Advanced
Cyclone
Systems

Food, Chemical &
Pharmaceutical
Powder Recovery

Hurricane & ReCyclone® Systems

Advanced Cyclone Systems (ACS)

Towards total particle capture with optimized cyclone systems

ACS is a company exclusively dedicated to the development and supply of the most efficient cyclone systems in the world.

ACS Focus

We focus on **particulate matter (PM) emission control (EC)** in boilers, furnaces and dryers.
We also work on enhancing **powder recovery (PR)** in pharmaceutical, food and chemical processes.

ACS Mission

Achieving particle capture **exclusively with cyclones** by continuously researching and innovating, freeing the client from the costs and problems of **Electrostatic Precipitators (ESPs), Bag filters (BFs) and Wet Scrubbers (WS)**.

ACS Approach

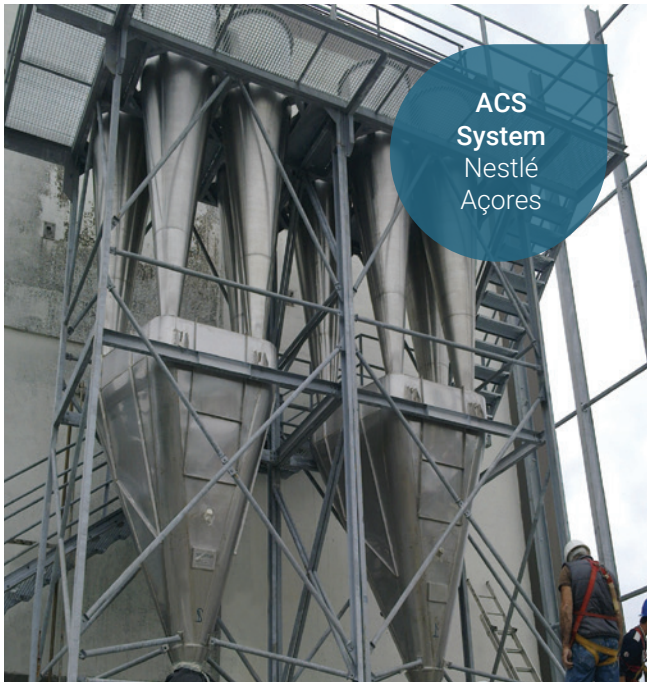
We work in close cooperation with our clients, designing customized cyclones that solve their filtration problems. Unlike most cyclone providers, we give **strict guarantees of emissions and efficiency**.

ACS has been the chosen company for over 400 projects in 37 countries worldwide.

About ACS Cyclones

ACS cyclone systems contradict the general thinking that cyclones are inefficient powder collectors.

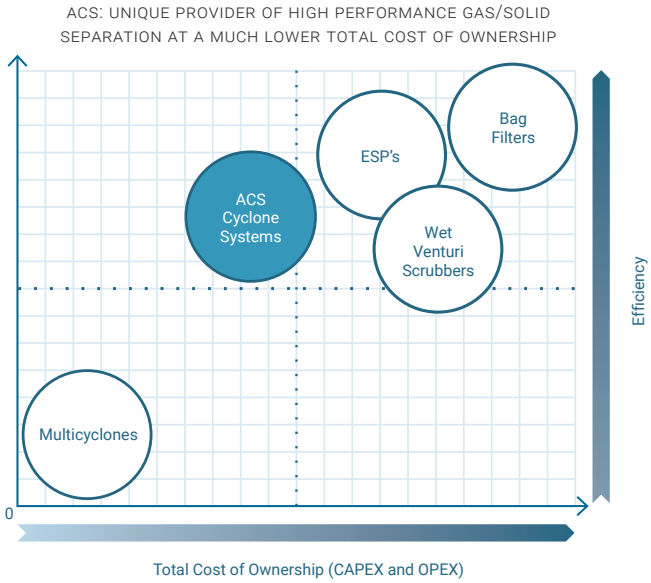
Hurricane cyclone geometries, with the possibility of recirculation (**ReCyclone Systems**) have proven to be an alternative to ESPs and BFs in numerous plants all over the world to comply with strict limits, reaching emissions as low as 30mg/Nm^3.



Why are our cyclones better?

We have a **specialized scientific knowledge** in particle agglomeration modeling (PACyc) and numerical optimization in partnership with the Engineering Faculty of Porto (FEUP) where we run one of our pilot systems for R&D.

The revolutionary concept of **particle agglomeration** is essential to explain how cyclones really work and, consequently, to optimise them. The outcome of our research is not universal solution, but a set of very different cyclone families and systems serving particular client needs and customizable for each given application.



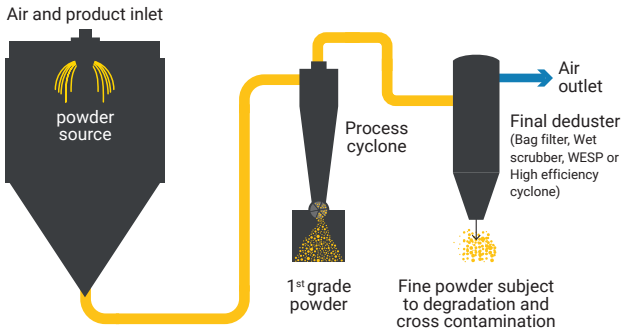
The problem with Powder Collection & Emission Control

More efficient cyclones can play an important role after drying, milling and micronization processes

Application Fields

- Food ingredients
- Pharmaceutical ingredients
- Chemicals
- Fertilizers
- Mineral processing
- Nanoparticles
- Milling & drying processes
- General dedusting & recovery

In multiple industries, products are manufactured in the powder form in sources such as dryers, mixers, or mills. Examples go from **dairy powders** to **pharmaceuticals** and from **fertilizers** to **nanoparticles**. The separation of these products from the air is unavoidable. Multiple industrial filtration systems can be used for that purpose.



