A Maharatna Company

NETRA

CFD Analysis of ESP internal flow of Ramagundam St-II Unit

By

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PRESENTATION OUTLINE

- ESP performance improvement thru conventional method
- CFD modeling – Introduction
- CFD modeling of Ramagundam St-II units-Objectives
- Flue gas flow analysis of FG duct between APH and ESP
- Flue gas analysis of ESP internal flow
- Modification Strategy and proposed modifications
- Comparison of flow in as built ESP and modified ESP
- Estimated quantification of effect of modification CFD modeling
- Modification carried out
- Conclusions

ESP PERFORMANCE IMPROVEMENT- CONVENTIONAL METHODOLOGY

CONVENTIONAL METHOD OF ESP PERFORMACNE IMPROVEMENT

- Increase the specific collection area based on Modified Deutsch Equation
  - Increasing the height of the ESP Fields
  - Increasing the number of ESP Fields
  - Increasing no of ESP Passes
- Decision is based on the target SPM and height/area available around ESP
- ESP R&M entails long shutdown of ESP passes
- ESP R&M cost depends on Unit size, added SCA and can vary from 25-100 Cr/Unit

Is there alternate methodology to increase the SCA within the same ESP structure?

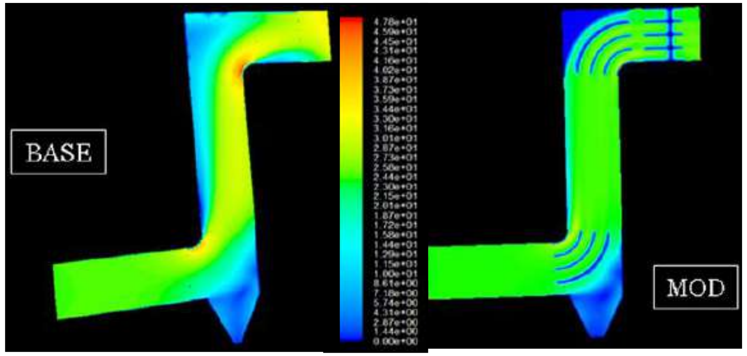
CFD provides a methodology to increase SCA in a given ESP?

HOW THE IDEA OF CFD MODELING OF ESP CAME ABOUT

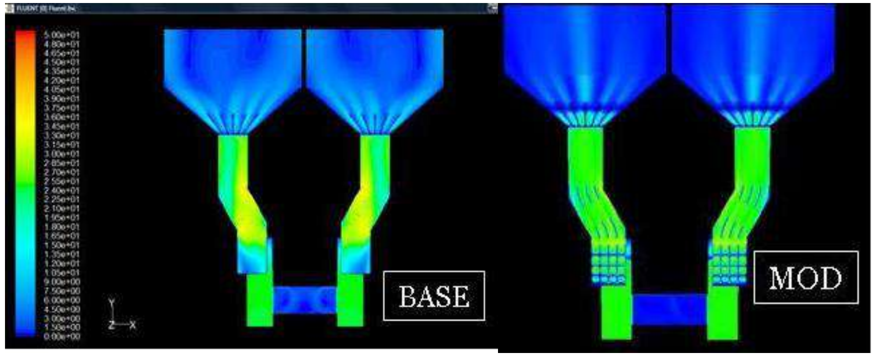
- A visit of NTPC official to Germany where STEAG shared their experience of improvement in ESP using CFD modeling
- NETRA's own experience with modifications carried out in Flue Gas (FG) duct.
- Major findings of the analysis and modifications:
  - The flow through the FG duct is not uniform leading to localized high velocity, recirculation causing duct erosion and/or ash deposition
  - Unequal flow through ESP passes even after GD screen test.
- Can it be possible that the flow is not uniform in ESP fields reducing the effecting SCA
- How the FG flow behaves inside the ESP
- If the above is true, how can the flow be corrected to increase SCA

Tanda ST-I 110 MW- 4 Units- 2011-2013

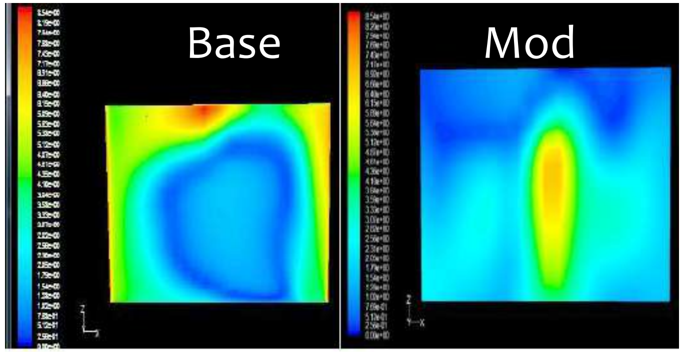
❖ Velocity Profile in FG duct and ESP



APH to ESP- Side View



APH to ESP- Top View



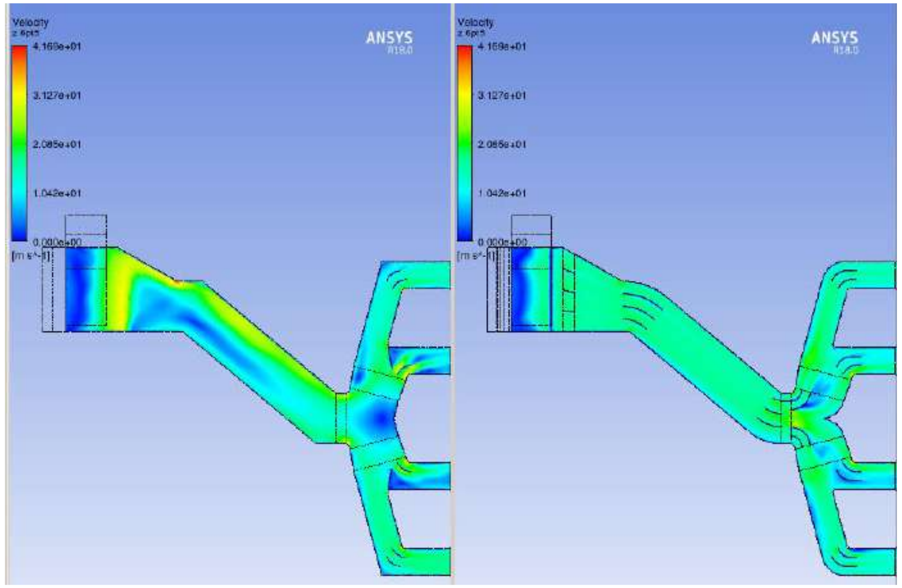
ESP Inlet at end of funnel

❖ Result of Modifications

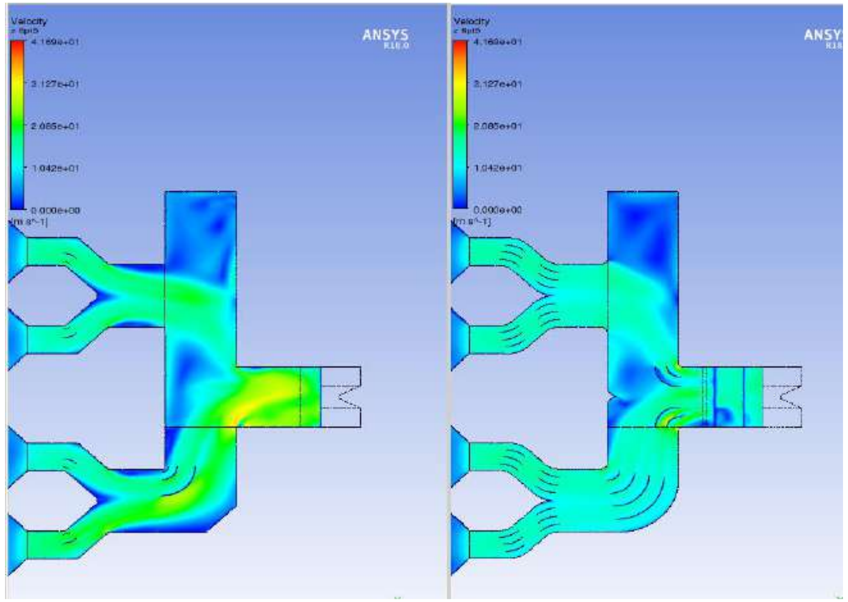
- **ID Fan Power reduction by 100 MW/Unit**
- **Reduction in duct erosion**
- **Site intimated improvement in ESP (although this was not part of the project)**

