REINHOLD ENVIRONMENTAL Ltd.

2018 NOx-Combustion Round Table & Expo Presentation

February 19-20, 2018, in St. Louis, MO / Hosted by Dynegy

HEAT MANAGEMENT

PREVENTIVE ON-LINE CLEANING USING INFRASOUND

On-line cleaning today

- Sonic Horns
- Compressed air soot blowers
- Steam Soot blowers
- Explosion cleaning
- **Infrasound turbulence**

Objective

What is infrasound?

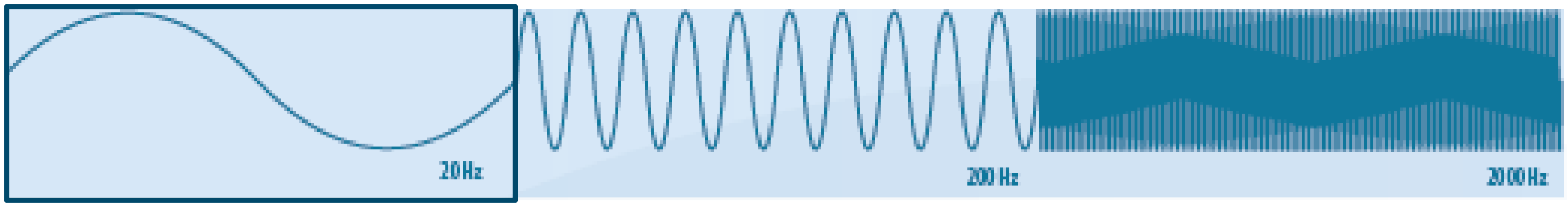
Why does frequency of sound matter?

When is infrasound a suitable method for on-line cleaning?

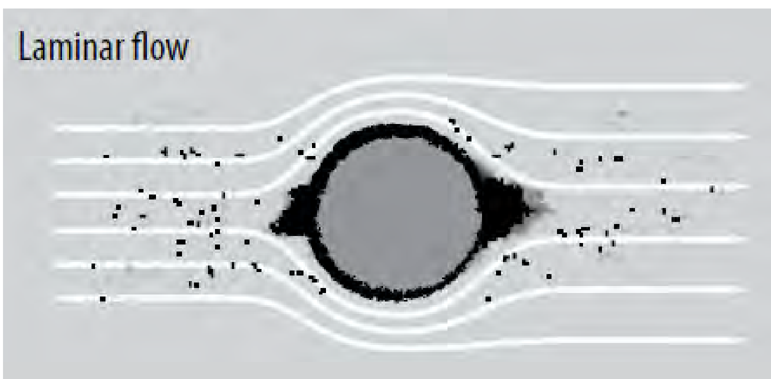
How does it work?

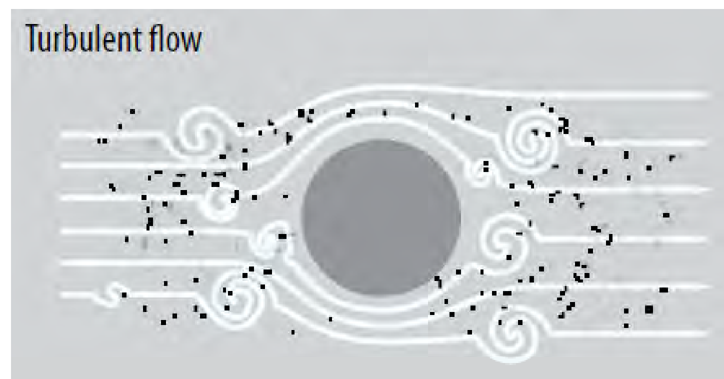
Why does it work?

What is infrasound?



Infrasound **Ultrasound**





- Sound waves are pressure variations in a medium, e.g. flue gas
- The pressure variations oscillates the flue gas
- The resulting turbulence, prevents fouling of surfaces

Why does frequency matter?

Absorption

The absorption of sound waves by a medium, is connected to the viscosity and heat conductivity of said medium. Absorption leads to sound attenuation (sound wave energy loss) and is proportional to the square of frequency of the sound wave.

