

GIANT YELLOWKNIFE MINES

Determination of  
Sulphur Dioxide Emission from  
Stack Gas Analyses and  
Velocity Measurements

July 25, 1990

Prepared By  
Ron S. Tamura  
WESTERN RESEARCH

5278/90-1  
3845J



**Western Research**

A member of the BOVAR group

August 29, 1990

Giant Yellowknife Mines  
Bag 3000  
Yellowknife, N.W.T.  
X1A 2M2

Attn: Gary Halverson

RE: STACK EMISSION SURVEY AT GIANT YELLOWKNIFE MINES  
WESTERN RESEARCH FILE NUMBER 5278/90-1

The attached report presents the results of the Sulphur Emission Survey conducted on July 25, 1990.

The tests indicated:

Average Sulphur Dioxide Emission - Tonnes Per Day as Sulphur	17.5404
Average Stack Gas Exit Speed - Metres Per Second	3.3999
Average Stack Gas Temperature during the Test Period at the Sampling Level - °C	82

Should you have any questions regarding the survey results, please contact us at your convenience.

Yours truly,

WESTERN RESEARCH

Ron S. Tamura, C.E.T.  
Staff Technologist  
Analytical and Testing Services

RST/jm  
3845J(65-67)  
Attch.

## INTRODUCTION

Western Research conducted a source emission survey at Giant Yellowknife Mines on July 25, 1990.

The purpose of this program was to determine the concentration and mass emission rate of sulphur dioxide from the roaster stack.

## DISCUSSION

Three tests were conducted, during each test the following flue gas parameters were determined:

1. Velocity/temperature profiles and static pressure
2. Sulphur dioxide/water content
3. Dry gas composition

## CALCULATIONS AND RESULTS

The computer output that contains summaries of field and laboratory data plus detailed results is presented in Appendix A. Results for each test are given in the Standard International System of Units (SI). The final results of the test are shown in the summary of emission test results.

## METHODS AND PROCEDURES

Appendix B provides details of the test methods and procedures.

The sampling train used was last calibrated February, 1990. The pitot tube used was last calibrated February, 1990.

TABLE 1  
SUMMARY OF SOURCE EMISSION TEST RESULTS

GIANT YELLOWKNIFE MINES  
YELLOWKNIFE

90/07/25  
5278/90-1

PARAMETER	TEST 1	TEST 2	TEST 3	AVERAGE
TEST PERIOD	08:54-09:54	10:15-11:15	11:39-12:39	
Measured Average Temp. of Flue Gas at Sample Level - Deg.C	79	84	84	82
Measured Average Velocity of Flue Gas at Sample Level - m/s	3.3571	3.6134	3.2292	3.3999
Calculated Average Velocity of Flue Gas at Exit Level - m/s	3.3571	3.6134	3.2292	3.3999
Flue Gas Flow Rate *				
- m <sup>3</sup> /s	16.4605	17.4641	15.6070	16.5105
- 1000m <sup>3</sup> /d	1422.1879	1508.8979	1348.4425	1426.5094
Average H <sub>2</sub> O Content of Flue Gas - mole percent	6.35	6.40	6.70	6.48
SULPHUR DIOXIDE				
Concentration - mole percent	0.9274	0.9428	0.9032	0.9245
Flow Rate - m <sup>3</sup> /s *	0.1527	0.1647	0.1410	0.1528
Emission (S1) - t/d	17.5287	18.9065	16.1860	17.5404
Trace Sulphur				
- ppm, wet - H <sub>2</sub> S	0	0	0	0
- COS	0	0	0	0
- CS <sub>2</sub>	0	0	0	0

\* At 21.1 Deg.C and 760 mm Hg.

TABLE 2  
GAS CHROMATOGRAPHIC ANALYSES

GIANT YELLOWKNIFE MINES  
YELLOWKNIFE

90/07/25  
5278/90-1

SITE TIME PARAMETER	STACK GAS		
	09:34 TEST 1	10:45 TEST 2	12:09 TEST 3
H2	0.0000	0.0000	0.0000
Ar	0.0000	0.0000	0.0000
O2	18.7000	18.3670	18.6000
N2	80.9990	80.7650	81.1990
C1	0.0000	0.0000	0.0000
CO	0.0010	0.0010	0.0010
CO2	0.3000	0.8670	0.2000
C2+	0.0000	0.0000	0.0000
H2S	0.0000	0.0000	0.0000
COS	0.0000	0.0000	0.0000
SO2	0.0000	0.0000	0.0000
CS2	0.0000	0.0000	0.0000
TOTAL	100.0000	100.0000	100.0000

Mole percents (sulphur free, water free basis)

0.0000 - analyzed for but not detected

0.0001 - detected but not quantifiable

TABLE 3  
TITRATION DATA

GIANT YELLOWKNIFE MINES  
YELLOWKNIFE

90/07/25  
5278/90-1

H<sub>2</sub>SO<sub>4</sub> FROM H<sub>2</sub>O<sub>2</sub> ABSORPTION OF SO<sub>2</sub>  
0.1048 N Ba(ClO<sub>4</sub>)<sub>2</sub>  
THORIN, METHYLENE BLUE INDICATORS

	TEST 1	TEST 2	TEST 3	BLANK
TEST SOLUTION				
INITIAL VOLUME	500.00	500.00	500.00	
FINAL VOLUME	514.00	515.00	516.00	
WASH VOLUME	100.00	100.00	100.00	
ALiquot TITRATED	5.00	5.00	5.00	5.00
TITRANT VOLUME	0.00 0.00	0.00 0.00	0.00 0.00	0.00
PPM AS SO <sub>4</sub> (TOTAL SAMPLE) BY ION CHROMATOGRAPH	20846.50	22530.00	21476.00	

## APPENDIX A

### Computer Output

FILE NUMBER 5278/90-1  
90/07/25

TEST 1

PAGE 1

YELLOWKNIFE

LOCATION OF SAMPLING POINT	21.0	METRE LEVEL
DIAMETER AT STACK SAMPLING POINT	2.743	METRES
DIAMETER AT STACK EXIT	2.743	METRES
BAROMETRIC PRESSURE	755.6	MM HG
AMBIENT TEMPERATURE	16.0	DEG.C

AVERAGE COMPOSITION OF FLUE GAS

	DRY BASIS PERCENT	WET BASIS PERCENT
O2	18.700	17.339
CO2	0.300	0.278
N2 *	81.000	75.104
H2O		6.352
SO2		0.927
* BY DIFFERENCE		