Simhadri St-II: 500 MW Units

❖ Velocity Profile from BOF to ESP



❖ Velocity Profile ESP to ID Fan

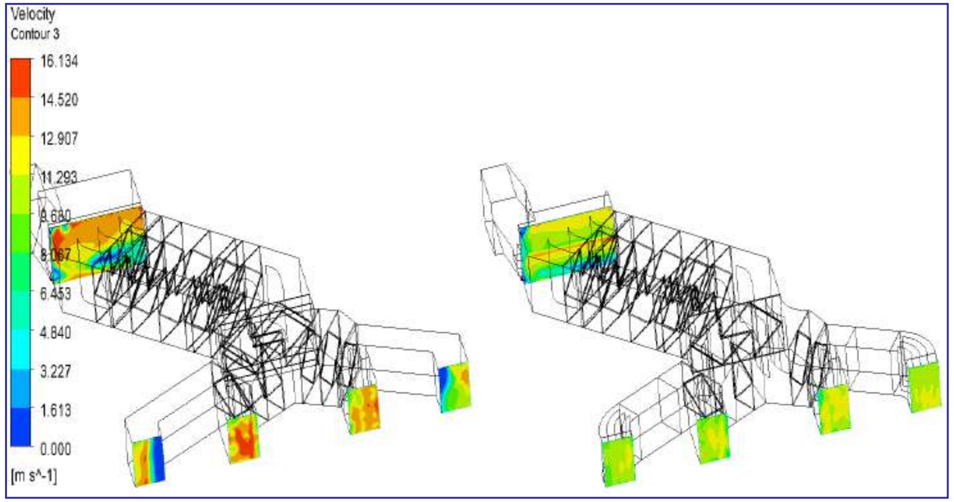


❖ Result of Modifications

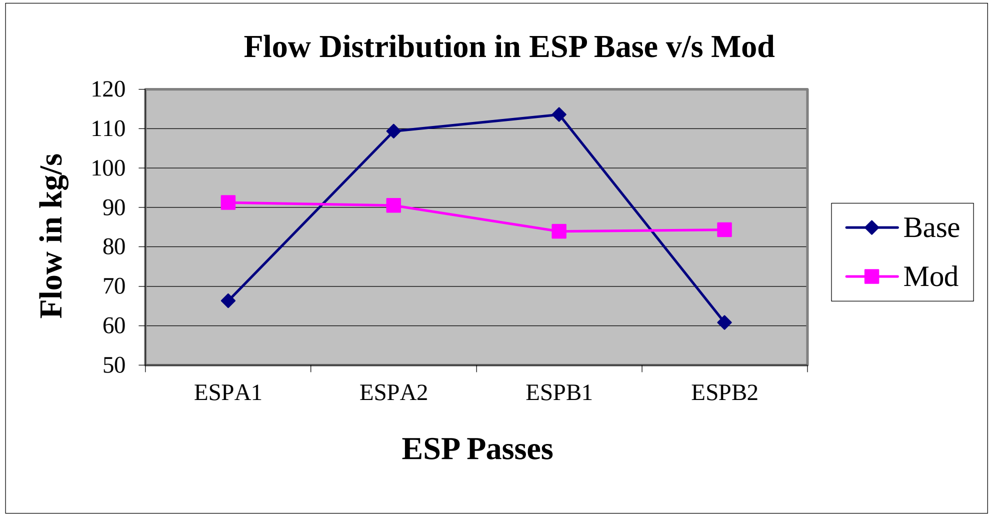
- 115 T of fabrication
- ID Fan Power reduction by 325 MW/Unit
- Reduction in duct erosion and ash deposition

Simhadri St-I: 500 MW Units

❖ Velocity Profile at ESP Inlets St-I



❖ FG flow distribution in ESP Passes



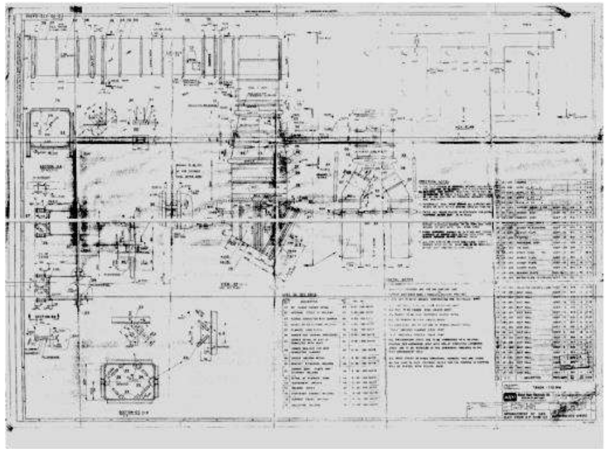
❖ Result of Modifications

- 100 Ton of fabrication
- ID Fan Power reduction by ~300 KW/Unit
- Reduction in duct erosion and ash deposition

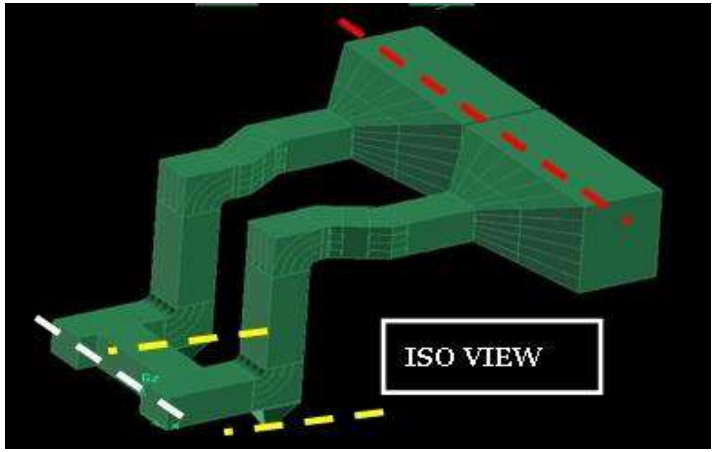
COMPUTATIONAL FLUID DYNAMICS-INTRODUCTION

COMPUTATIONAL FLUID DYNAMICS (CFD)- INTRODUCTION

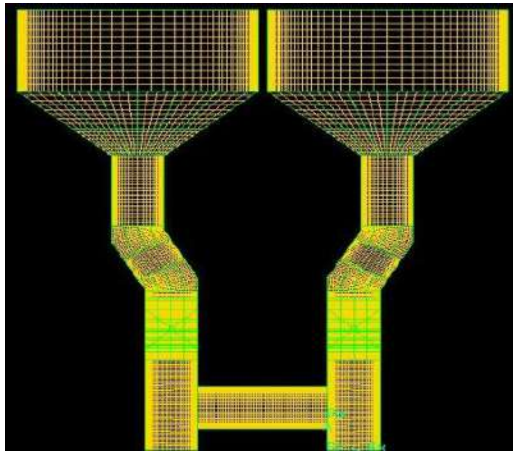
- A virtual simulation using the exact geometry of the process
- Process equations of mass, momentum, energy, reaction etc solved for the total domain
- Result is a continuous parametric profile- like having infinite sensors
- CFD analysis process involves the following:



DRAWING & MEASUREMENT

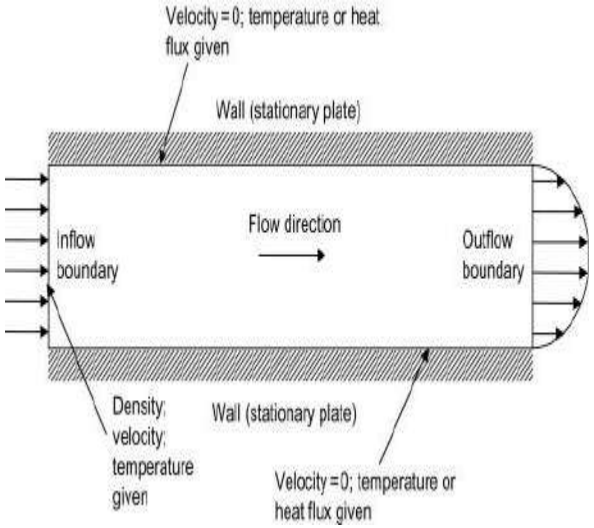


DIGITAL TWIN-3D DIGITAL GEOMETRY

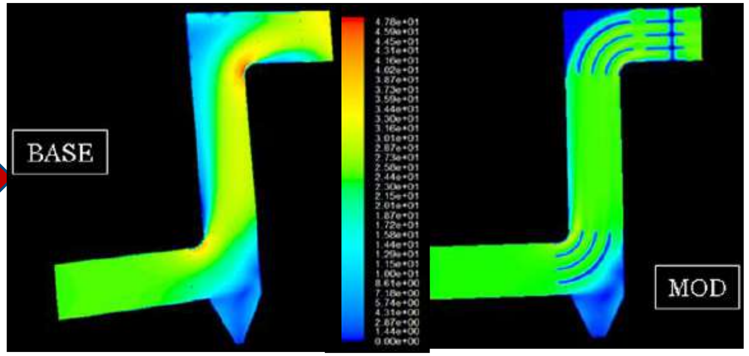


GEOMTERY DIVIDED INTO CELLS-MESHING

COMPUTATIONAL FLUID DYNAMICS (CFD)- INTRODUCTION



	Generic transport equation	
	$\frac{\partial(\rho\phi)}{\partial t}+\frac{\partial(\rho u_i\phi)}{\partial x_i}=\frac{\partial}{\partial x_i}\left(\Gamma\frac{\partial\phi}{\partial x_i}\right)+S_\phi+S_{\rho\phi}$	(1)
Equation	Expression	
Continuity	$\frac{\partial\rho}{\partial t}+\frac{\partial(\rho u_i)}{\partial x_i}=0$	(2)
Continuity	$\frac{\partial}{\partial t}(\gamma_c\rho_c)+\frac{\partial}{\partial x_j}(\gamma_c\rho_c\overline{u_j})=S_{MS,c}+\sum_{d=1}^{N_p}\Gamma_{cd}$	(3)
Momentum	$\frac{\partial(\rho u_i)}{\partial t}+\frac{\partial(\rho u_i u_j)}{\partial x_i}=-\frac{\partial p}{\partial x_i}+\frac{\partial}{\partial x_j}\left[\mu\left(\frac{\partial u_i}{\partial x_j}+\frac{\partial u_j}{\partial x_i}\right)+\delta_{ij}\lambda\frac{\partial u_i}{\partial x_j}\right]+\rho g_i+S_{mom}$	(4)
Energy	$\frac{\partial(\rho h_{tot})}{\partial t}+\frac{\partial(\rho u_i h_{tot})}{\partial x_i}-\frac{\partial p}{\partial t}=\frac{\partial}{\partial x_i}\left(k\frac{\partial T}{\partial x_i}+\frac{\mu_t}{\mathrm{Pr}_t}\frac{\partial h}{\partial x_j}\right)+S_E$	(5)
Species	$\frac{\partial(\rho Y_i)}{\partial t}+\frac{\partial(\rho u_j Y_i)}{\partial x_j}=\frac{\partial}{\partial x_j}\left(\Gamma_{i,eff}\frac{\partial Y_i}{\partial x_j}\right)+S_i$	(6)
Energy and species	$\frac{\partial(\rho h_{tot})}{\partial t}+\frac{\partial(\rho u_j h_{tot})}{\partial x_j}-\frac{\partial p}{\partial t}=\frac{\partial}{\partial x_j}\left(k\frac{\partial T}{\partial x_{ij}}+\sum_i^N\Gamma_i h_i\frac{\partial Y_i}{\partial x_j}+\frac{\mu_t}{\mathrm{Pr}_t}\frac{\partial h}{\partial x_j}\right)+S_E$	(7)



