Reinhold Environmental Ltd.

2010 NOx-Combustion Round Table & Expo Presentation

February 8 & 9, 2010 Chattanooga, TN

PARAGON
Airheater Technologies

AIR HEATER NOX ISSUES

Smaltiflex
dal 1963

UNIVERSITY OF BOLOGNA
Engineering Faculty

TOPICS

- AIR HEATER LEAKAGE
- SCR ABS AIR HEATER ISSUES
- REMEDIES FOR ABS FOULING

- POLLUTION CONTROL

LEAKAGE

EFFECTS OF LEAKAGE

- Increased NOX Production
- Increased Desuperheater Spray
- Poor Flame Stability
- Increased Heat Rate
- Increased LOI

EFFECTS OF LEAKAGE

- Degrades APC Performance
- Poor Coal Drying Mill Fires, Explosions
- Low Fan Capacity –Load Limits
- Added Station Load for Fans

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International Journal of Heat and Mass Transfer 48 (2005) 1608–1632
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Modeling and effect of leakages on heat transfer performance of fixed matrix regenerators

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Received 20 September 2003; received in revised form 21 July 2004

Abstract

The following undesired leakages are inherent in operation of fixed matrix regenerators: gas pressure leakages due to

PERGAMON

Applied Thermal Engineering 19 (1999) 685–705

APPLIED THERMAL ENGINEERING

Influence of leakage distribution on the thermal performance of a rotary regenerator

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Received 1 October 1997

doi:10.1016/j.ijheatmasstransfer.2006.05.027

A numerical model for the analyses of heat transfer and leakages in a rotary air preheater

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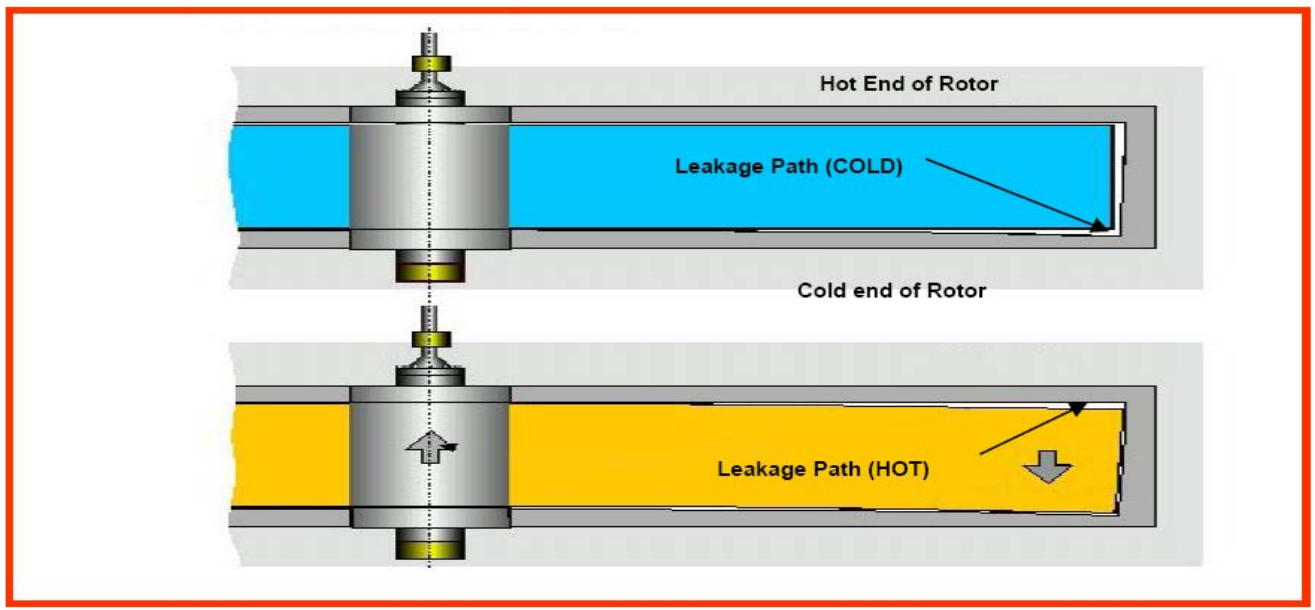
Received 5 October 2005. Available online 22 August 2006.

Abstract

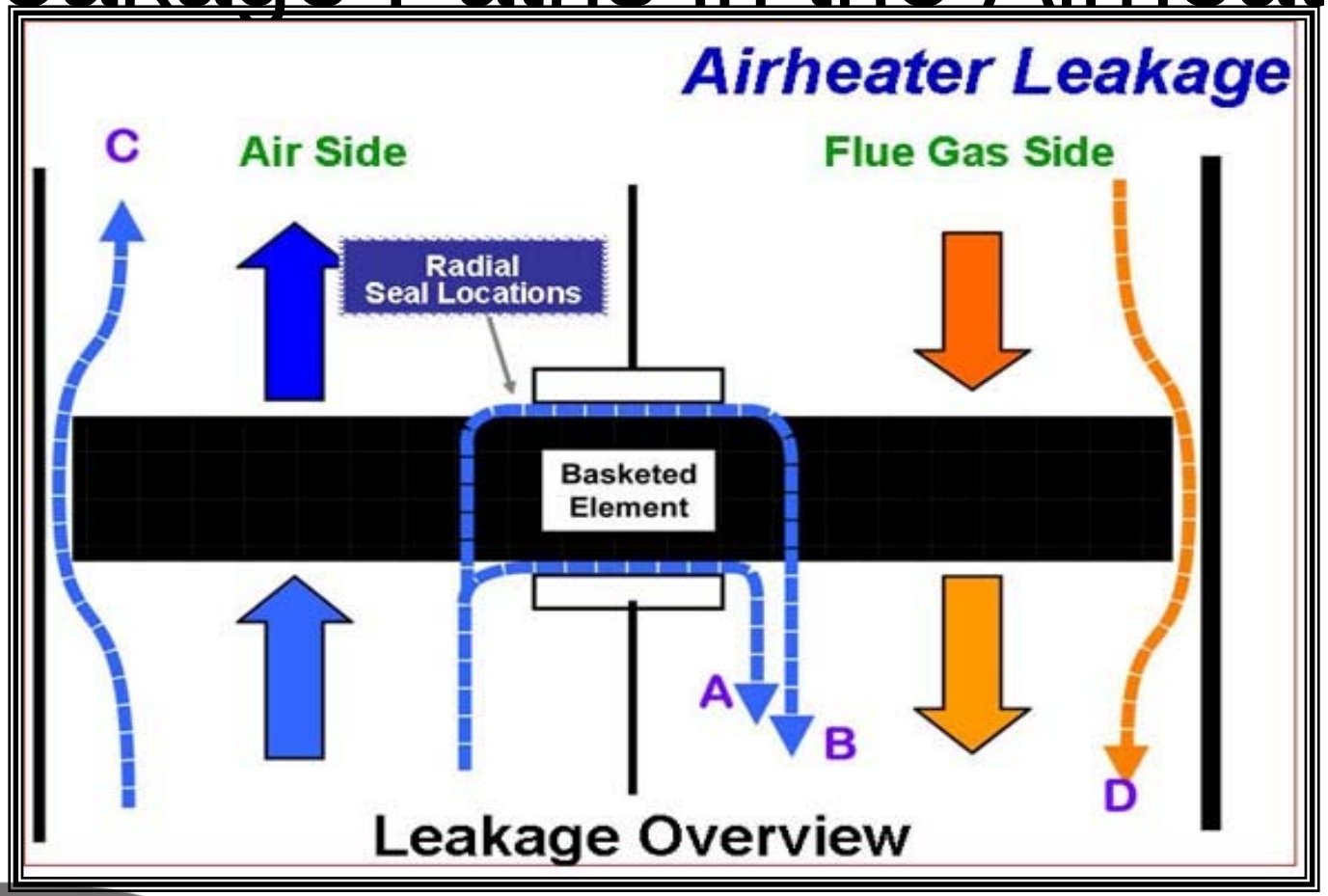
Thermal Turndown

Blue = Cold Condition of Rotor
Yellow = Hot Condition of Rotor

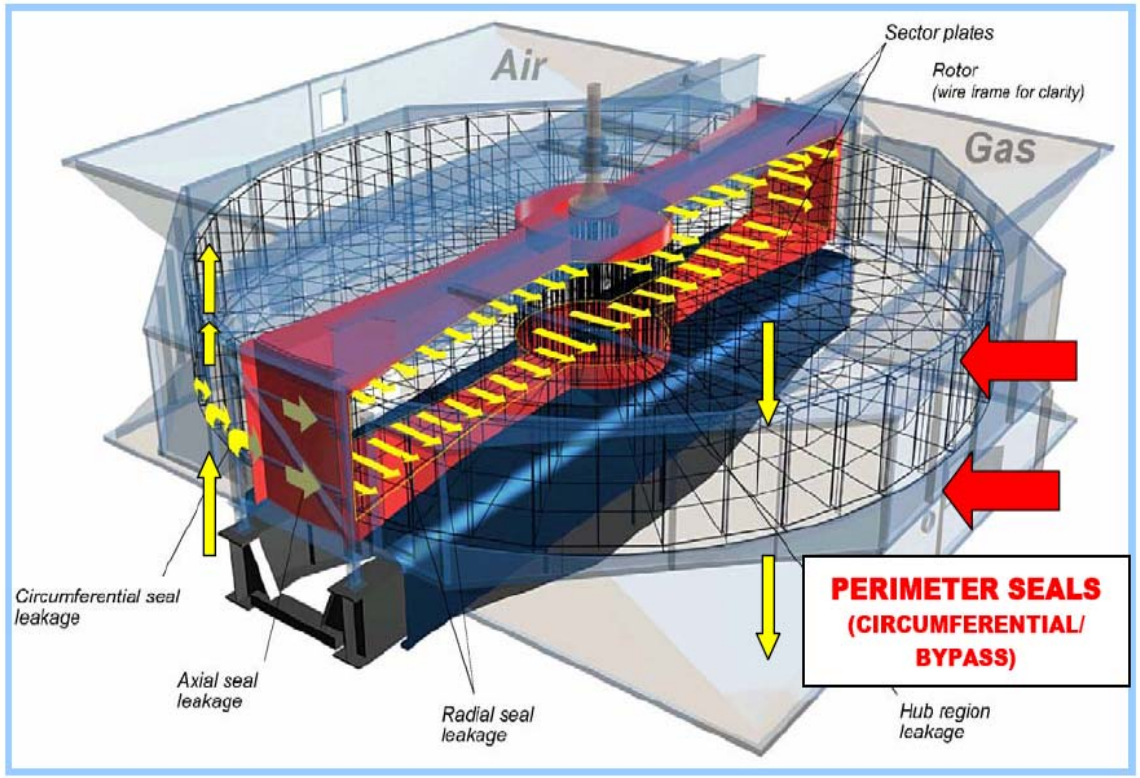


APPENDIX 1
FIGURE 3

Leakage Paths in the Airheater



What is leakage ?



APPENDIX 1
FIGURE 1

Holes / Erosion in
Bypass seals

Figure 6
Standard Circumferential Seal

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Figure 5
DuraFlex Circumferential Seal

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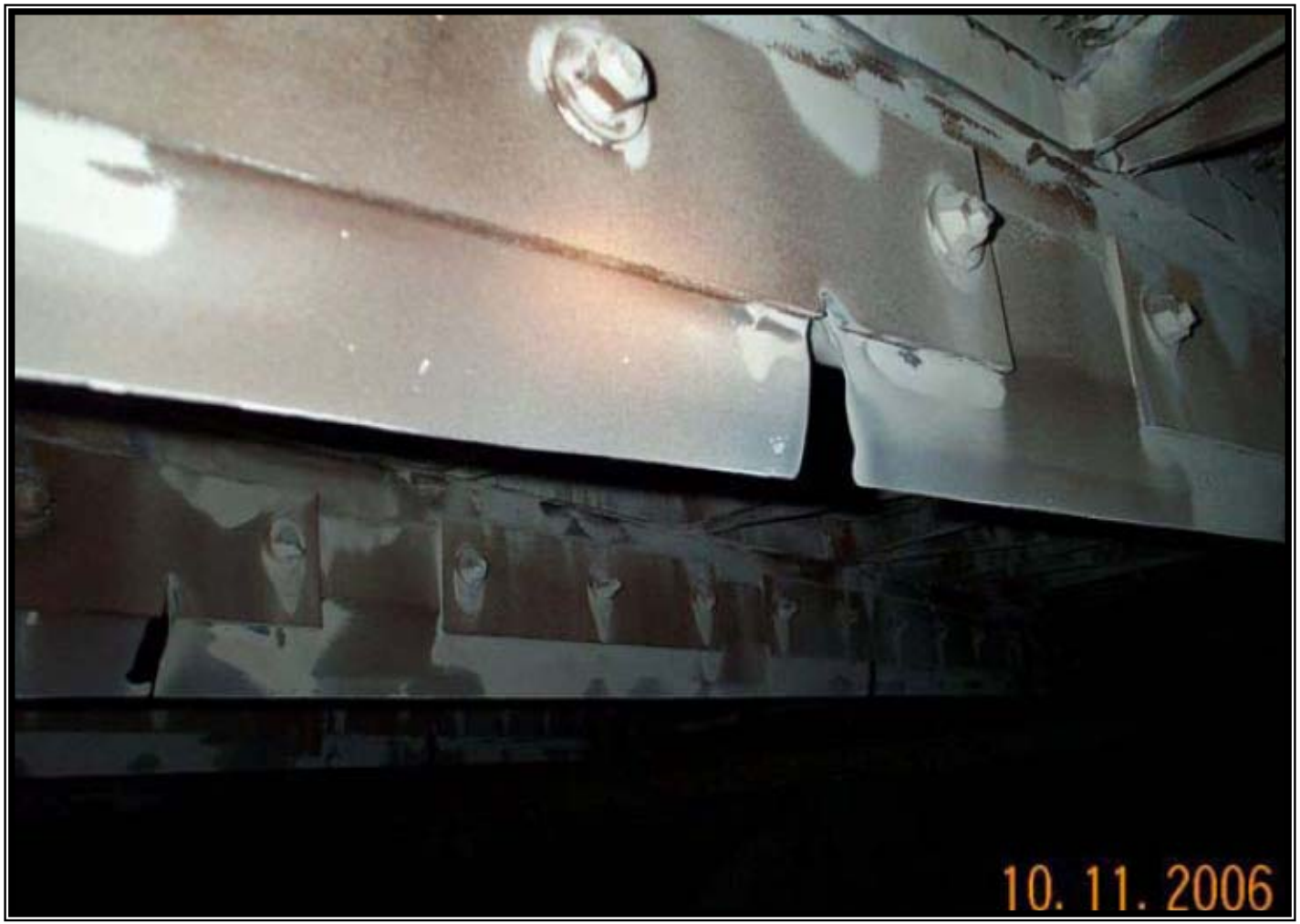

