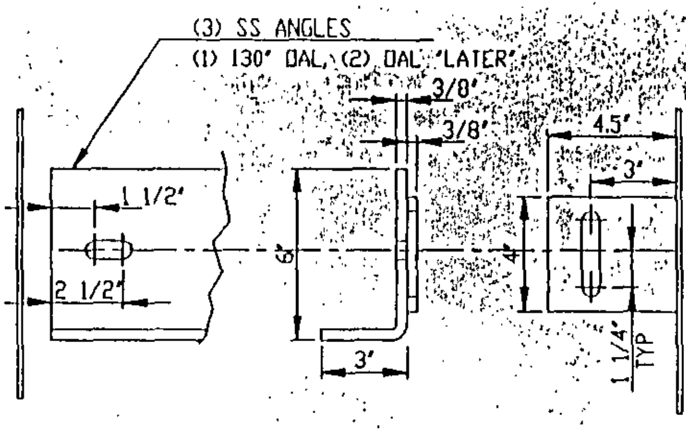
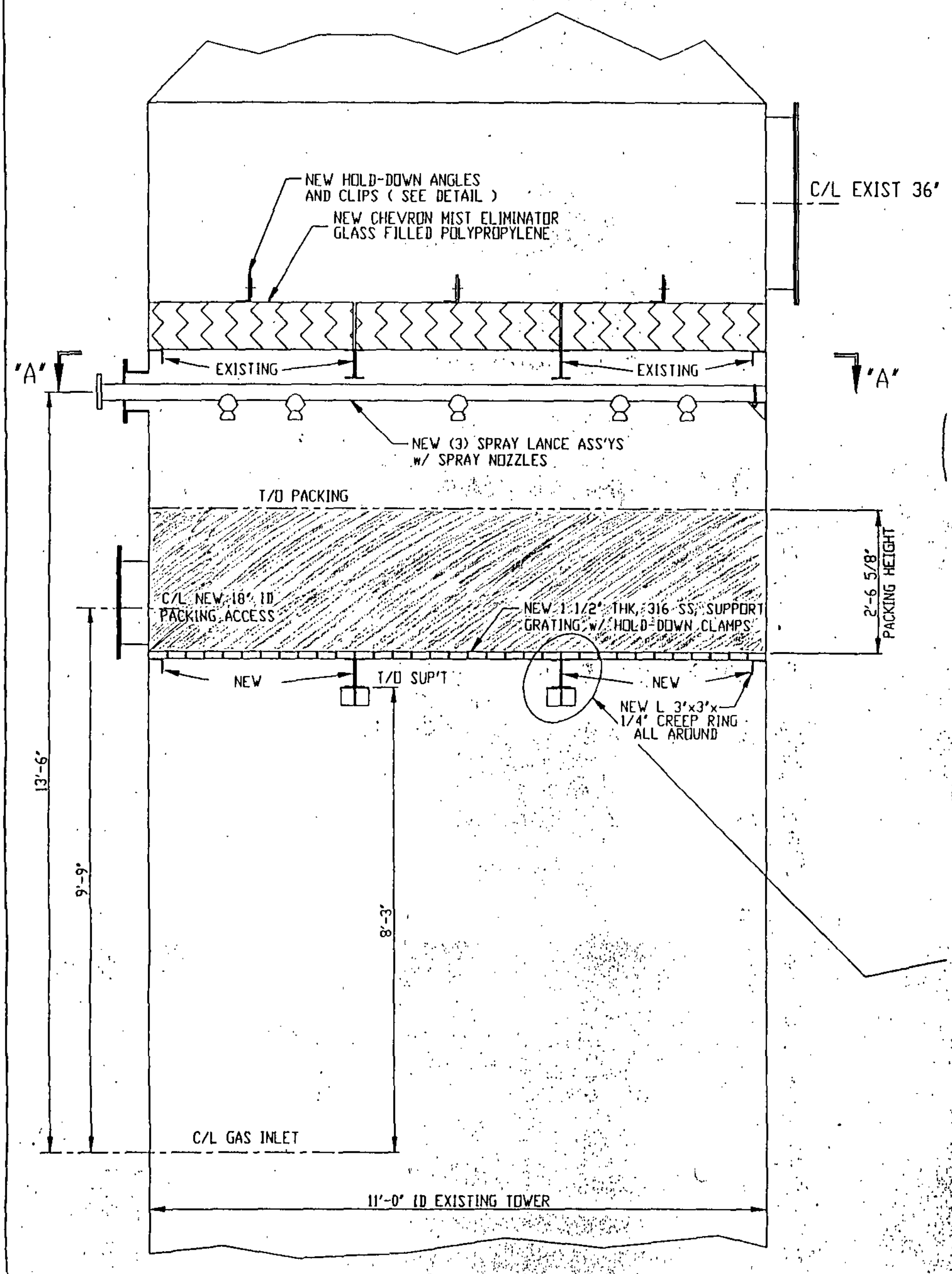


DETAIL 'C'
TYPICAL



Department of Environmental Protection

Lawton Chiles
Governor

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

Virginia B. Wetherell
Secretary

March 11, 1996

CERTIFIED MAIL - RETURN RECEIPT REQUESTED

Mr. David B. Jellerson, P.E.
Environmental Superintendent
Cargill Fertilizer, Inc.
P.O. Box 9002
Bartow, Florida 33830

RE: BACT Revision (PSD-FL-224/Bartow Phosphoric Acid Plants 4 & 5)

Dear Mr. Jellerson:

The Department received Cargill's March 7 letter and sketch showing that the newly-installed venturi/cyclonic scrubber will be modified by including a packed scrubbing section with a demister.

Since this modification resolves the Department's concerns regarding BACT, the emission limit revision mentioned in our March 4 letter is no longer necessary.

If there are any questions, please call Al Linero or John Reynolds at 904-488-1344.

Sincerely,

C. H. Fancy, P.E.
Chief
Bureau of Air Regulation

CHF/AAL/JR

cc: B. Thomas, SWD
R. Harwood, Polk County
D. Buff, KBN

Z 127 633 186

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Cargill Fertilizer
PO Box 9002
Bartow, Fl 33830

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P.O. Box 9002 - Bartow, Florida 33830 - Telephone 941-534-9610 - FAX 941-534-9680

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MARCH 7, 1996

Mr. Al Linero, P.E.
Bureau of Air Regulation
Florida Department of Environmental Protection
2600 Blair Stone Road
Tallahassee, FL 32399-2400

Dear Mr. Reynolds:

Re: Cargill Fertilizer, Inc. - Bartow Facility
Phosphoric Acid Plants - Permit AC53-262532; PSD-FL-224

As per our telephone conversation on 3/5/96 with Mr. John Reynolds of your staff, Cargill agrees to modify our proposed venturi-spray-cyclonic scrubber by the addition of a packed section with the understanding that the Department will not conduct a new BACT determination.

The modified scrubber will consist of a venturi followed by a spray duct and cyclonic section as previously described to you with the addition of a new packed section and chevron mist eliminator following the separation zone of the cyclonic. A schematic of the proposed modifications is attached for you information. As discussed in our previous correspondence and during our phone conversations, we are confident that this scrubbing system will be able to achieve the 2.29 lb/hr fluoride emission limitation contained in the permit and, with the modification, that it meets the Department's requirements outlined in the BACT analysis

If you have any questions please contact me at (941) 534-9613.

