Department of Environmental Protection

Twin Towers Office Building
2600 Blair Stone Road
Tallahassee, Florida 32399-2400

Lawton Chiles
Governor

Virginia B. Wetherell
Secretary

October 17, 1996

CERTIFIED MAIL - RETURN RECEIPT REQUESTED

Mr. Steven J. Susick
General Manager
U.S. Agri-Chemicals Corporation
3225 State Road 630 West
Ft. Meade, Florida 33841-9799

Re: Prilled Monoammonium Phosphate Plant - Ft. Meade
Permit No. AC53-260190 (PSD-FL-222)

Dear Mr. Susick:

The Department has reviewed the various submittals regarding the air pollution control equipment to be used at the new prilled MAP plant.

The IMC data appear to a logical basis for setting a final fluoride emission limit. We recommend a limit of 0.019 lb F/ton P_2O_5 and intend to modify your construction permit accordingly. We can provide USAC a 12 month period to test and take subsequent measures (if necessary) to install additional or different control equipment (such as that previously specified by the Department) in order to meet our proposed limit.

Attached is a review of the most recent submittal sent to us on behalf of USAC.

Sincerely,

C. H. Fancy, Chief
Bureau of Air Regulation

CHF/chf/l

cc: Brian Beals, EPA
John Bunyak, NPS
Al Linero, BAR
Bill Thomas, SWD
John Koogler, K&A

P 339 251 171

US Postal Service

Receipt for Certified Mail

No Insurance Coverage Provided.
Do not use for International Mail *(See reverse)*

Sent to Steven Susick	
Street & Number US Agri-Chem	
Post Office, State, & ZIP Code Ft. Meade, Fl	
Postage	$
Certified Fee	
Special Delivery Fee	
Restricted Delivery Fee	
Return Receipt Showing to Whom & Date Delivered	
Return Receipt Showing to Whom, Date, & Addressee's Address	
TOTAL Postage & Fees	$
Postmark or Date 10-18-96 PSD-Fl-222	

PS Form **3800**, April 1995

Fold at line over top of envelope to the right of the return address

Is your RETURN ADDRESS completed on the reverse side?

SENDER:
- Complete items 1 and/or 2 for additional services.
- Complete items 3, and 4a & b.
- Print your name and address on the reverse of this form so that we can return this card to you.
- Attach this form to the front of the mailpiece, or on the back if space does not permit.
- Write "Return Receipt Requested" on the mailpiece below the article number.
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I also wish to receive the following services (for an extra fee):
1. ☐ Addressee's Address
2. ☐ Restricted Delivery

Consult postmaster for fee.

3. Article Addressed to:
Steven Susick, Gen. Mgr
US Agri-Chemicals, Corp.
3225 State Rd 630 West
Ft. Meade, Fl 33841-9799

4a. Article Number
P 339 251 171

4b. Service Type
☐ Registered ☐ Insured
☒ Certified ☐ COD
☐ Express Mail ☐ Return Receipt for Merchandise

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10-22-96

5. Signature (Addressee)
[signature]

6. Signature (Agent)

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PS Form **3811**, December 1991 ☆U.S. GPO: 1993—352-714 **DOMESTIC RETURN RECEIPT**

Thank you for using Return Receipt Service.

EVALUATION OF INFORMATION SUBMITTED
BY US AGRI-CHEMICALS, INC.
ON OCTOBER 1, 1996

This is an evaluation of the information presented in the September 26 and October 1, 1996 letters from Koogler & Associates and Jacobs Engineering Group, Inc., concerning PSD-FL-222 for the US Agri-Chemicals (USAC) Prilled MAP Plant. Before addressing the details of USAC's latest submittals, a review of the history of this permit is summarized below.

Rather than proposing a conventional scrubbing system where the gas is contacted with relatively clean pond water, USAC sought approval for a venturi scrubber that uses a recirculated scrubbing medium for product recovery reasons. USAC's proposal was to use a high-solids, environmentally inferior, recirculated scrubbing slurry (up to 15% P2O5), part of which could be recycled to the prill tower. This hot slurry (122 F.) would result in a higher fluoride content in the gas compared to pond water, since it is well known that temperature has a far greater effect on fluoride emissions than concentration. The Department found that this would not be acceptable for best available control technology (BACT) and issued a BACT determination requiring neutralization of the scrubber water and a dedicated pond for cooling and settling of solids (USAC proposed the pond in their application).

Due to the limited emission test data available for this type of plant, the Department issued a permit to USAC requiring that limits be established following completion of the compliance tests, <u>as long as USAC followed the BACT requirements</u>. USAC accepted the permit and its conditions, then submitted engineering calculations claiming that the venturi with its high-solids scrubbing water will provide gaseous fluoride removal equivalent to that of a packed scrubber using once-through pond water.

The Department responded on July 3 taking issue with USAC's claim of equivalent results. Our analysis was based in part on a technical paper we enclosed showing that about 3.5 mass transfer units (vs. USAC's 5.3) would be the most that could reasonably be expected for a venturi removing fluorides using neutralized pond water. On September 26, Jacobs Engineering sent a letter to USAC claiming 6.0 transfer units for their high-solids scrubbing water. This was based on their analysis of data in the article which was obtained using neutralized scrubbing water.

The Department cannot agree with these latest calculations submitted by Jacobs. The extrapolated curve that Jacobs drew on Figure 5 of the article is not relevant for their unneutralized scrubbing slurry. Secondly, the data in Figure 5 cannot be infinitely extrapolated at constant L/G because the short contact time in the venturi throat prevents the mass transfer from increasing beyond a certain gas velocity.

Attached is an extrapolation performed on Figure 6 which shows the variation of transfer units with the same variables as in Figure 5 but with pressure drop added. As shown, a maximum of 4.0 transfer units is obtained for the conditions specified by Jacobs, again keeping in mind that this is applicable only for neutralized water. The highest actual test result reported in the article was 3.6 NTU with neutralized water, therefore, the Department's 2.7 NTU estimate is reasonable for the high-solids scrubbing slurry Jacobs has proposed.

The limitations on gas/liquid mass transfer in a venturi scrubber result primarily from the short contact time. Since the time is so short, there is a point beyond which mass transfer will not increase as additional transfer area is created by the smaller liquid drops formed with increased pressure drop. Consequently, transfer unit values cannot be extrapolated as Jacobs attempted.

To further substantiate the Department's analysis, attached is a copy of Dr. Aaron J. Teller's October 4 letter describing what would be required to achieve greater than 3.5 NTU. As he states, a throat velocity of 400 ft/s (122 m/s vs. Jacobs' 74 m/s), L/G of 12 gpm/1000 cfm (1.60 m3/1000 m3 vs. Jacobs' 1.23 m3/1000 m3), and pressure drop of 130 in.wc (3300 mm.wc vs. Jacobs' 483 mm.wc), would be required to achieve 4.2-5.2 NTU. The energy consumption required would be about 6-7 times higher than the Jacobs design calls for.

Conclusion:

Jacobs' venturi design will not accomplish the fluoride removal that they have represented to the Department. Therefore, the USAC proposal is not representative of BACT for fluorides. The final emission limits for the MAP prill tower and cooler should be the same as proposed in the Department's July 3 letter.

John Reynolds 10-17-96

John Reynolds, Permit Engineer
New Source Review Section
Bureau of Air Regulation
Department of Environmental Protection

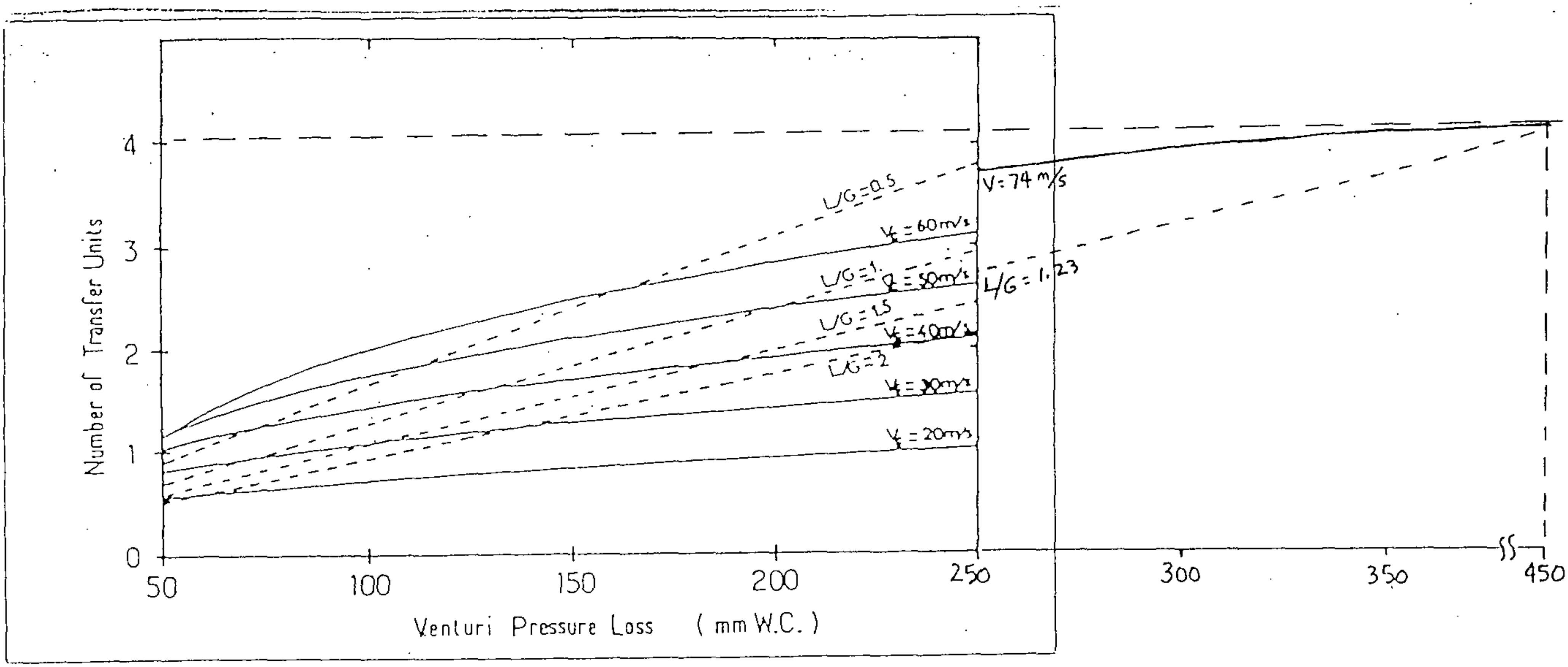

Figure 6. NTU vs. pressure loss. L/G and V_c are taken as parameters. T_{GE} = 60°C and Lv/Dc = 8.5.

DR. AARON J. TELLER
47 ST. JAMES DRIVE
PALM BEACH GARDENS, FL 33418

4 Oct 1996

RECEIVED
OCT 11 1996
BUREAU OF
AIR REGULATION

Mr. John Reynolds
Dept of Environmental Protection
Twin Towers Office Bldg
2600 Blair Stone Rd.
Tallahassee, FL 32399-2400

Dr. Mr. Reynolds,

It was indicated that a claim for achievement of 5.3 Transfer units was made for a fluoride scrubbing process using a venturi.

It should be noted that the venturi is inherently a particulate collection device and is used only as a scrubber of last resort. The reason is that the mass transfer is limited because of minimal surface renewal. The deficiency can be overcome by decreasing the particle size of the spray and increasing the L/G, provided cost of operation is not restrictive.

Inasmuch as a venturi is generally followed by a cyclone separator, an additional transfer unit can be attained due to wetted wall action.

A comparison of performance of venturi-cyclone systems is attached (Table I). As noted, the rational range of operation will provide in the region of 3.5 transfer units. The 5 transfer unit range can be achieved if the client will accept an energy consumption of 370 HP/1000 CFM.

Sincerely
[signature]

TABLE I

VENTURI - CYCLONE SEPARATOR PERFORMANCE

SYSTEM	THROAT VEL, FPS	L/G GAL/1000CFM	ΔP in w.g.	HP - GAS + LIQ / 1000 CFM	NTU Transfer UNITS
VENTURI - CYCLONE	140	12	16	45	2.2 - 2.6
VENTURI - CYCLONE	250	12	50	150	3.2 - 4.0
VENTURI - CYCLONE	400	12	130	370	4.2 - 5.2

DR. AARON J. TELLER
47 ST. JAMES DRIVE
PALM BEACH GARDENS, FL 33418

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Sincerely
AJT

DR. AARON J. TELLER
47 ST. JAMES DRIVE
PALM BEACH GARDENS, FL 33418

PM
8 OCT
1996

USA 32

Mr. John Reynolds
Dep't of Environmental Protection
Twin Towers Office Bldg.
2600 Blair Stone Rd.
Tallahassee, FL 32399-2400

32399/6364

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VENTURI - CYCLONE	250	12	50	150	3.2 - 4.0
VENTURI - CYCLONE	400	12	130	370	4.2 - 5.2

Acct. No. ____ Page ____ of ____
Comptd. By ____ Date ____
Ck'd. By ____ Date ____

KOOGLER & ASSOCIATES
ENVIRONMENTAL SERVICES
4014 NW THIRTEENTH STREET
GAINESVILLE, FLORIDA 32609
904/377-5822 • FAX 377-7158

KA 173-94-04

October 1, 1996

Mr. A. A. Linero
Florida Department of
Environmental Protection
Twin Towers Office Building
2600 Blair Stone Road
Tallahassee, Florida 32399-2400

Subject: USAC Powdered MAP Plant
AC53-260190 (PSD-FL-222)

Dear Mr. Linero:

On behalf of U.S. Agri-Chemicals, Inc. (USAC), I am forwarding under cover of this letter final drawings and additional information to describe the performance of the venturi scrubber/cyclonic separator that USAC is proposing to control fluoride (gaseous and particulate) and particulate matter emissions from a powdered MAP plant. Based upon information developed by the Jacobs Engineering Group, Inc. (Jacobs) using the reference in the November 1978 issue of Chemical Engineering Progress (*Absorbing Fluorine Compounds from Waste Gases*, C. Djololian and D. Billaud, Rhone-Poulenc, Paris, France) provided by FDEP, the scrubber system proposed by USAC will achieve six or more transfer units. This is the number of transfer units typically required to achieve acceptable fluoride emission rates from a phosphoric acid plant.

During the May 21, 1996, meeting between the Department and USAC, scrubber performance based on NTUs rather than on efficiency of fluoride removal was agreed to. This matter was discussed as a scrubber with about six NTUs operating on a phosphoric acid plant can achieve a fluoride removal efficiency in the range of 99+ percent and Jacobs explained that the MAP plant venturi cyclonic scrubber would achieve an NTU comparable to this. Based upon supporting documentation being provided to FDEP, USAC would be allowed to construct the scrubbing system and conduct tests to demonstrate the performance of the system. Based on these tests, a permittable emission rate for the plant would be established.

As stated previously, Jacobs, using the reference provided by FDEP, has determined that the venturi scrubber/cyclonic separator system proposed for the USAC powdered MAP plant can achieve six NTUs and is therefore equivalent to the performance achieved by scrubbing systems permitted for phosphoric acid plants.

With your approval, I will proceed with the development of a protocol that can be used to establish a permittable fluoride (gaseous plus particulate) emission rate for the plant once the plant is operating.

Regarding particulate matter emission limits, USAC concurs with the limit of 24.0 lb/hr of particulate matter from the spray tower/cooler system as stated in the Department's July 3, 1996, letter. Based on applicable Department standards, the opacity limit for this system should be 20 percent.

I appreciate your review of this information and look forward to a final resolution of this matter. If you have any questions, please give me a call or contact Bryan Blythe of Jacobs at 941-665-1511.

Very truly yours,

KOOGLER & ASSOCIATES

John B. Koogler, Ph.D., P.E.

JBK:wa
Enc.

cc: J. Reynolds

KOOGLER & ASSOCIATES

JE JACOBS ENGINEERING GROUP INC.

POST OFFICE BOX 2008 • LAKELAND, FL 33806-2008 • HIGHWAY 98S AT STATE ROAD 540 • LAKELAND, FL 33813-9763
TELEPHONE (941) 665-1511 • FAX (941) 665-5323

September 26, 1996

Mr. Steven J. Susick, P.E.
U.S. Agri-Chemicals Corporation
3225 State Road 630 West
Fort Meade, FL 33841-9799

Fax No: ***285-9779***

Subject: **USAC Prilled MAP Plant**
Particulate and Fluoride Emissions

Dear Mr. Susick:

As you requested, I have reviewed the July 3, 1996, letter from A.A. Linero concerning emissions from your prilled MAP plant. The following comments are relevant:-

<u>Rhone-Poulenc Article</u>

Rhone-Poulenc was a major fertilizer producer in Europe in the 1970's when this article was written and they also licensed their fertilizer plant technology for plants built throughout the world. Jacobs has competed against Rhone-Poulenc for international fertilizer projects on several occasions. I believe they sold their fertilizer licensing technology to Spechim in the 1990's. Rhone-Poulenc may be considered skilled in the art of fertilizer technology and we are, indeed, indebted to the Florida Department of Environmental Protection for providing this authoritative reference which was also used by the vendor in the design of the scrubber.

However, we do not agree with the Florida Department of Environmental Protection's conclusion, drawn from this article, that the venturi cyclonic scrubber on the MAP spray tower effluent will achieve only about half of the 5.3 transfer units. We also believe that percentage approach to equilibrium concentration is no better a yard stick for scrubber evaluation than the original percentage removal approach used by the department.

Figure 5 of this article shows the number of transfer units at five for a throat velocity of 60 meters per second and a liquid to gas ratio ($m^3/1{,}000m^3$) of 1.9. Our specification (attached) shows a pressure drop of 19 inches of water, an irrigation rate of 900 gpm and a gas flow of 97,626 acfm.

Using Figure 3 and Figure 5 of this article, these data correspond to a gas velocity in the throat of 74.5 meters per second, a liquid to gas ratio of 1.23 and six transfer units. This corresponds to an approach to equilibrium at 1.7% of the equilibrium vapor concentration

Our calculations of the number of transfer units for the spray tower venturi cyclonic scrubber, based upon the Rhone-Poulenc article provided by the Florida Department of Environmental Protection, are attached in Exhibit 1.

<u>Particulate</u>

The letter of July 3, 1996, concludes that the venturi cyclonic scrubber will pass 52 pounds per hour of particulate, or .87 pounds per ton of MAP product and uses this as a basis for the further calculations that the addition of a second scrubber will reduce the particulate emission to 27.86 pounds per hour of particulate. Our warranty from the scrubber vendor, D R Technologies, corresponds to an emission rate of 0.4 pounds per ton of MAP product which also corresponds with the requested permitted level.

The following two facts are well known:-

- The efficiency of a venturi cyclonic scrubber to remove particulate falls as the pressure drop across the unit is reduced.
- Packed Towers are ineffective in removing fine particulate and aerosol mists

As IMC has already certified that "The MAP plant's fluoride emissions tested lower after replacement of the original two-stage venturi/packed scrubber with a low energy venturi cyclonic unit", and this supports the conclusions of my letter of June 4, no further comment will be made on the FDEP's particulate analysis at this time.

If you have any questions on the data presented here, please call.

Yours sincerely,

JACOBS ENGINEERING GROUP INC.

Bryan M. Blythe
Technical Center Director

BMB:ree

Attachments

Exhibit 1

Rhone-Poulenc Article CEP November 1978

Liquid Rate $L = 900$ gpm or $\frac{900x60}{7.48x35.316}$ = 204.4 m^3/Hr

Gas Rate $G = 97626$ acfm or $\frac{97626x60}{35.316}$ = 165861 m^3/Hr

Pressure Drop $\Delta P = 19$ inches WG or $\frac{19x62.43x3.28^2}{12x2.20462}$ = 482 Kg/m^2

Gravitational Acceleration g_c = 9.817 m/sec^2

Gas Density $\rho_g = 0.0585$ lb/cuft or $\frac{0.0585x35.316}{2.20462}$ = 0.937 Kg/m^3

Volume Ratio L/G= 204.4/165.861 = 1.232

from Figure 3 - Pressure Loss Factor C = 1.833

i.e. $C = \frac{\Delta P x 2 x g_c}{\rho_g x V_G^2}$ or $V_G^2 = \frac{\Delta P x 2 x g_c}{\rho_g x C}$

$V_G^2 = \frac{482x2x9.817}{0.937x1.833}$ $V_G^2 = 5510$ V_G = 74.2 m/sec

from Figure 5 - Number of transfer Units = 6.0

Notes:

1) Spray Tower Venturi Flow Area is 6.65 ft^2 equivalent to 890mm throat diameter. Top curve used in Figure 3 to give most conservative calculation of transfer units.

2) V_G linearly extrapolated - regression would give higher value for Number of Transfer Units

3) This calculation is for the Number of Transfer Units achieved by the Venturi. Sprays in the throat and the cyclonic separator will also contribute to mass transfer.

4) Approach to equilibrium as a percentage of equilibrium concentration. - Using the calculation previously submitted to FDER - Where y_1 and y_2 are inlet and outlet concentrations of fluorine and y* is the equilibrium concentration.

$$NTU = 6.0 = \ln \frac{(y_1 - y^*)}{(y_2 - y^*)} = \ln \frac{(23 - 2.9)}{(y_2 - 2.9)}: \quad (y_2 - y^*) = 2.95 \quad \frac{(y_2 - y^*)}{y^*} = 1.7\%$$

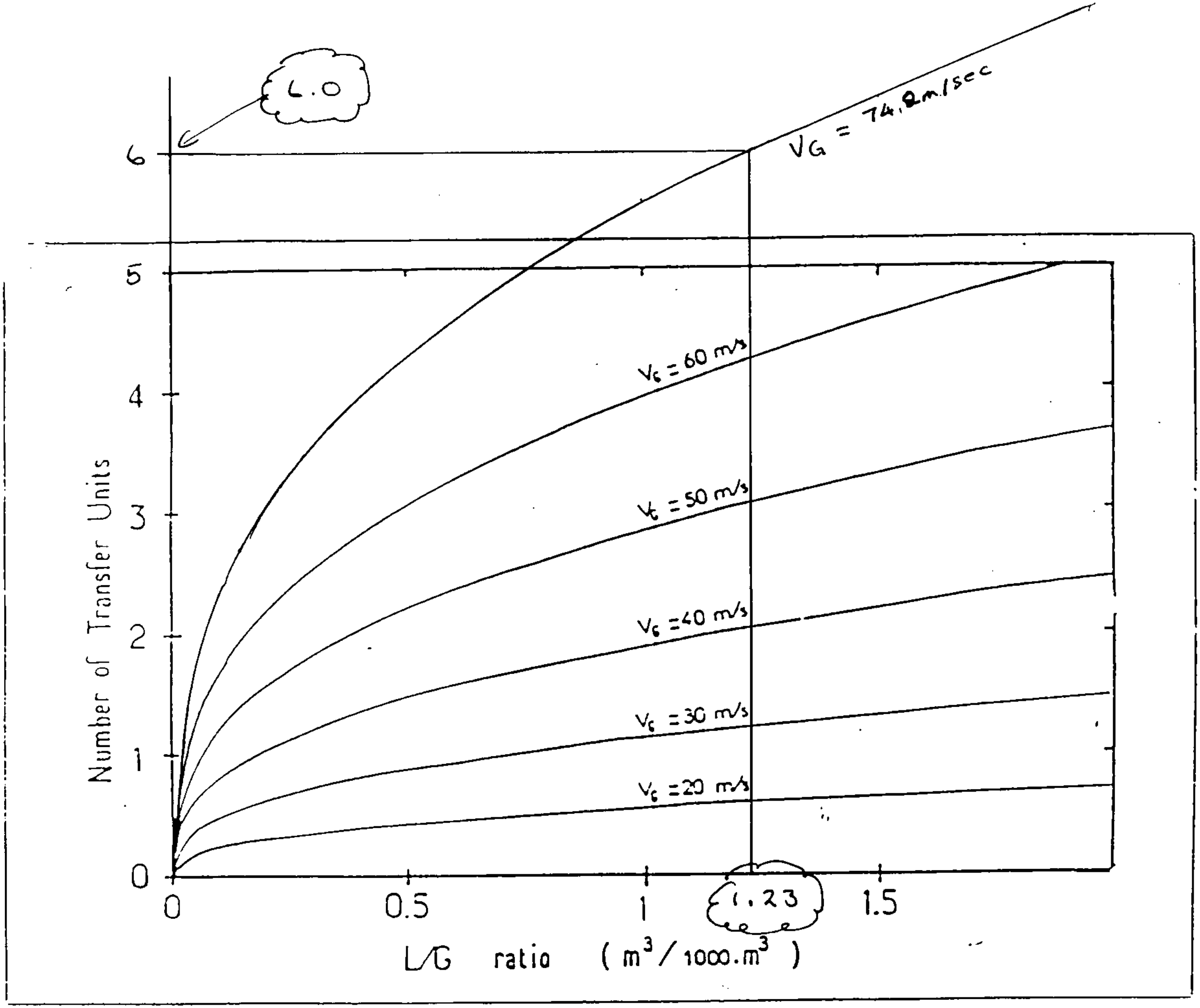


Figure 5. Variation of NTU with L/G ratio and V_G calculated from the empirical law. Using $T_{..}$ = 60°C and saturated gases; Lv/Dc = 8.5.

(subscript 2):

$$\Delta P = (\rho_{G_1} V_{G_1}^2/2g)\cdot C_1 + (\rho_{G_2} V_{G_2}^2/2g)\cdot C_2 \quad (1)$$

A stepwise correlation method, to keep the essential controlled variables, has been used and is based on the prin-

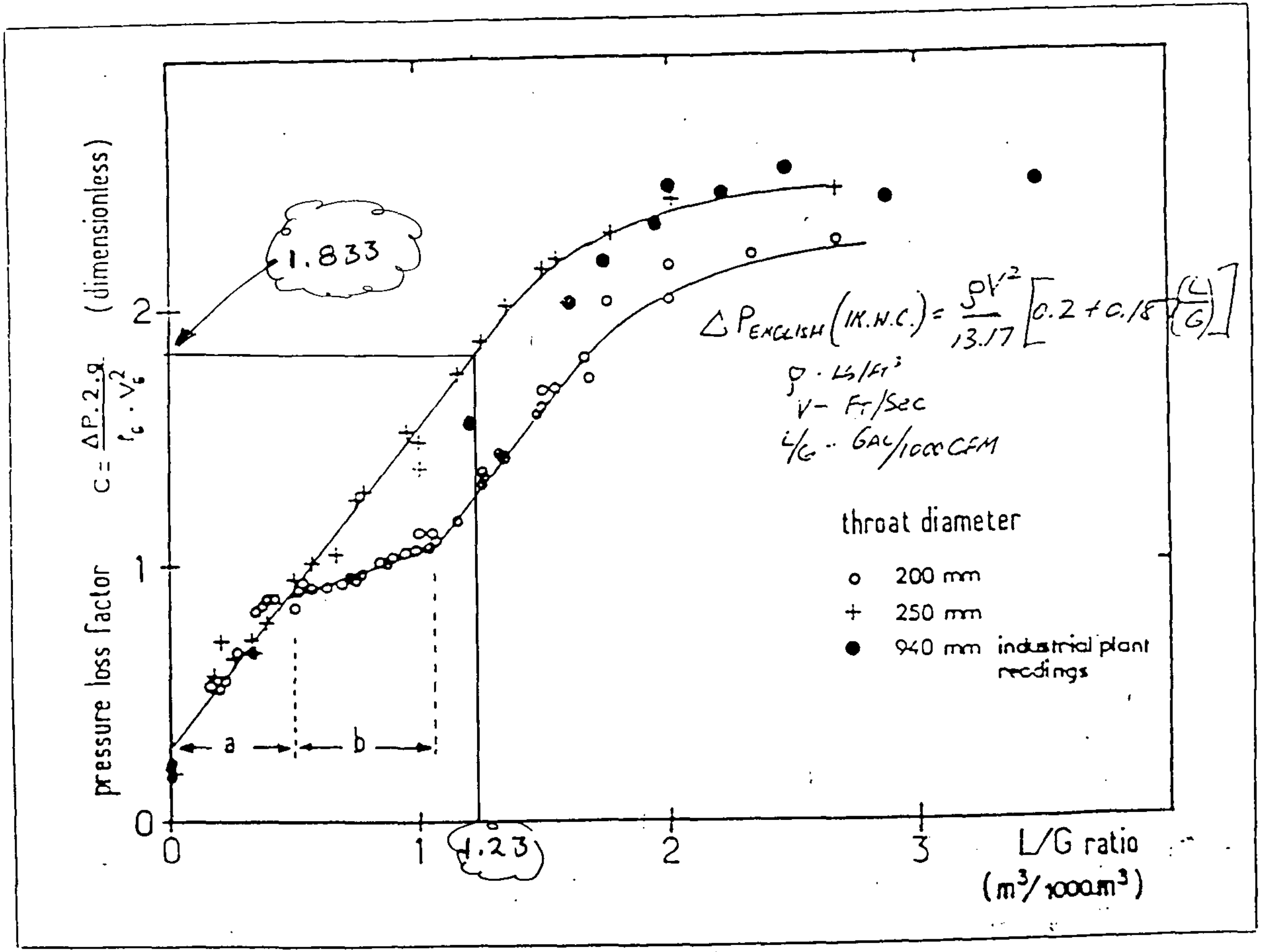


Figure 3. Pressure loss factor vs. L/G ratio.