Generally, a **process cyclone** serves the purpose of separating the main fraction of **1st grade powder** and a **final deduster** avoids the fines to escape to the atmosphere. Depending on how sensitive the powder is and on the process characteristics (e.g. product rotation), fines may or not be considered as waste due to the limitations of the final deduster.

Main dedusters and drawbacks

Process Cyclones | Problem: **Low Efficiency**

Easily handle a wide range of operating temperature, pressure and moisture conditions. By its simple and aseptic design, without any moving parts, cyclones have low maintenance costs and can be effectively cleaned, minimizing bacteria contamination or product cross contamination. Main drawback: low efficiency for small particles (< 10µm), powder losses and non-compliance with emission limits.

Bag & Ceramic Filters | Problem: **Cleaning**

BFs are very efficient barrier filters, but the true collection efficiency is frequently lower, due to the difficulty in cleaning filter elements, whenever there is product rotation. Indeed, even BFs with Clean in Place (CIP) technology do not avoid some product retention, which can contaminate the next product in the line. Also, for very sensitive food ingredients, BFs cannot be used as product collectors due to contamination with filter fibers. BFs are often used as final dedusters, though with some OPEX drawbacks (e.g. clogging of filter elements in drying applications).

Wet Venturi Scubbers and WESPs | Problem: **Cannot be used for powder recovery**

Wet based particulate traps are also very efficient and are generally used only for emissions control, overcoming the clogging problem of BFs. However, they give rise to secondary pollution and are also a source of bacteria.

ACS SOLUTION:

ACS cyclones can be designed both to increase product yield and emissions compliance.

About Hurricane Cyclones

ACS numerically optimized cyclones

hurricane

How can cyclones be improved?

Since the early 1900's cyclones have been mostly designed and improved by empirical means, due to the difficulty of building a good prediction method that handles the modeling complexity related with multiphase and highly turbulent flows. Computerized Flow Dynamics (CFD) can be used for partial cyclone optimization but it is still incomplete for full cyclone optimization, due to the very large computational burden associated with highly vorticial, assimetrical and multiphase flows with polidispersity. Sub-optimization of cyclones, and notably low collection efficiency result from **particle agglomeration in cyclones** having been disregarded until recently.

What is ACS solution?

Near 400 projects implemented in the past 12 years have helped ACS develop a complete line of very different **Hurricane cyclone** families, with each family responding to a particular need from the client and considering how inter-particle agglomeration / clustering affects collection efficiency. From coarse particle pre-separation achieved by compact and low pressure drop cyclones, such as the **SD and DX**, to fine particulate capture with high-end geometries such as the **EX and MK**, ACS provides solutions for a wide range of industrial cases, being able to reach emissions comparable to ESPs (down to less than 30mg/Nm^3).

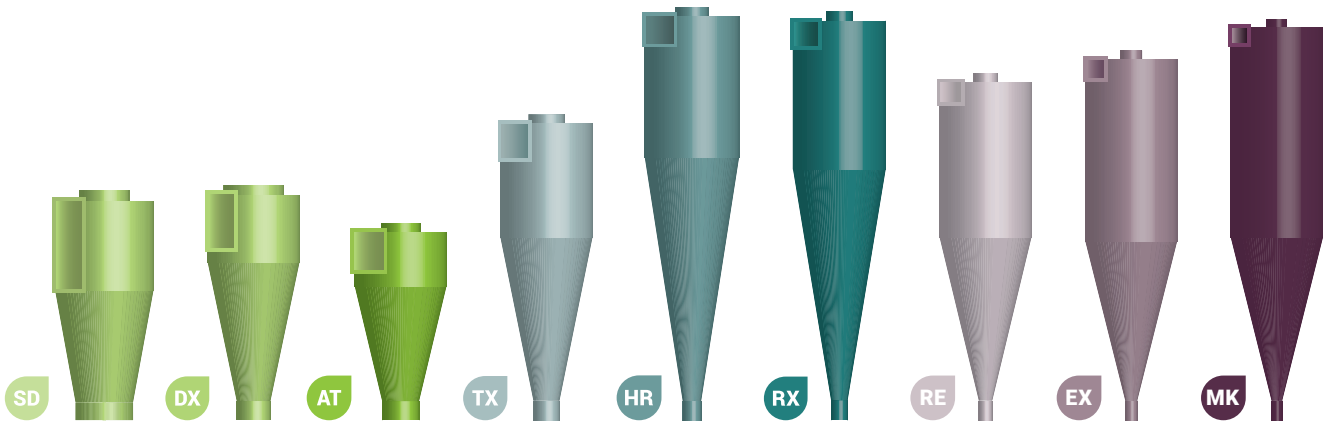
Particle agglomeration and numerical optimization

ACS research team has been investigating this phenomenon since its foundation. Several related technical and scientific articles were published, among which the **"Impact of particle agglomeration in cyclones" (Chemical Engineering Journal 162 (2010) 861–876)".** This knowledge has helped ACS build very accurate models of efficiency prediction, capable of explaining why sub-micrometer particles are often captured with much higher efficiency than expected. Indeed, particles tend to form bigger agglomerates (clusters) much easier to collect than the original particles. Agglomeration increases in the **presence of wide particle size distributions, long residence times in the cyclone and high inlet particle concentrations.** This knowledge has been incorporated in ACS numerical simulation tool, combining a sophisticated stochastic algorithm with a classical numerical model to predict cyclone performance: **the PACyc (Particle Agglomeration in Cyclones) model.**