SPECIFIC GRAVITY OF FLUE GAS (AIR = 1.0)	0.982
MOLECULAR WEIGHT OF FLUE GAS	28.437 KG/KGMOLE

FLUE GAS FLOW RATE DATA AND CALCULATIONS

AVERAGE SQUARE ROOT VELOCITY HEAD	0.184
AVERAGE STATIC PRESSURE	-0.392 MM HG
AVERAGE FLUE GAS TEMPERATURE	79.1 DEG.C
PITOT CALIBRATION FACTOR	0.808
AVERAGE FLUE GAS VELOCITY - SAMPLE LEVEL	3.357 M/S
- STACK EXIT	3.357 M/S
TOTAL EFFLUENT FLOW RATE	16.461 M3/S **
	2456.105 KGMOLE/H

\*\* AT REFERENCE ( 21.1 DEG.C AND 760.0 MM HG )



FILE NUMBER 5278/90-1  
90/07/25

TEST 1

PAGE 2

YELLOWKNIFE

POLLUTANT DATA AND CALCULATIONS

SULPHUR DIOXIDE DETERMINATION

VOLUME OF FLUE GAS METERED	0.3141	M3
DRY GAS METER TEMPERATURE	18.5	DEG.C
VACUUM AT CONDENSER	53.1	MM HG
WATER VAPOUR PRESSURE	6.3390	MM HG
VOLUME OF WATER CONDENSED	14.0	CC
VOLUME OF Ba(C104)2	0.0	CC
NORMALITY OF Ba(C104)2	0.1048	N
OR PPM, TOTAL SAMPLE, AS SO4	20846.5	PPM
AVERAGE SULPHUR DIOXIDE CONCENTRATION	0.9274	MOLE %
FLOW RATE	0.1527	M3/S **
EMISSION RATE (AS SO2)	35.0219	TONNE/D
EMISSION RATE (AS S1)	17.5287	TONNE/D

\*\* AT REFERENCE ( 21.1 DEG.C AND 760.0 MM HG )

FILE NUMBER 5278/90-1  
90/07/25

TEST 2

PAGE 3

YELLOWKNIFE

LOCATION OF SAMPLING POINT	21.0	METRE LEVEL
DIAMETER AT STACK SAMPLING POINT	2.743	METRES
DIAMETER AT STACK EXIT	2.743	METRES
BAROMETRIC PRESSURE	755.6	MM HG
AMBIENT TEMPERATURE	16.0	DEG.C

AVERAGE COMPOSITION OF FLUE GAS

	DRY BASIS PERCENT	WET BASIS PERCENT
O2	18.367	17.019
CO2	0.867	0.803
N2 *	80.766	74.837
H2O		6.398
SO2		0.943
* BY DIFFERENCE		

SPECIFIC GRAVITY OF FLUE GAS (AIR = 1.0)	0.984
MOLECULAR WEIGHT OF FLUE GAS	28.509 KG/KGMOLE

FLUE GAS FLOW RATE DATA AND CALCULATIONS

AVERAGE SQUARE ROOT VELOCITY HEAD	0.197
AVERAGE STATIC PRESSURE	-0.392 MM HG
AVERAGE FLUE GAS TEMPERATURE	84.2 DEG.C
PITOT CALIBRATION FACTOR	0.808
AVERAGE FLUE GAS VELOCITY - SAMPLE LEVEL	3.613 M/S
- STACK EXIT	3.613 M/S
TOTAL EFFLUENT FLOW RATE	17.464 M3/S **
	2605.852 KGMOLE/H

\*\* AT REFERENCE ( 21.1 DEG.C AND 760.0 MM HG )

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90/07/25

TEST 2

PAGE 4

YELLOWKNIFE

POLLUTANT DATA AND CALCULATIONS

SULPHUR DIOXIDE DETERMINATION

VOLUME OF FLUE GAS METERED	0.3351	M3
DRY GAS METER TEMPERATURE	19.2	DEG.C
VACUUM AT CONDENSER	56.6	MM HG
WATER VAPOUR PRESSURE	6.4010	MM HG
VOLUME OF WATER CONDENSED	15.0	CC
VOLUME OF Ba(ClO4)2	0.0	CC
NORMALITY OF Ba(ClO4)2	0.1048	N
OR PPM, TOTAL SAMPLE, AS SO4	22530.0	PPM
AVERAGE SULPHUR DIOXIDE CONCENTRATION	0.9428	MOLE %
FLOW RATE	0.1647	M3/S **
EMISSION RATE (AS SO2)	37.7747	TONNE/D
EMISSION RATE (AS S1)	18.9065	TONNE/D

\*\* AT REFERENCE ( 21.1 DEG.C AND 760.0 MM HG )

FILE NUMBER 5278/90-1  
90/07/25

TEST 3

PAGE 5

YELLOWKNIFE

LOCATION OF SAMPLING POINT	21.0	METRE LEVEL
DIAMETER AT STACK SAMPLING POINT	2.743	METRES
DIAMETER AT STACK EXIT	2.743	METRES
BAROMETRIC PRESSURE	755.6	MM HG
AMBIENT TEMPERATURE	16.0	DEG.C

AVERAGE COMPOSITION OF FLUE GAS

	DRY BASIS PERCENT	WET BASIS PERCENT
O2	18.600	17.185
CO2	0.200	0.185
N2 *	81.200	75.023
H2O		6.703
SO2		0.903
* BY DIFFERENCE		

SPECIFIC GRAVITY OF FLUE GAS (AIR = 1.0)	0.979
MOLECULAR WEIGHT OF FLUE GAS	28.372 KG/KGMOLE

FLUE GAS FLOW RATE DATA AND CALCULATIONS

AVERAGE SQUARE ROOT VELOCITY HEAD	0.176
AVERAGE STATIC PRESSURE	-0.392 MM HG
AVERAGE FLUE GAS TEMPERATURE	84.2 DEG.C
PITOT CALIBRATION FACTOR	0.808
AVERAGE FLUE GAS VELOCITY - SAMPLE LEVEL	3.229 M/S
- STACK EXIT	3.229 M/S
TOTAL EFFLUENT FLOW RATE	15.607 M3/S **
	2328.748 KGMOLE/H

\*\* AT REFERENCE ( 21.1 DEG.C AND 760.0 MM HG )