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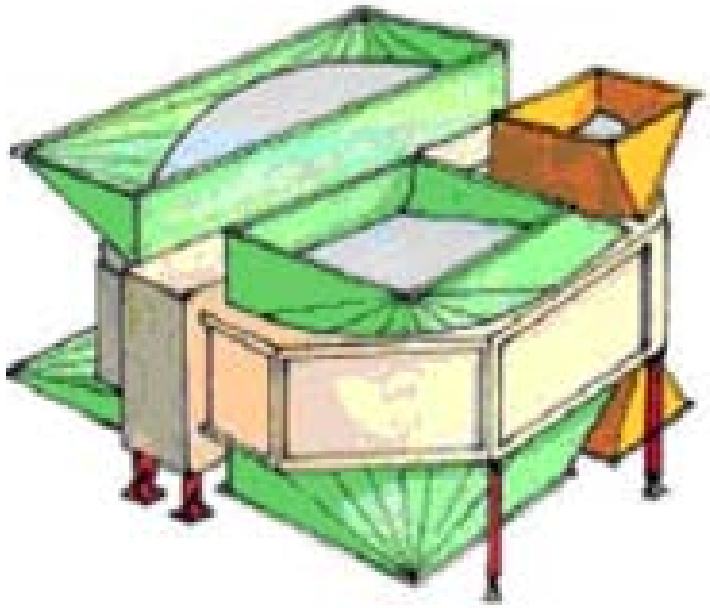
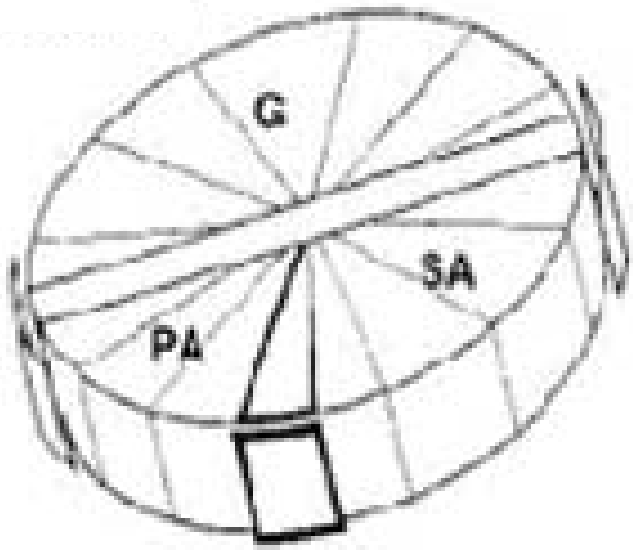
High Performance Radial Seal

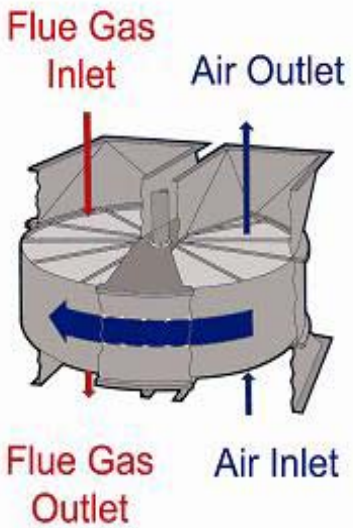
Tri-Sector Air Preheater





COMBUSTION

Combustion Airflow Distribution & Control



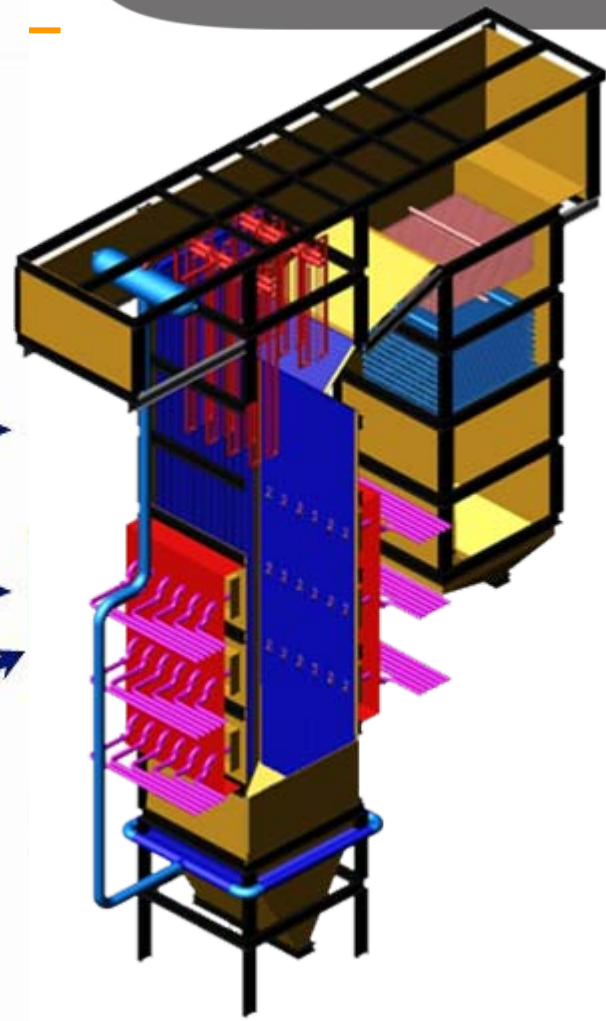
Over-Fire Air
(15 - 20%)

Secondary Air
(55%-65%)

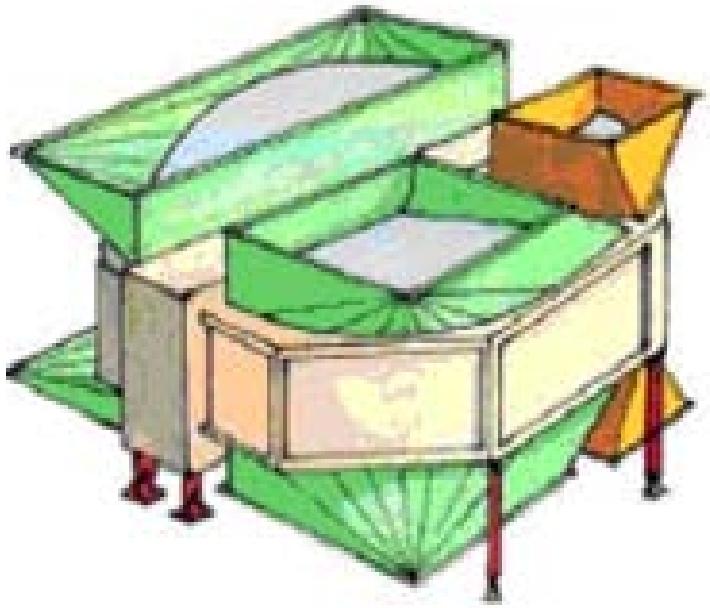
Fuel

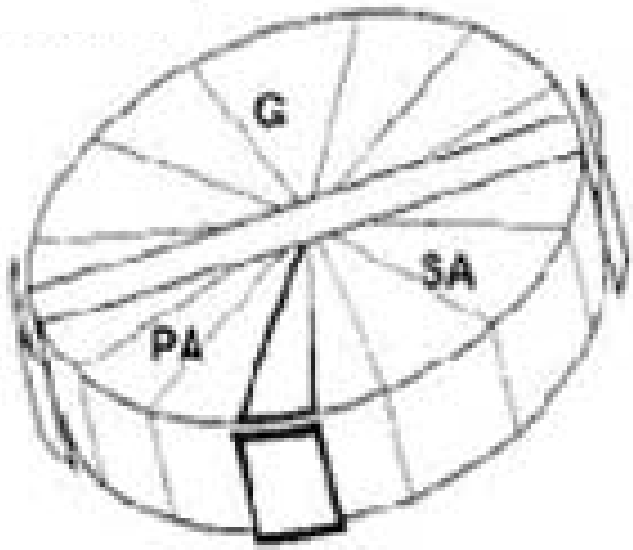
Primary Airflow

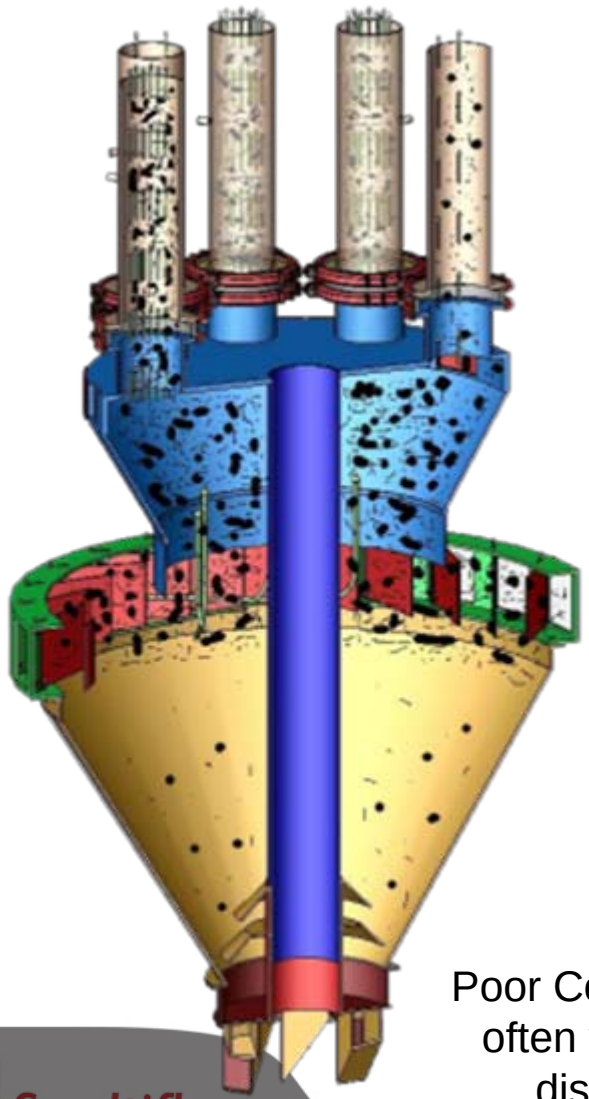
(15%-20%)



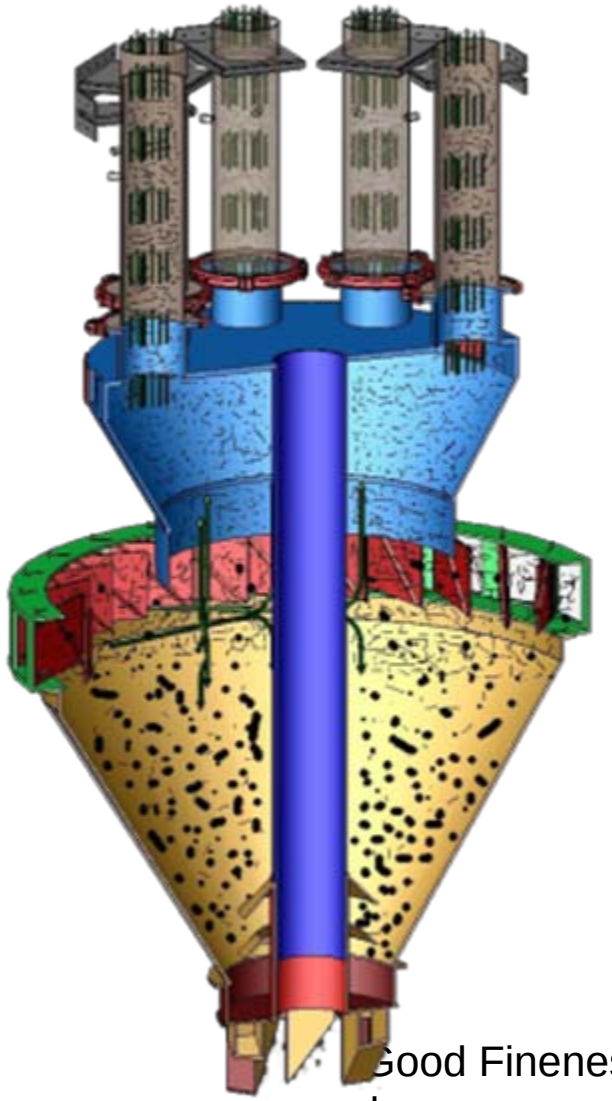
Tri-Sector Air Preheater







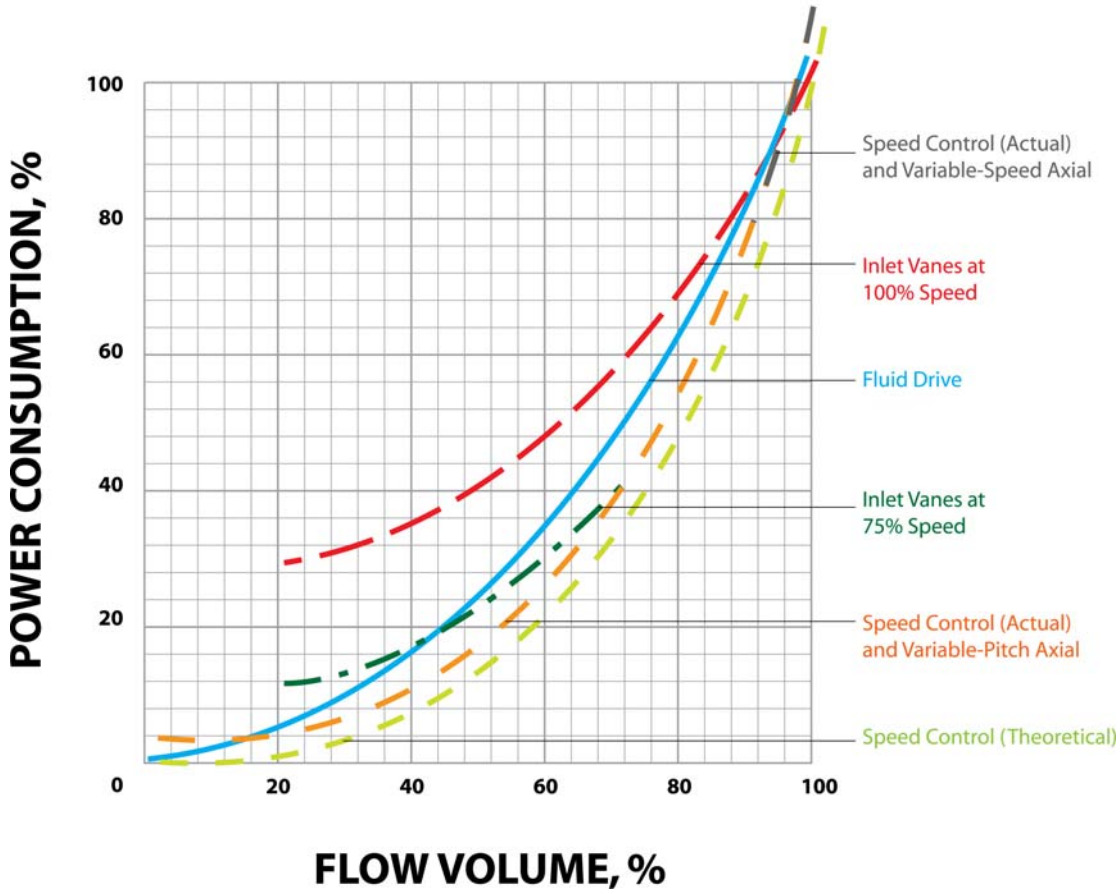
Poor Coal Fineness often yields poor distribution