Creating multiple cyclones for multiple needs

Thanks to the PACyc Model, and considering several economic and operation constraints (such as size and pressure loss), it is possible to **simulate millions of virtual prototypes** with numerical optimization within an affordable period. Considering this approach as the best path to obtain truly optimized cyclones, sound theories of cyclone collection and pressure loss were chosen for each process application. These numerical optimization problems have resulted in several families of cyclones, some of those patented. Indeed, different industrial cases have **different needs** for which the optimization functions to incorporate in the PACyc model may be as complex as **minimizing cost or space, subject to a minimum efficiency result**.

The following cyclone families, always subject to further customization, are the result of very different client demands ACS has come across this far.



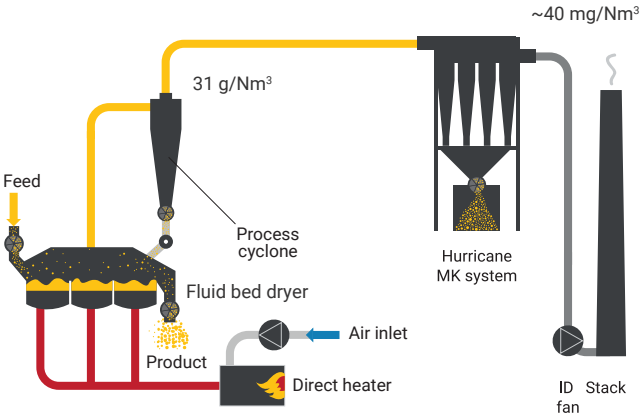
Alternative Cyclone Solutions

Real Case Analysis: Fluidized Bed Drying of Sulphanilic Acid

Designing cyclones to increase yield & reduce emissions:

Processing industries are facing both an environmental and a plant efficiency challenge. For some clients ACS has come across, such as **Bondalti** in Portugal, high efficiency MK type cyclones were placed downstream of the process cyclones of the fluid bed dryer (see figure) in order to reduce emissions of sulphanilic acid under 40mg/Nm³. That's a near **99.9% efficiency** for particles escaping other cyclones! Other cyclone families could be used, producing different results, as seen below. The **more efficient** the solution is, the **larger the number** of specific cyclones are needed to increase residence time and promote particle agglomeration. ACS will always search for the most cost-efficient solution for each given case. Please check the performance of the several families below.

System layout and operating conditions



Global Efficiency (%):

MK	99.93
EX	99.89
RE	99.85
RX	99.75
HR	99.64
TX	99.62

Emissions (mg/Nm³):

MK	22
EX	34
RE	46
RX	80
HR	112
TX	119

Strict PM Emissions Compliance

Moderatly strict PM Emissions Compliance

Cyclones needed (ø800mm):

MK ||||||||||

EX |||||

RE

RX |||

HR ||

TX |

Objectives / Applications:

MK	The agglomerator cyclone – Maximum agglomeration Most efficient cyclones available on the market.
EX	Ultra high efficiency with agglomeration to compete with WESPs.
RE	Very high efficiency cyclones for process and end-stage applications. Emissions can be cut by ~75% when compared with other cyclones.
RX	Very high efficiency cyclones for process and end-stage applications.
HR	High efficiency cyclones for process and end-stage applications. Emissions can be cut by >50% when compared with other cyclones.
TX	Compact process cyclones to increase powder yield.

ACS has a variety of very different high efficiency cyclones which can not only increase the collection of powder but also comply with strict emission limits.

ReCyclone Systems®

Mechanical and Electrostatic Recirculation

ReCyclone® System

ReCyclone® (MH and EH)

A ReCyclone is made up of a high efficiency **Hurricane** cyclone and a **particle separator** placed downstream, called the **"recirculator"** (please see figure) and which can be either purely mechanical or electrostatic.

The main purpose of the recirculators is to reintroduce the uncaptured particles into the cyclones after they have been driven to the outer walls of the recirculators by centrifugal and/or electrostatic forces. While this gas is enriched in particles, the axial gas stream exhaust to the stack is clean. Recirculation is achieved by an additional fan.

Since the recirculation system only serves the purpose of dust separation (and not collection), the particles are exclusively collected in the cyclones and the need of rapping mechanisms is avoided. ReCyclone systems are arranged in groups of cyclones and recirculators.

