AP42 Section:	11.18
Title:	*Correspondence and comments*

MEMORANDUM

DATE: August 25, 1988

TO: Ken Schuster/Jerry Clayton

FROM: **Robert Wooten**

SUBJECT: Revision of Review of Emission Test Report for American Rockwool, Inc., Spring Hope, Nash Co., N.C., performed May 17-19, 1988.

The subject report was received July 1, 1988 with additional information received August 8, 1988. The test was performed by personnel of the Aluminum Company of America (ALCOA). The main purpose of the test was to determine fluoride emissions when producing rockwool with spent pot linings (SPL) salvaged from ALCOA's aluminum production operations. It was desired to show to what extent fluoride emissions increase when SPL is substituted for coke. It was also desired to show to what extent the addition of lime decreases fluoride emissions. The filter used for fluoride testing was weighed for particulate determination. Sulfur dioxide was also measured.

The method used for particulate determination involved weighing the sampling thimble used to collect particulate fluorides. Due to the filter being cellulose, it tended to gain atmospheric moisture readily which made the accuracy of the weighings slightly uncertain. Also, probe and filter holder washings were omitted. The particulate values should be somewhat less accurate than a properly performed Method 5 test.

The particulate emission test is insufficient to determine compliance. EPA Method 5 should be performed on the cupola stack and the duct scrubber stack. To meet the requirement of condition 5 of the permit, it will be necessary to determine the input to the blow chamber, the cleaning process transfer cyclone, and the bagging process transfer cyclone.

Sulfur dioxide emissions were determined using a method said to be like EPA Method 15. None of the necessary supporting data was provided. It is not possible to accept the SO_2 results since there is nothing to show that correct procedures were followed. Also, the heat input is undetermined and SO_2 may come from other than fuel.

The method used for fluoride measurement was ALCOA Method 4075A. This method is similar to EPA Method 13B. After discussing certain details of the the test method with Gary McAllister of the EPA, I have concluded that Method 4075A should give accurate results for this source.

The attached table summarizes the fluoride emissions for the three operating conditions tested. The charge makeup and number of charges per hour given in Table 1 on page 2 of the report should be regarded as only nominal. I computed SPL, Lime, and coke charge rates from the production records covering the shift during which testing was performed. You may wish to have American Rockwool verify my numbers as their production records as reproduced in the report are a little confusing.

The first test run of condition B showed lower fluorides than the next three runs. It is not possible to say if the test run is flawed. If it is omitted, the average fluoride emission rate increases 23% (7.84 lbs/hr to 9.67 lbs/hr).

Only two fluoride runs were performed for condition D due to process problems. I accept the results of the two test runs performed.

For condition A, I calculated an emission factor of .000259 lb F/ lb coke. For condition B, I got .00557 lb F/ lb SPL (using 7.41 lb F/hr). This is 21.5 times greater than for coke pound for pound. Since more than a pound of SPL will replace a pound of coke, the actual fluoride increase should be greater.

For condition D, I found .00205 lb F/ lb SPL with .107 lb lime/ lb SPL. The emission factor for SPL with lime is 7.9 times that for coke. Note again that more SPL will be used than the weight of coke reduced.

The fluoride emission standard for this source is given in condition 11 of Permit # 3578R7. The use of 1420 lbs/hr of SPL in both cupolas combined is allowed. The fluoride emissions must not increase over 2.8 lbs/hr (total) when using SPL compared to what the fluoride emissions would be without SPL.

Test condition B shows a fluoride increase of 7.11 lb/hr over condition A with an SPL input of 1329.8 lb/hr (90 lb/hr less than the maximum allowed). If the first test run is omitted, the increase is 8.94 lb/hr. The B condition test shows that the cupolas violate the permitted fluoride increase limit set in the permit when SPL without lime is used.

Test condition D was allowed by permit for a limited time to establish emissions if lime is added along with the SPL. Condition D shows a fluoride increase of 4.37 lb/hr over condition A with a SPL input of 2382 lb/hr. If the emission factor found from this test is applied to the 1420 lb/hr SPL allowed by the permit, the fluoride emission due to SPL is 2.911 lb/hr. Of course, when SPL is used, it replaces coke at somewhat more than a pound of SPL per pound of coke. If it were a pound for a pound, the fluoride increase would be .001791 lbF/lb SPL or, for 1420 lb SPL/hr, 2.54 lbF/hr increase which is within the 2.8 lb/hr increase allowed.

As I understand it, the condition D test was not intended to determine compliance with Permit # 3578R7 operating conditions and emission limits. The results are useful for predicting fluoride emissions when lime is added to the cupolas in the proportions used for the Condition D test.

According to Ken Schuster, the real fluoride concern is that actual fluoride emissions not exceed six (6) pounds per hour and that the annual fluoride increase due to using SPL not exceed three tons. The six lb/hr figure comes from modeling. The 2.8 lb/hr increase figure in the permit comes from assumptions (apparently incorrect) about pre-SPL fluoride emissions and the six lb/hr modeling value.

Attachment

cc: Mike Aldridge
    Central File via Lee Daniel

OPERATING CONDITIONS AND FLUORIDE EMISSIONS

	lbs/charge		charges/hr		lbs charged/hr			Average Fluoride lbs/hr
Cuploa	I	II	I	II	I	II	Total	combined
17MAY88 - Condition A								
SPL	0	0	0	0	0	0	0	
Lime	0	0	0	0	0	0	0	.73
Coke	388.8	388.6	3.63	3.63	1411	1411	2822	
18MAY88 - Condition B								
SPL	207.3	218.7	3.25	3.00	673.7	656.1	1329.8	
Lime	0	0	0	0	0	0	0	7.84
Coke	264.8	268.5	3.25	3.00	860.6	805.5	1666.1	* 9.67
19MAY88 - Condition D								
SPL	427.3	428.0	3.11	2.46	1329	1053	2382	
Lime	23.86	24.38	6.00	4.56	243.2	111.2	254.4	5.10
Coke	143.8	145.7	3.11	2.46	447.2	358.4	805.6	

* If the first of the four runs is omitted since it is much lower than the other three.

This attachment contains:

A) Field testing raw data.
B) Preliminary field testing reduced data.
C) Laboratory raw and reduced data.
    - Sulfur dioxide data.
    - Fluoride.
        1) Nozzle data.
        2) Thimble data.
        3) Impinger data.
        4) SIE calibration plots.

For ease of identification, the LSN/ID# is provided for each sample obtained in Run 4.

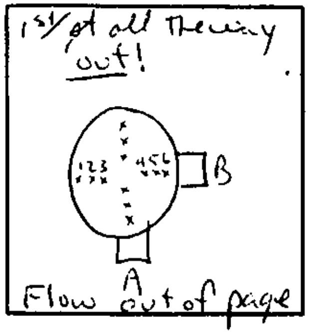
Sample	LSN/ID#
SO_2 - Impinger	804222/539030
SO_2 - Blank	804221/539026
F - Nozzle	804244/539022
F - Thimble	804233/539011
F - Impingers	804004/539000
F - Nozzle Blank	804240/539018
F - Thimble Blank	Blk Thimble
F - Impinger Blank	804229/539007

PARTICULATE TESTING
RAW DATA SET

ALCOA

Plant SPRING HOPE
Unit# ______ Inlet/Outlet OUTLET
Operator S J ROBUCK
Date 2/5/88
Run No. 4
Sample Box No. ______
Meter Box No. 1874
Meter DH@ 1.90
K Factor 8.1
Pitot Cp ______ Pitot Leak Ck ______
Leak Rate Before .006 CFM @ 15 Hg
Leak Rate After .005 CFM @ 12 Hg
Static Press., In. H₂O (+/−) ______

Start Time 7 : 45 [✓ AM] PM
Finish Time 8 : 59 [✓ AM] PM
Meter Yd 1.00



SCHEMATIC OF TESTING LOCATION

Filter #'s ______
Thimble # ______
Beaker # ______

Ambient Temperature, °F 35
Barometric Pressure, In. Hg ______
Assumed Moisture, % ______
Heater Box Setting ______
Probe Length, Ft. ______ No. ______
Nozzle Diameter, In. ______
Probe Heater Setting ______
% O_2 ______
% CO_2 ______
H_2O, ml 10
Silica Gel, gm 9.1
Total Vlc 19.1
Stack Area, Ft² ______
Pyrometer No. ______

TRAVERSE POINT NUMBER	MIN/PT ___ SAMPLING TIME θ, min.	VACUUM In. Hg	STACK TEMPERATURE T_s, °F	VELOCITY HEAD DP_s	PRESSURE DIFFERENTIAL ACROSS ORIFICE METER DH, In. H_2O	Initial Volume: 493.987 GAS SAMPLE VOLUME V_m, Ft³	GAS SAMPLE TEMPERATURE AT DRY GAS METER INLET T_m in, °F	GAS SAMPLE TEMPERATURE AT DRY GAS METER OUTLET T_m out, °F	TEMP. OF GAS LEAVING CONDENSER OR LAST IMPINGER T_c, °F	SAMPLE BOX TEMPERATURE T_b °F
B 6	5	3	78	.17	1.4	497.30	52	41	33	
5	10	3	78	.19	1.5	500.64	59	44	36	
4	15	3	78	.25	2.0	504.30	64	47	40	
3	20	4	76	.21	1.7	507.73	67	49	40	
2	25	5	75	.29	2.3	511.75	72	51	41	
1	30	5	75	.22	1.8	515.473	72	52	41	
A 1	5	6	76	.21	1.7	519.05	65	52	44	
2	10	6	77	.28	2.3	523.22	71	53	47	
3	15	7	75	.28	2.3	527.21	73	53	49	
4	20	7	77	.30	2.6	531.77	78	54	53	
5	25	6	76	.32	2.7	536.17	78	55	53	
6	30	5	77	.18	1.5	539.725	77	55	53	
TOTAL			918	5.868			AVG. 828	AVG. 606		
AVERAGE			77	0.489	1.98	45.738	AVG. 60			

Page ______ of ______

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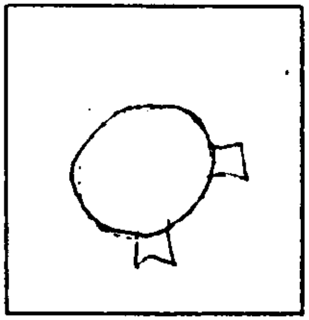
PARTICULATE TESTING
RAW DATA SET

ALCOA

Plant Am Rockwood
Unit# BCM Inlet/[✓ Outlet] STACK
Operator JVA
Date 09-02-05
Run No. 4
Sample Box No.
Meter Box No. 2165
Meter DH@ 1.86
K Factor 3,13
Pitot Cp .84 Pitot Leak Ck ✓
Leak Rate Before 0.013 CFM @ 15 Hg
Leak Rate After 0.008 CFM @ 10 Hg
Static Press., In. H_2O (+/−) 0.22

Start Time 7:48 [✓ AM] PM
Finish Time 8:59 [✓ AM] PM
Meter Yd 0,95



SCHEMATIC OF TESTING LOCATION

Filter #'s
Thimble #
Beaker #

Ambient Temperature, °F
Barometric Pressure, In. Hg 30,28
Assumed Moisture, %
Heater Box Setting
Probe Length, Ft. No.
Nozzle Diameter, In.
Probe Heater Setting
% O_2
% CO_2
H_2O, ml -5
Silica Gel, gm 12.8
Total Vlc 7.8
Stack Area, Ft²
Pyrometer No.

TRAVERSE POINT NUMBER	MIN/PT 5 SAMPLING TIME θ, min.	VACUUM In. Hg	STACK TEMPERATURE T_s, °F	VELOCITY HEAD DP_s	PRESSURE DIFFERENTIAL ACROSS ORIFICE METER DH, In. H_2O	Initial Volume: 589.68 GAS SAMPLE VOLUME V_m, Ft³	GAS SAMPLE TEMPERATURE AT DRY GAS METER INLET T_m in, °F	GAS SAMPLE TEMPERATURE AT DRY GAS METER OUTLET T_m out, °F	TEMP. OF GAS LEAVING CONDENSER OR LAST IMPINGER T_c, °F	SAMPLE BOX TEMPERATURE T_b °F
A-1	5	5	78	0,20	1,6	593,09	51	36	30	252
2	10	5	78	0,25	2.0	596.86	61	38	33	246
3	15	5	78	0,28	2,28	600.90	66	40	34	250
4	20	5	79	0,22	1,8	604,60	68	42	34	253
5	25	6	79	0.31	2,5	608,84	68	42	34	255
6	30	5	77	0,21	1,7	612,47	72	46	JV ~~34~~ 37	258
B-1	35	~~6~~5	75	0,28	2,28	616,56	51	43	36	270
2	40	5	76	0.28	2,28	620,56	64	45	39	267
3	45	6	75	0.31	2.5	624,85	71	46	40	260
4	50	5	77	0,26	2,1	628,83	75	47	42	258
5	55	5	76	0,25	2,0	632,69	78	48	43	250
6	60	5	75	0,15	1,2	635,89	77	50	45	252
TOTAL			923	5,97	24,24		AVG. 802	AVG. 523		
AVERAGE			77	0.498	2.02	46.21	AVG. 54			

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Page 1 of 1

PARAMETER SHEET

ALCOA

PLANT Am Rockwool
CITY SpHope STATE NC
DATE 88-02-05

RUN 4 METHOD 5/6
UNIT Both
○ INLET
☒ OUTLET STACK
START TIME 7:48 [✓ AM] PM
FINISH TIME 8:59 [✓ AM] PM
METER OPERATOR JVA

COMMENTS:
~ 99%
Preliminary Results

METER BOX NO. 2168
DH @ 1.86

FILTER NO. 5
THIMBLE NO.

Assume Bws = 2%

	DATA		
1	Pb	30.28	"Hg
2	Static	-0.22	"wc
3	Vlc	7.8	ml
4	Mn		g
5	θ	60	min
6	% O_2	19	
7	% CO_2	2	
8	DH	2.02	"wc
9	Cp	0.84	
10	Tm	54	F
11	$\sqrt{Dp}$	0.498	$\sqrt{"wc}$
12	Ts	77	F
13	Vm	46.21	ft^3
14	Dn	0.294	in
15	As	28.27	ft^2
16	Yd	0.95	cf/cf

RESULTS			
Vmstd	45.84	dscf	
Vwstd	0.367	scf	
Bwo	0.008		
Md	29.08	lb/lb-mole	29.08
Ms	28.99	lb/lb-mole	28.86
Vs	27.98	ft/s	28.04
% I	98.0		99.0
acfm	47460		47570
dscfm	46820		46360
Particulate		gr/dscf	
		lb/hr	
SO_2	104.5	lb/hr	
Gaseous F		lb/hr	
Particulate F		lb/hr	
Total F		lb/hr	

PARAMETER SHEET

ALCOA

PLANT Am Rockwood
CITY Sp Hope STATE NC
DATE 88-02-05

RUN 4 METHOD 4075-A
UNIT Both
○ INLET
☒ OUTLET STACK
START TIME 7:45 [✓ AM]/PM
FINISH TIME 8:59 [✓ AM]/PM
METER OPERATOR SJR

COMMENTS:
~103%
Preliminary Results

METER BOX NO. 1874
DH @ 1.90

FILTER NO.
THIMBLE NO. 4

DATA

1	Pb	30.28	"Hg
2	Static	-0.22	"wc
3	Vlc	19.1	ml
4	Mn		g
5	θ	60	min
6	% O_2	19	
7	% CO_2	2	
8	DH	1.98	"wc
9	Cp	0.84	
10	Tm	60	F
11	$\sqrt{Dp}$	0.489	$\sqrt{\text{"wc}}$
12	Ts	77	F
13	Vm	45.738	ft^3
14	Dn	0.294	in
15	As	28.27	ft^2
16	Yd	1.00	cf/cf

RESULTS

Vmstd	47.21	dscf
Vwstd	0.9	scf
Bwo	0.019	
Md	29.08	lb/lb-mole
Ms	28.87	lb/lb-mole
Vs	27.53	ft/s
% I	103.7	
acfm	46700	
dscfm	45570	
Particulate	—	gr/dscf
	—	lb/hr
SO_2	—	lb/hr
Gaseous F	0.08	lb/hr
Particulate F	0.63	lb/hr
Total F	0.70	lb/hr

— misc Leg — E.C.L — L.Penny — 86100110 — method 6

System ID: American Rockwool Compliance

Submitted: 8 Samples

LSN 804218 thru 804225

SO$_2$ By EPA method-6

Barium Perchlorate = 0.01 N

Bl ml	10/100/5 (T. Vol 760ml) 804218 ml	10/100/5 (T. Vol 720ml) 804219 ml
0.05	2.70	4.80
0.00	0.05	2.70
0.05	2.65	2.10
	.05	.05
	2.60 ✓	2.05 ✓
	1665.56 mg/L ✓	1,313.23 mg/L ✓
	(1265.8) 1266. Total mg ✓	(945.5) 946. Total mg ✓

10/100/5 (T. Vol 620) 804220 ml	20ml (T. Vol 1,150) 804221 ml	10/100/5 (T. Vol 625) 804222 ml
7.35	7.40	9.40
4.80	7.35	7.40
2.55	0.05	2.00
.05	.05	.05
2.50 ✓	0.00 ✓	1.95 ✓
1,601.5 mg/L ✓		1249.17 mg/L ✓
(992.9) 993. Total mg ✓	NOT DETECTED ✓	(780.7) 781. Total mg ✓

$$\frac{\text{ml} \times N \times 32.03 \times 1000 \times \text{Dilution}}{\text{ml Sample}} = \text{mg/L}$$

mg/L × Total Volume (Decimal) = Total mg as SO$_2$

88-021018 14H100089

10/100/5 (T. vol 675)	10/100/5 (T. vol 675)	10/100/5 (T. vol 830
804223 ml	804224 ml	804225 ml
11.50	13.30	15.05
9.40	11.50	13.30
2.10	1.80	1.75
.05	.05	.05
2.05 ✓	1.75 ✓	1.70 ✓
1313.23 mg/L	1121.05 mg/L ✓	1089.02 mg/L ✓
(886.4) 886 Total mg. ✓	(756.7) 757. Total mg ✓	(903.9) 904 ✓ Total mg

RUN 5

10/100/10 (T. vol 675 ml)
804224 DUPLICATE ml

18.50
15.05
3.45 ✓
.05
3.40 ✓

1089.02 mg/L ✓

(735.1) 735. Total mg. ✓

10/100/5 + 5.052 mg S × 1.998 = 10.094 mg SO_2
804218 Spike ml

31.85
0.00
31.85
.05
31.80 ✓

✓

SPIKED SAMPLE ANALYSIS = 10.186 mg
UNSPIKED SAMPLE ANALYSIS = 0.833 mg ✓
RECOVERED = 9.353 mg ✓
ADDED = 10.094 mg ✓
% RECOVERY = 92.66 ✓
= 92.7%

8-5
Syste
Subm
LS
Sulf
Fac
0.1

TOTAL VOLUME OF SAMPLE RECEIVED

LSN	Total Volume	LSN	Total Volume
804218	760 ml	804222	625 ml
219	720 ml	223	675 ml
220	620 ml	224	675 ml
221	1,150 ml	225	830 ml

mfH 88-08-18

2760:189

L.Penix
14H1000891
amer Rods
nozzle wash

88-021020
ECL
//

- all samples directly distilled to 500ml c H2SO4 SIE
804245 contained acetone
not analyzed.

88/01/04 07:25:50
TRAY NO. 1 TRAY I.D. 1 JOB ORDER NO.
CALIBRATION BASED ON TRAY 1
MV READOUT ONLY 16 POSITIONS

POS. 1 MV= 1441
POS. 2 MV= 1492
POS. 3 MV= 1490
POS. 4 MV= 917
POS. 5 MV= 325
POS. 6 MV= -258
POS. 7 MV= 325 20 ppm
POS. 8 MV= 600 804237
POS. 9 MV= 449 238
POS. 10 MV= 399 239
POS. 11 MV= 1599 240
POS. 12 MV= 1607 240
POS. 13 MV= 1715 240
POS. 14 MV= 1352 241
POS. 15 MV= 1515 242
POS. 16 MV= 1541 243

88-021020

88/01/04 09:47:33
TRAY NO. 2 TRAY I.D. 2 JOB ORDER NO.
CALIBRATION BASED ON TRAY 1
MV READOUT ONLY 8 POSITIONS

POS. 1 MV= ~~1354~~
POS. 2 MV= 1355 804244
POS. 3 MV= 1333 246
POS. 4 MV= 1416 247
POS. 5 MV= ~~1451~~
POS. 6 MV= 1453 801719 88-01
POS. 7 MV= -126 804000 .5013
POS. 8 MV= -125

88-021020

```
CALIBRATION; MV/KB; 16POSITIONS-NO DISTILLED STD.:

 1            2 MG F/L          17 MV


88/01/04                       13:08:10
TRAY NO. 1               TRAY I.D. 1             JOB ORDER NO.88-021020
CALIBRATION BASED ON TRAY  1
CALIBRATION; MV/KB;  16POSITIONS-NO DISTILLED STD.:

 1            2 MG F/L          917 MV
 2            20 MG F/L      325 MV       MG/L FLUORIDE= 20.000
          SLOPE(MV20-MV2)= -592
 3            0.20 MG F/L       1490 MV          MG/L FLUORIDE=  .200
 4            200 MG F/L        -258 MV         MG/L FLUORIDE=  200.00
                      SLOPE(MV200-MV20)= -583

POS 5              JOB ORDER#88-021020          LSN#=20 PPM
MV= 325              ALIQUOT= 10 MLS
ORIG. SPL.= 500 MLS
S. WT.= 0              DIL. VOL.= 500 MLS           MG F/L= 20
KNOWN CONC.= 0         CALC. CONC.= 20.000(MG F/L)
DIST. FACTOR 0 APPLIED


POS 6              JOB ORDER#88-021020          LSN#=804237
MV= 600              ALIQUOT= 10 MLS
ORIG. SPL.= 0 MLS
S. WT.= 0              DIL. VOL.= 500 MLS           MG F/L= 6.863
KNOWN CONC.= 0         CALC. CONC.= 3.432(MG TF)
DIST. FACTOR 0 APPLIED


POS 7              JOB ORDER#88-021020          LSN#=804238
MV= 449              ALIQUOT= 10 MLS
ORIG. SPL.= 0 MLS
S. WT.= 0              DIL. VOL.= 500 MLS           MG F/L= 12.347
KNOWN CONC.= 0         CALC. CONC.= 6.174(MG TF)
DIST. FACTOR 0 APPLIED


POS 8              JOB ORDER#88-021020          LSN#=804239
MV= 399              ALIQUOT= 10 MLS
ORIG. SPL.= 0 MLS
S. WT.= 0              DIL. VOL.= 500 MLS           MG F/L= 14.998
KNOWN CONC.= 0         CALC. CONC.= 7.499(MG TF)
DIST. FACTOR 0 APPLIED


POS 9              JOB ORDER#88-021020          LSN#=804240
MV= 1607              ALIQUOT= 10 MLS
ORIG. SPL.= 100 MLS
S. WT.= 0              DIL. VOL.= 500 MLS           MG F/L= .121
KNOWN CONC.= 0         CALC. CONC.= .605(MG F/L)
DIST. FACTOR 0 APPLIED                x1,040 ml = .62 mg


POS 10              JOB ORDER#88-021020          LSN#=804240 } avg 0.5 mg
MV= 1715              ALIQUOT= 10 MLS
ORIG. SPL.= 100 MLS
S. WT.= 0              DIL. VOL.= 500 MLS           MG F/L= .073
KNOWN CONC.= 0         CALC. CONC.= .365(MG F/L)
DIST. FACTOR 0 APPLIED               x1,040 ml = 0.38


POS 11              JOB ORDER#88-021020          LSN#=804241
MV= 1352              ALIQUOT= 10 MLS
ORIG. SPL.= 0 MLS
S. WT.= 0              DIL. VOL.= 500 MLS           MG F/L= .354
KNOWN CONC.= 0         CALC. CONC.= .177(MG TF)
DIST. FACTOR 0 APPLIED
```

```
 IG. SPL.= 0 MLS
 . WT.= 0                DIL. VOL.= 500 MLS         MG F/L= 14.998
 NOWN CONC.= 0           CALC. CONC.= 7.499(MG TF)
DIST. FACTOR 0 APPLIED


POS 9             JOB ORDER#88-021020          LSN#=804240
MV= 1607              ALIQUOT= 10 MLS
ORIG. SPL.= 100 MLS
S. WT.= 0                DIL. VOL.= 500 MLS         MG F/L= .121
KNOWN CONC.= 0           CALC. CONC.= .605(MG F/L)
DIST. FACTOR 0 APPLIED                x1,040 ml = .62 mg


POS 10            JOB ORDER#88-021020          LSN#=804240 ) ave 0.5 mg
MV= 1715              ALIQUOT= 10 MLS
ORIG. SPL.= 100 MLS
S. WT.= 0                DIL. VOL.= 500 MLS         MG F/L= .073
KNOWN CONC.= 0           CALC. CONC.= .365(MG F/L)
DIST. FACTOR 0 APPLIED               x1,040 ml = 0.38


POS 11            JOB ORDER#88-021020          LSN#=804241
MV= 1352              ALIQUOT= 10 MLS
ORIG. SPL.= 0 MLS
S. WT.= 0                DIL. VOL.= 500 MLS         MG F/L= .354
KNOWN CONC.= 0           CALC. CONC.= .177(MG TF)
DIST. FACTOR 0 APPLIED


POS 12            JOB ORDER#88-021020          LSN#=804242
MV= 1515              ALIQUOT= 10 MLS
ORIG. SPL.= 0 MLS
S. WT.= 0                DIL. VOL.= 500 MLS         MG F/L= .18
KNOWN CONC.= 0           CALC. CONC.= .090(MG TF)
DIST. FACTOR 0 APPLIED


POS 13            JOB ORDER#88-021020          LSN#=804243
MV= 1541              ALIQUOT= 10 MLS
ORIG. SPL.= 0 MLS
S. WT.= 0                DIL. VOL.= 500 MLS         MG F/L= .161
KNOWN CONC.= 0           CALC. CONC.= .081(MG TF)
DIST. FACTOR 0 APPLIED


POS 14            JOB ORDER#88-021020          LSN#=804244
MV= 1355              ALIQUOT= 10 MLS                              500 ml
ORIG. SPL.= 0 MLS
S. WT.= 0                DIL. VOL.= 500 MLS         MG F/L= .35
KNOWN CONC.= 0           CALC. CONC.= .175(MG TF)
DIST. FACTOR 0 APPLIED


POS 15            JOB ORDER#88-021020          LSN#=804246
MV= 1333              ALIQUOT= 10 MLS
ORIG. SPL.= 0 MLS
S. WT.= 0                DIL. VOL.= 500 MLS         MG F/L= .383
KNOWN CONC.= 0           CALC. CONC.= .192(MG TF)
DIST. FACTOR 0 APPLIED


POS 16            JOB ORDER#88-021020          LSN#=804247
MV= 1416              ALIQUOT= 10 MLS
ORIG. SPL.= 0 MLS
S. WT.= 0                DIL. VOL.= 500 MLS         MG F/L= .272
KNOWN CONC.= 0           CALC. CONC.= .136(MG TF)
DIST. FACTOR 0 APPLIED
```

2760:187

Penix 88-020916
4H4000891 ECL
Rockwool 10
thimb

thimbles scraped out + total particulate weighed. thimbles were cut in half and .5g CaO added to ½ thimble, ashed, fused c̄ NaOH. Dist H_2SO_4. SIE.
5g CaO added to x.5g part. ashed. fused, dist. SIE
803999 + 804000 had 2 thimbles each. ½ of each thimble was taken and the 2 halves were combined,

```
88/01/04                   08:53:16
TRAY NO. 1              TRAY I.D. 1             JOB ORDER NO.
CALIBRATION BASED ON TRAY  1
MV READOUT ONLY       16 POSITIONS

          POS.   1              MV=  1481
          POS.   2              MV=  1486 .2
          POS.   3              MV=  ~~1481~~
          POS.   4              MV=  906 2
          POS.   5              MV=  321 20
          POS.   6              MV= -263 200
          POS.   7              MV=  1612
          POS.   8              MV=  820
          POS.   9         47N  MV=  819 804001 thimble  )
          POS.  10         N85  MV=  915    002    "     )  outlets
          POS.  11          4N  MV=  944    003    "     )
          POS.  12          2N  MV=  512    004          )  88-020916
          POS.  13         48N  MV=  457    005          )
          POS.  14         N71  MV=  418    006          )
          POS.  15        N520  MV=  412 804007 thimble  )
          POS.  16              MV=  ~~1484~~

88/01/04                   09:48:58
TRAY NO. 2              TRAY I.D. 2             JOB ORDER NO.
CALIBRATION BASED ON TRAY  1
MV READOUT ONLY       14 POSITIONS

          POS.   1              MV=  ~~1508~~
          POS.   2          1N  MV=  1514 Blk sm. thimble
          POS.   3              MV=  1139
          POS.   4         N58  MV=  1139 Lge Blk thimble
          POS.   5          3N  MV=  122 sm. thimble +.05g NaF
          POS.   6              MV=  ~~349~~
          POS.   7         N76  MV=  351 803998 thimble x 2
          POS.   8          15  MV=  13 803999     "    x 2
          POS.   9         N87  MV= -42 804000     "    x 2
          POS.  10          14  MV=  251 803998 .5023
          POS.  11          N1  MV= -166 803999 .5124
          POS.  12           5  MV= -179    999 .5182
          POS.  13         N10  MV= -189 804000 .5013
          POS.  14          16  MV= -304    000 .5013 spike
```

```
88/01/04                  14:12:56
TRAY NO. 1             TRAY I.D. 1          JOB ORDER NO.88-020916
CALIBRATION BASED ON TRAY  1
CALIBRATION; MV/KB;  16POSITIONS-NO DISTILLED STD.;

 1            2 MG F/L        906 MV✓
 2            20 MG F/L     321 MV ✓    MG/L FLUORIDE= 20.000
          SLOPE(MV20-MV2)= -585
 3            0.20 MG F/L       1486 MV✓          MG/L FLUORIDE=  .200
 4            200 MG F/L         -263 MV✓        MG/L FLUORIDE=  200.00
                     SLOPE(MV200-MV20)= -584

POS 5              JOB ORDER#88-020916          LSN#=804001
MV= 819 ✓            ALIQUOT= 10 MLS
ORIG. SPL.= 0 MLS
S. WT.= 0              DIL. VOL.= 500 MLS           MG F/L= 2.817
KNOWN CONC.= 0         CALC. CONC.= 1.409(MG TF)
DIST. FACTOR 0 APPLIED


POS 6              JOB ORDER#88-020916          LSN#=804002
MV= 915 ✓            ALIQUOT= 10 MLS
ORIG. SPL.= 0 MLS
S. WT.= 0              DIL. VOL.= 500 MLS           MG F/L= 1.93
KNOWN CONC.= 0         CALC. CONC.= .965(MG TF)
DIST. FACTOR 0 APPLIED


POS 7              JOB ORDER#88-020916          LSN#=804003
MV= 944 ✓            ALIQUOT= 10 MLS
ORIG. SPL.= 0 MLS
S. WT.= 0              DIL. VOL.= 500 MLS           MG F/L= 1.722
KNOWN CONC.= 0         CALC. CONC.= .861(MG TF)
DIST. FACTOR 0 APPLIED


POS 8              JOB ORDER#88-020916          LSN#=804004
MV= 512 ✓            ALIQUOT= 10 MLS
ORIG. SPL.= 0 MLS
S. WT.= 0              DIL. VOL.= 500 MLS           MG F/L= 9.43
KNOWN CONC.= 0         CALC. CONC.= 4.715(MG TF)
DIST. FACTOR 0 APPLIED


POS 9              JOB ORDER#88-020916          LSN#=804005
MV= 457✓             ALIQUOT= 10 MLS
ORIG. SPL.= 0 MLS
S. WT.= 0              DIL. VOL.= 500 MLS           MG F/L= 11.71
KNOWN CONC.= 0         CALC. CONC.= 5.855(MG TF)
DIST. FACTOR 0 APPLIED


POS 10              JOB ORDER#88-020916          LSN#=804006
MV= 418✓             ALIQUOT= 10 MLS
ORIG. SPL.= 0 MLS
S. WT.= 0              DIL. VOL.= 500 MLS           MG F/L= 13.653
KNOWN CONC.= 0         CALC. CONC.= 6.827(MG TF)
DIST. FACTOR 0 APPLIED


POS 11              JOB ORDER#88-020916          LSN#=804007
MV= 412✓             ALIQUOT= 10 MLS
ORIG. SPL.= 0 MLS
S. WT.= 0              DIL. VOL.= 500 MLS           MG F/L= 13.979
KNOWN CONC.= 0         CALC. CONC.= 6.99(MG TF)
DIST. FACTOR 0 APPLIED
```

```
POS 11                  JOB ORDER#88-020916           LSN#=804007
MV= 412                   ALIQUOT= 10 MLS
ORIG. SPL.= 0 MLS
S. WT.= 0                  DIL. VOL.= 500 MLS            MG F/L= 13.979
KNOWN CONC.= 0             CALC. CONC.= 6.99(MG TF)
DIST. FACTOR 0 APPLIED


POS 12                  JOB ORDER#88-020916           LSN#=SM BLK THIMBLE
MV= 1514 ✓                  ALIQUOT= 10 MLS
ORIG. SPL.= 0 MLS
S. WT.= 0                  DIL. VOL.= 500 MLS            MG F/L= .179
KNOWN CONC.= 0             CALC. CONC.= .09(MG TF)
DIST. FACTOR 0 APPLIED


POS 13                  JOB ORDER#88-020916           LSN#=LG BLK THIMBLE
MV= 1139 ✓                  ALIQUOT= 10 MLS
ORIG. SPL.= 0 MLS
S. WT.= 0                  DIL. VOL.= 500 MLS            MG F/L= .797
KNOWN CONC.= 0             CALC. CONC.= .399(MG TF)
DIST. FACTOR 0 APPLIED


POS 14                  JOB ORDER#88-020916           LSN#=SM THIMBLE .05G NAF
MV= 122 ✓                 ALIQUOT= 10 MLS
ORIG. SPL.= 0 MLS
S. WT.= 0                  DIL. VOL.= 500 MLS            MG F/L= 43.831
KNOWN CONC.= 0             CALC. CONC.= 21.916(MG TF)
DIST. FACTOR 0 APPLIED
```