Lower frequency means less attenuation and longer range of the sound wave

Diffraction

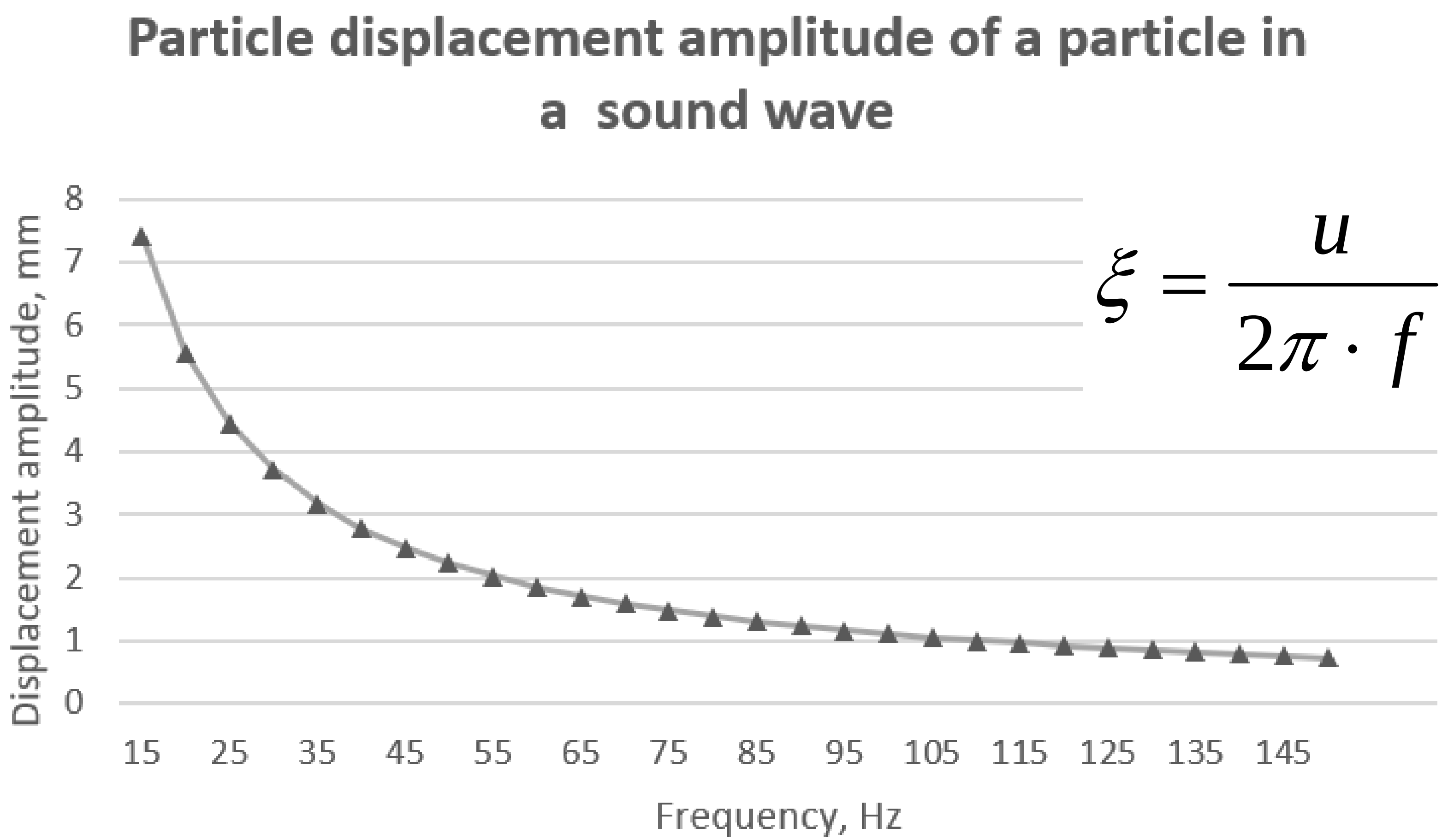
Low frequency means long wavelength waves. These sound waves can only be screened off by objects that are large in relation to the wavelength.

Sound waves with lower frequencies, easier move through obstacles and around corners

Directivity

High frequency sound can be directed but low frequency sound is omnidirectional. It spreads out spherically from the source, with the same intensity in all directions.

Why does frequency matter?



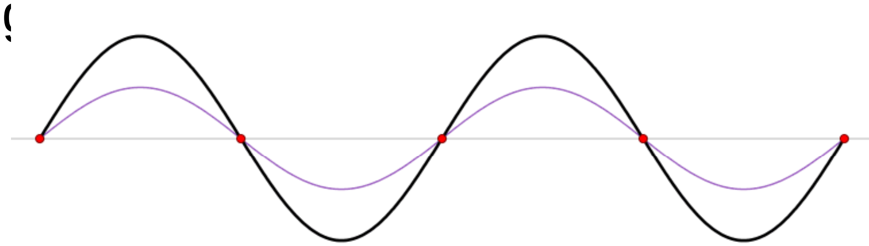
$$\xi = \frac{u}{2\pi \cdot f}$$

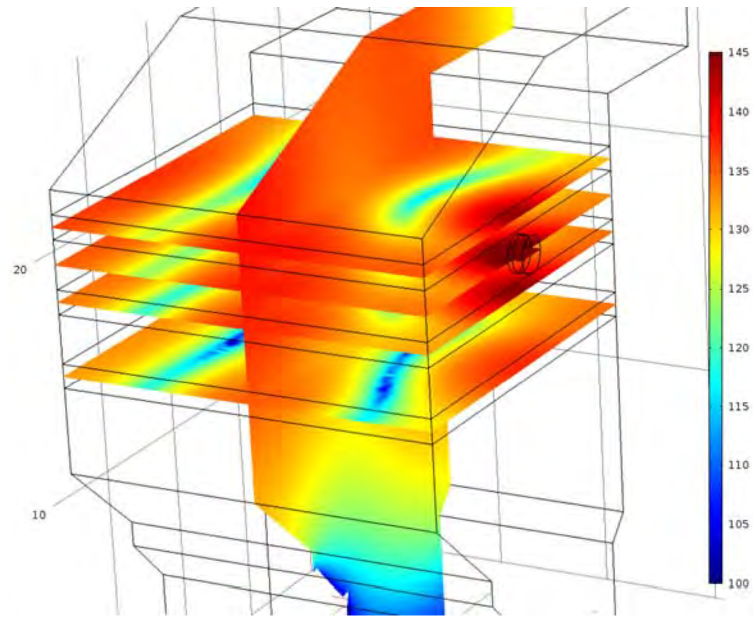
f= frequency, u= particle velocity amplitude, ξ =particle displacement amplitude

How does sound at different frequencies look?

