propane	3.04×10^{-5}	3.53×10^{-5}	2.40×10^{-5}	5.51×10^{-6}	5.9×10^{-7}	4.7×10^{-7}	2.7×10^{-7}	8.2×10^{-8}
lb/ft3a/ as Carbon	2.49×10^{-5}	2.89×10^{-5}	1.97×10^{-5}	4.5×10^{-6}	4.8×10^{-7}	3.8×10^{-7}	2.2×10^{-7}	6.7×10^{-8}
lb/hr as Propane	150	173	118	23.5	2.8	2.2	1.3	0.39
lb/hr as Carbon	123	141	96.2	19.2	2.3	1.8	1.0	0.32
% Efficiency	85	80	88	97.5	99.7	99.8	99.9	99.96

Note: All compounds were originally measured as ppm of propane. Other units shown are derived from the propane response.

Retention Index = 300

a/ Dry standard conditions

TABLE 7. GAS CHROMATOGRAPHY ANALYSES FOR PROPYNE AND METHANOL

Process off-gas	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9
ppm as Propane		2.8	2.8	3.1	3.2	3.9		2.6
ppm as Propyne b/		2.9	2.9	3.2	3.3	4.0		2.7
ppm as Carbon		8.7	8.7	9.7	1.0	12.1		8.1
G/M^3 as Propyne a,b/		4.8×10^{-3}	4.8×10^{-3}	5.3×10^{-3}	5.5×10^{-3}	6.7×10^{-3}		4.5×10^{-3}
G/M^3 as Carbon a/		4.3×10^{-3}	4.3×10^{-3}	4.8×10^{-3}	5.0×10^{-3}	6.0×10^{-3}		4.0×10^{-3}
G/sec as Propyne b/	ND c/	0.0907	0.0924	0.100	0.102	0.12	ND	0.0816
G/sec as Carbon		0.0816	0.0831	0.0900	0.0920	0.111		0.0734
lb/ft^3 as Propyne a,b/		3.0×10^{-7}	3.0×10^{-7}	3.3×10^{-7}	3.4×10^{-7}	4.2×10^{-7}		2.8×10^{-7}
lb/ft^3 as Carbon a/		2.7×10^{-7}	2.7×10^{-7}	3.0×10^{-7}	3.1×10^{-7}	3.8×10^{-7}		2.5×10^{-7}
lb/hr as Propyne b/		0.72	0.73	0.79	0.81	0.98		0.65
lb/hr as Carbon		0.65	0.66	0.71	0.73	0.89		0.58

Note: Retention index = 330 Not Detected at Other Locations

Suction vent	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9
ppm as Propane	85.9	54.1	13.4					
ppm as Methanol b/	514.0	323.0	80.1					
ppm as Carbon	514.0	323.0	80.1					
G/M^3 as Methanol a,b/	0.682	0.429	0.106					
G/M^3 as Carbon a/	0.256	0.161	0.0399					
G/sec as Methanol b/	4.00	2.53	0.624	ND	ND	ND	ND	ND
G/sec as Carbon	1.503	0.949	0.234					
lb/ft^3 as Methanol a,b/	4.25×10^{-5}	2.68×10^{-5}	6.63×10^{-6}					
lb/ft^3 as Carbon a/	1.60×10^{-5}	1.00×10^{-5}	2.49×10^{-6}					
lb/hr as Methanol b/	31.8	20.1	4.95					
lb/hr as Carbon	11.92	7.52	1.86					

Note: Retention index = 370 Not Detected at Other Locations

Note: All compounds were originally measured as ppm of propane. Other units shown are derived from the propane response.

a/ Dry standard conditions.

b/ Identification is uncertain; the peak may be this compound.

c/ ND = None detected.

TABLE 8. GAS CHROMATOGRAPHY ANALYSES FOR ACETALDEHYDE

	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9
Suction vent								
ppm as Propane	6.2	1.5	2.9	3.2	1.46	1.65	2.7	4.5
ppm as Acetaldehyde	16.8	4.05	7.84	8.65	3.95	4.46	7.30	12.2
ppm as Carbon	33.5	8.11	15.7	17.3	7.89	8.92	14.6	24.3
G/M^3 as Acetaldehyde a/	0.0306	7.40×10^{-3}	0.0143	0.0158	7.20×10^{-3}	8.14×10^{-3}	0.0133	0.0222
G/M^3 as Carbon a/	0.0167	4.04×10^{-3}	7.81×10^{-3}	8.61×10^{-3}	3.93×10^{-3}	4.44×10^{-3}	7.27×10^{-3}	0.0121
G/sec as Acetaldehyde	0.180	0.0436	0.0840	0.0924	0.0421	0.0479	0.0805	0.133
G/sec as Carbon	0.0981	0.0238	0.0458	0.0504	0.0229	0.0261	0.0439	0.0725
lb/ft^3 as Acetaldehyde a/	1.91×10^{-6}	4.62×10^{-7}	8.92×10^{-7}	9.85×10^{-7}	4.49×10^{-7}	5.08×10^{-7}	8.31×10^{-7}	1.38×10^{-6}
lb/ft^3 as Carbon a/	1.04×10^{-6}	2.52×10^{-7}	4.87×10^{-7}	5.37×10^{-7}	2.45×10^{-7}	2.77×10^{-7}	4.53×10^{-7}	7.55×10^{-7}
lb/hr as Acetaldehyde	1.43	0.346	0.667	0.732	0.334	0.380	0.638	1.05
lb/hr as Carbon	0.778	0.189	0.363	0.400	0.182	0.207	0.348	0.575
Process off-gas	(24%) b/	(26%) b/	(25%) b/	(22%) b/	(19%) b/	(16%) b/	(9%) b/	(17%) b/
ppm as Propane	36.5	39.4	38.8	35.6	43.4	37.0	35.2	41.1
ppm as Acetaldehyde	98.8	108.7	105.0	96.2	117.3	100.0	95.1	111.2
ppm as Carbon	198.0	217.4	210.0	192.3	235.0	200.0	190.3	222.4
G/M^3 as Acetaldehyde a/	0.18	0.199	0.192	0.176	0.214	0.183	0.174	0.203
G/M^3 as Carbon a/	0.094	0.108	0.104	0.096	0.117	0.10	0.095	0.111
G/sec as Acetaldehyde	3.69	3.73	3.67	3.23	3.97	3.38	3.22	3.70
G/sec as Carbon	2.01	2.04	2.0	1.79	2.17	1.84	1.75	2.02
lb/ft^3 as Acetaldehyde a/	1.12×10^{-5}	1.24×10^{-5}	1.20×10^{-5}	1.10×10^{-5}	1.34×10^{-5}	1.14×10^{-5}	1.08×10^{-5}	1.27×10^{-5}
lb/ft^3 as Carbon a/	6.13×10^{-6}	6.75×10^{-6}	6.52×10^{-6}	5.97×10^{-6}	7.29×10^{-6}	6.21×10^{-6}	5.91×10^{-6}	6.91×10^{-6}
lb/hr as Acetaldehyde	29.24	29.61	29.10	26.1	31.48	26.77	25.51	29.33
lb/hr as Carbon	15.95	16.15	15.87	14.23	17.17	14.60	13.91	16.0
Outlet	(4%) b/	(29%) b/	(ND) d/	(ND)	(ND)	(ND)	(ND)	
ppm as Propane	14.2	25.0	16.0	4.2	1.1	0.45	0.63	
ppm as Acetaldehyde	44.5	67.5	43.0	11.4	2.97	1.22	1.70	
ppm as Carbon	76.9	135.0	86.0	22.7	5.95	2.43	3.41	
G/M^3 as Acetaldehyde a/	0.070	0.123	0.079	0.0207	5.43×10^{-3}	2.22×10^{-3}	3.11×10^{-3}	
G/M^3 as Carbon a/	0.038	0.0681	0.043	0.0113	2.46×10^{-3}	1.21×10^{-3}	1.70×10^{-3}	
G/sec as Acetaldehyde	2.72	4.75	3.0	0.694	0.204	0.0833	0.113	ND
G/sec as Carbon	1.49	2.59	1.66	0.379	0.111	0.0454	0.0619	
lb/ft^3 as Acetaldehyde a/	4.38×10^{-6}	7.69×10^{-6}	4.9×10^{-6}	1.29×10^{-6}	3.39×10^{-7}	1.38×10^{-7}	1.94×10^{-7}	
lb/ft^3 as Carbon a/	2.39×10^{-6}	4.20×10^{-6}	2.7×10^{-6}	7.05×10^{-7}	1.85×10^{-7}	7.55×10^{-8}	1.06×10^{-7}	
lb/hr as Acetaldehyde	21.6	37.7	24.1	5.51	1.61	0.660	0.900	
lb/hr as Carbon	11.8	20.5	13.2	3.00	0.880	0.360	0.491	
% Efficiency	29.0	c/	79.0	79.0	95.0	97.6	96.5	

Note: All compounds were originally measured as ppm of propane. Other units shown are derived from the propane response.

Note: Retention index = 390

a/ Dry standard conditions.

b/ Fraction found in condensate.

c/ Negative efficiency.

d/ None detected.

TABLE 9. GAS CHROMATOGRAPHY ANALYSES FOR BUTENES

	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9
Suction Vent								
ppm as Propane	2.5	2.6	3.7	2.5	3.4	4.1	2.8	3.7
ppm as Butenes	1.9	2.0	2.9	1.9	2.6	3.2	2.2	2.9
ppm as Carbon	7.7	8.0	11	7.7	10.5	12.6	8.6	11
g/m^3 a/ as Butenes	4.5×10^{-3}	4.7×10^{-3}	6.6×10^{-3}	4.5×10^{-3}	6.1×10^{-3}	7.3×10^{-3}	5.0×10^{-3}	6.6×10^{-3}
g/m^3 a/ as Carbon	3.8×10^{-3}	4.0×10^{-3}	5.7×10^{-3}	3.8×10^{-3}	5.2×10^{-3}	6.3×10^{-3}	4.3×10^{-3}	5.7×10^{-3}
g/sec as Butenes	0.026	0.027	0.039	0.026	0.0355	0.043	0.030	0.040
g/sec as Carbon	0.023	0.0235	0.033	0.022	0.0305	0.037	0.026	0.034
lb/ft^3 a/ as Butenes	2.8×10^{-7}	2.9×10^{-7}	4.1×10^{-7}	2.8×10^{-7}	3.8×10^{-7}	4.6×10^{-7}	3.1×10^{-7}	4.1×10^{-7}
lb/ft^3 a/ as Carbon	2.4×10^{-7}	2.5×10^{-7}	3.5×10^{-7}	2.4×10^{-7}	3.3×10^{-7}	3.9×10^{-7}	2.7×10^{-7}	3.5×10^{-7}
lb/hr as Butenes	0.21	0.22	0.31	0.21	0.28	0.34	0.24	0.31
lb/hr as Carbon	0.18	0.19	0.26	0.18	0.24	0.29	0.21	0.27
Process Off-Gas								
ppm as Propane	5.7	5.6	5.5	5.3	3.9	4.8	5.6	5.2
ppm as Butenes	4.4	4.3	4.2	4.1	3.0	3.7	4.3	4.0
ppm as Carbon	17.6	17.3	16.9	16.3	12	14.8	17.3	16
g/m^3 a/ as Butenes	0.0102	0.0100	9.8×10^{-3}	9.5×10^{-3}	7.0×10^{-3}	8.6×10^{-3}	0.0100	9.3×10^{-3}
g/m^3 a/ as Carbon	8.7×10^{-3}	8.6×10^{-3}	8.4×10^{-3}	8.1×10^{-3}	6.0×10^{-3}	7.4×10^{-3}	8.6×10^{-3}	8.0×10^{-3}
g/sec as Butenes	0.21	0.19	0.19	0.18	0.13	0.16	0.19	0.17
g/sec as Carbon	0.18	0.16	0.16	0.15	0.11	0.14	0.16	0.15
lb/ft^3 a/ as Butenes	6.4×10^{-7}	6.3×10^{-7}	6.1×10^{-7}	5.9×10^{-7}	4.4×10^{-7}	5.4×10^{-7}	6.3×10^{-7}	5.8×10^{-7}
lb/ft^3 a/ as Carbon	5.5×10^{-7}	5.4×10^{-7}	5.3×10^{-7}	5.1×10^{-7}	3.7×10^{-7}	4.6×10^{-7}	5.4×10^{-7}	5.0×10^{-7}
lb/hr as Butenes	1.7	1.5	1.5	1.4	1.0	1.3	1.5	1.3
lb/hr as Carbon	1.4	1.3	1.3	1.2	0.88	1.1	1.3	1.2
Outlet								
ppm as Propane	2.7		2.6	1.0				
ppm as Butenes	2.1		2.0	0.77				
ppm as Carbon	8.4		7.9	3.1				
g/m^3 a/ as Butenes	4.9×10^{-3}		4.6×10^{-3}	1.8×10^{-3}				
g/m^3 a/ as Carbon	4.3×10^{-3}		3.9×10^{-3}	1.5×10^{-3}				
g/sec as Butenes	0.20		0.178	0.0600				
g/sec as Carbon	0.17	ND b/	0.152	0.0514	ND b/	ND b/	ND b/	ND b/
lb/ft^3 a/ as Butenes	3.0×10^{-7}		3.0×10^{-7}	1.1×10^{-7}				
lb/ft^3 a/ as Carbon	2.6×10^{-7}		2.4×10^{-7}	9.6×10^{-8}				
lb/hr as Butenes	1.50		1.4	0.48				
lb/hr as Carbon	1.29		1.2	0.41				
% Efficiency	20		23	70				

Note: All compounds were originally measured as ppm of propane. Other units shown are derived from the propane response.