Setting up physics
- Boundary conditions
- Flow properties
- Fluid properties
- Mass, momentum & Energy eq.

Numerical Solutions of equations

Results extraction
Like having infinite flow sensors

CFD MODELLING OF RAMAGUNDAM ST-II UNIT
OBJECTIVES

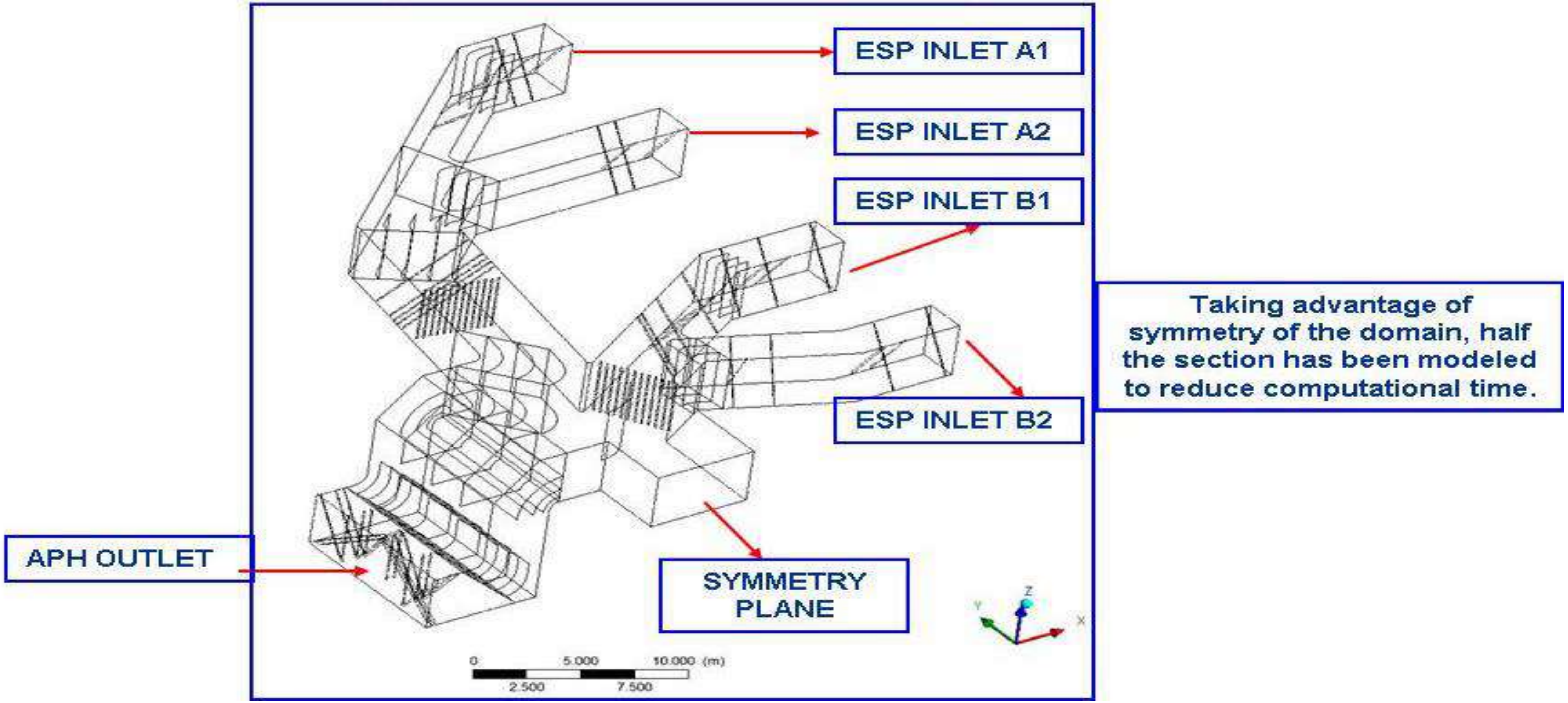
OBJECTIVES FOR CFD MODELING

- To provide uniform flow to all ESP passes
  - Requires evaluating the FG flow pattern from APH outlet to ESP inlet ducts
- To assess the flow condition within ESP
  - Reducing zones of high localized velocities
  - Reducing zones of recirculation of flue gas flow
  - Reducing any entrapment zones
- To providing better uniform flow in ESP outlet
  - Reduce the pressure drop
  - To compensate for any extra pressure drop in ESP due to any correction measures within ESP

FLUE GAS FLOW ANALYSIS OF APH-ESP DUCT

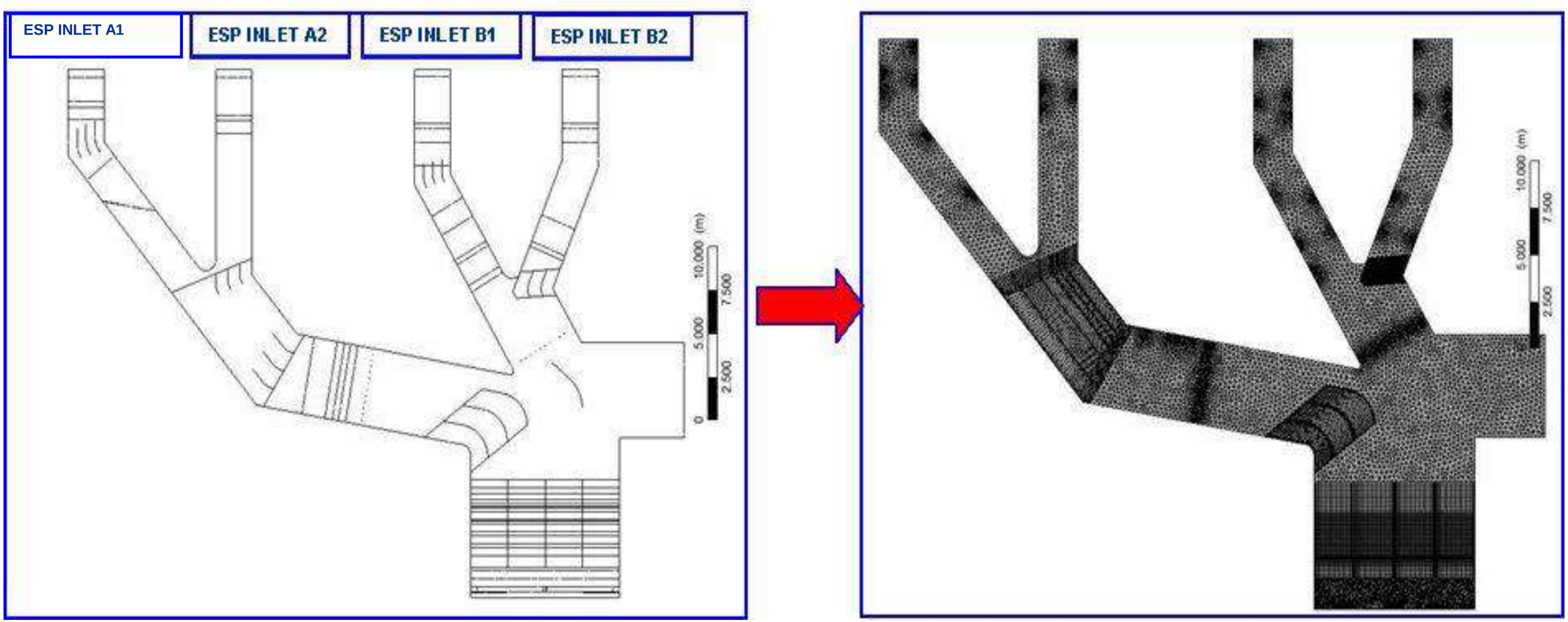
3D Geometry of flue gas duct from APH outlet to ESP