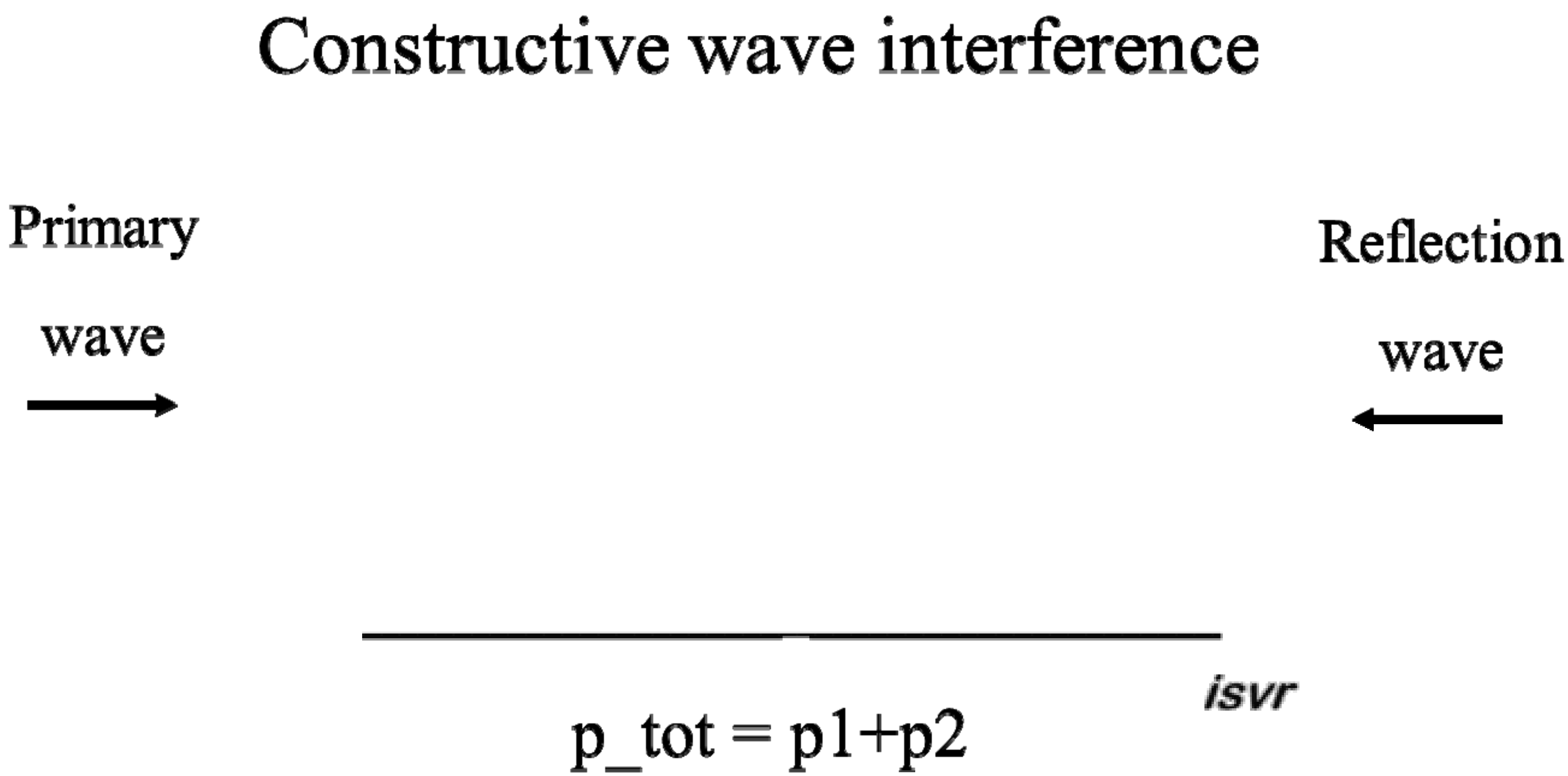
Why does it work? Design for the specific application

By tuning the infrasound cleaner frequency, to that of the reactor volume, a standing sound pressure wave can be generated, along the flue

