

**THE STATE OF THE ART
IN GAS CLEANING
FOR THE FERTILIZER INDUSTRY**

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INTRODUCTION

The fertilizer industry has earned recognition for having contributed directly to increase world grain yields in the past century. Based on the conservative estimate of the world population growth, total fertilizer use in the future is expected to grow more than 200 million tons from the current level of 165 million tons. In U.S.A. and other countries the industries have always been challenged to meet the current and future air quality emissions standards set by local/state/federal governments under the Clean Air Acts and other regulations.

Accordingly, less polluting technologies emerged by way of reducing SO_x and NO_x in exhaust air from the Sulfuric and Nitric/Ammonia/Phosphate/Nitro-Phosphate plants in order to minimize “acid rain” problems in the atmosphere.

Fluoride emissions have similarly been lower from phosphoric acid /Di and Mono-Ammonium Phosphate, Granular Triple or Single Super Phosphate plants at or below 0.02 lbs. F per ton P₂O₅ input by scrubber technology and control mechanisms so far. Further advances in technology for developing ladder-like structured mono-filament media as a packing material for absorption and mist elimination purposes have reduced its level from 0.02 to 0.013 lbs. F or less per ton in the industry at present.

This paper will discuss about gas cleaning equipment in general and advances in cross/semi-cross flow scrubber technology with KON-TANE® / B-GON® / AEROSEP® in particular, as a packing media for prevention of air pollution in the fertilizer industry.

GAS CLEANING

The primary purposes of gas cleaning are:

- Recovery of raw materials and products/by-products.
- Meet present and future pollution emission standards set by the local, state and federal governments and/or other regulatory agencies.
- Minimize ozone depletion by reducing fluorine SO_x, NO_x, levels in air.

The phosphate fertilizer industry covers different chemical processes in order to manufacture phosphoric/fluosilicic acids and different products. This generates off-gases and particulate matter from various steps during the process e.g.

- | | |
|-----------------|--------------------------------|
| • Reaction | • Granulation |
| • Filtration | • Drying/Cooling/Screening |
| • Clarification | • Product storage/handling |
| • Evaporation | • Crushing/Grinding/Reclaiming |

Different types of gas cleaning (dry and/or wet) are adopted depending upon types and size of particles/gaseous components present in vent air as liberated from the operating units in the process. Also, handling characteristics, electrical properties, wetability, toxicity and flammability are some of the particle properties that are taken into account for design and operation purposes.

Dust collectors, e.g. cyclones, are utilized to recover large size particles in gaseous effluents greater than 10µm whereas fabric filters (bag-house) and electrostatic precipitators can be considered to remove small size particles less than 10µm size from dust laden air in the process.

In addition, wet scrubbers of different types are used for final cleanup of particles and pollutants from the process vent gases before it is emitted to the atmosphere.

GAS CLEANING MECHANISMS (Fig. 1)

- Inertial Impaction
- Interception
- Brownian Capture or diffusion
- Gas Absorption

Inertial impaction and Interception are the predominant mechanisms of particulate capture in wet gas scrubbers for larger size particles ($> 1 \mu\text{m}$ in size) whereas Brownian diffusivity of particles increases as size decreases and so, removal mechanism is most important for smaller particles ($< 1 \mu\text{m}$).

Inertial Impaction

Inertial impaction results often as the particle fails to follow the rapidly curving stream lines around a droplet or obstacle and continues to move toward the droplet along a path of less curvature due to inertia. Inertial impaction relates to the collection of particles on small droplets whereas, inertial impingement relates to the collection of particles on large surface or into liquid, whereby gas stream carrying the particles is small.

Interception

The mechanism of collection of particles by interception depends on size of the particles rather than on its mass or inertia. The particles, in this case, follow a gas stream line around the droplet and interception occurs as they pass half the distance of particle diameter (D_p) away from the droplet surface. Thus, collection by interception is a function of interception parameters ($K_I = D_p/D_f$, D_p = particle diameter, D_f = fiber diameter) and Reynolds number. Single-fiber efficiency can be calculated based on an empirical formula in the turbulent region (Ref. 2).

Brownian Capture or Diffusion

Brownian capture results when smaller particles below $<1 \mu\text{m}$ size do not move along the gas streamline and diffuse from the gas to the surface of the droplet and get captured. This particular type of separation mechanism is more applicable for mist elimination purpose in order to achieve 99.98% separation efficiency for $0.3\mu\text{m}$ and below particle sizes. Particle removal by Brownian diffusion and gravitational separation is usually absent due to high velocity and low 'hold-up' time available.

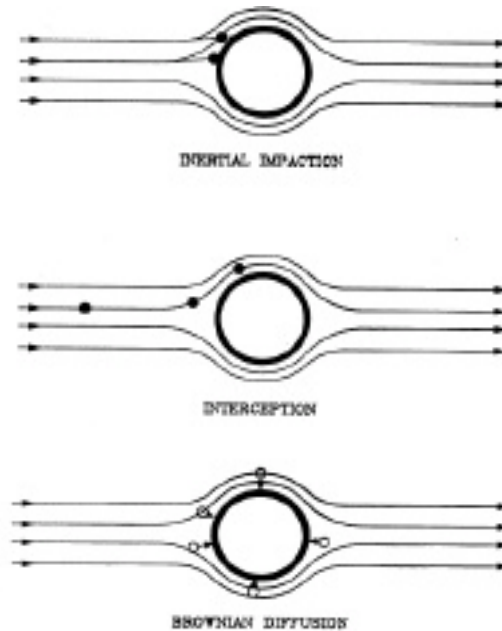


Figure 1: Mechanisms of Collection

Gas Absorption

The mechanism of gas cleaning by absorption of soluble pollutant gases in a liquid relates to mass transfer equation for transfer unit calculations shown below

$$NTU = \int_{Y_1}^{Y_2} \frac{dY}{Y - Y^*} = \ln \left[\frac{Y_1 - Y_2^*}{Y_2 - Y_1^*} \right] \quad \text{where } \begin{matrix} NTU = \text{Number of Transfer Units} \\ Y_1, Y_2 = \text{Initial and final concentration of solute gas} \\ Y^* = \text{Equilibrium concentration of solute in gas} \end{matrix}$$

Only for linear equilibrium lines with linear operating lines (Figure 2).

