HIGH TEMPERATURE SCR SYSTEMS ON FRAME SIZE COMBUSTION TURBINES

Jef Potters

Hamon Research-Cottrell

Jef.potters@hamonusa.com

Overview

- NOx Controls
  - ✓ SCR Details
  - ✓ Catalyst
  - ✓ NOx Controls on Frame Size Combustion Turbines

NOx Control by **S**elective **C**atalytic **R**eduction

- **NOx reacts with NH_3 given the right Environment**
- **"Active Sites" on the Catalyst facilitate the Reaction between NOx & Ammonia**

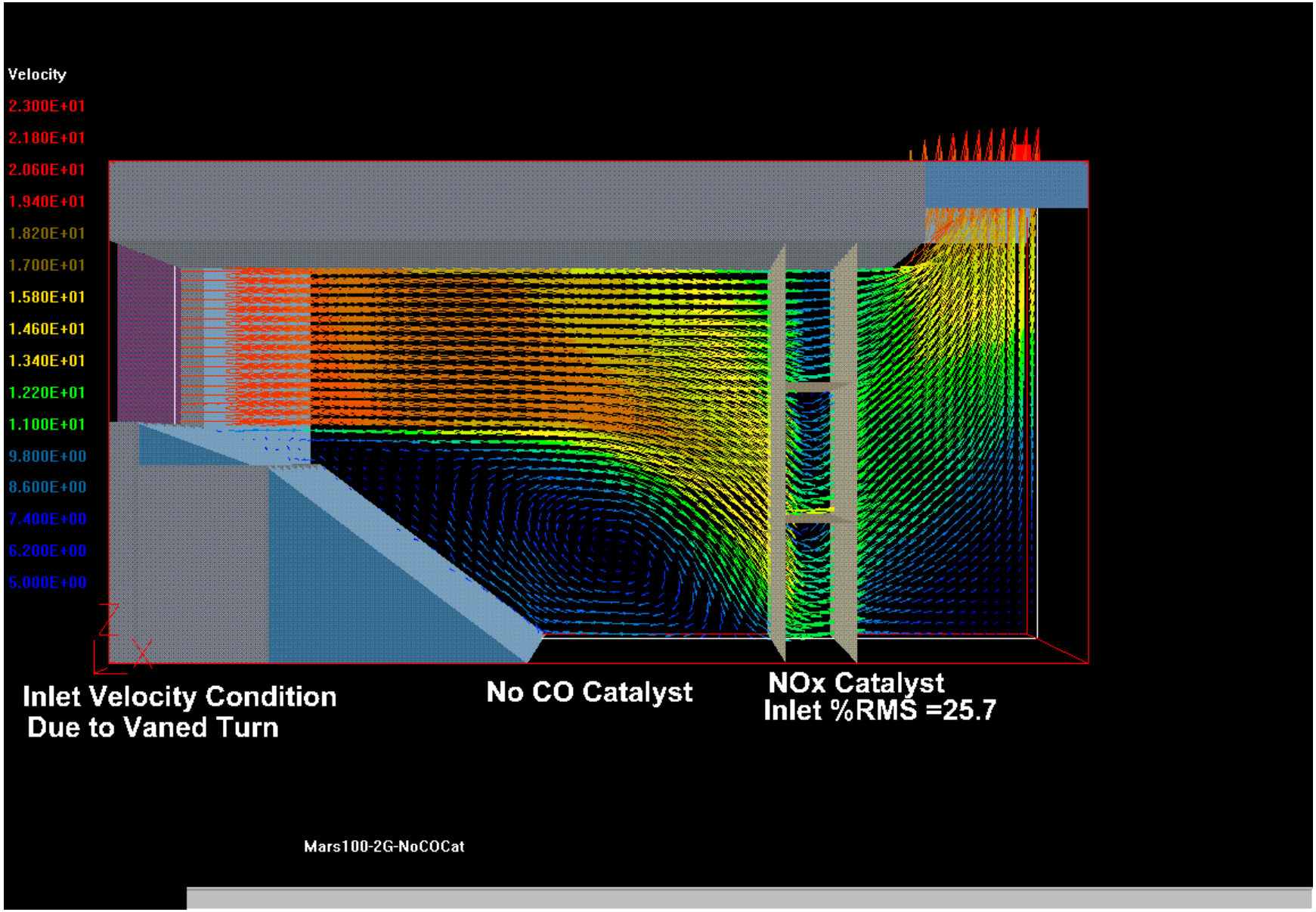
SCR Chemistry

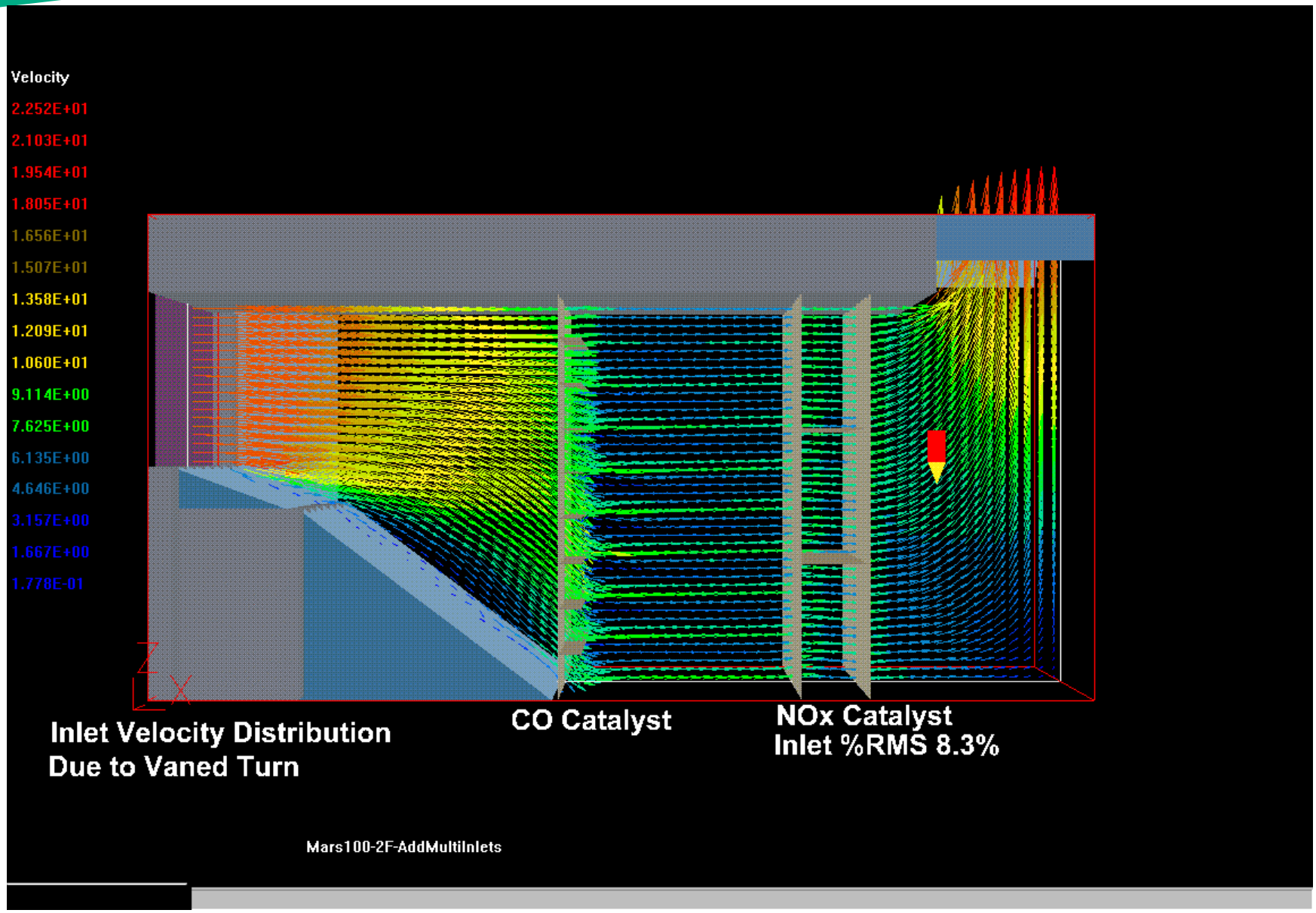
- $4NO + 4NH_3 + \boxed{O_2} \Longrightarrow 4N_2 + 6H_2O$
- $NO + NO_2 + 2NH_3 \Longrightarrow 2N_2 + 3H_2O$
- $2NO_2 + 4NH_3 + \boxed{O_2} \Longrightarrow 3N_2 + 6H_2O$
- $6\ NO_2 + 8\ NH_3 \Longrightarrow 7N_2 + 12H_2O$