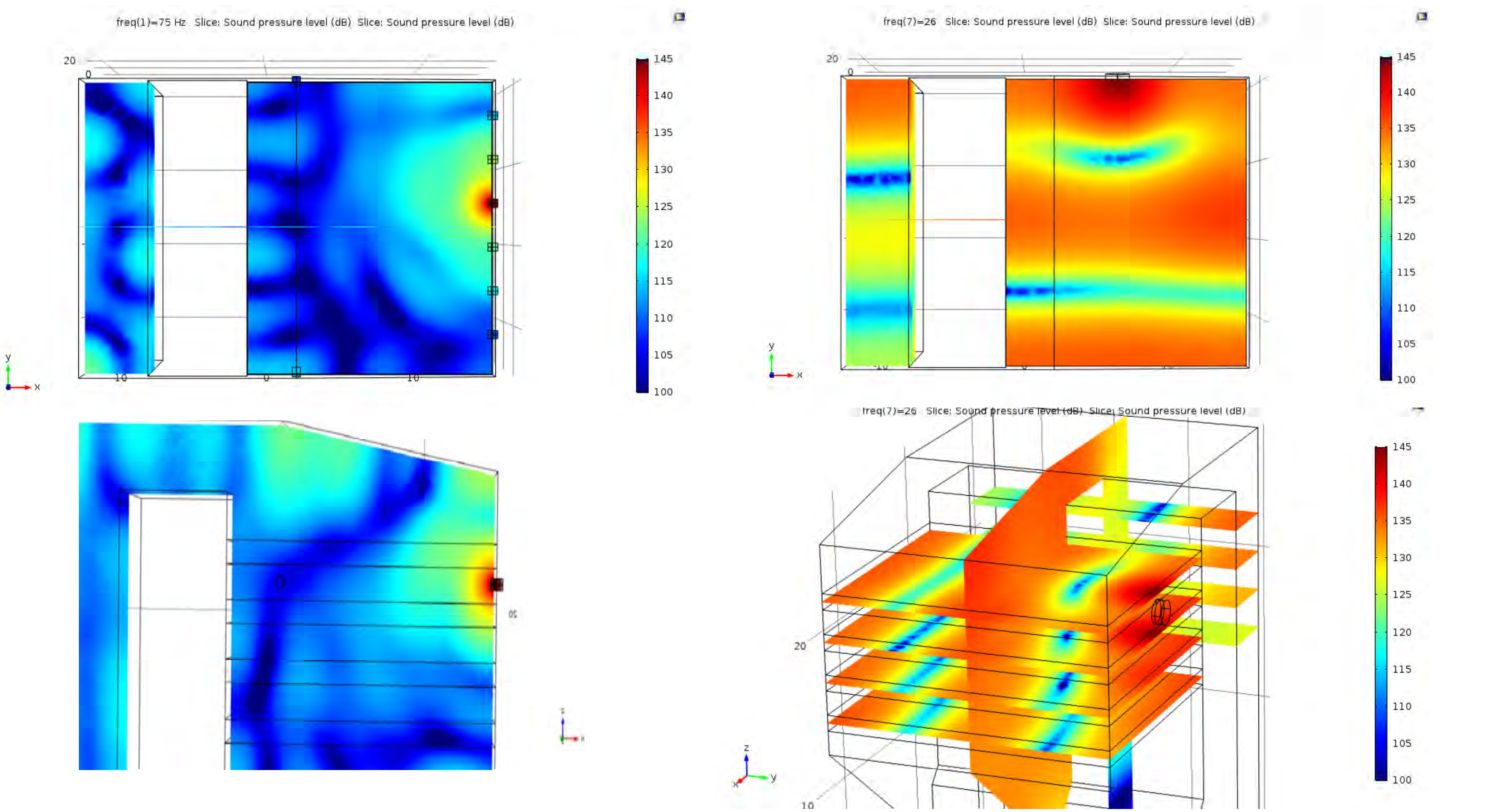




Why does it work? Find the resonance frequency



Why does it work? Resonance boosts the sound pressure



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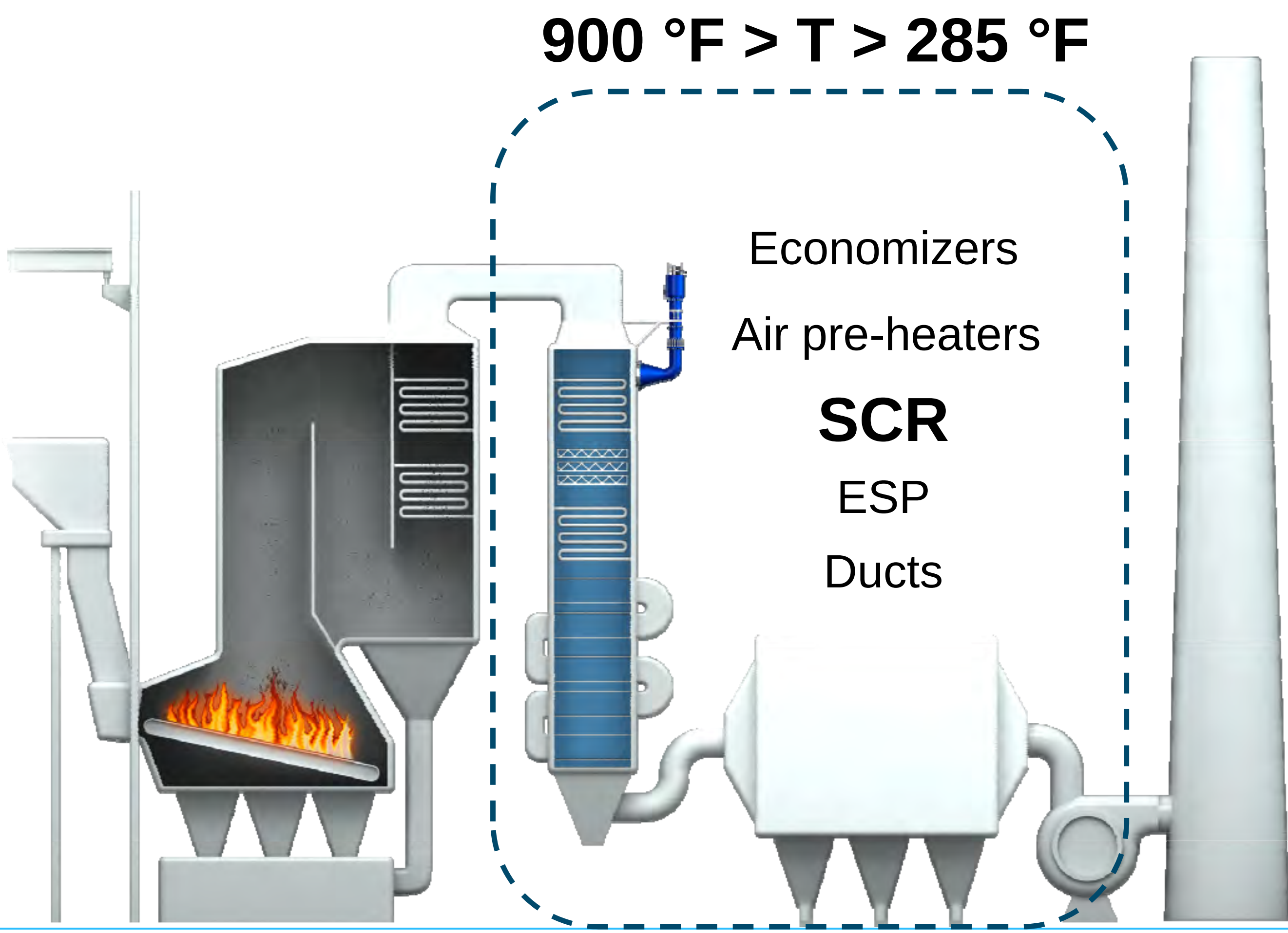
Possible applications for Infrasound



When to use infrasound for on-line cleaning

Infrasound-derived turbulence is suitable for <u>preventive</u> on-line cleaning in tight applications where the <u>deposits are dry and powdery</u>.

Low absorption and long wave range, i.e. an economizer, exhaust gas duct or SCR reactor needs only one or two infrasound generators

Moves unhindered through obstacles and around corners, i.e. unaffected by tube bundles or catalyst layers

Spreads omnidirectionally from the source, with the same intensity in all directions, i.e. does not need to be directed at the deposits

<u>The infrasound cleaning cycle is started up following manual cleaning, generating turbulence for 2 seconds every 4 minutes.</u>

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Example from inside a boiler