Sincerely,

David B. Jellerson, P.E.
Environmental Superintendent

cc: Pinney, Morris
Buff (KBN)
P20-03

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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

March 4, 1996

CERTIFIED MAIL - RETURN RECEIPT REQUESTED

Mr. David B. Jellerson, P.E.
Environmental Superintendent
Cargill Fertilizer, Inc.
P. O. Box 9002
Bartow, Florida 33830

RE: BACT Revision (PSD-FL-224/Bartow Phosphoric Acid Plants 4 & 5)

Dear Mr. Jellerson:

This will confirm the Department's decision reached today pursuant to your phone call of February 27 inquiring about the consequences of starting up Cargill's newly installed venturi scrubber in the face of the Department's previously stated concerns that a venturi scrubber is not representative of BACT for fluoride removal.

Since the subject permit was recently amended to no longer require evacuation of numerous acid clarification tanks to the new scrubber, the BACT limit must be revised. The former limit for the new filter <u>and</u> clarifier tanks was 0.7 lb F/hr (based on 58 tons/hr @ 0.012 lb F/ton P2O5). The revised BACT limit for the new scrubber will be based on the adjusted 95% confidence level data for the Riverview filter (58 tons/hr @ 0.0047 lb F/ton = 0.27 Lb F/hr). Therefore, the revised permit limits will be 1.59 + 0.27 = 1.86 lb F/hr and 8.15 tons/yr. This amounts to a reduction of less than 20% in the total allowable fluoride emissions for the reconfigured plant. The paperwork required to effect this change is currently being drafted.

If there are any questions regarding this matter, please call Al Linero or John Reynolds at 904-488-1344.

Sincerely,

C. H. Fancy, P.E.
Chief
Bureau of Air Regulation

CHF/AAL/JR
cc: B. Thomas, SWD
R. Harwood, Polk County
D. Buff, KBN

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Department of Environmental Protection

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2600 Blair Stone Road
Tallahassee, Florida 32399-2400

Virginia B. Wetherell
Secretary

February 23, 1996

CERTIFIED MAIL - RETURN RECEIPT REQUESTED

Mr. David B. Jellerson, P.E.
Environmental Superintendent
Cargill Fertilizer, Inc.
P. O. Box 9002
Bartow, Florida 33830

Dear Mr. Jellerson:

This is in response to KBN's February 1 letter submitting scrubber design calculations and explaining Cargill's position regarding the installation of a venturi/cyclonic vs. packed scrubber for the new Bartow phos acid filter (PSD-FL-224).

Since Cargill's proposed venturi scrubber reflects a fluoride removal efficiency of slightly over 60% (2.6 mass transfer units, not counting the small added effect of the cyclonic spray section), the Department cannot agree that this represents best available control technology (BACT). The calculations indicate that the 0.70 lb F/hr arrived at in the BACT determination is in fact too high, meaning that the 0.012 lb F/ton P2O5 should be closer to the 0.009 lb F/ton that we originally proposed.

To address KBN's argument that BACT is only an emission limit and that Cargill is not required to install specific equipment, it should be pointed out that a BACT emission limit must be based on the maximum degree of reduction achievable (considering costs and other factors on a case by case basis).

We are now evaluating the course of action that should be taken in light of this new information. If Cargill decides to proceed with the venturi scrubber installation, it should be with the realization that additional mass transfer capacity would be required if the BACT limit is lowered.

If you have any questions regarding this matter, please call John Reynolds at (904)488-1344.

Sincerely,

2/23

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

AAL/JR
cc: B. Thomas, SWD
J. Harper, EPA
J. Bunyak, NPS
R. Harwood, Polk Co.
D. Buff, P.E.

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3. Article Addressed to:

Mr. David B. Jellerson, P.E.
Environmental Superintendent
Cargill Fertilizer, Inc.
Post Office Box 9002
Bartow, Florida 33830

4a. Article Number
Z-127-633-171

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KBN

February 1, 1996

Received 2/2/96

Mr. Al Linero, P.E.
Bureau of Air Regulation
Florida Department of Environmental Protection
2600 Blair Stone Road
Tallahassee, FL 32399-2400

Re: Cargill Fertilizer, Inc. - Bartow Facility
Phosphoric Acid Plants - Permit AC53-262532; PSD-FL-224

Dear Mr. Linero:

On behalf of Cargill Fertilizer, Inc., this letter is in response to the Department's letter dated November 22, 1995, regarding our request for a minor amendment of the above-referenced permit. In your letter you expressed concerns as to whether Cargill's new proposed venturi scrubber is consistent with the BACT determination. Additional information regarding the scrubber system is provided below and in the attachments.

The proposed scrubber consists of a high-energy venturi using approximately 1,000 gpm of scrubbing liquid and having a pressure drop of 12 to 16 inches of water. The venturi will be followed by a spray cyclonic scrubber also using approximately 1,000 gpm of scrubbing liquid. As indicated by the attached calculations, the system is more than capable of providing the necessary control to attain the emission limitation established by the BACT analysis.

It is also noted that "Best Available Control Technology" is defined in Rule 62-212.200 as "An emission limitation...". Under this rule, if the Department determines that technological or economic limitations on the application of measurement methodology to a particular part of an emissions unit would make the imposition of an emission standard infeasible, then a design, equipment, work practice, operational standard, or combination therefore, may be prescribed instead to satisfy the requirement of the application of BACT.

In the case of the Cargill Bartow phosphoric acid plants, the Department has set an emission limitation as BACT. Work practice, equipment, or other standards were not set since it was practical to set an emission limitation. Although the Department has based the BACT emission limit on certain technology capable of achieving the emission limit, Cargill's obligation under the rules is to meet the BACT emission limit, not to install a specified control technology. Therefore, the rules do not bind Cargill to the use of the specific control equipment upon which the BACT determination was based. The permittee is obligated to provide reasonable assurance to the Department that whatever control technology is installed is capable of meeting the BACT emission limit. The attached information should satisfy this requirement.

If you have any questions concerning this information, please contact me at (352) 336-5600.

Sincerely,

David A. Buff

David A. Buff, P.E.
Principal Engineer
Florida P.E. #19011

SEAL

Attachments
DB/mk

cc: David Jellerson, Cargill
File (2)

14364A/1

KBN ENGINEERING AND APPLIED SCIENCES, INC.

6241 Northwest 23rd Street, Suite 500, Gainesville, Florida 32653-1500, 352-336-5600 FAX 352-336-6603
5405 West Cypress Street, Suite 215, Tampa, Florida 33607, 813-287-1717 FAX 813-287-1716
1801 Clint Moore Road, Suite 105, Boca Raton, Florida 33487, 407-994-9910, FAX 407-994-9393
7785 Baymeadows Way, Suite 105, Jacksonville, Florida 32256, 904-739-5600 FAX 904-739-7777
1616 'P' Street NW, Suite 350, Washington, DC 20036, 202-462-1100, FAX 202-462-2270

CARGILL FERTILIZER, BARTOW, FLORIDA — Pg. 1

SCRUBBER TO REMOVE "FLUORIDE" FROM FILTER VENT

PERFORMANCE: BASIS: ENTERING GAS RATE - 60,000 ACFM
TEMPERATURE: 150°F / HUMIDITY - 0.0688 $\frac{LB\ H_2O}{LB\ Dry\ Gas}$
ENTERING FLUORIDE LEVEL - 300 MICROGRAM/CU. FOOT (DRY)
DESIRED OUTLET - 0.7 LB/HR FLUORIDE
LIQUID CONTAINS 5500 WT PPM @ 100°F

DESIGN: HIGH LIQUID TO GAS RATIO VENTURI SCRUBBER FOLLOWED BY HIGH CONTACT SPRAY SECTION WITH CYCLONIC DISENGAGING VESSEL.

