Advanced
Cyclone
Systems

Particulate Matter
Emission Control
& Air Dedusting

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 worldwide.

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

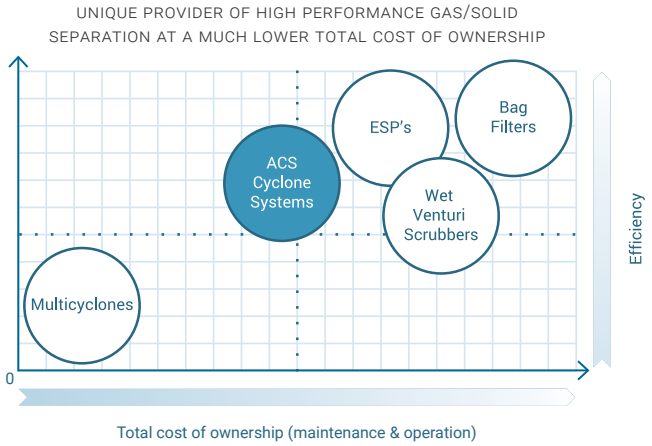
Achieving particle capture **exclusively with cyclones** by continuously researching and innovating, freeing the client from the costs and problems of **Electrostatic Precipitators (ESPs) and Bag filters (BF)**.

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**. That's why ACS has been the chosen company for over **170 projects in 34 countries** all over the world.

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 are a **specialized scientific knowledge** in particle agglomeration modeling (PACyc) and numerical optimization in partnership with the Engineering Faculty of Porto (FEUP) where we run a pilot system 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 an universal solution, but a set of very different cyclone families and systems serving particular client needs and customizable for each given application.

Particulate Matter Emission Control & Air Dedusting

A problem common to many industries

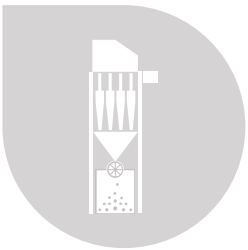
Application Fields

- Biomass and Coal Combustion
- Biomass Dryers
- Pyrolisis, Incineration and Gasification
- Fuel Oil Combustion
- Clinker Cooler and Pre Heater Dedusting
- Steel and Ferroalloys
- Calcination Processes
- Air Caption & Dedusting
- Glass & Ceramic Furnaces
- High Temperature Separation Processes for Energy Recovery

Particulate matter (PM) emission control is a common problem in industries that operate **boilers** or **incinerators** for **energy production**, or **furnaces**, **kilns** and **dryers** for the **manufacturing of products**, such as **ceramics**, **cement** or **pellets**.

Complying with stack emission limits, **avoiding the carry through of particles** to downstream processes or **purifying ambient air**, are the main motivations for clients to **reduce PM emissions**.

Main dedusters and drawbacks



Multicyclones | Problem: **Low Efficiency**

Industrial cyclones, such as multicyclones, are, in terms of their robust construction, absence of moving parts and general application, the preferred technology for particle collection in industrial boilers and furnaces.

Nevertheless, cyclones are no more an option to comply with emission limits in most countries, due to its relatively low efficiency, particularly for small particles (volume-based particule size <10µm).

Bag & Ceramic Filters | Problem: **O&M costs**

Bag Filters (BFs) are financially affordable and very efficient (> 99.9 %), but can be very maintenance demanding in the presence of high temperature due to frequent changing and cleaning of filter elements. Apart from these operational costs, filters are frequently attacked by glowing particles released from harsh combustion processes, such as in biomass boilers, which heavily increase emissions. The ceramic filter solution is more expensive and costly to operate. In drying applications, filter clogging is a frequent problem due to high moisture.

ESPs and WESPs | Problem: **High Investment**

ESPs are robust equipments and very effective for a given range of dust resistivity. However, efficiency frequently drops outside that range as a consequence of temperature changes. In applications with risk of explosion, such as drying of biomass, WESPs or Venturi Scrubbers are an alternative solution, though at the cost of secondary wet pollution. As with BFs, ESPs require to be operated by trained and specialized personel. Ultimately, ESPs' and WESPs present and future high investment costs are out of reach for many companies.

ACS Solution: Very high efficiency cyclones complying with strict emission guarantees

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 with 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 the fact that **particle agglomeration in cyclones** has been disregarded until present days.

