Advances in Grinding, Classifying, and Shaping Technology for Color Toners

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Abstract

Technical progress and more than 20 years of experience characterise Alpine's fully automatic toner production systems. Besides the particle size itself, it is the high degree of cost-effectiveness and the compactness of the system design that stand out. Leading toner producers the world over rely on Alpine as the top supplier and trendsetter for production lines or complete turnkey systems for one- and two-component toner and coloured toner.

The presentation introduces the TFG and TSP/TTSP systems for the production of toner powder. Besides considerable energy advantages, the TFG fluidised bed opposed jet mills produce powders with a d_{50} in the range of 5.5 - 10 µm and a sharp top-size limitation. And even the new toner types with their extremely low melting points can be processed without problem. Hosokawa Alpine has continuously adapted its successful classifier technology to meet the growing market demands, and the Alpine TTSP classifiers set new standards in the field of toner dedusting.

For rounding the toner particles Hosokawa Alpine offers two different solutions that both successfully work different customers' plants. One is the Faculty processing unit that combines a classifying process and a highly efficient mechanical dispersion process. This multi-functional process allows improvement of the particle surface properties. This technology generates higher-grade products in one single process step at low energy consumption values. The other the Cyclomix that is a new revolutionary high speed intensive mixer applying high shear and impact forces to the toner powders

The Hosokawa Micron Group

The Hosokawa Micron Group is an international provider of equipment and systems serving a broad range of industries which includes chemical, minerals, pharmaceutical, polymer, food, blown film processing, confectionery and bakery, and specialised food.

The Hosokawa Micron Group´s broad range of powder and particle processing capabilities includes equipment and technologies for a variety of applications including:

- Agglomeration / Granulation
- Compaction / Low-Pressure Extrusion
- Size Reduction / Micronisation
- Mixing / Powder Blending
- Screening / Air Classification
- Drying / Vacuum Drying
- Product Collection / Containment
- Hygienic Filling and Weighing
- Bulk Packaging
- Toll Processing
- Particle Design & Nano Technology

Since the advent of modern office equipment such as printers and photocopiers, we have focused our efforts on the processing of toner powder. And during the process, we have not just been an onlooker, but rather have been instrumental together with our customers in setting milestones.

To date, Hosokawa has supplied over 200 processing systems to leading toner manufacturers. The product range covers small test or laboratory systems just as it does large production scale systems, with the throughput rates ranging up to 500 kg/h. In spite of the fact that toner systems all basically operate in the same way, it is the details which make the difference and which we tailor to suit the customers' individual requirements. Explosion protection is an issue which takes top priority during the design and manufacture of our toner systems. Hosokawa specialises in complete toner systems – from the design and manufacture to the installation, maintenance and service.

Single machines or turn-key Plants

The decision whether off-line or in-line process is a question of the philosophy:

Advantages of the OFF-LINE process:

- maximum flexibility
- modest overall height
- simple optimisation

Advantages of the IN-LINE process:

- automatic mode
- reduced container handling
- less space requirement

The following description concentrates on an off-line process, because this is what most of our customers prefer. In off-line mode, the material is filled into containers after every process step, which then serve as feed bins for the next process step. Some system components can be cleaned or maintained while other components are in use. Each process step can be individually optimised.

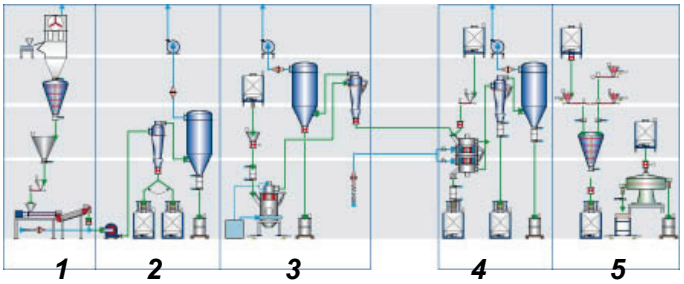

Figure 1 *Toner production process (**1** Preliminary mixing, extrusion, cooling, **2** Preliminary grinding, **3** Fine grinding, **4** Classification, **5** Additives, Safety screening)*

Preliminary mixing, extrusion, cooling

The individual components are prepared, weighed and then filled into a high-speed preliminary mixer. The pre-mixed raw materials are metered to an extruder. The pasty toner mass is discharged from the extruder into a cooling unit (e.g. chill roll, metal cooling conveyor, etc.). At the end of the cooling section, a flake breaker pre-crushes the cooled toner mass to the size of chips.