REFERENCES: ① VAPOR PRESSURE OF "F" OVER TYPICAL POND WATER GRAPHS

② TEST DATA DEVELOPED BY RHONE - POULENC AS PUBLISHED IN NOV '78 CHEMICAL ENGINEERING PROGRESS.

① CALCULATE DRY STANDARD CUBIC FEET:

STANDARD CUBIC FEET = $60000\left[\frac{520}{150+460}\right] = 51,150$

MOL FRACTION OF WATER @ .0688 LB/LB DG

$$= \frac{.0688/18}{.0688/18 + (1-.0688)/29.3} = 0.101$$

OR DSCF = $51150(1-0.101) = 46000$ FT³/MIN

② "INLET "F" RATE:

300 MICROGRAM/DSCF → "F" = $\frac{46000 \times 300}{454} \times \frac{1g}{10^6} \times 60 = 1.823$ LB/HR

OVERALL EFFICIENCY = $\frac{1.823 - .7}{1.823} \times 100 = 61.6\%$

③ "F" VAPOR PRESSURE OVER 100°F POND WATER @ 5500 PPM "F" IS 100 MICROGRAM/FT³ (SEE GRAPH). THIS REPRESENTS THE BACK PRESSURE OF "F" THROUGH THE SCRUBBER

(OVER)

D.R. TECHNOLOGY, INC.
CLARKSBURG, N.J.
(908) 780-4664

NO

CARGILL FERTILIZER (CT D) — Pg 2

(4) SO OVERALL SCRUBBER MUST ACHIEVE
300 MICROGRAMS IN → (1-.6166)(300) = 115 OUT

(5) NUMBER OF TRANSFER UNITS ? (NTU ?)
THIS IS EXPRESSED AS

$$Ln_e\left\{\frac{300-100}{115-100}\right\} = 2.59\ NTU$$

(6) VENTURI THROAT PRESSURE DROP = 12 INCHES WATER COLUMN
LIQUID RATE TO VENTURI = 1000 GPM

(7) GAS FLOW AFTER VENTURI (QUENCHED) = 61,600 ACFM @ 124°F (51°C)
USING CHEMICAL ENGINEERING PROGRESS ARTICLE
@ ABOVE CONDITIONS THROAT VELOCITY THROUGH VENTURI SCRUBBER = 150 FEET/SECOND = 46 M/S

(8) L/G IN M^3 LIQ / 1000 M^3 GAS = $\frac{1000/7.48}{61,600/1000}$ = 2.17
EXTRAPOLATING THE GRAPH IN FIGURE 5, THIS TYPE OF OPERATION WILL YIELD 3.1 TRANSFER UNITS

(9) THE SPRAY SECTION OF THE TANGENTIAL INLET INTRODUCES AN ADDITIONAL 1000 GALLONS OF POND WATER (EQUIVALENT TO $^{1000}/_{61.6}$ = 16.2 GALLONS/1000 FT^3)
THIS WILL BE AT LEAST ONE MORE TRANSFER UNIT, MEANING THAT THE COMPLETE SCRUBBER WILL PROVIDE BETTER THAN THE REQUIRED 2.59

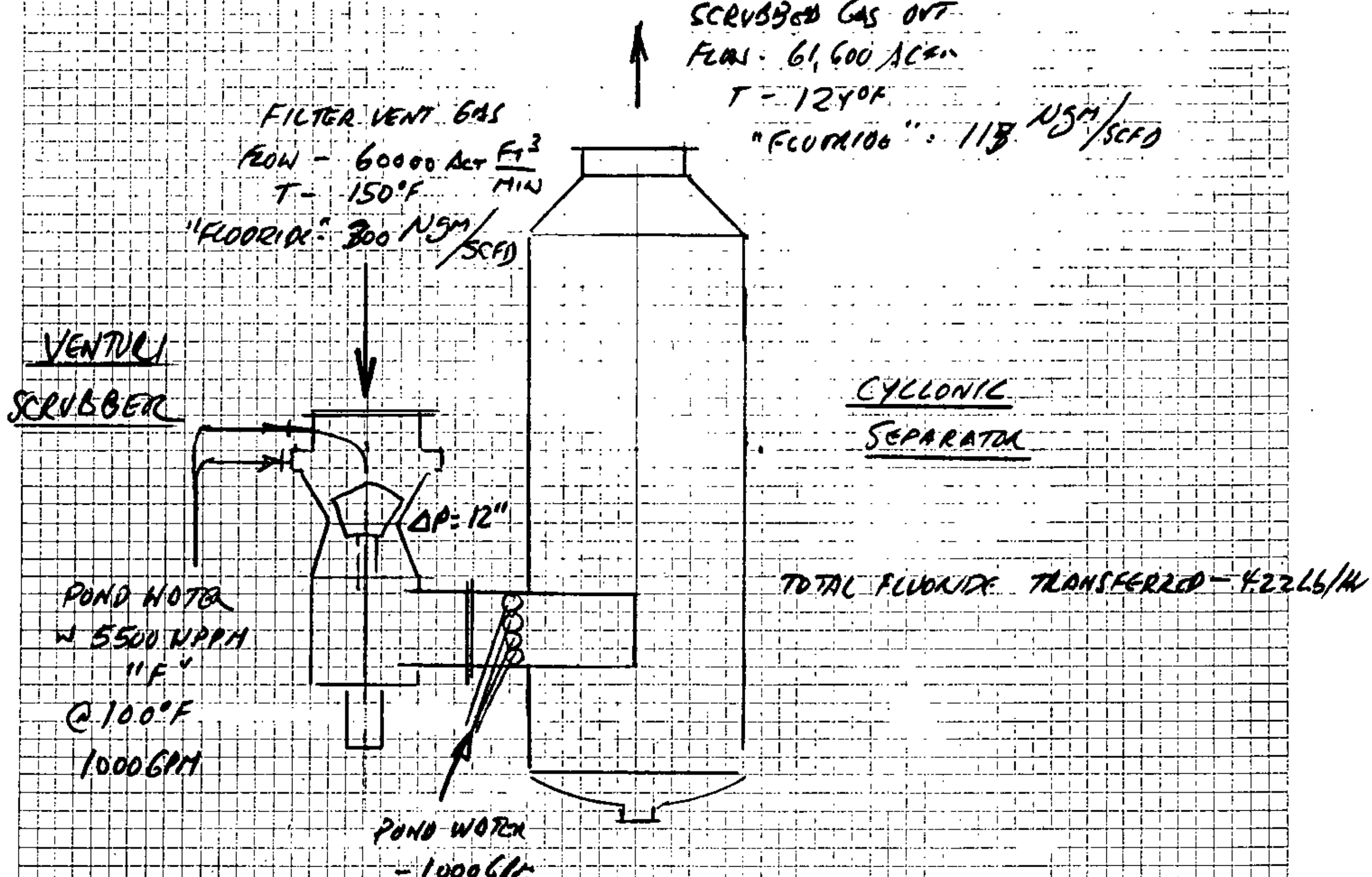
D.R. TECHNOLOGY, INC.
CLARKSBURG, N.J.
780-4664

NO.