JE **JACOBS ENGINEERING GROUP INC.**

SCRUBBER DATA SHEET

PROJECT No. 28-J697-00 ITEM No. 10.110

SPECIFICATION No. 10000-2

FOR	*US Agri-Chemicals*	SERVICE	*MAP spray tower scrubber*
SITE	*Fort Meade, Florida*	MANUFACTURER	*D.R. Technology* /0\
NUMBER REQUIRED	*1*	TYPE	*Adjustable throat venturi*

DESIGN: [X] API 650 [ ] PS 15-69 [ ] ASTM D3299 [ ] OTHER

OPERATING CONDITIONS

		INLET	OUTLET
GAS HANDLED	*Moist air containing MAP dust and traces of fluorine*		
FLOW	lb/hr	*342,557*	*see note 1*
	SCFM	*79,977*	
	ft3/min @ T,P	*97,626*	*95300*
PRESSURE	psig (in WATER)	*(-1)*	*(-20)*
TEMPERATURE	°F	*185*	*126* /0\
DENSITY	lb/ft3	*0.0585*	*0.062*
MOLECULAR WEIGHT			
HUMIDITY	lb WATER/lb DRY GAS	*0.0909*	
PARTICULATE LOADING *see note 2*	gr/ft3 (stp)	*0.572*	
PARTICULATE COMPOSTION	% WT.	*100% MAP (10-50-0) with 2.1% F*	
FLUORINE LOADING Gaseous/Total	gr/ft3 (stp)	*0.0055/0.0179*	
SCRUBBING LIQUID		/0\ *MAP Solution*	
FLOW	gals/min @ FT	*900*	7.4 ... 1000 ...
FEED TEMPERATURE	°F	*122*	
SPECIFIC GRAVITY @ FT		*1.1 - 1.2*	
VISCOSITY @ FT	cP	*1-2*	
COMPOSITION	by WT.	*5-15% P2O5*	
		1500 ppm F	

PERFORMANCE

PARTICULATE REMOVAL	*96.9%*	GAS TURNDOWN RATIO	
FLUORINE REMOVAL	*94.75%* /0\		

DESIGN AND CONSTRUCTION

OPERATING PRESSURE /0\ *(-20)* psig (in WATER) @ *185 °F*

DESIGN PRESSURE (INTERNAL) *(-25)* psig (in WATER) @ *185 °F*

(EXTERNAL) *14.7* psia (in WATER) @ *185 °F*

CORROSION ALLOWANCE: SHELL *None* HEADS *None* INTERNALS *None*

[ ] STRESS RELIEVE [ ] X-RAY

WIND LOAD: UBC MAP AREA

SEISMIC ZONE:

FIREPROOFING: THICKNESS *None*

INSULATION: THICKNESS *None*

SURFACE PREPARATION SPECIFICATION *Carbon Steel Surfaces**

PAINTING SPECIFICATION *Carbon Steel Surfaces**

FAB WT *4250 lb.* /0\ OPERATING WT * TEST WT

REMARKS: * INDICATES INFORMATION TO BE FURNISHED/CONFIRMED BY VENDOR

Note 1. Scrubber outlet discharges into Cyclonic Separator item no. 10.130

Note 2. Particulates size are 99% > 1 micron

REV/DATE	A / 6/22/95	B / 7/14/95	C / 11/14/9	0 / 1/29/96	
PREP/DATE	DMI / 6/22/95	DMI / 7/14/95	JME / 11/14/9	JME / 1/16/96	
CHK'D/DATE	DRK / 6/30/95	/	DMI / 11/14/9	FHE / 1/29/96	
APP'D/DATE	/	/	/	/	
APP'D/DATE	/	/	/	/	

SCRUBBER DATA SHEET

PROJECT No. 28-J697-00 ITEM No. 10.110

SPECIFICATION No. 10000-2

FOR *US Agri-Chemicals* SERVICE *MAP spray tower scrubber*

SITE *Fort Meade, Florida* MANUFACTURER *D-R Technology*

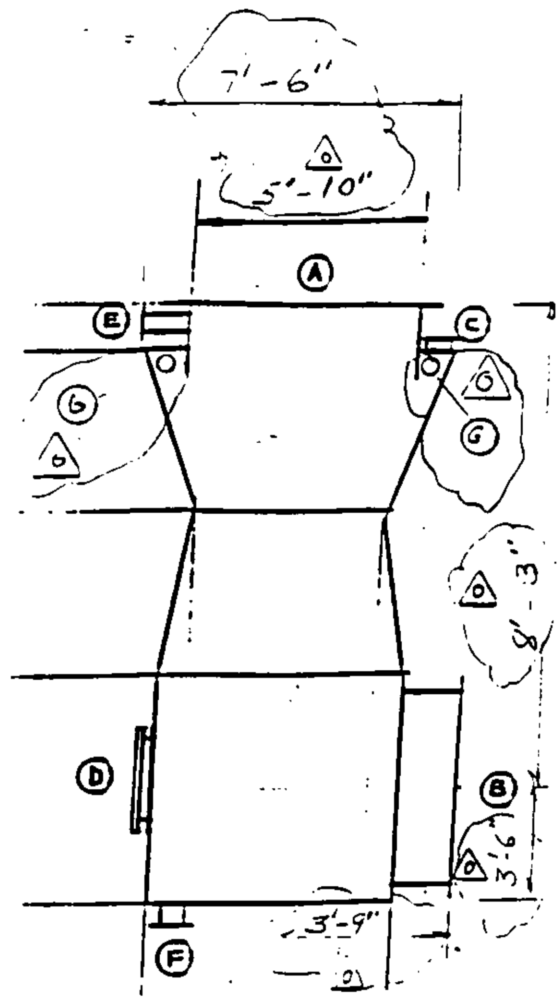
DESIGN AND CONSTRUCTION

PART	MATERIAL	DESCRIPTION
SHELL	*316 L SS*	*See Remarks*
HEADS		☐ SEMIELLIP ☐ DISHED
LINING	*None*	
MANHOLES	*316 L SS*	X HINGE ☐ DAVIT
NOZZLES	*316 L SS*	*See Remarks*
COUPLINGS		
INTERNALS	*316 L SS*	*See Remarks*
CLIPS		
LUGS		
RINGS		☐ INSULATION
DAVIT		LOADING

NOZZLES

MARK	SERVICE	QTY	SIZE	RATING	FACING
A	*Gas Inlet*	*1*	*70"*		
B	*Gas Outlet*	*1*	*54"x68"*		
C	*Inspection hatches*	*4*	*4"x6"*		
D	*Manway*	*1*	*24"*		
E	*Liquor In*	*1*	*6"*		
F	*Drain*	*1*	*4"*		
G	*Liquor In (tangential)*	*4*	*2"*		

△0



REMARKS: * INDICATES INFORMATION TO BE FURNISHED BY VENDOR

1. Minimum plate thickness 3/16". △0

REV/DATE	A / 6/22/95	C / 11/14/9	0 / 11-29-96	/	
PREP/DATE	DMI / 6/22/95	JME / 11/10/9	JTE / 11-19-96	/	
CHK'D/DAT	DRK / 6/30/95	DMI / 11/14/9	EAK / 11-29-96	/	
APP'D/DATE	/	/	/	/	
APP'D/DATE	/	/	/	/	

SCRUBBER DATA SHEET

PROJECT No. 28-J697-00 ITEM No. 10. 120
SPECIFICATION No. 10000-2

FOR	US Agri-Chemicals	SERVICE	Cooler scrubber
SITE	Fort Meade, Florida	MANUFACTURER	D.R. Technology
NUMBER REQUIRED	1	TYPE	Adjustable throat venturi
DESIGN:	[X] API 650 [ ] PS 15-69 [ ] ASTM D3299 [ ] OTHER		

OPERATING CONDITIONS

		INLET	OUTLET
GAS HANDLED	Moist air containing MAP dust		
FLOW	lb/hr	103,407 max	see note 1
	SCFM	23,231 max	
	ft3/min @ T,P	27,999 max	26700
PRESSURE	psig (in WATER)	(-5)	(-17)
TEMPERATURE	°F	171	97
DENSITY	lb/ft3	0.0616	0.067
MOLECULAR WEIGHT			
HUMIDITY	lb WATER/lb DRY GAS	0.020	
PARTICULATE LOADING see note 2	gr/ft3 (stp)	0.850	
PARTICULATE COMPOSTION	% WT.	100% MAP (10-50-0) with 2.1 % F	
FLUORINE LOADING Gaseous/Total	gr/ft3 (stp)	traces/0.018	
SCRUBBING LIQUID			MAP Solution
FLOW	gals/min @ FT	265	193 [illegible]
FEED TEMPERATURE	°F	121	
SPECIFIC GRAVITY @ FT		1.1 - 1.2	
VISCOSITY @ FT	cP	1-2	
COMPOSITION	by% WT.	5-15% P2O5	
		1500 ppm F	

PERFORMANCE

PARTICULATE REMOVAL	97.92%	GAS TURNDOWN RATIO	
FLUORINE REMOVAL	94.78%		

DESIGN AND CONSTRUCTION

OPERATING PRESSURE (-17) psig (in WATER) @ 171°F
DESIGN PRESSURE (INTERNAL) (-23) psig (in WATER) @ 180 °F
(EXTERNAL) 14.7 psia (in WATER) @ 180 °F
CORROSION ALLOWANCE: SHELL None HEADS None INTERNALS None
[ ] STRESS RELIEVE [ ] X-RAY
WIND LOAD: UBC MAP AREA
SEISMIC ZONE:
FIREPROOFING: THICKNESS None
INSULATION: THICKNESS None
SURFACE PREPARATION SPECIFICATION Carbon Steel Surfaces*
PAINTING SPECIFICATION Carbon Steel Surfaces*

FAB WT 2300 lb. OPERATING WT * TEST WT

REMARKS: * INDICATES INFORMATION TO BE FURNISHED/CONFIRMED BY VENDOR
Note 1. Scrubber outlet discharges into Cyclonic Separator item no.10.130
Note 2. Particulates size are 99% > 1 micron.

REV/DATE	A / 6/22/95	B / 11/14/9	0 / 1-29-96	/	
PREP/DATE	DMI / 6/22/95	JME / 11/14/9	JME / 1/14/96	/	
CHK'D/DATE	DRK / 6/30/95	DMI / 11/14/9	[illegible] / 1-29-96	/	
APP'D/DATE	/	/	/	/	
APP'D/DATE	/	/	/	/	

JE JACOBS ENGINEERING GROUP INC.

SCRUBBER DATA SHEET

PROJECT No. 28-J697-00 ITEM No. 10. 120

SPECIFICATION No. 10000-2

FOR *US Agri-Chemicals* SERVICE *Cooler scrubber*

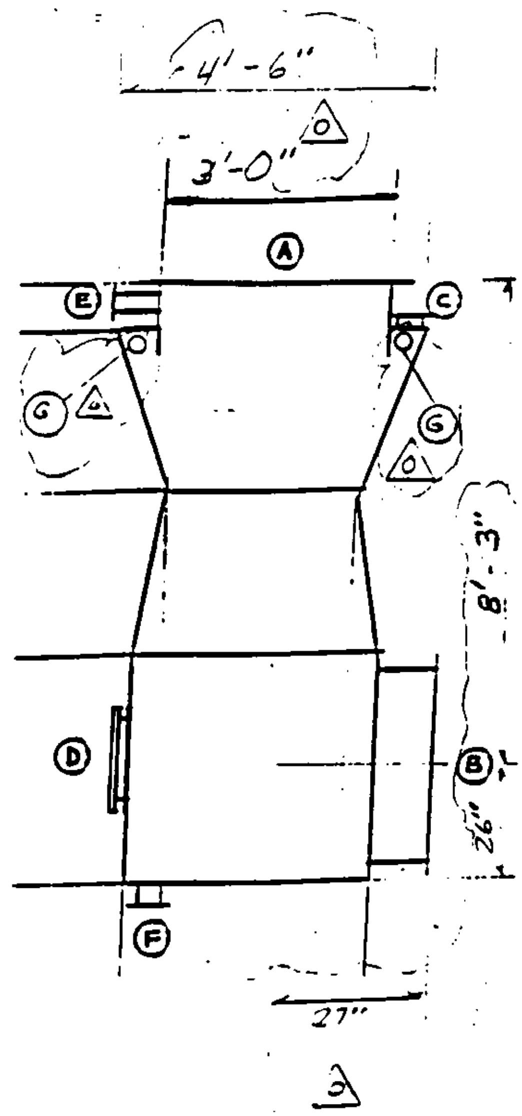
SITE *Fort Meade, Florida* MANUFACTURER *D.R Technology*

DESIGN AND CONSTRUCTION

PART	MATERIAL	DESCRIPTION
SHELL	*316 L SS*	*See Remarks*
HEADS		☐ SEMIELLIP ☐ DISHED
LINING	*None*	
MANHOLES	*316 L SS*	☒ HINGE ☐ DAVIT
NOZZLES	*316 L SS*	*See Remarks*
COUPLINGS		
INTERNALS	*316 L SS*	*See Remarks*
CLIPS		
LUGS		
RINGS		☐ INSULATION
DAVIT		LOADING

NOZZLES

MARK	SERVICE	QTY	SIZE	RATING	FACING
A	Gas Inlet	1	36"		
B	Gas Outlet	1	30"x36"		
C	Inspection hatches	4	4"x6"		
D	Manway	1	24"		
E	Liquor In	1	3"		
F	Drain	1	4"		
G	Liquor In (tangential)	4	1"		



REMARKS: * INDICATES INFORMATION TO BE FURNISHED BY VENDOR

1. Minimum plate thickness 3/16".

REV/DATE	A / 6/22/95	B / 11/14/9	/ 11-22-96	/
PREP/DATE	DMI / 6/22/95	JME / 11/10/9	JME / 11-19-96	/
CHK'D/DAT	DRK / 6/30/95	DMI / 11/14/9	AH / 11-20-96	/
APP'D/DATE	/	/	/	/
APP'D/DATE	/	/	/	/

10120A

JE | JACOBS ENGIN_ERING GROUP INC.

SCRUBBER DATA SHEET

PROJECT No. 28-J697-00 ITEM No. 10. 130
SPECIFICATION No. 23031-1

FOR	*US Agri-Chemicals*	SERVICE	*Cyclonic Separator*
SITE	*Fort Meade, Florida*	MANUFACTURER	*D.R. Technology* △0
NUMBER REQUIRED	*1*	TYPE	*Cyclonic*
DESIGN: [X] API 650	[ ] PS 15-69	[ ] ASTM D3299	[ ] OTHER

OPERATING CONDITIONS

			INLET	OUTLET
GAS HANDLED	*Saturated air containing traces of MAP dust and fluorine*			
FLOW		lb/hr	see note 1	*451,364*
		SCFM		*105,357*
		ft3/min @ T,P		*123,739*
PRESSURE		psig (in WATER)		△0 *(-25)*
TEMPERATURE		°F		*125*
DENSITY		lb/ft3		*0.0608*
MOLECULAR WEIGHT				
HUMIDITY		lb WATER/lb DRY GAS		*0.088*
PARTICULATE LOADING		gr/ft3 (stp)		*<0.0177*
PARTICULATE COMPOSTION		% WT.	*100% MAP (10-50-0) with 2.1% F*	
FLUORINE LOADING	Total	gr/ft3 (stp)		*<0.00094*
SCRUBBING LIQUID	*see note 2*		*MAP Solution*	
FLOW		gals/min @ FT	△0 *380@20 psig*	3.07 gals / 1000 ft³
FEED TEMPERATURE		°F	*122*	
SPECIFIC GRAVITY @ FT			*1.1 - 1.2*	
VISCOSITY @ FT		cP	*1-2*	
COMPOSITION		by WT.	*5-15% P2O5*	
			1500 ppm F	

PERFORMANCE

PARTICULATE REMOVAL GAS TURNDOWN RATIO

FLUORINE REMOVAL

DESIGN AND CONSTRUCTION

OPERATING PRESSURE	△0 *(-25)* psig (in WATER) @ *125 °F*		
DESIGN PRESSURE (INTERNAL)	*(-28)* psig (in WATER) @ *185 °F*		
(EXTERNAL)	*14.7* psia (in WATER) @ *185 °F*		
CORROSION ALLOWANCE: SHELL	*None*	HEADS *None*	INTERNALS *None*
[ ] STRESS RELIEVE	[ ] X-RAY		
WIND LOAD: UBC MAP AREA			
SEISMIC ZONE:			
FIREPROOFING: THICKNESS	*None*		ft²
INSULATION: THICKNESS	*None*		ft²
SURFACE PREPARATION SPECIFICATION			
PAINTING SPECIFICATION			
FAB WT	*40000 lb.* △0	OPERATING WT *	TEST WT

REMARKS: * INDICATES INFORMATION TO BE FURNISHED/CONFIRMED BY VENDOR

Note 1. Cyclonic Separator inlets are from the discharge of Venturi Scrubbers item nos. 10.110 & 10.120

Note 2. Vendor to recommend flow, duration and frequency of washing Mist Eliminator with Process water (165 gpm @ 40 psig, intermittent) △0

REV/DATE	A / 6/29/95	B / 11/14/9	0 / 1-20-9*	/
PREP/DATE	DMI / 6/29/95	JME / 11/14/9	JME / 1-19-96	/
CHK'D/DATE	DRK / 6/30/95	DMI / 11/14/9	EAK / 1-29-96	/
PP'D/DATE	/	/	/	/
APP'D/DATE	/	/	/	/

SCRUBBER DATA SHEET

PROJECT No. 28-J697-00 ITEM No. 10. 130

SPECIFICATION No. 23031-1

FOR *US Agri-Chemicals* SERVICE *Cyclonic Separator*

SITE *Fort Meade, Florida* MANUFACTURER *D. R. Technology*

DESIGN AND CONSTRUCTION

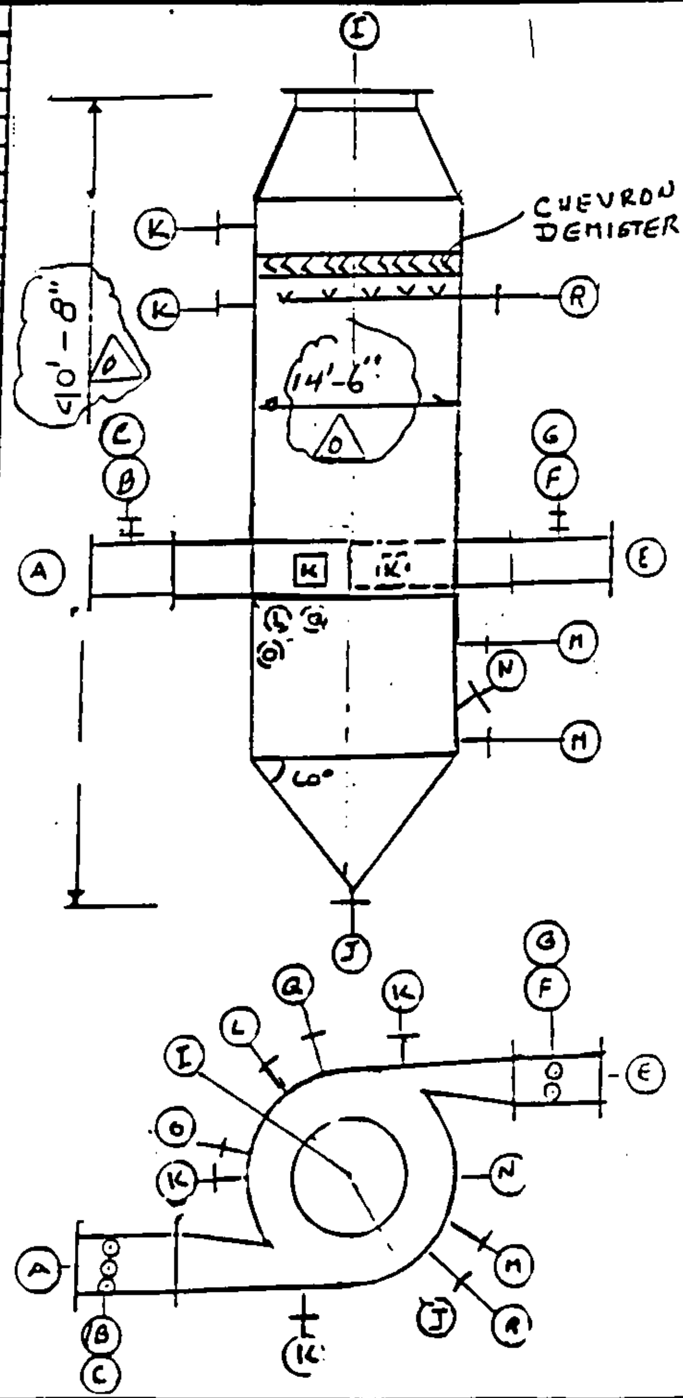
PART	MATERIAL	DESCRIPTION
SHELL	Carbon Steel	
HEADS	Carbon Steel	☐ SEMIELLIP ☐ DISHED
LINING	Rubber	3/16" Triflex or equivalent
MANHOLES	Carbon Steel	X HINGE ☐ DAVIT
NOZZLES	Carbon Steel	
COUPLINGS		
INTERNALS	316 L SS	Spray Nozzles
	PP with glass reinforcing	Chevron demister
LUGS		
RINGS		☐ INSULATION ☐ VACUUM
DAVIT		LOADING

NOZZLES

MARK	SERVICE	QTY	SIZE
A	Gas Inlet	1	54" W x 68" H
B	Mount for nozzles C	3	4"
C	Liquor Inlets	3	1½"
E	Gas Inlet	1	30" W x36" H
F	Mount for nozzles G	2	3"
G	Liquor Inlets	2	1"
I	Gas Outlet	1	78"
J	Liquor Outlet	1	14"
K	Manholes	4	24"
L	Process Water Inlet	1	2"
M	Level Transmitter	2	3"
N	Temperature Probe	1	2"
O	Overflow	1	8"
Q	Effluent Sump Inlet	1	2"
R	Demister Wash Water	1	4"

NOTES

1. Full cone spray nozzles will be fitted in each of the gas inlet throats to the separator.
   Nozzles selected should operate at pressure of 20 psig. or less.
2. Rubber lining to be in accordance with Spec. No. 66200-3 & 66200-2.



REMARKS: * INDICATES INFORMATION TO BE FURNISHED BY VENDOR

REV/DATE	A / 6/30/95	B / 11/14/9	0 / 11-09-96	/	
PREP/DATE	DMI / 6/30/95	JME / 11/14/9	JME / 11-26-96	/	
CHK'D/DATE	DRK / 6/30/95	DMI / 11/14/9	EAC / 11-24-96	/	
APP'D/DATE	/	/	/	/	
APP'D/DATE	/	/	/	/	

10133A

FLORIDA

Department of Environmental Protection

Lawton Chiles
Governor

Twin Towers Office Building
2600 Blair Stone Road
Tallahassee, Florida 32399-2400

Virginia B. Wetherell
Secretary

July 3, 1996

CERTIFIED MAIL - RETURN RECEIPT REQUESTED

Mr. Steven J. Susick, P.E.
General Manager
US Agri-Chemicals Corporation
3225 State Road 630 West
Fort Meade, Florida 33841-9799

RE: Prilled MAP Construction Permit PSD-FL-222 (AC53-260190)

Dear Mr. Susick:

This is in response to the June 4 letters from Koogler & Associates (K&A) and Jacobs Engineering Group, Inc. (JEGI), providing additional information concerning PSD-FL-222 for the US Agri-Chemicals (USAC) Prilled MAP Plant to be constructed in Ft. Meade. These letters were requested to provide the Department with proper time for review of new information that was presented at the May 21 meeting.

The Department reviewed the information submitted and found that the venturi scrubber system as proposed by USAC will achieve only about half of the 5.3 transfer units claimed. The claim was made that the proposed venturi scrubber would achieve 5.3 mass transfer units using unneutralized scrubber water. To achieve that level of mass transfer at the assumed inlet concentration, a venturi scrubber must be capable of achieving an approach to equilibrium of about 3% of the equilibrium vapor concentration for fluoride, which is not possible for this device. (Mass transfer units provide a method of expressing the closeness to equilibrium concentrations that a gas-contacting device is capable of achieving relative to the pollutant concentration of the inlet gas stream). A published technical paper disproving USAC's mass transfer units claim is enclosed and is discussed in detail later.

Also, USAC did not follow the Department's BACT requirement for use of neutralized scrubbing water for the venturi-only option. Scrubber water neutralization is a demonstrated technology in the phosphate industry and is required in the BACT determination for the venturi-only option.

Scrubber water will contain fluorides principally as fluosilicic acid along with sodium and potassium fluosilicates and hydrofluoric acid. If untreated, the fluoride concentrations will build to high levels at low pH. Lime treatment of the water to a pH level of 3.5 to 4.0 allows the fluorides to precipitate out of solution, mainly as calcium fluoride. At this point the water would contain as low as 30-60 ppm fluoride. With second-stage lime treatment to a pH of 6.0 or more, the calcium compounds (mainly dicalcium phosphate) precipitate out along with additional calcium fluoride. Upon settling, the clear neutralized water would contain as low as 15 ppm fluoride, depending on the quality of the neutralization facilities and the mixing efficiency.

In an effort to install a control system with low maintenance requirements, USAC has proposed a scrubber system with high energy requirements and less than optimum capability for removal of gaseous fluorides. The claim that a venturi scrubber will achieve results comparable to that of phosphoric acid plant packed scrubbers in terms of transfer units is invalid. The 5.3 transfer units calculated by JEGI correspond to 87% removal of gaseous fluorides. The Department's calculations show that the actual transfer units are less than 3 at a gaseous fluoride removal efficiency just barely over 80%. Gaseous fluoride removal in wet process phosphoric acid plants typically exceeds 99% with 7-8 NTUs. Therefore, the number of transfer units for USAC's proposed scrubber is not comparable to the number typically used in wet process phosphoric acid plants. (We should point out that the wrong limit was used for a new phosphoric acid plant. It is 0.012 lb F/ton P_2O_5 and not 0.016. The BACT determination for Cargill Fertilizer (PSD-FL-224) states that the 0.016 limit applies only to Cargill since they were combining new and existing sources).