3D Geometry of Flue gas duct from APH to ESP

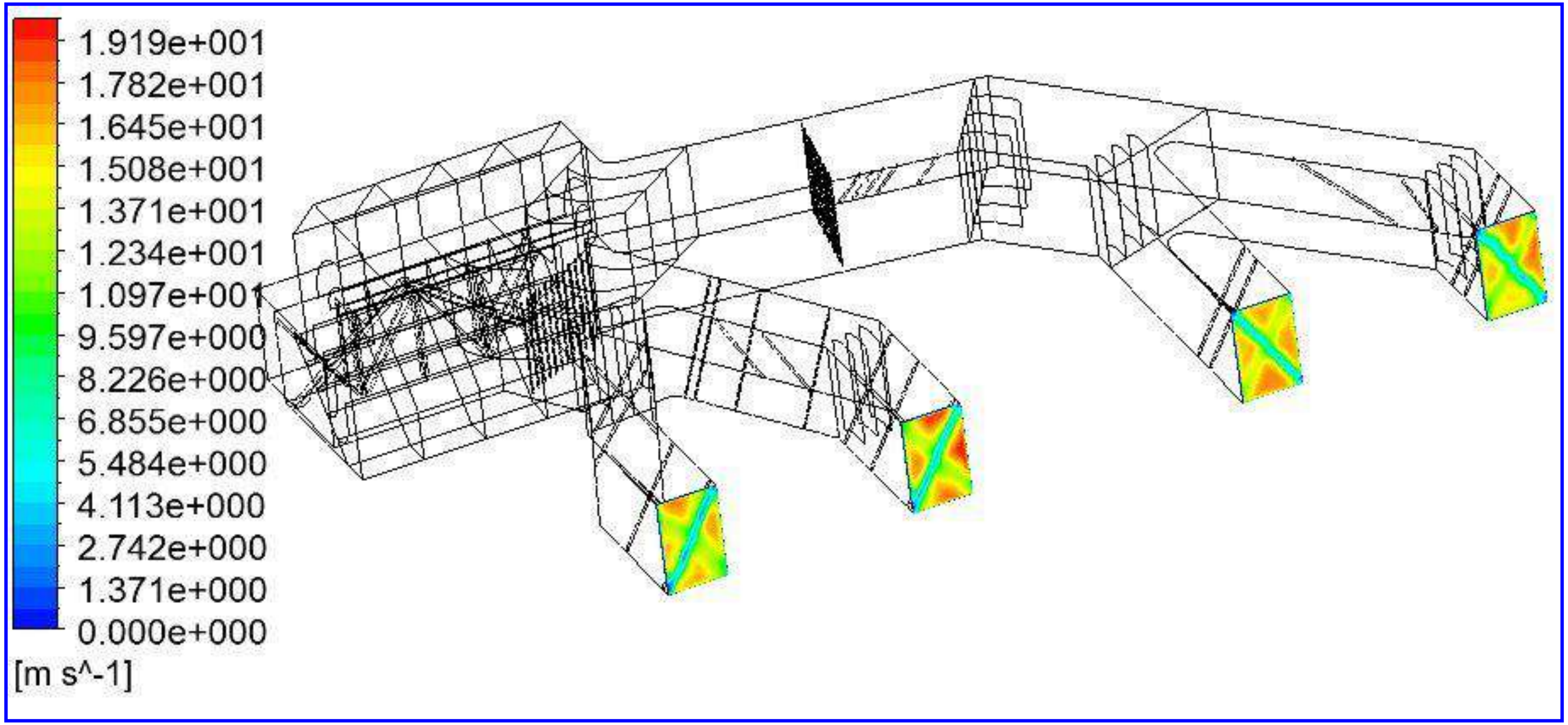


3D Geometry of flue gas duct from APH outlet to ESP: Meshing

TOP VIEW



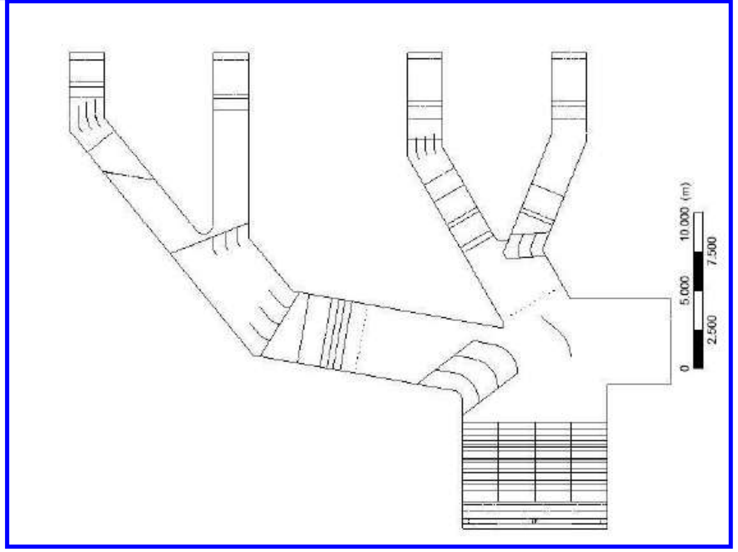
3D Geometry of flue gas duct from APH outlet to ESP: Results



- ❖ As it was found that the flow at ESP inlet is almost uniform with equal flow in all ESP passes,
- ❖ No modification was proposed in the section from APG to ESP

3D Geometry of flue gas duct from APH outlet to ESP: Results

ESP INLET A1 | ESP INLET A2 | ESP INLET B1 | ESP INLET B2



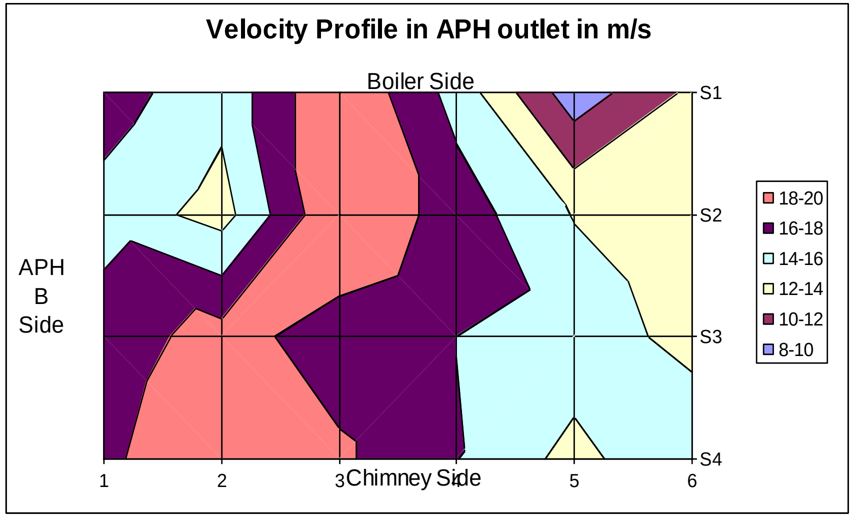
APH outlet

CFD MODEL INPUT	
APH OUTLET	MASS FLOW RATE OF 333 kg/s
ESP INLET A1	Atmospheric pressure
ESP INLET A2	Atmospheric pressure
ESP INLET B1	Atmospheric pressure
ESP INLET B2	Atmospheric pressure

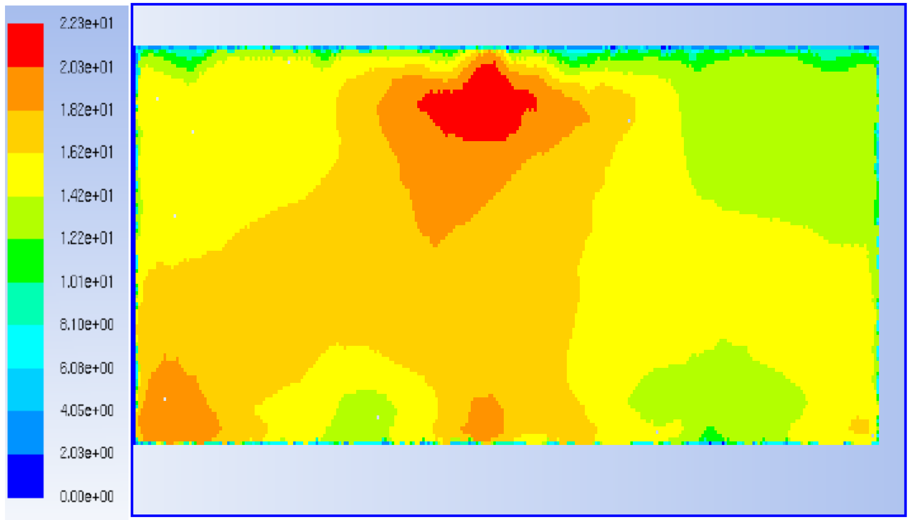
CFD RESULTS	
ΔP APH OUTLET – ESP INLET	22 mmWC
ESP OUTLET A1 MFR	82.10 kg
ESP OUTLET A1 MFR	86.65 kg
ESP OUTLET B1 MFR	84.50 kg
ESP OUTLET B2 MFR	79.75 kg

3D Geometry of flue gas duct from APH outlet to ESP: Validations

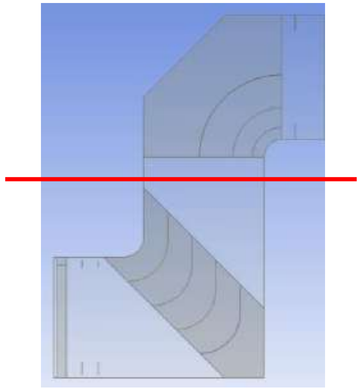
Validation of Velocity Profile at Measurement Plane