Preliminary grinding of the chips

Dependent on the grindability and the wear behaviour of the material, the following Hosokawa mills can be used:

- Rotoplex granulator
- Fine impact mill UPZ
- Sieving mill

Preground to granules, the material is collected in a cyclone or filter and then filled into containers.

Fine grinding

A vibrating table empties the preground granules out of the container. The toner is now metered via a variable-speed metering unit and a double flap valve to the opposed jet mill TFG. Dependent on the grindability of the different toner types, either Laval or particularly efficient Mega-Jet nozzles are employed. The level of material in the mill is monitored and regulated by load cells. If necessary, the speed of the metering unit is adjusted accordingly. The ground material is conveyed further to a cyclone and then either discharged into a container or direct into the downstream classifier.

Classification

The classifier can either be fed from a container or from the cyclone of the fine grinding step. The problem specification dictates which of the two specially developed toner classifiers, i.e. TSP or TTSP, is employed. A specially designed flap valve serves as the air seal for the coarse material discharge. The fines are collected either in a cyclone or a filter. The advantage of off-line mode is that the classifier can be operated and optimised independent of the mill.

Additives

In order to improve the flow behaviour and to influence the surface properties, the toner is coated with different additives. The container with the coarse material from the classifier then becomes the feed bin. Both toner and additives are metered by gravity into a high-speed fluid mixer, after which the blended material is either refilled into a container or fed to a screening machine via an intermediate bin.

Safety screening

Any flakes still remaining in the product are screened out here. In most cases, a tumbler screening machine with a screen mesh width of 125 µm is used. The coarse material is waste and the fine material is the finished toner, which is filled via airtight devices into containers or drums positioned on floor scales.

Explosion protection

Toner is a material which is prone to dust explosions. Because of this, special safety measures must be taken. The following concepts are in use:

- Pressure venting
- Explosion suppression
- Pressure-shock-proof design to 10 bar overpressure
- Preliminary mixing
- The different toner raw materials such as resin, pigments, and additives, etc. are mixed in high-speed mixers, e.g. Cyclomix.

The demands made on the mixers are many and varied:

- Easy to clean
- Double-walled mixing vessel to permit cooling if necessary
- Simple filling of the different raw materials into the mixer
- Mixer must be simple to completely empty after the mixing process
- High peripheral speeds of the mixing media for short mixing times and good blending
- Product-contact surfaces polished to Ra 0.8 µm for simple cleaning
- Pressure-shock-proof design to 10 bar overpressure
- Pole-reversible or frequency-regulated motor
- Wear-protected mixing media

Extrusion

A feeding unit feeds this premix continuously into the feed barrel of a compounder. The product is drawn in by the closely intermeshing co-rotating screws of the extruder, conveyed downstream and then compressed. Kneading elements in the plasticising zone serve to melt the product. During and after plastification, the individual components are dispersed, compounded and homogenised. The throughput rate depends on the product quality, the product feed behaviour and the drive power of the extruder.

Cooling

The product is cooled in a cooling unit and then coarsely crushed before being ground.

Preliminary grinding

The machines used for the preliminary crushing step are selected as a function of the toner quality, i.e. whether the toner is tough and resilient, brittle, or has abrasive properties.