It should be pointed out also that JEGI's drawing of the packed scrubber depicts it as being a countercurrent packed tower. A countercurrent tower is a poor design and will not work for this application. There are numerous technical articles in the literature referring to plugging problems with countercurrent operation. This was never proposed by the Department.

Environmental impacts of fluoride emissions are characterized by K&A as being so minimal as to render the expenditure for the second stage BACT control as pointless. They cited a statement in an EPA guideline document to the effect that fluorides are not a health related pollutant and they refer to the very low estimated ambient air impact. The Department's calculations show that K&A's estimate of 1.53 tons F/yr removed by the second stage actually could exceed the PSD significance level of 3 tons per year based on the inlet concentrations assumed. The Department cannot ignore the equivalent of a PSD source. The EPA set the fluoride PSD-significance level at a low figure because gaseous fluorides diffuse and are carried for much greater distances than particulates and have a far greater potential for deleterious impact.

In its answers to comments submitted when the phosphate industry new source performance standards were promulgated in 1975, the EPA addressed the arguments of fluoride emissions being localized and of minimal ambient impact by pointing out that fluoride, due to its documented toxic effects on plants and animals, was the only pollutant other than the criteria pollutants that was specifically named as requiring federal action by the 91st Congress.

As discussed above, the Department found that the mass transfer capability of USAC's venturi scrubber for fluoride removal was overstated. An authoritative technical article that we have used before in pointing out the limitations of a venturi scrubber was published in the November 1978 issue of Chemical Engineering Progress. It describes a gas-atomized venturi scrubber that was designed for high efficiency fluoride removal from the off-gases of a phosphoric acid reactor. A copy of that article is enclosed for your review. The initial objective was to achieve a level of mass transfer approaching that of packed scrubbers, i.e. 6-7 NTUs, while dealing with a limited water supply such as was mentioned by JEGI and USAC during our meeting.

A pilot plant was constructed to evaluate performance under well-monitored conditions and resulted in an empirical model describing the fluoride absorption process. It was found that the pilot plant venturi achieved only about 3.5 NTUs with fully neutralized scrubber water. (This 3.5 limitation on NTUs achievable with a venturi scrubber was also indicated by Dr. Teller in his article). A full scale system was then designed for 3.5 NTUs handling a gas flow about 12% above that for the USAC MAP plant with a fluoride concentration of about 500 mg/m^3 (the pilot plant concentrations varied from 10 to 500 mg/m^3). Recirculated scrubber water was neutralized to a constant pH of 7.

Results from the commercial plant closely paralleled the pilot plant data and validated the empirical model which showed that gas viscosity has the most influential effect on the NTUs, which vary inversely with the gas viscosity. This explains to a large extent why a venturi scrubber is not the most effective mass transfer device. The gas film resistance limits the amount of fluoride gas that can be transferred from the gas-liquid film interface to such an extent that sufficient contact cannot be provided by only one highly turbulent exposure which the venturi scrubber provides. A venturi simply cannot do the scrubbing job on a gaseous pollutant that a properly designed packed scrubber is capable of. (We should point out an error in the Becker textbook, p. 402, concerning the lower end of the range where the Henry's Law shift begins - it should be 0.005% instead of 0.05% F).

The Department disagrees with the JEGI conclusion that the packed scrubber removes only 10% of the particulates left by the venturi/cyclonic scrubber. Actual field data show otherwise as discussed in the following excerpt from "Particulate Collection with Packed Crossflow Scrubbers", Journal of the Air Pollution Control Association, April 1972, p. 281:

> "Theoretical particulate removal efficiency by inertial impaction as calculated from the equation presented by Langmuir and Blodgett indicate 95% removal of 3 microns and larger particles at a superficial gas velocity of 9 ft/sec through the scrubber. Data obtained from crossflow scrubbers under actual field conditions indicate high removal efficiency on 1-2 micron particulate and as high as 20% removal of submicron particulate. Obviously, mechanisms other than inertial impaction enter into the removal of particulate in this system."

JEGI's assumption was apparently based on the comment in the 1977 article in Chemical Engineering that they enclosed which stated:

> "Several important types of scrubbers have performance characteristics such that a particle whose aerodynamic diameter is half the cut diameter would be collected at about 10% efficiency, whereas a particle with an aerodynamic diameter twice the cut diameter would be collected at about 90% efficiency."

JEGI evidently assumed that the aerodynamic diameter downstream of the venturi would be half of the 2 micron cut diameter derived from Curve 2 of the chart in the article, i.e. 1 micron, collected at 10% efficiency. However, we note that Curve 2 was obtained with 1-inch rings or saddles (extended surface packing) and not filamentous packings such as Tellerettes. The impact of this error can be seen from the following discussion in the aforementioned article on crossflow scrubber particulate efficiency (p.280):

> "Particulate removal efficiency and solids handling capacity of a crossflow scrubber are dependent to a great degree on the type of packing used. Two basic types of packing are in use today for wet packed scrubbers - extended surface packings (such as Rasching Rings, Pall Rings, and Intalox Saddles), and filamentous packings (such as Tellerettes).
>
> As reported by Calvert and Jackson, extended surface packings can efficiently remove particles down to 3-5 microns at high pressure drops of 20-30 in. w.c. The high energy loss is due to the fact that extended surface packings remove particles by centrifugal force. Good collection efficiency must therefore be obtained by using relatively high velocities which results in high pressure drop characteristics. Filament

size of extended surface packings is too large for efficient removal of particles by impingement or impaction.
A filamentous packing removes liquid and solid particles by the mechanism of inertial impaction. This packing offers a series of ribbons with small width to keep deviation of the gas stream and the resultant energy consumption to a minimum. The cross section of the filament is square giving it sharp edges and, as reported by Langmuir and Blodgett, a higher target efficiency than spherical or cylindrical shapes of the same width."

The Department found also that the claimed performance of USAC's scrubber for particulate removal was overstated. Since all of JEGI's calculations were not shown, we checked the performance against their assumptions. First, it is required that "cut diameter" be properly defined. JEGI referred to it as the average particle size removed by the device. In theory, it is the diameter at which the removal efficiency for all larger particles is 100%, and that for all smaller particles is 0%. In practice, it is the diameter of a particle for which the efficiency curve has a value of 0.50, i.e., 50% removal.

It is often expressed in "aerodynamic diameters" which means that the particle diameter has been adjusted to reflect its aerodynamic behavior for control system design. In air pollution control engineering terminology, the "aerodynamic particle diameter" is the square root of the term $(D^2)(\rho)(C)$ which appears in the equation for "Stokes Stopping Distance", which is the distance required for a particle to settle out of an air stream under given conditions ("D" is the actual diameter, ρ is the particle density, and "C" is a constant). Thus, if the constant "C" has a value of 2.0, and we have a 1 micron particle with a density of 2.5 g/cm^3, the diameter in "aerodynamic" units is $(1)(2.5 \times 2.0)^{0.5} = 2.24$ microns$_a$. Any two particles with this value, though structurally different, would exhibit the same behavior in different kinds of control devices.

Empirical aerodynamic cut diameter and pressure drop data are available for typical venturi scrubbers so that cut diameter can be predicted at a given pressure drop and liquid to gas ratio. These curves typically show a venturi cut diameter of 0.5 microns aerodynamic at a pressure drop of about 80 in. w.c. or above as opposed to the 0.47 microns at 19 in. w.c. claimed for USAC's venturi. The curves showing the cut diameter on a logarithmic ordinate and the liquid to gas ratio on a logarithmic abcissa are essentially flat at volumetric liquid to gas ratios between 0.6 and 2.0, indicating that within that range a 25% decrease in pressure drop would correspond to a 12% increase in the aerodynamic cut diameter. The effect is slightly higher at ratios below 0.6. One of these graphs for a typical venturi scrubber is enclosed.

No single method is infallible for predicting the effect of reduced venturi pressure drop on collection efficiency. However, a method that usually gives good results involves another form of transfer unit analogous to the mass transfer unit for gases. It is defined as $N_t = \ln(1/1-E)$ where E is the fractional removal. It provides a better method of correlating the energy expended in the scrubber with its collection efficiency. The value obtained for N_t at a given pressure drop, or vice versa, will vary over an order of magnitude depending on the type of scrubber and the particulate.

For a given scrubber and particulate, a distinct relationship between N_t and pressure drop usually appears and can be plotted linearly on log-log paper according to the equation $N_t = a(\text{delta P})^b$ where a and b are constants. For a venturi scrubber in an application involving an aerosol-sized particulate such as talc dust, values of a and b have been published as 2.97 and 0.362, respectively. Therefore, if the pressure drop is reduced by 25%, N_t is reduced by 9.9% and the collection efficiency is reduced by 3.3%. Specific parameters for MAP dust are not available to the Department, so the difference of 4.5% in JEGI's calculations cannot be verified.

Since no particle size distribution data are available for MAP dust, we calculated efficiencies for assumed mean diameters using a log-normal distribution. The efficiency vs. diameter ratio relationship was assumed to follow the conventional empirical equation: $\text{Eff.} = (D/D_{cut})^2 / 1 + (D/D_{cut})^2$. Based on JEGI's statements about substantial aerosol formation, we started out with a "worst case" assumed mean particle diameter of 1 micron with a standard deviation of 1.25.

The following table shows how this was done. The particle distribution was divided into size fractions; those from 0 to 0.1 of the total mass, from 0.1 to 0.2, etc. The second column shows "z", the number of standard deviations (sigma) from the mean, that will correspond to "C", the cumulative distribution fraction at the end of each interval. The next column shows the value of D/D_{mean} at the end of the size interval, found by $D/D_{mean} = e^{z(\text{sigma})}$. For example, at the 0.1 size fraction, 10% of the particles have diameters less that 0.2014 x 1.0 micron = 0.2014 micron. The next column gives the average diameter ratio for the interval. The fifth column shows the collection efficiency for the midrange diameter calculated by the above equation where $D/D_{cut} = (D/D_{mean})(D_{mean}/D_{cut})$. The sixth column shows the fraction of mass for each interval that is uncollected. The last column shows the cumulative fraction uncollected.

C	z	(D/D_{mean}) end	(D/D_{mean}) mid	Eff.	$p\Delta C$	$\Sigma p\Delta C$
0.1	-1.282	0.2014	0.1007	0.0439	0.0956	0.0956
0.2	-0.842	0.3491	0.2752	0.2553	0.0744	0.1700
0.3	-0.524	0.5194	0.4343	0.4606	0.0539	0.2239
0.4	-0.253	0.7289	0.6242	0.6382	0.0362	0.2601
0.5	0	1.0000	0.8644	0.7718	0.0228	0.2829
0.6	0.253	1.3720	1.1860	0.8643	0.0136	0.2965
0.7	0.524	1.9251	1.6486	0.9248	0.0075	0.3040
0.8	0.842	2.8648	2.3950	0.9629	0.0037	0.3077
0.9	1.282	4.9654	3.9151	0.9858	0.0014	0.3091
1.0		1.0000	4.9654	0.9911	0.0009	0.3100

We see that the total fraction collected is 0.69 which is the result of the very low mean diameter assumed. Therefore, it can be concluded that the actual mean diameter is much larger, while the actual cut diameter may be larger as well.

After more trials it was found that a mean particle diameter of 10 microns provides results that match the 96+% design efficiency while assuming the same cut diameter of 0.47 micron. From these calculations, it is reasonable to assume that the particle mass distribution ahead of the packed scrubber would be indicated by the fifth column for the case with D_{mean} = 10 microns:

$p\Delta C$
0.0318
0.0028
0.0012
0.0006
0.0003
0.0002
0.0001
--
--
0.0370

The mass mean diameter of the particulate ahead of the packed scrubber is the diameter that corresponds to half of the above total, or 0.0185, which is near the front end of the first size range interval from 0 to 0.1. Therefore, the mass mean diameter would be about 1 micron (0.0185/0.2014 x 10) if the venturi cut diameter has been correctly assigned at 0.47.

On the other hand, if the venturi cut diameter is equal to 1 micron as indicated on the aforementioned enclosed chart from A.C. Stern's Air Pollution, 3rd Edition (at about 50 cm H_2O or 19.7 in. w.c.), the results are dramatically different as shown below:

Cut Diameter = 0.47 micron		Cut Diameter = 1 micron	
Venturi D_{mean}	10 microns	Venturi D_{mean}	10 microns
Venturi pΔC	0.0370	Venturi pΔC	0.0714
Packed $D_{m(mass)}$	1 micron	Packed $D_{m(mass)}$	2 microns

Our staff's experience in scrubber design, testing and operation suggests to us that the true performance would prove to be closer to the 1 micron case. That is more in line with what we have seen from venturis operating in the 19-20 in. w.c. range. For a cut diameter in the 0.5 micron range, a pressure drop in the range of 30-32 in. w.c. across the venturi throat would usually be required for 97-99% collection efficiency.

In the absence of actual particle size information for MAP prill tower dust, and specific information on scrubber guarantees, we must conclude that the published cut diameter data are more appropriate since they appeared in an article by Dr. Seymour Calvert, the same expert that JEGI refers to.

Our assessment of the best attainable performance using the USAC-proposed recirculated water system for the venturi and a crossflow scrubber with an independent supply of once-through pond water is presented in the next table. Consistent with the prior discussion, we have assumed an overall venturi particulate removal efficiency of 93% vs. 96+% (cut diameter of 1 vs. 0.47 $micron_a$), and venturi scrubbing at 81% gaseous fluoride efficiency (2.67 NTUs using unneutralized water with Beker's equilibrium data).

We have assumed crossflow scrubber results consistent with those presented in the aforementioned articles; i.e., about 75% removal of particulate fluorides, considering solubility, and 65% efficiency with about 5 NTUs on gaseous fluorides based on 2.0 mg/m^3 at equilibrium. Our fluoride inlet estimate is higher than USAC's and is based on 113,330 lb/hr of 54% H_3PO_4 @ 1.2% F coming in. With 1,360 lb/hr of fluorides entering the tower, it is conceivable that it may be higher than USAC assumed as indicated below:

	Combined Inlet	Venturi Exit 18"	Venturi Exit "24"	Crossflow Exit 18"	Crossflow Exit 24"
P	743.00	81.73	52.01	20.43	13.00
PF	29.54	3.24	2.04	0.81	0.51
GF	10.46	1.36	1.36	0.47	0.47
TF	40.00	4.60	3.40	1.28	0.98

For the venturi-only approach, the BACT determination calls for a dedicated scrubber pond with neutralization and fresh water makeup. The results expected on gaseous fluorides using a venturi with fully neutralized water would be about 3.5 NTUs (95.8% removal assuming 0.5 mg/m^3 at equilibrium). The performance in lb/hr would be approximately:

	Venturi Exit
P	52.01
PF	2.04
GF	0.43
TF	2.47

The above results are contrasted with the original BACT concept in the following analysis. The original two-stage control strategy contemplated a design goal of 99+% removal of gaseous fluorides, assuming Dr. Teller's equilibrium concentration of 0.7 mg/m^3 for once-through pond water (allows for cooling effect of scrubber air on pond water), and 99% removal of particulate over 5 microns. The goal was to maximize gaseous fluoride control while removing particulate sufficiently to avoid plugging problems with a packed cross-flow scrubber. Assuming a mean particle diameter of 10 microns and a cut diameter of about 2.0 $micron_a$ at a pressure drop far below 50 cm w.c. according to the chart by Dr. Calvert, the particle distribution would be approximately:

C	z	(D/D_{mean}) end	(D/D_{mean}) mid	Eff.	p ΔC	%>5u Removed
0.1	-1.282	0.2014	0.1007	0.2022	0.0797	-
0.2	-0.842	0.3491	0.2752	0.6544	0.0346	-
0.3	-0.524	0.5194	0.4343	0.8250	0.0175	-
0.4	-0.253	0.7289	0.6242	0.9069	0.0093	99.07
0.5	0	1.0000	0.8644	0.9492	0.0051	99.49
0.6	0.253	1.3720	1.1860	0.9723	0.0028	99.72
0.7	0.524	1.9251	1.6486	0.9855	0.0015	99.85
0.8	0.842	2.8648	2.3950	0.9930	0.0007	99.93
0.9	1.282	4.9654	3.9151	0.9974	0.0003	99.97
1.0		1.0000	4.9654	0.9983	0.0002	99.98
					0.1517	

As shown, the low energy venturi under these conditions will have an overall particulate efficiency of 85% while accomplishing greater than 99% removal of particulate above 5 microns. The performance of the low energy venturi (about 8 in. w.c.) on gaseous fluorides using unneutralized water is assumed to be about 2 NTUs on the basis of the article discussed previously:

Gas Flow Rate = 110,014 m^3/hr
Gaseous F @ Inlet = 10.46 lb/hr
Inlet Concentration =

$$\frac{10.46 \times 454 \times 1000}{110,014} = 43.17 \text{ mg/m}^3$$

Dr. Teller's Eq. Conc. = 0.70 mg/m^3
Outlet Conc. @ 2 NTUs: ln 43.17-0.70/"c"-0.70 = 2
"c" = 6.45 mg/m^3 = 1.55 lb/hr
Gaseous F Eff. = (43.17 - 6.45)/43.17 = 85%

Performance of the packed crossflow scrubber under this scenario is determined likewise:

Gaseous F @ Inlet = 6.45 mg/m^3 = 1.55 lb/hr
Dr. Teller's Eq. Conc. = 0.70 mg/m^3
Dr. Teller's Max. NTUs = 8 - 2 (venturi) = 6
Outlet Conc. @ 6 NTUs: ln 6.45-0.70/"c"-0.70 = 6
"c" = 0.714 mg/m^3 = 0.17 lb/hr
Gaseous F Eff. = (6.45 - 0.714)/6.45 = 89%
Total System Gaseous F Eff. = (43.17 - 0.714)/43.17
= 98.4%

The performance would be 0.9% less than the 99.3% design goal set for gaseous fluorides in the BACT determination, but 11.4% better than the 87% that USAC proposes. The lb/hr performance chart then becomes:

	Combined Inlet	Venturi Exit	Crossflow Exit
P	743.00	111.45	27.86
PF	29.54	4.43	1.11
GF	10.46	1.55	0.17
TF	40.00	5.98	1.28

Results of the above analyses are summarized in the following table of emissions along with a comparison of USAC's scrubber performance claims vs. the Department's assessment of those claims. The Department's BACT calculations assume 87% more fluoride in the scrubber inlet stream than USAC assumed.

	USAC's Claims	DEP's Review	DEP's BACT Calculations @ Higher F In 24"Venturi Only	8"Venturi/Crossflow
P (lb/hr)	24.00	52.01	52.01	27.86
PF " "	0.55	1.10	2.04	1.11
GF " "	0.72	1.03	0.43	0.17
TF " "	1.27	2.13	2.47	1.28
lb F/ton	0.04	0.07	0.08	0.04
GF NTUs	5.30	2.67	3.50	8.00
GF Eff.	86.96	81.35	95.80	98.40
TF Eff.	94.05	90.02	93.83	96.80
TPY GF	3.15	4.51	1.88	0.74
TPY TF	5.56	9.33	10.82	5.61

In regard to the cost effectiveness issues, we could not do a complete analysis because we never received the breakdown of the installation costs that we requested through K&A on several occasions. These costs appear to have been highly inflated based on other cost information we have. Also, the incremental costing approach that was used in this instance is clearly problematical as indicated by the following excerpt from the EPA's New Source Review Workshop Manual, (Draft 1990), p. B.43:

> "As a precaution, differences in incremental costs among dominant alternatives cannot be used by itself to argue one dominant alternative is preferred to another. For example, suppose dominant alternatives B, D, and F on the least-cost envelope (see Figure B-1) are identified as alternatives for a BACT analysis. We may observe the incremental cost effectiveness between dominant alternative B and D is $500 per ton whereas between dominant alternative D and F it is $1000 per ton. Alternative D does not dominate alternative F. Both alternatives are dominant and hence on the least-cost envelope. Alternative D cannot legitimately be preferred to F on grounds of incremental cost effectiveness." (emphasis added)

This means that for a situation where two devices are required because each is the most efficient for a different pollutant, the total cost of control should be applied to every ton removed instead of pitting one device against the other incrementally.

We contacted Ceilcote Air-Cure Dynamics, Inc., to see if they had any data on prilled MAP or similar processes generating fine particulate emissions. Ceilcote's Air Cure Gmbh Division in Germany sent us information on a system they designed for a granular NPK plant in Greece. They used an ionizing wet scrubber (IWS) designed for 99.7% removal of total fluorides based on 200 kg/hr (441 lb/hr) of total fluorides entering the IWS from the 95,000 Nm^3/hr reactor off-gas stream. No actual test results are available, however, and the scrubbing medium was not described.

All of the foregoing analyses regarding the proper BACT emission limits for USAC are based on assumptions and calculations rather than actual test data from a prilled MAP plant. While reviewing this permit application originally, the Department considered using test data for IMC-Agrico's New Wales Prilled MAP plant as a basis for USAC's BACT limits. That idea was rejected due to the age of the plant and IMC-Agrico's use of a low energy venturi. Now, after reexamining the IMC-Agrico test data, the Department is at a loss to resolve the discrepancy between the USAC calculations and the test data. The only explanation that can be reasonably presumed is that IMC-Agrico is using partially defluorinated acid, or, there is not as much fluoride coming off as has been assumed by USAC. Whatever the reason, the IMC-Agrico results are lower than for any of the calculated USAC scenarios. The IMC-Agrico data for the last five years are tabulated below:

Test Date	Tons P_2O_5/hr	Lb F/hr	lb F/ton P_2O_5
11/2/95	24.0	0.10	0.0042
4/12/95	24.0	0.14	0.0058
11/1/94	24.0	0.30	0.0125
5/2/94	24.0	0.20	0.0083
11/9/93	24.0	0.20	0.0083
4/22/93	24.0	0.10	0.0042
10/28/92	23.0	0.18	0.0078
4/28/92	24.0	0.08	0.0033
12/26/91	22.2	0.24	0.0108
4/24/91	24.0	0.15	0.0063

The Department was contacted by Mr. Edward M. Newberg, a Vice President of IMC-Agrico, on May 31, 1996, at USAC's request. Mr. Newberg told us that the MAP plant's fluoride emissions tested lower after replacement of the original two-stage venturi/packed scrubber with a low energy venturi/cyclonic unit. When we replied that our calculations show this would not be possible, Mr. Newberg insisted that emissions have decreased compared to those from the original packed scrubber. Since these results have now been certified by IMC-Agrico as accurately representing prilled MAP emissions, the Department can no longer disregard them.

The Department's usual practice involves setting the limit marginally above the highest representative test result thus providing a margin for compliance. With a 50% margin above the highest result, the BACT fluoride limit would be 0.0125 x 1.50 = 0.019 lb F/ton P_2O_5. The limit would be 0.019 x 30.46 = 0.58 lb/hr and 2.54 tons/yr which would end PSD applicability for fluoride emissions and resolve the impasse over the packed scrubber issue. A particulate limit of 24 lb/hr as requested by USAC will be proposed along with a visible emission limit of 15% opacity.

USAC will be allowed to proceed with its design plans for the venturi scrubber since we have assurance that the emissions from this project will not exceed PSD-significant amounts and will be substantially less than they would have been had USAC selected the granulation process.

We will wait for comments from USAC before issuing any changes to reflect a lower achievable emission rate. If there are any questions regarding this letter, please call me or John Reynolds at (904) 488-1344.

Sincerely,

A. A. Linero 7/3

A. A. Linero, P.E.
Administrator
New Source Review Section

AAL/JR

Enclosures

c: B. Thomas, SWD
R. Harwood, Polk Co.
J. Harper, EPA
J. Bunyak, NPS
J. Koogler, K&A
B. Blythe, JEGI

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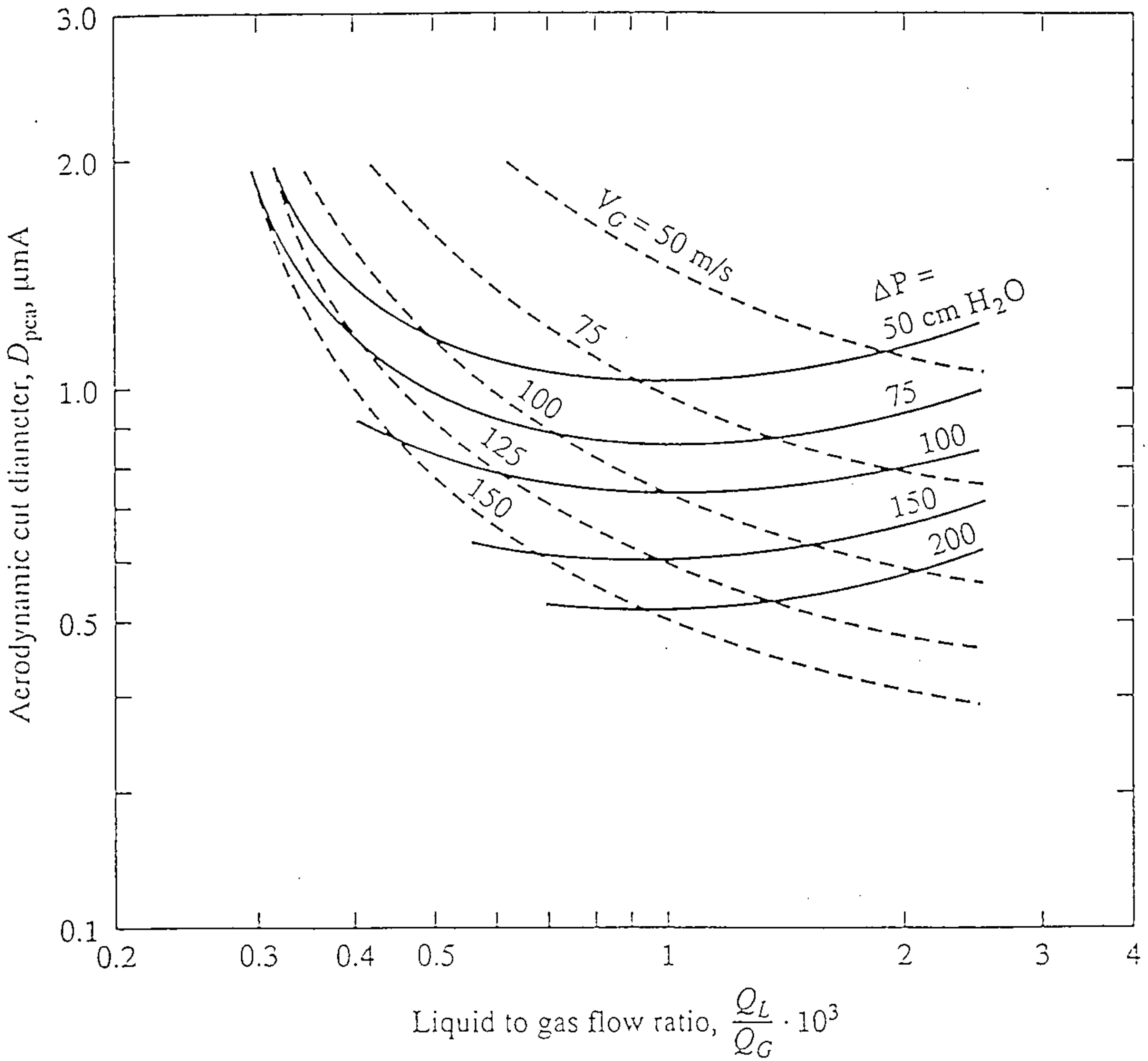
Aerodynamic cut diameter and pressure drop predictions for a typical venturi scrubber. V_G is the velocity at the throat. (From Ref. 19.)



Calvert, S.: "Scrubbing," in A. C. Stern (ed.), *Air Pollution,* 3d ed., Vol. 5, Academic Press, New York, 1977.

