STATE OF THE ART

HOT GAS FILTRATION in GLASS INDUSTRY

A Holistic Approach to Emission Control and Heat Recovery

LESSONS LEARNED

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125 JAHRE
VERANTWORTUNG & BEGEISTERUNG

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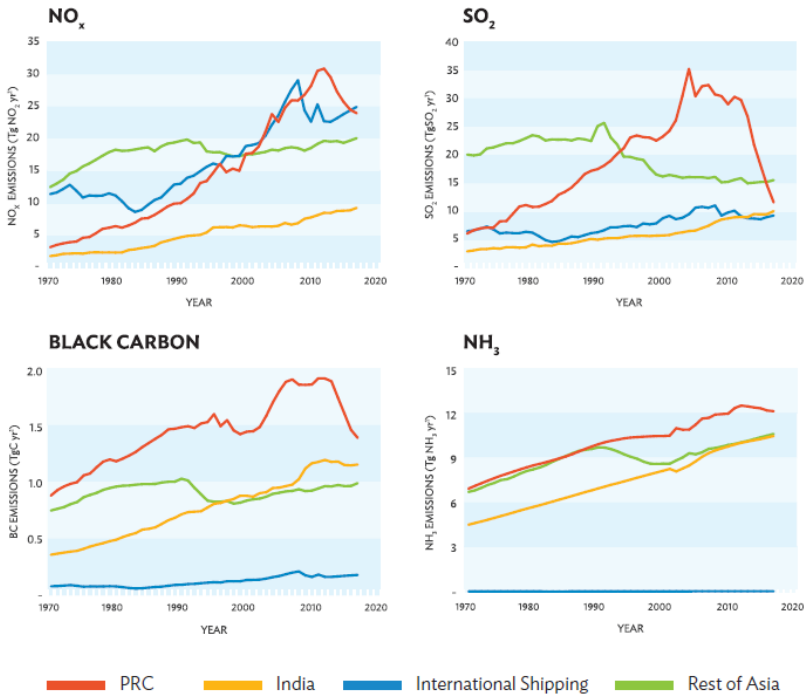
Content

Emission Control Limits in the Glass Industry / Trends in Asia

Pollutant *(mg/Nm³ @10%O_2)*		*Float Glass*	*Container Glass*
Particulate Matter PM)	**PM**	**10**-20	**10**-20
Acid Gases	**SOx (as SO_2)**	300(500)[1] 500(1.500)[2] **300(700)[1]** **500(1.400)[2]**	200(500)[1] 500(1.200)[2] **300(700)[1]** **700(1.400)[2]**
	HCl	10-25 **(20)**	10-20
	HF	1-**4**	1-5
Nitrogen Oxides	**NOx (as NO_2)**	400-700 **500**	**500**
Ammonia	**NH_3**	5-30 -	5-30 -
Dioxin u. Furans	**PCCD/F**	-	-
VOC / HAP (OHAP)	**TOC**	-	-
Carbon Monoxide	**CO**	**100**	**100**
Heavy Metals	***diverse***	1-3 (Se)	0,2-1,0[3] 1-5[4]

[1] *Natural Gas -fired* [2] *Oil-fired;* [3] *As, Co, Ni, Cd, Se, Cr6 (Group 1);* [4] *Group 1 + Sb, Pb, Cr3, Cu,Mn, V, Sn*