Hosokawa Alpine fine impact mill type 315 UPZ

- For abrasive toner which is difficult to grind
- Minimum fine dust generation
- Pneumatic product feed and discharge
- Design: pressure-shock-proof to 10 bar overpressure
- Tangential material discharge
- Grinding media: swing beater unit with short grinding track and 2-mm sieve insert

- Reduced-speed mode
- Drive motor: 7.5 kW
- Throughput range: 100-300 kg/h

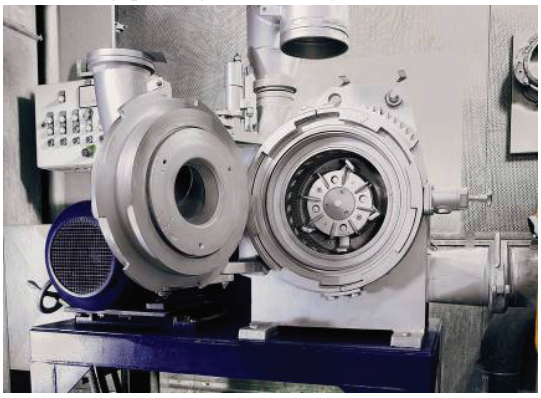

Figure 2 *Alpine impact mill type 315 UPZ*

Hosokawa Alpine granulator type 28/40 Rotoplex

- For toner which is tough and resilient but not abrasive
- Extremely small fines portion due to the particularly gentle size reduction method
- Special designs available for direct transfer of material from the cooling conveyor which permit a compact system set-up
- Design: not pressure-shock-proof
- Grinding media: cross-scissor-cut rotor and 2-mm screen
- Reduced-speed mode
- Drive motor: 7.5 kW
- Throughput range: 100-300 kg/h

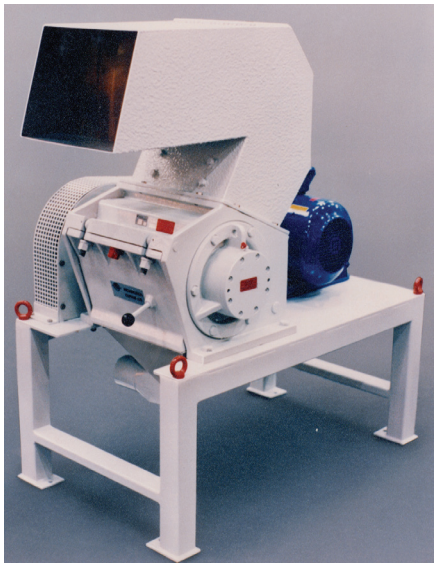

Figure 3 *Alpine granulator type 28/40 Rotoplex*

Hosokawa Bepex sieving mill type FC

- Low-speed grinding system for types of toner which are easy to grind
- Pressure-shock-proof design not necessary
- Extremely small fines portion
- No additional venting via cyclone or filter necessary
- Compact design
- Simple integration into process sequence
- Design: not pressure-shock-proof
- Grinding media: rotor with sieve grate and 2-mm sieve
- Drive motor: 2.2 kW
- Throughput range: 100-300 kg/h

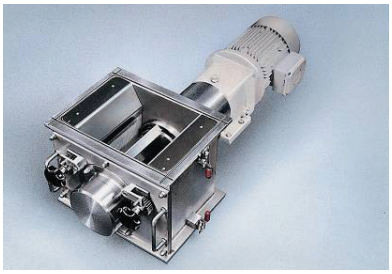

Figure 4 *Sieving mill type FC*

Fine Grinding

Toner Fluidised Bed opposed jet mill TFG

Systematic refinement of the Alpine jet milling technology led to development of the TFG opposed jet mill. The TFG jet mill was designed especially for fine grinding toner. A steep particle size distribution with clean-cut top size particles and a low fines portion characterize the TFG. The special advantages of this new mill generation are the ease of handling, the accessibility and easy cleaning. System users are enthusiastic about the high degree of flexibility of the TFG, especially when colored toners are being processed and the color needs to be changed frequently. The typical feed size of the raw material – normally preground chips from the extruder – is approx. < 1–2 mm. The TFG can be fed either by gravity or pneumatically.