NaF/F
.05/2.21 = 22.6 mg added

```
POS 15                  JOB ORDER#88-020916           LSN#=803998
MV= 351 ✓                 ALIQUOT= 10 MLS
ORIG. SPL.= 0 MLS
S. WT.= 0                  DIL. VOL.= 500 MLS            MG F/L= 17.772
KNOWN CONC.= 0             CALC. CONC.= 8.886(MG TF)
DIST. FACTOR 0 APPLIED
```

thimble

x2 = 17.8 mg F in thimble

```
POS 16                  JOB ORDER#88-020916           LSN#=803999
MV= 13 ✓                 ALIQUOT= 10 MLS
ORIG. SPL.= 0 MLS
S. WT.= 0                  DIL. VOL.= 500 MLS            MG F/L= 67.364
KNOWN CONC.= 0             CALC. CONC.= 33.682(MG TF)
DIST. FACTOR 0 APPLIED
```

thimbles
2 ½'s

x2 = 67.4 mg F in 2 thimbles

```
88/01/04                     14:17:39
TRAY NO. 2            TRAY I.D. 2          JOB ORDER NO.88-020916
CALIBRATION BASED ON TRAY  2
CALIBRATION; MV/KB;  7POSITIONS-NO DISTILLED STD.;


88/01/04                     14:20:03
TRAY NO. 2            TRAY I.D. 2          JOB ORDER NO.88-020916
CALIBRATION BASED ON TRAY  2
CALIBRATION; MV/KB;  11POSITIONS-NO DISTILLED STD.;

 1           .2 MG F/L          906 MV
 2           20 MG F/L       321 MV       MG/L FLUORIDE= 20.000
         SLOPE(MV20-MV2)= -585
 3          0.20 MG F/L       1486 MV          MG/L FLUORIDE=  .200
 4          200 MG F/L        -263 MV        MG/L FLUORIDE=  200.00
                    SLOPE(MV200-MV20)= -584
```

```
TRAY NO. 2                TRAY I.D. 2              JOB ORDER NO.88-020916
'CALIBRATION BASED ON TRAY  2
CALIBRATION; MV/KB;  11POSITIONS-NO DISTILLED STD.;

✓1           2 MG F/L          906 MV
 2          20 MG F/L      321 MV       MG/L FLUORIDE= 20.000
        SLOPE(MV20-MV2)= -585
 3          0.20 MG F/L       1486 MV          MG/L FLUORIDE=  .200
 4          200 MG F/L          -263 MV        MG/L FLUORIDE=  200.00
                       SLOPE(MV200-MV20)= -584

POS 5             JOB ORDER#88-020916          LSN#=804000
MV=-42 ✓           ALIQUOT= 10 MLS
ORIG. SPL.= 0 MLS
S. WT.= 0              DIL. VOL.= 500 MLS           MG F/L= 83.677
KNOWN CONC.= 0         CALC. CONC.= 41.839(MG TF)
DIST. FACTOR 0 APPLIED
```

thimbles
2 "2's"

✓ x 2 = 83.7 mg F = 2 Thimbles

```
POS 6             JOB ORDER#88-020916          LSN#=803998
MV= 251 ✓           ALIQUOT= 10 MLS
ORIG. SPL.= 0 MLS
S. WT.= .5023              DIL. VOL.= 500 MLS           MG F/L= 26.357
KNOWN CONC.= 0         CALC. CONC.= 2.624(%F)
DIST. FACTOR 0 APPLIED
```

part wt = 4.0395

✓ x 4.0395 = 106.00 mg

106.0 mg + 17.8 mg thimble = 123.8 Total mg ✓

```
POS 7             JOB ORDER#88-020916          LSN#=803999
MV=-166 ✓           ALIQUOT= 10 MLS
ORIG. SPL.= 0 MLS
S. WT.= .5124              DIL. VOL.= 500 MLS           MG F/L= 136.43
KNOWN CONC.= 0         CALC. CONC.= 13.313(%F)
DIST. FACTOR 0 APPLIED
```

part wt = 2.6905

x 2.6905 = 358.19 mg ✓

358.2 mg + 67.4 mg in thimble = 425.6 ✓ T. mg

```
POS 8             JOB ORDER#88-020916          LSN#=803999
MV=-179 ✓           ALIQUOT= 10 MLS
ORIG. SPL.= 0 MLS
S. WT.= .5182              DIL. VOL.= 500 MLS           MG F/L= 143.61
KNOWN CONC.= 0         CALC. CONC.= 13.857(%F)
DIST. FACTOR 0 APPLIED
```

duplicate

x 2.6905 = 372 mg ✓

report 13.3% and 13.8% as duplicates

```
POS 9             JOB ORDER#88-020916          LSN#=804000
MV=-189 ✓           ALIQUOT= 10 MLS
ORIG. SPL.= 0 MLS
S. WT.= .5013              DIL. VOL.= 500 MLS           MG F/L= 149.38
KNOWN CONC.= 0         CALC. CONC.= 14.899(%F)
DIST. FACTOR 0 APPLIED
```

part wt = 2.5238

✓ x 2.5238 = 376.02 mg F ✓

376.0 mg + 83.7 mg = 459.7 ✓ T. mg

14.9 x .5013 = 74.7 mg F samp ✓

```
POS 10            JOB ORDER#88-020916          LSN#=804000
MV=-304 ✓           ALIQUOT= 10 MLS
ORIG. SPL.= 0 MLS
S. WT.= .5013              DIL. VOL.= 500 MLS           MG F/L= 235.09
KNOWN CONC.= 0         CALC. CONC.= 23.448(%F)
DIST. FACTOR 0 APPLIED
```

✓ x .5013 = 117.54 mg F in spike

− 74.7 ✓ mg samp

42.8 ✓ mg ÷ 45.2 mg = 94.7% ✓

NaF / F

.1 / 2.21 = 45.2 mg ✓

```
POS 11            JOB ORDER#88-020916          LSN#=804000
MV=-106 ✓           ALIQUOT= 10 MLS
ORIG. SPL.= 0 MLS
S. WT.= .5013              DIL. VOL.= 500 MLS           MG F/L= 107.69
KNOWN CONC.= 0         CALC. CONC.= 10.741(%F)
DIST. FACTOR 0 APPLIED
```

x 2 = 21.5 chcl low

2760:184

hix
+ H1000891
Rockwell compliance
impingers

88-021019
ECL
11

direct duct c H_2SO_4 SIE

```
88/01/04                       12:48:55
TRAY NO. 1                TRAY I.D. 1                 JOB ORDER NO.
CALIBRATION BASED ON TRAY  2
MV READOUT ONLY        16 POSITIONS

             POS.   1                MV=   1468
             POS.   2                MV=   1487
             POS.   3                MV=   1483
             POS.   4                MV=   904
             POS.   5                MV=   314
             POS.   6                MV=  -275
             POS.   7                MV=   315 20ppm
             POS.   8                MV=   ~~1670~~ 804236
             POS.   9                MV=   1711 804236
             POS.   10                MV=   968 80#227
             POS.   11                MV=   923      228
             POS.   12                MV=   1851     229
             POS.   13                MV=   1613     230
             POS.   14                MV=   1700     231
             POS.   15                MV=   1656     232
             POS.   16                MV=   ~~[illegible]~~

88/01/04                       13:40:59
TRAY NO. 2                TRAY I.D. 2                 JOB ORDER NO.
CALIBRATION BASED ON TRAY  2
MV READOUT ONLY        6 POSITIONS

             POS.   1                MV=   1632 80#233
             POS.   2                MV=   1637    233 dup
             POS.   3                MV=   1678    234
             POS.   4                MV=   1802    235
             POS.   5                MV=   953     236 -
             POS.   6                MV=   823     236 spike
```

```
88/01/04                    11:25:19
TRAY NO. 1            TRAY I.D. 1          JOB ORDER NO.88-021019
CALIBRATION BASED ON TRAY  1
CALIBRATION; MV/KB;  16POSITIONS-NO DISTILLED STD.;

 1             2 MG F/L        904 MV
 2            20 MG F/L      314 MV       MG/L FLUORIDE= 20.000
            SLOPE(MV20-MV2)= -590
 3            0.20 MG F/L        1483 MV          MG/L FLUORIDE=  .200
 4            200 MG F/L         -275 MV       MG/L FLUORIDE=  200.00
                      SLOPE(MV200-MV20)= -589

POS 5             JOB ORDER#88-021019          LSN#=
MV= 315               ALIQUOT= 10 MLS
ORIG. SPL.= 500 MLS
S. WT.= 0              DIL. VOL.= 500 MLS          MG F/L= 19.922
KNOWN CONC.= 0         CALC. CONC.= 19.922(MG F/L)
DIST. FACTOR 0 APPLIED


POS 6             JOB ORDER#88-021019          LSN#=804236
MV= 1711               ALIQUOT= 10 MLS
ORIG. SPL.= 50 MLS
S. WT.= 0              DIL. VOL.= 500 MLS          MG F/L= .076
KNOWN CONC.= 0         CALC. CONC.= .760(MG F/L)
DIST. FACTOR 0 APPLIED                    x.480 = .36 Total mg ✓

POS 7             JOB ORDER#88-021019          LSN#=804227
MV= 968               ALIQUOT= 10 MLS
ORIG. SPL.= 50 MLS
S. WT.= 0              DIL. VOL.= 500 MLS          MG F/L= 1.556
KNOWN CONC.= 0         CALC. CONC.= 15.560(MG F/L)
DIST. FACTOR 0 APPLIED                   x.335 = 5.2 Total mg ✓

POS 8             JOB ORDER#88-021019          LSN#=804228
MV= 923               ALIQUOT= 10 MLS
ORIG. SPL.= 50 MLS
S. WT.= 0              DIL. VOL.= 500 MLS          MG F/L= 1.856
KNOWN CONC.= 0         CALC. CONC.= 18.560(MG F/L)
DIST. FACTOR 0 APPLIED                   x.385 = 7.1 Total mg ✓

POS 9             JOB ORDER#88-021019          LSN#=804229
MV= 1851              ALIQUOT= 10 MLS
ORIG. SPL.= 50 MLS
S. WT.= 0              DIL. VOL.= 500 MLS          MG F/L= .04
KNOWN CONC.= 0         CALC. CONC.= .402(MG F/L)
DIST. FACTOR 0 APPLIED                   x.575 = 0.2 Total mg ✓

POS 10            JOB ORDER#88-021019
MV= 1613               ALIQUOT= 10 MLS
ORIG. SPL.= 50 MLS
S. WT.= 0
KNOWN CO
DIST.                                    x.505 = .59 Total mg ✓


POS                                            LSN#=804231


                       DIL. VOL.= 500 MLS          MG F/L= .08
```

```
KNOWN CONC.= 0          CALC. CONC.= .400(MG F/L)
DIST. FACTOR 0 APPLIED
```

x.575 = 0.2 Total mg /

```
POS 10               JOB ORDER#88-021019          [illegible]
MV= 1613                ALIQUOT= 10 MLS
ORIG. SPL.= 50 MLS
S. WT.= 0               DIL. [illegible]
KNOWN CONC.= 0          [illegible]
DIST. FACTOR 0 APPLIED
```

x.505 = .59 Total mg /

```
[illegible]                                       LSN#=804231

                        DIL. VOL.= 500 MLS         MG F/L= .08
KNOWN CONC.= 0          CALC. CONC.= .800(MG F/L)
DIST. FACTOR 0 APPLIED
```

x.595 = .48 Total mg /

```
POS 12               JOB ORDER#88-021019          LSN#=804232
MV= 1656                ALIQUOT= 10 MLS
ORIG. SPL.= 50 MLS
S. WT.= 0               DIL. VOL.= 500 MLS         MG F/L= .097
KNOWN CONC.= 0          CALC. CONC.= .970(MG F/L)
DIST. FACTOR 0 APPLIED
```

x.500 = .48 Total mg

```
POS 13               JOB ORDER#88-021019          LSN#=804233
MV= 1632                ALIQUOT= 10 MLS
ORIG. SPL.= 50 MLS
S. WT.= 0               DIL. VOL.= 500 MLS         MG F/L= .107
KNOWN CONC.= 0          CALC. CONC.= 1.070(MG F/L)
DIST. FACTOR 0 APPLIED
```

x.525 = .56 ✓

```
POS 14               JOB ORDER#88-021019          LSN#=804233 DUPLICTE
MV= 1637                ALIQUOT= 10 MLS
ORIG. SPL.= 50 MLS
S. WT.= 0               DIL. VOL.= 500 MLS         MG F/L= .105
KNOWN CONC.= 0          CALC. CONC.= 1.050(MG F/L)
DIST. FACTOR 0 APPLIED
```

x.525 = .55 ✓

```
POS 15               JOB ORDER#88-021019          LSN#=804234
MV= 1678                ALIQUOT= 10 MLS
ORIG. SPL.= 50 MLS
S. WT.= 0               DIL. VOL.= 500 MLS         MG F/L= .088
KNOWN CONC.= 0          CALC. CONC.= .880(MG F/L)
DIST. FACTOR 0 APPLIED
```

x.515 = .45

```
POS 16               JOB ORDER#88-021019          LSN#=804235
MV= 1802                ALIQUOT= 10 MLS
ORIG. SPL.= 50 MLS
S. WT.= 0               DIL. VOL.= 500 MLS         MG F/L= .051
KNOWN CONC.= 0          CALC. CONC.= .510(MG F/L)
DIST. FACTOR 0 APPLIED
```

x.465 = .24

```
88/01/04                     11:30:32
TRAY NO. 2               TRAY I.D. 2               JOB ORDER NO.88-021019
CALIBRATION BASED ON TRAY  2
```

```
CALIBRATION BASED ON TRAY  2
CALIBRATION; MV/KB;  6POSITIONS-NO DISTILLED STD.;

 1           2 MG F/L          904 MV
 2          20 MG F/L        314 MV      MG/L FLUORIDE= 20.000.
         SLOPE(MV20-MV2)= -590
 3          0.20 MG F/L        1483 MV          MG/L FLUORIDE= .200
 4          200 MG F/L          -275 MV        MG/L FLUORIDE=  200.00
                        SLOPE(MV200-MV20)= -589

POS 5               JOB ORDER#88-021019          LSN#=804206
MV= 953               ALIQUOT= 10 MLS
ORIG. SPL.= 50 MLS
S. WT.= 0               DIL. VOL.= 500 MLS            MG F/L= 1.65
KNOWN CONC.= 0          CALC. CONC.= 16.500(MG F/L)
DIST. FACTOR 0 APPLIED
```

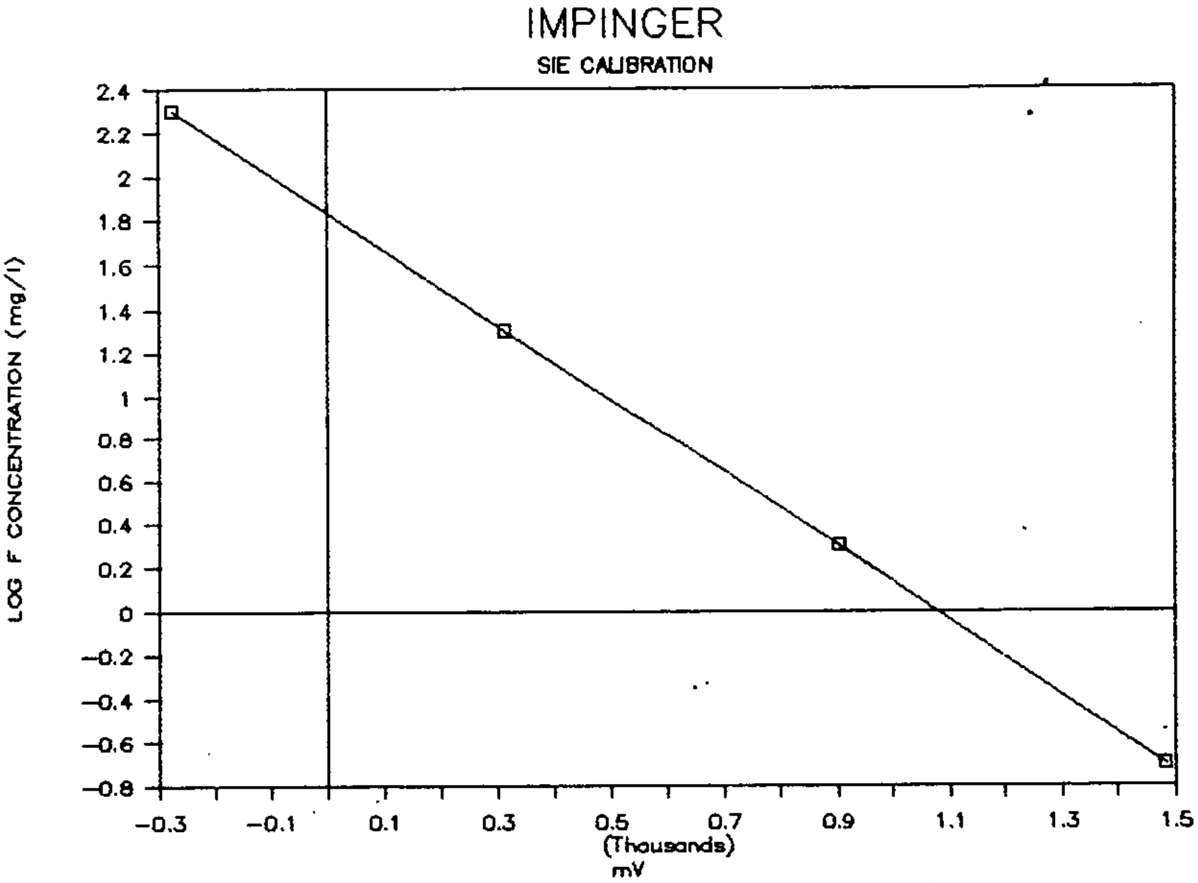
x .255 = 4.2 ✓

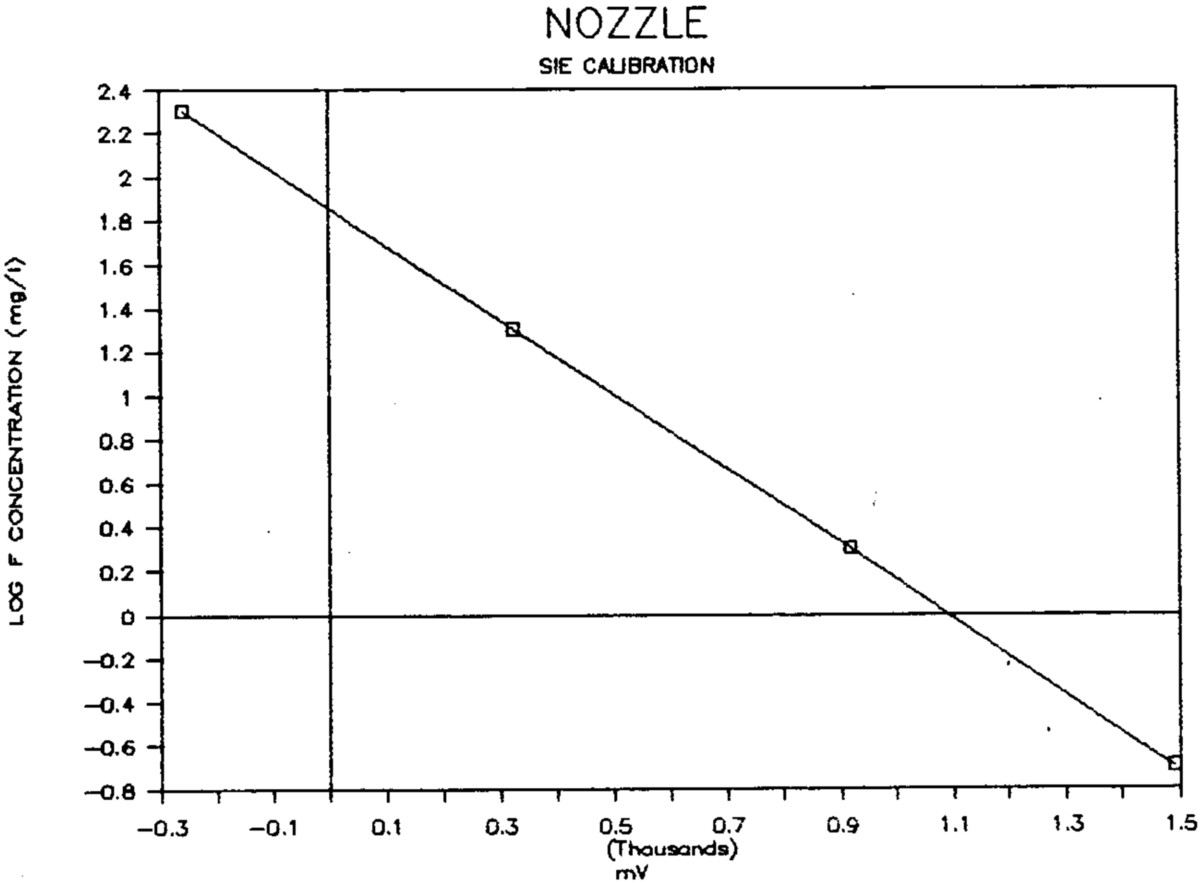
```
POS 6               JOB ORDER#88-021019          LSN#=804206 SPIKE
MV= 823               ALIQUOT= 10 MLS
ORIG. SPL.= 50 MLS
S. WT.= 0               DIL. VOL.= 500 MLS            MG F/L= 2.744
KNOWN CONC.= 0          CALC. CONC.= 27.440(MG F/L)
DIST. FACTOR 0 APPLIED
```

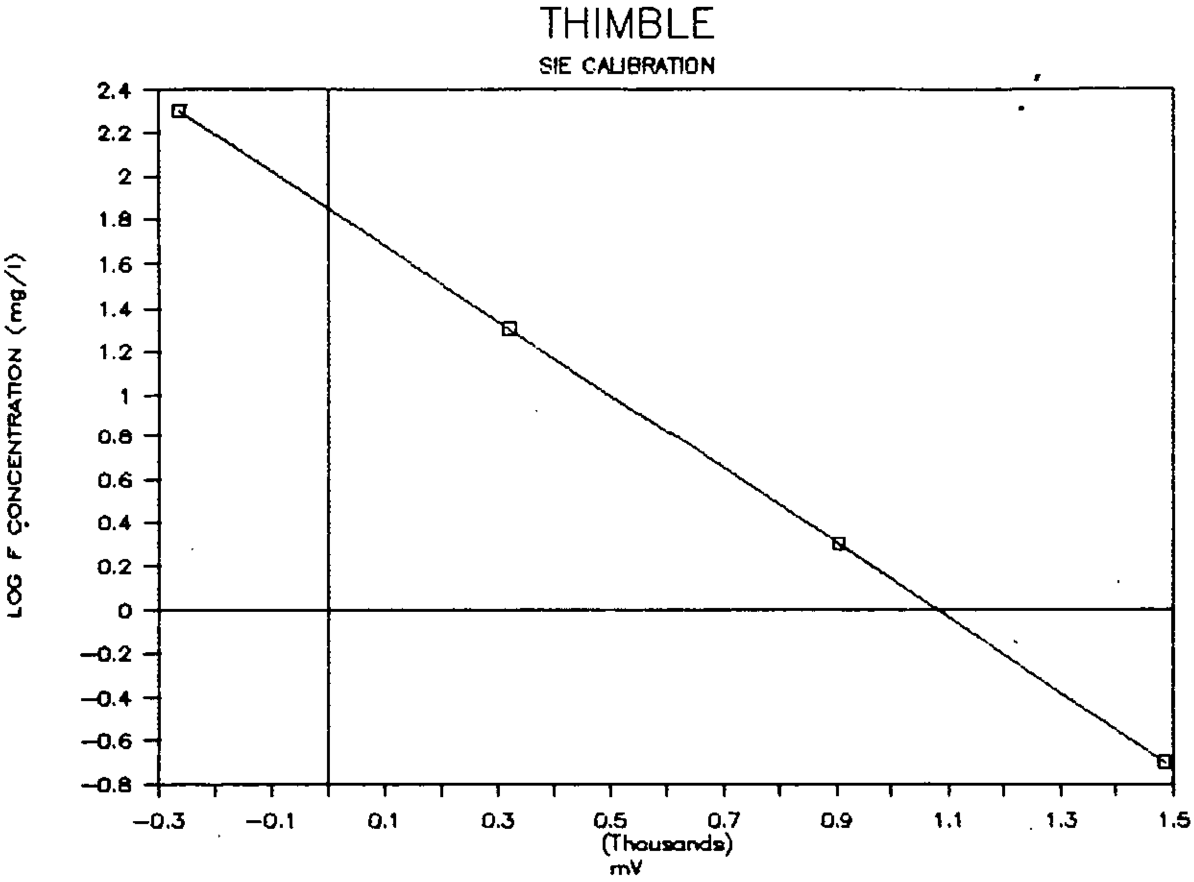
-16.5

10.9 or 109%

5ml of 100 mg/L F std
50 ml samp / 500 ml
(10 ppm spike)


IMPINGER
SIE CALIBRATION
LOG F CONCENTRATION (mg/l)
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-0.3
-0.1
0.1
0.3
0.5
0.7
0.9
1.1
1.3
1.5
(Thousands)
mV


NOZZLE
SIE CALIBRATION
LOG F CONCENTRATION (mg/l)
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-0.3
-0.1
0.1
0.3
0.5
0.7
0.9
1.1
1.3
1.5
(Thousands)
mV


THIMBLE
SIE CALIBRATION
LOG F CONCENTRATION (mg/l)
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
−0.3
−0.1
0.1
0.3
0.5
0.7
0.9
1.1
1.3
1.5
(Thousands)
mV

DIVISION OF ENVIRONMENTAL MANAGEMENT
AIR QUALITY SECTION
RALEIGH REGIONAL OFFICE

April 25, 1988

MEMORANDUM

TO: Mike Aldridge/Bob Wooten

FROM: Ken Schuster

SUBJECT: American Rockwool - Emission Test Reports
Spring Hope, Nash County

Several test reports for the subject company have been forwarded to you for review. The test reports forwarded were conducted on January 12-16 and February 3-5, 1988. Additional information refers to April 1986 testing and a rockwool emission test in Texas. In addition to fluorides, particulate, sulfur dioxide, and opacity were tested.

As per our earlier discussion, AR (American Rockwool Co.) initiated the use of spent pot lining (SPL) from aluminum smelting pots as a partial replacement for coke in the rockwool manufacturing process. AR began using SPL at the Spring Hope facility in August of 1986. However, AR does state that SPL was used for testing in April of 1986.

From the various tests, AR has come up with factors utilized to determine fluoride emissions both when SPL is used and when it is not. The primary concern with the fluoride emissions is that the increase due to using SPL is less than 3 tons per year. As per the permit, the hourly fluoride emissions increase is limited to 2.8 lb/hr (as per AR request) due to vegetative concerns.

At the time of the permit review (12/11/87), only information from the April 1986 testing was available. In order to determine the allowable annual increase of 1793 hr/yr and the hourly allowable of 2.8 pounds, a factor of 0.002 (.00197) lb Fl./hr/lb SPL was used (see attached Appendix I, page 9, column (B-D)/F). The January and February tests (February tests were the observed compliance tests) appear to demonstrate a lower fluoride increase of 0.0004 lb/hr/lb SPL. Due to the Jan/Feb testing showing a lower fluoride emission increase, AR plans to submit a new application for permit revision of increased SPL usage.

It should be noted that the February test appears to show compliance with the particulate and opacity standards. The source modeled SO_2 at 100 lb/hr. The actual as per testing was 144.1 lb/hr. The company will submit application for revision of modeling. Also, during the February test, 810 pounds of SPL were charged per hour per cupola. The permit application is for 710 pounds per hour per cupola. The company did not want to undercharge the amount of SPL as DEM wanted the maximum permitted charged.

Part of the permitted fluoride emissions increase is due to the crusher which is presently permitted for 13 hrs/yr of operation and as an uncontrolled source. However, AR plans to install a baghouse and application for such is forthcoming.

The Raleigh Regional Office has two primary concerns. One concern is whether the source is presently in compliance, and the other is whether the source previously operated in compliance. The February testing appears to demonstrate compliance with the present permit. The SO_2 modeling requires adjustment. The second concern arises since the source previously utilized a charge with less limestone and for which the Jan/Feb testing may not be representative. The background fluoride rate was established using the two years prior to SPL usage (October 1984 to September 1986) and determined from the actual monthly charges. The actual background fluoride rate is then dependent on a factor, most logically from the April 1986 testing. Appendix B, page 7 shows what the background could be using both the April 1986 and February 1988 factors (.02 and .002, respectively). Due to the significant difference in the factors, the background can range from 6522 lb fluoride/yr to 19,368 lb fluoride/yr. The factors discussed above are found in Appendix I, page 8, column B/A. Note that Jan/Feb SPL testing shows 0.003 vs. 0.002 as per the company. This is due to some differences in reported charges, etc. Calculations used 0.002 for the background factor. The second group of factors are listed in Appendix I, page 9, column (B-D)/(A-G). These are factors used with the SPL charge to determine fluoride out from the SPL.

On 3/17/88, AR submitted the February charge rates. Attached to this was a twelve month running average of fluoride emissions as required by the permit. What is not specified in the permit is what "factors" will be used. On this report, factors were used as follows:

No SPL Fl. x .02; SPL Fl. x .008 - until September 1987
No SPL Fl. x .002; SPL Fl. x .004 - begin October 1987

The twelve month running average of 12,242 lb is less than the 19,682 lb/yr allowable. The two different factors were used since prior to October 1987 a significantly different mix was used. The limestone going into the cupola may have a significant impact on reducing fluoride emissions. For this reason, factors from both the April 1986 and January 1988 tests were used.

In Appendix B attached, I have also run the running average for fluoride emissions using three different scenarios:

(1) using the .02/.008 factor through September 1987
using the .002/.004 factor beginning October 1987
(results on page 8)

(2) using the .002/.004 factors for all months
(results on page 16)

(3) using the 0.02/0.012* factor through September 1987
using the 0.002/0.004 factor beginning October 1987
(results on page 18)

*The 0.012 factor comes from April 1986, Massena (M) SPL testing (see Appendix I, page 9)

Numbers (1) and (2) above would show compliance with the running average while scenario (3) would not.

For compliance and future permitting, in addition to any future testing, the factors to be used must now be determined, in addition to any future testing. It has recently been observed that four of their five mixes do not have limestone in them (see Appendix I, page 4). The worst case of these would most likely require testing either prior to or after any permit revision.

I am also attaching a recent submittal sent by the consultant. It contains the % fluoride of the materials input during testing. The SPL % fluoride is somewhat higher than the initial permit value (12.6% vs. 10.75%). There are some other differences (both positive and negative) which total approximately the same % fluoride.

In summary, we need to determine which "factors" will be used to determine compliance for past, present, and future running averages, and what future testing, material sampling, etc. will be required. Please let me know if you would like to get together and discuss this prior to forwarding your comments. As this is still scheduled to go to hearing unless the running average can be resolved, we will need to let OLA know our decision soon.

KS/jf

att.

APPENDIX A.

AMERICAN ROCKWOOL,NASH COUNTY 880404
II
(BOTH CUPOLAS)

TEST DATE	#SO2/HR	LB SO2/ MMBTU	PART. W/BACK-HALF	H2S	OPACITY	FLUORIDE
APRIL 86						
(BKGRD)						1.6
(SPL,B)						2.45
(SPL,M)						3.6
JAN 88						
(BKGRD)	148		1.5			0.27
(SPL350)	120		1.8			0.53
(SPL700)	110		1.7			0.87
FEB 5,88						
(BACKGRD)	144.1	1.1	3		5	0.023
(710 SPL)	111	0.9	4		5	0.86
TEXAS						
(BKGRD)						0.6
(SPL1000)						1.4
(SPL1500)						1.4
PERMIT	100	2.3	10 (as per 2D.0515)	12	20	6

AMERICAN ROCKWOOL,NASH COUNTY 880404
III
#'S/CHARGCHARGE PER CUPOLA (#'S)

TEST DATE	COKE	SPL	DUQ SLAG	TRAP ROCK	LIME	STEEL	TENN SLAG
APRIL 86							
(BKGRD)							
(SPL,B)							
(SPL,M)							
JAN 88							
(BKGRD)	398	0	1278	1090	49	394	396
(SPL350)	226	100	1270	1088	50	396	393
(SPL700)	259	215	1119	1006	44	371	377
FEB 5,88							
(BACKGRD)	400	0	1300	1100	50	400	400
(710 SPL)	260	225	1300	1100	50	400	400
TEXAS							
(BKGRD)	400	0	0	1050	0	0	400
(SPL1000)	278						
(SPL1500)	417						

3

```
CHARGES/
HOUR

--------

     3.3
     3.3
     3.3


    3.37
    3.37
    3.37


     3.6
     3.6


     3.3
     3.3
     3.3
```

4.

