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Air

EPA

Acrylic Acid and Esters Production

Emission Test Report
Union Carbide Corporation
Taft, Louisiana

EMISSION TEST OF AN ACRYLIC ACID AND ESTER MANUFACTURING PLANT

by

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FINAL REPORT

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

Attn: Mr. J. C. McCarley, Jr.

PREFACE

This work was conducted by Midwest Research Institute under Environmental Protection Agency Contract No. 68-02-2814, Work Assignment No. 14.

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, Al Myers, Dan Vogel, Jeff Thomas, and Tom Altpeter of Midwest Research Institute, and by Mr. Gary Hipple of Pollution Control Science, Inc. Laboratory assistance was provided by Mr. Ron Jones and Ms. Alice Shan.

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SECTION 1

INTRODUCTION

This report presents the results of source testing performed during the period November 27 to December 8, 1978, by Midwest Research Institute (MRI) at the acrylic acid facility of Union Carbide Corporation at Taft, Louisiana. The inlet and outlet of a low temperature, long 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 an acrolein plant. Both units used partial oxidation of propylene to produce their products. Most of the sampling was done with only the acrylic acid process operating. Both processes were operating on one day and an additional gas sample was taken from the acid process off-gas before the acrolein process stream joined the combustor feedline. A sample of the contents of the liquid knockout trap at the combustor inlet was also obtained.

The vapor streams were analyzed for methane, ethylene, ethane, propane, propylene, acetaldehyde, acrolein, acetone, acrylic acid, and total hydrocarbons by gas chromatography (GC). Duct temperature, flow rate, oxygen, carbon monoxide, carbon dioxide, and aldehydes were also determined by manual sampling on 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 Table 1 through 15. The first 14 tables show results for each component observed, from methane to acrylic acid, at the inlet and outlet to the incinerator. Table 15 shows the sum of all 14 components. All actual meausrements were made as parts per million (ppm) of propane with the other units reported derived from the equivalent values. The values were measured by digital inegration. The tables include any contribution from the portion of each sample which condensed in the sampling train trap. These condensates were generally small.

The gas stream at the incinerator inlet had considerable entrained liquid. Therefore, since samples were not taken isokinetically, the fractions shown for the condensate fractions may not be representative of the sample streams. The condensate sample taken from the plant knock-out trap at the inlet showed about 7 μg/g acetaldehyde, 31.4 μg/g of butenes and 120 μg/g of acetone (all expressed as acetone response).

The incinerator combustion temperature for the first six runs was about 625°C. Runs 7 through 9 were made at an incinerator temperature of about 800°C. Only during Run 3 was the acrolein process operating. Its contribution to the total inlet load is the difference of the 3-I and 3-AOG concentrations. The higher temperature during Runs 7 through 9 caused most 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 Figure 1 through 3 for examples). Only acetic acid was never detected in any sample.

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 No. 1-I	Run No. 2-I	Run No. 3-I	Run No. 3-AOG	Run No. 4-I	Run No. 5-I	Run No. 6-I	Run No. 7-I	Run No. 8-I	Run No. 9-I
Propane, ppm	362	318	490	426	293	397	438	367	377	498
Methane, ppm	1,006	883	1,361	1,183	814	1,103	1,217	1,019	1,047	1,383
Carbon, ppm	1,006	883	1,361	1,183	814	1,103	1,217	1,019	1,047	1,383
Methane, g/m^3 a/	0.668	0.586	0.904	0.786	0.540	0.732	0.808	0.677	0.695	0.918
Carbon, g/m^3 a/	0.501	0.440	0.678	0.589	0.405	0.549	0.606	0.508	0.521	0.689
Methane, lb/sec	5.84	7.07	10.87	8.09	5.15	6.60	7.03	6.08	6.68	8.04
Carbon, g/sec	4.38	5.30	8.15	6.07	3.87	4.95	5.27	4.56	5.01	6.03
Methane, lb/ft^3 a/	4.16×10^{-5}	3.66×10^{-5}	5.64×10^{-5}	4.90×10^{-5}	3.37×10^{-5}	4.13×10^{-5}	4.57×10^{-5}	3.83×10^{-5}	4.22×10^{-5}	5.16×10^{-5}
Carbon, lb/ft^3 a/	3.12×10^{-5}	2.74×10^{-5}	4.23×10^{-5}	3.67×10^{-5}	2.53×10^{-5}	3.42×10^{-5}	3.78×10^{-5}	3.17×10^{-5}	3.25×10^{-5}	4.30×10^{-5}
Methane, lb/hr	46.3	56.1	86.2	64.1	40.9	52.3	55.7	48.2	53.0	63.8
Carbon, lb/hr	34.8	42.1	64.6	48.1	30.7	39.2	41.8	36.2	39.8	47.8
	Run No. 1-0	Run No. 2-0	Run No. 3-0		Run No. 4-0	Run No. 5-0	Run No. 6-0	Run No. 7-0	Run No. 8-0	Run No. 9-0
Propane, ppm	19	56	70		27	26	33	0.80	0.07	0.08
Methane, ppm	53	156	194		75	72	92	2.2	0.19	0.22
Carbon, ppm	53	156	194		75	72	92	2.2	0.19	0.22
Methane, g/m^3 a/	0.035	0.103	0.129		0.050	0.048	0.061	1.5×10^{-3}	1.3×10^{-4}	1.5×10^{-4}
Carbon, g/m^3 a/	0.026	0.077	0.097		0.037	0.036	0.046	1.1×10^{-3}	9.7×10^{-5}	1.1×10^{-4}
Methane, g/sec	0.83	2.8	3.3		1.26	1.20	1.47	0.035	3.2×10^{-3}	3.6×10^{-3}
Carbon, g/sec	0.62	2.1	2.5		0.95	0.90	1.10	0.027	2.4×10^{-3}	2.7×10^{-3}
Methane, lb/ft^3 a/	2.2×10^{-6}	6.4×10^{-6}	8.1×10^{-6}		3.1×10^{-6}	3.0×10^{-6}	3.8×10^{-6}	9.2×10^{-8}	8.1×10^{-9}	9.2×10^{-9}
Carbon, lb/ft^3 a/	1.6×10^{-6}	4.8×10^{-6}	6.0×10^{-6}		2.3×10^{-6}	2.2×10^{-6}	2.8×10^{-6}	6.9×10^{-8}	6.0×10^{-9}	6.9×10^{-9}
Methane, lb/hr	6.6	22	26		10.0	9.5	11.7	0.28	0.025	0.029
Carbon, lb/hr	4.9	16	20		7.5	7.1	8.7	0.21	0.019	0.021
% Efficiency	85.1	62.0	69.0		75.6	81.9	79.2	99.4	99.95	99.96

a/ Dry standard conditions

Note: Retention index = 100

TABLE 2. GAS CHROMATOGRAPHY ANALYSES FOR ETHYLENE

	Run No. 1-I	Run No. 2-I	Run No. 3-I	Run No. 3-AOG	Run No. 4-I	Run No. 5-I	Run No. 6-I	Run No. 7-I	Run No. 8-I	Run No. 8-I
Propane, ppm	208	156	159	174	181	178	162	187	183	173
Ethylene, ppm	314	236	240	263	273	269	245	283	277	261
Carbon, ppm	629	471	480	526	547	538	490	565	553	523
Ethylene, g/m^3 a/	0.365	0.274	0.279	0.305	0.318	0.312	0.284	0.328	0.321	0.304
Carbon, g/m^3 a/	0.313	0.235	0.239	0.262	0.272	0.268	0.244	0.281	0.275	0.260
Ethylene, g/sec	3.20	3.30	3.36	3.14	3.03	2.82	2.48	2.95	3.09	2.66
Carbon, g/sec	2.74	2.83	2.88	2.70	2.60	2.41	2.12	2.53	2.65	2.28
Ethylene, lb/ft^3 a/	2.28×10^{-5}	1.71×10^{-5}	1.74×10^{-5}	1.91×10^{-5}	1.98×10^{-5}	1.95×10^{-5}	1.77×10^{-5}	2.05×10^{-5}	2.00×10^{-5}	1.89×10^{-5}
Carbon, lb/ft^3 a/	1.95×10^{-5}	1.46×10^{-5}	1.49×10^{-5}	1.63×10^{-5}	1.70×10^{-5}	1.67×10^{-5}	1.52×10^{-5}	1.75×10^{-5}	1.72×10^{-5}	1.62×10^{-5}
Ethylene, lb/hr	25.3	26.2	26.6	24.9	24.0	22.3	19.6	23.4	24.5	21.1
Carbon, lb/hr	21.7	22.4	22.8	21.4	20.6	19.1	16.8	20.0	21.0	18.1

	Run No. 1-0	Run No. 2-0	Run No. 3-0		Run No. 4-0	Run No. 5-0	Run No. 6-0	Run No. 7-0	Run No. 8-0	Run No. 9-0
Propane, ppm	52	182	192		84	84	92	0.022	0.051	0.078
Ethylene, ppm	79	275	290		127	127	139	0.033	0.077	0.118
Carbon, ppm	157	550	580		254	254	278	0.066	0.154	0.236
Ethylene, g/m^3 a/	0.091	0.320	0.337		0.147	0.147	0.162	3.86×10^{-5}	9.0×10^{-5}	1.37×10^{-4}
Carbon, g/m^3 a/	0.078	0.274	0.289		0.126	0.126	0.138	3.31×10^{-5}	7.7×10^{-5}	1.17×10^{-4}
Ethylene, g/sec	2.16	8.54	8.63		3.73	3.70	3.90	9.3×10^{-4}	2.2×10^{-3}	3.3×10^{-3}
Carbon, g/sec	1.85	7.32	7.40		3.20	3.17	3.34	8.0×10^{-4}	1.9×10^{-3}	2.9×10^{-3}
Ethylene, lb/ft^3 a/	5.70×10^{-6}	1.99×10^{-5}	2.10×10^{-5}		9.20×10^{-6}	9.20×10^{-6}	1.01×10^{-5}	2.4×10^{-9}	5.6×10^{-9}	8.5×10^{-9}
Carbon, lb/ft^3 a/	4.90×10^{-6}	1.71×10^{-5}	1.80×10^{-5}		7.90×10^{-6}	7.90×10^{-6}	8.60×10^{-6}	2.1×10^{-9}	4.8×10^{-9}	7.3×10^{-9}
Ethylene, lb/hr	17.1	67.7	68.4		29.6	29.3	30.9	7.4×10^{-3}	0.018	0.026
Carbon, lb/hr	14.7	58.0	58.7		25.4	25.1	26.5	6.3×10^{-3}	0.015	0.023
% efficiency	32.3	b/	b/		b/	b/	b/	99.97	99.93	99.9

a/ Dry standard conditions.

b/ Negative efficiency.

Note: Retention index = 185.

TABLE 3. GAS CHROMATOGRAPHY ANALYSES FOR ACETYLENE

	Run No. 1-I	Run No. 2-I	Run No. 3-I	Run No. 3-AOG	Run No. 4-I	Run No. 5-I	Run No. 6-I	Run No. 7-I	Run No. 8-I	Run No. 9-I
	←				NONE DETECTED AT INLET					→

	Run No. 1-0	Run No. 2-0	Run No. 3-0		Run No. 4-0	Run No. 5-0	Run No. 6-0	Run No. 7-0	Run No. 8-0	Run No. 9-0
Propane, ppm	↑	3.4	3.8		1.7	1.6	2.2	↑	↑	↑
Acetylene, ppm		5.3	5.9		2.6	2.5	3.4			
Carbon, ppm		10.6	11.8		5.3	5.0	6.8			
Acetylene, g/m^3[a]		5.7×10^{-3}	6.4×10^{-3}		2.8×10^{-3}	2.7×10^{-3}	3.7×10^{-3}			
Carbon, g/m^3[a]		5.3×10^{-3}	5.9×10^{-3}		2.6×10^{-3}	2.5×10^{-3}	3.2×10^{-3}			
Acetylene, g/sec	ND[b]	0.152	0.163		0.072	0.067	0.089	ND	ND	ND
Carbon, g/sec		0.140	0.150		0.067	0.062	0.082			
Acetylene, lb/ft^3[a]		3.6×10^{-7}	4.0×10^{-7}		1.8×10^{-7}	1.7×10^{-7}	2.3×10^{-7}			
Carbon, lb/ft^3[a]		3.3×10^{-7}	3.7×10^{-7}		1.6×10^{-7}	1.5×10^{-7}	2.1×10^{-7}			
Acetylene, lb/hr		1.21	1.29		0.57	0.53	0.71			
Carbon, lb/hr	↓	1.11	1.19		0.53	0.49	0.65	↓	↓	↓

a/ Dry standard conditions

b/ ND - None detected

Note: Retention index = 195

TABLE 4. GAS CHROMATOGRAPHY ANALYSES FOR ETHANE

	Run No. 1-I	Run No. 2-I	Run No. 3-I	Run No. 3-AOG	Run No. 4-I	Run No. 5-I	Run No. 6-I	Run No. 7-I	Run No. 8-I	Run No. 9-I
Propane, ppm	138	113	102	52	118	92	97	104	104	114
Ethane, ppm	204	167	151	77	175	136	144	154	154	169
Carbon, ppm	409	335	302	154	350	273	287	308	308	338
Ethane, g/m^3 [a]	0.254	0.208	0.188	0.096	0.218	0.170	0.179	0.192	0.192	0.210
Carbon, g/m^3 [a]	0.204	0.167	0.150	0.077	0.174	0.136	0.143	0.153	0.153	0.168
Ethane, g/sec	2.23	2.51	2.26	0.99	2.04	0.153	1.56	1.72	1.84	1.84
Carbon, g/sec	1.78	2.01	1.81	0.79	1.63	0.122	1.25	1.38	1.48	1.47
Ethane, lb/ft^3 [a]	1.59×10^{-5}	1.30×10^{-5}	1.17×10^{-5}	6.00×10^{-6}	1.36×10^{-5}	1.06×10^{-5}	1.12×10^{-5}	1.20×10^{-5}	1.20×10^{-5}	1.31×10^{-5}
Carbon, lb/ft^3 [a]	1.27×10^{-5}	1.04×10^{-5}	9.40×10^{-6}	4.80×10^{-6}	1.09×10^{-5}	8.50×10^{-6}	9.90×10^{-6}	9.60×10^{-6}	9.60×10^{-6}	1.05×10^{-5}
Ethane, lb/hr	17.7	19.9	17.9	7.8	16.1	12. 1	12.3	13.7	14.6	14.6
Carbon, lb/hr	14.1	15.9	14.3	6.3	12.9	9.7	9.9	10.9	11.7	11.7