What is ACS solution?

Near 200 projects implemented in the past 7 years, helped ACS develop a complete line of very different **hurricane cyclone** families for each different need, considering how inter-particle agglomeration / clustering affects collection efficiency. From coarse particle pre-separation proportioned by compact and low pressure drop cyclones, such as the **SD and DX lines**, 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 until now.

Alternative Cyclone Solutions – A Real Case Analysis: Biomass Boiler Dedusting

Designing a cyclone solution for PM reduction:

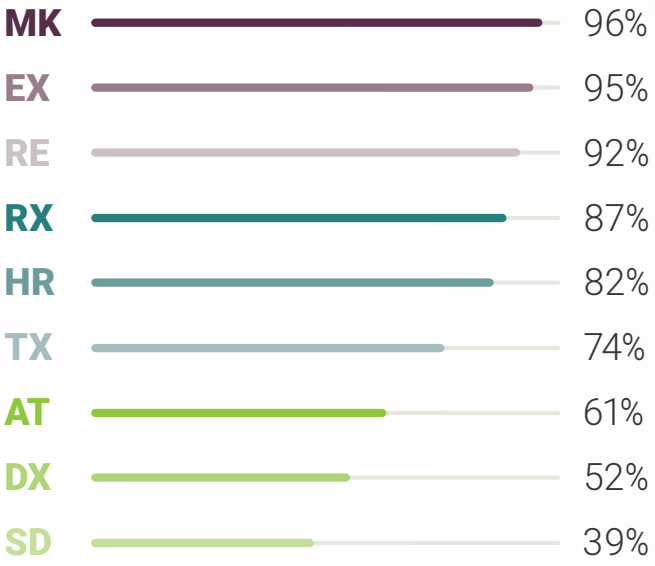
Depending on the requirements of the client ACS may design solutions that go from a compact pre-separator for sparks and silica reduction (protection of downstream equipment) to a final stage dust collector. The more efficient the solution is, the larger the number of cyclones needed to increase residence time and promote particle agglomeration with impact of space and cost. ACS will always search for the most cost efficient solution which can be upgraded with recirculation in the future. Please compare the performance of several products below.

Operating Conditions:

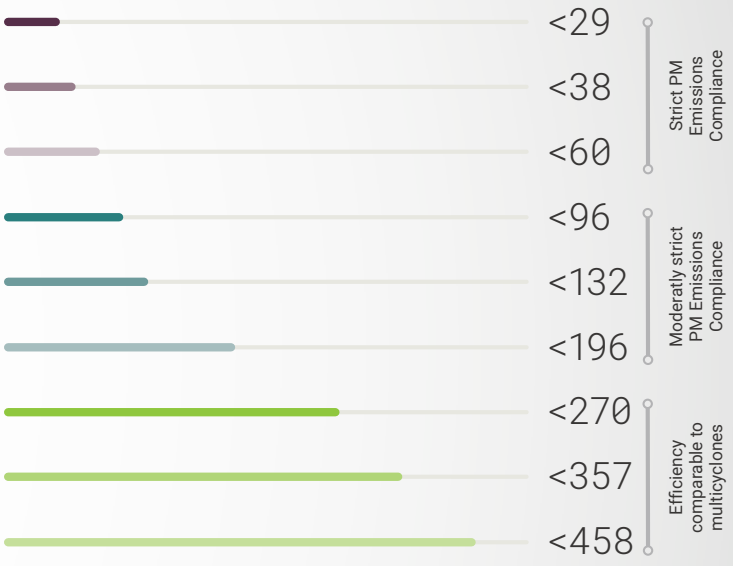
$4MW_{th}$ wood chips moving grate boiler

FUEL	Wood Chips
MEDIAN VOLUME BASED PARTICLE SIZE	11µm
INLET CONCENTRATION	750mg/Nm³
GAS TEMPERATURE	180ºC
FLOW RATE	18 000m³/h
MOISTURE CONTENT IN FLUE GASES	8%(v/v)

Global Efficiency (%):



Emissions (mg/Nm³):



Cyclones needed (ø1000mm):

System size:

100%
65%
53%
33%
23%
15%
10%
7%
6%

Objectives / Applications:

- The agglomerator cyclone – Maximum agglomeration
  Most efficient cyclones available on the market
- Ultra high effciency with agglomeration to compete with ESPs
- Very high efficiency cyclone with agglomeration for strict emissions
- Final stage dedusting for stricter emission limits
- Compact high efficiency cyclones for multiple applications
  Half the emissions of Multicyclones
- Final stage dedusting for moderate emission limits
  Better performance than multicyclones
- Enhanced Pre-Separation
  Sparks & silica reduction upstream of dryers
- Improved pre-Separation for coarse and medium particle size
  Alternative to axial multicyclones
- Coarse particle separation
  Abrasion reduction before other cyclones and FANS

Recyclone Systems®

Mechanical and Electrostatic Recirculation

ReCyclone®
MH System

Mechanical ReCyclone® (MH)

ACS holds a patent of a recirculation system to increase the efficiency of cyclones. A mechanical ReCyclone® (**ReCyclone® MH**) is made up of a high efficiency **Hurricane** and a particle separator, placed downstream, called the "mechanical recirculator" (please see figure). **In 2016, ACS introduced more compact recirculators that can be placed on top of cyclones, exempting the need of additional footprint.**

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 forces. While this gas is enriched in particles, the axial gas stream exhaust to the stack is clean of particles. Recirculation is achieved through 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. Systems are arranged in groups of cyclones and recirculators.

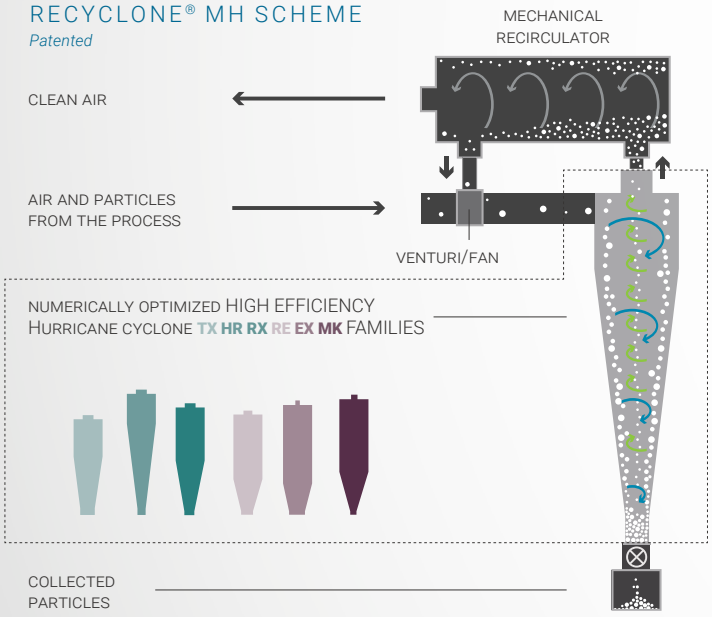
Efficiency increase

Efficiency increases due to recirculation and agglomeration of very small particles with larger ones coming directly from the process. A **ReCyclone® MH** decreases emissions of Hurricane cyclones alone by 30 to 60%.Finally recirculation control has the benefit of **handling variable process** flow rates very well.

A ReCyclone® MH is the most efficient purely mechanical collector in the market, as it further enhances efficiency of any given cyclone geometry.

RECYCLONE® MH SCHEME

Patented



RECYCLONE® MH FEATURES

- Very high efficiencies: decreases emissions of any ACS Cyclones by [30-60]%
- Very low emissions: [15-45]mg/Nm³ is achievable for many combustion sources
- Pressure drop: [150-200] mm w. g.
- No temperature restrictions with an appropriate alloy steel or refractory selection
- Recirculation assures a reasonable velocity in the cyclones
- Robust construction with no moving parts (no rapping mechanisms)
- Near zero maintenance and downtime costs
- Low investment costs

EXAMPLES OF FINISHED AND ONGOING PROJECTS

APPLICATION	EFFECTIVE FLOW RATE (m³/h)	TEMP. (°C)	MEDIAN PARTICLE SIZE (µm)	CYCLONES DIAMETER (mm)	PRESSURE DROP (mm w. g.)	INLET CONCENTRATION (g/Nm³)	EFFICIENCY (%)	EMISSIONS (mg/Nm³)
France - Wood chips grate boiler	5 460	180	8	600	200	0.25	> 86	< 50
Brazil - Biomass boiler	101 206	160	15	900	120	0.45	> 90	< 46
Indonesia - Palm shell BFB boiler	3 595	230	30	700	190	5.60	> 99	< 50
Spain - Drying of organic fertilizer	50 400	40	35	1050	200	1.58	> 97	< 50