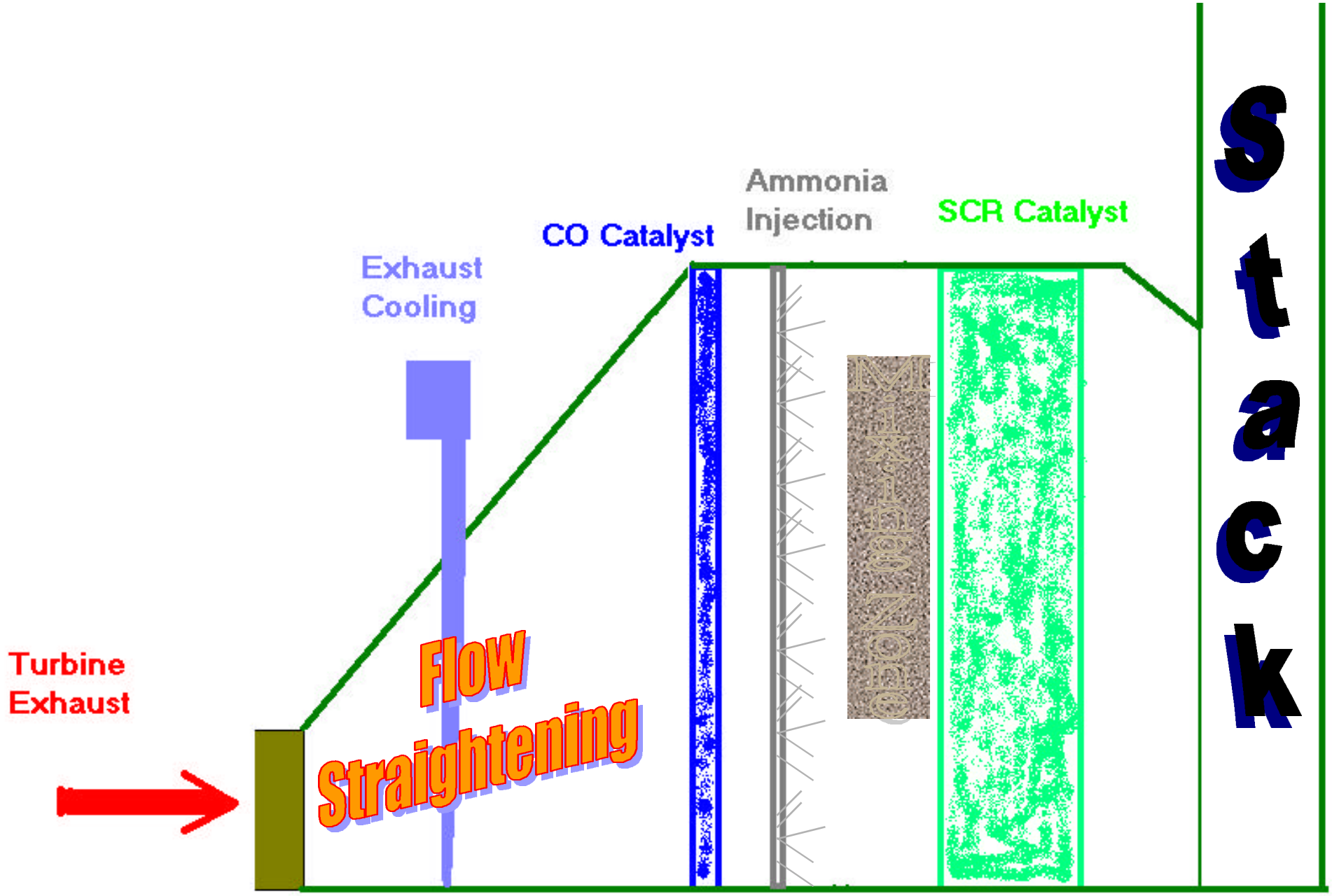
SCR
From Laboratory to Field

Flow Modeling

- Computational Fluid Dynamics (CFD)
- Physical Models

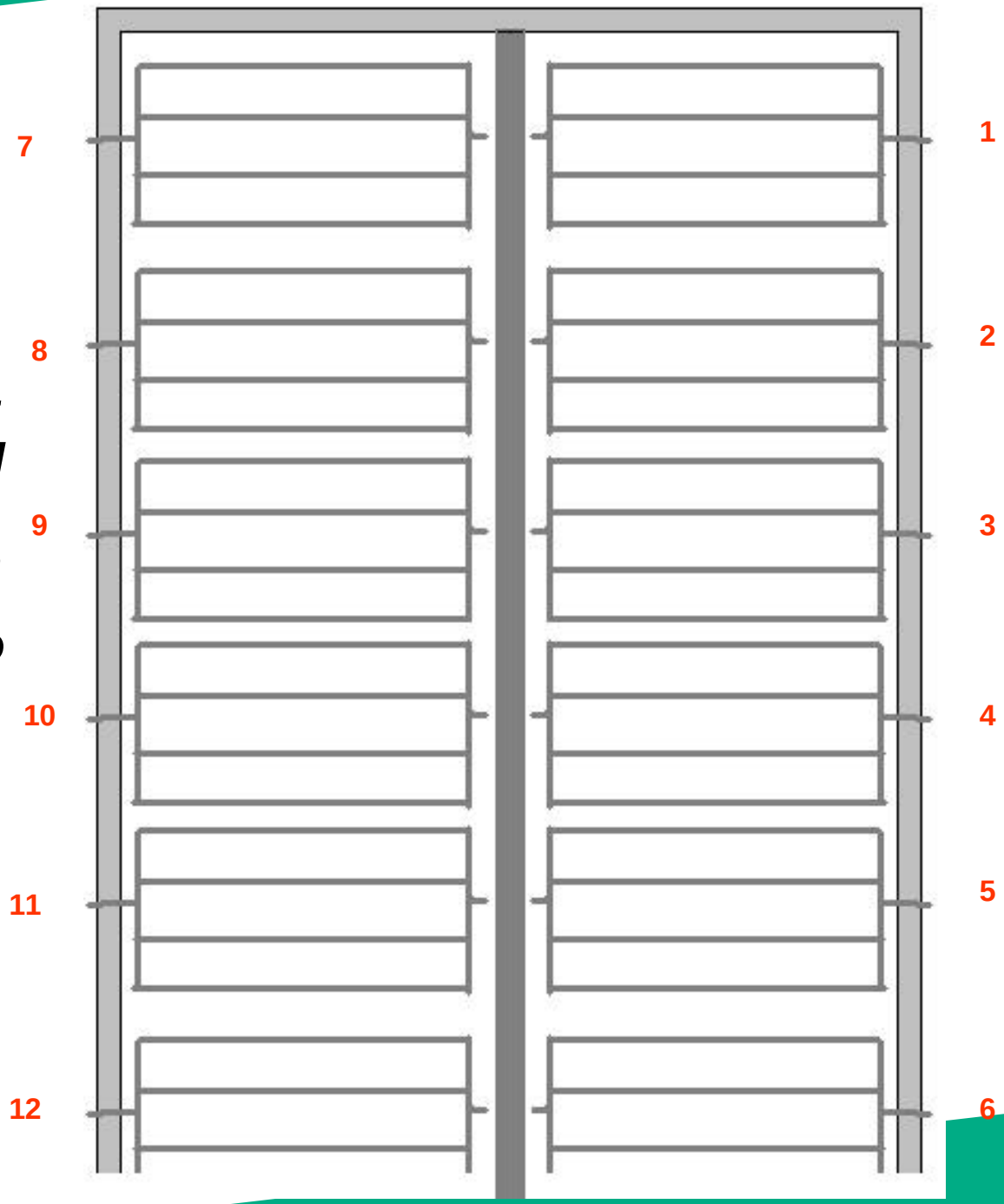

Velocity
2.300E+01
2.180E+01
2.060E+01
1.940E+01
1.820E+01
1.700E+01
1.580E+01
1.460E+01
1.340E+01
1.220E+01
1.100E+01
9.800E+00
8.600E+00
7.400E+00
6.200E+00
5.000E+00
Inlet Velocity Condition
Due to Vaned Turn
No CO Catalyst
NOx Catalyst
Inlet %RMS =25.7
Mars100-2G-NoCOCat


Velocity
2.252E+01
2.103E+01
1.954E+01
1.805E+01
1.656E+01
1.507E+01
1.358E+01
1.209E+01
1.060E+01
9.114E+00
7.625E+00
6.135E+00
4.646E+00
3.157E+00
1.667E+00
1.778E-01
Inlet Velocity Distribution
Due to Vaned Turn
CO Catalyst
NOx Catalyst
Inlet %RMS 8.3%
Mars100-2F-AddMultiInlets

