Gas-Gas Mixing as applied to SCR's

Presented by :

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Static Mixers

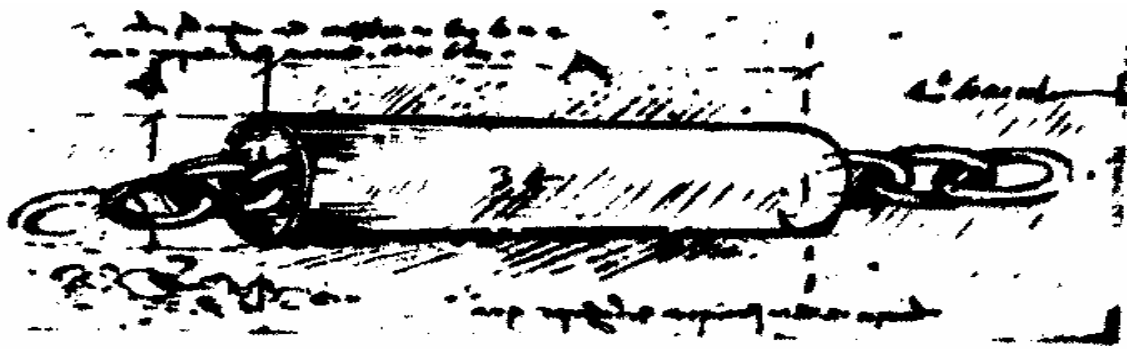
Background

Principles of Operation

Applicaton in DENOx

Case Study - Roxboro 1 Plant

Background

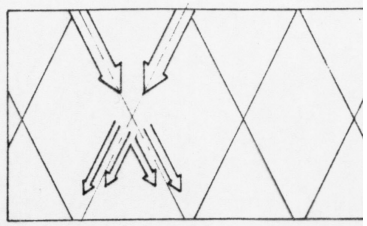


- Oldest patent dated 1895.
- Spiral developed in the 1960's by the Arthur D. Little Company (Boston)
- 1971 : Sulzer develops Baffle plate type Static Mixer. Various Spiral type mixers also developed by Phillips Petroleum, Dow, and others.
- Importance: Successful production of nylon and polyester due to quality improvements made with the use of static mixers in the fabrication process.

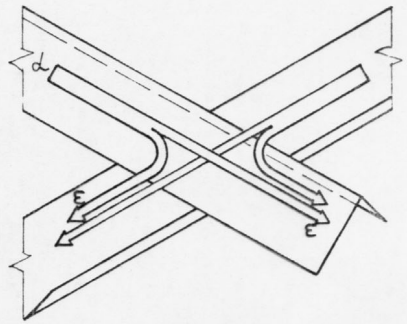
Static Mixer provides homogenization without the use of moving parts.

The stationary guiding vanes split the product stream into partial streams. The partial streams are then redirected inside the guiding vanes such that a mixture is obtained.

1) Lateral Displacement in the Channels



2) Shearing off at each intersection



Principles of Operation

The geometric structure of the static mixer causes both small scale mixing and by creating strong cross flows, large scale homogenization over the pipe or duct cross section.

A SULZER SMV mixing element consists of several corrugated plates which form part ducts that are open to one side.

For mixing in ducts the flow is divided, deflected in different directions and sectioned off at points of intersection, where vortices move gas from one part of the duct into adjacent crossing channels.

Strong eddies with intensive mixing effects are created both in the mixing element and in the empty duct downstream of the mixer.

Principles of Operation

In the Industry there are two types of static mixers

- **Mixers that create small eddies**
- **Mixers that create large eddies**

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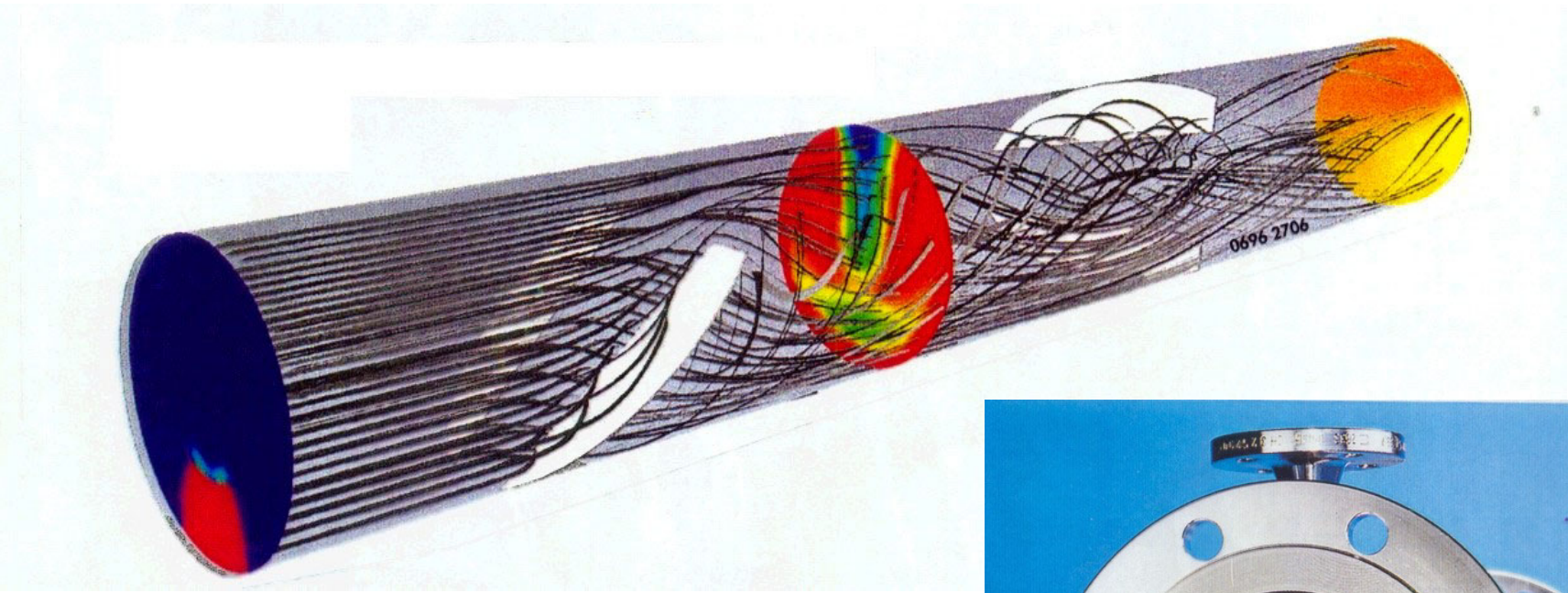
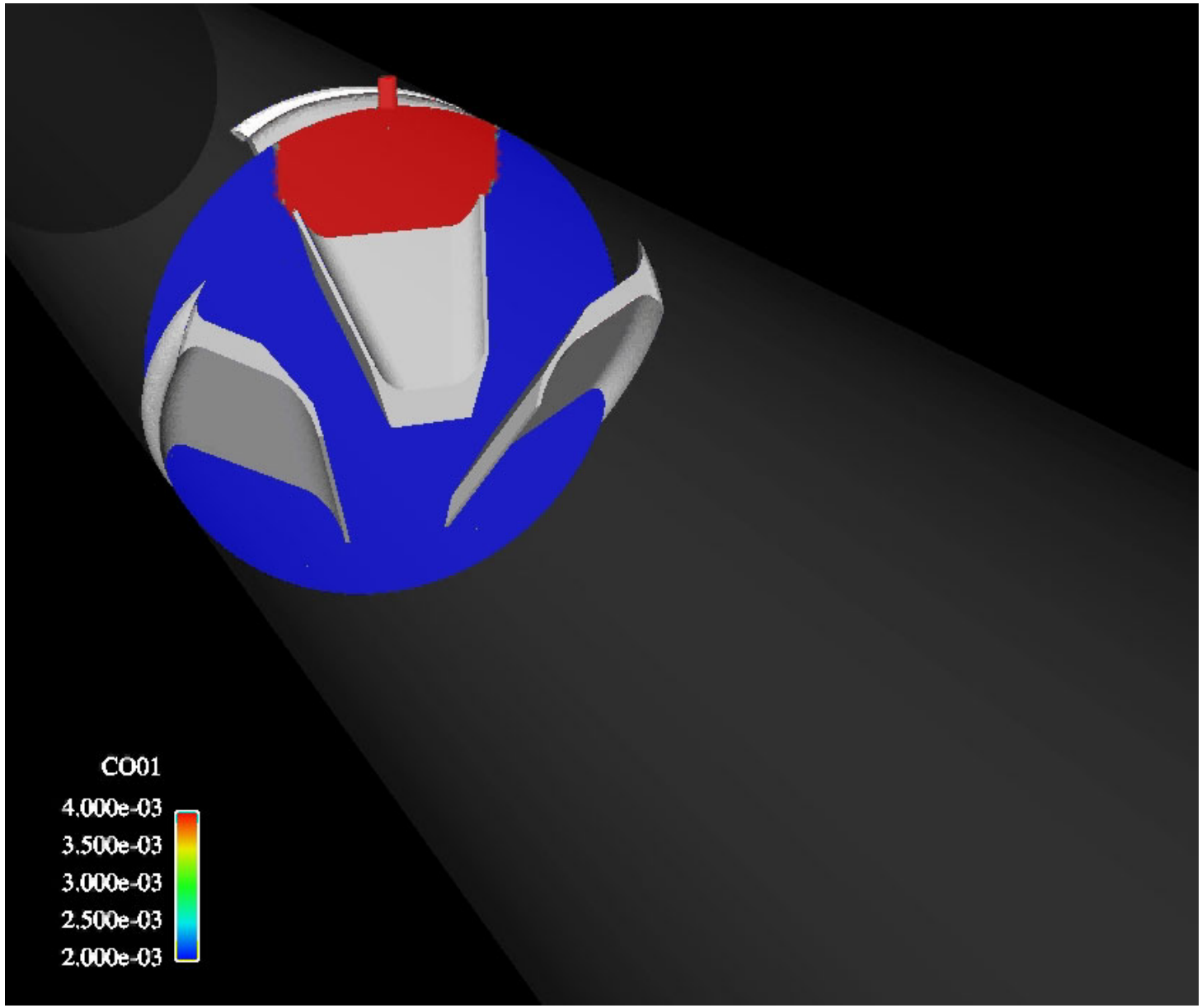