ReCyclone® EH System

Electrostatic ReCyclone® (EH)

Recent adoption of **electrostatic recirculation** in the same cyclone system has successfully proven to further reduce particle emissions, even in the [1;5] µm particle size range, assuring future regulation compliance, particularly where legal limits are very strict.

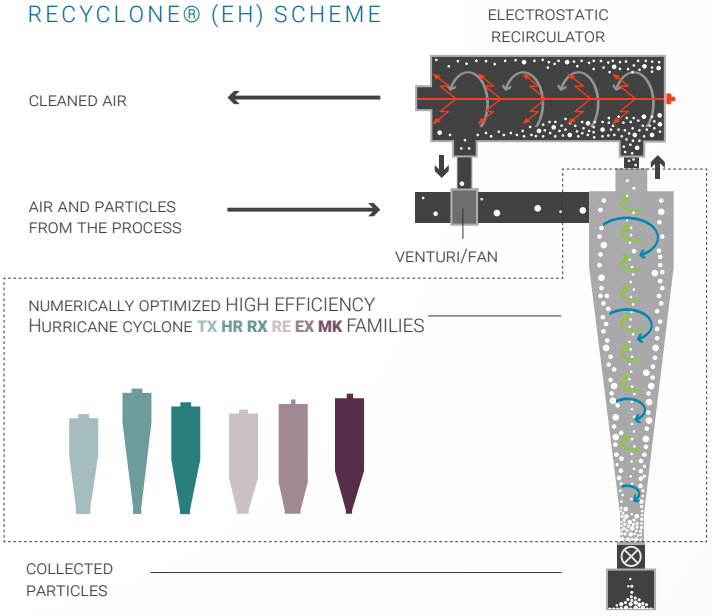
A DC high voltage is applied to the recirculator, allowing the **recirculation of very fine nanometric particles, more resistant to centrifugal forces, to the cyclone collector.** After having been separated in the recirculator and concentrated in the recirculation flow, electrically charged fine particles are attracted by the cyclone walls, while agglomerating with larger particles entering the system – both promoting their easier capture.

Since particles are not captured on the walls of the recirculator, contrary to ESPs, **ReCyclone®** systems avoid the problem of dust accumulation and condensation.

Additionally, ReCyclone® EH systems have low sensitivity to either low or high dust electrical resistivity while the high voltage required power is only 10 to 15 % of that used in ESPs.

Electrostatic recirculation for fine particle capture was the winner of the Portuguese Environmental Press Award in 2008 and nominee for the European Environmental Press Award 2008.

RECYCLONE® (EH) SCHEME



RECYCLONE® (EH) FEATURES

- Very high efficiencies: decreases emissions of a ReCyclone MH by [40-70]%
- "Bag Filter comparable" emissions: [5-25]mg/Nm³ is achievable for many combustion sources
- Pressure drop: [120-170] mm w. g.
- Operates up to 400ºC
- Not sensitive to variable flow rates
- Robust construction with no moving parts (no rapping mechanisms)
- Low maintenance and downtime costs
- Reasonable investment costs

EXAMPLES OF FINISHED AND ONGOING PROJECTS

APPLICATION	EFFECTIVE FLOW RATE (m³/h)	TEMP. (ºC)	MEDIAN PARTICLE SIZE (µm)	CYCLONES DIAMETER (mm)	PRESSURE DROP (mm w. g.)	INLET CONCENTRATION (g/Nm³)	EFFICIENCY (%)	EMISSIONS (mg/Nm³)
D. Republic - Wood pellet grate boiler	25 306	250	8	800	150	0.30	> 95	< 15
France - Pine residues grate boiler	3 900	180	11	600	160	0.2	> 90	< 20
Indonesia - Coal BFB boiler	40 865	350	30	2000	170	5.60	> 99.1	< 50
Turkey - MSW Gasification	3 225	350	11.5	600	160	0.32	> 94	< 20