Source: McDuffie et al.,2020

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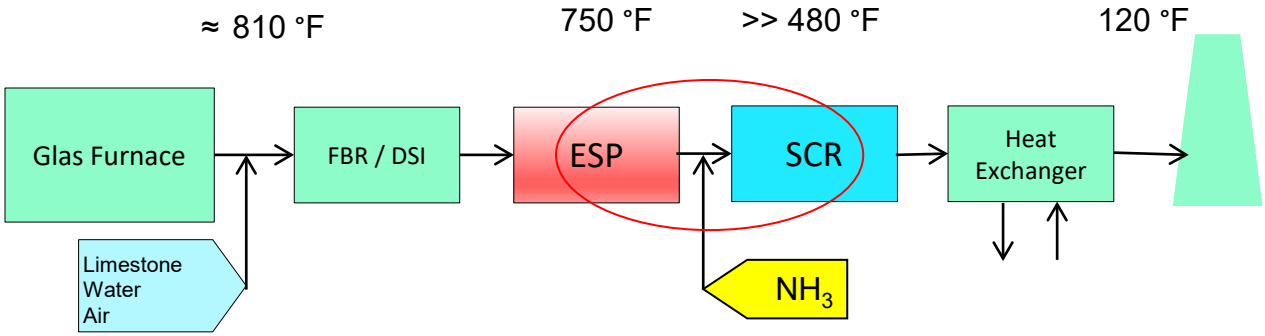
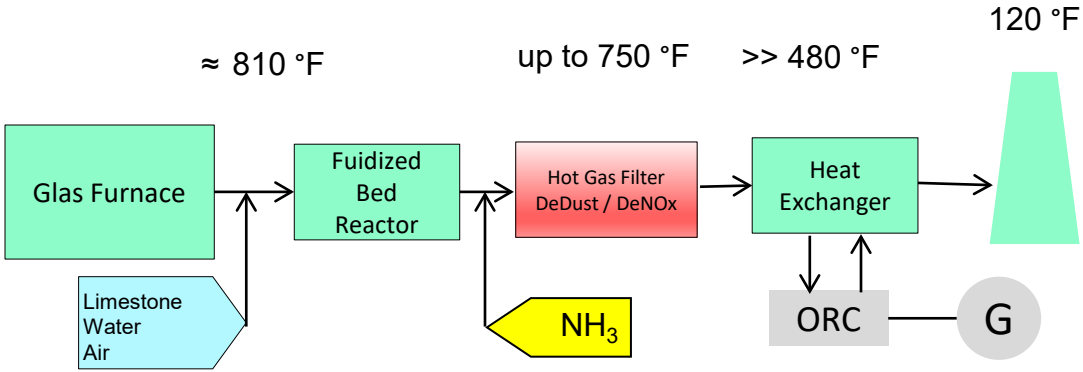
Conventional Emission Control System



- In the past emissions from glass melting furnaces were controlled by ESP and LDSCR.
- The dust collection efficiency of a standard ESP is at around 10-20 mg/Nm3. It is too high for the SCR units (should be below 10 mg/m3), for high-efficiency heat exchangers, and for the emission standards in many countries.

State of the Art Emission Control System with a multifunctional Hot Gas Filter



Advantages

- Combined PM removal (Sorbent for Sox capture and Dust) and NOx reduction in ONE STEP
- Highest PM removal efficiency (> 99.9 %) due to the ceramic filter elements – important for the use in heat exchangers etc.
- High temperature resistance of the ceramic filter elements => No need to reheat the off-gases
- Better overall energy balance and lower cost for CO2-certificates due to the re-use of already existing heat downstream of the glass melting process.

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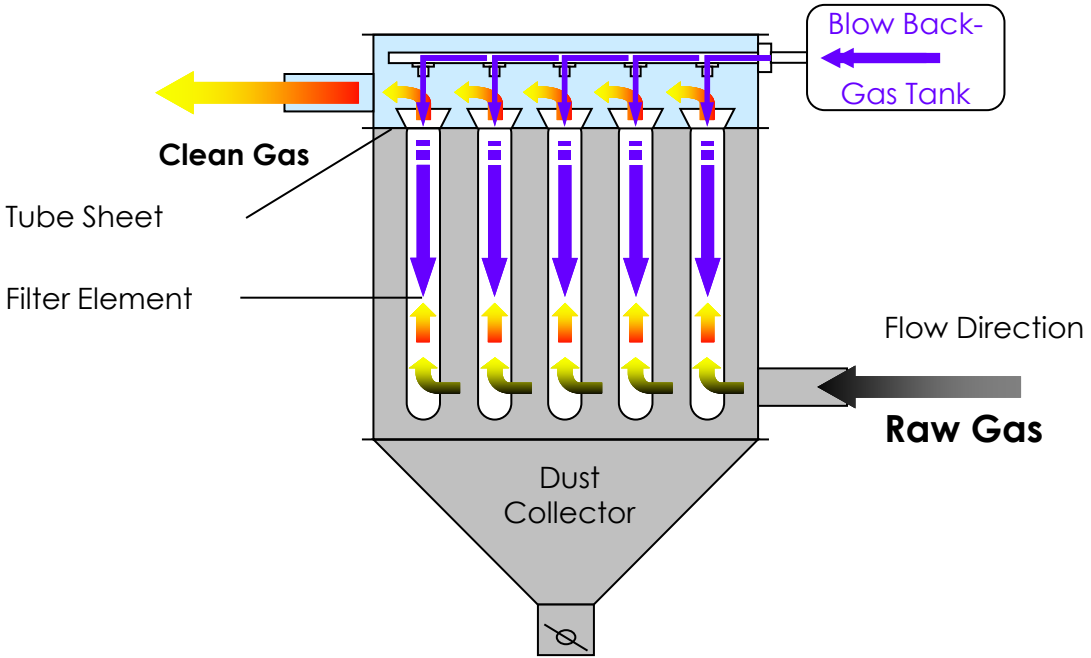
Operation Principle of a Jet-Pulse Hot Gas Filter