AMERICAN ROCKWOOL,NASH COUNTY 880404
IV
CHARGE/CUPOLA (#/HR)

TEST DATE	COKE	SPL	DUQ SLAG	TRAP ROCK	LIME	STEEL	TENN SLAG
APRIL 86							
(BKGRD)	1164	0	4239	1668	83	200	2000
(SPL,B)	683	1020	0	1668	83	200	2000
(SPL,M)	683	1014	0	1668	83	200	2000
JAN 88							
(BKGRD)	1341.26	0	4306.86	3673.3	165.13	1327.78	1334.52
(SPL350)	761.62	337	4279.9	3666.56	168.5	1334.52	1324.41
(SPL700)	872.83	724.55	3771.03	3390.22	148.28	1250.27	1270.49
FEB 5,88							
(BACKGRD)	1440	0	4680	3960	180	1440	1440
(710 SPL)	936	810	4680	3960	180	1440	1440
TEXAS							
(BKGRD)	1320	0	0	3465	0	0	1320
(SPL1000)	917.4	0	0	0	0	0	0
(SPL1500)	1376.1	0	0	0	0	0	0

	COKE	SPL	DUQ SLAG	TRAP ROCK	LIME	STEEL	TENN SLAG
PERMIT	1300	710	5500	2500	250	3000	3000
% FL	0	11.3	0.45	0	0.41	0	2.4

NOTE: THE MASSENA FL.=10.2%, BADIN=11.3%

ACTUAL BLENDS;

	COKE	SPL	DUQ SLAG	TRAP ROCK	LIME	STEEL	TENN SLAG
STANDARD ROCKWOOL							
W/O	1285	0	4329	3663	167	1332	1332
W/SPL	866	700	4329	3663	167	1332	1332
WHITE ROCKWOOL							
W/O	1285	0	7326	0	0	0	1665
W/SPL	866	700	7326	0	0	0	1665
FIBER-GRO ROCKWOOL							
W/O	1285	0	1000	4995	0	3330	
W/SPL	866	700	1000	4995	0	3330	
DARK ROCKWOOL							
W/O	1285	0	0	4329	0	3330	666
W/SPL	866	700	0	4329	0	3330	666
CRYOGENIC ROCKWOOL							
W/O	1285	0	0	3164	0	5162	1665
W/SPL	866	700	0	3164	0	5162	1665

FELDSPAR (NR)	BOF SLAG
0	0
1000	
1000	
	1000
	1000
	1998
	1998

AMERICAN ROCKWOOL,NASH COUNTY 880404
V
#'S OF FL INPUT/CUPOLA

TEST DATE	COKE	SPL	DUQ SLAG	TRAP ROCK	LIME	STEEL	TENN SLAG
APRIL 86							
(BKGRD)	0.0	0.0	19.1	0.0	0.3	0.0	48.0
(SPL,B)	0.0	115.3	0.0	0.0	0.3	0.0	48.0
(SPL,M)	0.0	114.6	0.0	0.0	0.3	0.0	48.0
JAN 88							
(BKGRD)	0.0	0.0	19.4	0.0	0.7	0.0	32.0
(SPL350)	0.0	38.1	19.3	0.0	0.7	0.0	31.8
(SPL700)	0.0	81.9	17.0	0.0	0.6	0.0	30.5
FEB 5,88							
(BACKGRD)	0.0	0.0	21.1	0.0	0.7	0.0	34.6
(710 SPL)	0.0	91.5	21.1	0.0	0.7	0.0	34.6
TEXAS							
(BKGRD)							
(SPL1000)							
(SPL1500)							

	COKE	SPL	DUQ SLAG	TRAP ROCK	LIME	STEEL	TENN SLAG
PERMIT	1300.0	710.0	5500.0	2500.0	250.0	3000.0	3000.0
% FL	0.0	11.3	0.5	0.0	0.4	0.0	2.4
ACTUAL BLENDS;							
STANDARD ROCKWOOL							
W/O	0.0	0.0	19.5	0.0	0.7	0.0	32.0
W/SPL	0.0	79.1	19.5	0.0	0.7	0.0	32.0
WHITE ROC	0.0	0.0	0.0	0.0	0.0	0.0	0.0
W/O	0.0	0.0	33.0	0.0	0.0	0.0	40.0
W/SPL	0.0	79.1	33.0	0.0	0.0	0.0	40.0
FIBER-GRO	0.0	0.0	0.0	0.0	0.0	0.0	0.0
W/O	0.0	0.0	4.5	0.0	0.0	0.0	0.0
W/SPL	0.0	79.1	4.5	0.0	0.0	0.0	0.0
DARK ROCK	0.0	0.0	0.0	0.0	0.0	0.0	0.0
W/O	0.0	0.0	0.0	0.0	0.0	0.0	16.0
W/SPL	0.0	79.1	0.0	0.0	0.0	0.0	16.0
CRYOGENIC	0.0	0.0	0.0	0.0	0.0	0.0	0.0

7-

AMERICAN ROCKWOOL,NASH COUNTY 880404
VI
TOTALS (BOTH CUPOLAS AT SPRING HOPE)

TEST DATE	FLUORIDE IN (#,S)	FLUORIDE OUT #'S	FL OUT/ FL IN
APRIL 86			
(BKGRD)	134.8	3.2	0.02373
(SPL,B)	327.2	0.6	0.00183
(SPL,M)	325.8	1.1	0.00338
JAN 88			
(BKGRD)	104.2	0.3	0.00262
(SPL350)	179.6	0.5	0.00295
(SPL700)	259.9	0.9	0.00335
FEB 5,88			
(BACKGRD)	112.7	0.2	0.00204
(710 SPL)	295.8	0.9	0.00291
TEXAS			
(BKGRD)	45.0	0.6	0.01333
(SPL1000)	145.0	1.4	0.00966
(SPL1500)	195.0	1.4	0.00718

	FLUORIDE IN (#,S)	FLUORIDE OUT #'S
PERMIT		
% FL		
ACTUAL BLENDS;		
STANDARD ROCKWOOL		
W/O	104.3	
W/SPL	262.5	
WHITE ROCKWOOL		
W/O	145.9	
W/SPL	304.1	
FIBER-GRO ROCKWOOL		
W/O	9.0	
W/SPL	167.2	
DARK ROCKWOOL		
W/O	32.0	
W/SPL	190.2	
CRYOGENIC ROCKWOOL		
W/O	79.9	

AMERICAN ROCKWOOL,NASH COUNTY 880413
VIII
PER CUPOLA BASIS/HOUR FL IN IS FOR BOTH CUPOLAS(JAN&FEB)

TEST DATE	A FLUORIDE IN (#,S)	B FL OUT (#'S)	B/A FL OUT FL IN	D FL OUT BKGRD ONLY	E SPL FL IN (#'S)	(B-D)/(A-E) FL OUT/ IN -BKGRD	(B-D)/A FL OUT/ IN TOTAL
APRIL 86							
(BKGRD)	**67.4**	1.60	0.0237	1.6	0.0	0.0000	0.0000
(SPL,B)	163.6	2.45	**0.0150**	1.6	115.3	0.0176	0.0052
(SPL,M)	162.9	3.60	**0.0221**	1.6	114.6	0.0414	0.0123
JAN 88							
(BKGRD)	104.2	0.27	0.0026	0.27	0.0	0.0000	0.0000
(SPL350)	179.6	0.53	**0.0030**	0.27	38.1	0.0018	0.0014
(SPL700)	259.9	0.87	**0.0033**	0.27	81.9	0.0034	0.0023
FEB 5,88							
(BACKGRD)	72.1*	0.23	**0.0032**	0.23	0.0	0.0000	0.0000
(710 SPL)	274.0*	0.86	**0.0031**	0.23	91.5	0.0035	0.0023
	as given from American Rockwool						
TEXAS							
(BKGRD)	45.0	0.60	0.0133	0.6	0.0	0.0000	0.0000
(SPL1000)	145.0	1.40	0.0097	0.6	0.0	0.0055	0.0055
(SPL1500)	195.0	1.40	0.0072	0.6	0.0	0.0041	0.0041

9.

value used in permit application

9.

AMERICAN ROCKWOOL,NASH COUNTY 880413
IX
PER HOUR BASIS   FL IN IS FOR BOTH CUPOLAS(JAN&FEB)

TEST DATE	A FLUORIDE IN (#,S)	B FL OUT (#'S)	D FL OUT BKGRD ONLY	F #OF SPL CHARGED	(B-D)/F FL INCR. FROM SPL #/HR/#SPL	G BKGRD CHARGE OF FL #/HR	(B-D)/(A-G) EMISSION FACTOR
APRIL 86							
(BKGRD)	67.4	1.60	1.6				
(SPL,B)	163.6	2.45	1.6	1020.0	0.0008		**0.0052**
(SPL,M)	162.9	3.60	1.6	1014.0	**0.0020**		0.0123
JAN 88							
(BKGRD)	104.2	0.27	0.27			104	
(SPL350)	179.6	0.53	0.27	674.0	0.0004	104	**0.0034**
(SPL700)	259.9	0.87	0.27	1450.0	0.0004	104	**0.0038**
FEB 5,88							
(BACKGRD)	72.1	0.23	0.23			72	
(710 SPL)	274.0	0.86	0.23	1620.0	0.0004	72	**0.0031**
TEXAS							
(BKGRD)	45.0	0.60	0.6			45	
(SPL1000)	145.0	1.40	0.6	1000.0	0.0008	45	0.0080
(SPL1500)	195.0	1.40	0.6	1500.0	0.0005	45	0.0053

APPENDIX B

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                          ***AMERICAN ROCKWOOL***

FLOURIDES:                .02/.008 THOUGH SEPT 87                    D880415
                          .002/.004 BEGIN OCT 87
MONTH/YR:AUGUST 86

MATERIAL AMOUNT     FLUORIDE                           BURDEN    SPL
TYPE     USED(#)    %*.01    FL IN(#) FACTOR     #FL/MONTH  #FL/MONTH
-------- ---------- -------- -------- -------    --------   --------
DUQ. SLAG   2948700   0.0045  13269.2   0.0200       265.38
TENN SLAG    995750   0.0240  23898.0   0.0200       477.96
LIME          53699   0.0041    220.2   0.0200         4.40
SPL            6355   0.1075    683.2   0.0080                     5.47


         TOTAL FL/MONTH IN =  38070.5
                                      TOTAL FL/MONTH OUT=      753.21
         HRS/MONTH :
         #FL/HR  =        ERR

MONTH/YR:SEPTEMBER 86

MATERIAL AMOUNT     FLUORIDE                           BURDEN    SPL
TYPE     USED(#)    %*.01    FL IN(#) FACTOR     #FL/MONTH  #FL/MONTH
-------- ---------- -------- -------- -------    --------   --------
DUQ. SLAG   4275200   0.0045  19238.4   0.0200       384.77
TENN SLAG   1553075   0.0240  37273.8   0.0200       745.48
LIME          36336   0.0041    149.0   0.0200         2.98
SPL          535300   0.1075  57544.8   0.0080                   460.36


         TOTAL FL/MONTH IN = 114205.9
                                      TOTAL FL/MONTH OUT=     1593.58
         HRS/MONTH :
         #FL/HR  =        ERR

MONTH/YR:OCTOBER 86

MATERIAL AMOUNT     FLUORIDE                           BURDEN    SPL
TYPE     USED(#)    %*.01    FL IN(#) FACTOR     #FL/MONTH  #FL/MONTH
-------- ---------- -------- -------- -------    --------   --------
DUQ. SLAG   3357900   0.0045  15110.6   0.0200       302.21
TENN SLAG   1194000   0.0240  28656.0   0.0200       573.12
LIME              0   0.0041      0.0   0.0200         0.00
SPL          560850   0.1075  60291.4   0.0080                   482.33


         TOTAL FL/MONTH IN = 104057.9
                                      TOTAL FL/MONTH OUT=     1357.66
         HRS/MONTH :
         #FL/HR  =        ERR

MONTH/YR:NOVEMBER 86
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MATERIAL AMOUNT     FLUORIDE                             BURDEN     SPL
TYPE     USED(#)    %*.01     FL IN(#)  FACTOR   #FL/MONTH  #FL/MONTH
-------- ---------- --------  --------  -------  ---------  ---------
DUQ. SLAG   3345700   0.0045   15055.7   0.0200     301.11
TENN SLAG   1191500   0.0240   28596.0   0.0200     571.92
LIME            300   0.0041       1.2   0.0200       0.02
SPL          698120   0.1075   75047.9   0.0080                 600.38


         TOTAL FL/MONTH IN = 118700.8
                                       TOTAL FL/MONTH OUT=     1473.44
         HRS/MONTH :
         #FL/HR   =        ERR

MONTH/YR:DECEMBER 86

MATERIAL AMOUNT     FLUORIDE                             BURDEN     SPL
TYPE     USED(#)    %*.01     FL IN(#)  FACTOR   #FL/MONTH  #FL/MONTH
-------- ---------- --------  --------  -------  ---------  ---------
DUQ. SLAG   2460000   0.0045   11070.0   0.0200     221.40
TENN SLAG    809150   0.0240   19419.6   0.0200     388.39
LIME              0   0.0041       0.0   0.0200       0.00
SPL          626825   0.1075   67383.7   0.0080                 539.07


         TOTAL FL/MONTH IN =  97873.3
                                       TOTAL FL/MONTH OUT=     1148.86
         HRS/MONTH :
         #FL/HR   =        ERR

MONTH/YR:JANUARY 87

MATERIAL AMOUNT     FLUORIDE                             BURDEN     SPL
TYPE     USED(#)    %*.01     FL IN(#)  FACTOR   #FL/MONTH  #FL/MONTH
-------- ---------- --------  --------  -------  ---------  ---------
DUQ. SLAG   1824900   0.0045    8212.1   0.0200     164.24
TENN SLAG    618250   0.0240   14838.0   0.0200     296.76
LIME              0   0.0041       0.0   0.0200       0.00
SPL          579275   0.1075   62272.1   0.0080                 498.18


         TOTAL FL/MONTH IN =  85322.1
                                       TOTAL FL/MONTH OUT=      959.18
         HRS/MONTH :
         #FL/HR   =        ERR

MONTH/YR:FEBRUARY 87

MATERIAL AMOUNT     FLUORIDE                             BURDEN     SPL
TYPE     USED(#)    %*.01     FL IN(#)  FACTOR   #FL/MONTH  #FL/MONTH
-------- ---------- --------  --------  -------  ---------  ---------
DUQ. SLAG   2759050   0.0045   12415.7   0.0200     248.31
TENN SLAG    980500   0.0240   23532.0   0.0200     470.64
LIME              0   0.0041       0.0   0.0200       0.00
SPL          573300   0.1075   61629.8   0.0080                 493.04
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          TOTAL FL/MONTH IN =  97577.5
                                           TOTAL FL/MONTH OUT=    1211.99

          HRS/MONTH :
          #FL/HR  =        ERR

MONTH/YR:MARCH 87

MATERIAL AMOUNT     FLUORIDE                      BURDEN     SPL
TYPE     USED(#)    %*.01     FL IN(#) FACTOR    #FL/MONTH  #FL/MONTH
-------- ---------- --------  -------- -------   --------   --------
DUQ. SLAG   2979550   0.0045  13408.0   0.0200     268.16
TENN SLAG   1048900   0.0240  25173.6   0.0200     503.47
LIME              0   0.0041      0.0   0.0200       0.00
SPL          612700   0.1075  65865.3   0.0080                526.92


          TOTAL FL/MONTH IN = 104446.8
                                           TOTAL FL/MONTH OUT=    1298.55

          HRS/MONTH :
          #FL/HR  =        ERR

MONTH/YR:APRIL 87

MATERIAL AMOUNT     FLUORIDE                      BURDEN     SPL
TYPE     USED(#)    %*.01     FL IN(#) FACTOR    #FL/MONTH  #FL/MONTH
-------- ---------- --------  -------- -------   --------   --------
DUQ. SLAG   3270850   0.0045  14718.8   0.0200     294.38
TENN SLAG   1155100   0.0240  27722.4   0.0200     554.45
LIME              0   0.0041      0.0   0.0200       0.00
SPL          689725   0.1075  74145.4   0.0080                593.16


          TOTAL FL/MONTH IN = 116586.7
                                           TOTAL FL/MONTH OUT=    1441.99

          HRS/MONTH :
          #FL/HR  =        ERR

MONTH/YR:MAY 87

MATERIAL AMOUNT     FLUORIDE                      BURDEN     SPL
TYPE     USED(#)    %*.01     FL IN(#) FACTOR    #FL/MONTH  #FL/MONTH
-------- ---------- --------  -------- -------   --------   --------
DUQ. SLAG   2907000   0.0045  13081.5   0.0200     261.63
TENN SLAG   1219800   0.0240  29275.2   0.0200     585.50
LIME              0   0.0041      0.0   0.0200       0.00
SPL          709100   0.1075  76228.3   0.0080                609.83


          TOTAL FL/MONTH IN = 118585.0
                                           TOTAL FL/MONTH OUT=    1456.96

          HRS/MONTH :
          #FL/HR  =        ERR

MONTH/YR:JUNE 87
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MATERIAL AMOUNT      FLUORIDE                             BURDEN     SPL
TYPE     USED(#)     %*.01     FL IN(#) FACTOR    #FL/MONTH  #FL/MONTH
-------- ----------  --------  -------- -------   --------   --------
DUQ. SLAG   3692850   0.0045   16617.8   0.0200     332.36
TENN SLAG   1654300   0.0240   39703.2   0.0200     794.06
LIME              0   0.0041       0.0   0.0200       0.00
SPL         1182100   0.1075  127075.8   0.0080                 1016.61


         TOTAL FL/MONTH IN = 183396.8
                                         TOTAL FL/MONTH OUT=    2143.03
         HRS/MONTH :
         #FL/HR   =         ERR

MONTH/YR:JULY 87

MATERIAL AMOUNT      FLUORIDE                             BURDEN     SPL
TYPE     USED(#)     %*.01     FL IN(#) FACTOR    #FL/MONTH  #FL/MONTH
-------- ----------  --------  -------- -------   --------   --------
DUQ. SLAG   4028200   0.0045   18126.9   0.0200     362.54
TENN SLAG   1761300   0.0240   42271.2   0.0200     845.42
LIME              0   0.0041       0.0   0.0200       0.00
SPL         1321800   0.1075  142093.5   0.0080                 1136.75


         TOTAL FL/MONTH IN = 202491.6
                                         TOTAL FL/MONTH OUT=    2344.71
         HRS/MONTH :
         #FL/HR   =         ERR

MONTH/YR:AUGUST 87

MATERIAL AMOUNT      FLUORIDE                             BURDEN     SPL
TYPE     USED(#)     %*.01     FL IN(#) FACTOR    #FL/MONTH  #FL/MONTH
-------- ----------  --------  -------- -------   --------   --------
DUQ. SLAG   3816100   0.0045   17172.5   0.0200     343.45
TENN SLAG   1748400   0.0240   41961.6   0.0200     839.23
LIME              0   0.0041       0.0   0.0200       0.00
SPL          647275   0.1075   69582.1   0.0080                  556.66


         TOTAL FL/MONTH IN = 128716.1
                                         TOTAL FL/MONTH OUT=    1739.34
         HRS/MONTH :
         #FL/HR   =         ERR

MONTH/YR:SEPTEMBER 87

MATERIAL AMOUNT      FLUORIDE                             BURDEN     SPL
TYPE     USED(#)     %*.01     FL IN(#) FACTOR    #FL/MONTH  #FL/MONTH
-------- ----------  --------  -------- -------   --------   --------
DUQ. SLAG   4142600   0.0045   18641.7   0.0200     372.83
TENN SLAG   1938600   0.0240   46526.4   0.0200     930.53
LIME          22650   0.0041      92.9   0.0200       1.86
SPL               0   0.1075       0.0   0.0080                    0.00
```

```
          TOTAL FL/MONTH IN =  65261.0
                                         TOTAL FL/MONTH OUT=     1305.22
          HRS/MONTH :
          #FL/HR   =        ERR

MONTH/YR:OCTOBER 87

MATERIAL AMOUNT     FLUORIDE                     BURDEN    SPL
TYPE     USED(#)    %*.01     FL IN(#) FACTOR    #FL/MONTH #FL/MONTH
-------- ---------- --------  -------- -------   --------  --------
DUQ. SLAG   4445475   0.0045   20004.6   0.0020     40.01
TENN SLAG   2147000   0.0240   51528.0   0.0020    103.06
LIME          73637   0.0041     301.9   0.0020      0.60
SPL               0   0.1075       0.0   0.0040                  0.00

          TOTAL FL/MONTH IN =  71834.5
                                         TOTAL FL/MONTH OUT=      143.67
          HRS/MONTH :
          #FL/HR   =        ERR

MONTH/YR:NOVEMBER 87

MATERIAL AMOUNT     FLUORIDE                     BURDEN    SPL
TYPE     USED(#)    %*.01     FL IN(#) FACTOR    #FL/MONTH #FL/MONTH
-------- ---------- --------  -------- -------   --------  --------
DUQ. SLAG   3313650   0.0045   14911.4   0.0020     29.82
TENN SLAG   1385550   0.0240   33253.2   0.0020     66.51
LIME          61022   0.0041     250.2   0.0020      0.50
SPL               0   0.1075       0.0   0.0040                  0.00

          TOTAL FL/MONTH IN =  48414.8
                                         TOTAL FL/MONTH OUT=       96.83
          HRS/MONTH :
          #FL/HR   =        ERR

MONTH/YR:DECEMBER 87

MATERIAL AMOUNT     FLUORIDE                     BURDEN    SPL
TYPE     USED(#)    %*.01     FL IN(#) FACTOR    #FL/MONTH #FL/MONTH
-------- ---------- --------  -------- -------   --------  --------
DUQ. SLAG   3147350   0.0045   14163.1   0.0020     28.33
TENN SLAG   1071550   0.0240   25717.2   0.0020     51.43
LIME          62062   0.0041     254.5   0.0020      0.51
SPL               0   0.1075       0.0   0.0040                  0.00

          TOTAL FL/MONTH IN =  40134.7
                                         TOTAL FL/MONTH OUT=       80.27
          HRS/MONTH :
          #FL/HR   =        ERR

MONTH/YR:JANUARY 88
```

```
MATERIAL AMOUNT     FLUORIDE                    BURDEN     SPL
TYPE     USED(#)    %*.01    FL IN(#) FACTOR   #FL/MONTH  #FL/MONTH
-------- ---------- -------- -------- -------  --------   --------
DUQ. SLAG   1194879   0.0045   5377.0  0.0020     10.75
TENN SLAG    331177   0.0240   7948.2  0.0020     15.90
LIME          35359   0.0041    145.0  0.0020      0.29
SPL           77410   0.1075   8321.6  0.0040                  33.29


         TOTAL FL/MONTH IN =  21791.8
                                      TOTAL FL/MONTH OUT=      60.23
         HRS/MONTH :
         #FL/HR   =       ERR

*  MONTH/YR:

MATERIAL AMOUNT     FLUORIDE                    BURDEN     SPL
TYPE     USED(#)    %*.01    FL IN(#) FACTOR   #FL/MONTH  #FL/MONTH
-------- ---------- -------- -------- -------  --------   --------
DUQ. SLAG             0.0045      0.0              0.00
TENN SLAG             0.0240      0.0              0.00
LIME                  0.0041      0.0              0.00
SPL                   0.1075      0.0                          0.00


         TOTAL FL/MONTH IN =      0.0
                                      TOTAL FL/MONTH OUT=       0.00
         HRS/MONTH :
         #FL/HR   =       ERR

   MONTH/YR:

MATERIAL AMOUNT     FLUORIDE                    BURDEN     SPL
TYPE     USED(#)    %*.01    FL IN(#) FACTOR   #FL/MONTH  #FL/MONTH
-------- ---------- -------- -------- -------  --------   --------
DUQ. SLAG             0.0045      0.0              0.00
TENN SLAG             0.0240      0.0              0.00
LIME                  0.0041      0.0              0.00
SPL                   0.1075      0.0                          0.00


         TOTAL FL/MONTH IN =      0.0
                                      TOTAL FL/MONTH OUT=       0.00
         HRS/MONTH :
         #FL/HR   =       ERR

   MONTH/YR:

MATERIAL AMOUNT     FLUORIDE                    BURDEN     SPL
TYPE     USED(#)    %*.01    FL IN(#) FACTOR   #FL/MONTH  #FL/MONTH
-------- ---------- -------- -------- -------  --------   --------
DUQ. SLAG             0.0045      0.0              0.00
TENN SLAG             0.0240      0.0              0.00
LIME                  0.0041      0.0              0.00
SPL                   0.1075      0.0                          0.00
```

2 YEAR HISTORY (OCT 1984-SEP 1986):

140.6#/HR*423HR/YR*12MONTHS/YR=713,686#FL IN/YR
*(.02)=14273#FL IN/YR +5095 =19368 ALLOWABLE #FL OUT/YR

*(.002)=1427#FL IN/YR +5095 =6522 ALLOWABLE #FL OUT/YR

```
(.02/.008) / (.002/.004) SCENARIO
         FL IN/     FL OUT/  CUMULATIVE
MONTH    MONTH      MONTH    #FL/YEAR
------   --------   -------  ---------
AUG86
            38070.5
                      753.21
SEPT86
           114205.9
                     1593.58
OCT 86
           104057.9
                     1357.66
NOV86
           118700.8
                     1473.44
DEC86
            97873.3
                     1148.86
JAN87
            85322.1
                      959.18
FEB87
            97577.5
                     1211.99
MAR87
           104446.8
                     1298.55
APRIL87
           116586.7
                     1441.99
MAY87
           118585.0
                     1456.96
JUNE87
           183396.8
                     2143.03
JULY87
           202491.6
                     2344.71
                                17183
AUG87
           128716.1
                     1739.34
                              18169.3
SEPT87
            65261.0
                     1305.22
                              17880.9
OCT87
            71834.5
                      143.67
                              16666.9
NOV87
            48414.8
```

```
                                          13290.5
          DEC87
                    40134.7
                              80.27
                                          14221.7
          JAN88
                    21791.8
                              60.23
                                          13322.8
```

```
                         ***AMERICAN ROCKWOOL***

 FLOURIDES:              .002/.004 ALL MONTHS***                  D880415

 MONTH/YR:AUGUST 86

 MATERIAL AMOUNT     FLUORIDE                           BURDEN    SPL
 TYPE     USED(#)    %*.01     FL IN(#) FACTOR     #FL/MONTH  #FL/MONTH
 -------- ---------- --------  -------- -------    ---------  --------

 DUQ. SLAG   2948700   0.0045  13269.2   0.0020        26.54
 TENN SLAG    995750   0.0240  23898.0   0.0020        47.80
 LIME          53699   0.0041    220.2   0.0020         0.44
 SPL            6355   0.1075    683.2   0.0040                      2.73


        TOTAL FL/MONTH IN =  38070.5
                                      TOTAL FL/MONTH OUT=        77.51
        HRS/MONTH :
        #FL/HR  =         ERR

 MONTH/YR:SEPTEMBER 86

 MATERIAL AMOUNT     FLUORIDE                           BURDEN    SPL
 TYPE     USED(#)    %*.01     FL IN(#) FACTOR     #FL/MONTH  #FL/MONTH
 -------- ---------- --------  -------- -------    ---------  --------

 DUQ. SLAG   4275200   0.0045  19238.4   0.0020        38.48
 TENN SLAG   1553075   0.0240  37273.8   0.0020        74.55
 LIME          36336   0.0041    149.0   0.0020         0.30
 SPL          535300   0.1075  57544.8   0.0040                    230.18


        TOTAL FL/MONTH IN = 114205.9
                                      TOTAL FL/MONTH OUT=       343.50
        HRS/MONTH :
        #FL/HR  =         ERR

 MONTH/YR:OCTOBER 86

 MATERIAL AMOUNT     FLUORIDE                           BURDEN    SPL
 TYPE     USED(#)    %*.01     FL IN(#) FACTOR     #FL/MONTH  #FL/MONTH
 -------- ---------- --------  -------- -------    ---------  --------

 DUQ. SLAG   3357900   0.0045  15110.6   0.0020        30.22
 TENN SLAG   1194000   0.0240  28656.0   0.0020        57.31
 LIME              0   0.0041      0.0   0.0020         0.00
 SPL          560850   0.1075  60291.4   0.0040                    241.17


        TOTAL FL/MONTH IN = 104057.9
                                      TOTAL FL/MONTH OUT=       328.70
        HRS/MONTH :
        #FL/HR  =         ERR

 MONTH/YR:NOVEMBER 86
```

```
MATERIAL AMOUNT     FLUORIDE                    BURDEN     SPL
TYPE     USED(#)    %*.01    FL IN(#) FACTOR   #FL/MONTH  #FL/MONTH
-------- ---------- -------- -------- -------  --------   --------
DUQ. SLAG   3345700   0.0045  15055.7  0.0020      30.11
TENN SLAG   1191500   0.0240  28596.0  0.0020      57.19
LIME            300   0.0041      1.2  0.0020       0.00
SPL          698120   0.1075  75047.9  0.0040                 300.19


         TOTAL FL/MONTH IN = 118700.8
                                   TOTAL FL/MONTH OUT=        387.50
         HRS/MONTH :
         #FL/HR   =         ERR

MONTH/YR:DECEMBER 86

MATERIAL AMOUNT     FLUORIDE                    BURDEN     SPL
TYPE     USED(#)    %*.01    FL IN(#) FACTOR   #FL/MONTH  #FL/MONTH
-------- ---------- -------- -------- -------  --------   --------
DUQ. SLAG   2460000   0.0045  11070.0  0.0020      22.14
TENN SLAG    809150   0.0240  19419.6  0.0020      38.84
LIME              0   0.0041      0.0  0.0020       0.00
SPL          626825   0.1075  67383.7  0.0040                 269.53


         TOTAL FL/MONTH IN =  97873.3
                                   TOTAL FL/MONTH OUT=        330.51
         HRS/MONTH :
         #FL/HR   =         ERR

MONTH/YR:JANUARY 87

MATERIAL AMOUNT     FLUORIDE                    BURDEN     SPL
TYPE     USED(#)    %*.01    FL IN(#) FACTOR   #FL/MONTH  #FL/MONTH
-------- ---------- -------- -------- -------  --------   --------
DUQ. SLAG   1824900   0.0045   8212.1  0.0020      16.42
TENN SLAG    618250   0.0240  14838.0  0.0020      29.68
LIME              0   0.0041      0.0  0.0020       0.00
SPL          579275   0.1075  62272.1  0.0040                 249.09


         TOTAL FL/MONTH IN =  85322.1
                                   TOTAL FL/MONTH OUT=        295.19
         HRS/MONTH :
         #FL/HR   =         ERR

MONTH/YR:FEBRUARY 87

MATERIAL AMOUNT     FLUORIDE                    BURDEN     SPL
TYPE     USED(#)    %*.01    FL IN(#) FACTOR   #FL/MONTH  #FL/MONTH
-------- ---------- -------- -------- -------  --------   --------
DUQ. SLAG   2759050   0.0045  12415.7  0.0020      24.83
TENN SLAG    980500   0.0240  23532.0  0.0020      47.06
LIME              0   0.0041      0.0  0.0020       0.00
SPL          573300   0.1075  61629.8  0.0040                 246.52
```

```
         TOTAL FL/MONTH IN =  97577.5
                                         TOTAL FL/MONTH OUT=     318.41
         HRS/MONTH :
         #FL/HR  =        ERR

MONTH/YR:MARCH 87

MATERIAL AMOUNT    FLUORIDE                      BURDEN     SPL
TYPE     USED(#)   %*.01    FL IN(#) FACTOR     #FL/MONTH  #FL/MONTH
-------- --------- -------- -------- -------    --------   --------
DUQ. SLAG  2979550   0.0045  13408.0   0.0020      26.82
TENN SLAG  1048900   0.0240  25173.6   0.0020      50.35
LIME             0   0.0041      0.0   0.0020       0.00
SPL         612700   0.1075  65865.3   0.0040                 263.46


         TOTAL FL/MONTH IN = 104446.8
                                         TOTAL FL/MONTH OUT=     340.62
         HRS/MONTH :
         #FL/HR  =        ERR

MONTH/YR:APRIL 87

MATERIAL AMOUNT    FLUORIDE                      BURDEN     SPL
TYPE     USED(#)   %*.01    FL IN(#) FACTOR     #FL/MONTH  #FL/MONTH
-------- --------- -------- -------- -------    --------   --------
DUQ. SLAG  3270850   0.0045  14718.8   0.0020      29.44
TENN SLAG  1155100   0.0240  27722.4   0.0020      55.44
LIME             0   0.0041      0.0   0.0020       0.00
SPL         689725   0.1075  74145.4   0.0040                 296.58


         TOTAL FL/MONTH IN = 116586.7
                                         TOTAL FL/MONTH OUT=     381.46
         HRS/MONTH :
         #FL/HR  =        ERR

MONTH/YR:MAY 87

MATERIAL AMOUNT    FLUORIDE                      BURDEN     SPL
TYPE     USED(#)   %*.01    FL IN(#) FACTOR     #FL/MONTH  #FL/MONTH
-------- --------- -------- -------- -------    --------   --------
DUQ. SLAG  2907000   0.0045  13081.5   0.0020      26.16
TENN SLAG  1219800   0.0240  29275.2   0.0020      58.55
LIME             0   0.0041      0.0   0.0020       0.00
SPL         709100   0.1075  76228.3   0.0040                 304.91


         TOTAL FL/MONTH IN = 118585.0
                                         TOTAL FL/MONTH OUT=     389.63
         HRS/MONTH :
         #FL/HR  =        ERR

MONTH/YR:JUNE 87
```

```
MATERIAL AMOUNT     FLUORIDE                     BURDEN    SPL
TYPE     USED(#)    %*.01    FL IN(#) FACTOR     #FL/MONTH #FL/MONTH
-------- ---------- -------- -------- -------    --------  --------
DUQ. SLAG  3692850  0.0045  16617.8   0.0020        33.24
TENN SLAG  1654300  0.0240  39703.2   0.0020        79.41
LIME             0  0.0041      0.0   0.0020         0.00
SPL        1182100  0.1075 127075.8   0.0040                   508.30


         TOTAL FL/MONTH IN = 183396.8
                                      TOTAL FL/MONTH OUT=      620.95

         HRS/MONTH :
         #FL/HR   =       ERR

MONTH/YR:JULY 87

MATERIAL AMOUNT     FLUORIDE                     BURDEN    SPL
TYPE     USED(#)    %*.01    FL IN(#) FACTOR     #FL/MONTH #FL/MONTH
-------- ---------- -------- -------- -------    --------  --------
DUQ. SLAG  4028200  0.0045  18126.9   0.0020        36.25
TENN SLAG  1761300  0.0240  42271.2   0.0020        84.54
LIME             0  0.0041      0.0   0.0020         0.00
SPL        1321800  0.1075 142093.5   0.0040                   568.37


         TOTAL FL/MONTH IN = 202491.6
                                      TOTAL FL/MONTH OUT=      689.17

         HRS/MONTH :
         #FL/HR   =       ERR

MONTH/YR:AUGUST 87

MATERIAL AMOUNT     FLUORIDE                     BURDEN    SPL
TYPE     USED(#)    %*.01    FL IN(#) FACTOR     #FL/MONTH #FL/MONTH
-------- ---------- -------- -------- -------    --------  --------
DUQ. SLAG  3816100  0.0045  17172.5   0.0020        34.34
TENN SLAG  1748400  0.0240  41961.6   0.0020        83.92
LIME             0  0.0041      0.0   0.0020         0.00
SPL         647275  0.1075  69582.1   0.0040                   278.33


         TOTAL FL/MONTH IN = 128716.1
                                      TOTAL FL/MONTH OUT=      396.60

         HRS/MONTH :
         #FL/HR   =       ERR

MONTH/YR:SEPTEMBER 87

MATERIAL AMOUNT     FLUORIDE                     BURDEN    SPL
TYPE     USED(#)    %*.01    FL IN(#) FACTOR     #FL/MONTH #FL/MONTH
-------- ---------- -------- -------- -------    --------  --------
DUQ. SLAG  4142600  0.0045  18641.7   0.0020        37.28
TENN SLAG  1938600  0.0240  46526.4   0.0020        93.05
LIME         22650  0.0041     92.9   0.0020         0.19
SPL              0  0.1075      0.0   0.0040                     0.00
```

```
          TOTAL FL/MONTH IN =  65261.0
                                          TOTAL FL/MONTH OUT=      130.52
          HRS/MONTH :
          #FL/HR   =        ERR

 MONTH/YR:OCTOBER 87

 MATERIAL AMOUNT     FLUORIDE                         BURDEN      SPL
 TYPE     USED(#)    %*.01     FL IN(#) FACTOR     #FL/MONTH   #FL/MONTH
 -------- ---------- -------- -------- -------    --------    --------
 DUQ. SLAG   4445475  0.0045  20004.6   0.0020       40.01
 TENN SLAG   2147000  0.0240  51528.0   0.0020      103.06
 LIME          73637  0.0041    301.9   0.0020        0.60
 SPL               0  0.1075      0.0   0.0040                     0.00


          TOTAL FL/MONTH IN =  71834.5
                                          TOTAL FL/MONTH OUT=      143.67
          HRS/MONTH :
          #FL/HR   =        ERR

 MONTH/YR:NOVEMBER 87

 MATERIAL AMOUNT     FLUORIDE                         BURDEN      SPL
 TYPE     USED(#)    %*.01     FL IN(#) FACTOR     #FL/MONTH   #FL/MONTH
 -------- ---------- -------- -------- -------    --------    --------
 DUQ. SLAG   3313650  0.0045  14911.4   0.0020       29.82
 TENN SLAG   1385550  0.0240  33253.2   0.0020       66.51
 LIME          61022  0.0041    250.2   0.0020        0.50
 SPL               0  0.1075      0.0   0.0040                     0.00


          TOTAL FL/MONTH IN =  48414.8
                                          TOTAL FL/MONTH OUT=       96.83
          HRS/MONTH :
          #FL/HR   =        ERR

 MONTH/YR:DECEMBER 87

 MATERIAL AMOUNT     FLUORIDE                         BURDEN      SPL
 TYPE     USED(#)    %*.01     FL IN(#) FACTOR     #FL/MONTH   #FL/MONTH
 -------- ---------- -------- -------- -------    --------    --------
 DUQ. SLAG   3147350  0.0045  14163.1   0.0020       28.33
 TENN SLAG   1071550  0.0240  25717.2   0.0020       51.43
 LIME          62062  0.0041    254.5   0.0020        0.51
 SPL               0  0.1075      0.0   0.0040                     0.00