Also, the height of transfer units (HTU) or packing height(Z) can be determined from a knowledge of overall gas mass transfer coefficient (Ky) and gas mass flow rate (Gy) per unit cross sectional area as commonly expressed by

$$Z = \frac{Gy}{Kya} \int_{Y_1}^{Y_2} \frac{dy}{Y - Y^*} = HTU \cdot NTU$$

Linear systems are infrequent in fertilizer plants (Figure 3).

However, where the equilibrium solubility of polluted gas in a particular liquid is not known, a cooling tower type calculation can be used based on enthalpy balance of a specific scrubber chosen assuming adiabatic saturation process takes place.

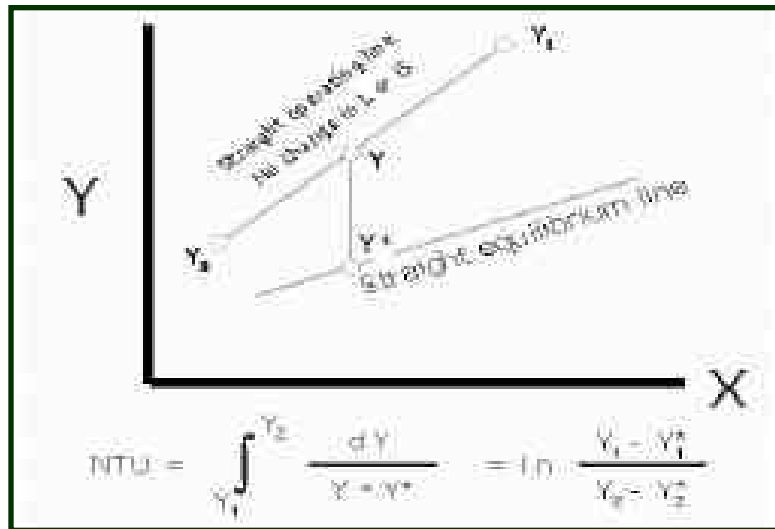


Figure 2: Counter-current mass transfer – simple case.

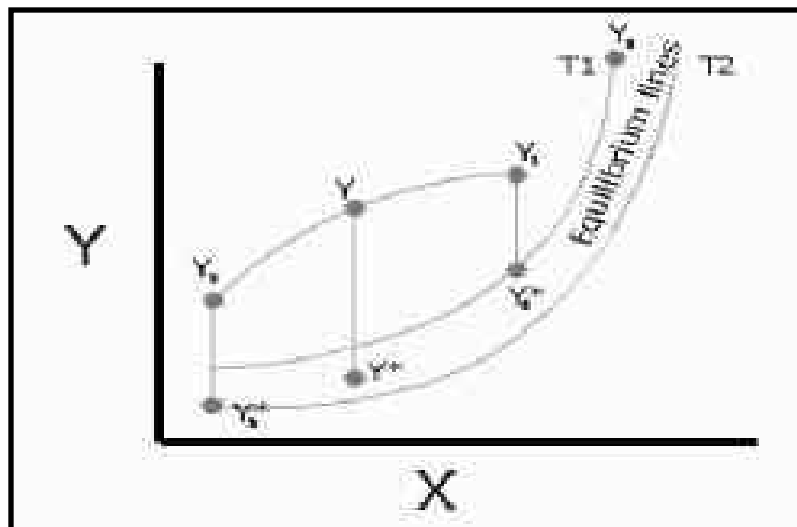


Figure 3: Counter-current mass transfer – general case.

WET SCRUBBERS

There are about four different types of wet gas scrubbers that are common in the fertilizer industry where gaseous pollutants/particulate matter are scrubbed either with a recycle solution or contaminated pond water of varying compositions. They are broadly classified as low, medium and high energy scrubbers.

Types of Scrubbers (Fig. 4 – “A thru F”)

- Spray (Simple/Cyclonic/Water Impact)
- Packed Tower
- Venturi (Cyclonic/Coaxial)
- Cross / Semi-Cross Flow

Figure 4

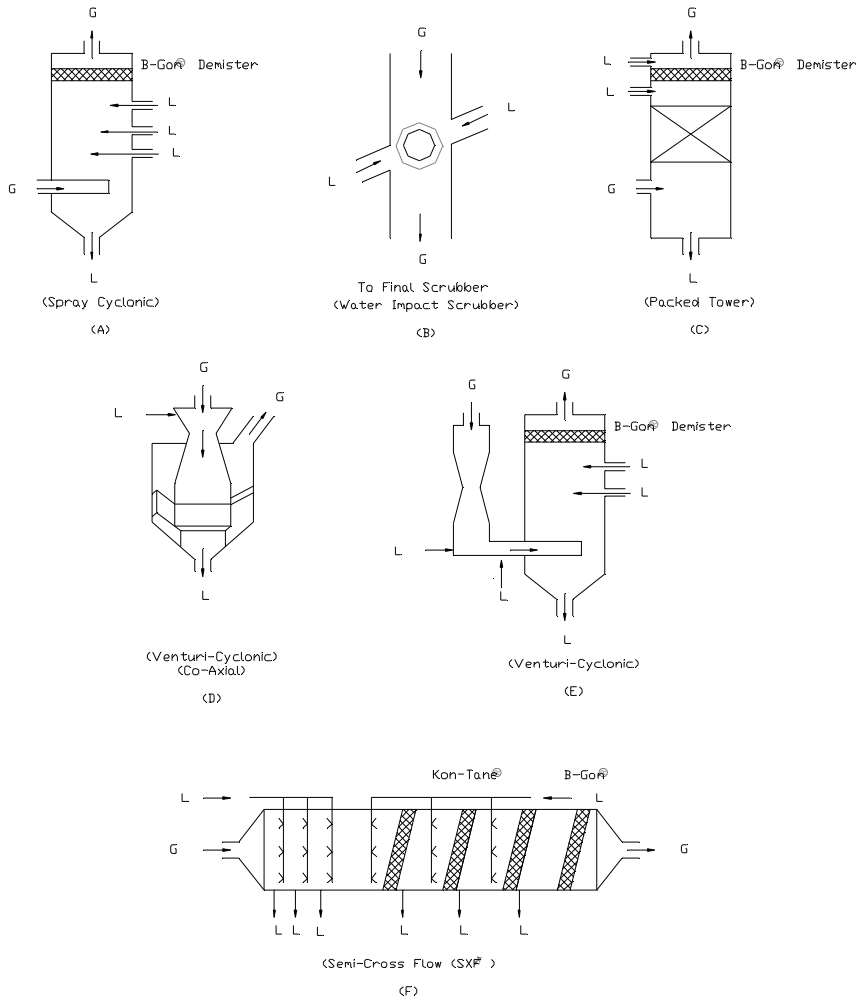


Figure 4: Types of wet scrubbers: a) Spray cyclonic; b) Water impact; c) Packed tower; d) Venturi-cyclonic (co-axial); e) Venturi-cyclonic; f) Semi-cross flow

In general, low energy scrubbers having 3-6 in. water gauge of pressure drop ΔP include spray (simple / cyclonic / water impact) towers whereas packed bed and cross or semi-cross flow scrubbers are categorized as medium energy units having 6-9 in. water gauge ΔP . Venturi types either “cyclonic” or coaxial scrubbers on the other hand, are classified as high energy scrubbers that generally operate between 9-12 in. water gauge ΔP .