CARGILL FERTILIZER; BARTOW, FLORIDA ORDER A80483

FILTER VENT SCRUBBER

PROPOSED OPERATION:



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CLARKSBURG, N.J.

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CARGILL, BARTOW FLORIDA

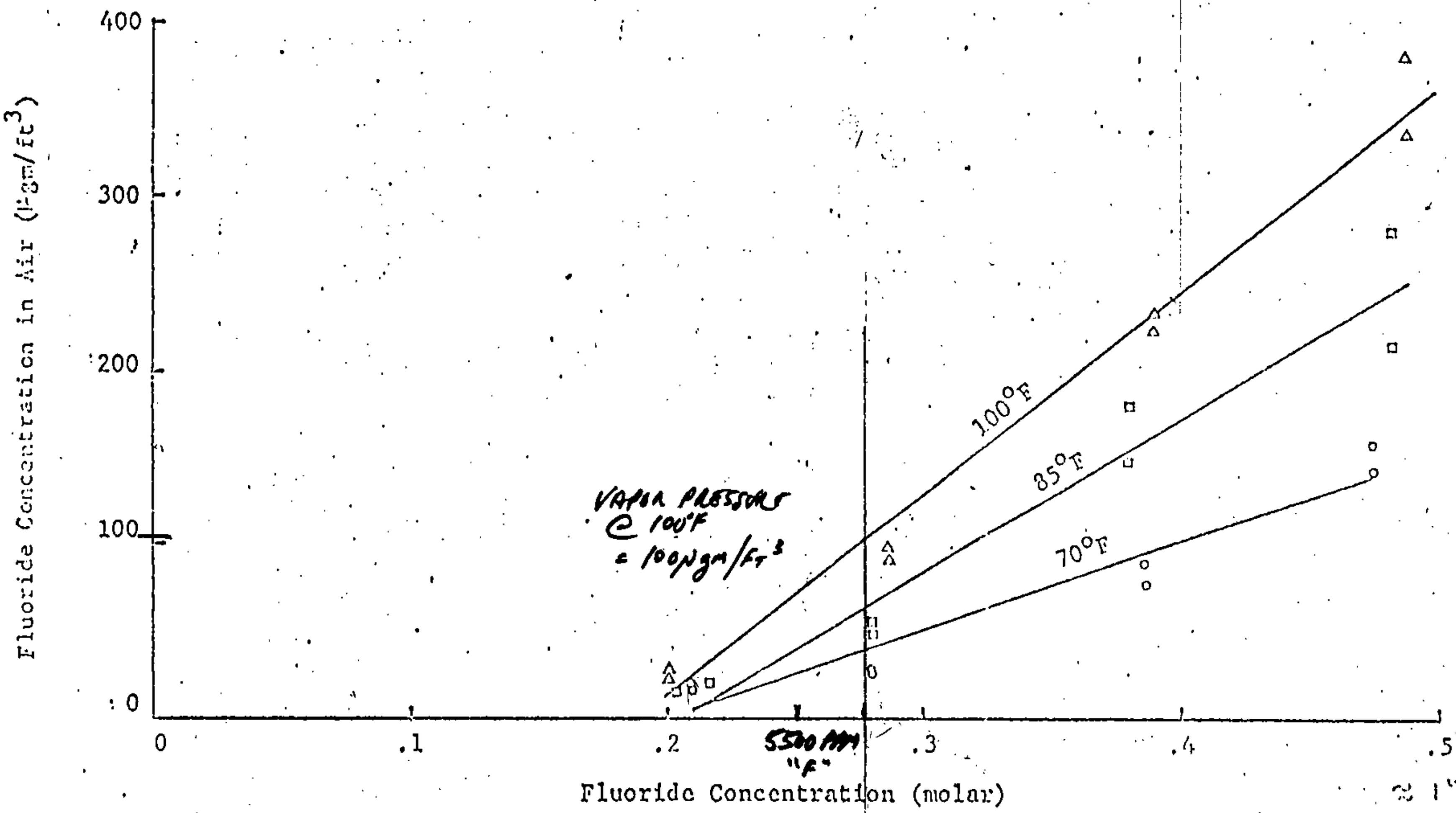

FIGURE 13 - THE EFFECT OF FLUORIDE CONCENTRATION ON THE SATURATED FLUORIDE CONCENTRATION IN AIR FROM SOLUTIONS OF GYPSUM WATER AND HF