Technology comparison

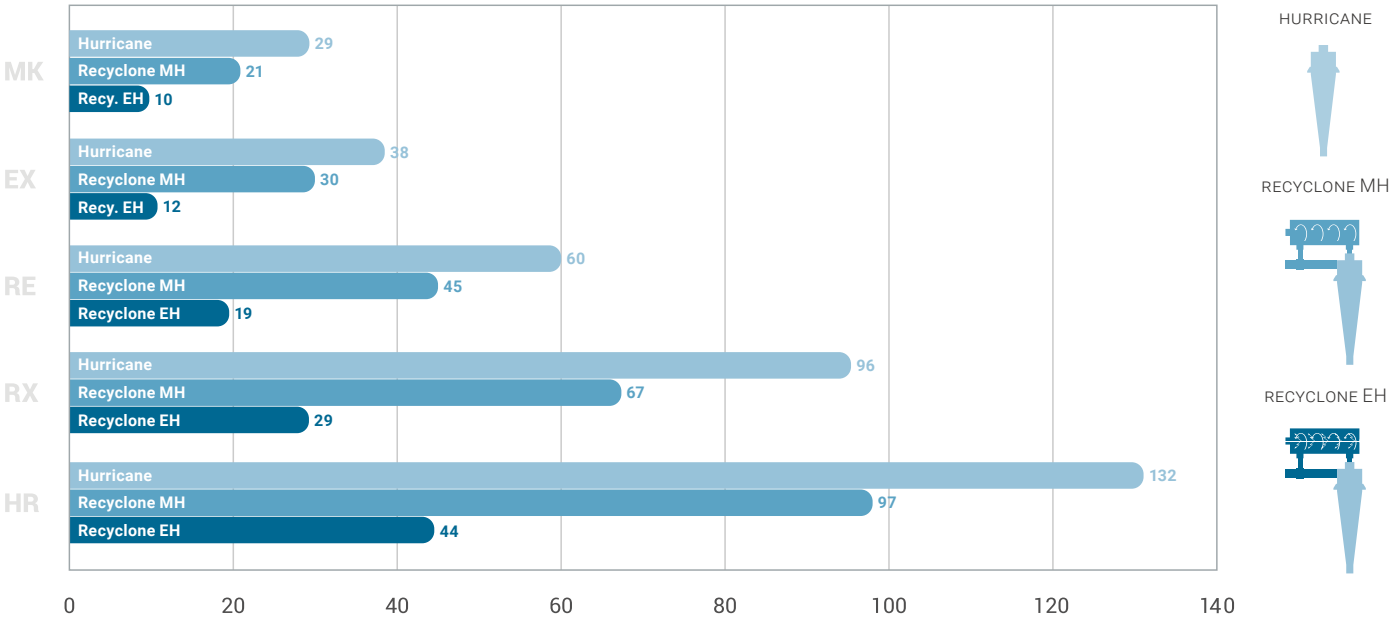
Hurricane cyclones | ReCyclone MH | Recyclone EH | Other technologies

Approach to any new project

Whenever it's possible to achieve a requested emission limit or efficiency with a given optimized cyclone geometry, ACS will avoid recirculation, in order to reduce investment and operating costs (mainly power consumption of FANS). Whenever emission limits become stricter, in the future though, any hurricane family can be coupled with mechanical or electrostatic recirculation to increase efficiency. This staged investment is much easier to support than a one expenditure in a Bag Filter or ESP.