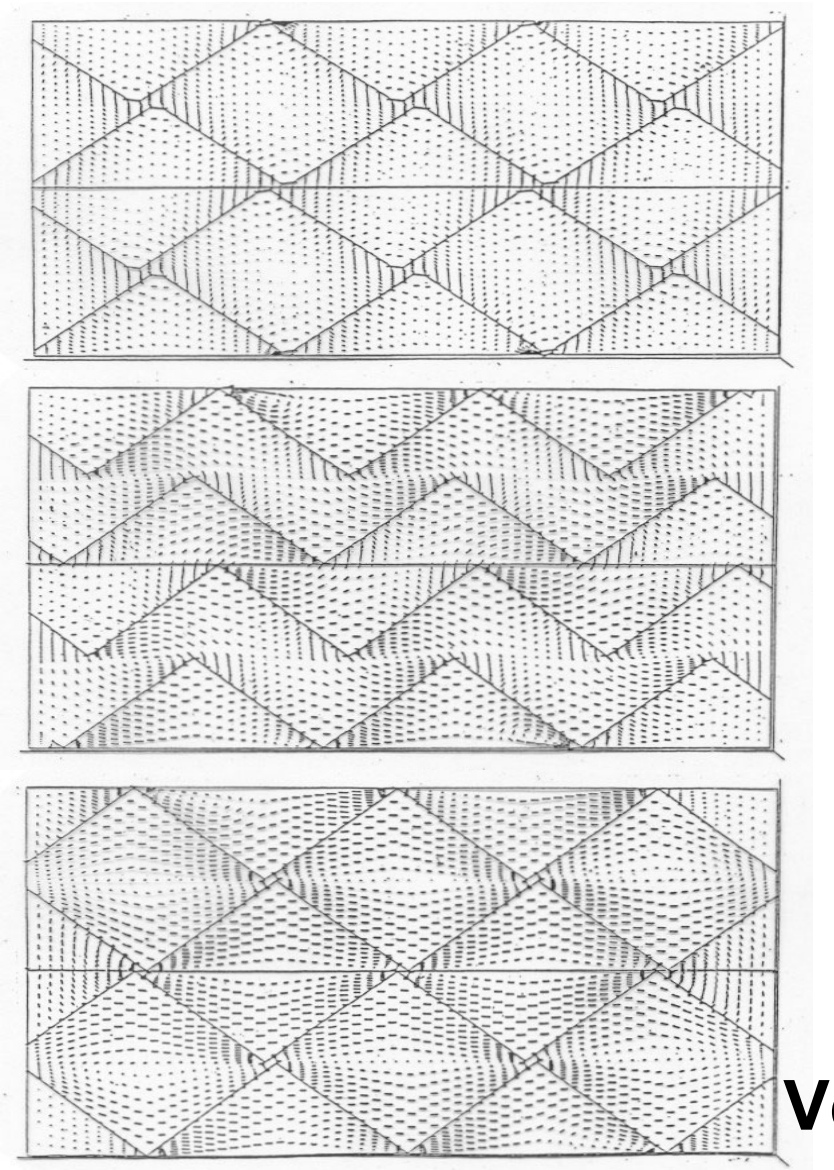
Sulzer mixer SMI for turbulent flow

Benefits: Principles of Operation
CFD Animation of a large vortex

mixer



SMV - mixer



Velocity vectors short distance after mixer inlet

Eddies are small

Velocity vectors in the centre of the mixer

Eddies are increasing

Velocity vectors at mixer outlet

Eddies are strong

Velocity vectors in SMV - mixer

Turbulent Flow

Example : Air in Water

Influence mal distribution on front of mixer

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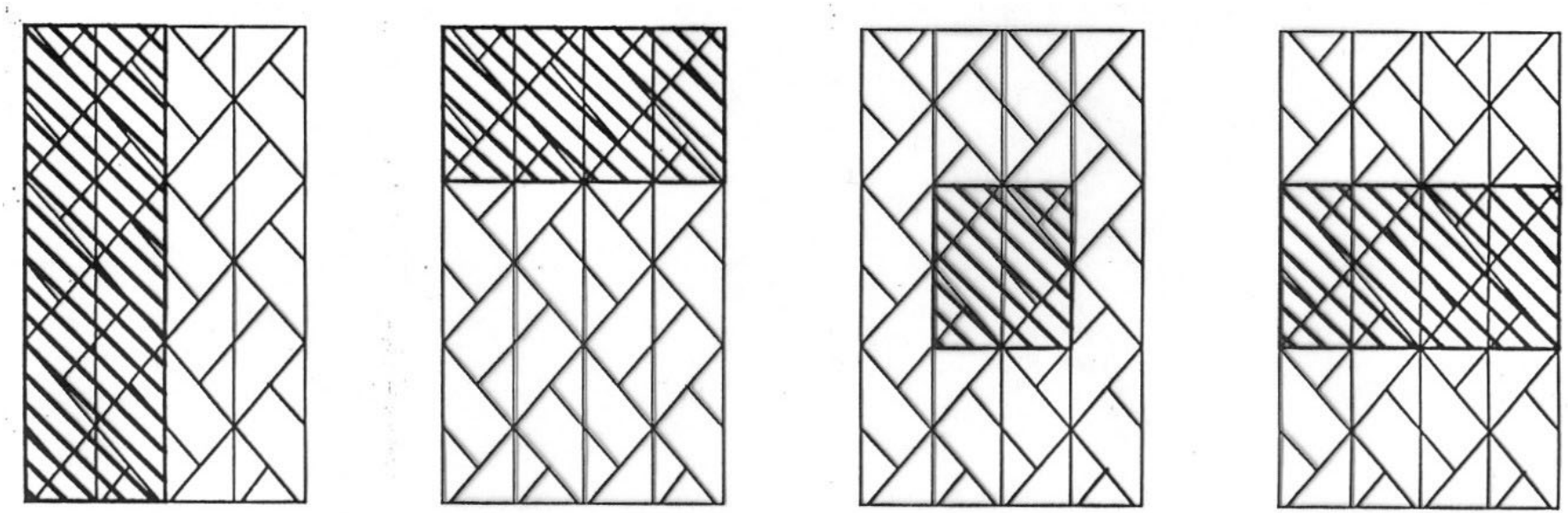
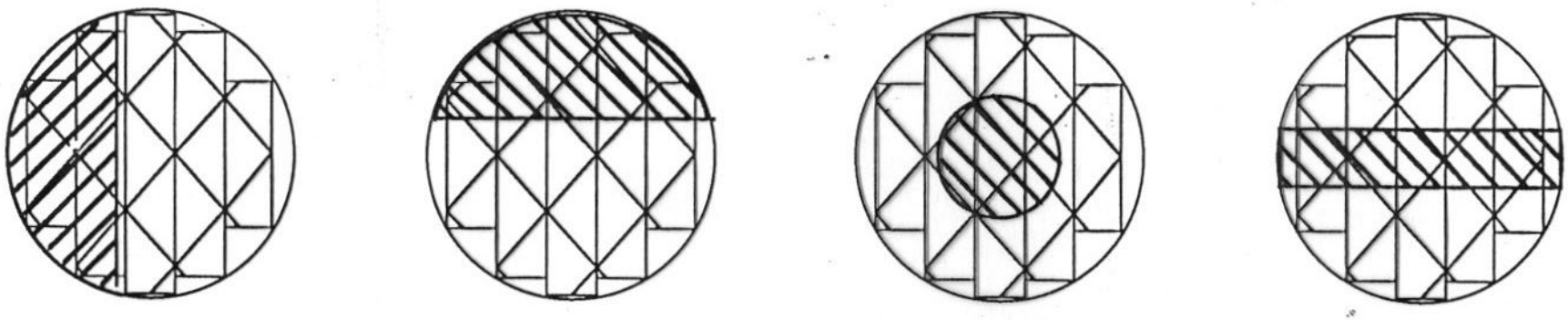