Most Important

OVER

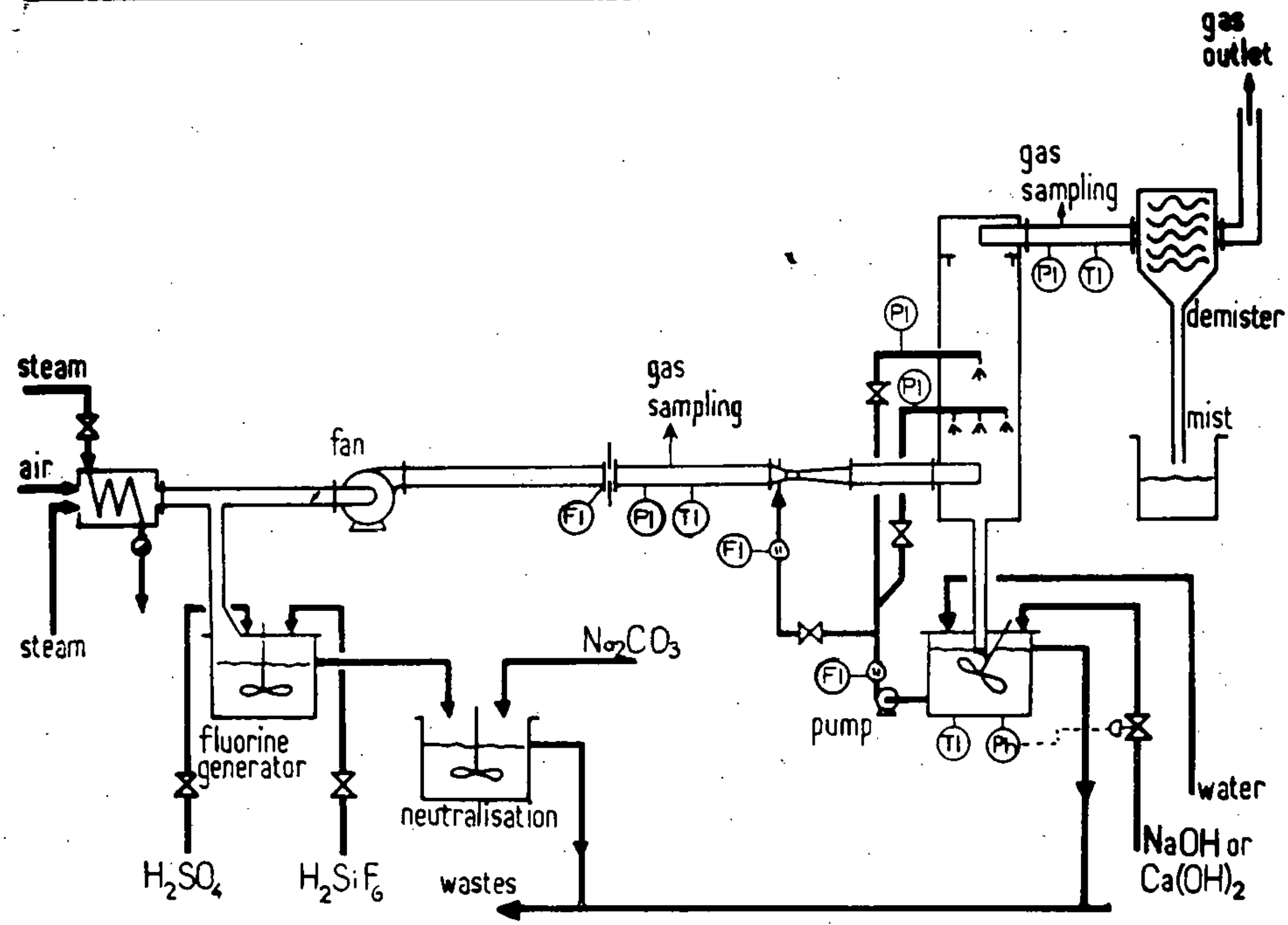

Figure 1. Pilot plant flow scheme.

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

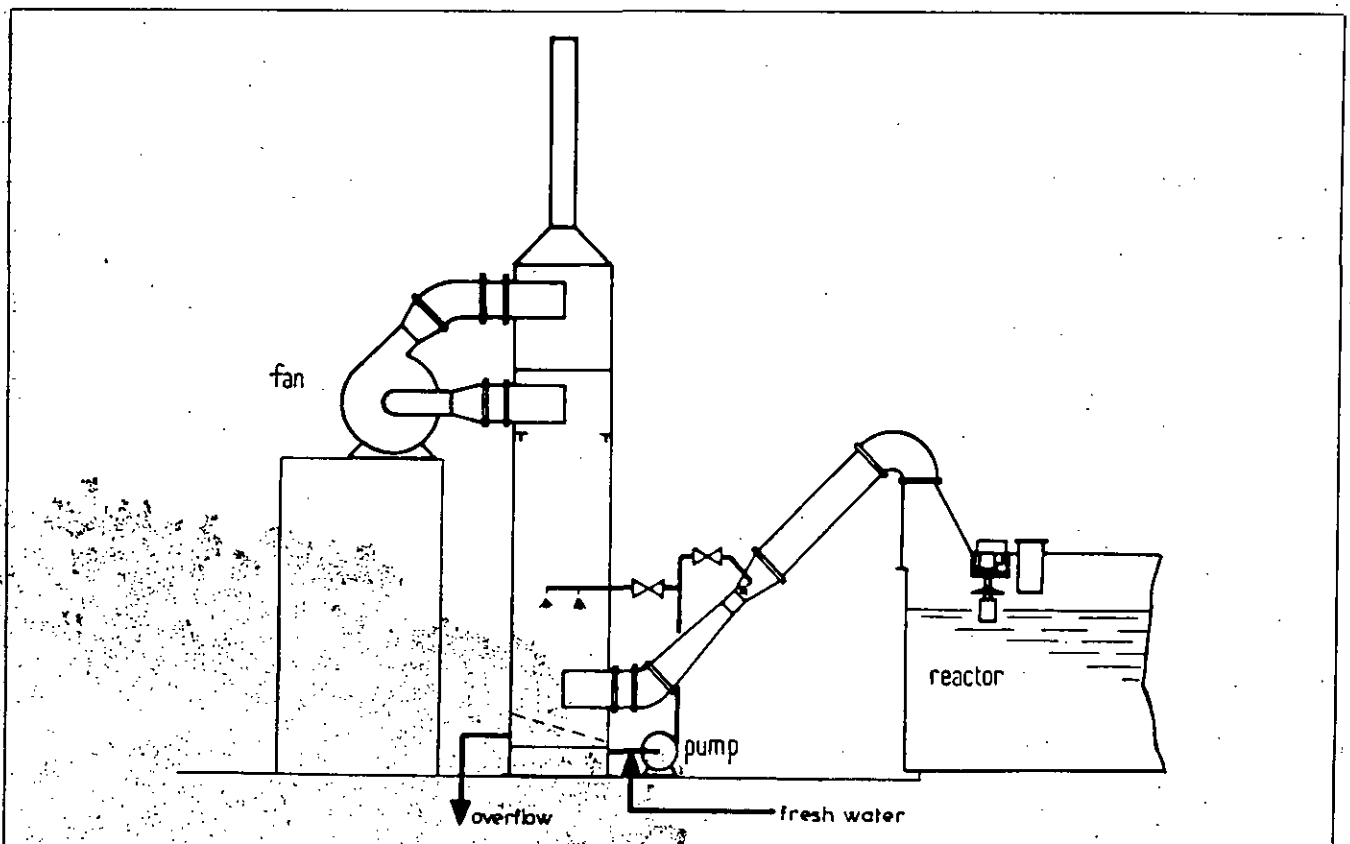

Figure 2. Commercial scale unit at the Les Roches de Condrieu factory.

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

$$NTU = \frac{h_t}{HUT} = \frac{K_G P Y^*_{BM} a_v}{G} \times h_t \quad (2)$$

$a_v \times h_t$ 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:

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

therefore:

$$NTU = \frac{K_G \cdot P \cdot Y^*_{BM}}{G} \times 6 \frac{L}{dp} \quad (4)$$

which could also be written as follows:

$$NTU = (cste) \times \rho^m_{G_1} \times \mu^n_{G_1} \times D^p_c \times V^q_{G_1} \times \left(\frac{L}{G}\right)^r \times \left(\frac{1}{dp}\right)^s \quad (5)$$

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

$$NTU = (cste) \times \rho^m_{G_1} \times \mu^n_{G_1} \times \rho^p_L \times \mu^q_L \times \sigma^r_L \times \left(\frac{L_V}{Dc}\right)^s \times \left(\frac{L}{G}\right)^t \times (V_{G_1})^u \quad (6)$$

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:

$$NTU = e^{11.9647} \cdot V^{1.8}_{G_1} \cdot (L_V/Dc)^{-0.9572} \cdot (L/G)^{0.3699} \cdot \rho^{-5.9201}_{G_1} \cdot \mu^{3.4131}_{G_1} \quad (7)$$

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:

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

$$L/G = 1$$

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

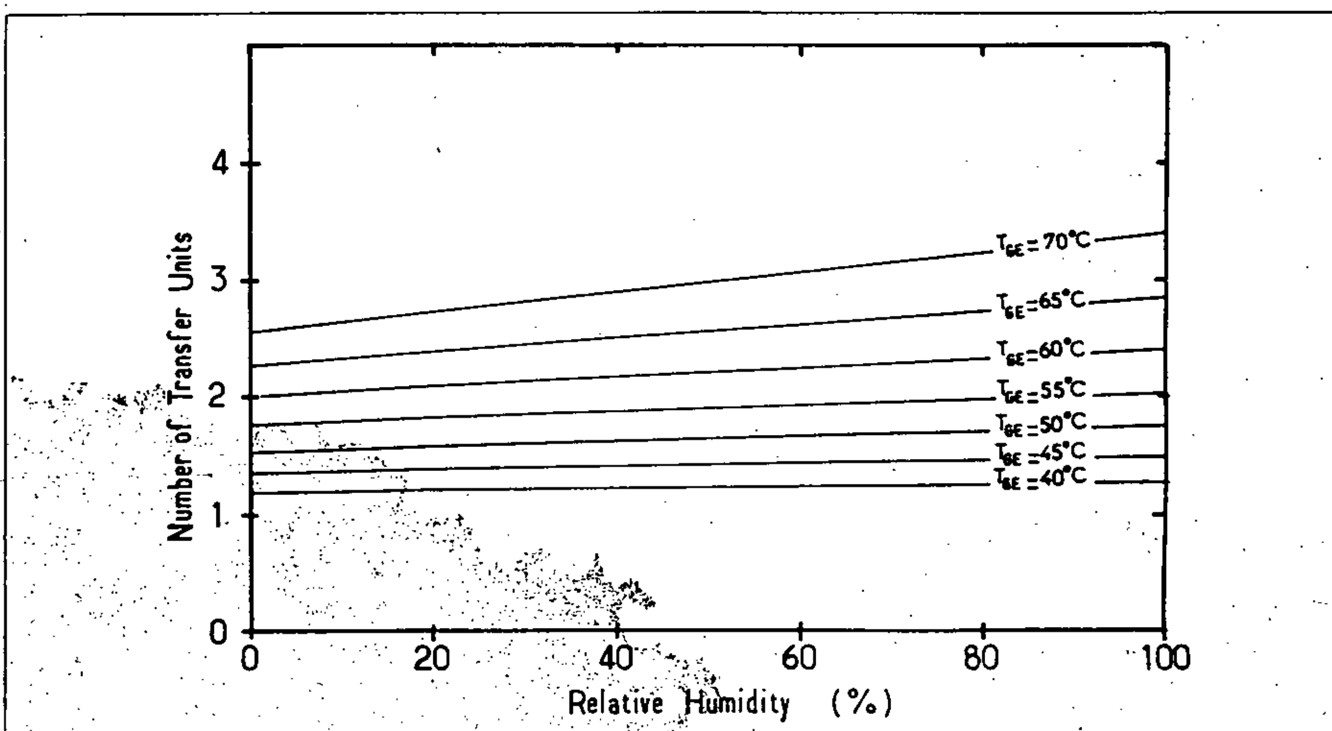

Figure 4. Influence of gas saturation on the absorption efficiency from the correlation using V_G = 50 m./sec.; L/G = cu. m./1,000 cu. m.; Lv/Dc = 8.5.

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-

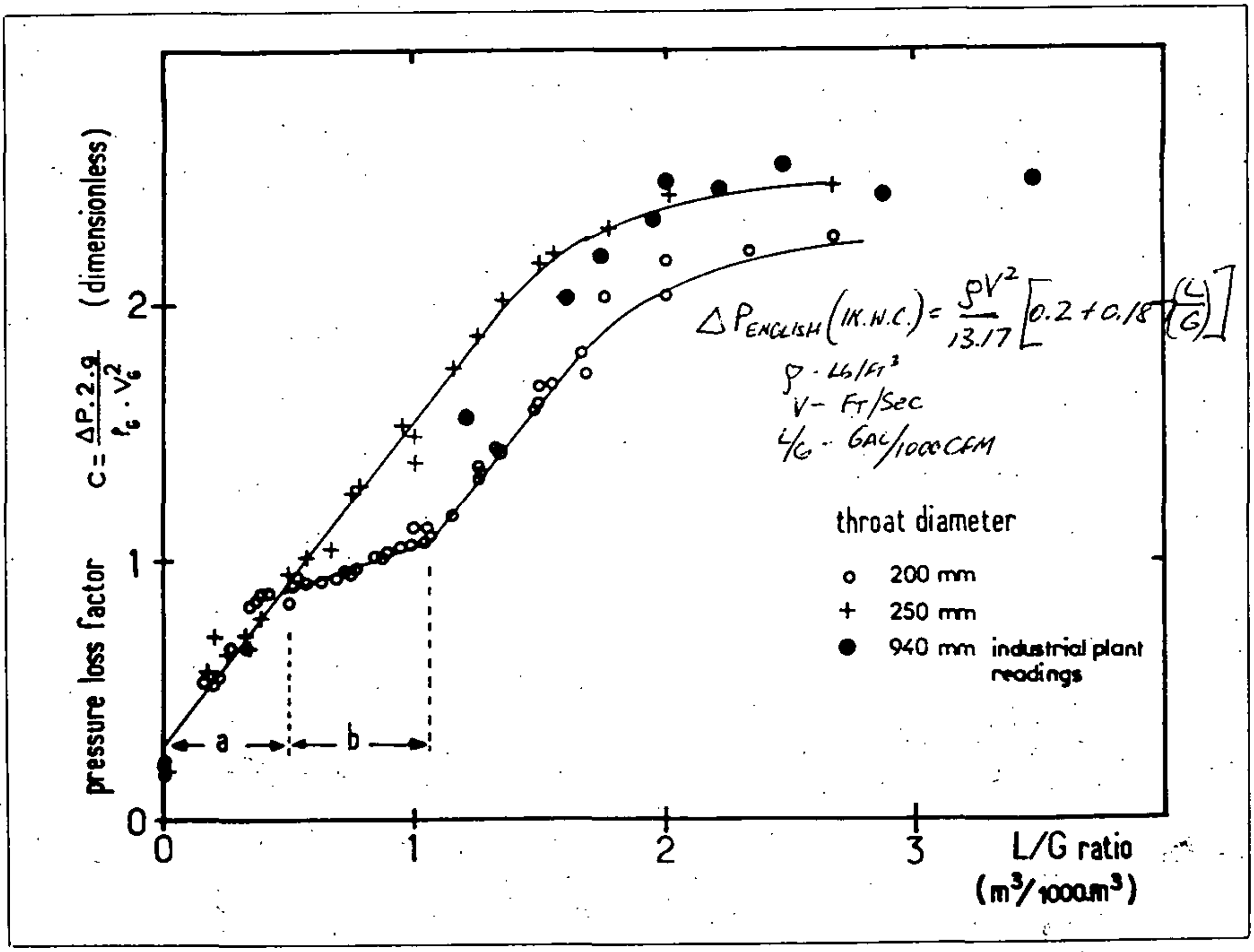

Figure 3. Pressure loss factor vs. L/G ratio.