Good Fineness Creates a homogenous & balanced mixture

Smaltiflex dal 1963

Power Consumption vs. Volumetric Flow



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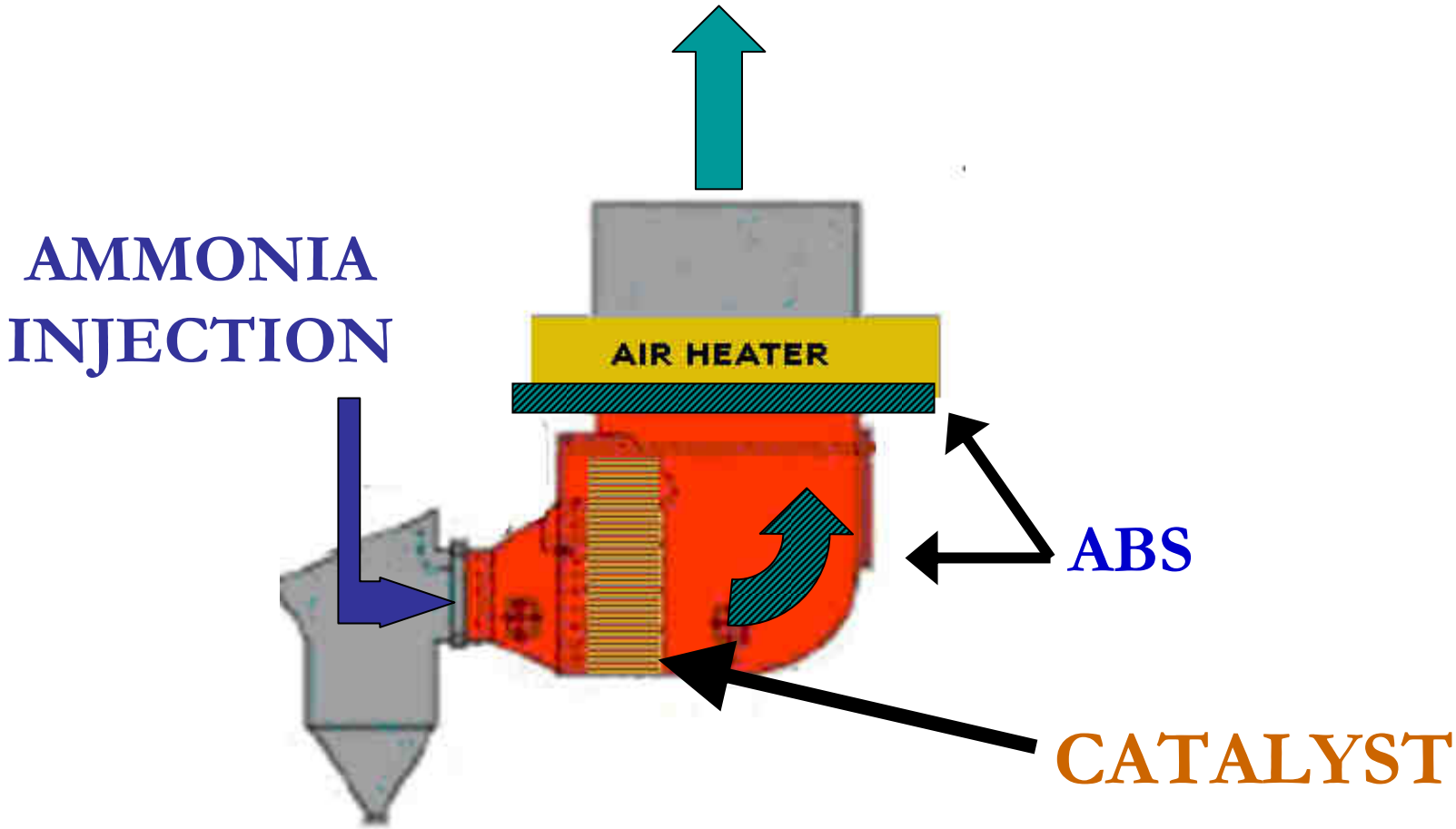
ABS

ABS FOULING AND CORROSION

SCR in Relation to Air Heater

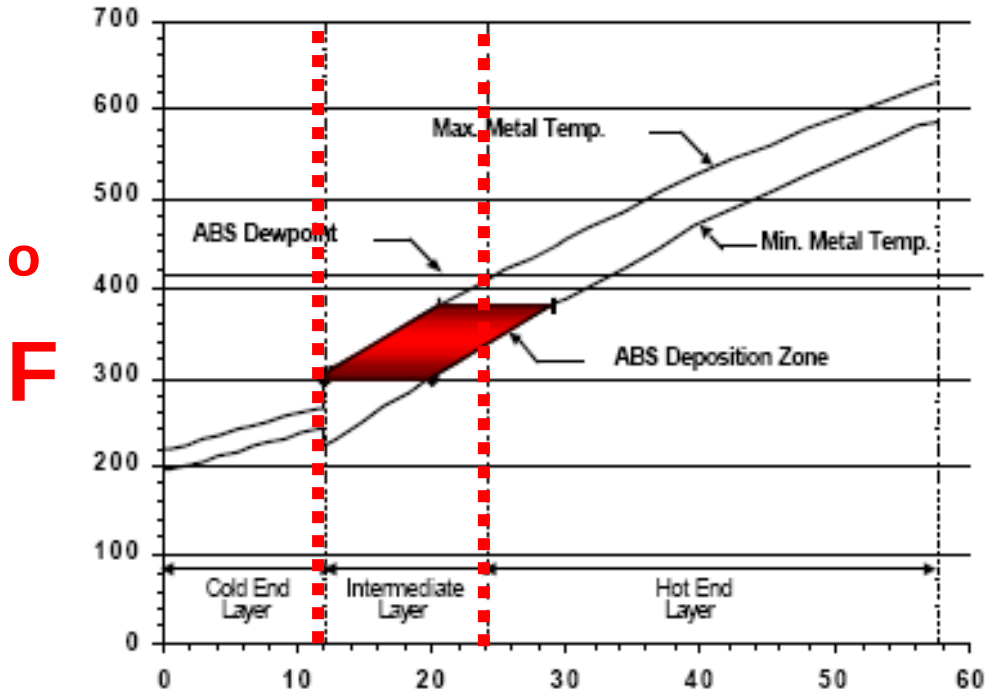


Formation of Ammonium Bisulfate

$$NH_3 + SO_3 + H_2O = NH_4HSO_4$$

ABS Buildup at Precipitator Inlet

ABS Temperature Zone



°F

DEPTH OF ELEMENT

ABS

12 INCHES TO 30 INCHES

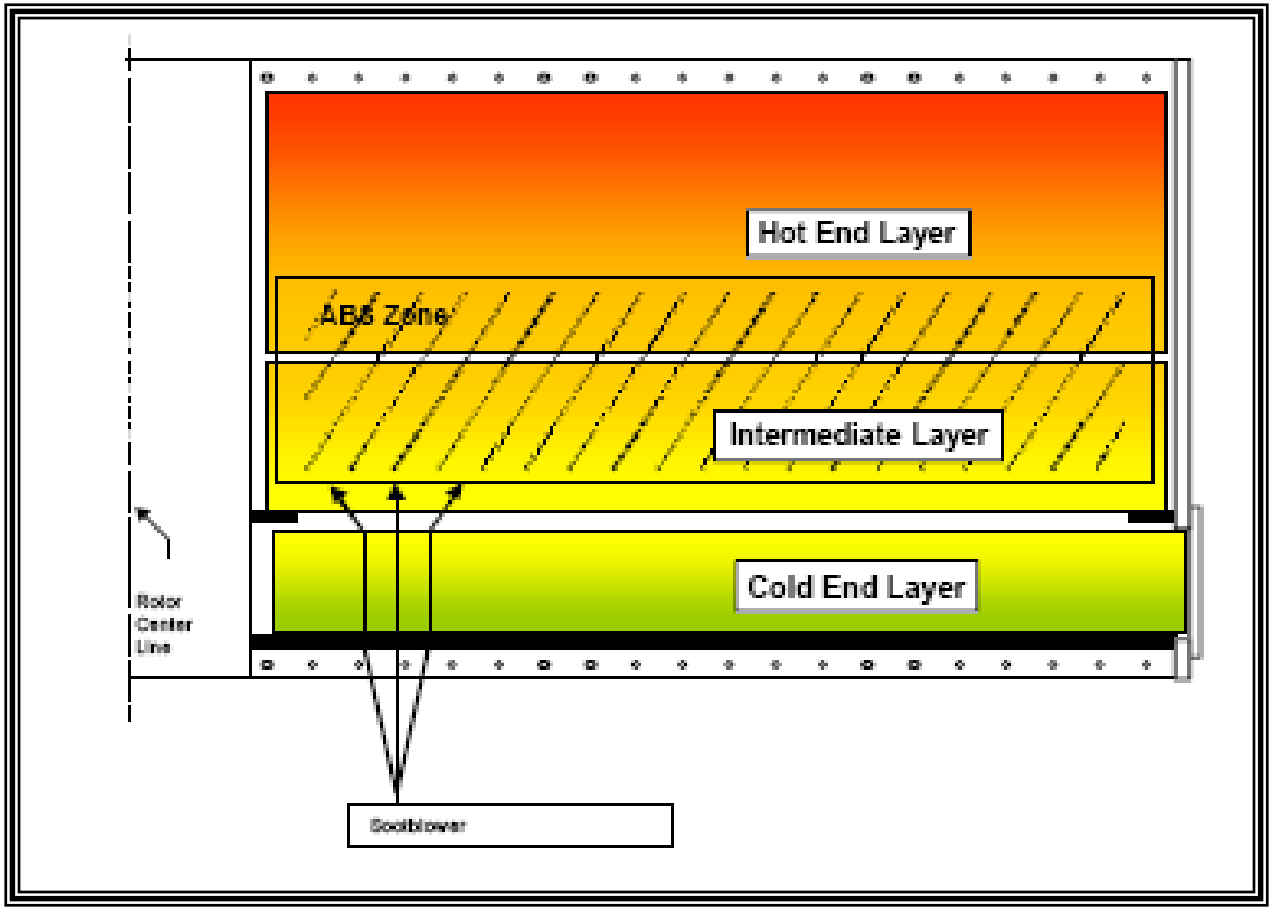
300°F TO390°F

Cost Penalty Attributed To ABS Buildup In Air Heaters

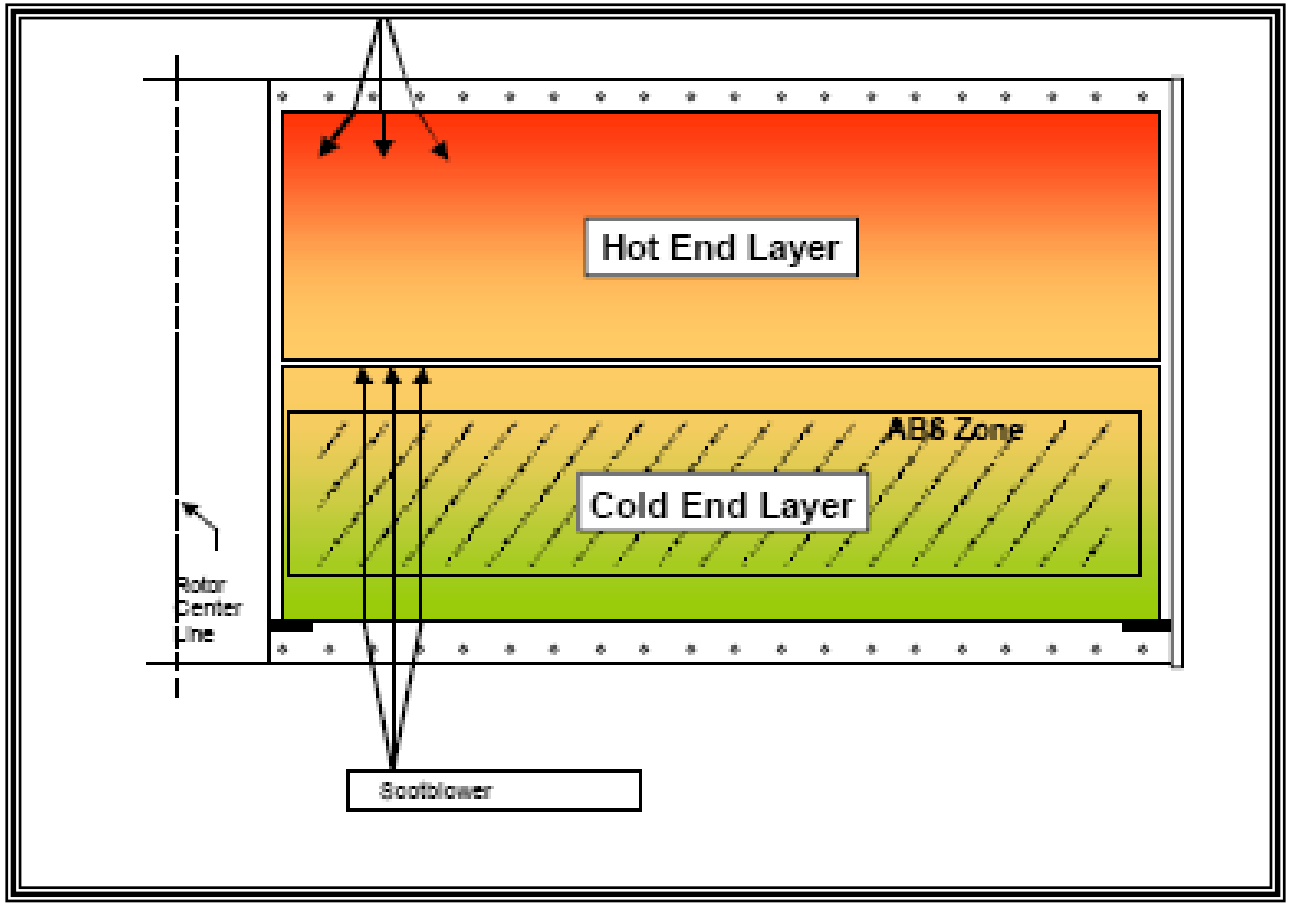
500 MW Coal Unit

Parameter	Quantity	Annual Penalty
Increased Pressure Drop	4 inches H2O	$ 198,000
Gas Outlet Temperature Increase	10°F	$ 217,000
Water Wash Outages	12 days/yr	$ 5,760,000
Increased Leakage in Radial Seals	3%	$ 63,000
Increased Circumferential Seal Leakage	5000 ACFM	$ 95,000
Total Penalty		**$ 6,333,000**

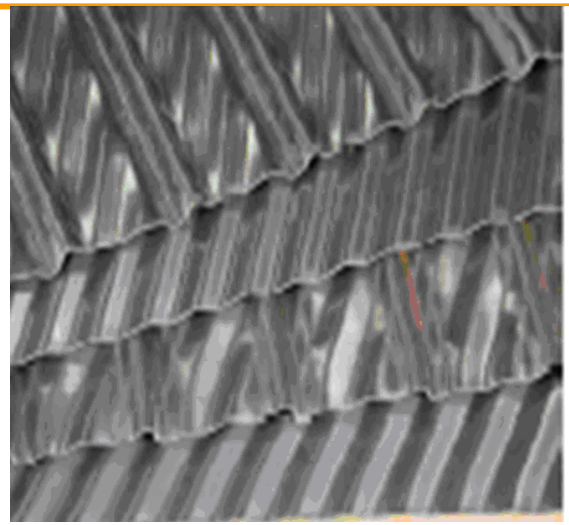
ABS Build-up Zone in Traditional Airheater Layers



