United States
Environmental Protection
Agency

Office of Air Quality
Planning and Standards
Research Triangle Park NC 27711

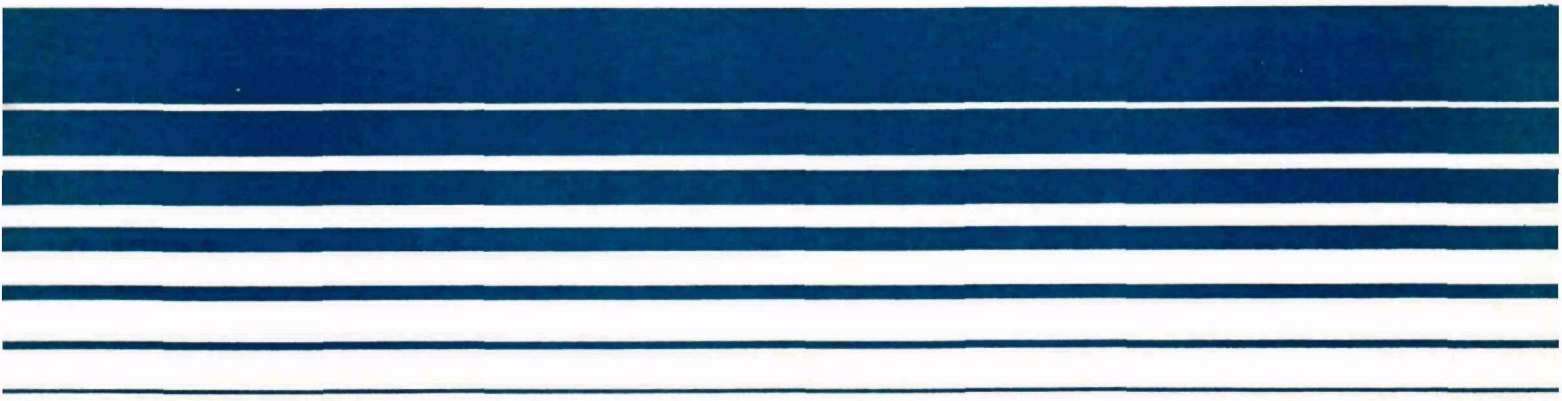
EMB Report 78-NHF-3
December 1979

Air

EPA

Urea Manufacture

Emission Test Report
W. R. Grace & Company
Memphis, Tennessee



REPORT ON PROCESS EMISSIONS TESTS AT THE W. R. GRACE AND CO. UREA MANUFACTURING FACILITY IN MEMPHIS, TENNESSEE

Prepared By:

Willard A. Wade III, P.E., Project Manager

Reed W. Cass, Project Engineer

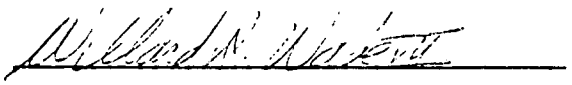
July 9, 1980

Thomas M. Bibb
EPA Project Manager

Clyde E. Riley
EPA Technical Manager

EPA Contract #68-02-2820
Work Assignment #9
TRC Project #0988-E80-10

TRC-Environmental Consultants, Inc.



Willard A. Wade III, P.E.
Project Manager

July 9, 1980

Note: Mention of trade names or commercial products in this publication does not constitute endorsement or recommendation for use by the Environmental Protection Agency.

PREFACE

The work reported herein was performed by personnel from TRC Environmental Consultants, Inc. (TRC), The GCA/Technology Division (GCA), W. R. Grace and Co., Memphis, Tennessee, and the U.S. Environmental Protection Agency (EPA).

The scope of work, issued under EPA Contract No. 68-02-2820, Work Assignment No. 9, was under the supervision of the TRC Project Manager, Mr. Willard A. Wade, III. Mr. Reed W. Cass of TRC served as Project Engineer and was responsible for summarizing the test and analytical data presented in this report. Sample analysis was performed at the W. R. Grace and Co., Memphis, Tennessee plant under the direction of Ms. Margaret M. Fox, and at the TRC laboratory in Wethersfield, Connecticut under the direction of Mr. David F. Dawson.

Mr. Mark L. Bornstein and Mr. Timothy L. Curtin of GCA were responsible for monitoring the process operations during the emissions testing program. GCA personnel were also responsible for preparing Section 3.0, Process Description and Operations, and Appendix L of this report.

Personnel of W. R. Grace and Co., Memphis, Tennessee whose assistance and guidance contributed greatly to the success of this emission test program include Mr. Norman E. Picquet, General Manager, and Mr. George T. Griesheimer, Manager, Chemical Services Department.

Mr. Eric A. Noble, Office of Air Quality Planning and Standards, Industrial Studies Branch, EPA, served as Test Process Project Engineer and was responsible for coordinating the process operations monitoring.

Mr. Clyde E. Riley, Office of Air Quality Planning and Standards, Emission Measurement Branch, EPA, served as Technical manager and was responsible for coordinating the emission test program.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

APPENDICES

APPENDICES
(Continued)

1.0 INTRODUCTION

1.1 Background

Section 111 of the Clean Air Act of 1970 charges the Administrator of the United States Environment Protection Agency (EPA) with the responsibility of establishing Federal standards of performance for new stationary sources which may significantly contribute to air pollution. When promulgated, these standards of performance for new stationary sources (SPNSS) are to reflect the degree of emission limitation achievable through application of the best demonstrated emission control technology. Emission data, collected from controlled sources in the particular industry of concern, provide a portion of the data base used by EPA to develop the SPNSS.

EPA's Office of Air Quality Planning and Standards (OAQPS) selected the W. R. Grace and Co. urea manufacturing plant in Memphis, Tennessee, as a site for an emission test program. This plant produces feed and fertilizer grade urea, and is considered to employ process and emission control technology representative of modern urea solution formation and fluidized-bed prilling processes.

EPA engaged TRC to conduct tests designed to characterize and quantify uncontrolled emissions from the solids production and cooling (prill tower) processes, and to determine emission control equipment efficiencies. Figure 1-1 shows a flow diagram of the complete urea production process. Emission tests were performed during August 1979 on the inlets and outlets of two of the eight prill tower scrubbers during production of both fertilizer and feed grade urea. In addition, emission tests were performed on the main solution formation vent on the synthesis tower during the production of feed grade urea.

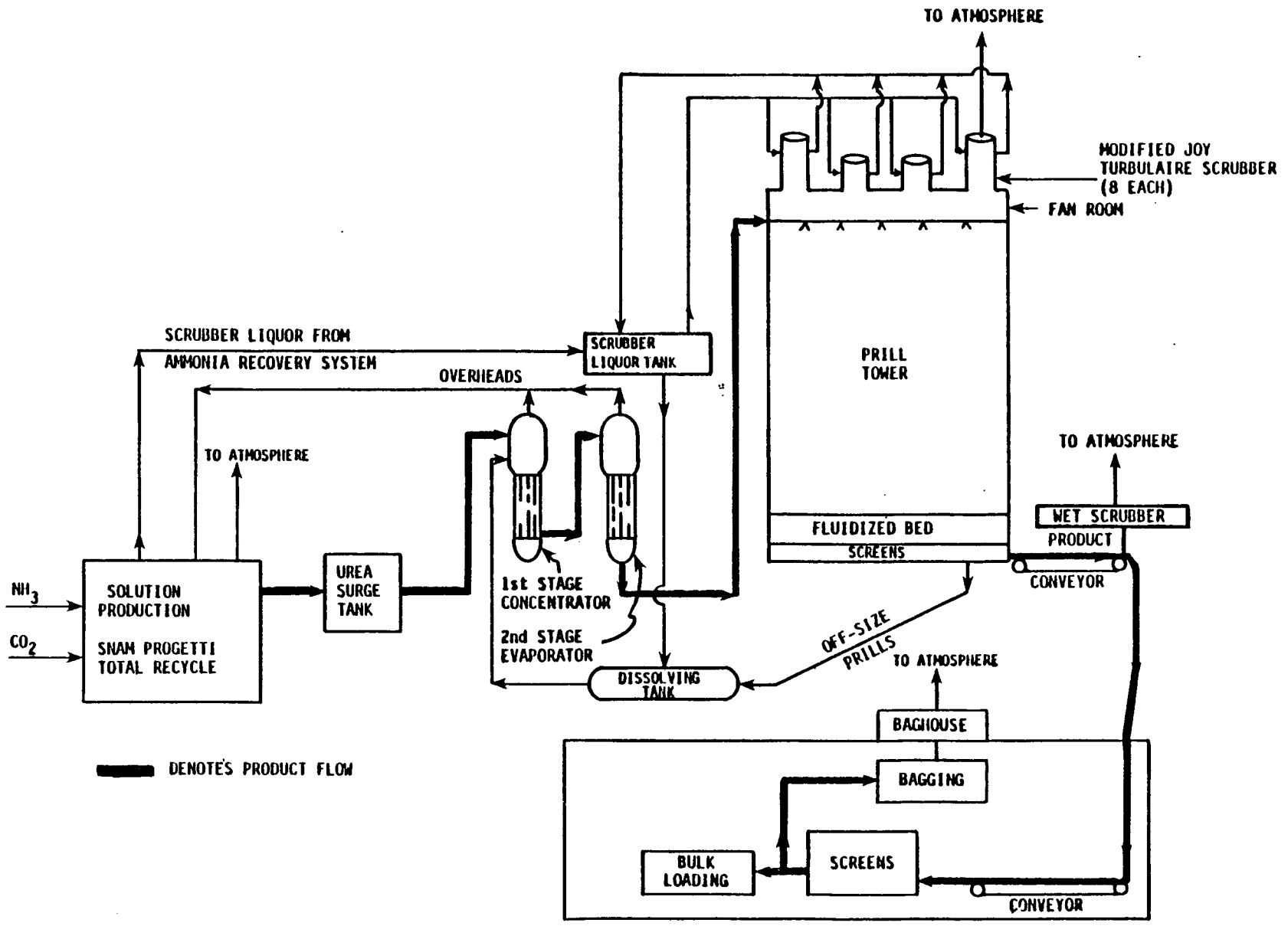


FIGURE 1-1: PROCESS FLOW DIAGRAM, W.R. GRACE AND CO., MEMPHIS, TENNESSEE

0988-001

1.2 Brief Process Description

Urea is produced in a single production line by reacting ammonia and carbon dioxide using the Snamprogetti total recycle process. The urea solution leaving the sythesis process proceeds to a two-stage evaporator where it is concentrated to 99+ percent urea. A formaldehyde additive is added to prevent caking of the product. The urea melt is pumped directly to the top of the prill tower and then sprayed downward against an induced countercurrent of air. As they fall, the melt droplets solidify. These solid prills are cooled at the base of the tower by a fluidized bed cooler and are sent through a set of sizing screens. Correctly sized prills are then conveyed to a bulk warehouse for bagging or bulk-loading of trucks or railcars.

Eight impingement scrubbers (labelled A through H) located on the roof of the prill tower control the air flow through the prill tower and fluidized-bed cooler. The conveyor transfer points and bagging operation are controlled by a wet scrubber and a baghouse, respectively.

1.3 Emissions Measurement Program

The emissions measurement program was primarily conducted August 13-22, 1979 at the W. R. Grace and Co., Memphis, Tennessee urea manufacturing plant. In addition, visible emissions observations on the bagging operation baghouse were performed on December 18, 1979. The measurement program consisted specifically of the following:

Prill Tower Measurements (Fertilizer and Feed Grade)

1. Urea, ammonia, formaldehyde, and insoluble particulate in the inlet and outlet gas streams of scrubbers A and C.
2. Particle size distributions in the inlet gas streams of scrubbers A and C.

3. Visible emissions from individual and combined scrubber outlets, and from the baghouse controlling the bagging operation.

4. Gas pressure drop across all scrubbers.

5. Urea, ammonia, formladehyde and solids content, temperature and pH of the inlet and outlet liquors of scrubbers A and C.

6. Bulk density and sieve analysis of the prill tower unscreened product.

7. Volumetric flowrates of the scrubbers not tested for emissions.

8. Ambient air temperature and relative humidity during emission tests.

Urea Synthesis Tower Measurements (Feed Grade)

1. Urea, ammonia and insoluble particulate in the gas stream of the main vent.

2. Oxygen and carbon dioxide content of the main vent gas stream, using integrated gaseous bag samples.

TRC personnel were responsible for collecting the above emissions data. Concurrently, GCA was responsible for monitoring and recording pertinent process operation parameters. Concurrent test runs were conducted at the outlet and inlet on scrubbers A and C. The chronology of these runs and other emissions tests is contained in the Daily Summary Logs in Appendix H. Most interruptions (labelled as "stop" in the logs) that occurred during the scrubber test runs were due to scrubber operational procedures or skipping over no-flow points.

The following sections of this report present the results of the fertilizer grade and feed grade emissions tests (Section 2.0), process description (Section 3.0), location of sampling points (Section 4.0), and sampling and analysis methods (Section 5.0). Descriptions of methods and procedures, field and laboratory data, and calculations are presented in the various appendices as noted in the Table of Contents.

Appendix J.5 contains the results of the cleanup evaluations performed on the sampling train equipment. The sampling train was assembled and charged as if ready to perform a test for urea, ammonia and formaldehyde. The unexposed impinger contents were then recovered, prepared and analyzed according to procedure in order to establish background/contamination levels resulting from the sampling equipment itself.

Appendix J.4 contains the results of audit sample analyses. Urea standards were prepared by EPA and were then analyzed by TRC in accordance with EPA instructions in order to assess the accuracy of the urea analysis procedure.

2.0 SUMMARY OF RESULTS

This section presents summary tables of results and narrative on the emissions testing conducted during the weeks of August 13-17 and August 20-24, 1979, at the W. R. Grace and Co. urea manufacturing facility in Memphis, Tennessee. Testing was performed on gas and liquid streams entering and exiting the prill tower scrubbers, and on the gas stream venting from the urea synthesis tower. One additional day of visible emissions observations was performed on December 18, 1979.

During the week of August 13-17, 1979, the plant was producing fertilizer grade urea. The following week the plant was producing feed grade urea.

Urea concentrations were determined with the p-dimethylaminobenzaldehyde colorimetric (with preliminary distrillation) analysis method. Two methods of ammonia analysis were used throughout this testing program: the direct Nessler method and the specific ion electrode method. The direct Nessler analysis results are presented here as the primary ammonia data. Formaldehyde concentrations were determined with the chromotropic acid method. All four analysis methods are discussed in Section 5.0 and in Appendices I and J.

2.1 Prill Tower Scrubber Urea Collection Efficiencies

The calculated urea collection efficiencies for prill tower scrubbers A and C are shown in Table 2-1. For scrubber A the fertilizer scrubber efficiency was consistently slightly higher than the feed scrubber efficiency. For scrubber C, the opposite was true. Overall, the average combined scrubber efficiencies were essentially the same for fertilizer and feed production (85.6% and 86.6%, respectively).

TABLE 2-1

SUMMARY OF UREA SCRUBBING EFFICIENCY OF SCRUBBERS A AND C
DURING EMISSIONS TESTING AT
W.R. GRACE AND CO., MEMPHIS, TENNESSEE

Run Number	Run 1				Run 2				Run 3				Average *			
Product Grade	Fertilizer		Feed		Fertilizer		Feed		Fertilizer		Feed		Fertilizer		Feed	
Date	08-15-79		08-20-79		08-16-79		08-21-79		08-17-79		08-22-79					
Scrubber Identification	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C
Scrubber Efficiency (Percent)	93.7	88.9	93.5	92.7	88.2	72.8	86.7	84.2	90.7	78.6	82.7	82.6	90.6	80.6	87.1	86.2
Average Efficiency (Percent)	91.3		93.1		80.0		85.5		84.7		82.7		85.6		86.6	

* These values do not represent exact averages of the individual run efficiencies. As noted on Tables 2-2 through 2-5, sample weights were averaged; then from these average sample weights, average mass flow rates and efficiencies were calculated. Conversion factors and rounding methods may yield minor discrepancies between average efficiencies calculated this way and averages calculated from the individual run efficiencies.

2.2 Prill Tower Emissions Test Results

Tables 2-2 (Scrubber A) and 2-3 (Scrubber C) present the urea, ammonia and formaldehyde results for the fertilizer test runs. Tables 2-4 (Scrubber A) and 2-5 (Scrubber C) present the same data for the feed test runs. Both inlet and outlet data are on all these tables, and only the direct Nessler ammonia data are shown. The average scrubbing efficiencies are as follows:

	Collection Efficiencies (percent)					
	Fertilizer			Feed		
Scrubber	Urea	Ammonia	Form.	Urea	Ammonia	Form.
A	90.6	0	96.6	87.1	53.3	76.6
B	80.6	0	93.2	86.2	46.1	73.1

Why the ammonia scrubbing efficiency for both scrubbers is less than zero for the fertilizer test runs is not evident. The major differences between the fertilizer and feed products are that the feed product is smaller in size and more formaldehyde is added to the feed production process. Ammonia stripping by the scrubbing liquor was initially suspected. The scrubber liquor analysis data (Section 2.9), however, show no evidence of ammonia stripping.

Tables 2-6 through 2-9 show the fertilizer data for both scrubbers, with the individual inlet and outlet data on separate tables; Tables 2-10 through 2-13 show the feed data. The insoluble particulate data and the results of both ammonia analysis methods are shown on these separated inlet and outlet tables.

As is discussed in Sections 2.6 and 5.1, cyclonic flow was evident in all the prill tower scrubber inlets; no cyclonic flow was evident in the outlets. Maintaining isokinetic sampling under cyclonic flow conditions is difficult at best. This difficulty is reflected in the calculated percent isokinetics (I)

TABLE 2-2a (English)

SUMMARY OF RESULTS OF UREA, AMMONIA AND FORMALDEHYDE TESTS
OF GASES ENTERING AND EXITING PRILL TOWER SCRUBBER A
ON AUGUST 15-17 1979 AT W.R. GRACE AND CO., INC.
MEMPHIS, TENNESSEE

RUN NUMBER	Fertilizer 1		Fertilizer 2		Fertilizer 3		Average*	
DATE	08-15-79		08-16-79		08-17-79			
LOCATION	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet
VOLUME OF GAS SAMPLED (DSCF)[a]	99.14	109.2	104.1	106.4	95.94	105.9	99.71	107.2
STACK GAS FLOWRATE (DSCFM)[b]	65680	62180	68880	60510	70150	60530	68250	61073
STACK TEMPERATURE (^{o}F)	113	90	112	90	116	89	114	90
PERCENT MOISTURE	2.382	3.655	1.881	3.556	1.844	3.677	2.036	3.633
PERCENT ISOKINETIC	108.0	98.4	106.4	98.5	97.8	98.1	104.1	98.3
PRODUCTION RATE (TONS/HOUR)	43.5	43.5	45.8	45.8	45.5	45.5	44.9	44.9
UREA DATA[c]								
Total Sampling Weight (milligrams)	449	33.0	622	85.4	502	59.7	524	59.4
Grains/DSCF	0.0699	0.00465	0.0922	0.01236	0.0807	0.00868	0.0811	0.00853
Pounds/Hour	39.35	2.478	54.43	6.410	48.51	4.503	47.45	4.466
Pounds/Ton	0.905	0.0570	1.188	0.1399	1.066	0.0990	1.056	0.0995
Collection Efficiency (percent)	93.7		88.2		90.7		90.6	
AMMONIA DATA[d]								
Total Sample Weight (milligrams)	182	745	253	821	236	683	224	750
Grains/DSCF	0.0283	0.1051	0.0375	0.1188	0.0380	0.0993	0.0347	0.1077
Pounds/Hour	15.93	56.01	22.14	61.61	22.84	51.51	20.29	56.37
Pounds/Ton	0.366	1.287	0.483	1.345	0.502	1.132	0.452	1.255
Collection Efficiency (percent)	<0		<0		<0		<0	
FORMALDEHYDE DATA[e]								
Total Sample Weight (milligrams)	1.31	0.0578	1.92	0.0706	1.75	0.0761	1.66	0.0682
Grains/DSCF	0.000204	0.0000082	0.000285	0.0000102	0.000281	0.0000111	0.000257	0.0000098
Pounds/Hour	0.1148	0.00437	0.1683	0.00529	0.1689	0.00576	0.1505	0.00513
Pounds/Ton	0.002639	0.0001005	0.003675	0.0001155	0.003712	0.0001266	0.003347	0.0001142
Collection Efficiency (percent)	96.2		96.9		96.6		96.6	

a Dry standard cubic feet @ 68^{o}F and 29.92 inches Hg

b Dry standard cubic feet per minute

c p-dimethylamino benzaldehyde colorimetric (with preliminary distillation) analysis method

d Direct Nessler analysis method.

e Chromotropic acid analysis method

* Only sample weights from all three runs were averaged, and then mass flow rates and efficiencies were calculated from these average sample weights

TABLE 2-2b (Metric)

SUMMARY OF RESULTS OF UREA, AMMONIA, AND FORMALDEHYDE TESTS
ON GASES ENTERING AND EXITING PRILL TOWER SCRUBBER A
ON AUGUST 15-17, 1979 AT W.R. GRACE AND CO., MEMPHIS, TENNESSEE

Run Number	Fertilizer 1		Fertilizer 2		Fertilizer 3		Average *	
Date	08-15-79		08-16-79		08-17-79			
Location	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet
Volume of Gas Sampled (Nm^3 [a])	2.8076	3.0925	2.9481	3.0133	2.7170	2.9991	2.8243	3.0350
Stack Gas Flow Rate (Nm^3/min [b])	1860.1	1760.94	1950.7	1713.64	1986.1	1714.21	1932.3	1729.59
Stack Temperature (^oC)	45	32	44	32	47	32	46	32
Percent Moisture	2.382	3.655	1.881	3.556	1.844	3.677	2.036	3.633
Percent Isokinetic	108.0	98.4	106.4	98.5	97.8	98.1	104.1	98.3
Production Rate (Mg/Hour)	39.46	39.46	41.55	41.55	41.28	41.28	40.73	40.73
Urea Data [c]								
Total Sample Weight (Milligrams)	449	33.0	622	85.4	502	59.7	524	59.4
Grams/Nm^3	0.1599	0.01064	0.2110	0.02828	0.18465	0.01986	0.18556	0.01952
Kg/Hour	17.849	1.124	24.689	2.907	22.004	2.043	21.514	2.026
Kg/Mg	0.4525	0.0285	0.5940	0.06995	0.5330	0.0495	0.5280	0.0498
Collection Efficiency (Percent)	93.7		88.2		90.7		90.6	
Ammonia Data [d]								
Total Sample Weight (Milligrams)	182	745	253	821	236	685	224	750
Grams/Nm^3	0.06475	0.24048	0.08580	0.27183	0.08695	0.22721	0.07940	0.24643
Kg/Hour	7.226	25.406	10.043	27.946	10.360	23.365	9.204	25.569
Kg/Mg	0.1830	0.6435	0.2415	0.6725	0.2510	0.566	0.2260	0.6275
Collection Efficiency (Percent)	<0		<0		<0		<0	
Formaldehyde Data [e]								
Total Sample Weight (Milligrams)	1.31	0.0578	1.92	0.0706	1.75	0.0761	1.66	0.0682
Grams/Nm^3	0.000467	0.0000188	0.000652	0.0000233	0.000643	0.0000254	0.000588	0.011738
Kg/Hour	0.05207	0.00198	0.07634	0.00240	0.07661	0.00261	0.06818	0.00235
Kg/Mg	0.001320	0.00005025	0.001838	0.00005775	0.001856	0.0000635	0.001674	0.0000571
Collection Efficiency (Percent)	96.2		96.9		96.6		96.6	

a Normal cubic meters @ 20°C, 760 mm Hg.
b Normal cubic meters per minute.
c p-dimethylamino benzaldehyde colorimetric (with preliminary distillation) analysis method.
d Direct Nessler Analysis method.
e Chromotropic Acid Analysis method.
* Only sample weights from all three runs were averaged, and then mass flow rates and efficiencies were calculated from these average sample weights.

TABLE 2-3a (English)

SUMMARY OF RESULTS OF UREA, AMMONIA AND FORMALDEHYDE TESTS
ON GASES ENTERING AND EXITING THE PRILL TOWER SCRUBBER C
ON AUGUST 15-17, 1979 AT W.R.GRACE AND CO., INC.
MEMPHIS, TENNESSEE

RUN NUMBER	Fertilizer 1		Fertilizer 2		Fertilizer 3		Average*	
DATE	08-15-79		08-16-79		08-17-79			
LOCATION	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet
VOLUME OF GAS SAMPLED (DSCF)[a]	101.1	99.84	82.54	98.08	87.38	109.4	90.34	102.4
STACK GAS FLOWRATE (DSCFM)[b]	62360	56220	53660	56450	59050	62410	58357	58360
STACK TEMPERATURE (^{o}F)	113	86	111	80	116	82	113	83
PERCENT MOISTURE	2.029	3.314	1.395	3.371	1.371	4.012	1.598	3.566
PERCENT ISOKINETIC	120.1	99.8	121.3	97.6	114.3	98.5	118.6	98.6
PRODUCTION RATE (TONS/HOUR)	43.5	43.5	45.8	45.8	45.5	45.5	44.9	44.9
UREA DATA[c]								
Total Sample Weight (Milligrams)	304	37	217	67	275	70	265	58
Grains/DSCF	0.0464	0.00571	0.0406	0.01052	0.0486	0.00985	0.0455	0.00872
Pounds/Hour	24.80	2.750	18.67	5.089	24.60	5.270	22.66	4.363
Pounds/Ton	0.570	0.0632	0.408	0.1111	0.541	0.1158	0.505	0.0972
Collection Efficiency (Percent)	88.9		72.8		78.6		80.6	
AMMONIA DATA[d]								
Total Sample Weight (Milligrams)	135	167	127	255	173	245	145	222
Grains/DSCF	0.0206	0.0258	0.0237	0.04004	0.0306	0.03449	0.0248	0.03339
Pounds/Hour	11.01	12.41	10.90	19.37	15.49	18.45	12.11	16.70
Pounds/Ton	0.253	0.285	0.238	0.423	0.340	0.405	0.276	0.372
Collection Efficiency (Percent)	<0		<0		<0		<0	
FORMALDEHYDE DATA[e]								
Total Sample Weight (Milligrams)	0.849	0.041	0.582	0.068	0.790	0.0625	0.740	0.057
Grains/DSCF	0.0001296	0.0000063	0.0001088	0.0000107	0.0001396	0.0000088	0.0001261	0.0000086
Pounds/Hour	0.06927	0.003047	0.05004	0.005165	0.07066	0.004706	0.06525	0.004287
Pounds/Ton	0.001592	0.0000700	0.001093	0.0001128	0.001553	0.0001034	0.001408	0.0000955
Collection Efficiency (Percent)	95.6		89.7		93.3		95.2	

a Dry Standard Cubic Feet @ 68^{o}F and 29.92 inches Hg.

b Dry Standard Cubic Feet per minute.

c p-dimethylamino benzaldehyde colorimetric (with preliminary distillation) analysis method.

d Direct Nessler analysis method.

e Chromotropic acid analysis method.