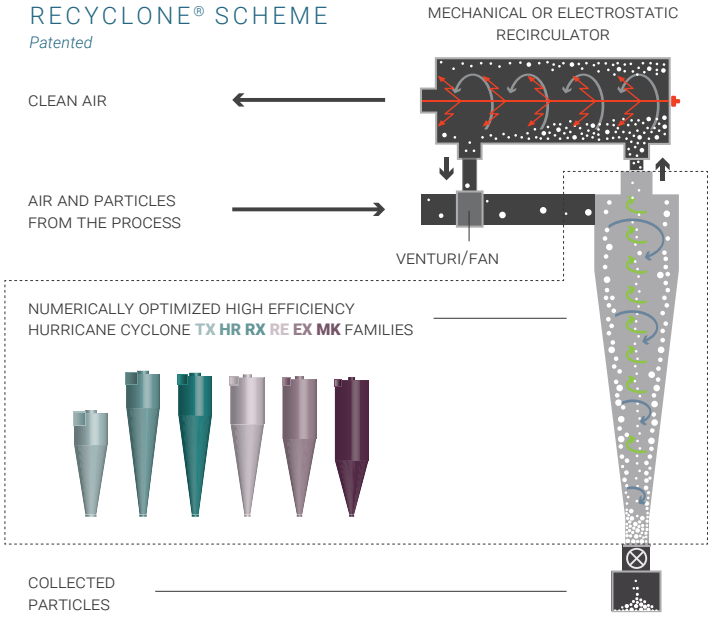
Efficiency increase

Efficiency increases due to recirculation and agglomeration of very small particles with larger ones coming directly from the process. A **ReCyclone** decreases emissions of Hurricane cyclones alone by 30 to 80%. Controlling recirculation also has the benefit of handling **variable flowrates** better than with cyclones alone.

A ReCyclone® enhances the efficiency of any given cyclone family decreasing its emissions by 30 to 80%

RECYCLONE® SCHEME

Patented



RECYCLONE® FEATURES

- Very high efficiencies: decreases emissions of any ACS Cyclones by [30-80]%
- Very low powder emissions: [10-45]mg/Nm³ is achievable for many powder sources
- Pressure drop: [150-220] mm w. g.
- Up to 350°C
- Recirculation ensures a reasonable velocity in the cyclones
- Robust construction with no moving parts (no rapping mechanisms)
- Low maintenance and downtime costs
- Low investment costs

APPLICATION	EFFECTIVE FLOW RATE (m^3/h)	TEMP. (°C)	MEDIAN PARTICLE SIZE (µm)	CYCLONES DIAMETER (mm)	PRESSURE DROP (mm w. g.)	INLET CONCENTRATION (g/Nm^3)	EFFICIENCY (%)	EMISSIONS (mg/Nm^3)
Mechanical HR | Drying Organic fertilizer	100 - 800	40	13-17	1050	190	7.08	>97	<100
Mechanical HR | Sulphanilic Acid recovery	6 700 - 12 000	115	20	900	180	31.4	>99	<100
ReCyclone EH | ZnO Nanopaticle recovery	260	Amb.	0.6	230	180	30	>80	-
ReCyclone EH | Silicon Nanoparticles	62	100	0.025	80	10	26.7	>90	-

Technology Comparison

Hurricane® Cyclones | ReCyclone® MH | ReCyclone® EH | Other Technologies

Approach to any new project

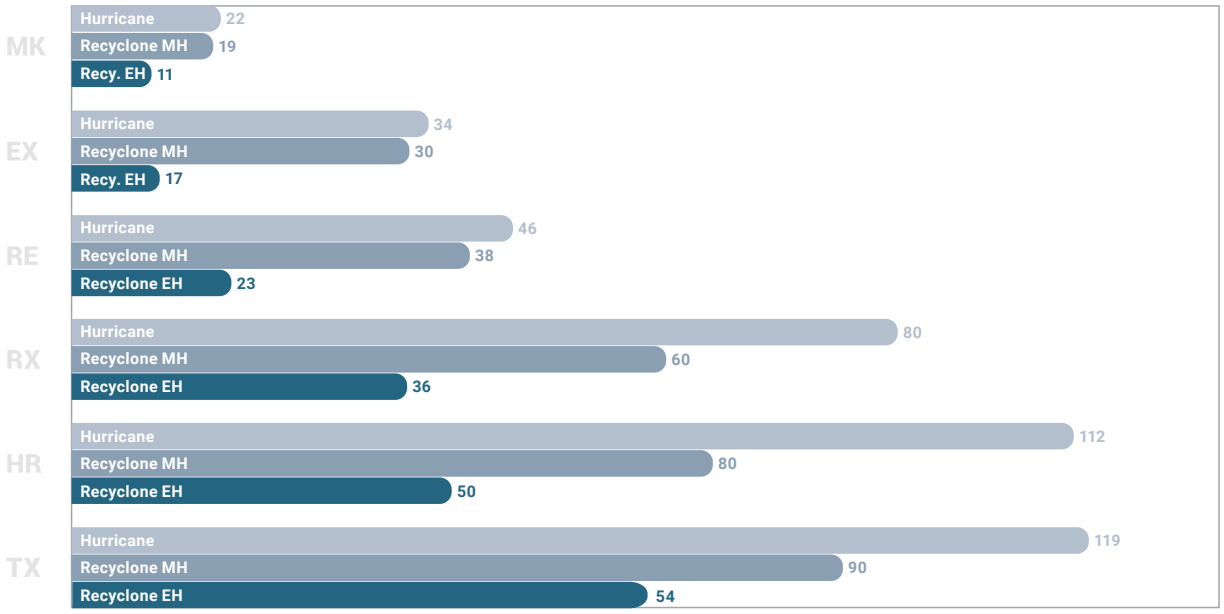
Whenever it is possible to achieve a requested emission limit or powder collection objective with a given optimized cyclone family, ACS will avoid recirculation in order to reduce investment and operating costs (mainly power consumption of fans) and to improve the system cleanability.

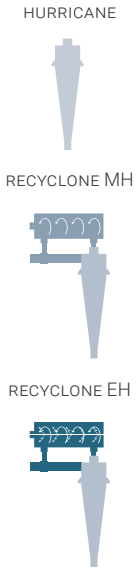
For the recovery of **very fine products**, such as **nanoparticles**, or when emissions need to be minimal, electrostatic recirculation may be mandatory.