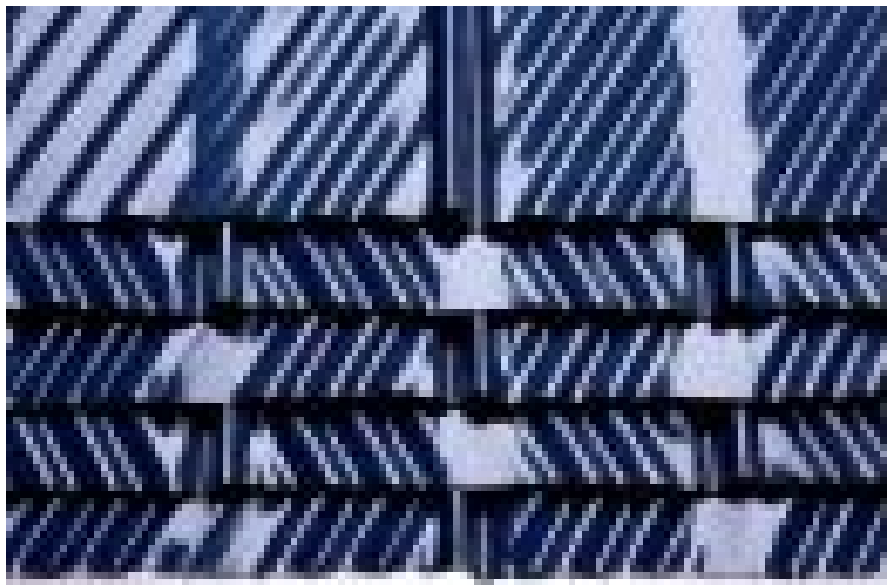
ABS Build-up Zone in Two Layer Airheater Modifications



STANDARD



ABS STYLE



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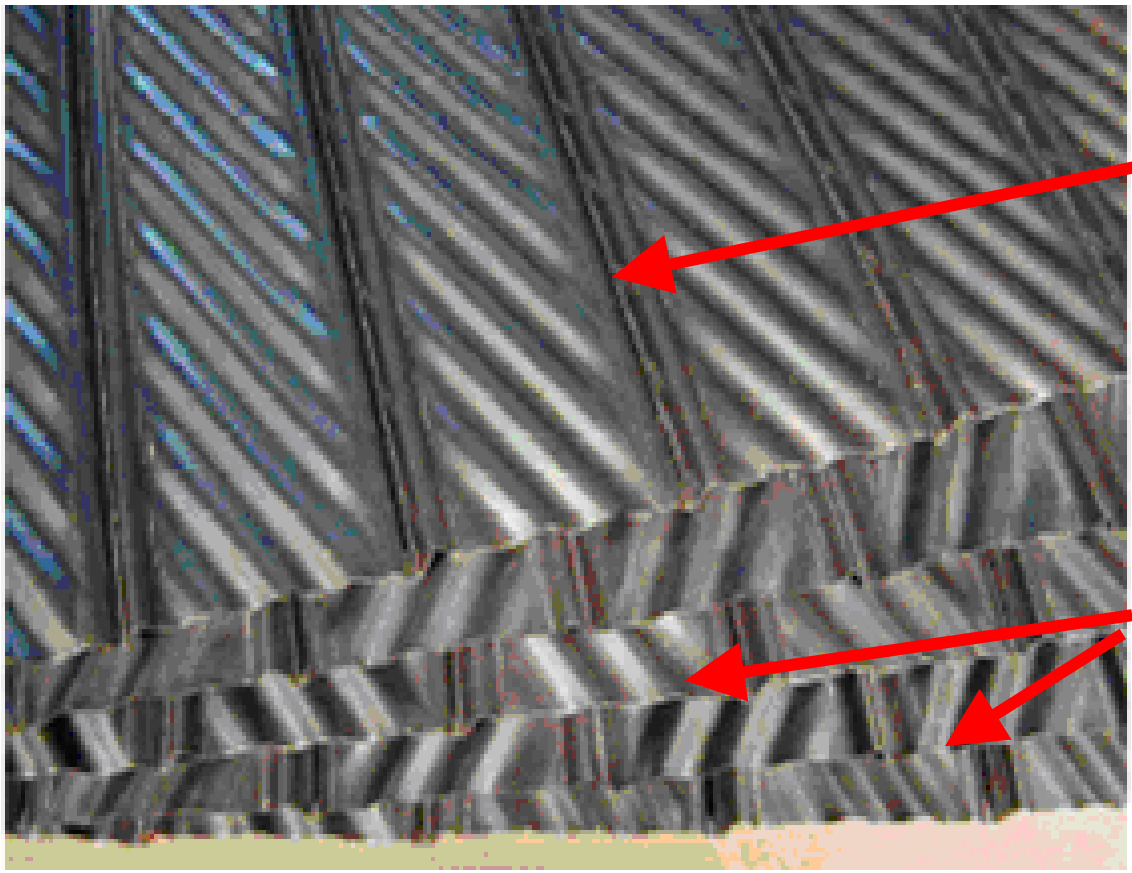
Element Substitute



TWO LAYER COLD END DAMAGE

TWO LAYER COLD END DAMAGE

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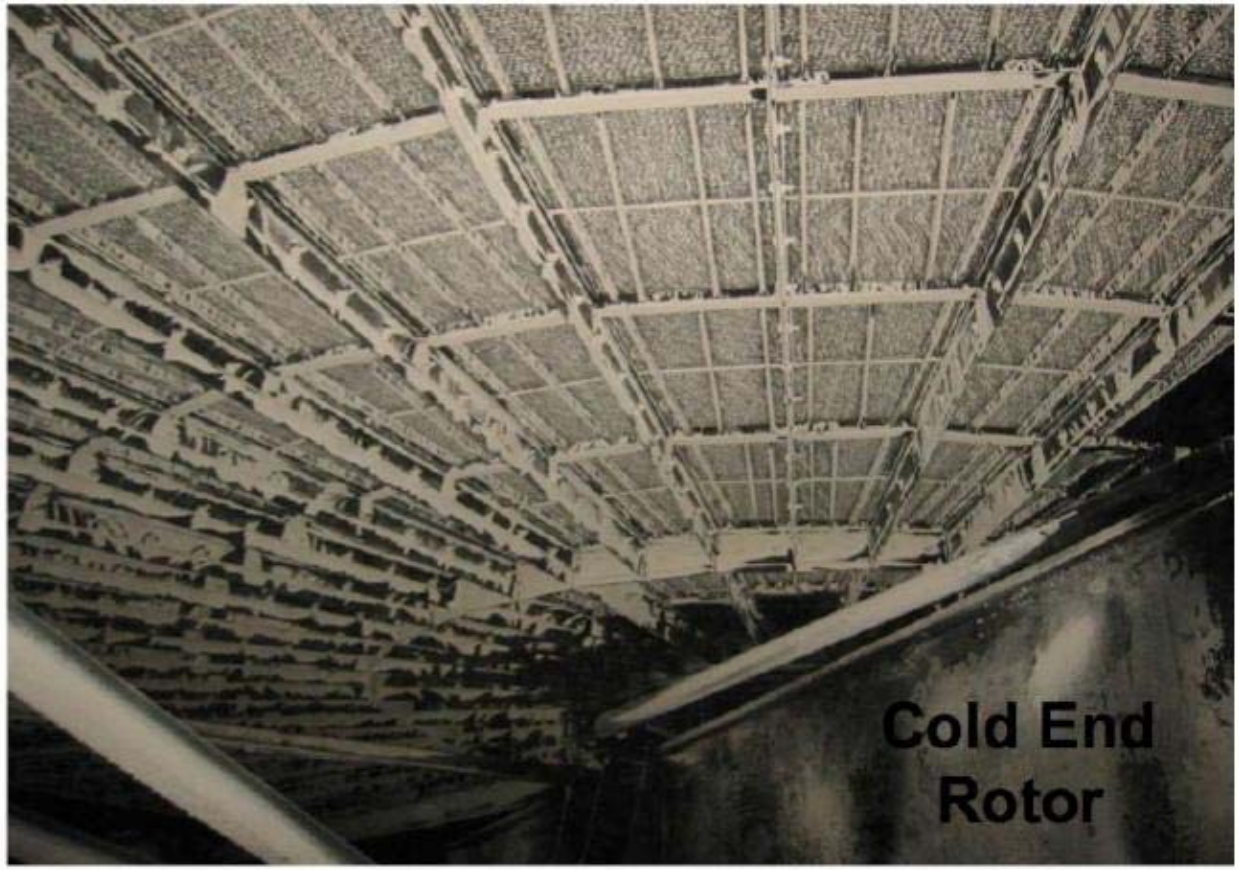
CONDENSATION DEPOSITS



TWO ABS ELEMENT STYLES

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COLD END WATER WASH HEADER

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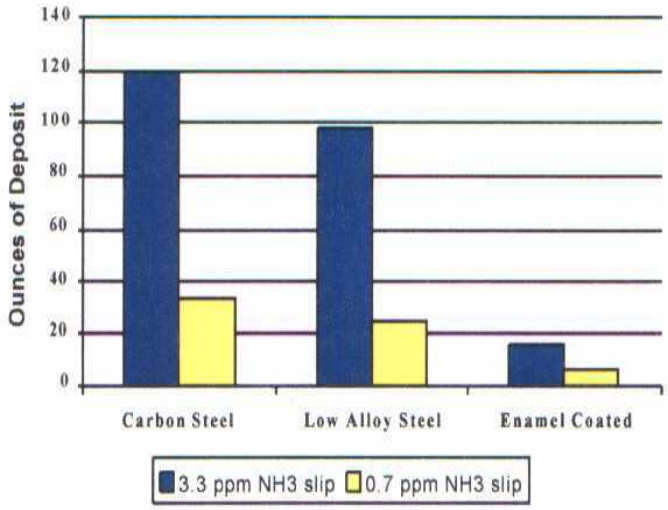
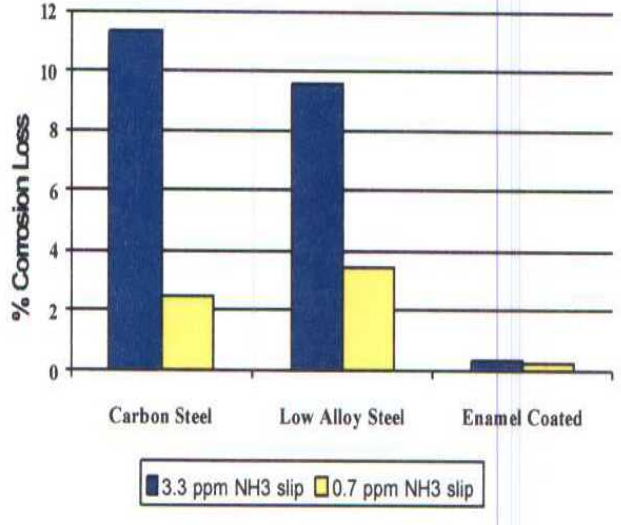
ABS

COATINGS TO CONTROL ABS FOULING AND CORROSION

Benefits of Corrosion Resistant and Lubric Coating in the ABS Zone





Copyright 1999, Louis Boundyrant “SCR Compatibility of the Ljungström® Air Preheater. The technical info represented in the graphs are not associated or endorsed by Louis Boundyrant

Problems with Current Coating Systems

BRITTLENESS

- Enamel class coatings are mostly glass
- Enamels crack easy under stress
- Compression of basket assemblies leaves micro-cracks.
- Stresses in Rotation of Horizontal units cause additional cracking
- Micro-cracks leave paths for acids to attack substrate.

CORROSION

- Enamel class coatings are melted onto substrate at 1500+F
- At 1500F carbon in steel will burn and produce CO2 bubbles – causing voids
- Enamel is used over a specific steel called Enameling Iron with almost no carbon
- Enameling Iron corrodes very rapidly in sulfuric acid
- Enameling iron is brittle after forming – stress cracking failures can occur

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“NEWER” Coating

ELEMENT CRACKING FAILURES MOST LIKELY DUE TO CORROSION UNDERMINING THE COATING AND NON-DUCTILE METAL SUBSTRATE FATIGUE FAILURES

Failed Coated Element Showing Substrate Failure

THE USE OF A FORMABLE CORROSION RESISTANT SUBSTRATE IS CRITICAL TO SUCCESS

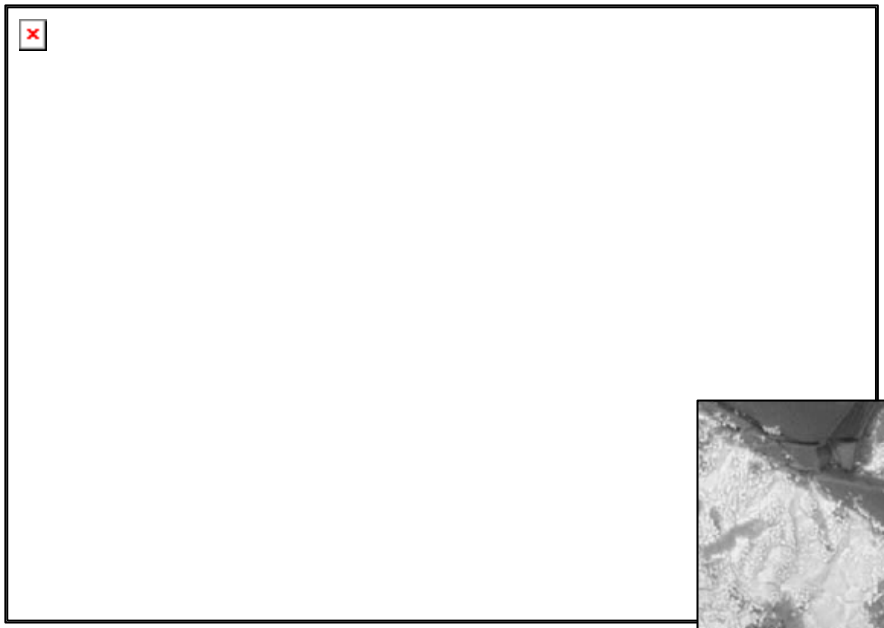
Failed Coated Element Sheets with Substrate Failure Station

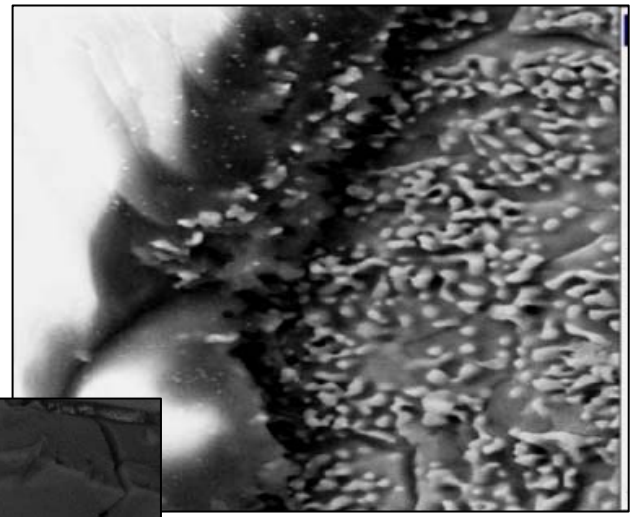
Enameling Future – No-Stick

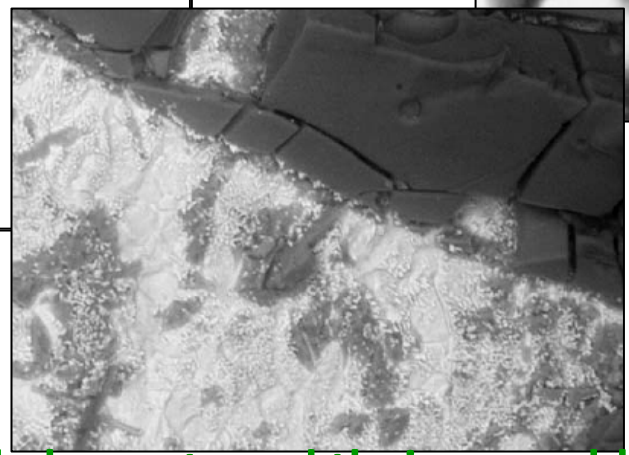
Why NO-STICK ENAMEL should be strategic?