	Run No. 1-0	Run No. 2-0	Run No. 3-0		Run No. 4-0	Run No. 5-0	Run No. 6-0	Run No. 7-0	Run No. 8-0	Run No. 9-0
Propane, ppm	0.86	2.1	3.2		↑	↑	0.84	↑	↑	↑
Ethane, ppm	1.27	3.1	4.7				1.24			
Carbon, ppm	2.55	6.2	9.5				2.49			
Ethane, g/m^3 [a]	1.59×10^{-3}	3.9×10^{-3}	5.9×10^{-3}				1.55×10^{-3}			
Carbon, g/m^3 [a]	1.27×10^{-3}	3.1×10^{-3}	4.7×10^{-3}				1.24×10^{-3}			
Ethane, g/sec	0.038	0.104	0.151		ND[b]	ND	0.037	ND	ND	ND
Carbon, g/sec	0.030	0.083	0.121				0.030			
Ethane, lb/ft^3 [a]	9.90×10^{-8}	2.4×10^{-7}	3.7×10^{-7}				9.70×10^{-8}			
Carbon, lb/ft^3 [a]	7.90×10^{-8}	1.9×10^{-7}	2.9×10^{-7}				7.70×10^{-8}			
Ethane, lb/hr	0.297	0.82	1.20				0.297			
Carbon, lb/hr	0.238	0.66	0.96				0.237			
% efficiency	98.3	95.8	93.3		↓	↓	97.6	↓	↓	↓

a/ Dry standard conditions

b/ ND = None detected

Note: Retention index = 200

TABLE 5. GAS CHROMATOGRAPHY ANALYSES FOR PROPYLENE

	Run No. 1-I	Run No. 2-I	Run No. 3-I	Run No. 3-AOG	Run No. 4-I	Run No. 5-I	Run No. 6-I	Run No. 7-I	Run No. 8-I	Run No. 9-I
Propane, ppm	5,140	4,650	4,910	5,640	7,510	6,870	6,850	6,230	6,680	5,450
Propylene, ppm	5,379	4,780	5,040	5,790	7,710	7,060	7,040	6,400	6,860	5,600
Carbon, ppm	15,840	14,330	15,130	17,380	23,140	21,170	21,110	19,200	20,580	16,790
Propylene, g/m^3 a/	9.20	8.32	8.79	10.09	13.44	12.30	12.26	11.15	11.96	9.76
Carbon, g/m^3 a/	7.89	7.13	7.53	8.65	11.52	10.54	10.51	9.56	10.25	8.36
Propylene, g/sec	80.5	100.4	105.7	103.9	128.2	110.8	106.7	100.2	115.0	85.4
Carbon, g/sec	69.0	86.0	90.6	89.1	109.9	95.0	91.5	85.9	98.5	73.2
Propylene, lb/ft^3 a/	5.74×10^{-4}	5.19×10^{-4}	5.48×10^{-4}	6.30×10^{-4}	8.38×10^{-4}	7.67×10^{-4}	7.65×10^{-4}	6.96×10^{-4}	7.46×10^{-4}	6.08×10^{-4}
Carbon, lb/ft^3 a/	4.92×10^{-4}	4.45×10^{-4}	4.70×10^{-4}	5.40×10^{-4}	7.19×10^{-4}	6.57×10^{-4}	6.55×10^{-4}	5.96×10^{-4}	6.39×10^{-4}	5.22×10^{-4}
Propylene, lb/hr	639	796	838	824	1,017	879	846	794	912	677
Carbon, lb/hr	547	682	718	706	872	753	725	681	781	581
	Run No. 1-0	Run No. 2-0	Run No. 3-0		Run No. 4-0	Run No. 5-0	Run No. 6-0	Run No. 7-0	Run No. 8-0	Run No. 9-0
	<------ NONE DETECTED AT OUTLET ------>									

a/ Dry standard conditions

Note: Retention index = 295

TABLE 6. GAS CHROMATOGRAPHY ANALYSES FOR PROPANE

	Run No. 1-I	Run No. 2-I	Run No. 3-I	Run No. 3-AOG	Run No. 4-I	Run No. 5-I	Run No. 6-I	Run No. 7-I	Run No. 8-I	Run No. 9-I
Propane, ppm	2,890	2,620	2,760	3,170	4,220	3,860	3,850	3,510	3,760	3,070
Propane, ppm	2,890	2,620	2,760	3,170	4,220	3,860	3,850	3,510	3,760	3,070
Carbon, ppm	8,670	7,860	8,280	9,510	12,660	11,580	11,550	10,530	11,280	9,210
Propane, g/m^3 a/	5.28	4.78	5.04	5.79	7.70	7.05	7.03	6.41	6.86	5.60
Carbon, g/m^3 a/	4.32	3.91	4.12	4.74	6.30	5.77	5.75	5.24	5.62	4.59
Propane, g/sec	46.2	57.7	60.6	59.6	73.5	63.5	61.2	57.6	66.0	49.1
Carbon, g/sec	37.8	47.2	49.6	48.8	60.1	52.0	50.1	47.1	54.0	40.1
Propane, lb/ft^3 a/	3.29×10^{-4}	2.98×10^{-4}	3.14×10^{-4}	3.61×10^{-4}	4.81×10^{-4}	4.40×10^{-4}	3.82×10^{-4}	4.38×10^{-4}	4.00×10^{-4}	3.50×10^{-4}
Carbon, lb/ft^3 a/	2.69×10^{-4}	2.44×10^{-4}	2.57×10^{-4}	2.95×10^{-4}	3.93×10^{-4}	3.60×10^{-4}	3.12×10^{-4}	3.59×10^{-4}	3.27×10^{-4}	2.86×10^{-4}
Propane, lb/hr	366	457	480	473	583	504	485	456	523	389
Carbon, lb/hr	300	374	393	387	477	412	397	373	428	318
	Run No. 1-0	**Run No. 2-0**	**Run No. 3-0**		**Run No. 4-0**	**Run No. 5-0**	**Run No. 6-0**	**Run No. 7-0**	**Run No. 8-0**	**Run No. 9-0**
Propane, ppm	12	63	69		39	36	33	0.172	0.089	0.056
Propane, ppm	12	63	69		39	36	33	0.172	0.089	0.056
Carbon, ppm	36	189	207		117	108	99	0.516	0.267	1.68
Propane, g/m^3 a/	0.022	0.115	0.126		0.071	0.066	0.060	3.14×10^{-4}	1.62×10^{-4}	1.02×10^{-4}
Carbon, g/m^3 a/	0.018	0.094	0.103		0.058	0.054	0.049	2.57×10^{-4}	1.33×10^{-4}	8.40×10^{-5}
Propane, g/sec	0.52	3.1	3.23		1.80	1.65	1.46	7.56×10^{-3}	4.04×10^{-3}	2.50×10^{-3}
Carbon, g/sec	0.42	2.5	2.64		1.47	1.35	1.19	6.18×10^{-3}	3.31×10^{-3}	2.00×10^{-3}
Propane, lb/ft^3 a/	1.40×10^{-6}	7.20×10^{-6}	7.90×10^{-6}		4.40×10^{-6}	4.10×10^{-6}	3.80×10^{-6}	1.96×10^{-8}	1.01×10^{-8}	6.40×10^{-9}
Carbon, lb/ft^3 a/	1.10×10^{-6}	5.90×10^{-6}	6.40×10^{-6}		3.60×10^{-6}	3.40×10^{-6}	3.10×10^{-6}	1.60×10^{-8}	8.30×10^{-9}	5.20×10^{-9}
Propane, lb/hr	4.1	24.4	25.6		14.3	13.1	11.5	0.060	0.032	0.020
Carbon, lb/hr	3.4	19.9	20.9		11.7	10.7	9.4	0.049	0.026	0.016
% efficiency	98.9	94.7	94.7		97.5	97.4	97.6	99.99	99.994	99.995

a/ *Dry standard conditions*

Note: Retention index = 300

TABLE 7. GAS CHROMATOGRAPHY ANALYSES FOR ACETALDEHYDE

	Run No. 1-I (1%)b/	Run No. 2-I	Run No. 3-I (1%)b/	Run No. 3-AOG (1%)b/	Run No. 4-I (6%)b/	Run No. 5-I (4%)b/	Run No. 6-I (1%)b/	Run No. 7-I (1%)b/	Run No. 8-I (1%)b/	Run No. 9-I (1%)b/
Propane, ppm	116	56	70	4.7	78	69	63	76	74	88
Acetaldehyde, ppm	314	151	189	12.7	21	186	170	205	200	238
Carbon, ppm	627	303	378	25	422	373	341	411	400	476
Acetaldehyde, g/m^3 a/	0.572	0.28	0.35	0.023	0.385	0.340	0.311	0.375	0.365	0.434
Carbon, g/m^3 a/	0.312	0.151	0.188	0.0126	0.210	0.186	0.170	0.205	0.199	0.237
Acetaldehyde, g/sec	5.01	3.3	4.2	.59	3.69	3.05	2.71	3.37	3.51	3.80
Carbon, g/sec	2.73	1.82	2.27	.32	2.01	1.66	1.48	1.84	1.92	2.07
Acetaldehyde, lb/ft^3 a/	3.57×10^{-5}	1.72×10^{-5}	2.15×10^{-5}	1.45×10^{-6}	2.40×10^{-5}	2.12×10^{-5}	1.94×10^{-5}	2.34×10^{-5}	2.28×10^{-5}	2.71×10^{-5}
Carbon, lb/ft^3 a/	1.95×10^{-5}	9.4×10^{-6}	1.18×10^{-5}	7.9×10^{-7}	1.31×10^{-5}	1.16×10^{-5}	1.06×10^{-5}	1.28×10^{-5}	1.24×10^{-5}	1.48×10^{-5}
Acetaldehyde, lb/hr	39.7	26.4	32.9	4.7	29.3	24.2	21.5	26.7	27.8	30.1
Carbon, lb/hr	21.7	14.4	18.0	2.6	16.0	13.2	11.7	14.6	15.2	16.4