FILE NUMBER 5278/90-1  
90/07/25

TEST 3

PAGE 6

YELLOWKNIFE

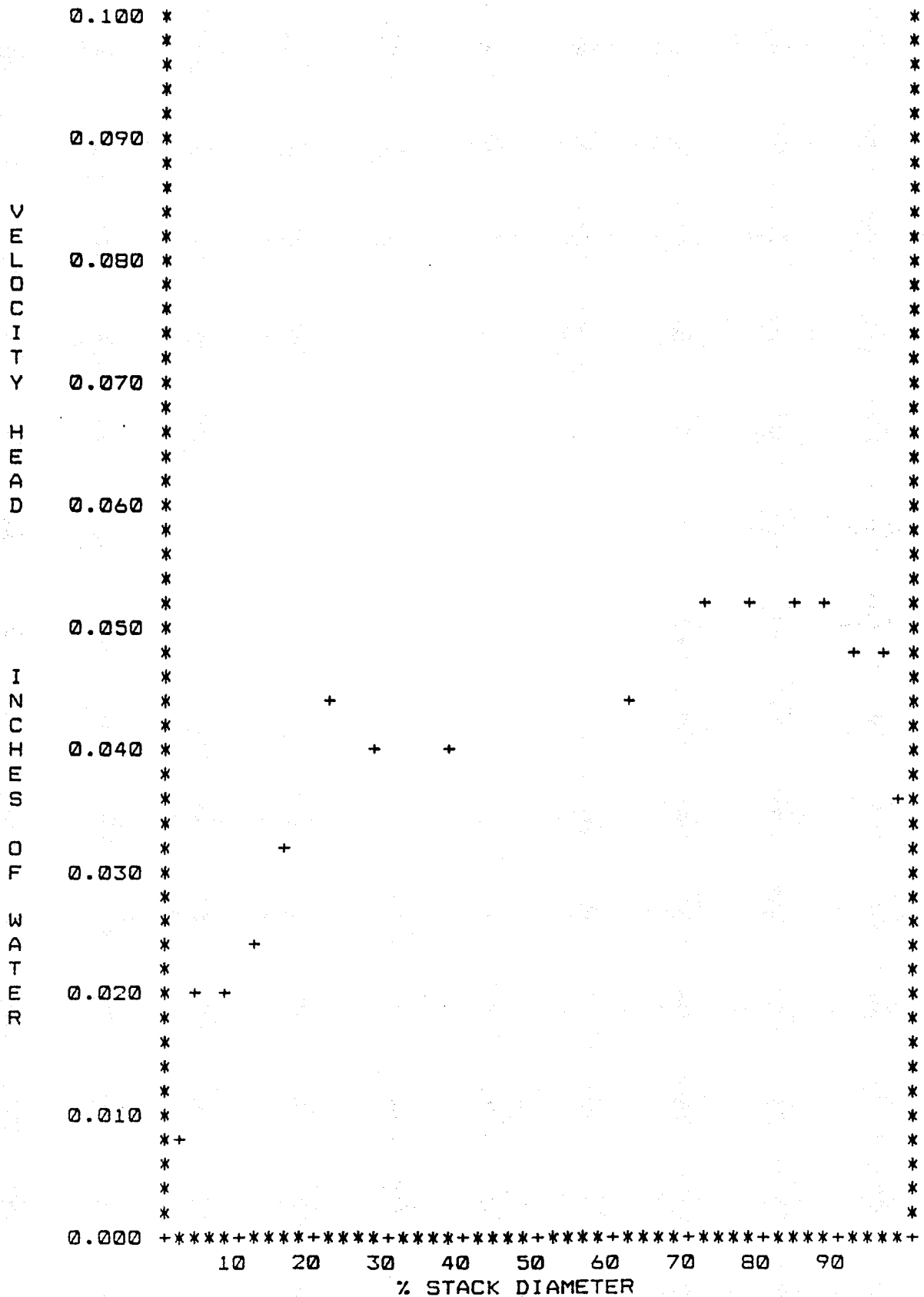
POLLUTANT DATA AND CALCULATIONS

SULPHUR DIOXIDE DETERMINATION

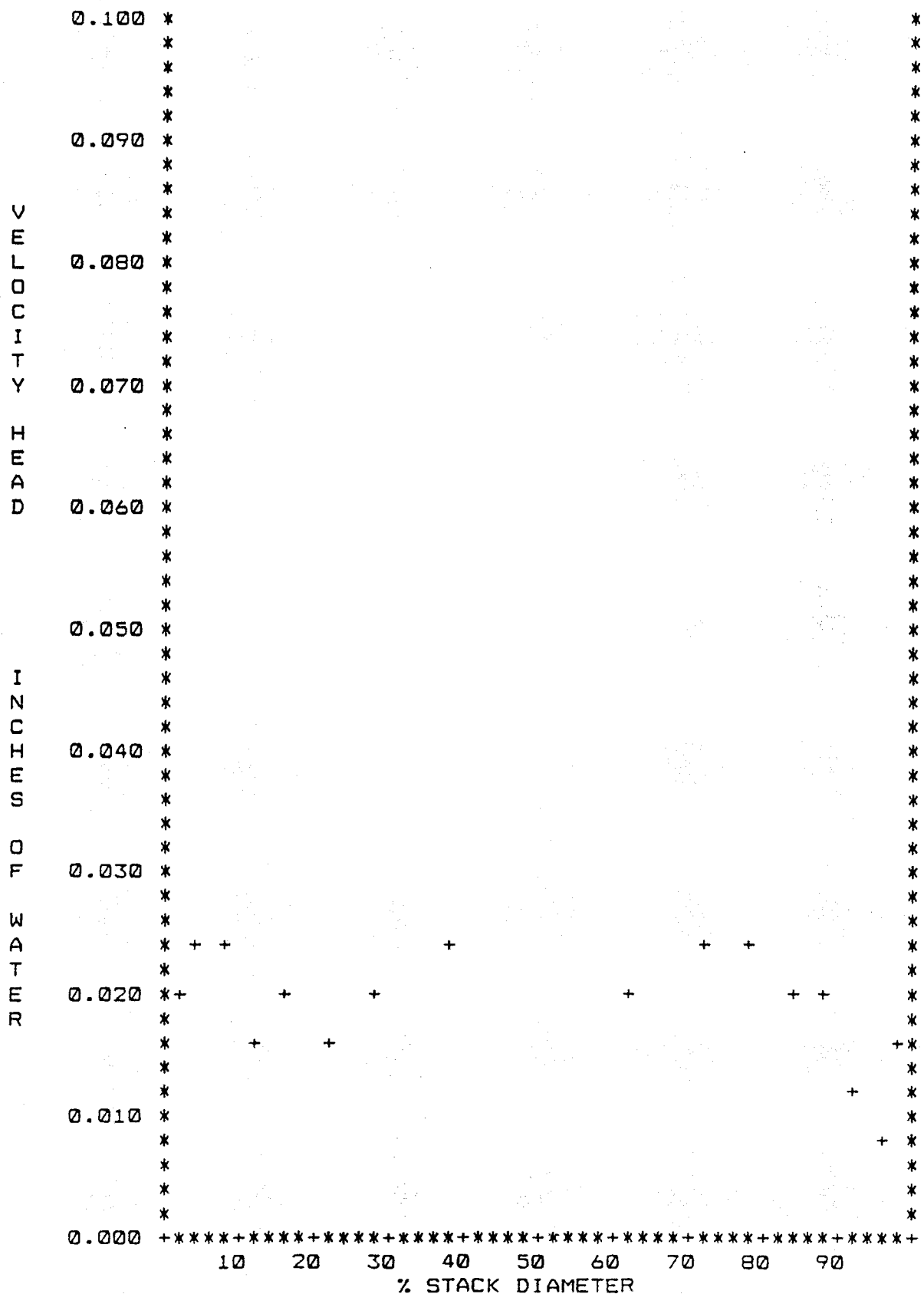
VOLUME OF FLUE GAS METERED	0.3355	M3
DRY GAS METER TEMPERATURE	21.4	DEG.C
VACUUM AT CONDENSER	56.9	MM HG
WATER VAPOUR PRESSURE	5.7930	MM HG
VOLUME OF WATER CONDENSED	16.0	CC
VOLUME OF Ba(ClO4)2	0.0	CC
NORMALITY OF Ba(ClO4)2	0.1048	N
OR PPM, TOTAL SAMPLE, AS SO4	21476.0	PPM
AVERAGE SULPHUR DIOXIDE CONCENTRATION	0.9032	MOLE %
FLOW RATE	0.1410	M3/S **
EMISSION RATE (AS SO2)	32.3392	TONNE/D
EMISSION RATE (AS S1)	16.1860	TONNE/D