Spray Scrubber (Simple/Cyclonic/Water Impact)

These type of units are suitable for handling large gas volumes with high dust content. Pressure drops fall within a range 3-6 in. water gauge that includes a mist eliminator to control entrainment problem. The design of these types is developed to handle large particles 5-10 μm size or more by absorption of soluble gases e.g. NH_3 , SO_2 , SiF_4/HF etc. as well as dust/particulate matter.

Spray scrubbers are used in the absorption of NH_3 , NO_x , fluorides, urea, dust, SO_2 etc., using a weak acid or alkali solution with an absorption efficiency around 94-95%. However to date these types are only used in the industry combined with a

Packed Tower

This type of scrubber is most suitable for gas absorption rather than dust or particle collection utilizing mass transfer between a liquid and a gas stream flowing counter current wise through a specific packing material. Packed towers have been very commonly used in the fertilizer industry due to high efficiency at increased ‘ΔP’ in order to meet the present environmental pollution standards.

The absorption efficiency may drop due to quality of scrubbing liquid and type of packing material selected because of solids ‘build-up’ as common as in the fertilizer industry.

Venturi Scrubber (Venturi Cyclonic and Coaxial)

Both venturi cyclonic and coaxial types have been in use in phosphoric acid and DAP/MAP/GTSP plants for handling dirty gas loaded with dust and particulate matter at a pressure drop varying between 6-12 in. water gauge ΔP.

Additional pressure drop of 5 in. water gauge is required to reduce dust concentration from 0.06 to 0.03 gr/scf equivalent to 135 mg. to 65 mg/Nm³ depending on particle size of the specific dust, fume or mist to be removed and absorption efficiency of SOx , NOx, NH₃ desired. The mechanism of particle collection in the venturi scrubber is known to be by inertia impaction followed by mass transfer of soluble component from gaseous to liquid phase.

Cross / Semi-Cross Flow (SXF™) Scrubber

A Cross or Semi-Cross flow (SXF™) Cross Flow Scrubber has been found to be the most successful applications in Phosphoric acid, DAP/MAP/TSP/SSP fertilizer processes for the past twenty-two years with an advanced technology , see Fig. 4G, H, and I (Ref. 4) .

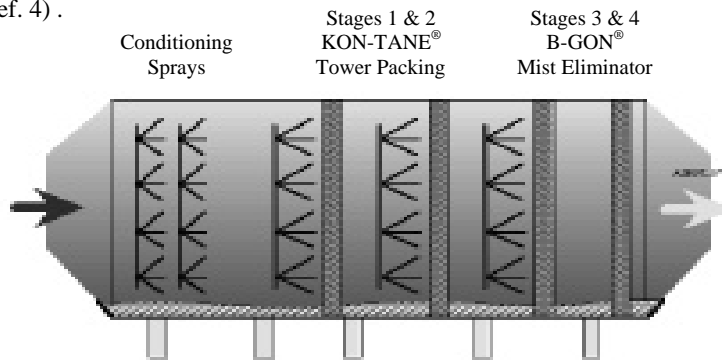


Figure 4G: SXF scrubber, once-through water

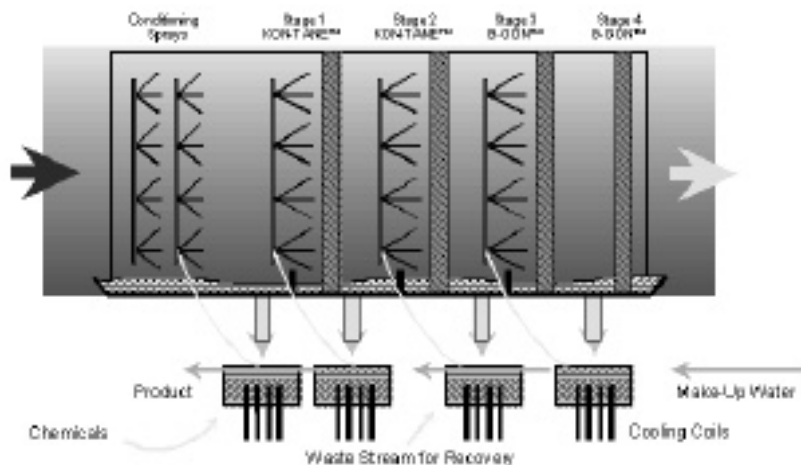


Figure 4H: SXF scrubber, counter-flow liquid, with cooling, chemicals, and waste stream addition (tower packing and mist elimination as in Figure 4G).

This type of wet scrubbers is developed as a combined unit of a spray and packed bed sections housed horizontally in a box with a mist eliminator inside for maximum separation of soluble gases, particulate matter and mist particles below 0.5 μm size. They are classified under medium energy scrubbers having a pressure drop (ΔP) 6-9 in. water gauge unlike packed towers or venturi cyclonic/coaxial scrubbers when used separately.