	Run No. 1-0	Run No. 2-0 (2%)b/	Run No. 3-0 (2%)b/	Run No. 4-0 (5%)b/	Run No. 5-0 (1%)b/	Run No. 6-0 (2%)b/	Run No. 7-0	Run No. 8-0	Run No. 9-0
Propane, ppm	0.89	4.5	4.8	1.9	1.6	1.4	0.25	0.058	0.107
Acetaldehyde, ppm	2.41	12.1	12.9	5.1	4.3	3.9	0.68	0.157	0.289
Carbon, ppm	4.81	24.2	25.9	10.2	8.6	7.7	1.4	0.31	0.578
Acetaldehyde, g/m^3 a/	4.39×10^{-3}	0.0221	0.0237	9.3×10^{-3}	7.9×10^{-3}	7.0×10^{-3}	1.2×10^{-3}	2.9×10^{-4}	5.28×10^{-4}
Carbon, g/m^3 a/	2.40×10^{-3}	0.0120	0.0129	5.1×10^{-3}	4.3×10^{-3}	3.8×10^{-3}	6.7×10^{-4}	1.56×10^{-4}	2.88×10^{-4}
Acetaldehyde, g/sec	0.104	0.60	0.606	0.24	0.20	0.17	0.030	7.1×10^{-3}	.0129
Carbon, g/sec	0.057	0.32	0.329	0.13	0.11	0.093	0.016	3.9×10^{-3}	7.02×10^{-3}
Acetaldehyde, lb/ft^3 a/	2.74×10^{-7}	1.38×10^{-6}	1.48×10^{-6}	5.8×10^{-7}	4.9×10^{-7}	4.3×10^{-7}	7.7×10^{-8}	1.78×10^{-8}	3.29×10^{-8}
Carbon, lb/ft^3 a/	1.49×10^{-7}	7.6×10^{-7}	8.1×10^{-7}	3.2×10^{-7}	2.7×10^{-7}	2.4×10^{-7}	4.2×10^{-8}	9.7×10^{-9}	1.80×10^{-8}
Acetaldehyde, lb/hr	0.82	4.7	4.8	1.9	1.6	1.3	0.24	0.056	0.102
Carbon, lb/hr	0.449	2.53	2.62	1.0	0.86	0.73	0.13	0.031	0.056
% Efficiency	97.9	82.4	85.4	93.8	93.5	93.8	99.1	99.8	99.7

a/ Dry standard conditions

b/ Found in condensate fraction

Note: Retention index = 375

TABLE 8. GAS CHROMATOGRAPHY ANALYSES FOR BUTENES

	Run No. 1-I (1%)b/	Run No. 2-I	Run No. 3-I (3%)b/	Run No. 3-AOG (5%)b/	Run No. 4-I (60%)b/	Run No. 5-I (52%)b/	Run No. 6-I (10%)b/	Run No. 7-I (5%)b/	Run No. 8-I (20%)b/	Run No. 9-I (6%)b/
Propane, ppm	12.2	13.8	15.9	14.9	31.4	30.9	15.2	14.9	16.0	16.1
Butenes, ppm	9.4	10.6	12.3	11.4	24.2	23.7	11.7	11.5	12.3	12.4
Carbon, ppm	37.6	42.5	48.9	46.0	96.9	95.1	46.8	45.9	49.3	49.6
Butenes, g/m^3 a/	0.0218	0.0247	0.0284	0.0267	0.0562	0.0552	0.0272	0.0267	0.0286	0.0288
Carbon, g/m^3 a/	0.0187	0.0212	0.0243	0.0229	0.0482	0.0474	0.0233	0.0229	0.0245	0.0247
Butenes, g/sec	0.191	0.298	0.341	0.275	0.537	0.498	0.237	0.240	0.275	0.252
Carbon, g/sec	0.164	0.255	0.293	0.236	0.460	0.427	0.203	0.205	0.236	0.216
Butenes, lb/ft^3 a/	1.36×10^{-6}	1.54×10^{-6}	1.78×10^{-6}	1.66×10^{-6}	3.51×10^{-6}	3.45×10^{-6}	1.70×10^{-6}	1.66×10^{-6}	1.79×10^{-6}	1.80×10^{-6}
Carbon, lb/ft^3 a/	1.17×10^{-6}	1.32×10^{-6}	1.52×10^{-6}	1.43×10^{-6}	3.00×10^{-6}	2.96×10^{-6}	1.45×10^{-6}	1.43×10^{-6}	1.53×10^{-6}	1.54×10^{-6}
Butenes, lb/hr	1.52	2.36	2.71	2.18	4.26	3.95	1.88	1.90	2.18	2.00
Carbon, lb/hr	1.30	2.02	2.32	1.87	3.65	3.38	1.61	1.63	1.87	1.72

	Run No. 1-0	Run No. 2-0 (all)b/	Run No. 3-0 (16%)b/	Run No. 4-0 (45%)b/	Run No. 5-0 (16%)b/	Run No. 6-0 (50%)b/	Run No. 7-0	Run No. 8-0	Run No. 9-0
Propane, ppm	NDc/	0.14	1.4	0.94	0.64	0.38	NDc/	NDc/	NDc/
Butenes, ppm	NDc/	0.11	1.1	0.73	0.49	0.29	NDc/	NDc/	NDc/
Carbon, ppm	NDc/	0.43	4.4	2.90	1.96	1.17	NDc/	NDc/	NDc/
Butenes, g/m^3 a/	NDc/	2.5×10^{-4}	2.59×10^{-3}	1.69×10^{-3}	1.14×10^{-3}	6.8×10^{-4}	NDc/	NDc/	NDc/
Carbon, g/m^3 a/	NDc/	2.1×10^{-4}	2.2×10^{-3}	1.45×10^{-3}	9.8×10^{-4}	5.8×10^{-4}	NDc/	NDc/	NDc/
Butenes, g/sec	NDc/	6.4×10^{-3}	.066	0.043	0.028	1.64×10^{-2}	NDc/	NDc/	NDc/
Carbon, g/sec	NDc/	5.5×10^{-3}	.056	0.037	0.024	1.41×10^{-2}	NDc/	NDc/	NDc/
Butenes, lb/ft^3 a/	NDc/	1.6×10^{-8}	1.6×10^{-7}	1.05×10^{-7}	7.1×10^{-8}	4.2×10^{-8}	NDc/	NDc/	NDc/
Carbon, lb/ft^3 a/	NDc/	1.3×10^{-8}	1.3×10^{-7}	9.0×10^{-8}	6.1×10^{-8}	3.5×10^{-8}	NDc/	NDc/	NDc/
Butenes, lb/hr	NDc/	0.51	0.52	0.34	0.23	0.130	NDc/	NDc/	NDc/
Carbon, lb/hr	NDc/	0.044	0.45	0.290	0.194	0.116	NDc/	NDc/	NDc/
% Efficiency	NDc/	97.8	80.6	92.1	94.3	92.8	NDc/	NDc/	NDc/

a/ Dry standard conditions

b/ Found in condensate fraction

c/ ND - Not detected

Note: Retention index = 410

TABLE 9. GAS CHROMATOGRAPHY ANALYSES FOR ACROLEIN

	Run No. 1-I	Run No. 2-I	Run No. 3-I	Run No. 3-AOG	Run No. 4-I	Run No. 5-I	Run No. 6-I	Run No. 7-I	Run No. 8-I	Run No. 9-I
Propane, ppm	1,360	652	909	990	906	766	662	795	754	893
Acrolein, ppm	2,270	1,090	1,520	1,660	1,510	1,280	1,110	1,330	1,260	1,490
Carbon, ppm	6,820	3,270	4,560	4,970	4,540	3,840	3,320	3,990	3,780	4,480
Acrolein, g/m^3[a]	5.28	2.53	3.53	3.85	3.52	2.98	2.57	3.09	2.93	3.47
Carbon, g/m^3[a]	3.40	1.63	2.27	2.47	2.26	1.91	1.65	1.99	1.88	2.23
Acrolein, g/sec	46.2	30.5	42.5	39.6	33.6	26.8	22.4	27.7	28.2	30.4
Carbon, g/sec	29.7	19.6	27.3	25.5	21.6	17.2	14.4	17.8	18.1	19.5
Acrolein, lb/ft^3[a]	3.29×10^{-4}	1.58×10^{-4}	2.20×10^{-4}	2.47×10^{-4}	2.20×10^{-4}	1.86×10^{-4}	1.60×10^{-4}	1.93×10^{-4}	1.83×10^{-4}	2.16×10^{-4}
Carbon, lb/ft^3[a]	2.12×10^{-4}	1.02×10^{-4}	1.42×10^{-4}	1.54×10^{-4}	1.41×10^{-4}	1.19×10^{-4}	1.03×10^{-4}	1.24×10^{-4}	1.17×10^{-4}	1.39×10^{-4}
Acrolein, lb/hr	367	242	337	314	266	213	177	220	223	241
Carbon, lb/hr	236	156	216	202	171	137	114	141	144	155

	Run No. 1-0	Run No. 2-0	Run No. 3-0		Run No. 4-0	Run No. 5-0	Run No. 6-0	Run No. 7-0	Run No. 8-0	Run No. 9-0
Propane, ppm	0.24	5.6	14.6		1.0	0.31	0.54	↑	↑	↑
Acrolein, ppm	0.40	9.4	24.4		1.7	0.52	0.90			
Carbon, ppm	1.20	28.1	73.2		5.0	1.6	2.7			
Acrolein, g/m^3[a]	9.3×10^{-4}	0.0218	0.0567		3.9×10^{-3}	1.2×10^{-3}	2.1×10^{-3}			
Carbon, g/m^3[a]	5.0×10^{-4}	0.0140	0.0365		2.5×10^{-3}	7.7×10^{-4}	1.3×10^{-3}			
Acrolein, g/sec	0.022	0.58	1.45		0.098	0.030	0.051	ND[b]	ND[b]	ND[b]
Carbon, g/sec	0.0142	0.37	0.93		0.063	0.019	0.033			
Acrolein, lb/ft^3[a]	5.8×10^{-8}	1.36×10^{-6}	3.54×10^{-6}		2.4×10^{-7}	7.5×10^{-8}	1.31×10^{-7}			
Carbon, lb/ft^3[a]	3.7×10^{-8}	8.7×10^{-7}	2.27×10^{-6}		1.6×10^{-7}	4.8×10^{-8}	8.4×10^{-8}			
Acrolein, lb/hr	0.175	4.6	11.5		0.78	0.24	0.40			
Carbon, lb/hr	0.112	2.96	7.40		0.50	0.15	0.26			
% efficiency	99.95	98.1	96.6		99.7	99.9	99.8	↓	↓	↓

a/ Dry standard conditions.

b/ None detected.

Note: Retention index = 495.

TABLE 10. GAS CHROMATOGRAPHY ANALYSES FOR ACETONE

	Run No. 1-I (< 1%)[b]	Run No. 2-I	Run No. 3-I (3%)[b]	Run No. 3-AOG (4%)[b]	Run No. 4-I (25%)[b]	Run No. 5-I (28%)[b]	Run No. 6-I (5%)[b]	Run No. 7-I (3%)[b]	Run No. 8-I (2%)[b]	Run No. 9-I (2%)[b]
Propane, ppm	62	59	82	89	141	124	128	99	117	106
Acetone, ppm	94	90	124	135	214	188	194	150	178	161
Carbon, ppm	282	269	375	407	640	565	583	450	534	483
Acetone, g/m^3 [a]	0.226	0.215	0.301	0.327	0.515	0.453	0.468	0.361	0.428	0.387
Carbon, g/m^3 [a]	0.141	0.134	0.186	0.203	0.319	0.282	0.290	0.224	0.266	0.240
Acetone, g/sec	1.98	2.60	3.62	3.36	4.91	4.08	4.07	3.24	4.12	3.39
Carbon, g/sec	1.23	1.61	2.25	2.09	3.05	2.54	2.53	2.01	2.56	2.11
Acetone, lb/ft^3 [a]	1.41×10^{-5}	1.34×10^{-5}	1.87×10^{-5}	2.03×10^{-5}	3.21×10^{-5}	2.82×10^{-5}	2.92×10^{-5}	2.25×10^{-5}	2.66×10^{-5}	2.41×10^{-5}
Carbon, lb/ft^3 [a]	8.8×10^{-6}	8.3×10^{-6}	1.16×10^{-5}	1.26×10^{-5}	1.99×10^{-5}	1.75×10^{-5}	1.81×10^{-5}	1.40×10^{-5}	1.65×10^{-5}	1.50×10^{-5}
Acetone, lb/hr	15.7	20.6	28.7	26.6	39.0	32.4	32.3	25.7	32.6	26.9
Carbon, lb/hr	9.8	12.8	17.8	16.5	24.2	20.1	20.0	16.0	20.3	16.7

	Run No. 1-0	Run No. 2-0 (2%)[b]	Run No. 3-0 (2%)[b]	Run No. 4-0 (23%)[b]	Run No. 5-0 (3%)[b]	Run No. 6-0 (17%)[b]	Run No. 7-0	Run No. 8-0	Run No. 9-0
Propane, ppm	0.43	4.1	4.5	0.69	2.3	0.80	↑	↑	↑
Acetone, ppm	0.65	6.2	6.8	1.05	3.4	1.22			
Carbon, ppm	1.96	18.6	20.4	3.13	10.3	3.66			
Acetone, g/m^3 [a]	1.57×10^{-3}	0.0149	0.0164	2.52×10^{-3}	8.3×10^{-3}	2.94×10^{-3}			
Carbon, g/m^3 [a]	9.7×10^{-4}	9.10×10^{-3}	0.0102	1.56×10^{-3}	5.1×10^{-3}	1.82×10^{-3}			
Acetone, g/sec	0.037	0.40	0.42	0.064	0.207	0.071	ND[c]	ND[c]	ND[c]
Carbon, g/sec	0.023	0.25	0.26	0.0395	0.129	0.044			
Acetone, lb/ft^3 [a]	9.8×10^{-8}	9.3×10^{-7}	1.02×10^{-6}	1.57×10^{-7}	5.2×10^{-7}	1.82×10^{-7}			
Carbon, lb/ft^3 [a]	6.1×10^{-8}	5.8×10^{-7}	6.4×10^{-7}	9.8×10^{-8}	3.3×10^{-7}	1.13×10^{-7}			
Acetone, lb/hr	0.29	3.2	3.3	0.50	1.64	0.56			
Carbon, lb/hr	0.183	1.96	2.07	0.313	1.02	0.35			
% efficiency	98.1	84.7	88.4	98.7	94.9	98.2	↓	↓	↓

a/ Dry standard conditions.

b/ Found in condensate fraction.

c/ None detected.

Note: Retention index = 505.

