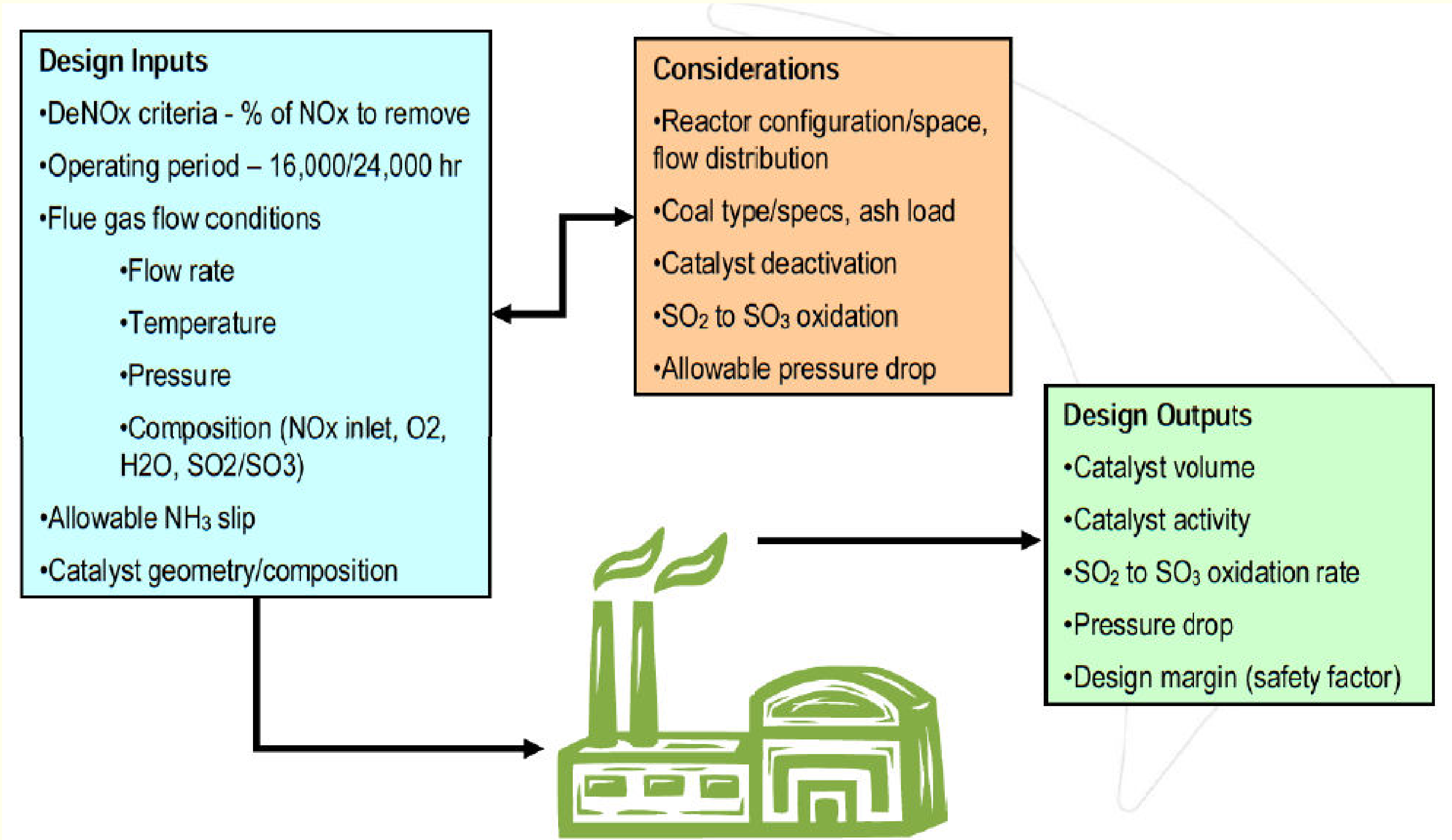
SCR DESIGN PROCESS

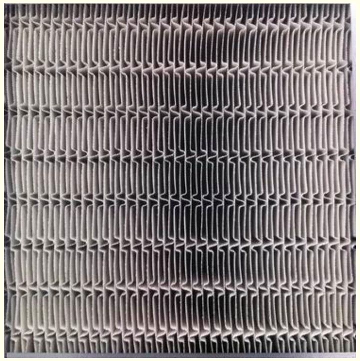


SCR CATALYST

- The primary base material of catalyst is titanium dioxide (TiO_2), with smaller amounts of other metal oxides including tungsten oxide (WO_2) for thermal support and vanadium pentoxide (V_2O_5), which is the primary active material.
- Two predominant styles of catalyst are used in SCRs - honeycomb and plate type.
- Honeycomb catalyst provides the greater surface area of the two designs, but can be susceptible to fly ash fouling.
- BHEL has capability to manufacture both honey comb as well as plate type catalysts