Sulzer Chemtech



increase ⟵ Pressure drop to achieve the homogeneity

Distance to achieve the homogeneity ⟶ decrease



DeNOx

FLOW RATIO: $NH_{3\ vapor}$: Flue Gas = 1 : 10,000 !
FLOW RATES : 30% to 120 % load.

Turbulent Gas flow having components with different densities will cause layer flows.
Without a mixing device, long pipe lengths (50-100 pipe diameters) are required to equalise such differences in concentration or temperature.

SCR Process requirements

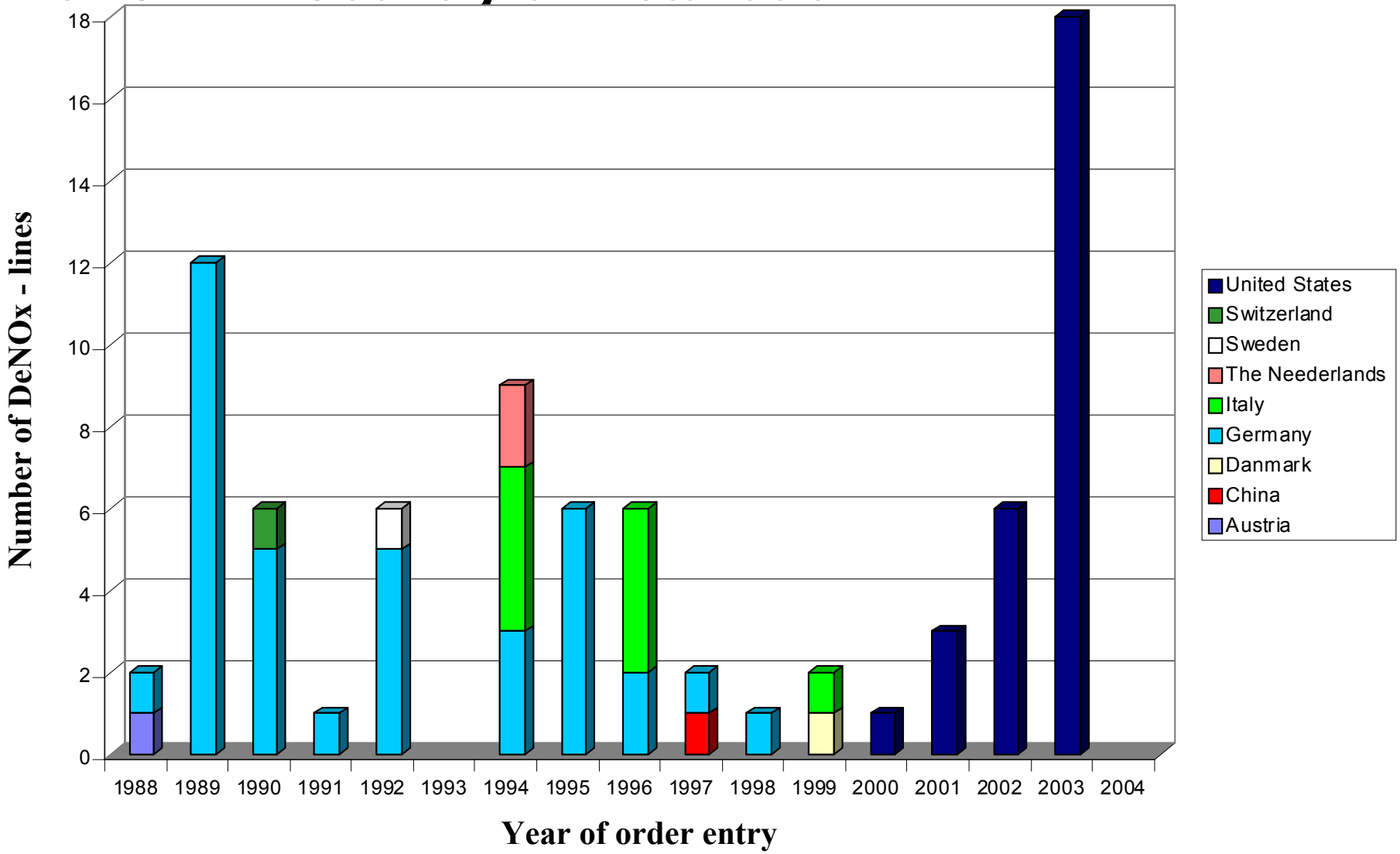
maximum NOx conversion
no ammonia slip
low pressure drop
no dust deposits