Figure 5 *Toner fluidised bed opposed jet mill type 800 TFG*

More features of the TFG

- No need to reset the gap when changing the classifying wheel
- Minimum downtime, easy opening with hydraulic opening mechanism
- The central screw makes it easy to exchange the inside components
- Simplified handling and maintenance
- Filling level control by means of load cells thus optimum throughput rate and constant product quality
- End product free from spatter grain
- Low-wear grinding
- Low energy consumption compared with other jet mills
- Alpine Mega-Jet nozzles for cost-effective operation

Figure 6 *TFG completely open*

TFG Toner Fluidised Bed Opposed Jet Mill

Type		**400**	**500**	**630**	**800**	**1000**
Scale-up factor	f	1.0	1,6	2.5	4.0	6.4
Motor power	kW	7.5	11	18.5	30	45
Grinding air	Nm³/h	1130	1800	2860	4540	7200

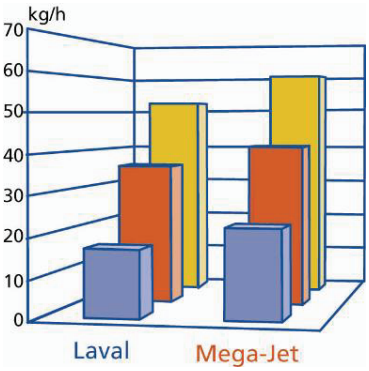

Figure 7 *Comparison of nozzles*
(blue) = Difficult to grind
(red) = Limited grindability
(yellow) = Easy to grind

Use of the patented Mega-Jet nozzles results in a greater jet surface and allows a higher feed rate, meaning that up to 20% higher throughput rates are possible at simultaneously drastically reduced specific energy consumption rates.

Machine design options

- Systems in pressure-shock-proof design to 10 bar overpressure
- Mild steel
- Stainless steel
- To order, surfaces polished to Ra=0.8 µm
- Product feed either by gravity or pneumatic
- Mega-Jet or Laval nozzles, dependent on the grindability of the toner
- Wear-protected (hard-metal-coated) classifying wheel

Classifying

In order to meet the rising market demands, Alpine has systematically refined its classifying technology and the result is the Alpine Tandem Toner Classifier TTSP that puts a completely new slant on classifying technology. The design of the TTSP classifier differs from conventional classifier types in the following points:

- Two-stage classification in one machine
- Product feed option: either pneumatic or by gravity
- Separate classifying stages with independent drives
- Hydraulic opening mechanism permits easy opening and machine cleaning, thus
- minimum downtime when changing over to a different colour
- Good accessibility and quick classifying wheel change
- Compact design
- Conversion to one-stage classifying if demanded by the application
- High coarse material yield
- Excellent product quality brought about by steep particle size distribution and low portion of fines

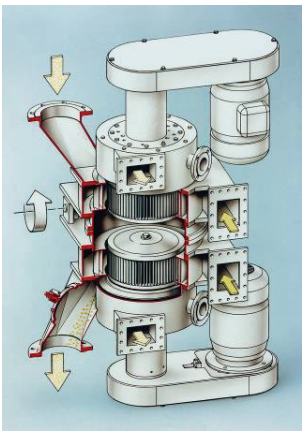

Figure 8 *Principle of operation tandem toner classifier TTSP*

- Low pressure drop, thus use of conventional fans possible
- High feed rates, thus small units possible
- Finer separations possible compared with conventional high-efficiency classifiers

- Low energy requirement, thus possible to process toner, e.g. coloured toner, with a low melting point
- Fine/coarse classification, thus three fractions in one process step, or fine/fine classification, thus extremely low fines portion in coarse material

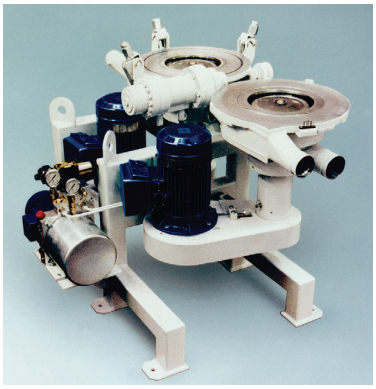

Figure 9 *simple to clean 200 TTSP open*

TTSP Classifier Type	**200**	**250**	**315**	**400**	**500**
Scale-up factor f	0.4	0.6	1	1.6	2.5
Motor power 2 x kW	3	5.5	7.5	11	18.5
Air flow rate Nm³/h	1120	1800	2800	4600	7200
Feed rate kg/h	170	270	420	690	1080