Retention Index = 410

a/ Dry standard conditions.

b/ None detected.

Table 10 is in the ESED Confidential Data Files

Table 11 is in the ESED Confidential Data Files

TABLE 12. GAS CHROMATOGRAPHY ANALYSES FOR ACETONE

	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9
Suction vent								
ppm as Propane	57.0	68.0	67.0	61.0	64.0	77.0	67.0	117.0
ppm as Acetone	86.5	103.0	102.0	93.0	97.0	117.0	102.0	178.0
ppm as Carbon	259.0	310.0	305.0	278.0	291.0	350.0	305.0	533.0
G/M^3 as Acetone[a]	0.208	0.248	0.245	0.223	0.234	0.281	0.245	0.427
G/M^3 as Carbon[a]	0.129	0.154	0.152	0.138	0.145	0.175	0.152	0.265
G/sec as Acetone	1.22	1.46	1.44	1.30	1.36	1.65	1.48	2.56
G/sec as Carbon	0.759	0.908	0.891	0.809	0.847	1.03	0.917	1.59
lb/ft^3 as Acetone[a]	1.3×10^{-5}	1.55×10^{-5}	1.53×10^{-5}	1.39×10^{-5}	1.46×10^{-5}	1.75×10^{-5}	1.53×10^{-5}	2.66×10^{-5}
lb/ft^3 as Carbon[a]	8.06×10^{-6}	9.61×10^{-6}	9.47×10^{-6}	8.62×10^{-6}	9.05×10^{-6}	1.09×10^{-5}	9.47×10^{-6}	1.65×10^{-5}
lb/hr as Acetone	9.7	11.60	11.4	10.3	10.8	13.1	11.7	20.3
lb/hr as Carbon	6.02	7.20	7.07	6.41	6.72	8.14	7.27	12.6
Process off-gas								
	(19%)[b]	(19%)[b]	(19%)[b]	(17%)[b]	(16%)[b]	(4%)[b]	(11%)[b]	(4%)[b]
ppm as Propane	140.0	175.0	155.0	151.0	164.0	1,279.0	152.0	709.0
ppm as Acetone	212.0	265.0	236.0	229.0	249.0	1,940.0	231.0	1,076.0
ppm as Carbon	637.0	796.0	705.0	688.0	747.0	5,820.0	693.0	3,228.0
G/M^3 as Acetone[a]	0.512	0.638	0.566	0.552	0.600	4.67	0.556	2.59
G/M^3 as Carbon[a]	0.318	0.396	0.351	0.343	0.372	2.90	0.345	1.61
G/sec as Acetone	10.5	12.0	10.8	10.3	11.1	86.4	10.3	47.2
G/sec as Carbon	6.49	7.45	6.73	6.42	6.90	53.6	6.39	29.3
lb/ft^3 as Acetone[a]	3.19×10^{-5}	3.98×10^{-5}	3.53×10^{-5}	3.44×10^{-5}	3.74×10^{-5}	2.91×10^{-4}	3.47×10^{-5}	1.62×10^{-4}
lb/ft^3 as Carbon[a]	1.98×10^{-5}	2.47×10^{-5}	2.19×10^{-5}	2.14×10^{-5}	2.32×10^{-5}	1.81×10^{-4}	2.15×10^{-5}	1.0×10^{-4}
lb/hr as Acetone	83.0	95.2	85.9	82.1	88.2	684.0	81.7	374.0
lb/hr as Carbon	51.5	59.1	53.3	50.9	54.7	425.0	50.7	232.0
Outlet								
		(47%)[b]						
ppm as Propane	10.0	7.7	7.0	1.4			0.28	0.39
ppm as Acetone	15.2	11.7	10.6	2.12			0.425	0.592
ppm as Carbon	45.6	35.0	32.0	6.37			1.27	1.78
G/M^3 as Acetone[a]	0.035	0.028	0.026	5.11×10^{-3}			1.02×10^{-3}	1.42×10^{-3}
G/M^3 as Carbon[a]	0.023	0.0174	0.0158	3.17×10^{-3}			6.35×10^{-4}	8.84×10^{-4}
G/sec as Acetone	1.42	1.08	0.98	0.171	ND[c]	ND[c]	0.037	0.054
G/sec as Carbon	0.88	0.67	0.61	0.106			0.023	0.033
lb/ft^3 as Acetone[a]	2.3×10^{-6}	1.75×10^{-6}	1.59×10^{-6}	3.19×10^{-7}			6.38×10^{-8}	8.88×10^{-8}
lb/ft^3 as Propane[a]	1.4×10^{-6}	1.09×10^{-6}	9.9×10^{-7}	1.98×10^{-7}			3.96×10^{-8}	5.51×10^{-8}
lb/hr as Acetone	11.3	8.6	7.8	1.36			0.296	0.425
lb/hr as Carbon	7.0	5.3	4.8	0.84			0.18	0.26
% Efficiency	88.0	92.0	92.0	98.5			99.7	99.9

Note: All compounds were originally measured as ppm of propane. Other units shown are derived from the propane response.

Note: Retention index = 510.

a/ Dry standard conditions.

b/ Fraction found in condensate.

c/ None detected.

TABLE 13. GAS CHROMATOGRAPHY ANALYSES FOR METHYL ACRYLATE

	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9
Suction Vent								
ppm as Propane	28	36	35	34	39	39	40	34
ppm as Methyl Acrylate	34	44	43	41	48	48	49	41
ppm as Carbon	140	180	170	170	190	190	190	170
g/m^3 a/ as Methyl Acrylate	0.12	0.16	0.15	0.15	0.17	0.17	0.17	0.15
g/m^3 a/ as Carbon	0.0680	0.0873	0.0849	0.0825	0.0946	0.0946	0.0970	0.0825
g/sec as Methyl Acrylate	0.72	0.92	0.89	0.86	1.0	1.0	1.1	0.89
g/sec as Carbon	0.40	0.51	0.50	0.48	0.55	0.56	0.57	0.49
lb/ft^3 a/ as Methyl Acrylate	7.6×10^{-6}	9.8×10^{-6}	9.5×10^{-6}	9.2×10^{-6}	1.1×10^{-5}	1.1×10^{-5}	1.1×10^{-5}	9.2×10^{-6}
lb/ft^3 a/ as Carbon	4.2×10^{-6}	5.4×10^{-6}	5.3×10^{-6}	5.1×10^{-6}	5.9×10^{-6}	5.9×10^{-6}	6.1×10^{-6}	5.1×10^{-6}
lb/hr as Methyl Acrylate	5.7	7.3	7.1	6.9	7.9	7.9	8.3	7.0
lb/hr as Carbon	3.2	4.1	4.0	3.8	4.4	4.4	4.6	3.9
Process Off-Gas								
ppm as Propane	1.7	1.5	-	-	3.3	2.9	-	-
ppm as Methyl Acrylate	2.1	1.8	ND b/	ND b/	4.0	3.5	ND b/	ND b/
ppm as Carbon	8.3	7.3			16	14		
g/m^3 a/ as Methyl Acrylate	7.4×10^{-3}	6.5×10^{-3}			0.0143	0.0126		
g/m^3 a/ as Carbon	4.1×10^{-3}	3.6×10^{-3}			8.0×10^{-3}	7.0×10^{-3}		
g/sec as Methyl Acrylate	0.15	0.12			0.27	0.23		
g/sec as Carbon	0.0843	0.0685			0.15	0.13		
lb/ft^3 a/ as Methyl Acrylate	4.6×10^{-7}	4.1×10^{-7}			8.9×10^{-7}	7.9×10^{-7}		
lb/ft^3 a/ as Carbon	2.6×10^{-7}	2.3×10^{-7}			5.0×10^{-7}	4.4×10^{-7}		
lb/hr as Methyl Acrylate	1.2	0.97			2.1	1.8		
lb/hr as Carbon	0.67	0.54			1.2	1.0		
Outlet								
ppm as Propane	5.0	ND b/	ND b/	ND b/	ND b/	0.95	ND b/	ND b/
ppm as Methyl Acrylate	6.1					1.15		
ppm as Carbon	24					4.6		
g/m^3 a/ as Methyl Acrylate	0.022					4.1×10^{-3}		
g/m^3 a/ as Carbon	12.2×10^{-3}					2.30×10^{-3}		
g/sec as Methyl Acrylate	0.85					0.155		
g/sec as Carbon	0.47					0.0864		
lb/ft^3 a/ as Methyl Acrylate	1.35×10^{-6}					2.57×10^{-7}		
lb/ft^3 a/ as Carbon	7.6×10^{-7}					1.44×10^{-7}		
lb/hr as Methyl Acrylate	6.7					1.23		
lb/hr as Carbon	3.8					0.69		
% Efficiency	-0-					98.3		

Note: All compounds were originally measured as ppm of propane. Other units shown are derived from the propane response.

Note: Retention index = 520

a/ Dry standard conditions

b/ None detected.

TABLE 14. GAS CHROMATOGRAPHY ANALYSES FOR UNKNOWN PEAK NO. 3

Not Detected at Suction Vent

Process off-gas	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9
ppm as Propane	8.4	8.6	8.8	8.2	8.4	9.6	9.0	10.0
ppm as Propane	8.4	8.6	8.8	8.2	8.4	9.6	9.0	10.0
ppm as Carbon	25.2	25.8	26.4	24.6	25.2	28.8	27.0	3.0
G/M^3 as Propane a/	0.0153	0.0157	0.0161	0.0150	0.0153	0.0175	0.0164	0.0183
G/M^3 as Carbon a/	0.0125	0.0128	0.0131	0.0125	0.0125	0.0143	0.0134	0.0150
G/sec as Propane	0.31	0.30	0.31	0.28	0.28	0.32	0.30	0.33
G/sec as Carbon	0.26	0.24	0.25	0.23	0.23	0.27	0.25	0.27
lb/ft^3 as Propane a/	9.6×10^{-7}	9.8×10^{-7}	1.0×10^{-6}	9.3×10^{-7}	9.6×10^{-7}	1.1×10^{-6}	1.0×10^{-6}	1.1×10^{-6}
lb/ft^3 as Carbon a/	7.8×10^{-7}	8.0×10^{-7}	8.2×10^{-7}	7.6×10^{-7}	7.8×10^{-7}	8.9×10^{-7}	8.4×10^{-7}	9.3×10^{-7}
lb/hr as Propane	2.49	2.34	2.44	2.2	2.3	2.6	2.4	2.6
lb/hr as Carbon	2.03	1.92	2.0	1.8	1.8	2.1	2.0	2.2

Not Detected at Outlet

Note: All compounds were originally measured as ppm of propane. Other units shown are derived from the propane response.

Note: Retention index = 640

a/ Dry standard conditions.