SULZER SCR Mixers Installation List - USA

Power stations with DeNOx - SCR's utilizing Sulzer Mixer/AIG system

Plant	Country	Supplier	Nr. of lines	M - Number	Year
AES Cayuga Unit 1	USA	Foster Wheeler	1	46458	2000
W.A. Parish Unit 5	USA	Sargent ¬ Lundy	2	46514	2001
W.A. Parish Unit 6	USA	Sargent ¬ Lundy	2	46514	2001
W.A. Parish Unit 7	USA	Sargent ¬ Lundy	2	46514	2001
W.A. Parish Unit 8	USA	Sargent ¬ Lundy	2	46514	2001
CP&L Roxboro 1	USA	Foster Wheeler	1	46559	2002
CP&L Roxboro 3	USA	Foster Wheeler	2	46559	2002
CP&L Mayo Unit 1	USA	Foster Wheeler	2	46684	2002
Owensboro Elmer Smith Unit 1	USA	Sargent ¬ Lundy	1	46645	2002
Exelon Mt. Creek Unit 8	USA	Foster Wheeler	1	46621	2002
Marion Unit 4 - SIPCO	USA	Sargent ¬ Lundy	1	46545	2001
Consumers Karn 1	USA	Babcock & Wilcox	2	46567	2001
Consumers Karn 2	USA	Babcock & Wilcox	2	46567	2001
Consumers Campbell Unit 2	USA	Babcock & Wilcox	2	46567	2001
AES Petersburg Unit 2	USA	Foster Wheeler	2	46754	2003
AES Petersburg Unit 3	USA	Foster Wheeler	2	46754	2003
Consumers Campbell Unit 3	USA	Foster Wheeler	2	46567	2003

DeNOx Country of installation



Ammonia Injection Grids

Simple AIG with Mixers

No Valves

Multi-Zone AIG with adjustment valves

AIG alignment with First Mixer

NOx Reduction Guarantees

Roxboro 1 : Objective

The catalyst performance guarantees are contingent on a relatively uniform gas mixture at the catalyst inlet.

A static mixer is required in the SCR duct section between the inlet of the economizer by-pass duct and the catalytic reactor downstream to achieve maximum NOx reduction.

Roxboro 1 NOx Reduction Guarantees

Design Criteria @ Gas Flowrate of 3,552,000 lb/hr

INLET NOx : 0.50 lb OUTLET NOx: 0.08 lb

DeNOx Efficiency 84% NOx removal

Uniform distribution is the key to achieving higher removal rates.

Ammonia Consumption: 563 lb/hr (anhydrous)

Ammonia slip: < 2 ppmvd

Roxboro 1: Performance and Guarantees

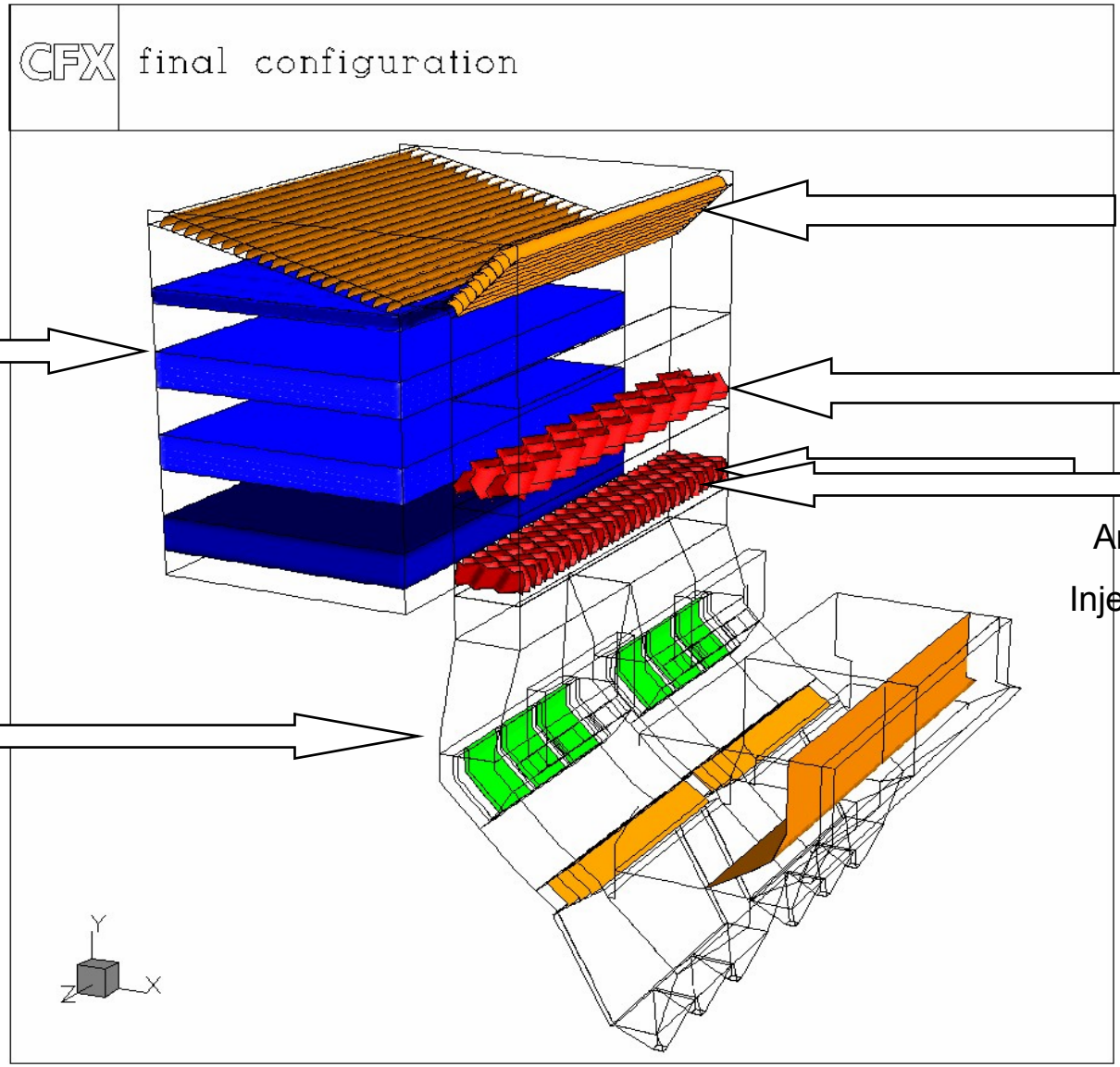
Static Mixer/AIG at 30%,50%,80% and 100% operating loads to meet :