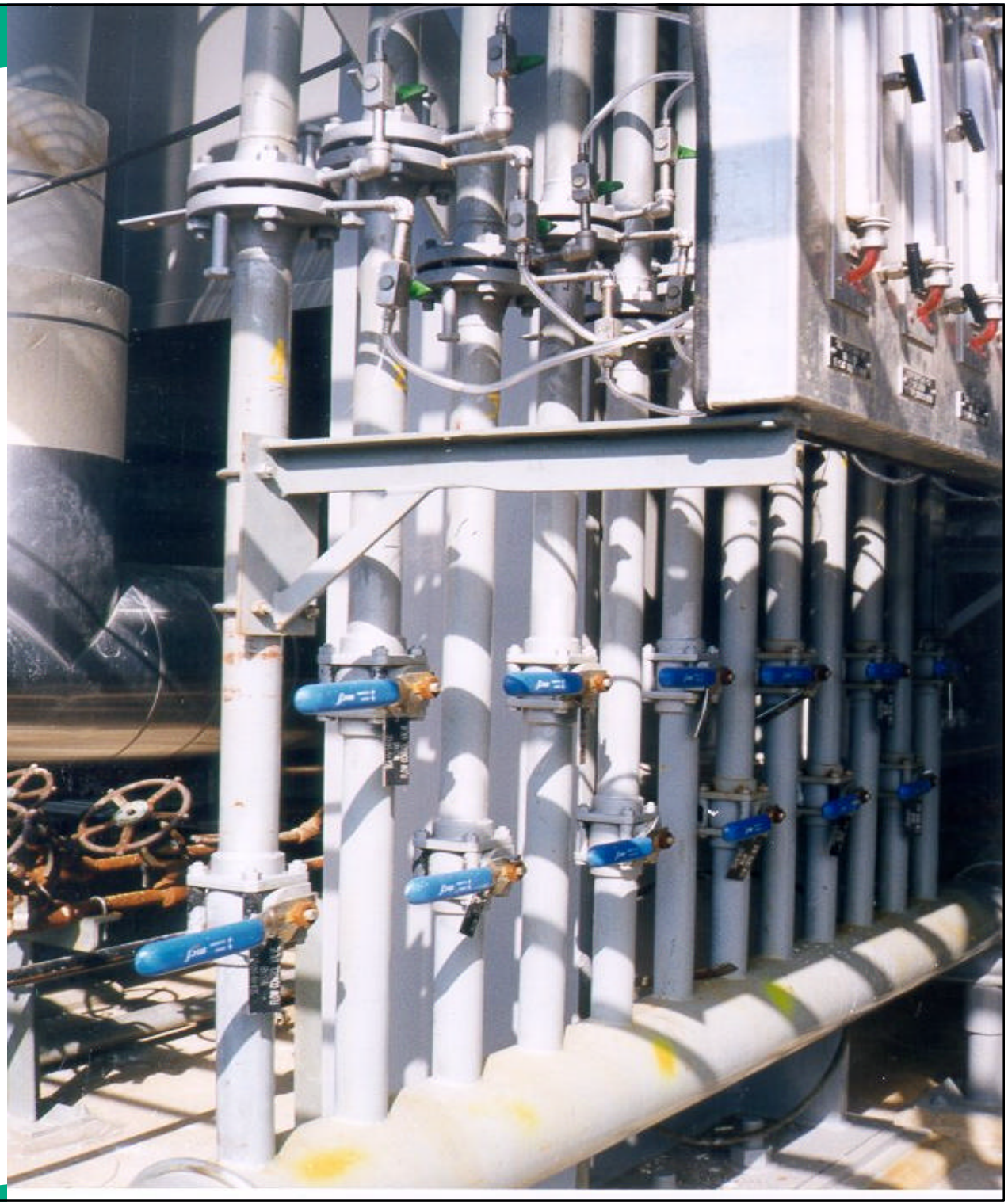

Turbine
Exhaust
Exhaust
Cooling
Flow
Straightening
CO Catalyst
Ammonia
Injection
Mixing Zone
SCR Catalyst
Stack

1
2
3
4
5
6
NOV 1 2001

Ammonia Injection Grid for High Efficiency SCR



AIG Tuning Valves for High Efficiency SCR



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Catalyst Sizing

- Exhaust Mass Flow
- Exhaust Temperature
- Exhaust Gas Composition
- Exhaust NOx
- NOx reduction efficiency
- Ammonia Slip
- Catalyst Life & Starts/Stops
- Fuels - Gas, Distillate
- System Pressure Drop