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: $4MW_{th}$ biomass boiler

TECHNOLOGY COMPARISON BETWEEN ACS AND OTHER PRODUCTS

Technology comparison for wood chip combustion	Multicyclones	Wet Venturi Scrubbers	Bag filters	ESP´s	Hurricane systems	ReCyclone® MH systems	ReCyclone® EH systems	
Efficiency (%)	50 to 80	89 to 93	98-99 +	95 to 99	82 to 96	87 to 97	94 to 99	Maximize Efficiency
Emissions: (depending on Hurricane collector)	> 150	49 to 70	< 20	5 to 35	29 to 132	21 to 97	10 to 44	
Temperature limitations (°C)	No	No	< 250	Yes	No	No	<400	Universal Application
Fire risk	No	No	Yes	No	No	No	No	
Resistivity sensitivity?	No	No	No	High	No	No	Low	
Pre-separation needed?	No	No	Always	Frequently	Unfrequent	Unfrequent	Unfrequent	
Consequences of electrical field failure	None	None	None	Plant shut down	None	None	Works mechanically	Minimize Total Cost of Ownership
Moving/replacement parts	No	No	Yes	Yes	No	No	No	
Relative investment costs	20/100	(45 to 55)/100	60/100	100/100	(35 to 55)/100	(45 to 65)/100	(60 to 70)/100	
Relative operating costs (Energy and Maint.)	4/100	20/100	20/100	10/100	4/100	6/100	10/100	
Future retrofitting costs	Very low	Low	Low	Very high	Very low	Very low	Very low	
Downtime costs	Very low	Low	High	Low	Very low	Very low	Low	
Comments	Dry-System	Sec. Pollution Needs Treatment	Dry-System	Dry-System	Dry-System	Dry-System	Dry-System	

Indicated values are from page 5. Example: $4MW_{th}$ biomass boiler. Range of emissions figures depend on the type of cyclone family used

Case Study Hurricane HR cyclones for the wood panel board industry

Resumed Design Conditions:

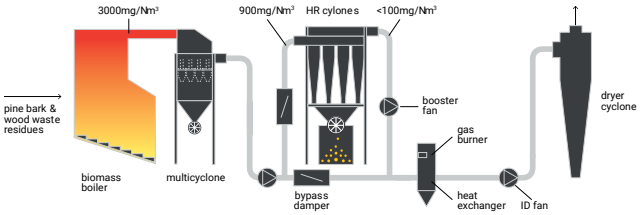
Fuel	Pine bark and wood waste residues
Median particle size	10.2µm
Inlet dust concentration (after multicyclone)	900mg/Nm³
Gas flow temperature	303ºC
Effective flow rate	247 000m³/h

Output/Performance:

Residual emissions	<100mg/Nm³
Pressure drop	1.0kPa
ACS system	60HR1000

The client Sonae Indústria is one of the largest wood-based panel producers in the world. The company faces many dust filtration problems, including the **main biomass boiler**, the **MDF/particle board dryer** and other multiple processes such as **hammer mills** and **flakers**.

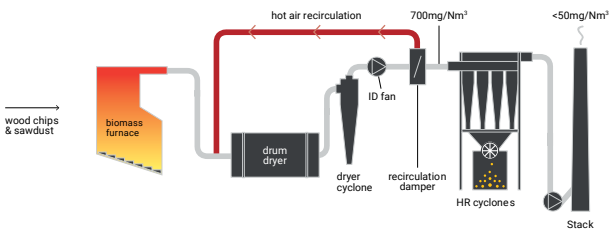
The problem and solution Sonae was forced to use a natural gas hot gas generator for drying fiber, despite having the necessary amount of thermal energy available in the exhaust stream of a wood waste thermal oil heater (TOH). The problem of using the TOH laid on the emissions of ash and unburnt particulate which were carried over with the dried fiber and deposited on the final product – the wood panel boards. These were systematically rejected by quality inspections. ACS enabled using the TOH with a system comprising 60 Hurricane HR numerically optimized cyclones with ø1000mm designed to reduce particulate under 100mg/Nm³ and unburnt particulate to a level which could fully eliminate quality control rejections.



Case Study Hurricane HR cyclones to reduce PM emissions in the pellet making industry

The client Glowood produces 100,000 tons of **pellets** per year in Cercal, Alentejo, Portugal, mainly for export. As other pellet makers, Glowood faces many dust filtration problems, including a pre-separation of ash and sparks before the **drum dryer, dryer dust control** after the process cyclones and other applications such as the **hammer mills**.

The problem and solution Glowood runs a biomass furnace with the exhaust stream drying the feedstock in a drum dryer. Due to furnace and cyclone inefficiency, PM emissions at the stack were as high as 700mg/Nm³, representing losses of material and essentially an environmental problem. ACS designed a system comprising 6 Hurricane HR numerically optimized cyclones with ø1550mm, disposed in line, to reduce emissions under 50mg/Nm³.