          TOTAL FL/MONTH IN =  40134.7
                                          TOTAL FL/MONTH OUT=       80.27
          HRS/MONTH :
          #FL/HR   =        ERR

 MONTH/YR:JANUARY 88
```

```
MATERIAL AMOUNT     FLUORIDE                          BURDEN      SPL
TYPE     USED(#)    %*.01     FL IN(#) FACTOR         #FL/MONTH   #FL/MONTH
-------- ---------- --------  -------- -------        --------    --------
DUQ. SLAG   1194879   0.0045    5377.0   0.0020          10.75
TENN SLAG    331177   0.0240    7948.2   0.0020          15.90
LIME          35359   0.0041     145.0   0.0020           0.29
SPL           77410   0.1075    8321.6   0.0040                         33.29


         TOTAL FL/MONTH IN =  21791.8
                                         TOTAL FL/MONTH OUT=            60.23
         HRS/MONTH :
         #FL/HR  =        ERR
```

II AMERICAN ROCKWOOL ANNUAL FLUORIDE TOTALS
(.002/.004) SCENARIO

MONTH	FL IN/ MONTH	FL OUT/ MONTH	CUMULATIVE #FL/YEAR
AUG86	38070.5	77.51	
SEPT86	114205.9	343.50	
OCT 86	104057.9	328.70	
NOV86	118700.8	387.50	
DEC86	97873.3	330.51	
JAN87	85322.1	295.19	
FEB87	97577.5	318.41	
MAR87	104446.8	340.62	
APRIL87	116586.7	381.46	
MAY87	118585.0	389.63	
JUNE87	183396.8	620.95	
JULY87	202491.6	689.17	4503.2
AUG87	128716.1	396.60	4822.2
SEPT87	65261.0	130.52	4609.3
OCT87	71834.5	143.67	4424.2
NOV87			

```
            48414.8
                       96.83
                               4133.6
DEC87
            40134.7
                       80.27
                               3883.3
JAN88
            21791.8
                       60.23
                               3648.4
```

```
*  II AMERICAN ROCKWOOL ANNUAL FLUORIDE TOTALS
             .02/.012 THROUGH SEPT 87
             .002/.004 BEGIN OCT 87
             ALLOWABLE IS 19368 #FL OUT/YR

             FL IN/       FL OUT/   CUMULATIVE
   MONTH     MONTH        MONTH     #FL/YEAR
   ------    --------     -------   ---------
   AUG86
                38070.5
                             755.94
   SEPT86
               114205.9
                            1823.76
   OCT 86
               104057.9
                            1598.83
   NOV86
               118700.8
                            1773.63
   DEC86
                97873.3
                            1418.40
   JAN87
                85322.1
                            1208.27
   FEB87
                97577.5
                            1458.51
   MAR87
               104446.8
                            1562.01
   APRIL87
               116586.7
                            1738.57
   MAY87
               118585.0
                            1761.87
   JUNE87
               183396.8
                            2651.33
   JULY87
               202491.6
                            2913.08
                                       20664.2
   AUG87
               128716.1
                            2017.67
                                       21925.9
   SEPT87
                65261.0
                            1305.22
                                       21407.4
   OCT87
                71834.5
                             143.67
```

```
                                               10852.27
NOV87
              48414.8
                            96.83
                                               18275.4
DEC87
              40134.7
                            80.27
                                               16937.3
JAN88
              21791.8
                            60.23
                                               15789.3
```

RECEIVED
APR 13 1988
RALEIGH REGIONAL OFFICE

RT. 4 BOX 283
CRESTHILL DR.
LOUISVILLE, TN 37777
615/970-2313

DENNIS WEETER
ASSOCIATES
CONSULTING ENGINEERS

April 12, 1988

Mr. Ken Schuster, P.E.
N.C. Dept. of Natural Resources
3800 Barrett Drive
P.O. Box 27687
Raleigh, N.C. 27611-7687

Re: American Rockwool; Spring Hope,NC;Solids/Raw Material/Product Flouride Analyses

Dear Ken:

Please find enclosed a communication from Mr. Apicella which summarizes the flouride analyses for the Feb. 1988 testing.

Based upon a communication to you dated 2/27/88, I would like to point out a few differences. The background F input in Feb. was 71-72.1 #/hr not 119.3 (derived from using April´86 % F numbers and the Feb.´88 burden mass loadings.) The effect is to change the JAN/FEB´88"NO SPL" emission factors to 0.0030-0.0038. Note the calculated F input was 264.7#/hr when actual was 274#/hr for the maximun SPL burn. This would reduce emission factors to 0.00288 for the "SPL" burn. When we shortly submit a permit modification request, I will present detailed calculations on these emission factors.

With regard to a mass balance on F, closure was between 8.5-13.1%. The error is probably in the baghouse catch and cupola drop since methods are not available to accurately measure mass.

Note also that Duquesne and Tennessee slags measured lower F concentrations whereas SPL was slightly higher. Trap, lime, steel slag, and coke have traces of F. The analysis in Feb´88 was to the 1/100 of a percent. For future monthly reports we will use these Feb´88 F concentrations.

Sincerely,

Dennis W. Weeter,Ph.D,P.E.

Enclosure
cc:Bart Bromley;Ron Small;Lee Blayden;Jim Apicella

cc: BOB WOOTEN
4·18·88

INDUSTRIAL WASTES - HAZARDOUS WASTES - TOXICS MANAGEMENT - RESOURCE RECOVERY

ALUMINUM COMPANY OF AMERICA
ALCOA TECHNICAL CENTER
ALCOA CENTER, PA. 15069
(412) 339-6651

ALCOA

1988 April 8

Dr. Dennis Weeter
Dennis Weeter Associates
Route 4, Box 283
Louisville, TN 37777

RE: FLUORIDE BALANCE AT AMERICAN ROCKWOOL'S SPRING HOPE, NC FACILITY

Dear Dr. Weeter:

Environmental Control Laboratory personnel with assistance from American Rockwool personnel conducted a fluoride material balance on the No. 1 cupola and No. 2 cupola in 1988 February. The purpose of this material balance was to show where the deposition of fluorides introduced into the system occurred and the relative accuracy (closure) of these measurements. The fluoride distribution results are shown in Table 1 with the balances of 1988 February 3 (Background Tests 1 and 2), 1988 February 4 (Background Test 3) and 1988 February 5 (710 lb/hr SPL per cupola-Tests 4 through 7) having closures of 110.7%, 113.1% and 108.5%, respectively (Table 2).

PROCEDURES AND CALCULATIONS

The mass flow rate of solids for the raw materials, products and sparkbox/baghouse catches was determined by obtaining the total process weight of each item per unit time. For the raw materials, each component of every charge was weighed and recorded with the actual charging time. Samples of all raw materials were obtained and prepared for analysis as detailed in Report 93-88-003. The mineral wool was collected in 29 lb bags and production was tracked by the number of bags produced per hour and one bag was randomly selected from each operating condition for analysis. The sparkbox/baghouse catch was collected in tared 55 gallon drums over specific time periods then weighed. Random 2 lb samples from every barrel were analyzed for each operating condition. The amount of particulate air emissions was determined by EPA Method 5 and the amount of particulate and gaseous fluorides was determined by Alcoa Method 4075-A. The cupola drop could not be directly measured because there was no practical solution to the problem of collecting the molten cupola drop material. Cupola drop was estimated by subtracting solids out from solids in and then subtracting the amount of carbon burned. A random five gallon sample was obtained for each operating condition.

Fluoride analyses on all the collected materials were completed by the Analytical Chemistry Division of Alcoa using Method 4076A.

DISCUSSION OF RESULTS

While the emission test runs were one hour in duration, the other materials were collected over longer periods of time during "steady state" operation of the system in order to obtain better representative weights and unbiased composite samples for analysis.

The data in Table 2 show the closures to range from 108.5% to 113.1%. The collection and analysis of the air emissions, product and raw materials were controlled to the extent they would not cause this deviation from 100%. The sparkbox/baghouse catch was determined by collecting what was discharged from that system. This will not give the exact sparkbox/baghouse weight values but has the best accuracy possible without shutting down the process and cleaning out each baghouse between trials. Even so, the sparkbox/baghouse should not see a total weight of solids much more/less than reported. Therefore, the majority of fluoride "overcollection" must come from the cupola drop. The cupola drop mass flow is not a measured quantity, but rather a calculated estimate that comes from a basic material balance that cannot account for losses such as unusable product and shot.

Yours truly,

James V. Apicella

James V. Apicella
Environmental Scientist
Environmental Control Laboratory

TABLE 1

Fluoride Distribution

	Background 1&2 88-02-03			Background 3 88-02-04			710 SPL 88-02-05		
	Solids	%F	lb F/hr	Solids	%F	lb F/hr	Solids	%F	lb F/hr
Raw Materials	26267	--[1a]	72.1	25527	--[1b]	71.0	27308	--[1c]	274.0
Products	14616	0.3	43.8	15157	0.3	45.5	13322	1.1	146.5
SP Box and Baghouse[2]	294.7	--	8.9	383.3	--	11.8	307.5	--	30.8
Emissions[3]	2.2	--	0.23	2.2	--	0.23	3.7	--	0.86
Cupola Drop	8963[4]	0.3	26.9	7602[4]	0.3	22.8	11125[4]	1.07	119.0

1a See breakdown of raw materials Table R1
1b See breakdown of raw materials Table R2
1c See breakdown of raw materials Table R3
2 See breakdown of spark box and baghouse Table R4
3 See ECL Report 93-88-003, Compliance Report on Particulate and Sulfur Dioxide, Fluoride and Visual Emissions from Mineral Wool Production, American Rockwool, Inc., Spring Hope, NC, Test Period: 1988 February 3-5
4 Estimate from carbon balance

TABLE 2

Fluoride Balance

	Background 1&2 88-02-03	Background 3 88-02-04	710 SPL 88-02-05
Total Fluoride in lb/hr	72.1	71.0	274.0
Total Fluoride out lb/hr	79.8	80.3	297.2
% Closure	110.7	113.1	108.5

TABLE R1

```
 SPRING HOPE PRODUCTION DATA 88-02-03          ;
  TIME     10:30AM - 5:30PM BACKGROUND TESTS   ;
                   UNIT 1   UNIT 2    TOTAL    ;
                 ------------------------------;
  PRODUCT   BAGS      1764     1764            ; PRODUCT       LB/HR
           POUNDS    51156    51156            ;     0.3 %F     43.8
           TIME (hr)     7        7            ;
            LB/HR     7308     7308     14616  ;
---------------------------------------------------------------------
   COKE    POUNDS     9464    10301            ;  COKE
           TIME (hr)  7.02     7.00            ;    0.04 %F      1.1
            LB/HR     1348     1472      2820  ;

    SPL    POUNDS        0        0            ;  SPL
           TIME (hr)  7.02     7.00            ;    12.6 %F      0.0
            LB/HR        0        0         0  ;

 DUQUESNE  POUNDS    31201    34575            ;DUQUESNE
           TIME (hr)  7.02     7.00            ;    0.14 %F     13.1
            LB/HR     4445     4939      9384  ;

   TRAP    POUNDS    26338    29188            ;  TRAP
           TIME (hr)  7.02     7.00            ;    0.05 %F      4.0
            LB/HR     3752     4170      7922  ;

   LIME    POUNDS     1162     1317            ;  LIME
           TIME (hr)  7.02     7.00            ;    0.02 %F      0.1
            LB/HR      166      188       354  ;

   STEEL   POUNDS     9958    10970            ;  STEEL
           TIME (hr)  7.17     7.22            ;    0.07 %F      2.0
            LB/HR     1389     1519      2908  ;

TENNESSEE POUNDS      9669    10515            ;TENNESSEE
           TIME (hr)  7.02     7.00            ;     1.8 %F     51.8
            LB/HR     1377     1502      2879  ;
===============================================;=====================
TOTAL CHARGE LB/HR   12476    13790     26267  ;FLUORIDES        72.1
```

TABLE R2

SPRING HOPE PRODUCTION DATA 88-02-04

TIME 8:00AM - 11:00AM

		UNIT 1	BKGRD UNIT 2	TESTS TOTAL			
PRODUCT	BAGS	784	784		PRODUCT		LB/HR
	POUNDS	22736	22736			0.3 %F	45.5
	TIME (hr)	3	3				
	LB/HR	7579	7579	15157			
COKE	POUNDS	4491	4440		COKE		
	TIME (hr)	3.18	3.12			0.04 %F	1.1
	LB/HR	1412	1423	2835			
SPL	POUNDS	0	0		SPL		
	TIME (hr)	3	3			12.6 %F	0.0
	LB/HR	0	0	0			
DUQUESNE	POUNDS	14109	14190		DUQUESNE		
	TIME (hr)	3.18	3.12			0.14 %F	12.6
	LB/HR	4437	4548	8985			
TRAP	POUNDS	12142	12160		TRAP		
	TIME (hr)	3.18	3.12			0.05 %F	3.9
	LB/HR	3818	3897	7716			
LIME	POUNDS	504	499		LIME		
	TIME (hr)	3.18	3.12			0.02 %F	0.1
	LB/HR	158	160	318			
STEEL	POUNDS	4477	4441		STEEL		
	TIME (hr)	3.17	3.15			0.07 %F	2.0
	LB/HR	1412	1410	2822			
TENNESSEE	POUNDS	4479	4501		TENNESSE		
	TIME (hr)	3.18	3.12			1.8 %F	51.3
	LB/HR	1408	1443	2851			
TOTAL CHARGE LB/HR		12646	12881	25527	FLUORIDES		71.0

TABLE R3

```
SPRING HOPE PRODUCTION DATA 88-02-05                     ¦
 TIME      8:00AM - 4:00PM 710# SPL                      ¦
                   UNIT 1   UNIT 2     TOTAL             ¦
                 ----------------------------------------¦
 PRODUCT   BAGS      1862     1813                       ¦ PRODUCT        LB/HR
          POUNDS    53998    52577                       ¦     1.1 %F     146.5
         TIME (hr)      8        8                       ¦
           LB/HR     6750     6572     13322             ¦
---------------------------------------------------------------------------------
  COKE    POUNDS     7155     8222                       ¦  COKE
         TIME (hr)      8        8                       ¦   0.04 %F        0.8
           LB/HR      894     1028      1922             ¦

   SPL    POUNDS     6056     6715                       ¦   SPL
         TIME (hr)      8        8                       ¦   12.6 %F      201.1
           LB/HR      757      839      1596             ¦

DUQUESNE  POUNDS    36435    39675                       ¦DUQUESNE
         TIME (hr)      8        8                       ¦   0.14 %F       13.3
           LB/HR     4554     4959      9514             ¦

  TRAP    POUNDS    30468    33600                       ¦  TRAP
         TIME (hr)      8        8                       ¦   0.05 %F        4.0
           LB/HR     3809     4200      8009             ¦

  LIME    POUNDS     1436     1606                       ¦  LIME
         TIME (hr)      8        8                       ¦   0.02 %F        0.1
           LB/HR      180      201       380             ¦

  STEEL   POUNDS    11343    12384                       ¦  STEEL
         TIME (hr)      8        8                       ¦   0.07 %F        2.1
           LB/HR     1418     1548      2966             ¦

TENNESSEE POUNDS    11142    12224                       ¦TENNESSE
         TIME (hr)      8        8                       ¦    1.8 %F       52.6
           LB/HR     1393     1528      2921             ¦
=========================================================¦=======================
TOTAL CHARGE LB/HR  13004    14303     27308             ¦FLUORIDES         274.0
```

TABLE R4

```
AMERICAN ROCKWOOL  SPRING HOPE PLANT           COMPLIANCE TESTS 88-02-03 THRU 88-02-05
SPARKBOX AND BAGHOUSE CATCH                    SOLIDS AND FLUORIDES

                          UNIT 1                  UNIT 2                  BOTH UNITS              SUMMARY

                           101.0 LB/HR TOTAL       101.0 LB/HR TOTAL       202.0 LB/HR TOTAL       294.7 LB/HR
                BAGHOUSE     3.5 %F                  4.2 %F                  7.8 LB/HR F             8.9 LB/HR F
                             3.5 LB/HR F             4.2 LB/HR F
BACKGROUND # 1&2
                            37.8 LB/HR TOTAL        54.8 LB/HR TOTAL        92.7 LB/HR TOTAL
                SPARK BOX    1.2 %F                  1.3 %F                  1.2 LB/HR F
                             0.5 LB/HR F             0.7 LB/HR F

                          UNIT 1                  UNIT 2                  BOTH UNITS              SUMMARY

                           133.5 LB/HR TOTAL       147.8 LB/HR TOTAL       281.3 LB/HR TOTAL       383.3 LB/HR
                BAGHOUSE     4.2 %F                  3.3 %F                 10.5 LB/HR F            11.8 LB/HR F
                             5.6 LB/HR F             4.9 LB/HR F
BACKGROUND #3
                            37.3 LB/HR TOTAL        64.8 LB/HR TOTAL       102.0 LB/HR TOTAL
                SPARK BOX    1.3 %F                  1.3 %F                  1.3 LB/HR F
                             0.5 LB/HR F             0.8 LB/HR F

                          UNIT 1                  UNIT 2                  BOTH UNITS              SUMMARY

                           117.5 LB/HR TOTAL       124.3 LB/HR TOTAL       241.8 LB/HR TOTAL       307.5 LB/HR
                BAGHOUSE    11.5 %F                 12.8 %F                 29.4 LB/HR F            30.8 LB/HR F
                            13.5 LB/HR F            15.9 LB/HR F
710 SPL
                            19.8 LB/HR TOTAL        46.0 LB/HR TOTAL        65.8 LB/HR TOTAL
                SPARK BOX    2.1 %F                  2.0 %F                  1.3 LB/HR F
                             0.4 LB/HR F             0.9 LB/HR F
```

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[redacted]

Date 8/5/88

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Your Phone Number (Very Important): (412) 337-2975

Company:

Department/Floor No.: AEC-C

Street Address:

City:

State:

ZIP Required For Correct Invoicing:

2 To (Recipient's Name) Please Print: MR. ROBERT WOOTEN

Recipient's Phone Number (Very Important): (919) 733-3340

Company: NC DNR
NC DEPT. NATURAL RESOURCES

Department/Floor No.: AIR QUALITY SEC.

Exact Street Address (Use of P.O. Boxes or P.O.® Zip Codes Will Delay Delivery And Result in Extra Charge.): 3800 BARRETT DRIVE

City: RALEIGH

State: NC

ZIP Street Address Zip Required: 27611

3 YOUR BILLING REFERENCE INFORMATION (FIRST 24 CHARACTERS WILL APPEAR ON INVOICE.)

83A00070

PAYMENT ☒ Bill Sender ☐ Bill Recipient's FedEx Acct. No. ☐ Bill 3rd Party FedEx Acct. No. ☐ Bill Credit Card
☐ Cash

[redacted]

4 SERVICES
CHECK ONLY ONE BOX

1 ☐ PRIORITY 1
Overnight Delivery
Using Your Packaging

6 ☒ OVERNIGHT LETTER*
(Our Packaging)
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OVERNIGHT DELIVERY
USING OUR PACKAGING

2 ☐ Courier-Pak Overnight Envelope*
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3 ☐ Overnight Box
12½" x 17½" x 3"
A ☐

4 ☐ Overnight Tube
38" x 6" x 6" x 6"
B ☐

*Declared Value Limit $100.

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5 ☐ Delivery not later than second business day

SERVICE COMMITMENT

PRIORITY 1 - Delivery is scheduled early next business morning in most locations. It may take two or more business days if the destination is outside our primary service areas.

STANDARD AIR - Delivery is generally next business day or not later than second business day. It may take three or more business days if the destination is outside our primary service areas.

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CHECK SERVICES REQUIRED

1 ☐ HOLD FOR PICK-UP (Fill in Section H at right)
2 ☒ DELIVER WEEKDAY
3 DELIVER SATURDAY (Extra charge) ☐
4 ☐ DANGEROUS GOODS (P-1 and Standard Air Packages only Extra charge)
5 ☐ CONSTANT SURVEILLANCE SERVICE (CSS) (Extra charge) (Do Not Complete Section 5)
6 ☐ DRY ICE ________ Lbs.
7 ☐ OTHER SPECIAL SERVICE ________
8 ☐
9 ☐ SATURDAY PICK-UP (Extra charge)
10 ☐

PACKAGES	WEIGHT	YOUR DECLARED VALUE	OVER SIZE
1	[illegible]		
	[illegible]		
	[illegible]		
	[illegible]		
Total 1	Total 1	Total	

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1 ☒ Regular Stop
2 ☐ On-Call Stop
3 ☐ Drop Box
4 ☐ B.S.C.
5 ☐ Station

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Date

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☐ Third Party ☐ Chg. To Del. ☐ Chg. To Hold

Street Address

City

State

Zip

Received By:
X

Date/Time Received

FedEx Employee Number

Federal Express Use

Base Charges

Declared Value Charge

Origin Agent Charge

Other

Total Charges

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ALUMINUM COMPANY OF AMERICA
ALCOA TEC [illegible]
[illegible]

1988 August 4

NC NRDC
Air Quality Section
P.O. Box 27687
Raleigh, NC 27611
Attn: Mr. Robert Wooten

RE: 1988 MAY AMERICAN ROCKWOOL, SPRING HOPE, NC, EMISSION CALCULATIONS

Dear Mr. Wooten:

As per your request, this letter demonstrates how fluoride emissions were calculated from the 1988 May testing at American Rockwools Spring Hope, NC, Facility. Run 1, 1988 May 17, has been chosen for specific examples. All referenced data can be found in the formal report, #93-88-005, dated 1988 May 14, or in the attachment.

Fluoride Emissions - Fluoride emissions were determined using Alcoa Sampling Method 4075A coupled with Alcoa Analytical Method 4076A. The equation used for mass emission of F is as follows:

$$\text{lb/hr F} = \frac{M_F}{\text{Vmstd}} (Q_{std}) \left[\frac{1 \text{ lb}}{453600 \text{ mg}}\right] \left[\frac{60 \text{ min}}{1 \text{ hr}}\right] \qquad (A)$$

In equation (A) Vmstd is the dry standard volume of stack gas sampled during Run 1 and Q_{std} is the dry standard volumetric flow rate for the stack gas during Run 1. The term M_F stands for the total mass of fluoride recovered from the Method 4075-A sampling train. This particular train has three areas that collect fluoride - the nozzle, the thimble and the impingers. Particulate fluoride is collected in the nozzle and thimble while gaseous fluoride is captured in the impingers. For analysis, the nozzle wash and a 100 ml sample from the impinger solution were directly distilled (sulfuric acid distillation) to 500 ml volume. They were then directly analyzed by Specific Ion Electrode (SIE) and the impinger value was corrected for a dilution. The contents of the thimble had CaO added, were ashed and then fused with NaOH before being distilled (sulfuric acid distillation) for analysis by SIE. (Refer to Method 4076A.)

why not and [illegible]

no visible particulate - in nozzle wash.
Gary McAllister says it should be OK

For an SIE analysis, a calibration is completed with known concentrations (analytical standards) of fluoride solutions. For each fluoride solution SIE yields a specific millivolt reading. From the millivolt readings and their respective fluoride concentrations a line can be determined. The millivolt reading is plotted vs the log of the F concentration. The F concentration of a sample solution (usually a 10 ml aliquot from the H_2SO_4 distillate) is determined from this graph (or by the equation of the line) by taking the antilog of the Y-axis value for the corresponding X-axis voltage. The fluoride concentration obtained is then factored for dilution (when applicable) and converted to total fluoride mass. Sample calculations for the nozzle wash, thimble and impinger (F_n, F_t and F_i, respectively) F content follow.

ALCOA
CENTENNIAL
1988

Please note that the total mass of fluoride (M_F) collected by this train is equal to the sum of F_n, F_t and F_i.

The nozzle:

	Y	X	LOG Y
Calibrations:	2 mg F/l	828 mV	0.301
	20 mg F/l	244 mV	1.301
	0.20 mg F/l	1341 mV	-0.699
	200 mg F/l	-346 mV	2.301

These values can either be plotted (X vs log Y) or an equation can be developed:

$$Y = 10^{mx+b} \text{ where } m = \text{slope}$$
$$b = \text{intercept}$$

The Run 1 nozzle wash sample produced an SIE millivolt reading of 1205 mV which corresponded to a concentration of 0.395 mg F/l. Since the distillation volume was 500 ml (0.5 l):

Fn = (0.395 mg F/l) (0.5 l) = 0.198 mg F or 0.20 mg F

Calibration plots can be found in the attachments.

The Thimble:

	Y	X	LOG Y
Calibrations:	2 mg F/l	844 mV	0.301
	20 mg F/l	266 mV	1.301
	0.20 mg F/l	1357 mV	-0.699
	200 mg F/l	-327 mV	2.301

SIE for the Run 1 thimble sample gave a reading of 728 mV which corresponded to a concentration of 3.175 mg F/l. Therefore, total fluoride for the thimble is equal to:

Ft = (3.175 mg F/l) (0.5 l) = 1.588 mg F or 1.59 mg F

The Impingers:

	Y	X	LOG Y
Calibrations:	2 mg F/l	898 mV	0.301
	20 mg F/l	308 mV	1.301
	0.20 mg F/l	1420 mV	-0.699
	200 mg F/l	-279 mV	2.301

The analysis of the impingers differs from that of the nozzle and thimble. The nozzle and thimble analyses make use of the entire submitted sample. Due to the large volume of the impinger field sample (V_f = 0.510 l) only a 100 ml aliquot (Va) is used for analysis. This fluoride containing aliquot is distilled by sulfuric acid distillation to a fluoride containing distillate volume (V_d) of 500 ml. This is equivalent to a five-fold dilution in the fluoride concentration because the same mass of fluoride that was originally in the 100 ml aliquot is now in the 500 ml distillate.

From the distillate a 10 ml aliquot is taken for SIE analysis where it produced a reading of 1238 mV. This value corresponded to a distillate fluoride concentration (Cd) of 0.479 mg F/l. The distillate concentration is not equal to field sample concentration (Ca).

Therefore:

$$Ca = (Vd/Va)\ Cd = (500\ ml/100\ ml)\ (0.479\ mg\ F/l) = 2.395\ mg\ F/l$$

Since the field sample volume was 0.510 l and its concentration was 2.395 mg F/l, the same as the 100 ml aliquot, the total mass of fluoride contained in the impingers (Fi) equals:

$$Fi = V_f\ Ca = (0.510\ l)\ (2.395\ mg\ F/l) = 1.22\ mg\ F.$$

Total Fluoride:

$$M_F = Fn + Ft + Fi = 0.20\ mg + 1.59\ mg + 1.22\ mg = 3.01\ mg\ F.$$

Therefore, equation (A) yields:

$$lb/hr\ F = \frac{3.01\ mg\ F_3}{38.28\ dsft^3}\left[\frac{38019\ ds\ ft^3}{min}\right]\left[\frac{1\ lb}{453600\ mg}\right]\left[\frac{60\ min}{hr}\right] = 0.39\ lb\ F/hr$$

Review of the laboratory data in the attachment shows QA/QC measures (spiked samples, duplicate samples and blanks) that have been taken.

I hope this letter addresses your needs regarding laboratory calculations. If I can be of any further assistance, please do not hesitate to call.

Sincerely,

James V. Apicella

JAMES V. APICELLA

ext. 2975

Attachments

CC: L. C. Blayden, ATC-C
R. G. Small, Pittsburgh 23
D. Weeter Associates, Louisville, TN
B. W. Bromley, American Rockwool, Spring Hope, NC.

This attachment contains:

A) Field testing raw data.
B) Preliminary field testing reduced data.
C) Fluoride laboratory raw and reduced data.

    1) Nozzle data.
    2) Thimble data.
    3) Impinger data.
    4) SIE calibration plots.

For ease of identification, the LSN/ID# is provided for each fluoride sample obtained in Run 1.

SAMPLE	LSN/ID#
Nozzle	816053/539375
Thimble	816064/539386
Impingers	816041/539363

RAW DATA SET

ALCOA

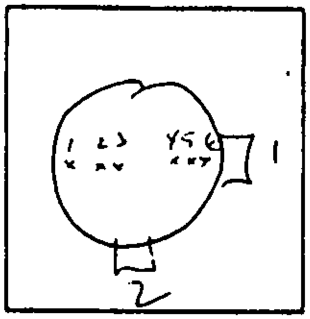
Plant Spring Hope
Unit# both Inlet/[✓ Outlet] Stack
Operator JVH
Date 88-05-17
Run No. 1
Sample Box No.
Meter Box No. ZP
Meter DH@ 1.93
K Factor 7.31 @ 90/135
Pitot Cp 0.84 Pitot Leak Ck ✓
Leak Rate Before -0- CFM @ 19 Hg
Leak Rate After -0- CFM @ 5 Hg
Static Press., In. H₂O (+ [✓ -]) 0.12

Start Time
9 : 25 [✓ AM] PM

Finish Time
10 : 28 [✓ AM] PM

Meter Yd
1.00

K: 7.50 75/105



SCHEMATIC OF TESTING LOCATION

Filter #'s —
Thimble # 1
Beaker #

Ambient Temperature, °F 70
Barometric Pressure, In. Hg 29.84
Assumed Moisture, % 2
Heater Box Setting N/A
Probe Length, Ft. No.
Nozzle Diameter, In. 0.243
Probe Heater Setting N/A
% O_2 18
% CO_2 2
H_2O, ml
Silica Gel, gm 11.8
Total Vlc 16.8
Stack Area, Ft² 28.27
Pyrometer No.

TRAVERSE POINT NUMBER	MIN/PT 5 SAMPLING TIME θ, min.	VACUUM In. Hg	STACK TEMPERATURE T_s, °F	VELOCITY HEAD DP_s	PRESSURE DIFFERENTIAL ACROSS ORIFICE METER DH, In. H_2O	Initial Volume: 175.02 GAS SAMPLE VOLUME V_m, Ft³	GAS SAMPLE TEMPERATURE AT DRY GAS METER INLET T_m in, °F	OUTLET T_m out, °F	TEMP. OF GAS LEAVING CONDENSER OR LAST IMPINGER T_i, °F	SAMPLE BOX TEMPERATURE T_b °F
1-1	5	3	102	0.18	1.3	178.40	74	69	59	NA
2	10	3	102	0.19	1.4	181.71	78	71	41	
3	15	4	100	0.21	1.6	185.26	83	72	42	
4	20	4	101	0.21	1.6	188.83	85	73	44	
5	25	3	101	0.19	1.4	192.17	86	75	46	
6	30	2	101	0.10	0.75	194.65	86	76	48	
2-1	35	3	104	0.16	1.2	197.76	83	76	55	
2	40	2	106	0.13	0.98	200.61	86	77	58	
3	45	4	104	0.21	1.6	204.13	88	78	59	
4	50	4	104	0.21	1.6	207.65	87	78	60	
5	55	4	105	0.24	1.8	211.38	86	78	60	
6	60	2	106	0.13	0.98	214.16	86	78	62	
TOTAL			1236	5.056	16.21		AVG. 1008	AVG. 901		
AVERAGE			103	0.421	1.35	39.14	AVG. 80			

Page 1 of 1

We can't wait for tomorrow ALCOA

PARAMETER SHEET

ALCOA

PLANT Am. Rockwool Spring Hope

CITY Sp Hop STATE NC

DATE 88-05-17

RUN 1 METHOD 4075-A

UNIT Ln#1

○ INLET

☒ OUTLET STACK

START TIME 9:25 [✓ AM]/PM

FINISH TIME 10:28 [✓ AM]/PM

METER OPERATOR SVA

COMMENTS:

Preliminary Reduced Data

METER BOX NO. 2 P

DH @ 1.83

FILTER NO.

THIMBLE NO. 1

DATA

1	Pb	29.84	"Hg
2	Static	-0.12	"wc
3	Vlc	16.8	ml
4	Mn		g
5	θ	60	min
6	% O_2	18	
7	% CO_2	2	
8	DH	1.35	"wc
9	Cp	0.84	
10	Tm	80	F
11	$\sqrt{Dp}$	0.421	$\sqrt{"wc}$
12	Ts	103	F
13	Vm	39.14	ft^3
14	Dn	0.293	in
15	As	28.27	ft^2
16	Yd	1.00	cf/cf

RESULTS

Vmstd	38.28	dscf
Vwstd	0.791	scf
Bwo	0.02	
Md	29.04	lb/lb-mole
Ms	28.82	lb/lb-mole
Vs	24.47	ft/s
% I	101.4	
acfm	41500	
dscfm	38020	
Particulate		gr/dscf
		lb/hr
SO_2		lb/hr
Gaseous F		lb/hr
Particulate F		lb/hr
Total F		lb/hr
K-F	7.6	

ALCOA TECHNICAL CENTER
ANALYTICAL CHEMISTRY DIVISION

88-6-15 8:55 PAGE 1

****
* FINAL REPORT *
****

J.O. : 88-052325 NO. SAMP. : 28 APPROVED : 88-06-03

SUBMITTED BY : L.D.PENIX PHONE : 2572
LOCATION : ENVIRONMENTAL CONTROL LAB
SHOP ORDER : 14H1000891 TID :
SYSTEM ID. : SPRING HOPE 4075A'S AM. ROCKWOOL
PROJ. LEADER : JOE GIBB PHONE : 2597

REPORT CC : L.C.BLAYDEN,J.E.GIBB,J.V.APICELLA

LSN	SAMPLE IDENTIFICATION
816041	539363 IMPINGERS 1
816042	539364 IMPINGERS 2
816043	539365 IMPINGERS 3
816044	539366 IMPINGERS 4
816045	539367 IMPINGERS 5
816046	539368 IMPINGERS 6
816047	539369 IMPINGERS 7
816048	539370 IMPINGERS 8
816049	539371 IMPINGERS 9
816052	539374 BLANK
816053	539375 NOZZLE 1
816054	539376 NOZZLE 2
816055	539377 NOZZLE 3
816056	539378 NOZZLE 4
816057	539379 NOZZLE 5
816058	539380 NOZZLE 6
816059	539381 NOZZLE 7
816060	539382 NOZZLE 8
816061	539383 NOZZLE 9
816064	539386 THIMBLE 1
816065	539387 THIMBLE 2
816066	539388 THIMBLE 3
816067	539389 THIMBLE 4
816068	539390 THIMBLE 5
816069	539391 THIMBLE 6
816070	539392 THIMBLE 7
816071	539393 THIMBLE 8
816072	539394 THIMBLE 9

N.D. (OR ND) = NOT DETECTED
\- (OR BLANK) = NOT DETERMINED

```
ALCOA TECHNICAL CENTER                                    88-06-15 8:55 PAGE 2
ANALYTICAL CHEMISTRY DIVISION                             J.O. NO. 88-052325

AREA: 201 - FLUORIDE LAB                                     APPROVED:88-06-03

ANALYSIS: FLUORIDE

          UNITS:TOTAL MG

LSN/ID    FLUORIDE
======    ==========
816041       1.2
539363 IMP
INGERS 1
------------------------------------------------------------------------------
816042       4.8
539364 IMP
INGERS 2
------------------------------------------------------------------------------
816043       4.9
539365 IMP
INGERS 3
------------------------------------------------------------------------------
816044      12.8
539366 IMP
INGERS 4
------------------------------------------------------------------------------
816045      46.9  ✓
539367 IMP
INGERS 5
------------------------------------------------------------------------------
816046      87.2
539368 IMP
INGERS 6
------------------------------------------------------------------------------
816047      66.0
539369 IMP
INGERS 7
------------------------------------------------------------------------------
816048      26.0
539370 IMP
INGERS 8
------------------------------------------------------------------------------
816049      37.5
539371 IMP
INGERS 9
------------------------------------------------------------------------------
816052       #
539374 BLA
NK
------------------------------------------------------------------------------
```