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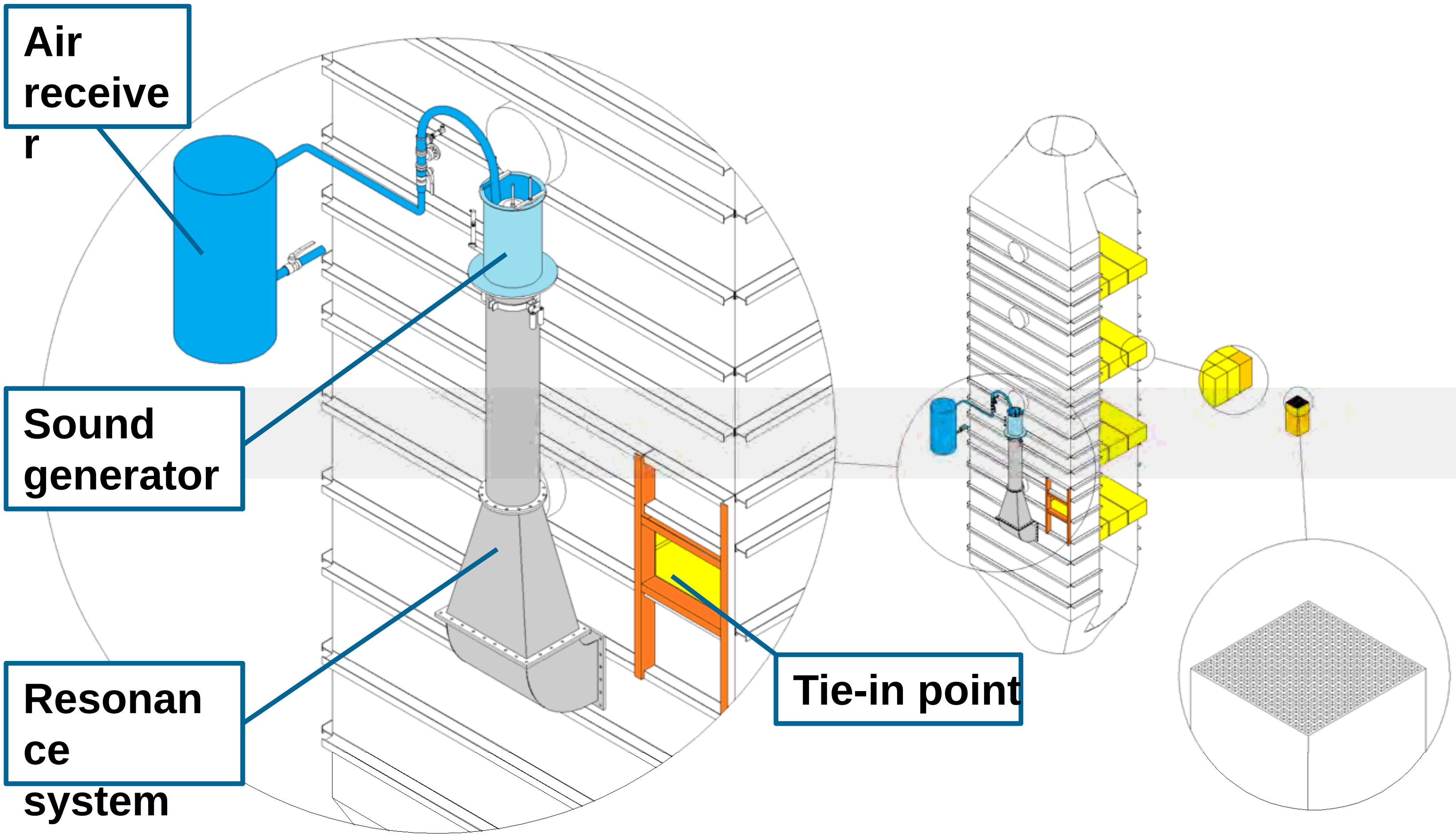
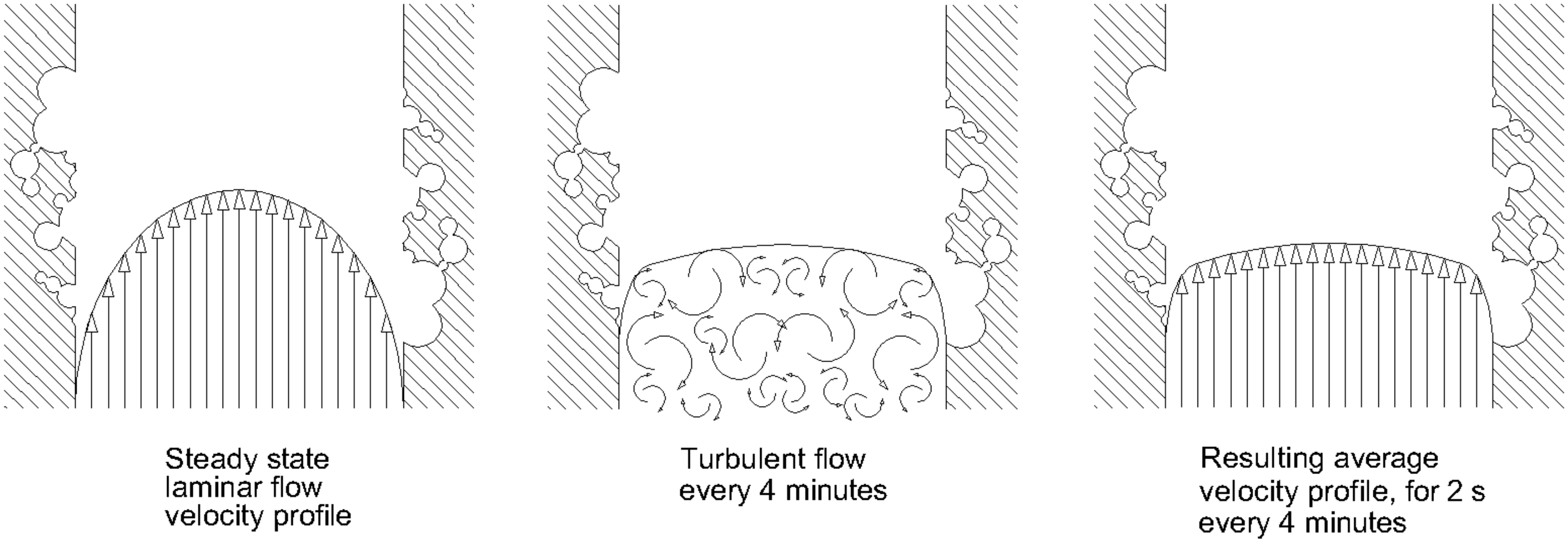
System description- Infrasound for SRC reactor



Preventive cleaning mechanism in SCRs

The infrasound induced turbulence (for 2 seconds every 4 minutes) changes the flue gas velocity profile, in each channel in the honeycomb monolith.

This relatively high velocity closest to the walls, gives rise to a local under pressure at the surface of the pores. The result is a suction effect on the loose, dry deposits that have deposited on/inside the pores.