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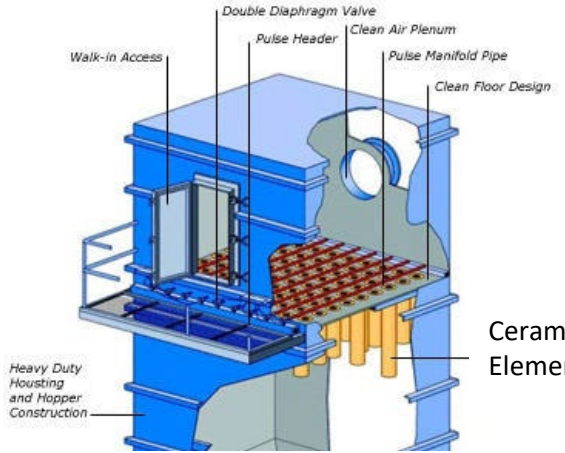
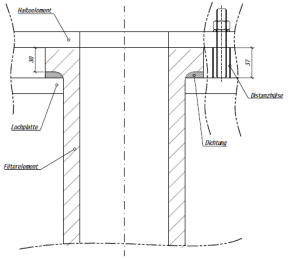
HGF - Typical Design For Low Pressure Applications

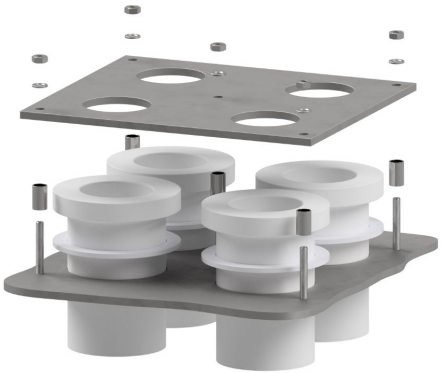


Ceramic Filter Elements

Typical Filter Vessel Design



Clamping Systems



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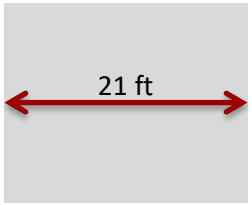
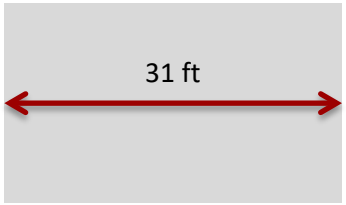
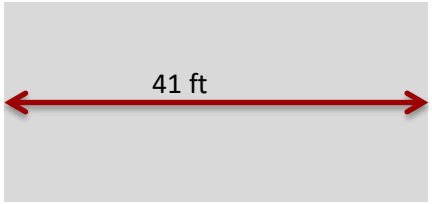
Available Filter Element Lengths – Impact on Footprint