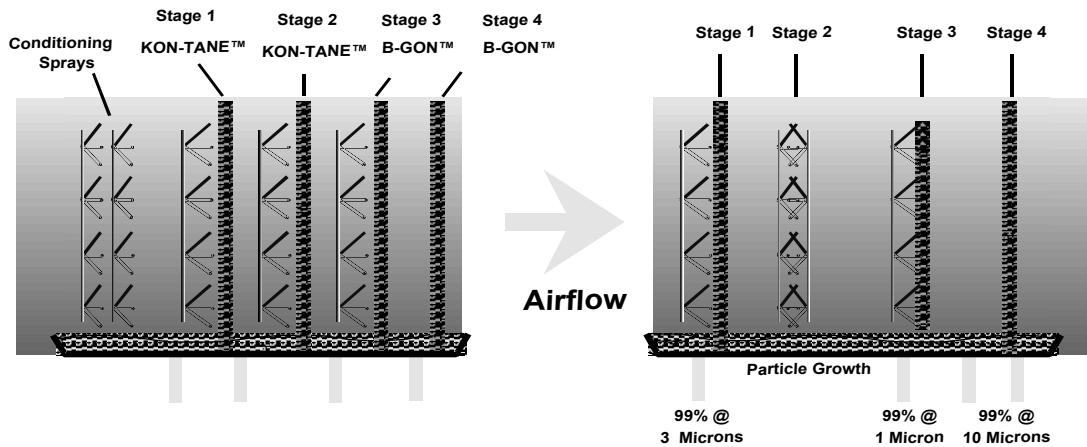


Figure 4I: SXF scrubber for absorption, fog, and solids collection followed by AEROSEP® Multi-Stage Aerosol Separation System for sub-micron aerosol collection.

Design of ‘Cross’ or ‘Semi-Crossflow (SXFTM)’ scrubbers includes the following (Figure 5, Ref. 5) :

- Pre-cooling/Wetting/Pre-cleaning of particulate matter and gaseous effluents.
- Humidification/Cooling/Separation of medium to large size particles of approximate 94-99% efficiency between 5µm-50µm size and soluble gases.
- Stage-wise absorption of soluble gases and fine to medium size (between 1-5µm) particulate matter using interlaced, ladder like structured filament media e.g. KON-TANE®.
- Final separation of fine (<1µm) size particles as mist and ‘aerosol’ particles using B-GON® filament media of finer styles but similarly structured like KON-TANE® in order to achieve 99.7%-99.9% recovery (Figure 6) .

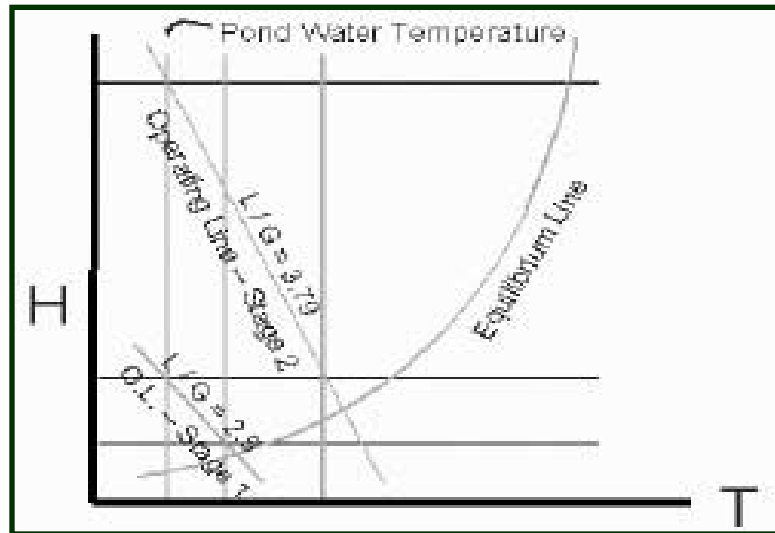


Figure 5: Enthalpy calculations SXF, once-through water.

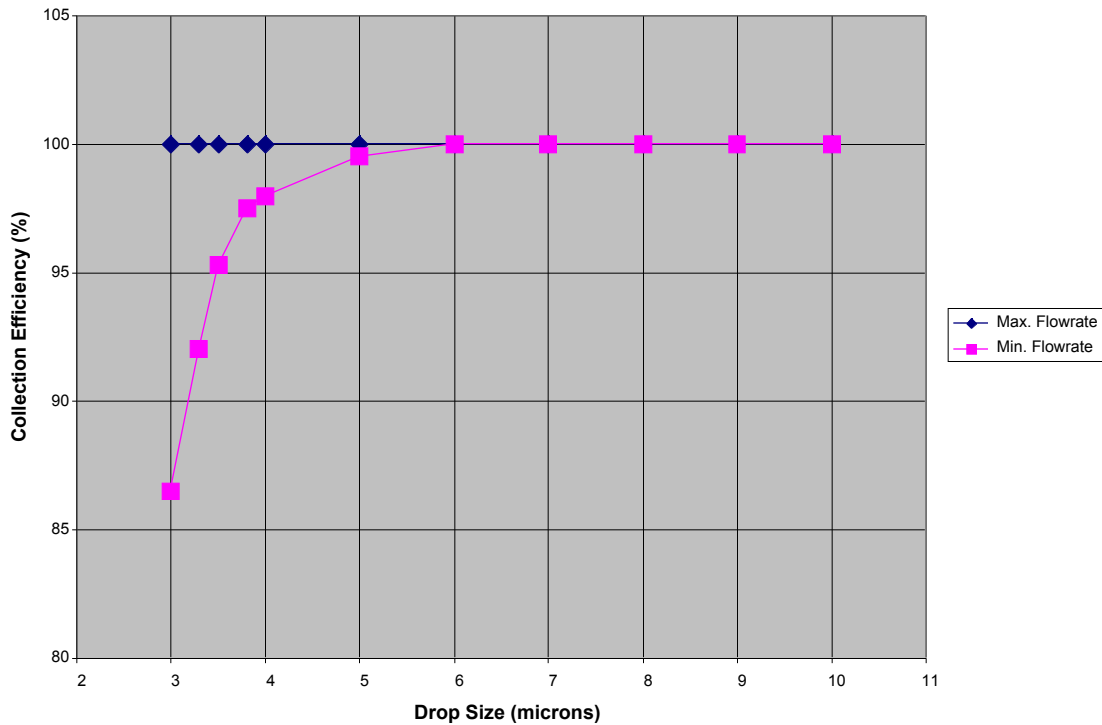


Figure 6: Illustration of the collection efficiency of B-GON® Mist Eliminator.

The authors have presented several papers comparing SXF semi-cross flow contactors with counter-flow dumped packing contactors, which show substantial differences (Pedersen & Bhattacharjee, 1996).

Regrettably, the differences between counter-flow contactors and SXF cross-flow, or other semi-cross-flow, or cross-flow contactors, has not been covered in the general literature nor at the university level so there is little familiarity with the applicable concepts. The lack of use, and lack of familiarity, is unfortunate because cross-flow or semi-cross-flow contactors offer characteristics which are very beneficial in many situations (Table 1).

Table 1: Comparative summary between SXF and counter-flow packed bed scrubbers.