\*\* AT REFERENCE ( 21.1 DEG.C AND 760.0 MM HG )

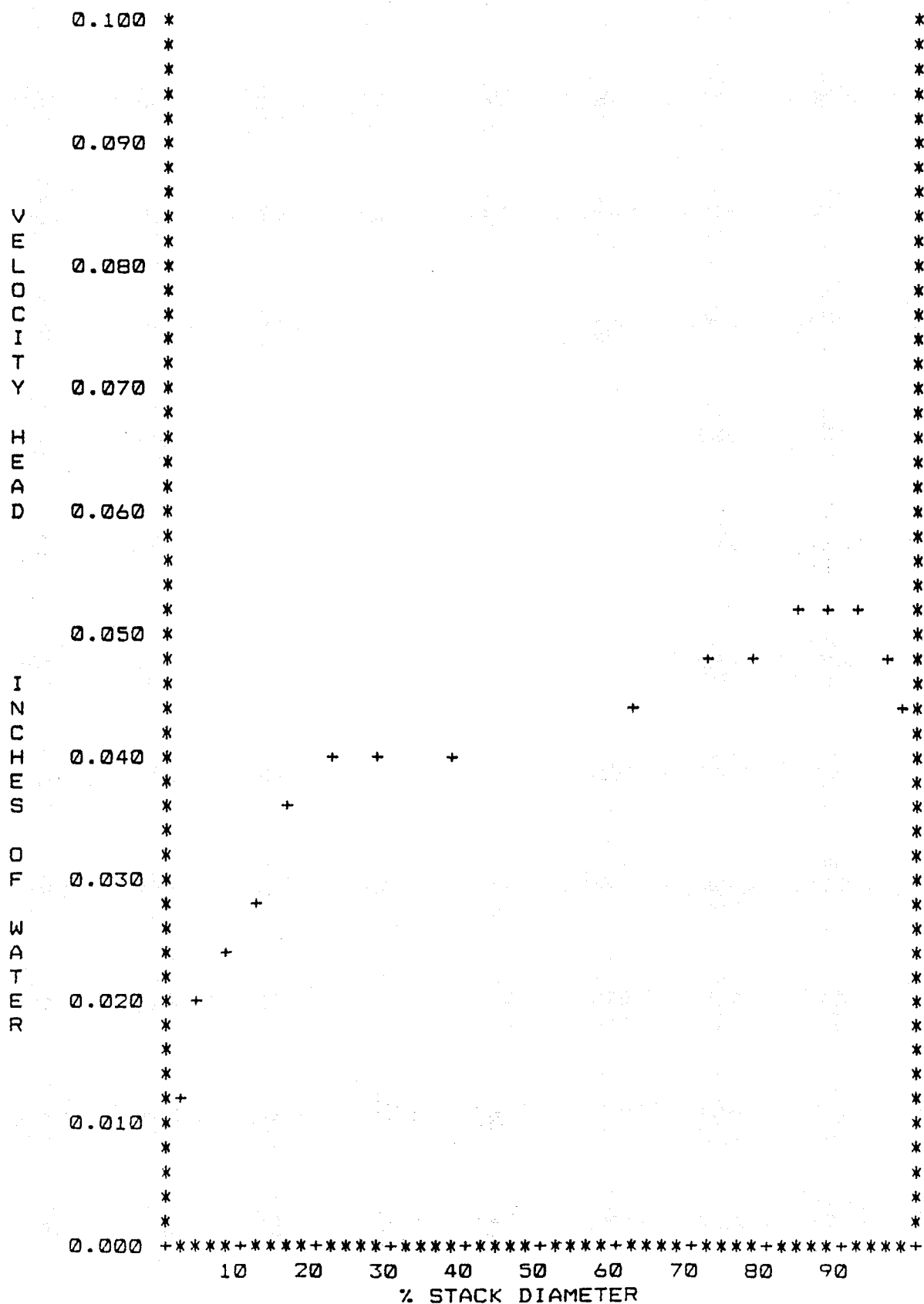
TEST ONE  
VELOCITY PROFILE 1  
YELLOWKNIFE