Catalyst Types

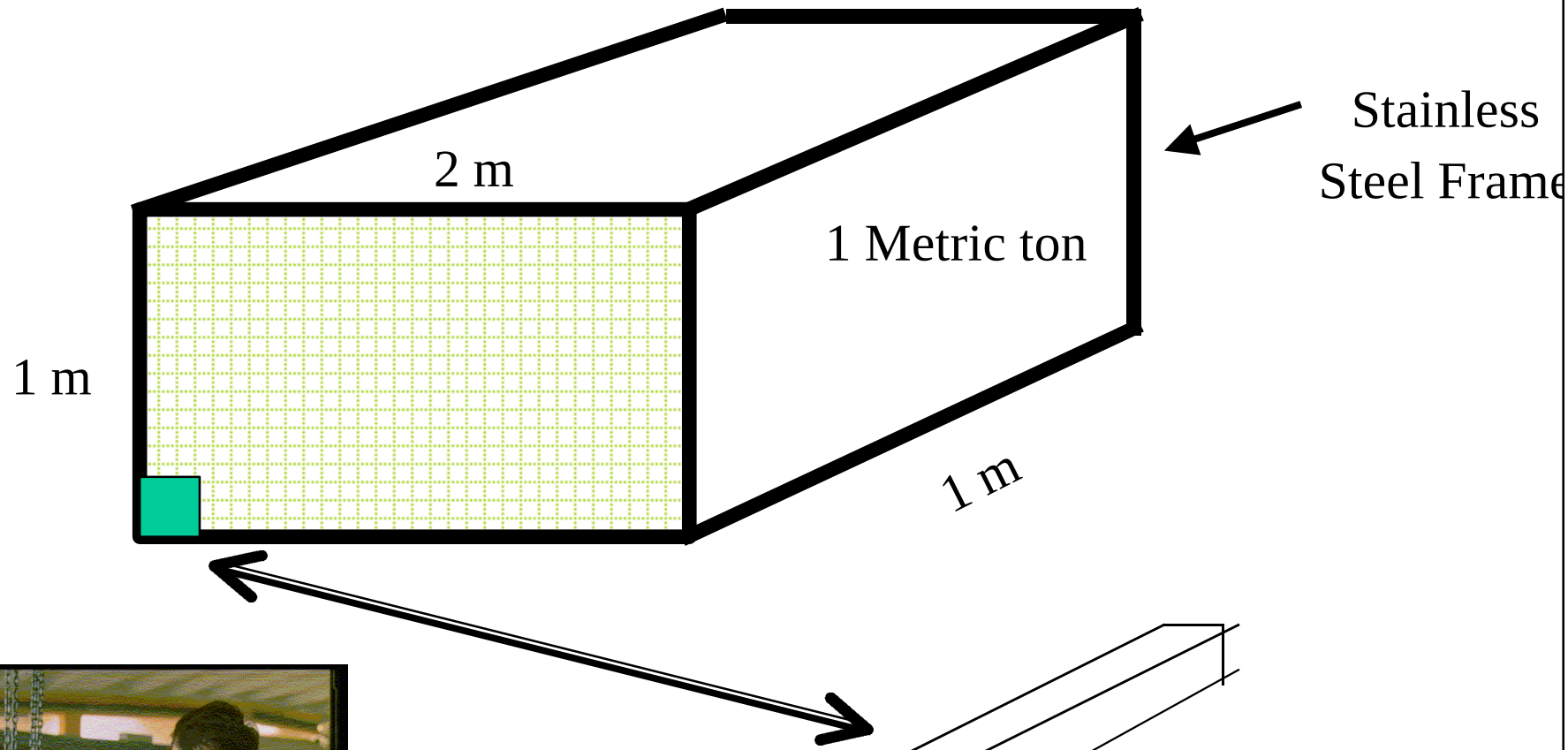
PHYSICAL

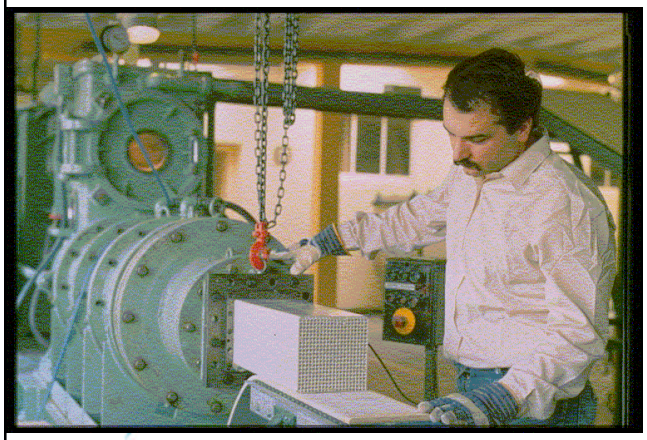
- Plate
- Coated Honeycomb
- Extruded Honeycomb
- Pellet