TABLE 11. GAS CHROMATOGRAPHY ANALYSES FOR UNKNOWN PEAK

	Run No. 1-I	Run No. 2-I	Run No. 3-I	Run No. 3-AOG	Run No. 4-I	Run No. 5-I	Run No. 6-I	Run No. 7-I	Run No. 8-I	Run No. 9-I
Propane, ppm	2.0	2.2	3.0	3.9	5.0	↑	2.4	4.4	4.0	4.0
Propane, ppm	2.0	2.2	3.0	3.9	5.0		2.4	4.4	4.0	4.0
Carbon, ppm	6.0	6.6	9.0	11.7	15.0		7.2	13.2	12.0	12.0
Propane, g/m3a/	3.7×10^{-3}	4.0×10^{-3}	5.5×10^{-3}	7.1×10^{-3}	9.1×10^{-3}		4.4×10^{-3}	8.0×10^{-3}	7.3×10^{-3}	7.3×10^{-3}
Carbon, g/m3a/	3.0×10^{-3}	3.3×10^{-3}	4.5×10^{-3}	5.8×10^{-3}	7.5×10^{-3}		3.6×10^{-3}	6.6×10^{-3}	6.0×10^{-3}	6.0×10^{-3}
Propane, g/sec	0.032	0.048	0.066	0.073	0.087	NDb/	0.038	0.072	0.070	0.064
Carbon, g/sec	0.026	0.040	0.054	0.060	0.071		0.031	0.059	0.057	0.052
Propane, lb/ft3a/	2.3×10^{-7}	2.5×10^{-7}	3.4×10^{-7}	4.4×10^{-7}	5.7×10^{-7}		2.7×10^{-7}	5.0×10^{-7}	4.6×10^{-7}	4.6×10^{-7}
Carbon, lb/ft3a/	1.9×10^{-7}	2.0×10^{-7}	2.8×10^{-7}	3.6×10^{-7}	4.7×10^{-7}		2.2×10^{-7}	4.1×10^{-7}	3.7×10^{-7}	3.7×10^{-7}
Propane, lb/hr	0.25		0.52	0.50	0.69		0.30	0.57	0.56	0.51
Carbon/lb/hr	0.21		0.43	0.48	0.56	↓	0.25	0.47	0.46	0.41

	Run No. 1-0	Run No. 2-0	Run No. 3-0	Run No. 4-0	Run No. 5-0	Run No. 6-0	Run No. 7-0	Run No. 8.0	Run No. 9-0
Propane, ppm	↑	↑	1.5	↑	↑	↑	↑	↑	↑
Propane, ppm			1.5						
Carbon, ppm			4.5						
Propane, g/m3a/			2.7×10^{-3}						
Carbon, g/m3a/			2.2×10^{-3}						
Propane, g/sec			0.070						
Carbon, g/sec	ND	ND	0.057	ND	ND	ND	ND	ND	ND
Propane, lb/ft3a/			1.7×10^{-7}						
Carbon, lb/ft3a/			1.4×10^{-7}						
Propane, lb/hr			0.56						
Carbon, lb/hr			0.46						
% efficiency	↓	↓	negative	↓	↓	↓	↓	↓	↓

a/ Dry standard conditions

b/ ND - None detected

Note: Retention index = 590

TABLE 12. GAS CHROMATOGRAPHY ANALYSES FOR 1-HEXENE

	Run No. 1-I	Run No. 2-I	Run No. 3-I	Run No. 3-AOG	Run No. 4-I	Run No. 5-I	Run No. 6-I	Run No. 7-I	Run No. 8-I	Run No. 9-I
Propane, ppm	3.8	1.6	3.0	1.8	2.2	4.3	4.0	4.6	5.4	4.4
1-hexene, ppm	2.0	0.83	1.6	0.93	1.1	2.2	2.1	2.4	2.8	2.3
Carbon, ppm	11.8	5.0	9.3	5.6	6.8	13.4	12.4	14.3	16.8	13.7
1-hexene, g/m^3 [a]	6.9×10^{-3}	2.9×10^{-3}	5.4×10^{-3}	3.3×10^{-3}	4.0×10^{-3}	7.8×10^{-3}	7.2×10^{-3}	8.3×10^{-3}	9.8×10^{-3}	8.0×10^{-3}
Carbon, g/m^3 [a]	5.9×10^{-3}	2.5×10^{-3}	4.6×10^{-3}	2.8×10^{-3}	3.4×10^{-3}	6.7×10^{-3}	6.2×10^{-3}	7.1×10^{-3}	8.4×10^{-3}	6.8×10^{-3}
1-hexene, g/sec	0.060	0.035	0.065	0.034	0.038	0.070	0.063	0.075	0.094	0.070
Carbon, g/sec	0.052	0.030	0.056	0.029	0.033	0.060	0.054	0.064	0.80	0.060
1-hexene, lb/ft^3 [a]	4.3×10^{-7}	1.8×10^{-7}	3.4×10^{-7}	2.0×10^{-7}	2.5×10^{-7}	4.8×10^{-7}	4.5×10^{-7}	5.2×10^{-7}	6.1×10^{-7}	5.0×10^{-7}
Carbon, lb/ft^3 [a]	3.7×10^{-7}	1.5×10^{-7}	2.9×10^{-7}	1.7×10^{-7}	2.1×10^{-7}	4.2×10^{-7}	3.9×10^{-7}	4.4×10^{-7}	5.2×10^{-7}	4.3×10^{-7}
1-hexene, lb/hr	0.48	0.28	0.52	0.27	0.30	0.56	0.50	0.60	0.74	0.55
Carbon, lb/hr	0.41	0.24	0.44	0.23	0.26	0.48	0.43	0.51	0.64	0.47

	Run No. 1-0	Run No. 2-0	Run No. 3-0	Run No. 4-0	Run No. 5-0	Run No. 6-0	Run No. 7-0	Run No. 8-0	Run No. 9-0
Propane, ppm	↑	↑	1.1	↑	↑	↑	↑	↑	↑
1-hexene, ppm			0.57						
Carbon, ppm			3.4						
1-hexene, g/m^3 [a]			2.0×10^{-3}						
Carbon, g/m^3 [a]			1.7×10^{-3}						
1-hexene, g/sec	ND[b]	ND	0.051	ND	ND	ND	ND	ND	ND
Carbon, g/sec			0.044						
1-hexene, lb/ft^3 [a]			1.2×10^{-7}						
Carbon, lb/ft^3 [a]			1.1×10^{-7}						
1-hexene, lb/hr			0.40						
Carbon, lb/hr			0.35						
% efficiency	↓	↓	20	↓	↓	↓	↓	↓	↓

a/ Dry standard conditions

b/ ND - None detected

Note: Retention index = 615

TABLE 13. GAS CHROMATOGRAPHY ANALYSES FOR 2-HEXENE

	Run No. 1-I	Run No. 2-I	Run No. 3-I	Run No. 3-AOG	Run No. 4-I	Run No. 5-I	Run No. 6-I	Run No. 7-I	Run No. 8-I	Run No. 9-I
Propane, ppm	11.6	6.6	1.5	12	19	20	17	21	21	22
2-Hexene, ppm	6.0	3.4	7.8	6.2	9.9	10.4	8.8	10.9	10.9	11.4
Carbon, ppm	36.1	20.5	47	37	59	62	53	65	65	68
2-Hexene, g/m^3 [a]	0.0210	0.0119	0.027	0.022	0.034	0.036	0.031	0.038	0.038	0.040
Carbon, g/m^3 [a]	0.0180	0.0102	0.023	0.019	0.029	0.031	0.036	0.033	0.033	0.034
2-Hexene, g/sec	0.184	0.144	0.33	0.22	0.33	0.33	0.27	0.34	0.36	0.35
Carbon, g/sec	0.157	0.123	0.28	0.19	0.28	0.28	0.23	0.29	0.31	0.30
2-Hexene, lb/ft^3 [a]	1.31×10^{-6}	7.4×10^{-7}	1.7×10^{-6}	1.4×10^{-6}	2.1×10^{-6}	2.3×10^{-6}	1.9×10^{-6}	2.4×10^{-6}	2.4×10^{-6}	2.5×10^{-6}
Carbon, lb/ft^3 [a]	1.12×10^{-6}	6.4×10^{-7}	1.4×10^{-6}	1.2×10^{-6}	1.8×10^{-6}	1.9×10^{-6}	1.6×10^{-6}	2.0×10^{-6}	2.0×10^{-6}	2.1×10^{-6}
2-Hexene, lb/hr	1.46	1.14	2.6	1.8	2.6	2.6	2.1	2.7	2.9	2.8
Carbon, lb/hr	1.25	0.98	2.2	1.5	2.2	2.2	1.8	2.3	2.5	2.4

	Run No. 1-0	Run No. 2-0	Run No. 3-0		Run No. 4-0	Run No. 5-0	Run No. 6-0	Run No. 7-0	Run No. 8-0	Run No. 9-0
Propane, ppm	↑	↑	4.2		↑	↑	↑	↑	↑	↑
2-Hexene, ppm			2.2							
Carbon, ppm			13.1							
2-Hexene, g/m^3 [a]			7.6×10^{-3}							
Carbon, g/m^3 [a]			6.5×10^{-3}							
2-Hexene, g/sec	ND[b]	ND[b]	0.194		ND[b]	ND[b]	ND[b]	ND[b]	ND[b]	ND[b]
Carbon, g/sec			0.167							
2-Hexene, lb/ft^3 [a]			4.7×10^{-7}							
Carbon, lb/ft^3 [a]			4.1×10^{-7}							
2-Hexene, lb/hr			1.54							
Carbon, lb/hr			1.32							
% Efficiency	↓	↓	40		↓	↓	↓	↓	↓	↓

a/ Dry standard conditions

b/ ND - None detected

Note: Retention index = 635

TABLE 14. GAS CHROMATOGRAPHY ANALYSES FOR ACRYLIC ACID

	Run No. 1-I	Run No. 2-I	Run No. 3-I	Run No. 3-AOG	Run No. 4-I	Run No. 5-I	Run No. 6-I	Run No. 7-I	Run No. 8-I	Run No. 9-I
Propane, ppm	34	28	40	48	61	61	49	58	56	57
Acrylic Acid, ppm	53	44	63	75	96	96	77	91	88	89
Carbon, ppm	160	132	188	226	287	287	230	273	263	268
Acrylic Acid, g/m^3 [a]	0.159	0.131	0.187	0.225	0.286	0.286	0.229	0.272	0.262	0.267
Carbon, g/m^3 [a]	0.080	0.066	0.094	0.112	0.143	0.143	0.115	0.136	0.131	0.133
Acrylic Acid, g/sec	1.39	1.58	2.25	2.31	2.72	2.57	2.00	2.44	2.52	2.34
Carbon, g/sec	0.70	0.79	1.13	1.16	1.36	1.29	1.00	1.22	1.26	1.17
Acrylic Acid, lb/ft^3 [a]	9.9×10^{-6}	8.2×10^{-6}	1.17×10^{-5}	1.40×10^{-5}	1.78×10^{-5}	1.78×10^{-5}	1.43×10^{-5}	1.70×10^{-5}	1.64×10^{-5}	1.66×10^{-5}
Carbon, lb/ft^3 [a]	5.0×10^{-6}	4.1×10^{-6}	5.8×10^{-6}	7.0×10^{-6}	8.9×10^{-6}	8.9×10^{-6}	7.2×10^{-6}	8.5×10^{-6}	8.2×10^{-6}	8.3×10^{-6}
Acrylic Acid, lb/hr	11.0	12.5	17.9	18.4	21.6	20.4	15.8	19.3	20.0	18.5
Carbon, lb/hr	5.5	6.3	8.9	9.2	10.8	10.2	7.9	9.7	10.0	9.3

	Run No. 1-0	Run No. 2-0	Run No. 3-0		Run No. 4-0	Run No. 5-0	Run No. 6-0	Run No. 7-0	Run No. 8-0	Run No. 9-0
Propane, ppm	↑	↑	18		↑	↑	↑	↑	↑	↑
Acrylic Acid, ppm			28							
Carbon, ppm			85							
Acrylic Acid, g/m^3 [a]			0.084							
Carbon, g/m^3 [a]			0.042							
Acrylic Acid g/sec			2.2							
Carbon, g/sec	ND [b]	ND	1.1		ND	ND	ND	ND	ND	ND
Acrylic Acid, lb/ft^3 [a]			5.3×10^{-6}							
Carbon, lb/ft^3 [a]			2.6×10^{-6}							
Acrylic Acid, lb/hr			17							
Carbon, lb/hr			8.6							
% efficiency	↓	↓	3.4		↓	↓	↓	↓	↓	↓

a/ Dry standard conditions

b/ ND - None detected

Note: Retention index = 750

TABLE 15. GAS CHROMATOGRAPHY ANALYSES FOR TOTAL HYDROCARBONS[b/]