TABLE 15. GAS CHROMATOGRAPHY ANALYSES FOR UNKNOWN PEAK NO. 4

	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9
Suction Vent			None Detected at Suction Vent b/					
Process Off-Gas								
ppm as Propane		2.5	2.1		6.6	3.0	2.8	5.2
ppm as Propane		2.5	2.1		6.6	3.0	2.8	5.2
ppm as Carbon		7.5	6.3		19.8	9.0	8.4	15.6
G/M^3 as Propane a/		4.6×10^{-3}	3.8×10^{-3}		0.120	5.5×10^{-3}	5.1×10^{-3}	9.5×10^{-3}
G/M^3 as Carbon a/		3.7×10^{-3}	3.1×10^{-3}		9.9×10^{-3}	4.5×10^{-3}	4.2×10^{-3}	7.8×10^{-3}
G/sec as Propane		0.0859	0.0734	ND d/	0.22	0.10	0 0947	0.17
G/sec as Carbon		0.0702	0.0601		0.183	0.0829	0.0775	0.14
lb/ft^3 as Propane a/		2.8×10^{-7}	2.4×10^{-7}		7.5×10^{-7}	3.4×10^{-7}	3.2×10^{-7}	5.9×10^{-7}
lb/ft^3 as Carbon a/		2.3×10^{-7}	2.0×10^{-7}		6.1×10^{-7}	2.8×10^{-7}	2.6×10^{-7}	4.8×10^{-7}
lb/hr as Propane		0.68	0.58		1.8	0.80	0.75	1.4
lb/hr as Carbon		0.56	0.48		1.4	0.66	0.61	1.1
Outlet								
ppm as Propane		1.8	12.9	1.2		1.2		4.1
ppm as Propane		1.8	12.9	1.2		1.2		4.1
ppm as Carbon		5.4	38.6	3.6		3.6		12.3
G/M^3 as Propane a/		3.3×10^{-3}	0.0236	2.2×10^{-3}		2.2×10^{-3}		7.5×10^{-3}
G/M^3 as Carbon a/		2.8×10^{-3}	0.0193	1.8×10^{-3}		1.8×10^{-3}		6.1×10^{-3}
G/sec as Propane		0.13	0.90	0.0734	ND d/	0.0822	ND d/	0.28
G/sec as Carbon		0.11	0.74	0.0600		0.0672		0.23
lb/ft^3 as Propane a/		2.0×10^{-7}	1.47×10^{-6}	1.4×10^{-7}		1.4×10^{-7}		4.7×10^{-7}
lb/ft^3 as Carbon a/		1.7×10^{-7}	1.20×10^{-6}	1.2×10^{-7}		1.1×10^{-7}		3.8×10^{-7}
lb/hr as Propane		1.03	7.2	0.58		0.65		2.2
lb/hr as Carbon		0.85	5.9	0.48		0.53		1.8
% Efficiency		c/	c/			20.0		c/

Note: All compounds were originally measured as ppm of propane. Other units shown are derived from the propane response.

Note: Retention index = 685

a/ Dry standard conditions.

b/ Peak present at suction vent, but is assumed to be the shifted acrylic acid peak.

c/ Negative efficiency.

d/ None detected.

TABLE 16. GAS CHROMATOGRAPHY ANALYSES FOR ACRYLIC ACID

	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9
Suction Vent[a]								
ppm as Propane	832	948	899	1,120	1,020	1,130	991	865
ppm as Acrylic Acid	1,300	1,490	1,410	1,750	1,600	1,770	1,550	1,360
ppm as Carbon	3,910	4,460	4,230	5,260	4,790	5,310	4,660	4,070
g/m^3[b] as Acrylic Acid	3.89	4.44	4.21	5.24	4.77	5.29	4.64	4.05
g/m^3[b] as Carbon	1.95	2.22	2.10	2.62	2.39	2.64	2.32	2.02
g/sec as Acrylic Acid	22.9	26.1	24.7	30.7	27.9	31.1	28.0	24.3
g/sec as Carbon	11.5	13.1	12.4	15.3	13.9	15.6	14.0	12.1
lb/ft^3[b] as Acrylic Acid	2.43×10^{-4}	2.77×10^{-4}	2.62×10^{-4}	3.27×10^{-4}	2.98×10^{-4}	3.30×10^{-4}	2.89×10^{-4}	2.53×10^{-4}
lb/ft^3[b] as Carbon	1.21×10^{-4}	1.38×10^{-4}	1.31×10^{-4}	1.64×10^{-4}	1.49×10^{-4}	1.65×10^{-4}	1.45×10^{-4}	1.26×10^{-4}
lb/hr as Acrylic Acid	182	207	196	243	221	247	222	192
lb/hr as Carbon	90.8	104	97.9	122	111	123	111	96.2
Process Off-gas								
ppm as Propane	60.0	60	60	64	65	59	57	64
ppm as Acrylic Acid	94.0	94	94	100	100	92	89	100
ppm as Carbon	280	280	280	300	310	280	270	300
g/m^3[b] as Acrylic Acid	0.281	0.28	0.28	0.30	0.30	0.28	0.27	0.30
b/m^3[b] as Carbon	0.140	0.140	0.140	0.150	0.152	0.138	0.133	0.149
g/sec as Acrylic Acid	5.74	5.3	5.4	5.6	5.6	5.1	4.9	5.5
g/sec as Carbon	2.9	2.6	2.7	2.8	2.8	2.6	2.5	2.7
lb/ft^3[b] as Acrylic Acid	1.75×10^{-5}	1.8×10^{-5}	1.8×10^{-5}	1.9×10^{-5}	1.9×10^{-5}	1.7×10^{-5}	1.7×10^{-5}	1.9×10^{-5}
lb/ft^3[b] as Carbon	8.76×10^{-6}	8.8×10^{-6}	8.8×10^{-6}	9.3×10^{-6}	9.5×10^{-6}	8.6×10^{-6}	8.3×10^{-6}	9.3×10^{-6}
lb/hr as Acrylic Acid	45.5	42	43	45	45	40	39	43
lb/hr as Carbon	22.8	21	21	22	22	20	20	22
Outlet								
ppm as Propane	8.8	3.3	2.8	0.75	36.2	2.2	1.4	1.2
ppm as Acrylic Acid	13.8	5.2	4.4	1.17	56.7	3.4	2.2	1.9
ppm as Carbon	41	16	13	3.5	170	10.3	6.6	5.6
g/m^3[b] as Acrylic Acid	0.041	0.015	0.013	3.5×10^{-3}	0.169	0.0103	6.6×10^{-3}	5.6×10^{-3}
g/m^3[b] as Carbon	0.021	7.7×10^{-3}	6.4×10^{-3}	1.8×10^{-3}	0.0847	5.1×10^{-3}	3.3×10^{-3}	2.8×10^{-3}
g/sec as Acrylic Acid	1.60	0.59	0.50	0.118	6.35	0.39	0.24	0.21
g/sec as Carbon	0.81	0.29	0.26	0.0588	3.18	0.19	0.12	0.11
lb/ft^3[b] as Acrylic Acid	2.57×10^{-6}	9.8×10^{-7}	8.1×10^{-7}	2.19×10^{-7}	1.06×10^{-5}	6.4×10^{-7}	4.1×10^{-7}	3.5×10^{-7}
lb/ft^3[b] as Carbon	1.29×10^{-6}	4.8×10^{-7}	4.0×10^{-7}	1.09×10^{-7}	5.28×10^{-6}	3.2×10^{-7}	2.0×10^{-7}	1.8×10^{-7}
lb/hr as Acrylic Acid	12.8	4.8	3.9	0.93	50.4	3.1	1.9	1.7
lb/hr as Carbon	6.4	2.4	2.0	0.47	25.2	1.5	0.95	0.84
% Efficiency	94.4	98	98.4	99.7	81	99.0	99.3	99.3

Note: All compounds were originally measured as ppm of propane. Other units shown are derived from the propane response.

Note: Retention Index = 710

a/ Acrylic Acid peak appears to have shifted on top of unknown peak No. 4 at suction vent.

b/ Dry standard conditions

TABLE 17. GAS CHROMATOGRAPHY ANALYSES FOR ETHYL ACRYLATE

Suction vent	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9
ppm as Propane	439	474	481	364	492	447	486	517
ppm as Ethyl acrylate	386	417	423	320	433	393	428	455
ppm as Carbon	1,930	2,090	2,120	1,600	2,160	1,970	2,140	2,270
G/M^3 as Ethyl acrylate[a]	1.60	1.73	1.76	1.33	1.80	1.63	1.775	1.89
G/M^3 as Carbon[a]	0.96	1.04	1.05	0.80	1.08	0.98	1.065	1.13
G/sec as Ethyl acrylate	9.43	10.19	10.31	7.78	10.49	9.60	10.43	11.31
G/sec as Carbon	5.66	6.12	6.19	4.67	6.29	5.76	6.26	6.78
lb/ft^3 as Ethyl acrylate[a]	10.0×10^{-5}	1.08×10^{-4}	1.10×10^{-4}	8.29×10^{-5}	1.20×10^{-4}	1.02×10^{-4}	1.11×10^{-4}	1.18×10^{-4}
lb/ft^3 as Carbon[a]	6.0×10^{-5}	6.48×10^{-5}	6.57×10^{-5}	4.97×10^{-5}	6.72×10^{-5}	6.11×10^{-5}	6.64×10^{-5}	7.06×10^{-5}
lb/hr as Ethyl acrylate	74.7	80.8	81.8	61.7	83.1	76.1	82.7	89.7
lb/hr as Carbon	44.8	48.5	49.0	37.0	49.9	45.7	49.6	53.8
Process off-gas								
ppm as Propane		5.2	2.6			5.3	6.1	2.1
ppm as Ethyl acrylate		4.6	2.3			4.7	5.3	1.8
ppm as Carbon		22.9	11.44			23.3	26.8	9.2
G/M^3 as Ethyl acrylate[a]		0.02	9.49×10^{-3}			0.02	0.02	7.7×10^{-3}
G/M^3 as Carbon[a]		0.01	5.70×10^{-3}			0.01	0.01	4.6×10^{-3}
G/sec as Ethyl acrylate	ND[b]	0.36	0.18	ND[b]	ND[b]	0.36	0.41	0.14
G/sec as Carbon		0.21	0.11			0.21	0.25	0.08
lb/ft^3 as Ethyl acrylate[a]		1.18×10^{-6}	5.9×10^{-7}			1.21×10^{-6}	1.39×10^{-6}	4.8×10^{-7}
lb/ft^3 as Carbon[a]		7.1×10^{-7}	3.6×10^{-7}			7.24×10^{-7}	8.3×10^{-7}	2.9×10^{-7}
lb/hr as Ethyl acrylate		2.83	1.44			2.84	3.27	1.11
lb/hr as Carbon		1.70	0.86			1.70	1.96	0.66

None Detected at Outlet

Note: All compounds were originally measured as ppm of propane. Other units shown are derived from the propane response.

Note: Retention index = 730

a/ Dry standard conditions.

b/ None detected.

TABLE 18. GAS CHROMATOGRAPHY ANALYSES FOR PROPYL AND BUTYL ACRYLATE

Suction vent	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 7	Run 8
ppm as Propane	243	318	304	390	362	418	342	328
ppm as Propyl acrylate	167	219	210	269	249	288	236	226
ppm as Carbon	1,000	1,320	1,260	1,610	1,500	1,730	1,410	1,360
G/M^3 as Propyl acrylate a/	0.792	1.04	0.991	1.27	1.18	1.36	1.12	1.07
G/M^3 as Carbon a/	0.500	0.655	0.626	0.803	0.745	0.861	0.704	0.675
G/sec as Propyl acrylate	4.66	6.11	5.82	7.44	6.89	8.01	6.73	6.41
G/sec as Carbon	2.94	3.86	3.67	4.70	4.35	5.06	4.25	4.05
lb/ft^3 as Propyl acrylate a/	4.94×10^{-5}	6.47×10^{-5}	6.18×10^{-5}	7.93×10^{-5}	7.36×10^{-5}	8.50×10^{-5}	6.95×10^{-5}	6.67×10^{-5}
lb/ft^3 as Carbon a/	3.12×10^{-5}	4.08×10^{-5}	3.90×10^{-5}	5.01×10^{-5}	4.65×10^{-5}	5.37×10^{-5}	4.39×10^{-5}	4.21×10^{-5}
lb/hr as Propyl acrylate	35.9	48.4	46.1	59.0	54.7	63.5	53.5	50.8
lb/hr as Carbon	23.3	30.6	29.1	37.3	34.5	40.1	33.7	32.1

Note: Retention index = 845

a/ Dry standard conditions.

None detected at outlet or process off-gas locations.

ppm as Propane	92	105	92	120	111		125	99
ppm as Butyl acrylate	52	59.2	51.8	67.6	62.6		70.4	55.8
ppm as Carbon	363	414	363	473	438		493	391
G/M^3 as Butyl acrylate a/	0.276	0.314	0.275	0.359	0.332		0.374	0.296
G/M^3 as Carbon a/	0.181	0.206	0.181	0.236	0.218		0.246	0.194
G/sec as Butyl acrylate	1.62	1.85	1.62	2.10	1.94	ND b/	2.26	1.78
G/sec as Carbon	1.06	1.21	1.06	1.38	1.27		1.48	1.16
lb/ft^3 as Butyl acrylate a/	1.72×10^{-5}	1.96×10^{-5}	1.72×10^{-5}	2.24×10^{-5}	2.07×10^{-5}		2.33×10^{-5}	1.85×10^{-5}
lb/ft^3 as Carbon a/	1.13×10^{-5}	1.29×10^{-5}	1.13×10^{-5}	1.47×10^{-5}	1.36×10^{-5}		1.53×10^{-5}	1.21×10^{-5}
lb/hr as Butyl acrylate	12.8	14.7	12.8	16.7	15.4		17.9	14.1
lb/hr as Carbon	8.4	9.63	8.41	10.9	10.1		11.8	9.24

Note: Retention index = 980

a/ Dry standard conditions.

b/ None detected.