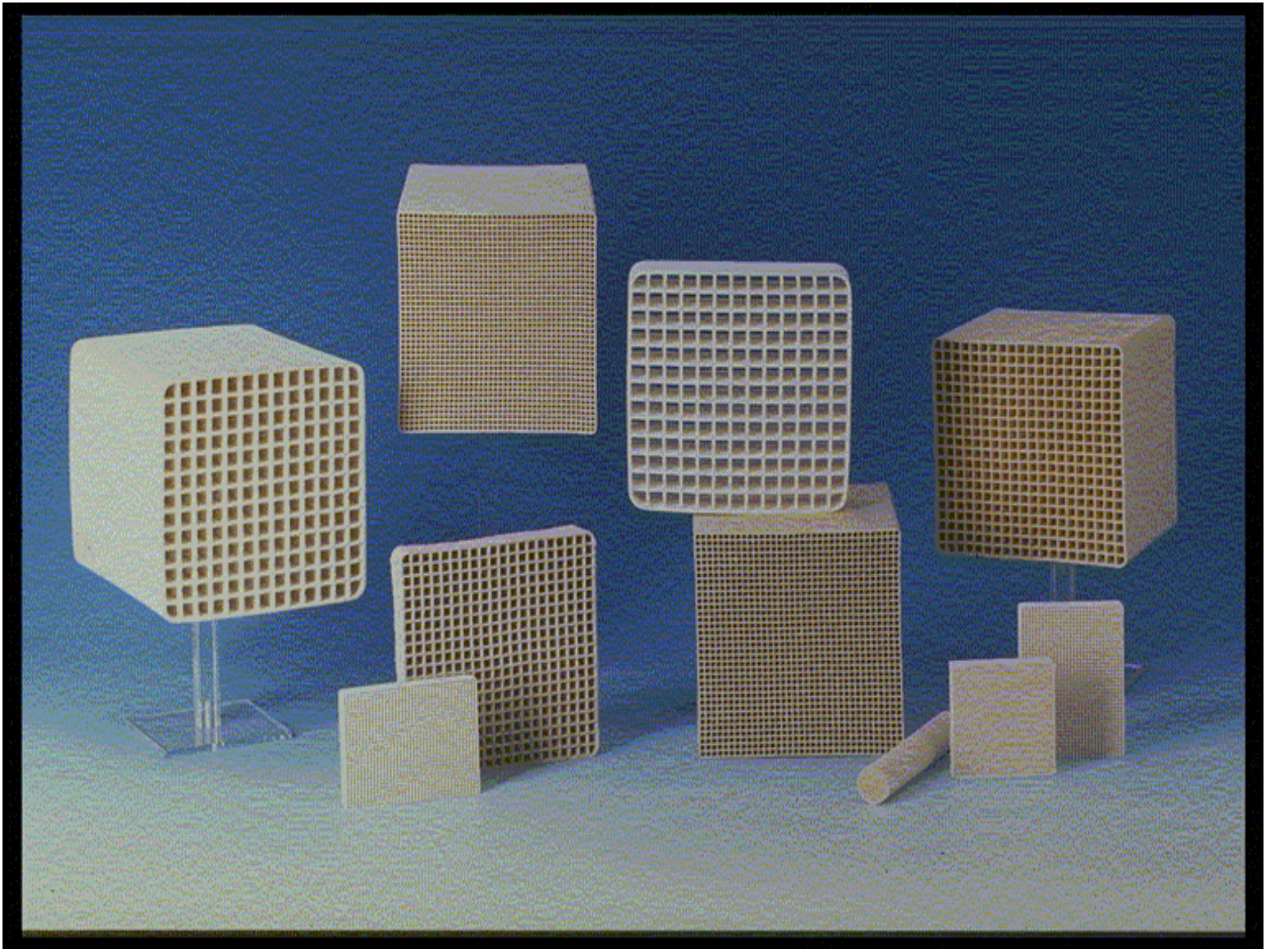
CHEMICAL

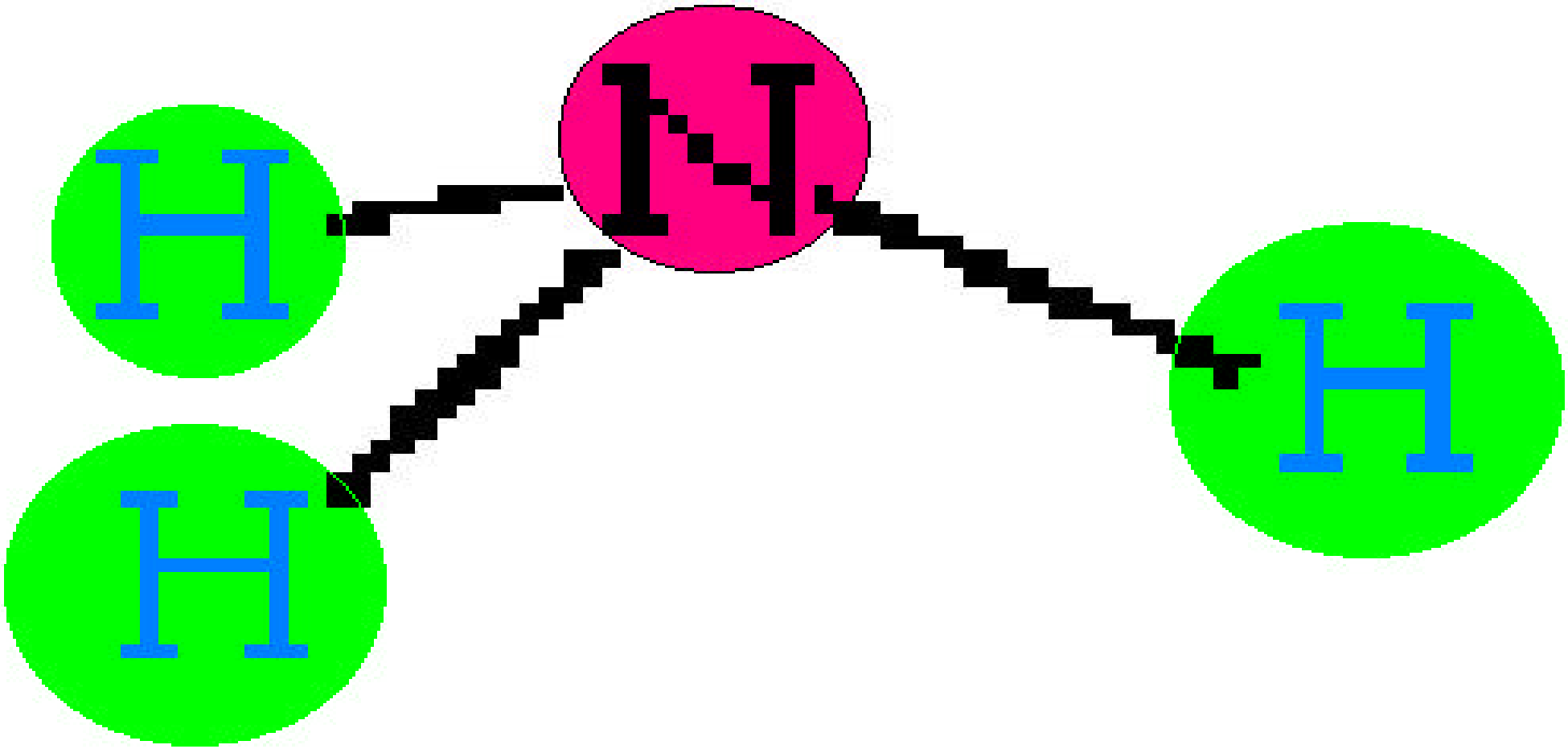
- 3% Vanadium
- 0.5% Vanadium
- Titanium Dioxide
- Zeolite

Catalyst Block









NH_3 AMMONIA SLIP

Ammonia Slip

- Over Feeding of NH_3
- Imperfect Distribution of NH_3 in the Exhaust Gasses
- Imperfect mixing of NH_3 with the Exhaust Gasses
- Imperfect Temperature and/or flow Uniformity at the Catalyst
- Insufficient Exposure of the NOx/NH_3 Mixture to Active Catalyst Sites

Catalyst SO_2 to SO_3 Conversion

More Function of Temperature

Less Function of Catalyst Type

Example

- 3% V_2O_5 @ 716°F — 1.5% Conversion
- 0% V_2O_5 @ 716°F — 0.2% Conversion
- 0% V_2O_5 @ 1022°F — 10% Conversion