HONEY COMB

PLATE TYPE



MAJOR LIST OF EQUIPMENTS FOR SCR

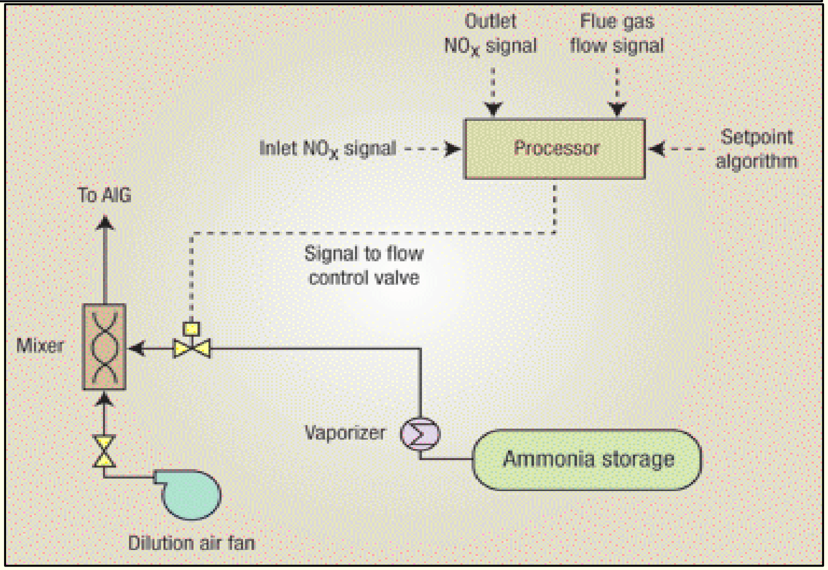
SCR reactors (1–2)	Vertical flow type, equipped with ceramic honeycomb catalyst, insulated casing, soot blowers or sonic horns, hoppers, and hoisting mechanism for catalyst replacement
Anhydrous ammonia tank (1 or more)	Horizontal tank, 250 psig design pressure, storage tanks
Air compressor (2)	Centrifugal type
Vaporizers (2)	Electrical type
Mixing chamber	Carbon steel vessel for mixing or air and ammonia
Ammonia injection grid	Stainless steel construction, piping, valves and nozzles
Ammonia supply piping	Piping for ammonia unloading and supply, carbon steel pipe
Soot blowing steam	Steam supply piping for the reactor soot-piping blowers
Air ductwork	Ductwork between air blowers, mixing chamber, and ammonia injection grid, carbon steel
Flue gas ductwork	Ductwork modifications to install the SCR modifications reactors, consisting of insulated duct, static mixers, turning vanes, and expansion joints
Economizer bypass	Ductwork addition to increase flue gas temperature during low loads consisting of insulated duct, flow control dampers, static mixers, turning vanes, expansion joints, and an opening in the boiler casing
Ash handling	Modification of existing fly ash handling system
Induced draft fans	Extra Load of SCR to be taken.
Controls and instrumentation	Stand-alone, microprocessor-based controls for the SCR system with feedback from the plant controls for the unit load, NOx emissions, etc., including NOx analyzers, air and ammonia flow monitoring devices, ammonia sensing and alarming devices at the tank area
Electrical supply	Electrical wiring, raceway, and conduit to connect the new equipment and controls to the existing plant supply systems
Electrical equipment	System service transformer
Foundations	Foundations for the equipment and ductwork/piping, as required
Structural steel	Steel for access to and support of the SCR reactors and other equipment, ductwork, and piping