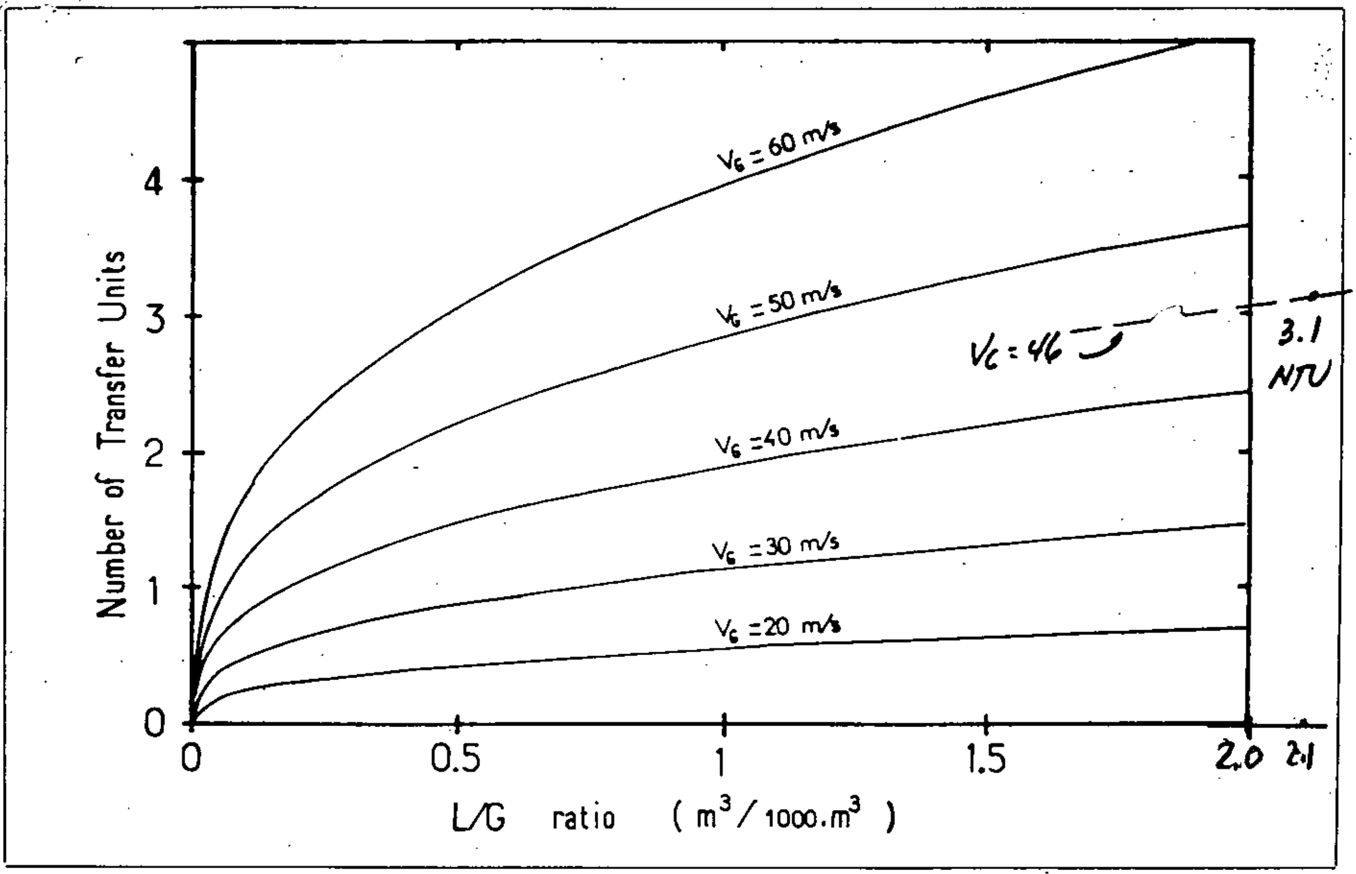

Figure 5. Variation of NTU with L/G ratio and V_G calculated from the empirical law. Using T_{GE} = 60°C and saturated gases; Lv/Dc = 8.5.

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_1 = 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. #

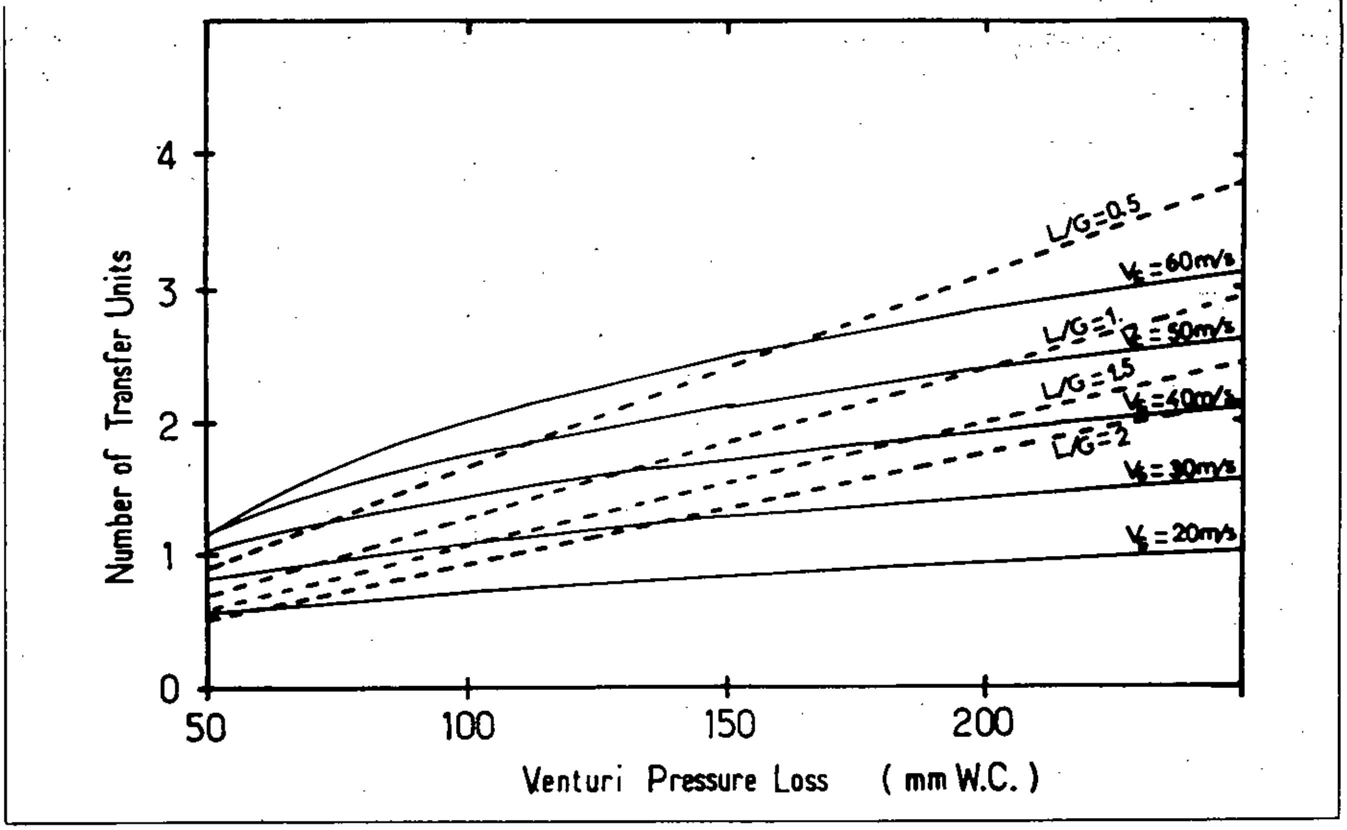

Figure 6. NTU vs. pressure loss. L/G and V_G are taken as parameters. T_{GE} = 60°C and Lv/Dc = 8.5.

