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An Efficient Scrubber

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An efficient scrubber

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Horizontal crossflow scrubbers using Kimre Inc's monofilament pad material have been in successful service at a Brazilian NPK plant for 2½ years. They are cheaper both to install and to run than normal venturi-based systems.

When a conventional NPK granulation unit is required to meet rigorous emission limits for particulate material, fluorides and ammonia, it is normal to think in terms of venturi systems with their associated high power consumptions. This article reports on the successful application of a low-energy cross-flow scrubber based on the KON-TANE™ and B-GON™ packing materials produced by Kimre Inc., of Perrine, Florida. During the 1970s Manah SA constructed two NPK granulation plants based on Fisons technology at its Cubatão site in the state of São Paulo using a low-recycle solid-feeds process. These plants had a nominal throughput of 90 t/h with product rates varying from 24 to 45 t/h, depending on the composition. They were fitted with gas cleaning equipment which was standard for that time: medium-efficiency cyclones on the dryer, cooler and deduster systems followed by a void spray tower, which was also fitted with a radial-blade spray drop eliminator. The gases from the granulator were vented through a natural-draught stack directly to atmosphere.

In the early 1980s, when problems with air and water pollution had earned Cubatão an international reputation as 'Death Valley', the São Paulo state environmental protection agency - CETESB - instigated the first series of emission limits for Manah's installations. They were not particularly strict by today's standards, but it was necessary to make changes and install new pollution control equipment to meet them.

Stage 1 modifications

Being basically a production company, we did not at that time have sufficient technical staff to design and project such equipment, so it contracted the necessary consultants and specialist engineering and equipment companies.

The following alterations and additions were made to the granulation units. The four medium-efficiency cyclones on the dryer and cooler gas streams were replaced by six high-efficiency cyclones. To compensate for the increased resistance to gas flow it was necessary to uprate the four fans from 6,000 Am³/h to 7,000 Am³/h and from 300 mm WG to 400 mm WG, with a corresponding increase in the size of the motors.

The granulators were fitted with a three-stage venturi scrubber, using either phosphoric acid or water as the scrubbing medium. These required high-pressure drop fans (around 1,200 mm WG). Venturi systems were also fitted to the superphosphate units.

With the exception of the cyclones, all the other equipment suffered from serious process and mechanical problems. The most severe problems were encountered in the high-pressure drop fans. Their rotors were rubber-lined mild steel, and the bonding between the rubber and the steel left much to be desired.

Stage 2 modifications

In 1984 the pressure on CETESB had increased, and the agency announced specifically for Cubatão. There was no 'Grandfather' clause in this legislation. The new emission limits were as follows:

Particulates	75 mg/Nm³
Total fluorides	0.1 kg/tonne P_2O_5 fed
Ammonia	0.02 kg NH_3/ton product

This time we called in Brazil's most respected consultant on environmental control projects for the fertilizer industry. CETESB had targeted the superphosphate units as the top priority for the Manah site. These are two identical parallel trains using mixers of our own design which discharge onto belt dens. The two units share a common exhaust and scrubber system.