None detected at outlet or process off-gas locations.

Note: All compounds were originally measured as ppm of propane. Other units shown are derived from the propane response.

TABLE 19. GAS CHROMATOGRAPHY ANALYSES FOR TOTAL HYDROCARBONS[b/]

	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9
Suction vent								
ppm as Propane	1,820.0	2,050.0	1,952.0	2,140.0	2,140.0	2,170.0	1,700.0	2,020.0
ppm as Hydrocarbons	2,620.0	2,730.0	2,402.0	2,630.0	2,570.0	2,700.0	2,500.0	2,410.0
ppm as Carbon	8,350.0	9,290.0	8,760.0	9,673.0	9,590.0	9,980.0	9,400.0	9,050.0
G/M^3 as Hydrocarbons[a/]	7.74	8.51	7.91	8.74	8.63	8.91	8.47	8.06
G/M^3 as Carbon[a/]	4.16	4.62	4.35	4.80	4.78	4.87	4.68	4.49
G/sec as Hydrocarbons	45.5	50.0	46.4	51.2	50.9	53.0	51.2	48.8
G/sec as Carbon	24.5	27.3	25.7	28.0	28.3	29.3	28.3	27.4
lb/ft^3 as Hydrocarbons[a/]	4.83×10^{-4}	5.29×10^{-4}	4.93×10^{-4}	5.45×10^{-4}	5.47×10^{-4}	5.57×10^{-4}	5.29×10^{-4}	5.51×10^{-4}
lb/ft^3 as Carbon[a/]	2.58×10^{-4}	2.78×10^{-4}	2.71×10^{-4}	3.00×10^{-4}	2.98×10^{-4}	3.06×10^{-4}	2.93×10^{-4}	3.02×10^{-4}
lb/hr as Hydrocarbons	362.0	396.0	368.0	405.0	404.0	421.0	399.0	386.0
lb/hr as Carbon	193.0	216.0	201.0	221.0	225.0	232.0	231.0	217.0
Propane from THC mode (column bypass) ppm	740.0[c/]	3,670.0	3,530.0	3,550.0	3,270.0	3,670.0	3,265.0	3,390.0
Process off-gas								
ppm as Propane	11,360.0	10,780.0	11,170.0	10,660.0	11,160.0	12,060.0	14,650.0	11,490.0
ppm as Hydrocarbons	12,010.0	11,460.0	11,830.0	11,330.0	11,820.0	13,260.0	15,420.0	12,380.0
ppm as Carbon	35,460.0	33,830.0	25,580.0	31,290.0	34,890.0	39,340.0	45,730.0	36,760.0
G/M^3 as Hydrocarbons[a/]	28.3	20.5	21.1	21.2	21.2	24.8	27.4	22.8
G/M^3 as Carbon[a/]	17.6	16.8	17.4	16.6	17.4	19.5	22.8	18.3
G/sec as Hydrocarbons	438.0	386.0	404.0	378.0	393.0	458.0	508.0	417.0
G/sec as Carbon	361.0	316.0	333.0	311.0	322.0	362.0	422.0	264.0
lb/ft^3 as Hydrocarbons[a/]	1.34×10^{-3}	1.28×10^{-3}	1.32×10^{-3}	33.4	1.32×10^{-3}	1.55×10^{-3}	1.71×10^{-3}	1.43×10^{-3}
lb/ft^3 as Carbon[a/]	1.42×10^{-3}	1.05×10^{-3}	1.08×10^{-3}	26.7	1.09×10^{-3}	1.22×10^{-3}	1.42×10^{-3}	1.14×10^{-3}
lb/hr as Hydrocarbons	3,490.0	3,050.0	3,210.0	3,010.0	3,110.0	3,630.0	4,020.0	3,300.0
lb/hr as Carbon	2,860.0	2,510.0	2,640.0	2,460.0	2,560.0	2,870.0	3,350.0	2,640.0
Propane from THC mode (column bypass) ppm	11,300.0	11,500.0	12,200.0	12,500.0	11,300.0	12,600.0	11,600.0	12,100.0
Outlet								
ppm as Propane	1,890.0	1,690.0	1,870.0	374.0	128.0	67.8	62.4	21.1
ppm as Hydrocarbons	2,630.0	2,450.0	2,530.0	582.0	476.0	105.0	99.8	30.6
ppm as Carbon	5,780.0	5,350.0	5,670.0	1,210.0	1,010.0	209.0	191.0	65.8
G/M^3 as Hydrocarbons[a/]	3.56	3.30	3.45	7.45×10^{-1}	0.691	0.137	0.120	4.20×10^{-2}
G/M^3 as Carbon[a/]	2.81	2.67	2.82	0.601	0.498	0.135	9.13×10^{-2}	3.29×10^{-2}
G/sec as Hydrocarbons	138.0	127.0	132.0	24.7	20.50	4.80	4.26	1.56
G/sec as Carbon	112.0	103.0	109.0	20.2	13.0	3.49	3.44	1.23
lb/ft^3 as Hydrocarbons[a/]	2.40×10^{-4}	2.06×10^{-4}	2.15×10^{-4}	4.61×10^{-5}	4.31×10^{-5}	8.24×10^{-6}	7.35×10^{-6}	2.62×10^{-6}
lb/ft^3 as Carbon[a/]	1.79×10^{-4}	1.67×10^{-4}	1.78×10^{-4}	4.28×10^{-5}	3.13×10^{-5}	6.49×10^{-6}	5.93×10^{-6}	4.68×10^{-6}
lb/hr as Hydrocarbons	1,090.0	1,010.0	1,060.0	198.0	148.0	35.4	33.9	12.5
lb/hr as Carbon	942.0	814.0	860.0	160.0	105.0	27.9	27.2	9.69
Propane from THC mode (column bypass) ppm	585.0	519.0	539.0	298.0	72.3	73.3	77.5	23.8
% Efficiency	69.1	70.1	69.8	94.0	96.2	99.1	99.2	99.7

Note: All compounds were measured as ppm of propane. Other units shown are derived from the propane response.

a/ Dry standard conditions.

b/ Measured as the sum of observed peaks.

c/ GC temperature too high, pyrolysis probably occurred before detection.

Figure 1 is in the ESED Confidential Data Files

Figure 2 is in the ESED Confidential Data Files

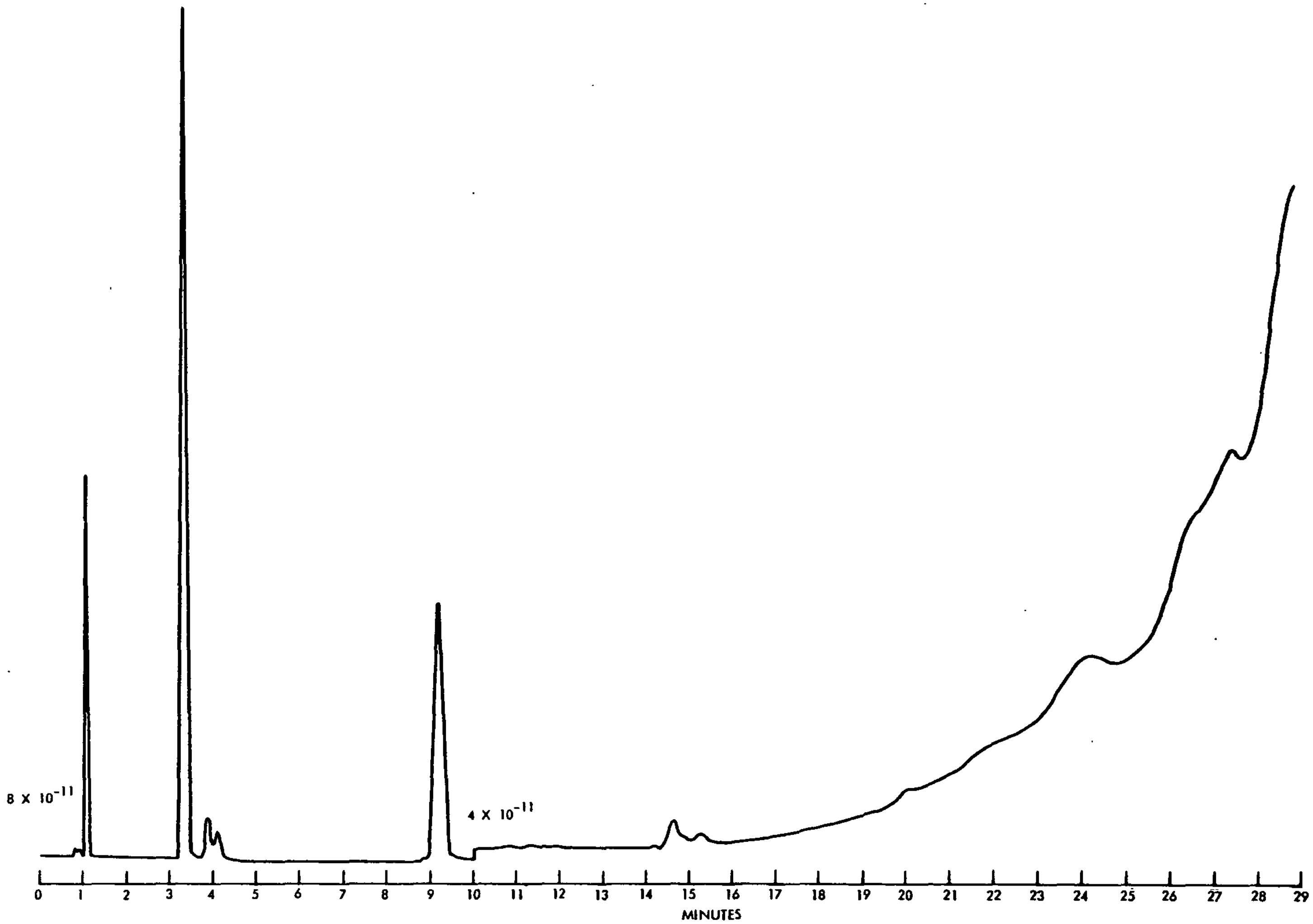

Figure 3. Outlet chromatogram for Run No. 8.

The identification of the acrylic acid peak in the suction vent samples is uncertain. The peak which is assumed to be acrylic acid is about 30 sec early and lies where a small unidentified peak occurs in the outlet and process off-gas samples. Without further information from the plant it is assumed that the acrylic acid peak was shifted due to high loading and the effect of nearby large peaks.

A continuous total hydrocarbon analyzer was used initially for monitoring concentration variations at the suction vent. Two days of operation showed that the total hydrocarbon levels were stable, with no observable variations.

Then the analyzer was moved to the outlet breeching for the remainder of the test. The outlet showed extremely high variability at all times varying by a factor of 2 to 10 over 5 sec or less. This monitor was then used to measure the general hydrocarbon levels for adjusting the incinerator controls and detecting process upsets. A condensate trap was necessary on the inlet of the analyzer to prevent blockage of the instrument pressure regulator which responded very slowly (later traced to blockage of the gauge capillary). The difficulties with the pressure gauge readings and the extreme variability of the sample concentrations limited the instrument to general trends. An attempted traverse of the breeching ports with the THC monitor indicated that the hydrocarbon content may be higher near the west wall at the breeching although the general variability makes this uncertain.

The probe used for the integrated gas sampling had an air leak through its outer sheath which caused the outlet hydrocarbon CO_2 and CO readings to be low and oxygen to read correspondingly high for the first three runs.

The leak was finally found and sealed and no further difficulty occurred during sampling. For the three leaking runs the observed oxygen and CO_2 readings were corrected back to the values from Run 4 after the leak was fixed to obtain an average measurement of the degree of dilution, which was then applied to the CO, CO_2, and O_2 and hydrocarbon readings for these runs. The apparent dilution factors were 1.52 for Run 2, 1.84 for Run 3, and 1.84 for Run 4 (all ± 15%).

Grab samples taken simultaneously from the outlet integrated gas sampling port and the upper stack ports showed that hydrocarbon levels were within 10% at the two locations.

Table 20 shows the results of the total gaseous nonmethane organic (TGNMO) sampling performed simutaneously with the GC integrated gas sampling. Also included are comparison readings made by GC/FID from each tank sample on site as well as comparison totals from the integrated gas samples. The general drop in the tank samples between the on-site measurements and final tank analyses may indicate that some components are unstable. Propylene polymerization is one possibility. Some samples show signs of possible contamination, especially Runs 7 through 9. There is a high probability that the true hydrocarbon levels are close to the values reported by GC/FID integrated sampling. Appendix A includes the TGNMO sampling and analysis data.