MEASUREMENT



CFD PREDICTION



MEASUREMENT PLANE

DUCT SECTION	Δp (Measured) mmWC	Δp (CFD) mmWC
APH -ESP	23.8	23.55

FG FLOW ANALYSIS OF ESP INTERNAL

DETAIL OF RAMAGUNDAM ST-II ESP

S. NO.	PARAMETER	VALUE
1	NO. OF PRECIPITATOR PER BOILER	4
2	NO. OF GAS PATH PER BOILER	4
3	NO OF FILEDS IN SERIES IN EACH GAS PATH	6
4	GAS FLOW RATE	750 m^3/s
5	TEMPERATURE	135˚C
6	DUST CONCENTRATION	42 gm/ NM^3
7	DESIGN PRESSURE DROP	20 mmWC
8	VELOCITY OF GAS IN ELECTRODE ZONE ON TOTAL AREA	0.81 m/s

DETAIL OF RAMAGUNDAM ST-II ESP

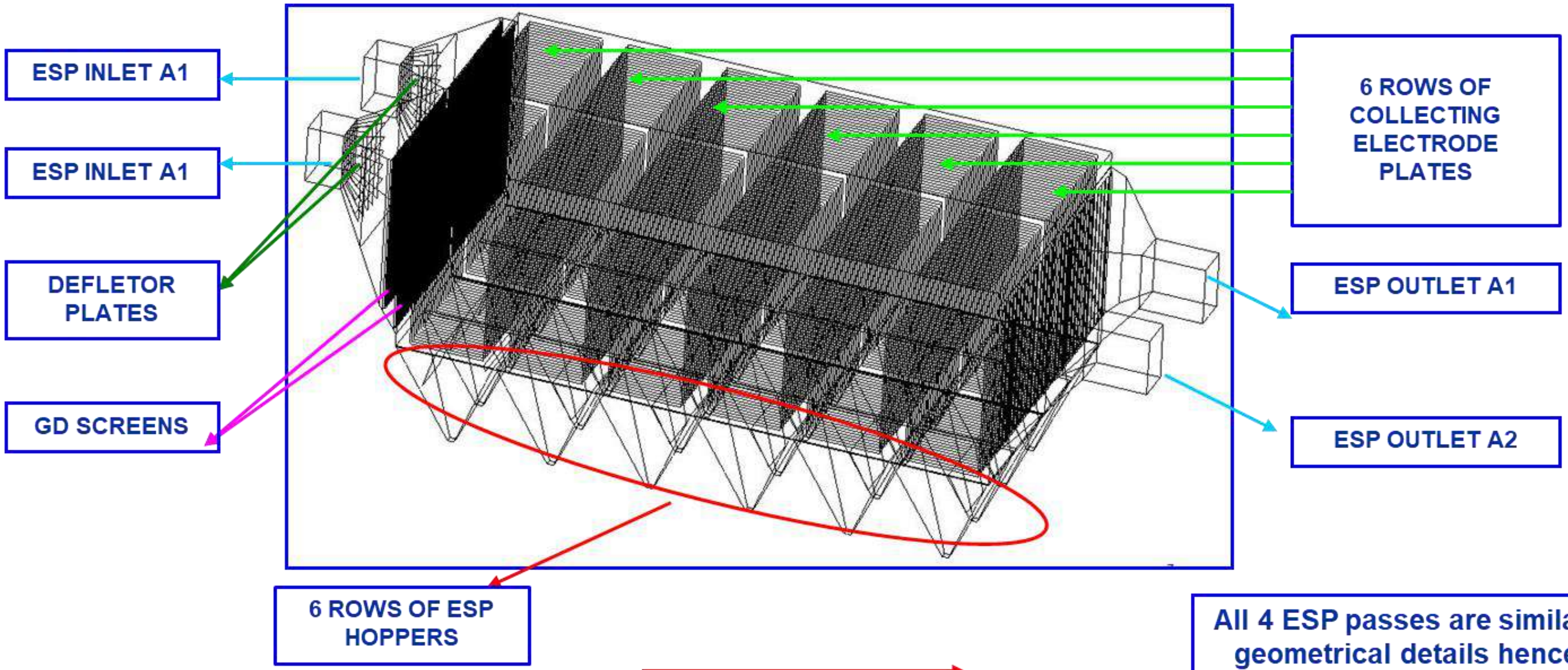
S. NO.	PARAMETERS	VALUES
9	TREATMENT TIME	33.33 sec
10	SPECIFIC COLLECTION AREA	221.9 $m^2/m^3/s$
11	GUARANTEED COLLECTION EFFICIENCY	99.9 %
12	NO. OF ROWS OF COLLECTING ELECTRODES PER FIELD	61
13	TOTAL NO. OF COLLECTING PLATES PER BOILER	8784
14	NOMINAL HEIGHT OF COLLECTING PLATES	12.5 m
15	NOMINAL WIDTH OF COLLECTING PLATE	750 mm
16	EMITTING ELECTRODE TYPE: SPIRAL WITH HOOKS	2.7 MM DIA
17	NO. OF ELECTRODES PER BOILER	77760

DETAIL OF RAMAGUNDAM ST-II ESP

S.NO	PARAMETERS	VALUES
18	TOTAL LENGTH OF ELECTRODES PER BOILER	16590 m
19	TOTAL NO. OF ELECTRODES PER FIELD	3240
20	PLATE WIRE SPACING	150 MM