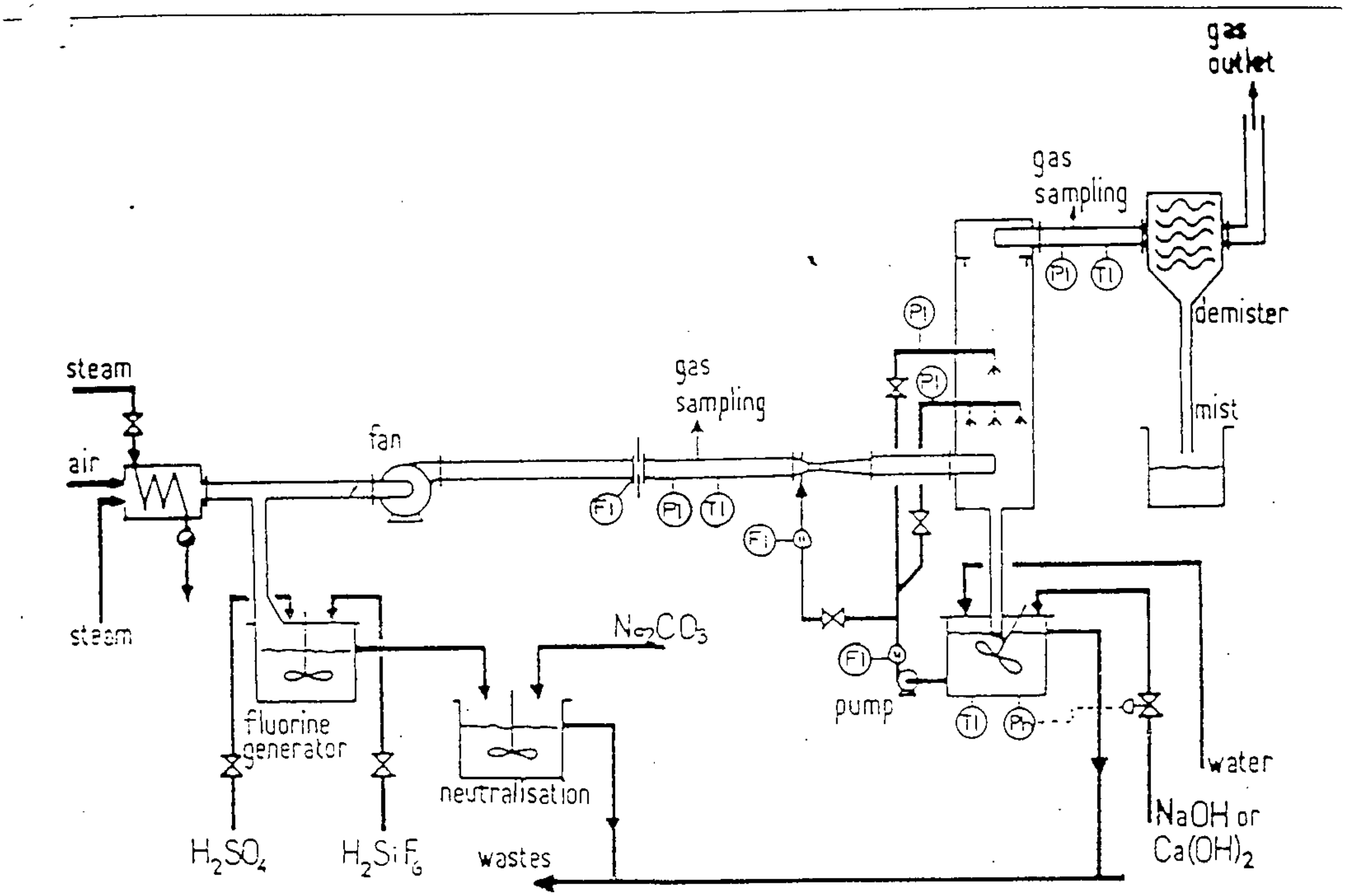


Figure 1. Pilot plant flow scheme.

Phosphoric Acid Plant Problems:

Absorbing Fluorine Compounds From Waste Gases

The atomizing agent of this venturi scrubbing system is a gas, which eliminates the corrosive and plugging risks of a liquid sprinkler.

C. Djololian and D. Billaud, Rhone-Poulenc-Chimie Minerrale, Paris, France

Rhone-Pouleuc has designed a venturi scrubber system that deals with the problem of fluorine absorption in the cooling gases of phosphoric acid plant reactors. Our intent was to design a unit with the following characteristics:

1. A high efficiency rate, the number of transfer units (NTU) required frequently being in the range of 6–7.
2. Total energy expenditure limited on both the gas and liquid sides.
3. A low rate of water consumption and in-plant water recycling.

Our aim was to build an apparatus of reasonable size to keep investment costs down and to reduce space problems, and a unit that had few internal parts given the fouling property of the gas in question.

The venturi scrubber was found to meet all these requirements. It is connected to a cyclone column fitted with sprays that continue the absorption process, and that

0360-7275/78/1418-0046 $01.00

neutralize misting.

The pilot plant apparatus shown in Figure 1 has been designed to operate up to a maximum of 6,000 cu.m./hr. Column diameter is 0.785 m. and its performance can be observed in a given range of overall velocities between 3 and 4 m./sec. A system of shutters is used to vary the entry velocity of the gases and modify the shape of the entry in terms of height and width. A series of full jet sprays working at low pressure (0.5 to 1 bar.) are fitted in the column.

The venturi, which precedes the column, is adaptable to three different sizes of throat. Hence the throat velocity is within a range from 20 to 80 m./sec., at the same time maintaining the same operating characteristics for the column. The washing liquid is fed through small tubes fitted at right angles to the axis of the apparatus just before the throat. Pressure varies between 0.2 to 1 bar., optimum pressure being about 0.5 bar. A mist eliminator fitted with baffles, giving a reading of the mist eliminating capacity of the column, is located after the cyclonic column. A diaphragm flowmeter measuring gas-flow is inserted in a length of straight pipe ahead of the venturi. An air heater and a steam jet regulate air humidity and temperature. The quantity of fluorine in the gas is controlled separately in the production process of $HF + SiF_4$.

The phosphoric acid production plant at Rhone-Pouleuc's Les Roches de Condrieu factory, Figure 2, was equipped with a gas cleaning unit based on the first results indicated by the pilot plant. Operating requirements of the plant are 60 ton/hr. of phosphate rock, giving a gas-flow of 124,000 cu.m./hr. at 65°C. Total bulk concentration of fluorine in the gas leaving the reactor is close to 500 mg./N cu.m. dry air.

If total bulk concentration of fluorine in the gas released into the atmosphere is to be kept below 15 mg./N cu.m. dry air, then the NTU should be at 3.5 which is a figure fairly easy to obtain with only one venturi and cyclonic column. The basic design specifications are: venturi throat diameter, 0.540 m.; column diameter, 3.6 m.; and column height, 15 m.

Two-stage hydrodynamic study

The hydrodynamic study of the pilot apparatus was carried out in two different stages: the cyclonic column first, and then the entire apparatus, including the venturi. Factors determining pressure loss as well as mist eliminating efficiency of the cyclonic column were thus identified. Experimentation on the cyclonic column will not be described in detail here, but the main results will be presented. The study of the whole of the apparatus (venturi and column) has, of course, taken into account the results of trials on the column by itself.

The following observations can be made. To reduce excessive entrainment, it is necessary to: reduce overall gas velocity; increase inlet gas velocity; reduce spraying pressure; increase height of area of activity of the mist eliminator; increase height/width ratio of the inlet port; and fix an anti-creep ring at the upper part of the mist deposition area.

To reduce pressure loss, one must: reduce overall gas velocity; reduce inlet speed; and reduce flow of scrubbing liquid.

Each of these parameters has been studied separately and thus their relative importance has been evaluated. The hydrodynamic study of the whole apparatus (venturi plus column) required the same sort of testing.

On the other hand, the inlet port of the column remained permanently at the same setting throughout the trials so as to give a high rate of mist eliminating efficiency, irrespective of the flow of gas moving through the apparatus. The influence of the ratio L/G (inlet flow of liquid in cu.m./hr. per 1,000 cu.m./hr. of gas) and of velocity at

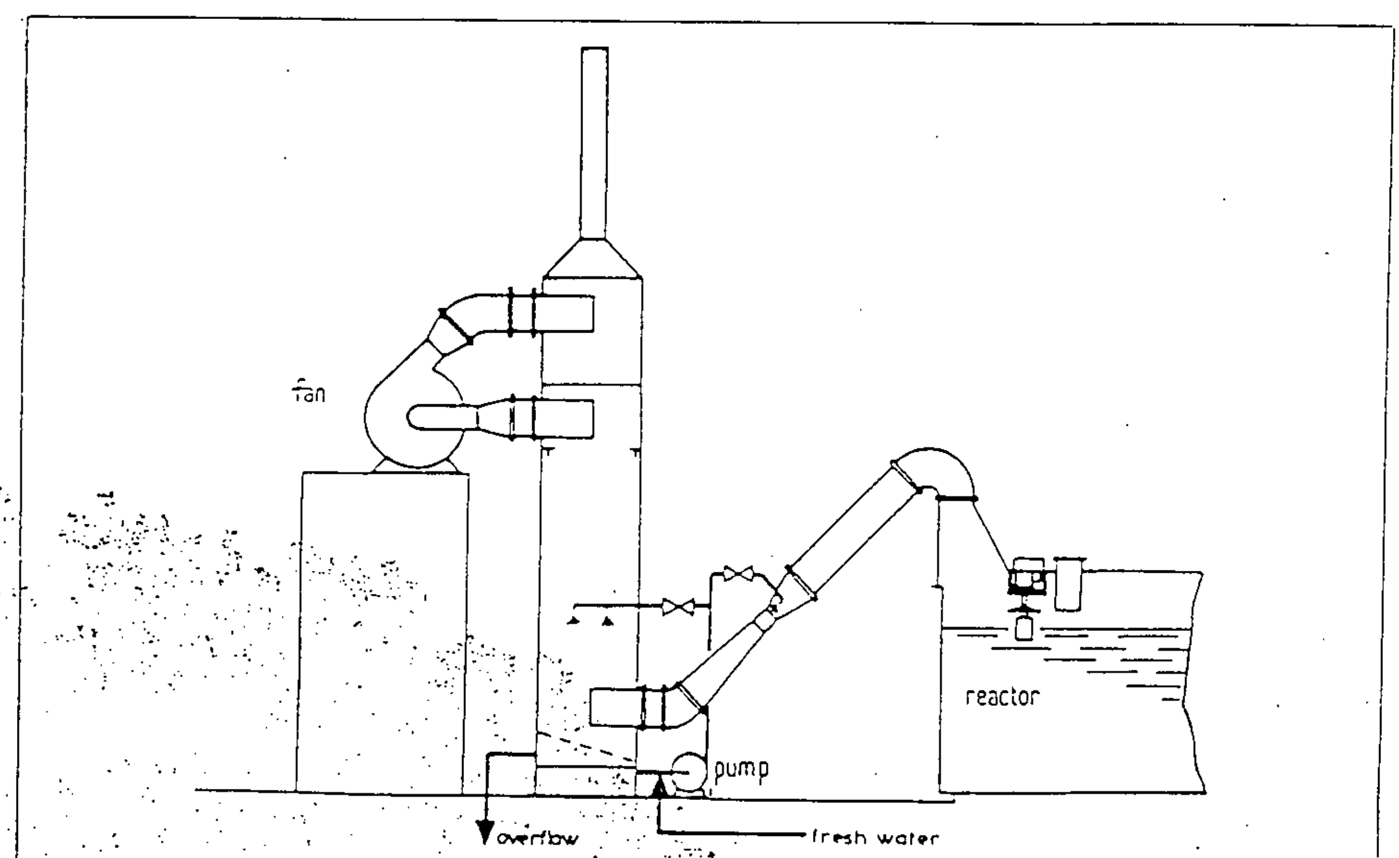


Figure 2. Commercial scale unit at the Les Roches de Condrieu factory.

the throat of the venturi on pressure loss has thus been established.

In addition, readings taken on the commercial plant during the test run can be compared to data obtained with the pilot apparatus, and furthermore can be used to check the validity of the empirical model, which has been established in the light of results given by the pilot apparatus.

The supply of fluorine, in a molecular ratio HF/SiF_4 close to 2, is produced by the action of sulfuric acid on a diluted solution of fluosilicic acid.

Readings were taken of the absorption process in a range of concentration running from 10 to 500 mg./N cu.m. dry air. If the molecular ratio of HF/SiF_4 is above 2 results are less favorable, as HF has a low level of solubility. This peculiarity can be frequently observed in later stages when gas scrubbers are connected in series.

The main parameters considered were throat velocity, L/G ratio, inlet gas temperature, relative humidity, liquid temperature, and fluorine content.

During tests, the scrubbing liquor was neutralized either by lime or by soda, and the pH of the scrubbing liquor was held at 7.

The findings set out below are expressed in NTU thus: NTU = ln Y_e/Y_s. Given the low partial pressure of water and fluorine this equation is hence expressed as follows: NTU = ln (inlet fluorine in mg./N cu.m. dry air)/(outlet fluorine in mg./N cu.m. dry air).

The following equation was retained to explain pressure loss throughout the venturi (subscript 1) and the column (subscript 2):

$$\Delta P = (\rho_{G_1} V_{G_1}^2/2g) \cdot C_1 + (\rho_{G_2} V_{G_2}^2/2g) \cdot C_2 \qquad (1)$$

The column's geometry being constant throughout tests, and since the ratio L/G was known to have had a negligible influence on the column's pressure loss, C_2 may therefore be said to remain constant. C_2 was found to have a value of 2.1. The venturi pressure loss (ΔP_1) can thus be calculated, and consequently the value C_1 can be known.

A significant difference between the venturi ϕ 200 and ϕ 250 is shown by the curves obtained and shown in Figure 3. Though different in value, the initial and final curves describe a similar pattern. It should be pointed out, however, that when larger venturi are used, this phenomenon is rarely observed, and the curve normally describes a similar pattern to that of the ϕ 250's.

In the commercial scale plant operations, scrubbing liquor flow rate remains constant at about 100 cu.m./hr. Gas flow rate varies from 20,000 to 124,000 cu.m./hr. Figures obtained from the pilot and industrial units compared well. They can be expressed thus: when $L/G \leq 2$, then $C_1 = (0.2 + 1.4 \times L/G)$; and when $L/G > 2$, then $C_1 \simeq 2.5$.

In the correlation analysis of fluorine absorption in the venturi scrubber, the technique employed involved the correlation of the NTU as a function of the following controlled variables: gas density, gas viscosity, liquid density, liquid velocity, liquid surface tension, throat velocity (of gas), L/G, characteristic value of condensation or of evaporation, and fluorine concentration in inlet gases.

Correlation based on packed tower method

A stepwise correlation method, to keep the essential controlled variables, has been used and is based on the prin-

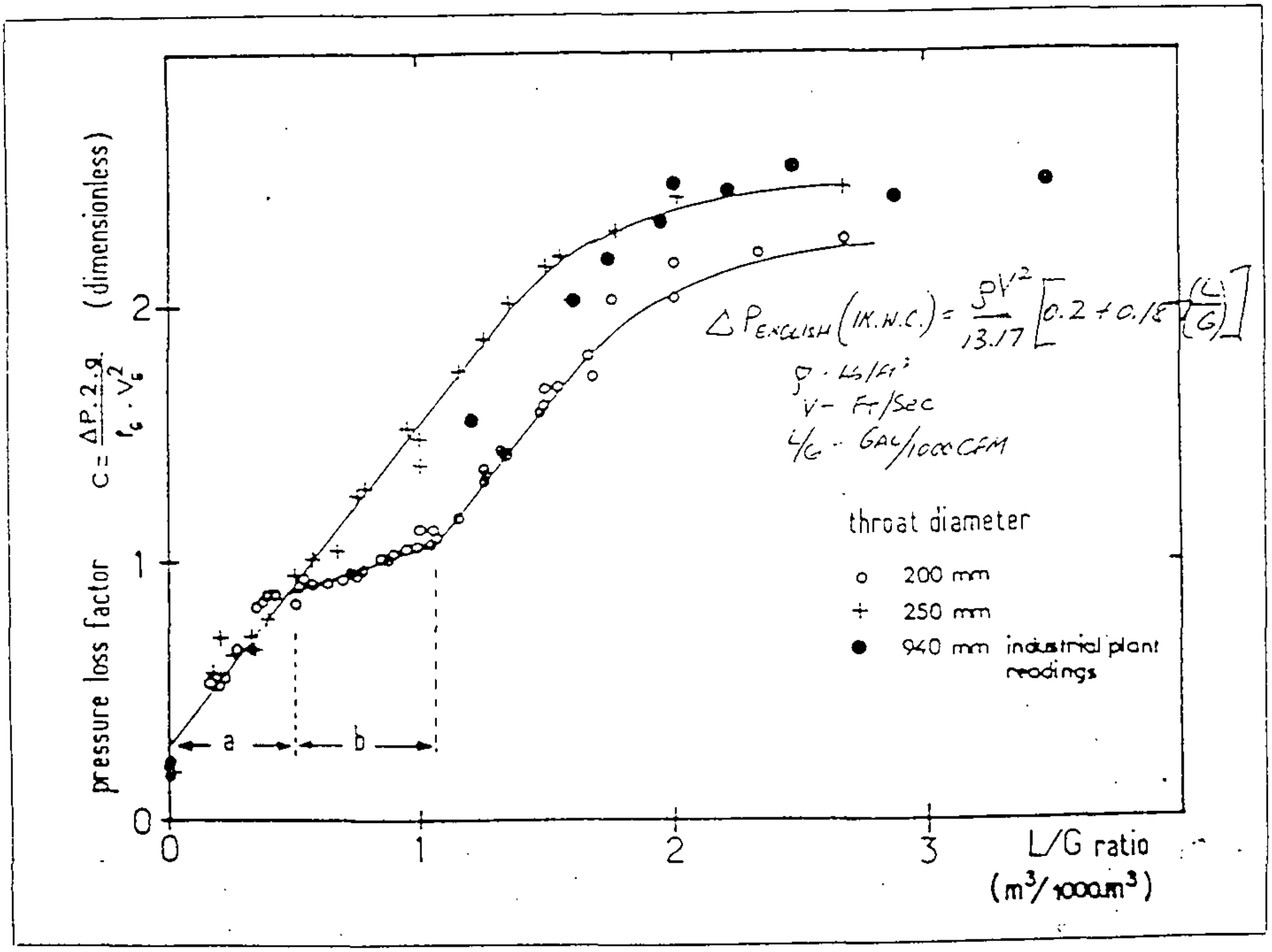


Figure 3. Pressure loss factor vs. L/G ratio.

ciples described below: The NTU concept was developed to provide the design specification of packed columns. There is no reason why this technique should not be applied to other types of absorbers.

It is known that

$$\text{NTU} = \frac{h_t}{\text{HUT}} = \frac{K_G P Y_{BM}^{-} a_v}{G} \times h_t \qquad (2)$$

$a_v \times h_t$ symbolizes the effective mass transfer surface, and if we suppose that the droplets are spherical in shape, and are of the same diameter, then we may say that:

$$a_v \times h_t = 6 \times \frac{L}{dp} \qquad (3)$$

therefore:

$$\text{NTU} = \frac{K_G \cdot P \cdot Y_{BM}^{-}}{G} \times 6 \frac{L}{dp} \qquad (4)$$

which could also be written as follows:

$$\text{NTU} = (cste) \times \rho_{G_1}^{m} \times \mu_{G_1}^{n} \times D_c^{p} \times V_{G_1}^{q} \times \left(\frac{L}{G}\right)^{r} \times \left(\frac{1}{dp}\right)^{s} \qquad (5)$$

Average diameter of droplet can be expressed by a formula of the type suggested by Nukiyama and Tanasawa, (1) who introduced the following parameters:

$$V_{G_2}, \rho_L, \mu_L, \sigma_L, \frac{L}{G}$$

Finally, the dimensions of the apparatus are also a factor influencing mass transfer and are expressed in terms of the relationship of the total length of the venturi L_V (convergent, throat, divergent) and the diameter of the throat Dc. Hence the formula describing NTU

$$\text{NTU} = (cste) \times \rho_{G_1}^{m} \times \mu_{G_1}^{n} \times \rho_L^{p} \times \mu_L^{q} \times \sigma_L^{r} \times \left(\frac{L_V}{Dc}\right)^{s} \times \left(\frac{L}{G}\right)^{t} \times (V_{G_1})^{u} \qquad (6)$$

Analysis has shown that the main controlled variables in descending order of importance are μ_{G_1}, ρ_{G_1}, (L_V/Dc), (L,G), ρ_L, V_{G_1}, σ_L, μ_L.

The best correlation obtained was:

$$\text{NTU} = e^{11.9647} \cdot V_{G_1}^{1.8} \cdot (L_V/Dc)^{-0.9572} \cdot (L/G)^{0.3699} \cdot \rho_{G_1}^{-5.9201} \cdot \mu_{G_1}^{3.4131} \qquad (7)$$

This would seem to confirm known information about the NTU performance of absorbers in general. The NTU is directly proportional to gas velocity and L/G ratio and inversely proportional to gas density. It is also worth pointing out the importance of the L_V/Dc ratio. This ratio should be seen as the key factor in determining acceleration of the gas during flow through the venturi. Energy loss is kept down when the gas is not accelerated; hence in these conditions the liquid can be atomized into finer or more numerous droplets.

For a given L flow-rate, the diameter and number of droplets depend on the operating conditions of the venturi. If condensation occurs, the droplets increase either in size or in number. Hence the mass transfer surface increases, improving the NTU. The reverse process takes place when evaporation occurs.

Condensation is favorable during absorption of fluorine ($HF + SiF_4$). Figure 4 shows the variations of the NTU as a function of inlet gas humidity at different temperatures (TGE). The other variables were given the following values:

$$V_{G_1} = 50 \text{ m./sec.}$$

$$L/G = 1$$

$$\frac{L_V}{Dc} = 8.5$$

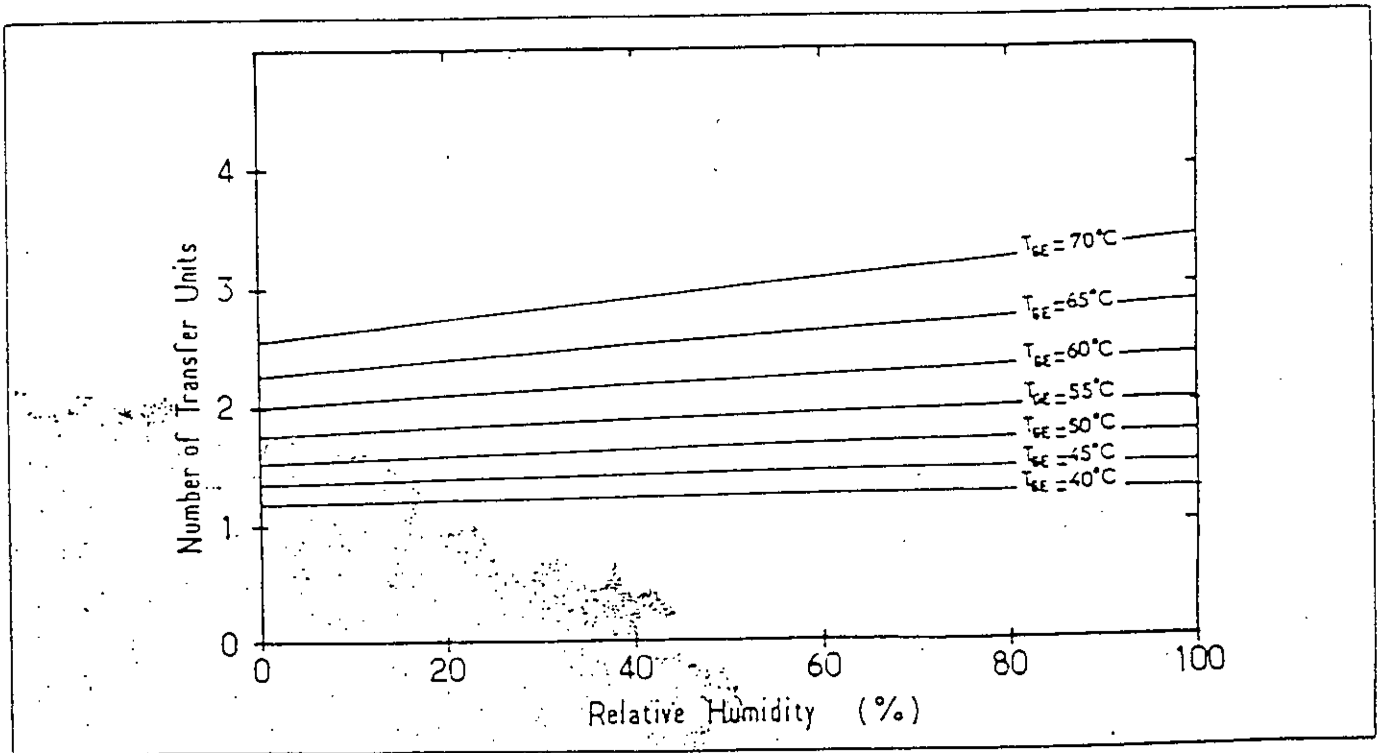


Figure 4. Influence of gas saturation on the absorption efficiency from the correlation using V_G = 50 m./sec.; L/G = cu. m./1,000 cu. m.; Lv/Dc = 8.5.

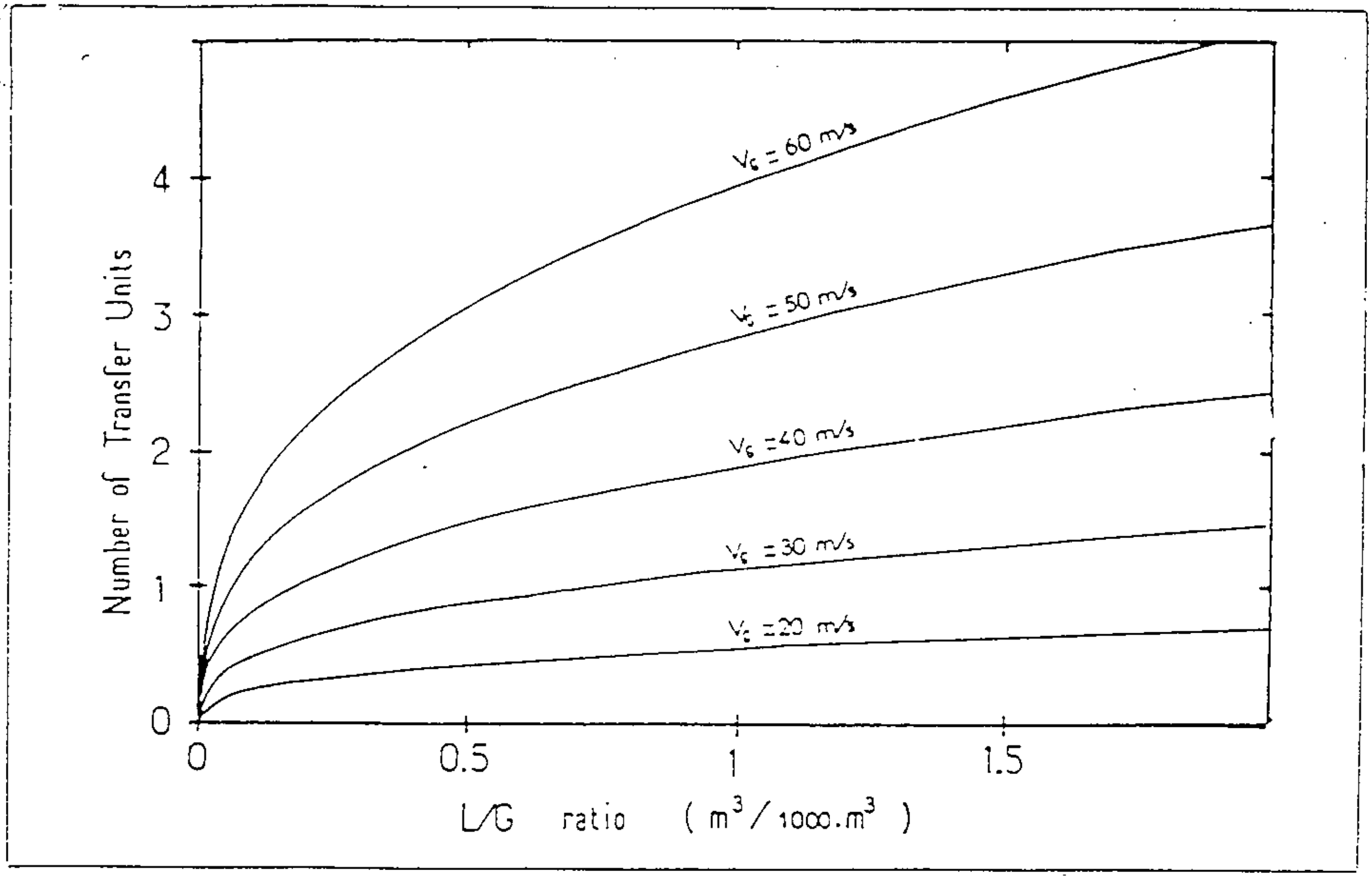


Figure 5. Variation of NTU with L/G ratio and V_G calculated from the empirical law. Using T_{GE} = 60°C and saturated gases; Lv/Dc = 8.5.