```
ALCOA TECHNICAL CENTER                                    88-06-15 8:55 PAGE 3
ANALYTICAL CHEMISTRY DIVISION                             J.O. NO. 88-052325


ANALYSIS: FLUORIDE

          UNITS:TOTAL MG

LSN/ID    FLUORIDE
======    ==========
816053       0.2
539375 NOZ
ZLE 1
-------------------------------------------------------------------------------
816054       0.2
539376 NOZ
ZLE 2
-------------------------------------------------------------------------------
816055       0.1
539377 NOZ
ZLE 3
-------------------------------------------------------------------------------
816056       0.7
539378 NOZ
ZLE 4
-------------------------------------------------------------------------------
816057       0.6  ✓
539379 NOZ
ZLE 5
-------------------------------------------------------------------------------
816058       0.3
539380 NOZ
ZLE 6
-------------------------------------------------------------------------------
816059       0.2
539381 NOZ
ZLE 7
-------------------------------------------------------------------------------
816060       0.2
539382 NOZ
ZLE 8
-------------------------------------------------------------------------------
816061       0.3
539383 NOZ
ZLE 9
-------------------------------------------------------------------------------
```

```
ANALYSIS: TOTAL PARTICULATE FLUORIDE

          UNITS:TOTAL MG

LSN/ID    TOTAL PARTICULATE FLUORIDE
======    ==============================
816064       1.6
539386 THI
MBLE 1
--------------------------------------------------------------------------------
816065       1.8
539387 THI
MBLE 2
--------------------------------------------------------------------------------
816066       1.9
539388 THI
MBLE 3
--------------------------------------------------------------------------------
816067       4.3
539389 THI
MBLE 4
--------------------------------------------------------------------------------
816068       5.8  ✓
539390 THI
MBLE 5
--------------------------------------------------------------------------------
816069       5.8
539391 THI
MBLE 6
--------------------------------------------------------------------------------
816070       6.6
539392 THI
MBLE 7
--------------------------------------------------------------------------------
816071       6.1
539393 THI
MBLE 8
--------------------------------------------------------------------------------
816072       6.7
539394 THI
MBLE 9
--------------------------------------------------------------------------------
```

COMMENTS:

SAMPLES WERE ANALYZED BY METHODS 913C (DISTILLATION) AND 914F (SIE)

DUPLICATE:	RUN 1 MG/L	RUN 2 MG/L
LSN#816047	122	123

SPIKE: LSN# 816045 - 5ML OF A 1000 MG/L FLUORIDE STD WAS ADDED TO 50 ML OF SAMPLE IN THE DISTILLATION FLASK. FINAL DISTILLATION VOLUME WAS 500 ML.

SPIKED SAMPLE ANALYSIS	200.8 MG/L
UNSPIKED SAMPLE ANALYSIS	99.9 MG/L
RECOVERED FLUORIDE	100.9 MG/L
ADDED FLUORIDE	100.0 MG/L
% RECOVERY	101 %

- NO VOLUME WAS RECEIVED ON LSN# 816052 (CAUSTIC BLANK)
THE FLUORIDE RESULT WAS 0.3 MG/L

NOZZLE WASH DUPLICATE:	RUN1 MG/L	RUN2 MG/L
LSN# 816055	1.6	1.6

SPIKE: LSN# 816058 - 5 ML OF A 1000 MG/L FLUORIDE STD WAS ADDED TO 50 ML OF SAMPLE IN DISTILLATION FLASK. FINAL DILUTION VOLUME WAS 500 ML.

SPIKED SAMPLE ANALYSIS	103.5 MG/L
UNSPIKED SAMPLE ANALYSIS	2.6 MG/L
RECOVERED FLUORIDE	100.9 MG/L
ADDED FLUORIDE	100.0 MG/L
% RECOVERY	101 %

SMALL BLK THIMBLE - 0.1 TOTAL MG FLUORIDE
SPIKE: .1050 G NAF WAS ADDED TO A BLK THIMBLE. TO ALL THIMBLES .5G CAO WAS ADDED. ALL WERE ASHED, FUSED WITH NAOH, DISTILLED AND ANALYZED SIE.
47.5 MG OF FLUORIDE WAS ADDED TO THE THIMBLE - 48.0 MG OF FLUORIDE WAS RECOVERED OR 101 %

LAB REFERENCES: 2760:213, 2760:214, 2760:215

ANALYST(S): SANDRA DEISEROTH

****

APPROVED BY: NORMA J. HORNUNG
FINAL APPROVED BY: NANCY M. FITZGERALD

*** END OF REPORT ***

2760, 213

L. Penix
14 H 1000291
Rockwood
-5- Spring, Hypo

88-052325
SCL
34

impingers dist
E 1/2 Sec SIE

check diced SIE
2760, 21~~8~~-2

88/05/23 13:18:34
TRAY NO. 1 TRAY I.D. 1 JOB ORDER NO.
CALIBRATION BASED ON TRAY 1
MV READOUT ONLY 16 POSITIONS

POS. 1 MV= 1417
POS. 2 MV= 1419 1420 ·2
POS. 3 MV= 1420 898 2
POS. 5 MV= 308 308 20
POS. 6 MV= -279 -279 200
POS. 7 MV= ~~326~~ 26 [illegible]
POS. 8 MV= ~~1232~~
POS. 9 MV= 1238 816041 — 816041 042
POS. 10 MV= 967 [illegible]
POS. 11 MV= 943 [illegible]
POS. 12 MV= 662 [illegible]
POS. 13 MV= 486 [illegible] 88-052325
POS. 14 MV= 307 [illegible]
POS. 15 MV= 372 046
POS. 16 MV= 434 047 — 816047

88/05/23 14:14:27
TRAY NO. 2 TRAY I.D. JOB ORDER NO.
CALIBRATION BASED ON TRAY 1
MV READOUT ONLY 9 POSITIONS

POS. 1 MV= ~~429~~
POS. 2 MV= 433 816047 0 up
POS. 3 MV= 522 048
POS. 4 MV= 371 049 88-052325
POS. 5 MV= 604 050
POS. 6 MV= 918 051
POS. 7 MV= ~~1593~~ 052
POS. 8 MV= 1080 814074
POS. 9 MV= 1237 814075 88-050916

88/05/23 14:43:32
TRAY NO. 3 TRAY I.D. JOB ORDER NO.
CALIBRATION BASED ON TRAY 1
MV READOUT ONLY 4 POSITIONS

POS. 1 MV= 389 20 ppm [illegible]
POS. 2 MV= ~~1572~~
POS. 3 [illegible] MV= 1601 816[illegible]

```
88/05/23                    15:10:25
TRAY NO. 1                 TRAY I.D. 1              JOB ORDER NO.88-052325
CALIBRATION BASED ON TRAY  1
CALIBRATION; MV/KB;  16POSITIONS-NO DISTILLED STD.;
                                                                      dist
 1            2 MG F/L          898 MV
 2            20 MG F/L      308 MV       MG/L FLUORIDE= 20.000
            SLOPE(MV20-MV2)= -590
 3            0.20 MG F/L      1420 MV          MG/L FLUORIDE=  .200
 4            200 MG F/L         -279 MV       MG/L FLUORIDE=  200.00
                        SLOPE(MV200-MV20)= -587

POS 5              JOB ORDER#88-052325            LSN#=816041
MV= 1238               ALIQUOT= 10 MLS
ORIG. SPL.= 100 MLS
S. WT.= 0                DIL. VOL.= 500 MLS              MG F/L= .479
KNOWN CONC.= 0           CALC. CONC.= 2.395(MG F/L)
DIST. FACTOR 0 APPLIED                x.510ml = 1.22 Total mg ✓

POS 6              JOB ORDER#88-052325            LSN#=816042
MV= 967                ALIQUOT= 10 MLS
ORIG. SPL.= 100 MLS
S. WT.= 0                DIL. VOL.= 500 MLS              MG F/L= 1.511
KNOWN CONC.= 0           CALC. CONC.= 7.555(MG F/L)
DIST. FACTOR 0 APPLIED                x.643 ml = 4.8 mg ✓

POS 7              JOB ORDER#88-052325            LSN#=816043
MV= 943                ALIQUOT= 10 MLS
ORIG. SPL.= 100 MLS
S. WT.= 0                DIL. VOL.= 500 MLS              MG F/L= 1.667
KNOWN CONC.= 0           CALC. CONC.= 8.335(MG F/L)
DIST. FACTOR 0 APPLIED              x 590 ml = 4.9 ✓

POS 8       -      JOB ORDER#88-052325            LSN#=816044
MV= 662                ALIQUOT= 10 MLS
ORIG. SPL.= 100 MLS
S. WT.= 0                DIL. VOL.= 500 MLS           MG F/L= 5.024
KNOWN CONC.= 0           CALC. CONC = 25.12 (MG F/L)
DIST. FACTOR 0 APPLIED                x 510 = 12.8 ✓

POS 9                                             LSN#=816045
MV 486                 ALIQUOT 10 MLS
ORIG SPL = 50 MLS
S. WT. = 0               DIL VOL = 500 MLS               MG F/L= 9.985      ✓
KNOWN CONC.= 0           CALC. CONC.= 99.850(MG F/L)
DIST. FACTOR 0 APPLIED                x 470 =                  ✓
```

```
CALIBRATION: [illegible] POSITIONS-NO DISTILLED STD.)
 1           2 MG F/L        898 MV
 2           20 MG F/L     308 MV      MG/L FLUORIDE= 20.000
          SLOPE(MV20-MV2)= -590
 3           0.20 MG F/L       1420 MV         MG/L FLUORIDE=  .200
 4           200 MG F/L         -279 MV       MG/L FLUORIDE=  200.00
                     SLOPE(MV200-MV20)= -587

POS 6             JOB ORDER#88-052325           LSN#=816052
MV= 1601             ALIQUOT= 10 MLS
ORIG. SPL.= 100 MLS
S. WT.= 0             DIL. VOL.= 500 MLS            MG F/L= .063
KNOWN CONC.= 0        CALC. CONC.= .315(MG F/L)
DIST. FACTOR 0 APPLIED

 POS 9             JOB ORDER#           LSN#=20 PPM
 MV= 309              ALIQUOT= 10 MLS
 ORIG. SPL.= 500 MLS
 S. WT.= 0             DIL. VOL.= 500 MLS            MG F/L= 19.922
 KNOWN CONC.= 0        CALC. CONC.= 19.922(MG F/L)
 DIST. FACTOR 0 APPLIED
```

```
S. WT.= 0               DIL. VOL.= 500 MLS          MG F/L= 9.985
KNOWN CONC.= 0          CALC. CONC.= 99.850(MG F/L)
DIST. FACTOR 0 APPLIED
```

x 470 = 46.9 mg ✓

```
POS 10             JOB ORDER#88-052325          LSN#=816045 SPIKE
MV= 307             ALIQUOT= 10 MLS
ORIG. SPL.= 50 MLS
S. WT.= 0               DIL. VOL.= 500 MLS          MG F/L= 20.079
KNOWN CONC.= 0          CALC. CONC.= 200.79(MG F/L)
DIST. FACTOR 0 APPLIED
```

− 99.85

5ml of 1000ppm added to 50ml   100.94 ✓ ÷ 100 = 101 % ✓

```
POS 11             JOB ORDER#88-052325          LSN#=816046
MV= 372             ALIQUOT= 10 MLS
ORIG. SPL.= 50 MLS
S. WT.= 0               DIL. VOL.= 500 MLS          MG F/L= 15.58
KNOWN CONC.= 0          CALC. CONC.= 155.80(MG F/L)
DIST. FACTOR 0 APPLIED
```

130.9

x 560 = 87.2 ✓

```
POS 12             JOB ORDER#88-052325          LSN#=816047
MV= 434             ALIQUOT= 10 MLS
ORIG. SPL.= 50 MLS
S. WT.= 0               DIL. VOL.= 500 MLS          MG F/L= 12.231
KNOWN CONC.= 0          CALC. CONC.= 122.31(MG F/L)
DIST. FACTOR 0 APPLIED
```

x 540 = 66.0 ✓

```
POS 13             JOB ORDER#88-052325          LSN#=816047 DUPLICTE
MV= 433             ALIQUOT= 10 MLS
ORIG. SPL.= 50 MLS
S. WT.= 0               DIL. VOL.= 500 MLS          MG F/L= 12.279
KNOWN CONC.= 0          CALC. CONC.= 122.79(MG F/L)
DIST. FACTOR 0 APPLIED
```

x 540 = 66.3 ✓

```
POS 14             JOB ORDER#88-052325          LSN#=816048
MV= 522             ALIQUOT= 10 MLS
ORIG. SPL.= 100 MLS
S. WT.= 0               DIL. VOL:= 500 MLS          MG F/L= 8.676
KNOWN CONC.= 0          CALC. CONC.= 43.380(MG F/L)
DIST. FACTOR 0 APPLIED
```

x 600 = 26.0 mg ✓

```
POS 15             JOB ORDER#88-052325          LSN#=816049
MV= 371             ALIQUOT= 10 MLS
ORIG. SPL.= 100 MLS
S. WT.= 0               DIL. VOL.= 500 MLS          MG F/L= 15.64
KNOWN CONC.= 0          CALC. CONC.= 78.200(MG F/L)
DIST. FACTOR 0 APPLIED
```

x 480 = 37.5 ✓

```
1988/06                        04:30:25
TRAY NO. 1               TRAY I.D. 1            JOB ORDER NO.88-052325
CALIBRATION BASED ON TRAY  1
CALIBRATION; MV/KB;  16POSITIONS-NO DISTILLED STD.;

 1             2 MG F/L         828 MV
 2             20 MG F/L      244 MV      MG/L FLUORIDE= 20.000
           SLOPE(MV20-MV2)= -584
 3             0.20 MG F/L       1341 MV          MG/L FLUORIDE=  .200
 4             200 MG F/L          -346 MV       MG/L FLUORIDE=  200.00
                      SLOPE(MV200-MV20)= -590

POS 5            JOB ORDER#88-052325          LSN#=20 PPM
MV= 242                ALIQUOT= 10 MLS
ORIG. SPL.= 500 MLS
S. WT.= 0              DIL. VOL.= 500 MLS          MG F/L= 20.157
KNOWN CONC.= 0         CALC. CONC.= 20.157(MG F/L)
DIST. FACTOR 0 APPLIED


POS 6            JOB ORDER#88-052325          LSN#=816053
MV= 1205                ALIQUOT= 10 MLS
ORIG. SPL.= 0 MLS
S. WT.= 0              DIL. VOL.= 500 MLS          MG F/L= .395
KNOWN CONC.= 0         CALC. CONC.= .198(MG TF)
DIST. FACTOR 0 APPLIED


POS 7            JOB ORDER#88-052325          LSN#=816054
MV= 1213                ALIQUOT= 10 MLS
ORIG. SPL.= 0 MLS
S. WT.= 0              DIL. VOL.= 500 MLS          MG F/L= .38
KNOWN CONC.= 0         CALC. CONC.= .190(MG TF)
DIST. FACTOR 0 APPLIED


POS 8            JOB ORDER#88-052325          LSN#=816055
MV= 1424                ALIQUOT= 10 MLS
ORIG. SPL.= 39 MLS
S. WT.= 0              DIL. VOL.= 500 MLS          MG F/L= .123
KNOWN CONC.= 0         CALC. CONC.= 1.577(MG F/L)
DIST. FACTOR 0 APPLIED
```

.06

x .079 = .12 Total mg ✓

79 ml imp vol

760:214

```
1988/05                    02:49:37
TRAY NO. 2                 TRAY I.D.             JOB ORDER NO.
CALIBRATION BASED ON TRAY  1
MV READOUT ONLY      16 POSITIONS

            POS.  1                MV=  1196
            POS.  2                MV=  1345
            POS.  3                MV=  1341 .2
            POS.  4                MV=  828 2
            POS.  5                MV=  244 20
            POS.  6                MV= -346 200
            POS.  7                MV=  ~~255~~
            POS.  8                MV=  242 20[illegible]
            POS.  9                MV=  1205 816053
            POS.  10                MV=  1213 054
            POS.  11                MV=  1424 055
            POS.  12                MV=  1414 05[illegible]
            POS.  13                MV=  906 056
            POS.  14                MV=  949 057
            POS.  15                MV=  1294 058
            POS.  16                MV=  411  058 spike

1988/06                    04:04:38
TRAY NO. 2                 TRAY I.D.             JOB ORDER NO.
CALIBRATION BASED ON TRAY  1
MV READOUT ONLY      6 POSITIONS

            POS.  1                MV=  ~~1129~~
            POS.  2                MV=  1175 816059
            POS.  3                MV=  1181 060
            POS.  4                MV=  1085 061
            POS.  5                MV=  1168 062
            POS.  6                MV=  956  063
```

L. Pellix 88-05-0[illegible]

14H1000891 ECL

rockwool 34

nozzle wash - directly dil'd c̄ H₂SO₄

SI c̄ c̄ Orion.

spike 5 ml dil'd 814058 - [illegible]

```
MV= 1414              ALIQUOT= 10 MLS
ORIG. SPL.= 40 MLS
S. WT.= 0               DIL. VOL.= 500 MLS         MG F/L= .131
KNOWN CONC.= 0          CALC. CONC.= 1.638(MG F/L)
DIST. FACTOR 0 APPLIED
```

x.079 = .13 Total mg dup ✓

```
POS 10           JOB ORDER#88-052325           LSN#=816056
MV= 906              ALIQUOT= 10 MLS
ORIG. SPL.= 0 MLS
S. WT.= 0               DIL. VOL.= 500 MLS         MG F/L= 1.451
KNOWN CONC.= 0          CALC. CONC.= .726(MG TF)
DIST. FACTOR 0 APPLIED
```

```
POS 11           JOB ORDER#88-052325           LSN#=816057
MV= 949              ALIQUOT= 10 MLS
ORIG. SPL.= 0 MLS
S. WT.= 0               DIL. VOL.= 500 ~~MLS~~         MG F/L= 1.213
KNOWN CONC.= 0          CALC. CONC.= .607(MG TF)
DIST. FACTOR 0 APPLIED
```

✓ ✓

```
POS 12           JOB ORDER#88-052325           LSN#=816058
MV= 1294              ALIQUOT= 10 MLS
ORIG. SPL.= 50 MLS
S. WT.= 0               DIL. VOL.= 500 MLS         MG F/L= .256
KNOWN CONC.= 0          CALC. CONC.= 2.560(MG F/L)
DIST. FACTOR 0 APPLIED
```

x .103 ml = 0.26 Total mg ✓

103 ml orig vol

```
POS 13           JOB ORDER#88-052325           LSN#=816058 SPIKE
MV= 411              ALIQUOT= 10 MLS
ORIG. SPL.= 50 MLS
S. WT.= 0               DIL. VOL.= 500 MLS         MG F/L= 10.353
KNOWN CONC.= 0          CALC. CONC.= 103.53(MG F/L)
DIST. FACTOR 0 APPLIED
```

5 ml of 1000 ppm std

2.6

100.9 or 101 % ✓

```
POS 14           JOB ORDER#88-052325           LSN#=816059
MV= 1175              ALIQUOT= 10 MLS
ORIG. SPL.= 0 MLS
S. WT.= 0               DIL. VOL.= 500 MLS         MG F/L= .454
KNOWN CONC.= 0          CALC. CONC.= .227(MG TF)
DIST. FACTOR 0 APPLIED
```

```
POS 15           JOB ORDER#88-052325           LSN#=816060
MV= 1181              ALIQUOT= 10 MLS
ORIG. SPL.= 0 MLS
S. WT.= 0               DIL. VOL.= 500 MLS         MG F/L= .441
KNOWN CONC.= 0          CALC. CONC.= .221(MG TF)
DIST. FACTOR 0 APPLIED
```

```
POS 16           JOB ORDER#88-052325           LSN#=816061
MV= 1085              ALIQUOT= 10 MLS
ORIG. SPL.= 0 MLS
S. WT.= 0               DIL. VOL.= 500 MLS         MG F/L= .679
KNOWN CONC.= 0          CALC. CONC.= .34(MG TF)
DIST. FACTOR 0 APPLIED
```

```
388/06                   04:34:41
RAY NO. 2             TRAY I.D. 2            JOB ORDER NO.88-052325
ALIBRATION BASED ON TRAY  2
ALIBRATION; MV/KB;  6POSITIONS-NO DISTILLED STD.;

1            2 MG F/L          828 MV
2            20 MG F/L      244 MV       MG/L FLUORIDE= 20.000
          SLOPE(MV20-MV2)= -584
3            0.20 MG F/L       1341 MV          MG/L FLUORIDE=  .200
4            200 MG F/L          -346 MV       MG/L FLUORIDE=  200.00
                    SLOPE(MV200-MV20)= -590
```

816055 dup

run1 mg/L	run 2 mg/L
1.6	1.6

816058 spike

5ml of 1000ppm added to 50ml of samp in dist flask. final dil vol 500ml

spiked 103.5 mg/L
un " 2.6 mg/L
recov 100.9 mg/L
added 100 mg/L
% recov 101 %

2760; 215

L. Penix
14H 100089
rockwool
Spring Hope

88-052325
ECL
34

filters - wet up .5g CaO added, ashed fused c̄ NaOH. dist c̄ H_2SO_4 SIE
No Blk filter received. ashed em. filter.
added .1050 g NaF to Blk Thimble for spike.

```
1988/06                 01:03:42
TRAY NO. 1              TRAY I.D. 1          JOB ORDER NO.
CALIBRATION BASED ON TRAY  1
MV READOUT ONLY      16 POSITIONS

          POS.   1              MV=   1358
          POS.   2              MV=   1362
          POS.   3              MV=   1357 .2
          POS.   4              MV=   844  2
          POS.   5              MV=   266  20
          POS.   6              MV=  -327  200
          POS.   7              MV=   258
          POS.   8          N58 MV=   728  816064
          POS.   9          N87 MV=   702  065
          POS.   10          2N MV=   687  [illegible]
          POS.   11          4N MV=   477  [illegible]
          POS.   12         N85 MV=   403  [illegible]
          POS.   13          16 MV=   404  069
          POS.   14         N7N MV=   372  070
          POS.   15         N81 MV=   389  071
          POS.   16           5 MV=   367  072

1988/06                 02:07:46
TRAY NO. 2              TRAY I.D.           JOB ORDER NO.
CALIBRATION BASED ON TRAY  1
MV READOUT ONLY      8 POSITIONS

          POS.   1              MV=   262 20ppm H2O std repeat
          POS.   2              MV=   261 20ppm dist std repeat
          POS.   3          N94 MV=   551 073
          POS.   4           N1 MV=   453 074
          POS.   5              MV=   1354 Blk thimble
          POS.   6              MV=   1354
          POS.   7              MV=  -138 Blk thimble +.105g NaF
          POS.   8              MV=  -138
```

2760:215

```
1988/06                     07:09:15
TRAY NO. 1                 TRAY I.D. 1          JOB ORDER NO.88-052325
CALIBRATION BASED ON TRAY   1
CALIBRATION; MV/KB;  16POSITIONS-NO DISTILLED STD.;

 1            2 MG F/L         844 MV
 2            20 MG F/L      266 MV      MG/L FLUORIDE= 20.000
          SLOPE(MV20-MV2)= -578
 3            0.20 MG F/L       1357 MV          MG/L FLUORIDE=  .200
 4            200 MG F/L         -327 MV        MG/L FLUORIDE=  200.00
                       SLOPE(MV200-MV20)= -593

POS 5            JOB ORDER#88-052325          LSN#=20 PPM
MV= 261              ALIQUOT= 10 MLS
ORIG. SPL.= 500 MLS
S. WT.= 0              DIL. VOL.= 500 MLS          MG F/L= 20.392
KNOWN CONC.= 0         CALC. CONC.= 20.392(MG F/L)
DIST. FACTOR 0 APPLIED


POS 6            JOB ORDER#88-052325          LSN#=816064
MV= 728              ALIQUOT= 10 MLS
ORIG. SPL.= 0 MLS
S. WT.= 0              DIL. VOL.= 500 MLS          MG F/L= 3.175
KNOWN CONC.= 0         CALC. CONC.= 1.588(MG TF)
DIST. FACTOR 0 APPLIED


POS 7            JOB ORDER#88-052325          LSN#=816065
MV= 702              ALIQUOT= 10 MLS
ORIG. SPL.= 0 MLS
S. WT.= 0              DIL. VOL.= 500 MLS          MG F/L= 3.521
KNOWN CONC.= 0         CALC. CONC.= 1.761(MG TF)
DIST. FACTOR 0 APPLIED


POS 8            JOB ORDER#88-052325          LSN#=816066
MV= 687              ALIQUOT= 10 MLS
ORIG. SPL.= 0 MLS
S. WT.= 0              DIL. VOL.= 500 MLS          MG F/L= 3.738
KNOWN CONC.= 0         CALC. CONC.= 1.869(MG TF)
DIST. FACTOR 0 APPLIED
```

```
POS 9             JOB ORDER#88-052325           LSN#=816067
MV= 477             ALIQUOT= 10 MLS
ORIG. SPL.= 0 MLS
S. WT.= 0             DIL. VOL.= 500 MLS           MG F/L= 8.629
KNOWN CONC.= 0        CALC. CONC.= 4.315(MG TF)
DIST. FACTOR 0 APPLIED


POS 10             JOB ORDER#88-052325           LSN#=816068
MV= 403             ALIQUOT= 10 MLS
ORIG. SPL.= 0 MLS
S. WT.= 0             DIL. VOL.= 500 MLS   ok      MG F/L= 11.588 OK
KNOWN CONC.= 0        CALC. CONC.= 5.794(MG TF)
DIST. FACTOR 0 APPLIED                    ✓


POS 11             JOB ORDER#88-052325           LSN#=816069
MV= 404             ALIQUOT= 10 MLS
ORIG. SPL.= 0 MLS
S. WT.= 0             DIL. VOL.= 500 MLS           MG F/L= 11.542
KNOWN CONC.= 0        CALC. CONC.= 5.771(MG TF)
DIST. FACTOR 0 APPLIED


POS 12             JOB ORDER#88-052325           LSN#=816070
MV= 372             ALIQUOT= 10 MLS
ORIG. SPL.= 0 MLS
S. WT.= 0             DIL. VOL.= 500 MLS           MG F/L= 13.111
KNOWN CONC.= 0        CALC. CONC.= 6.556(MG TF)
DIST. FACTOR 0 APPLIED


POS 13             JOB ORDER#88-052325           LSN#=816071
MV= 389             ALIQUOT= 10 MLS
ORIG. SPL.= 0 MLS
S. WT.= 0             DIL. VOL.= 500 MLS           MG F/L= 12.253
KNOWN CONC.= 0        CALC. CONC.= 6.127(MG TF)
DIST. FACTOR 0 APPLIED


POS 14             JOB ORDER#88-052325           LSN#=816072
MV= 367             ALIQUOT= 10 MLS
ORIG. SPL.= 0 MLS
S. WT.= 0             DIL. VOL.= 500 MLS           MG F/L= 13.375
KNOWN CONC.= 0        CALC. CONC.= 6.688(MG TF)
DIST. FACTOR 0 APPLIED
```

```
1988/06                      07:18:33
TRAY NO. 2              TRAY I.D. 2              JOB ORDER NO.88-052325
CALIBRATION BASED ON TRAY  2
CALIBRATION; MV/KB;  6POSITIONS-NO DISTILLED STD.;

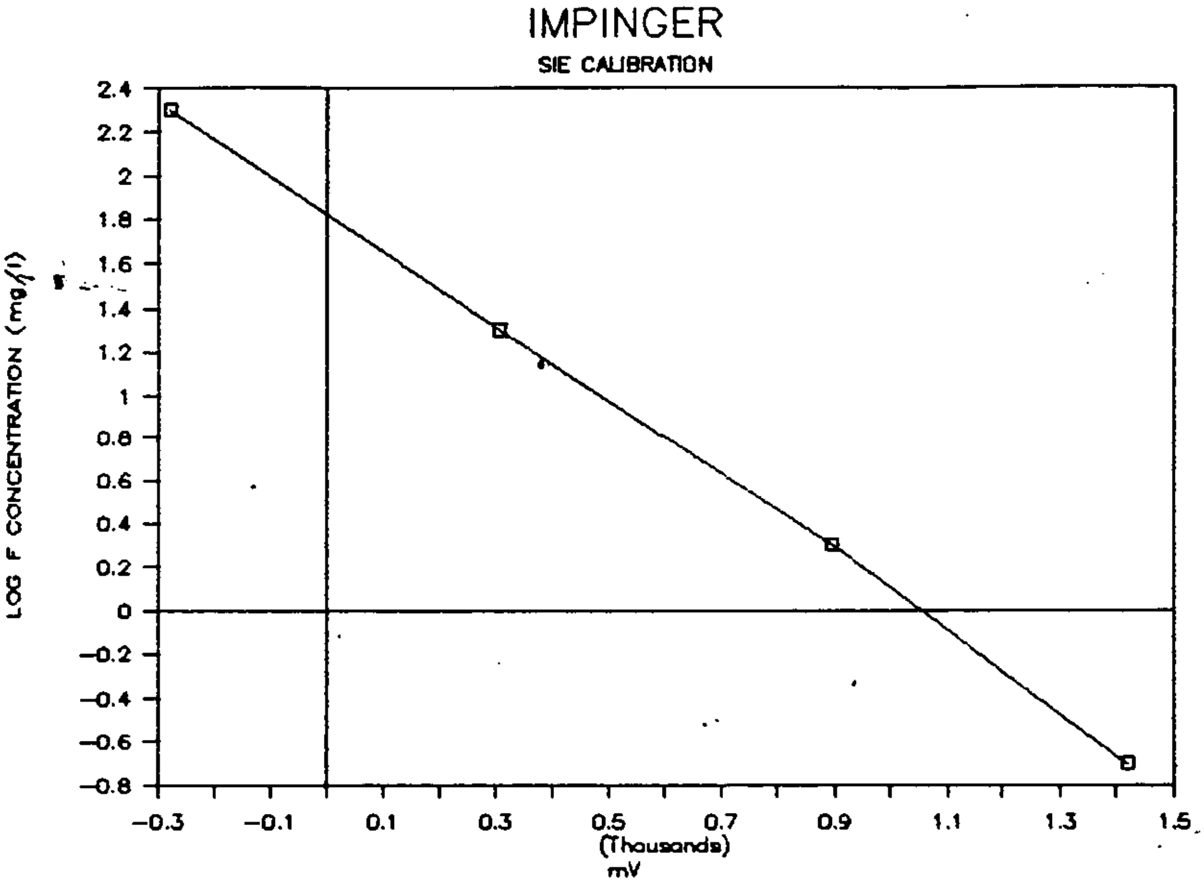
 1            2 MG F/L         844 MV
 2            20 MG F/L      266 MV       MG/L FLUORIDE= 20.000
         SLOPE(MV20-MV2)= -578
 3            0.20 MG F/L       1357 MV           MG/L FLUORIDE=  .200
 4            200 MG F/L         -327 MV       MG/L FLUORIDE=  200.00
                      SLOPE(MV200-MV20)= -593

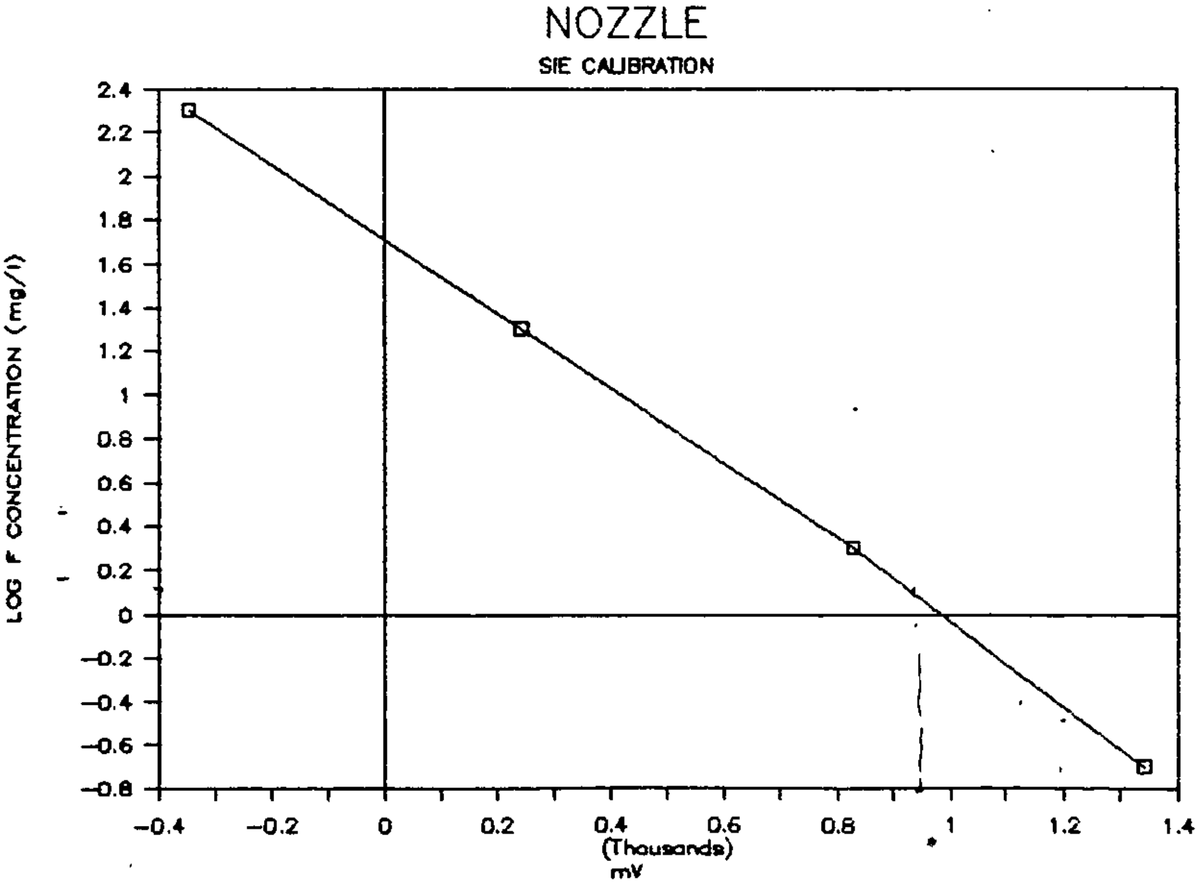
POS 5                JOB ORDER#88-052325           LSN#=BLK THIMBLE
MV= 1354                 ALIQUOT= 10 MLS
ORIG. SPL.= 0 MLS
S. WT.= 0                 DIL. VOL.= 500 MLS           MG F/L= .203
KNOWN CONC.= 0         CALC. CONC.= .102(MG TF)
DIST. FACTOR 0 APPLIED