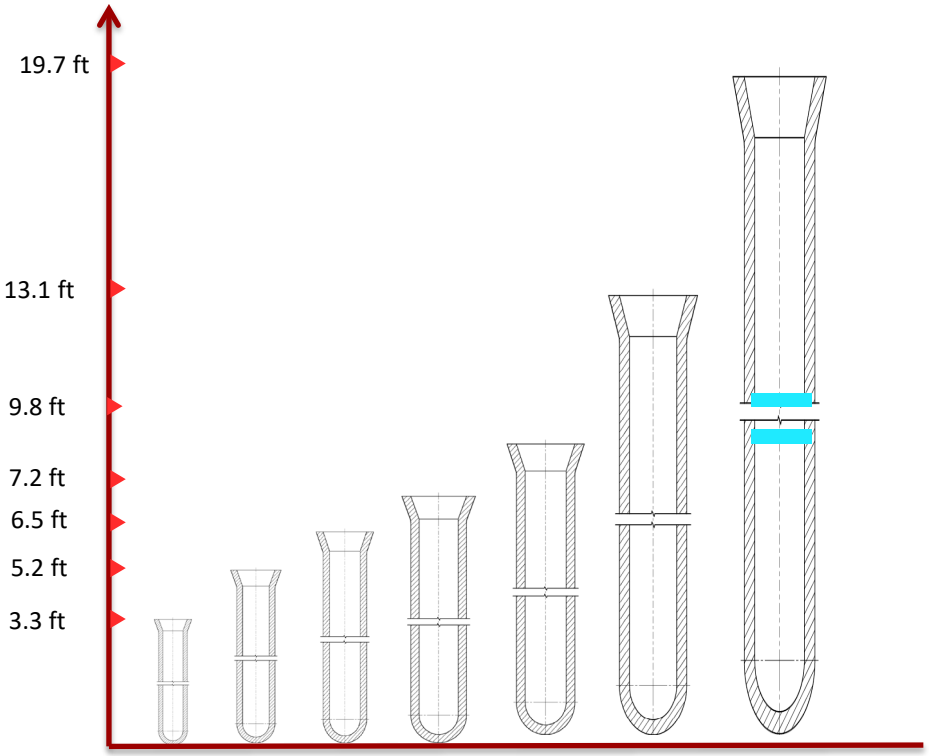
FE 19.7 ft long
Footprint of a filter vessel with 650 filter elements



FE 13.1 ft long
Footprint of a filter vessel with 925 filter elements



FE 9.8 ft long
Footprint of a filter vessel with 1,200 filter elements



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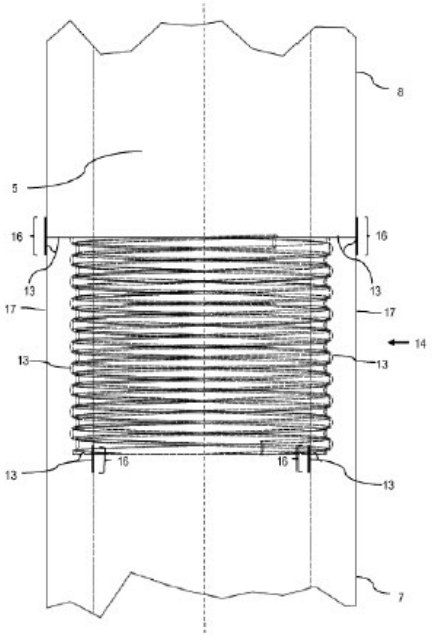
Screw & Glue Connection for Filter Elements > 13 ft
Patented Solution for High Flow Rate Applications



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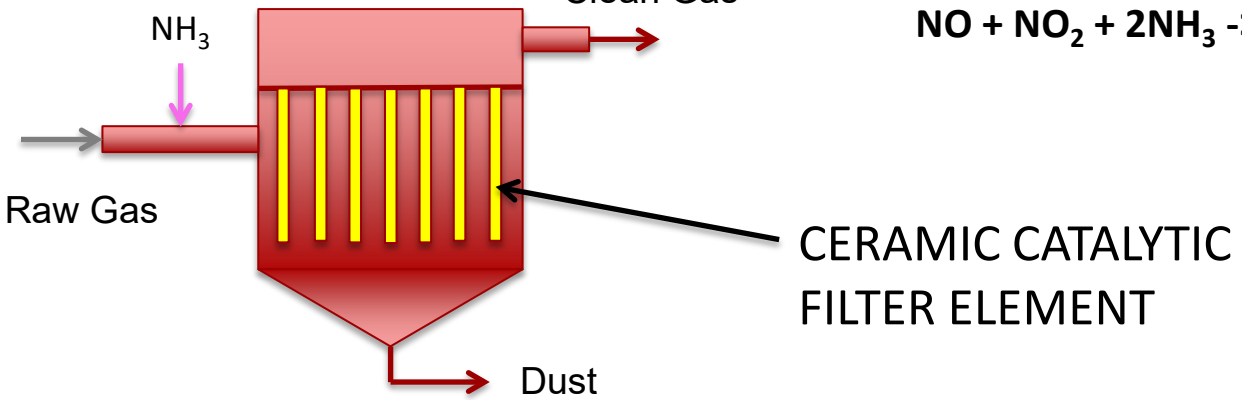
Catalytic NOx Reduction

The catalyst (e.g. TiO_2-V_2O_5-WO_3) deposited in the pores on the surface of the fibers promotes a reaction between NOx and ammonia (NH_3) injected upstream of the catalytic hot gas filter to form nitrogen and water vapor.