Design Variants TTSP / TSP

- Pressure-shock-proof design to 10 bar overpressure
- Mild steel
- Stainless steel
- Small classifiers in monobloc design
- To order, product-contact surfaces polished to Ra 0.8 µm
- Wear-protected (hard-metal-coated) classifying wheel

For simple problem specifications we recommend the TSP toner classifier with one classifying stage and one drive. The above-mentioned advantages regarding handling and cleaning also apply in essence to the TSP classifiers.

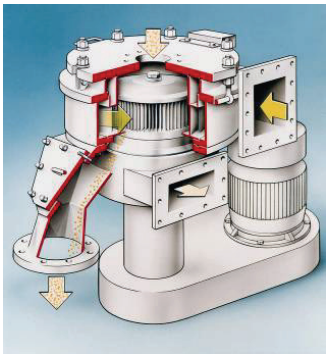

Figure 10 P*rinciple of operation of the toner classifier TSP*

Comparison Tandem Toner Classifier TTSP and Toner Classifier TSP: Steeper particle size distribution and less fines in the end product.

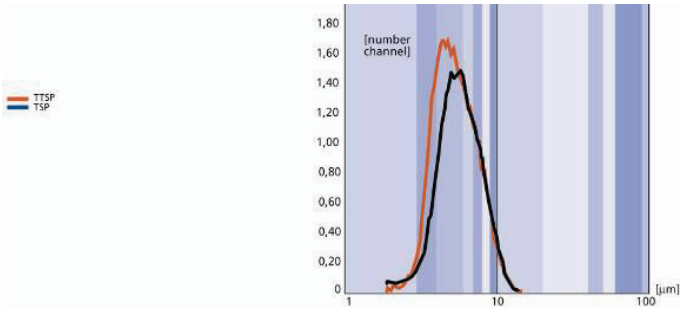

Figure 11 *Comparison TTSP and TSP*

TSP Classifier Type	**200**	**250**	**315**	**400**	**500**
Scale-up factor f	0.4	0.6	1	1.6	2.5
Motor power kW	3	5.5	7.5	11	18.5
Air flow rate Nm3/h	560	900	1400	2300	3600
Feed rate kg/h	60	90	140	230	360

Mixing, Blending, Safety Screening

Together with our sister company Hosokawa Micron BV, we supply mixing solutions which are convincing both in terms of technology and economy.

The mixer is fed via special weigh-belt feeders. Generally speaking, there are three feed units, one for toner and one each for the additives. The metering precision – especially of the additives – sets extremely high demands because it is usually only a few grams which need to be added. In the mixer, the toner particles are coated with the additives according to a fixed sequence in order to achieve the desired properties. The most important criteria here are the mixer size, the design of the mixing elements, the speed, the mixing time, and the batch temperature.

The Cyclomix high-intensity mixer

The new Cyclomix is a high-intensity mixer that combines shearing action with the proven advantages of an impact mixer. It has been designed specifically for post-additive blending in toner systems. Its conical design in combination with paddles rotating at high speed creates intense shear forces and rapid homogenisation.

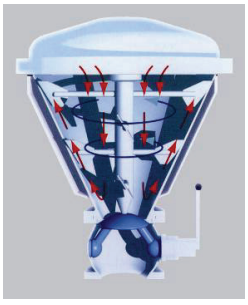

Figure 12 *Working principle of the Cyclomix*

The shear force is ideal for evenly distributing charge control agents and silica onto the toner particle. The entire vessel is jacketed so heating or cooling can be precisely controlled right at the heat transfer area. Discharging the finished product is simple thanks to the mixer's conical shape. Product change with the Cyclomix is made easy by virtue of its extremely accessible design. Quick-release clamps are located on both the cover and discharge valve. Once the clamps are removed, the entire cover with rotor can be lifted hydraulically at the push of a button.