* Only sample weights from all three runs were averaged, and then mass flow rates and efficiencies were calculated from these averaged sample weights.

TABLE 2-3b (Metric)

SUMMARY OF RESULTS OF UREA, AMMONIA AND FORMALDEHYDE TESTS
ON GASES ENTERING AND EXITING THE PRILL TOWER SCRUBBER C
ON AUGUST 15-17, 1979 AT W.R. GRACE AND CO., MEMPHIS, TENNESSEE

Run Number	Fertilizer 1		Fertilizer 2		Fertilizer 3		Average *	
Date	08-15-79		08-16-79		08-17-79			
Location	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet
Volume of Gas Sampled (Nm^3 [a])	2.86315	2.82747	2.33753	2.77763	2.47460	3.09821	2.55843	2.89997
Stack Gas Flow Rate (Nm^3/min [b])	1776.0	1592.2	1519.7	1601.2	1672.3	1767.5	1652.7	1652.7
Stack Temperature (^oC)	45	30	44	27	47	28	46	28
Percent Moisture	2.029	3.314	1.395	3.371	1.371	4.012	1.598	3.566
Percent Isokinetic	120.1	99.8	121.3	97.6	114.3	98.5	118.6	98.6
Production Rate (Mg/Hour)	39.46	39.46	41.55	41.55	41.28	41.28	40.75	40.75
Urea Data [c]								
Total Sample Weight (Milligrams)	304	37	217	67	275	70	265	58
Grams/Nm^3	0.10617	0.01307	0.09290	0.02407	0.11120	0.022538	0.10365	0.01995
Kg/Hour	11.249	1.247	8.469	2.308	11.159	2.390	10.279	1.979
Kg/Mg	0.285	0.0316	0.204	0.0556	0.271	0.0579	0.253	0.0486
Collection Efficiency (Percent)	88.9		72.8		78.6		80.6	
Ammonia Data [d]								
Total Sample Weight (Milligrams)	135	167	127	255	173	245	145	222
Grams/Nm^3	0.04713	0.05903	0.05423	0.09161	0.07002	0.07892	0.05674	0.07640
Kg/Hour	4.994	5.629	4.944	8.786	7.026	8.369	5.629	7.575
Kg/Mg	0.127	0.1425	0.119	0.2115	0.170	0.2025	0.138	0.186
Collection Efficiency (Percent)	<0		<0		<0		<0	
Formaldehyde Data [e]								
Total Sample Weight (Milligrams)	0.849	0.041	0.582	0.068	0.790	0.0625	0.740	0.059
Grams/Nm^3	0.0002965	0.0000144	0.0002489	0.0000245	0.0003194	0.0000201	0.0002892	0.0000197
Kg/Hour	0.031421	0.001382	0.022698	0.002343	0.032051	0.002135	0.028681	0.001945
Kg/Mg	0.000796	0.000035	0.000547	0.000056	0.000777	0.000052	0.000701	0.000048
Collection Efficiency (Percent)	95.4		88.9		92.8		92.8	

a Normal cubic meters @ 20°C, 760 mm Hg.
b Normal cubic meters per minute.
c p-dimethylamino benzaldehyde colorimetric (with preliminary distillation) analysis method.
d Direct Nessler Analysis method.
e Chromotropic Acid Analysis method.
* Only sample weights from all three runs were averaged, and then mass flow rates and efficiencies were calculated from these average sample weights.

TABLE 2-4a (English)

SUMMARY OF RESULTS OF UREA, AMMONIA AND FORMALDEHYDE TESTS
ON GASES ENTERING AND EXITING PRILL TOWER SCRUBBER A
ON AUGUST 20-22, 1979, AT W.R. GRACE AND CO., MEMPHIS, TENNESSEE

Run Number	Feed 1		Feed 2		Feed 3		Average *	
Date	08-20-79		08-21-79		08-22-79			
Location	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet
Volume of Gas Sampled (DSCF[a])	75.79	90.18	77.72	76.09	77.92	88.89	77.14	85.05
Stack Gas Flowrate (DSCFM[b])	51720	49750	51720	42270	53010	50390	52150	47470
Stack Temperature (^{o}F)	189	106	189	103	182	97	184	102
Percent Moisture	2.731	5.472	3.416	5.291	2.509	5.377	2.885	5.380
Percent Isokinetic	106.0	101.6	108.1	100.9	106.6	98.9	106.9	100.5
Production Rate (Tons/Hour)	47.2	47.2	47.4	47.4	45.9	45.9	46.8	46.8
Urea Data[c]								
Total Sample Weight (Milligrams)	380	30.4	590	94.0	534	111	501	78.5
Grains/DSCF	0.0774	0.00519	0.1172	0.01902	0.1058	0.01923	0.1002	0.01421
Pounds/Hour	34.31	2.213	51.96	6.892	48.07	8.305	44.79	5.782
Pounds/Ton	0.727	0.0469	1.096	0.1454	1.047	0.1809	0.957	0.1236
Collection Efficiency (Percent)	93.5		86.7		82.7		87.1	
Ammonia Data[d]								
Total Sample Weight (Milligrams)	512	293	570	292	636	390	574	325
Grains/DSCF	0.1043	0.05004	0.1132	0.05910	0.1260	0.06757	0.1148	0.05885
Pounds/Hour	46.24	21.33	50.18	21.41	57.25	29.18	51.32	25.94
Pounds/Ton	0.980	0.452	1.059	0.452	1.247	0.636	1.097	0.512
Collection Efficiency (Percent)	53.9		57.3		49.0		53.5	
Formaldehyde Data[e]								
Total Sample Weight (Milligrams)	0.409	0.133	0.622	0.178	0.644	0.166	0.558	0.159
Grains/DSCF	0.0000833	0.0000227	0.0001235	0.000360	0.0001275	0.0000288	0.000112	0.000288
Pounds/Hour	0.0369	0.00968	0.0547	0.01305	0.0579	0.01242	0.05006	0.01171
Pounds/Ton	0.000782	0.0002052	0.001154	0.0002753	0.001261	0.0002706	0.001070	0.0002505
Collection Efficiency (Percent)	73.8		76.1		78.5		76.6	

a Dry standard cubic feet @ 68^{o}F, 29.92 inches Hg.
b Dry standard cubic feet per minute.
c p-dimethylamino benzaldehyde colorimetric (with preliminary distillation) analysis method.
d Direct Nessler Analysis method.
e Chromotropic Acid Analysis method.
* Only sample weights from three runs were averaged, and then mass flow rates and efficiencies were calculated from these average sample weights.

TABLE 2-4b (Metric)

SUMMARY OF RESULTS OF UREA, AMMONIA AND FORMALDEHYDE TESTS
ON GASES ENTERING AND EXITING THE PRILL TOWER SCRUBBER A ON AUGUST 20-22, 1979
AT W.R. GRACE AND CO., MEMPHIS, TENNESSEE

Run Number	Feed 1		Feed 2		Feed 3		Average*	
Date	08-20-79		08-21-79		08-22-79			
Location	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet
Volume of Gas Sampled (Nm^3 [a])[b]	2.14637	2.55390	2.20103	2.15487	2.20670	2.51736	2.18460	2.40862
Stack Gas Flow Rate (Nm^3/min [b])	1464.7	1408.9	1464.7	1197.1	1501.2	1427.0	1476.9	1544.4
Stack Temperature (^oC)	82.2	41.1	87.2	39.4	83.3	36.1	84.4	38.9
Percent Moisture	2.731	5.472	3.416	5.291	2.509	5.377	2.885	5.380
Percent Isokinetic	106.0	101.6	108.1	100.9	106.6	98.9	106.9	100.5
Production Rate (Mg/Hr)	47.2	47.2	47.4	47.4	45.9	45.9	46.8	46.8
Urea Data [c]								
Total Sample Weight (Milligrams)	380	30.4	590	94.0	534	111	501	78.5
Grams/Nm^3	0.17710	0.01188	0.26817	0.04352	0.24208	0.04400	0.22927	0.03251
Kg/Hr	15.563	1.0038	23.569	3.126	21.805	3.767	20.317	2.623
Kg/Mg	0.3635	0.0235	0.5480	0.0727	0.5235	0.0905	0.4785	0.0618
Collection Efficiency (Percent)	93.5		86.7		82.7		87.1	
Ammonia Data [d]								
Total Sample Weight (Milligrams)	512	293	570	292	636	390	574	325
Grams/Nm^3	0.23865	0.11450	0.25901	0.13523	0.28830	0.15461	0.26267	0.15465
Kg/Hr	20.974	9.675	22.762	9.712	25.969	13.236	25.279	10.859
Kg/Mg	0.4900	0.226	0.5295	0.226	0.6235	0.318	0.5485	0.256
Collection Efficiency (Percent)	53.9		57.3		49.0		55.3	
Formaldehyde Data [e]								
Total Sample Weight (Milligrams)	0.409	0.133	0.622	0.178	0.644	0.166	0.558	0.159
Grams/Nm^3	0.000191	0.0000519	0.000283	0.0000824	0.000292	0.0000659	0.000256	0.0000659
Kg/Hr	0.01674	0.00439	0.02481	0.00592	0.02626	0.00563	0.02271	0.00531
Kg/Mg	0.000391	0.000103	0.000577	0.000138	0.000631	0.000135	0.000535	0.000125
Collection Efficiency (Percent)	73.8		76.1		78.5		76.6	

a Normal cubic meters @ 20°C, 760 mm Hg.
b Normal cubic meters per minute.
c p-dimethylamino benzaldehyde colorimetric (with preliminary distillation) analysis method.
d Direct Nessler Analysis method.
e Chromotropic Acid Analysis method.
* Only sample weights from all three runs were averaged and then mass flow rates and efficiencies were calculated from these average sample weights.

TABLE 2-5a (English)

SUMMARY OF RESULTS OF UREA, AMMONIA AND FORMALDEHYDE TESTS
ON GASES ENTERING AND EXITING THE PRILL TOWER SCRUBBER C
ON AUGUST 20-22, 1979, AT W.R. GRACE AND CO., MEMPHIS, TENNESSEE

Run Number	Feed 1		Feed 2		Feed 3		Average*	
Date	08-20-79		08-21-79		08-22-79			
Location	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet
Volume of Gas Sampled (DSCF[a])	64.53	83.59	69.63	83.39	68.85	91.57	67.67	86.18
Stack Gas Flowrate (DSCFM[b])	44150	46270	48880	45160	46920	50470	46650	47500
Stack Temperature (^{o}F)	184	104	179	103	174	99	179	102
Percent Moisture	3.041	5.833	2.863	6.388	2.493	6.160	2.799	6.127
Percent Isokinetic	105.7	101.5	104.8	103.8	105.3	102.0	105.3	102.4
Production Rate (Tons/Hour)	47.2	47.2	47.4	47.4	45.9	45.9	46.8	46.8
Urea Data[c]								
Total Sample Weight (Milligrams)	411	37	425	87	463	100	433	75
Grains/DSCF	0.0983	0.00682	0.0942	0.01610	0.1038	0.01682	0.0987	0.0154
Pounds/Hour	37.20	2.703	39.47	6.232	41.75	7.274	39.47	5.433
Pounds/Ton	0.788	0.0573	0.833	0.132	0.910	0.1585	0.843	0.1161
Collection Efficiency (Percent)	92.7		84.2		82.6		86.2	
Ammonia Data[d]								
Total Sample Weight (Milligrams)	540	322	480	288	483	408	501	339
Grains/DSCF	0.1291	0.05932	0.1064	0.05330	0.1083	0.06862	0.1145	0.0607
Pounds/Hour	48.86	23.52	44.58	20.63	43.56	29.68	45.70	24.61
Pounds/Ton	1.035	0.498	0.941	0.435	0.949	0.647	0.976	0.526
Collection Efficiency (Percent)	51.9		53.8		31.8		46.1	
Formaldehyde Data[e]								
Total Sample Weight (Milligrams)	0.419	0.131	0.563	0.182	0.440	0.168	0.474	0.160
Grains/DSCF	0.0001002	0.0000241	0.0001248	0.0000337	0.0000986	0.0000283	0.0001081	0.0000287
Pounds/Hour	0.03792	0.009570	0.05229	0.013045	0.03965	0.012221	0.04522	0.011656
Pounds/Ton	0.000803	0.0002028	0.001103	0.0002752	0.000864	0.0002662	0.000924	0.000249
Collection Efficiency (Percent)	74.7		75.0		69.2		73.1	

a Dry standard cubic feet @ 68^{o}F, 29.92 inches Hg.
b Dry standard cubic feet per minute.
c p-dimethylamino benzaldehyde colorimetric (with preliminary distillation) analysis method.
d Direct Nessler Analysis method.
e Chromotropic Acid Analysis method.
* Only sample weights from all three runs were averaged, and then mass flow rates and efficiencies were calculated from these average sample weights.

TABLE 2-5b (Metric)

SUMMARY OF RESULTS OF UREA, AMMONIA AND FORMALDEHYDE TESTS ON GASES ENTERING AND EXITING THE PRILL TOWER SCRUBBER C ON AUGUST 20-22, 1979 AT W.R. GRACE AND CO., MEMPHIS, TENNESSEE

Run Number	Feed 1		Feed 2		Feed 3		Average*	
Date	08-20-79		08-21-79		08-22-79			
Location	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet
Volume of Gas Sampled (Nm^3 [a])	1.827	2.367	1.972	2.362	1.950	2.595	1.916	2.441
Stack Gas Flowrate (Nm^3/min [b])	1250.3	1310.4	1384.3	1278.9	1328.8	1429.3	1321.1	1339.5
Stack Temperature (^oC)	84.4	40	81.7	39.4	78.9	37.2	81.7	38.9
Percent Moisture	3.041	5.833	2.863	6.388	2.493	6.160	2.799	6.127
Percent Isokinetic	105.7	101.5	104.8	103.8	105.3	102.0	105.3	102.4
Production Rate (Mg/Hour)	42.820	42.820	43.001	43.001	41.640	41.640	42.457	42.457
Urea Data [c]								
Total Sample Weight (Milligram)	411	37	425	87	463	100	433	75
Grams/Nm^3	0.22492	0.01560	0.21554	0.03684	0.23750	0.03849	0.22584	0.03066
Kg/Hr	16.874	1.226	17.904	2.827	18.938	3.299	17.904	2.464
Kg/Mg	0.394	0.0287	0.417	0.0660	0.455	0.0793	0.422	0.0581
Collection Efficiency (Percent)	92.7		84.2		82.6		86.2	
Ammonia Data [d]								
Total Sample Weight (Milligram)	540	322	480	288	483	408	501	339
Grams/Nm^3	0.29539	0.13573	0.24345	0.12196	0.24780	0.15701	0.26153	0.13889
Kg/Hr	22.163	10.669	20.221	9.358	19.759	13.463	20.730	11.163
Kg/Mg	0.518	0.249	0.471	0.218	0.475	0.324	0.488	0.265
Collection Efficiency (Percent)	51.9		53.8		31.8		46.1	
Formaldehyde Data [e]								
Total Sample Weight (Milligram)	0.419	0.131	0.563	0.182	0.440	0.168	0.474	0.160
Grams/Nm^3	0.000229	0.0000551	0.000286	0.0000771	0.000226	0.0000648	0.000247	0.0000657
Kg/Hr	0.017201	0.004341	0.023719	0.005917	0.017985	0.005543	0.019605	0.005278
Kg/Mg	0.0004015	0.0001014	0.0005515	0.0001376	0.0004320	0.0001331	0.000462	0.0001245
Collection Efficiency (Percent)	74.7		75.0		69.2		73.1	

a Normal cubic meters @ 20°C, 760 mm Hg.
b Normal cubic meters per minute.
c p-dimethylamino benzaldehyde colorimetric (with preliminary distillation) analysis method.
d Direct Nessler Analysis method.
e Chromotropic Acid Analysis method.
* Only sample weights from all three runs were averaged, and then mass flow rates and efficiencies were calculated from these average sample weights

TABLE 2-6

SUMMARY OF RESULTS OF UREA, AMMONIA AND FORMALDEHYDE TESTS
ON GASES ENTERING THE PRILL TOWER SCRUBBER A
ON AUGUST 15-17, 1979
AT W.R. GRACE AND CO., MEMPHIS, TENNESSEE

Run Number	Fertilizer 1		Fertilizer 2		Fertilizer 3		Average	
Date	08-15-79		08-16-79		08-17-79			
Volume of Gas Sampled (DSCF [a])	99.14		104.1		95.94		99.71	
Stack Gas Flowrate (DSCFM [b])	65680		68880		70130		68230	
Stack Temperature (^{o}F)	113		112		116		114	
Percent Moisture	2.382		1.881		1.844		2.036	
Percent Isokinetic	108.0		106.4		97.8		104.1	
Production Rate (Tons/Hour)	43.5		45.8		45.5		44.9	
Urea Data [c]								
Total Sample Weight (Milligrams)	449		622		502		524	
Grains/DSCF	0.0699		0.0922		0.0807		0.0811	
Pounds/Hour	39.35		54.43		48.51		47.43	
Pounds/Ton	0.905		1.188		1.066		1.056	
Ammonia Data	DN [d]	SIE [e]	DN	SIE	DN	SIE	DN	SIE
Total Sample Weight (Milligrams)	182	174	253	217	236	215	224	202
Grains/DSCF	0.0283	0.0271	0.0375	0.0322	0.0380	0.0346	0.0347	0.0313
Pounds/Hour	15.93	15.26	22.14	19.01	22.84	20.80	20.29	18.51
Pounds/Ton	0.366	0.351	0.483	0.415	0.502	0.457	0.452	0.408
Formaldehyde Data [f]								
Total Sample Weight (Milligrams)	1.31		1.92		1.75		1.66	
Grains/DSCF	0.000204		0.000285		0.000281		0.000257	
Pounds/Hour	0.1148		0.1683		0.1689		0.1503	
Pounds/Ton	0.002639		0.003675		0.003712		0.003347	
Insoluble Particulate Data								
Total Sample Weight (Milligrams)	0		0		0		0	
Pounds/Hour	0		0		0		0	

a Dry standard cubic feet @ 68^{o}F, 29.92 inches Hg.
b Dry standard cubic feet per minute.
c p-dimethylamino benzaldehyde colorimetric (with preliminary distillation) analysis method.
d Direct Nessler Analysis method.
e Specific Ion Electrode Analysis method.
f Chromotropic Acid Analysis method.

TABLE 2-7

SUMMARY OF RESULTS OF UREA, AMMONIA AND FORMALDEHYDE TESTS
ON GASES EXITING THE PRILL TOWER SCRUBBER A
ON AUGUST 15-17, 1979
AT W.R. GRACE AND CO., MEMPHIS, TENNESSEE

Run Number	Fertilizer 1		Fertilizer 2		Fertilizer 3		Average	
Date	08-15-79		08-16-79		08-17-79			
Volume of Gas Sampled (DSCF [a])	109.2		106.4		105.9		107.2	
Stack Gas Flowrate (DSCFM [b])	62180		60510		60530		61073	
Stack Temperature (^{o}F)	90		90		89		90	
Percent Moisture	3.655		3.556		3.677		3.633	
Percent Isokinetic	98.4		98.5		98.1		98.3	
Production Rate (Tons/Hour)	43.5		45.8		45.5		44.9	
Urea Data [c]								
Total Sample Weight (Milligrams)	33.0		85.4		59.7		59.4	
Grains/DSCF	0.00465		0.01236		0.00868		0.00853	
Pounds/Hour	2.478		6.410		4.503		4.465	
Pounds/Ton	0.0570		0.1399		0.0990		0.0994	
Ammonia Data	DN [d]	SIE [e]	DN	SIE	DN	SIE	DN	SIE
Total Sample Weight (Milligrams)	745	748	821	746	683	634	750	709
Grains/DSCF	0.1051	0.1055	0.1188	0.1079	0.0993	0.0922	0.1077	0.1018
Pounds/Hour	56.01	56.24	61.61	55.98	51.51	47.81	56.37	53.29
Pounds/Ton	1.287	1.292	1.345	1.222	1.132	1.051	1.255	1.186
Formaldehyde Data [f]								
Total Sample Weight (Milligrams)	0.0578		0.0706		0.0761		0.0682	
Grains/DSCF	0.0000082		0.0000102		0.0000111		0.0000098	
Pounds/Hour	0.00437		0.00529		0.00576		0.00513	
Pounds/Ton	0.000101		0.000116		0.000127		0.000114	
Insoluble Particulate Data								
Total Sample Weight (Milligrams)	0		0		0		0	
Pounds/Hour	0		0		0		0	

a Dry standard cubic feet @ 68^{o}F, 29.92 inches Hg.
b Dry standard cubic feet per minute.
c p-dimethylamino benzaldehyde colorimetric (with preliminary distillation) analysis method.
d Direct Nessler Analysis method.
e Specific Ion Electrode Analysis method.
f Chromotropic Acid Analysis method.

TABLE 2-8

SUMMARY OF RESULTS OF UREA, AMMONIA AND FORMALDEHYDE TESTS
ON GASES ENTERING THE PRILL TOWER SCRUBBER C
ON AUGUST 15-17, 1979
AT W.R. GRACE AND CO., MEMPHIS, TENNESSEE

Run Number	Fertilizer 1		Fertilizer 2		Fertilizer 3		Average	
Date	08-15-79		08-16-79		08-17-79			
Volume of Gas Sampled (DSCF [a])	101.1		82.54		87.38		90.34	
Stack Gas Flowrate (DSCFM [b])	62360		53660		59050		58357	
Stack Temperature (^{o}F)	113		111		116		113	
Percent Moisture	2.029		1.395		1.371		1.598	
Percent Isokinetic	120.1		121.3		114.3		118.6	
Production Rate (Tons/Hour)	43.5		45.8		45.5		44.9	
Urea Data [c]								
Total Sample Weight (Milligrams)	304		217		275		265	
Grains/DSCF	0.0464		0.0406		0.0486		0.0453	
Pounds/Hour	24.80		18.67		24.60		22.66	
Pounds/Ton	0.570		0.408		0.541		0.505	
Ammonia Data	DN [d]	SIE [e]	DN	SIE	DN	SIE	DN	SIE
Total Sample Weight (Milligrams)	135	132	127	113	173	155	145	133
Grains/DSCF	0.0206	0.0201	0.0237	0.0211	0.0306	0.0274	0.0248	0.0227
Pounds/Hour	11.01	10.74	10.90	9.70	15.49	13.87	12.41	11.35
Pounds/Ton	0.253	0.247	0.238	0.212	0.340	0.305	0.276	0.253
Formaldehyde Data [f]								
Total Sample Weight (Milligrams)	0.849		0.582		0.790		0.740	
Grains/DSCF	0.0001296		0.0001088		0.0001396		0.0001264	
Pounds/Hour	0.06927		0.05004		0.07066		0.06325	
Pounds/Ton	0.001592		0.001093		0.001553		0.001408	
Insoluble Particulate Data								
Total Sample Weight (Milligrams)	0		0		0		0	
Pounds/Hour	0		0		0		0	

a Dry standard cubic feet @ 68^{o}F, 29.92 inches Hg.
b Dry standard cubic feet per minute.
c p-dimethylamino benzaldehyde colorimetric (with preliminary distillation) analysis method.
d Direct Nessler analysis method.
e Specific Ion Electrode Analysis method.
f Chromotropic Acid Analysis method.

TABLE 2-9

SUMMARY OF RESULTS OF UREA, AMMONIA AND FORMALDEHYDE TESTS
ON GASES EXITING THE PRILL TOWER SCRUBBER C
ON AUGUST 15-17, 1979
AT W.R. GRACE AND CO., MEMPHIS, TENNESSEE

Run Number	Fertilizer 1		Fertilizer 2		Fertilizer 3		Average	
Date	08-15-79		08-16-79		08-17-79			
Volume of Gas Sampled (DSCF.[a])	99.84		98.08		109.4		102.4	
Stack Gas Flowrate (DSCFM [b])	56220		56450		62410		58360	
Stack Temperature (^{o}F)	86		80		82		83	
Percent Moisture	3.314		3.371		4.012		3.566	
Percent Isokinetic	99.8		97.6		98.5		98.6	
Production Rate (Tons/Hour)	43.5		45.8		45.5		44.9	
Urea Data [c]								
Total Sample Weight (Milligrams)	37		67		70		58	
Grains/DSCF	0.00571		0.01052		0.00985		0.00872	
Pounds/Hour	2.750		5.089		5.270		4.363	
Pounds/Ton	0.0632		0.1111		0.1158		0.0972	
Ammonia Data	DN [d]	SIE [e]	DN	SIE	DN	SIE	DN	SIE
Total Sample Weight (Milligrams)	167	175	255	230	245	232	222	212
Grains/DSCF	0.0258	0.0270	0.0400	0.0361	0.0345	9.0327	0.0334	0.0319
Pounds/Hour	12.41	13.00	19.37	17.47	18.45	17.47	16.70	15.95
Pounds/Ton	0.285	0.299	0.423	0.382	0.405	0.384	0.372	0.355
Formaldehyde Data [f]								
Total Sample Weight (Milligrams)	0.041		0.068		0.063		0.057	
Grains/DSCF	0.0000063		0.0000107		0.0000088		0.0000086	
Pounds/Hour	0.003047		0.005165		0.004706		0.004287	
Pounds/Ton	0.000070		0.000113		0.000103		0.000096	
Insoluble Particulate Data								
Total Sample Weight (Milligrams)	0		0		0		0	
Pounds/Hour	0		0		0		0	

a Dry standard cubic feet @ 68^{o}F, 29.92 inches Hg.
b Dry standard cubic feet per minute.
c p-dimethylamino benzaldehyde colorimetric (with preliminary distillation) analysis method.
d Direct Nessler analysis method.
e Specific Ion Electrode analysis method.
f Chromotropic Acid analysis method.