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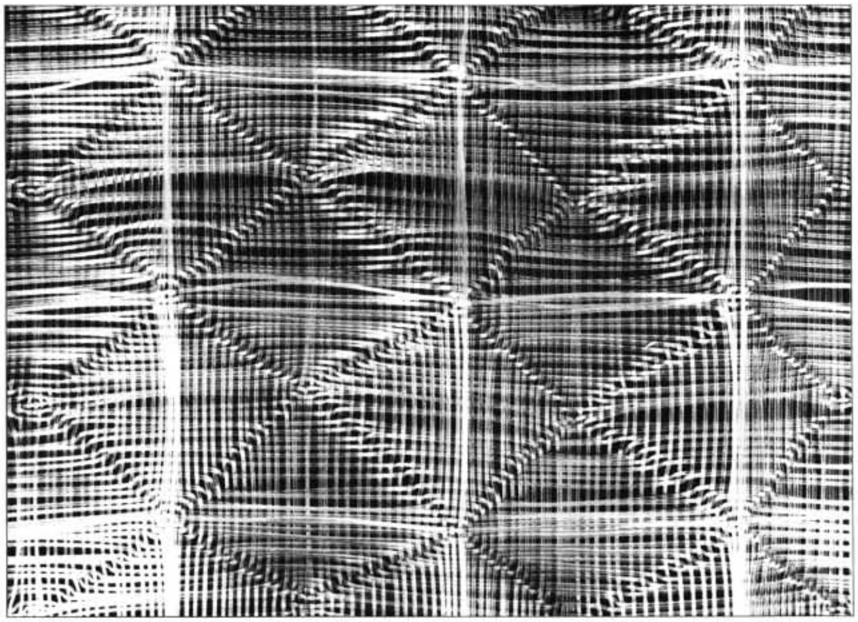
The consultant's answer to the problem was a conventional system comprising a first-stage venturi and separator, a second-stage spray tower and a third-stage packed tower. It was with some reluctance that the company went ahead with the project, the deciding factors being the deadline set by CETESB and the lack of a proven alternative. The system went into operation in late 1985, and while not being a complete disaster it did not meet the emission standards and was plagued by equipment failures, most notably in the fans and the recirculation pumps.

At that stage we halted work on the granulation plant pollution control system and decided that all future project design should be done 'in house'. To that end, the technical department was strengthened to form a new projects section. At the same time it so happened that we first came across the application of Kimre packings in fertilizer plant scrubbers and made their first contacts with Kimre.

Our new project team discovered that we did not have enough basic information on the compositions and size analysis of the dirty gas streams to calculate the parameters for the venturi scrubbers. None of our previous consultants had asked for this information in detail, so we could only assume that they had used typical values for the particle size distribution and not real ones. Measurements did, however, confirm the high efficiency of the cyclones, which removed all particles down to 10 µm, so they were not to blame.

As our the granulation plant dryer and cooler exhaust cleaning projects developed we became alarmed at the size and power requirements of the fans which would be needed for a classical venturi system. This prompted us to make a more detailed evaluation of Kimre's technology and packings, in the course of which we made a series of visits to cross-flow scrubbing systems in the United States and France. The information gained was sufficiently convincing for us to halt the venturi-based projects and start designing cross-flow systems using the Kimre packings.



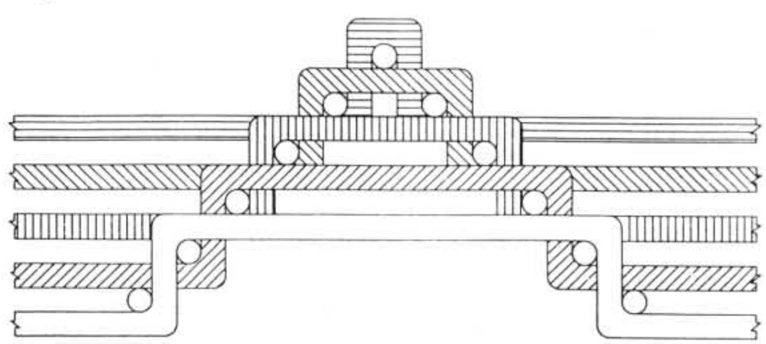
A close-up view of Kimre B-GON™ filtration medium. What does not show up very plainly in this photograph is that filament rows inside the squares in fact define pyramidal depressions. Because of the way it is woven (a closely-guarded secret, by the way), this structure is durable, and it presents a good profile for capturing dust and droplets but minimum resistance to bulk gas flow.