DETAIL OF RAMAGUNDAM ST-II ESP: Geometry

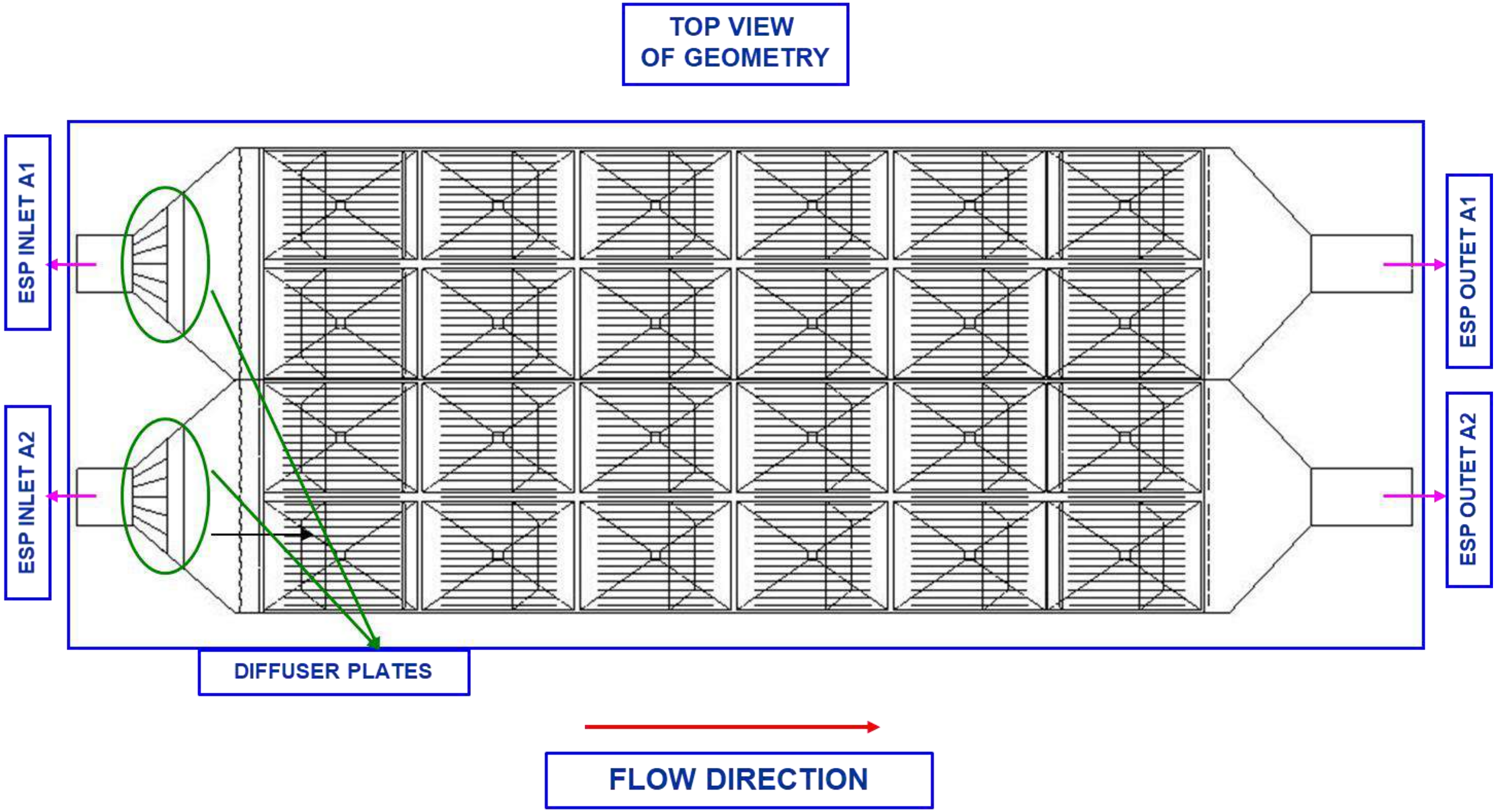
ISOMETRIC VIEW OF GEOMETRY



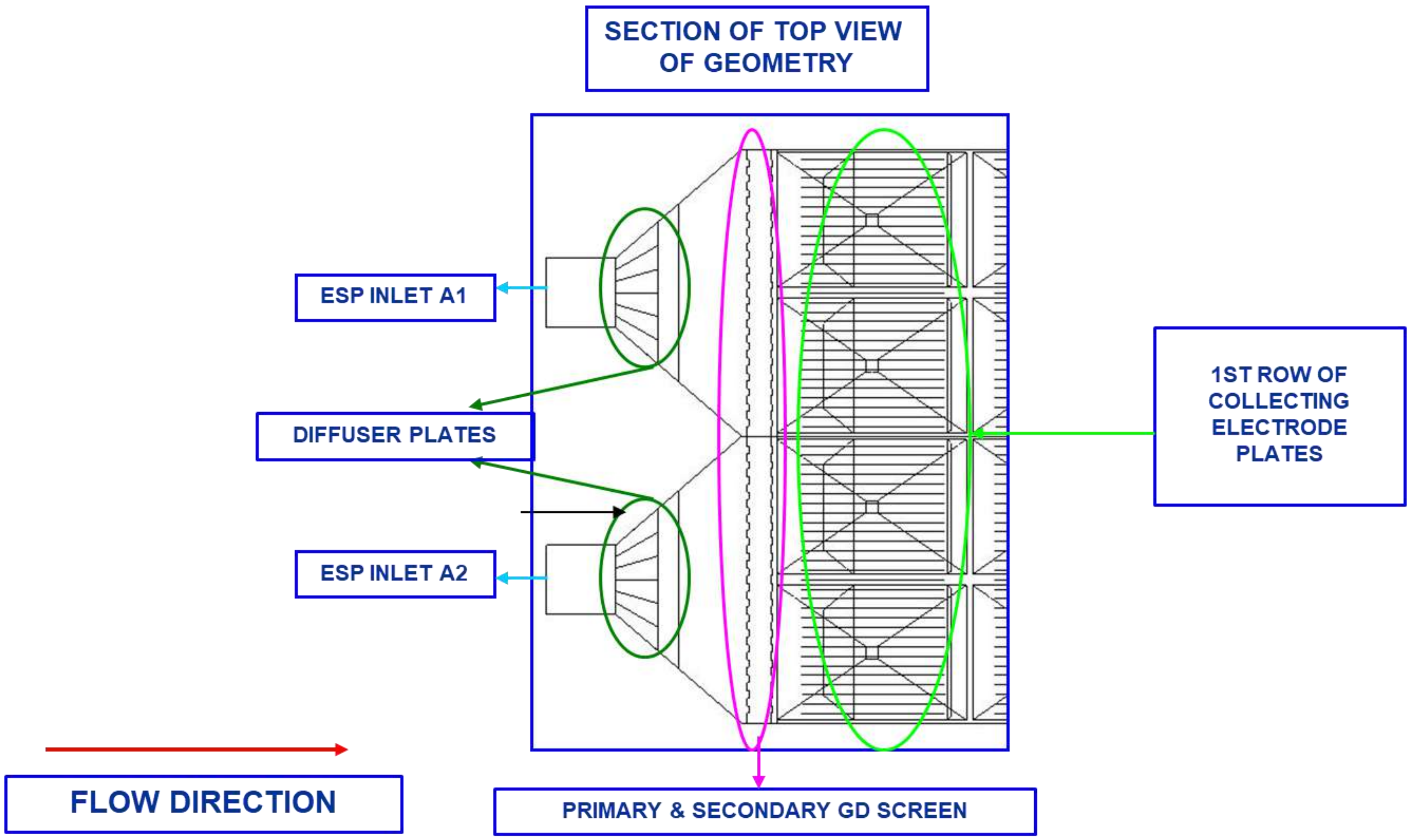
FLOW DIRECTION

All 4 ESP passes are similar in geometrical details hence 1 pass has been considered for modeling