Example of basket containing elements coated by standard enamel. The concretion formed into the heat exchanging channels reduce the efficiency of the heat exchanger.

A Vision to the future of
Enameled Heating Elements



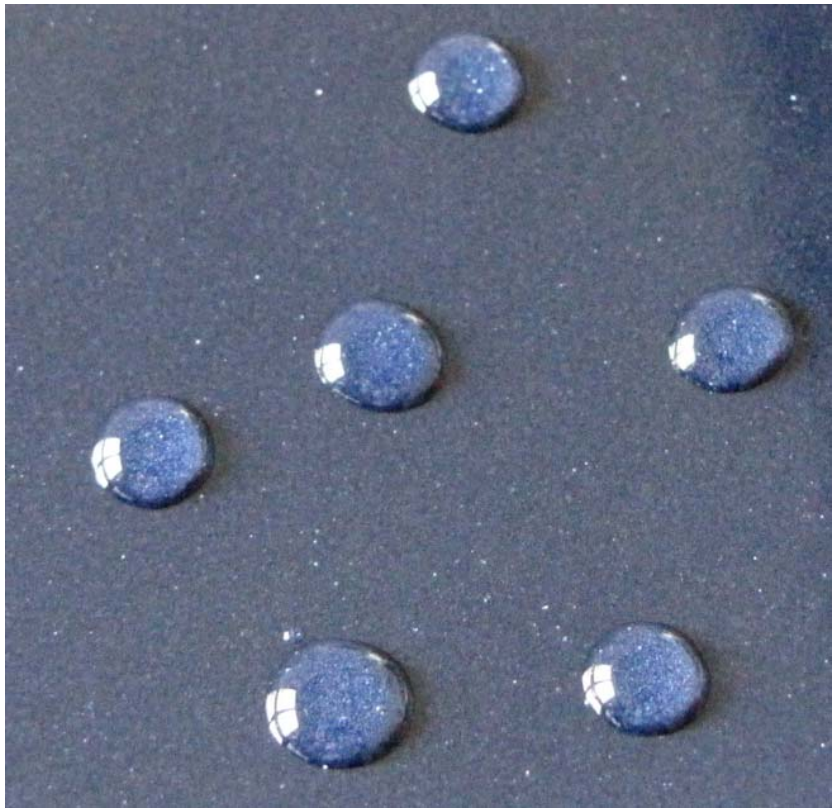




Vitreous enameled elements and their assembling into baskets

Enameling Future

Recent advances on enameled elements



- **Self-repairing enamel coating to increase the coating reliability**
- ***"Non Stick"* enamel to reduce the surface wetability**

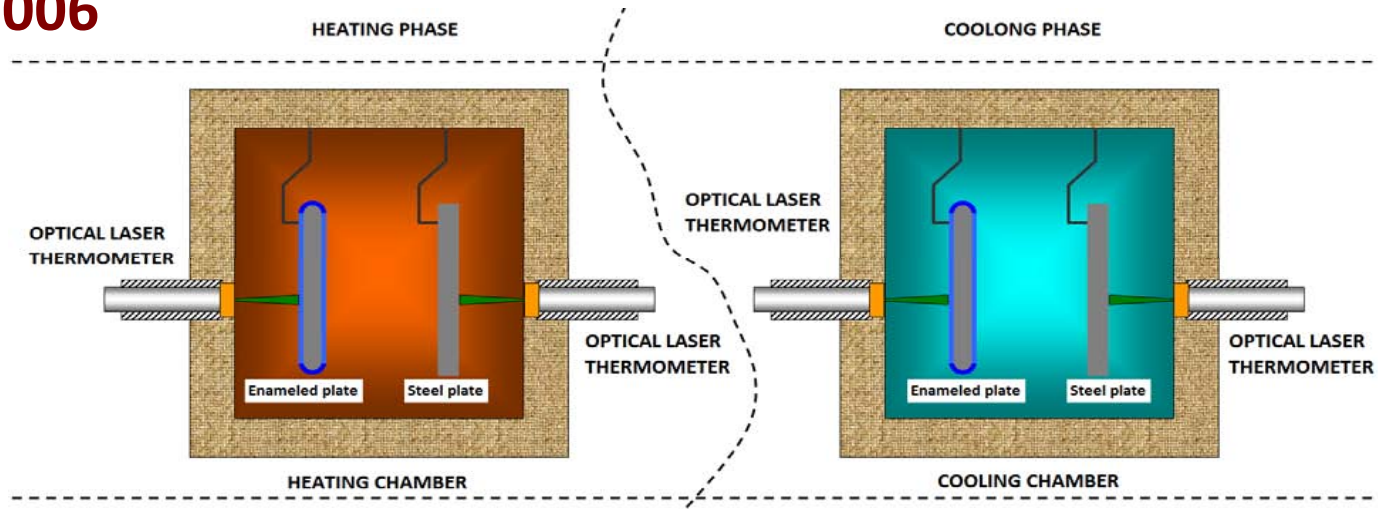
Enamel Coating Overview

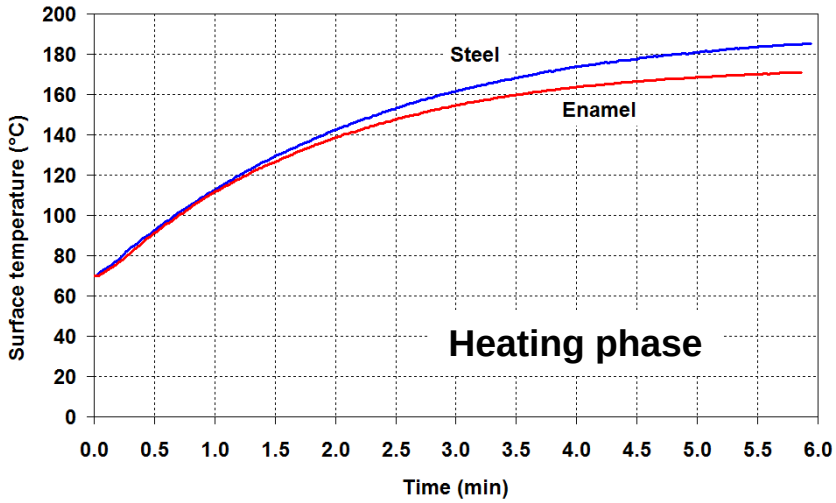
What it is ?

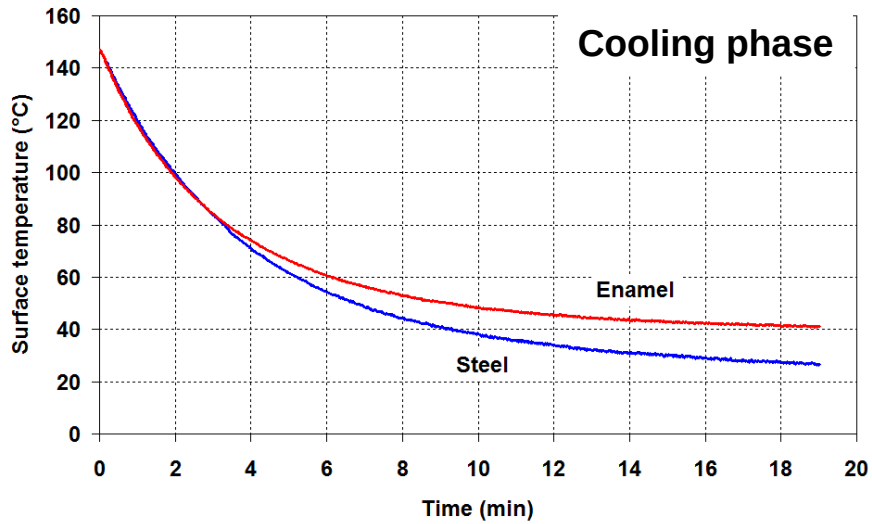
Vitreous enamels are inorganic coatings for metals obtained by a special ceramic-vitreous matrix in which specific additives could be dispersed to form the coating and/or its surface.

Heat Exchanging Capability

Test: SM006







Metals for vitreous enameling process

Metal significantly contributes to the quality and reliability of enameled product.

The following characteristics must be considered:

- **metal composition**
- **metal metallographic structure**
- **metal pre-treatment before enameling**

Enamel Coating Overview

Metals for vitreous enameling process

In principle all metals can be coated by a boron-silicate based material

however

the metal and frit must be chemically and physically compatible at different temperatures.

The first examples of metal enameling was gold and silver jewelry made 3500 years ago in Egypt. Nowadays the enameling technique has been extended also to aluminum steel, cast iron and to iron steel in general. The basic fact is that the available industrial frits (frits that are standardized by the producers) are designed for specific types of metals. To obtain good product quality **using industrial frits** the **metal substrate has to respect specific standards:**

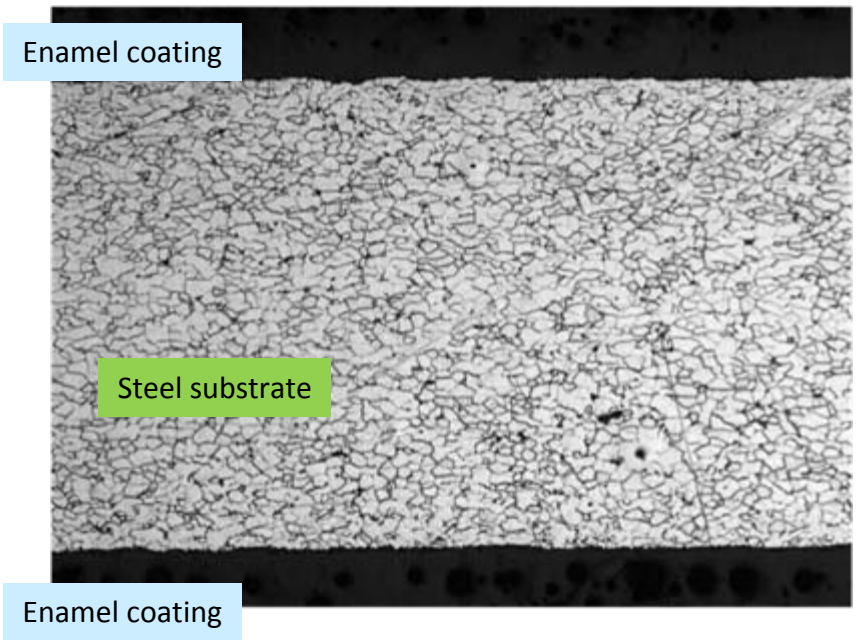
- chemical composition
- metallographic structure

Enamel Coating Overview

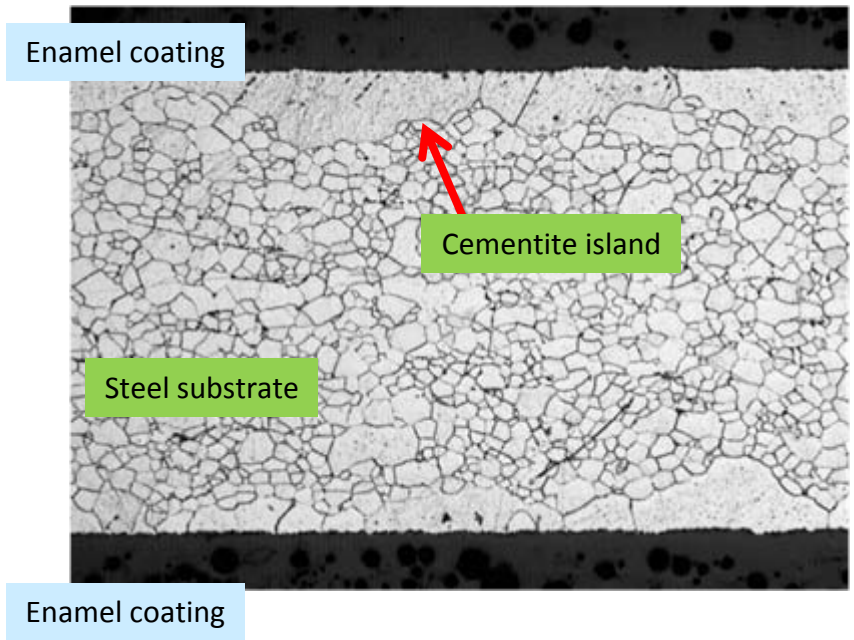
Metals for vitreous enameling process

Steel structure:

Good microstructure and good interface quality



Bad microstructure and bad interface quality



Transversal micrograph of two enameled sheets of low-carbon steel from different suppliers

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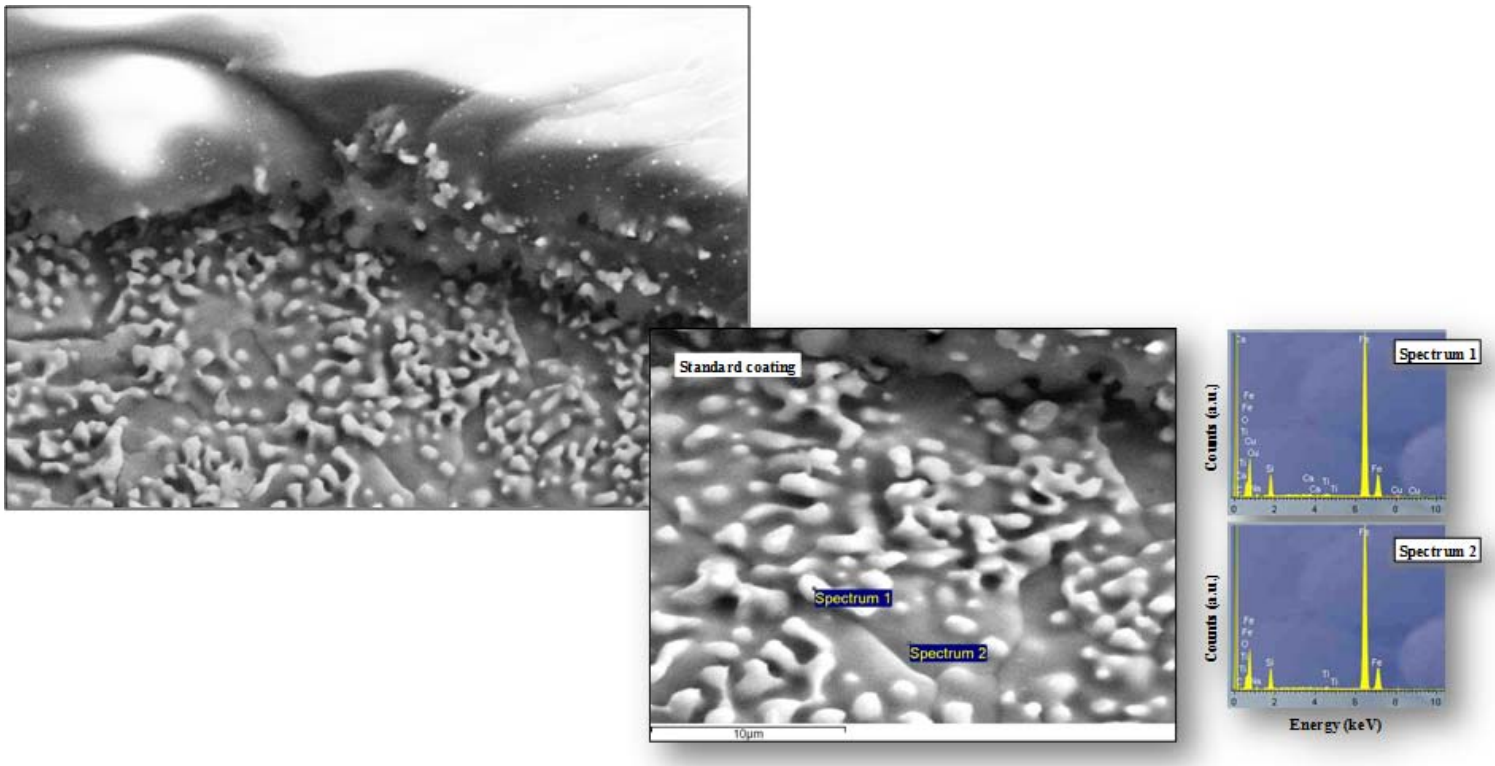
Enamel – steel interaction during firing