POS 6                JOB ORDER#88-052325           LSN#=THIMBLE, .1050G NAF
MV=-138                 ALIQUOT= 10 MLS
ORIG. SPL.= 0 MLS
S. WT.= 0                 DIL. VOL.= 500 MLS           MG F/L= 96.009
KNOWN CONC.= 0         CALC. CONC.= 48.005(MG TF)
DIST. FACTOR 0 APPLIED
```

.1050g NaF/2.21 = 47.5 ✓ mg F added

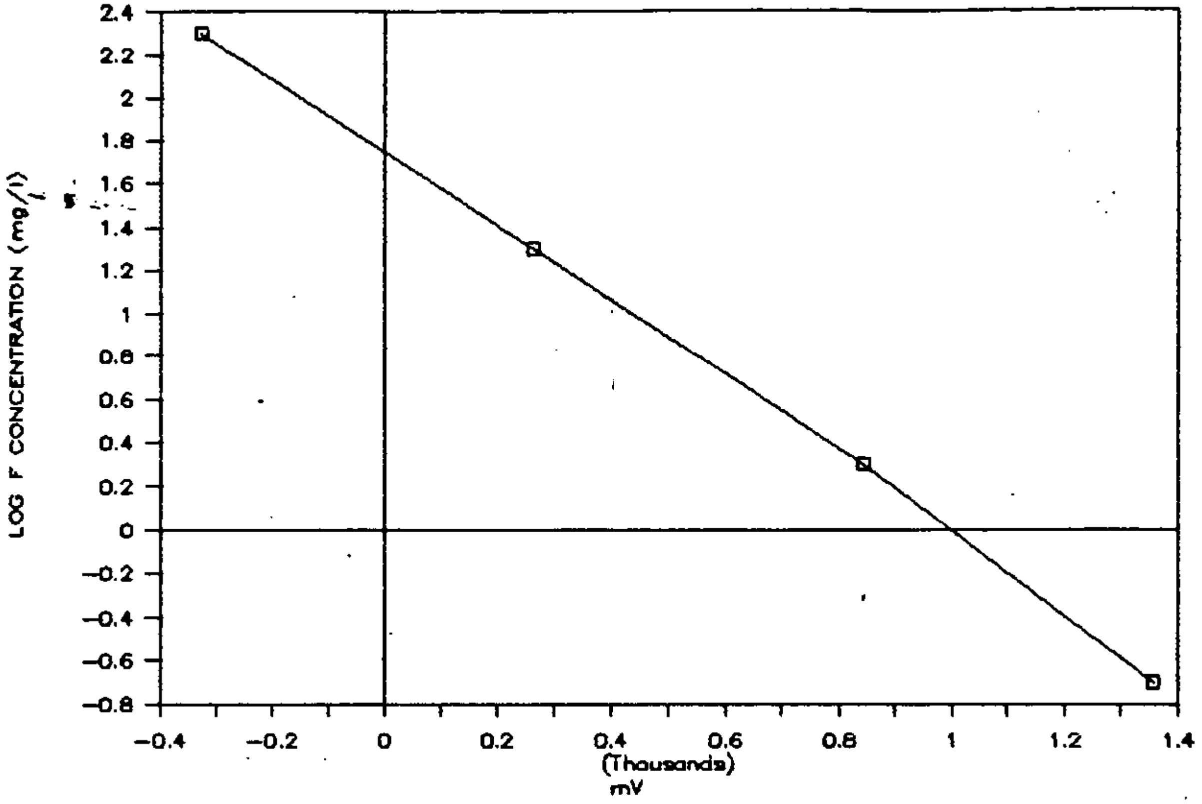
48 ÷ 47.5 = 101% ✓


IMPINGER
SIE CALIBRATION
LOG F CONCENTRATION (mg/l)
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
−0.3
−0.1
0.1
0.3
0.5
0.7
0.9
1.1
1.3
1.5
(Thousands)
mV


NOZZLE
SIE CALIBRATION
LOG F CONCENTRATION (mg/l)
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
−0.4
−0.2
0
0.2
0.4
0.6
0.8
1
1.2
1.4
(Thousands)
mV

THIMBLE

SIE CALIBRATION



MINERAL WOOL EMISSION FACTORS DEVELOPED FROM AP-40

Process	Pollutant	Production rate, tons/hr	Mass flux, lbs/hr	Emission factor			
				kg/Mg	lbs/ton	%	flow rate, DSCFM
Cupola	PM (filt.)	3525/2000	50	14	28		
	PM (filt.)	4429/2000	46	10	21	Concen., mg/DSCF	
	PM (filt.)	3625/2000	29	8.0	16		
	AVERAGE			11	22		
	SO2	3525/2000	20	5.6	11	32.6	4550
	SO3	3525/2000	11	3.2	6.3	18.5	4550
						%	
	CO	3525/2000	160	45	91	0.9	4550
Reverberatory furnace	PM (filt.)	3050/2000	7.3	2.4	4.8		
Blow chamber	PM (filt.)	3525/2000	9.2	2.6	5.2		
	PM (filt.)	3625/2000	7.1	2.0	3.9		
	PM (filt.)	3525/2000	98	28	56	Concen., mg/DSCF	
	PM (filt.)	4120/2000	8.3	2.0	4.0		
	AVERAGE			8.6	17		
	SO2	3525/2000	1.5	0.43	0.87	1.04	11,100
	aldehydes	3525/2000	1.5	0.43	0.86	1.03	11,100
Curing oven	PM (filt.)	3525/2000	9.0	2.5	5.1	8.2	1,530
	PM (filt.)	3625/2000	5.2	1.4	2.9		
	PM (filt.)	3050/2000	2.3	0.7	1.5		
	PM (filt.)	5180/2000	15	2.9	5.9	Concen., mg/DSCF	
	PM (filt.)	3500/2000	5.0	1.4	2.9		
	AVERAGE			1.8	3.6		
	SO2	3525/2000	2.0	0.58	1.2	3.23	4,740
	aldehydes	5180/2000	1.9	0.37	0.73		
	aldehydes	3500/2000	2.2	0.63	1.3		
	AVERAGE			0.50	1.00		
	NO2	5180/2000	0.60	0.12	0.23		
	NO2	3500/2000	0.15	0.043	0.086		
	AVERAGE			0.079	0.16		
cooler	PM (filt.)	3525/2000	0.75	0.21	0.43		
	PM (filt.)	3700/2000	2.6	0.69	1.4		
	PM (filt.)	3050/2000	3.6	1.2	2.3	Concen., mg/DSCF	
	PM (filt.)	3050/2000	8.4	2.8	5.5		
	AVERAGE			1.2	2.4		
	SO2	3525/2000	0.12	0.034	0.068	0.49	1,850
	aldehydes	3525/2000	0.074	0.021	0.042	0.30	1,850

AQMD PROGRAM
REVIEW TRACKING FORM

Document name: WOOL
MRI Lead: Rick Marinshaw
Project name: Mineral Products AP-42
EPA Lead: Ron Myers
Charge no. (project-task-subtask): 9711-30-53
Due to client: / /
Last reviewer return document to: Brian Shrager
Return by: / /

Route to: ~~Joanne~~ Darryl
On: 8/20/92
Review instructions: Joanne can't get to this until next week. (AP-42 Mineral Wool)

Review comments: Brian - I'm sorry I did not get but half way thru this today. I am returning it because I will be out next week. I got to page 22. I be happy to review on Aug 31.

Ready for transmit? yes no
Initials: DLL 8/21/92

Route to: ~~Darryl~~ Joanne
No later than: / /
Review instructions:

Review comments: Looks good! Need to make Times 11 pt (9-pt supers & sub's). Questions/comments noted - see me if you have any questions/want to go over this. Thanks!

Ready for transmit? yes no
Initials: JMK 8/26/92

Route to: Dennis
No later than: / /
Review instructions: Dennis, several comments that change the meaning of what you wrote were made. I'm not sure what to do w/ these comments!

Review comments:

Ready for transmit? yes no
Initials: / /

AQMD PROGRAM
REVIEW TRACKING FORM

Document name: MRI Lead:

Project name: EPA Lead:

Charge no. (project-task-subtask): Due to client: / /

Last reviewer return document to: Return by: / /

Route to: Rick M. On: 8 / 20 / 92

Review instructions: Rick, Heres mineral wool. I thought you might want to look @ it before WP does final corrections. 1 question - see Reference 4 on last page (also Ref 4 pg 10).

Review comments:

Ready for transmit? yes no Initials: / /

Route to: No later than: / /

Review instructions:

Review comments:

Ready for transmit? yes no Initials: / /

Route to: No later than: / /

Review instructions:

Review comments:

Ready for transmit? yes no Initials: / /

Ext. Review comment

Southerland

Myers

5. DRAFT AP-42 SECTION 8.16

8.16 MINERAL WOOL MANUFACTURING

8.16.1 General[1,2]

Mineral wool often is defined as any fibrous glassy substance made from minerals (typically natural rock materials such as basalt or diabase) or mineral products such as slag and glass. Because glass wool production is covered separately in AP-42 (Section 8.11), this section deals only with the production of mineral wool from natural rock and slags such as iron blast furnace slag, the primary material, and copper, lead, and phosphate slags. These materials are processed into insulation and other fibrous building materials that are used for structural strength and fire resistance. Generally, these products take one of four forms: "blowing" wool or "pouring" wool, which is put into the structural spaces of buildings; batts, which may be covered with a vapor barrier of paper or foil and are shaped to fit between the structural members of buildings; industrial and commercial products such as high-density fiber felts and blankets, which are used for insulating boilers, ovens, pipes, refrigerators, and other process equipment; and bulk fiber, which is used as a raw material in manufacturing other products, such as ceiling tile, wall board, spray-on insulation, cement, and mortar.

Mineral wool manufacturing facilities are included in Standard Industrial Classification (SIC) Code 3296, mineral wool. This SIC code also includes the production of glass wool insulation products, but those facilities engaged in manufacturing textile glass fibers are included in SIC Code 3229. The six digit source category code (SCC) for mineral wool manufacturing is 3-05-017.

8.16.2 Process Description[1,4,5]

Most mineral wool produced in the United States today is produced from slag or a mixture of slag and rock. Most of the slag used by the industry is generated by integrated iron and steel plants as a blast furnace byproduct from pig iron production. Other sources of slag include the copper, lead, and phosphate industries. The production process has three primary components--molten mineral generation in the cupola, fiber formation and collection, and final product formation. Figure 8.16-1 illustrates the mineral wool manufacturing process.

The first step in the process involves melting the mineral feed. The raw material (slag and rock) is loaded into a cupola in alternating layers with coke at weight ratios of about 5 to 6 parts mineral to 1 part coke. As the coke is ignited and burned, the mineral charge is heated to the molten state at a temperature of 1300° to 1650°C (2400° to 3000°F). Combustion air is supplied through tuyeres located near the bottom of the furnace. Process modifications at some plants include air enrichment and the use of natural gas auxiliary burners to reduce coke consumption. One facility also reported using an aluminum flux byproduct to reduce coke consumption.

The molten mineral charge exits the bottom of the cupola in a water-cooled trough and falls onto a fiberization device. Most of the mineral wool produced in the United States is made by variations of two fiberization methods. The Powell process uses groups of rotors revolving at a high rate of speed to form the fibers. Molten material is distributed in a thin film on the surfaces of the rotors and then is thrown off by centrifugal force. As the material is discharged from the rotor, small globules develop on the rotors and form long, fibrous tails as they travel horizontally. Air or steam may be blown around the rotors to assist in fiberizing the material. A second fiberization method, the Downey process, uses a spinning concave rotor with air or steam attenuation. Molten material is distributed over the surface of the rotor, from which it flows up and over the edge and is captured and directed by a high-velocity stream of air or steam.

During the spinning process, not all globules that develop are converted into fiber. The nonfiberized globules that remain are referred to as "shot." In raw mineral wool, as much as half of the mass of the product may consist of shot. As shown in Figure 8.16-1, shot is usually separated from the wool by gravity immediately following fiberization.

Depending on the desired product, various chemical agents may be applied to the newly formed fiber immediately following the rotor. In almost all cases, an oil is applied to suppress dust and, to some degree, anneal the fiber. This oil can be either a proprietary product or a medium- weight fuel or lubricating oil. If the fiber is intended for use as loose wool or bulk products, no further chemical treatment is necessary. If the mineral wool product is required to have structural rigidity, as in batts and industrial felt, a binding agent is applied with or in place of the oil treatment. This binder is

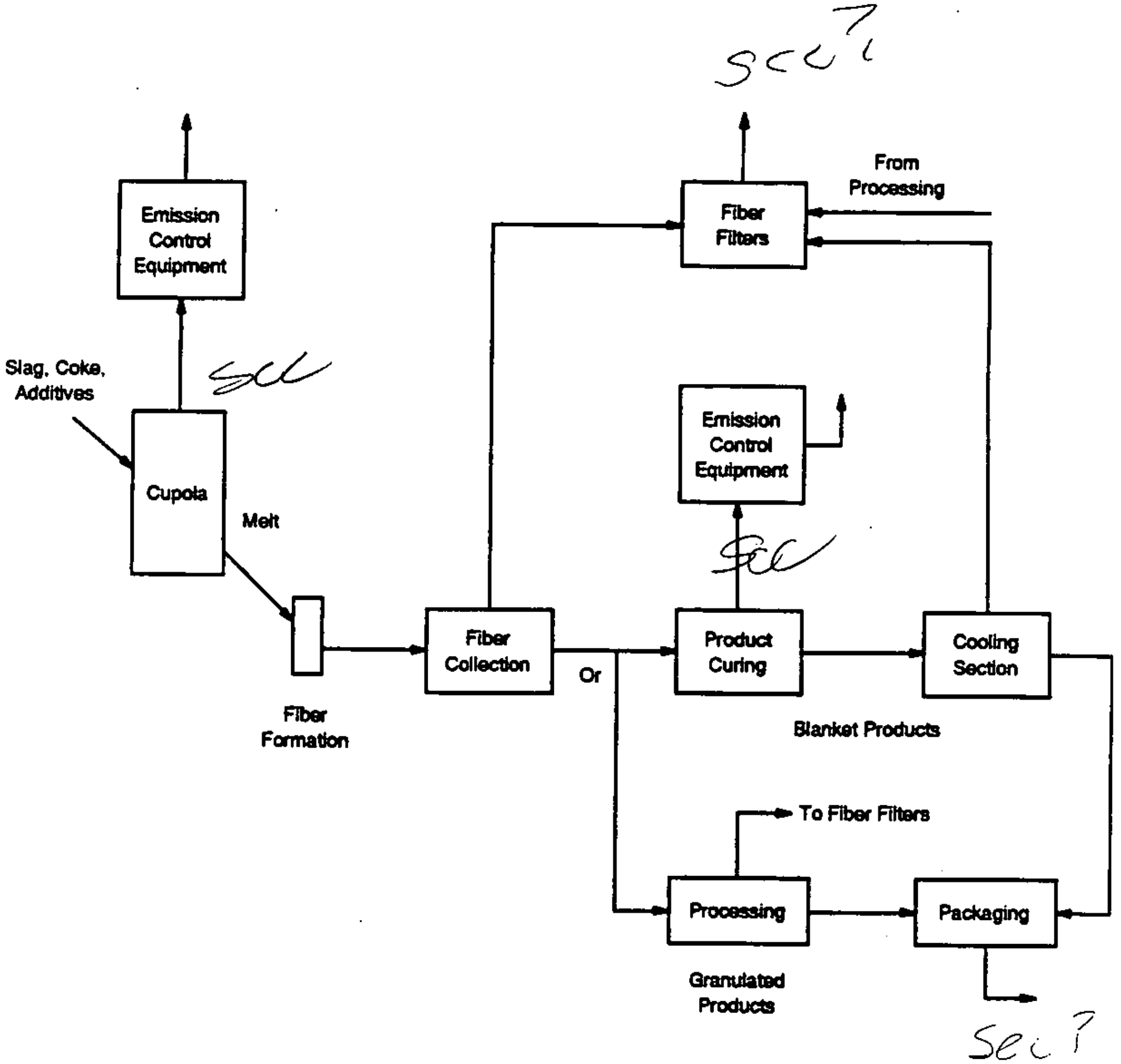


Figure 8.16-1. Mineral wool manufacturing process flow diagram.

typically a phenol-formaldehyde resin that requires curing at elevated temperatures. Both the oil and the binder are applied by atomizing the liquids and spraying the agents to coat the airborne fiber.

After formation and chemical treatment, the fiber is collected in a blowchamber. Resin-and/or oil-coated fibers are drawn down on a wire mesh conveyor by fans located beneath the collector. The speed of the conveyor is set so that a wool blanket of desired thickness can be obtained.

Mineral wool containing the binding agent is carried by conveyor to a curing oven, where the wool blanket is compressed to the appropriate density and the binder is baked. Hot air, at a temperature of 150° to 320°C (300° to 600°F), is forced through the blanket until the binder has set. Curing time and temperature depend on the type of binder used and the mass rate through the oven. A cooling section follows the oven, where blowers force air at ambient temperatures through the wool blanket.

To make batts and industrial felt products, the cooled wool blanket is cut longitudinally and transversely to the desired size. Some insulation products are then covered with a vapor barrier of aluminum foil or asphalt-coated kraft paper on one side and untreated paper on the other side. The cutters, vapor barrier applicators, and conveyors are sometimes referred to collectively as a batt machine. Those products that do not require a vapor barrier, such as industrial felt and some residential insulation batts, can be packed for shipment immediately after cutting.

Loose wool products consist primarily of blowing wool and bulk fiber. For these products, no binding agent is applied, and the curing oven is eliminated. For granulated wool products, the fiber blanket leaving the blowchamber is fed to a shredder and pelletizer. The pelletizer forms small, 1-inch diameter pellets and separates shot from the wool. A bagging operation completes the processes. For other loose wool products, fiber can be transported directly from the blowchamber to a baler or bagger for packaging.

8.16.3 Emissions and Controls[1]

The sources of emissions in the mineral wool manufacturing industry are the cupola, the blow chamber, the curing oven, the mineral wool cooler, and possibly materials handling and bagging operations. With the exception of lead, the industry emits the full range of criteria pollutants. Also, depending on the particular types of slag and binding agents used, the facilities may emit both metallic and organic hazardous air pollutants (HAP's).

The primary source of emissions in the mineral wool manufacturing process is the cupola. It is a significant source of particulate matter (PM) emissions and is likely to be a source of PM less than 10 micrometers (μm) in diameter (PM-10) emissions, although no particle size data are available. Coke combustion in the furnace produces carbon monoxide (CO), carbon dioxide (CO_2), and nitrogen oxide (NO_x) emissions. Finally, because blast furnace slags contain sulfur, the cupola is also a source of sulfur dioxide (SO_2) and hydrogen sulfide (H_2S) emissions.

The blowchamber is a source of PM (and probably PM-10) emissions. Also, the annealing oils used in the process can lead to VOC emissions from the process. Other sources of VOC emissions include batt application and the curing oven. Finally, fugitive PM emissions can be generated during cooling, handling, and bagging operations. Table 8.16-1 presents emission factors for filterable PM emissions from various mineral wool manufacturing processes; Table 8-16.2 shows emission factors for CO, CO_2, SO_2, and sulfates; and Table 8.16-3 presents emission factors for fluorides.

Mineral wool manufacturers use a variety of air pollution control techniques, but most are directed toward PM control with minimal control of other pollutants. The industry has given greatest attention to cupola PM control, with two-thirds of the cupolas in operation having fabric filter control systems. Some cupola exhausts are controlled by wet scrubbers and electrostatic precipitators (ESP's); cyclones are also used for cupola PM control either alone or in combination with other control devices. About half of the blow chambers in the industry also have some level of PM control, with the predominant control device being low-energy wet scrubbers. Cyclones and fabric filters have been used to a limited degree on blow chambers. Finally, afterburners have been used to control VOC emissions from blow chambers and curing ovens and CO emissions from cupolas.

TABLE 8.16-1. (METRIC UNITS)
EMISSION FACTORS FOR MINERAL WOOL MANUFACTURING[a]

No PM-10 data or assumptions?

All emission factors in kg/Mg of product unless noted
Ratings (A-E) follow each emission factor

Process (SCC)	Filterable PM[b]	
Cupola[c] (30501701)	8.2	E
Cupola with fabric filter[d] (30501701)	0.051	D
Reverberatory furnace[e] (30501702)	2.4	E
Batt curing oven[e] (30501704)	1.8	E
Batt curing oven with ESP[f] (30501704)	0.36	D
Blow chamber[c] (30501703)	6.0	E
Blow chamber with wire mesh filter[g] (30501703)	0.45	D
Cooler[e] (30501705)	1.2	E

[a] Factors represent uncontrolled emissions unless otherwise noted.
[b] Filterable PM is that PM collected on or prior to the filter of an EPA Method 5 (or equivalent) sampling train.
[c] References 1, 12. Activity level is assumed to be total feed charged.
[d] References 6, 7, 8, 10, and 11. Activity level is total feed charged.
[e] Reference 12.
[f] Reference 9.
[g] Reference 7. Activity level is mass of molten mineral feed charged.

TABLE 8.16-1. (ENGLISH UNITS)
EMISSION FACTORS FOR MINERAL WOOL MANUFACTURING[a]

All emission factors in lb/ton of product unless noted
Ratings (A-E) follow each emission factor

Process (SCC)	Filterable PM[b]	
Cupola[c] (30501701)	16	E
Cupola with fabric filter[d] (30501701)	0.10	D
Reverberatory furnace[e] (30501702)	4.8	E
Batt curing oven[e] (30501704)	3.6	E
Batt curing oven with ESP[f] (30501704)	0.72	D
Blow chamber[c] (30501703)	12	E
Blow chamber with wire mesh filter[g] (30501703)	0.91	D
Cooler[e] (30501705)	2.4	E

[a] Factors represent uncontrolled emissions unless otherwise noted.

[b] Filterable PM is that PM collected on or prior to the filter of an EPA Method 5 (or equivalent) sampling train.

[c] Reference 1, 12. Activity level is assumed to be total feed charged.

[d] References 6, 7, 8, 10, and 11. Activity level is total feed charged.

[e] Reference 12.

[f] Reference 9.

[g] Reference 7. Activity level is mass of molten mineral feed charged.

10/10/96

9/4/96

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TABLE 8.16-2 (METRIC UNITS)
EMISSION FACTORS FOR MINERAL WOOL MANUFACTURING[a]

All emission factors in kg/Mg of total feed charged unless noted
Ratings (A-E) follow each emission factor

Source (SCC)	CO[b]		CO_2[b]		SO_2		SO_3	
Cupola (30501701)	125	D	260	D	4.0[c]	D	3.2[d]	E
Cupola with fabric filter (30501701)	NA		NA		NA		0.077[b]	E
Cupola with fabric filter (30501701)	NA		NA		NA		e	
Batt curing oven (30501704)	e		e		0.58[d]	E	e	
Blow chamber (30501703)	e		80[f]	E	0.43[d]	E	e	
Cooler (30501705)	e		e		0.034[d]	E	e	

NA = Not applicable.

[a] Factors represent uncontrolled emissions unless otherwise noted.
[b] Reference 6.
[c] References 6, 10, and 11.
[d] Reference 12.
[e] No data available.
[f] Reference 9.

Combine on one page?

NA or ND (for No data)?

TABLE 8.16-2 (ENGLISH UNITS)
EMISSION FACTORS FOR MINERAL WOOL MANUFACTURING[a]

All emission factors in lb/ton of total feed charged unless noted
Ratings (A-E) follow each emission factor

Source (SCC)	CO^b		$CO_2{}^b$		SO_2		SO_3	
Cupola (30501701)	250	D	520	D	8.0[a]	D	6.3[d]	E
Cupola with fabric filter (30501701)	NA		NA		NA		0.15[b]	E
Cupola with fabric filter (30501701)	NA		NA		NA		e	
Batt curing oven (30501704)					1.2[d]	E		
Blow chamber (30501703)			160[f]	E	0.087[d]	E		
Cooler (30501705)					0.068[d]	E		

NA = Not applicable.
[a] Factors represent uncontrolled emissions unless otherwise noted.
[b] Reference 6.
[c] References 6, 10, and 11.
[d] Reference 12.
[e] No data available.
[f] Reference 9.

TABLE 8.16-3 (METRIC UNITS)
EMISSION FACTORS FOR MINERAL WOOL MANUFACTURING[a]

All emission factors in kg/Mg of total feed charged unless noted
Ratings (A-E) follow each emission factor

Process (SCC)	NO_x		N_2O		H_2S		Fluorides	
Cupola (30501701)	0.8[b]	E	[c] ND		1.5[b]	E	[c] ND	
Cupola with fabric filter (30501701)	[c] ND		[c] ND		[c] ND		0.019[d]	D
Cupola with fabric filter (30501701)	[c] ND		[c] ND		[c] ND		0.19[e]	D
Batt curing oven (30501714)	[c] ND		0.079	E	[c] ND		[c] ND	

[a] Factors represent uncontrolled emissions unless otherwise noted.
[b] Reference 1.
[c] No data available.
[d] References 10 and 11. Coke only used as fuel.
[e] References 10 and 11. Fuel combination of coke and aluminum smelting byproducts.

TABLE 8.16-3 (ENGLISH UNITS)
EMISSION FACTORS FOR MINERAL WOOL MANUFACTURING[a]

All emission factors in lb/ton of total feed charged unless noted
Ratings (A-E) follow each emission factor

Process (SCC)	NO_x		N_2O		H_2S		Fluorides	
Cupola (30501701)	1.6[b]	E	c		3.0[b]	E	c	
Cupola with fabric filter (30501701)	c		c		c		0.038[d]	D
Cupola with fabric filter (30501701)	c		c		c		0.38[e]	D
Batt curing oven (30501714)	c		0.16	E	c		c	

[a] Factors represent uncontrolled emissions unless otherwise noted.
[b] Reference 1.
[c] No data available.
[d] References 10 and 11. Coke only used as fuel.
[e] References 10 and 11. Fuel combination of coke and aluminum smelting byproducts.

Combine on one page
w/ 1 set footnotes

REFERENCES FOR SECTION 8.16

1. Source Category Survey: Mineral Wool Manufacturing Industry, EPA-450/3-80-016, U. S. Environmental Protection Agency, Research Triangle Park, NC, March 1980.

2. The Facts on Rocks and Slag Wool, Pub. No. N 020, North American Insulation Manufacturers Association, Alexandria, VA, Undated.

3. ICF Corporation, Supply Response to Residential Insulation Retrofit Demand, Report to the Federal Energy Administration, Contract No. P-14-77-5438-0, Washington, D.C., June 1977.

4. Personal communication between F. May, U.S.G. Corporation, Chicago, Illinois, and R. Marinshaw, Midwest Research Institute, Cary, NC, June 5, 1992.

5. Memorandum from K. Schuster, N.C. Department of Environmental Management, to M. Aldridge, American Rockwool, April 25, 1988.

6. Sulfur Oxide Emission Tests Conducted on the #1 and #2 Cupola Stacks in Leeds, Alabama for Rock Wool Company, November 8 & 9, 1988, Guardian Systems, Inc., Leeds, AL, Undated.

7. Particulate Emissions Tests for U.S. Gypsum Company on the Number 4 Dry Filter and Cupola Stack Located in Birmingham, Alabama on January 14, 1981, Guardian Systems, Inc., Birmingham, AL, Undated.

8. Untitled Test Report, Cupolas Nos. 1, 2, and 3, U.S. Gypsum, Birmingham, AL, June 1979.

9. Particulate Emission Tests on Batt Curing Oven for U.S. Gypsum, Birmingham, Alabama on October 31-November 1, 1977, Guardian Systems, Inc., Birmingham, AL, Undated.

10. J.V. Apicella, Particulate, Sulfur Dioxide, and Fluoride Emissions from Mineral Wood Emission, with Varying Charge Compositions, American Rockwool, Inc. Spring Hope, N.C. 27882, Alumina Company of America, Alcoa Center, PA, June 1988.

11. J.V. Apicella, Compliance Report on Particulate, Sulfur Dioxide, Fluoride, and Visual Emissions from Mineral Wood Production, American Rockwool, Inc., Spring Hope, NC 27882, Aluminum Company of America, Alcoa Center, PA, February 1988.

12. J.L. Spinks, "Mineral Wool Furnaces," In: Air Pollution Engineering Manual, J.A. Danielson, ed., U. S. DHEW, PHS, National Center for Air Pollution Control, Cincinnati, OH. PHS Publication Number 999-A-40, 1967, pp. 343-347.

EMISSION FACTOR DOCUMENTATION FOR AP-42 SECTION 8.16

Mineral Wool Manufacturing

1. INTRODUCTION

The document Compilation of Air Pollutant Emission Factors (AP-42) has been published by the U. S. Environmental Protection Agency (EPA) since 1972. Supplements to AP-42 have been routinely published to add new emission source categories and to update existing emission factors. AP-42 is routinely updated by EPA to respond to new emission factor needs of EPA, State and local air pollution control programs, and industry.

An emission factor relates the quantity (weight) of pollutants emitted to a unit of activity of the source. The uses for the emission factors reported in AP-42 include:

1. Estimates of areawide emissions;

2. Estimates of emissions for a specific facility; and

3. Evaluation of emissions relative to ambient air quality.

The purpose of this report is to provide background information from test reports and other information to support preparation of AP-42 Section 8.16, Mineral Wool Manufacturing.

This background report consists of five sections. Section 1 includes the introduction to the report. Section 2 gives a description of the mineral wool industry. It includes a characterization of the industry, an overview of the different process types, a description of emissions, and a description of the technology used to control emissions resulting from mineral wool production operations. Section 3 is a review of emission data collection and laboratory analysis procedures. It describes the literature search, the screening of emission data reports, and the quality rating system for both emission data and emission factors. Section 4 details revisions to the existing AP-42 section narrative and pollutant emission factor development. It includes a review of specific data sets and the results of data analyses. Section 5 presents AP-42 Section 8.16, Mineral Wool Manufacturing.

2. INDUSTRY DESCRIPTION[1,2]

Mineral wool often is defined as any fibrous glassy substance made from minerals (typically natural rock materials such as basalt or diabase) or mineral products such as slag and glass. Because glass wool production is covered separately in AP-42 (Section 8.11), this section deals only with the production of mineral wool from natural rock and slags such as iron blast furnace slag, the primary material, and copper, lead, and phosphate slags. These materials are processed into insulation and other fibrous building materials that are used for structural strength and fire resistance. Generally, these products take one of four forms: "blowing" wool or "pouring" wool, which is put into the structural spaces of buildings; batts, which may be covered with a vapor barrier of paper or foil and are shaped to fit between the structural members of buildings; industrial and commercial products such as high-density fiber felts and blankets, which are used for insulating boilers, ovens, pipes, refrigerators, and other process equipment; and bulk fiber, which is used as a raw material in manufacturing other products, such as ceiling tile, wall board, spray-on insulation, cement, and mortar.

Mineral wool manufacturing facilities are included in Standard Industrial Classification (SIC) Code 3296, mineral wool. This SIC code also includes the production of glass wool insulation products, but those facilities engaged in manufacturing textile glass fibers are included in SIC Code 3229. The six digit source category code (SCC) for mineral wool manufacturing is 3-05-017.

2.1 CHARACTERIZATION OF THE INDUSTRY[1,3]

Because the U.S. Department of Commerce aggregates the mineral wool manufacturing industry, as defined in this document, into a single SIC category with glass wool manufacturing, industry statistics are difficult to obtain. The available U. S. Government publications do not present information on rock and slag wool production, nor was such information found in the open literature. The most recent data related strictly to rock and slag wool production appear to be those generated by EPA in 1980. These data form the basis for the discussion below.

TABLE 2-1. DISTRIBUTION OF MINERAL WOOL MANUFACTURING FACILITIES[1]

State	No. of facilities	
Alabama	3	4
California	1	0
Colorado	1	0
Illinois	1	✓
Indiana	5	4
Minnesota	2	1
Missouri	2	~~1~~ 0
New Jersey	1	0
North Carolina	1	✓
Ohio	1	✓
Pennsylvania	3	2
Tennessee	1	✓
Texas	3	1
Virginia	1	0
Washington	1	✓
Wisconsin	1	

These are the plants in each state that are currently operating based on information we have gathered,

[illegible] Disguise?
[illegible]

As of 1980, approximately 26 mineral wool manufacturing facilities were operating in the United States. Table 2-1 lists the number of facilities by State. These facilities were estimated to have shipped about 2.7 x 10^5 megagrams (Mg) (3.0 x 10^5 tons) of structural mineral wool insulation products with a value of about $100 million during 1980. A growth rate of less than 2 percent per year was projected at that time.

PROCESS DESCRIPTION[1,4,5]

Most mineral wool produced in the United States today is produced from slag or a mixture of slag and rock. Most of the slag used by the industry is generated by integrated iron and steel plants as a blast furnace byproduct from pig iron production. Other sources of slag include the copper, lead, and phosphate industries. The production process has three primary components–molten mineral generation in the cupola, fiber formation and collection, and final product formation. Figure 2-1 illustrates the mineral wool manufacturing process.

The first step in the process involves melting the mineral feed. The raw material (slag and rock) is loaded into a cupola in alternating layers with coke at weight ratios of about 5 to 6 parts mineral to 1 part coke. As the coke is ignited and burned, the mineral charge is heated to the molten state at a temperature of 1300° to 1650°C (2400° to 3000°F). Combustion air is supplied through tuyeres located near the bottom of the furnace. Process modifications at some plants include oxygen enrichment and the use of natural gas auxiliary burners to reduce coke consumption. One facility also reported using an aluminum flux byproduct to reduce coke consumption.

The molten mineral charge exits the bottom of the cupola in a water-cooled trough and falls onto a fiberization device. Most of the mineral wool produced in the United States is made by variations of two fiberization methods. The Powell process uses groups of rotors revolving at a high rate of speed to form the fibers. Molten material is distributed in a thin film on the surfaces of the rotors and then is thrown off by centrifugal force. As the material leaves the surface, small globules develop and form long, fibrous tails as they travel horizontally. Air or steam may be blown around the rotors to assist in fiberizing the material. A second fiberization method, the Downey process, uses a spinning concave rotor with air or steam attenuation. Molten material is distributed over the

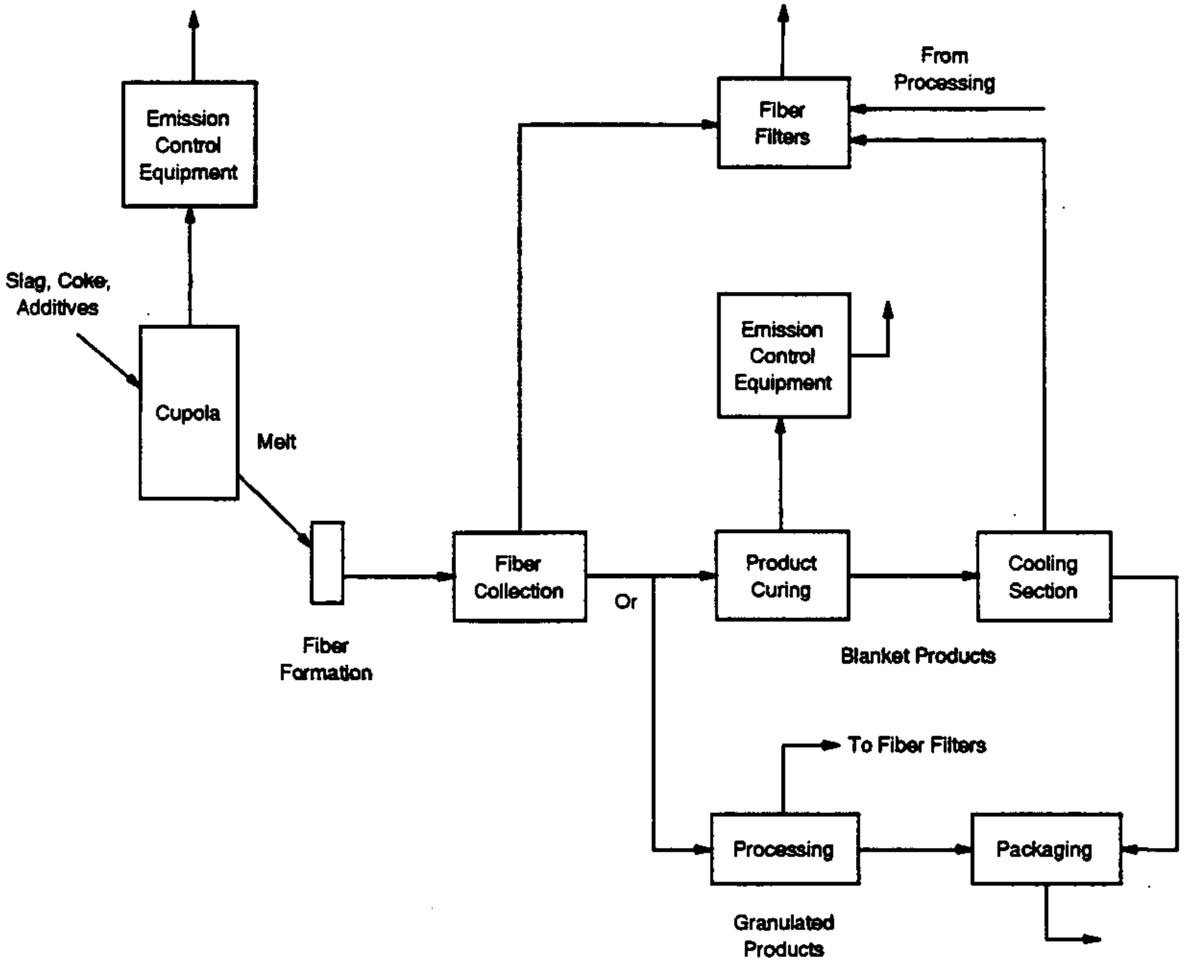

Figure 2-1. Mineral wool manufacturing process flow diagram.

surface of the rotor, from which it flows up and over the edge and is captured by a high-velocity stream of air or steam.

During the spinning process, not all globules that develop are converted into fiber. The nonfiberized globules that remain are referred to as "shot." In raw mineral wool, as much as half of the mass of the product may consist of shot. Shot is usually separated from the wool by gravity immediately following fiberization.

Depending on the desired product, various chemical agents may be applied to the newly formed fiber immediately following the rotor. In almost all cases, an oil is applied to suppress dust and, to some degree, anneal the fiber. This oil can be either a proprietary product or a medium-weight fuel or lubricating oil. If the fiber is intended for use as loose wool or bulk products, no further chemical treatment is necessary. If the mineral wool product is required to have structural rigidity, as in batts and industrial felt, a binding agent is applied with or in place of the oil treatment. This binder is typically a phenol-formaldehyde resin that requires curing at elevated temperatures. Both the oil and the binder are applied by atomizing the liquids and spraying the agents to coat the airborne fiber.

After formation and chemical treatment, the fiber is collected in a blowchamber. Resin- and/or oil-coated fibers are drawn down on a wire mesh conveyor by fans located beneath the collector. The speed of the conveyor is set so that a wool blanket of desired thickness can be obtained.

Mineral wool containing the binding agent is carried by conveyor to a curing oven, where the wool blanket is compressed to the appropriate density and the binder is baked. Hot air, at a temperature of 150° to 320°C (300° to 600°F), is forced through the blanket until the binder has set. Curing time and temperature depend on the type of binder used and the mass rate through the oven. A cooling section follows the oven, where blowers force air at ambient temperatures through the wool blanket.

To make batts and industrial felt products, the cooled wool blanket is cut longitudinally and transversely to the desired size. Some insulation products are then covered with a vapor barrier of aluminum foil or asphalt-coated kraft paper on one side and untreated paper on the other side. The cutters, vapor barrier applicators, and conveyors are sometimes referred to collectively as a batt machine. Those products that do not require a vapor barrier, such as industrial felt and some residential insulation batts, can be packed for shipment immediately after cutting.