	Run No. 1-I	Run No. 2-I	Run No. 3-I	Run No. 3-AOG	Run No. 4-I	Run No. 5-I	Run No. 6-I	Run No. 7-I	Run No. 8-I	Run No. 9-I
Propane, ppm	10,340	8,676	9,559	10,630	13,566	12,470	12,340	11,470	12,150	10,500
Hydrocarbons, ppm	12,540	10,080	11,470	12,390	15,263	14,210	14,070	13,170	13,850	12,490
Carbon, ppm	34,530	27,928	31,170	34,481	30,918	39,900	39,250	36,884	38,888	34,094
Hydrocarbons, g/m^3[a/]	22.1	17.4	19.6	21.6	27.0	24.7	24.2	22.9	24.1	21.4
Carbon, g/m^3[a/]	17.2	13.9	15.5	17.2	23.6	19.87	19.5	18.1	19.4	19.1
Hydrocarbons, g/sec	193	209.5	236.2	222.2	257.8	221.3	210.8	206.0	231.8	187.7
Carbon, g/sec	150	592	186.7	177.0	207.0	177.9	170.2	165	186	149
Hydrocarbons, lb/ft^3[a/]	1.38×10^{-3}	1.08×10^{-3}	1.22×10^{-3}	1.34×10^{-3}	1.69×10^{-3}	1.54×10^{-3}	1.45×10^{-3}	1.47×10^{-3}	1.48×10^{-3}	1.34×10^{-3}
Carbon, lb/ft^3[a/]	1.07×10^{-3}	8.68×10^{-4}	9.68×10^{-4}	1.07×10^{-3}	1.35×10^{-3}	1.24×10^{-3}	1.17×10^{-3}	1.18×10^{-3}	1.18×10^{-3}	1.06×10^{-3}
Hydrocarbons, lb/hr	1,530	1,660	1,972	1,760	2,045	1,770	1,670	1,630	1,840	1,490
Carbon, lb/hr	1,190	1,330	1,480	1,400	1,640	1,420	1,350	1,310	1,480	1,180
Propane from THC mode (column bypass), ppm	8,990	8,340	8,160	10,040	12,440	10,930	13,240	10,480	10,460	9,590

	Run No. 1-0	Run No. 2-0	Run No. 3-0		Run No. 4-0	Run No. 5-0	Run No. 6-0	Run No. 7-0	Run No. 8-0	Run No. 9-0
Propane, ppm	85	321	388		160	149	163	1.2	0.27	0.32
Hydrocarbons, ppm	150	530	641		252	242	273	3.1	0.51	0.68
Carbon, ppm	257	983	1,230		473	450	487	4.2	0.92	2.14
Hydrocarbons, g/m^3[a/]	0.156	0.607	0.800		0.288	5.1	0.296	3.1×10^{-3}	6.7×10^{-4}	9.2×10^{-4}
Carbon, g/m^3[a/]	0.115	0.404	0.614		0.234	0.228	0.242	2.1×10^{-3}	4.6×10^{-4}	6×10^{-4}
Hydrocarbons, g/sec	3.71	16.3	20.5		7.26	6.8	7.1	7.3×10^{-2}	1.65×10^{-2}	2.23×10^{-2}
Carbon, g/sec	3.01	13.1	15.8		5.96	5.6	5.8	5×10^{-2}	1.15×10^{-2}	2.0×10^{-2}
Hydrocarbons, lb/ft^3[a/]	9.8×10^{-6}	3.78×10^{-5}	5.00×10^{-5}		1.80×10^{-5}	1.7×10^{-5}	1.88×10^{-5}	1.91×10^{-7}	4.36×10^{-8}	5.1×10^{-8}
Carbon, lb/ft^3[a/]	7.9×10^{-6}	3.1×10^{-5}	3.82×10^{-5}		1.46×10^{-5}	1.4×10^{-5}	1.53×10^{-5}	1.64×10^{-7}	2.9×10^{-8}	3.2×10^{-8}
Hydrocarbons, lb/hr	29.4	129	162		58	54.3	56.5	0.59	0.131	0.183
Carbon, lb/hr	24.0	103	125		47.2	44.3	46.3	0.4	0.091	0.116
Propane from THC mode (column bypass), ppm	58	205	231		97	94	99	11.3	9.2	9.2
% efficiency	98.0	92.3	91.6		97.1	96.9	96.6	99.97	99.99	99.99

a/ Dry standard conditions.

b/ Measured as the sum of observed peaks.

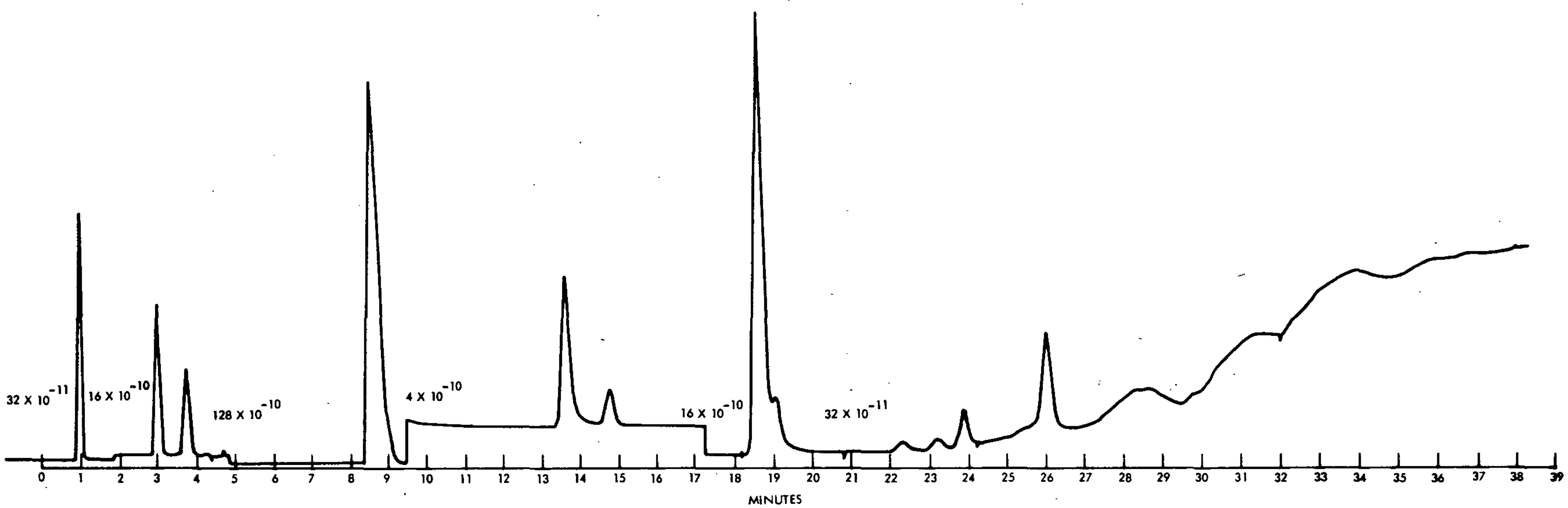

Figure 1. Run 3 - Inlet chromatogram, Taft, Louisiana.

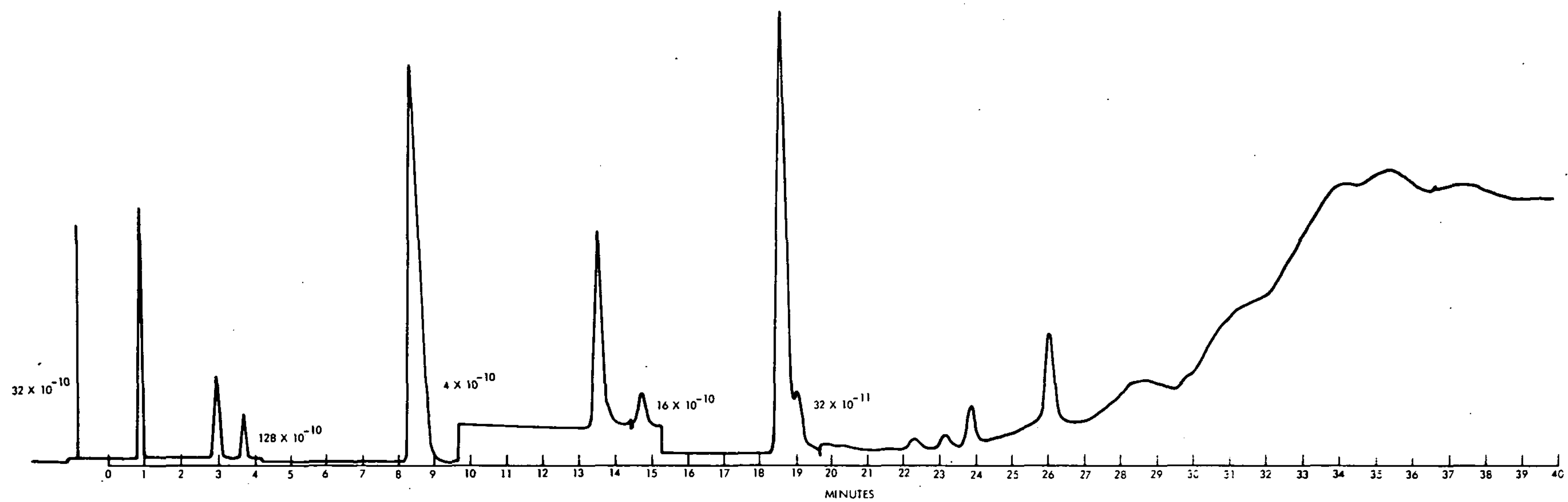

Figure 2. Run 3 - Acrylic acid off-gas gas chromatogram, Taft, Louisiana.

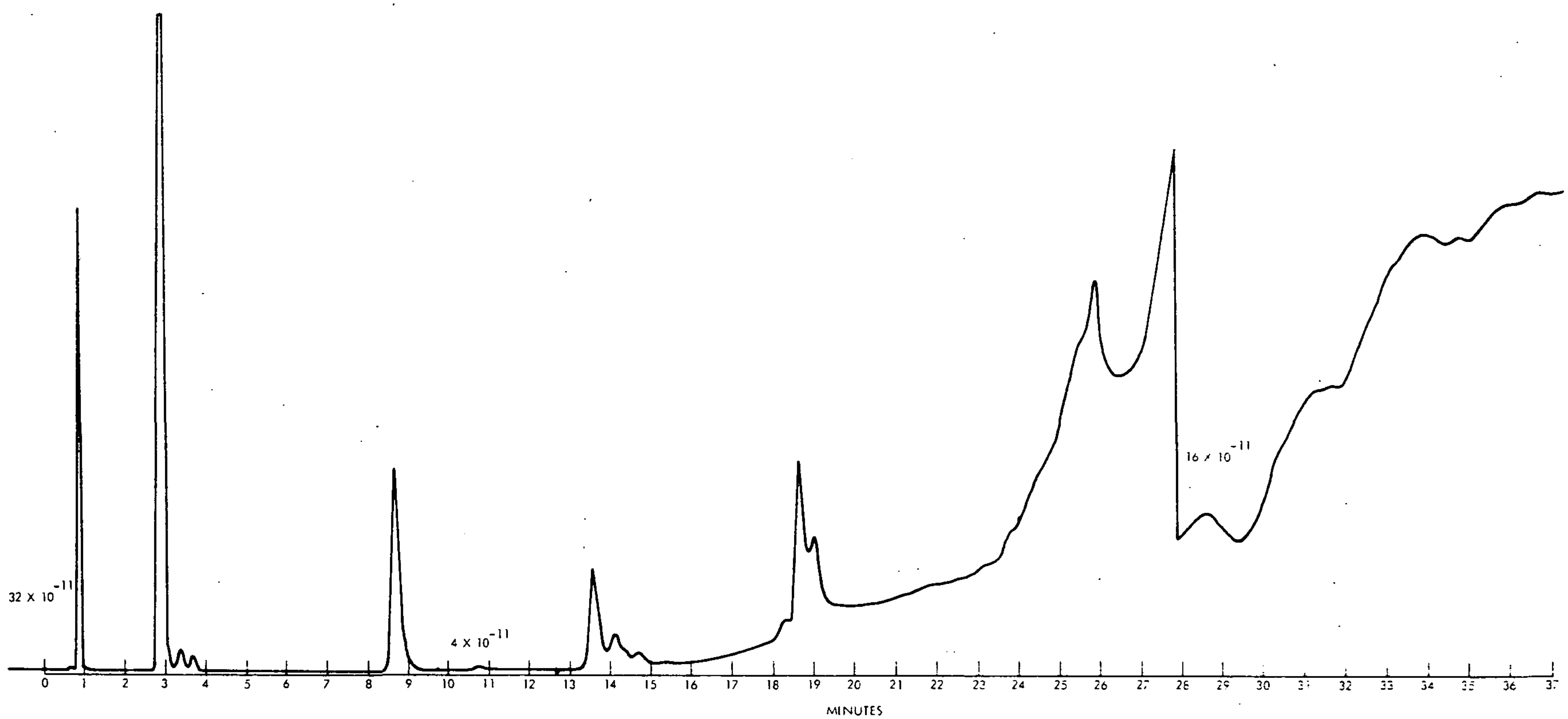

Figure 3. Run 3 - Outlet chromatogram, Taft, Louisiana.