TABLE 2-10

SUMMARY OF RESULTS OF UREA, AMMONIA AND FORMALDEHYDE TESTS
ON GASES ENTERING THE PRILL TOWER SCRUBBER A
ON AUGUST 20-22, 1979
AT W.R. GRACE AND CO., MEMPHIS, TENNESSEE

Run Number	Feed 1		Feed 2		Feed 3		Average	
Date	08-20-79		08-21-79		08-22-79			
Volume of Gas Sampled (DSCF [a])	75.79		77.72		77.92		77.14	
Stack Gas Flowrate (DSCFM [b])	51720		51720		53010		52150	
Stack Temperature (^{o}F)	180		189		182		184	
Percent Moisture	2.731		3.416		2.509		2.885	
Percent Isokinetic	106.0		108.1		106.6		106.9	
Production Rate (Tons/Hour)	47.2		47.4		45.9		46.8	
Urea Data [c]								
Total Sample Weight (Milligrams)	380		590		534		501	
Grains/DSCF	0.0774		0.1172		0.1058		0.1002	
Pounds/Hour	34.31		51.96		48.07		44.79	
Pounds/Ton	0.727		1.096		1.047		0.957	
Ammonia Data	DN [d]	SIE [e]	DN	SIE	DN	SIE	DN	SIE
Total Sample Weight (Milligrams)	512	467	570	550	636	609	574	542
Grains/DSCF	0.1043	0.0951	0.1132	0.1092	0.1260	0.1206	0.1148	0.1084
Pounds/Hour	46.24	42.16	50.18	48.41	57.25	54.80	51.32	48.45
Pounds/Ton	0.980	0.893	1.059	1.021	1.247	1.194	1.097	1.035
Formaldehyde Data [f]								
Total Sample Weight (Milligrams)	0.409		0.622		0.644		0.558	
Grains/DSCF	0.0000833		0.0001235		0.0001275		0.000112	
Pounds/Hour	0.0369		0.0547		0.0579		0.05006	
Pounds/Ton	0.000782		0.001154		0.001261		0.001070	
Insoluble Particulate Data								
Total Sample Weight (Milligrams)	0.04		0		0		0.013	
Pounds/Hour	<0.001		0		0		<0.001	

a Dry standard cubic feet @ 68^{o}F, 29.92 inches Hg.
b Dry standard cubic feet per minute.
c p-dimethylamino benzaldehyde colorimetric (with preliminary distillation) analysis method.
d Direct Nessler Analysis method.
e Specific Ion Electrode Analysis method.
f Chromotropic Acid Analysis method.

TABLE 2-11

SUMMARY OF RESULTS OF UREA, AMMONIA AND FORMALDEHYDE TESTS
ON GASES EXITING THE PRILL TOWER SCRUBBER A
ON AUGUST 20-22, 1979
AT W.R. GRACE AND CO., MEMPHIS, TENNESSEE

Run Number	Feed 1		Feed 2		Feed 3		Average Feed	
Date	08-20-79		08-21-79		08-22-79			
Volume of Gas Sampled (DSCF [a])	90.18		76.09		88.89		85.05	
Stack Gas Flowrate (DSCFM [b])	49750		42270		50390		47470	
Stack Temperature (^{o}F)	106		103		97		102	
Percent Moisture	5.472		5.291		5.377		5.380	
Percent Isokinetic	101.6		100.9		98.9		100.5	
Production Rate (Tons/Hour)	47.2		47.4		45.9		46.8	
Urea Data [c]								
Total Sample Weight (Milligrams)	30.4		94.0		111		78.5	
Grains/DSCF	0.00519		0.01902		0.01923		0.01421	
Pounds/Hour	2.213		6.892		8.305		5.782	
Pounds/Ton	0.0469		0.1454		0.1809		0.1236	
Ammonia Data	DN [d]	SIE [e]	DN	SIE	DN	SIE	DN	SIE
Total Sample Weight (Milligrams)	293	290	292	279	390	402	325	324
Grains/DSCF	0.05004	0.04953	0.05910	0.05647	0.06757	0.06965	0.05885	0.05867
Pounds/Hour	21.33	21.11	21.41	20.46	29.18	30.08	23.94	23.87
Pounds/Ton	0.452	0.447	0.452	0.432	0.636	0.656	0.512	0.510
Formaldehyde Data [f]								
Total Sample Weight (Milligrams)	0.133		0.178		0.166		0.159	
Grains/DSCF	0.0000227		0.0000360		0.0000288		0.0000288	
Pounds/Hour	0.00968		0.01305		0.01242		0.01171	
Pounds/Ton	0.000205		0.000275		0.000271		0.000250	
Insoluble Particulate Data								
Total Sample Weight (Milligrams)	0		0		0		0	
Pounds/Hour	0		0		0		0	

a Dry standard cubic feet @ 68^{o}F, 29.92 inches Hg.
b Dry standard cubic feet per minute.
c p-dimethylamino benzaldehyde colorimetric (with preliminary distillation) analysis method.
d Direct Nessler Analysis method.
e Specific Ion Electrode Analysis method.
f Chromotropic Acid Analysis method.

TABLE 2-12

SUMMARY OF RESULTS OF UREA, AMMONIA AND FORMALDEHYDE TESTS
ON GASES ENTERING THE PRILL TOWER SCRUBBER C
ON AUGUST 20-22, 1979
AT W.R. GRACE AND CO., MEMPHIS, TENNESSEE

Run Number	Feed 1		Feed		Feed 3		Average	
Date	08-20-79		08-21-79		08-22-79			
Volume of Gas Sampled (DSCF [a])	64.53		69.63		68.85		67.67	
Stack Gas Flowrate (DSCFM [b])	44150		48880		46920		46650	
Stack Temperature	184		179		174		179	
Percent Moisture	3.041		2.863		2.493		2 799	
Percent Isokinetic	105.7		104.8		105.3		105.3	
Production Rate (Tons/Hour)	47.2		47.4		45.9		46.8	
Urea Data [c]								
Total Sample Weight (Milligrams)	411		425		463		433	
Grains/DSCF	0.0983		0.0942		0.1038		0.0987	
Pounds/Hour	37.20		39.47		41.75		39.47	
Pounds/Ton	0.788		0.833		0.910		0.843	
Ammonia Data	**DN [d]**	**SIE [e]**	**DN**	**SIE**	**DN**	**SIE**	**DN**	**SIE**
Total Sample Weight (Milligrams)	540	513	480	447	483	476	501	479
Grains/DSCF	0.1291	0.1227	0.1064	0.0991	0.1083	0.1067	0.1145	0.1092
Pounds/Hour	48.86	46.43	44.58	41.52	43.56	42.91	45.70	43.66
Pounds/Ton	1.035	0.984	0.941	0.876	0.949	0.935	0.976	0.933
Formaldehyde Data [f]								
Total Sample Weight (Milligrams)	0.419		0.563		0.440		0.474	
Grains/DSCF	0.0001002		0.0001248		0.0000986		0.0001081	
Pounds/Hour	0.03792		0.05229		0.03965		0.04322	
Pounds/Ton	0.000803		0.001103		0.000864		0.000924	
Insoluble Particulate Data								
Total Sample Weight (Milligrams)	1.30		0		0		0.45	
Pounds/Hour	<0.001		0		0		<0.001	

a Dry standard cubic feet @ 68°F, 29.92 inches Hg.
b Dry standard cubic feet per minute.
c p-dimethylamino benzaldehyde colorimetric (with preliminary distillation) analysis method.
d Direct Nessler analysis method.
e Specific Ion Electrode Analysis method.
f Chromotropic Acid Analysis method.

TABLE 2-13

SUMMARY OF RESULTS OF UREA, AMMONIA AND FORMALDEHYDE TESTS
ON GASES EXITING THE PRILL TOWER SCRUBBER C
ON AUGUST 20-22, 1979
AT W.R. GRACE AND CO., MEMPHIS, TENNESSEE

Run Number	Feed 1		Feed 2		Feed 3		Average	
Date	08-20-79		08-21-79		08-22-79			
Volume of Gas Sampled (DSCF [a])	83.59		83.39		91.57		86.18	
Stack Gas Flowrate DSCFM [b])	46270		45160		50470		47500	
Stack Temperature (°F)	104		103		99		102	
Percent Moisture	5.833		6.388		6.160		6.127	
Percent Isokinetic	101.5		103.8		102.0		102.4	
Production Rate (Tons/Hour)	47.2		47.4		45.9		46.8	
Urea Data [c]								
Total Sample Weight (Milligrams)	37		87		100		75	
Grains/DSCF	0.00682		0.01610		0.01682		0.01348	
Pounds/Hour	2.703		6.232		7.274		5.462	
Pounds/Ton	0.0573		0.1315		0.1585		0.1167	
Ammonia Data	DN [d]	SIE [e]	DN	SIE	DN	SIE	DN	SIE
Total Sample Weight (Milligrams)	322	320	288	271	408	422	339	338
Grains/DSCF	0.05932	0.05895	0.05330	0.05015	0.06862	0.07097	0.06092	0.06074
Pounds/Hour	23.52	23.37	20.63	19.41	29.68	30.70	24.69	24.62
Pounds/Ton	0.498	0.495	0.435	0.409	0.647	0.669	0.528	0.526
Formaldehyde Data [f]								
Total Sample Weight (Milligrams)	0.131		0.182		0.168		0.160	
Grains/DSCF	0.0000241		0.0000337		0.0000283		0.0000288	
Pounds/Hour	0.009570		0.013045		0.012221		0.011653	
Pounds/Ton	0.000203		0.000275		0.000266		0.000249	
Insoluble Particulate Data								
Total Sample Weight (Milligrams)	0		0		0		0	
Pounds/Hour	0		0		0		0	

a Dry standard cubic feet @ 68°F, 29.92 inches Hg.
b Dry standard cubic feet per minute.
c p-dimethylamino benzaldehyde colorimetric (with preliminary distillation) analysis method.
d Direct Nessler analysis method.
e Specific Ion Electrode analysis method.
f Chromotropic Acid analysis method.

shown in Tables 2-2 through 2-6. For scrubbers A and C during both fertilizer and feed grade tests, the calculated I averaged 99.9 percent at the outlets and 108.7 percent at the inlets. The inlet isokinetics are consistently higher than the outlet isokinetics, with the scrubber C fertilizer data (Table 2-3) most conspicuous (averaging 118.6 percent). These latter test runs also exhibited the largest average cyclonic flow angles.

The differences between the scrubber A inlet and outlet flow rates during the fertilizer and feed test runs (Tables 2-2 and 2-4) may also be due to the inlet cyclonic flow.

2.3 Synthesis Tower Main Vent Emissions Test Results

Table 2-14 shows the results of the urea and ammonia test runs conducted at the urea synthesis tower main vent. These test runs were performed on August 22, 1979, during feed grade urea production. The urea concentrations were at the threshold of detection. The results of the two ammonia analysis methods agreed with each other within 5% in terms of total sample weight. However, because of the large absolute amounts of ammonia in the gas stream (about 70% of the dry gas stream was ammonia), the differences between calculated amounts of ammonia yield appreciable differences in calculated stack gas volumetric flowrates. Thus, two sets of data are presented: one for direct Nessler analysis results and one for specific ion electrode analysis results.

Integrated gaseous bag samples were collected during each particulate test run at the synthesis tower vent. These samples were collected directly from the vent stack using an Integrated Orsat Sampler. The samples were then analyzed for CO_2 and O_2 using the EPA Reference Method 3 Orsat analyzer procedure. Results of these sample analyses are as follows:

TABLE 2-14

SUMMARY OF RESULTS OF UREA AND AMMONIA TESTS
ON GASES SAMPLED AT THE SYNTHESIS TOWER MAIN VENT
ON AUGUST 22, 1979
AT W.R. GRACE AND CO., MEMPHIS, TENNESSEE

Run Number	Run 1		Run 2		Run 3		Average	
Ammonia Analysis Method:	DN [a]	SIE [b]	DN	SIE	DN	SIE	DN	SIE
Volume of Gas Sampled (DSCF [c])	5.07	4.84	5.10	5.17	5.01	4.69	5.06	4.90
Stack Gas Flowrate (DSCFM [d])	786.4	761.1	742.4	747.8	740.4	707.6	756.4	738.8
Stack Temperature (^{o}F)	180	180	181	181	181	181	181	181
Percent Moisture	73.1	74.0	74.1	73.8	73.9	75.1	73.7	74.3
Percent Isokinetic	124.4	122.7	132.6	133.4	130.7	127.9	129.2	128.0
Production Rate (Tons/Hour)	47.9	47.9	47.9	47.9	49.9	49.9	48.6	48.6
Urea Data [e]								
Total Sample Weight (Milligrams)	<28.2	<28.2	<24.4	<24.4	<23.2	<23.2	<25.3	<25.3
Grains/DSCF	<0.0858	<0.0899	<0.0738	<0.0728	<0.0715	<0.0763	<0.0770	<0.0796
Pounds/Hour	<0.578	<0.586	<0.470	<0.467	<0.454	<0.461	<0.499	<0.504
Pounds/Ton	<0.0121	<0.0122	<0.0098	<0.0097	<0.0091	<0.0092	<0.0103	<0.0104
Ammonia Data								
Total Sample Weight (Milligrams)	69439	64773	72296	73836	71218	64774	70984	67794
Grains/DSCF	211.3	206.5	218.7	220.4	219.3	213.1	216.4	213.5
Pounds/Hour	1424.0	1347.1	1391.8	1412.6	1391.7	1292.5	1403.3	1351.8
Pounds/Ton	29.73	28.12	29.06	29.49	27.89	25.90	28.88	27.82
Insoluble Particulate Data								
Total Sample Weight (Milligrams)	0	0	0	0	0.12	0.12	0.04	0.04
Pounds/Hour	0	0	0	0	<0.001	<0.001	<0.001	<0.001

a Direct Nessler Analysis method.
b Specific Ion Electrode Analysis method.
} Two sets of data are presented because each analysis method produces a measurably different gaseous ammonia volume and, consequently, a measurably different stack gas flowrate.

c Dry standard cubic feet @ 68^{o}F, 29.92 inches Hg (including ammonia gas volume). Ammonia gaseous volume (DSCF) = Sample weight (mg) X 0.0000499.
d Dry standard cubic feet per minute.
e p-dimethylamino benzaldehyde colorimetric (with preliminary distillation) analysis method.

Run No.	Percent CO_2	Percent O_2
1	10.6	11.8
2	33.2	9.2
3	14.0	11.0

The Run 2 data is the average of three samples. All data were recorded on the synthesis tower field data sheets shown in Appendix B.

2.4 Visible Emissions

The opacity of the individual plumes from the outlets of scrubbers A and C, and the opacity of the combined plumes from all operating scrubbers, were monitored during the two week test period. Observations were made from ground level and from atop the prill tower by certified smoke observers.

During the period of fertilizer grade urea production (August 15-17, 1979) scrubber C and combined scrubbers A through H were monitored. The six-minute average opacities ranged from 10% to 40% for scrubber C and from 10% to 35% for combined scrubbers A through H. These data are shown graphically in Figures 2-1 and 2-2.

During the period of feed grade urea production (August 20-22, 1979) scrubbers A and C and combined scrubbers A through D were monitored. The six-minute average opacities ranged from 3% to 30% for scrubber A, from 6% to 33% for scrubber C, and from 6% to 19% for combined scrubbers A through D. These data are shown graphically in Figure 2-3 and 2-4.

The opacity of the plume from the bagging operation baghouse was monitored December 18, 1979. The highest six-minute opacity was 1%; overall the opacity averaged zero percent. These data were not graphed and are presented in tabular form in Appendix C along with all visible emissions data.

A description of all visible emission observations locations is shown in Table 2-15.

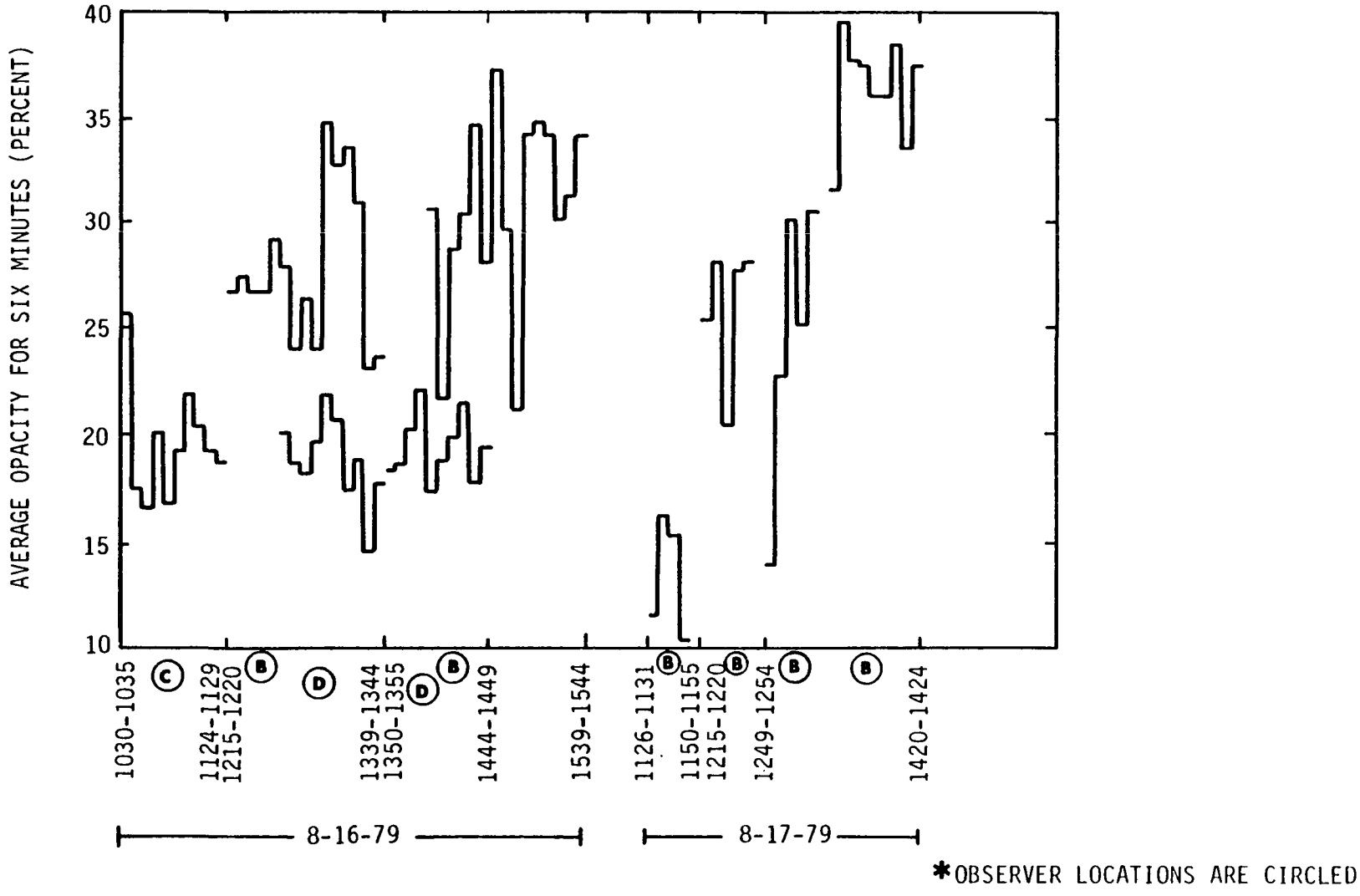


FIGURE 2-1: SIX MINUTE AVERAGE OPACITY READINGS FOR PRILL TOWER SCRUBBER C DURING FERTILIZER TESTS AT W. R. GRACE AND CO., MEMPHIS, TENNESSEE

0988-002

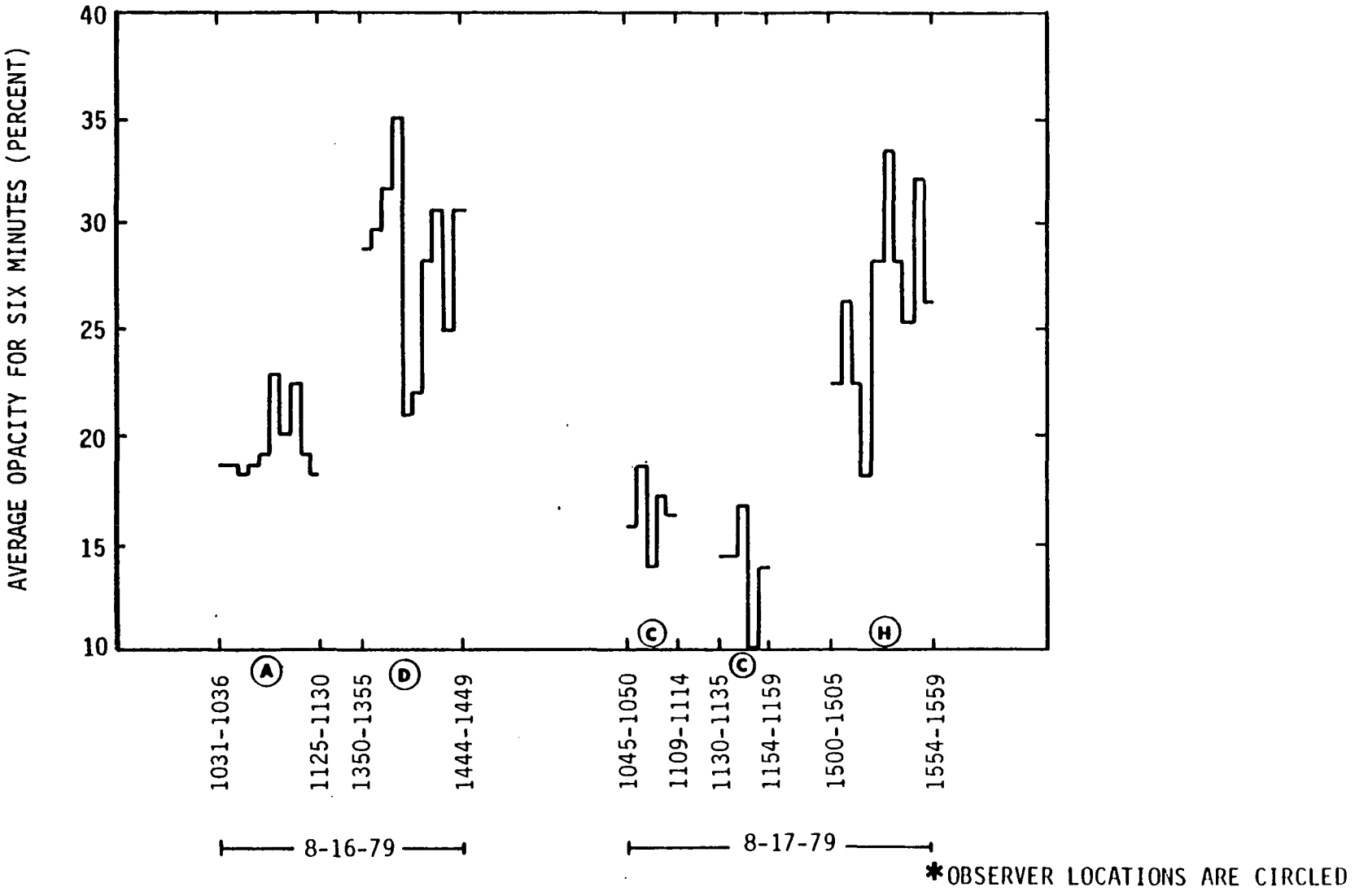


FIGURE 2-2: SIX MINUTE AVERAGE OPACITY READINGS FOR PRILL TOWER COMBINED SCRUBBERS A-H DURING FERTILIZER TESTS AT W. R. GRACE AND CO., MEMPHIS, TENNESSEE

0988-003

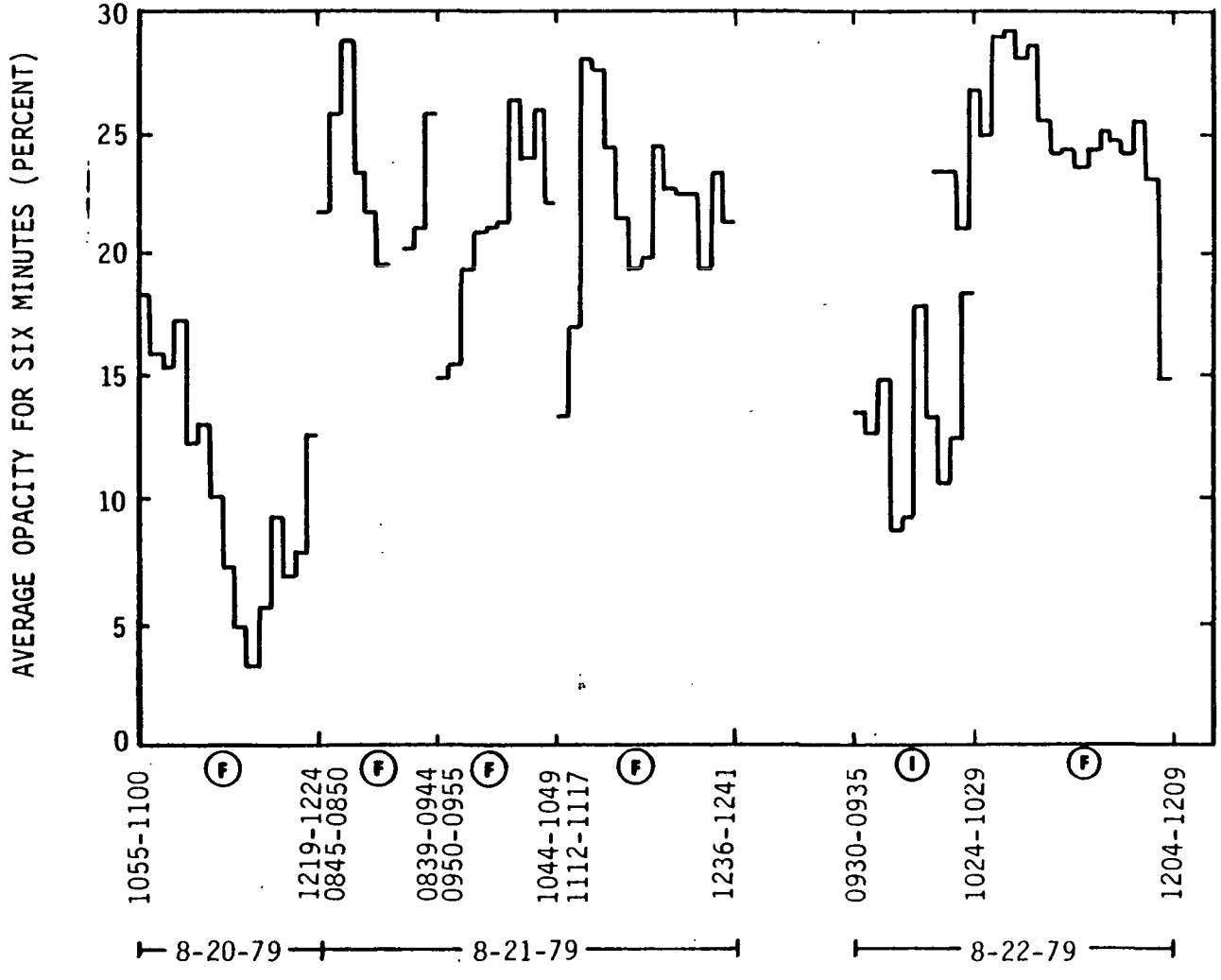


FIGURE 2-3: SIX MINUTE AVERAGE OPACITY READINGS FOR PRILL TOWER SCRUBBER A DURING FEED TESTS AT W. R. GRACE AND CO., MEMPHIS, TENNESSEE