Nomenclature

- a_v = effective mass transfer surface per unit packed height, sq.m./m.
- C = pressure loss factor $\dfrac{\Delta P \times 2 \times g}{\rho_G V_G^2}$
- 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).

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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.

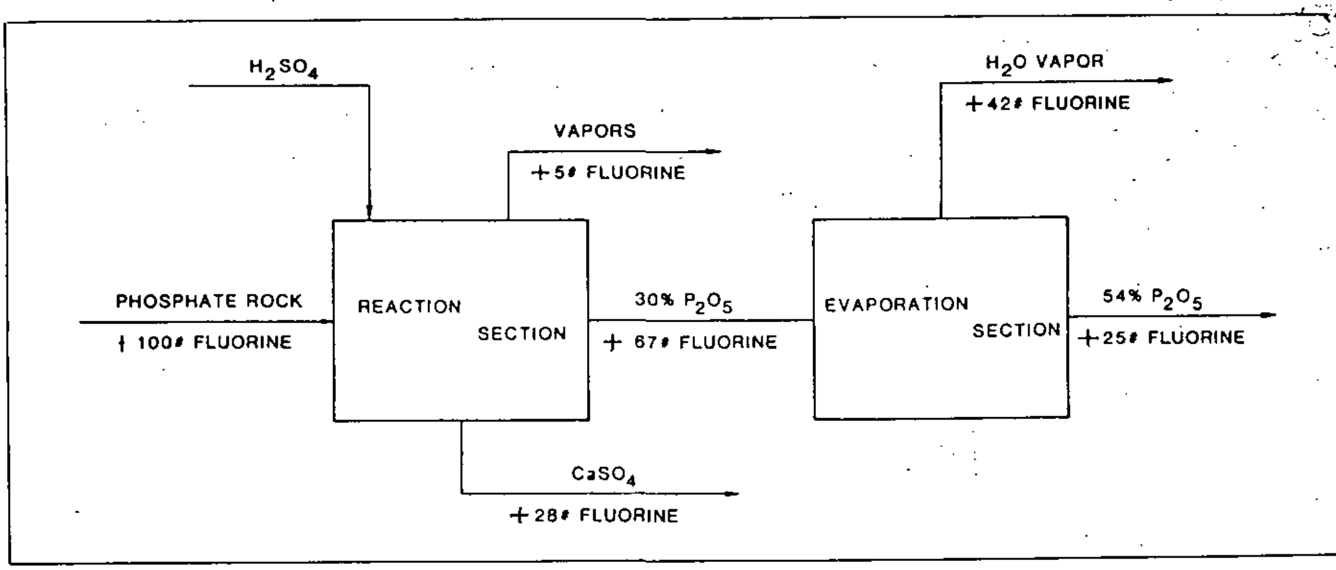

Figure 1. Fluorine distribution in phosphoric acid plant.

Phosphoric Acid Plant Problems:

Defluorination of Wet Process Acid

A method of diluting and re-evaporating phosphoric acid has been developed that reduces its fluorine content sufficiently to make it suitable as an animal feed supplement.

W. E. Rushton, Whiting Corp., Harvey, Ill.

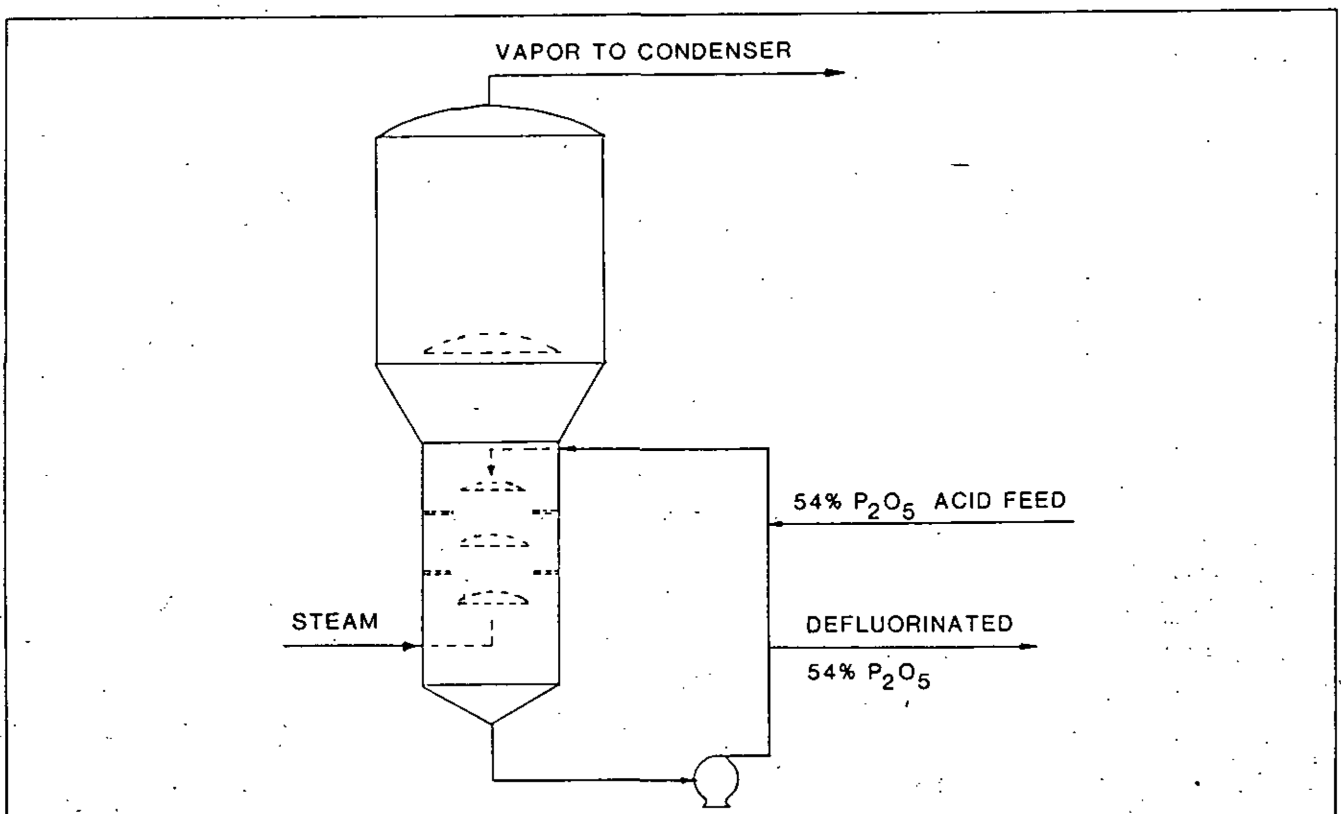

Figure 2. Fluorine stripping column.