ITEMS	VERTICAL COUNTER-FLOW	HORIZONTAL SEMI CROSS-FLOW
DESIGN CONSIDERATIONS		
Heat Effects	Handled only with difficulty	Easily Handled based on well established cooling principles with stage-wise cooling or heating of the liquid.
External Liquid to Gas Ratio (L/G)	Does not work at low L/G. Problem of flooding and entrainment occur at very high L/G and theoretical NTU limited by packing (Dumped) types	No lower limit on external L/G. High ext.L/G can be used, if required, but is usually not necessary since more theoretical NTU's are Available.
Stage L/G	N/A	Independently Controlled
Stages of Absorption in Each Vessel	Single	Multiple
Solution Recovery	Single dilute concentration is feasible.	Different concentration levels from high to low are feasible.
Gas and Liquid Inlet Concentration	Applications only for Steady State slowly changing conditions.	Applications for non-steady state and highly variable conditions.
Area of Installation	Less	More
Flexibility	Less	More
Size and Shape	Circular	Rectangular or Circular
Packing	Regular "Intalox" saddle/ Rachig or Pall Rings, etc...	KON-TANE® Tower Packing
Pressure Drop	Low	Low
Efficiency	Highly Variable	Higher
APPLICATIONS		
Sensitivity to Component Failure	Dramatically affected	Less affected. Unit capability can be restored quickly
Adaptability	Less	More
Maintainability	Hard due to removal of all packing at one time. On-Line maintenance is not recommended	Easy due to lighter packing weight and easy removal from one-stage both labor and time- wise. On-line maintenance arrangement can be built in, ie. No shut downs for maintenance.
Multi-Functionality	Minimum	Maximum and so enables to handle many applications
COST		
Installed	Basic	Higher
Operating	Higher	Lower

In summary, SXF contacting concepts can be used for:

- Direct contact heat transfer, and/or
- Mass transfer to any level of removal, and/or
- Mist elimination and/or particulate scrubbing to 1µm (and with the addition of AEROSEP technology, to sub-micron)

Most importantly, for any combination of the above, the functionality of the technology provides the benefit of “lowest-cost-per-ton-of-production” at a given performance level.

The higher fluorine recovery or lowering of fluoride pollution emission in air at or below 0.013 lb. Per ton P₂O₅ input has been proven in the fertilizer industry for past several years in many places within U.S.A., Canada, Europe, Japan and other Asian and South American Countries utilizing Kimre™ advanced technology.

“KIMRE” LADDER-LIKE MASS TRANSFER MEDIA (KON-TANE® / B-GON®)

In gas cleaning, there is clearly a trade-off between contaminant removal efficiency vs. energy consumption based on pressure drop (ΔP) applied in the process. But, the trade-offs between technologies are not sometimes clear if benefits of removal efficiency are not recovered fully well.

Years of long service in the U.S. and other countries with “Kimre” mass transfer media technology have given a strong reputation in gas cleaning within the fertilizer and other industries. This unique technology provides superior particle elimination from the process at a low pressure drop within 6-7 in. water gauge.

The unique interlacing media is available in a variety of coarseness or styles (Table 2).

Table 2: Styles of available Kimre mass transfer media

STYLE*	USE
2/96	Ultra – high – plus efficiency mist elimination and/or coalescing with 50 micron filaments.
4/96	Ultra – high – efficiency mist elimination and/or coalescing with 100 micron filaments.
8/96	Very-high efficiency mist elimination and/or coalescing With 200 micron filaments.
16/96	High-efficiency mist elimination with 400 micron filaments.
16/97	Like 16/96 with improved liquid handling.
37/94	Mist elimination and tower packing for dirty service.
37/97	Mist elimination and tower packing for extremely dirty service and high velocities.

* The left-hand number identifies the filament diameter in 0.001 inches.
 The right-hand number is the approximate percentage of free void space.
 These styles are standard. Other variations are available on special order.

Different styles can be combined in a single pad to provide the optimum performance based on particulate separation efficiency, pressure drop vs. cost, etc.

The ladder-like structured monofilament media (see Figure 7) creates sufficient flow turbulence to cause intimate gas-liquid mixing over maximum contact surface areas available for

- Mass transfer and
- Particle separation by inertial impaction, interception and Brownian diffusion to take place with high recovery of particulate matter and pollutants in vent air.

“Kimre” monofilament media KON-TANE® utilizes the combined effects of three mechanisms to maximize phase separation and particle collection efficiency by providing sufficient drainage of liquid through a predetermined void space depending on application to application.

These pads can be configured according to different functions:

- Removal of heavy liquid load by proper drainage
- Plugging resistance to avoid blinding
- Coalescing or removal of small particles coalescing of small (0.8-3 μ) to large (10 + μ) droplets.
- Entrainment separation for removal of large particles using B-GON® media.

The effectiveness of one layer of any type B-GON® mist eliminator can easily be calculated on proprietary software.

Liquid removal from mist eliminators should operate below the flooding point as determined from the Sherwood Shipley-Holloway correlation and pressure drop for a single layer of media can be calculated from an empirical equation.

The pressure drop across B-GON® pads has been experienced around 1" Δ P water gauge.

The pads of different styles and combinations are provided in rectangular or circular frames suitable for a particular design and shapes of a scrubber vessel. For ease of operation and maintenance purposes, "Pants Hanger™" types have become very popular in the industries lately by utilizing in semi-cross SXF™ scrubbers for Phosphoric acid, SSP/GTSP/DAP/MAP applications.

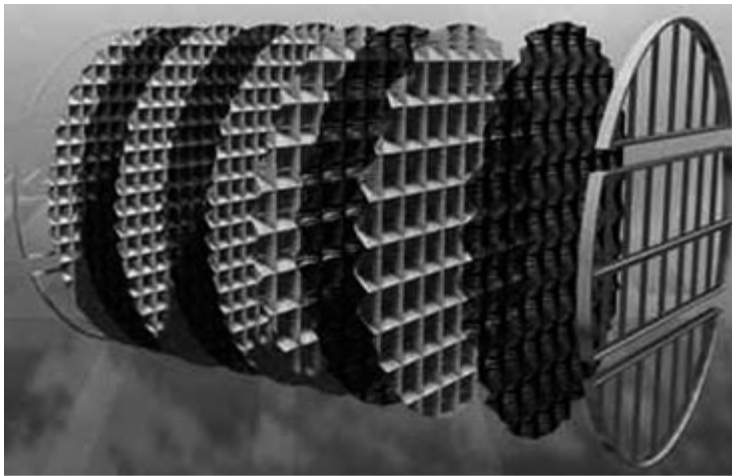


Figure 7: Exploded view of B-GON® Mist Eliminator.