0988-004

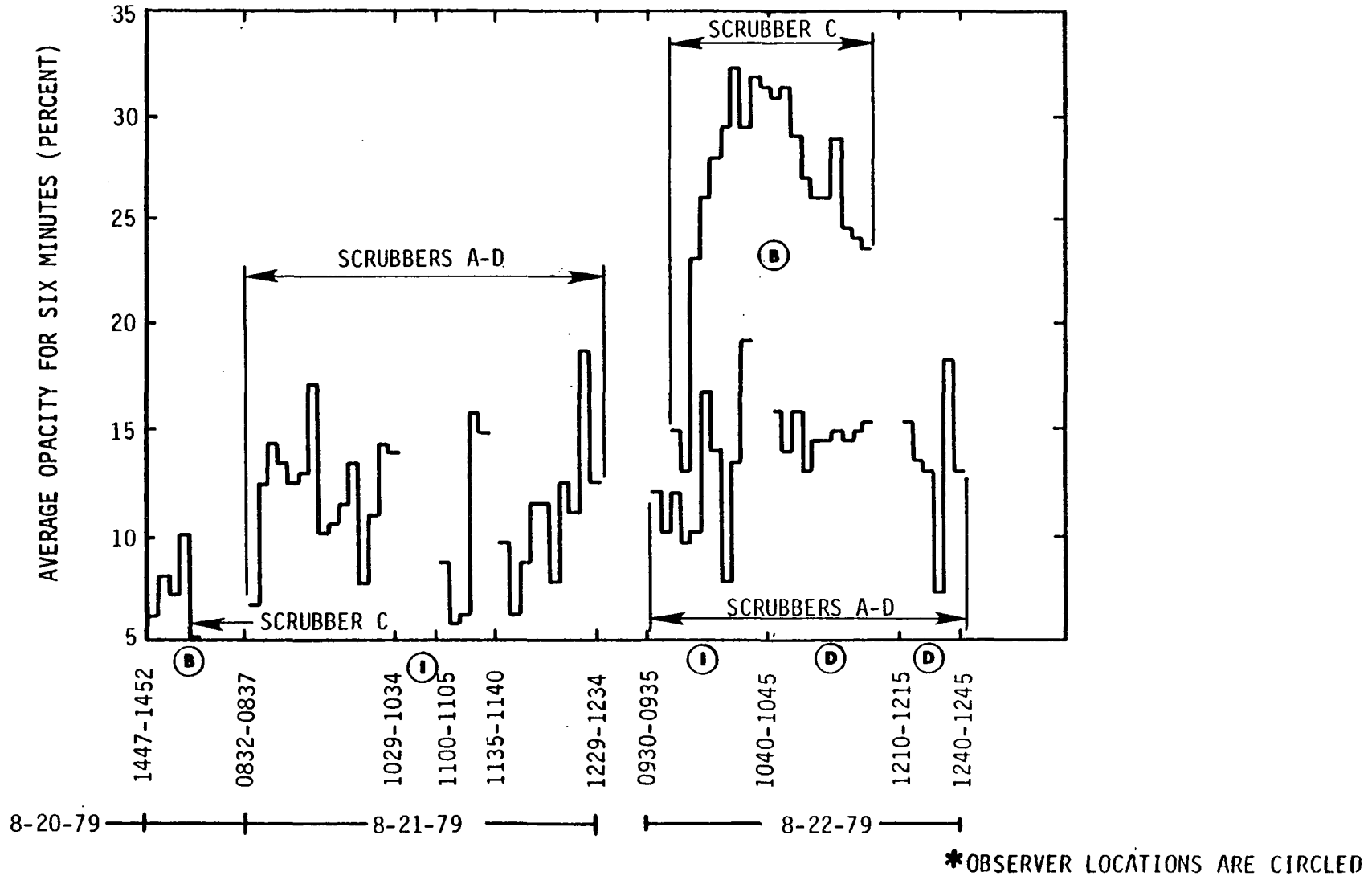


FIGURE 2-4: SIX MINUTE AVERAGE OPACITY READINGS FOR PRILL TOWER SCRUBBER C AND COMBINED SCRUBBERS A-D DURING FEED TESTS AT W. R. GRACE AND CO., MEMPHIS, TENNESSEE

0988-005

TABLE 2-15

VISIBLE EMISSION OBSERVATION LOCATIONS
AT W.R. GRACE AND CO., MEMPHIS, TENNESSEE

Observer Location	Distance To Discharge Point (Feet)	Height Above Ground (Feet)	Direction From Discharge Point	Discharge Description
A	450	0	SE	Prill Tower
B	40	200	SSE	"
C	450	0	E	"
D	450	0	SE	"
E	450	0	SSW	"
F	40	200	E	"
G	400	0	SW	"
H	500	0	S	"
I	400	0	ESS	"
J	5-15	0	S	Bag House

2.5 Particle Size Tests

Particle size distribution tests were performed on the inlet gas stream of both scrubbers A and C during each of the emission test runs. The tests were performed with an Anderson cascade impactor with pre-impactor at a single average flow point in each duct.

The results for the fertilizer tests are summarized in Table 2-16 and are shown as cumulative size distribution curves in Figures 2-5 (scrubber A) and 2-6 (scrubber C). The feed test results are shown in Taole 2-17 and Figures 2-7 and 2-8. All particle size field and laboratory data are contained in Appendix D.

2.6 Volumetric Flowrates in the Prill Tower Scrubber Inlets

Velocity traverses were performed at scrubber inlets B, D, E, F, G and H immediately before and immediately after each fertilizer emissions test run; similar velocity traverses were made at scrubber inlets B and D before and after each feed test run. The calculated flowrates resulting from these velocity traverses and from the scrubbers A and C emission tests are shown in Table 2-18.

Cyclonic flow caused by the axial flow fans in each duct was evident to some degree in all eight scrubber inlets. The cyclonic flow angles were measured at each traverse point in inlets B, D, E, F, G and H before the velocity traverses and in inlets A and C before the emission tests. The average

TABLE 2-16

SUMMARY OF INLET PARTICLE SIZING TEST RESULTS
ON SCRUBBERS A & C
DURING FERTILIZER GRADE UREA PRODUCTION
AT W.R. GRACE AND CO., MEMPHIS, TENNESSEE

Test Number	Sampling Location	Test Date	Test Time	Particulate Concentration GR/DSCF	Aerodynamic Size Range µm	Mass In Size Range Percent	Cumulative Percent
1	A Inlet	08-14-79	1252	0.040	>13.3	48.5	
					9.17-13.3	3.4	51.5
					6.22-9.17	3.2	48.1
					4.24-6.22	2.3	44.9
					2.72-4.24	13.8	42.6
					1.36-2.72	4.0	28.8
					0.84-1.36	7.3	24.8
					0.57-0.84	6.6	17.5
					<0.57	10.9	10.9
2	A Inlet	08-15-79	0955	0.034	>14.5	24.9	
					10.0-14.5	9.2	75.1
					6.8-10.0	1 8	65.9
					4.63-6.8	12.8	64 1
					2.97-4.63	6.4	51.3
					1.5-2.97	10.7	44.9
					0.93-1.5	0	34.2
					0.63-0.93	20.9	34.2
					<0.63	13.3	13.3
3	A Inlet	08-15-79	1126	0.039	>15.3	17.2	
					10.6-15.3	3.0	82 8
					7.16-10.6	11.5	79 8
					4.89-7.16	7.9	68 3
					3.14-4.89	17.1	60.4
					1.58-3.14	3.0	43.3
					0.98-1.58	21.4	40 3
					0.67-0.98	14.7	18.9
					<0.67	4.2	4.2

TABLE 2-16 (Cont.)

SUMMARY OF INLET PARTICLE SIZING TEST RESULTS
ON SCRUBBERS A & C
DURING FERTILIZER GRADE UREA PRODUCTION
AT W.R. GRACE AND CO., MEMPHIS, TENNESSEE

Test Number	Sampling Location	Test Date	Test Time	Particulate Concentration Gr/DSCF	Aerodynamic Size Range μm	Mass In Size Range Percent	Cumulative Percent
1	C Inlet	08-16-79	1122	0.022	>12.3	49.0	
					8.5-12.3	0.0	51.0
					5.76-8.5	0.4	51.0
					3.92-5.76	3.0	50.6
					2.52-3.92	1.2	47.6
					1.26-2.52	11.5	46.4
					0.78-1.26	19.5	34.9
					0.53-0.78	10.8	15.4
					<0.53	4.6	4.6
2	C Inlet	08-16-79	1543	0.027	>12.2	21.2	
					8.4-12.2	0	78.8
					5.69-8.4	1.4	78.8
					3.88-5.69	2.5	77.4
					2.49-3.88	3.1	74.9
					1.25-2.49	22.8	71.8
					0.77-1.25	22.2	49.0
					0.52-0.77	21.2	26.8
					<0.52	5.6	5.6
3	C Inlet	08-17-79	1430	0.013	>13.0	66.5	
					8.93-13.0	3.7	33.5
					6.05-8.93	0.0	29.8
					4.13-6.05	0.0	
					2.65-4.13	1.5	29.8
					1.33-2.65	0.0	28.3
					0.82-1.33	15.0	28.3
					0.56-0.82	6.0	13.3
					<0.56	7.3	7.3

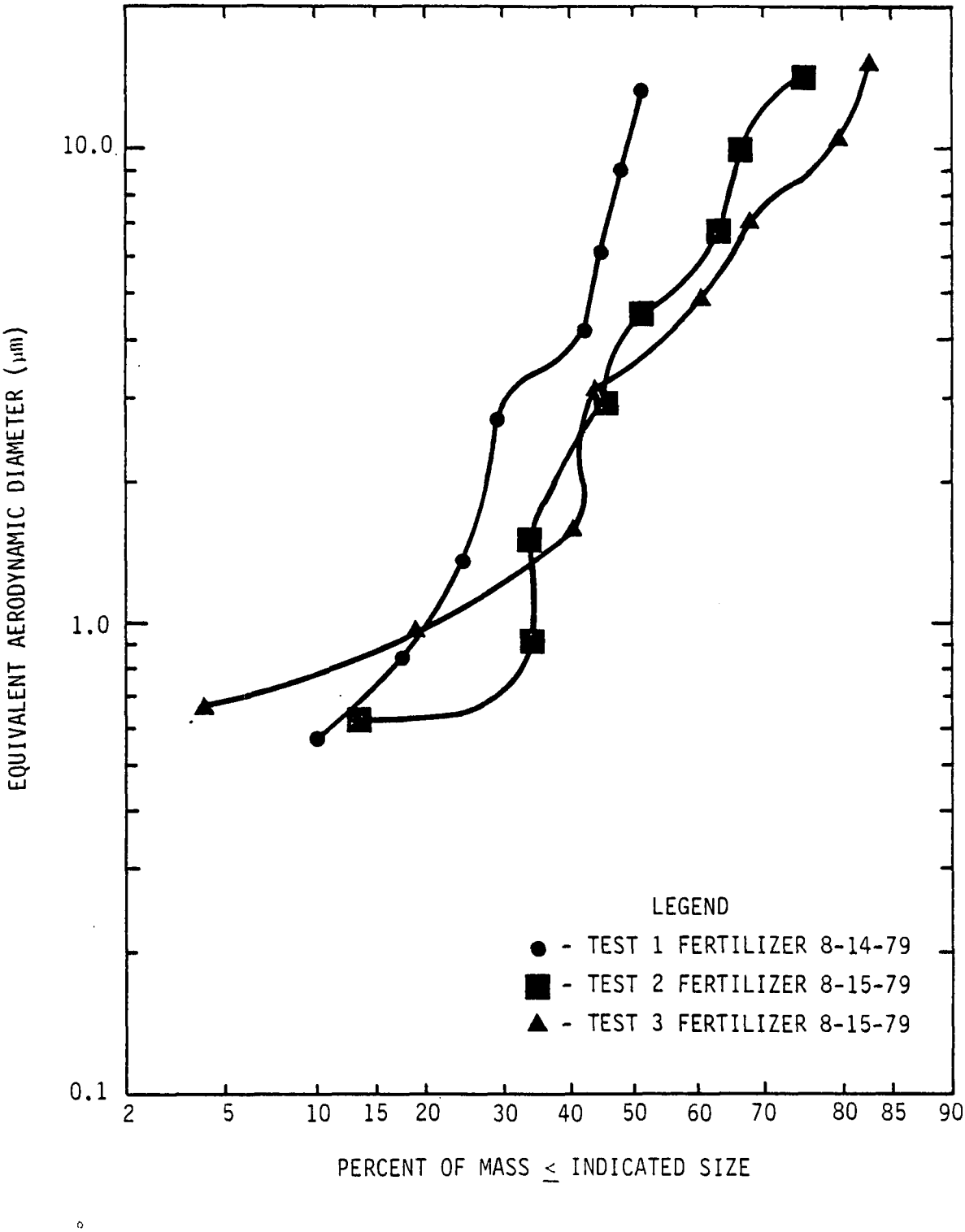


FIGURE 2-5: CUMULATIVE SIZE DISTRIBUTIONS OF PARTICULATE IN SCRUBBER A DURING FERTILIZER TESTS AT W. R. GRACE AND CO., MEMPHIS, TENNESSEE

0988-006

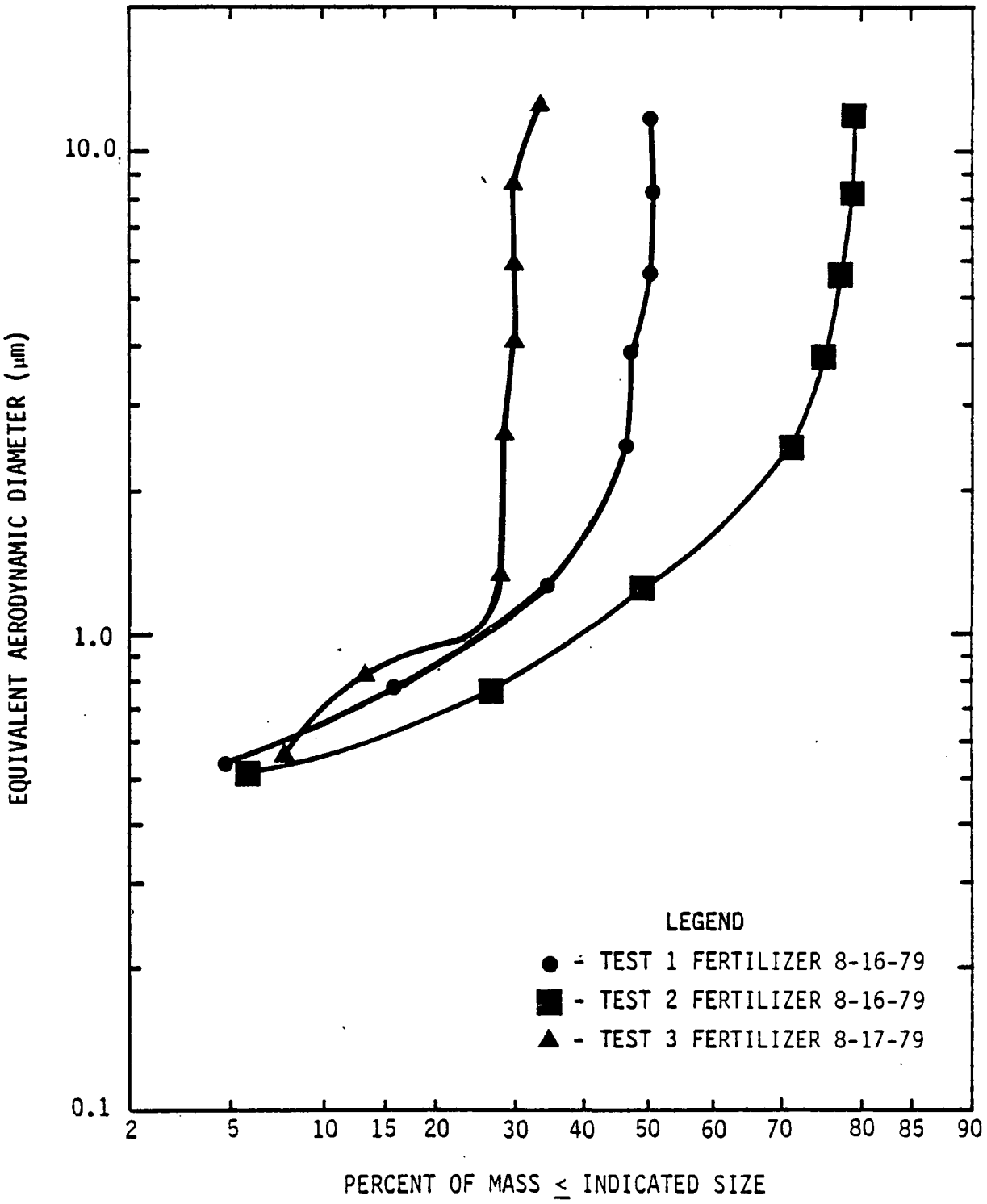


FIGURE 2-6: CUMULATIVE SIZE DISTRIBUTIONS OF PARTICULATE IN SCRUBBER C DURING FERTILIZER TESTS AT W. R. GRACE AND CO., MEMPHIS, TENNESSEE

0988-007

TABLE 2-17

SUMMARY OF INLET PARTICLE SIZING TEST RESULTS
ON SCRUBBERS A & C
DURING FEED GRADE UREA PRODUCTION
AT W.R. GRACE AND CO., MEMPHIS, TENNESSEE

Test Number	Sampling Location	Test Date	Test Time	Particulate Concentration Gr/DSCF	Aerodynamic Size Range μm	Mass In Size Range Percent	Cumulative Percent
1	A Inlet	08-21-79	1605	0.031	>15.9	88.6	
					10.9-15.9	0.0	11.4
					7.4-10.9	0.0	
					5.05-7.4	0.0	
					3.24-5.05	0.0	
					1.63-3.24	5.3	11.4
					1.00-1.63	6.1	6.1
					0.69-1.00	0.0	0.0
					<0.69	0.0	0.0
2	A Inlet	08-22-79	0935	0.054	>16.3	84.4	
					11.2-16.3	0.1	15.6
					7.0-11.2	0.0	15.5
					5.18-7.60	7.9	15.5
					3.33-5.18	0.0	7.6
					1.67-3.33	1.9	7.6
					1.03-1.67	0.0	5.7
					0.71-1.03	0.0	5.7
					<0.71	5.7	5.7
3	A Inlet	08-22-79	1430	0.020	>14.7	98.1	
					10.1-14.7	0.0	1.9
					6.87-10.1	0.0	
					4.68-6.87	0.0	
					3.0-4.68	0.0	
					1.5-3.0	0.0	
					0.93-1.5	0.0	
					0.63-0.93	0.0	
					<0.63	1.9	1.9

TABLE 2-17 (Cont.)

SUMMARY OF INLET PARTICLE SIZING TEST RESULTS
ON SCRUBBERS A & C
DURING FEED GRADE UREA PRODUCTION
AT W.R. GRACE AND CO., MEMPHIS, TENNESSEE

Test Number	Sampling Location	Test Date	Test Time	Particulate Concentration Gr/DSCF	Aerodynamic Size Range μm	Mass In Size Range Percent	Cumulative Percent
1	C Inlet	08-20-79	1555	0.048	>15.10	71.8	
					10.4-15.1	0	28.2
					7.04-10.4	6.0	28.2
					4.8-7.04	3.5	22.2
					3.08-4.8	4.9	18.7
					1.54-3.08	3.4	13.8
					0.95-1.54	5.0	10.4
					0.65-0.95	0	5.4
					<0.65	5.4	5.4
2	C Inlet	08-21-79	1018	0.084	>13.40	36.0	
					9.22-13.4	5.4	64.0
					6.25-9.22	11.9	58.6
					4.26-6.25	8.7	46.7
					2.73-4.26	5.7	38.0
					1.36-2.73	7.2	32.3
					0.84-1.36	7.6	25.1
					0.57-0.84	7.0	17.5
					<0.57	10.5	10.5
3	C Inlet	08-22-79	0935	0.052	>16.7	78.3	
					11.5-16.7	0.0	21.7
					7.81-11.5	0.7	21.7
					5.32-7.81	9.4	21.0
					3.42-5.32	0.0	11.6
					1.72-3.42	6.8	11.6
					1.07-1.72	0.0	4.8
					0.73-1.07	0.0	4.8
					<0.73	4.8	4.8

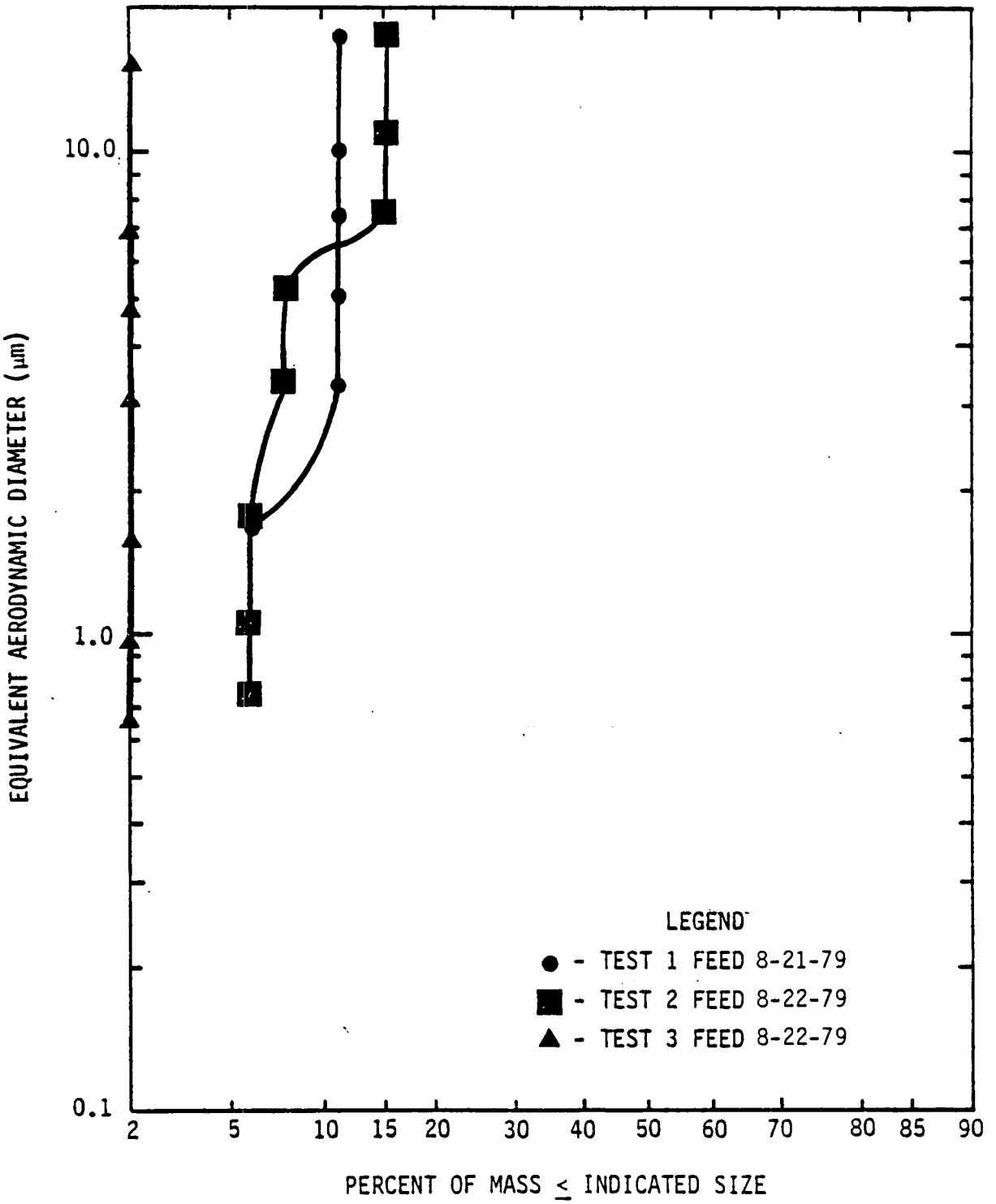


FIGURE 2-7: CUMULATIVE SIZE DISTRIBUTIONS OF PARTICULATE IN SCRUBBER A DURING FEED TESTS AT W. R. GRACE AND CO., MEMPHIS, TENNESSEE