Figure 5 shows the NTU as a function of the gas velocity at the throat and of the L/G ratio. Let the temperature of the inlet gas be 60°C and the relative humidity 100%. Figure 6 shows the NTU as a function of pressure loss when gases are at 60°C and when relative humidity is at 100%.

Suppose that we need to design a venturi scrubber capable of treating 150,000 cu.m./hr. of saturated gas at 60°C. Assume that the gas throat velocity is 60 m./sec. and that the L/G ratio is equal to 1.

The pressure loss in the venturi will therefore be:

$$(0.2 + 1.4 \times 1) \times \frac{0.981 \cdot (60)^2}{2 \times 9.81} = 288 \text{ mm. water column}$$

Inlet gas density, gas viscosity, and L_V/Dc ratio have respectively the following values: 0.981 kg./cu.m.; 0.0184 cp.; 8.5. These operating conditions will give NTU = 3.21.

When throat velocity is 50 m./sec., results obtained will be ΔP_t = 200 mm. water column, and NTU = 2.31.

If the operating results of the commercial plant are compared to the empirical laws established statistically by the results of the pilot scheme, the figures for the former are noticeably better. The commercial plant was designed to produce a NTU = 3.5. Design specifications were: throat velocity = 50 m./sec.; scrubbing liquid on arrival in the venturi = 100 cu.m./hr.; and scrubbing liquid atomized in the column = 120 cu.m./hr. Thus the L/G ratio is about 1.1 cu.m./1,000 cu.m.

The following data have been obtained by testing at the commercial plant. At indicated throat velocities, in m./sec., the NTU measured (venturi only) is shown in parentheses: 38 m./sec. (3.6); 24 m./sec. (3); 20 m./sec. (2.6); and 18 m./sec. (2.4).

Heat loss that occurred in the Les Roches de Condrieu plant is very high compared to that of the pilot apparatus. The difference observed between measured and calculated values of NTU can be explained by the resulting condensation; and this becomes more obvious when the throat velocity falls due to the rather low mass transfer efficiency of the venturi in such conditions.

In conclusion

We have found the venturi scrubber system to be very efficient for absorbing fluorine (HF + SiF_4), The NTU achieved is sometimes higher than a value of 3.5. Pressure loss ranges from 150 to 200 mm. water column, cyclonic column included.

This type of equipment is highly suitable, therefore, for the treatment of phosphoric acid plant reactor gas cooling. The simplicity of design is of particular merit. The atomizing agent is gas, thus eliminating the corrosive and plugging risks of a liquid sprinkler.

The apparatus has also proved to be extremely adaptable to different operating conditions. The rate of flow of the liquid can be kept constant and even if the gas flow drops, operating efficiency remains much the same.

From a theoretical viewpoint it is worth pointing out that the statistical analysis shows that gas viscosity is the most important variable, which supports the theory that the gas-side resistance film controls mass transfer. Finally, statistical evidence would seem to suggest that the effect of condensation is one of the determining parameters in the absorption of fluorine.

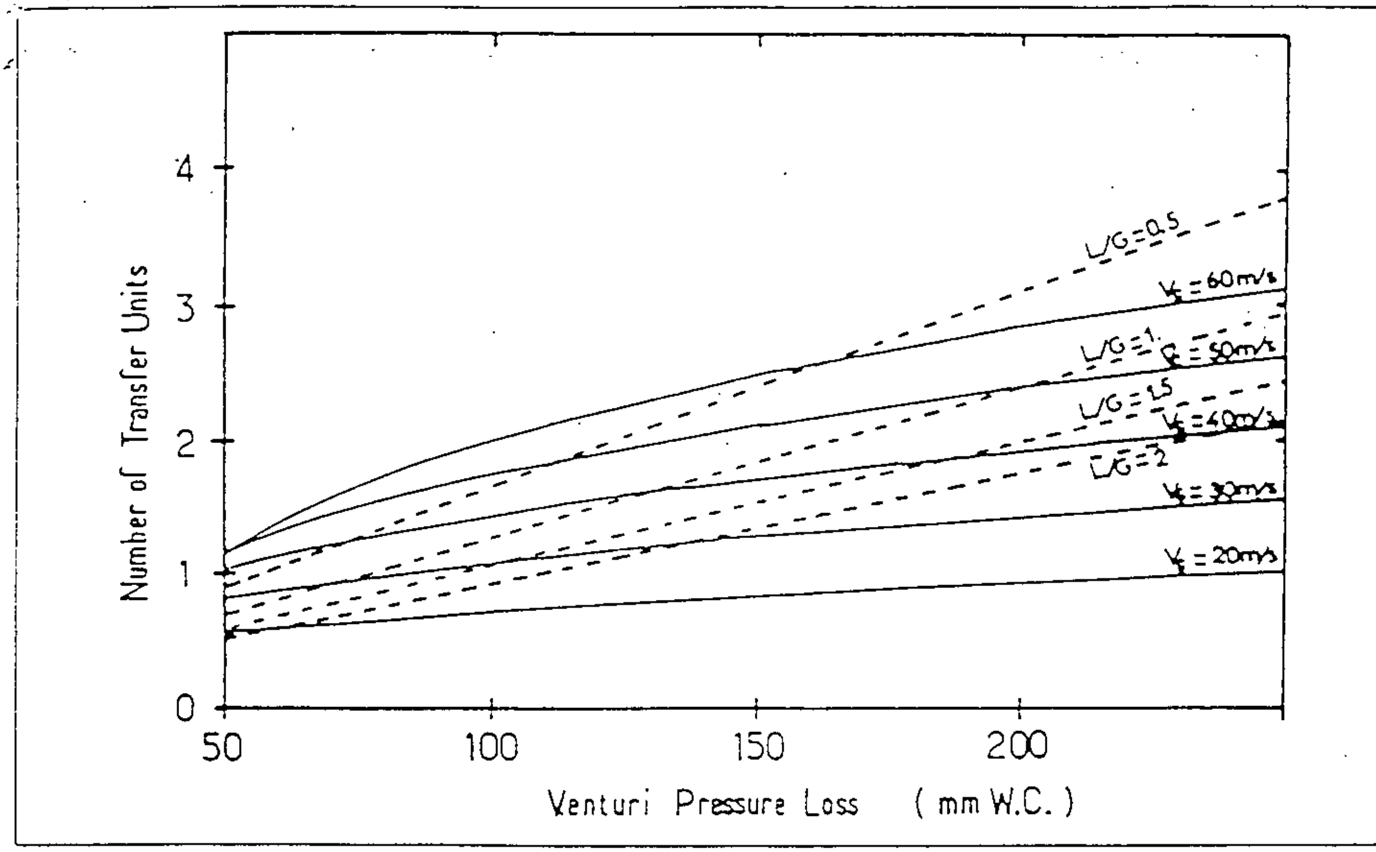


Figure 6. NTU vs. pressure loss. L/G and V_G are taken as parameters. T_{GE} = 60°C and Lv/Dc = 8.5.

Nomenclature

- c_v = effective mass transfer surface per unit packed height, sq.m./m.
- C = pressure loss factor $\frac{\Delta P \times 2 \times g}{\rho_G V_G^2}$
- d = pipe diameter, m.
- dp = droplets diameter, m.
- D = molecular diffusion coefficient, sq.m./sec.
- Dc = venturi throat diameter, m.
- g = gravitational acceleration, m./sec./sec.
- G = volumic gas flow, cu.m./hr.
- h_t = absorber total height, m.
- HTU = height of a transfer unit, m.
- K = pressure drop coefficient
- K_G = overall gas-phase mass transfer coefficient, mole/(hm2atm)
- l = pipe length, m.
- L = liquid flowrate, cu.m./hr.
- L_V = venturi overall length (convergent + throat + divergent), m.
- NTU = number of transfer unit
- P = total pressure, mm. water column
- T = temperature, °C
- V = velocity, m./sec.
- Y = mole fraction in the gas
- Y_{BM}^* = Log-mean mole fraction of inert component in gas

Greek

- α = characteristic length, m.
- ΔP = pressure drop, mm. water column
- λ = friction factor
- μ = viscosity, cp.
- ρ = fluid density, kg./cu.m.
- σ = liquid surface tension, dyne/sq.cm.

Subscripts

- $_G$ = gas
- $_L$ = liquid
- $_e$ = inlet
- $_s$ = outlet
- $_1$ = at venturi throat
- $_2$ = at cyclonic column inlet

Literature cited

1. Nukiyama and Tanasawa. *Trans. Soc. Mech. Engr.* (Tokyo) 4, 5, 6 (1938–40), cited in Perry "Chemical Engineers' Handbook" 4th ed., Section 18, McGraw-Hill, New York (1968).

D. Bilhaud, a process engineer in the Inorganic Div. of Rhône-Poulenc, graduated from Conservatoire National des Arts-et-Metiers in 1973. At his present position, he specializes in gas purification.

C. Djololian, a graduate of the Institut de Genie Chimique, Toulouse, France, has worked with Rhône-Poulenc since 1967. At present, he is responsible for the development of processes related to phosphoric acids and its derivatives.

FLORIDA

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Department of Environmental Protection

Lawton Chiles
Governor

Twin Towers Office Building
2600 Blair Stone Road
Tallahassee, Florida 32399-2400

Virginia B. Wetherell
Secretary

June 10, 1996

Dr. A. J. Teller
c/o Cooper Union
7th Floor
30 Cooper Square
New York, NY 10003

Dear Dr. Teller:

You probably don't remember me but I worked with you briefly at Wellman-Lord when you were consulting with them in the 60's and I met with you in your Worcester office in 1973. I was with EPA at that time and you provided me with information that proved very helpful in developing the federal new source performance standards for the phosphate industry.

I presume you are now in retirement enjoying the well earned rewards of a very distinguished career. It is understandable that you would not want to be bothered by requests such as this, but I thought I would ask since we cannot locate the precise information we need from the early 70's.

We would be interested in knowing if you have any recollection of the design basis of the IMC Prilled MAP scrubber (TESI Venturi/ Crossflow) that was installed in 1975 at the New Wales facility. Records indicate this scrubber was replaced in 1980 with a venturi/cyclonic after alleged plugging problems with the packed section. The issue of the moment concerns a permit application submitted by US Agri-Chemicals, Ft. Meade, for a new prilled MAP plant. They are strongly opposing our BACT determination which requires either a venturi/crossflow, as IMC had initially, or a venturi/cyclonic scrubber using neutralized pond water.

Specifically, we are trying to establish what the proper design goal should be for fluoride removal from Prilled MAP plants. The 24" w.c. venturi/cyclonic scrubber USAC has proposed is only 83% efficient on gaseous fluorides. We believe it should be above 98%. If you can recall anything about this, we would greatly appreciate it. If you have time to discuss it over the phone, please call or FAX us your phone number and I'll call you at your convenience. Our phone number is 904-488-1344; our FAX number is 904-922-6979.

Sincerely,

John Reynolds

John Reynolds
Permitting Engineer
New Source Review Section

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KA 173-94-04

June 4, 1996

Mr. Clair H. Fancy
Florida Department of
Environmental Protection
Twin Towers Office Building
2600 Blair Stone Road
Tallahassee, Florida 32399-2400

Subject: USAC Prilled MAP Plant
AC53-260190 (PSD-FL-222)
BACT Determinations

Dear Mr. Fancy:

On behalf of Steve Susick of U.S. Agricultural Chemicals, Inc. (USAC) and the others present at our meeting on May 21, 1996, I would like to express our appreciation for your time and your consideration of the information we presented. Attached hereto are two documents; (1) a letter from Bryan Blythe of the Jacobs Engineering Group, Inc. (Jacobs) summarizing the scrubber performance information that he presented during our meeting and (2) a summary of refined scrubber cost information prepared by Koogler & Associates (K&A) that I presented during the meeting.

At issue are the Departments BACT determinations for particulate matter/PM10 (PM/PM10) and total gaseous fluoride from USAC's prilled MAP plant. The BACT determinations for the combined tower and cooler emissions address both emission limits and control technology. The emission limits for both PM/PM10 and fluorides are to be established after a series of performance tests once the plant is constructed and operating. The control technology establishes "target" control efficiencies for PM/PM10 (99.0 percent) and total gaseous fluorides (99.3 percent).

When the subject permit was drafted, we discussed the BACT determination with John Reynolds (9/17/95) and confirmed the conversation by letter dated September 12, 1995. In that letter, we stated:

1. We were not opposed to emission limits being set at a later date if the limits were based on plant performance over a reasonable period of time, and

2. It was our understanding that the control technology efficiencies stated by the Department were "target" efficiencies for design purposes only as there are no relevant data from other prilled MAP plants.

We received no correspondence, written or oral, from the Department stating the efficiencies were anything other than what we stated in our September 12, 1996, letter. In fact, we received later correspondence from the Department (March 4, 1996) referring to the 99.3 percent fluoride removal efficiency as a "goal".

It should be recognized that if USAC had any reason to believe the removal efficiencies stated in the BACT determinations were anything other than "targets" or "goals", the permit would not have been accepted and/or an Administrative Hearing would have been requested.

The Jacobs document summarizes (in Table 1) why it is possible to achieve a 99+ percent fluoride control efficiency on a wet process phosphoric acid plant and why it is not practical to achieve this control efficiency on a prilled MAP plant. The efficiencies are purely a function of the amount of fluoride in the gas stream approaching the scrubber and the equilibrium fluoride concentration in the gas stream leaving the scrubber. The latter is a function of natural laws and, as a result, the addition of more scrubber transfer units is not going to reduce the concentration of gaseous fluoride in the gas stream leaving the scrubbing system below the equilibrium vapor pressure. Thus, with the gaseous fluoride concentration at the scrubber exit set by natural laws, the scrubber efficiency is dictated by the fluoride concentration in the gas stream approaching the scrubber. As pointed out in the Jacobs document, the fluoride (gaseous and particulate) generated by a prilled MAP plant is inherently low. Thus, the scrubbing efficiency that can be achieved in a prilled MAP plant is low when compared to the efficiency that can be achieved by scrubbers on phosphoric acid plants and when compared with the efficiency quoted by Teller in his 1967 paper in Chemical Engineering Progress (Vol. 63, No. 3, pg. 75-79).

In Exhibit 2 of the Jacobs document, it is demonstrated that on a phosphoric acid plant, a fluoride scrubbing efficiency of 99.7 percent can be achieved with 6.1 scrubber transfer units. In this same Exhibit, it is demonstrated that the 24-inch pressure drop venturi-cyclonic scrubber system (without a packed scrubber) as proposed for the USAC plant, will achieve a total fluoride (gaseous and particulate) scrubbing efficiency of 94.0 percent with 5.3 scrubber transfer units. This number of transfer units is comparable to the number typically used in wet process phosphoric acid plant scrubber design to achieve BACT.

If the number of transfer units proposed by USAC is doubled to about 10.6 by installing a packed scrubber following the 24-inch pressure drop venturi-cyclonic scrubber, the total fluoride scrubbing efficiency would only be increased to 95.7 percent (from 94.0 percent). And, this assumes no aerosol mist formations or droplet carry-over (see Jacobs letter).

Thus, while keeping in line with scrubber performance (in terms of transfer units) typically designed for other fluoride sources in the phosphate fertilizer industry, the 99.3 percent "target" efficiency stated in Permit AC53-260190 (PSD-FL-222) cannot be achieved.

Aside from the natural laws that govern scrubber performance, one must consider the cost of scrubbing systems. Updated scrubber system cost data are presented in the attached K&A memo dated May 30, 1996. Data are presented for three scrubber systems; a 24-inch pressure drop venturi-cyclonic system; an 18-inch pressure drop venturi-cyclonic system followed by a packed scrubber, and a 24-inch pressure drop venturi-cyclonic system followed by a packed scrubber. The 18-inch pressure drop venturi-cyclonic system followed by a packed scrubber resulted in higher total fluoride emissions and higher particulate matter emissions than the 24-inch pressure drop venturi-cyclonic system with no packed scrubber at a significantly higher cost. As a result, this system was rejected as impractical (see K&A cost data and the Jacobs performance analysis).

The two remaining systems both begin with the same 24-inch pressure drop venturi-cyclonic scrubber system. In both cases, the venturi-cyclonic scrubber system will remove 96.5 percent (66.6 tpy) of the particulate fluoride, 87.1 percent (21.3 tpy) of gaseous fluoride, and 94.0 percent (87.9 tpy) of the total fluoride. The installed cost of this system is $1,750,000 and the annual cost is $557,947/yr (see K&A cost data). The unit cost of total fluoride removal by the 24-inch pressure drop venturi-cyclone scrubber system is $6,348/ton.

The addition of the packed scrubber to the 24-inch pressure drop venturi-cyclonic scrubber system will increase the installed cost to $3,227,000 and the annual cost to $786,126/yr (see K&A cost data). The system scrubbing efficiency will be 96.8 percent (66.8 tpy removal) for particulate fluoride, 92.5 percent (22.6 tpy removed) for gaseous fluoride and 95.7 percent (89.4 tpy removed) for total fluoride. The unit cost of total fluoride removal for the entire system (venturi-cyclonic-packed scrubber) is $8,793/ton.

However, as the packed scrubber is an add-on to the originally designed venturi-cyclonic scrubber system, one must look at the incremental efficiency and cost effectiveness of the added section. Of the total fluoride leaving the venturi-cyclone scrubber, the packed scrubber will remove a conservatively estimated 9.1 percent (0.22 tpy) of particulate fluoride, 41.7 percent (1.31 tpy) of gaseous fluoride and 27.6 percent

(1.53 tpy) of total fluoride. The annual incremental cost of removing the 1.53 tpy of total fluoride is $148,845/ton - a cost far beyond any reasonable effective cost.

To spend this amount of money and the attendant energy resources is especially pointless when one considers that EPA has stated that fluorides are not a health related pollutant (see USEPA, Final Guideline Document, Control of Fluoride Emissions from Existing Phosphate Fertilizer Plants, Research Triangle Park, NC, November 1976)

Considering the welfare related effects of fluorides in the environment, the 1.53 tpy (0.35 lb/hr) of the fluorides that could be removed by the packed scrubber would result in an annual ambient air concentration of about 0.01 micrograms per cubic meter. This is only 0.5 percent of the fluoride levels measured in the vicinity of the USAC plant during the gypsum stack expansion study and 0.02 percent of the Florida Air Reference Concentration for fluorides.

Truly, the expenditure of $148,845 to remove a ton of fluoride is control for the sake of control when one considers there will be no benefit to human health and an insignificant reduction in ambient fluoride levels affecting welfare related values.

The data in the attached Jacob's letter demonstrates the problems associated with the attempt to achieve the targeted 99.3 percent total fluoride control level and the cost analysis in the attached K&A memo demonstrates the inordinate cost of reducing fluoride emissions below the proposed limit of 0.0417 pounds per ton of P_2O_5 (the limit achievable with a 24-inch pressure drop venturi-cyclonic scrubber with no packed scrubber). From the data presented by Jacobs, it is apparent that a reduction in the venturi-cyclonic system pressure drop will result in an increase in fluoride emissions, regardless of what type of packed scrubber is added after this system, because of the increase in particulate fluoride emissions. It is also apparent from the Jacobs data that whatever improvements are made to the 24-inch pressure drop venturi-cyclonic system will result in a marginal increase in fluoride removal efficiency and a marginal reduction in fluoride emissions because of the very low emission rate (1.27 lb/hr and 5.6 tpy) from the proposed system. The cost data in the K&A memo demonstrates that whatever improvements are made to the 24-inch pressure drop venturi-cyclonic scrubber system will be made at a prohibitively high incremental cost.

As a result of the data presented herein and the engineering conclusions that are apparent from these data, it is urged that the Department accept the proposed and designed scrubber system consisting of 24-inch pressure drop venturi scrubbers followed by a cyclonic separator as a technology that represents BACT. This could be approved under Provision No. 3 of the Department's BACT Determination that allows for "other systems with equivalent removal efficiencies approved by the Department." As pointed out previously, the system is designed with a number of transfer units that is equivalent with the number of transfer units required to meet BACT emission limits for other fluoride sources in the phosphate fertilizer industry. As discussed during our meeting, the emission rate from the plant is designed at 0.0417 pounds of total fluoride per ton of P_2O_5. The plant is expected to perform better than designed (see Jacobs letter) and, as stated in the permit, the final permitted emission limit will be based on a series of tests conducted after the plant is operating.

It is further urged that the Department base the permitted fluoride emission limit and demonstration of BACT on emission measurements only and not on scrubber system inlet/outlet tests and an evaluation of the number of transfer units actually achieved. The reason for this request is that the actual fluoride emission rate is expected to be lower than the design emission rate of 0.0417 lb F/ton P_2O_5 and 1.27 lb F/hr (see Jacobs letter). This being the case, the data presented in the two attachments (Jacobs and K&A) demonstrate that any reduction in the fluoride emission rate below what is proposed will be prohibitively costly regardless of how many transfer units actually exist in the scrubber system at the time of testing.

We appreciate your review and consideration of the information provided herein and request that the information presented herein be reviewed as expeditiously as possible so that USAC can meet the construction schedule that has been established. If there are any questions regarding this information, please contact Bryan Blythe of Jacobs (941-665-1511) or Pradeep Raval or me (352-377-5822).

Very truly yours,

KOOGLER & ASSOCIATES

John B. Koogler, Ph.D., P.E.

JBK:wa

c: Mr. Al Linero, FDEP, Tallahassee
Mr. John Reynolds, FDEP, Tallahassee
Mr. Steve Susick, USAC
Mr. Ron Brunk, USAC
Mr. Bryan Blythe, Jacobs
Mr. Larry Curtin, Holland & Knight
Mr. Pradeep Raval, K&A

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June 4, 1996

Mr. Clair H. Fancy
Florida Department of
Environmental Protection
Twin Towers Office Building
2600 Blair Stone Road
Tallahassee, Florida 32399-2400

Subject: USAC Micro Prill MAP Plant
Total Fluoride Emission Limit

Dear Mr. Fancy:

It was a pleasure to meet you in Tallahassee on May 21, 1996. This letter provides the slides that I showed you in this meeting and summarizes our presentation on the scrubbing system for particulates and fluorides at U.S. Agri-Chemicals.

Gaseous Fluoride Removal Efficiencies

An inherent feature of the Micro Prill MAP plant is that it produces less pollutants than conventional methods of fertilizer manufacturer. Table 1 shows the typical gaseous fluoride inlet concentrations for gas streams passing to scrubbers on phosphoric acid, conventional granular DAP, and USAC's Micro Prill MAP plant.

- The vigorous attack of sulfuric acid on phosphate rock in phosphoric acid reactors liberates a gas containing high concentrations of gaseous fluoride, 700 mg/Nm^3 is typical.

- Conventional granular DAP production involves sparging part of the ammonia feed stock through a tumbling bed of granules in an ammoniator granulator. The resulting effluent stream contains large quantities of ammonia which must be removed and these are conventionally removed by scrubbing the outlet gases from the ammoniator granulator system and other areas of the granular DAP plant with phosphoric acid. The phosphoric acid is effective in removing the ammonia, but the airstream may strip fluoride from the phosphoric acid in the venturi cyclonic systems used and leaves a gas which contains typically 65 mg/Nm^3 gaseous fluoride.

- The pipe reactor in a Micro Prill MAP plant is very effective in reacting ammonia and phosphoric acid and the amount of ammonia slip is much lower than in conventional DAP plants. It is therefore only necessary to scrub the gas stream with water to remove the small amount of residual ammonia that remains, the considerable amount of particulate generated by the production of a prill, and a small amount of fluoride.

The recirculated water that is used to scrub fluoride from the spray tower and cooler effluents in the USAC plant exhibits an equilibrium back pressure of about 3 mg/Nm^3 of dry air. This equilibrium vapor pressure, together with a scrubbing system which incorporates 5.4 transfer units, is used to illustrate the relative ease of achieving high efficiencies in the phosphoric acid systems that are being used to predicate a removal efficiency for the USAC prill MAP plant.

- In the case of the phosphoric acid reactor, which starts with pollutant fluoride concentrations almost two orders of magnitude higher than the prill MAP plant, it is possible to achieve a 99% removal efficiency.
- In the case of the granular DAP plant, the efficiency that it is possible to achieve is reduced to 95%, because the outlet concentration approaches the equilibrium vapor pressure over the solution.
- In the case of the prill MAP plant venturi cyclonic, it is only possible to achieve an 87% gaseous removal efficiency because of the very low inlet concentration of the pollutant and the approach of the outlet concentration to the equilibrium vapor pressure.
- If one adds an additional packed tower to the first scrubbing system with the same number of transfer units, in other words, twice the amount of scrubbing, it is only possible to remove 42% of the remaining fluoride, again because of equilibrium vapor pressure.

<u>Effect of Adding A Packed Tower Scrubber To The Venturi Cyclonic System Presently Incorporated In The Design</u>

Figure 1 shows the venturi cyclonic scrubber as designed with the addition of a packed tower scrubber. Effluent gases from the spray tower and from the cooler cyclone pass through individual venturi systems, large amounts of energy are dissipated out over the venturi and the majority of the particulate and its associated fluoride and the gaseous fluoride are removed.

The overall efficiency of the venturi cyclonic scrubber on total fluoride removal is 94%.

In the present design, the gas from the cyclonic separator passes directly to the scrubber fan and stack.

The packed tower suggested by FDEP is shown following the venturi cyclonic system. The effluent gases pass from the venturi cyclonic through the packed tower and then to the scrubber fan and stack.

Approximately 16,000 lb/hr. of process water make-up is fed to the packed tower and because of the large gas volumes involved, this is arranged in a pump-around system so that there is sufficient water to irrigate the packing. The recirculated water then advances to the venturi cyclonic system which is fitted with a similar pump-around system and the water stream containing the removed particulates and fluoride is then blown down from the system as make-up to the process. Three sets of economics of the cost of fluoride removal have been calculated.

- Venturi cyclonic scrubber alone with a 24 in. pressure drop. (current design)
- Venturi cyclonic scrubber with 24 in. pressure drop, packed tower, auxiliary fan, scrubber fan and stack.
- Venturi cyclonic scrubber with 18 in. pressure drop, packed tower, scrubber fan and stack.

Reduction of the pressure drop across the venturi system more than doubles the amount of particulate leaving the venturi and results in a commensurate increase in particulate fluoride.