TABLE 20. TOTAL GASEOUS NONMETHANE ORGANIC (TGNMO) SAMPLING RESULTS

	RHO-1A	RHO-1B	RHO-2A	RHO-2B	RHO-3A	RHO-3B	RHO-4A	RHO-4B	RHO-5A	RHO-5B	RHO-6A	RHO-6B	RHO-7A	RHO-7B	RHO-8A [a/]	RHO-9A	RHO-9B
Trap fraction - ppm C_1	1,240	1,080	1.840	1,140	970	1,970	400	890	1,030	1,480	900	1,660	220	330	855	330	400
Tank fraction - ppm C_1	3,160	3,810	2,780	2,340	3,180	2,670	3,550	3,800	373	700	115	151	123	123	133	118	123
Total - ppm C_1	4,400	4,890	4,620	3,480	4,150	4,640	3,950	4,690	1,403	2,180	1,015	1,811	343	453	988	448	523
Total hydrocarbon/FID mode reading of tank - ppm as propane (as is)	684	656	644	585	686	573	d/	725	115	80	30.2	27.1	23.8	25.8	63.6	6.8	7.9
THC/FID reading of tank, N_2 dilution corrected, ppm as C_1 [b/]	4,570	5,430	4,070	5,120	4,220	4,390	d/	5,100	1,060	2,000	289	307	209	190	377	73	69
GC/FID sum - ppm as carbon [c/] of integrated gas sample	-	-	5,540	5,540	5,130	5,130	5,520	5,520	1,130	1,130	980	980	186	186	163	60	60

a/ Single sample due to shortage of equipment.

b/ Three times the value measured as propane. The tanks were originally at negative pressure and pressurized on-site for the THC field readings.

c/ Excluding methane.

d/ Not analyzed.

Table 21 shows GC/FID analyses for selected tank TGNMO samples for component identification/quantification. The sum of the peaks is in reasonable agreement with the total hydrocarbon (THC) values in Table 20. Figure 4 shows a typical chromatogram from the tank samples.

Table 22 shows the evacuated flask aldehyde sampling results with comparison values by GC/FID and is on file at ESED. Data sheets for the aldehyde sampling are in Appendix B. The outlet values reported are of limited value, since the sensitivity limits were being approached. The aldehyde method may also be responding to interferences or high molecule aldehydes not detectable by GC/FID.

Tables 23 (metric) and 24 (English) summarize the general process parameters, flow rates, and bulk gas compositions for the different sampling streams. Appendix C includes the pitot traverse data. Appendix D contains the integrated gas sampling data sheets, and Appendix E contains the moisture train data. The carbon monoxide measurements are included as part of Appendix B. The water knockout trap for the continuous THC analyzer was used for moisture measurements for the last runs. The higher sample volume allowed a much more accurate moisture measurement. Process off-gas moisture was assumed at 20% based upon measurements found at a similar facility. The moisture readings measured at the process off-gas line are too low due to problems with the physical construction of the sampling ports. Much of the condensation ran back into the duct before it could enter the sample train.

Table 25 shows the results of the fuel gas analyses by GC/FID. A typical chromatogram is shown in Figure 5. Table 26 shows the results of the NO_x sampling. Data sheets for NO_x sampling are in Appendix F. The high NO_x readings for some runs is probably caused by ambient ammonia entering in the combustion air supply. A strong odor of ammonia was sometimes noted in the general process area.

TABLE 21. TGNMO TANK SAMPLES ANALYZED BY GAS CHROMATOGRAPHY

Component	Run 4 - RHO-4A		Run 4 - RHO-4B		Run 5 - RHO-5A		Run 5 - RHO-5B		Run 8 - RHO-8A		Run 9 - RHO-9A		Run 9 - RHO-9B	
	ppm as propane[a/]	ppm as C_1[b/]	ppm as propane[a/]	ppm as C_1[b/]	ppm as propane[a/]	ppm as C_1[b/]	ppm as propane[a/]	ppm as C_1[b/]	ppm as propane[a/]	ppm as C_1[b/]	ppm as propane[a/]	ppm as C_1[b/]	ppm as propane[a/]	ppm as C_1[b/]
Methane	41	240	35.8	252	10.3	95	4.8	120	6.3	37	0.8	9	0.9	7.9
Ethylene	144	852	158	1,110	37.6	347	16.5	412	18.8	111	2.8	30	3.3	29
Acetylene	7.4	44	5.5	39	1.6	15	-	-	0.9	5	0.07	0.8	0.14	1.2
Ethane	6.4	38	6.5	46	1.0	9	-	-	0.4	2	-	-	0.06	0.5
Propylene/propane	232	1,370	456	3,210	41.9	386	18.0	450	10.2	60	1.26	13.5	1.48	12.9
Acetaldehyde	4.8	28	5.5	39	0.9	8	-	-	-	-	-	-	0.06	0.5
Acrolein	2.1	12	-	-	-	-	-	-	-	-	-	-	-	-
Acetone	1.8	11	-	-	-	-	-	-	-	-	-	-	-	-
Total of all peaks	440	2,600	667	4,700	93	860	39	980	37	215	4.9	53	5.9	52

a/ Not corrected for N_2 dilution (as is basis).

b/ These data are corrected for the N_2 pressurization and multiplied by three to convert from propane to C_1 response.

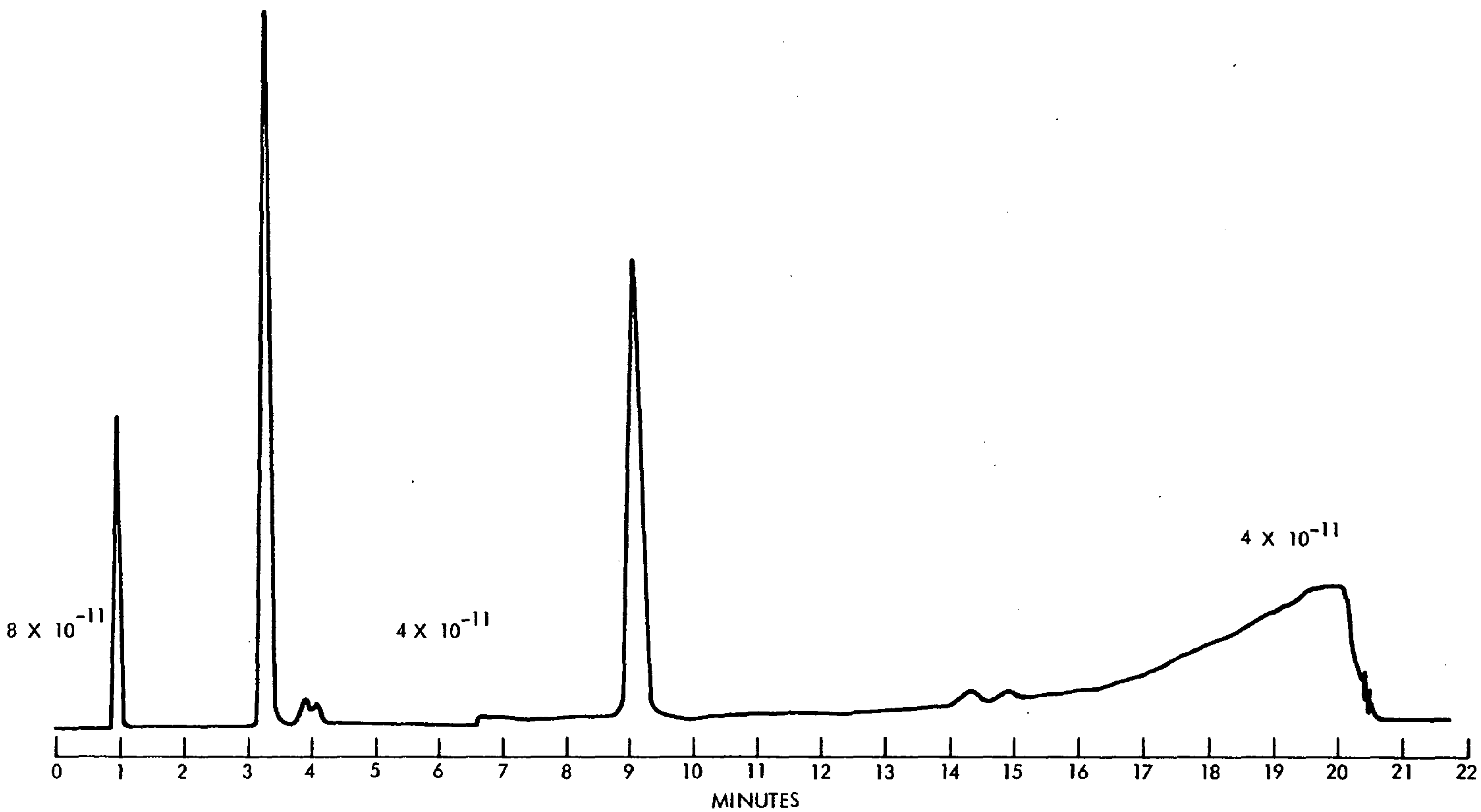

Figure 4. TGNMO tank gas chromatogram (outlet) for Run No. 8.

Table 22 is in the ESED Confidential Data Files

TABLE 23. COMPOSITION/FLOW SUMMARY (METRIC UNITS)

	Run No. 1	Run No. 2	Run No. 3	Run No. 4	Run No. 5	Run No. 6	Run No. 7	Run No. 8	Run No. 9
Outlet									
Stack velocity m/sec		10.67	10.31	10.31	9.40	10.82	10.82	11.07	11.33
Flow rate dscm/sec		38.8	38.5	38.5	33.5	37.5	37.5	36.5	37.6
Mass flow kg/sec		47.5	51.8	46.7	42.2	47.0	47.3	47.0	48.6
Temperature C		201.1	193.9	193.9	193.9	204.4	204.4	201.1	207.8
Oxygen %		3.5[a]	6.3[a]	4.8[a]	4.05	5.1	4.5	4.45	4.25
Carbon dioxide %		5.9[a]	6.4[a]	5.8[a]	7.5	6.0	7.0	6.0	6.75
Moisture %		2.6	1.1	1.1	5.3	5.6	5.6	10.9[b]	9.6[b]
Carbon monoxide ppm		5,530[a]	3,550[a]	5,540[a]	1,960	1,000	600	980	340
Combustor									
Fuel gas flow m^3/sec		0.364	0.356	0.352	0.378	0.426	0.425	0.441	0.343
Combustion air flow m^3/sec		10.03	10.46	10.40	8.87	11.93	11.96	12.0	11.81
Combustion temperature °C		-	-	-	-	-	-	-	-
Suction Vent									
Flow rate dscm/sec		5.88	5.89	5.87	5.85	5.84	5.88	6.04	5.99
Mass flow kg/sec		7.03	7.05	7.03	7.00	6.99	7.04	7.23	7.17
Temperature °C		9	20	20	26	25	32	27	26
Oxygen %		21	21	21	21	21	21	21	21
Carbon dioxide %		0	0	0	0	0	0	0	0
Moisture %		0	0	0	0	0	0	0	0
Carbon monoxide ppm		10	10	10	10	10	10	10	10
Acid Off Gas [d]									
Flow rate dscm/sec		20.45[c]	18.81[c]	19.15[c]	18.74[c]	18.54[c]	18.49[c]	18.52[c]	18.22[c]
Mass flow kg/sec		28.0	26.0	26.4	26.1	25.6	25.5	25.5	25.1
Oxygen %		4.95	5.65	5.7	5.8	5.4	4.55	4.5	4.4
Moisture %		20[c]	20[c]	20[c]	20[c]	20[c]	20[c]	20[c]	20[c]
Carbon monoxide ppm		9,640	9,910	10,200	10,200	9,970	9,970	10,400	10,300
Temperature °C		77.8	85.6	85.6	86.1	83.3	86.7	86.1	86.7

a/ Corrected for dilution.

b/ Preferred value.

c/ Assume 20% moisture.

d/ Carbon dioxide content is in the ESED confidential data files.