0988-008

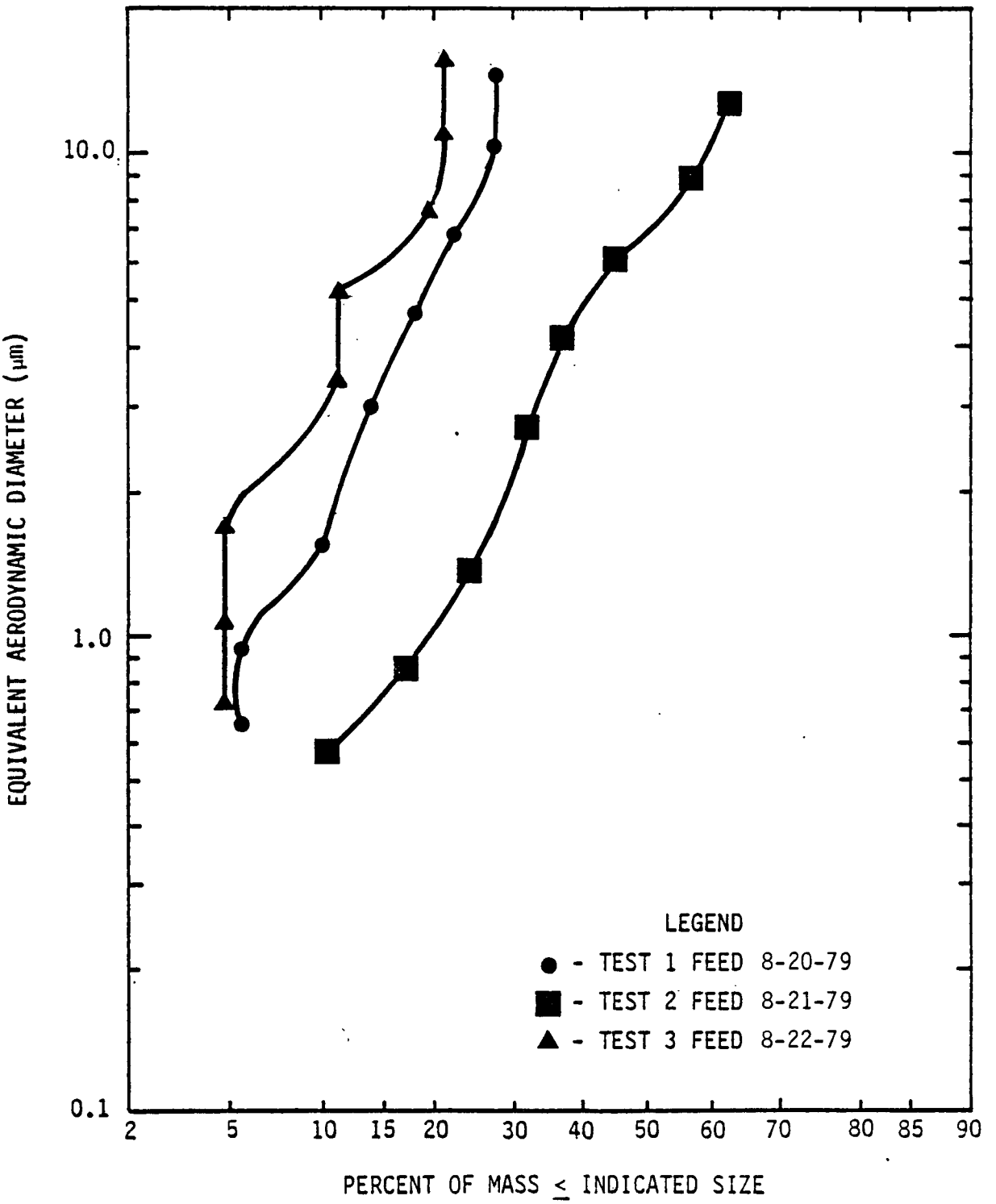


FIGURE 2-8: CUMULATIVE SIZE DISTRIBUTIONS OF PARTICULATE IN SCRUBBER C DURING FEED TESTS AT W. R. GRACE AND CO., MEMPHIS, TENNESSEE

0988-009

TABLE 2-18

SCRUBBER INLET FLOWRATES* AT W.R. GRACE AND CO., MEMPHIS, TENNESSEE

		FERTILIZER				FEED			
Scrubber	Time	1	2	3	Average	1	2	3	Average
A	During	65680	68880	70130	68230	51720	51720	53010	52150
B	Before[a]	59150	50320	44760	51410	34600	34910	39190	36233
	After[b]	54980	56890	50720	54197	34200	36890	39760	36950
	Average	57065	53605	47740	52803	34400	35900	39475	36592
C	During	62360	53660	59050	58357	44150	48880	46920	46650
D	Before	57970	48350	51330	52550	49140	46060	45740	46980
	After	57250	54370	51780	54467	45690	44870	46300	45620
	Average	57610	51360	51555	53508	47415	45465	46020	46300
E	Before	65330	59000	60900	61743				
	After	60010	60900	58610	59840				
	Average	62670	59950	59755	60792				
F	Before	60950	61890	62130	61657				
	After	59480	61030	57810	59440				
	Average	60215	61460	59970	60548				
G	Before	72230	69990	69230	70483				
	After	68450	70180	64820	67817				
	Average	70340	70085	67025	69150				
H	Before	56410	58540	58540	57830				
	After	56210	60140	55330	57227				
	Average	56310	59340	56935	57528				
Total[c]		492000	478000	472000	481000	178000	182000	185000	182000

a Flowrates calculated from velocity traverses performed before the indicated runs at scrubbers A and C.

b Flowrates calculated from velocity traverses performed after the indicated runs at scrubbers A and C.

c Sum of averages, rounded to the nearest 1000 DSCFM.

* Dry standard cubic feet per minute @ 68°F, 29.92 inches Hg.

flow angles measured at each inlet (averaged over all traverse points) are as follows:

	Average Flow Angle (degrees)					
	Fertilizer Runs			Feed Runs		
Scrubber	1	2	3	1	2	3
A	11.9	11.0	11.0	13.0	11.9	12.0
B	11.0	2.9	1.5	4.0	11.3	2.0
C	15.0	24.4	22.5	14.0	13.5	9.0
D	7.4	2.9	4.3	10.4	6.0	9.0
E	12.2	15.7	18.4			
F	21.0	2.5	2.4			
G	16.0	14.9	12.3			
H	13.8	11.3	11.2			

The flowrates shown in Table 2-18 were calculated with the cyclonic flow angles taken into account, as described in Section 5.1 and Appendix G.

During each emission test run, single point velocity head (Δp) and temperature (T) measurements were taken approximately every 15 minutes in inlets B, D, E, F, G and H (fertilizer tests) and in inlets B and D (feed tests). This was done in order to have some measure of the consistency of flow in these inlets during the emission tests. Averages of these data, along with average Δp and T values from the complete before and after velocity traverses, are shown in Table 2-19. These single-point measurements were made with account given to cyclonic flow angles.

All velocity traverse and single-point data are shown in Appendix F.

TABLE 2-19

SUMMARY OF VELOCITY HEAD (INCHES WATER) AND TEMPERATURE (°F)
MEASUREMENTS ON SCRUBBER INLETS NOT TESTED FOR EMISSIONS
AT W.R. GRACE AND CO., MEMPHIS, TENNESSEE

This table is claimed confidential by W.R. Grace and Co.

See Confidential Addendum: Contact Eric Noble, EPA,
(919) 541-5213

2.7 Pressure Drops Across the Prill Tower Scrubbers

This section is claimed confidential by W. R. Grace and Co. See confidential addendum: contact Eric Noble, EPA, (919) 541-5213.

2.8 Analysis of the Scrubbing Liquor

The scrubbing liquor entering and exiting the A and C scrubbers was sampled approximately every 30 minutes during each emission test run. Half-liter samples were taken from the common liquor-stream inlet and from the two separate liquor-stream outlets. The liquor temperature was measured immediately after the sample was collected, and when the sample reached room temperature the pH was measured and recorded. After each emission test run, the liquor samples taken during that run were combined into three composite samples (one inlet and two outlet samples). These composite samples were then analyzed for urea, ammonia, formaldehyde and undissolved solids. A summary of these data is shown in Tables 2-20 (fertilizer test runs) and 2-21 (feed test runs). The temperature and pH data for each individual scrubber liquor sample are shown in Appendix E.

2.9 Ambient Air Temperature and Relative Humidity Measurements

The temperature and relative humidity of the ambient air were measured periodically at the base of the prill tower during each emission test run. These data are presented in Table 2-22 (fertilizer test runs) and 2-23 (feed test runs).

TABLE 2-20

SUMMARY OF SCRUBBERS A AND C LIQUOR ANALYSIS RESULTS
FERTILIZER GRADE UREA PRODUCTION
W.R. GRACE AND CO., MEMPHIS, TENNESSEE

This table is claimed confidential by W.R. Grace and Co.

See Confidential Addendum: Contact Eric Noble, EPA,
(919) 541-5213

TABLE 2-21

SUMMARY OF SCRUBBERS A AND C LIQUOR ANALYSIS RESULTS
FEED GRADE UREA PRODUCTION
W.R. GRACE AND CO., MEMPHIS, TENNESSEE

This table is claimed confidential by W.R. Grace and Co.

See Confidential Addendum: Contact Eric Noble, EPA
(919) 541-5213

TABLE 2-22

AMBIENT AIR TEMPERATURE AND RELATIVE HUMIDITY
MEASUREMENTS DURING FERTILIZER GRADE UREA PRODUCTION
AT W.R. GRACE AND CO., MEMPHIS, TENNESSEE

Run Number	Date	Time	Wet Bulb (^{o}F)	Dry Bulb (^{o}F)	Relative Humidity (%)
1	08-15-79	1000	71	77	74
		1134	72	80	68
		1529	72	82	61
		1620	73	82	65
		1657	73	81	68.5
		1749	70	76	74
		1843	68	74	74
		Average	71	79	69
2	08-16-79	1125	63	75	51
		1250	64	76	51
		1330	63	78	43
		1400	65	82	39
		1500	64	82	36
		1600	65	80	44
		Average	64	79	46
3	08-17-79	1141	66	78	53
		1200	66	79	50
		1236	65	80	44
		1307	66	80	41
		1337	65	82	39
		1407	63	82	33
		1440	65	83	36.5
		1500	67	83	42.5
		Average	65	81	43

TABLE 2-23

AMBIENT AIR TEMPERATURE AND RELATIVE HUMIDITY MEASUREMENTS DURING FEED GRADE UREA PRODUCTION AT W.R. GRACE AND CO., MEMPHIS, TENNESSEE

Run Number	Date	Time	Wet Bulb (^{o}F)	Dry Bulb (^{o}F)	Relative Humidity (%)
1	08-20-79	1103	76	84	69
		1236	78	84	76
		1305	78	88	64
		1337	78	88	64
		1404	79	89	64.5
		1435	78	87	66.5
		1505	78	89	61
		1535	76	89	54.5
		1605	76	86	63
		Average	77	87	65
2	08-21-79	0945	76	84	69
		1020	76	84	69
		1105	76	85	66
		1135	77	86	66
		1205	76	85	66
		1235	76	86	63
		1305	77	87	63.5
		1335	77	89	57.5
		1405	77	89	57.5
		1435	78	89	61
		Average	77	86	64
3	08-22-79	0853	72	78	75
		0940	71	78	71
		1005	71	78	71
		1050	72	80	68
		1115	72	81	64.5
		1206	73	82	65
		1234	72	82	61
		1304	73	82	65
		1334	74	85	59.5
		1428	74	85	59.5
		1505	73	84	59
		1523	74	83	65.5
		Average	73	82	66

2.10 Process Product Sampling

Samples of the prill tower unscreened product were taken by TRC personnel during each emission test run. Bulk density and sieve analyses were then performed on these samples in the W. R. Grace and Co. laboratory. The results of these analyses are shown in Table 2-24.

Chemical analyses of samples of the urea melt and solid product were performed by W. R. Grace and Co. personnel at the plant laboratory. These analysis results are considered confidential by W. R. Grace and Co. and are not presented in this report.

TABLE 2-24

SUMMARY OF BULK DENSITY AND SIEVE ANALYSES
ON THE UNSCREENED PRODUCT SAMPLES
AT W.R. GRACE AND CO., MEMPHIS, TENNESSEE

	Percent Total Mass					Percent Total Mass			
	Fertilizer					Feed			
Date:	08-15-79	08-16-79	08-16-79	08-17-79		08-20-79	08-21-79	08-22-79	
Time:	1820	1619	1720	1510		1615	1345	1250	
Run Number:	1	2	2	3		1	2	3	
Sieve No.									
8	24.6	8.5	7.0	12.4		0.7	0.35	1.97	
10	-	-	-	41.0		0.32	0.15	0.47	
12	59.0	77.5	74.6	35.3		1.75	0.97	1.32	
14	13.7	11.9	14.8	10.1		6.47	4.34	5.49	
16	1.6	1.2	1.7	0.7		15.45	12.23	14.32	
20	0.6	-	1.0	0.2		43.04	41.83	42.23	
30	0.2	0.65	0.5	0.0		25.90	31.27	27.85	
50	0.2	0.05	0.2	0.0		6.33	8.62	6.14	
Pan	0.1	0.75	0.1	0.1		0.025	0.22	0.20	
					Average				Average
Bulk Density (g/cc)	0.730	0.750	0.750	0.754	0.746	0.760	0.780	0.770	0.770
Bulk Density (lbs/ft^3)	45.6	46.7	46.7	46.7	46.4	47.22	48.19	47.75	47.72

3.0 PROCESS DESCRIPTION

Emissions measurements were made at the W. R. Grace and Co. Agricultural Chemicals Group Facility in Memphis, Tennessee, in order to obtain data necessary to develop a new source performance standard for the urea industry. This plant is considered to employ process and emission control technology representative of modern urea solution formation and fluidized bed prilling processes.

Figure 3-1 presents a flow diagram of the solution formation and prill tower operations and indicates the location of process sampling locations (S1-S5) and emission test points (T1-T5). Emissions tests were designed to characterize and quantify uncontrolled emissions from the solids production and cooling (prill tower) processes, and to determine emission control equipment efficiencies. During the emissions tests, conducted August 13-22, 1979, process parameters pertinent to the operation of the various process streams were monitored in order to determine if the process was operating at representative steady-state conditions. Detailed information on this process monitoring is contained in Appendix L.

3.1 Process Equipment

There is one urea production line at this facility. Urea is produced by reacting ammonia and carbon dioxide using the Snamprogetti total recycle process built by C and I Gridler. The plant first started operation in October 1975. The . . . Note 1 . . . urea solution leaving the synthesis process proceeds to a two-stage vacuum evaporator where it is concentrated to 99+ percent urea. A formaldehyde additive is injected . . . Note 2 . . . to prevent caking of the product.

Note 1 - See Item 1, Confidential Addendum, contact Eric Noble, EPA, (919)541-5213.
Note 2 - See Item 1, Confidential Addendum, contact Eric Noble, EPA, (919)541-5213.

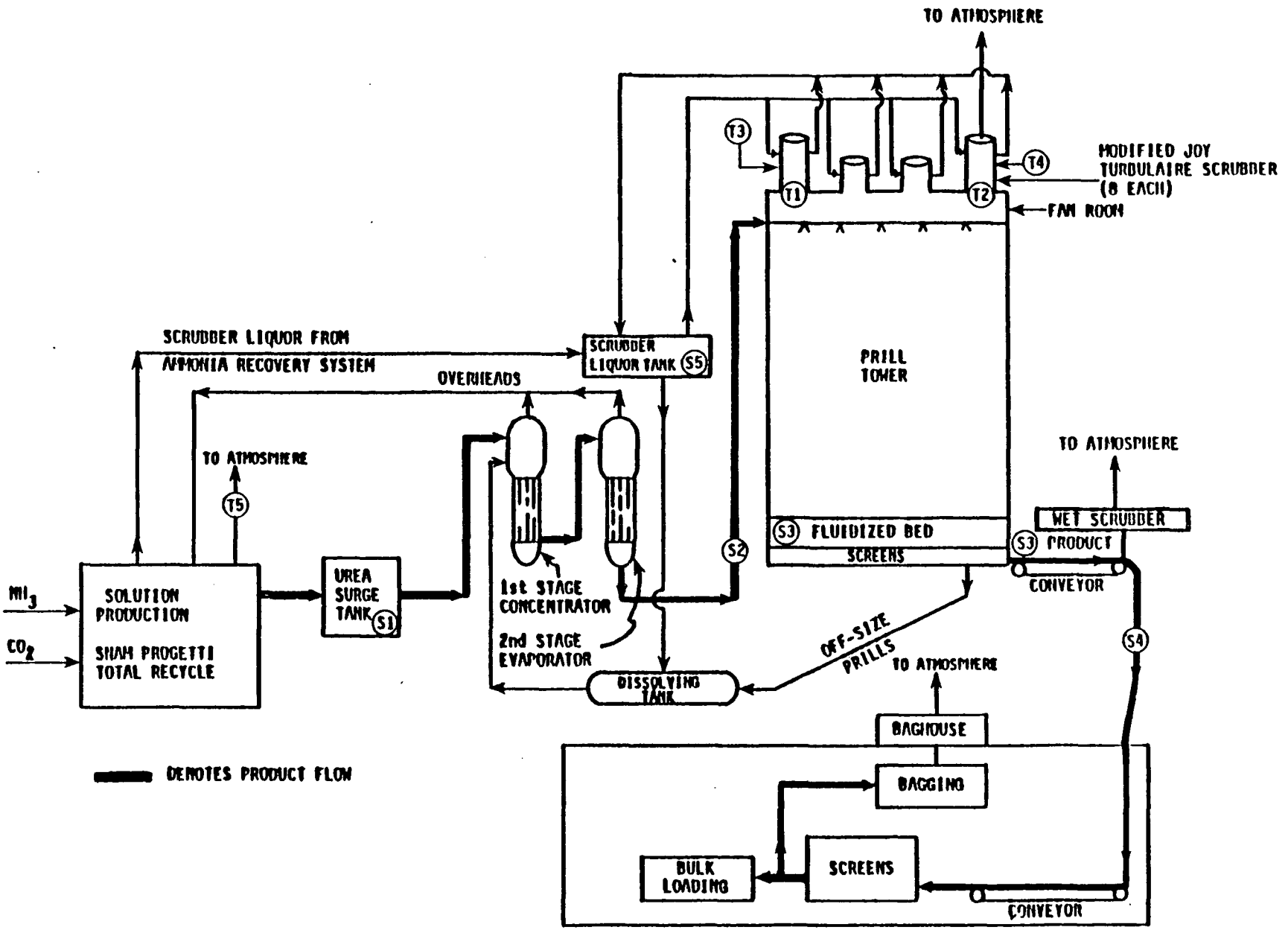


FIGURE 3-1: PROCESS FLOW DIAGRAM, W. R. GRACE AND CO., MEMPHIS, TENNESSEE

The urea melt is pumped directly to the top of the prill tower. There are . . . Note 3 . . . fittings at the top of the tower for either feed or fertilizer grade spray plates depending upon the grade being produced . . . Note 4 . . . the only difference between the two grades is the size of the prills (the feed grade being smaller) and the amount of additive injected. The number of plates in use is determined by the desired production rate and the ambient weather conditions. The maximum design production rate for the prill tower is . . . Note 5 . . . for either feed or fertilizer grade.

This prill tower employs a fluidized bed cooler near the base of the tower, eliminating the need for a separate piece of cooling equipment. The product leaving the fluidized bed cooler proceeds to a set of sizing screens. One set is used for fertilizer grade and another set is used for feed grade. The off-size material is conveyed to a dissolving tank and combined with the prill tower scrubber liquor blowdown. The contents of the dissolving tank are recycled to the process.

The correctly sized product prills are conveyed to a bulk warehouse. The conveyor transfer points are controlled by a wet scrubber. The product is temporarily stored in large piles on the warehouse floor. Front end loaders move the urea to another conveyor belt which transports the prills to . . . Note 6 . . . screens to remove . . . Note 7 . . . material. The urea can be either bagged in corner fill bagging machines or bulk shipped via truck or railcar. A baghouse controls the particulate emissions from the bagging operation. The baghouse was built by General Resource Corporation and controls about 141.6 cubic meters (500 cf) of air per minute with approximately 99.9

Note 3 - See Item 1, Confidential Addendum, Contact Eric Noble, EPA, (919) 541-5213.
Note 4 - See Item 1, Confidential Addendum, Contact Eric Noble, EPA, (919) 541-5213.
Note 5 - See Item 1, Confidential Addendum, Contact Eric Noble, EPA, (919) 541-5213.
Note 6 - See Item 1, Confidential Addendum, Contact Eric Noble, EPA, (919) 541-5213.
Note 7 - See Item 1, Confidential Addendum, Contact Eric Noble, EPA, (919) 541-5213.

percent particulate removal. Emission rates from this operation are estimated at 0.00091 kg (0.002 lbs) per hour at a velocity of 25.3 meters (83 feet) per second, while bagging 9432 kg (20800 lbs) per hour. Material collected by the baghouse is redissolved and sent back to the process.

3.2 Emission Control Equipment

There are no major emission points from the urea synthesis and concentration steps since these are total recycle operations. The overheads from the two stages of concentration are totally condensed and returned to the synthesis operation. The major constituent of emissions is clean steam which is used to keep the pressure safety valves free. Other emissions to the atmosphere include air, used to stabilize the CO_2 feed stock; and a small amount of ammonia vented from various sources, including the urea surge tank, dilute carbamate tank, carbamate condenser, and aqua solution cooler.

On the roof of the prill tower, eight modified Joy Turbulaire Type "D" impingement scrubbers control the total air flow through the prill tower and the fluidized bed. The number of scrubbers in use at any one time depends upon factors such as the feed rate of urea melt, desired prill size, and ambient temperature and humidity . . . Note 8 . . .

The eight scrubbers were installed when the plant was built as originally designed. Each scrubber used two fans in series, rated at 149200 watts (200 horsepower) each. In addition, a packed bed was installed to help control ammonia emissions. As a result of stack emission tests after the plant started operation, the units were redesigned so that only one fan was required for each scrubber. This redesign was performed in conjunction with the elimination of the packed bed . . . Note 9 . . .

Note 8 - See Item 1, Confidential Addendum, Contact Eric Noble, EPA, (919) 541-5213.
Note 9 - See Item 1, Confidential Addendum, Contact Eric Noble, EPA, (919) 541-5213.

Scrubber liquor used for the Joy scrubbers comes from the ammonia recovery strippers . . . Note 10 . . . A bleed stream is taken from the scrubber liquor holding tank on top of the tower and is concentrated to 50 percent by the addition of off-size urea prills from the product screens. This stream is recycled back to the concentrator.

3.3 Production Rate Monitoring

In order to determine whether the production line was operating at representative steady-state conditions during testing, various process and control equipment operating parameters were monitored . . . Note 11 . . .

During testing of the prill tower, a radioactive source product counter was used to measure the weight of the product leaving the screens . . . Note 12 . . . Before the testing was started the product counter was calibrated by filling a railcar directly and weighing the railcar before and after. The weight difference was compared with the product counter readings and a calibration factor was calculated . . . Note 13 . . . Table 3-1 presents average production rates for the prill tower during fertilizer grade and feed grade tests.

During testing of the urea synthesis and concentration operations, the flowrate of the urea solution to the concentrators was monitored and recorded. A urea surge tank is located between the synthesis and concentration steps. This surge tank was maintained at a constant level, thus allowing the use of the flow meter to relate the synthesis production rate to the concentration production flow. Both the NH_3 and CO_2 feed rates to the

Note 10 - See Item 1, Confidential Addendum, Contact Eric Noble, EPA, (919) 541-5213.
Note 11 - See Item 1, Confidential Addendum, Contact Eric Noble, EPA, (919) 541-5213.
Note 12 - See Item 1, Confidential Addendum, Contact Eric Noble, EPA, (919) 541-5213.
Note 13 - See Item 1, Confidential Addendum, Contact Eric Noble, EPA, (919) 541-5213.

TABLE 3-1

AVERAGE PRODUCTION RATES
DURING EMISSIONS TESTS
AT W.R. GRACE AND CO., MEMPHIS, TENNESSEE

Process	Test	Production Rate Tons/Hr	Mg/Hr**
Prill Tower-Fertilizer	Inlets & Outlets to A & C Scrubbers Test No. 1	43.5	39.4
	Inlets & Outlets to A & C Scrubbers Test No. 2	45.8	41.6
	Inlets & Outlets to A & C Scrubbers Test No. 3	45.5	41.3
	Inlet to A Scrubber Particle Size Test No. 1	57.2*	51.9
	Inlet to A Scrubber Particle Size Test No. 2	45.5	41.3
	Inlet to A Scrubber Particle Size Test No. 3	45.8	41.5
	Inlet to C Scrubber Particle Size Test No. 1	48.3	43.8
	Inlet to C Scrubber Particle Size Test No. 2	46.9	42.5
	Inlet to C Scrubber Particle Size Test No. 3	45.8	41.5
Prill Tower-Feed	Inlets & Outlets to A & C Scrubbers Test No. 1	47.2	42.8
	Inlets & Outlets to A & C Scrubbers Test No. 2	47.4	43.0
	Inlets & Outlets to A & C Scrubbers Test No. 3	45.9	41.6
	Inlet to A Scrubber Particle Size Test No. 1	46.4	42.1
	Inlet to A Scrubber Particle Size Test No. 2	45.3	41.1
	Inlet to A Scrubber Particle Size Test No. 3	46.5	42.2
	Inlet to C Scrubber Particle Size Test No. 1	44.7	40.5
	Inlet to C Scrubber Particle Size Test No. 2	46.9	42.5
	Inlet to C Scrubber Particle Size Test No. 3	46.8	42.4
Synthesis Tower	Synthesis & Concentration Test No. 1	47.9	43.4
	Synthesis & Concentration Test No. 2	47.9	43.4
	Synthesis & Concentration Test No. 3	49.9	45.3

* Although the production rate data indicated this production rate, this value is questionable.

**10^6 grams per hour.

synthesis process were also monitored to provide a check on the urea solution flow meter . . . Note 14 . . . The average production rates for each synthesis and concentration test are shown in Table 3-1 also.