Bituminous coal experience 2 x 225MW

High dust application

4 x 65 m² reactors

2 layer plate type, pitch 5.6 mm

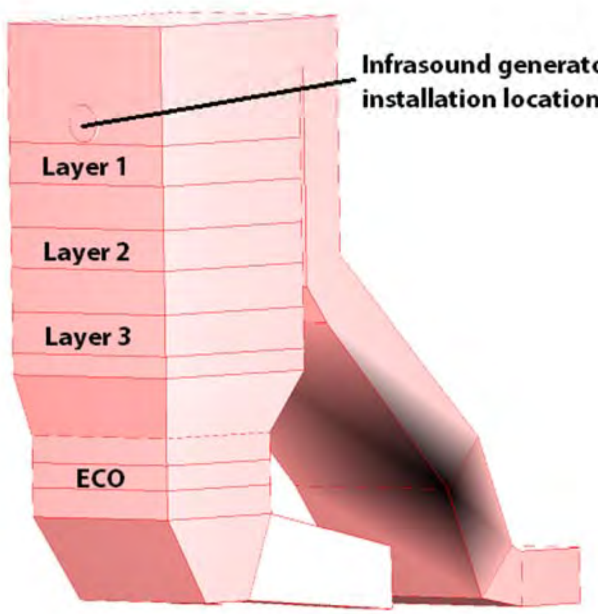
Dust load 32 g/Nm^3

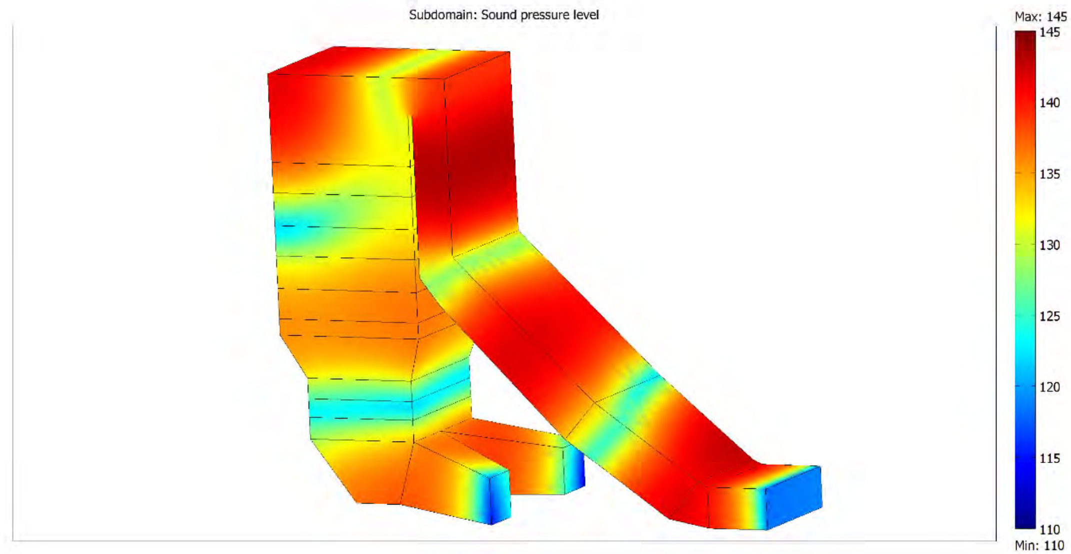
One infrasound cleaner per reactor

Operated 2 seconds, every 4 minutes

Bituminous coal experience 2 x 225MW

Acoustic modelling, 65 m² SCR



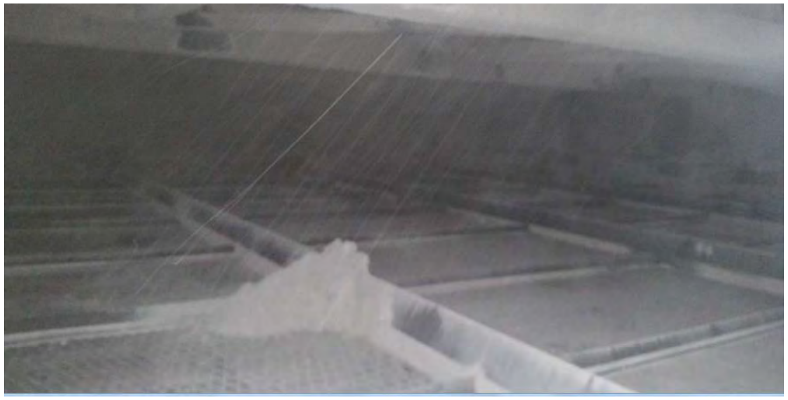


Bituminous coal experience 2 x 225MW

Photos after 14 months operation

Top layer, +35,840

Lower layer, +32,400



Waste-to-Energy experience, 3 x 60 MW

3 x 20 m² reactors

2 layer honeycomb Pitch 3,57 mm

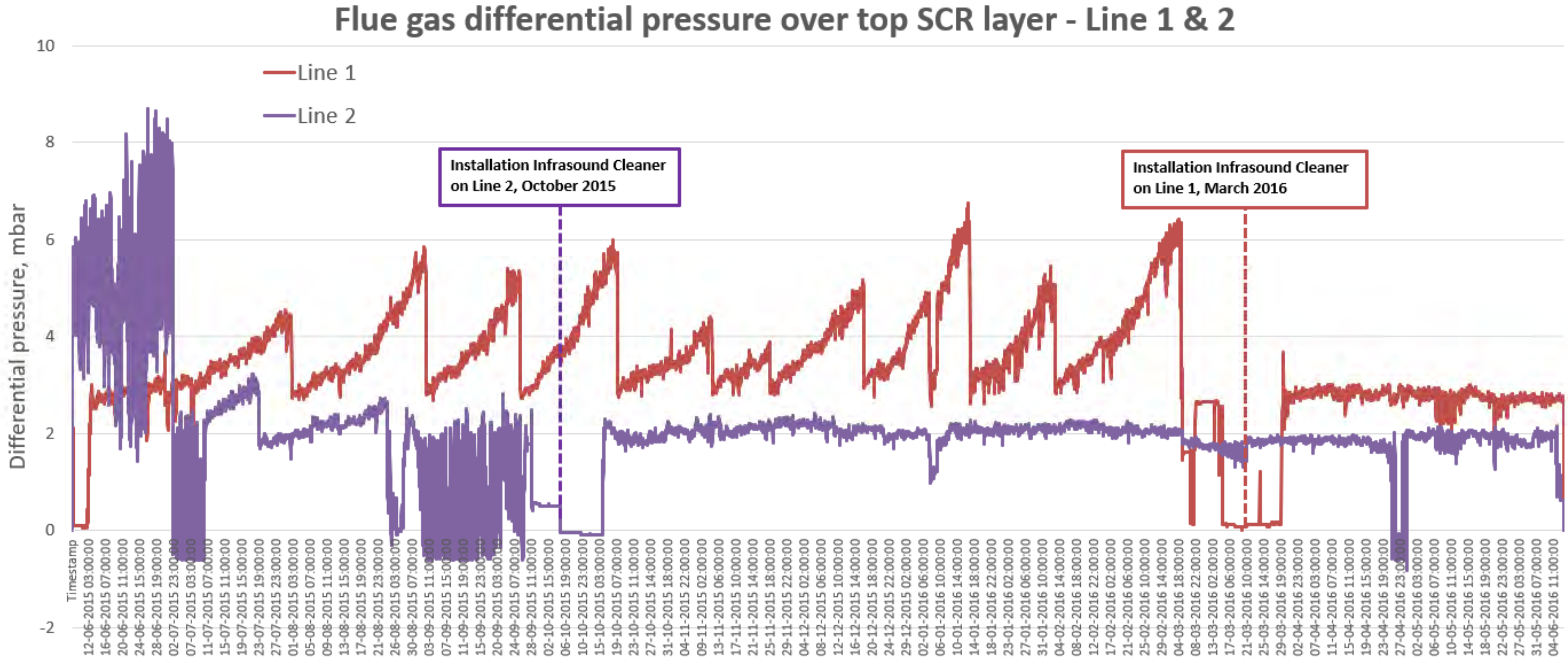
Dust load 30 mg/Nm^3

Plant experienced increasing flue gas dP over top catalyst layer, requiring manual cleaning every month

One infrasound cleaner per reactor

Operated 2 seconds, every 4 minutes

Waste-to-Energy experience, 3 x 60 MW



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Thank you!

Infrasound turbulence SCR experiences

Year	MW_{th}	Type	Fuel	Application	Pitch (mm)	Position