Monofilament packings

What are Kon-tane™ and B-Gon™ packing materials? They are made in the form of a uniquely interlaced structure of a monofilament material. The combination of the specific structure, illustrated diagrammatically in Fig. 1, and the flow patterns through the material (Fig. 2) are responsible for the intrinsic efficiency of the material in collecting dust and mists and as a heat and mass transfer medium. Two other critical properties which are also a result of the structure of the medium are its high liquid handling *capacity* and its mechanical resilience, which makes it much easier to clean. When the gas flow is perpendicular to the packing medium several effects are produced, including very predictable pressure drop and liquid handling capacity as well as highly uniform gas flow distribution. The high liquid handling capacity also greatly assists in making the structure resistant to blocking and plugging. These features will be mentioned again in describing the design philosophy used by Manah for the granulation plant's dryer and cooler.

The Kimre material is available in a wide range of thermoplastics with many different filament diameters. For our project, in common with the majority of fertilizer projects, we only used pads made from 'normal' polypropylene and only

Fig. 1: **Monofilament Structure**



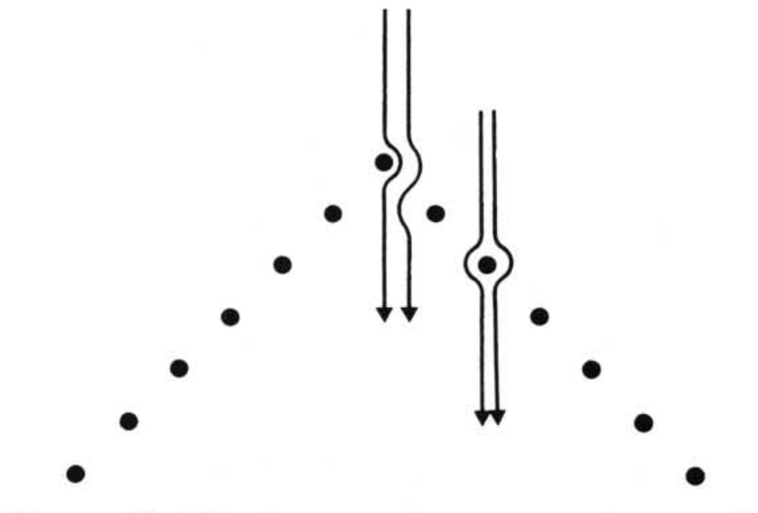


Fig. 2: **Flow Pattern through B-GON™ Structure**

two of the range of filament diameters: the 37/97 and 16/96 materials. The number before the slash in these figures represents the monofilament diameter in 'mils', or thousandths of an inch, while the number after the slash indicates the percentage of free space in the pad. In metric terms, the 37-mil filament is 940 μm in diameter, the 16-mil is 406 μm. The available Kimre pads range from 2/96, 4/96, 4/97, 8/96, 8/97, 16/96, 16/97, 32/94, 32/97, 37/94, 37/97 and 62/97. The majority of pads are available in the following thermoplastics:

Polypropylene
High-temperature polypropylene
Kynar™
Tefzel™
FEP Teflon™
PFA Teflon™

Scrubber design

When we came to design and specify the dryer and cooler scrubbers for our granulation plants, our objective was to create a scrubber that would not only meet the previously stated emission limits for the most economical overall cost but would also be endowed with sufficient flexibility to enable it to meet any future tightening of the emission standards with the minimum of additional investment. In determining the 'most economical overall cost' the elements considered were the initial investment cost, operating costs, 'on-stream' utilization, maintenance cost, and flexibility with respect to changes in process inputs or output requirements.

We discussed with Kimre the basic process requirements, such as the type and number of pads, the number of stages and the irrigation liquid-gas ratio needed to safeguard against plugging. The other important process parameter - gas velocity - was used to determine the basic cross-sectional area of the scrubbers.