WET SCRUBBER SELECTION

Choosing a scrubber largely depends on the following criteria for a particular air pollution problem in the fertilizer industry.

- Process
- Type of contaminants/characteristics
- Separation efficiency
- Design considerations for:
 - a) Single or stage-wise absorption
 - b) Packing type
 - c) Pressure drop
 - d) Liquid (L) to Gas (G) ratio
 - e) Solution recovery
 - f) Temperature change
- Flexibility of operation/maintenance
- Costs (installation and operation)
- Performance history

WET SCRUBBER APPLICATIONS IN THE FERTILIZER INDUSTRY

The major contaminants for air pollution in the fertilizer industry are NH₃, NO_x, SO_x, Fluorides, Ammonium nitrate, Ammonium phosphate, Urea, Superphosphates (Normal/Triple) and NPK dusts.

Ammonia

Ammonia process uses a high and low pressure spray type water scrubbers with a mist eliminator to recover 95%-96% ammonia. This can further be improved with a filament type B-GON® mist eliminator as proven in other processes.

Nitric acid

Nitric acid process can utilize similar type droplet separators in order to lower NO_x emission levels below 100 ppm.

Ammonium nitrate/CAN/NPK

processes have been using packed column or venturi cyclonic scrubbers and a demister for removal of ammonia less than 15 mg/Nm³. However, removal of sub-micron ammonium nitrate particles can be difficult using regular scrubbing methods as have been experienced in Urea and Mono/Diammonium Phosphate (MAP/DAP) processes.

To reduce emissions of 'aerosols'/sub-micron particles in air, cross/semi-cross flow scrubbers using KON-TANE®/B-GON®/AEROSEP® Filament type media have been found most suitable for dealing with the following:

- High dust loads
- 'Aerosol'/sub-micron size (NH₄ NO₃, NH₄F/NH₄HF and other reaction products in gaseous phase)
- High air volumes from prilling/granulation
- Fugitive ammonia/fluoride gases
- Unstable operating conditions
- Increased maintenance problems
- Low operating cost
- Most stringent air pollution limits under the current and proposed U.S. Clean Air Quality Act.

Industrial Experiences

A. Proven applications related to Phosphate fertilizers/Acids plants include the following:

- Rock Dryer: B-GON® Mist Eliminator for maximum rock particle recovery.
- Fume Scrubbers: KON-TANE® packing followed by B-GON® Mist Eliminator for maximum fluorides and particulate recovery worldwide.
- Fluosilicic Acid (FSA) Scrubbers: B-GON® Mist Eliminator for fluorides recovery.
- Evaporators: B-GON® Mist Eliminator for P₂O₅ recovery.
- Ammonium Phosphate/Single/Triple Super Phosphate Scrubbers: Widely used with KON-TANE® packing media followed by B-GON® Mist Eliminator in cross/semi-cross flow (SXF™) scrubbers for chemical recovery and minimum fluorides/particulates in exit air in Australia, Brazil, Canada, China, France, India, Philippines, S. Korea, U.S.A., etc.
- Sulfuric Acid Absorption/Drying Tower: B-GON® Mist Eliminators offer superior efficiency in U.S.A. and abroad.

B. Retrofit applications related to the Nitrogenous fertilizer industry have proved B-GON® media to be:

- Less susceptible to fouling
- Easy to clean and
- Able to reduce droplet and particulate entrainment from Ammonium Nitrate and Urea, granulation and prilling towers in U.S.A.

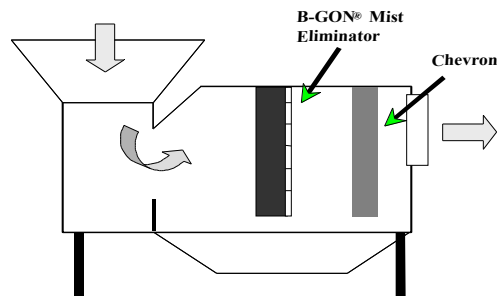
INSTALLATIONS AND CASE HISTORIES

A selection of installations in phosphoric acid and phosphate fertilizer is listed in the Appendix. This is about one half of such installations. Similar information is available for nitrogenous fertilizers and sulfuric acid production.

Urea Granulation Plant – Case History # 56

At BP Chemicals Urea Plant in Lima, Ohio, USA, process gas from a granulator is routed to a venturi scrubber followed by chevrons to reduce particulate matter and ammonia emissions. The existing venturi scrubber and chevron mist eliminators were installed with poor flow distribution. The limited space in the vessels lead to re-entrainment through the chevrons in areas where the velocity exceeded the maximum operating velocity of the chevrons. In addition to the poor flow distribution, the chevron mist eliminators were experiencing problems with pluggage. The flow rate through the mist eliminators was over 1000 fpm (5.1 m/s).

Figure 8
Urea Granulation Scrubber



An inclined B-GON® Mist Eliminator was recommended to replace both of the banks of chevrons. However, based on the customer's preferences, Kimre designed a single-stage B-GON® Mist Eliminator to replace the first-stage chevron (Figure 8). The mist eliminator was assembled with varying concentrations of media to re-distribute the air flow to the final stage chevron. The mist eliminator is over 90" tall x 94" wide (2280mm H x 2390 mm W). The flow through the vessel is over 76,000 ACFM (129,000 Am³/hr) and the pressure drop through the mist eliminator is between 2-4" WC (50-100 mm WC).

The granulator scrubber was retrofit in 1995. Since this installation the emissions are acceptable and the re-entrainment problem has been solved. In addition to correcting the flow-distribution, the B-GON® Mist Eliminators have improved the collection efficiency of droplets down to 10 microns in diameter.

Urea Granulation Plant – Case History # 57

At BP Chemicals Urea Granulation Plant in Lima, Ohio, process gas from an evaporator and granulator scrubber is routed to a duct scrubber to reduce particulate matter and ammonia emissions.

In 1998, Kimre, Inc. was contacted for a new project at the urea granulation plant. The previous successes at the plant lead the customer to contact Kimre, Inc. for the project. The plant was applying for an expansion project and needed to meet a 5.4 kg/hr particulate matter (PM) and extremely low ammonia emission limit.