The particulate cut-off for the venturi cyclonic scrubber and packed tower are also shown on Figure 1. This is the average particle diameter removed by the device. The cut-off for the venturi cyclonic scrubber is just under half a micron and for the packed tower is 2 microns. As a result, the packed tower recovers only a small percentage of the particulate leaving the venturi cyclonic scrubber (10% recovery has been assumed).

The particulate, particulate fluoride, gaseous fluoride, and total fluoride concentrations are shown on Figure 1 at both the exit of the venturi scrubber system and at the exit of the packed tower. The addition of the packed tower system results in a reduction in particulate from 24 lb/hr. to 21.82 lb/hr. and a reduction in total fluoride from 1.27 to 0.92 lb/hr, if a venturi pressure drop of 24 in. is maintained.

However, if the venturi pressure drop is reduced to 18 in. to remove the necessity for an auxiliary fan and its commensurate power consumption, the overall system results in an increase in particulate from 24 lb/hr. to 51.39 lb/hr. and of total fluoride from 1.27 lb/hr. to 1.55 lb/hr. over the venturi cyclonic system currently proposed.

<u>Cut Diameter vs. Gas Phase Pressure Drop For Various Types of Scrubbers</u>

Figure 2 is reproduced from an article by Dr. Seymour Calvert in *Chemical Engineering*, August 29, 1977, which was provided to you at the meeting. Dr. Calvert was an air pollution control officer for Brookpark, Ohio, Chairman of the Cleveland Advisory Board on Air and Water Pollution, Dean of Engineering at the University of California (Riverside), and Director of the Air Pollution Control Association. Figure 2 provides the "cut diameter" against pressure drop for a number of different types of particulate removal systems. The pressure drop across the venturi cyclonic separator at USAC as designed is 24 in. with 5 in. being consumed by the cyclonic section. This leaves 19 in. for the spray tower venturi which corresponds to a cut diameter of approximately 0.5 microns on curve 4. With a 1 in. allowance for ductwork pressure drop, 5 in. of pressure drop is available for the packed tower which corresponds to a cut diameter of 2 microns on curve 2. Mr. Calvert says the following on the fourth page of his article,

> "The reason cut diameter is so useful a parameter is that a curve of collection efficiency vs. particle diameter for collection by inertial impaction is fairly steep. Several important types of scrubbers have performance characteristics such that a particle whose aerodynamic diameter is half the cut diameter would be collected at about 10% efficiency whereas a particle with an aerodynamic diameter twice the cut diameter would be collected at about 90% efficiency.
>
> Because the cut is fairly sharp, one can use as a rough approximation, a concept that the scrubber collects everything larger than the cut diameter and passes everything smaller."

As stated above, we have assumed that the packed tower is capable of removing 10% of the particulates left in the gas stream by the venturi cyclonic separator.

<u>Venturi Cyclonic Quoted Removal Efficiencies vs. Pressure Drop</u>

Table 2 and Figure 3 are a tabulation and curve for the removal efficiencies of venturi cyclonic scrubbers against venturi pressure drop provided to Jacobs by DR Technologies, the scrubber vendor, in a letter on January 9, 1995. This data plus a performance allowance were used to generate the particulate value shown on Figure 1.

<u>Limitations in Gaseous Fluoride Removal Capability</u>

Exhibit 1 and Figure 4 are an extract from Pierre R. Becker's recent textbook on phosphates and phosphoric acid (Marcell Decker 1989), the most recent and definitive work on phosphoric acid and phosphate manufacture. Becker, on Exhibit 1, describes the reasons for low scrubbing efficiencies when fluoride scrubbing is attempted.

- High Operating Temperatures with Recirculated Water Systems resulting in high H_2SiF_6 equilibrium partial pressures (the recirculated liquor in the USAC scrubber system will be at about 50°C.)

- Mist formation and droplet entrainment. Sub-micron mists act very much like particles and require a high energy venturi type of scrubber to remove.

- Precipitation of silica and potential plugging of the scrubbing system.

- Dissociation of fluosilicic acid to hydrogen fluoride at low fluosilicic acid concentrations in the 4 g/liter to 0.05 g/liter range.

Maximum Possible Packed Tower Performance

Figure 4 which plots fluoride equilibrium partial pressure in milligrams per cubic meter of dry air against fluoride concentration in the liquid phase in g/liter demonstrates the effect of fluosilicic acid dissociation on the fluoride vapor pressures which remain essentially constant in the concentration range 4 g/liter to .05 g/liter.

The performance of the packed scrubber was evaluated using this most recent fluoride equilibrium vapor pressure data in Table 3 and Figure 5.

Table 3 shows the effect of fluoride absorption from 0 to 0.7 lb/hr. on the residual fluoride left in the gas phase and on the equilibrium fluoride partial pressure which is shown in grams per cubic meter of dry air and converted to lb/hr.

Fluoride left in the gas stream and the equilibrium fluoride quantity in the gas stream are plotted against fluoride absorbed in Figure 5. This data shows that the fluoride left in the gas stream and the equilibrium fluoride quantity meet at an approximate absorption of 0.3 lb/hr. of fluoride and this is further emphasized by the number of stages required in Table 3. The #NUM! values given by the spreadsheet show that for these amounts of fluoride absorption, the tower is acting as an absorber at the inlet and a stripper at the exit. At an absorption of 0.7 lb/hr., the number of stages is shown as -2.25 and this indicates that the tower becomes a stripper throughout its length.

In other words, the maximum possible removal of gaseous fluoride is 0.3 lb/hr. no matter how many transfer units are installed in the packed tower. This maximum fluoride removal is used to calculate the gaseous fluoride removal across the packed tower shown on Figure 1.

Actual Plant Operating Data

Table 4 shows data from the Namhae Chemical, Korea, DAP/NPK plant. Jacobs added an additional scrubber to this granular fertilizer plant in a very similar attempt to reduce the final concentrations of fluoride in the fertilizer plant effluent gases. From the results, one can conclude that:

- Very little fluoride is removed at low levels when scrubbing with fresh water. In fact, in the first set of data from July 31, 1995, the analyses show an actual fluoride increase which is, of course, not possible.

- The remaining data shows a reduction in fluoride concentration of only about 15% compared with the 40% reduction calculated from the Becker data for USAC.

Effect of Aerosol Mists and Carry Over

It should be emphasized that the removal of 0.3 lb/hr. of gaseous fluoride estimated from vapor pressure data above assumes that none of this gaseous fluoride is bound up as an aerosol, which will probably not be the case. Because submicron aerosol mists act like particulates in scrubber systems, any fluoride that is present in this form entering the packed scrubber will not be removed and it is quite probable that the fluoride removal achieved by the additional packed scrubber would fall to the 0.1 lb/hr. range and mimic the performance that we have seen in Korea.

If there is any carry over of scrubbing solution in the form of droplets, this will also reduce the removal capabilities of the scrubber.

Equivalent Transfer Units

The scrubbing system for the U.S. Agri-Chemicals Prill MAP plant has been designed according to standards comparable with other plants in the phosphate industry using the number of theoretical equilibrium stages or transfer units of its scrubbing system as a basis for comparison.

In order to achieve the new BACT emission standard for fluoride of 0.016 lb/ton P_2O_5 fed for phosphoric acid plants, approximately 6 transfer units are necessary. The calculations to demonstrate this are shown in Exhibit 2.

The scrubbing system to be provided for U.S. Agri-Chemicals can be shown to require at least 5.4 transfer units to achieve the permitted emissions of 0.4 lbs. particulate/ton MAP and 0.0417 lbs. total fluoride/ton P_2O_5. We are confident that scrubbing system to be installed will perform better than the permit levels. Calculations for the number of transfer units for a typical phosphoric acid plant and for the USAC micro prill MAP plant are attached in Exhibit 2.

Best regards,

JACOBS ENGINEERING GROUP INC.

Bryan M. Blythe
Technical Center Director

BMB:ree

Enclosures

Table 1

GASEOUS FLUORIDE SCRUBBING

Assumptions

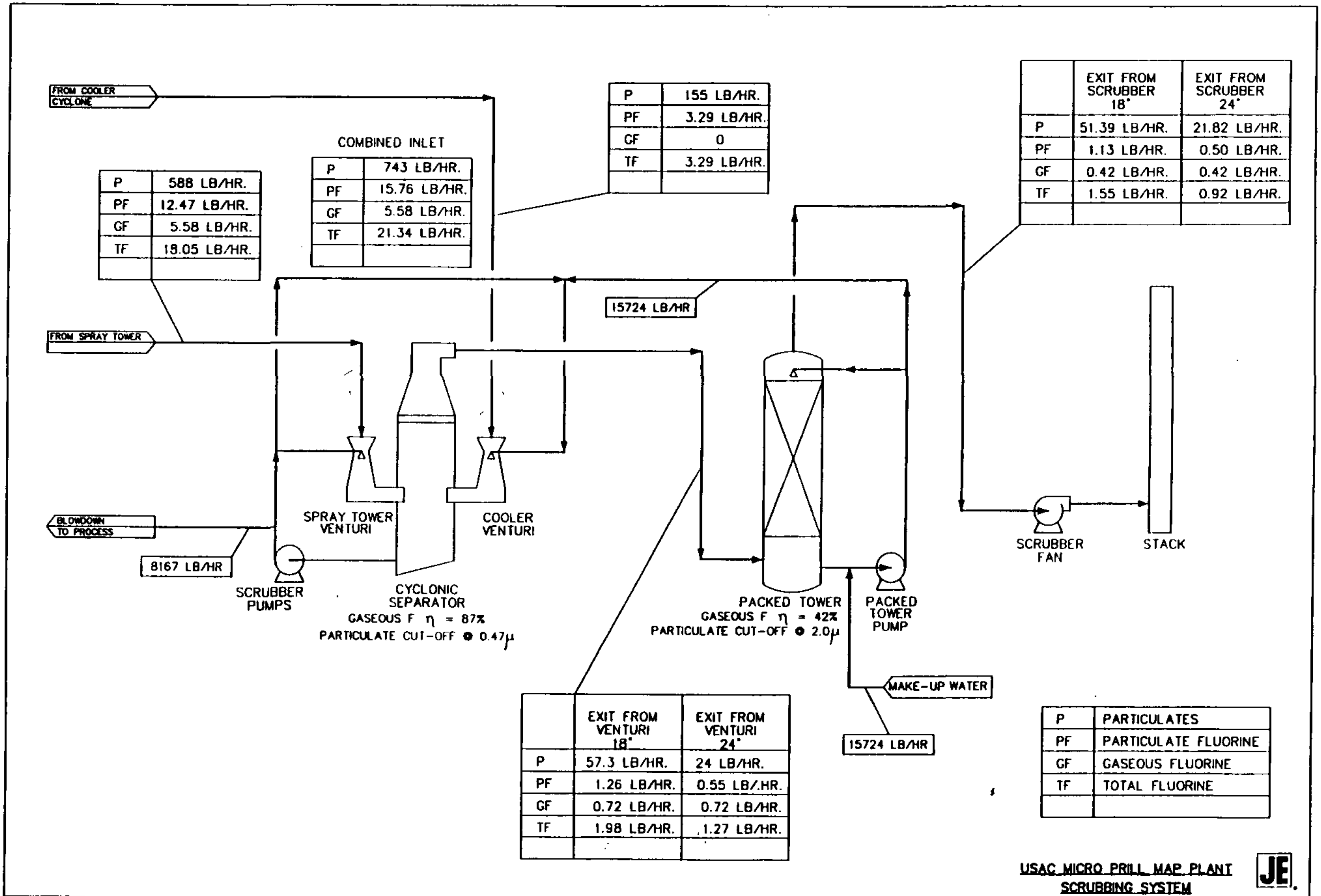
1. Equilibrium vapor pressure is 3 mg/Nm3
2. Scrubbing system has 5.4 transfer units

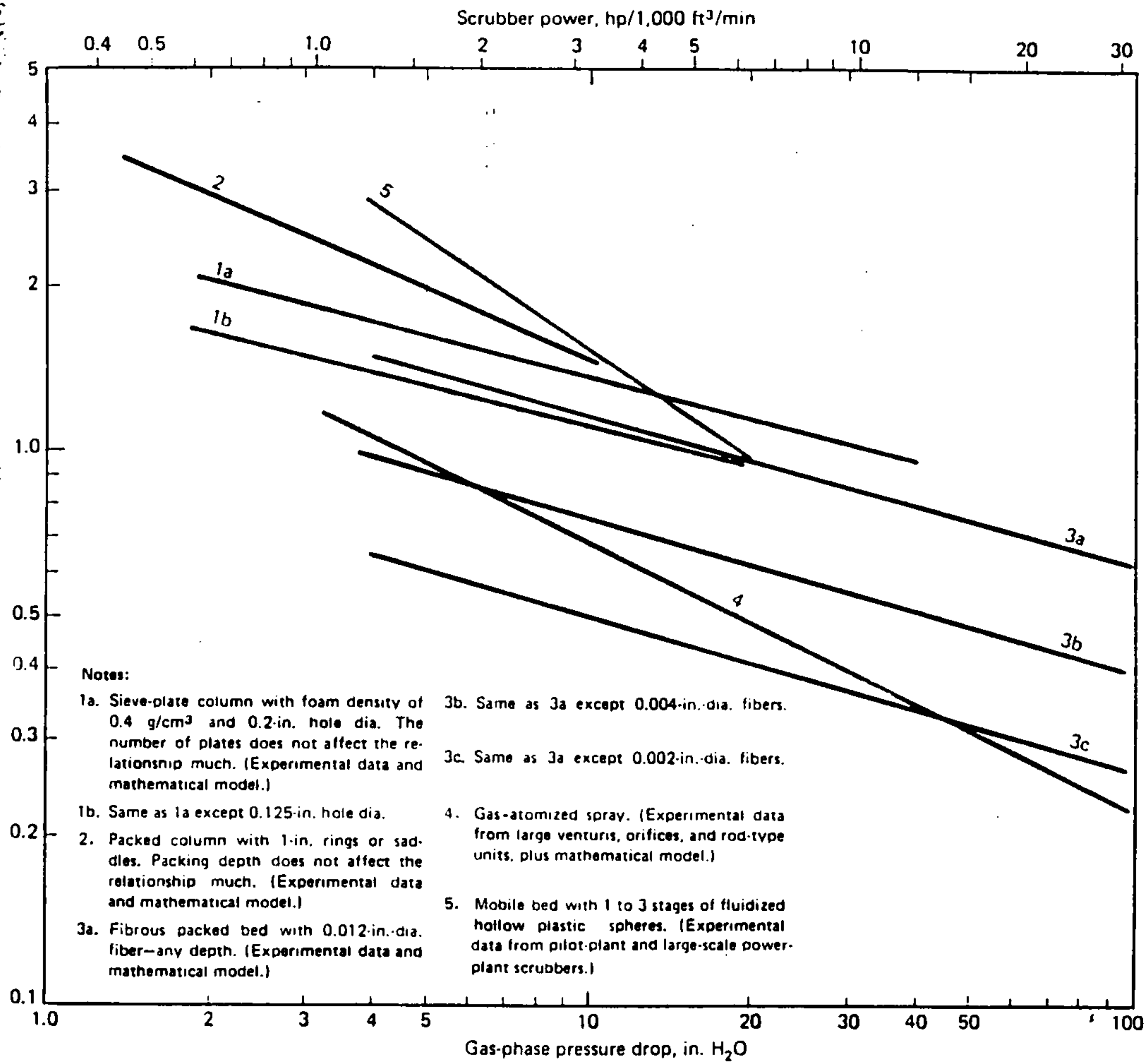
Plant	Inlet Conc. mg/Nm3 (mg/scf)	Outlet Conc. mg/Nm3 (mg/scf)	Efficiency %
Phos. Acid	700 (18.75)	6.15 (0.165)	99.1
Gran. DAP	65 (1.74)	3.28 (0.086)	95.0
Powder MAP - Venturi Cyclonic	23 (0.62)	3.09 (0.081)	86.6
Powder MAP - Packed Tower	2.24 (0.060)	1.31 (0.034)	41.7

Conclusions

1. Much easier to obtain high efficiencies with phos acid because driving force is considerably higher.
2. Packed tower efficiency is very low because driving force is very small.

Figure 1


FROM COOLER CYCLONE
FROM SPRAY TOWER
BLOWDOWN TO PROCESS
8167 LB/HR
P 588 LB/HR.
PF 12.47 LB/HR.
GF 5.58 LB/HR.
TF 18.05 LB/HR.
COMBINED INLET
P 743 LB/HR.
PF 15.76 LB/HR.
GF 5.58 LB/HR.
TF 21.34 LB/HR.
P 155 LB/HR.
PF 3.29 LB/HR.
GF 0
TF 3.29 LB/HR.
15724 LB/HR
EXIT FROM SCRUBBER 18"
EXIT FROM SCRUBBER 24"
P 51.39 LB/HR. 21.82 LB/HR.
PF 1.13 LB/HR. 0.50 LB/HR.
GF 0.42 LB/HR. 0.42 LB/HR.
TF 1.55 LB/HR. 0.92 LB/HR.
SPRAY TOWER VENTURI
COOLER VENTURI
SCRUBBER PUMPS
CYCLONIC SEPARATOR
GASEOUS F η = 87%
PARTICULATE CUT-OFF @ 0.47μ
PACKED TOWER
GASEOUS F η = 42%
PARTICULATE CUT-OFF @ 2.0μ
PACKED TOWER PUMP
SCRUBBER FAN
STACK
MAKE-UP WATER
15724 LB/HR
EXIT FROM VENTURI 18"
EXIT FROM VENTURI 24"
P 57.3 LB/HR. 24 LB/HR.
PF 1.26 LB/HR. 0.55 LB/.HR.
GF 0.72 LB/HR. 0.72 LB/HR.
TF 1.98 LB/HR. 1.27 LB/HR.
P PARTICULATES
PF PARTICULATE FLUORINE
GF GASEOUS FLUORINE
TF TOTAL FLUORINE
USAC MICRO PRILL MAP PLANT
SCRUBBING SYSTEM
JE



ut/power relationship simplifies process design for many scrubber configurations — Fig. 2 0

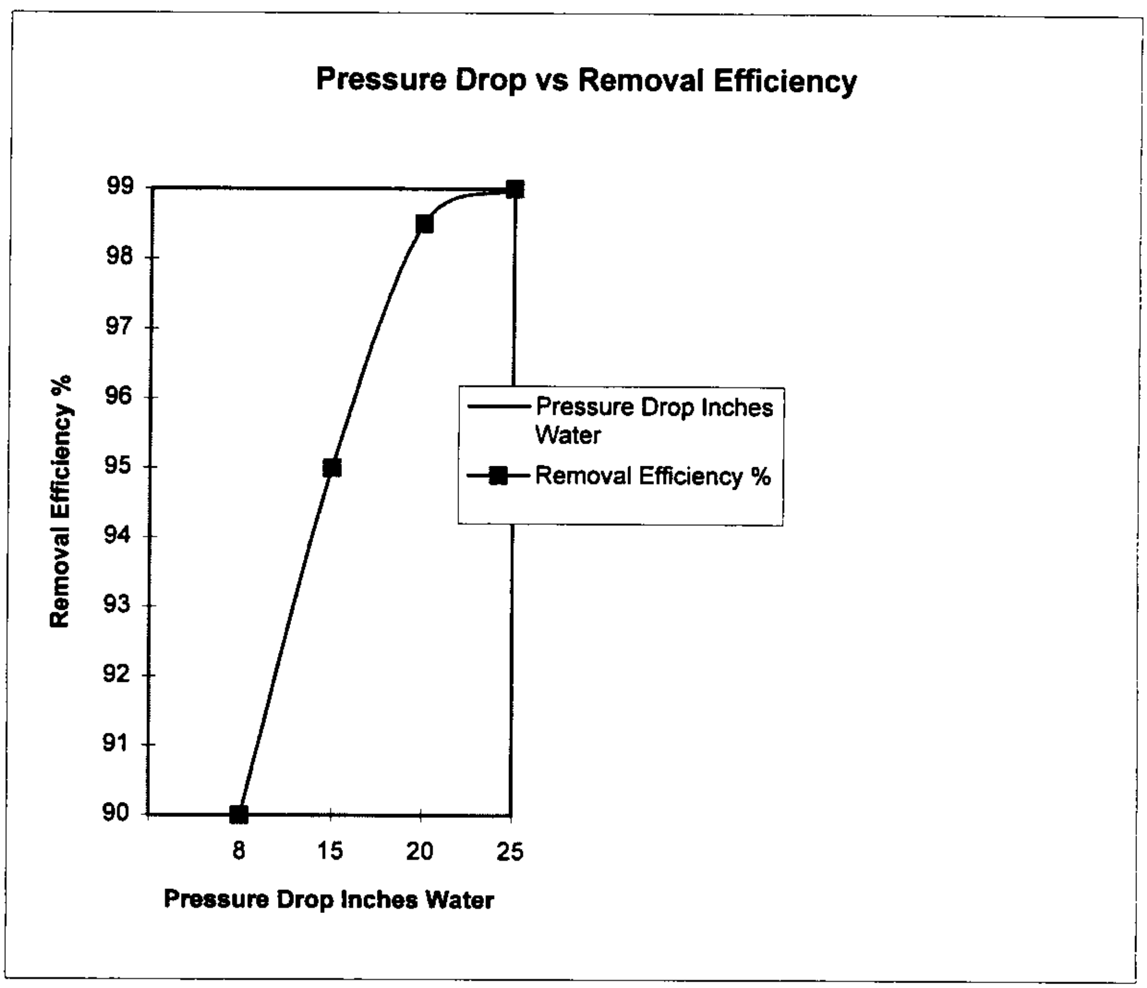
Figure 2

Table 2

D.R. Technology Venturi Cyclonic Scrubbers
Quoted Removal Efficiencies vs Pressure Drop

Pressure Drop Inches Water	Removal Efficiency %
8	90
15	95
20	98.5
25	99

Figure 3



Several reasons for low scrubbing efficiencies can be listed:

1. The effluent gases leaving the reactor are moist and warm (65–70°C), almost saturated, and consequently difficult to cool. Unless very large amounts of scrubbing water within an open cycle can be used (with large quantities of contaminated water leaving the plant) the system will necessarily operate at temperatures close to 60–65°C. Partial pressures of H_2SiF_6 liquors are very sensitive to the effect of temperature.
2. Scrubbing wash liquors containing hydrofluoric and hydrofluosilicic acids are readily subject to droplet entrainment and mist formation.
3. There is a tendency to precipitate silica at the front end of the system, possibly plugging the scrubbing system. This precipitation increases the F/SiO_2 ratio and subsequently the partial pressure of F in the following stages.
4. At lower H_2SiF_6 concentrations in the wash liquor, there is an increase in the F in gas/F in liquor partial pressure ratio. The ratio is subject to a 100-fold increase within the F in liquor concentration of about 0.4–0.05%. To overcome this phenomenon, highly efficient scrubbing systems with several stages must be used [29]. There are two explanations for this phenomenon:
   a. With increasing pH values when the H_2SiF_6 concentration drops in the wash liquor, the equilibrium

$$4H_2O + H_2SiF_6 \rightleftharpoons 6HF + Si(OH)_4 \qquad (71)$$

   is pushed to the right. When the concentration of F is below 0.05% F in the liquor, all of F can be considered as HF.

   b. Hydrofluosilicic acid in solution presents a more complex composition, such as $H_2SiF_6(SiF_4)_n$, n being affected by the concentration of F in the liquor. A lower concentration would favor low n values with consequent higher F vapor pressure due to HF release:

$$H_2SiF_6(SiF_4)_n + 4H_2O \longrightarrow H_2SiF_6(SiF_4)_{n-2} + H_2SiF_6 + 2HF + Si(OH)_4 \qquad (72)$$

Whatever the explanation, the scrubbing system has to cope with the fact of a 100-fold increase in the relative F vapor/F liquor ratio, disturbing Henry's law. The empirical partial pressure diagram (Fig. 5.23) demonstrates a shift from H_2SiF_6 lines to HF lines between 0.4 and 0.05% F in liquor.

Pierre Becker Phosphates and Phosphoric Acid Marcel Dekker, Inc. 1989.

Figure 4

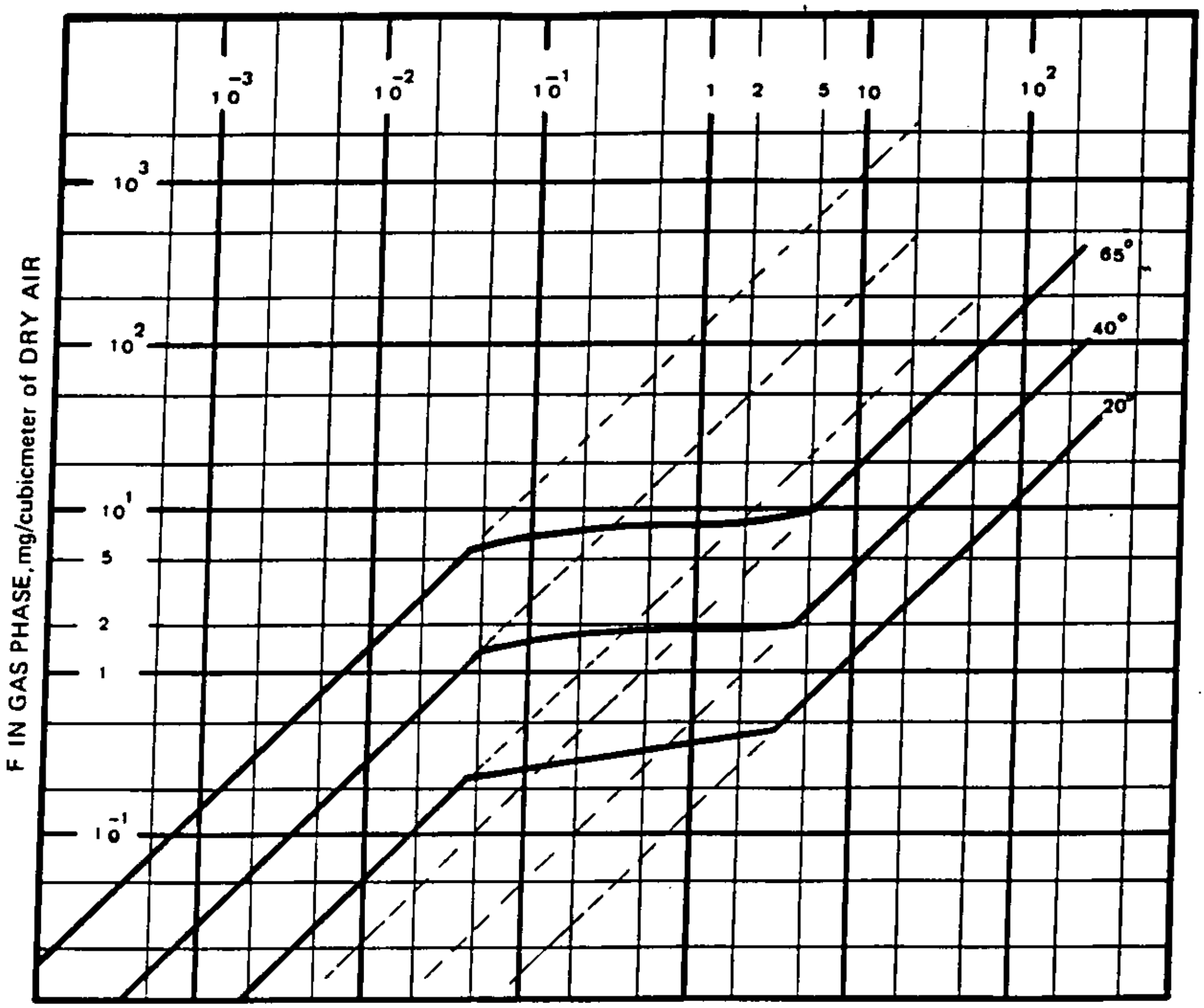


FIG. 5.23 Effect of fluoride concentration in H_2SiF_6 liquor on fluorides in gas phase.