TEST ONE  
VELOCITY PROFILE 2  
YELLOWKNIFE

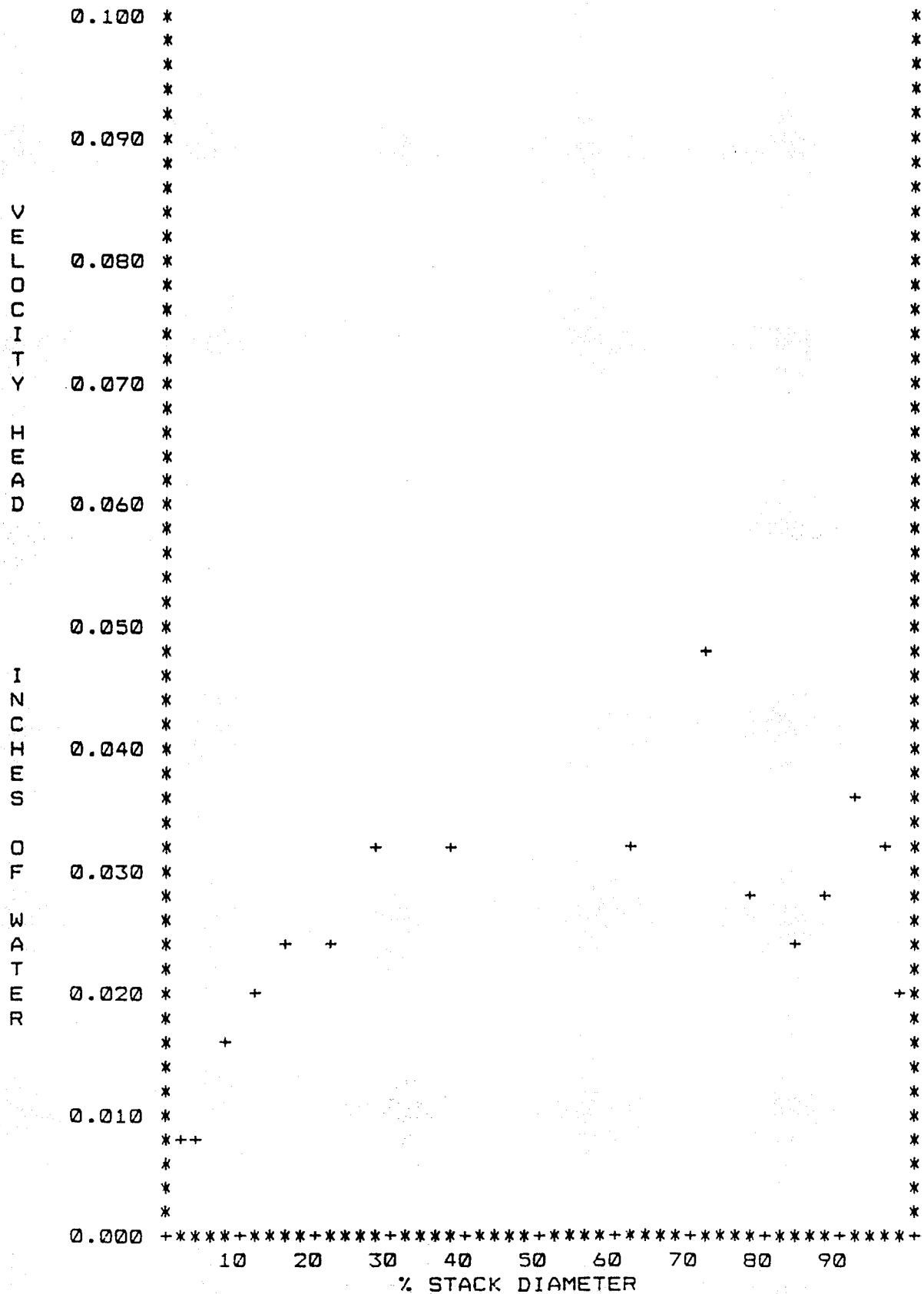


TEST TWO  
VELOCITY PROFILE 1  
YELLOWKNIFE

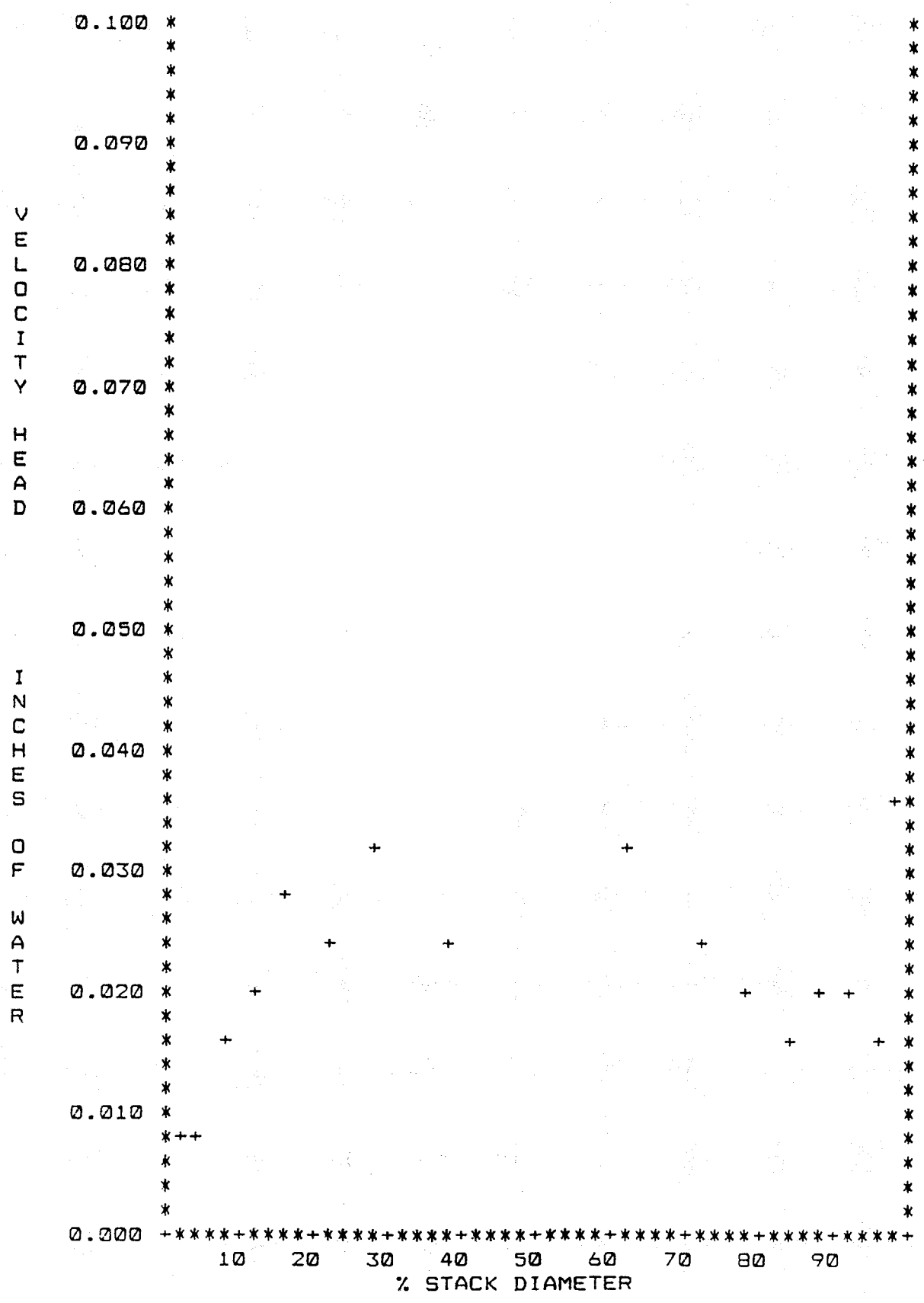




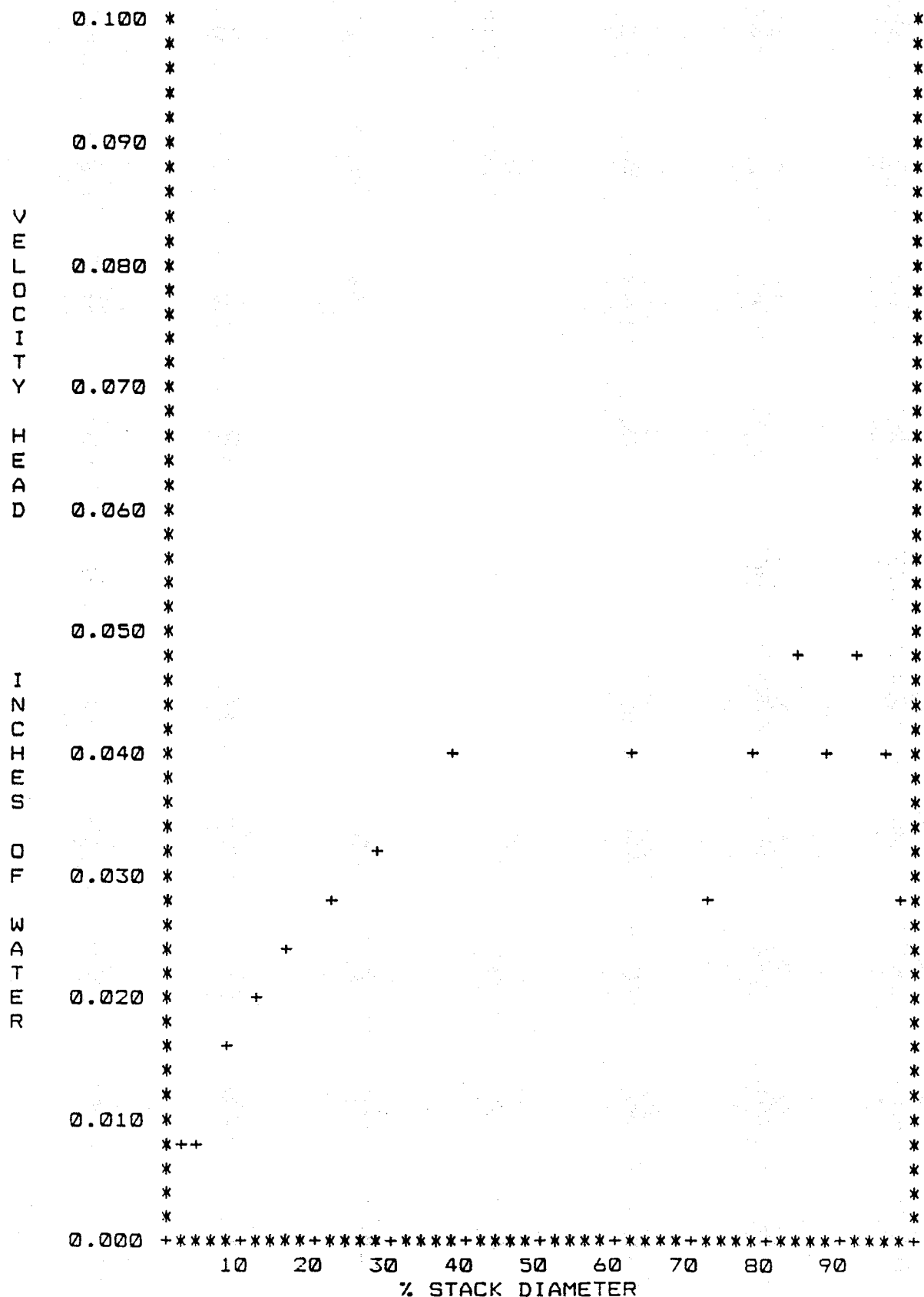
TEST TWO  
VELOCITY PROFILE 2  
YELLOWKNIFE



TEST THREE  
VELOCITY PROFILE 1  
YELLOWKNIFE



TEST THREE  
VELOCITY PROFILE 2  
YELLOWKNIFE



# EMISSION TEST DATA

COMPANY NAME	CLINT YELLOWKNIFE	TEST DATE	90-07-25	PITCH FACTOR/1	#15
PLANT LOCATION	YELLOWKNIFE	JOB NUMBER	5278	02 %	CO2 %
SOURCE TESTED	ROASTER STK	TEST NUMBER	ONE	18.7	0.3
OPERATOR	F.L. M.S.	BAROMETRIC PRESSURE	29.75 mm Hg.	18.7	0.5
KIT USED	SO2 #2	AMBIENT TEMPERATURE	19° C	18.7	0.5

SOLUTION	67 H2O2	CYCLOHIC	YES (NO)	ANGLE
INITIAL mls.	500	STATIC	.21 in.H2O	+(-)
FINAL mls.	514	PRESSURE CHECK	BEFORE	AFTER
WASH mls.	100		YES/NO	YES/NO

SAMPLE TIME	CLOCK TIME	VOLUME CUSC FT.	dH in.H2O	VACUUM in.Hg	TEMPERATURES C		
					meter	condenser	stock
0	8:54	1.545	N/A	2.0	59°F	8°C	N/A
10	9:04	3.417		2.1	61°F	5°C	
20	9:14	5.262		2.1	63°F	5°C	
30	9:24	7.185		2.1	63°F	5°C	
40	9:34	8.940		2.1	63°F	3°C	
50	9:44	10.800		2.1	63°F	3°C	