Frame Size Combustion Turbine

- High Exhaust Flow
- High Temperature

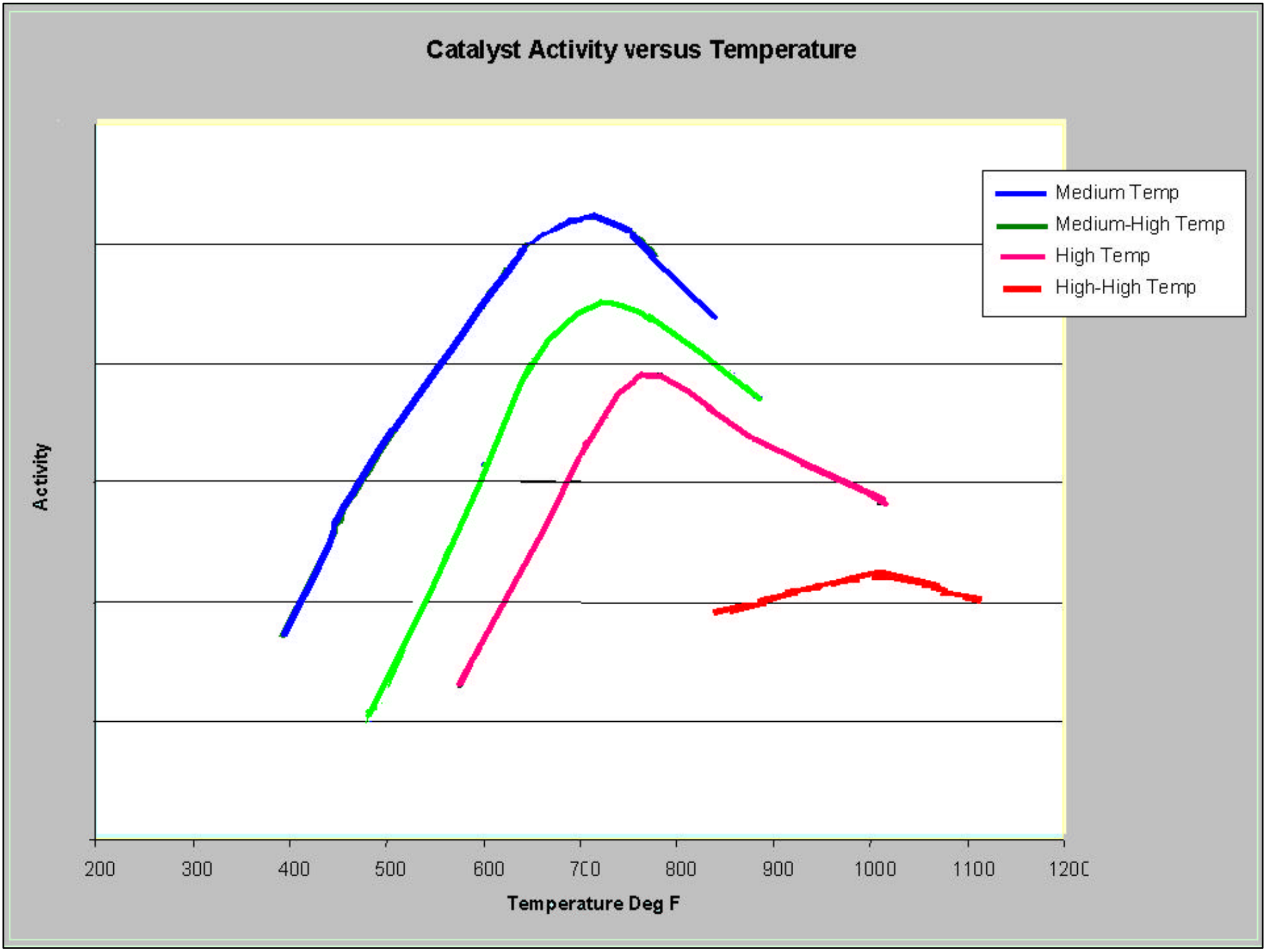
Frame Size Combustion Turbine

To Cool or Not To Cool

That is the question

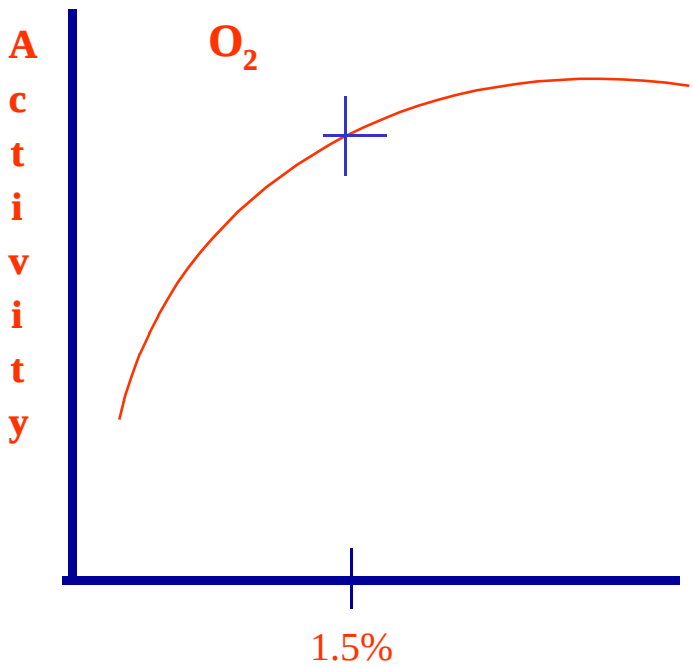
Frame 7E
90% NOx Reduction
No Exhaust Cooling

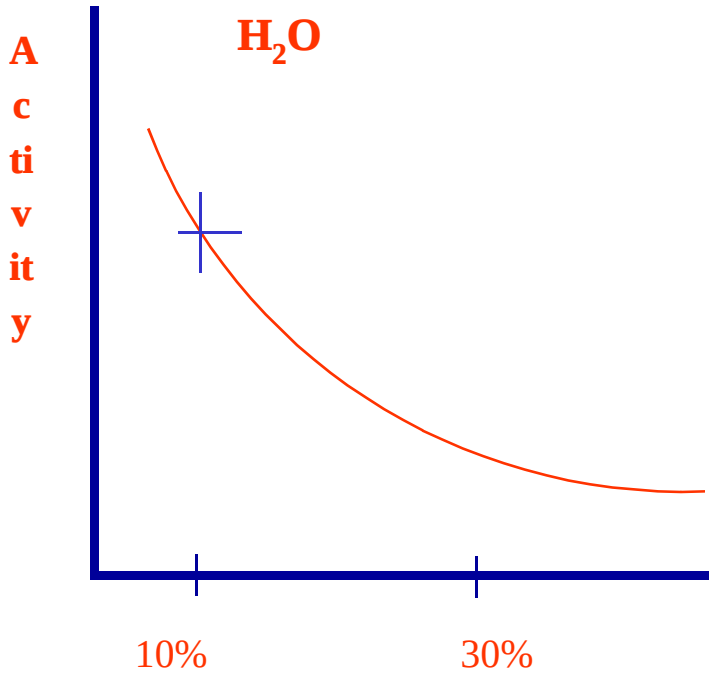
S-W 501 FD
70% NOx Reduction
With Exhaust Cooling
2001 10 31


Catalyst Activity versus Temperature
Medium Temp
Medium-High Temp
High Temp
High-High Temp
Activity
200
300
400
500
600
700
800
900
1000
1100
1200
Temperature Deg F