3.4 Production and Control Equipment Monitoring

In addition to the production rate determinations mentioned above, other parameters were also monitored. During testing of the prill tower and its scrubber emissions, spray header pressure, temperature of the melt after the second evaporator, flowrate of the first concentrator, evaporator level, flow rate of formaldehyde additive, density of the scrubber liquor in the holding tank, and the level in the tank between the synthesis and concentration operations were monitored and recorded . . . Note 15 . . .

Other synthesis and concentration operations parameters monitored and recorded were: the ammonia feed rate and pressure; the carbon dioxide feed rate, pressure, and temperature; the reactor skin and top temperatures; the urea surge tank level and temperature; the dilute carbamate tank pressure; the carbamate condenser pressure; aqua solution cooler pressure; and the percent oxygen in the carbon dioxide feed . . . Note 16 . . .

Due to the confidential nature of the monitored parameters, averages and standard deviations cannot be presented. Instead, relative averages and relative standard deviations expressed as percents are shown in Tables 3-2, 3-3 and 3-4. A value of one hundred percent represents the exact average of all the values of that parameter for that series of tests. Standard deviations were not calculated for particle size tests due to the limited number of readings (three or less) . . . Note 17 . . .

Note 14 - See Item 1, Confidential Addendum, Contact Eric Noble, EPA, (919) 541-5213.
Note 15 - See Item 1, Confidential Addendum, Contact Eric Noble, EPA, (919) 541-5213.
Note 16 - See Item 1, Confidential Addendum, Contact Eric Noble, EPA, (919) 541-5213.
Note 17 - See Item 1, Confidential Addendum, Contact Eric Noble, EPA, (919) 541-5213.

TABLE 3-2

RELATIVE VALUES OF OPERATING PARAMETERS
DURING FERTILIZER GRADE PRILL TOWER EMISSION TESTS
(EXPRESSED AS PERCENT OF THE AVERAGE)*

	Scrubber Efficiency Tests						Particle Size Tests					
	Test No. 1		Test No. 2		Test No. 3		Inlet to A Scrubber			Inlet to C Scrubber		
Parameter	AVG.	Std. Dev.	AVG.	Std. Dev.	AVG.	Std. Dev.	Test 1	Test 2	Test 3	Test 1	Test 2	Test 3
Spray Header Pressure	94	300	93	0.00	93	0.00	133	100	100	101	93	93
Melt Temperature	100	0.00	100	135	100	165	99	100	100	100	100	101
Flow to 1st Concentrator	100	182	99	59	99	59	-	102	102	100	99	99
Evaporator Level	98	45	94	151	101	104	93	95	95	98	100	127
Additive Flow Rate	84	80	90	112	125	108	-	92	92	102	82	133
S. G.** of Scrubber Liquor	100	0.00	100	0.00	100	300	100	100	100	100	100	100
Urea Surge Tank Level	71	149	84	44	157	106	52	75	75	54	122	209
Unscreened Product Temperature	98	101	101	114	101	85	-	-	-	-	-	-

** Specific Gravity

* The numbers presented in this Table were derived by averaging all the values from all three of the fertilizer grade tests and dividing that number into the average for a particular test. Standard deviations were not calculated for particle size tests due to the limited number of readings (three or less).

TABLE 3-3

RELATIVE VALUES OF OPERATING PARAMETERS
DURING FEED GRADE PRILL TOWER EMISSION TESTS
(EXPRESSED AS PERCENT OF THE AVERAGE)*

	Scrubber Efficiency Tests						Particle Size Tests					
	Test No. 1		Test No. 2		Test No. 3		Inlet to A Scrubber			Inlet to C Scrubber		
Parameter	AVG.	Std. Dev.	AVG.	Std. Dev.	AVG.	Std. Dev.	Test 1	Test 2	Test 3	Test 1	Test 2	Test 3
Spray Head Pressure	101	129	97	147	101	24	97	99	111	95	89	109
Melt Temperature	100	98	100	105	100	98	100	100	100	100	100	100
Flow to 1st Concentrator	103	102	99	130	99	68	99	99	99	102	99	99
Evaporator Level	90	93	95	102	95	105	89	85	137	90	85	136
Additive Flow Rate	92	188	107	46	99	65	106	100	100	89	107	99
S. G.** of Scrubber Liquor	100	0.00	100	300	100	0.00	100	100	100	100	100	100
Urea Surge Tank Level	169	0.00	149	148	21	152	169	15	44	169	139	26
Unscreened Product Temperature	103	30	102	100	95	170	-	-	-	-	-	-

** Specific Gravity

* The numbers presented in this table were derived by averaging all the values from all three of the feed grade tests and dividing that number into the average of a particular test. Standard deviations were not calculated for particle size tests due to the limited number of readings (three or less).

TABLE 3-4

RELATIVE VALUES OF OPERATING PARAMETERS
DURING SYNTHESIS VENT EMISSION TESTING
(EXPRESSED AS PERCENT OF THE AVERAGE)*

	Test 1		Test 2		Test 3	
Parameter	AVG.	Std. Dev.	AVG.	Std. Dev.	AVG.	Std. Dev.
NH_3 Feed Rate	101	0.00	99	0.00	100	300
CO_2 Feed Rate	99	0.00	100	0.00	101	300
NH_3 Pressure to Reactor	103	0.00	98	0.00	99	300
CO_2 Pressure to Reactor	98	0.00	101	0.00	101	0.00
Reactor Skin Temperature	100	0.00	100	0.00	100	0.00
Reactor Top Temperature	100	0.00	100	0.00	100	0.00
Urea Surge Tank Temperature	100	0.00	100	0.00	100	0.00
Urea Surge Tank Level	56	0.00	111	0.00	133	0.00
Flow to 1st Concentrator	98	0.00	98	0.00	104	300
Dilute Carbamate Tank Pressure	96	100	99	88	105	112
Carbamate Condensor Pressure	100	0.00	100	0.00	100	0.00
Aqua Solution Cooler Pressure	100	0.00	100	0.00	100	0.00
% O_2 in CO_2 Feed	94	0.00	107	300	99	0.00
CO_2 Feed Temperature	99	0.00	100	0.00	100	0.00

* Note: The numbers presented in this table are derived by averaging all the values from all three of the synthesis vent tests and dividing that number into the average for a particular test.

3.5 General Plant Operation

Overall, the entire urea plant operated smoothly, as the data in Tables 3-1 through 3-4 indicate. However, just before the first fertilizer grade particulate test on the inlets and outlets to scrubbers A and C, the fan belts on scrubber C broke causing a one hour and fifteen minute delay in starting the test. In addition to the fan belts problem, some of the CO_2 compressors went down occassionally for short periods of time, but not during synthesis tower tests. During the third test of the synthesis vent, the feed rate of the urea melt to the concentrators had to be slightly increased in order to maintain the level in the urea surge tank. None of these problems should affect the test results.

4.0 LOCATION OF SAMPLING POINTS

This section presents descriptions of the sampling locations used during the emissions testing program conducted at the W. R. Grace and Co. urea manufacturing plant in Memphis, Tennessee during August and December 1979. Figure 4-1 shows an overhead schematic of the prill tower and adjacent facilities. Figure 4-2 shows a cross-sectional schematic of the prill tower and one of the eight identical scrubbers atop the prill tower.

4.1 Prill Tower Scrubber Inlets

The scrubber A and scrubber C inlet sampling sites were each located in 59 3/8 inch I.D. vertical sections of steel duct. A schematic of these identical inlets, including traverse point locations, is present in Figure 4-3.

Two four-inch pipe flange sampling ports positioned 90 degrees apart were located 77 inches (1.3 duct diameters) downstream from the top of the inside of the prill tower; the nearest disturbance downstream from the ports was a contraction beginning 38 1/2 inches (0.7 duct diameters) from the ports.

The inlet sampling locations did not meet the "eight and two diameters" criterion as described in EPA Method 1; hence 24 sampling points were used on each of the two traverse axes, for a total of 48 sampling points. Figure 4-3 shows a cross-sectional view of the duct at the sampling location and the exact distance of each traverse point from the outside flange edge.

The scrubber A and scrubber C inlets were tested for particulate, while scrubber inlets B, D, E, F, G and H (each identical to the A and C inlets) were monitored only for temperature and gas velocity. Consequently, for these six inlets only 14 sampling points were used on each traverse axis, for a total of 28 sampling points for each inlet as specified by EPA Method 1. These points were located as shown in Figure 4-4, which shows a cross-

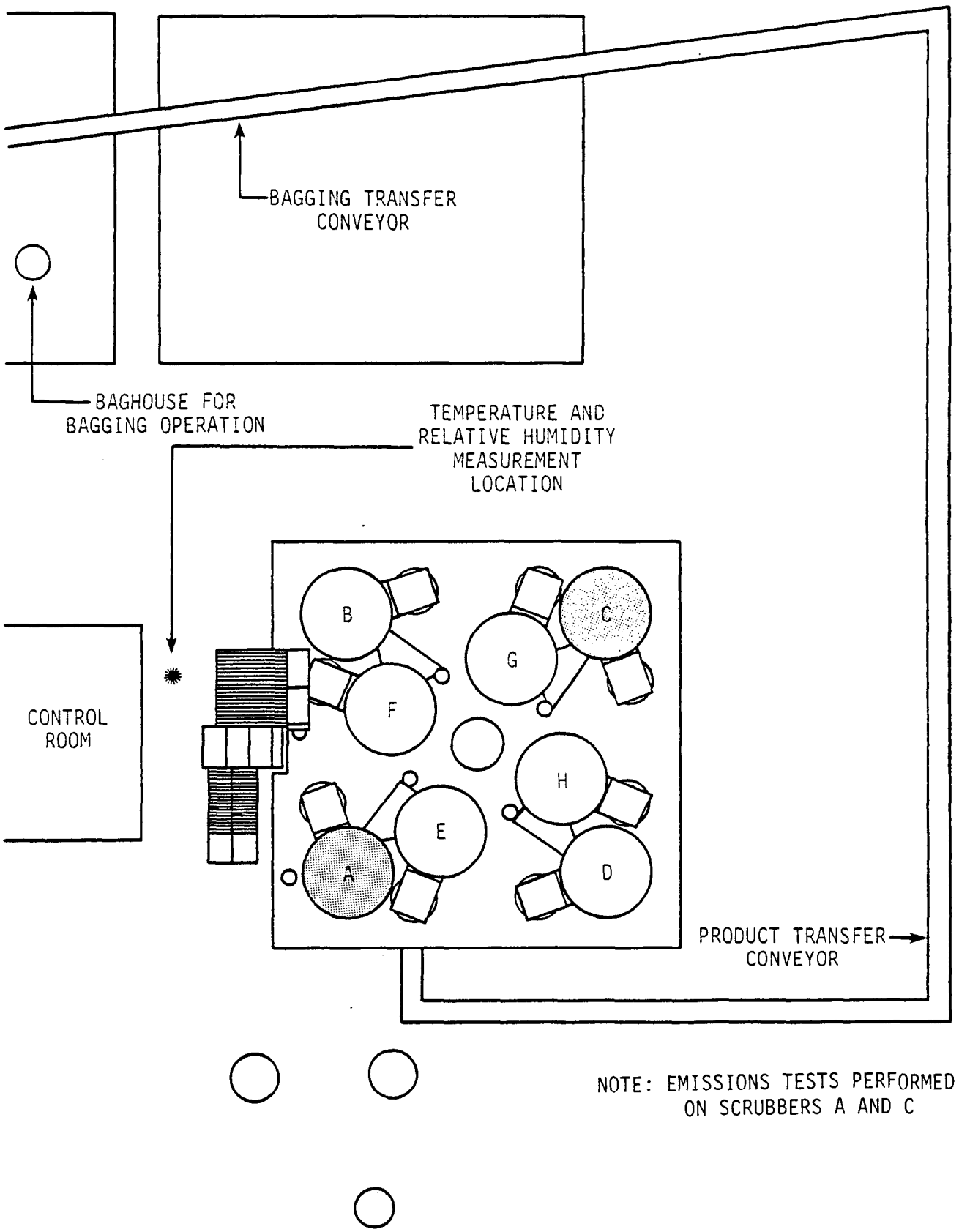


FIGURE 4-1: OVERHEAD VIEW OF PRILL TOWER AT W. R. GRACE AND CO., MEMPHIS, TENNESSEE

0988-011-001

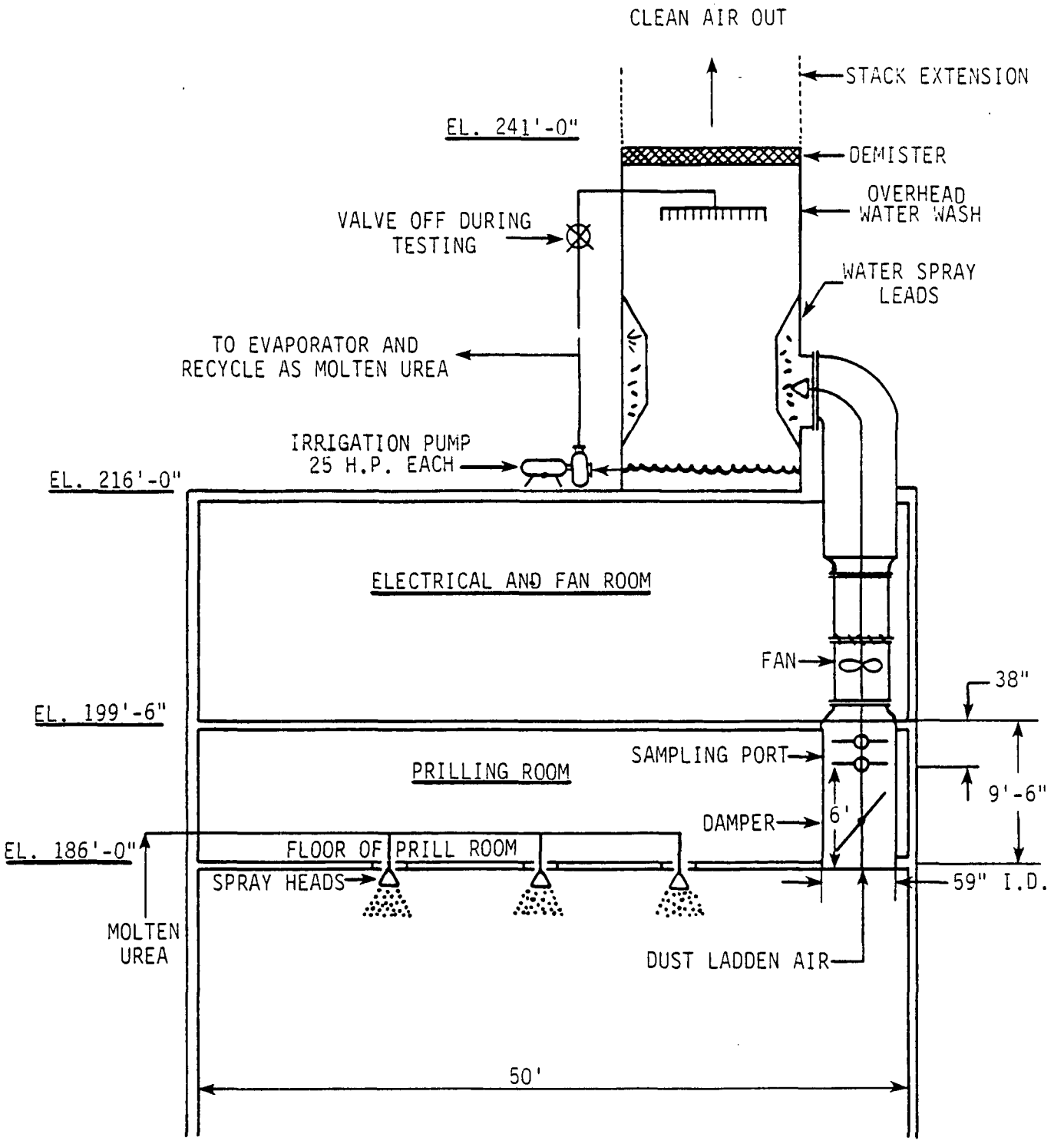


FIGURE 4-2: SCHEMATIC OF PRILL TOWER AND TYPICAL SCRUBBER AT W. R. GRACE AND CO., MEMPHIS, TENNESSEE

0988-012-001

TRAVERSE POINT NUMBER	TRAVERSE POINT LOCATION FROM OUTSIDE OF NIPPLE (INCHES)
1	5
2	5-7/8
3	7-1/4
4	8-5/8
5	10-1/4
6	11-3/4
7	13-1/2
8	15-1/2
9	17-5/8
10	20
11	23
12	27-1/2
13	39-1/2
14	43-7/8
15	47
16	49-3/8
17	51-1/2
18	53-1/2
19	55-1/4
20	56-3/4
21	58-3/8
22	59-3/4
23	61-1/8
24	62

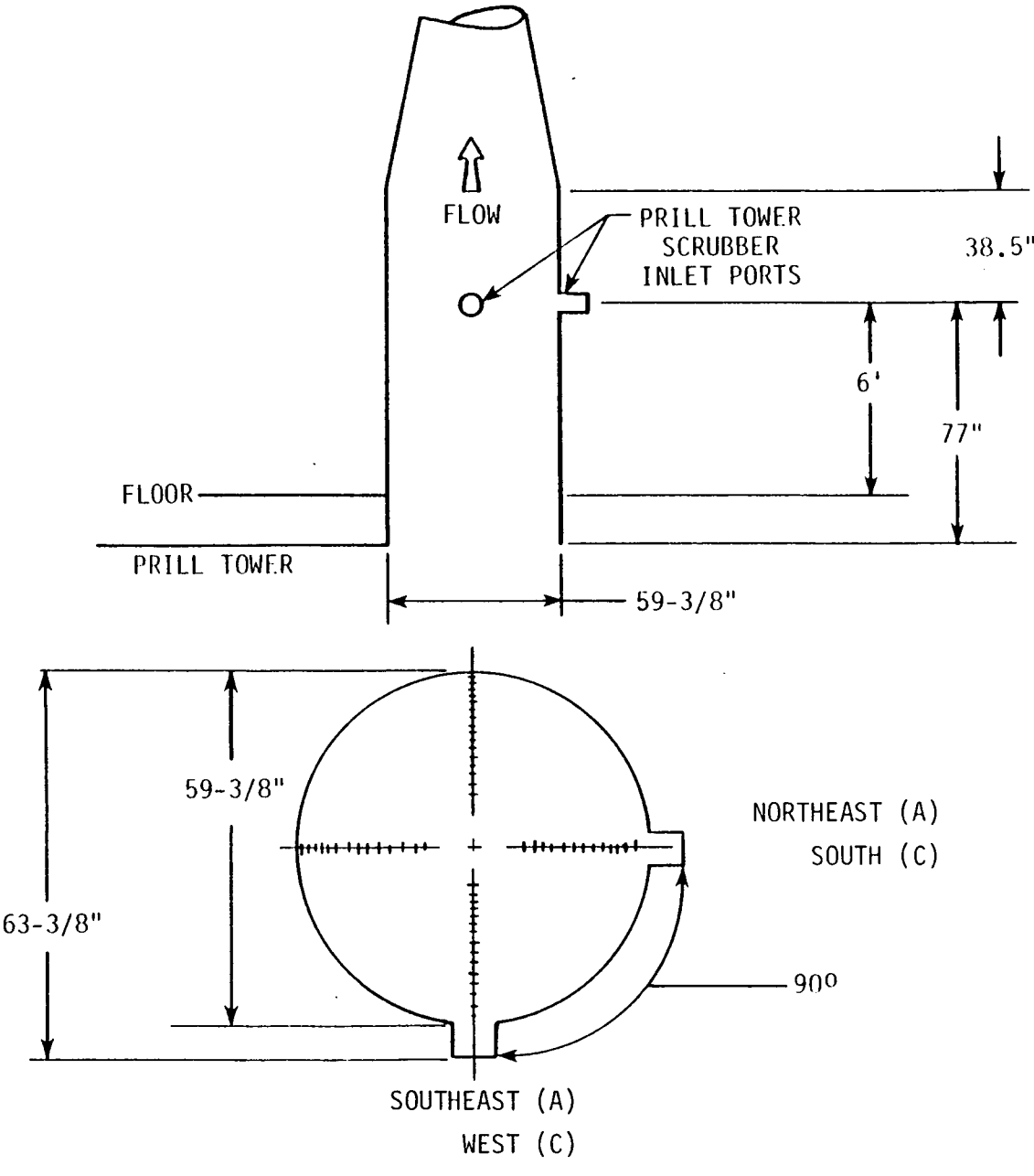


FIGURE 4-3: SCRUBBERS A AND C INLET SAMPLING LOCATIONS (BOTH IDENTICAL)
W. R. GRACE AND CO., MEMPHIS, TENNESSEE

0988-013-001

TRAVERSE POINT NUMBER	TRAVERSE POINT LOCATION FROM OUTSIDE OF NIPPLE (INCHES)
1	5.1
2	7.4
3	9.8
4	12.6
5	15.9
6	19.9
7	25.6
8	41.4
9	47.1
10	51.1
11	54.4
12	57.2
13	59.6
14	61.9

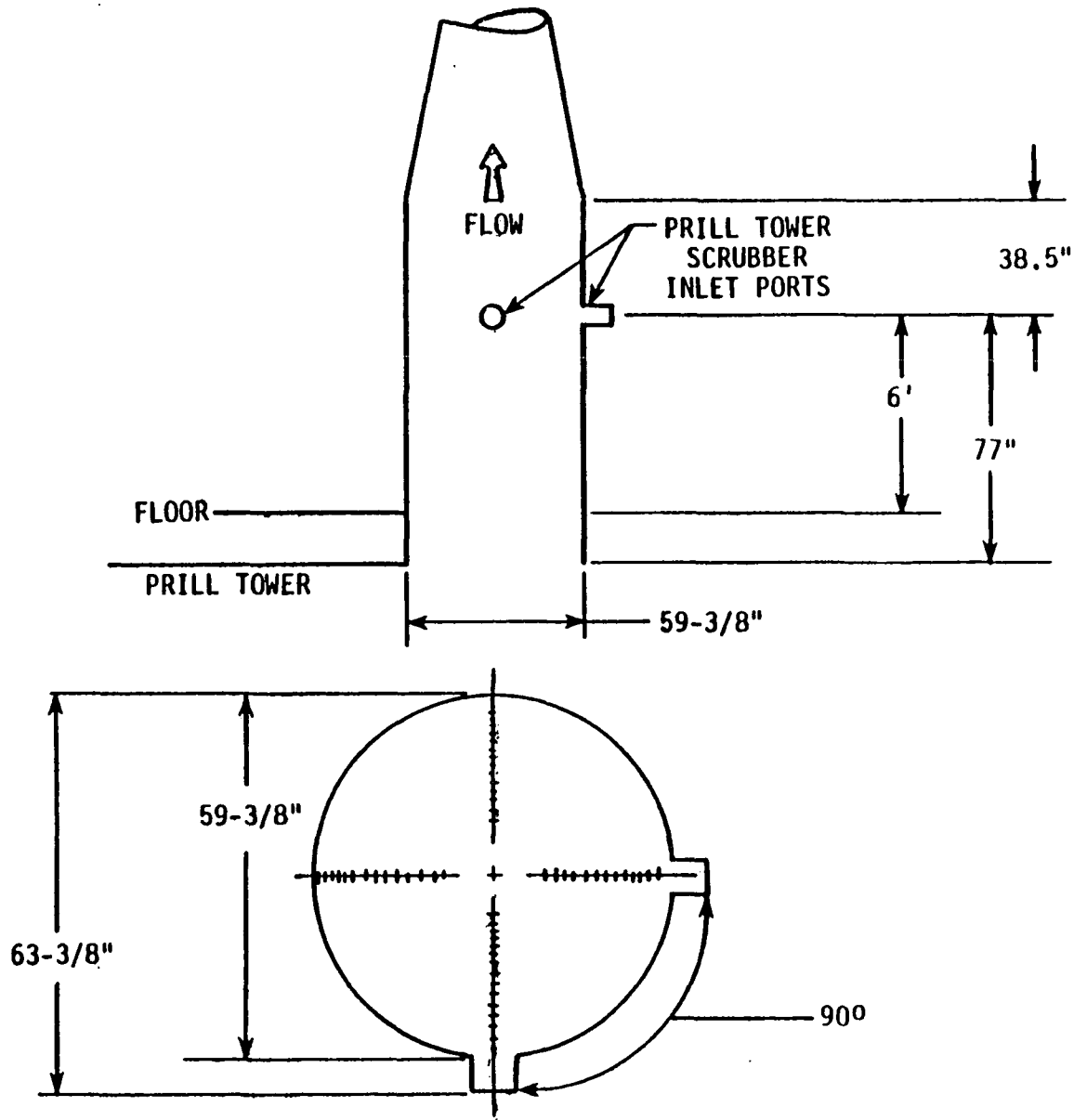


FIGURE 4-4: SCRUBBERS B,D,E,F,G,H INLET SAMPLING LOCATIONS (ALL IDENTICAL)
W. R. GRACE AND CO., MEMPHIS, TENNESSEE

0988-014

sectional view of a duct at the sampling location and lists the exact distance of each traverse point from the outside flange edge.

4.2 Scrubber A and C Outlets

After passing the inlet test section, the prill tower dust-laden gases are drawn through a fan which discharges to the scrubber. The cleaned gases are then exhausted to the atmosphere through a mist pad. A stack extension approximately 10 feet in height was added so that a reasonable sampling traverse plane could be established free from interferences from the mist pad and the wind.

The A and C scrubber outlet stacks were 144 inches in internal diameter and were fitted with two 1-3/4 inch pipe flange sampling ports positioned 90^{o} apart. The sampling ports were located 2 feet 6 inches (0.2 duct diameters) downstream from the mist pad, and 8 feet 3 inches (0.7 duct diameters) upstream from the top of the stack extension.

The outlet sampling locations did not meet the "eight and two diameters" criterion as outlined in EPA Method 1; hence 24 sampling points were chosen for each traverse axis for a total of 48 sampling points at each outlet. These points were located as detailed in Figure 4-5, which shows the cross-sectional view of the duct at the sampling location and lists the exact distance of each traverse point from the outside flange edge.