$4NO + 4NH_3 + O_2 \rightarrow 4N_2 + 6H_2O$

$NO + NO_2 + 2NH_3 \rightarrow 2N_2 + 3H_2O$

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Main Operating Issues Impacting the Performance and the Availability of Hot Gas Filters – rare but annoying!

1. High Operating Pressure Drop (Across Tube Sheet)
2. Filter System Leakage
3. Poor NOx Conversion - very rare!

All operating issues are completely avoidable!

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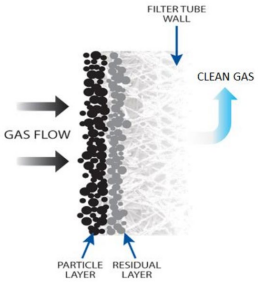
Too High Operating Pressure Drop / Poor Filter Element Cleaning Intensity

- Raw gas flow rate above the specified volume
  - higher dust load than specified
  - higher filtration velocity than specified and changed dust cake characteristic
  - higher can velocity and re-flow of the dust to the surface of the filter elements

- Failure of the blowback system
  - too little blowback gas for cleaning of the filter elements!
  - Overcleaning of the filter elements and operational mistakes in precoating
  - Failure of delta p – measurement if dp triggered
  - In case of manual cleaning operation wrong cleaning cycle time

- Changed dust properties and dust load

- Operation below dew point mainly during start-up and cooling down and re-start – unfortunately very often!



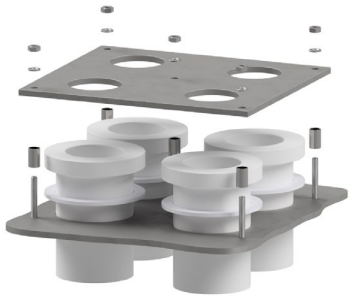
LESSONS LEARNED

Filter System Leakage

- Broken filter element — Reasons on next slide

- Hole in filter element
  - Abrasion mainly of a filter element positioned close to a broken filter element
  - Hole in the end cap (closed end) caused due to wet conditions below the dew point
  - Damage during installation – very seldom, if without a leakage test

- Gasket slippage
  - Poor clamping unit design. The filter elements are unevenly clamped.
  - Wrong length of the spacers
  - Mixture of different gaskets under the same clamping plate



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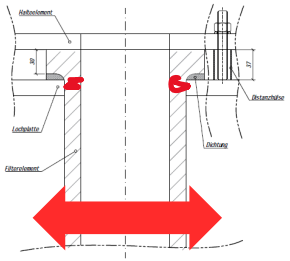
Main reasons for breakage of filter elements



- Axial movement caused by a lateral force applied to the media due to uneven raw gas distribution
  - Uneven raw gas distribution is a design failure!
- Operation below dew point makes the filter elements wet and it lowers the mechanical strength of the filter elements.
  - Hot Gas Filtration is a dry method of dust control.
- Dust bridges between the filter elements due to an insufficient cleaning of the filter elements or failure of the blowback cleaning system or a failure of a valve providing the blowback gas.
- Abrasion close to the flange of the filter element due to an open hole in the tube sheet or a leak elsewhere.
  - A broken filter element must be replaced or the hole in the tube sheet must be closed as soon as possible.

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Poor DeNOx performance / Too high NH_3-slip

- Too high filtration velocity and insufficient contact time to the catalyst in the filter media
- Insufficient injection and/or distribution of a reductant upstream of the filter leads to poor conversion rates => Poor atomization of the NH_3 droplets
- Too low operating temperatures cause a formation of species (NH_4NO_3, $(NH_4)_2SO_4$ and NH_4HSO_4) which deposit on and foul (deactivate) the catalyst.
- Too high operating temperatures can deactivate or even damage the catalyst.
- Too high NH_3/NOx ratio. That results in the undesirable release of ammonia to the atmosphere.

SUMMARY

- All operating issues listed in this presentation are completely avoidable
- It is essential to follow the instructions given by the suppliers of the filter system and the suppliers of the ceramic filter elements.
- The operators of hot gas filter systems can timely avoid many operating failures by timely intervention and consultations with the filter supplier.
- Continuous maintenance of the blowback device, of all instruments for measurements of important gas/dust inlet and outlet parameters is of great importance for high availability and long life of the filter system.

IF YOU HAVE ANY QUESTIONS PLEASE CONTACT ME!

THANK YOU FOR YOUR ATTENTION!

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