COMPARISON OF SCR REAGENT INJECTION SYSTEMS

Anhydrous Ammonia	Aqueous Ammonia (19 or 29% by weight NH_3)	Urea to Ammonia
Lowest capital cost	Moderate capital cost	Highest capital costs
Lowest operating cost	High energy usage	Moderate energy consumption
Fewest product deliveries	Largest number of product deliveries	Moderate product deliveries
Highest safety risk	Lower risks than anhydrous	Lowest safety risk
Highest permitting costs	Moderate permitting issues	Lowest permitting issues
Largest number of regulatory issues	Moderate regulatory issues	Lowest regulatory issues

COMPARISON OF SCR REAGENT INJECTION SYSTEMS

- Although aqueous ammonia has perceived safety advantages, its cost is significantly higher than anhydrous ammonia.
- Aqueous ammonia has the double disadvantage of transporting and storing large quantities of water and evaporating that water prior to reaction in the SCR system.
- Vaporizing aqueous ammonia requires approximately 10 times the energy required to vaporize anhydrous ammonia.
- Finally, aqueous systems require liquid pumps and approximately 3-4 times the storage volume for an equivalent amount of reagent, resulting in additional capital costs.



SCR OPERATIONAL ISSUES

- ❑ Safety issues in ammonia handling and storage
- ❑ Ammonia slip in the flue gas steam and subsequent stack emission
- ❑ Formation of ammonium salts (ABS) and fouling of downstream equipment including APH
- ❑ Catalyst deactivation due to ash plugging and poisoning
- ❑ Catalyst erosion due to ash loading
- ❑ Ash disposal due to elevated level of absorbed ammonia in the fly ash
- ❑ Impact on ESP performance
- ❑ SCR catalyst disposal issues

COSTS OF SCR SYSTEM

Capital Cost

- Catalyst and reactor system
- Flow control skid and valving system
- Ammonia injection grid
- Ammonia storage
- All piping
- Flues, expansion joints and dampers
- Fan upgrades/booster fans
- Foundations, structural steel and electricals
- Installation

Operating Cost

- Ammonia usage
- Pressure drop changes
- Excess air change
- Unburned carbon change
- Ash disposal
- Catalyst replacement
- Vaporization/injection energy requirement
- Other auxiliary power usage

IN HOUSE CAPABILITY OF BHEL

IN HOUSE CAPABILITY OF BHEL

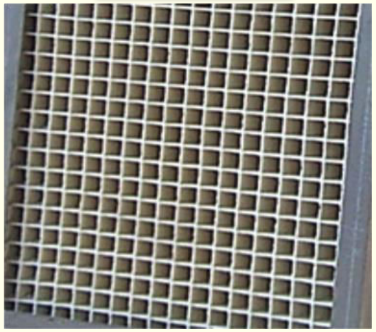
Catalyst Design Strategy for high Ash content coal

- Proper Geometry (Shape & Pitch) to Pass Ash
- Sized to Accommodate Deactivation
- Protective erosion resistant honeycomb layer
- Mechanical stability (ceramic fibre reinforcement)

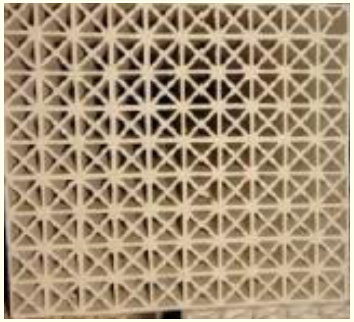
In-house capability at BHEL's Ceramic Technology Institute, Bangalore

- Expertise to design & fabricate honeycomb die
- Enable realizing quickly new shape & pitch of honeycomb as needed based on computational reactive mechanics analysis – manufacturing protected by national and international patents
- CTI developed erosion resistant honeycomb layer protecting the catalysts downstream