Ultimately, any hurricane family can be coupled with mechanical or electrostatic recirculation to increase efficiency and comply with stricter emissions. For the shown industrial case in page 5, these are the residual emissions of each cyclone family coupled with mechanical or electrostatic recirculation. EX and MK cyclones are already so efficient that only electrostatic recirculation can further reduce emissions significantly.

Residual emissions comparison between ACS products - Operating conditions in page 5

RESIDUAL EMISSIONS COMPARISON BETWEEN ACS PRODUTCS





Residual emissions (mg/Nm³) at the stack from page 5. Example: Fluidized Bed Drying of Sulphanilic Acid

TECHNOLOGY COMPARISON BETWEEN ACS AND OTHER PRODUCTS

Comparison of fine powder secondary collectors (placed after process cyclones in a fluid bed dryer)	Wet Venturi Scrubbers	"CIPable" Bag Filter	Competitor Hight Efficiency Cyclone	Hurricane cyclones: TX, HR, RX, RE, EX, MK	ReCyclone® MH systems	ReCyclone® EH systems	
Efficiency (%)	>99.85	99.98+	<99.5	99.62 to 99.93	99.1 to 99.94	99.83 to 99.97	Maximize Efficiency & Reduce Emissions
Emissions: (depending on system configuration)	<50	<10	>150	22 to 119	19 to 90	11 to 54	
Quality of separated product	Waste	Second grade	First grade	First grade	First grade	Waste, if organic	Improve Powder Quality
Contamination risk (sanitary conditions)	Very high	Considerable	Minimal	Minimal	Minimal	Minimal	
Cleaning perfection with CIP	Bad	Reasonable	Very Good	Very Good	Good	Good	
Investment costs	Low	Very high	Low	Low / Reasonable	Reasonable	High	Minimize Total Cost of Ownership
Maintenance and operating costs	High	High	Low	Low	Low	Low	

Performance of different equipments for the recovery of Sulphanilic Acid
Median Particle Size in Volume (MVD) = 27µm | Inlet concentration: 31 567mg/Nm³

Case Studies for Food Ingredients

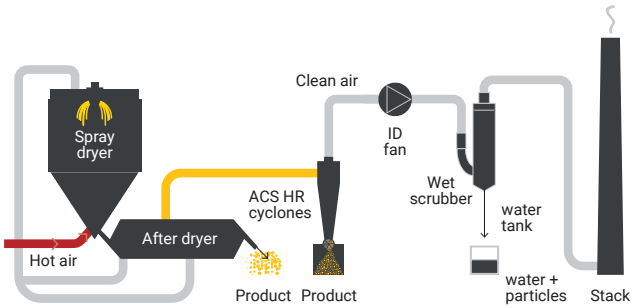
The need to separate powder based Food Ingredients occurs in many industries, from the **dairy** to **chocolate making** and from **beverages** to **starches and yeasts. Spray Drying** is commonly used to design and produce a variety of powders, many of those quite valuable and sensitive, such as Demineralized Whey or Whey Protein Concentrate. Frequently, Bag Filters are excluded to be used as powder collectors due to potential contamination with filter fibers, cross contamination or heat degradation. ACS cyclones are therefore a very good alternative both as process cyclones and as end stage collectors to control emissions. Other examples of applications include separation after **pneumatic transport, micronization and classification.**

Hurricane HR cyclones to reduce caseinate escaping spray drying process cyclones

Arla Foods is a global dairy company.

Problem and solution existing cyclones installed on the MSD Spray Dryer provided 96.9% capture efficiency (emissions of about 500mg/Nm³). The remaining product (emissions from existing cyclones) was being lost, captured in a wet scrubber installed downstream.

Separation efficiency could be increased with two new numerically optimized **HR** cyclones to replace existing ones. The improved separation efficiency of ~99,0%, a reduction in 70% of product losses, resulted in considerable savings for the company. The success verified in this installation led to another supply of 2 Hurricane Cyclones for another spray dryer.



Resumed Design Conditions:

Powder	milk proteins
Median particle size	15µm
Inlet powder concentration	15g/Nm³
Temperature	65°C
Effective flow rate	92 140m³/h

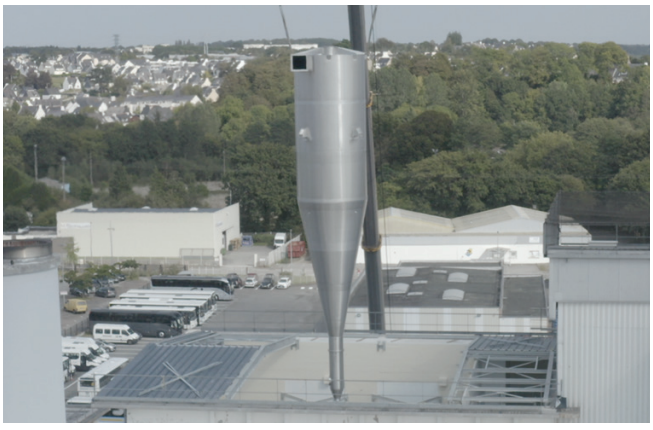
Output/Performance:

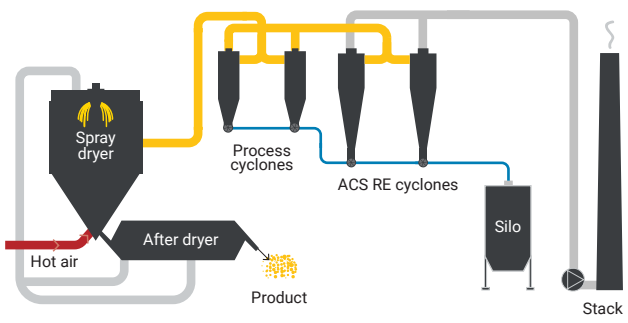
Efficiency	98.9 - 99.3%
Pressure drop	1.9kPa
ACS system	2HR2800

Hurricane RE cyclones to reduce whey powder escaping spray dryer process cyclones

Lactalis is a French multinational dairy products corporation.