NH_3 concentration distribution at the catalyst inlet **RMS ≤ 5%**

The flue gas temperature distribution at the catalyst inlet shall be less than ± **25°F** from the mean temperature.

The pressure drop across the mixer shall not exceed **0.94 inches w.c.** at the 100% load case.

SCR Arrangement



SCR Mixers and AIG

Pressure drop over the mixers:

	100 % load	80 % load	50 % load	30 % load
Guaranteed pressure drop	0,94 inch W.C.	0,60 inch W.C.	0,25 inch W.C.	0,13 inch W.C.

Pressure drop over the AIG:
The ammonia injection grid create a pressure drop of 14 inch W.C. by a flow rate of 19'186 lbs/ hr air and 564 lbs/ hr ammonia (temperature 68 ° F).

AIG: 20 lances , each with 10 nozzles

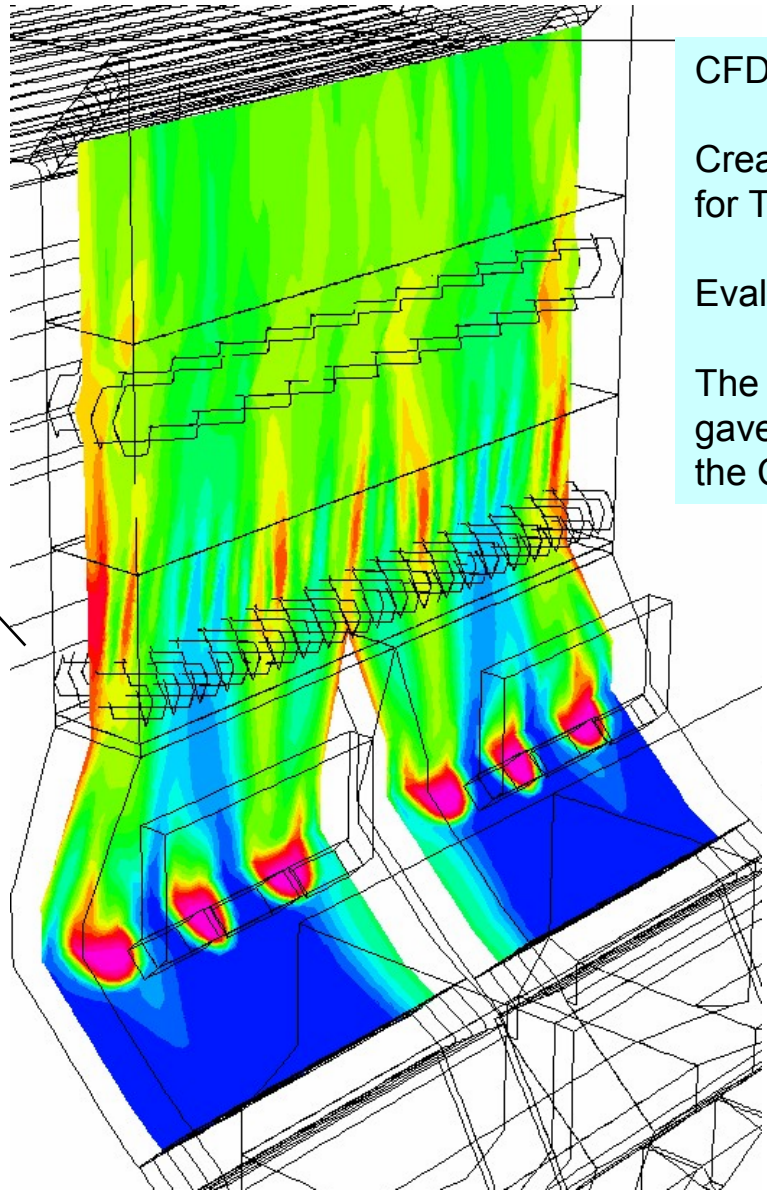
MIXER 1: 8’10” x 59’6” x 3’2” 40 layers

MIXER 2: 8’10” x 59’6” x 4 layers

Temperature homogenization

mixing element

From heater

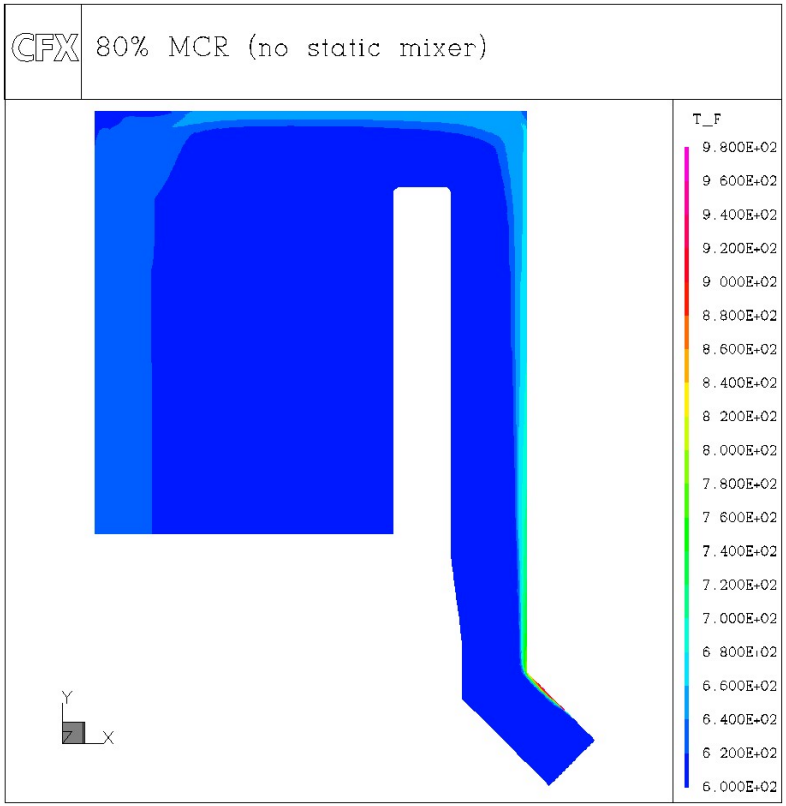


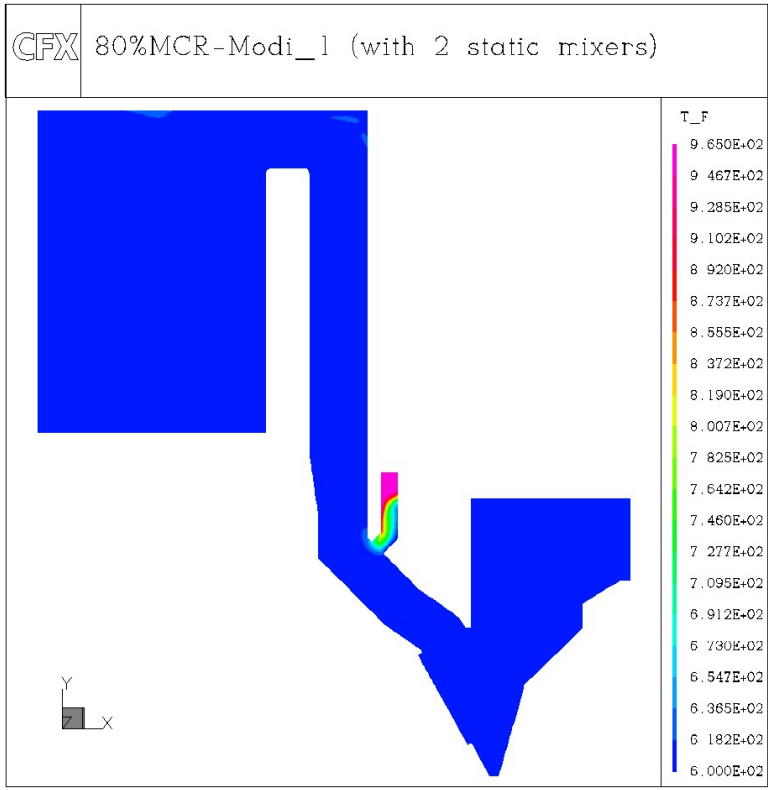
CFD Study assisted in:

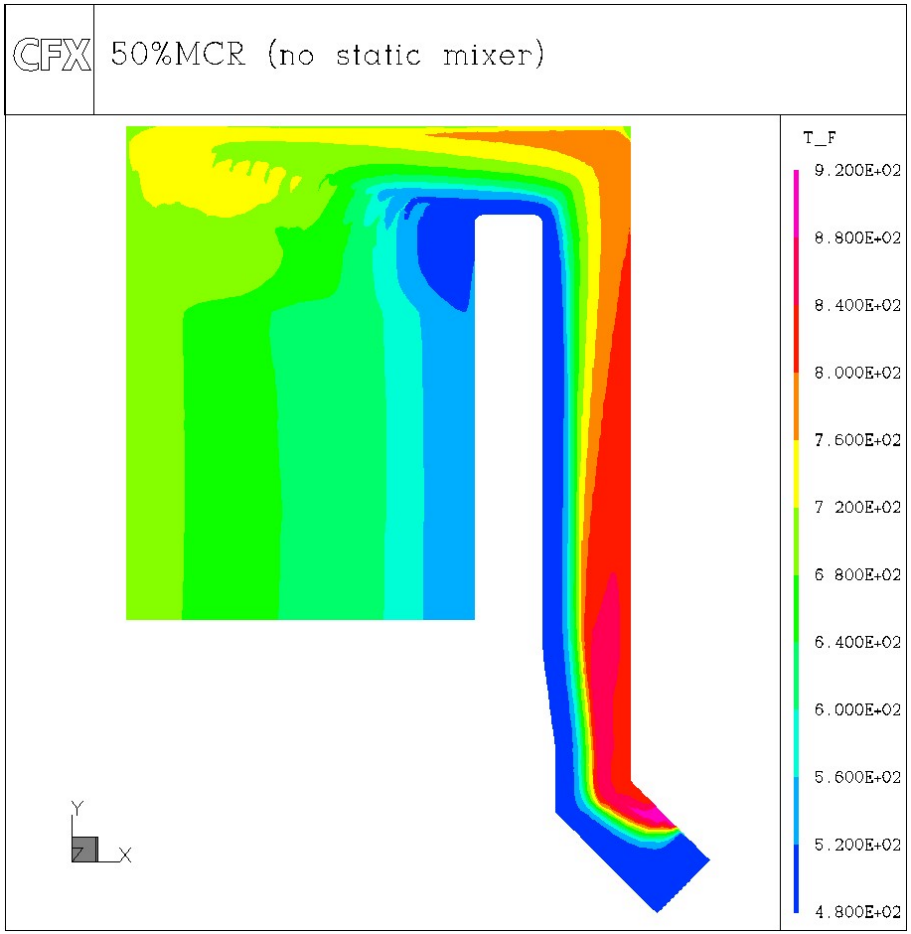
Creating Inlet guide vanes for Temperature distribution.

