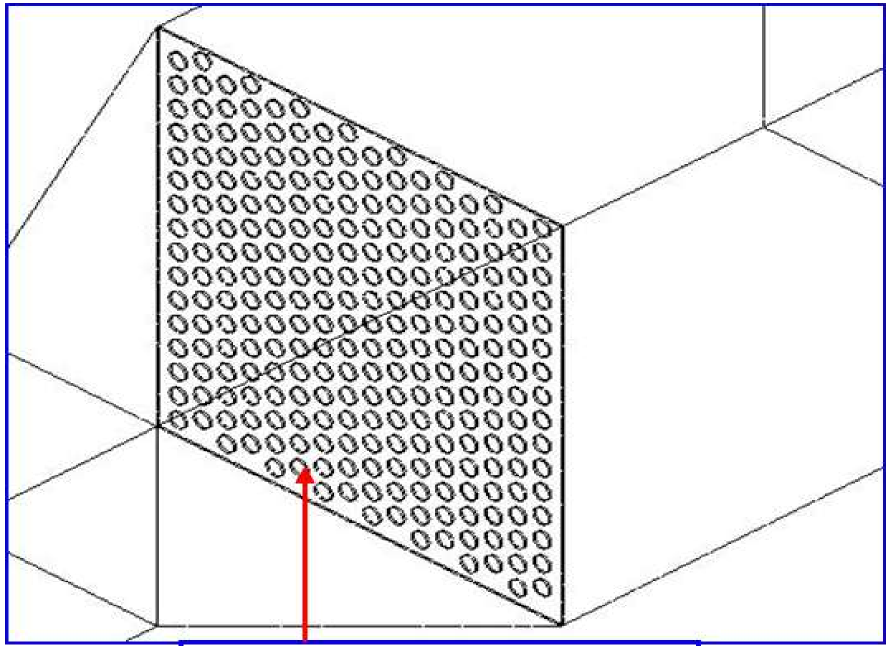
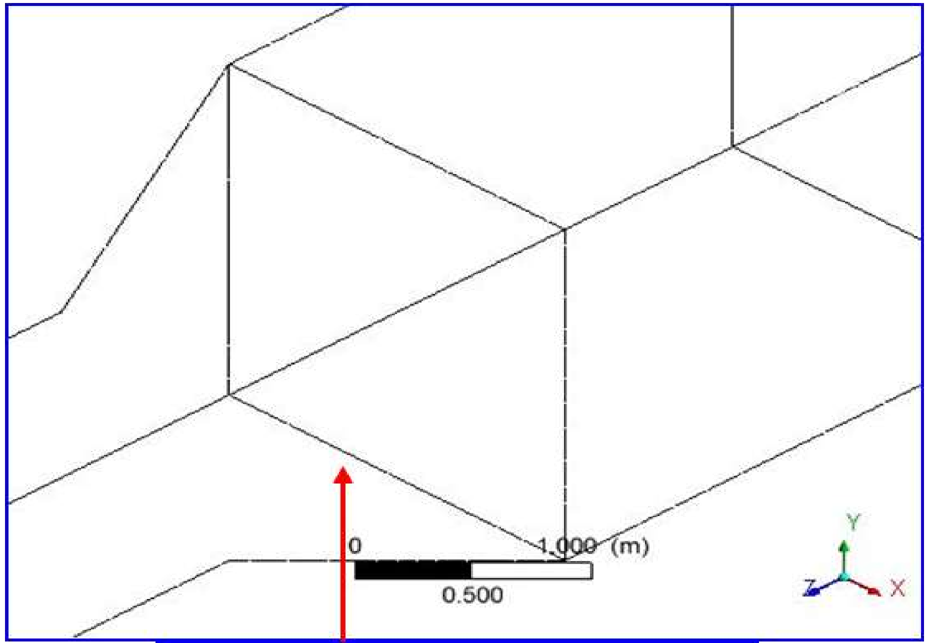
DETAIL OF RAMAGUNDAM ST-II ESP: GD Screen modeling