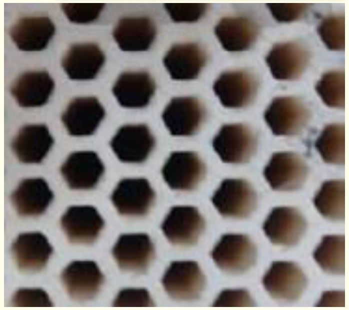
SQUARE



DIAGONAL

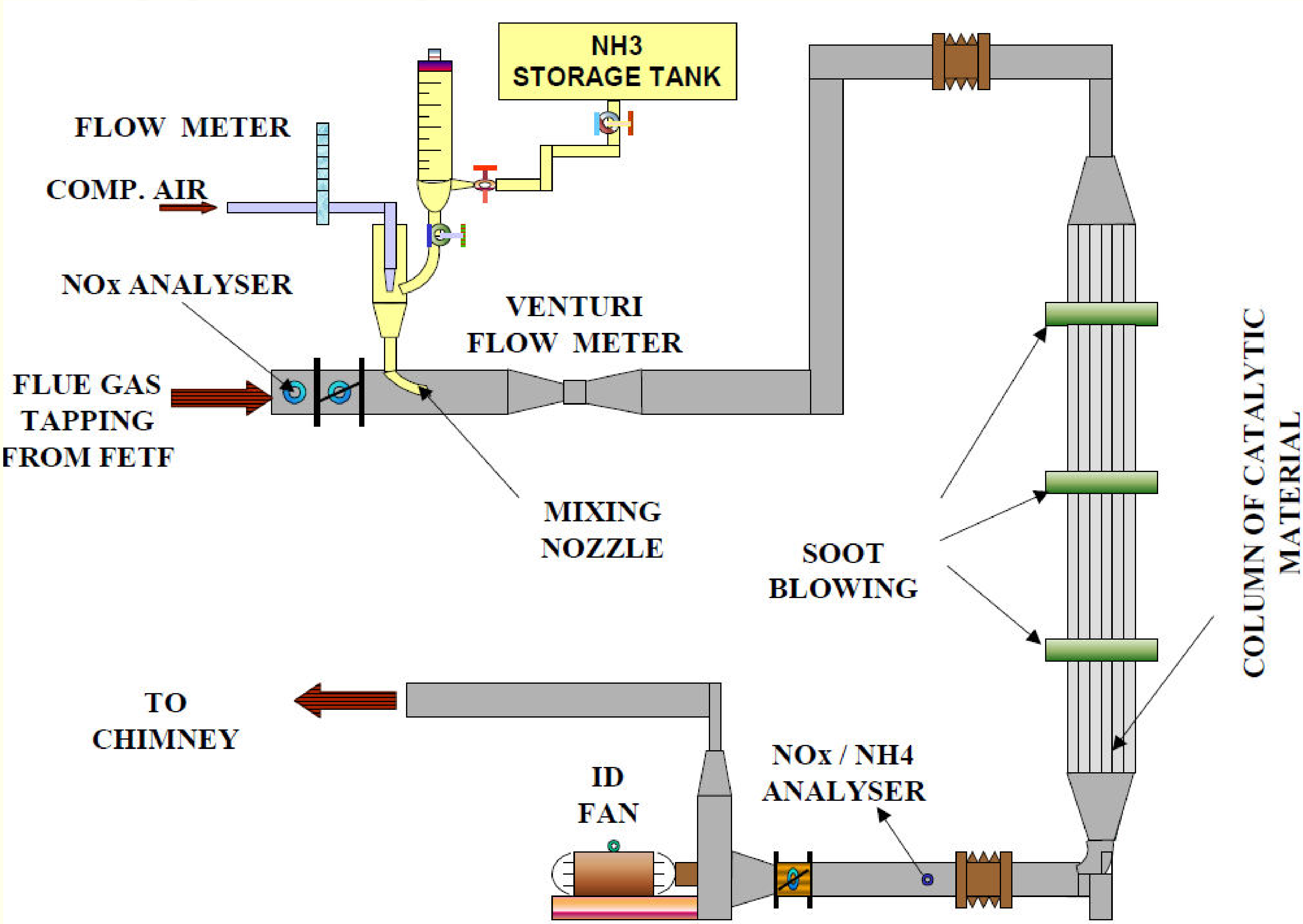


HEXAGONAL



BHEL SCR TEST FACILITY - FETF

SCR PILOT PLANT AT FETF



DETAILS OF INDIAN COAL USED DURING FETF TESTING

Proximate analysis, %	Ultimate analysis, %	Ash composition, %
Moisture -- 3.6	C -- 45.64	SiO_2 -- 65.6
VM -- 25.7	H -- 2.98	Al_2O_3 -- 23.6
Fc -- 33.13	S -- 0.61	Fe_2O_3 -- 5.2
Ash -- 37.13	N -- 1.01	TiO_2 -- 1.7
C V -- 4385cal/g	O -- 4.91	CaO -- 0.8
		MgO -- 0.4
		Na_2O -- 0.2
		K_2O -- 1.7
		SO_3 -- 0.4