An agglomerator B-GON® Mist Eliminator with significant amounts of some of Kimre's finest media was recommended to reach the new requirements. The mist eliminator was supplied in Batten Bar™ Media Holding Systems to ensure proper sealing across the agglomerator stage. The engineering firm that contracted Kimre, Inc. to design the mist eliminator installed the B-GON® Mist Eliminator in the 3650 x 3650 mm scrubber in between banks of chevron mist eliminators.

The duct scrubber successfully achieves an average emission of 0.3 kg/hr of PM at a flow rate of 109,000 Nm³/hr. The plant has decided not to go through with the planned expansion and is satisfied with the lowered ammonia and urea emissions. Before the installation of the B-GON® Mist Eliminator System, the urea emission was higher than 6.45 kg/hr. Based on the low emissions and the changes in expansion plans, the plant has modified the configuration of the agglomerator stage, resulting in lower pressure drops, higher throughputs, and insignificant changes in PM emissions.

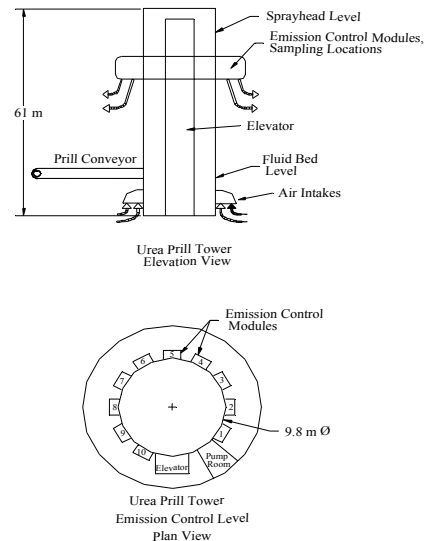
Urea Prill Tower – Case History # 58

Repeated success at the BP Chemicals Urea Granulation plants in Lima, enabled Kimre, Inc. to discuss possible improvement in the 9.8 m Prill Tower with the Engineering Department at BP Chemicals (Figure 9). An important objective of the team was to significantly increase the throughput of the tower. The pressure drop across the existing foam and knitted mesh mist eliminators prevented the customer from achieving this improvement in capacity.

Several reasons were cited by the customer for replacing the existing mist eliminators: higher quality product, increased throughput, lower pressure drop, decreased emissions, and less maintenance requirements. In order to decide the best B-GON® Mist Eliminator design for the installation, Kimre, Inc. worked with Lucas Process Systems and the local Kimre representative on a pilot study. After running several tests in the tower, Kimre, Inc. recommended a composite mist eliminator to be installed by others in a Batten Bar™ Media Holding System.

The unique, interlocking structure of the B-GON® Mist Eliminators and the variety of styles available enabled Kimre, Inc. to engineer a mist eliminator capable of lower pressure drops at higher gas velocities. The liquid handling ability of the mist eliminator was also improved with the addition of more coarse styles of material to the design. The Batten Bar™ Media Holding System improved the sealing of the mist eliminators in the tower and prevented the media from sagging due to the tall module heights.

Figure 9: Urea prill tower with mist eliminators



NPK Tail Gas Scrubber – Case History # 59

In 1997, Incro S.A. contacted Kimre to help meet design a scrubbing system that would meet the stringent Fluorine emission limits for Dongbu Hannong Chemicals NPK plant in Ulsan, South Korea. This project would prove to be an extremely aggressive undertaking. The plant is designed to supply up to thirty different phosphatic grades to target the relatively short seasons of the domestic small plot fertilizer market. Production runs would be fairly short. Process fluctuations would be extreme. Planned shutdowns were to be minimal.

The design conditions for the Tail Gas Scrubber were as follows:

- Gas Flow Rate: 135,000 Am³/hr
- Temperature: 50°C
- Inlet Loadings: Dust = 300-1000 mg/Am³
Fluorine = 50-100 mg/Am³ (200 mg/m³ max)
Ammonia = 50-300 mg/Am³

- Outlet Guarantees: Dust = 90% removal
Fluorine = 3 mg/m³ (Outlet design = 2 mg/m³)
Ammonia = 85% removal

Furthermore, the client required a ZERO LIQUID DISCHARGE FROM THE PLANT. This additional specification understandably increases the constraints under which any type of scrubbing system operates.

Kimre proposed a system incorporating its SXF™ Semi-Crossflow Scrubber Technology to meet or exceed all of the specified design requirements. The packing components would be installed in a vessel with a cross-section of 3800 mm H x 5600 mm W. Kimre's proposed system utilized three (3) stages of its KON-TANE® Tower Packing and one stage of B-GON® Mist Eliminator to achieve the desired results. The packing and mist eliminator stages were supplied in frames using our Pants Hanger™ Media Holding System to allow for easy access to the media for on-line maintenance: The system can continue to operate IN COMPLIANCE while doing maintenance.

The low liquid discharge guarantee is met by utilizing counterflow stage-wise recirculation of scrubbing liquid. This optimizes mass transfer driving forces with limited availability of scrubbing liquid by contacting the most concentrated liquid streams with the most polluted gas, and the clean liquid streams with the least polluted gas. The effluent from the first scrubbing stage was fed to venturi scrubbers directly upstream of the SXF™ Scrubber.

Kimre's offer was contingent upon approval of vessel drawings and vessel construction according to specifications. Several days following order acceptance, it was revealed that vessel fabrication was already 80% complete and the optimum vessel design would not be possible. With startup less than three months away, Kimre was able to alter its design. The system with the new modifications was delivered early, demonstrating the flexibility of the SXF™ System.

This system has been operational since 1997. Dongbu engineers report that the system continues to meet all performance guarantees and has proven to be easy to maintain and operate. Further, the Kimre media has held up extremely well under a wide range of operating conditions, and the client continues to operate the vessel with the original media intact and operational.

Phosphoric Acid Plant Fume Scrubber – Case History # 60

In March 1998, Kimre was invited to submit an offer for supply of tower packing and mist eliminator components for the Oswal Chemicals & Fertilizer Ltd. (OCFL) project to develop three 2000 tpd DAP plants at its Paradeep, India location. Kimre's technology would be utilized in the planned 2650 P₂O₅ tpd phosphoric acid plant - the world's largest phosphoric acid plant to date. The design of the plant was provided by Jacobs Engineering Group, and its subsidiary, Humphrey & Glasgow Consultants Ltd., provided the detailed engineering and construction consulting. Jacobs Engineering required a Tail Gas Fume Scrubber for its phosphoric acid plant to meet a very low Fluorine emission limit.