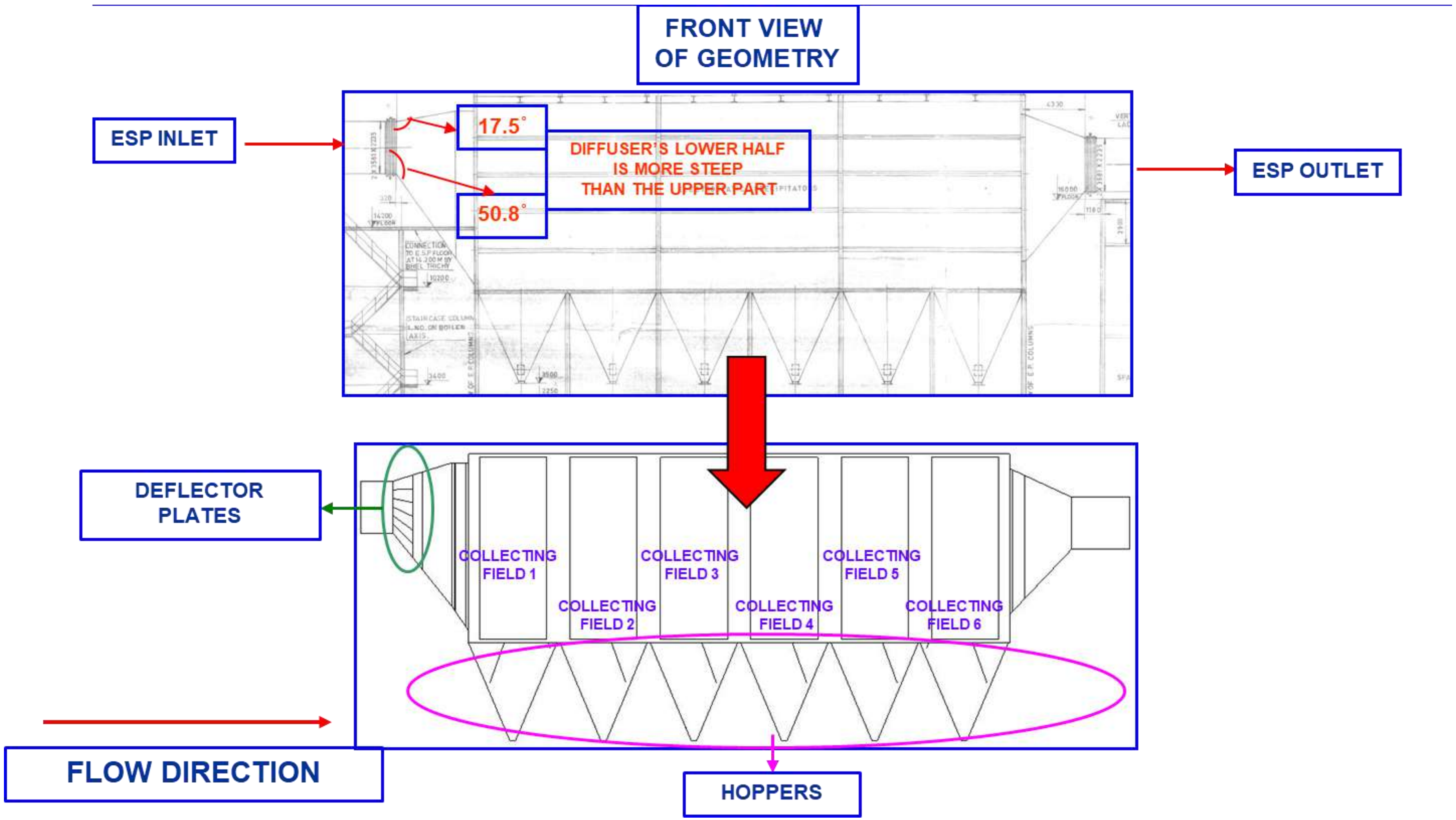
DETAIL OF RAMAGUNDAM ST-II ESP-Geometry



DETAIL OF RAMAGUNDAM ST-II ESP-Geometry

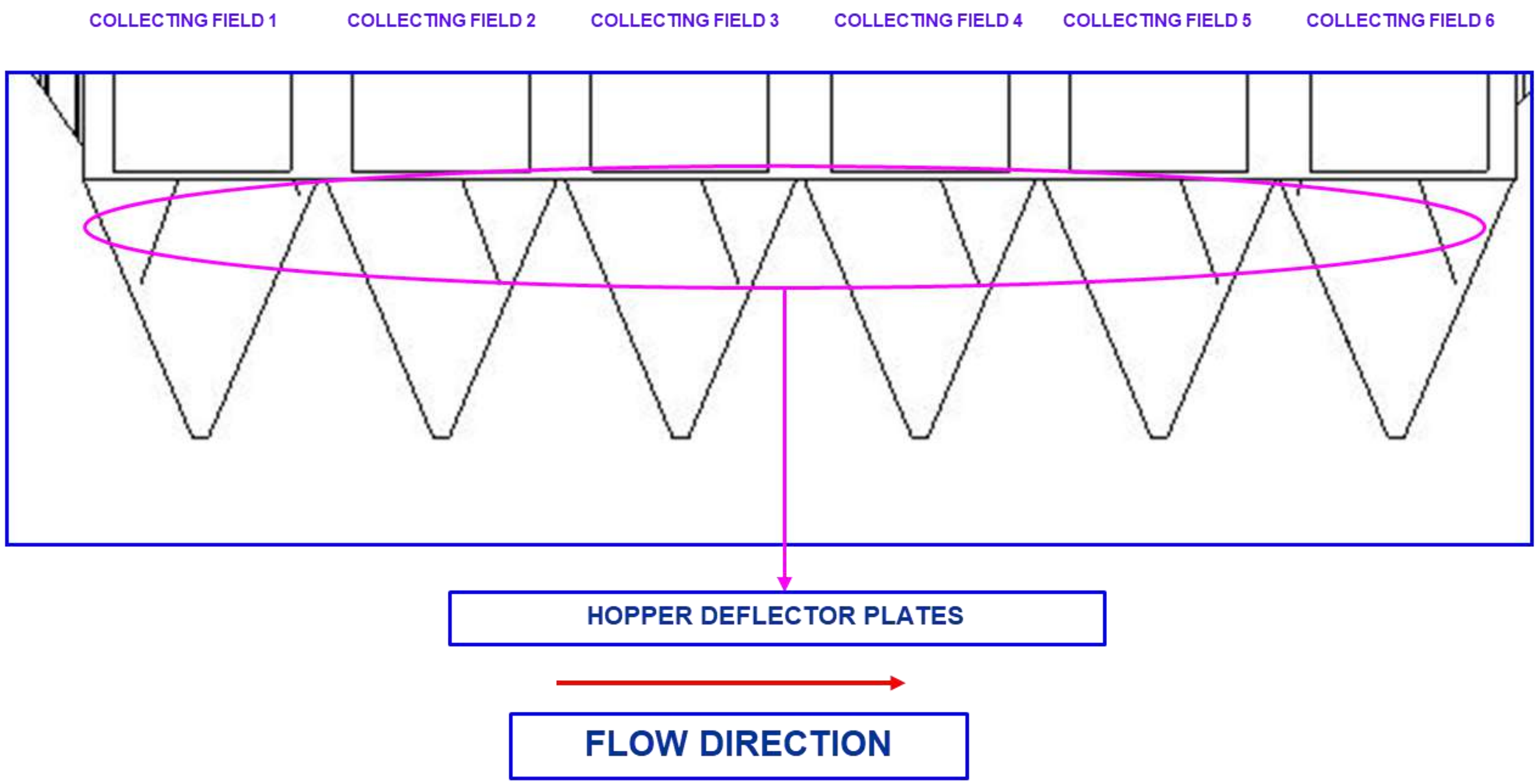


DETAIL OF RAMAGUNDAM ST-II ESP-Geometry



DETAIL OF RAMAGUNDAM ST-II ESP-Geometry

SECTION OF FRONT VIEW OF GEOMETRY



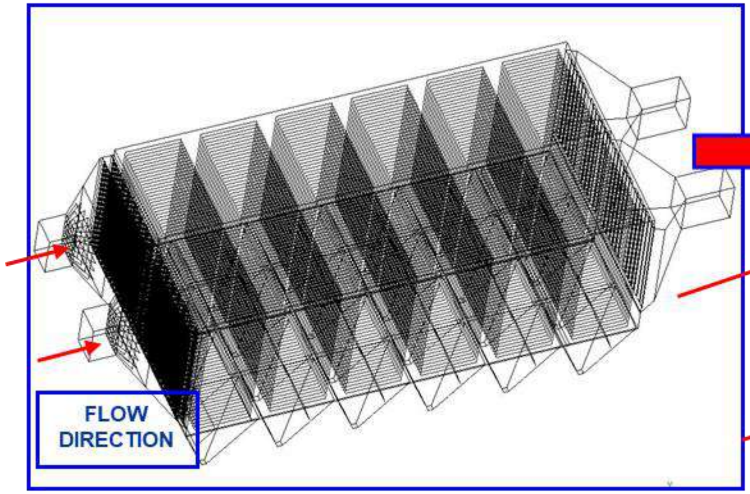
DETAIL OF RAMAGUNDAM ST-II ESP-Condition of diffuser plates

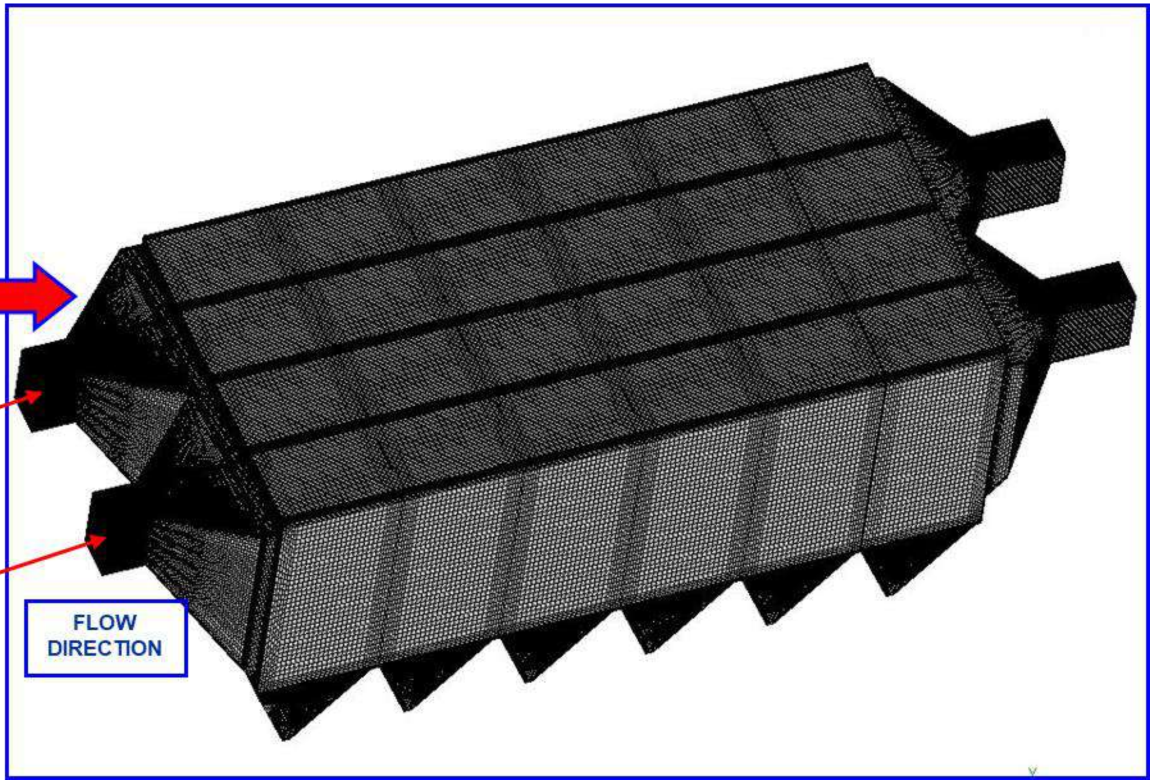
Worn out condition of diffuser plates

- Unit #4 during 2106 O/H
- Indicates plates obstructing the flow
- High localized velocity in downward section
- Zones of recirculation in downward section

DETAIL OF RAMAGUNDAM ST-II ESP: Meshing

ISO VIEW





DETAIL OF RAMAGUNDAM ST-II ESP: Results

Flow separation after splitter plate:

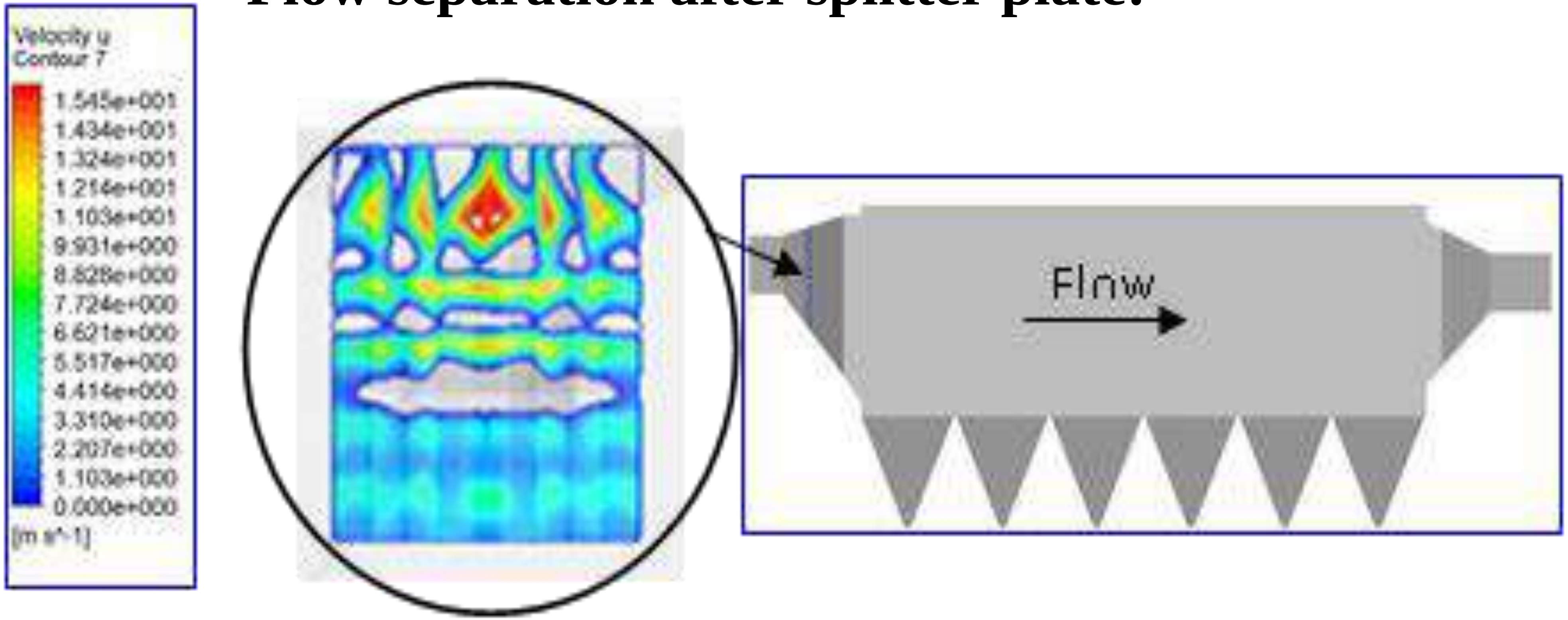
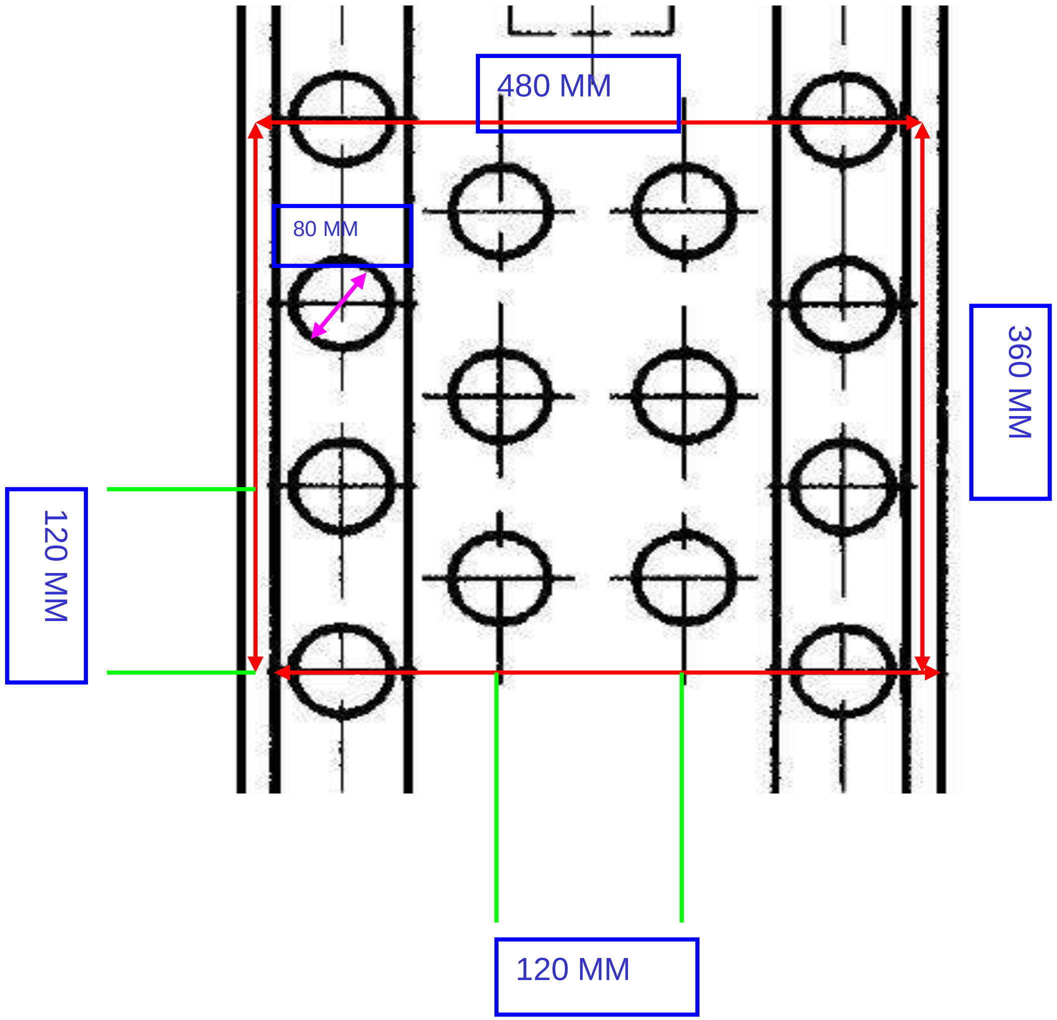


Fig-21: Flue gas flow pattern after splitter plate in ESP. The flow separates

DETAIL OF RAMAGUNDAM ST-II ESP: GD Screen modeling



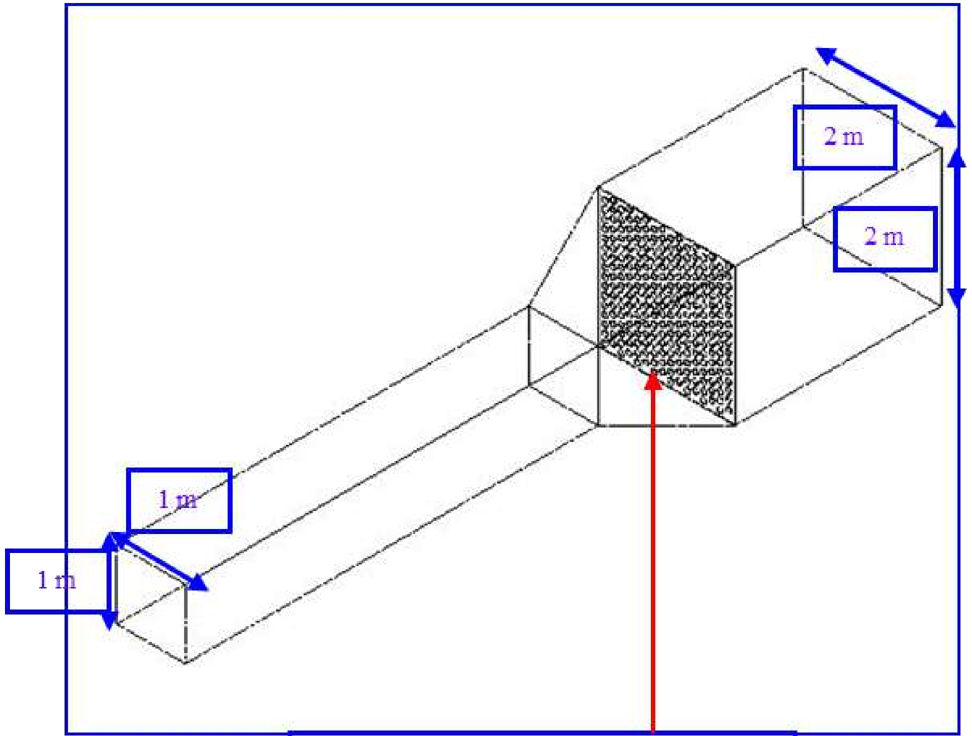
Porosity = Open Area / Total Area

$$= \frac{12 \cdot pi \cdot 80 \cdot 80}{4 \cdot 480 \cdot 360}$$

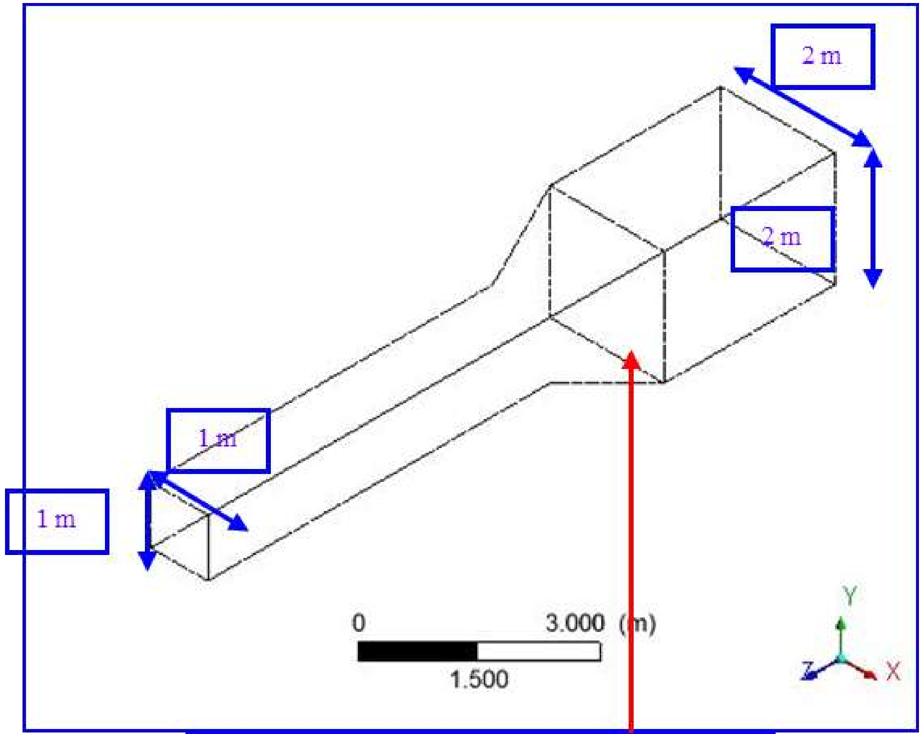
= 0.349

DETAIL OF RAMAGUNDAM ST-II ESP: GD Screen modeling

SAME SIZE DOMAIN



DOMAIN WITH 10 MM GD SCREEN WITH STAGGERED HOLE ARRANGEMENT



DOMAIN WITH POROUS JUMP APPROXIMATION OF UNIFORM HOLE ARRANGEMENT

Comparison of flow pattern between actual GD screen and porous jump plane-Geometry