SCR CATALYST PROPERTIES

Catalyst type	
Element size	**mm**
Length	**mm**
Number of cells	
Cell density	**cells/cm^2**
Wall thickness (inner)	**mm**
Pitch	**mm**
Geom. surface area	**m^2/m^3**
Void fraction	
Specific pressure drop	**mbar/m**

SCR CATALYST EVALUATION IN FETF

BHEL developed Catalyst showed better NOx reduction efficiency (90%) as of imported catalyst when tested at BHEL- Trichy's Fuel evaluation test facility

SCR catalyst Honeycomb Module

Characteristics

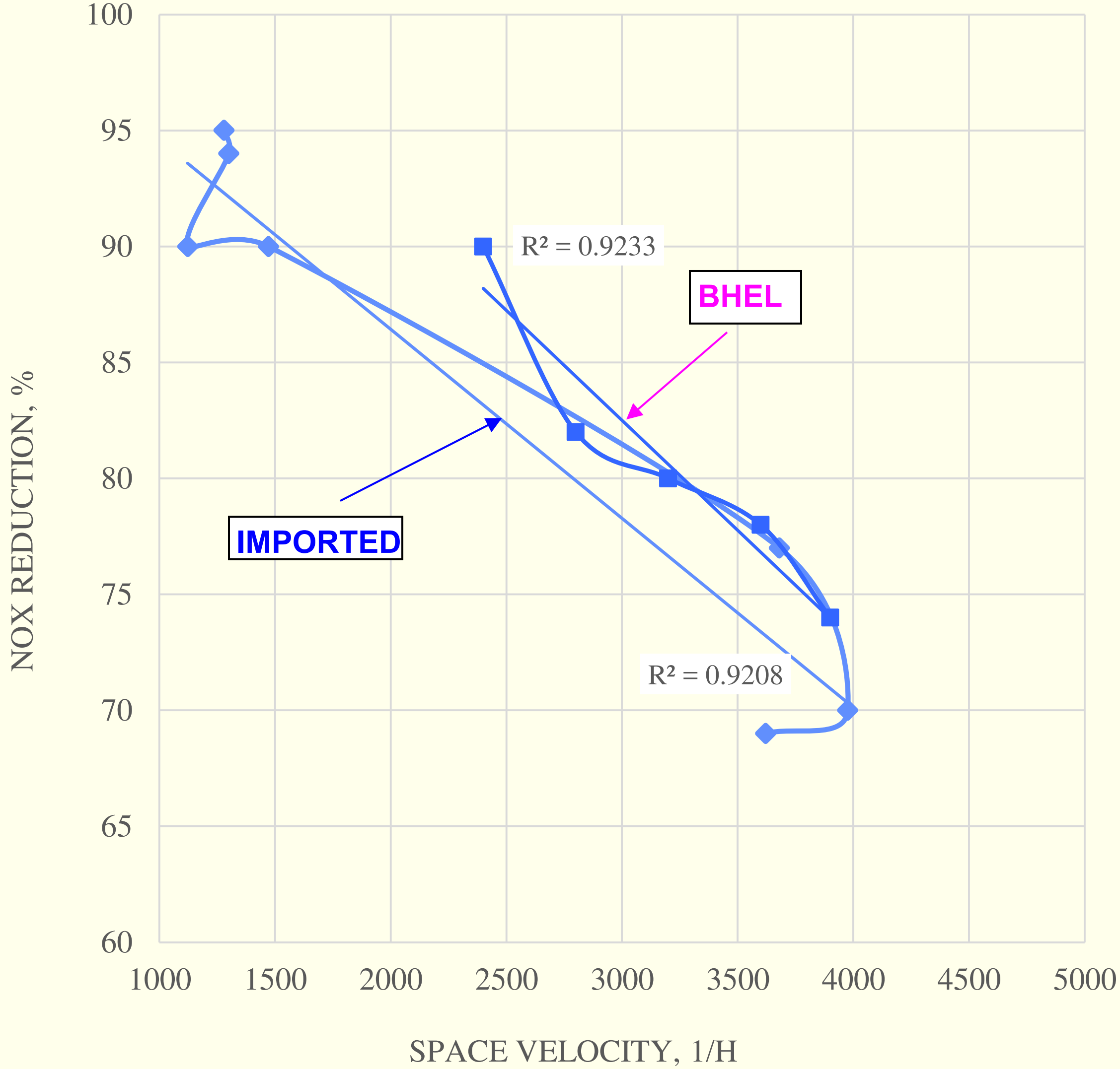
- Tested in coal fired boiler exhaust
- Module Size : 150X150X1000 mm
- Honeycomb Pitch : 6.5X6.5 mm
- Catalyst surface area : 115 m2/g
- Module surface area : 400 m2/m3
- Draft loss : 50 mm of WC (max.)
- Catalyst type : Ti-V-W