2018	104	BFB	Wood chips and forest residue	32 m^2, 1 layer, Honeycomb	5	In duct
2018	Marine	Cruise	HFO (3 %)	9,5 / 6,3 m^2, 2 layer, Honeycomb	4,3	Marine
2017	60	Grate	WtE, household waste	20 m^2, 2 layer, Honeycomb	3,57	Low dust
2016	60	Grate	WtE, household waste	20 m^2, 2 layer, Honeycomb	3,57	Low dust
2015	60	Grate	WtE, household waste	20 m^2, 2 layer, Honeycomb	3,57	Low dust
2014	125	CFB	Wood chips	41.5 m^2, 1 layer, Honeycomb	5	In duct
2014	225	Pulverized	Coal	2x65 m2, 2 layer, Plate	5,6	High dust
2014	225	Pulverized	Coal	2x65 m^2, 2 layer, Plate	5,6	High dust
2009	100	CFB	Wood chips and peat	36 m^2, 1 layer, Honeycomb	5,5	In duct
2001	3x600	Pulverized	Coal	232 m^2, 3 layer, Honeycomb	6.5	In duct
1996	2x75	Pulverized	Coal	2x44 m^2, 3 layer, Honeycomb	6.75	In duct
2012	Marine	Cargo	HFO (0.5 %)	SINOx, 2 layer, honeycomb		Marine
2012	Marine	Cargo	HFO (0.5 %)	SINOx, 2 layer, honeycomb		Marine
2012	Marine	Cargo	HFO (0.5 %)	SINOx, 2 layer, honeycomb		Marine
2004	Marine	Cargo	MGO	5 m2, 2 layer, honeycomb		Marine
2004	Marine	Cargo	HFO (0.5 %)	SINOx, 2 layer, honeycomb		Marine