Flexibility

The Cyclomix can be supplied with high polishing qualities such as 220 grit and electropolished for even easier cleaning. The cover as seen on the 50 L Cyclomix lifts upwards to open. For larger sizes, the cover can be mounted at floor level and the vessel lowered onto it hydraulically.

Cyclomix model	**1**	**5**	**50**	**150**	**250**	**500**	**1000**	**2000**
Motor power kW	1.1	3	15	22	37	55	110	160
		-5.5	-30	-55	-75	-110	-220	-310
Product volume (l)	0.3	1.5	15	45	75	150	300	600
	-1	-5	-50	-150	-250	-500	-1000	-2000

Key features

- 1-litre laboratory mixer to 2000-litres production mixer
- Exceptional heating and cooling capabilities
- Perfect discharge of material
- Hydraulic opening mechanism
- Bearings in top cover have no contact with the product
- High-shear rotor with the added knife blade option for impact action

The product is filled from the top into the conical mixing vessel and the main motor drives the high-speed rotor. The shaft is equipped with blade-shaped mixing elements which rotate close to the inside vessel wall. Due to this and the conical design, the bulk material is transported from bottom to top. In the upper zone there is an inwards and downwards movement which leads to quick macromixing. The moving blades accelerate the particles which are thoroughly mixed through friction at the tank wall (micromixing).

Figure 13 *Cyclomix*

Safety Screening

Downstream of the mixer, the finished toner is fed to a protective screening machine such as the TSM screen with ultrasonic cleaning device. This ensures that the toner which comes onto the market is free from any lumps which could possibly form during the pneumatic transport. To ensure a high degree of quality at simultaneously high screening efficiency even with the finest mesh widths, the TSM screening machines are equipped with an ultrasonic system. By introducing a high-frequency vibration into the screen fabric, friction and adhesion forces in the product mat are overcome, thus resulting in trouble-free screening. Sound propagation across the entire screen surface ensures that no product remains to clog the screen fabric, even with extremely large-surface screens.

Figure 14 *TSM Screen*

Process control systems

Thanks to the advances made in the field of electronics, it has been possible to continuously refine the complex control units supplied for the toner systems. Today, we predominantly use switch cabinets and control systems with visualisation options. Process steps, flowcharts and actual values are displayed clearly on PLCs, and the operating status can be monitored and retrieved at any time. All error messages are registered and can also be printed out at any time.

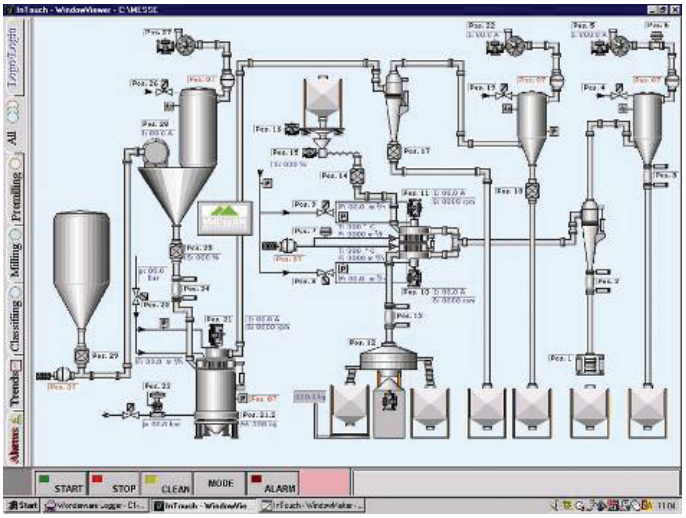

Figure 15 *Process Visualisation*

The latest trends in toner processing

As an option to toner manufactured in the conventional way, the latest trend is towards toner made chemically by means of polymerisation. This results in the following process and quality advantages:

- Finer and more closely defined particle size distributions
- Improved homogeneity
- Manufacture of functional particles possible
- Improved colour characteristics and transparency
- Controlled particle shape