SAME SIZE DOMAIN



DOMAIN WITH 10 MM GD SCREEN WITH STAGGERED HOLE ARRANGEMENT



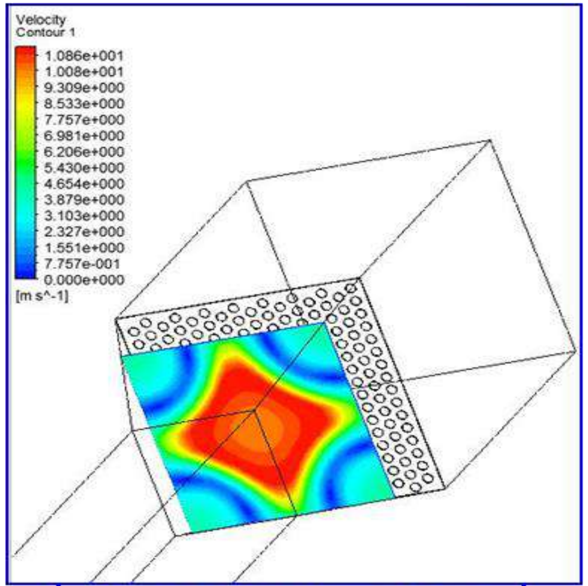
DOMAIN WITH POROUS JUMP APPROXIMATION OF UNIFORM HOLE ARRANGEMENT

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

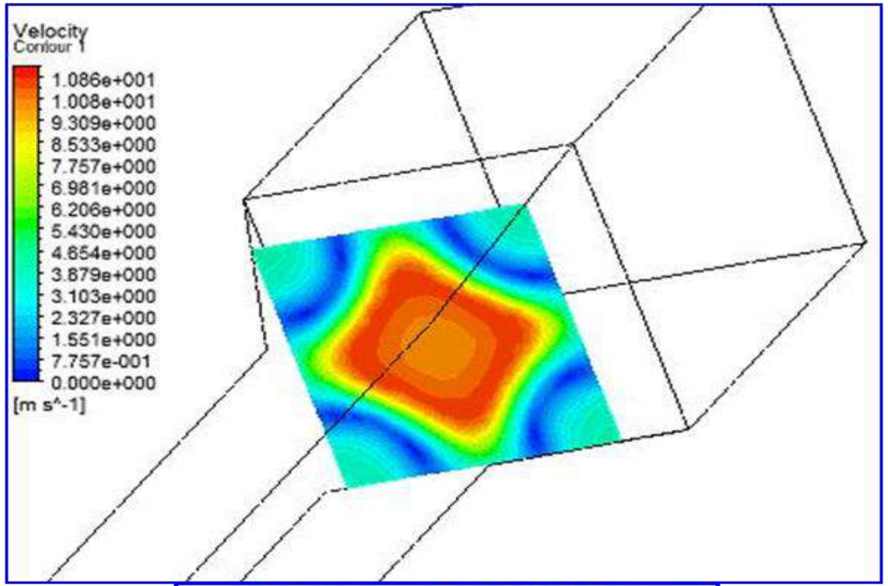
DETAIL OF RAMAGUNDAM ST-II ESP: GD Screen modeling

VELOCITY CONTOUR

SECTION UPSTREAM OF GD SCREEN



DOMAIN WITH 10 MM GD SCREEN WITH STAGGERED HOLE ARRANGEMENT



DOMAIN WITH POROUS JUMP APPROXIMATION OF UNIFORM HOLE ARRANGEMENT

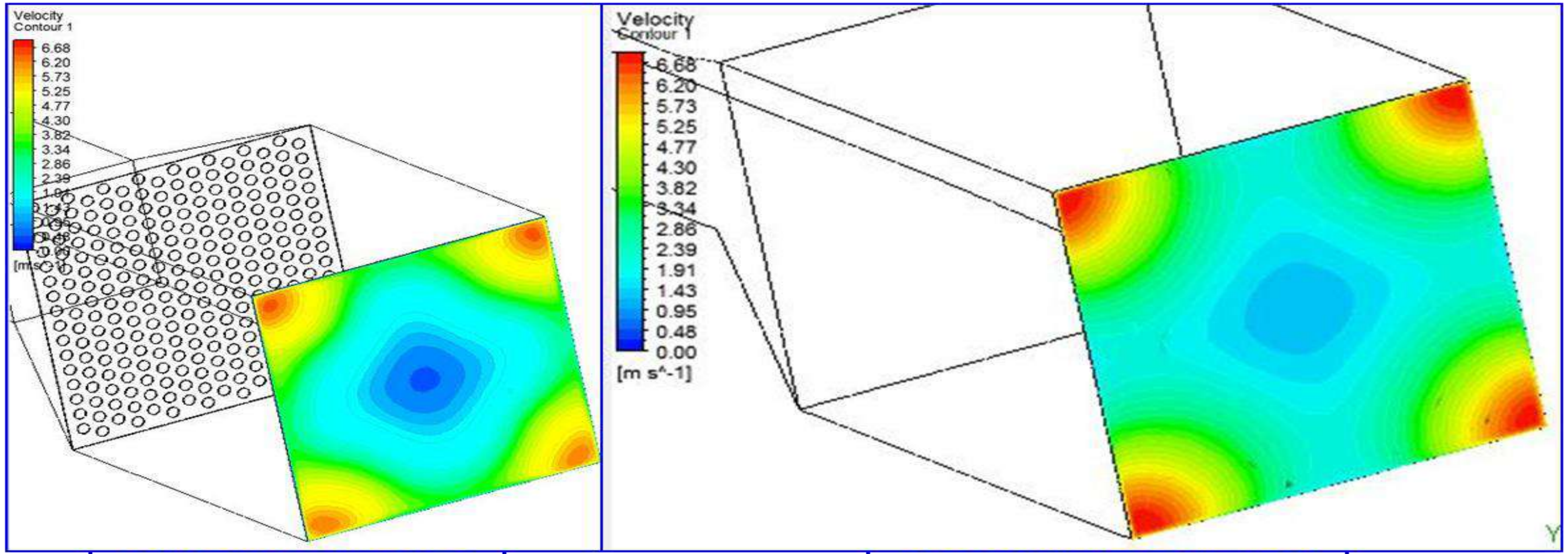
SIMILAR VELOCITY PROFILE IS OBSERVED IN BOTH THE CASES

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

DETAIL OF RAMAGUNDAM ST-II ESP: GD Screen modeling

VELOCITY CONTOUR

SECTION DOWNSTREAM OF GD SCREEN (OUTLET)