Dendrites



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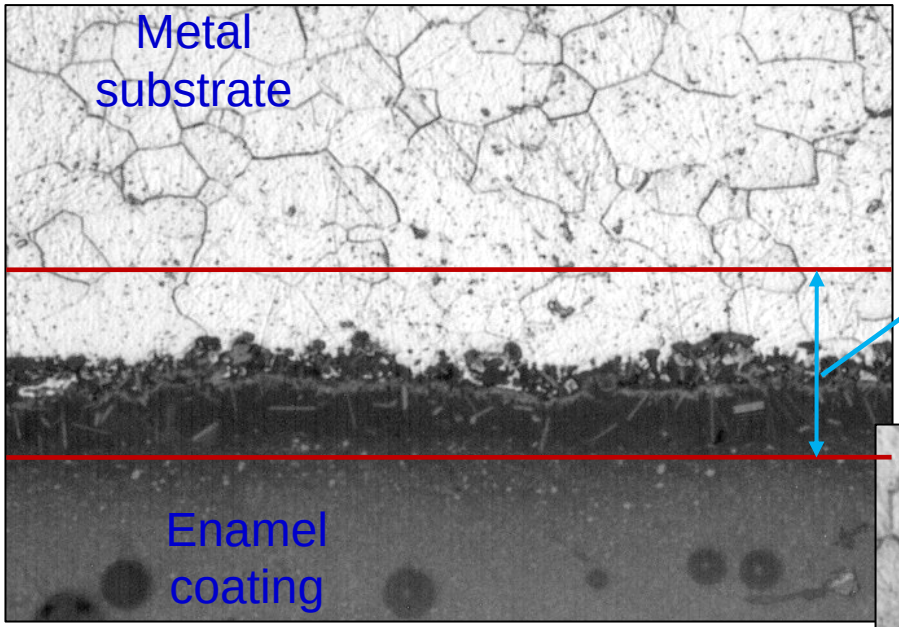
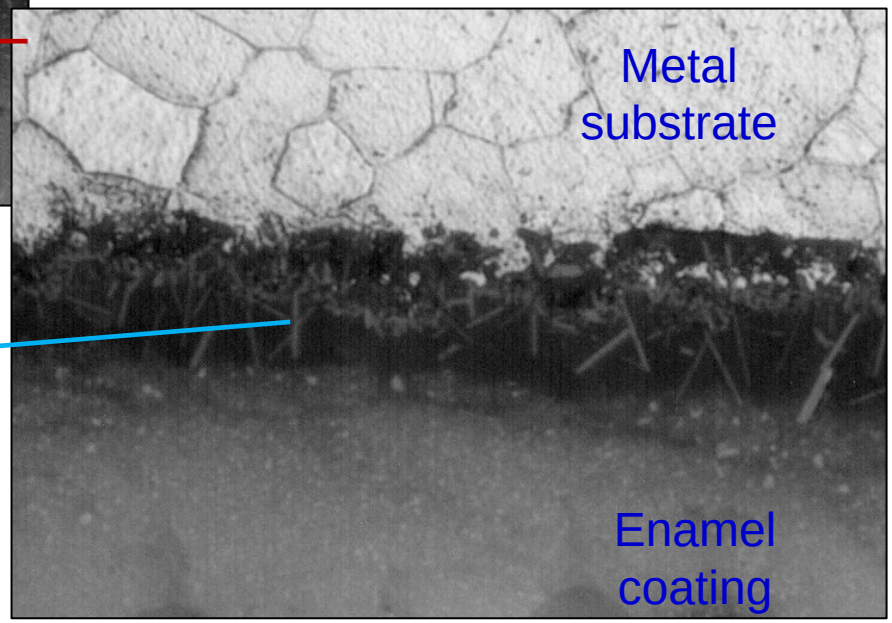
Enamel Coating Overview

Enamel – steel interaction during firing



Interphase between metal and enamel coating

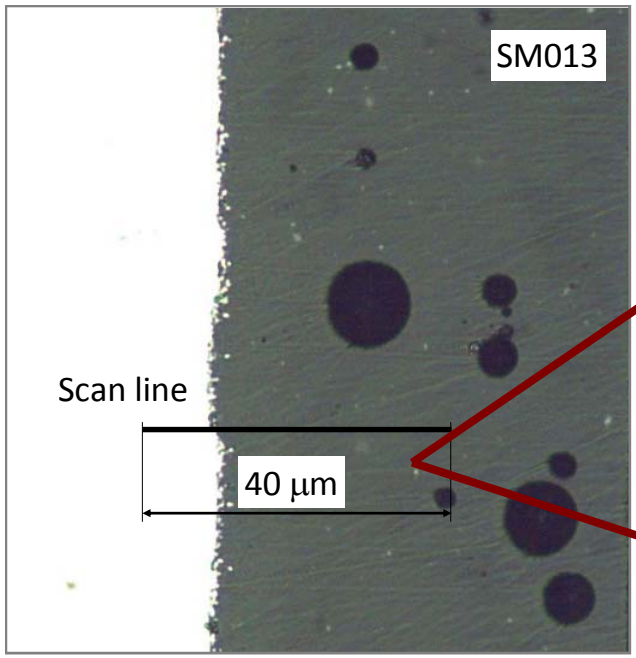


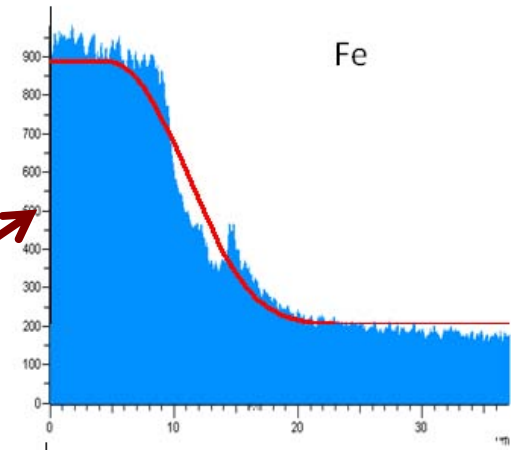
Dendrites

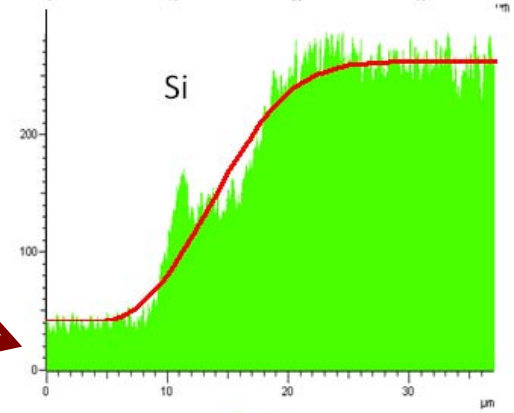
Enamel – steel interaction during firing

Energy Dispersive X-ray analysis

EDX has applied to investigate the element distribution at the interface area.



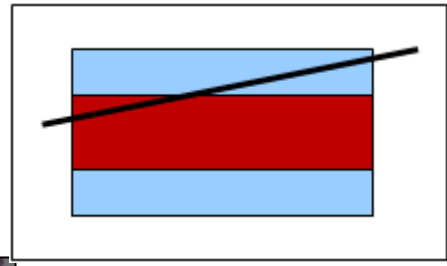




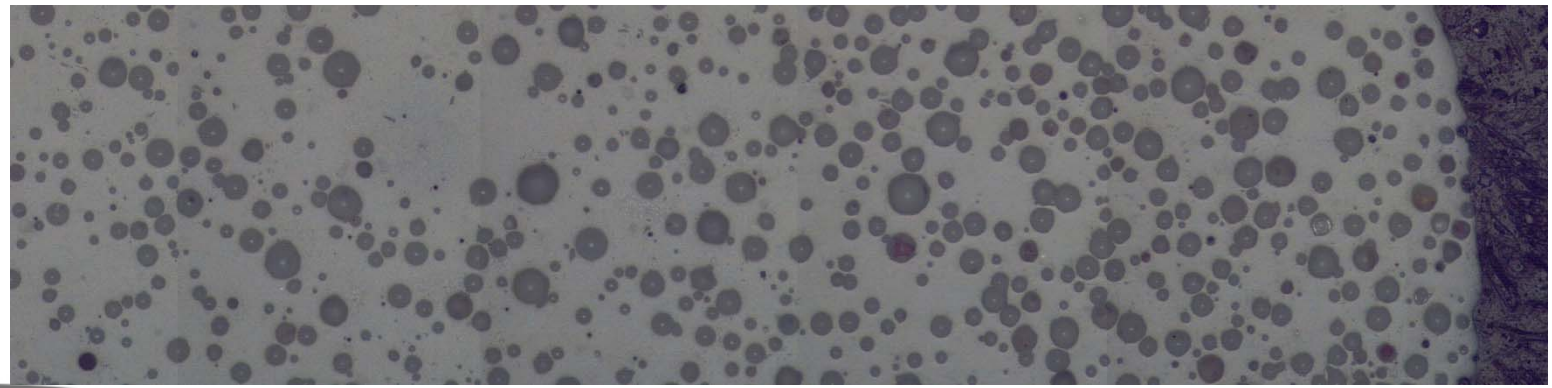
Enamel Coating Overview

Enamel – steel interaction during firing

Enameled steel: a functionally graded material



Steel **Enamel coating**



Enamel coating **External face**

Enameling Future – Self Repair

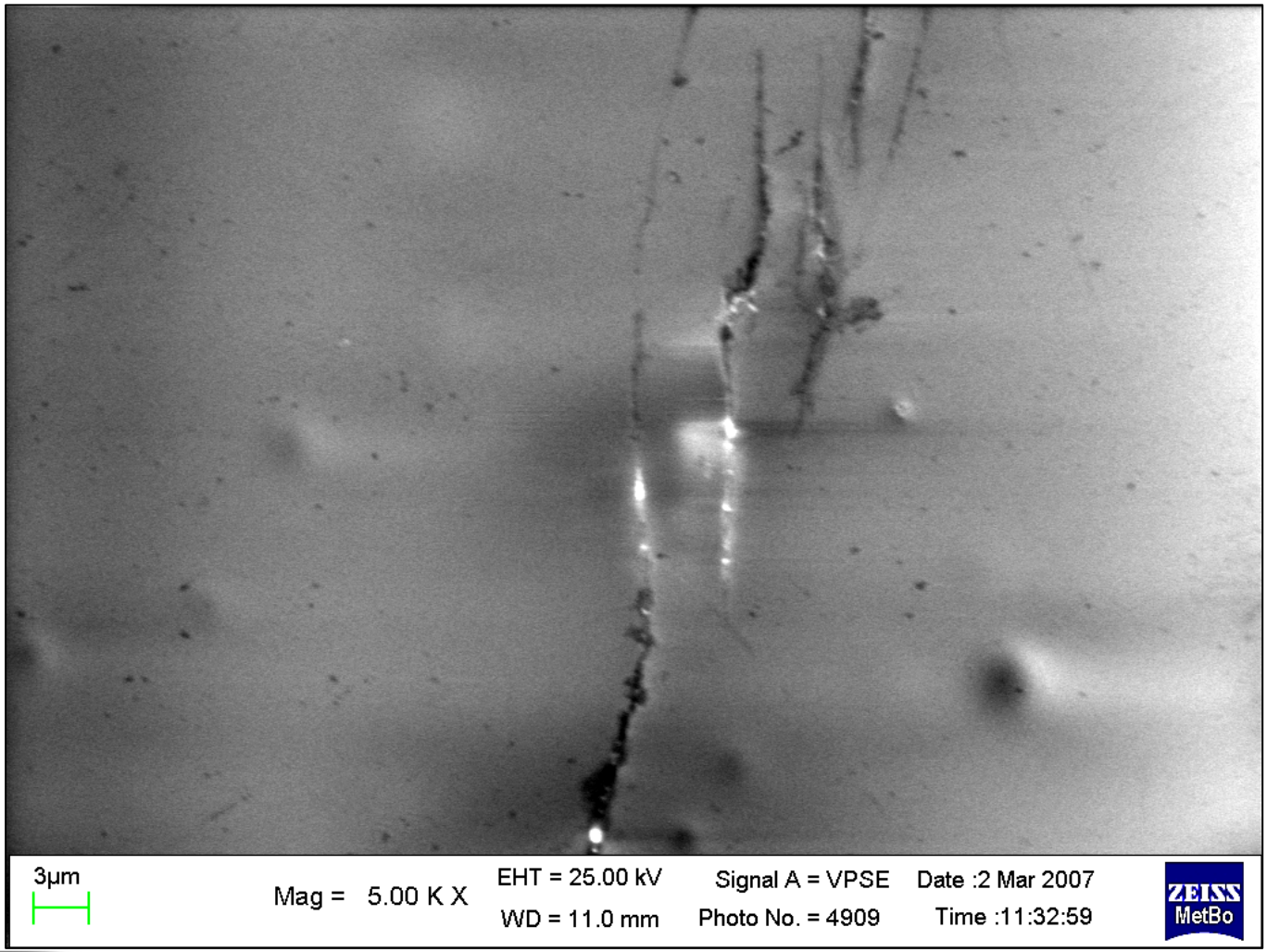
Why coating can fail?