Problem and solution existing cyclones installed after the Spray Dryer at the plant had whey powder emissions of near 1g/Nm³, representing both an environmental and an economical problem. To reduce emissions to near 50mg/Nm³, ACS designed two Hurricane **RE** type numerically optimized cyclones with a diameter of ø2900 mm. The cyclones were placed downstream of the existing cyclones, treating only the fine powder escaping the process cyclones.





Resumed Design Conditions:

Powder	whey
Median particle size	9µm
Inlet powder concentration	811mg/Nm³
Temperature	78°C
Effective flow rate	49 955m³/h

Output/Performance:

Efficiency	96.9%
Pressure drop	2.5kPa
ACS system	2RE2900

Case Studies for Active Pharmaceutical Ingredients

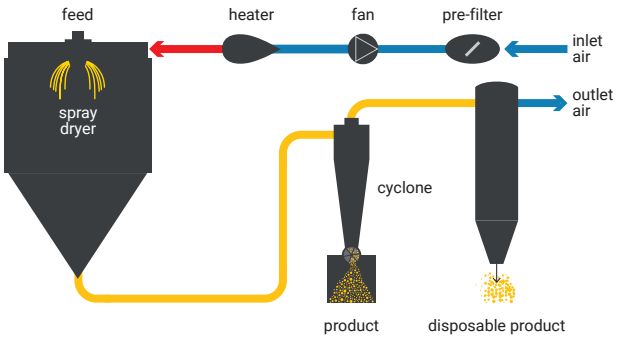
ACS has multiple references for the separation of Active Pharmaceutical Ingredients (APIs) and Final Product Formulations (FPFs). These typically occur in **Spray Drying** arrangements where the cyclones are the exclusive powder collectors. Indeed, potential contamination with filter fibers and heat degradation precludes other filters, which results in important economical losses if cyclone efficiency is low. Other examples of applications include **micronization**, **cryogrinding** and the separation of powders after **tablet pressing machines**.

Hurricane HR to increase the yield of inhalable API capture after a pharma spray dryer

Hovione is a Portuguese multinational pharmaceutical company.

Problem and solution Active Pharmaceutical Ingredients are designed to penetrate the lungs and thereby are extremely fine, with a median particle size near 1 micron (1.6 µm).

To meet Hovione's requirements, considering a design flow rate of 82 kg/h, a median particle size of 1.6µm and a true particle density of 1.61g/ml, ACS designed and supplied a high efficiency Hurricane HR cyclone with ø130mm. Powder losses were reduced to one fourth of what was achieved by the previous cyclone.



Resumed Design Conditions:

Powder	inhalable API
Median particle size	1.6µm
Temperature	70°C
Effective flow rate	112kg/h

Output/Performance:

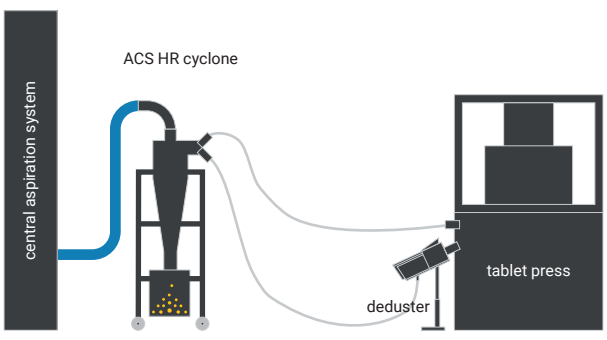
Efficiency	78.3–83.1%
Pressure drop	1.9kPa
ACS system	1HR130

Hurricane HR to capture pharmaceutical waste particles (deduster & tablet press machine)

Teva is the leading generics company in North America..

Problem and solution Having a cyclone system in each tablet press room allows Teva to isolate the waste powder of each equipment individually, making it possible to calculate the wasted product of each machine. The system is comprised by a cyclone in AISI 316L, a catch pot in the same material with sight glass and a support structure with wheels for smooth mobility. All pieces are attached with quick clamps for easy assembly.

ACS originally provided an HR275 system and went on to supply Teva with 7 similar ones and another 3 larger HR400 systems for the same purpose.



Resumed Design Conditions:

Powder	waste particles from a pharma tablet press and a deduster
Median particle size	180µm
Temperature	ambient
Effective flow rate	45m³/h

Output/Performance:

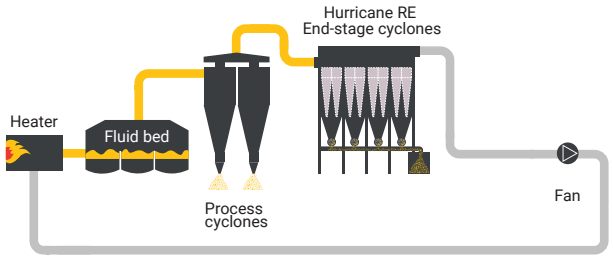
Efficiency	>98%
Pressure drop	1.8kPa
ACS system	1HR275

Case Studies for Chemical Powders

Similarly to food and pharma, chemical powders are often obtained through drying processes. These include **potash** and other compounds for **fertilizers**, **medical application chemicals**, various **inorganic compounds**, such as **lithium hydroxide,** and many other powder based substances including **tungsten carbides** and **zync oxides**. In addition to **Spray Dryers, Fluid Bed Dryers** are also often used to dry chemical powders where process cyclones return the powder to the fluid bed and additional high efficiency cyclones are used to control emissions.