Table 16 shows the results of the total gaseous nonmethane organic (TGNMO) sampling performed simultaneously 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 inlet samples between the on-site measurements and final tank analyses may indicate that even the lighter components are unstable. Propylene polymerization is one possibility. The outlet 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. Also, some of the outlet tanks showed extreme variability for successive injections. Some of the tank samples by GC/FID are averaged over 10 and 20 injections. Appendix A includes the original TGNMO sampling and analysis data.

Table 17 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 16 except for the expected inflated THC readings at low levels. Figures 4 and 5 show typical chromatograms from the tank samples.

Table 18 shows the evacuated flask aldehyde sampling results with comparison values by GC/FID. 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 weight aldehydes not detectable by GC/FID.

Table 19 (metric) and 20 (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.

Table 21 shows the results of the fuel gas analyses by GC/FID. A typical chromatogram is shown in Figure 6. Table 22 shows the results of the NO_x sampling. Data sheets for NO_x sampling are in Appendix F.

TABLE 16. TOTAL GASEOUS NON-METHANE ORGANIC (TGNMO) SAMPLING RESULTS

	UCI-1	UCI-1F	UCI-2	UCI-2F	UCI-3	UCI-3F	UCI-4	UCI-4F	UCI-5	UCI-5F	UCI-6	UCI-7	UCI-8	UCI-9
Trap fraction - ppm C_1	2,700	3,330	700	4,070	1,860	6,270	4,530	6,680	5,880	6,220	3,390	4,890	4,560	6,000
Tank fraction - ppm C_1	18,590	17,040	16,180	16,510	17,470	15,570	23,650	23,600	21,600	21,560	20,310	18,590	20,440	10,920
Total - ppm C_1	21,290	20,370	16,880	20,580	19,330	21,840	28,180	30,280	27,480	27,780	23,700	23,480	25,000	16,920
Total Hydrocarbon/FID mode reading of tank ppm as propane (as is-uncorrected for N_2 dilution)	3,720	3,160	2,270	2,150	2,720	2,170	4,220	3,540	2,960	3,480	3,680	3,650	3,450	-
THC/FID reading of tank N_2 dilution corrected ppm as C_1[a]	31,340	28,000	22,670	22,350	23,800	22,830	33,790	32,720	29,780	29,850	30,760	29,890	28,870	-
GC/FID sum - ppm as carbon[b] of integrated gas sample	34,530	34,530	27,930	27,930	31,170	31,170	30,920	30,920	39,900	39,900	39,250	36,880	38,890	34,090

	UCO-1F	UCO-3A	UCO-3B	UCO-4A	UCO-4B	UCO-5A	UCO-5B	UCO-6	UCO-7	UCO-8	UCO-9
Trap fraction - ppm C_1	80	735	520	640	235	308	513	329	234	219	c/
Tank fraction - ppm C_1	56	209	144	114	91	84	91	140	50	34	55
Total - ppm C_1	136	944	664	754	326	392	604	469	284	253	-
Total hydrocarbon/FID mode reading of tank ppm as propane (as is-uncorrected for N_2 dilution)	25.7	101	94	47	42	52	49	33	21.4	12.4	4.8
THC/FID reading of tank N_2 dilution corrected ppm as C_1[a/d]	206	1,090	1,143	387	297	453	447	448	178	105	42
GC/FID sum - ppm as carbon[b] of integrated gas sample	257	1,230	1,230	473	473	450	450	487	4.2	0.92	2.1

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

b/ Excluding methane.

c/ Sample lost.

d/ Note that THC readings by column bypass tend to be high at low levels due to flame upsets and pressure changes from injection.

TABLE 17. TGNMO TANK SAMPLES ANALYZED BY GAS CHROMATOGRAPHY

Components	Run 6				Run 8		Run 9	
	UCO-6 (ppm as propane)[a]	ppm as C_1[b]	UCI-6 (ppm as propane)[a]	ppm as C_1[b]	UCI-8 (ppm as propane)[a]	ppm as C_1[b]	UCO-9 (ppm as propane)[a]	ppm as C_1[b]
Methane	7.6	103	83	690	125	1,040	0.051	.45
Ethylene	21.0	285	56	470	64	530	0.023	.20
Acetylene	0.33	4	-	-	-	-	-	-
Ethane	-	-	34	280	36	300	-	-
Propylene	-	-	2,455	20,500	2,220	18,500	-	-
Propane	9.6	130	1,505	12,600	1,360	11,300	1.0	8.8
Acetaldehyde	-	-	8.0	67	9.0	75	-	-
Butenes	-	-	4.8	40	4.8	40	-	-
Acrolein	0.11	1.5	32	270	19.8	165	-	-
Acetone	0.78	10.6	17	140	-	-	-	-
Unknown peak	-	-	-	-	-	-	-	-
1-Hexene	-	-	-	-	-	-	-	-
2-Hexene	-	-	-	-	-	-	-	-
Acrylic acid	-	-	-	-	-	-	-	-
Total of all peaks	39.4	535	4,195	35,100	3,840	32,000	1.1	9.6

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.

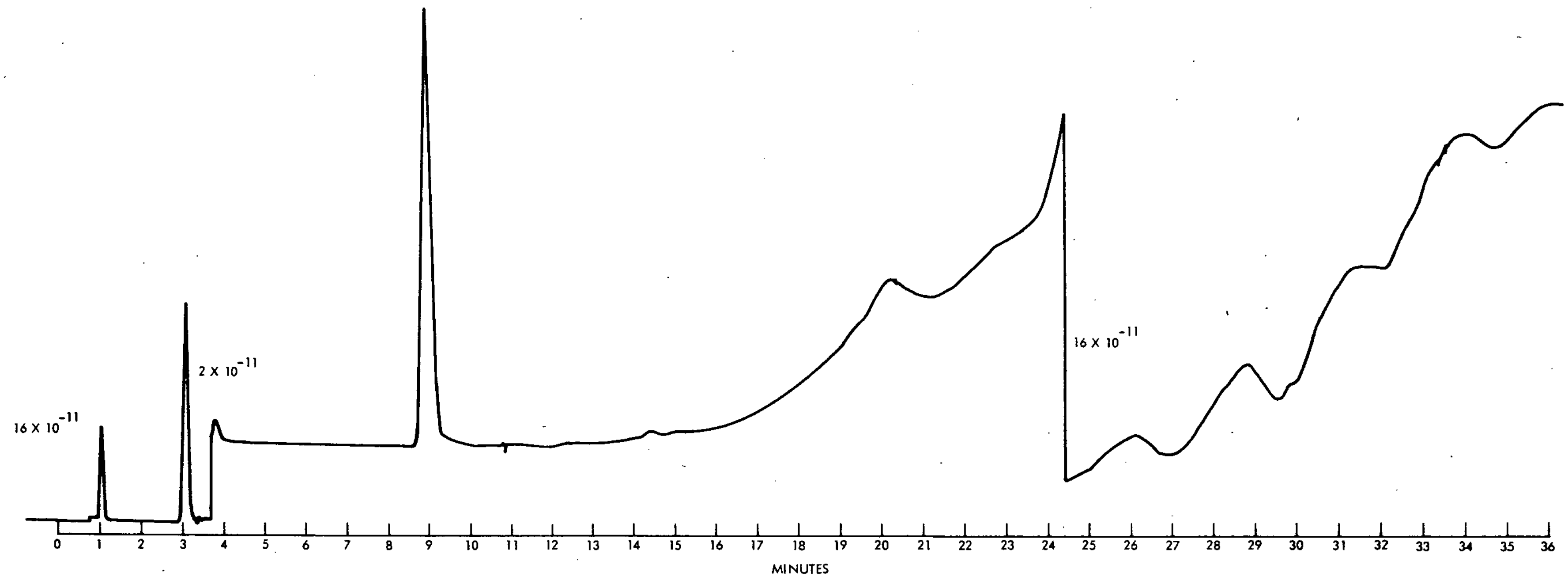

Figure 4. Run 6 - TGNMO Tank UCO-6 chromatogram, Taft, Louisiana.

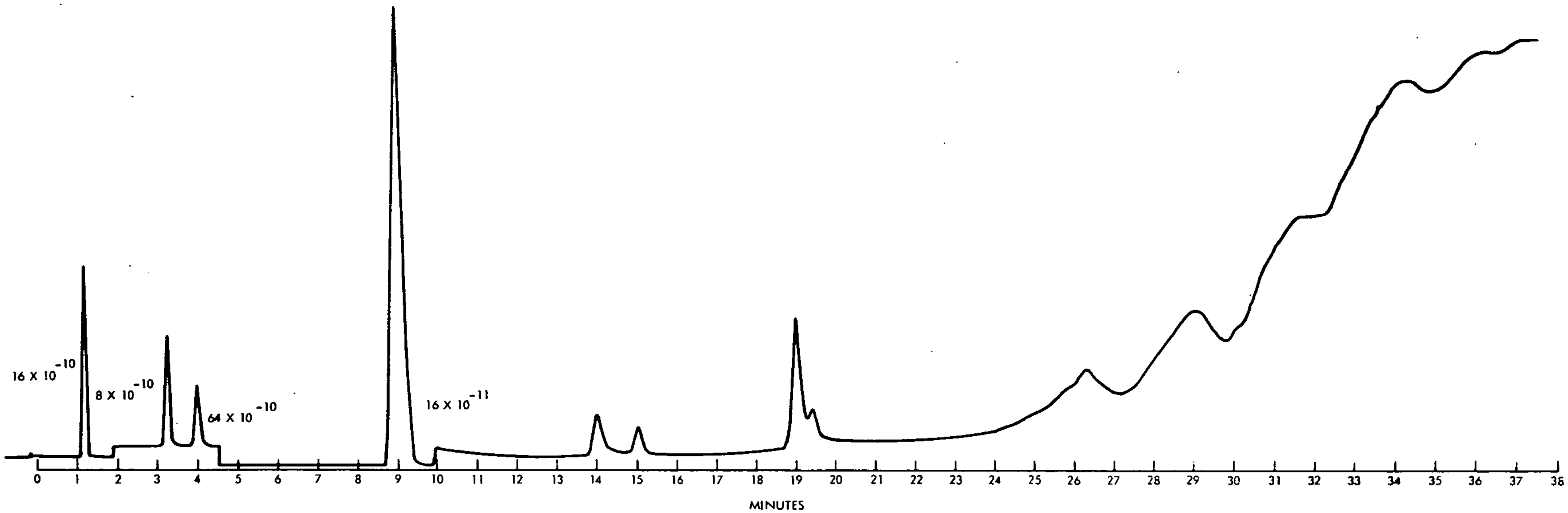

Figure 5. Run 5 - TGNMO Tank UCI-6 chromatogram, Taft, Louisiana.

TABLE 18. ALDEHYDE ANALYSIS RESULTS - BISULFITE REACTION

	Aldehyde method		Aldehydes[a/] by GC
	g/m^3 as acrolein	ppm as acrolein	ppm total
Run 1-I	6.74	2,900	2,680
Run 2-I	3.22	1,380	1,330
Run 3-I	4.74	2,040	1,830
Run 3-AOG	5.00	2,150	1,810
Run 4-I	3.56	1,530	1,940
Run 5-I	2.96	1,270	1,650
Run 6-I	2.79	1,200	1,460
Run 7-I	3.41	1,470	1,680
Run 8-I	3.58	1,540	1,640
Run 9-I	3.90	1,680	1,890
Run 1-O	0.027	12	3.5
Run 2-O	0.083	36	27.7
Run 3-O	0.107	46	44.1
Run 4-O	0.053	23	7.8
Run 5-O	0.055	24	8.2
Run 6-O	0.055	24	6.0
Run 7-O	0.019	8	0.7
Run 8-O	0.020	9	0.16
Run 9-O	0.012	5	0.29

a/ Sum of acetaldehyde, acrolein, and acetone peaks.

TABLE 19. 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
Date--Time of start	11/29--1600	12/2--0900	12/2--1400	12/5--0920	12/5--1500	12/6--1120	12/7--0930	12/7--1230	12/8--0900
Outlet:									
Stack velocity, m/sec	21.59	24.99	23.88	22.40	22.25	21.64	21.64	21.39	21.54
Flow rate, dsm^3/sec	23.65	26.73	25.61	25.31	25.06	24.16	24.06	24.86	24.39
Mass flow, kg/sec	31.51	35.67	34.04	33.24	32.95	32.19	33.12	34.95	31.79
Temperature, °C	211	222	227	202	207	208	221	221	223
Oxygen, %	7.5	6.2	6.5	8.1	7.6	7.8	7.2	7.2	7.6
Carbon dioxide, %	2.7	3.2	3.8	3.8	3.2	3.6	4.4	5.0	5.4
Moisure, %	-[a]	16.0	15.2	14.9	14.0	15.4	13.0	8.8	11.3
Carbon monoxide, ppm	530	7,510	7,750	4,840	5,000	5,320	<10	<10	<10
Combustor:									
Fuel gas flow, kg/sec	0.0995	0.1289	0.1260	0.0980	0.1012	0.1027	0.1180	0.1170	0.1255
Combustion airflow, kg/sec	12.21	11.76	11.62	12.36	12.13	11.94	11.98	11.87	11.94
Combustion temperature, °C	621	627	627	627	627	627	799	799	800
Air preheater, °C	282	279	281	265	265	268	281	282	282
Inlet, combined feed:									
Flow rate, dsm^3/sec	8.753	12.059	12.025	9.539	9.012	8.704	8.983	9.615	8.756
Mass flow, kg/sec[b]	12.30	15.60	15.52	12.89	12.80	12.69	12.12	12.06	10.98
Temperature, °C	-[a]	-[a]	63	69	67	68	58	57	61
Oxygen, %	0.7	2.8	2.0	2.0	2.0	1.6	2.6	1.4	1.8
Carbon dioxide, %	1.1	1.0	0.8	2.0	1.8	1.9	2.9	1.9	2.9
Moisture, %	-[a]	14.0	14.0	18.9	25.7	27.4	18.1	9.5	20.4
Carbon monoxide, ppm	12,900	12,000	12,000	12,400	12,400	9,000	12,800	12,000	12,800
Acid off-gas:									
Flow rate, dsm^3/sec		-	10.300						
Mass flow, kg/sec		-	13.29						
Oxygen, %		-	0.25						
Carbon dioxide, %		-	0.75						
Moisture, %		-	8.0						
Carbon monoxide, ppm		-	12,800						

a Data not obtained--assumed to be the same as next run.

b Measured by plant Annubar flow measuring device.