- **In-adequate enamel composition can mean**:
  - Cracks during elements assembly of baskets
  - Deep crack propagation during service
  - excessive loss of weight during service

- **No enamel adherence to the metal can mean**:
  - coating detaching during basket assembly
  - loss of part of the coating during service

Our objective is to obtain a new enamel coating able to guarantee higher mechanical performances and higher adhesion in comparison to standard enameling

A - Self-repairing enamel coating to increase the coating reliability



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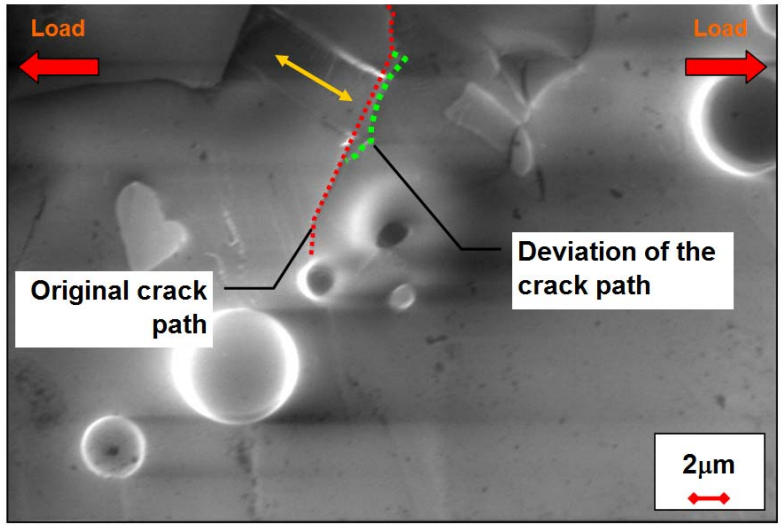
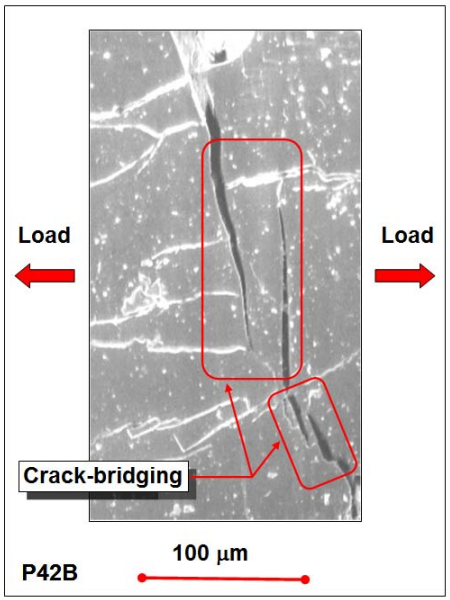
Enameling Future – Self Repair

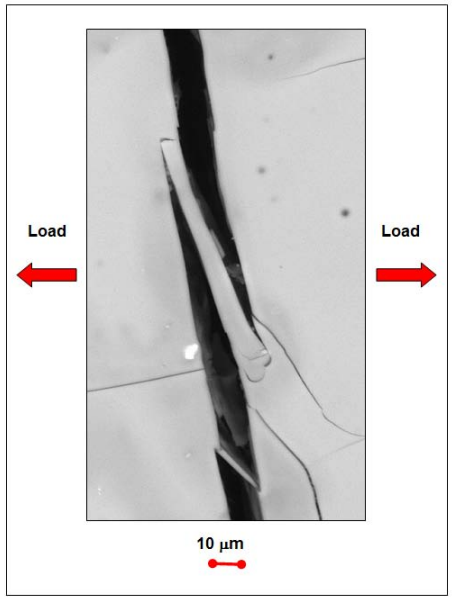
Self-repairing mechanisms:

Crack shifting



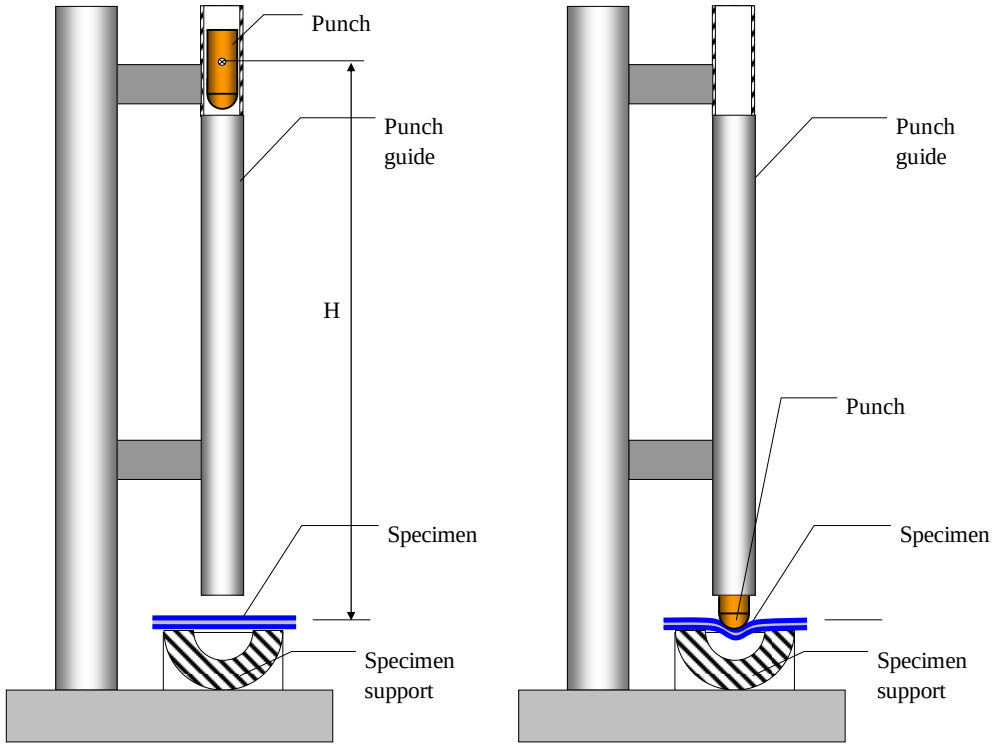
Crack bridging

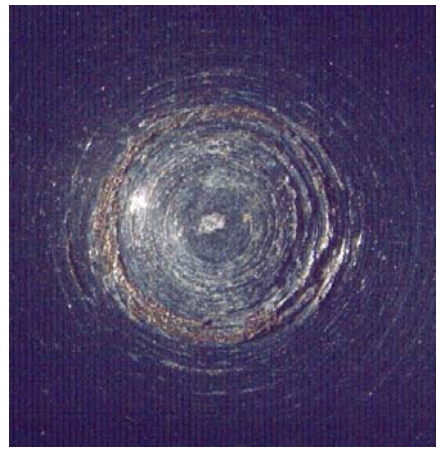




Quality Assurance

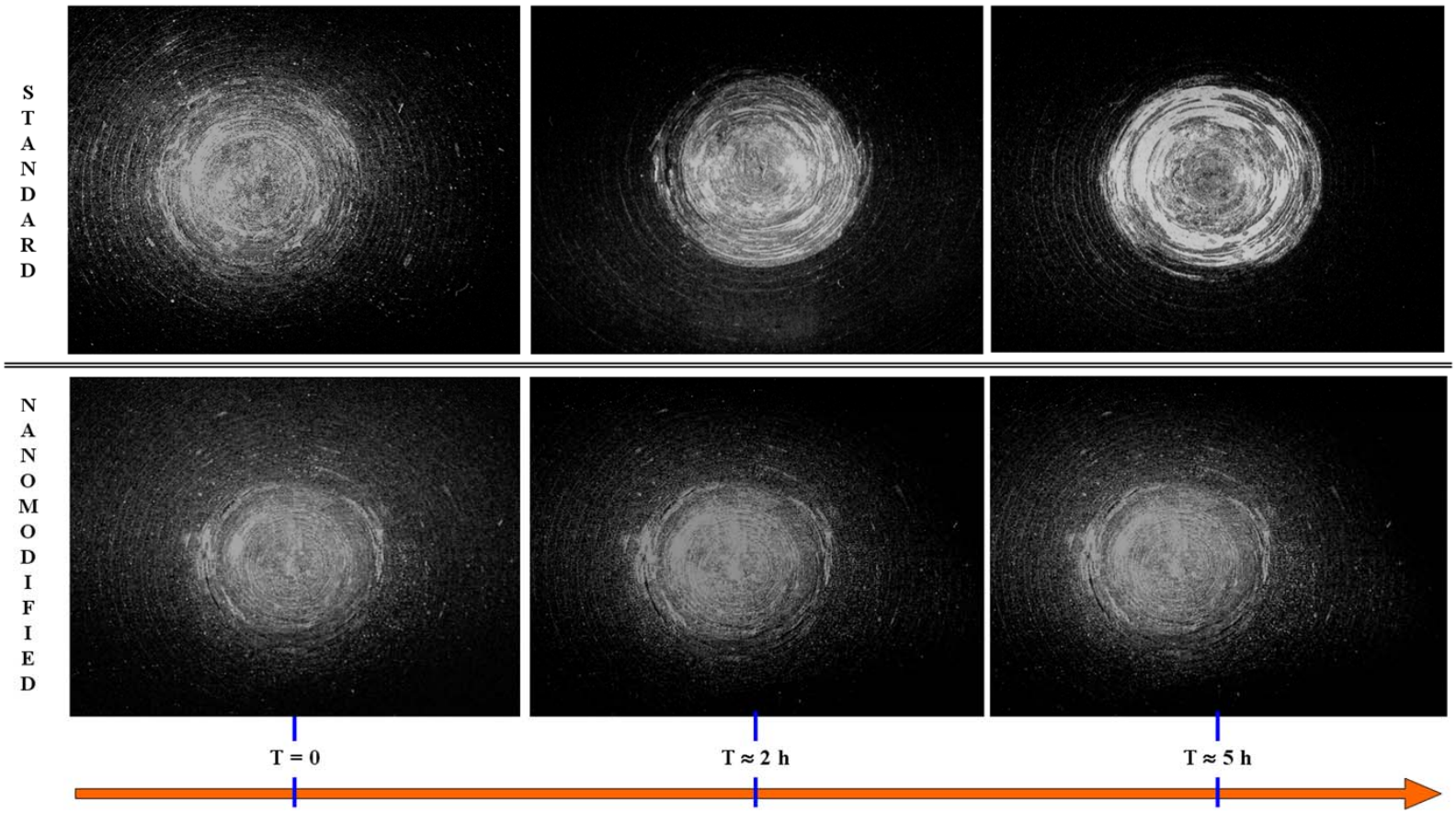
Adherence of the enamel coating to the metal substrate





Enameling Future – Self Repair

A - Self-repairing enamel coating to increase the coating reliability



Adherence test

Residual stresses

Since **enamel coating** is a glass-brittle material, and it almost always fails in tension, enamels **are designed to be in a state of compression with respect to the metal on which they are applied**.

This is accomplished by compounding the enamels so that they have a lower overall thermal contraction and expansion than metal.

Enameling Future – "Non-Stick"

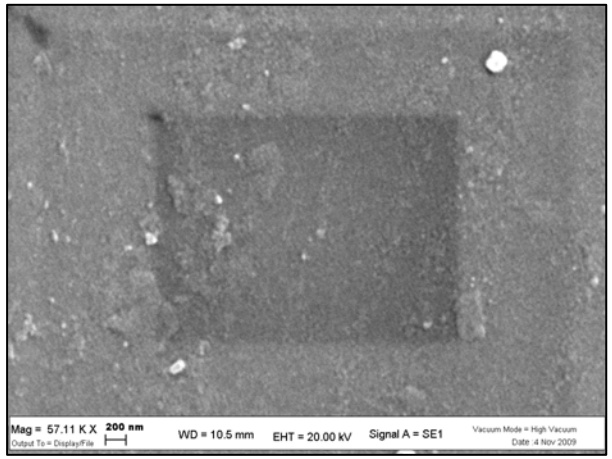
A new enamel coating - surface is less wettable than the standard enamel

By reducing the wettability of the enamel surface the ash deposition is reduced thus reducing the maintenance requirements

Standard enamel

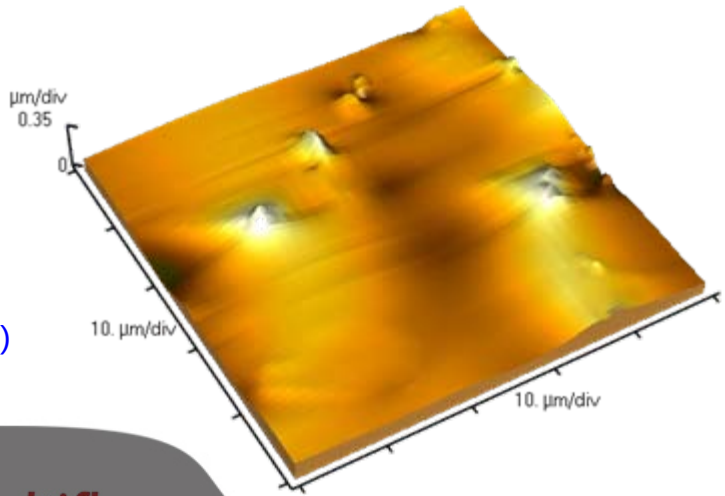
A "None Stick" enamel

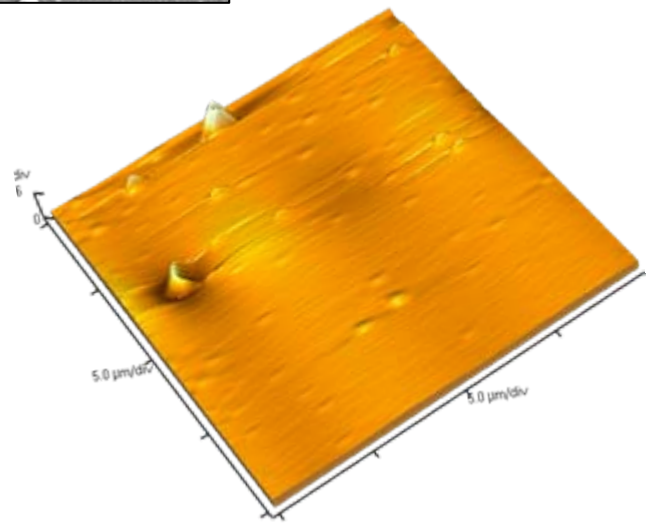
Enameling Future – "None Stick"



Standard enamel surface quality

Scanning Electron Microscope (SEM) analysis

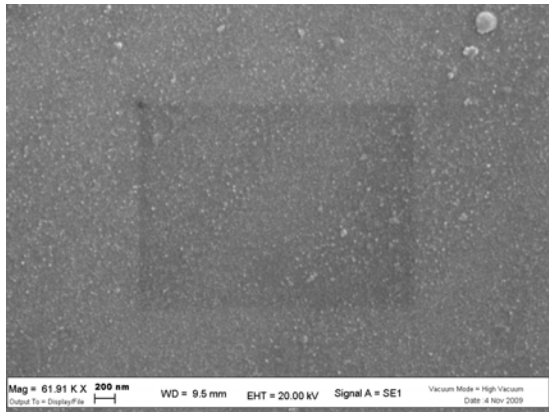




Atomic Force Microscope (AFM) analysis

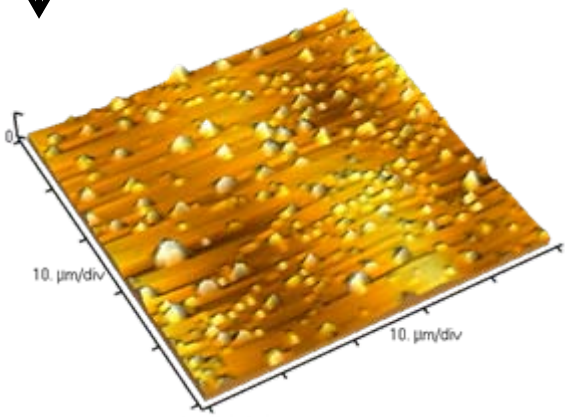
Enameling Future – "None Stick"