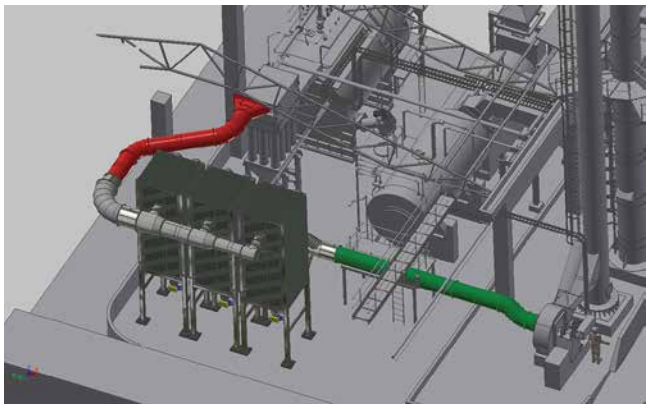
Resumed Design Conditions:

Fuel	Fines of mill sawdust escaping dryer cyclones
Median particle size	20µm
Inlet dust concentration	700mg/Nm³
Gas flow temperature	87ºC
Effective flow rate	71 839m³/h

Output/Performance:

Residual emissions	<50mg/Nm³
Pressure drop	1.2kPa
ACS system	6HR550

Case Study Hurricane RE cyclones to reduce PM emissions from a coal grate boiler



Resumed Design Conditions:

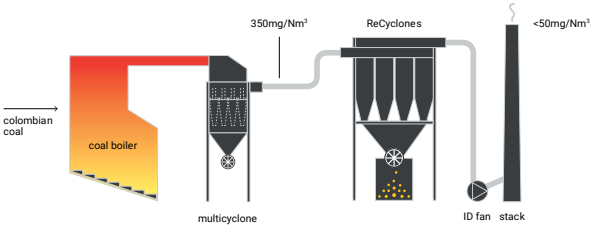
Fuel	Colombian Coal
Median particle size	5,5µm
Inlet dust concentration (after multicyclone)	327mg/Nm³
Gas flow temperature	155°C
Effective flow rate	25 485m³/h

Output/Performance:

Residual emissions	<50mg/Nm³
Pressure drop	1.3kPa
ACS system	12RE900

The client Proteicol is a Colombian company dedicated to the transformation of byproducts of animal origin directed to the animal feed industry. As in many other industries in the country, a Coal Boiler (brand JCT) is used to produce steam for the process. Coal is an unavoidable source of energy in Colombia but so is the need to reduce PM emissions, which have reached very serious levels. New regulation forces users to have their boilers under the 50mg/Nm³ threshold.

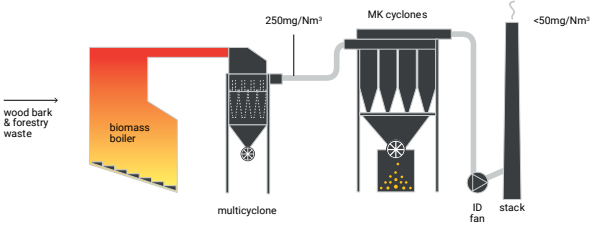
The problem and solution Proteicol runs a moving grate boiler from manufacturer JCT equipped with Multicyclones reaching emissions between 250 and 350mg/Nm³. In order to reduce the level to less than 50mg/Nm³ and considering a design flow rate of 25 485m³/h at 155°C, ACS designed a Hurricane RE system, comprising 12 RE type cyclones of ø900mm to be placed after the Multicyclones, thereby treating only the residual fines escaping to the atmosphere.



Case Study Hurricane MK cyclones to reduce PM emissions from a wood bark & forestry boiler

The client Sciérie de Miremont is a French company working in the forest exploitation sector and forestry waste. ADEME – the French agency for the environment and efficient energy use – co-finances dedusting systems for biomass boilers that can operate below 50mg/Nm³ at 6% O_2. The boiler was from Austrian manufacturer Agroforst.

The problem and solution Taking advantage of being in a forest area, Miremont burns forestry waste with more than 50% moisture to produce steam and provide energy for several recent areas. To comply with emission limits imposed by ADEME, ACS designed a system of 6 Hurricane MK cyclones of ø600mm to be placed after the boiler's multicyclone and reduce the residual fine escaping to the atmosphere from 250mg/Nm³ at 11%O_2 to below 50mg/Nm³ at 11%O_2 considering a design flow of 3 200m³/h at 190°C.