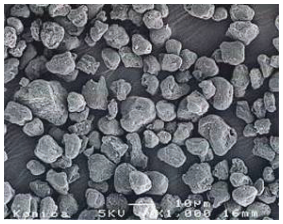

Figure 16 *Conventional toner*

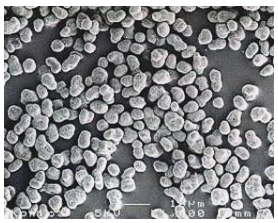

Figure 17 *Polymerised toner*

We at Hosokawa are also well-equipped to meet this new challenge. On the one hand, we use the vacuum dryer to gently dry the suspension, and on the other hand, the TTSP Tandem Toner Classifier is capable of manufacturing three fractions in one single process step, i.e. both the top-size particles and the superfine portion can be classified simultaneously.

Mixing

The Cyclomix is ideal for the blending process required here.

Drying

Chemically produced toner has to be dried after the polymerisation step. A considerable amount of water can be pressed out of the product by means of mechanical dewatering, however, a second step should be used to remove the last traces of moisture. The Vrieco Nauta Vacuum Dryer is the ideal solution for this step. Heat is transferred into the product essentially through a jacketed vessel wall which causes moisture to evaporate. A rotating screw orbits along the vessel wall and helps the vapour to escape to the surface, providing at the same time a frequent exchange of particles in contact with the heated surface. A vacuum system keeps the vessel under constant vacuum and removes the vapour from the vessel, having separated the dust particles from the vapour first in a dust filter on top of the vessel. The vacuum conditions within the vessel reduce the saturated vapour pressure of the moisture and this makes drying at much lower temperatures possible.

Hosokawa Vacuum Dryers are built as totally enclosed systems and when operated under full vacuum, offer the following features:

- Low energy consumption
- Gentle to the product
- Good heat transfer rates
- Fast drying times

The dryers range from 5 litres capacity up to 12 m3 and larger models are available on request.

Figure 18 *Vrieco Nauta vacuum dryer*

Application testing centre

In most cases, the design of a toner system is based on tests. Although such tests are extremely complex and time-consuming, and furthermore demand a wide range of available plant and machinery, it is the only way to guarantee an optimum machine combination. Skilled and highly qualified engineers with years of experience carry out these tests at Hosokawa. Once the test series is complete, our customers can be assured that the right machine combination has been found.

Figure 22 *Toner classifying system 200 TTSP in the Alpine testing centre*

Our testing centres are equipped with a wide range of grinding and classifying systems, not only production-size systems, but also laboratory and pilot plants. Annexed to the testing centre is a highly modern laboratory equipped with exactly the same kind of

measuring and analysis equipment which the customer will use later for purposes of quality assurance. To ensure accurate baseline data, the test systems must always be state of the art, which is why we constantly renew and add newly developed machines to our stock of machines and equipment. One of the newer machines is the 200 TTSP classifying system shown in the figure, which has been available for classifying trials since early 2001. The test system is characterised by a high degree of flexibility, this especially with regard to the gravity feed unit and the entire control and measuring technology needed to set the required operating parameters. All the operating data of this system can be recorded so that the test results can be documented in their entirety.

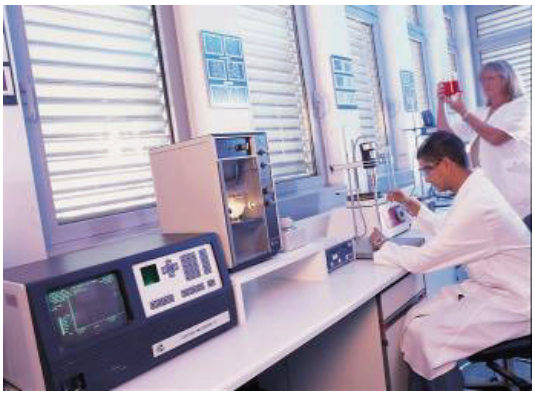

Figure 20 *Alpine laboratory with Coulter counter multisizer*

Figure 21 *Alpine laboratory with the Alpine air jet sieve 200 LS-N*