The packing material is supplied in 6-foot widths, and to avoid both cutting and waste this value was fixed as the width of the scrubber. The height was fixed to give the optimum gas velocity for the expected range of gas flow rates. This meant, in practical terms, that the dryer and cooler were run in separate scrubber bodies. The length of each stage was fixed by the spray angles from the recirculation liquid nozzles. We departed from the number of stages that had been suggested by Kimre. We included empty stages which could, if necessary, be fitted out at a later stage if it became necessary to increase the performance of the system to conform with changes in the legal standards or to accommodate increasing loads from upsets or changes in the process units. And since, to our knowledge, these were to be the first cross-flow scrubbers based on Kimre pads to be used in a granulation plant without a venturi stage between the cyclones and the cross-flow system, we were worried that the first stage might receive an excessive load of solids. The first stage was set up to use a single pad, which was sprayed in both cocurrent and countercurrent sense with high rates of liquid.

The scrubbers consist of two rectangular boxes with a common wall. They have the following basic dimensions.

Height	4,500 mm
Width	2,000 mm
(in effective free area:	1,820 mm)
Length	11,100 mm

They are divided into nine stages (Fig. 3). Table I shows how these are configured.

The first and second stages comprise a single layer of material irrigated liberally on both sides with liquid recirculated from the seal tank. This modification to the normal Kimre design has worked very well, and in 2½ years of operation there have been no problems with blocking. The third stage is one of the spares, but it provides a space in which aspirated droplets from the first pad can coalesce and grow into more easily arrested particles. The final demisting stage is irrigated only intermittently and with clean water rather than seal tank liquid.

The pumps and seal tanks are separate from the scrubber body and are common to both the cooler and the dryer scrubber, to which they are linked through hydraulic seals. Each scrubber does, however, have its own fan, but these discharge into a common stack.

Operation and problems

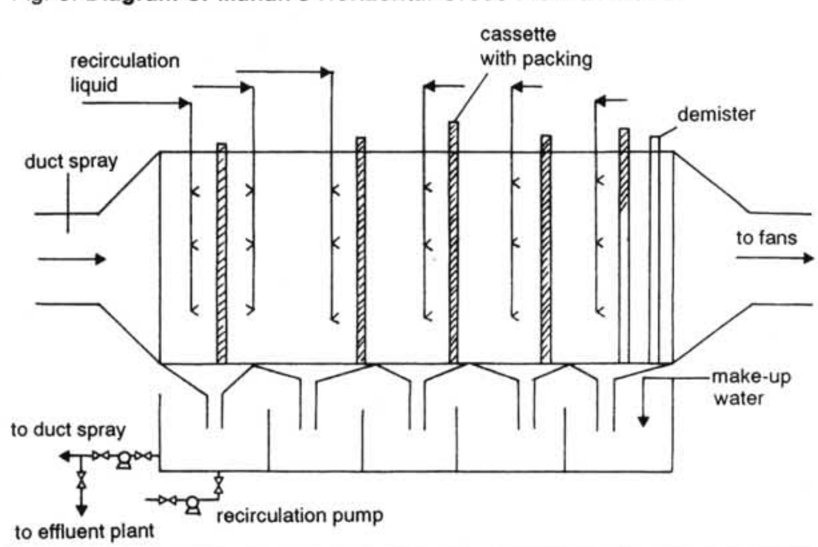
Scrubber liquor from the first stage is sprayed into the inlet gas duct to presaturate the gases and, in the case of the dryer exhaust, to reduce its temperature so as to protect both the packing and the scrubber body. The pads were put into slide-in/slide-out envelopes to allow them to be removed for cleaning during operation. That greatly increases the on-line operating factor for the unit. As a standard feature a monorail hoist is installed above the scrub-

Table I: Configuration of Stages in Manah Cross-Flow Scrubber System

Stage	No. of layers	B-GON™ Packing	Rating	Irrigation rate (m^3/m^2h)
1	1		37/97	12
2				
3		Empty	-	
4	3		37/97	4.4
5	4		37/97	4.4
6	4		37/97	1.5
7		Empty	-	
8	4		37/97	1.5
9 (demister)	8		16/96	Intermittent

Provided sustained pressure is avoided, Kimre pads do not require especially careful handling; they can withstand farely robust treatment in transport and installation.