The horizontal cross-flow scrubber fume scrubber, which utilized Kimre's SXF™ Cross-Flow Scrubbing Technology, had the following design conditions:

- Gas Flow Rate: 143442 Nm³/hr
- Inlet Fluoride Loading: 7900 mg/m³
- Outlet Fluoride Emission: 8 mg/m³

The cross section of the fume scrubber is more than 11 meters wide x 3.6 meters high. Kimre supplied three (3) stages of our KON-TANE® Tower Packing to provide the 99.9% scrubbing efficiency required and one (1) stage of our B-GON® Mist Eliminator to prevent entrainment of the droplets.

Each packing and mist eliminator stage was comprised of ten (10) packing modules 2900 mm H x 874 mm W x 250 mm L (Figure 10). The polypropylene packing and mist eliminator media was supplied in modules of Alloy 20, and utilized our Pants Hanger™ Media Holding System.



Figure 10: SXF™ modules

With the Pants Hanger™ Technology, the modules are easily installed and removed from the top of the scrubber for maintenance. Also, the technology allows direct access to the Kimre media for thorough cleaning.

Phosphoric Acid Plant Fluorine Scrubber – Case History # 61

The Oswal Chemicals & Fertilizer Ltd. (OCFL) phosphoric acid plant, referenced above, included six (6) Fluorine Scrubbers, each with an inside diameter of 6400 mm and the following design conditions:

- Gas Flow Rate: 468,000 Am³/hr
- Temperature: 45°C
- Pressure: 58.4 mm Hg, absolute
- Composition: water vapor with 4.5% Fluorine

The B-GON® Mist Eliminator Pads were to provide 99+% collection efficiency for all droplets 10 µm and larger. Kimre provided mist eliminators in Style 37/97 to provide the maximum resistance to pluggage from silica scale, and the highest liquid handling capacity of any mist eliminator available.

Adding to the design complications, the vessels are rubber lined and, therefore, sensitive to temperature. If the pressure drop across the pads were to increase excessively, the temperature in the vessels would increase excessively and could damage the rubber lining. Therefore, the pressure drop across the mist eliminator was to be limited to a maximum of 50 mm WC at all times – even when pluggage of the mist eliminator occurs.

To meet this requirement, Kimre designed each of its mist eliminator with pressure-relief doors. The pressure relief doors are strategically located across the pad's cross-section (See Figure 11). Also, the doors are designed with a specific weight that would allow them to open when the pressure drop across the pad reached 50 mm WC. The doors would open, and allow the gas to bypass the material to avoid temperature excursions within the vessel. The entire construction was supplied in PP.

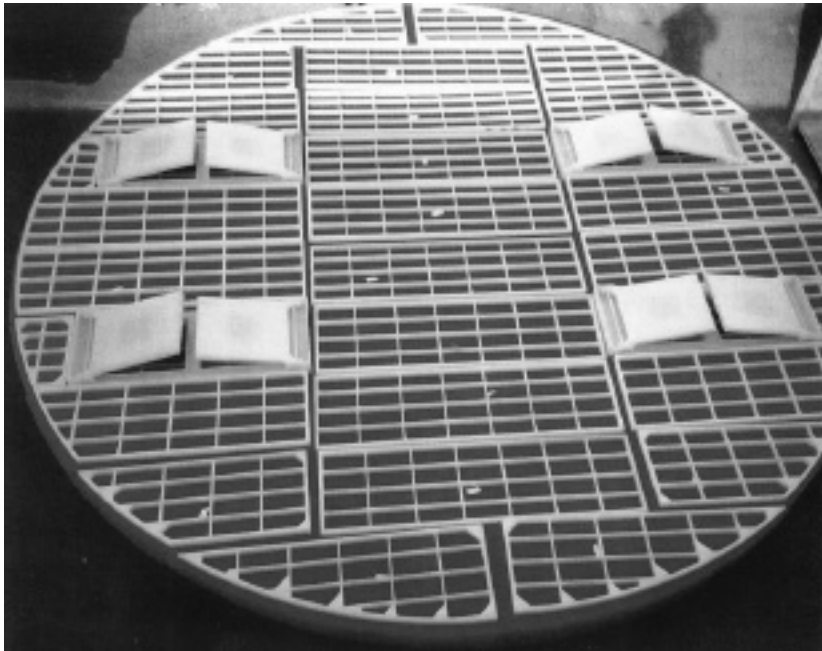


Figure 11: Fluorine scrubber mist eliminator with pressure relief doors.

Phosphoric Acid Plant Vacuum Cooler Pre-Condenser – Case History # 62

The Oswal Chemicals & Fertilizer Ltd. (OCFL) phosphoric acid plant also includes three (3) Vacuum Cooler Pre-condensers, each with an inside diameter of 3800 mm and the following design conditions:

- Temperature: 77°C
- Pressure: 292 mm Hg, absolute
- Composition: water vapor with trace Fluorine

As with the Fluorine Scrubber (Case History 62) the B-GON® Mist Eliminator Pads were to provide 99+% collection efficiency for all droplets 10 µm and larger. Kimre provided mist eliminators in Style 37/97, 100% PP construction to again provide maximum resistance to plugging and avoid re-entrainment of droplets. Also, the mist eliminators were again required to keep a maximum pressure drop of 50 mm WC, even if becoming blocked with insolubles. Pressure-relief doors were supplied to ensure this pressure drop limit was not exceeded.

Kimre supplied its components for the plant by May 1999. After many months of delays (including natural disasters), the phosphoric acid plant was started up successfully.

CONCLUSIONS

Advances in gas cleaning technology have been possible and practically proven by developments of theoretical ideas and integrating it with 'real-world' experiences in the different chemical processes involved in the fertilizer industry.

Selection of a scrubber is critical to deal with increased dust load and sub-micron particles /'aerosols' in order to avoid 'blue haze' and other visible plumes in the stack and meet 'BAT'/BACT'/BPEO' under USEPA and European Community (EC) environmental legislations.

Cross/Semi-Cross flow scrubbers with 'filament' media (KON-TANE®/B-GON®/AEROSEP®) have been used successfully in AmNO₃, Urea, Super/Triple and Mono/Diammonium phosphate and NPK fertilizer plants to meet world air pollution standards either as a primary or secondary unit.

Present pollution prevention by implementing advanced gas cleaning technology has already led to fluosilicic acid solution recovery in super phosphate plants and thereby minimization of wastes and hazards in the fertilizer industry.

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