4.3 Inlet Particle Sizing Locations

Particle sizing tests were performed in both the scrubber A and the scrubber C inlet gas streams. An in-stack cascade impactor was positioned in the duct through a port used for the particulate emissions tests. The impactor nozzle was positioned for each run at a point of average velocity as deter-

TRAVERSE POINT NUMBER	TRAVERSE POINT LOCATION FROM OUTSIDE OF NIPPLE (INCHES)
1	3-3/8
2	6-3/8
3	9-5/8
4	13-1/8
5	16-7/8
6	20-3/4
7	24-7/8
8	29-5/8
9	34-7/8
10	40-7/8
11	48-1/4
12	59
13	88-1/2
14	99-1/4
15	106-5/8
16	112-5/8
17	117-7/8
18	122-5/8
19	126-3/4
20	130-5/8
21	134-3/8
22	137-7/8
23	141-1/8
24	144-1/8

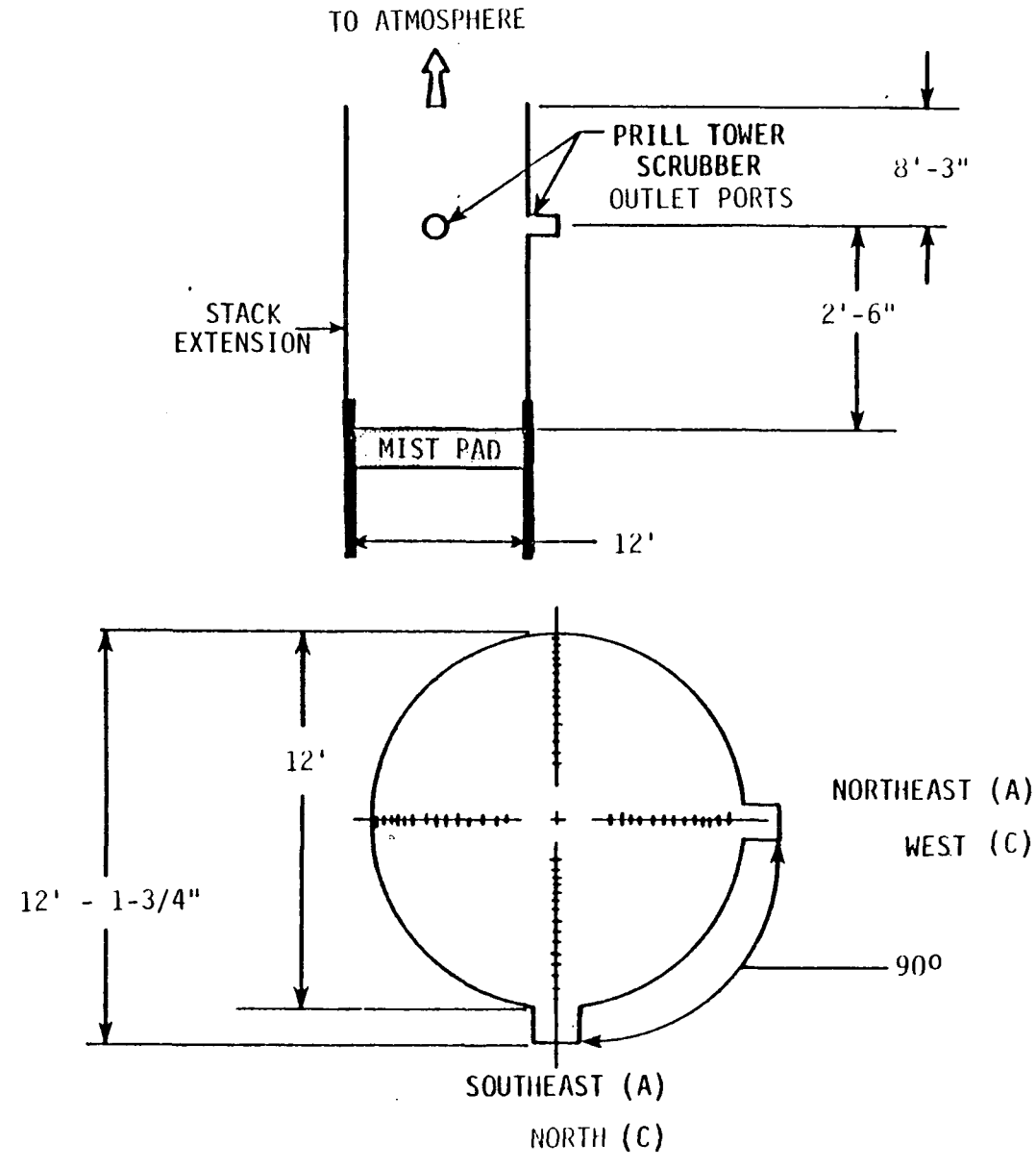


FIGURE 4-5: SCRUBBERS A AND C OUTLET SAMPLING LOCATIONS (BOTH IDENTICAL)
W. R. GRACE AND CO., MEMPHIS, TENNESSEE

0988-015-001

mined by preliminary velocity traverses performed before each particle size test run. The impactor nozzle was rotated directly into the gas stream at an angle determined by the cyclonic flow angle traverses.

The specific sampling ports and points used during the particle size test runs were as follows (see Figure 4-3):

Scrubber Inlet	Fertilizer Test Runs			Feed Test Runs		
	1	2	3	1	2	3
A	SE-11	NE-8	NE-8	SE-3	NE-8	NE-12
C	S-5	S-5	S-5	S-22	S-20	W-15

4.4 Urea Synthesis Tower Main Vent Sampling Location

The synthesis tower vent sampling location was in a 29-inch I.D. vertical section of steel duct containing one four-inch pipe flange sampling port. This port location met the "eight and two diameters" criterion which would have allowed, in this case, a total of 12 sampling points over two traverses. However, because of the physical limitations incurred by the use of an in-stack orifice, only the back half of the one traverse could be sampled for a total of 3 sampling points. These points were located as shown in Figure 4-6.

4.5 Visible Emissions Observation Locations

The white plumes exiting the prill tower scrubber stacks were observed from nine different locations. These locations were chosen to conform with EPA Reference Method 9 requirements and to allow observation of both individual and combined scrubber plumes. The plume from the baghouse on top of the bagging operation warehouse was observed from within 15 feet of the baghouse outlet. These locations are described in Table 4-1 and shown in Figures 4-7 and 4-8.

TRAVERSE POINT NUMBER	TRAVERSE POINT LOCATION FROM OUTSIDE OF NIPPLE (INCHES)
1	5-1/4
2	8-1/4
3	12-1/2
POINTS SAMPLED 4	24-3/8
POINTS SAMPLED 5	28-3/4
POINTS SAMPLED 6	31-3/4

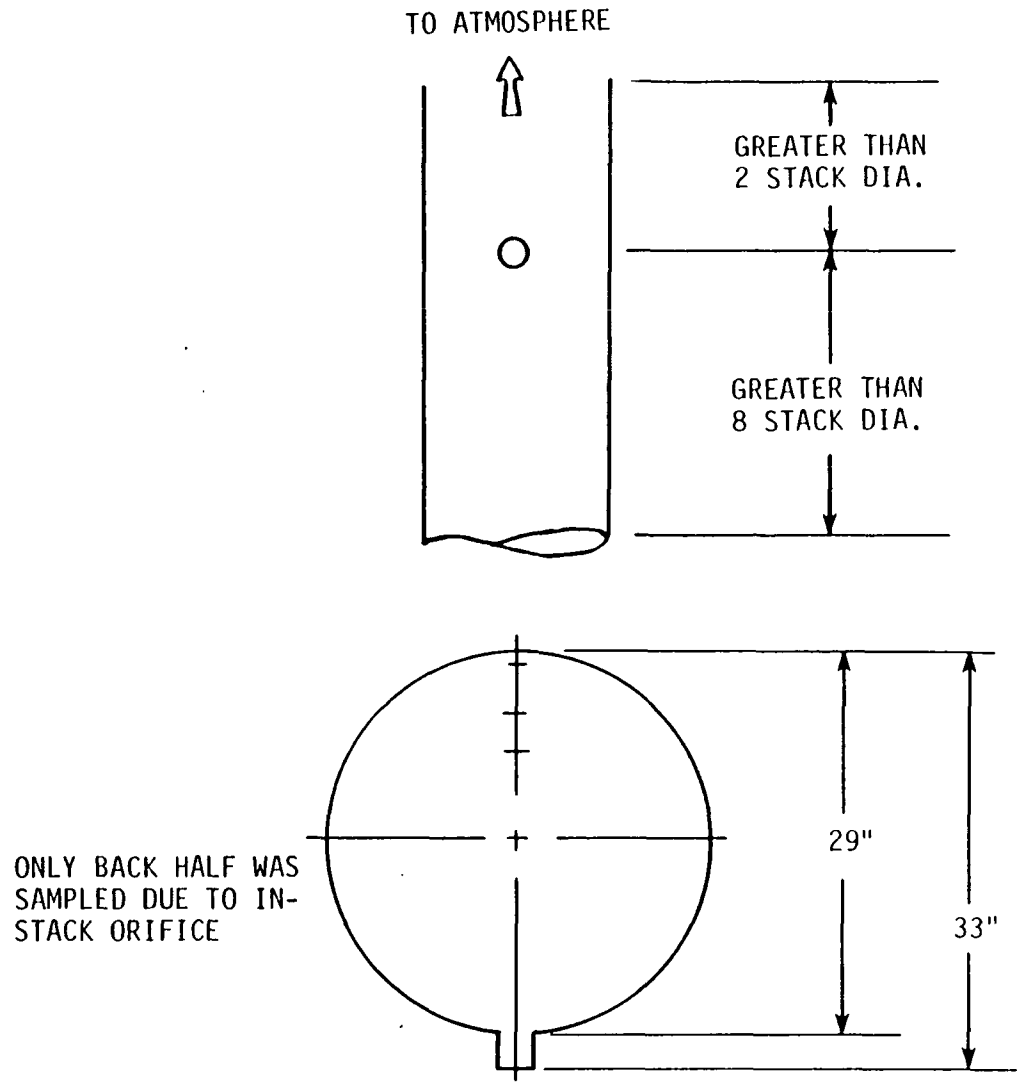


FIGURE 4-6: LOCATION OF SOLUTION TOWER TEST PORTS AND POINTS AT W. R. GRACE AND CO., MEMPHIS, TENNESSEE

0988-016

TABLE 4-1

VISIBLE EMISSION OBSERVATION LOCATIONS
AT W.R. GRACE AND CO., MEMPHIS, TENNESSEE

Observer Location	Distance To Discharge Point (Feet)	Height Above Ground (Feet)	Direction From Discharge Point	Discharge Description
A	450	0	SE	Prill Tower
B	40	200	SSE	"
C	450	0	E	"
D	450	0	SE	"
E	450	0	SSW	"
F	40	200	E	"
G	400	0	SW	"
H	500	0	S	"
I	400	0	ESS	"
J	5-15	0	S	Bag House

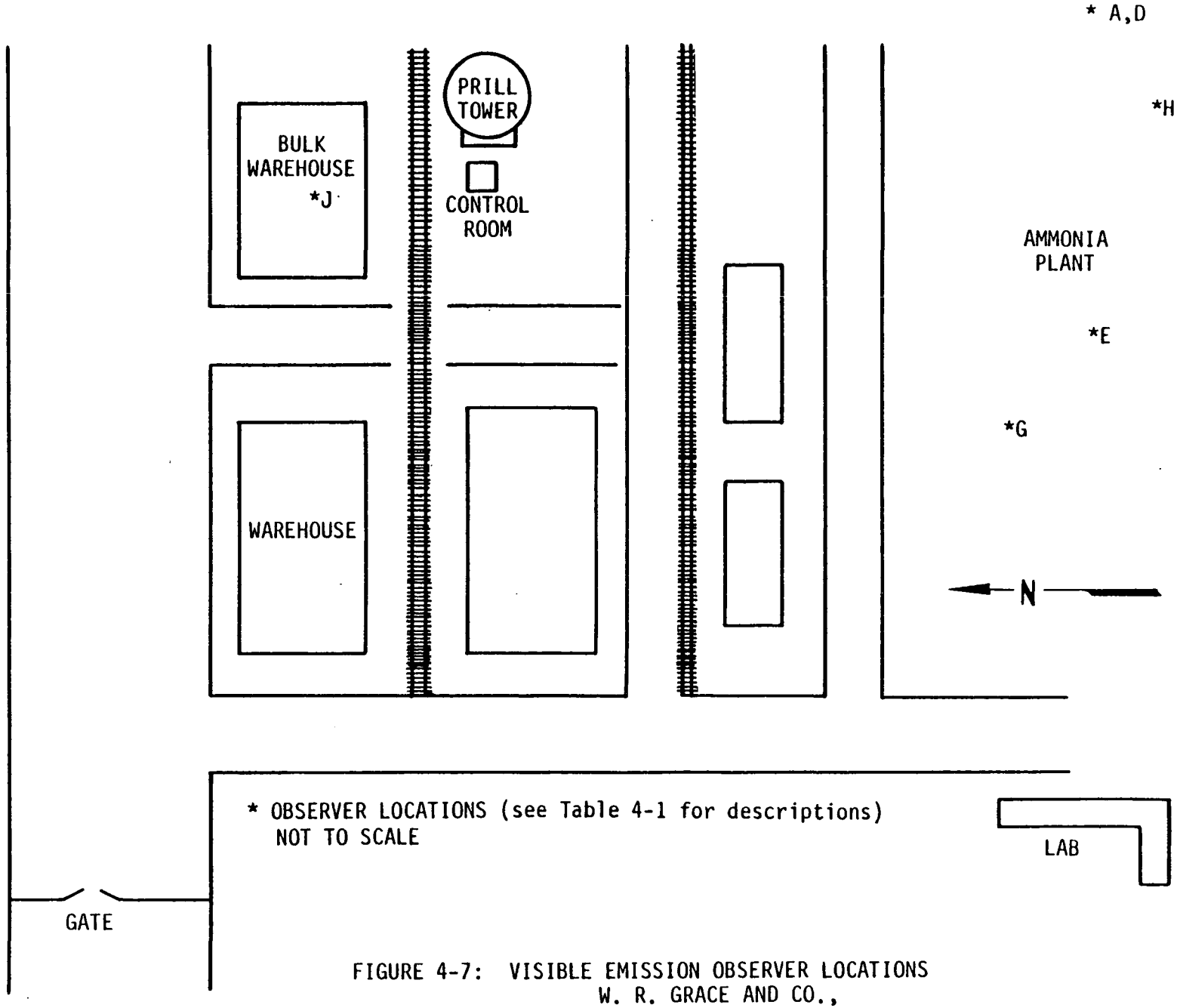
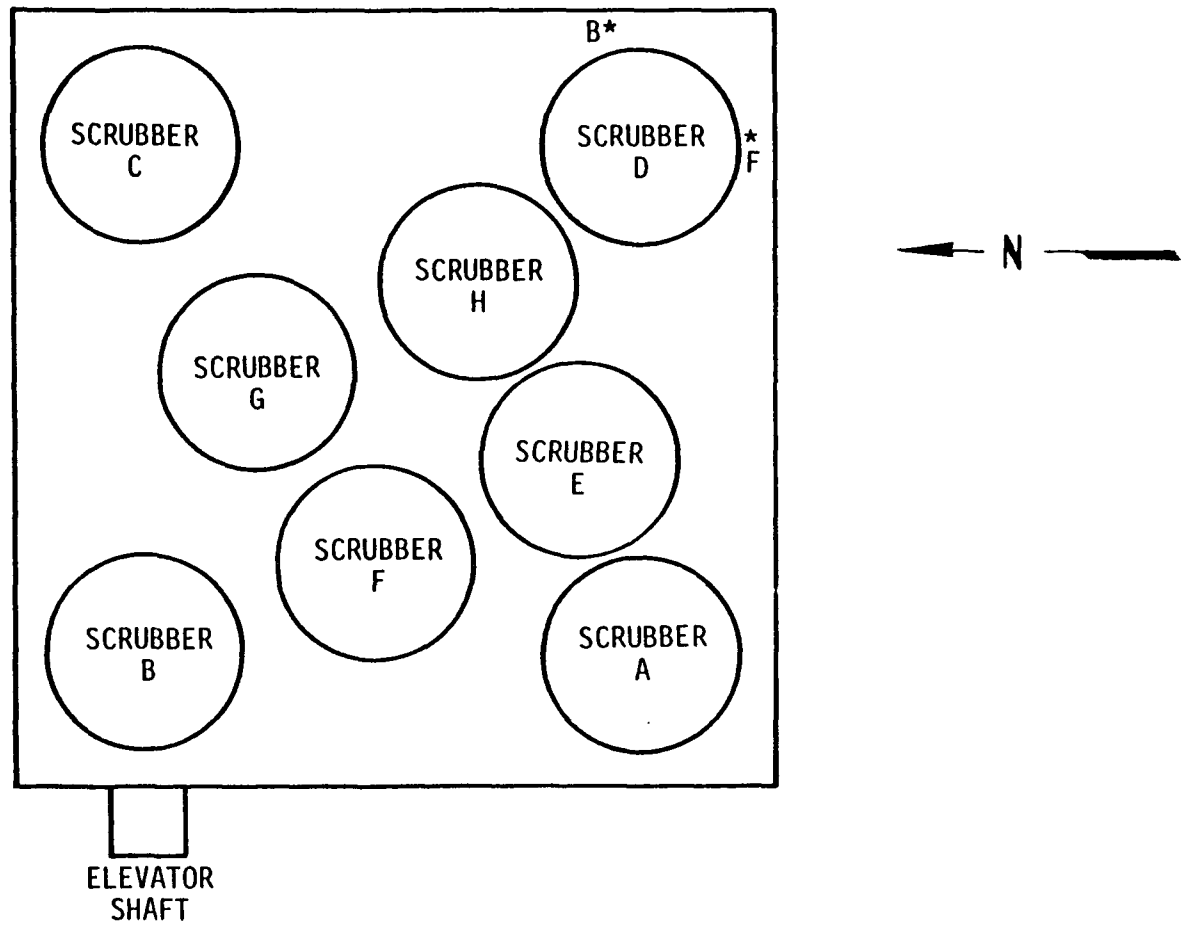


FIGURE 4-7: VISIBLE EMISSION OBSERVER LOCATIONS
W. R. GRACE AND CO.,
MEMPHIS, TENNESSEE

0988-017

TOP VIEW OF PRILL TOWER



POSITION B OBSERVING STACK C

POSITION F OBSERVING STACK A

* OBSERVER LOCATIONS
(see Table 4-1 for descriptions)

FIGURE 4-8: VISIBLE EMISSION OBSERVER LOCATIONS AT W. R. GRACE AND CO., MEMPHIS, TENNESSEE

0988-018

The plumes were all observed against partly cloudy or clear blue skies. The urea synthesis tower vent plume continuously mingled with some of the scrubber plumes so that separate opacity readings for the vent plume were not possible.

4.6 Scrubber Pressure Drop Measurement Locations

Pressure drops across the eight prill tower scrubbers were measured with a verticle U-tube water manometer connected across the venturi throat of each scrubber.

4.7 Process Sample Collection Locations

The unscreened solid product samples were collected during both fertilizer and feed grade tests. The samples were collected at the bottom of the prill tower, as the product fell onto the vibrator screens. Samples of the synthesis solution and urea melt were also taken directly from their associated processes.

4.8 Scrubber Liquor Collection Locations

Scrubber liquor samples were collected from the streams entering and exiting the prill tower A and C scrubbers. The samples were collected at three locations as shown in Figure 4-9. Outlet samples were collected from the separate return pipes adjacent to scrubbers A and C. The inlet samples were collected from one tap on the common sump feeding all of the scrubbers.

4.9 Ambient Air Temperature and Relative Humidity Measurement Location

Ambient air temperature and relative humidity measurements were taken at the base of the prill tower during each emission test run. Figure 4-1 shows the location of this measurement point.

TOP VIEW OF PRILL TOWER

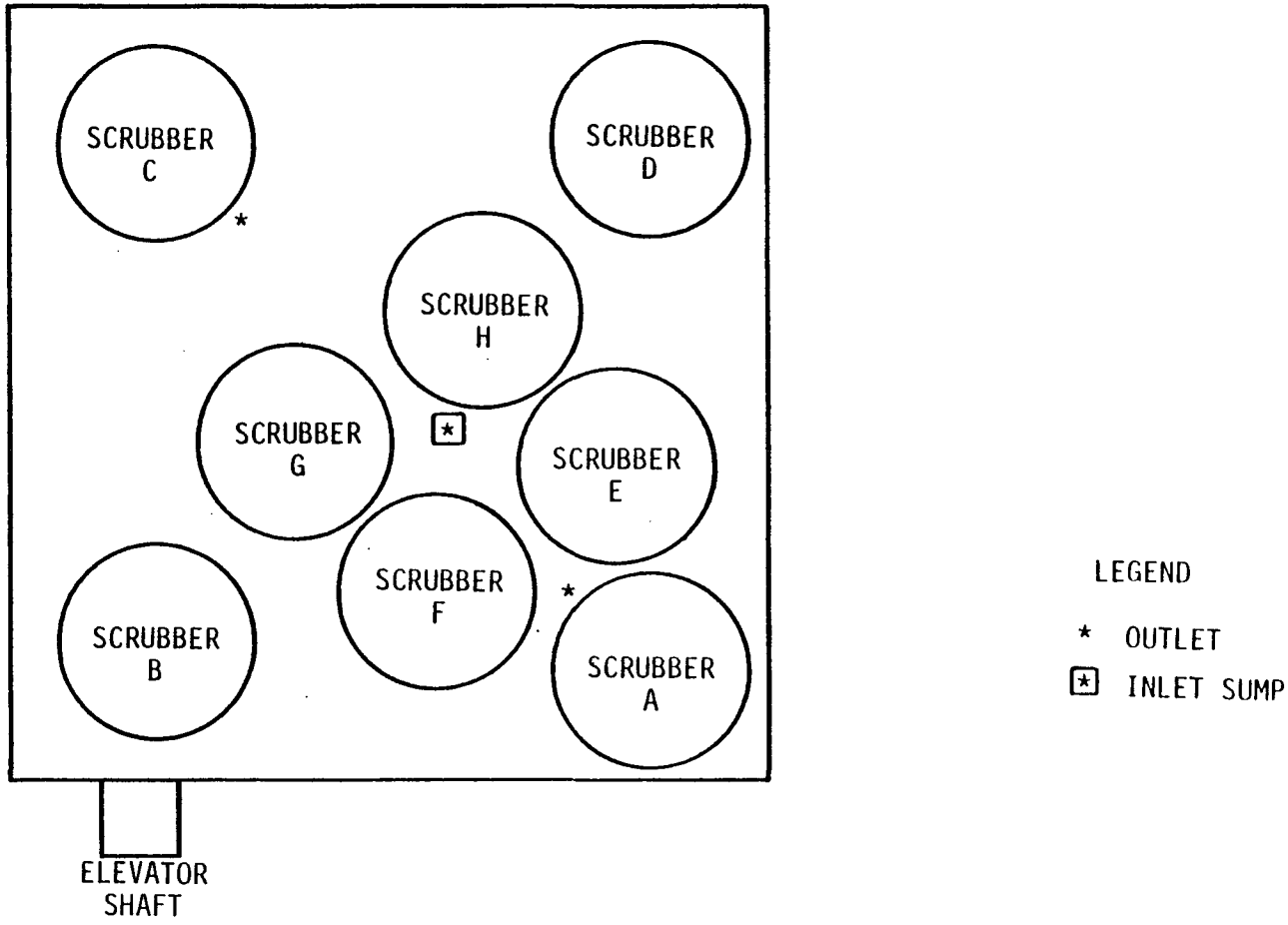


FIGURE 4-9: SCRUBBER LIQUOR SAMPLING POINTS ON THE PRILL TOWER AT W. R. GRACE AND CO., MEMPHIS, TENNESSEE

0988-019

5.0 SAMPLING AND ANALYSIS METHODS

This section presents general description of sampling and analysis procedures employed during the emissions testing program conducted at the W. R. Grace and Co., Memphis, Tennessee urea manufacturing facility during August 13-22, 1979. Details of sampling and analysis procedures are contained in Appendices I and J.

5.1 EPA Reference Methods Used in This Program

The following EPA Reference Methods were used during this emission testing program. These methods are taken from "Standards of Performance for New Stationary Sources", Appendix A, Federal Register, Volume 42, No. 160, Thursday, August 18, 1977, pp 41755 ff.

- Method 1 - Sample and Velocity Traverses for Stationary Sources

  This method specifies the number and location of sampling points within a duct, taking into account duct size and shape and local flow disturbances. In addition, this method discusses the pitot-nulling technique used to establish the degree of cyclonic flow in a duct.

- Method 2 - Determination of Stack Gas Velocity and Volumetric Flowrate

  This method specifies the measurement of gas velocity and flowrate using a pitot tube, manometer and temperature sensor. The physical dimensions of the pitot tube and its spatial relationship to the temperature sensor and any sample probe are also specified.

- Method 3 - Gas Analysis for CO_2, O_2, Excess Air and Dry Molecular Weight

  This method describes the extraction of a grab or integrated gas sample from a stack and the analysis of that sample for CO_2 and O_2 with an Orsat analyzer.

- Method 4 - Determination of Moisture Content in Stack Gases

  This method describes the extraction of a gas sample from a stack and the removal and measurement of the moisture in that sample by condensation impingers. The assembly and operation of the required sampling train is specified.

- Method 5 - Determination of Particulate Emissions from Stationary Sources

  This method specifies the isokinetic sampling of particulate matter from a gas stream utilizing techniques introduced in the above four methods. Sample collection and recovery, sampling train cleaning and calibration, and gas stream flowrate calculation procedures are specified.

- Method 9 - Visual Determination of the Opacity of Emissions from Stationary Sources

  This method describes how trained observers are to determine the opacity of emissions. The duration and frequency of observations, orientation of the observer with respect to the source, sun and background, methods of data recording and calculation, and qualifications of observers are specified.

Presently, methods of cyclonic flow measurement and interpretation are largely in their formative stages. As noted in Section 2.6, some degree of cyclonic flow was evident in all eight scrubber inlets, caused by the axial flow fans in these ducts. The alignment approach[1] was used during the inlet sampling tests to properly account for the effects of cyclonic flow, as follows:

1. A preliminary traverse was performed at each inlet before every test to establish the flow angles at each traverse point. The pitot-nulling technique, as detailed in EPA Reference Method 1, was used to measure the flow angles.