Fig. 3: **Diagram of Manah's Horizontal Cross-Flow Scrubber**



bers to facilitate the removal of the pads.

The liquid used in the scrubbers is recovered water from the liquid effluent treatment plant. The normal feed rate is 10-11 m^3/h. Only 3-5 m^3/h (depending on the product grade) is returned to the treatment plant, the remainder having been evaporated into the gas stream. This water is the source of one of the main problems in the scrubber. The waste water treatment plants are mainly there to remove fluorides and phosphates, using classical single-stage neutralization and precipitation with calcium hydroxide. That leaves the treated water with a final pH of 8-9. Unless this value is reduced to about 4-5 by acidification, there is a tendency for ammonia to be released from the final stage of the scrubber.

The water flow in the seal tanks is countercurrent to the gas flow in the scrubbers. As mentioned, the seal tanks are common to both scrubbers. Initially the fact that they were not part of the scrubber bodies gave rise to a problem with gas bypassing round the bottom of the pad envelopes because they were not sealing completely.

The problem was solved by installing better sealing materials. In any future installation the problem would be solved by integrating the seal tanks into the scrubber bodies so that the bottom of the pads would be immersed in the liquid. Kimre recommended such an arrangement from the start. The overwhelming majority (80-90%) of problems with cross-flow scrubbers are caused by gas bypassing either the sides or the bottom of the pads.

Table II sets out some of the results obtained with the system. The high ammonia emissions were, as mentioned, due to the pH of the treated water used in the scrubber.

Economics

From the point of view of operating costs, one very important factor is that the scrubber system has not caused any loss of production except during start-up, when despite being a low-speed medium-pressure fan, the dryer fan rotor shed part of its rubber lining, causing out-of-balance rotation.

Table II: Operating Data from Manah Cross-Flow Scrubber Installation

Date		**22.11.89**		**26.07.90**		**23.10.90**		**17.05.91**	
Product		**5-25-0**		**5-26-3**		**5-18-4**		**0-42-0**	
System		**Dryer**	**Cooler**	**Dryer**	**Cooler**	**Dryer**	**Cooler**	**Dryer**	**Cooler**
Δ P (mm WG) cyclones		200	170	200	180	190	160	160	150
ΔP scrubber (mm WG)	1st/2nd stage	25	20	25	18	50	30	20	30
	4th stage	30	15	22	15	40	15	35	10
	5th stage	30	15	31	29	55	45	35	55
	6th stage	35	15	44	16	55	40	40	25
	8th stage	30	35	22	38	55	45	45	35
	9th stage	35	55	28	56	65	65	95	50
ΔP fan (mm WG)		475	410	510	430	575	465		
Total airflow, Nm^3/h		103,540		90,200		102,700		116,780	
Particulate emission, mg/Nm^3		67.2		59.7		57.6		74.6	
fluoride emission, kg F/ton P_2O_5		0.03		0.016		0.001		N.D.	
Ammonia emission, g/ton product		10.3		24.7		25.3		N.D.	
Liquid effluent, m^3/h		3.0		3.5		3.3		N.D.	

N.D. = not determined

The combined installed rated power is 950 h.p., but actual consumption is 500-550 h.p. (around 400 kW). This compares very favourably with the 2,000-2,200 h.p. installed power and 1,300-1,400 h.p. (1,000 kW) normal consumption for a conventional 2- or 3-stage system. For a unit operating for 5,500 hours per year (which is average for Brazil), the power savings would amount to

$$(1,000\text{-}400) \times 5500 = 3.3 \times 10^6 \text{ kWh}$$

At a cost of US $0.03 per kWh, this translates into financial savings of $99,000. Electricity is relatively cheap in Brazil.

The total capital cost of the dryer-cooler scrubbers for the two granulation plants plus the liquid effluent treatment was $3.5 x 10^6$, which represented savings of approximately $1 million on systems based on 2- or 3-stage venturis. ■

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