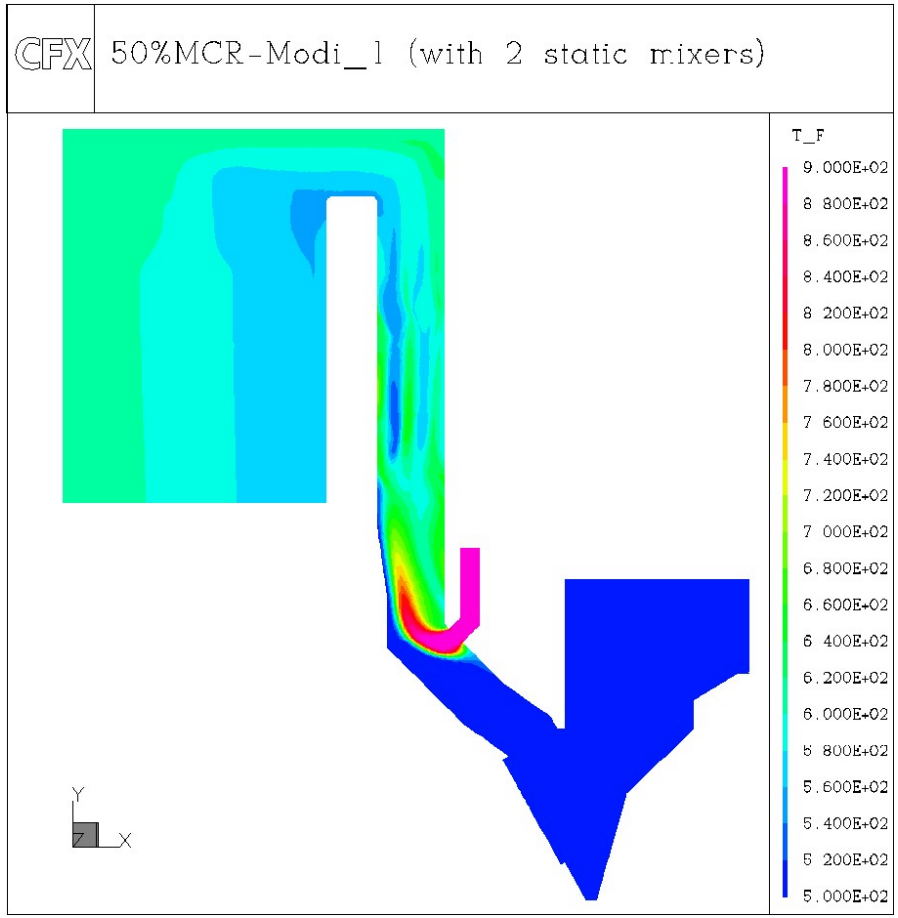
Evaluate Mixer location

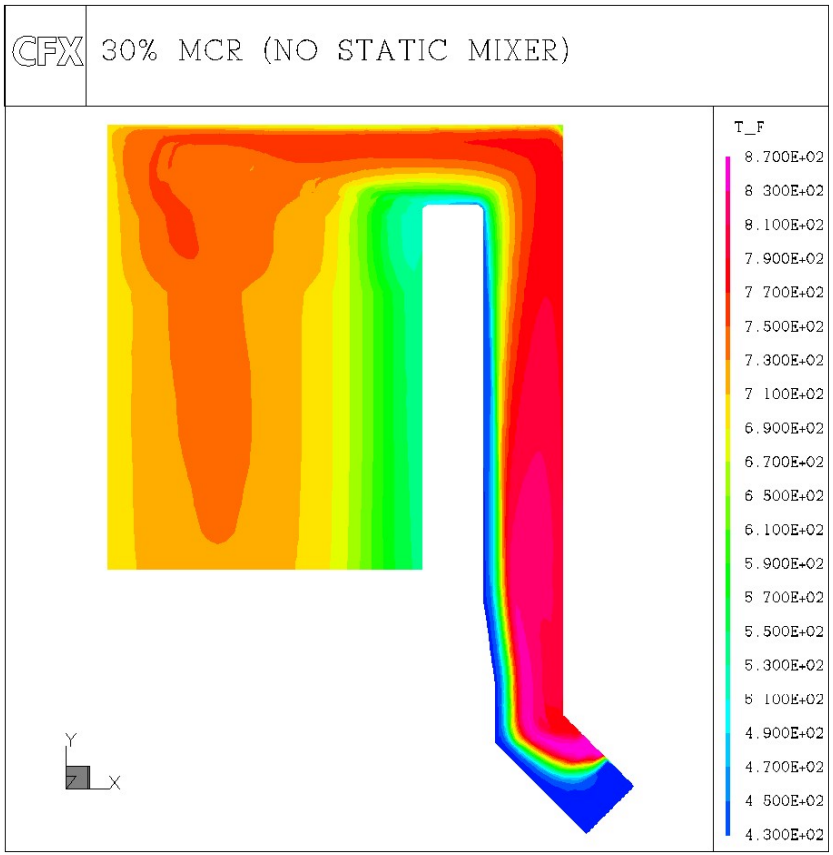
The physical model test gave better results than what the CFD predicted.


CFX
80% MCR (no static mixer)
T_F
9.800E+02
9.600E+02
9.400E+02
9.200E+02
9.000E+02
8.800E+02
8.600E+02
8.400E+02
8.200E+02
8.000E+02
7.800E+02
7.600E+02
7.400E+02
7.200E+02
7.000E+02
6.800E+02
6.600E+02
6.400E+02
6.200E+02
6.000E+02
Y
Z
X


CFX
80%MCR-Modi_1 (with 2 static mixers)
T_F
9.650E+02
9.467E+02
9.285E+02
9.102E+02
8.920E+02
8.737E+02
8.555E+02
8.372E+02
8.190E+02
8.007E+02
7.825E+02
7.642E+02
7.460E+02
7.277E+02
7.095E+02
6.912E+02
6.730E+02
6.547E+02
6.365E+02
6.182E+02
6.000E+02
Y
Z
X


CFX
50%MCR (no static mixer)
T_F
9.200E+02
8.800E+02
8.400E+02
8.000E+02
7.600E+02
7.200E+02
6.800E+02
6.400E+02
6.000E+02
5.600E+02
5.200E+02
4.800E+02
Y
Z
X


CFX
50%MCR-Modi_1 (with 2 static mixers)
T_F
9.000E+02
8.800E+02
8.600E+02
8.400E+02
8.200E+02
8.000E+02
7.800E+02
7.600E+02
7.400E+02
7.200E+02
7.000E+02
6.800E+02
6.600E+02
6.400E+02
6.200E+02
6.000E+02
5.800E+02
5.600E+02
5.400E+02
5.200E+02
5.000E+02
Y
Z
X


CFX
30% MCR (NO STATIC MIXER)
T_F
8.700E+02
8.300E+02
8.100E+02
7.900E+02
7.700E+02
7.500E+02
7.300E+02
7.100E+02
6.900E+02
6.700E+02
6.500E+02
6.100E+02
5.900E+02
5.700E+02
5.500E+02
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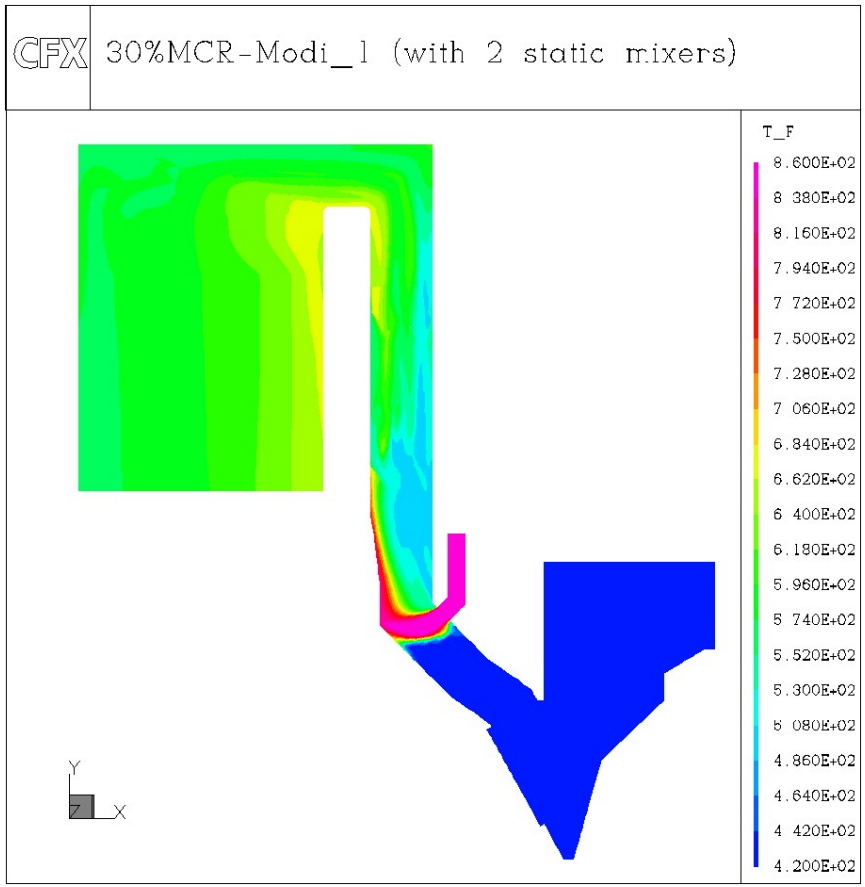
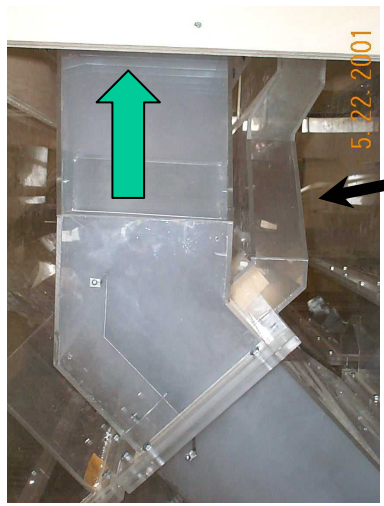
5.100E+02
4.900E+02
4.700E+02
4.500E+02
4.300E+02
Y
Z
X