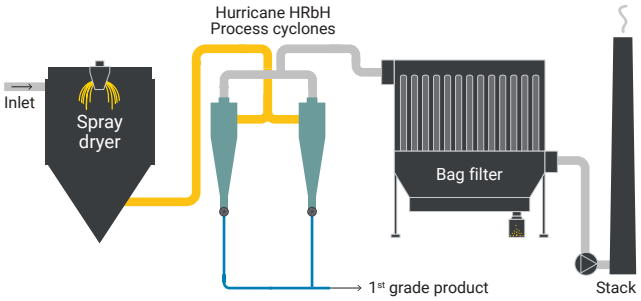
Hurricane RE cyclones to increase the collection of potash fines escaping the process cyclones in the re-circulation line, reducing fouling of the fluid bed and operational costs.

System: 32RE1000
Actual flow rate: 55 313m³/h
Temperature: 155°C
Expected efficiency: 92.9%
Country: Canada
Client: **Nutrien**



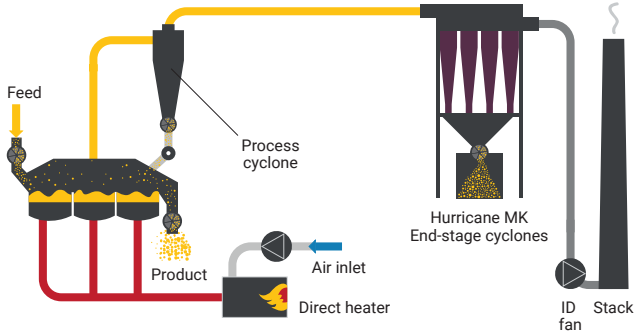
Hurricane HRbH high efficiency process cyclones with alumina tile to maximize the recovery of lithium hydroxide particles after a Spray Dryer.

System: 2HRbH2100
Actual flow rate: 51 000m³/h
Temperature: 140°C
Expected efficiency: 99.6%
Country: Poland
Client: **NTE Process**



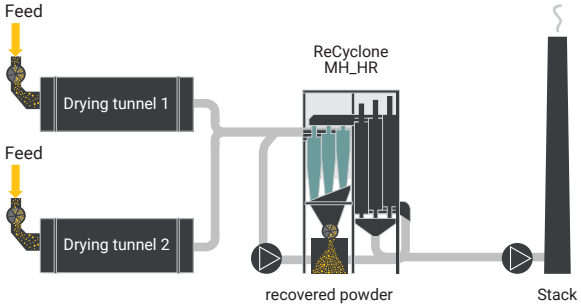
Hurricane MK cyclones to increase the collection of sulphanilic acid fines escaping the process cyclone after a fluidized bed dryer to meet emissions of ~50 mg/Nm³.

System: 6MK900
Actual flow rate: 14 000m³/h
Temperature: 115°C
Expected efficiency: 99.93%
Country: Portugal
Client: **Bondalti**



ReCyclone® MH convertible to a ReCyclone® EH for fertilizer dust emission control under 50mg/Nm³ after a double tunnel dryer.

System: 32MHHR1050
Actual flow rate: 100 800m³/h
Temperature: 40°C
Expected efficiency MH: 97%
Expected efficiency EH: 98.2%
Client: **Plateau**



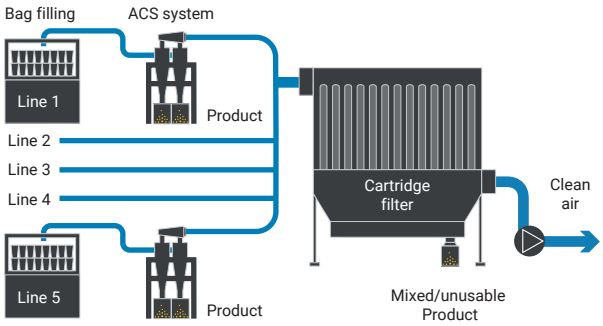
Case Studies for Air Capture, Dedusting & Recovery

The fact that cyclones are relatively simple separators, have no **moving parts** and can be **easily** and **effectively cleaned** makes them ideal devices to be used for general dedusting applications where there is a need to recover the powder. Whenever there are processes involving **coating, painting, cutting, filling** or **pressing**, powder is released and typically captured in a central filter where it is mixed with other powders from different sources or from the same source. Compact high efficiency cyclones placed upstream of this filter can dramatically enhance plant efficiency, increasing yield and reducing waste, towards a more socially and environmentally responsible behavior.

Hurricane AT Cyclones for juice powder recovery downstream of bag filling machines

Mondelez is a multinational food and beverage company.

Problem and solution The Tang plant in Curitiba, Brazil, has five bagging machines. During that process a small portion of the product escapes and resultes in losses of 600kg per day. ACS designed and supplied five Hurricane AT systems, each composed of two cyclones with ø530mm, a discharge hopper and a container. Cyclones were equipped with CIP nozzles for quick cleaning, as Mondelēz frequently changes the juice flavors and the system needs to be cleaned before the rotation. With this system, Mondelēz is now able to cut product losses by about 99% (from 600kg/day to 7kg/day).