These effects explain why many of the fluorine scrubbers operate far below the rated yield of efficiency. Hihg-efficiency effluent gas washing can be achieved only when we rely on proven equipment, systems, and operating conditions.

Pierre Becker Phosphates and Phosphoric Acid Marcel Dekker, Inc. 1989.

Table 3 USAC Micro Prill MAP Plant
Packed Scrubber
Fluorine Absorbed vs Equilibrium Fluorine

Fluorine Absorbed Lb/Hr	Fluorine Left Lb/Hr	Equilibrium Fluorine Lb/Hr	Fluorine Concentration Gm/Litre	Fluorine mg/cm Dry Air	Number of Stages
0	0.72	0	0	0.00	0.00
0.1	0.62	.1284	.0064	0.40	0.19
0.2	0.52	.2729	.0127	0.85	0.59
0.3	0.42	.3692	.0191	1.15	1.93
0.4	0.32	.4816	.0254	1.50	#NUM!
0.5	0.22	.5779	.0318	1.80	#NUM!
0.6	0.12	.6421	.0382	2.00	#NUM!
0.7	0.02	.8026	.0445	2.50	-2.25

Blowdown = 15724 Lb/Hr

Dry Air = 145628 Cm/Hr

Gaseous F exit Venturi 0.72 Lb/Hr

Figure 5

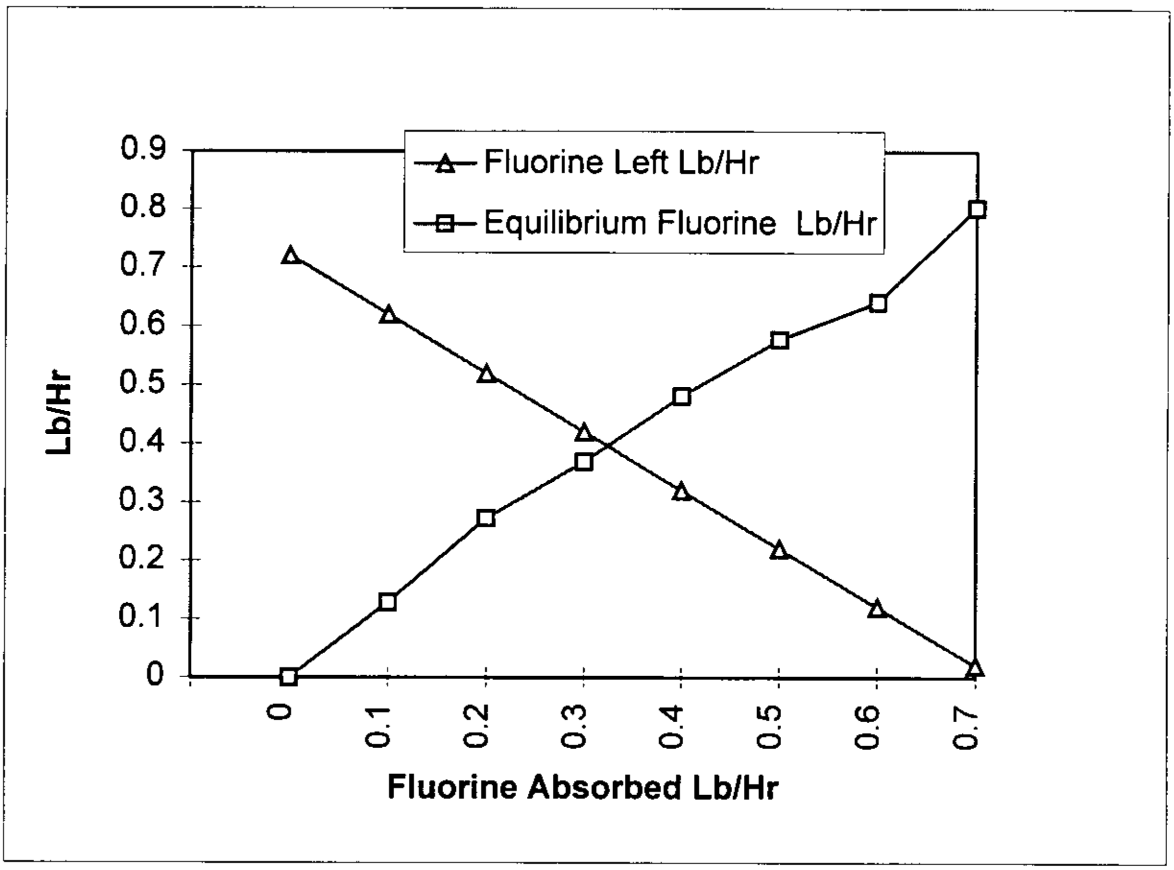


Table 4

Data From Namhae Chemical - Korea DAP/NPK plant

Capacity 90 tph

Venturi Cyclonic Followed by Kimre Scrubber

Date	Fluorine In ppm	Fluorine Out ppm
7/31/95	2.80	3.75
8/2/95	1.43	1.15
8/3/95	1.15	1.00
Scrubbing Medium	Fresh Water	

Exhibit 2

Number of Transfer Units (NTU's) Required in a Phosphoric Acid Plant for Fluorine Removal

From the article by Teller a typical phosphoric acid plant scrubbing system uses once-through pond water to treat the following airstreams.

	acfm	mgF / ft^3
Digestion	20,000	150
Filtration	20,000	10
Sumps & Vents	25,000	3
Overall	65,000	50.4 = 1,780 mg/m^3

BACT emissions from a modern day 1891.2 tpd P_2O_5 phosphoric acid plant would be about:

65,000 acfm (55,300 dry acfm)
30.3 lb/day fluorine
0.016 lb/ton P_2O_5
0.173 mg/ft^3 = 6.10 mg/m^3

The latest available information on equilibrium vapor pressure in weak fluosilicic acid solutions is provided by Becker (Figure 4). Typical pond water leaving a once through scrubber would have a concentration of 3000-5000 ppm (3-5 g/l), according to the Teller article, at 110°F. From the Becker data, equilibrium vapor pressure is approximately 2 mg/m^3:

Number of transfer units is defined as

$$\text{Ln}\ (P_1 - P^*/P_2 - P^*)$$

Where P_1 = Inlet Fluorine Pressure in gas phase
P_2 = Outlet Fluorine Pressure in gas phase
P^* = Equilibrium Fluorine Pressure

The number of transfer units required is therefore:

$$\text{Ln}\ (1780 - 2 / 6.10 - 2) = 6.07$$

Gaseous Fluoride Emission at USAC

Spray Tower Venturi Airflow		110,014 m^3/h dry air
Gaseous F at Venturi Inlet		5.58 lb/h
Concentration at Inlet	=	$\frac{5.58 \times 454}{110,014} \times 1000$
	=	23.03 mg/m^3 dry air
Scrubber Liquor Concentration		0.59 g/litre
Scrubber Liquor Temperature		120°F (49°C)
From Becker the equilibrium vapor pressure		2.9 mg/ m^3 dry air
Gaseous F at Exit	=	0.72 lb/hr
	=	$\frac{0.72 \times 454 \times 1000}{110,014}$
	=	3 mg/m^3
Number of Transfer Units (NTU)	=	$\ln \frac{23 - 2.9}{3 - 2.9} = 5.3$
Max particulates permitted	=	24 lb/h (0.4 lb/ton MAP)
	=	0.55 lb/h fluoride
Total fluoride Emission	=	0.72 + 0.55 = 1.27 lb/h (0.0417 lb/ton P_2O_5)

USAC MAP PROJECT - BACT CALCULATIONS
Dated 5-30-96

This updated BACT analysis includes the most recent cost/emissions information gathered on the three scrubbing system configurations evaluated for USAC's proposed prilled MAP plant. The cost and performance data represent the most recent cost information provided by the scrubber vendor and refinements to the performance calculations based on the Becker fluoride (F) vapor pressure data. The data presented herein supersede previous data submitted to the Department and are consistent with data submitted during our meeting with FDEP in Tallahassee on May 21, 1996.

Jacobs projects a total F emission rate as low as 0.92 lb/hr for a high energy venturi-cyclonic and cross flow scrubbing system combination; 1.27 lb/hr for a high energy venturi cyclonic scrubbing system; and, 1.55 lb/hr for a low energy venturi-cyclonic and cross flow scrubbing system combination. Jacobs Engineering, for reasons stated during our meeting and in the attached letter from Jacobs, are not in a position to guarantee the emission rates.

A. Low energy venturi-cyclonic and cross flow scrubber:

The following analysis pertains to a two-stage system with low energy venturi-cyclonic followed by a cross flow scrubber. The total F emission rate is 1.55 lb/hr (1.13 lb/hr particulate F and 0.42 lb/hr gaseous F).

Fluorides Control

The total F to scrubber of 21.33 lbs/hr represents 5.58 lbs/hr gaseous F and 15.75 lbs/hr particulate F.

Total F removed = (21.33 - 1.55) lb/hr x 8760 hrs x ton/2000 lbs
= 86.6 tpy

Scrubber F eff. = (21.33 lb/hr - 1.55 lb/hr)/21.33 lb/hr
= 92.7 percent

The total costs, submitted previously to FDEP (letter 5-7-96) are as follows:

Total installed costs = $ 2,888,000

Total annual costs = $ 671,054

The annual cost of control, based on expected F removal:

Annual cost of control = $671,054/86.6 tpyF
= $7749/ton F removed

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COMPARISON OF SYSTEM "A" TO THE PROPOSED SYSTEM

The incremental cost analysis presented below is simplified by evaluating the difference in annual costs to the difference in F removal for the two arrangements, assuming equivalent O&M costs and proportional capital (direct and indirect) costs.

Total annual cost = $557,947
(24 inch pressure drop Venturi, updated)

Total annual cost = $671,054
(Two-stage scrubber)

Annual Cost Difference = $113,107

Added Fluoride Removal = (1.27-1.55)lb/hr x 8760 hr/yr x ton/2000lbs
= - 1.2 tpy

The above analysis indicates that both cost and F emissions are expected to be higher for the low venturi-cross flow scrubber arrangement than for the 24 inch pressure drop venturi system.

B. High energy venturi-cyclonic and cross flow scrubber:

The following analysis pertains to a two-stage system with high energy (24 inch pressure drop) venturi-cyclonic followed by a cross flow scrubber. This arrangement requires a $98,000 additional booster fan (200 HP), adding to the capital and operating costs of scrubbing arrangement "A" discussed above. The total F emission rate is 0.92 lb/hr (0.50 lb/hr particulate F and 0.42 lb/hr gaseous F).

Fluorides Control

The total F to scrubber of 21.33 lbs/hr represents 5.58 lbs/hr gaseous F and 15.75 lbs/hr particulate F.

Total F removed = (21.33 - 0.92) lb/hr x 8760 hrs x ton/2000 lbs
= 89.4 tpy

Scrubber F eff. = (21.33 lb/hr - 0.92 lb/hr)/21.33 lb/hr
= 95.7 percent

Fixed Capital Costs

Venturi-Cyclonic Equipment Capital Costs:
(Updated venturi-cyclonic costs from Jacobs)

Cooler Cyclone	=	$ 37,000
Cooler Venturi, Spray Tower Venturi, Cyclonic Separator	=	$ 248,000
Fans	=	$ 220,000
Pumps	=	$ 24,000
Stack	=	$ 73,000
Total Equipment Cost	=	$ 602,000
Installation, including structural work, etc	=	$ 1,487,000
Subtotal (Installed Cost)	=	$ 2,089,000

Cross Flow W/Kimre Packing Equipment Capital Costs:

Scrubber	=	$ 270,000
Pumps	=	$ 22,000
Total Equipment Cost	=	$ 292,000
Installation including structural work, etc	=	$ 846,000
Subtotal (Installed Cost)	=	$ 1,138,000
Total Installed Cost	=	$ 3,227,000
Total Equipment Cost	=	$ (602,000 + 292,000)
	=	$ 894,000

Operation and Maintenance Costs

Operating Costs:

Electricity	=	(617+50+200)BHP x 0.746 kw/hp x 8760 hrs/yr x $0.059/kw
	=	$334,283
Water	=	32 gpm x 60 min/hr x 8760 hrs/yr x $0.20/1000 gals
	=	$3,364
Total operating costs	=	$337,647

Maintenance Costs:

Operating labor	=	2 hrs/shift x shift/8 hrs x 8760 hrs/yr x $12.96/hr
	=	$28,382
Supervisory labor	=	$28,382 x 0.15 (EPA factor)
	=	$4,257
Maintenance labor	=	1 hr/shift x shift/8 hrs x 8760 hrs/yr x $14.26/hr
	=	$15,615
Maintenance materials	=	$15,615 x 1.0 (EPA factor)
	=	$15,615
Total maintenance costs	=	$63,869
Total annual O&M costs	=	$337,647 + $63,869
	=	$401,516

Indirect Costs

Overhead	=	$63,869 x 0.6 (EPA factor)
	=	$38,321
Administration	=	$894,000 x 1.91 (EPA factor) x 0.02 (EPA factor)
	=	$34,151
Insurance	=	$894,000 x 1.91 (EPA factor) x 0.01 (EPA factor)
	=	$17,075
Property tax	=	$894,000 x 1.91 (EPA factor) x 0.01 (EPA factor)
	=	$17,075

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Capital recovery	=	$894,000 x 1.91 (EPA factor) x 0.1628 (EPA factor)
	=	$277,988
Total indirect costs	=	$38,321 + $34,151 + $17,075 + $17,075 + $277,988
	=	$384,610
Total annual costs	=	$384,610 + $401,516
	=	$786,126
Annual cost of control	=	$786,126/89.4 tpyF
	=	$8793/ton F removed

<u>**COMPARISON TO PROPOSED SYSTEM**</u>

Total annual cost (Venturis, updated)	=	$557,947
Total annual cost (Two-stage scrubber)	=	$786,126
Annual Cost Difference	=	$228,179
Added Fluoride Removal	=	(1.27-0.92)lb/hr x 8760 hr/yr x ton/2000lbs
	=	1.5 tpy
INCREMENTAL COST	=	**$228,179/1.5 tpyF**
	=	**$148,845 per ton of additional F removed.**

8/30/96

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Summary of Cost and Scrubber Performance Data

USAC Microprilled MAP Plant

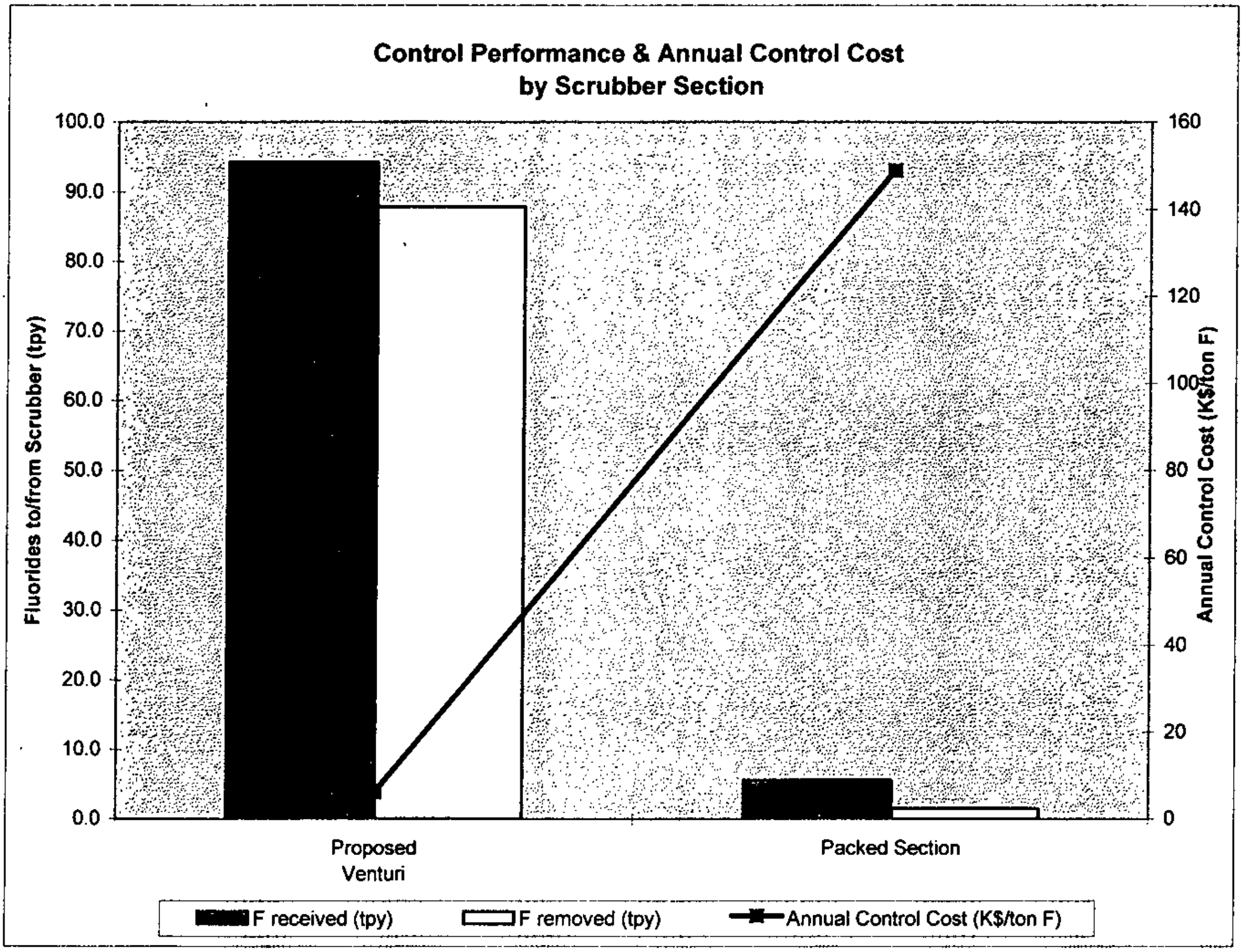
			Proposed	Dual-Medium Venturi		Dual-High Venturi		Expected Performance
		From	24"	18"		24"		24"
Exit streams	units	Process	Venturi	Venturi	Packed	Venturi	Packed	Venturi
Particulates	lbs/hr	743	24	57.3	57.3	24	24	
Particulate F	lbs/hr	15.75	0.55	1.26	1.13	0.55	0.55	0.44
Gaseous F	lbs/hr	5.58	0.72	0.72	0.42	0.72	0.42	0.53
Total F	lbs/hr	21.33	1.27	1.98	1.55	1.27	0.92	0.97
Efficiency			94.05	92.73		95.69		95.45
F emitted	lbs F/ton P2O5		0.042	0.052		0.031		0.032
F emitted	tpy		5.6	6.8		4.0		4.2
F removed	lbs/hr		20.1	19.8		20.4		20.4
F removed	tpy		87.9	86.6		89.4		89.2
Installed cost	K$		1,750	2,888		3,227		
Annual cost	K$/yr		558	671		786		
Annual Control Cost	K$/ton F		6.35	7.75		8.79		
Incremental Control Cost	K$/ton F			*		149		

* Increased total fluoride emissions at an increased annual cost

Incremental Venturi/Cyclonic and Packed Section Cost and Performance Data

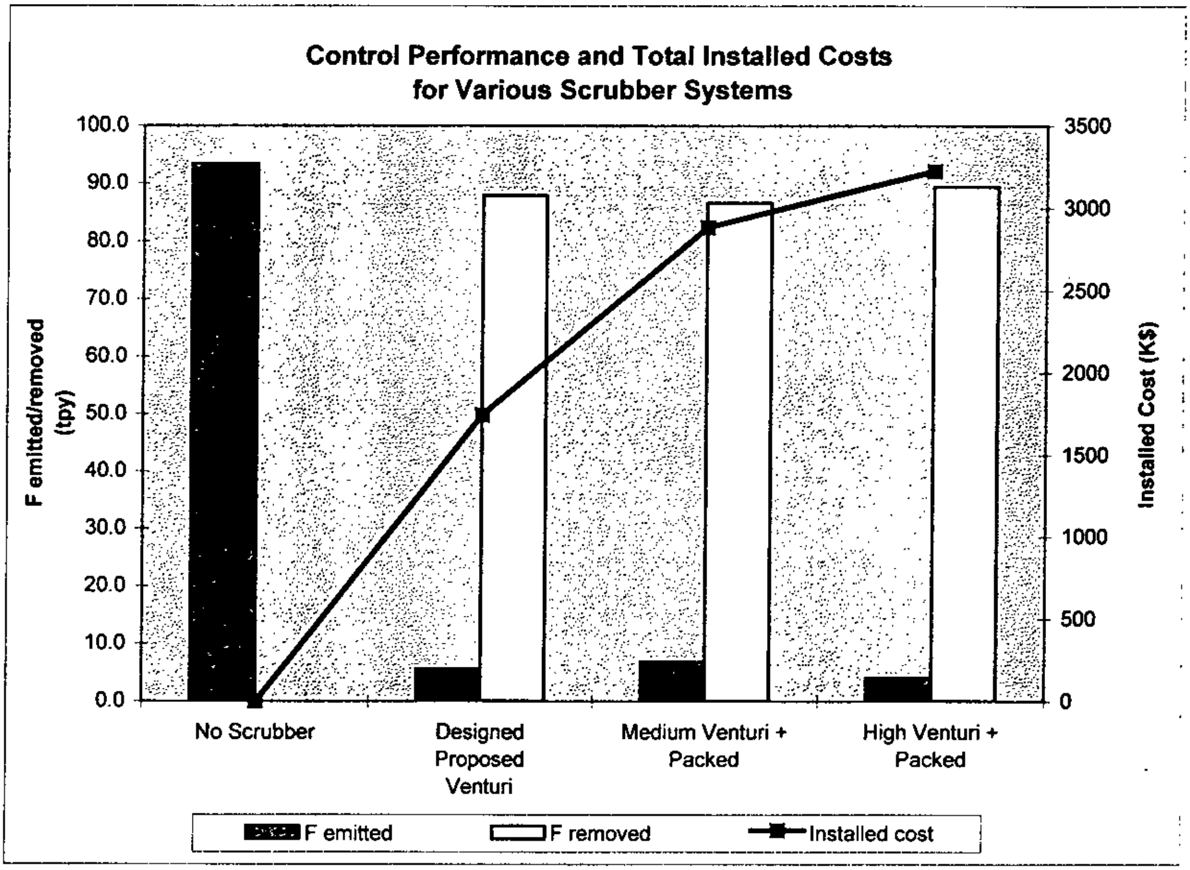
USAC Microprilled MAP Plant

Exit streams	Proposed Venturi	Packed Section
F received (tpy)	94.2	5.6
F removed (tpy)	87.9	1.5
Annual Control Cost (K$/ton F)	6.35	149



Exit streams	No Scrubber	Designed Proposed Venturi	Medium Venturi + Packed	High Venturi + Packed	Expected Proposed Venturi	units
F emitted	93.4	5.6	6.8	4.0	4.2	tpy
F removed	0	87.9	86.6	89.4	89.2	tpy
Installed cost	0	1,750	2,888	3,227	1,750	K$
Annual cost	0	558	671	786	558	K$/yr
Annual Control Cost	0	6.35	7.75	8.79	6.35	K$/ton F
Incremental Control Cost			*	149		K$/ton F
F emitted	0.711	0.042	0.052	0.031	0.032	lbs F/ton P2O5

* Increased total fluoride emissions at an increased annual cost



IMC AGRICO

EDWARD M. NEWBERG
Vice President
Chemicals - Florida

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JUN 4 1996

BUREAU OF
AIR REGULATION

May 31, 1996

Mr. A. A. Linero
Florida Department of Environmental
Protection
Twin Towers Office Building
2600 Blair Stone Road
Tallahassee, Florida 32399-2400

RE: U.S. Agri-Chemicals Corporation
Prill MAP Plant Air Permit Modification
Permit No. PSD-FL-222, AC53-260190

Dear Mr. Linero:

This letter is pursuant to your request for information regarding our experience with venturi-cyclonic scrubber systems. We understand that the intended use by the Department is to consider an air permit modification request by U.S. Agri-Chemicals Corporation, 3225 State Road 630 West, Fort Meade, Florida, for the construction of their new Prilled MAP Plant. We hope that the following is helpful to FDEP for that purpose.

The IMC-Agrico New Wales Prill MAP Plant was originally constructed with a scrubbing system that incorporated both venturi and packed scrubber technology. During operation it was discovered that excessive maintenance was required to maintain the packed scrubber resulting in downtime each month while the packing was cleaned or replaced. Soon after construction the production capacity was increased. During the permitting process for this modification, IMC-Agrico proposed and received approval for replacing the combination scrubber with a venturi-cyclonic scrubber system. Since that time, both emissions and maintenance have decreased.

We believe this information should be helpful in your deliberations.

Very truly yours,

Edward M. Newberg

EMN/d

cc: J. Reynolds, BAR

C: E. E. Helms - USAC

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ENVIRONMENTAL SERVICES
4014 NW THIRTEENTH STREET
GAINESVILLE, FLORIDA 32609
904/377-5822 • FAX 377-7158

KA 173-94-04
May 7, 1996

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BUREAU OF
AIR REGULATION

Mr. A. A. Linero
Florida Department of
Environmental Protection
Twin Towers Office Building
2600 Blair Stone Road
Tallahassee, Florida 32399-2400

Subject: Prilled MAP Plant BACT Determination
US Agri-Chemicals Corporation
Permit No. PSD-FL-222, AC53-260190

Dear Mr. Linero:

This is in response to your letter dated April 9, 1996 regarding the scrubbing system for the above referenced project.

The design engineers, Jacobs Engineering Group, Inc., have assessed FDEP's suggested two-stage scrubbing system and had specific comments, discussed below.

For granular DAP or MAP plants, two stage scrubbing is the norm and is justifiable. These plants are required to use phosphoric acid in the first stage scrubbers in order to recover ammonia. In so doing, fluorine is stripped from the acid and a further scrubbing stage, using water, is necessary to reduce the fluoride emissions to acceptable levels. USAC, however, is proposing to construct a powder MAP plant. In this process, ammonia slip is negligible because the reaction is carried out at a mole ratio of only 1.0 with no further ammoniation required. Scrubbing with phosphoric acid is therefore not necessary. To our knowledge, there are no powder MAP plants operating anywhere in the world with two stage scrubbing.

The scrubbing duty in a powder MAP plant is predominantly particulate recovery. As stated before, packed towers are not suitable for this duty due to their tendency to plug. By far, the best and most widely used arrangement in the fertilizer industry is venturi-cyclonic scrubbers. Packed towers are considered only when the duty is purely one of gaseous pollutant removal. The fertilizer industry has generally had problems with recirculating packed tower scrubber operations. For example, the powder MAP plant at IMC-Agrico, New Wales Plant, originally utilized a packed tail gas scrubber and had to replace it with a venturi-cyclonic scrubber. Jacobs own experience with packed towers has been unfavorable to the extent that vertical packed towers are no longer recommended, even on tail gas scrubbing duties, due to the excessive downtime associated with them.

In the case of the powder MAP process, the particulate matter loading to the scrubbing system is high and the gaseous fluoride is relatively low (estimated at 743 lb/hr and 5.58 lb/hr, respectively). The vast majority of the gaseous fluoride can be recovered in the proposed venturi-cyclonic system. The amount of total fluoride being emitted from the proposed system is estimated at only 1.27 lb/hr. The incremental cost associated with adding another stage (packed scrubber) is enormous in relation to the theoretical potential benefits.