CTI manufactured Catalyst Honeycomb Modules (including insulation) dismantled after testing at FETF

TEST RESULTS OF SCR CATALYSTS AT FETF

S.No	SPACE VELOCITY h^{-1}	AVG. FLUE GAS TEMPERATURE IN °C	NO_x REDUCTION %	
			BHEL Catalyst	Imported Catalyst
1	1100	330	-	90
2	1280	350	-	95
3	1500	335	-	90
4	2300	350	86	85
5	2670	340	90	88
6	3010	350	86	80
7	3680	335	88	78
8	3735	330	77	74
9	3780	360	78	72
10	3975	290	73	70

SCR CATALYST EVALUATION IN FETF



KEY FINDINGS FROM PILOT SCALE TESTING AT FETF

- Experiments carried out with imported as well as BHEL developed catalyst. The NOX reduction by SCR system in both the cases was in the range of 80 to 95%.
- The optimum flue gas temperature was found to be around 350°C. Maintaining operating temperature between 300 to 400 ^{0}C ensures higher NOx reduction efficiency. This also prevents Maintaining lower temperature limits leads to deposition of ammonium bi-sulphate while higher temperature limits favour SO_2 to SO_3 oxidation.
- Tests were carried out using gaseous Ammonia as well as liquid Ammonia of 25% concentration. The NOX reduction was comparatively better with the usage of gaseous ammonia due to uniform mixing.
- No plugging of fly ash particle in catalyst cells was found, during initial 100 hours of SCR operation when using coal with 40% ash content.
- Ammonia slip was less than 5 ppm.

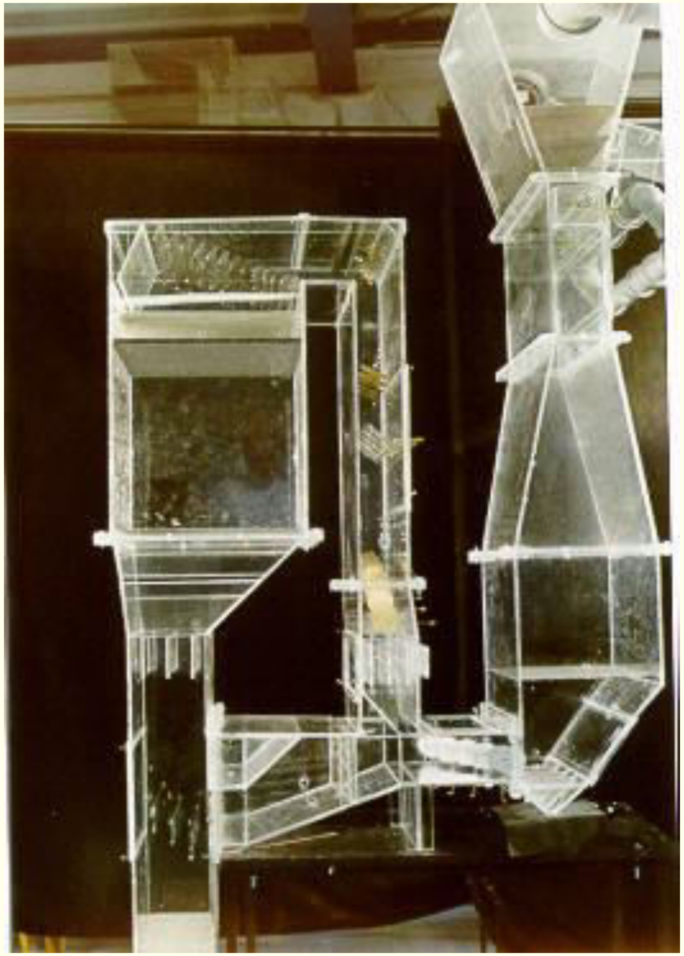
TYPICAL PLANTS WITH SCR

TYPICAL PLANT WITH SCR

TYPICAL PLANT WITH SCR

TYPICAL PLANT WITH SCR

SCR MODEL STUDY

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