CFX
30%MCR-Modi_1 (with 2 static mixers)
T_F
8.600E+02
8.380E+02
8.160E+02
7.940E+02
7.720E+02
7.500E+02
7.280E+02
7.060E+02
6.840E+02
6.620E+02
6.400E+02
6.180E+02
5.960E+02
5.740E+02
5.520E+02
5.300E+02
5.080E+02
4.860E+02
4.640E+02
4.420E+02
4.200E+02
Y
Z
X

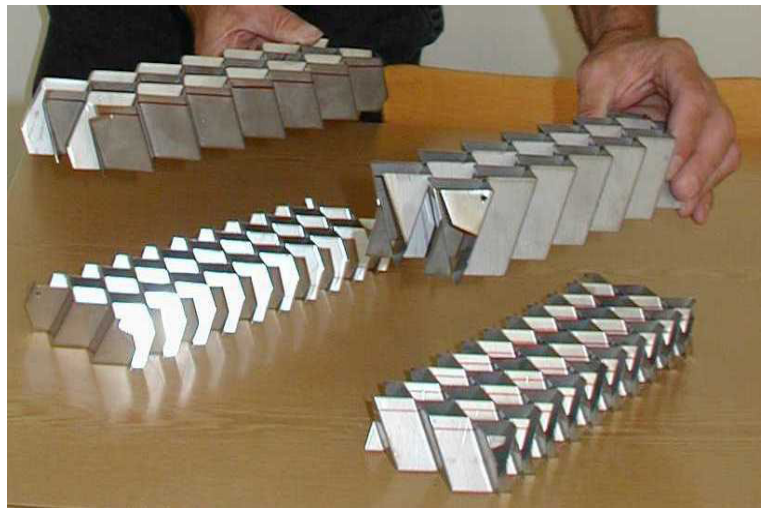
Flow Model Testing

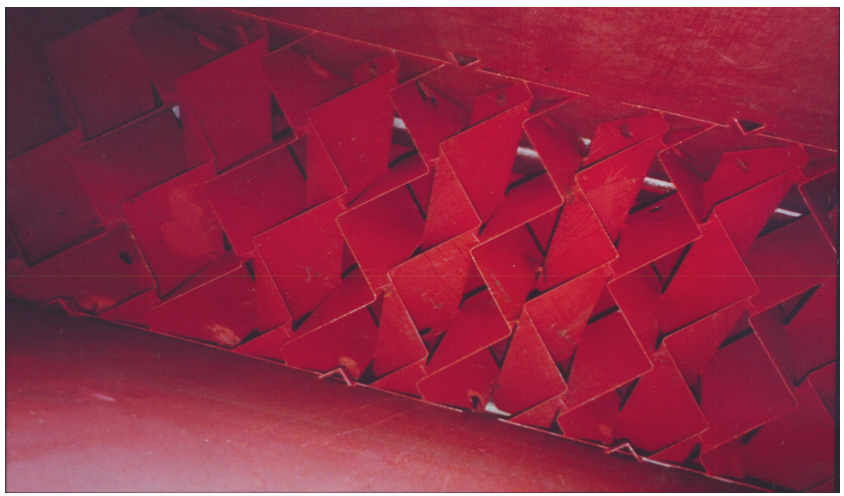
catalys
t

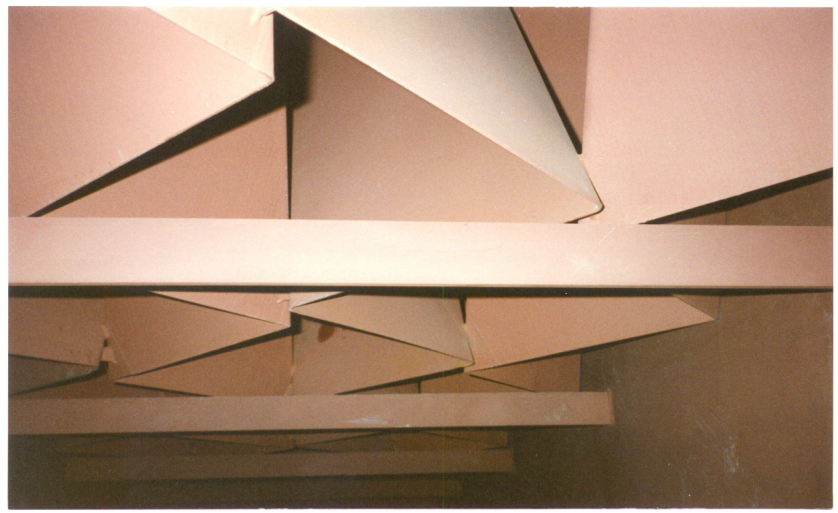
smoke test



Economizer by-pass







Field Installat

STATIC MIXERS ARE AN OPTION where:

- SCR's are in tight locations with little or no room for mixing distances.
- Hard to measure or predict inlet conditions in the field
- Need for temperature homogenization
- Need for > 90% NOx removal.

SULZER's European vs USA Experience

- Europe: SULZER provided guarantees to the catalyst supplier.
- CFD, Model Test, Mixers and AIG were done by SULZER.
- USA: Model Test, CFD, AIG and Mixers broken down to several vendors.
- Larger Duct sizes, Higher Nox removal.
- Catalyst supplier's scope includes for mixing and Nox reduction guarantees