60	9:54	12.645		2.1	63°F	3°C	
		11.710		2.09	62°F	3°C	

SOUTH				WEST				6.329						
	Ts C	dH in.H2O			Ts C	dH in.H2O			Ts C	dH in.H2O			Ts C	dH in.H2O
1	58	.01		1	77	.025		1				1		
2	62	.025		2	81	.03		2				2		
3	66	.025		3	84	.03		3				3		
4	71	.03		4	84	.02		4				4		
5	73	.04		5	84	.025		5				5		
6	74	.055		6	84	.02		6				6		
7	75	.05		7	84	.025		7				7		
8	77	.05		8	84	.03		8				8		
9	78	.055		9	84	.025		9				9		
10	79	.065		10	84	.03		10				10		
11	80	.065		11	84	.03		11				11		
12	80	.065		12	84	.025		12				12		
13	81	.065		13	83	.025		13				13		
14	81	.06		14	83	.015		14				14		
15	82	.06		15	84	.01						15		
16	82	.045		16	83	.02						16		

17.28  
52.9  
91.8  
135.0  
182.5  
23.7  
30.56  
40.5  
67.5  
77.4  
84.2  
89.7  
94.5  
98.8  
102.7  
166.27

Western Research, Alberta

# EMISSION TEST DATA

COMPANY NAME	GIANT YELLOWKNIFE MINES LTD.	TEST DATE	90-07-25	STAKE 3' ID	SAMPLE LEVEL 7
PLANT LOCATION	YELLOWKNIFE N.B.T.	JCS NUMBER		PITOT FACTOR/1	#15
SOURCE TESTED	ROASTER STK	TEST NUMBER	TWO	02	CO2
OPERATOR	K.L. M.S.	BAROMETRIC PRESSURE	29.75 mm Hg.	18.3	.6
KIT USED	503 #2	AMBIENT TEMPERATURE	16° C	18.4	1.0