TABLE 24. COMPOSITION/FLOW SUMMARY (ENGLISH UNITS)

	Run No. 2	Run No. 3	Run No. 4	Run No. 5	Run No. 6	Run No. 7	Run No. 8	Run No. 9
Outlet								
Stack velocity ft/min	2,100	2,030	2,030	1,850	2,130	2,130	2,180	2,230
Flow rate dscf/min	82,200	81,600	81,500	71,000	79,500	79,500	77,400	79,700
Mass flow lb/hr	377,000	411,000	371,000	335,000	373,000	375,000	375,000	386,000
Temperature F	394	381	381	381	400	400	394	406
Oxygen %	3.9[a]	6.3[a]	4.8[a]	4.05	5.1	4.5	4.45	4.25
Carbon dioxide %	5.9[a]	6.4[a]	5.8[a]	7.5	6.0	7.0	6.0	6.75
Moisture %	2.6	1.1	1.1	5.3	5.6	5.6	10.9[b]	9.6[b]
Carbon monoxide ppm	5,530[a]	3,550[a]	5,540[a]	1,960	1,000	600	980	340
Combustor								
Fuel gas flow scf/min	772	754.4	746	800	902	900	934	727
Combustion air flow scf/min	21,260	22,170	22,040	18,800	25,280	25,340	25,420	25,010
Combustion temperature °F	-	-	-	-	-	-	-	-
Suction Vent								
Flow rate dscf/min	12,450	12,480	12,440	12,390	12,380	12,460	12,800	12,690
Mass flow lb/hr	55,760	55,890	55,720	55,490	55,440	55,820	57,330	56,830
Temperature F	48	58	67	78	77	90	80	79
Oxygen %	21	21	21	21	21	21	21	21
Carbon dioxide %	0	0	0	0	0	0	0	0
Moisture %	0	0	0	0	0	0	0	0
Carbon monoxide ppm	10	10	10	10	10	10	10	10
Acid Off Gas [d]								
Flow rate dscf/min	43,330[c]	39,860[c]	40,570[c]	39,710[c]	39,270[c]	39,180[c]	39,240[c]	38,600[c]
Mass flow lb/hr	222,000	206,000	210,000	207,000	203,000	202,000	202,000	199,000
Oxygen %	4.95	5.65	5.7	5.8	5.4	4.55	4.5	4.4
Moisture %	20[c]	20[c]	20[c]	20[c]	20[c]	20[c]	20[c]	20[c]
Carbon monoxide ppm	9,640	9,910	10,200	10,200	9,970	9,970	10,400	10,300
Temperature °F	172	186	186	187	182	188	187	188

a/ Corrected for dilution.

b/ Preferred value.

c/ Assume 20% moisture.

d/ Carbon dioxide content is in the ESED confidential data files.

TABLE 25. FUEL GAS ANALYSIS
(ppm as propane)

RI		Run No. 2	Run No. 3	Run No. 4	Run No. 5	Run No. 6	Run No. 7	Run No. 8	Run No. 9
100	Methane	188,000	-	194,000	193,000	184,000	136,000	-	-
200	Ethane	21,200	15,800	18,800	18,300	18,200	18,500	18,100	18,200
300	Propane	7,700	6,800	6,990	6,700	7,320	7,710	7,580	7,040
375	Isobutane	2,130	2,080	1,940	1,900	2,230	2,330	2,290	2,070
400	n-Butane	2,190	1,990	2,110	1,880	2,110	2,230	2,250	1,990
480	Branched chain C5	1,110	1,070	1,080	960	1,100	1,200	1,150	1,030
500	n-Pentane	732	693	697	617	763	802	764	682
555	Branched chain C6	37.1	7.66	40	41.2	12.6	41.9	44.9	36.5
575	Branched chain C6	196	347	248	240	343	379	371	331
590	Branched chain C6	21.2	99	44.8	44.8	121	132	133	124
600	n-Hexane	194	274	205	176	267	294	298	267
630	Branched chain C7	142	80.1	133	124	132	171	154	139
670	Branched chain C7	160	167	158	139	156	196	171	164
700	n-Heptane	242	135	232	220	238	352	-	280
755	C8 and above	187	223	211	193	171	246	216	251
780	C8 and above	-	25.6	80.2	26.6	8.08	17.1	16.2	22.1
790	C8 and above	18.8	-	-	-	-	37.4	-	-
800	n-Octane	17.1	23	18.2	6.36	19.1	105	46.1	31.8
830	C8 and above	53.0	72.7	41.2	15.7	26.3	-	92.8	-
890	C8 and above	-	-	-	-	-	-	-	9.71

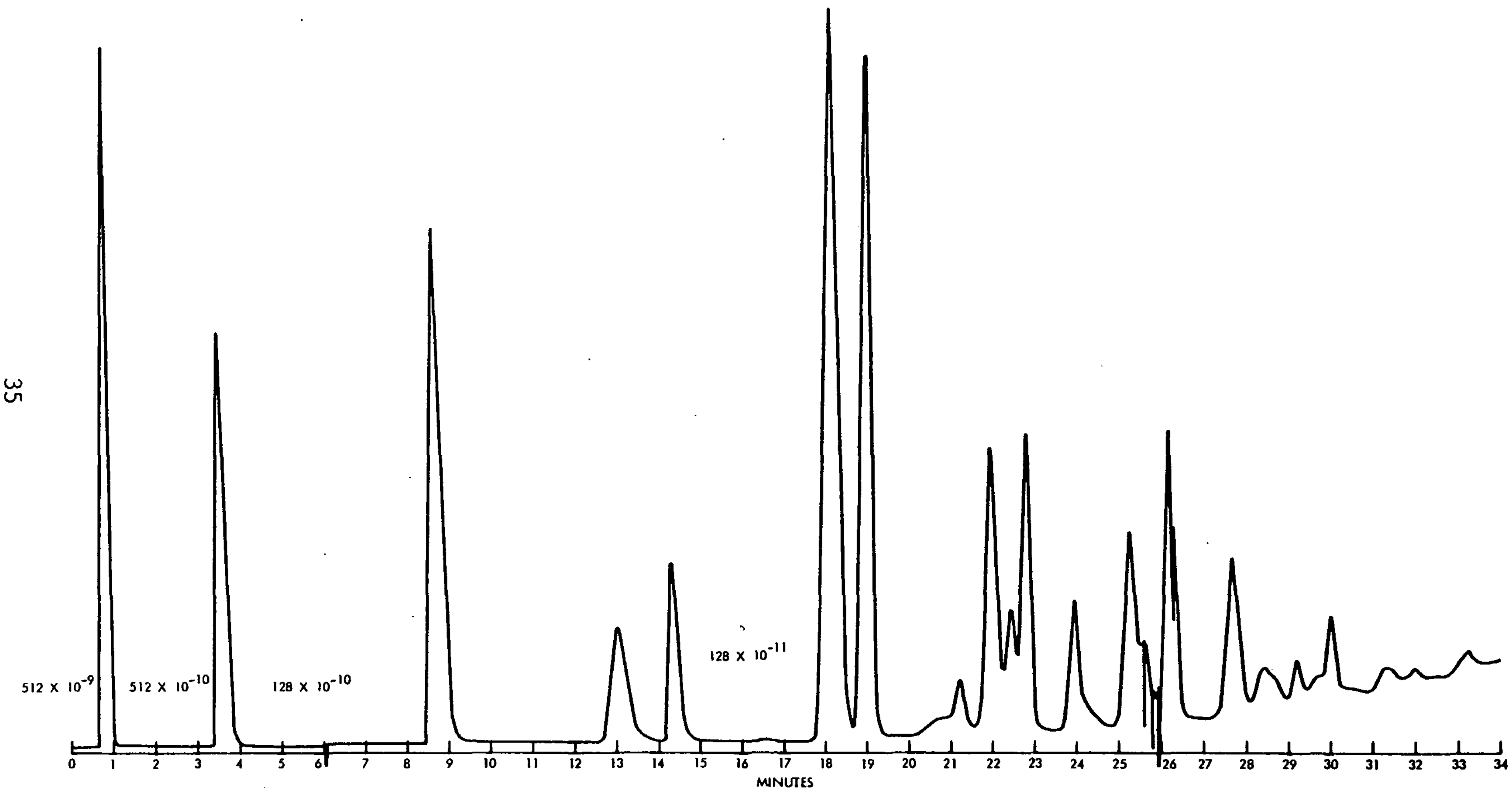

Figure 5. Fuel gas chromatogram for Run No. 8.

TABLE 26. NO_x RESULTS[a/]

Run No.[b/]	Reported as lb of NO_2/million ft^3, dry standard				Reported as mg/m^3, dry standard			
	1	2	3	Average	1	2	3	Average
3	5.1	4	4	4	83	65	65	70
4	4,940	6,400	1,210	4,200	80,100	104,000	19,600	68,000
5	7.5	247	15.7	90	122	4,010	255	1,500
6	28.3	16.9	24.9	23	460	275	405	370
7	15.7	4	1,120	380	255	65	18,200	6,200
8	4	6.3	4	5	65	102	65	80

a/ Strong odor of ammonia in the general area during several runs.

b/ No sampling during Runs 1 and 2. Samples for Run 9 lost during analysis.

SECTION 3

PROCESS DESCRIPTION AND OPERATION

Acrylic esters are produced using propylene, air and alcohols, with acrylic acid being produced as an intermediate.

Acrylic acid is produced directly from propylene by a vapor phase catalytic air oxidation process. The reactions take place in two steps both in the presence of steam as a diluent. Propylene is first oxidized to acrolein which is then oxidized to acrylic acid according to the following equations:

1. $CH_2 = CHCH_3 + O_2 \longrightarrow CH_2 = CHCHO + H_2O + \text{Heat}$
   Propylene   Oxygen (Air)   Acrolein   + Water

2. $CH_2 = CHCHO + 1/2\ O_2 \longrightarrow CH_2 = CHCOOH + \text{Heat}$
   Acrolein   Oxygen (Air)   Acrylic Acid

A small amount of acetic acid is produced as a by-product. The reactions take place in fixed-bed multi-tubed reactors which operate at high temperatures and atmospheric pressure. The heat of reaction is removed through indirect heat exchange with a cooling medium in the shell side of the reactors. This heat is then converted to steam in a boiler. There are two trains for the reaction step. Reactor effluent gas is sent to absorbers where acrylic acid is recovered in an aqueous solution. The acrylic acid is then extracted from the aqueous stream in an extraction system common to both trains. Acrylic acid suitable for esterification with the desired alcohol is available after solvent recovery. Butyl, ethyl, and methyl esters are produced in a liquid phase reaction using a catalyst.

The following equation represents the esterification reaction:

$$CH_2 = CHCOOH + ROH \xrightarrow{H^+} CH_2 = CHCOOR + H_2O$$

Acrylic Acid   Alcohol   Acrylic Ester Monomer   Water

The reaction product is purified in subsequent refining operations. Excess alcohol is recovered and heavy end by-products are incinerated.

The attached process schematic shows the general flow scheme of the process in a block diagram (Figure 6).

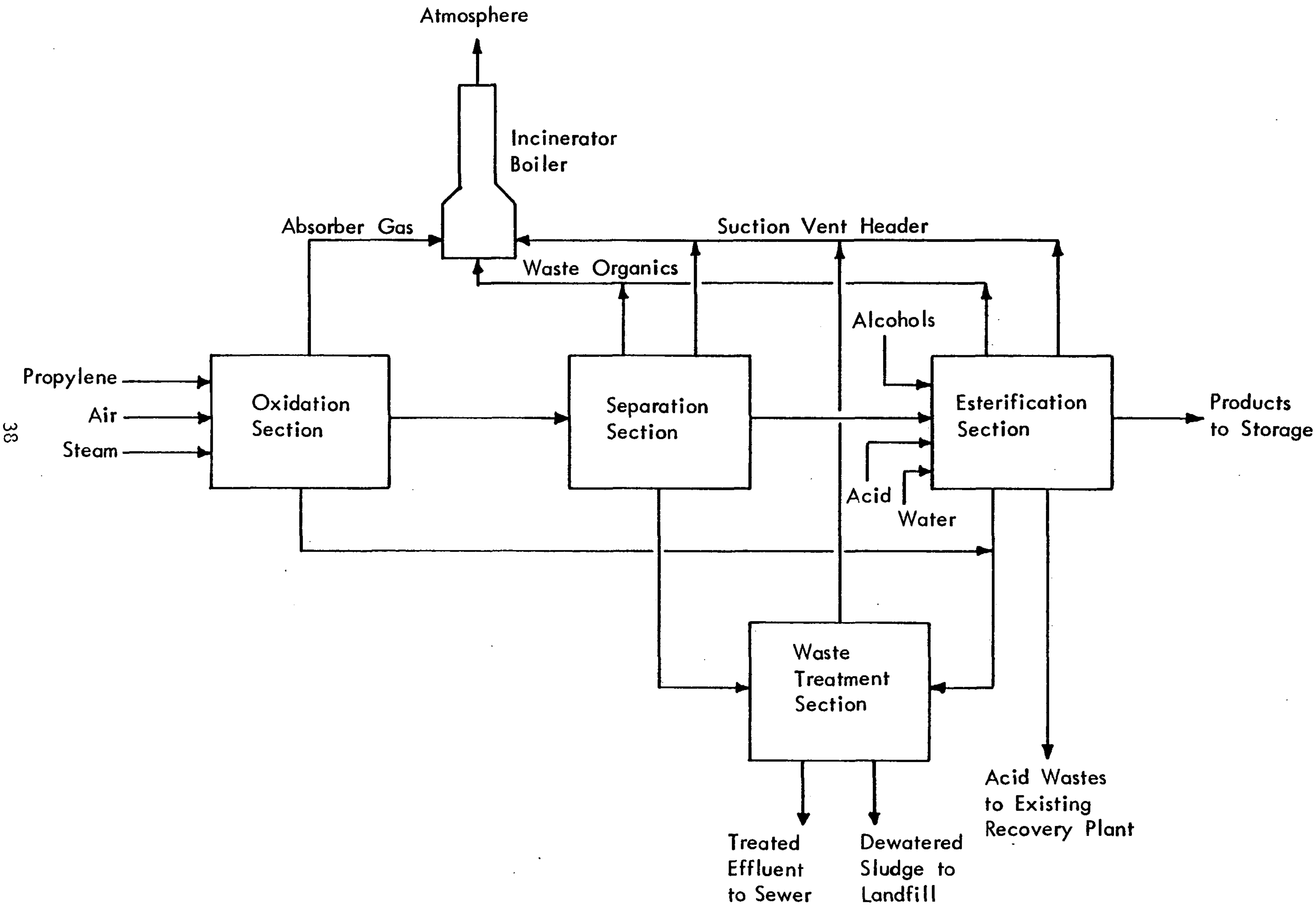

Figure 6. Acrylic ester process schematic.