Loose wool products consist primarily of blowing wool and bulk fiber. For these products, no binding agent is applied, and the curing oven is eliminated. For granulated wool products, the fiber blanket leaving the blowchamber is fed to a shredder and pelletizer. The pelletizer forms small, 1-inch-diameter pellets and separates shot from the wool. A bagging operation completes the processes. For other loose wool products, fiber can be transported directly from the blowchamber to a baler or bagger for packaging.

2.3 EMISSIONS

3\22 Sources of emissions? { wastewater storage & treatment
binder storage & mixing.

The sources of emissions in the mineral wool manufacturing industry are the cupola, the blow chamber, the curing oven, the mineral wool cooler, and possibly materials handling and bagging operations. With the exception of lead, the industry emits the full range of criteria pollutants. Also, depending on the particular types of slag and binding agents used, the facilities may emit both metallic and organic hazardous air pollutants (HAP's). However, with the exception of hydrogen sulfide (H_2S), no HAP data were obtained during this review.

The primary source of emissions in the mineral wool manufacturing process is the cupola. It is a significant source of particulate matter (PM) emissions and is likely to be a source of PM less than 10 micrometers in diameter (PM-10) emissions, although no particle size data are available. Coke combustion in the furnace produces carbon monoxide (CO), carbon dioxide (CO_2), and nitrogen oxide (NO_x) emissions. Finally, because coke and blast furnace slags contain sulfur, the cupola is also a source of sulfur dioxide (SO_2) and H_2S emissions.

metals?

The blowchamber is a source of PM (and probably PM-10) emissions. Also, the annealing oils used in the process can lead to volatile organic compound (VOC) emissions from the process. Other sources of VOC emissions include batt application and the curing oven. Finally, fugitive PM emissions can be generated during cooling, handling, and bagging operations.

[illegible]

√ Binder application →
organic emissions (of
phenol, formaldehyde)
[illegible]

2.4 CONTROL TECHNOLOGY[1]

Mineral wool manufacturers use a variety of air pollution control techniques, but most are directed toward PM control with minimal control of other pollutants. The industry has given greatest attention to cupola PM control, with two-thirds of the cupolas in operation having fabric filter control systems. Some cupola exhausts are controlled by wet scrubbers and electrostatic precipitators (ESP's); cyclones are also used for cupola PM control either alone or in combination with other control devices. About half of the blow chambers in the industry also have some level of PM control, with the predominant control device being low-energy wet scrubbers. Wire mesh filters also are often used to control PM emissions from blow chambers. Cyclones and fabric filters have been used to a limited degree on blow chambers. Finally, afterburners have been used to control VOC emissions from blow chambers and curing ovens and CO emissions from cupolas. Table 2-2 provides a summary of the extent of control in the industry as of 1980.

TABLE 2-2. SUMMARY OF AIR POLLUTION CONTROLS OPERATING IN THE U.S. MINERAL WOOL INDUSTRY

		Number of process sources controlled by indicated devices						
Process source	Total	Fabric Filters	ESP	Wet scrubbers	Cyclones	After-burners	Other	None
Cupolas[a]	53	35	2	3	20	2	2[b]	3
Blowchambers[c]	46	2	0	21	3	2	0	21[d]
Curing ovens	15	1	0	0	0	6	0	8
Coolers	6	0	0	0	0	1	0	5

[a] Two cupolas are controlled with fabric filters followed by direct-flame afterburners; two cupolas are controlled by wet scrubbers followed by ESP's; seven cupolas are controlled by cyclones followed by fabric filters; and one cupola is controlled by a cyclone followed by a wet scrubber.

[b] Carbon monoxide control system is operating on two cupolas with a fabric filter in one plant.

[c] Three blowchambers use two control devices in series; two plants use afterburners plus wet scrubbers, and one plant has cyclones plus a fabric filter.

[d] Includes nine units reported to use wire mesh filters.

We'll have updated information from responses to an industry questionnaire — probably mid-summer until we have a summary prepared

REFERENCES FOR SECTION 2

1. Source Category Survey: Mineral Wool Manufacturing Industry, EPA-450/3-80-016. U. S. Environmental Protection Agency, Research Triangle Park, NC, March 1980.

2. The Facts on Rocks and Slag Wool, Pub. No. N 020, North American Insulation Manufacturers Association, Alexandria, VA, Undated.

3. ICF Corporation, Supply Response to Residential Insulation Retrofit Demand, Report to the Federal Energy Administration, Contract No. P-14-77-5438-0, Washington, D.C., June 1977.

4. Personal communication between F. May, U.S.G. Corporation, Chicago, Illinois, and R. Marinshaw, Midwest Research Institute, Cary, NC, June 5, 1992.

5. Memorandum from K. Schuster, N.C. Department of Environmental Management, to M. Aldridge, American Rockwool, April 25, 1988.

3. GENERAL DATA REVIEW AND ANALYSIS

3.1 LITERATURE SEARCH AND SCREENING[1-3]

Data for this investigation were obtained from a number of sources within the Office of Air Quality Planning and Standards (OAQPS) and from outside organizations. The AP-42 Background Files located in the Emission Inventory Branch (EIB) were reviewed for information on the industry, processes, and emissions. The Crosswalk/Air Toxic Emission Factor Data Base Management System (XATEF) and VOC/PM Speciation Data Base Management System (SPECIATE) data bases were searched by SCC code for identification of the potential pollutants emitted and emission factors for those pollutants. A general search of the Air CHIEF CD-ROM also was conducted to supplement the information from these two data bases.

The Minerals Yearbook and Census of Manufactures were reviewed for information on the industry, including number of plants, plant location, and annual production capacities. However, because the data from these sources could not be disaggregated for mineral wool manufacturing, this information was obtained from the Source Category Survey Report. The Aerometric Information Retrieval System (AIRS) data base also was searched for data on the number of plants, plant location, and estimated annual emissions of criteria pollutants.

A number of sources of information were investigated specifically for emission test reports and data. A search of the Test Method Storage and Retrieval (TSAR) data base was conducted to identify test reports for sources within the mineral wool industry. Copies of these test reports were obtained from the files of the Emission Measurement Branch (EMB). The EPA library was searched for additional test reports. A list of plants that have been tested within the past 5 years was compiled from the AIRS data base. State and Regional offices were contacted about the availability of test reports. However, the information obtained from these offices was limited. Publications lists from the Office of Research and Development (ORD) and Control Technology Center (CTC) were also searched for reports on emissions from the mineral wool industry. In addition, representative trade associations, including the North American Insulation Manufacturers Association (NAIMA), were contacted for assistance in obtaining information about the industry and emissions.

To screen out unusable test reports, documents, and information from which emission factors could not be developed, the following general criteria were used:

1. Emission data must be from a primary reference:

a. Source testing must be from a referenced study that does not reiterate information from previous studies.

b. The document must constitute the original source of test data. For example, a technical paper was not included if the original study was contained in the previous document. If the exact source of the data could not be determined, the document was eliminated.

2. The referenced study must contain test results based on more than one test run.

3. The report must contain sufficient data to evaluate the testing procedures and source operating conditions (e.g., one-page reports were generally rejected).

A final set of reference materials was compiled after a thorough review of the pertinent reports, documents, and information according to these criteria.

3.2 EMISSION DATA QUALITY RATING SYSTEM ①

As part of the analysis of the emission data, the quantity and quality of the information contained in the final set of reference documents were evaluated. The following data were excluded from consideration:

1. Test series averages reported in units that cannot be converted to the selected reporting units;

2. Test series representing incompatible test methods (i.e., comparison of EPA Method 5 front half with EPA Method 5 front and back half);

3. Test series of controlled emissions for which the control device is not specified;

4. Test series in which the source process is not clearly identified and described; and

5. Test series in which it is not clear whether the emissions were measured before or after the control device.

Test data sets that were not excluded were assigned a quality rating. The rating system used was that specified by EIB for preparing AP-42 sections. The data were rated as follows:

A--Multiple tests that were performed on the same source using sound methodology and reported in enough detail for adequate validation. These tests do not necessarily conform to the methodology specified in EPA reference test methods, although these methods were used as a guide for the methodology actually used.

B--Tests that were performed by a generally sound methodology but lack enough detail for adequate validation.

C--Tests that were based on an untested or new methodology or that lacked a significant amount of background data.

D--Tests that were based on a generally unacceptable method but may provide an order-of-magnitude value for the source.

The following criteria were used to evaluate source test reports for sound methodology and adequate detail:

1. Source operation. The manner in which the source was operated is well documented in the report. The source was operating within typical parameters during the test.

2. Sampling procedures. The sampling procedures conformed to a generally acceptable methodology. If actual procedures deviated from accepted methods, the deviations are well documented. When this occurred, an evaluation was made of the extent to which such alternative procedures could influence the test results.

3. Sampling and process data. Adequate sampling and process data are documented in the report, and any variations in the sampling and process operation are noted. If a large spread between test results cannot be explained by information contained in the test report, the data are suspect and are given a lower rating.

4. Analysis and calculations. The test reports contain original raw data sheets. The nomenclature and equations used were compared to those (if any) specified by EPA to establish equivalency. The depth of review of the calculations was dictated by the reviewer's confidence in the ability and conscientiousness of the tester, which in turn was based on factors such as consistency of results and completeness of other areas of the test report.

3.3 EMISSION FACTOR QUALITY RATING SYSTEM ①

The quality of the emission factors developed from analysis of the test data was rated using the following general criteria:

A--Excellent: Developed only from A-rated test data taken from many randomly chosen facilities in the industry population. The source category is specific enough so that variability within the source category population may be minimized.

B--Above average: Developed only from A-rated test data from a reasonable number of facilities. Although no specific bias is evident, it is not clear if the facilities tested represent a random sample of the industries. The source category is specific enough so that variability within the source category population may be minimized.

C--Average: Developed only from A- and B-rated test data from a reasonable number of facilities. Although no specific bias is evident, it is not clear if the facilities tested represent a random sample of the industry. In addition, the source category is specific enough so that variability within the source category population may be minimized.

D--Below average: The emission factor was developed only from A- and B-rated test data from a small number of facilities, and there is reason to suspect that these facilities do not represent a random sample of the industry. There also may be evidence of variability within the source category population. Limitations on the use of the emission factor are noted in the emission factor table.

E--Poor: The emission factor was developed from C- and D-rated test data, and there is reason to suspect that the facilities tested do not represent a random sample of the industry. There also may be evidence of variability within the source category population. Limitations on the use of these factors are always noted.

The use of these criteria is somewhat subjective and depends to an extent upon the individual reviewer. Details of the rating of each candidate emission factor are provided in Chapter 4 of this report.

REFERENCES FOR SECTION 3

1. 1987 Census of Manufacturers, Industry Series-Abrasives, Asbestos and Miscellaneous Nonmetallic Mineral Products, U.S. Department of Commerce, Washington, D.C., May 1990.

2. Minerals Yearbook, Vol. I--Metals and Minerals, 1989, U.S. Department of the Interior, Bureau of Mines, Washington, D.C., 1991.

3. Source Category Survey: Mineral Wool Manufacturing Industry, EPA-450/3-80-016, U. S. Environmental Protection Agency, Research Triangle Park, NC, March 1980.

4. Technical Procedures for Developing AP-42 Emission Factors and Preparing AP-42 Sections (Draft), Office of Air Quality Planning and Standards, U. S. Environmental Protection Agency, Research Triangle Park, NC, March 6, 1992.

4. AP-42 SECTION DEVELOPMENT

4.1 REVISION OF SECTION NARRATIVE[1]

Section 8.16, Mineral Wool Manufacturing, was last revised in 1972. The narrative provided in that version was quite limited, and the discussion of emissions and emission controls provided almost no information. Consequently, the narrative was completely rewritten for this version. The draft section, which is based primarily on information presented in the Source Category Survey Report and in test reports reviewed as a part of this study, contains an expanded discussion of the process, emissions, and emission controls and provides a process flow diagram.

4.2 POLLUTANT EMISSION FACTOR DEVELOPMENT

In addition to a review of the data available in the background file for Section 8.16, this evaluation included an examination of the emission data contained in the Source Category Survey Report and reviews of nine emission test reports. All tests described in these nine reports were conducted by facilities to demonstrate compliance with State or local regulations. The tests documented in References 8, 9, and 10 were conducted at the same facility. However, no process data were provided for these tests. In addition, the two stacks that were sampled served several emission sources, including cupolas, fugitive dust collection systems, a curing oven, and pipe manufacturing machines. (Based on exhaust gas flow rates provided, the cupolas accounted for 5 to 8 percent of the total flow exiting the stacks.) For these reasons, these three references were not used to develop emission factors.

The remainder of this section is divided into five parts. First the data presented in the Source Category Survey Report are discussed. Then the six test reports that contain sufficient data for emission factor development are discussed individually. Emission factors for mineral wool manufacturing included in the XATEF and SPECIATE data bases were also reviewed, and a discussion of these emission factors is presented. Then a discussion of the review of the existing test data in the AP-42 background file is presented. Finally, the results of the data review and analysis are presented.

4.2.1 Review of Source Category Survey Data (Reference 1)

As part of a review of the mineral wool manufacturing industry to assess the need for a new source performance standard, EPA compiled a substantial amount of emission data from State and local agencies. Because the data were only presented in summary form, their quality cannot be evaluated. Consequently, they cannot be averaged with other available test data to obtain emission factors. In view of these limitations, the emission factors developed from these data were deemed to be useful for order of magnitude estimates only and are rated E. Table 4-1 summarizes the information on uncontrolled emission factors for mineral wool cupolas. For each pollutant, the table shows the number of tests reviewed during the study and a range and average emission factor. Table 4-2 summarizes uncontrolled PM emission factor information for blow chambers. Finally, one test on a cupola in San Bernadino County, California, generated particle size data that were obtained with an Andersen cascade impactor. These data are presented in Table 4-3.

4.2.2 Review of Specific Data Sets

4.2.2.1 Reference 2. This test was sponsored by the facility in 1988 to demonstrate that SO_2 emissions from the Nos. 1 and 2 cupolas were in compliance with State requirements. While the primary purpose of the test was to measure SO_2 levels, sufficient data were obtained from the associated Method 2 and 3 tests to calculate CO and CO_2 emission factors. The SO_2 measurements were made with a Standard EPA Method 8 train; sulfur trioxide (SO_3) measurements also were obtained from this train. Volumetric flow rates were obtained via EPA Method 2, and CO and CO_2 concentrations were obtained from Orsat measurements per EPA Method 3.

The process information contained in the test report was quite sparse. In fact, the only data that were available in the test report were process rate data sheets, which were contained in an appendix. Subsequently, the State agency supplied a process flow diagram for the facility. The information contained in the process flow diagram and in the process data appendix indicated that emissions from each cupola were controlled by a fabric filter, but no design or operating data on the system are available. During the tests, cupola No. 1 fired a mixture of coke (~ 15 percent) and slag

TABLE 4-1. SUMMARY OF SOURCE CATEGORY SURVEY EMISSION FACTOR DATA FOR UNCONTROLLED MINERAL WOOL CUPOLAS

		Emission factor			
		kg/Mg feed		lb/ton feed	
Pollutant	No. of tests	Range	Average	Range	Average
PM	3	2.3-6.8	5.3	4.6-13.7	10.6
SO_2	10	NA	5.3	NA	10.6
H_2S	3	NA	1.5	NA	3.0
CO	9	3-156	78	6-312	156
NO_x	6	0.1-1.9	0.8	0.2-3.7	1.6

NA = not available.

TABLE 4-2. SUMMARY OF SOURCE CATEGORY SURVEY EMISSION FACTOR DATA FOR UNCONTROLLED MINERAL WOOL BLOW CHAMBERS

		Emission factor			
		kg/Mg feed		lb/ton feed	
Source	No. of tests	Range	Average	Range	Average
PM	2	0.7 -0.9	0.8	1.4-1.8	1.6
VOC's	2	NA	0.2	NA	0.4

TABLE 4-3. SOURCE CATEGORY PARTICLE SIZE DATA FOR UNCONTROLLED MINERAL WOOL CUPOLAS

Particle size range, µm	Percent by weight
+30	5.6
9.2-30	0.1
5.5-9.2	0.5
3.3-5.5	1.0
2.0-3.3	5.0
1.0-2.0	67.8
0.2-1	20.0

(~85 percent), while cupola No. 2 fired a mixture of coke (~15 percent), slag (~80 percent), and ore (~5 percent).

The data are rated A for CO, CO_2, and SO_2 because standard methodology was used, no problems were reported, and all results were fully documented. Unlike these gaseous pollutants (CO, CO_2, and SO_2), which generally are not controlled by fabric filters, SO_3 is emitted as PM, and, thus, would be controlled by a fabric filter. Because the report did not include adequate information on the design and operation of the fabric filter, the SO_3 data are rated B.

4.2.2.2 Reference 3. This test program was sponsored by the facility in January 1981 to demonstrate that PM emissions from the cupola complied with State emission limits. The PM measurements were made on each operation at the outlet to an air pollution control device using EPA Method 5. Fyrite was used to quantify CO_2 emissions. Three runs were completed on the blow chamber; four runs were conducted on the cupola, but one was declared invalid because of sampling equipment problems. The results from that run were not reported.

The process information contained in the test report was limited to process data sheets contained in the appendix. However, the State agency provided flow diagrams indicating that the cupola was controlled by a fabric filter and the blowchamber was controlled by a wire mesh filter. No other information is available on the process.

The PM test data from this report are rated B. Tests were conducted with standard EPA methods, and no problems were reported. However, the process information contained in the report was insufficient to characterize the processes or control systems adequately. The CO_2 data are rated C due to the relative inaccuracy of the Fyrite analysis.

4.2.2.3 Reference 4. This test program was sponsored in June 1979 by the facility to demonstrate that the PM emissions from cupolas Nos. 1, 2, and 3 complied with State emission limits. Some data also were collected on organic emissions from the blow chamber. The sampling train used to collect the hydrocarbons included a heated glass probe with glass wool plug to collect the PM, followed by two tubes filled with activated charcoal. The samples were analyzed by placing carbon disulfide in the activated carbon tubes for 24 hours, then filtering and evaporating the liquid to dryness at room temperature. However, it is likely that a significant amount of sample was lost in the evaporation step. For that reason, the test method used was not considered to be acceptable for AP-42 emission factor development, and the results are not included in this review. The PM tests were conducted with EPA Methods 1 through 5, and no problems were noted. Fyrite was used to quantify CO_2 emissions.

The process information for the cupolas is limited to a process flow diagram supplied by the State agency and process data sheets contained in the report appendix. The process diagrams indicate that each cupola is equipped with a fabric filter. During the tests, the process data indicated that the cupola was fired with a blend of coke (~10.5 percent), shale (~6.4 percent), slag (probably blast furnace slag) (~62.3 percent), and phosphate slag (~20.8 percent). Some process data were supplied on the blow chamber operation, but they were insufficient to determine the basis for the process weights associated with these operations.

The PM test data are rated B. Tests were conducted with standard EPA methods and no problems were reported. However, the process information was inadequate to warrant a higher rating. The CO_2 data are rated C due to the relative inaccuracy of Fyrite analysis.

4.2.2.4 Reference 5. This facility-sponsored test was conducted to demonstrate that the PM emissions from the batt curing oven complied with State emission limits. Five test runs were conducted using EPA Methods 1 through 5. Run 1 was discarded because of a failed posttest leak check, and Run 2 was discontinued because of a process malfunction, leaving three valid runs. The report does not provide process or emission data for the two discarded runs. Fyrite was used to quantify CO_2 emissions.

The process information in the report is quite limited. The introduction does note that emissions are directed through an ESP, but no other process description is provided. Operational data are presented in Chapter IV of the report. However, these data are difficult to read, and the raw data could not be clearly related to the process weights presented in summary tables. The process weights appear to be in units of batt produced, but the exact basis for the process weights could not be confirmed from the raw data.

The test data from this report are rated C. Tests were conducted with standard EPA methods, and no problems were reported. However, the process information contained in the report was insufficient to characterize the processes or control systems adequately. Also, the basis for the process rates given in summary tables is unclear.

4.2.2.5 Reference 6. This test program was conducted by the facility to measure emissions of PM, SO_2, and fluorides. The tests were designed to evaluate the effect of substituting an aluminum smelting cell byproduct material (SPL) for coke on a pound-per-pound carbon basis. The typical charge compositions for the different test conditions are shown below.

AVERAGE CHARGE MAKEUP

Charge (1 lb)	Condition A	Condition B	Condition D
SPL[a]	0	210	450
Lime	0	0	50
Coke	385	260	140
Duquesne slag	1,300	1,300	1,300
Trap rock	1,100	1,100	1,100
Steel slag	400	400	400
Tennessee slag	400	400	400
Avg. No. charges/hr	3.5	3.4	3.0

The test design for this program was somewhat unusual. The facility operates two cupolas, each with its own spark arrestor and fabric filter. The exhaust from the fabric filters is combined and ducted to the atmosphere through a common stack. The sampling was conducted in this common stack. Sampling for fluorides was conducted using Alcoa Method 4075A (which was approved by the State and EPA) in conjunction with EPA Methods 1 through 4. Particulate matter emissions were obtained from a cellulose thimble in the front half of the Method 4075A. This procedure provides results that are comparable to EPA Method 5 front half results but are less accurate for emissions that include significant levels of condensible PM. However, for the reported stack gas temperatures, which ranged from 34° to 44°C (93° to 111°F), the condensible PM fraction should be negligible. Therefore, the filterable PM results should be relatively accurate for AP-42 emission factor development with a one-step quality down-rating. The SO_2 samples were obtained with a glass-bulb technique that is purported to be similar to EPA Method 15 procedures. The concentration of SO_2 was measured with a gas chromatograph/flame photometric detector. Although the test method appears to be acceptable, there is inadequate information to evaluate the validity of the analytical method used or to demonstrate that this method is equivalent to EPA Method 6 or 8. Consequently, the SO_2 data are rated D. Fyrite was used to quantify CO_2 emissions.

The test data for fluorides are rated A. Reference or equivalent methods were used, no problems were reported, and results were fully documented. The PM data were rated B because the method used is somewhat less reliable than EPA Method 5. The SO_2 data were rated D because a nonstandard method was used and no information was presented on its reliability, accuracy, precision, or equivalence to other methods. The CO_2 data are rated C due to the relative inaccuracy of Fyrite analysis.

4.2.2.6 Reference 7. This test program was sponsored by the facility to demonstrate that PM, SO_2, and fluoride emissions from the cupola were in compliance with State requirements. The tests were conducted in the common stack for the two cupolas as described in Reference 6 above. Tests were conducted with two different charge conditions as shown below.

CHARGE MAKEUP

Baseline		710 lb/hr SPL	
Charge	lb	Charge	lb
Coke	385-400	Coke	260
SPL	0	SPL	225
Duquesne slag	1,300	Duquesne slag	1,300
Trap rock	1,100	Trap rock	1,100
Lime	50	Lime	50
Steel	400	Steel	400
Tennessee slag	400	Tennessee slag	400

Three test runs were completed for the baseline conditions, and four were completed for the SPL runs. Standard EPA methods were used for PM (Methods 1 through 5) and SO_2 (Method 6). An Alcoa method (Method 4075A) that was approved by the State and EPA was used for fluorides. Fyrite was used to quantify CO_2 emissions.

The PM, SO_2, and fluoride test data from this report are rated A. Standard methods or acceptable equivalents were used, no problems were reported, and the test report fully documented results. The CO_2 data are rated C due to the relative inaccuracy of Fyrite analysis.

4.2.3 Review of XATEF and SPECIATE Data Base Emission Factors

The XATEF data base does not contain emission factors for mineral wool manufacturing.

The SPECIATE data base contains emission factors for emissions from mineral wool furnaces, curing ovens, and coolers. However, all of the emission factors are based on surrogate profiles. Consequently, they will not be used in the revised AP-42 section.

4.2.4 Review of Test Data in AP-42 Background Files

The current version of AP-42 contains uncontrolled PM emission factors for the cupola, reverberatory furnace, blow chamber, curing oven, and cooler and an uncontrolled SO_2 emission factor for the cupola. A review of the background file indicated that these emission factors are based on averaging a limited quantity of emission data that were reported in an early (1967) version of AP-40 (Reference 11). In addition, Reference 11 includes emission data on uncontrolled emissions of SO_3 and CO from cupolas; SO_2 and aldehydes from blow chambers; SO_2, nitrogen dioxide (NO_2), and aldehydes from curing ovens; and SO_2 and aldehydes from coolers. This reference reported average rather than run-specific test results, and the test methods were not documented. Given these limitations, the emission factors developed from these data were deemed to be useful for order of magnitude estimates only. The emission factors developed from these data are rated E, with the exception of the emission factors for aldehydes. Because the lack of documentation on the aldehyde emission tests and the fact that a reliable method for testing aldehydes was not available at the time of these tests, the aldehyde emission results are highly suspect and are unrated.

4.2.5 Results of Data Analysis

For mineral wool manufacturing cupolas, the test reports and documents described above provided sufficient data to develop emission factors for uncontrolled and controlled filterable PM emissions; uncontrolled CO, CO_2, SO_2, H_2S, and NO_x emissions; uncontrolled and controlled SO_3

OK

Not sure if this furnace is still in operation