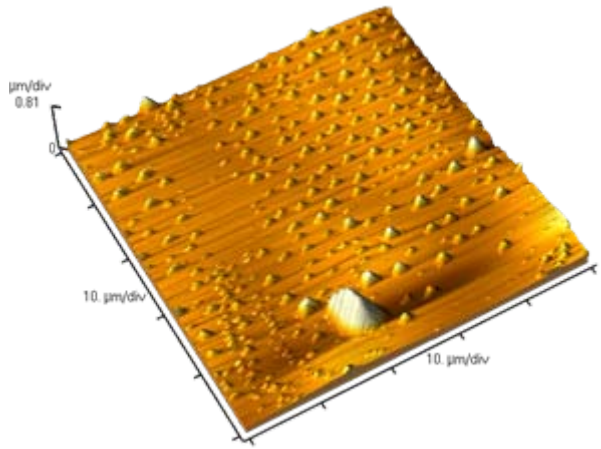
"None Stick" enamel surface quality

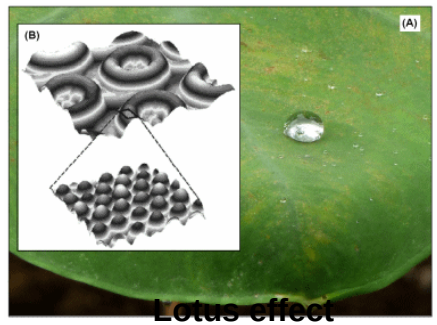


Scanning Electron Microscope (SEM) analysis

Atomic Force Microscope (AFM) analysis

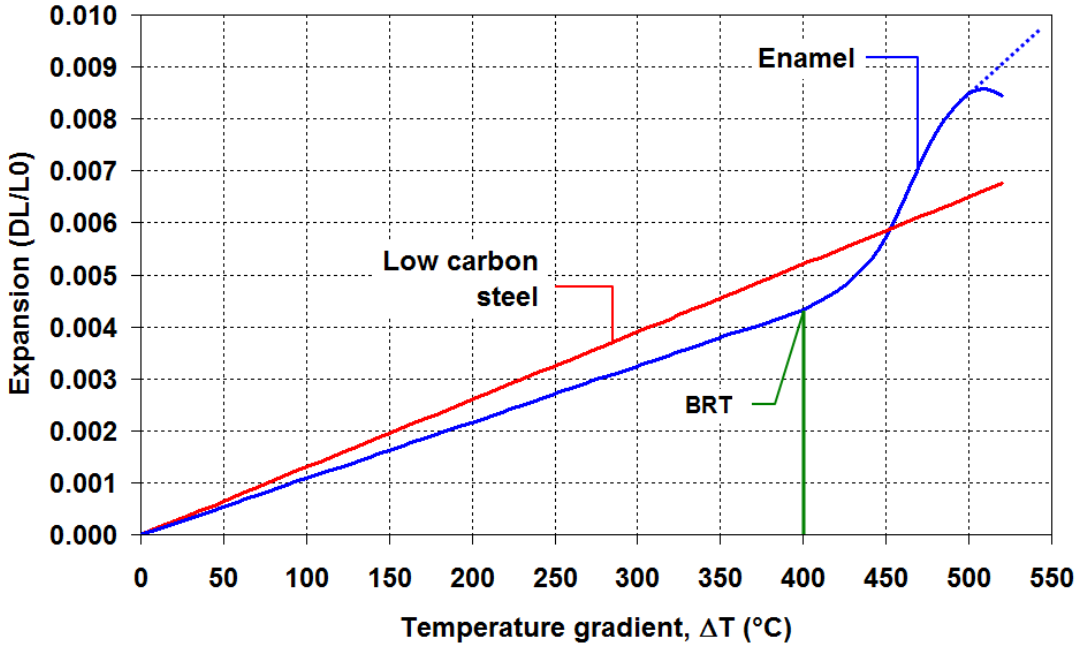






Enamel Coating Overview

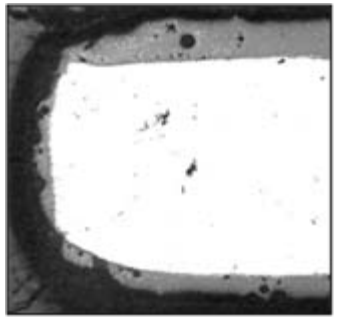
Coefficient of thermal expansion

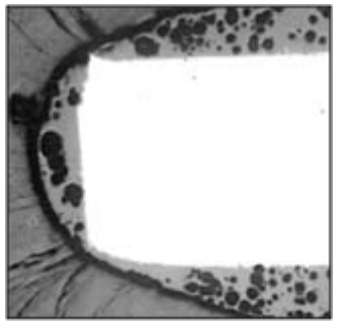


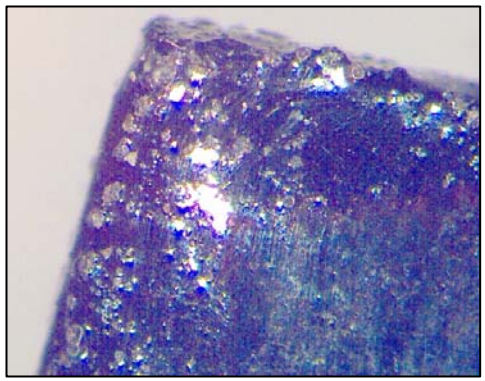
Quality Assurance

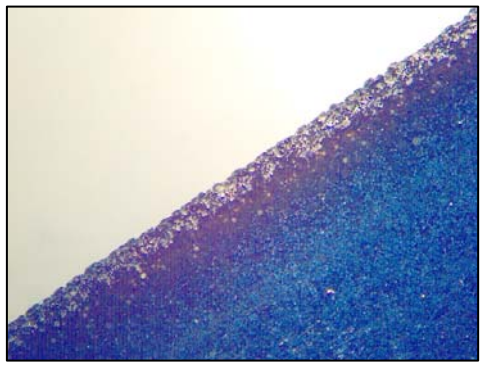
Bad edge coverage due to the effects of old forming and cutting processes

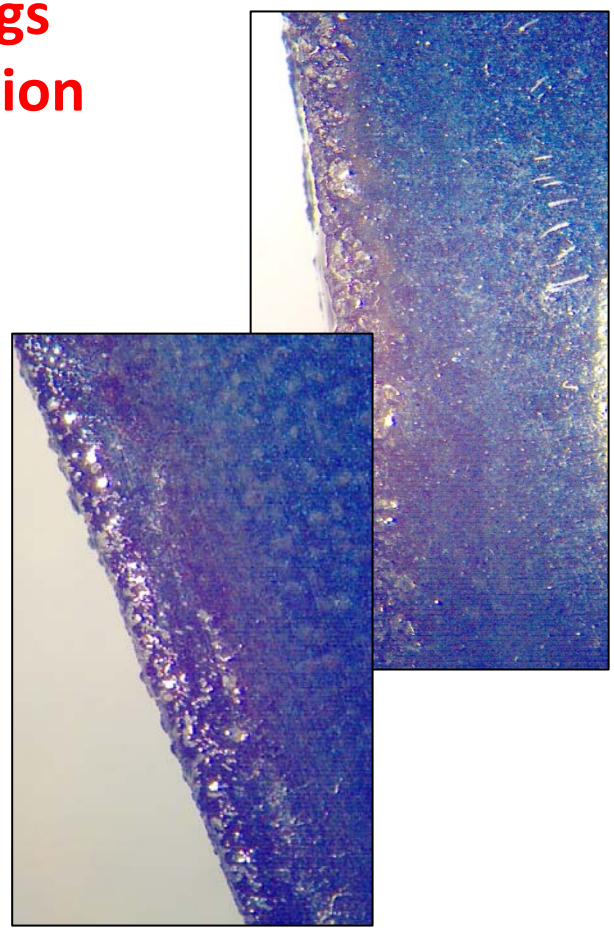
Several enamel burnings reduce the edge protection







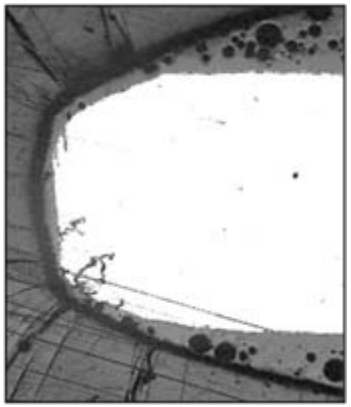


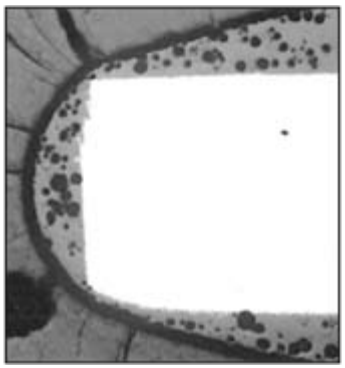


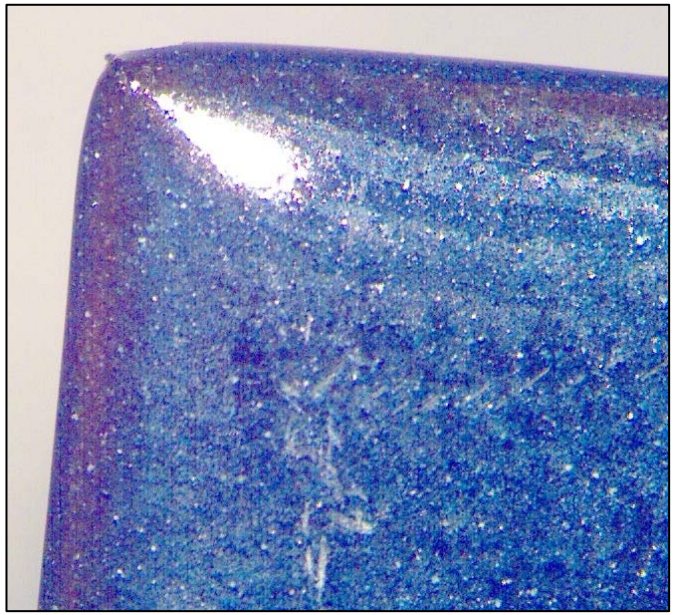
Smaltiflex dal 1963

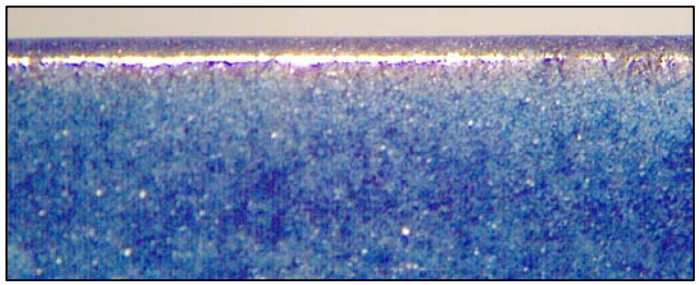
Quality Assurance

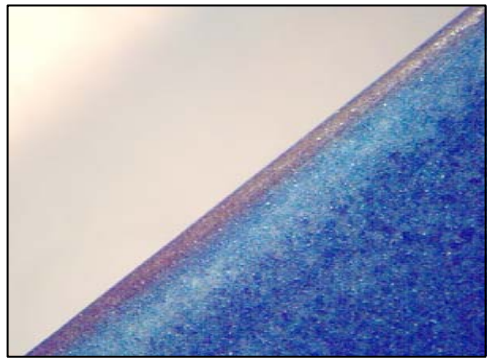
Benefit of new approach to product quality: **Edge Coverage**

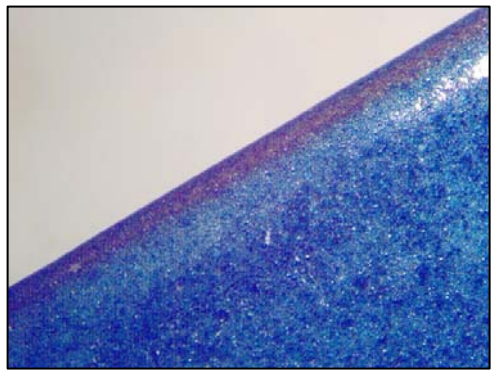












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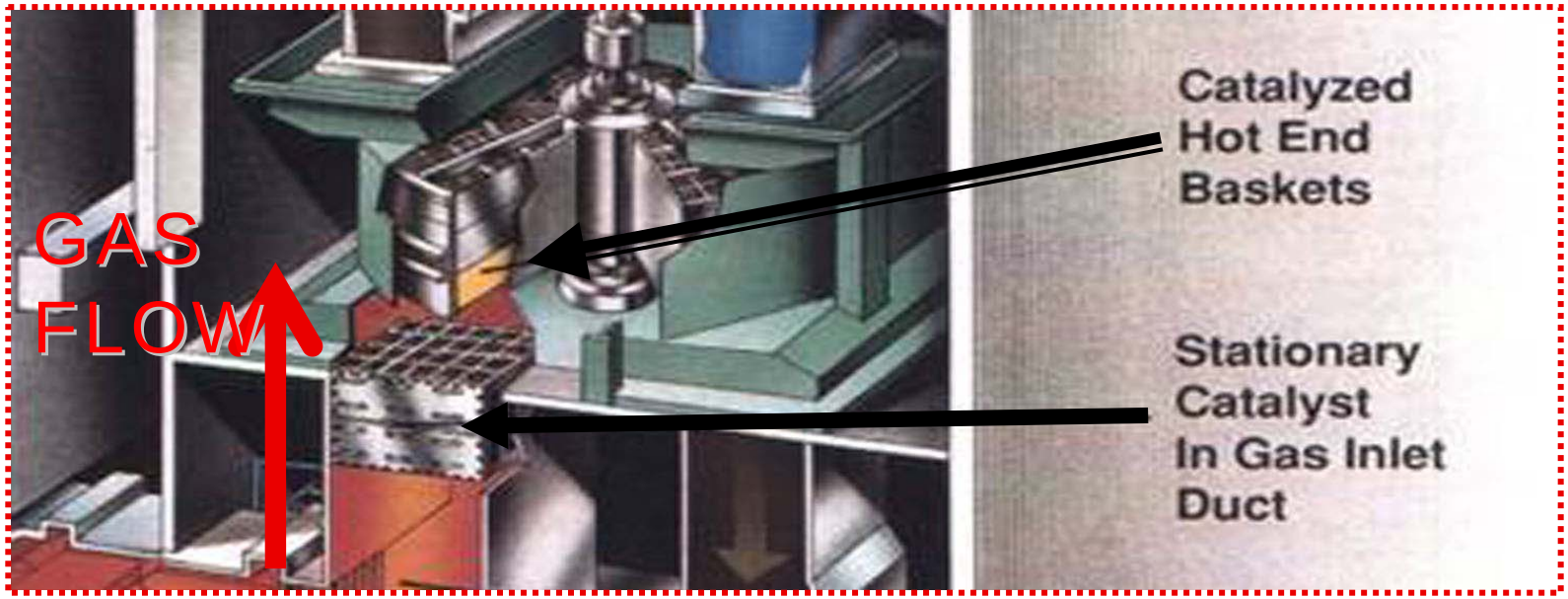
Catalyst in Airheaters



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