Resumed Design Conditions:

Powder	soluble juice powder
Median particle size	150µm
Temperature	30°C
Effective flow rate	3 957m³/h

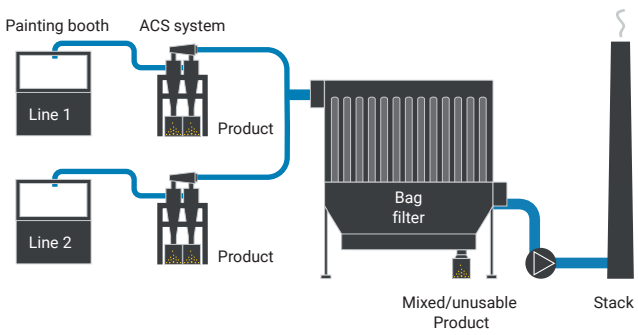
Output/Performance:

Efficiency	99%
Pressure drop	1.5kPa
ACS system	2AT530

Hurricane HR System for powder recovery

Thermolacage Vendee (TLV) is a company specialized in electrostatic powder coating.

Problem and solution TLV contacted ACS regarding its vertical line used for the painting/coating of 7m high aluminium sections. This powder coating line is equipped with 2 booths, for dark or white colour. With a daily consumption of around 800kg per booth, TLV was losing too much powder to the final bag filter, due to low efficiency of the existing cyclones. ACS designed optimized cyclones exceeding 97% separation efficiency to reduce losses in more than 65%.



Resumed Design Conditions:

Powder	powder coating
Median particle size	30µm
Temperature	31°C
Effective flow rate	20 745m³/h

Output/Performance:

Efficiency	97.1-97.6%
Absolute pressure	1.50 kPa
ACS system	2HR1400

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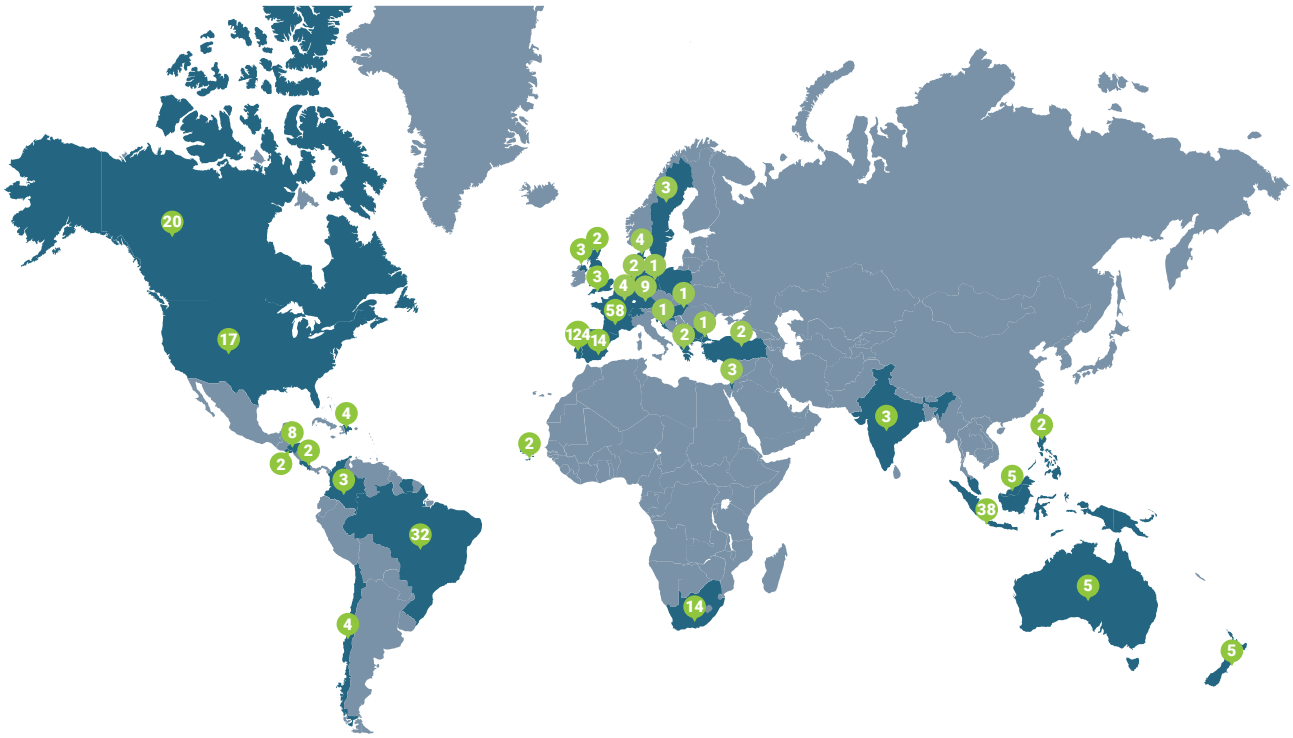
ACS around the world

Number of installations per country



North America

KMW
ANGUIL
TAFISA
resolute Forest Products
LSolé BIOMASS SOLUTIONS
AFS energy systems
OSPREY CORPORATION
Actavis
mannkind

South America

BREMER
com bio energias renováveis
BOZEL
VICAVI
agrosan
Florestal Doces emoções.
Colcafé
TECNO SULFUR
arauco

Europe

Nestlé
Valmet
John Cockerill
edp
HEIDELBERGCEMENT
AMORIM
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