The waste incinerator is designed to burn the off-gas from the two absorbers. In addition, process vents (from extractors, vent condensers and tanks) which might be a potential source of gaseous emissions are collected in a suction vent system and normally sent to the incinerator. An organic liquid stream generated in the process is also burned intermittently providing part of the fuel requirement. A separate natural gas line supplies the remainder. Air is added to an amount to produce about 6% O_2 in the effluent.

SECTION 4

LOCATION OF SAMPLE POINTS

Figure 7 shows a general diagram of the process with the sampling points marked. Point No. 1, the process off-gas, is at about 70°C, and at 4 in. mercury positive pressure, so that no sampling pump is necessary. A diagram of the sampling location is shown in Figure 8. A purged miniture S-type pitot welded inside a 1/2 in. stainless steel sheath was inserted through the packing glands and gate valve for sampling and flow traverses. The sampling trains were simply connected to one leg of the pitot. After each run a two-axis traverse was made.

Point No. 2, the suction vent (shown in Figure 9), is slightly above ambient temperature, again at positive pressure near ground level with a 1/4 in. valve and fitting used for sampling. This sample is dry ambient air plus vapors from several storage tanks in the area. No condensation occurred at ice temperature.

Point No. 3, the incinerator outlet (shown in Figure 10), was used for all sampling at the outlet except for volumetric flow and temperature, which were measured at the stack ports (Point No. 4). Sample Point No. 3 was used due to the difficulty of hoisting equipment to Point No. 4. The integrated gas sample was run simultaneously with the TGNMO method using separate probes. Then the moisture train was connected. This was the only sampling point which required a pump and gas box for integrated gas sampling.

Point No. 5, fuel gas, was taken from a tap near the incinerator. Small Tedlar bags were flushed and then filled directly from the line.

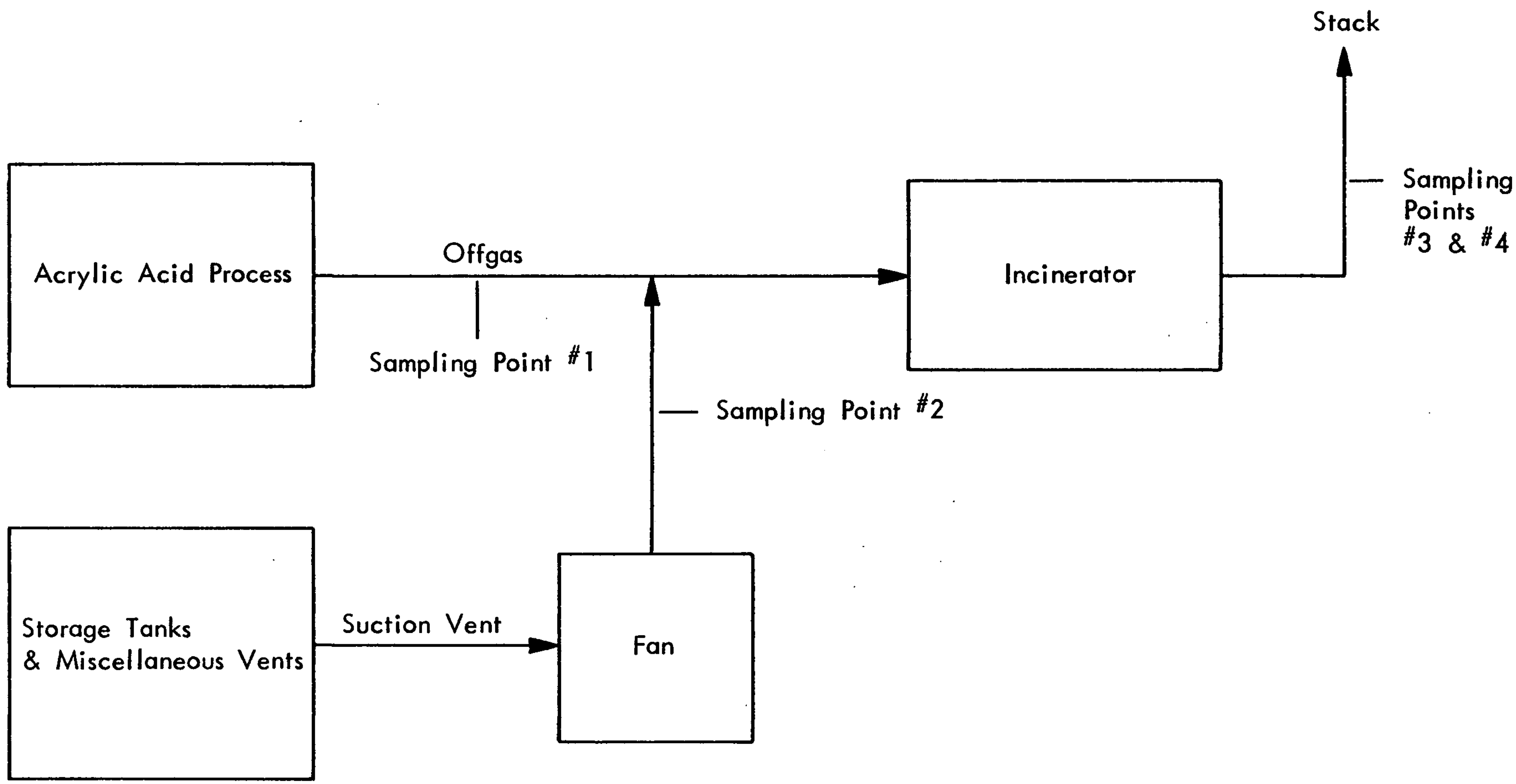

Figure 7. General process diagram.

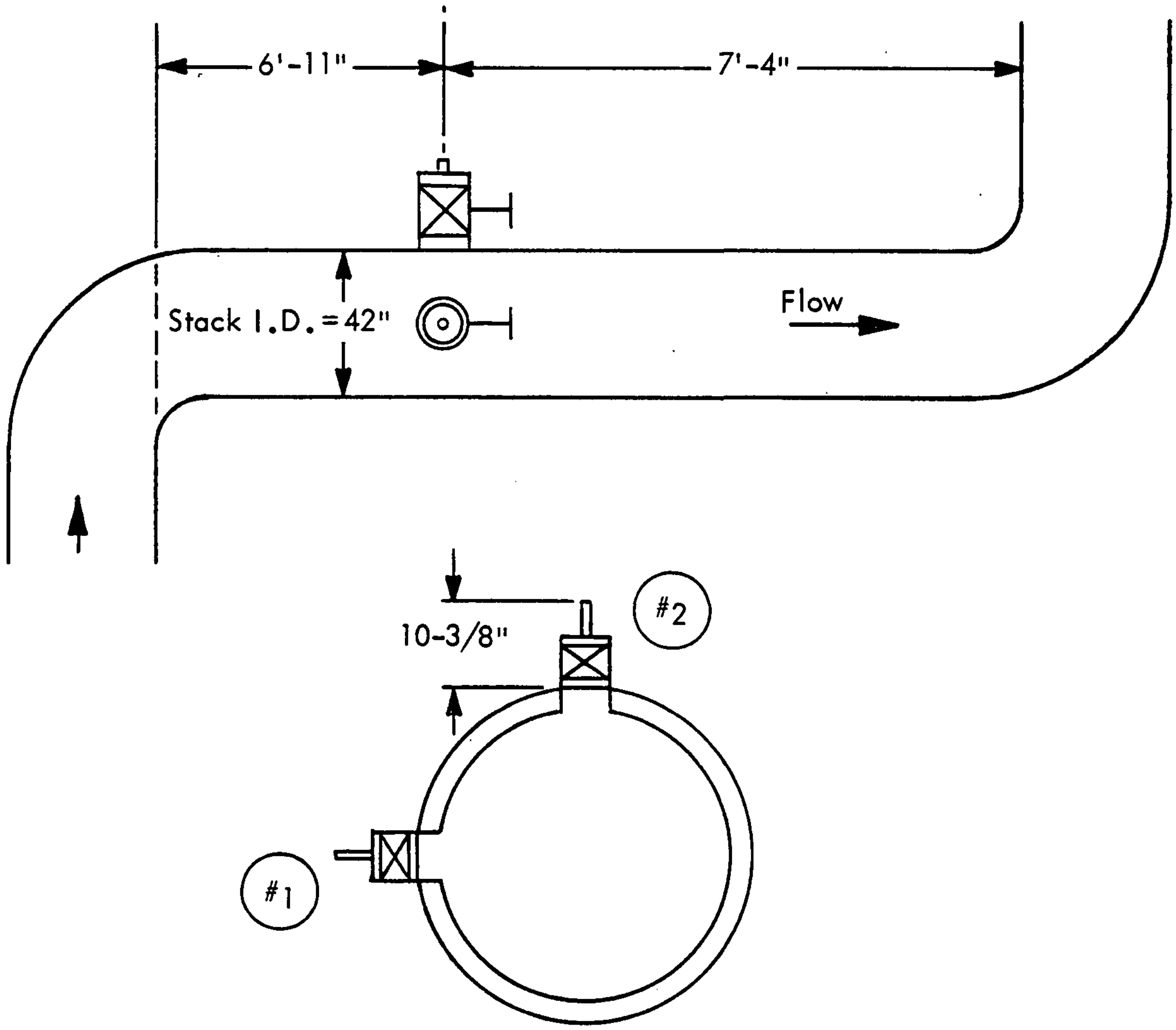

Figure 8. Process off-gas sampling location.

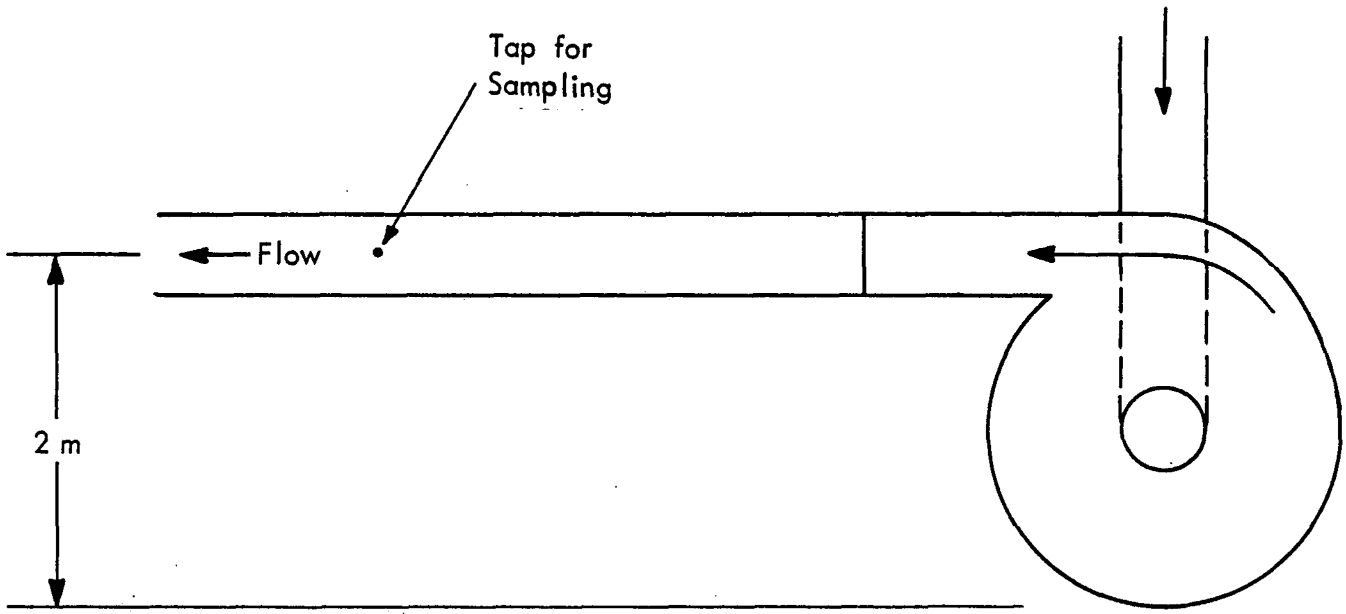

Figure 9. Suction vent sampling location.