TABLE 20. COMPOSITION/FLOW SUMMARY (ENGLISH 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
Date--Time of start	11/29--1600	12/2--0900	12/2--1400	12/5--0920	12/5--1500	12/6--1120	12/7--0930	12/7--1230	12/8--0900
Outlet:									
Stack velocity, ft/min	4,250	4,920	4,700	4,410	4,380	4,260	4,260	4,210	4,240
Flow rate, dscf/min	50,110	56,640	54,260	53,610	53,090	51,180	50,970	52,680	51,670
Mass flow, lb/hr	250,100	283,100	270,100	263,800	261,500	255,500	262,800	277,400	252,300
Temperature, °F	411	432	440	395	404	406	430	430	434
Oxygen, %	7.5	6.2	6.5	8.1	7.6	7.8	7.2	7.2	7.6
Carbon dioxide, %	2.7	3.2	3.8	3.8	3.2	3.6	4.4	5.0	5.4
Moisture, %	- [a]	16.0	15.2	14.9	14.0	15.4	13.0	8.8	11.3
Carbon monoxide, ppm	530	7,510	7,750	4,840	5,000	5,320	<10	<10	<10
Combustor:									
Fuel gas flow, lb/hr	790	1,023	999	778	803	815	936	925	992
Combustion airflow, lb/hr	96,900	93,300	92,200	98,100	96,300	94,800	95,100	94,200	94,800
Combusion temperature, °F	1,150	1,160	1,160	1,160	1,160	1,160	1,470	1,470	1,470
Air preheater, °F	540	535	537	509	509	514	538	540	540
Inlet, combined feed:									
Flow rate, dscf/min	18,540	25,550	25,480	20,210	19,090	18,440	19,030	20,370	18,550
Mass flow, lb/hr [b]	97,600	123,800	123,200	102,300	101,600	100,700	96,200	95,700	95,500
Temperature, °F	- [a]	- [a]	145	156	152	154	136	135	141
Oxygen, %	0.7	2.8	2.0	2.0	2.0	1.6	2.6	1.4	1.8
Carbon dioxide, %	1.1	1.0	0.8	2.0	1.8	1.9	2.9	1.9	2.9
Moisture	- [a]	14.0	14.0	18.9	25.7	27.4	18.1	9.5	20.4
Carbon monoxide, ppm	12,900	12,000	12,000	12,400	12,400	9,000	12,800	12,000	12,800
Acid off-gas:									
Flow rate, dscf/min		-	21,810						
Mass flow, lb/hr		-	100,600						
Oxygen, %		-	0.25						
Carbon dioxide, %		-	0.75						
Moisture, %		-	8.0						
Carbon monoxide, ppm		-	12,800						

a Data not obtained--assumed to be the same as next run.

b Measured by plant Annubar flow measuring device.

TABLE 21. FUEL GAS ANALYSIS (ppm as propane)

Retention Index	Compound	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9
100	Methane[a]	175,200	179,360	192,680	188,700	181,100	192,800	193,800	190,400
200	Ethane	12,880	12,960	12,810	12,650	11,490	11,817	12,500	12,675
300	Propane	1,868	1,695	2,218	963	1,411	1,281	1,636	1,664
375	Iosbutane	251	331	651	235	311	316	349	442
400	n-Butane	270	306	607	227	279	294	333	371
480	Branched chain C5	151	159	338	135	142	179	198	175
500	n-Pentane	97	99	214	93	89	116	129	105
555	Branched chain C6	-	11.2	5.1	6.8	7.3	10.9	10.0	8.4
575	Branched chain C6	63	60	54	63	52	66	61	66
590	Branched chain C6	25	19.3	19.0	26	17.6	21	27	26
600	n-Hexane	52	42	47	41	38	48	43	50
630	Branched chain C7	46	18.1	22	29	19.5	24	25	24
670	Branched chain C7	68	36	44	67	40	22	39	25
690	Branched chain C7	-	-	19.0	30	22	-	7.2	1.3
700	n-Heptane	133	36	69	116	68	53	49	49
755	C8 + above	108	33	55	100	68	35	45	114
780	C8 +	98	4.0	6.9	101	55	2.2	15.7	11.6
800	n-Octane	36	13.3	8.7	76	18.7	14.6	24.9	39
830	C8 +	147	4.8	50	13.4	28	11.0	29.2	39
850	C8 +	143	8.0	-	25	6.8	5.1	16.1	22
890	C8 +	252	27	20	92	67	45	91	53
920	C8 +	194	14.3	9.4	59	41	21	56	25
980	C8 +	-	-	4.1	85	120	51	78	24
1020	C8 +	-	-	5.6	43	97	39	55	4.1
1050	C8 +	-	-	-	-	-	-	4.4	3.9

a Total concentration will not add to 100% after correcting for response factors due to the detector overload which occurs during the methane peak.

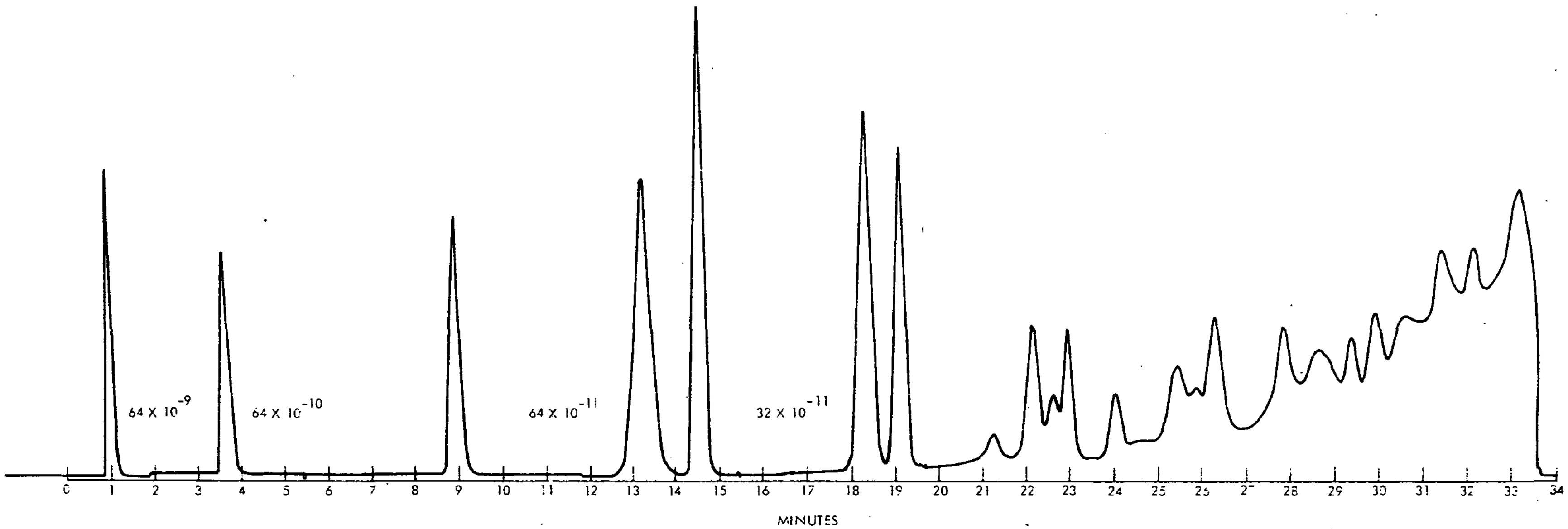

Figure 6. Run 3 - Fuel gas chromatogram, Taft, Louisiana.

TABLE 22. NO_x RESULTS

Run Number	Reported as lb of NO_2/million ft^3, dry standard				Reported as mg/m^3, dry standard			
	1	2	3	Avg.	1	2	3	Avg.
1	-	-	-	-	-	-	-	-
2	4.5	3.5	3.5	3.8	73	56	56	62
3	-	3.5	3.6	3.6	-	56	58	57
4	3.3	3.3	3.2	3.3	53	53	52	53
5	3.9	3.2	3.5	3.5	63	52	56	57
6	2.8	2.9	2.5	2.7	45	47	40	44
7	3.1	4.2	4.0	3.8	50	68	65	61
8	3.6	4.1	3.9	3.9	58	66	63	62
9	3.4	3.5	4.1	3.7	55	56	66	59

SECTION 3

PROCESS DESCRIPTION AND OPERATION

The fume incinerator sampled is a John Zink horizontal cylindrical unit averaging about 11.9 ft ID and 45.6 ft in length (5050 cu ft). The unit uses natural gas as a fuel and is normally controlled and operated at an outlet temperature of 625 to 650°C (1157 to 1202°F). The natural gas is fed into the center of the unit through a burner assembly. Preheated combustion air at about 500°F enters the fume incinerator tangentially, forming a vortex flow pattern. The blow-off enters the incinerator about 5 ft downstream of the combustion air inlet, where it is mixed with the combustion air by the vortex flow pattern. In addition to air preheat, energy is recovered from the combustion flue gas as steam. The intent of the sampling program was to obtain inlet and outlet composition data for the fume incinerator used to thermally oxidize the process waste vent gas (blow-off) from both the acrolein and acrylic acid (AA) processes. Because of acrolein process problems, this data could not be obtained. The original sampling plan was to obtain three sampling runs during operation of both processes at constant rates at one temperature and three sampling runs for the same process rate at a different temperature. Because of the acrolein process problems, the original plan could not be followed. Table 23 summarizes the conditions for the actual sampling program.

TABLE 23. Summary of Sampling Conditions

Date	Run No.	Processes Sampled	Blow-Off Rate (lb/hr)	Temp. of Incin. (°C)
11-29-78	1	AA	97,600	624
12-2-78	2	A+AA	123,800	624
	3	A+AA	123,200	625
12-5-78	4	AA	102,300	624
	5	AA	101,600	625
12-6-78	6	AA	100,700	624
12-7-78	7	AA	96,200	800
	8	AA	95,100	800
12-8-78	9	AA	95,500	800

Runs 4 through 9 are the data runs which are used for the study. Nine sampling runs were performed rather than six because of the acrolein process problems. Sampling of the AA process only was started on November 29 after being told by UCC that the acrolein process would be down for about a week. On November 30, just before the second sampling run was about to start, the AA production rate dropped by about 30%. At noon on November 30, UCC informed the sampling team that the acrolein process would be brought back on line during the night. The decision was then made by the sampling team and Bob Weber to wait until the acrolein process was at steady state and then to start sampling both processes as originally planned. On December 2 two sampling runs were made on the fume incinerator with both processes operating. On December 3, the acrolein plant was again shut down due to acrolein quality problems of an unknown origin and full crude storage tanks. Since it appeared that the acrolein process would be down for a number of days, the decision was made by EPA to stay an additional week and try to make additional sampling runs for the acrylic acid process only at two different temperatures. These runs were made between December 5 and December 8 as shown in Table 23.

SECTION 4

LOCATION OF SAMPLE POINTS

Figure 7 shows a general diagram of the process with the sampling points marked. The sampling points are some distance from one another. Point No. 1, the acrylic acid off-gas, is at about 70°C, and a few pounds per square inch positive pressure, so that no sampling pump is necessary. The sampling point is at an existing tap about 5 m above the grating on the third level of the unit. A 1/4-in. stainless steel insulated sampling line was run to near deck level. A diagram of the sample train setup is shown in Figure 8. The sampling probe was inserted to the center of the duct. The location is near a flow disturbance but only gas samples were taken.

Figure 9 shows the general layout of the incinerator with the remaining sample points shown.

Point No. 2, the combined inlet flow to the combustor, is slightly above ambient temperature, again, at positive pressure, and a 1/4-in. stainless steel line at the top of a 20-ft scaffold was used for sampling. The sample probe enters the top of the duct between two horizontal bends in the duct. A fixed, single-axis flow measuring device (Annubar) is installed in a straight section of the pipe, a few feet downstream from Point No. 2. The Annubar was mounted the required distances from the nearest flow disturbances. A thermocouple well is installed in the main duct downstream from the horizontal bend. The sample at both inlet and outlet was split three ways with two TGNMO trains and one integrated gas sample for GC analysis run simultaneously. A condensate knockout trap was located downstream from Point 2, since entrained liquid is present in this duct. A sample of this knockout trap contents was obtained and analyzed.