The suggestion of reducing the pressure drop across the venturi scrubbers, and using an additional packed tower with little or no increase in overall pressure drop, would result in a doubling of the particulates in the exhaust from the first stage scrubbers. It is expected that this arrangement would lead to frequent plugging in a second stage vertical packed tower. Based on Jacobs experience, the cleaning frequency would reflect perhaps once per month with a duration of two days. Consequently, a horizontal cross-flow scrubber with Kimre packing would be more operationally feasible because it has less tendency to block and is less difficult to clean. A capital cost breakdown for this type of scrubber system is attached.

If such a system were to be installed, it would not be possible to quantify or warrant an expected reduction in emissions during actual operation. This is because the quantity of fluoride leaving the first stage scrubber would already be very low, meaning that the concentration of fluoride in the second stage scrubber liquor would be very low. Accurate vapor pressure data, at these low levels of concentration, are not available and considerable interpolation is required. There would probably be some improvement in gaseous fluoride emissions due to the use of two stage scrubbing, however, it is not possible to quantify it.

The arrangement suggested for consideration under Item 6 of FDEP's letter would not be feasible for the following reasons:

1. The venturis would be of the flooded elbow type to avoid erosion problems and the scrubbing liquor from both venturis would pass into the packed cyclonic section. As the same scrubber liquor would be used in both venturi and packed sections, there would be no reduction in vapor pressure to enhance gaseous fluoride control.

2. The scrubber liquor would have a high concentration of particulates and would cause rapid plugging in the packed section. The plugging would result in channeling through the packing which would result in increasing emissions with time up to the regular cleaning session.

Jacobs would, therefore, not be able to warrant either the production rate from the plant, due to the frequent stoppages, or the emissions, due to channeling.

For all the reasons mentioned above, FDEP should approve the 1.27 lbF/hr emission limit proposed by USAC, consistent with BACT criteria, using two venturi scrubbers in parallel, followed by a cyclonic separator.

If you have any questions, please call Pradeep Raval or me.

Very truly yours,

KOOGLER & ASSOCIATES

John B. Koogler, Ph.D., P.E.

JBK:par
Enc.

c: R. Brunk, USAC
B. Thomas, FDEP, SW District

cc: J. Reynolds, BAR
B. Harwood, Polk Co
J. Harper, EPA
J. Bunyak, NPS

BACT CALCULATIONS
Dated 5-7-96

For purposes of this analysis, it is assumed that a fluoride emission rate as low as 0.9 lb/hr can be achieved by a low energy venturi-cyclonic and cross flow scrubbing system combination (based on vapor pressure loss addressed in letter to FDEP dated 3-22-96). Jacobs Engineering, for reasons stated in this letter, are not in a position to guarantee this emission rate.

The following analysis pertains to a two-stage system with low energy venturis followed by a cross flow scrubber. More recent cost information on the venturi system has been included herein to update the analysis.

Fluorides Control

The total F to scrubber of 21.33 lbs/hr represents 5.58 lbs/hr gaseous F and 15.75 lbs/hr particulate F.

Total F removed	=	(21.33 - 0.9) lb/hr x 8760 hrs x ton/2000 lbs
	=	89.5 tpy
Scrubber F eff.	=	(21.33 lb/hr - 0.9 lb/hr)/21.33 lb/hr
	=	95.8 percent

Fixed Capital Costs

Venturi-Cyclonic Equipment Capital Costs:
(Updated venturi-cyclonic costs from Jacobs)

Cooler Cyclone	=	$ 37,000
Cooler Venturi, Spray Tower Venturi, Cyclonic Separator	=	$ 248,000
Fan	=	$ 122,000
Pumps	=	$ 24,000
Stack	=	$ 73,000
Total Equipment Cost	=	$ 504,000
Installation, including structural work, etc	=	$ 1,246,000
Subtotal (Installed Cost)	=	$ 1,750,000

Cross Flow W/Kimre Packing Equipment Capital Costs:

Scrubber	=	$ 270,000
Pumps	=	$ 22,000
Total Equipment Cost	=	$ 292,000
Installation including structural work, etc	=	$ 846,000
Subtotal (Installed Cost)	=	$ 1,138,000
Total Installed Cost	=	$ 2,888,000

Operation and Maintenance Costs

Assume no significant change in operation and maintenance costs from those previously submitted to FDEP as the small reduction in power requirement on the primary scrubber is offset by additional power requirement for the secondary scrubber. Also, the make up water requirement will not vary significantly from the previously submitted information.

Operating costs	=	$ 260,534
Maintenance costs	=	$ 63,869
Total annual O&M costs	=	$ 324,403

Indirect Costs

Overhead = $63,869 x 0.6 (EPA factor)
= $38,321

Equipment costs are estimated at $504,000 for the venturi-cyclonic system (updated cost) and $292,000 for the cross flow system, or a total of $796,000.

Administration = $796,000 x 1.91 (EPA factor) x 0.02 (EPA factor)
= $30,407

Insurance = $796,000 x 1.91 (EPA factor) x 0.01 (EPA factor)
= $15,204

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Property tax	=	\$796,000 x 1.91 (EPA factor) x 0.01 (EPA factor)
	=	\$15,204
Capital recovery	=	\$796,000 x 1.91 (EPA factor) x 0.1628 (EPA factor)
	=	\$247,515
Total indirect costs	=	\$346,651
Total annual costs	=	\$324,403 + \$346,651
	=	\$671,054
Annual cost of control	=	\$671,054/89.5 tpyF
	=	\$7499/ton F removed

INCREMENTAL COSTS FOR SECONDARY SCRUBBER

The following analysis addresses the incremental costs for removal of fluorides by the additional packed cross flow scrubber in comparison to the proposed high energy venturi-cyclonic arrangement.

The analysis presented below is simplified by evaluating the difference in annual costs to the difference in fluoride removal for the two arrangements, assuming equivalent O&M costs and proportional capital (direct and indirect) costs.

Total annual cost (Venturis, updated)	=	\$557,947
Total annual cost (Two-stage scrubber)	=	\$671,054
Annual Cost Difference	=	\$113,107
Added Fluoride Removal	=	(1.27-0.9)lb/hr x 8760 hrs/yr x ton/2000lbs
	=	1.6 tpy
Incremental cost	=	\$113,107/1.6 tpy
	=	\$ 70,692 per ton additional F removed

It is apparent that while the proposed venturi scrubbing system cost is already in the upper range of BACT cost criteria, using a secondary cross flow scrubber would be well beyond the BACT cost range and is definitely not cost effective. Too large a cost would be incurred for too small a quantity of additional fluoride emission reduction (which can not be guaranteed due to the scientific uncertainty associated with the already low fluoride emissions). Further, as previously discussed, the potential for significant downtime with it's associated loss of production and increasing fluoride emissions due to channeling gas streams through the scrubber packing would still be problematic. Please note that neither of these issues have been reflected in this cost/benefit analysis.

KOOGLER & ASSOCIATES

Department of Environmental Protection

Lawton Chiles
Governor

Twin Towers Office Building
2600 Blair Stone Road
Tallahassee, Florida 32399-2400

Virginia B. Wetherell
Secretary

April 9, 1996

CERTIFIED MAIL - RETURN RECEIPT REQUESTED

Mr. Steven J. Susick, P.E.
General Manager
US Agri-Chemicals Corporation
3225 State Road 630 West
Fort Meade, Florida 33841-9799

Dear Mr. Susick:

The Department has the following concerns about the information in Koogler & Associates' March 22 letter regarding the proposed scrubbing system for the prilled MAP plant (PSD-FL-222).

1. Our March 4 letter asked for itemized equipment cost estimates. The March 22 response did not itemize capital costs.

2. While we agree on the need for a venturi scrubber installed ahead of the packed scrubber to reduce particulate loading, we can not agree that the venturi should be designed to remove the bulk of the fluoride emissions followed by a packed scrubber as an "incremental" system. A logical design approach dictates removing the bulk of the fluorides in the most efficient device, i.e. the packed scrubber, thus requiring only a low to medium energy venturi upstream for solids knockdown.

3. The Department is well aware of the industry's long standing concerns about higher maintenance efforts required to operate packed scrubbers vs. venturis. Nonetheless, the industry's long history of successful packed scrubber operation convinces us that packed scrubbers are justified, especially in view of their much higher fluoride removal efficiencies and lower energy requirements.

4. Regarding USAC's proposed emission limit of 0.0417 lb F/ton P2O5 on grounds that the EPA's proposed MACT limit for granular MAP is 0.058 lb F/ton P2O5, emissions from the prilled MAP process cannot be compared directly to those from the granular process. Also, for new sources, MACT cannot be less stringent than BACT, so it is BACT that "drives" MACT, and not the reverse. The Department is not required to set a BACT limit based on or "in line with" MACT.

5. The comments regarding the lack of ambient air impact-related benefits attributable to advanced fluoride controls are perhaps best addressed by pointing out that the primary element of BACT determinations is the control system efficiency. Although costs and other factors such as ambient benefits are considered in the analysis, they seldom override this primary one.

6. Since this is a BACT installation, the control efficiency and cost effectiveness of a packed scrubber must be evaluated as the primary spray tower control device. This design would involve both of the venturis discharging to the inlet of the packed tower with the possibility of eliminating the cyclonic separator.

Upon the receipt and analysis of the above information, we will reach a decision on BACT for this process and advise you promptly so that USAC can proceed without further delay. If there are any questions regarding this letter, please call me at 904-488-1344.

Sincerely,

John Reynolds

John Reynolds
Permit Engineer
New Source Review Section

c: B. Thomas, SWD
R. Harwood, Polk Co.
J. Harper, EPA
J. Bunyak, NPS
P. Raval, K&A

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US Agri Chemicals Corp
3225 State Road 630 W.
Ft. Meade, Fl 33841-9799

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PS Form **3800**, March 1993

KOOGLER & ASSOCIATES
ENVIRONMENTAL SERVICES
4014 NW THIRTEENTH STREET
GAINESVILLE, FLORIDA 32609
904/377-5822 ▪ FAX 377-7158

KA 173-94-04
March 22, 1996

RECEIVED
MAR 27 1996
BUREAU OF
AIR REGULATION

Mr. A. A. Linero
New Source Review Section
Florida Department of
Environmental Protection
Twin Towers Office Building
2600 Blair Stone Road
Tallahassee, Florida 32399-2400

Subject: Prilled MAP Plant BACT Determination
US Agri-Chemicals Corporation
Permit No. PSD-FL-222, AC53-260190

Dear Mr. Linero:

This is in response to your letter dated March 4, 1996 regarding the BACT determination for the above referenced project.

The design engineers, Jacobs Engineering Group, Inc., have identified a scrubbing system for the proposed prilled MAP plant consisting of two venturi scrubbers in parallel, followed by a cyclonic separator. The scrubbing medium will be recirculated water. This option, discussed in our letter to the Department dated February 15, 1996, represents the optimum scrubber design for control of fluorides from the proposed plant combined with on-line reliability. The resulting estimated cost of control, based on recent additional information, is $6308 per ton of fluorides removed.

The overall design system efficiency for fluorides, associated with the proposed design of the process and scrubbing system combined, is about 99.95 percent. However, in response to your suggestion, a packed scrubber to increase the projected fluoride removal efficiency for the proposed prilled MAP plant, has been evaluated.

Jacobs indicated that a packed tower alone would not be technically feasible for control of fluorides as the particulate loading from the process would result in excessive scrubber plugging. However, another option would be to add a packed tower in series after most of the particulates have been removed by the scrubbing system proposed by Jacobs. The installed cost of a packed tower is estimated at $950,000, or about half again of the cost of the proposed venturi scrubber system. Assuming that the operating and maintenance costs would also be halved (conservative estimate), the total annual cost of that unit would be half again that of the venturi scrubber system; about $275,000 per year. The annual cost for a packed cross-flow scrubber would be higher as the equipment cost would be much higher than that for a packed tower.

Jacobs indicated that even with an infinite number of transfer units, only an additional 0.51 lbF/hr (2.3 tpy at 8760 hrs/yr) could be removed due to the equilibrium vapor pressure of the fluorides in the scrubbing medium. This would mean an incremental control cost of about $125,000 per ton of fluorides removed for the additional packed scrubber. Obviously, this incremental cost is orders of magnitude above typical BACT control cost criteria.

Also, this cost estimate does not take into consideration the usual particulate matter related maintenance problems associated with packed scrubbers, nor the loss of production associated with down time. This MAP manufacturing process generates fine particulates which would cause chronic maintenance problems for packed scrubbers. The phosphate industry in general is very concerned about the on-line reliability and maintenance intensive aspects of packed scrubbers in such applications. Equipment down time significantly affects product costs. This is a sensitive issue which has to be considered in determining the BACT. It would not be prudent to install a high efficiency but high maintenance/low reliability oriented pollution control equipment. A situation, where excessive time is spent keeping the air pollution control equipment working properly rather than producing MAP, would not be economically viable.

Another alternative to improve fluorides removal, which is not viable for this project, is the use of once-through fresh water or treated water as the scrubbing medium. As discussed previously with FDEP staff, fresh water cannot be used due to stringent water use practices pursuant to an agreement with the South West Florida Water Management District and, further, additional fresh water use will adversely affect the plant's water balance. Regarding treated water, an applicant for a granular MAP plant recently submitted to FDEP a water treatment system cost estimate (using lime treatment and a dedicated pond) in excess of $70,000 per ton of fluoride removed.

Another consideration for determining what is reasonable as BACT is the fact that the proposed emission limit of 0.0417 lbsF/ton P205 is significantly below the proposed MACT standard of 0.058 lbF/ton P205; and, EPA expects MACT to be more stringent than BACT. FDEP should consider a BACT which is in line with, rather than more stringent than, a corresponding MACT.

Furthermore, it should be noted that there are no ambient air impact-related benefits to be gained by additional extravagant expenses on control equipment for fluorides. As you are well aware, there are no ambient air quality standards for fluorides and there are no health or welfare related concerns on the part of EPA or FDEP associated with the proposed project at an emissions level of 1.27 lbsF/hr.

For all the reasons mentioned above, FDEP should approve the 1.27 lbF/hr emission limit proposed by USAC, consistent with BACT criteria, using two venturi scrubbers in parallel, followed by a cyclonic separator.

If you have any questions, please call Pradeep Raval or me.

Very truly yours,

KOOGLER & ASSOCIATES

John B. Koogler, Ph.D., P.E.

JBK:par
Enc.

c: R. Brunk, USAC
B. Thomas, FDEP, SW District
B. Harwood, Polk Co.
EPA
NPS
~~J. Koogler, K+A~~

KOOGLER & ASSOCIATES

BACT CALCULATIONS

The following calculations indicate how the costs associated with fluoride control were estimated.

PROPOSED SCRUBBING SYSTEM

MAP Plant Production Rate	:	60 tph Prilled MAP; 30 tph P205
P205 Feed Rate	:	30.6 tph P205 input
Fluorides input	:	83 lbF/ton P205
Water makeup	:	32 gpm
Fan	:	617 BHP
Pump	:	50 BHP
Gaseous fluorides to scrubber	:	5.58 lbs/hr
Particulate fluorides to scrubber	:	15.75 lbs/hr
Total fluorides to scrubber	:	21.33 lbs/hr
Gaseous fluorides to stack	:	0.76 lb/hr
Particulate fluorides to stack	:	0.51 lb/hr
Total fluorides to stack	:	1.27 lbs/hr; 0.0417 lb/ton P205 input; 5.6 tpy
Total fluorides removed by scrubber	:	20.1 lbs/hr; 87.9 tpy

Fluorides Control Efficiencies

Scrubber F eff.	=	(21.33 lb/hr - 1.27 lb/hr)/21.33 lb/hr
	=	94.05 percent
Overall Plant F eff.	=	((83 lb/ton P205 x 30.6 tph P205) - 1.27)/(83 lb/ton P205 x 30.6 tph P205)
	=	99.95 percent

The following estimates pertain to the proposed venturi scrubbing system.

Fixed Capital Costs

Equipment Capital Costs	=	$495,000
Total Installed Cost	=	$1,720,000

Operation and Maintenance Costs

Operating Costs:

Electricity	=	(617 + 50)BHP x 0.746 kw/hp x 8760 hrs/yr x $0.059/kw
	=	$257,170
Water	=	32 gpm x 60 min/hr x 8760 hrs/yr x $0.20/1000 gals
	=	$3,364
Total operating costs	=	$260,534

KOOGLER & ASSOCIATES

Maintenance Costs:		
Operating labor	=	2 hrs/shift x shift/8 hrs x 8760 hrs/yr x $12.96/hr
	=	$28,382
Supervisory labor	=	$28,382 x 0.15 (EPA factor)
	=	$4,257
Maintenance labor	=	1 hr/shift x shift/8 hrs x 8760 hrs/yr x $14.26/hr
	=	$15,615
Maintenance materials	=	$15,615 x 1.0 (EPA factor)
	=	$15,615
Total maintenance costs	=	$63,869
Total annual O&M costs	=	$260,534 + $63,869
	=	$324,403

<u>Indirect Costs</u>

Overhead	=	$63,869 x 0.6 (EPA factor)
	=	$38,321
Administration	=	$495,000 x 1.91 (EPA factor) x 0.02 (EPA factor)
	=	$18,909
Insurance	=	$495,000 x 1.91 (EPA factor) x 0.01 (EPA factor)
	=	$9,455
Property tax	=	$495,000 x 1.91 (EPA factor) x 0.01 (EPA factor)
	=	$9,455
Capital recovery	=	$495,000 x 1.91 (EPA factor) x 0.1628 (EPA factor)
	=	$153,919
Total indirect costs	=	$38,321 + $18,909 + $9,455 + $9,455 + $153,919
	=	$230,059

Total annual costs = $230,059 + $324,403
= $554,462

Annual cost of control = $554,462/87.9 tpyF
= $6308/ton F removed

ADDITIONAL SCRUBBER

The following analysis addresses the incremental costs for removal of fluorides by adding a packed scrubber to the above discussed arrangement.

Additional capital cost = $950,000

Additional annual cost = $554,462/2
= $277,231

Additional F removed = 0.51 lb/hr
x 8760 hrs/yr x ton/2000 lbs
= 2.23 tpy

The overall cost of an arrangement of the proposed venturi scrubbing system followed by a packed scrubber can be estimated as follows:

Overall total cost = ($554,462 + $277,231)/(87.9 + 2.23)tpyF
= $9228/ton F removed

The incremental cost of fluorides control can be estimated as follows:

Cost of added control = $277,231/2.23 tpyF
= $124,319/ton additional F removed

It is apparent that while the proposed venturi scrubbing system cost is already in the upper range of BACT cost criteria, the additional packed scrubber cost is well beyond the range and is not cost effective. Too large a cost is involved for too small a quantity of emission reduction.

KOOGLER & ASSOCIATES

Ceilcote Air Pollution Control

Air-Cure Dynamics, Inc.

March 12, 1996

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Bureau of Air Regulations
Department of Environmental Protection
111 S. Magnolia Drive
Tallahassee, FL 32301

Attention : Mr. John Reynolds, Mail Station 5505

Reference : SiF4 Scrubbing

Per our phone conversation last week Ceilcote Air Pollution Control provides the following for your information. When scrubbing SiF4 with water hydrofluorsilic acid and silicon dioxide is formed as shown in the following reaction:

$$3\ SiF_4 + 2\ H_2O \rightarrow 2\ H_2SiF_6 + SiO_2$$

The hydrofluosilic acid can then be scrubbed and neutralized by the following reaction:

$$H_2SiF_6 + 2\ NaOH \rightarrow Na_2SiF_6 + 2\ H_2O$$

During this reaction silicon dioxide often precipitates from the solution as a white solid. When a packed tower is used as the only control device the system often requires periodic maintenance to remove, clean and / or replace the tower packing. Our recommendation when inlet loadings are high is to install a prescrubber consisting of a low pressure drop venturi prior to the packed tower.

The venturi promotes the hydrolysis reaction and minimizes the solids that accumulate in the packed tower scrubber. Use of only a venturi scrubber limits the achievable removal to 1-2 transfer units or 80 to 90 wt% for soluble gases. Multiple venturis installed in series would be required to achieve 95 to 99 wt% removal.

The packed tower can then be used to achieve the required acid removal without unusually high maintenance. A packed tower can easily achieve better than 99 wt% removal when using a caustic solution as the scrubbing media. Recycling a water solution can also be considered. However, the packing depths and water blowdown rates may be greater in order to achieve the same removal efficiency.

If we can be of further service please feel free to contact us.

Regards,

Steven A. George
Business Manager
Industrial Process Systems

P.O. Box 811630 ■ Cleveland, OH 44181-1630 ■ Tel: 216/243-0700 Fax: 216/243-9854 or 216/234-3486

File

Department of Environmental Protection

Lawton Chiles
Governor

Twin Towers Office Building
2600 Blair Stone Road
Tallahassee, Florida 32399-2400

Virginia B. Wetherell
Secretary

March 4, 1996

CERTIFIED MAIL - RETURN RECEIPT REQUESTED

Mr. Steven J. Susick, P.E.
General Manager
US Agri-Chemicals Corporation
3225 State Road 630 West
Fort Meade, Florida 33841-9799

Dear Mr. Susick:

This is in response to the February 15 letter from Koogler & Associates providing scrubber calculations pursuant to Specific Condition No. 5 of PSD-FL-222 (Prilled MAP Plant).

The Department does not agree that a total of 3.5 mass tranfer units (90.5% removal) is representative of BACT for fluoride control. Nor do we agree with Jacobs Engineering's inference that 90.5% is the maximum feasible removal due to the gas stream being dilute. A packed scrubber providing sufficient packing depth will do a far better job of fluoride control than a venturi/cyclonic system regardless of inlet concentration, and at significantly lower power cost.

Before U.S. Agrichem commits to a particular control system, the Department must agree that it is the best available technology. U.S. Agrichem should investigate packed scrubbing as the top choice and show the design details and itemized cost estimates for equipment and operation, using 99.3% fluoride removal as the goal.

If there are any questions concerning this letter, please call John Reynolds at 904-488-1344.

Sincerely,

A. A. Linero 3/4

A. A. Linero, P.E.
Administrator
New Source Review Section

AAL/JR

c: B. Thomas, SWD
L. Novak, Polk Co.
J. Harper, EPA
J. Bunyak, NPS
J. Koogler, K&A

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PS Form 3800, March 1993

KOOGLER & ASSOCIATES
ENVIRONMENTAL SERVICES
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GAINESVILLE, FLORIDA 32609
904/377-5822 • FAX 377-7158

KA 173-94-04
February 15, 1996

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Mr. John Reynolds
Florida Department of
Environmental Protection
Twin Towers Office Building
2600 Blair Stone Rd
Tallahassee, FL 32399-2400

Subject: PSD-FL-222 (AC53-260190) Prilled MAP Plant

Dear Mr. Reynolds:

This is a follow-up to our previous discussions regarding BACT determination for the above referenced project.

In accordance with Specific Condition No. 5 of the above referenced permit, please find the attached information from the scrubber designer indicating gaseous fluoride and particulate matter scrubbing efficiency. It should be noted that at a total fluoride emission rate of 0.04 lbs/ton of P2O5 and an estimated annual cost of $553,202, the cost of fluoride control would be $9,809 per ton of fluoride. It is our understanding that this "per ton" control cost is far above typical BACT control cost criteria. As a result, additional technical analysis on scrubber design is not warranted. Scrubber drawings will be submitted to you upon completion, in order to satisfy the remaining requirement under Specific Condition No. 5.

In addition, an emission rate of about 0.04 lbs F/ton P_2O_5 is significantly below the 0.058 lb/ton MACT proposed during the December 11th, 1995, pre-MACT meeting/teleconference between TFI and EPA which FDEP staff (including yourself) and U.S. Agri-Chemicals personnel (Steve Susick and Ron Brunk) participated in.

If you have any questions, please do not hesitate to call Pradeep Raval or me.

Very truly yours,

KOOGLER & ASSOCIATES

John B. Koogler, Ph.D., P.E.

JBK:par
enc.

c: Ron Brunk, USAC

JACOBS ENGINEERING GROUP INC.

POST OFFICE BOX 2008 LAKELAND, FL 33806-2008 HIGHWAY 98S AT STATE ROAD 540 LAKELAND, FL 33... 3703
TELEPHONE (813) 665-1511 TELEX 52-2466 JACOBSENG LKL TELECOPIER (813) 665-5323

February 5, 1996

Fax No. 285-9779

Mr. Ming Lei Chen
Project Manager
U.S. Agri-Chemicals Corporation
3225 State Road 630 West
Fort Meade, FL 33841-9799

Reference: JEG-USAC 029 (28-J697-00)

Subject: Gaseous Emissions

Dear Mr. Chen:

We refer to the USAC internal memo from Ron Brunk dated October 31, 1995 and to our telephone conversation last month. We are unable to give you either the completed venturi scrubber calculation sheets, or the exact capital cost of the equipment, as we have not yet selected the successful bidder for the scrubbers. However, we have attempted to explain below the calculations that we have carried out to enable the pollution control system to be specified. We have also attempted to give you the capital and operating costs (estimated) of the system.

Emissions

Both particulates and fluorides are discharged to the atmosphere. The total fluoride emissions consist of both gaseous fluoride and fluoride associated with the particulates. There are two major airflows in the processing train - one coming from the MAP spray tower and the other from the rotary drum cooler. Each airstream is scrubbed in a separate venturi scrubber. Each venturi scrubber discharges to a common cyclonic separator fitted with a demister. Scrubber liquor is also sprayed into each of the two inlets to the cyclonic separator. The cooler airstream passes through dry cyclones prior to the venturi scrubber.

The design pressure drops in the various sections are as follows:

Cooler Cyclones:	5.85"
Cooler Venturi	12"
Spray Tower Venturi	16"
Cyclonic Separator	5"

The pressure drops across the venturis can be controlled on-line by adjusting the throat area. Fan static pressure is 26".

Efficiency Estimates

Particulates

Spray Tower Venturi efficiency	97.8% (theoretical)
Cooler Cyclone efficiency	97.8% (theoretical)
Cooler Venturi efficiency	95.0% (theoretical)

The above estimates are based on theoretical cyclone and scrubber efficiencies. Efficiency of both the cyclones and the scrubber are related to pressure drop. The only way efficiencies can be increased further is at the expense of increased power consumption on the fan.

Fluorides

Gaseous fluorides are evolved in the reaction of phosphoric acid and ammonia. Efficiency estimates are based on the partial pressures of HF and SiF_4 above the scrubbing solution and the NTU's in the scrubbing system.

NTU's	3.5
% F in acid that finishes up in the product	99.96
% gaseous F recovery in scrubbers	90.54
% gaseous F recovery taking out the vapor pressure loss	97.10
% total F recovery in scrubbers	95.46

The 99.95%+ referred to by Teller in the 1967 article refers to phosphoric acid production where very much larger amounts of fluorine are evolved in comparison to MAP. Much higher efficiencies can therefore be achieved because the effect of the vapor pressure is much lower on a percentage basis.

The emissions can only be reduced further either by adding more scrubbing stages (more capital and power expenditure) or by reducing the vapor pressure of the scrubbing solution (either by cooling or neutralization). Both of these alternatives would add considerably to the capital and operating costs.

Costs

The pollution control system consists of the following equipment:

Cooler cyclones
Cooler venturi
Spray tower venturi
Cyclonic separator
Scrubber fan
Scrubber pumps
Stack

The approximate capital cost for the equipment only is $495,000. The total installed cost including steelwork, concrete, instrumentation, electrical, piping, painting, erection etc is estimated to be approximately $1,720,000.

The operating costs that Jacobs are able to provide are limited to electricity and water consumptions as follows:

Water	21 gpm	
Electricity	Fan	617 BHP
	Pump	50 BHP

We hope that this information is sufficient for you to prepare your submission to the state.

Sincerely Yours,

JACOBS ENGINEERING GROUP INC.

D. Ivell

D M Ivell
Senior Process Engineer

cc: VELeón
File: 28-J697-00