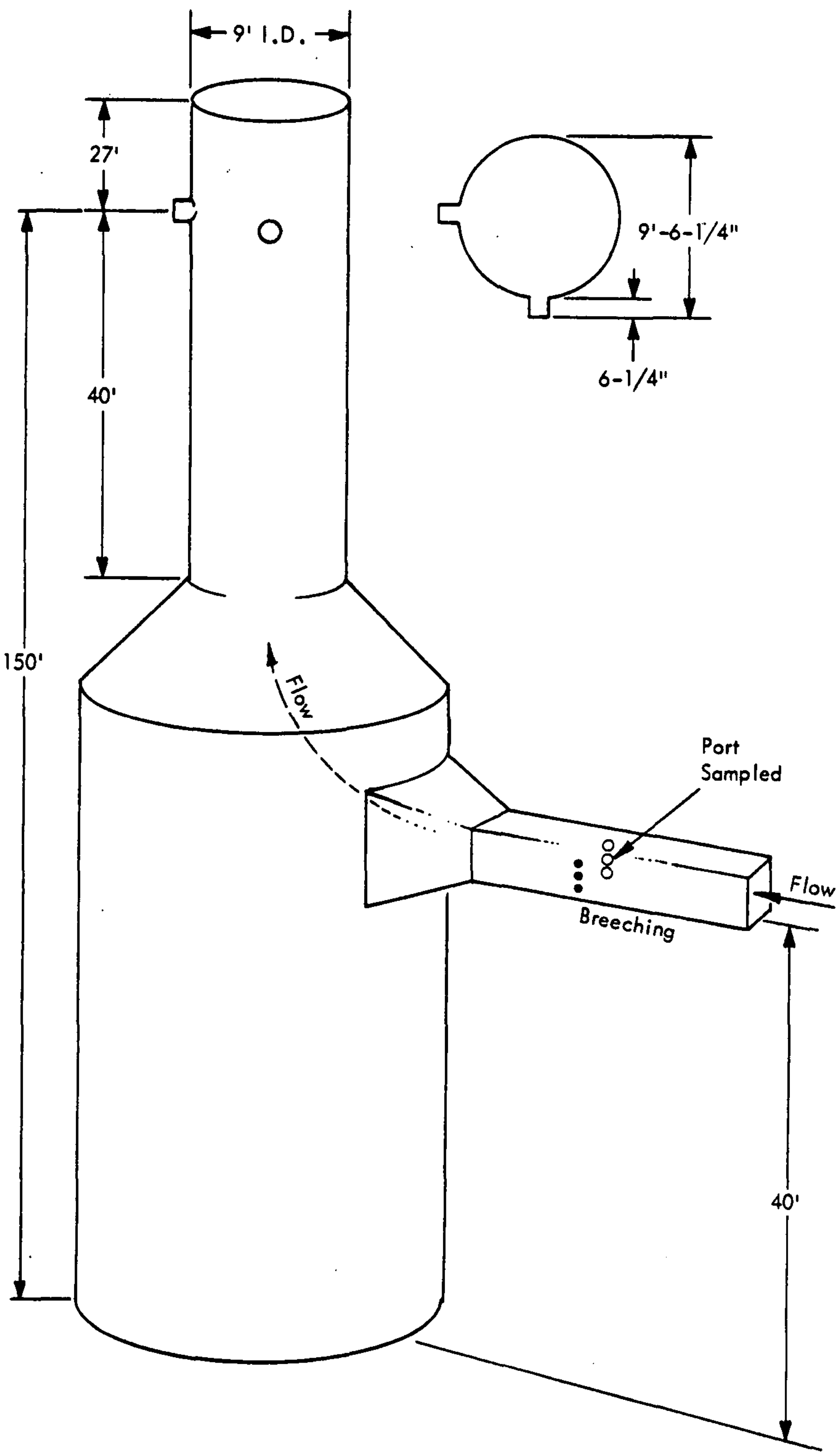

Figure 10. Incinerator outlet and stack.

SECTION 5

SAMPLING AND ANALYTICAL PROCEDURES

The integrated gas samples were obtained according to a modified version of the September 27, 1977, EPA draft benzene method (Appendix G). Seventy-liter aluminized Mylar or Tedlar bags were used at an approximate sampling rate of 0.5 liter/min for 1 hr. A glass vacuum trap immersed in water of ambient temperature was used as a condenser ahead of the bag at the outlet and process off-gas. No condenser was needed at the suction vent. The contents of the condensers were measured by weight difference and stored for later GC analysis. No heating of the sample bags was used.

At the suction vent and process off-gas sampling points, the duct pressure was sufficient to fill the bags directly from the duct without pumps or sample boxes. A needle valve was inserted on the sample tap to control the sampling rate. The sampling rate was set initially by connecting a rotameter in place of the bag. The rotameter was then removed and the bag connected for sampling. At the end of each run the flow rate was again checked.

Each integrated gas sample was analyzed on a Varian Model 2400 gas chromatograph with FID, and a heated Carle gas sampling valve with matched 2 cm^3 sample loops. A valved capillary bypass is used for THC analyses and a 2 m, 1/8 in. OD nickel column with Porapak P-S, 80-100 mesh packing used for component analyses. The column was programmed from 20 to 225°C at 6°C/min with temperature hold at upper limit. Nominal running time is 35 min. THC readings were obtained by peak areas (99 ppm propane is the primary standard for all analyses).

Peak area measurements were used for the individual component analyses. A Tandy TRS-80, 48K floppy disc computer interfaced via the integrator pulse output of a Linear Instruments Model 252A recorder acquired, stored, and analyzed the chromatograms. The computer is programmed in BASIC. The program listed in Appendix H was used for data acquisition and preliminary field data analyses.

The stored data were later reanalyzed using the more comprehensive program listed in Appendix I. The latter program allows noise filtering, graphic peak display, and a printed listing of the results. All results presented are from the filtered output of the second program. Duplicate runs were made for all samples unless the primary peak areas did not agree within approximately 10%, in which case further runs were necessary.

Normal sampling used a 3-sec integration interval with about 700 points recorded for each chromatogram. A count rate of 6,000 counts/min was used

(1 mv reference) with integrator overload occurring at 2.3 mv and integrator resolution of about 3 μv (1 count/3 sec) with normal accuracy of about 6 μv overall including the conversion accuracy of the recorder.

Programming allows appropriate descriptions of each chromatogram, selectable sampling interval, maximum chromatogram length of 1,000 data points, and on-line entry of attenuation changes via the keyboard. The programs sense peaks by two consecutive readings which increase by more than a selectable noise factor. The baseline is measured as a straight line from before peak start to peak end. Merged peaks are split by a vertical line through the minimum between then with an overall baseline factor. Both programs have difficulty giving accurate results for small slowly rising peaks due to the effect of counting noise. Concentrations are reported using a single external calibration factor (99 ppm propane standard) using the average of pre- and posttest standard runs (a minimum of six standard peaks total). The program result printouts are in Appendix J (in ESED confidential data files).

The propylene/propane peaks are not resolvable on the column used. The single observed peak was artificially split using the program in Appendix K, which compares the peak with a pure reference peak and uses a two equation, two unknown solution, assuming that both components have a shape similar to the reference and that the superimposition observed is additive (no interaction between the two components). A limited iteration range is used with the final values taken for the solution with a minimal sum of the squared residuals. Sample peaks from the various samples showed propane as a variable portion of the composite peak, with significant variations with sample run or site.

The GC data use no temperature or pressure corrections due to the use of a thermostated (± 1°C) valve and negligible barometric pressure changes during a normal analysis day.

The integrated gas samples were analyzed for oxygen and carbon dioxide by duplicate Fyrite readings. Carbon monoxide concentrations were obtained using a Beckman Model 215A nondispersive infrared (IR) analyzer using the integrated samples. A three-point calibration (1,000, 3,000, and 10,000 ppm CO standards) was used with a linear-log curve fit.

The integrated gas samples were also analyzed for total aldehydes using a midget impinger train according to the Los Angeles method given in Appendix B. The aldehyde titration gave a very unstable endpoint on the inlet samples. The inlet samples were finally titrated for the first persistent blue color (stable for 1 to 2 sec in a well-stirred flask). This endpoint is reproducible to ± 5%. The cause of the poor endpoint is still unknown. Analytical log sheets for this procedures are in Appendix L (in ESED confidential data files).

The residual bag volume was measured and an estimate of the sample volumes withdrawn was made to calculate the gas phase concentrations of the organics found in the condensates. The condensates were injected directly in 2 μl liquid portions using the conditions established for the gas sampling, buth with injection through a septum onto the column. Concentrations were calculated by peak area using a 1,600 μg/g acetone/1,500 μg/g acetaldehyde standard in water. The condensate analyses were performed by digital integration using an improved analysis program given in Appendix M. Output data from this program is included in Appendix J.

Stack traverses for outlet flow rate were made using EPA Methods 1 through 4 (midget impingers) and NO_x was sampled at the outlet using EPA Method 7.

Total organic carbon was sampled at the outlet using the tentative EPA procedure given in Appendix A. The VOC analytical procedure used by PCS followed the EPA proposed Method 25 except in the calibration procedure and catalyst checks:

1. Calibration of the analyzer for the analysis of the combusted trap contents is performed at the following conditions:

   a. Oxidation catalyst - on-line

   b. Reduction catalyst - on-line

   c. Column - 100°C

An attenuation is chosen based on estimated concentrations from the trap burnout traces (NDIR output) and triplicate injections of two or three standard (CO_2 in air) are made. Triplicate injections of the intermediate collection tank are then made and concentrations calculated by comparing peak areas to the best fit straight line of the standard data.

2. Calibration for the analysis of the tank portion of the sample is done again using standards chosen to bracket the expected range of the samples being analyzed. An attenuation is chosen on the FID to provide adequate sensitivity and two or three calibration standards are injected in triplicate. Peak areas are measured by an electronic integrator and the best fit straight line is calculated for the resulting area versus concentration data. From this, the sample concentrations are calculated for the nonmethane organics backflush peak. This calibration procedure is done at a minimum before and after analysis of a set of samples. Recalibration is of course done should any of the samples require a sensitivity change.

3. The oxidation catalyst efficiency check is made at the following conditions:

   a. Reduction catalyst - bypassed

   b. Oxidation catalyst - on-line at 860 ± 20°C

   c. Column - either at 0°C or 100°C

Injections of a standard mixture of CH_4 are made at maximum sensitivity and any response noted. If oxidation is 100% no response will show up. If a response is noted the concentration is measured and an efficiency of oxidation calculated. An average efficiency of 99.5% or greater for triplicate injections is judged acceptable.

4. The reduction catalyst check is performed as follows:

   a. Reduction catalyst - on-line at approximately 400°C

   b. Oxidation catalyst - bypassed

   c. Column - 0°C to permit separation of CO_2 and CH_4

Injections of a mixture of equal concentrations CO_2 and CH_4 are made and the resulting peak areas compared. Efficiencies typically are 99 to 100%, which is considered adequate since the manufacturers analysis of the standard mixture is accurate to only ± 2%.

THC readings via the field GC were made from each volatile fraction tank after pressurization with nitrogen which had been cleaned with molecular sieves. A few tanks were also analyzed for individual components by GC. The tanks and traps were then shipped to Pollution Control Science for analysis.

Single GC chromatograms were run for plant fuel gas samples taken during each run. Column conditions and analyses are identical to those used for organic component identification and quantification. No detailed analysis was made for the many observed peaks. Refer to Appendix N for a listing of all compound retention indices measured on the analytical column.

Sample calculations for the various methods used are listed in Appendix O.

A Beckman Model 402 continuous THC analyzer was used for monitoring general outlet performance and by plant personnel to adjust incinerator performance.