Resumed Design Conditions:

Fuel	Bark and forest waste
Median particle size	9µm
Inlet concentration	250mg/Nm³
Gas temperature	190°C
Flow rate	3 200m³/h

Output/Performance:

Residual emissions	<50mg/Nm$_3$ at 11%O_2
Pressure drop	1.2kPa
ACS system	6MK600

Case Study ReCyclone MH HR to reduce PM emissions from a 45ton/h wood chips boiler

Resumed Design Conditions:

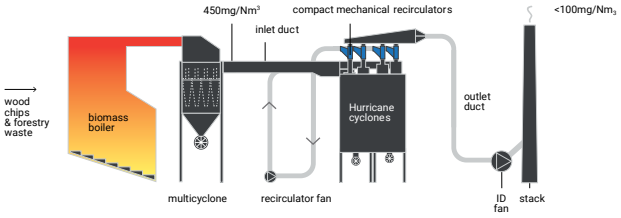
Fuel	Wood chips & forestry waste
Median particle size	15µm
Inlet concentration	450mg/Nm³at 8%O_2
Gas temperature	160ºC
Flow rate	40 755m³/h

Output/Performance:

Guaranteed residual emissions	<100mg/Nm³ at 8%O_2
Pressure drop	1.5kPa
ACS system	24MH-HR1000

The client ComBio Energia S.A., is a company that develops, implements and manages steam, outsourcing projects for companies in Brazil. As part of its services ComBio help customers solve PM emissions to comply with local legislation. The end customer was Votorantim Metais Holding, a company amongst the five largest producers of zinc in the world that holds a leading position in Latin America with a diversifies portfolio that includes copper, lead, silver and other minerals.

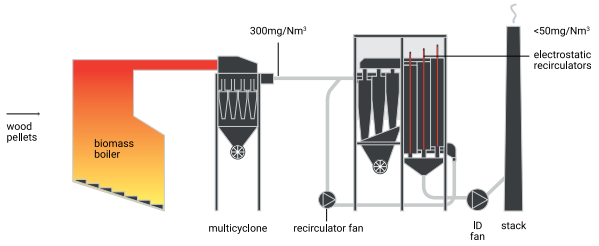
The problem and solution ComBio manages the wood chips and waste forestry biomass boiler (from Dan Power) at Votorantim's Três Marias plant in Brazil. The boiler reaches emissions up to 450mg/Nm³ at 8% O_2 thanks to a multicyclone but needs to comply with levels below 100mg/Nm³ at 8%O_2. Considering a design flow rate of 101 206m³/h at 160°C ACS designed a ReCyclone MH comprised of 24 Hurricane HR cyclones ø1000mm and 24 mechanical recirculors that could guarantee compliance with local legislation.



Case Study Recyclone EH-HR to reduce PM emissions from a 5MW$_{th}$ pellet boiler

The client Leche Rica is a corporate group with more than 50 years of experience in the food industry in the Dominican Market. With strict specifications, the company guarantees products of optimum quality and freshness, while seeking to maintain leadership in productivity and service.

The problem and solution The goal of Leche Rica was to have PM emissions below 50mg/Nm³$_{dry}$ at 11% O_2. To do so, the company needed to decrease the emissions level from the multicyclone by more than 84%. ACS made use of its particle size distribution (PSD) database collected in combination with computer simulations to design the system. After choosing the appropriate PSD, ACS proposed a ReCyclone EH system comprising 12 Hurricane HR coupled with 12 Electrostatic recirculators. The system is capable of guaranteeing emissions under 50mg/Nm³$_{dry}$ at 11% O_2 (expected emissions are under 25mg/Nm³$_{dry}$ at 11% O_2).



Resumed Design Conditions:

Fuel	Wood Pellets
Median particle size	40µm
Inlet concentration	300mg/Nm³dry at 11% O_2
Gas temperature	250ºC
Flow rate	25 306m³/h

Output/Performance:

Residual emissions	25mg/Nm³$_{dry}$ at 11% O_2
Pressure drop	1.5kPa
ACS system	12EH-HR8900

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ACS around the world

Number of installations per country

North America

KMW

ANGUIL

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