SOLUTION	67H2O2	CYCLONIC	YES/NO	ANGLE
INITIAL mls.	500	STATIC	21 in.H2O	+/-
FINAL mls.	515	PRESSURE CHECK	BEFORE	AFTER
WASH mls.	100		YES/NO 20"	YES/NO 20"

SAMPLE TIME	CLOCK TIME	VOLUME CUSC FT.	dH in.H2O	VACUUM in.Hg	TEMPERATURES C		
					meter	condenser	stack
0	10:15	12.670	NA	2.1	65°F	3'	N/A
10	:25	14.525		2.5	65°	5°	
20	:35	16.61		2.2	66°	5°	
30	:45	18.55		2.2	67°	5°	
40	:55	20.58		2.2	67°	5°	
50	11:05	22.57		2.2	68	5°	
60	:15	24.52		2.2	68	5°	
		11.840		2.23	19.2	4.71	

SOUTH				WEST				4.2				4.71			
								6.401							
	Ts C	dH in.H2O			Ts C	dH in.H2O			Ts C	dH in.H2O			Ts C	dH in.H2O	
1	78	.015		1	79	.01		1				1			
2	84	.025		2	81	.01		2				2			
3	85	.03		3	84	.02		3				3			
4	85	.035		4	86	.025		4				4			
5	84	.045		5	86	.03		5				5			
6	85	.05		6	85	.03		6				6			
7	85	.05		7	86	.04		7				7			
8	85	.05		8	86	.04		8				8			
9	85	.055		9	86	.04		9				9			
10	85	.06		10	85	.06		10				10			
11	84	.06		11	85	.035		11				11			
12	84	.065		12	85	.03		12				12			
13	84	.065		13	85	.035		13				13			
14	83	.065		14	85	.045		14				14			
15	83	.06		15	85	.04						15			
16	83	.055		16	85	.025									

Western Research, Calgary, Alberta

# EMISSION TEST DATA

COMPANY NAME	GIANT THERMAL LTD	TEST DATE	90-07-25	PITOT FACTOR/1	#15
PLANT LOCATION	YELLOWKNIFE	JOB NUMBER		02	002
SOURCE TESTED	ROADSIDE STK	TEST NUMBER	THREE	18.6	0.1
OPERATOR	EL M.S	BAROMETRIC PRESSURE	29.75 mm Hg.	18.6	0.3
KIT USED	SOL #2	AMBIENT TEMPERATURE	16° C		

SOLUTION	67 H <sub>2</sub> O	CYCLOHIC	YES/NO	ANGLE
INITIAL mls.	500	STATIC	.21 in.H <sub>2</sub> O	+10
FINAL mls.	516	PRESSURE CHECK	BEFORE	AFTER
WASH mls.	100		YES/NO	YES/NO

SAMPLE TIME	CLOCK TIME	VOLUME CUSEC FT.	dH in.H <sub>2</sub> O	VACUUM in.Hg	TEMPERATURES C		
					meter	condenser	stack
0	11:39	24.555	N/A	2.4	63°	6°	N/A
10	:49	26.550		2.2	63°	6°	
20	:59	28.545		2.2	63°	3°	
30	12:09	30.540		2.2	71°	2°	
40	:19	32.54		2.2	71°	2°	
50	:29	34.48		2.2	72°	2°	
60	:39	36.44		2.3	73°	2°	
		11.855		2.24	21.4	3.29	

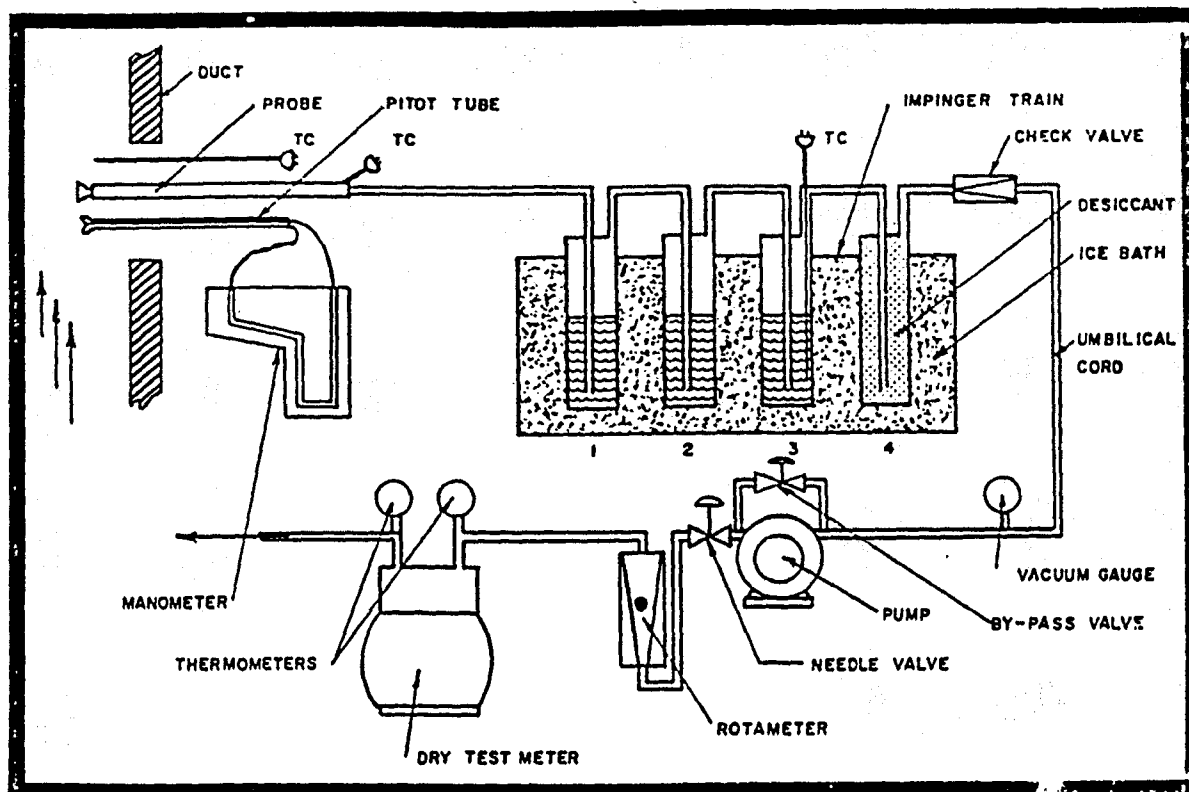
WEST				SOUTH				S. 79°			
	Ts C	dH in.H <sub>2</sub> O			Ts C	dH in.H <sub>2</sub> O			Ts C	dH in.H <sub>2</sub> O	
1	80	.01		1	80	.01		1			
2	83	.01		2	83	.01		2			
3	85	.02		3	84	.02		3			
4	85	.025		4	85	.025		4			
5	85	.03		5	85	.035		5			
6	85	.035		6	85	.03		6			
7	85	.04		7	85	.04		7			
8	85	.05		8	85	.03		8			
9	85	.05		9	85	.04		9			
10	85	.035		10	85	.03		10			
11	85	.05		11	84	.025		11			
12	85	.06		12	84	.02		12			
13	84	.05		13	84	.025		13			
14	84	.06		14	84	.025		14			
15	84	.05		15	84	.02		15			
16	84	.035		16	82	.045		16			