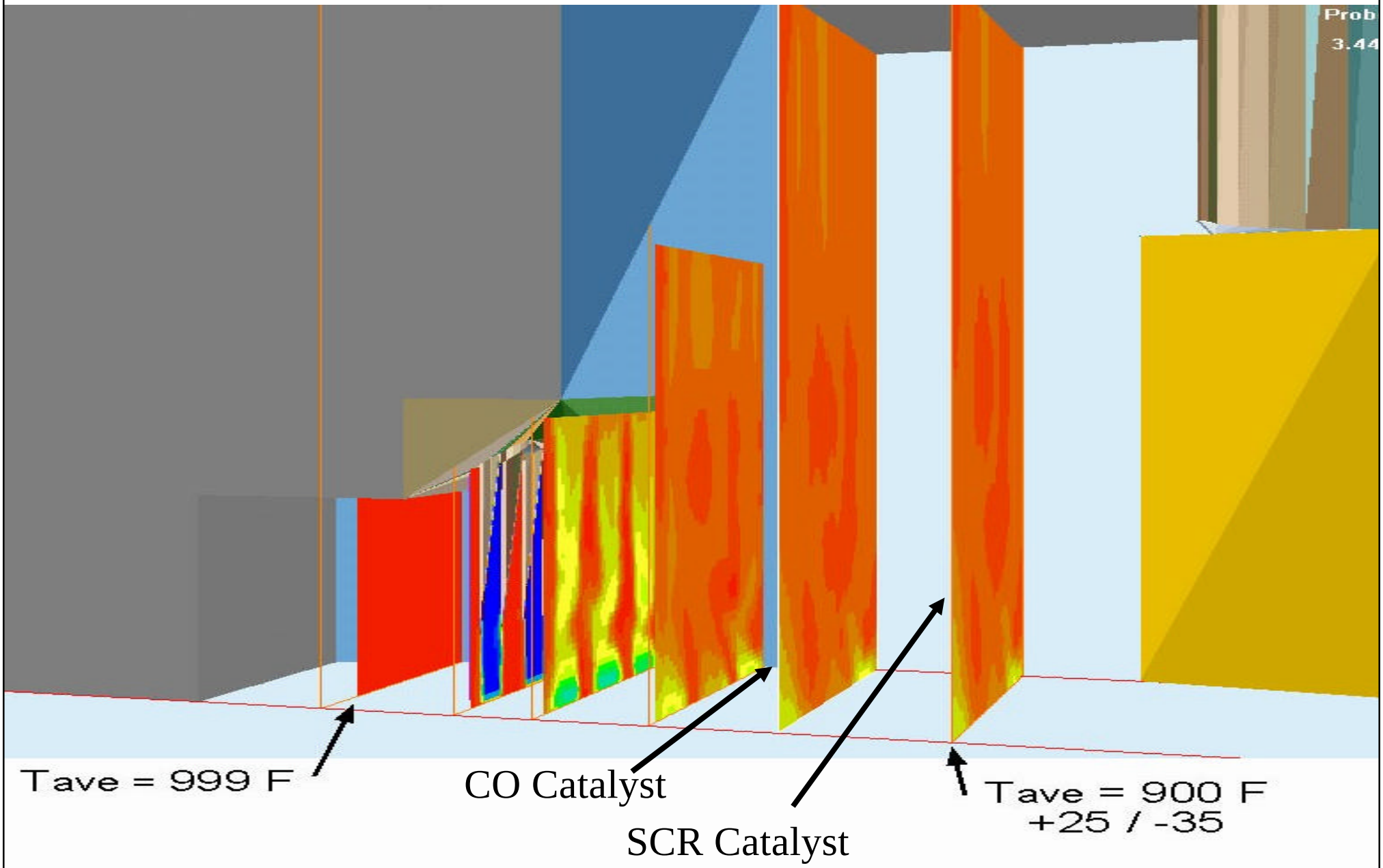
Catalyst Activity

Is Affected by O_2 and H_2O Content





Flow Model for 7EA



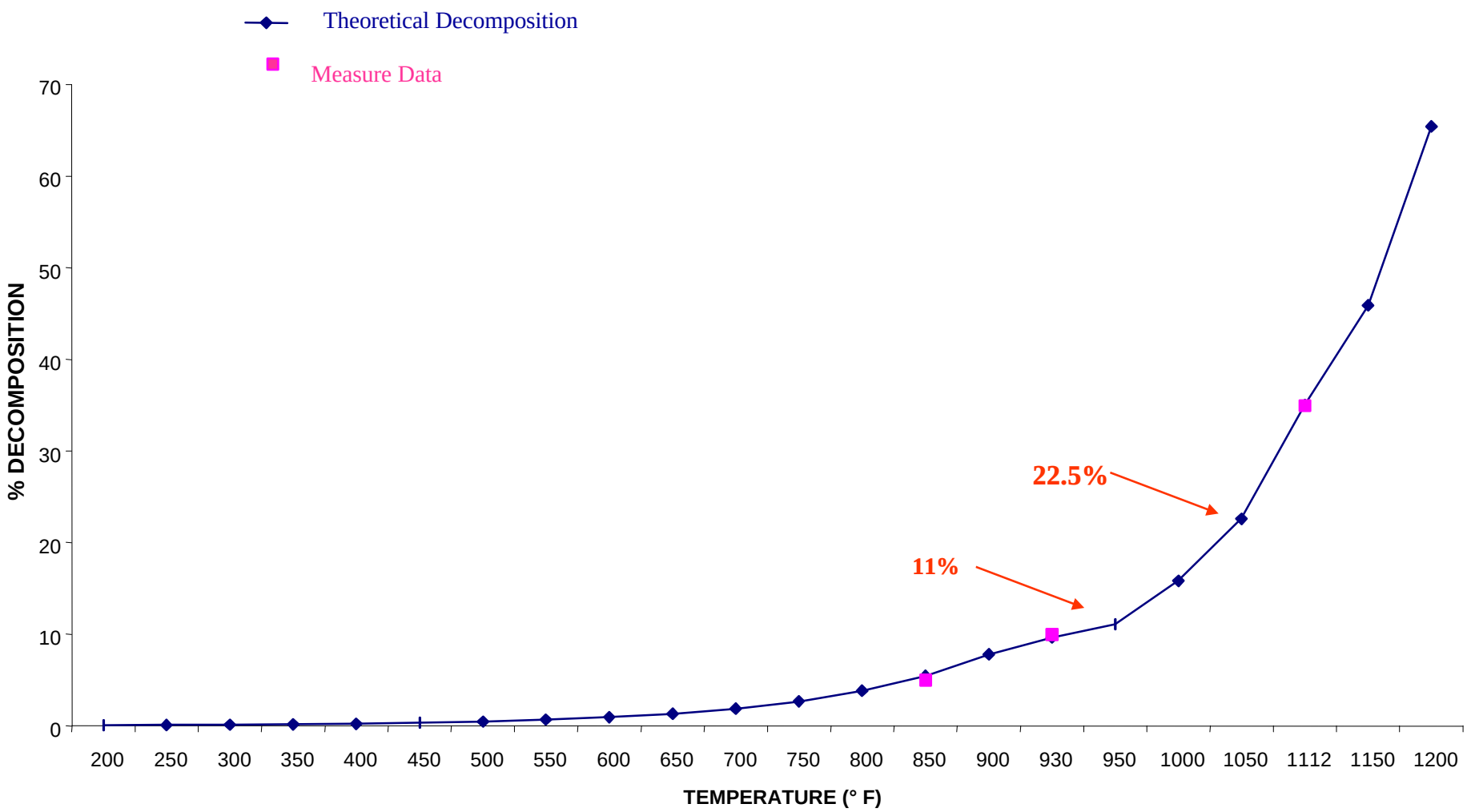
Flow Model for 7EA

NOx Catalyst

Average 900°F

+25/-35 °F

AMMONIA DECOMPOSITION WITH TEMPERATURE



CONCLUSION

- 80% to 90% NOx Reduction on Frame Size Combustion Turbines in Open Cycle is Possible.
- Flow Modeling to Assure Temperature & Flow Uniformity at the Catalyst is Required.
- Cool the Exhaust Gasses.
- Design the AFCU for Sufficient NH_3 Flow, Especially when Distillate Fuels are used.

Acknowledgements & References

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Materials & Information used from:

- **CERAM-Frauenthal**
- **Engelhard**
- **DOE Publications**
- **Haldor Tops¿e**
- **ICAC White Papers**

Contact Info:
908 333 2036
jef.potters@hamonusa.com