emissions; and controlled fluoride emissions. For reverberatory furnaces, an uncontrolled filterable PM emission factor was developed. For mineral wool batt curing ovens, emission factors were developed for uncontrolled and controlled filterable PM emissions and for uncontrolled SO_2 and N_2O emissions. For mineral wool blow chambers, emission factors were developed for uncontrolled and controlled filterable PM emissions and for uncontrolled SO_2 and CO_2 emissions. Finally, for mineral wool coolers, emission factors were developed for filterable PM and SO_2 emissions. The data used in the analysis are summarized in Tables 4-4 and 4-5. Table 4-6 summarizes the emission factors developed from data found in AP-40 (Reference 11). The final emission factors that were incorporated into the revised AP-42 section and their ratings are tabulated in Table 4-7. The paragraphs below describe how the emission factors were calculated and summarize the rationale for the ratings.

The filterable PM emission factor for cupola emissions was developed by averaging the data in the source category survey report (Reference 1) and AP-40 Reference 11. When compared to the fabric-filter-controlled data from References 3, 4, 6, and 7, the uncontrolled PM data indicate a control efficiency of 99 percent. Thus, although the emission factor is based on secondary references, the uncontrolled data are consistent with the controlled data from primary references. Because the emission factor is based on secondary data, it is rated E.

The emission factors included in the revised AP-42 section on mineral wool manufacturing for uncontrolled CO and CO_2 emissions from cupolas were developed from Reference 2. Emission factors for CO_2 emissions from cupolas also were developed from References 3, 4, 6, and 7. The Reference 2 data are rated A and indicated an emission factor of 125 kg/Mg (250 lb/ton), and the data from the other four references are rated C and average 205 kg/Mg (410 lb/ton). However, emission factors developed from C-rated data can only be rated E. For that reason, the emission factor for CO_2 emissions from cupolas developed from Reference 2 was used.

Although the CO and CO_2 emissions were measured downstream from a fabric filter, these emission factors are considered to be uncontrolled because fabric filters are not expected to affect CO and CO_2 emissions. These emission factors are rated D, because they are based on A- and B-rated data from only one plant.

TABLE 4-4. SUMMARY OF EMISSION TEST DATA FOR MINERAL WOOL MANUFACTURING CUPOLAS

Facility	Source ID	APCD	Pollutant	No. of runs	Data rating	Emission factor, kg/Mg (lb/ton) feed		Ref.
						Range	Average	
A	Cupola No. 1 (slag)	FF	CO	3	A	130-140 (260-280)	130 (260)	2
			SO_2	3	A	2.5-3.8 (5.1-7.6)	3.1 (6.2)	2
			CO_2	3	A	230-270 (470-550)	250 (510)	2
			SO_3	3	B	0.0085-0.43 (0.017-0.86)	0.15 (0.30)	2
	Cupola No. 2 (slag/ore)	FF	CO	3	A	120-130 (230-260)	120 (250)	2
			SO_2	3	A	3.3-3.8 (6.5-7.6)	3.4 (6.9)	2
			CO_2	3	A	250-310 (490-620)	270 (540)	2
			SO_3	3	B	0.0010-0.0050 (0.0040-0.010)	0.0034 (0.0067)	2
B	Cupola No. 4 (slag)	FF	PM	3	B	0.0020-0.049 (0.0041-0.098)	0.025 (0.050)	3
		None	CO_2	3	C	310-350 (610-690)	330 (650)	3
	Cupola No. 1	FF	PM	3	B	0.015-0.072 (0.030-0.14)	0.041 (0.082)	4
		None	CO_2	3	C	150-290 (290-580)	220 (430)	4
	Cupola No. 2	FF	PM	3	B	0.016-0.053 (0.033-0.11)	0.032 (0.065)	4
		None	CO_2	3	C	110-200 (210-390)	150 (290)	4
	Cupola No. 3 (slag, shale, phosphate slag)	FF	PM	3	B	0.037-0.073 (0.073-0.15)	0.050 (0.099)	4
		None	CO_2	3	C	200-250 (390-500)	230 (450)	4
C	Cond. 1[a]	FF	PM	3	B	0.035-0.057 (0.069-0.11)	0.049 (0.098)	6
			SO_2	3	D	3.7-4.5 (7.4-8.9)	4.2 (8.3)	6
			Fluorides	3	A	0.016-0.036 (0.031-0.072)	0.029 (0.058)	6
		None	CO_2	3	C	160-170 (320-330)	170 (330)	6
	Cond. 2	None	PM	4	B	0.019-0.095 (0.038-0.19)	0.074 (0.15)	6
			SO_2	4	D	1.9-4.1 (3.8-8.1)	3.8 (7.6)	6
			Fluorides	4	A	0.059-0.49 (0.19-0.98)	0.32 (0.63)	6
		None	CO_2	4	C	100-180 (200-360)	120 (240)	6
	Cond. 3	None	PM	2	B	0.076-0.079 (0.15-0.16)	0.18 (0.37)	6
			SO_2	2	D	2.0-2.9 (4.1-5.8)	2.5 (5.0)	6
			Fluorides	2	A	0.19-0.26 (0.37-0.51)	0.22 (0.44)	6
		None	CO_2	2	C	110-170 (220-340)	140 (280)	6
C	Cond. 1[a]	FF	PM	3	A	0.061-1.1 (0.12-2.2)	0.084 (0.17)	7
			SO_2	3	A	5.0-6.5 (10-13)	5.5 (11.0)	7
			Fluorides	3	A	0.0073-0.011 (0.015-0.021)	0.0085 (0.017)	7
		None	CO_2	3	C	240-260 (480-510)	250 (500)	7
	Cond. 2	None	PM	4	A	0.12-0.17 (0.24-0.33)	0.14 (0.28)	7
			SO_2	4	A	3.7-4.5 (7.5-9.0)	4.1 (8.2)	7
			Fluorides	4	A	0.026-0.036 (0.052-0.073)	0.032 (0.064)	7
		None	CO_2	3	C	230-240 (460-480)	240 (470)	7

[a] Refer to Section 4.2.2.5 for composition of charge material.

TABLE 4-5. SUMMARY OF EMISSION TEST DATA FOR MINERAL WOOL MANUFACTURING CURING AND BLOWING

Facility	Source ID	APCD	Pollutant	No. of runs	Data rating	Emission factor, kg/Mg (lb/ton) feed		Ref.
						Range	Average	
B	Batt curing oven	ESP	PM	3	C	0.23-0.60 (0.46-1.2)	0.36 (0.72)	5
		None	CO_2	3	C	60-110 (110-220)	80 (160)	5
B	Blow chamber	Wire mesh filter	PM	3	B	0.30-5.9 (0.59-1.2)	0.45 (0.91)	3

TABLE 4-6. SUMMARY OF UNCONTROLLED EMISSION FACTORS DEVELOPED FROM AP-40[11,a]

Process	Pollutant	No. of tests	Range		Average	
			kg/Mg	lb/ton	kg/Mg	lb/ton
Cupola	PM (filterable)	3	8.0-14	16-28	11	22
	SO_2	1			5.6	11
	SO_3	1			3.2	6.3
	CO	1			45	91
Reverberatory furnace	PM (filterable)	1			2.4	4.8
Blow chamber	PM (filterable)	4	2.0-28	4.0-56	8.6	17
	SO_2	1			0.43	0.87
	aldehydes[b]	1			0.43	0.86
Curing oven	PM (filterable)	5	0.74-2.9	1.5-5.9	1.8	3.6
	SO_2	1			0.58	1.2
	aldehydes[b]	2	0.37-0.63	0.73-1.3	0.50	1.00
	NO_2	2	0.043-0.12	0.086-0.23	0.079	0.16
Cooler	PM (filterable)	4	0.21-2.8	0.43-5.5	1.2	2.4
	SO_2	1			0.034	0.068
	aldehydes[b]	1			0.021	0.042

[a] All emission factors rated E except where indicated.

[b] Emission factors are unrated.

TABLE 4-7. MINERAL WOOL MANUFACTURING EMISSION FACTORS

Source	Control	Pollutant	Emission factor		Rating	Ref. No.
			kg/Mg	lb/ton		
Cupola[a]	Uncontrolled	Filterable PM	8.2	16	E	1, 11
		CO	125	250	D	2
		CO_2	260	520	D	2
		SO_2	4.0	8.0	D	2,7
		SO_3	3.2	6.3	E	11
		H_2S	1.5	3.0	E	1
		NO_2	0.8	1.6	E	1
	Fabric filter	Filterable PM	0.051	0.10	D	2,3,4,6,7
		SO_3	0.077	0.15	E	2
		Fluorides[b]	0.019	0.038	D	7
		Fluorides[c]	0.19	0.38	D	6
Reverberatory Furnace	Uncontrolled	Filterable PM	2.4	4.8	E	11
Batt curing oven[d]	Uncontrolled	Filterable PM	1.8	3.6	E	11
		SO_2	0.58	1.2	E	11
		NO_2	0.079	0.16	E	11
		CO_2	80	160	E	5
	ESP	Filterable PM	0.36	0.72	D	5
Blow chamber[e]	Uncontrolled	Filterable PM	6.0	12	E	1,11
		SO_2	0.43	0.87	E	11
	Wire mesh filter	Filterable PM	0.45	0.91	D	3
Cooler	Uncontrolled	Filterable PM	1.2	2.4	E	11
		SO_2	0.034	0.068	E	11

[a] Activity level is total feed-charged.

[b] Only coke was used as fuel.

[c] Fuel was a combination of coke and aluminum smelting byproducts.

[d] Activity level is mass of product.

[e] Activity level is mass of molten mineral feed.

For SO_2 emissions from cupolas, A- or B-rated data are available for three operating units--cupola Nos. 1 and 2 at Facility A and the combined stream at Facility C under different operating conditions. Examination of the data shows the data to fall in a reasonably narrow range. Consequently, the emission factor was obtained by simply averaging the four A- and B-rated test data. This emission factor is rated D because of the limited number of tests and facilities used.

Uncontrolled emission factors for SO_3, H_2S, and NO_x emissions from cupolas were developed from secondary references (References 1 and 11). The uncontrolled SO_3 emission factor for cupolas, which was developed from Reference 11, indicates a fabric filter control efficiency of 98 percent when compared to the data in Reference 2. For that reason, the uncontrolled SO_3 emission factor also appears to be reasonable. The uncontrolled emission factors for H_2S and NO_x also were developed from Reference 1. However, there are no controlled data to which these emission factors can be compared.

The controlled filterable PM emission factor for cupolas was obtained by averaging the average of the data from five tests at Facility C with the data from tests on the four cupolas at Facility B. Again, the emission factor is rated D because it is based on a very limited quantity of data. The remaining emission factors developed for mineral wool cupolas are for controlled SO_3 and fluoride emissions. The SO_3 emission factor is based on two B-rated tests at the same facility (Reference 2) and is rated D. Fluoride emission factors for two types of fuel were developed from one test each and are also rated D.

The emission factors for controlled filterable PM emissions from batt curing ovens and blow chambers were developed from References 5 and 3, respectively. These emission factors are each rated D, because they are based on a single emission test. All other emission factors for mineral wool manufacturing are based on secondary references and are rated E.

The uncontrolled filterable PM emission factor for blow chambers is based on an average of the data in References 1 and 11. This emission factor, when compared to the wire mesh filter-controlled emission factor developed from Reference 3, indicates a control efficiency of 93 percent, which seems reasonable. Also, a comparison of the uncontrolled (based on secondary data) and ESP-controlled PM emission factors for curing ovens indicates a control efficiency of 80 percent, which also appears to be reasonable. There are no other data with which the other emission factors developed from secondary data can be compared. However, they are considered to be useful for order-of-magnitude estimates and have been included in the revised AP-42 section.

REFERENCES FOR SECTION 4

1. Source Category Survey: Mineral Wool Manufacturing Industry, EPA-450/3-80-016, U. S. Environmental Protection Agency, Research Triangle Park, NC, March 1980.

2. Sulfur Oxide Emission Tests Conducted on the #1 and #2 Cupola Stacks in Leeds, Alabama for Rock Wool Company, November 8 & 9, 1988, Guardian Systems, Inc., Leeds, AL, Undated.

3. Particulate Emissions Tests for U.S. Gypsum Company on the Number 4 Dry Filter and Cupola Stack Located in Birmingham, Alabama on January 14, 1981, Guardian Systems, Inc., Birmingham, AL, Undated.

4. Untitled Test Report, Cupolas Nos. 1, 2, and 3, U.S. Gypsum, Birmingham, AL, June 1979.

5. Particulate Emission Tests on Batt Curing Oven for U.S. Gypsum, Birmingham, Alabama on October 31 - November 1, 1977, Guardian Systems, Inc., Birmingham, AL, Undated.

6. J.V. Apicella, Particulate, Sulfur Dioxide, and Fluoride Emissions from Mineral Wool Emissions with Varying Charge Compositions, American Rockwool, Inc. Spring Hope, NC 27882, Aluminum Company of America, Alcoa Center, PA, June 1988.

7. J.V. Apicella, Compliance Report on Particulate, Sulfur Dioxide, Fluoride, and Visual Emissions from Mineral Wood Production, American Rockwool, Inc., Spring Hope, NC 27882, Aluminum Company of America, Alcoa Center, PA, February 1988.

8. Particulate and VOC Emissions Test Report for Partek North America, Inc., Phenix City, Alabama, Stack Nos. 1 & 2, Sanders Engineering & Analytical Services, Inc., Mobile, AL, October 1990.

9. Compliance Test Report for Partek North America, Inc., Phenix City, Alabama, Stack 1, Sanders Engineering & Analytical Services, Inc., Mobile, AL, January 21, 1992.

10. Initial Compliance Test Report for Partek North America, Inc., Phenix City, Alabama, Stack 2, Sanders Engineering & Analytical Services, Inc., Mobile, AL, January 22, 1992.

11. J.L. Spinks, "Mineral Wool Furnaces," In: Air Pollution Engineering Manual, J.A. Danielson, ed., U. S. DHEW, PHS, National Center for Air Pollution Control, Cincinnati, OH. PHS Publication Number 999-^A^P-40, 1967, pp. 343-347.

5. DRAFT AP-42 SECTION 8.16

8.16 MINERAL WOOL MANUFACTURING

8.16.1 General[1,2]

Mineral wool often is defined as any fibrous glassy substance made from minerals (typically natural rock materials such as basalt or diabase) or mineral products such as slag and glass. Because glass wool production is covered separately in AP-42 (Section 8.11), this section deals only with the production of mineral wool from natural rock and slags such as iron blast furnace slag, the primary material, and copper, lead, and phosphate slags. These materials are processed into insulation and other fibrous building materials that are used for structural strength and fire resistance. Generally, these products take one of four forms: "blowing" wool or "pouring" wool, which is put into the structural spaces of buildings; batts, which may be covered with a vapor barrier of paper or foil and are shaped to fit between the structural members of buildings; industrial and commercial products such as high-density fiber felts and blankets, which are used for insulating boilers, ovens, pipes, refrigerators, and other process equipment; and bulk fiber, which is used as a raw material in manufacturing other products, such as ceiling tile, wall board, spray-on insulation, cement, and mortar.

Mineral wool manufacturing facilities are included in Standard Industrial Classification (SIC) Code 3296, mineral wool. This SIC code also includes the production of glass wool insulation products, but those facilities engaged in manufacturing textile glass fibers are included in SIC Code 3229. The six digit source category code (SCC) for mineral wool manufacturing is 3-05-017.

8.16.2 Process Description[1,4,5]

Most mineral wool produced in the United States today is produced from slag or a mixture of slag and rock. Most of the slag used by the industry is generated by integrated iron and steel plants as a blast furnace byproduct from pig iron production. Other sources of slag include the copper, lead, and phosphate industries. The production process has three primary components--molten

Wool

mineral generation in the cupola, fiber formation and collection, and final product formation. Figure 8.16-1 illustrates the mineral wool manufacturing process.

The first step in the process involves melting the mineral feed. The raw material (slag and rock) is loaded into a cupola in alternating layers with coke at weight ratios of about 5 to 6 parts mineral to 1 part coke. As the coke is ignited and burned, the mineral charge is heated to the molten state at a temperature of 1300° to 1650°C (2400° to 3000°F). Combustion air is supplied through tuyeres located near the bottom of the furnace. Process modifications at some plants include air enrichment and the use of natural gas auxiliary burners to reduce coke consumption. One facility also reported using an aluminum flux byproduct to reduce coke consumption.

The molten mineral charge exits the bottom of the cupola in a water-cooled trough and falls onto a fiberization device. Most of the mineral wool produced in the United States is made by variations of two fiberization methods. The Powell process uses groups of rotors revolving at a high rate of speed to form the fibers. Molten material is distributed in a thin film on the surfaces of the rotors and then is thrown off by centrifugal force. As the material is discharged from the rotor, small globules develop on the rotors and form long, fibrous tails as they travel horizontally. Air or steam may be blown around the rotors to assist in fiberizing the material. A second fiberization method, the Downey process, uses a spinning concave rotor with air or steam attenuation. Molten material is distributed over the surface of the rotor, from which it flows up and over the edge and is captured and directed by a high-velocity stream of air or steam.

During the spinning process, not all globules that develop are converted into fiber. The nonfiberized globules that remain are referred to as "shot." In raw mineral wool, as much as half of the mass of the product may consist of shot. As shown in Figure 8.16-1, shot is usually separated from the wool by gravity immediately following fiberization.

Depending on the desired product, various chemical agents may be applied to the newly formed fiber immediately following the rotor. In almost all cases, an oil is applied to suppress dust and, to some degree, anneal the fiber. This oil can be either a proprietary product or a medium- weight fuel or lubricating oil. If the fiber is intended for use as loose wool or bulk products, no further chemical treatment is necessary. If the mineral wool product is required to have structural rigidity, as in batts and industrial felt, a binding agent is applied with or in place of the oil treatment. This binder is

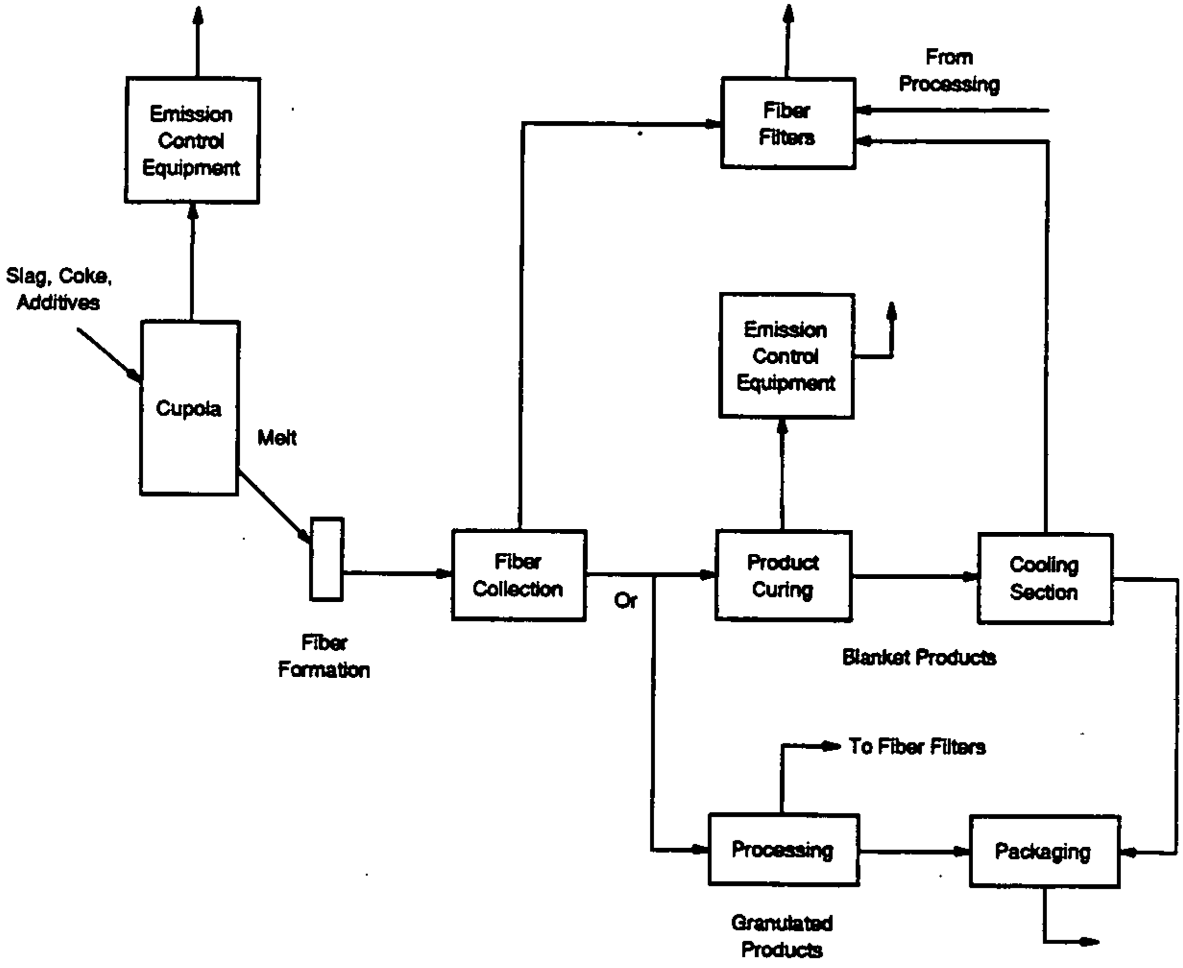

Figure 8.16-1. Mineral wool manufacturing process flow diagram.

typically a phenol-formaldehyde resin that requires curing at elevated temperatures. Both the oil and the binder are applied by atomizing the liquids and spraying the agents to coat the airborne fiber.

After formation and chemical treatment, the fiber is collected in a blowchamber. Resin-and/or oil-coated fibers are drawn down on a wire mesh conveyor by fans located beneath the collector. The speed of the conveyor is set so that a wool blanket of desired thickness can be obtained.

Mineral wool containing the binding agent is carried by conveyor to a curing oven, where the wool blanket is compressed to the appropriate density and the binder is baked. Hot air, at a temperature of 150° to 320°C (300° to 600°F), is forced through the blanket until the binder has set. Curing time and temperature depend on the type of binder used and the mass rate through the oven. A cooling section follows the oven, where blowers force air at ambient temperatures through the wool blanket.

To make batts and industrial felt products, the cooled wool blanket is cut longitudinally and transversely to the desired size. Some insulation products are then covered with a vapor barrier of aluminum foil or asphalt-coated kraft paper on one side and untreated paper on the other side. The cutters, vapor barrier applicators, and conveyors are sometimes referred to collectively as a batt machine. Those products that do not require a vapor barrier, such as industrial felt and some residential insulation batts, can be packed for shipment immediately after cutting.

Loose wool products consist primarily of blowing wool and bulk fiber. For these products, no binding agent is applied, and the curing oven is eliminated. For granulated wool products, the fiber blanket leaving the blowchamber is fed to a shredder and pelletizer. The pelletizer forms small, 1-inch diameter pellets and separates shot from the wool. A bagging operation completes the processes. For other loose wool products, fiber can be transported directly from the blowchamber to a baler or bagger for packaging.

8.16.3 Emissions and Controls[1]

binder storage & mixing ?
wastewater storage & treatment ?

The sources of emissions in the mineral wool manufacturing industry are the cupola, the blow chamber, the curing oven, the mineral wool cooler, and possibly materials handling and bagging operations. With the exception of lead, the industry emits the full range of criteria pollutants. Also, depending on the particular types of slag and binding agents used, the facilities may emit both metallic and organic hazardous air pollutants (HAP's).

The primary source of emissions in the mineral wool manufacturing process is the cupola. It is a significant source of particulate matter (PM) emissions and is likely to be a source of PM less than 10 micrometers (μm) in diameter (PM-10) emissions, although no particle size data are available. Coke combustion in the furnace produces carbon monoxide (CO), carbon dioxide (CO_2), and nitrogen oxide (NO_x) emissions. Finally, because blast furnace slags contain sulfur, the cupola is also a source of sulfur dioxide (SO_2) and hydrogen sulfide (H_2S) emissions.

binder

The blowchamber is a source of PM (and probably PM-10) emissions. Also, the annealing oils used in the process can lead to VOC emissions from the process. Other sources of VOC emissions include batt application and the curing oven. Finally, fugitive PM emissions can be generated during cooling, handling, and bagging operations. Table 8.16-1 presents emission factors for filterable PM emissions from various mineral wool manufacturing processes; Table 8-16.2 shows emission factors for CO, CO_2, SO_2, and sulfates; and Table 8.16-3 presents emission factors for fluorides.

Mineral wool manufacturers use a variety of air pollution control techniques, but most are directed toward PM control with minimal control of other pollutants. The industry has given greatest attention to cupola PM control, with two-thirds of the cupolas in operation having fabric filter control systems. Some cupola exhausts are controlled by wet scrubbers and electrostatic precipitators (ESP's); cyclones are also used for cupola PM control either alone or in combination with other control devices. About half of the blow chambers in the industry also have some level of PM control, with the predominant control device being low-energy wet scrubbers. Cyclones and fabric filters have been used to a limited degree on blow chambers. Finally, afterburners have been used to control VOC emissions from blow chambers and curing ovens and CO emissions from cupolas.

TABLE 8.16-1. (METRIC UNITS)
EMISSION FACTORS FOR MINERAL WOOL MANUFACTURING[a]

All emission factors in kg/Mg of product unless noted
Ratings (A-E) follow each emission factor

Process (SCC)	Filterable PM[b]	
Cupola[c] (30501701)	8.2	E
Cupola with fabric filter[d] (30501701)	0.051	D
Reverberatory furnace[e] (30501702)	2.4	E
Batt curing oven[e] (30501704)	1.8	E
Batt curing oven with ESP[f] (30501704)	0.36	D
Blow chamber[c] (30501703)	6.0	E
Blow chamber with wire mesh filter[g] (30501703)	0.45	D
Cooler[e] (30501705)	1.2	E

[a] Factors represent uncontrolled emissions unless otherwise noted.

[b] Filterable PM is that PM collected on or prior to the filter of an EPA Method 5 (or equivalent) sampling train.

[c] References 1, 12. Activity level is assumed to be total feed charged.

[d] References 6, 7, 8, 10, and 11. Activity level is total feed charged.

[e] Reference 12.

[f] Reference 9.

[g] Reference 7. Activity level is mass of molten mineral feed charged.

TABLE 8.16-1. (ENGLISH UNITS)
EMISSION FACTORS FOR MINERAL WOOL MANUFACTURING[a]

All emission factors in lb/ton of product unless noted
Ratings (A-E) follow each emission factor

Process (SCC)	Filterable PM[b]	
Cupola[c] (30501701)	16	E
Cupola with fabric filter[d] (30501701)	0.10	D
Reverberatory furnace[e] (30501702)	4.8	E
Batt curing oven[e] (30501704)	3.6	E
Batt curing oven with ESP[f] (30501704)	0.72	D
Blow chamber[c] (30501703)	12	E
Blow chamber with wire mesh filter[g] (30501703)	0.91	D
Cooler[e] (30501705)	2.4	E

[a] Factors represent uncontrolled emissions unless otherwise noted.

[b] Filterable PM is that PM collected on or prior to the filter of an EPA Method 5 (or equivalent) sampling train.

[c] Reference 1, 12. Activity level is assumed to be total feed charged.

[d] References 6, 7, 8, 10, and 11. Activity level is total feed charged.

[e] Reference 12.

[f] Reference 9.

[g] Reference 7. Activity level is mass of molten mineral feed charged.

TABLE 8.16-2 (METRIC UNITS)
EMISSION FACTORS FOR MINERAL WOOL MANUFACTURING[a]

All emission factors in kg/Mg of total feed charged unless noted
Ratings (A-E) follow each emission factor

Source (SCC)	CO[b]		CO_2[b]		SO_2		SO_3	
Cupola (30501701)	125	D	260	D	4.0[c]	D	3.2[d]	E
Cupola with fabric filter (30501701)	NA		NA		NA		0.077[b]	E
Cupola with fabric filter (30501701)	NA		NA		NA		e	
Batt curing oven (30501704)	e		e		0.58[d]	E	e	
Blow chamber (30501703)	e		80[f]	E	0.43[d]	E	e	
Cooler (30501705)	e		e		0.034[d]	E	e	

NA = Not applicable.

[a] Factors represent uncontrolled emissions unless otherwise noted.

[b] Reference 6.

[c] References 6, 10, and 11.

[d] Reference 12.

[e] No data available.

[f] Reference 9.

TABLE 8.16-2 (ENGLISH UNITS)
EMISSION FACTORS FOR MINERAL WOOL MANUFACTURING[a]

All emission factors in lb/ton of total feed charged unless noted
Ratings (A-E) follow each emission factor

Source (SCC)	CO[b]		CO_2[b]		SO_2		SO_3	
Cupola (30501701)	250	D	520	D	8.0[a]	D	6.3[d]	E
Cupola with fabric filter (30501701)	NA		NA		NA		0.15[b]	E
Cupola with fabric filter (30501701)	NA		NA		NA		e	
Batt curing oven (30501704)					1.2[d]	E		
Blow chamber (30501703)			160[f]	E	0.087[d]	E		
Cooler (30501705)					0.068[d]	E		

NA = Not applicable.
[a] Factors represent uncontrolled emissions unless otherwise noted.
[b] Reference 6.
[c] References 6, 10, and 11.
[d] Reference 12.
[e] No data available.
[f] Reference 9.

TABLE 8.16-3 (METRIC UNITS)
EMISSION FACTORS FOR MINERAL WOOL MANUFACTURING[a]

All emission factors in kg/Mg of total feed charged unless noted
Ratings (A-E) follow each emission factor

Process (SCC)	NO_x		N_2O		H_2S		Fluorides	
Cupola (30501701)	0.8[b]	E	c		1.5[b]	E	c	
Cupola with fabric filter (30501701)	c		c		c		0.019[d]	D
Cupola with fabric filter (30501701)	c		c		c		0.19[e]	D
Batt curing oven (30501714)	c		0.079	E	c		c	

[a] Factors represent uncontrolled emissions unless otherwise noted.
[b] Reference 1.
[c] No data available.
[d] References 10 and 11. Coke only used as fuel.
[e] References 10 and 11. Fuel combination of coke and aluminum smelting byproducts.

TABLE 8.16-3 (ENGLISH UNITS)
EMISSION FACTORS FOR MINERAL WOOL MANUFACTURING[a]

All emission factors in lb/ton of total feed charged unless noted
Ratings (A-E) follow each emission factor

Process (SCC)	NO_x		N_2O		H_2S		Fluorides	
Cupola (30501701)	1.6[b]	E	c		3.0[b]	E	c	
Cupola with fabric filter (30501701)	c		c		c		0.038[d]	D
Cupola with fabric filter (30501701)	c		c		c		0.38[e]	D
Batt curing oven (30501714)	c		0.16	E	c		c	

[a] Factors represent uncontrolled emissions unless otherwise noted.
[b] Reference 1.
[c] No data available.
[d] References 10 and 11. Coke only used as fuel.
[e] References 10 and 11. Fuel combination of coke and aluminum smelting byproducts.

REFERENCES FOR SECTION 8.16

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5. Memorandum from K. Schuster, N.C. Department of Environmental Management, to M. Aldridge, American Rockwool, April 25, 1988.

6. Sulfur Oxide Emission Tests Conducted on the #1 and #2 Cupola Stacks in Leeds, Alabama for Rock Wool Company, November 8 & 9, 1988, Guardian Systems, Inc., Leeds, AL, Undated.

7. Particulate Emissions Tests for U.S. Gypsum Company on the Number 4 Dry Filter and Cupola Stack Located in Birmingham, Alabama on January 14, 1981, Guardian Systems, Inc., Birmingham, AL, Undated.

8. Untitled Test Report, Cupolas Nos. 1, 2, and 3, U.S. Gypsum, Birmingham, AL, June 1979.

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COMPARISON OF MINERAL WOOL MANUFACTURING EMISSION FACTORS IN AP-40 (1967) AND SOURCE CATEGORY SURVEY (1980)

Process	Pollutant	Uncontrolled emission factors in kg/Mg				
		AP-40		Source cat. survey		
		EF	No. tests	EF	No. tests	
cupola	PM	11	3	5.3	3	take ave
	SO2	5.6	1	5.3	10	"
	SO3	3.2	1			
	H2S			1.5	3	is it part of SO_2
	CO	45	1	78	9	average all
	NOx			0.8	6	use
Blowchamber	PM	8.6	4	0.8	2	
	SO2	0.58	1			
	VOC's			0.2	2	
	aldehydes	0.43	1			
Curing oven	PM	1.8	5			✓ use
	SO2	0.58	1			
	NO2	0.079	2			
	aldehydes	0.5	2			
Cooler	PM	1.2	4			
	SO2	0.034	1			
	aldehydes	0.021	1			

check with EMB SO_2 vs H_2S
can we convert H_2S to SO_2
SO_3 to SO_2

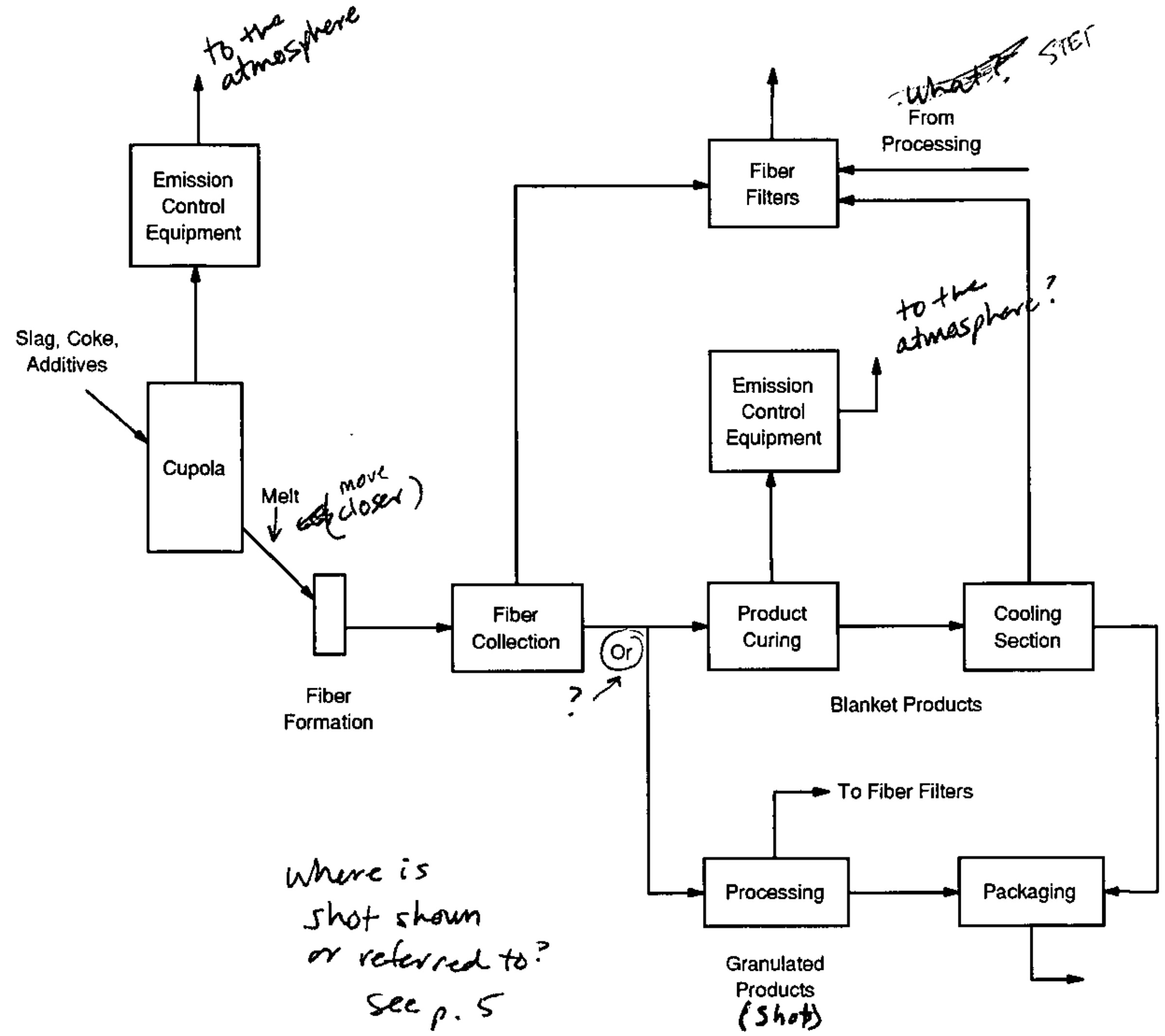
Compare with controlled (new data) &
see if realistic

MINERAL WOOL--CO2 BY FYRITE--SUMMARY OF EMISSION FACTORS

	Ref.	Run	CO2,	Volum. flow	Mass flux	Process rate	Emission factor,	
Process	No.	No.	%	rate, DSCFM	lb/hr	ton/hr	kg/Mg	lb/ton
Cupola	3	1	12	4,095	3,388	4.9	350	690
		2	11	4,138	3,138	4.9	320	640
		3	10	4,342	2,993	4.9	310	610
						Average	330	650
Cupola	4	1	6	5,460	2,258	5.4	210	420
		2	6	5,502	2,276	3.9	290	580
		3	4	5,664	1,562	5.4	150	290
						Average	220	430
		1	6.5	4,494	2,014	5.2	200	390
		2	4	4,535	1,251	4.9	130	260
		3	4	4,281	1,181	5.6	110	210
						Average	150	290
		1	7.5	4,093	2,116	5.4	200	390
		2	7.5	5,015	2,593	5.2	250	500
		3	8.1	4,377	2,444	5.2	240	470
						Average	230	450
Batt curing oven	5	1	0.5	8,942	308	2	80	150
		2	0.5	8,943	308	1.42	110	220
		3	0.5	8,779	303	2.79	60	110
						Average	80	160
Cupola	6	1	2	30,019	4,139	12.54	170	330
		2	1.5	38,947	4,028	12.54	160	320
		3	1.5	39,723	4,108	12.54	170	330
						Average	170	330
		1	1	35,997	2,482	12.48	100	200
		2	1	37,813	2,607	12.48	110	210
		3	1	35,985	2,481	12.48	100	200
		4	1.5	43,313	4,479	12.48	180	360
						Average	120	240
		1	1.5	38,129	3,943	11.52	170	340
		2	1	36,781	2,536	11.52	110	220
						Average	140	280
Cupola	7	1	2	48,160	6,640	13.09	260	510
		2	2	48,730	6,719	13.09	260	510
		3	2	45,790	6,314	13.09	240	480
						Average	250	500
		1	2	46,360	6,392	13.45	240	480
		2	2	45,870	6,325	13.45	240	470
		3	2	45,360	6,254	13.45	230	460
						Average	240	470

COMPARISON OF UNCONTROLLED MINERAL WOOL MANUFACTURING EMISSION FACTORS IN AP-40 (1967) AND SOURCE CATEGORY SURVEY (1980) WITH CONTROLLED EMISSION FACTORS DEVELOPED FROM EMISSION TESTS

		Uncontrolled emission factors in kg/Mg				Average		Controlled		Control
		AP-40		Source cat. survey		emission factor,		emission factors,		efficiency
Process	Pollutant	EF	No. tests	EF	No. tests	kg/Mg	lb/ton	APCD	kg/Mg	
cupola →	PM	11	3	5.3	3	8.2	16	fabric filter	0.051	0.994
x	SO2	5.6	1	5.3	10	5.3	11			
→	SO3	3.2	1			3.2	6.4	fabric filter	0.077	0.976
→	H2S			1.5	3	1.5	3.0			
x	CO	45	1	78	9	75	149			
→	NOx			0.8	6	0.8	1.6			
Blowchamber →	PM	8.6	4	0.8	2	6.0	12	dry filter	0.45	0.925
→	SO2	0.58	1			0.58	1.2			
x	VOC's			0.2	2	0.20	0.40			
x	aldehydes	0.43	1			0.43	0.86			
Curing oven →	PM	1.8	5			1.8	3.6	ESP	0.36	0.800
→	SO2	0.58	1			0.58	1.2			
→	NO2	0.079	2			0.079	0.16			
x	aldehydes	0.5	2			0.5	1			
Cooler →	PM	1.2	4			1.2	2.4			
→	SO2	0.034	1			0.034	0.068			
x	aldehydes	0.021	1			0.021	0.042			



Where is shot shown or referred to? see p. 5

Where is batt machining? cutting?

must be at least 11 pts, Times

Figure 2-1. Mineral Wool Manufacturing Process Flow Diagram.

COMPARISON OF EMISSION CONCENTRATIONS
MINERAL WOOL AP-42 REVISIONS

Section 4 refer. No.	Process	PM gr/dscf	SO2 PPM	CO	NOx	TVOC's PPM
2	cupola		0.86	7.8		
3	cupola	0.007				
3	blow cha	0.008				
4	cupola	0.011				
4	cupola	0.0094				
4	cupola	0.0093				
5	batt curin					
8	cupola+	0.018				6.26
8	cupola+	0.013				6.72
9	cupola+	0.025	0.278	5.78		
10	cupola+	0.014	16.17	10.7	0	0