Western Research, Calgary, Alberta

## APPENDIX B

### Methods and Procedures

## Determination of SO<sub>2</sub> and H<sub>2</sub>O in Gas Streams



The sampling train detailed above is used for the determination of SO<sub>2</sub> in gas streams. The gas sample is drawn at a constant rate through a glass or teflon lined probe from a single point near the centre of the duct. The appropriate sampling train parameters are monitored and recorded at regular intervals during the sampling period.

The SO<sub>2</sub> reacts quantitatively with the aqueous H<sub>2</sub>O<sub>2</sub> absorbing solution. The resulting H<sub>2</sub>SO<sub>4</sub> is determined by direct titration with NaOH to bromocresol green endpoint or by a Ba(ClO<sub>4</sub>)<sub>2</sub> titration in 2-propanol. For the latter, a back-titration with H<sub>2</sub>SO<sub>4</sub> and Arsenazo III indicator or a direct-titration with Thorin indicator is used.

Particulates are removed from the sample stream by a glass-wool-plug filter in the probe. The removal of SO<sub>3</sub> from the sample stream is accomplished with an aqueous 2-propanol solution in impinger 1, and a mist eliminator between impingers 1 and 2. At the end of a run in the latter case, the probe is removed, the ice bath is drained and filtered ambient air is drawn through the solutions in an attempt to displace the dissolved SO<sub>2</sub> from the 2-propanol solution into the H<sub>2</sub>O<sub>2</sub> solution. Only the H<sub>2</sub>O<sub>2</sub> solution, with appropriate washings, is then analyzed.

The probe is heated to keep the gas sample temperature above the H<sub>2</sub>O dewpoint.

By measuring the initial and final total volumes of the absorbing solutions, the H<sub>2</sub>O concentration in the stream can also be obtained. The H<sub>2</sub>O vapor that escapes from impinger 3, and is absorbed by the desiccant, is accounted for by one of two methods—by a computational method under the assumption that the gas sample stream is saturated at impinger 3 outlet temperature and pressure or by the mass gain of the desiccant.



### Analysis of Dry Gas Fraction

Gas chromatography is used to analyze the dry gas fraction of the gas stream, chiefly for the calculation of the average molecular weight of the gas mixture. The analysis includes the following components:  $H_2$ , A,  $O_2$ ,  $N_2$ ,  $CH_4$ , CO,  $CO_2$ ,  $C_2H_6$ ,  $H_2S$ , COS,  $SO_2$  and  $CS_2$ .

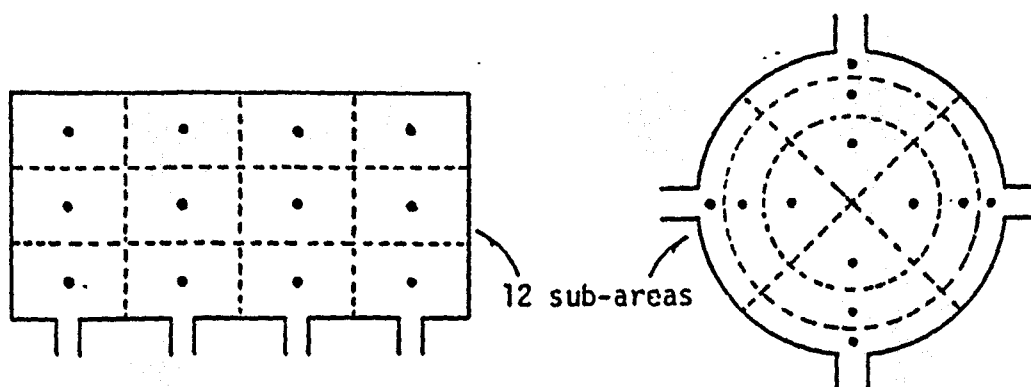
A grab sample is drawn into a glass envelope, directly from the gas stream or from an integrated stream sample. Particulates are removed by a Pyrex glass-wool-plug filter at the inlet of the  $P_2O_5$  dryer.

The  $H_2O$  concentration is determined separately.

## Sampling Facilities

1. Duct Dimensions The inner dimensions of the duct are obtained in a number of ways. Whenever possible and practical, the dimensions are obtained by direct measurement. When direct measurements are not possible, indirect methods (e.g. optical methods) are used. For those instances where on site measurements are not practical, or possible, recourse is made to as-constructed drawings.

2. Sampling Points The selection of sampling points within the gas stream is carried out in the following general manner. The cross-sectional area of the duct in the plan of the access ports is subdivided into equal-area segments, as noted in the sketches:



For rectangular ducts, measurements are made at the centroid of each sub-area. For round ducts, the measurements are made at the intersections of the diameters and the centroid arcs of the annular sub-areas. The number of sub-areas depends upon the dimensions of the duct and are selected under the following guidelines for a sampling plane at least 8 duct diameters downstream from and 2 duct diameters ahead of any flow disturbances.

Duct Diameter (d, (ft))	Minimum Number of Equal Areas
$d \leq 1$	2
$1 < d \leq 2$	4
$2 < d \leq 4$	6
$4 < d \leq 8$	10
$8 < d \leq 16$	16
$d > 16$	In Consultation with Regulatory Agency

For sampling planes that do not satisfy the 8- and 2-duct diameters criteria, the number of sub-areas is increased according to the guidelines established by the various regulatory agencies. For rectangular ducts, the longer dimension is used for the determination of the number of sub-areas.

## Stream Flow Rate

### 1. Gas Speed

Gas speed measurements are carried out indirectly with a calibrated "S"-type pitot tube and an inclined manometer. Pitot tube differential pressure measurements are made at the centroids of the equal-area subdivisions. For iso-kinetic sampling, the pitot tube measurements and gas sampling are carried out simultaneously.

### 2. Gas Temperature

The gas temperature is measured at each point with a sheathed thermocouple and an appropriate meter (portable potentiometer or calibrated digital pyrometer).

### 3. Stream Flow Rate

The gas speed and stream flow rate are calculated from the above data and the absolute pressure in the gas stream, average molecular weight of gas mixture and the duct dimensions. The average molecular weight is the weighted average of the molecular weights of the individual gaseous components in the mixture. (Calculated from the stream analyses).