Point No. 3, the incinerator outlet, 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 had to be used due to the difficulty of hoisting equipment to Point No. 4, and the limited room on the scaffolding at Point No. 4. The sample stream was split three ways as at the inlet. This was the only sampling point which required a pump and gas box for integrated gas sampling. Point No. 3 was an existing sample point located in an expansion zone near the incinerator exhaust. No detailed information of the duct internal dimensions was obtainable from the plant except that the probe end was well away from the walls.

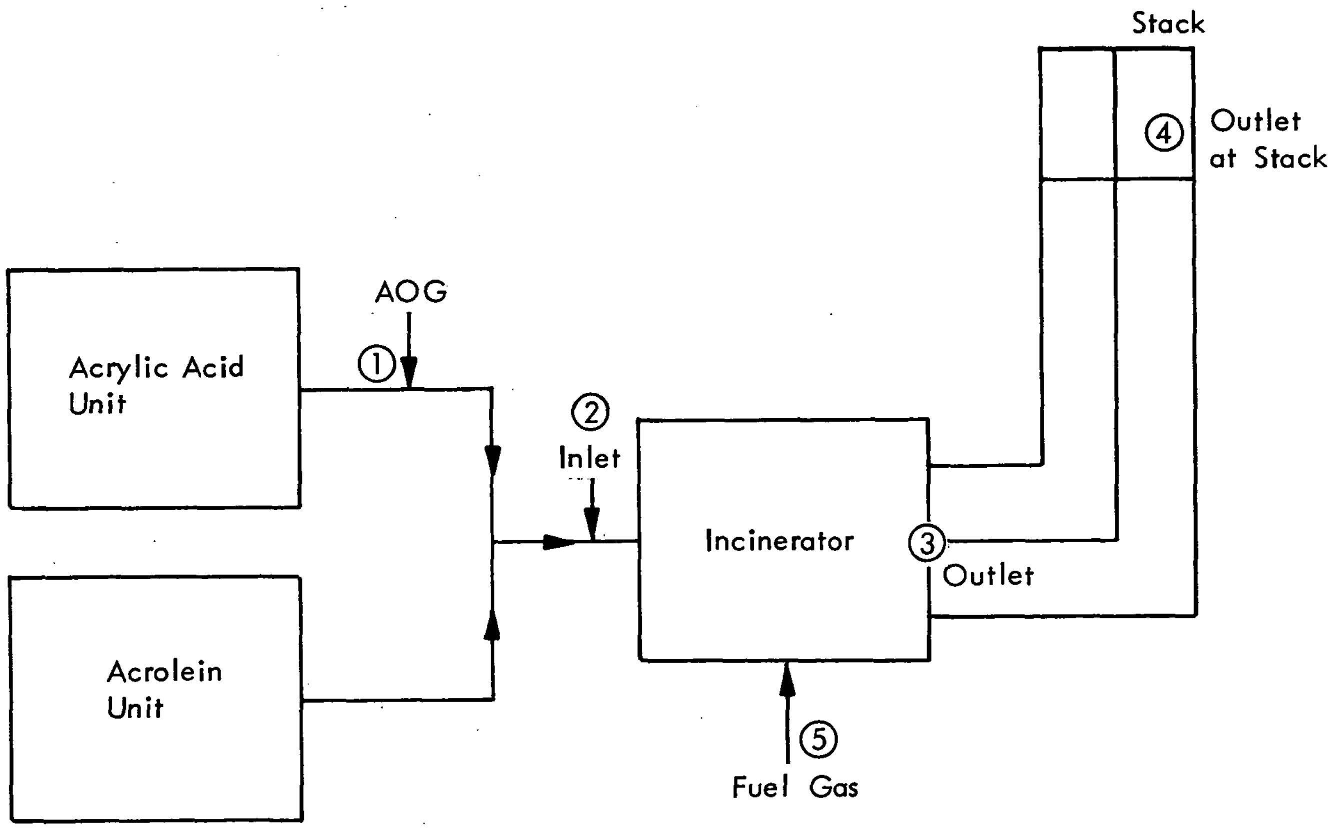

Figure 7. General process diagram showing sampling points.

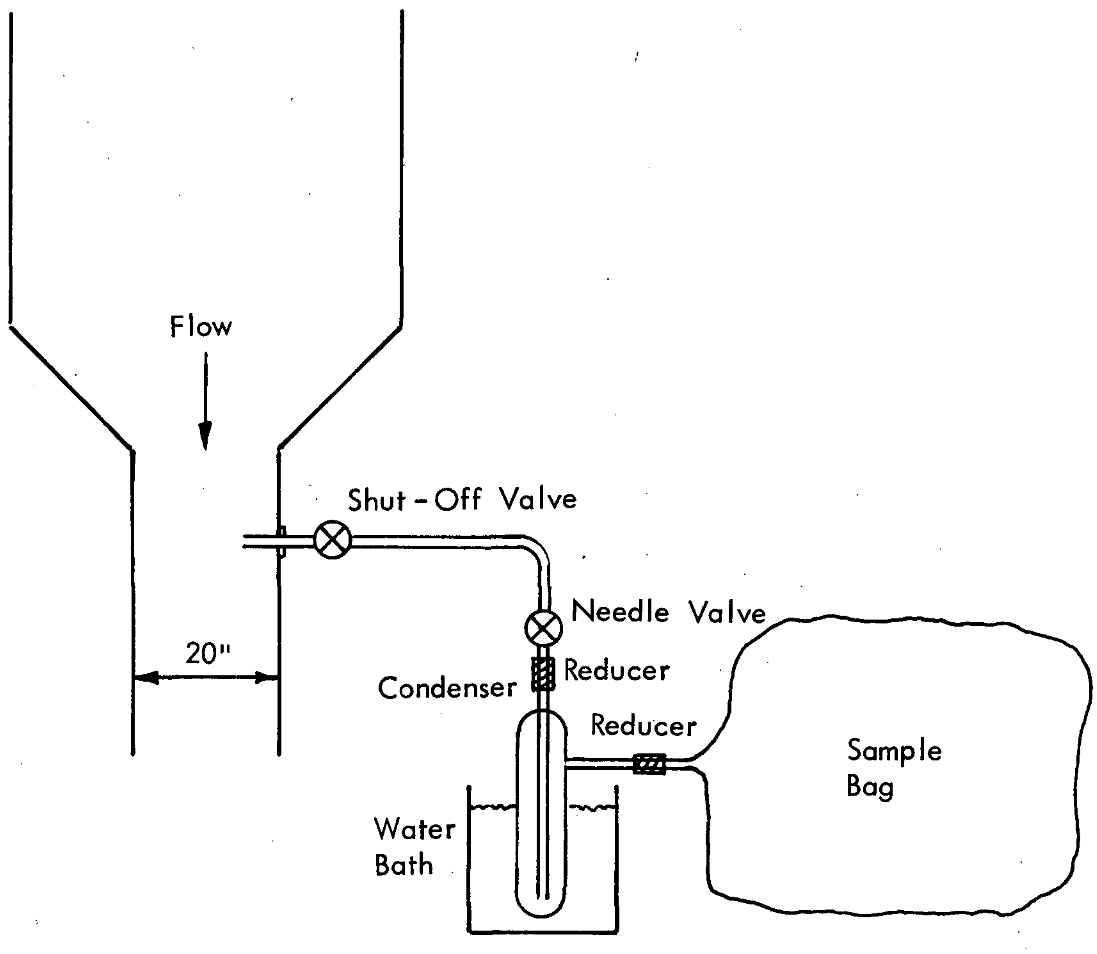

Figure 8. Sampling Point No. 1-(AOG) acrylic acid unit off-gas.

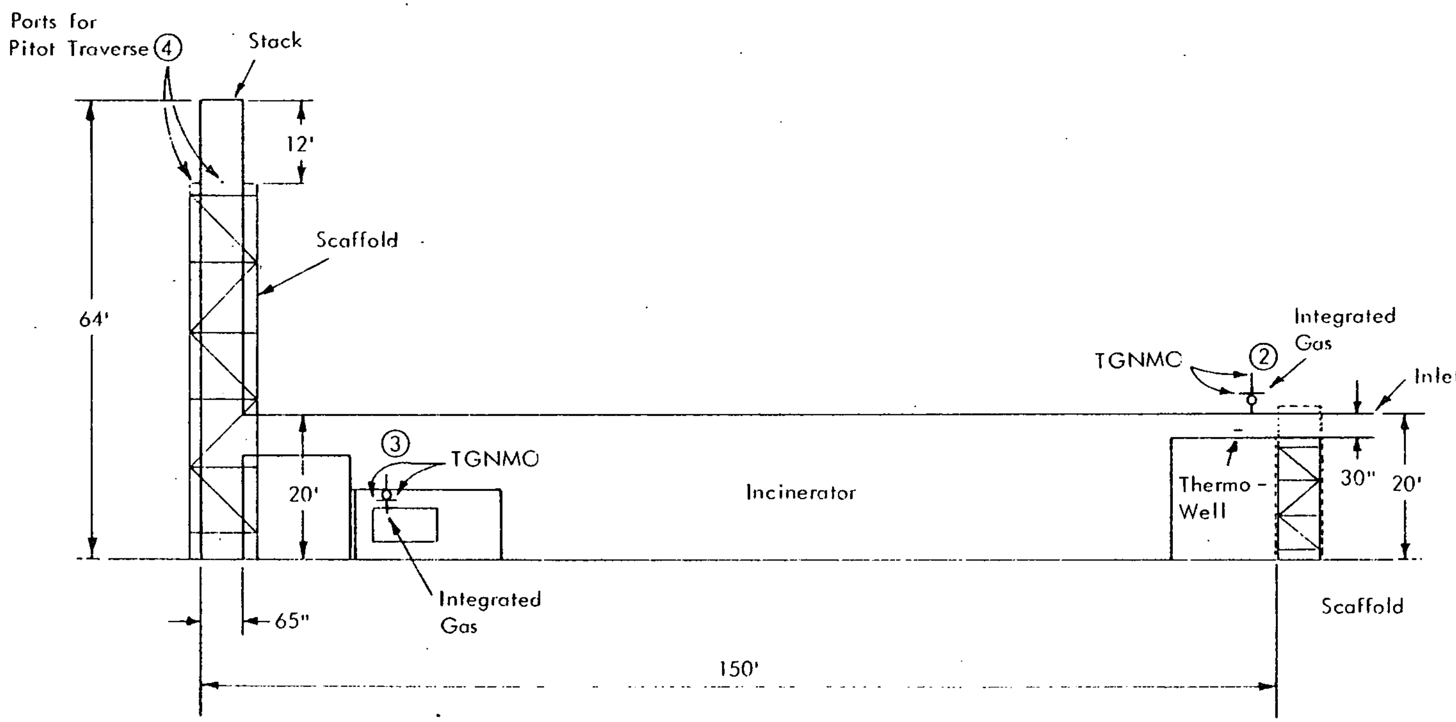

Figure 9. Incinerator layout with sampling locations.

Point No. 5, fuel gas, was taken at the main plant natural gas distribution center. Small Tedlar bags were flushed and then filled directly from the line.

SECTION 5

SAMPLING AND ANALYTICAL PROCEDURES

The integrated gas samples were obtained according to the September 27, 1977, EPA draft benzene method (Appendix G). Seventy-liter aluminized Mylar 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 each bag. 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 inlet and absorber 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°/min with temperature hold at upper limits. Nominal running time is 35 min. THC readings were obtained by peak height ratios for standards (99 ppm propane is the primary standard for all analyses) and samples.

Peak area measurements were used for the individual component analyses. A Tandy TRS-80, 48K floppy disk 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. Except for a few chromatograms which were accidentally lost from the storage disks, (single runs for 3-AOG, 6-OUT, 8-IN, 9-IN and all of run 7) all results presented are from the filtered output of the second program. The destroyed chromatograms use the field reported values. 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. The higher temperature outlet runs were conducted at least three times due to the very low sample concentration.

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 them 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 post-test standard runs (a minimum of six standard peaks total). The GC detector response is linear (within ± 5%) over wide concentration ranges (10-2000 ppm propane) but irreversible adsorption by the column can occur with reactive compounds which may cause low results for compounds such as acrylic acid. The program result printouts are in Appendix J.

The propylene/propane peaks are not resolvable on the column used. The single observed peak was artifically 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 inlet and AOG showed propane as 38% (± 3%) of the composite peak, with no significant variation with sample run or site. The outlet sample peaks are pure propane. No propylene component was observable at the outlet.

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 2-liter evacuated flasks 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 procedure are in Appendix L.

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, but with injection through a septum onto the column. Concentrations were calculated by peak area (height x width at 1/2 height) using a 2,000 μg/g acetone standard in water.

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

Total organic carbon was sampled from T-fittings at the inlet and outlet using the tentative EPA procedure given in Appendix A. 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 M for a listing of all compound retention indices measured on the analytical column.

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