2. During particulate or velocity traverses the probe tip was rotated according to the flow angles at each traverse point, so that the probe tip faced directly into the gas flow. The flow angle was recorded on the field data sheets along with all other pertinent data.

3. During the particulate traverses, the sampling time at each traverse point was weighted by the cosine of the flow angle at that point. These sampling times are noted on the field data sheets.

4. The cosine of the flow angle was applied to the velocity equations used to calculate the flowrate in the scrubber inlets.[2]

---

1 "Evaluation of Particulate Sampling Methods for Cyclonic Flow," Westlin, P.R., et al., OAQPS, ESED, EMB, TSS, August 2, 1979.

2 Source Sampling Reference Method, prepared by Entropy Environmentalists, Inc., for USEPA, November, 1977.

Angular flow in ducts is a complex phenomenon for which the measurement and analysis technique described above, as well as other proposed techniques, are only an approximation to what is actually occuring in a duct. For example, angle measurement by pitot-nulling is convenient, utilizing equipment already part of the particulate sampling train. However, only one component of the 3-dimensional flow vector is measured in this way, and whether or not this measured component is a significant component of the flow vector is not always known. Further work is needed to develop an accurate angular flow determination method that is readily adaptable to source sampling in the field.

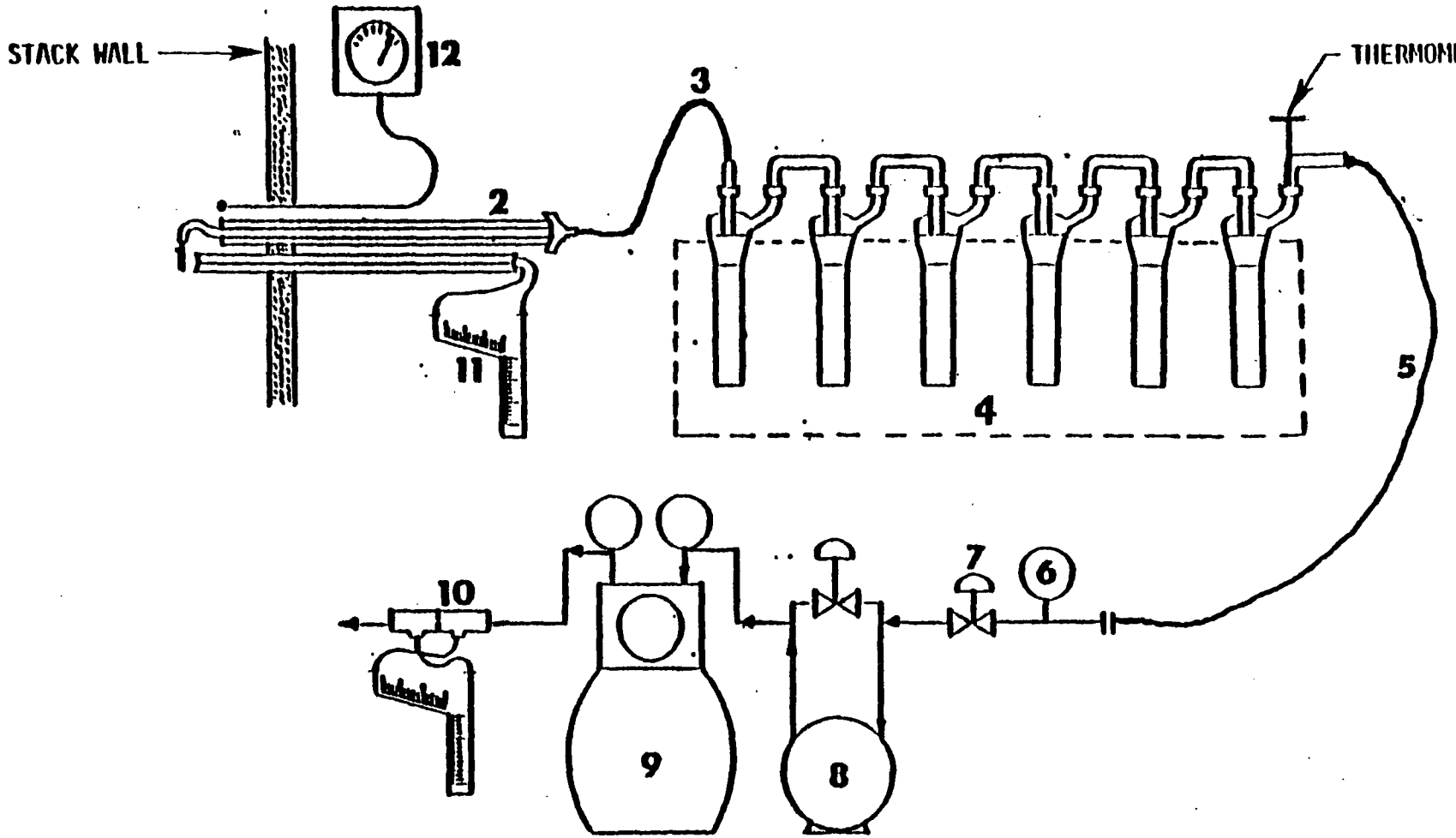
5.2 Urea Sampling and Analysis at the Prill Tower Scrubbers

5.2.1 Sampling Methods

Urea, ammonia and formaldehyde in the inlet and outlet gas stream of the prill tower scrubbers A and C were sampled at points located in accordance with the relationship, detailed by EPA Method 1, of the sampling ports to upstream and downstream flow disturbances. The velocity of the duct gas was measured using S-type pitot tubes constructed and calibrated in accordance with EPA Method 2. Cyclonic flow in the scrubber inlets was handled as described above in Section 5.1.

The sampling train used on this sampling program is shown in Figure 5-1 and is a modification of the standard EPA Method 5 particulate sampling train. The modifications used were: altered impinger sequence, absence of a filter and use of a teflon line.

The sampling train shown in Figure 5-1 consists of a nozzle, probe, teflon line, six impingers, vacuum pump, dry gas meter, and an orifice flow meter. The nozzle is stainless steel and of buttonhook shape. The nozzle was connected to a 5/8-inch stainless steel glass-lined probe wrapped with nichrome



LEGEND

1 - NOZZLE	7 - NEEDLE VALVE
2 - PROBE	8 - PUMP
3 - TEFLON LINE	9 - DRY GAS METER
4 - ICE BATH	10 - ORIFICE
5 - FLEXABLE LINE	11 - PITOT TUBE & INCLINED MANOMETER
6 - VACUUM GAGE	12 - POTENTIOMETER

FIGURE 5-1: MODIFIED EPA PARTICULATE SAMPLING TRAIN
AUGUST 18,1977, FEDERAL REGISTER

0988-020

heating wire and jacketed. Following the probe, the gas stream passed through a 3/8-inch I.D. teflon line into an ice bath/impinger system. The impinger system consisted of six impingers in series. The first two impingers contained deionized, distilled water (100 mls each). The next two impingers contained 1N H_2SO_4 (100 mls each). The fifth impinger was empty, and the sixth contained 200 grams of indicating silica gel. Leaving the last impinger, the sample stream flowed through flexible tubing, a vacuum gauge, needle valve, pump, and a dry gas meter. A calibrated orifice and inclined manometer completed the train. The stack velocity pressure was measured using a pitot tube and inclined manometer. Stack temperature was monitored with a thermocouple attached to the probe and connected to a potentiometer. A nomograph was used to quickly determine the orifice pressure drop required for any pitot velocity pressure and stack temperature in order to maintain isokinetic sampling conditions.

The probe temperature was maintained at about $10^{o}F$ above the duct gas temperature (if the gas temperature did not exceed approximately $160^{o}F$) in order to prevent condensation within the probe. Where the gas temperature exceeded $160^{o}F$, the probe was maintained at $160^{o}F$.

Test data recorded at each sampling point included test time, sampling duration at each traverse point, pitot pressure, stack temperature, dry gas meter volume and inlet-outlet temperature, orifice pressure drop and, at the scrubber inlets, the flow angle.

The only significant problem encountered during the sampling tests was the necessity of interrupting sampling runs while the fans in the scrubber inlet ducts were washed. These interruptions occurred frequently because of the heavy particulate load accumulated by the fans.

5.2.2 Sample Recovery and Preparation

At the completion of each test run the train was leak checked. Then the nozzle, probe, flexible teflon line, first two impingers, and their connecting glassware were rinsed with deionized, distilled water and brushed (three times). Samples were put in glass jars with teflon-lined caps, as follows:

Jar #1 - contents of the nozzle, probe, flexible teflon line, first two impingers, their connecting glassware, and their deionized, distilled water wash.

Jar #2 - contents of the third, fourth and fifth impingers, their connecting glassware, and their 1N H_2SO_4 solution rinse.

Jar #3 - silica gel from the sixth impinger.

The contents of the first jar were filtered using a tared Buchner funnel filter and a vacuum filtration apparatus in order to remove all traces of undissolved material. The funnel filter was then stored in a labelled petri dish and returned to the TRC chemical laboratory. A portion of the filtrate was set aside untreated for analysis for formaldehyde content. To the other portion, a small amount of sulfuric acid was added to bring the pH to less than 6; this portion was in turn divided into two portions for the urea and ammonia analyses.

5.2.3 Sample Analysis

The acid impinger samples (jar #2) and the acidified portion of the water impinger samples (jar #1) were analyzed for urea at the TRC laboratories. Prior to shipment to TRC, the samples were distilled at the W. R. Grace and Co. laboratory in order to remove any ammonia. At TRC the samples were analyzed with the p-dimethylaminobenzaldehyde colorimetric method within 20 days of sample collection. Preliminary distillation to remove ammonia was performed because ammonia is a known interference in this analysis.

One problem was encountered during these analyses. At the beginning of the urea analyses it was noted that the acid impinger samples (from jar #2) were yielding negative absorbances. The TRC chemist reasoned that since the acid impinger samples were preserved with 1N H_2SO_4 and the water impinger samples were preserved with H_2SO_4 at a concentration of only 2 ml/liter, the sulfuric acid may be a negative interference. A test of this hypothesis with distilled water blanks showed that H_2SO_4 did indeed cause negative interference. Based on this information, the urea analyses were then performed with standards prepared with the same H_2SO_4 concentration as the samples. Complete details of the urea analyses are contained in Appendix J.

5.3 Ammonia Sampling and Analysis at the Prill Tower Scrubbers

5.3.1 Sampling, Sample Recovery and Preparation

The same samples collected, recovered and prepared as described in Section 5.2.1 and 5.2.2 were analyzed for ammonia as well as urea.

5.3.2 Sample Analysis

The acid impinger samples and the acidified portions of the water impinger samples were analyzed for ammonia using two methods: specific ion electrode (SIE) method and direct Nessler method.

The SIE analyses were performed at the W. R. Grace and Co. laboratory within 48 hours of sample collection. An Orion model 95-10 ammonia electrode was used in accordance with the electrode manufacturer's procedures. This method is extremely specific for ammonia and is subject to few, if any, interferences.

The Nessler analysis method [1] was performed at the TRC laboratory within 20 days of sample collection. This is a colorimetric method subject to turbidity interference from a variety of species. In addition, delays in sample analysis may allow dissolved ammonia to diffuse out of solution, yielding reduced ammonia concentrations. Alternatively, delays in sample analysis may result in some species, like urea, breaking down or converting to ammonia and yielding falsely high ammonia concentrations.

These two ammonia methods yielded results that agree closely with each other, but a consistent difference is evident. The following is a summary of the ammonia sample catches:

	Average Ammonia Sample Weight (mg)			
	Fertilizer		Feed	
Sample Location	DN	SIE	DN	SIE
A inlet	224	202	574	542
A outlet	750	709	325	324
C inlet	145	133	501	479
C outlet	222	212	339	338
Syn. Tower	---	---	70984	67794

For all fertilizer tests at the A and C scrubbers, the direct Nessler (DN) results averaged 7.6% higher than the specific ion electrode (SIE) results. For all feed tests (excluding the synthesis tower), the DN results averaged 2.8% higher that the SIE results. One factor involved here may be the time

1 Standard Methods of Water and Wastewater Analysis, 14th Edition, 1975, p 412 ff.

elapsed between sample collection and sample analysis. The SIE analyses were performed within 48 hours after sample collection, while the DN analyses were performed up to 20 days after sample collection. Some conversion of urea to ammonia may have occurred in the samples waiting for DN analysis. Since the feed tests were performed one week after the fertilizer tests, less urea conversion occurred in the feed samples.

5.4 Formaldehyde Sampling and Analysis at the Prill Tower Scrubbers

The same samples collected, recovered and prepared as described in Section 5.2.1 and 5.2.2 were analyzed for formaldehyde as well as urea and ammonia. The untreated portions of the water impinger samples were analyzed for formaldehyde at the TRC laboratory within 20 days of sample collection using the chromotropic acid colorimetric analysis method.

5.5 Insoluble Particulate Sampling and Analysis at the Prill Tower Scrubbers

The water impinger samples (collected as described in Section 5.2.1) were analyzed for insoluble particulate (undissolved solids) as follows. The contents of jar #1 were suction-filtered using a previously desiccated, tared glass fiber filter, Buchner funnel and vacuum system, as described in Section 5.2.2. The filter was then placed in a petri dish and brought to TRC. In the TRC Laboratory, the filters were desiccated and weighed to a constant weight. This analysis took place within 20 days of sample collection.

5.6 Synthesis Tower Emissions Tests

5.6.1 Sampling and Analysis for Urea and Ammonia

Emissions tests at the urea synthesis tower main vent were performed in a manner similar to that described in Section 5.2, with the following modifications to the sampling train and sampling method:

1. An in-stack orifice was used to permit isokinetic sampling of the vent gas stream which had a moisture content greater than 50%. The in-stack orifice measures the sample stream flowrate in the probe at the same moisture and temperature conditions as in the stack.

2. Only three traverse points were used because of the physical limitations imposed by the in-stack orifice.

3. Two extra impingers were added to allow for more complete sample collection. Impingers 1-3 each contained 100 ml of distilled, deionized water; impingers 4-6 each contained 100 ml of 10N H_2SO_4; impinger 7 was empty, and impinger 8 contained 200 grams of silica gel. The empty impinger was placed immediately in front of the 8th impinger to act as a demister to prevent too rapid saturation of the silica gel.

The 10N H_2SO_4 was used in two of the three test runs. In the third test run, 5N H_2SO_4 was used. The reason for this was that the 10N solutions had to be substantially diluted in order to respond to the specific ion electrode ammonia analysis. With this analysis method, as the sample is diluted the sensitivity of the electrode decreases.

A procedure similar to that described for the prill tower scrubbers in Section 5.2 and 5.3 was followed for the synthesis tower sample recovery and preparation. The contents of the sample jars were:

Jar #1 - contents of the first 3 impingers and the distilled water wash of the nozzle, probe, teflon line and impinger connecting glassware.

Jar #2 - contents of impingers 4, 5, 6, and 7 and the concentrated acid rinse of these impingers and their connecting glassware.

Jar #3 - silica gel from impinger 8.

The contents of jars #1 and #2 were analyzed for urea, ammonia and insoluble particulate as described in Sections 5.2, 5.3 and 5.5, respectively.

The in-stack orifice was calibrated in the field at W. R. Grace and Co. prior to the synthesis tower tests. The purpose of the calibration was to determine a value for the coefficient B in the following equation:

$$\Delta h = (B)\ (\Delta P)$$

where Δh = pressure drop across the orifice (inches water)

ΔP = velocity pressure (inches water).

With B determined, a nomograph was used to establish isokinetic flow in the sampling train: for a given measured ΔP in the stack, the pressure drop Δh across the orifice was adjusted to the proper value.

A typical in-stack orifice assembly is shown in Figure 5-2. A detailed description of the in-stack orifice calibration is contained in Appendix K.

5.6.2 Integrated Gaseous Bag Samples

Integrated gaseous bag samples were collected from the synthesis tower main vent during each of the urea particulate test runs at this location. Samples were drawn directly from the gas stream with an Integrated Orsat Sampler. The bag samples were analyzed for CO_2 and O_2 at the W. R. Grace and Co. laboratory within one hour of sample collection using an EPA Method 3 Orsat analyzer.

5.7 Visible Emissions

The visible emission measurements of the prill tower scrubber plumes were conducted by two certified visual emission observers in accordance with EPA Reference Method 9. These measurements were taken from two general locations: one observer was atop the prill tower directly across from either the A or C scrubber outlet; the other observer was on the ground, observing either the same scrubber plume concurrently with the first observer or observing com-

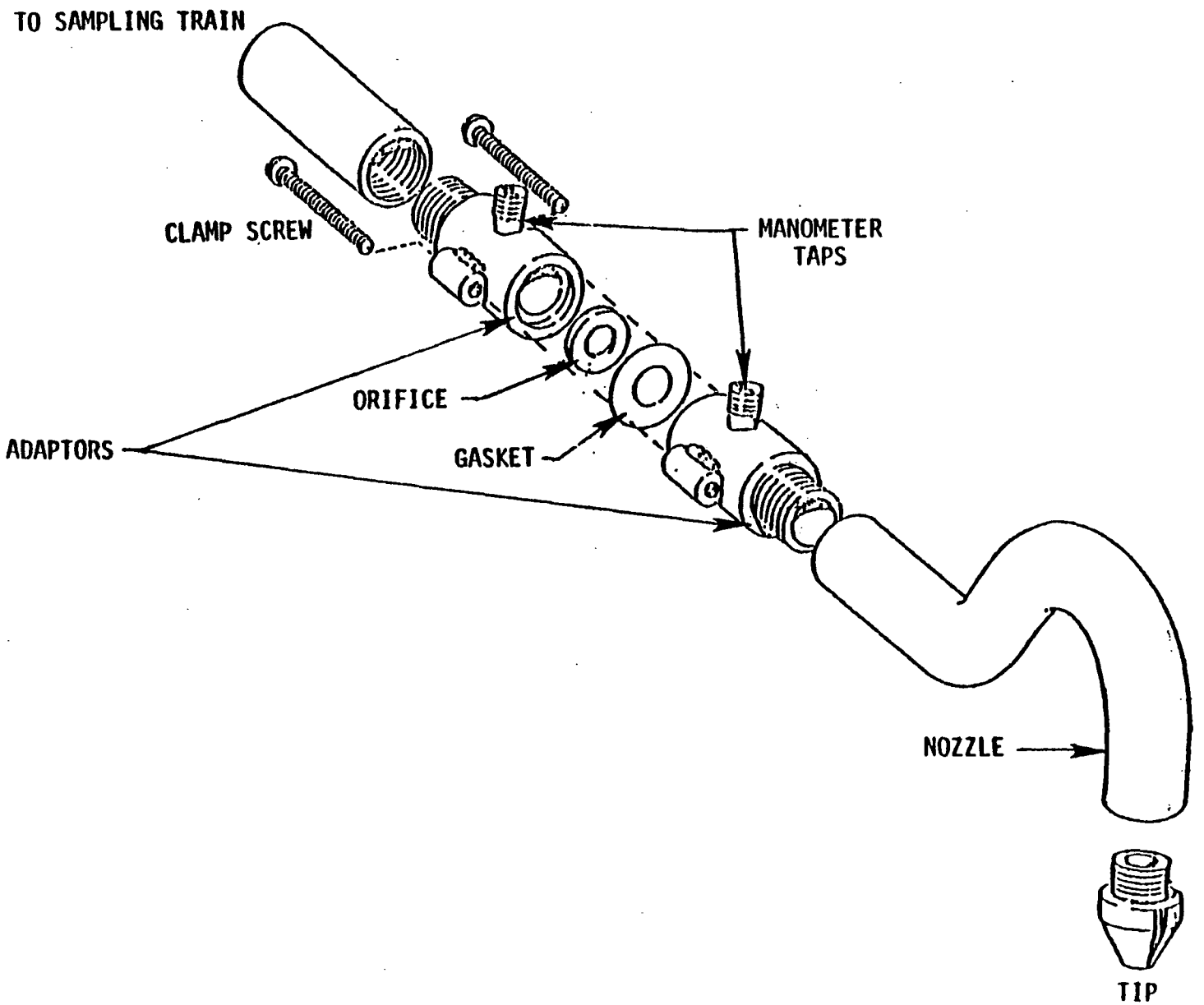


FIGURE 5-2: TYPICAL IN-STACK ORIFICE AND NOZZLE ASSEMBLY

0988-021

bined plumes from all operating scrubbers. Observations of a given plume lasted from one-half hour to about two hours, and within an observation period readings were taken and recorded at 15-second intervals.

Visible emission measurements of the baghouse plume were conducted over a period of five hours by a single certified observer positioned within 15 feet of the baghouse outlet atop the bagging operation warehouse.

Visible emission measurements of the synthesis tower main vent plume were specified in the original work assignment. These measurements were subsequently cancelled by the EPA technical manager because the vent plume mixed with the scrubber plumes.

5.8 Particle Size Tests

Particle size tests were performed at the inlets to scrubbers A and C using an Anderson cascade impactor with a pre-impactor. The impactor was operated in its in-stack mode in accordance with the manufacturer's procedures.

Prior to the initiation of sampling, the impactor was leak tested and placed in the duct for 20 minutes to allow it to heat to duct temperature in order to prevent condensation. Sampling began immediately upon rotation of the nozzle into the flow stream, taking into account the observed cyclonic flow angle. Sampling was performed isokinetically from a single average flow point that was predetermined from velocity traverses performed prior to each particle size test run. Each of the fertilizer tests lasted 30 minutes; each of the feed tests lasted 15 minutes.

The impactor was loaded before each test run with pre-weighed glass fiber collection substrates. Upon completion of a test run, the substrates were removed in a secluded, clean area and placed in petri dishes and sealed. The cyclone preseparator contents were brushed into a tared sample jar and

sealed. These samples were brought to TRC and were weighed on an analytical balance to 0.1 mg in a constant humidity environment.

5.9 Volumetric Flowrate Measurements in the Scrubber Inlets

Velocity traverses were performed in the inlets of scrubbers B, D, E, F, G, and H before and after each fertilizer emission test run, and in the inlets of scrubbers B and D before and after each feed emissions test run. Two perpendicular traverses were performed at each inlet during each velocity test, with velocity head and stack gas temperature monitored at each sampling point. The probe was rotated in accordance with the observed cyclonic flow angle at each point; cyclonic flow angles were measured at each sampling point prior to each "before" velocity test. From these data volumetric flowrates were calculated in accordance with the alignment approach for cyclonic flow calculations, as noted in Section 5.1.

During each fertilizer emission test run, single-point velocity head and temperature measurements were taken approximately every 15 minutes at each of these six scrubber inlets. Similar measurements were made at inlets B and D during the feed emission test runs. These single average-flow points were determined from preliminary velocity traverses, including the "before" traverses. The appropriate cyclonic flow angle was applied with these single-point measurements.

In order to compute the volumetric flowrates of each of these six inlets, assumptions on the values of two parameters were made, based on the results of the complete tests performed on scrubbers A and C. The duct static pressure was assumed to be -2.0 inches of water for fertilizer and feed tests; the percent moisture was asssumed to be 1.8% for the fertilizer tests, and 2.9% for the feed tests. With these assumptions other necessary parameter values were

calculated and, with the measured velocity head, temperature and cyclonic flow angles, the flowrates were calculated.

5.10 Pressure Drop Measurements Across Prill Tower Scrubbers

Pressure drop measurements were taken across all eight prill tower scrubbers during the fertilizer tests and across scrubbers A through D during the feed tests. Measurements were taken approximately every 15 minutes during each test run using a vertical U-tube water manometer connected to pressure taps across the throat of the scrubber venturi.

After the first fertilizer test run, the pressure drop across some of the scrubbers was adjusted to obtain a more constant value across all the scrubbers. This adjustment was made by modifying the liquor level in each scrubber.

5.11 Scrubber Liquor Sampling and Analysis

Samples were taken from the common liquor stream going to scrubbers A and C and from the separate streams returning from each of these two scrubbers. Half-liter aliquots of the scrubber liquor were collected approximately every 30 minutes during each test run. The sample temperature was measured immediately after collection, and the pH was measured in the W. R. Grace and Co. laboratory as soon as the sample reached room temperature. The individual samples were then combined to form three composite samples for each test run (one inlet sample and two outlet samples). These composite samples were then vacuum-filtered through a tared glass-fiber filter. Each filtrate sample was divided into two portions: to one portion concentrated sulfuric acid was added to bring the pH to less than 6; the second portion remained untreated.

The untreated portions were analyzed for urea and formaldehyde as described in Sections 5.2 and 5.4, respectively. Formaldehyde analyses were performed on samples from only one fertilizer test run and one feed test run.

The acidified portions were anlayzed for ammonia by the specific ion electrode and direct Nezzler methods as described in Section 5.3 above. The filter was desiccated and weighed to determined undissolved solids as described in Section 5.5 above.

5.12 Ambient Air Temperature and Relative Humidity

Ambient air temperature and relative humidity were recorded periodically at the base of the prill tower during each emission test run. Wet bulb and dry bulb temperature measurements were made with a Bendix psychron, and psychrometric tables were then used to compute relative humidity from these measurements.

5.13 Process Samples

One grab sample of the unscreened solid urea product was collected by TRC personnel at the hopper inlets to the vibrating screen during each emission test run. Bulk density and sieve analyses were then performed on these samples at the W. R. Grace and Co. laboratory within two hours of sample collection.

The bulk density was determined with a tared graduated cylinder and a platform balance. The sample was passed through a riffle and then poured into the graduated cylinder until it overflowed. The sample was then leveled with the top of the cylinder, and the cylinder and contents were weighed.

The particle size of the product was estimated by means of a sieve analysis. A small amount (about 250 grams) of sample was weighed to the nearest 0.01 gram. This sample was then poured into the top sieve and then shaken through the stack of sieves. After shaking, each sieve was weighed to determine the amount of material retained by it.

Samples of the urea process solution were taken by W. R. Grace and Co. personnel from various locations in the process. Chemical analyses were performed on these samples and on the solid product by W. R. Grace and Co. who requested that the analysis results remain confidential.