DOMAIN WITH 10 MM GD SCREEN WITH STAGGERED HOLE ARRANGEMENT

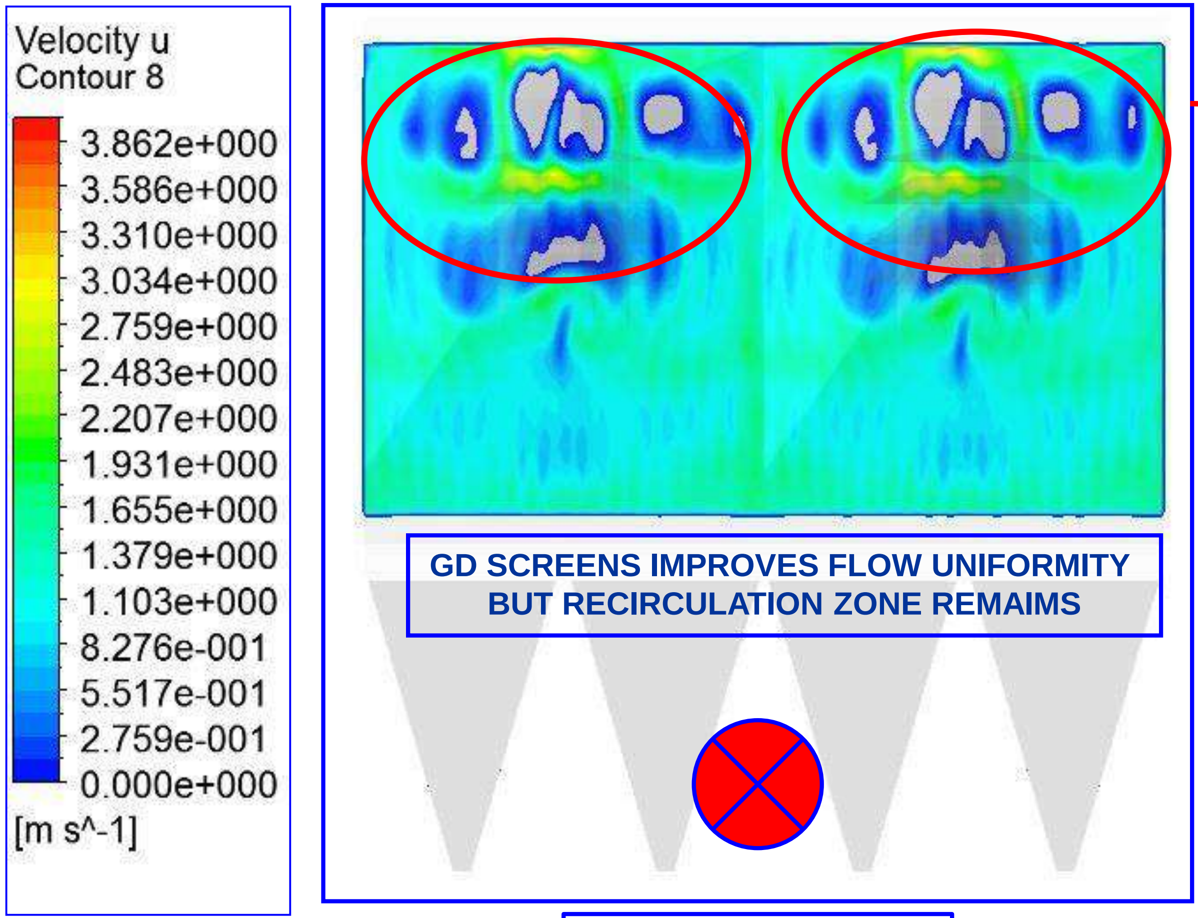
DOMAIN WITH POROUS JUMP APPROXIMATION OF UNIFORM HOLE ARRANGEMENT

SIMILAR VELOCITY PROFILE IS OBSERVED IN BOTH THE CASES

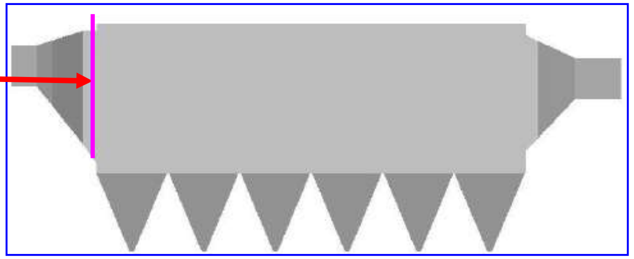
Conclusion: Porous jump can be used in place of actual simulation of GD screen

DETAIL OF RAMAGUNDAM ST-II ESP: Results

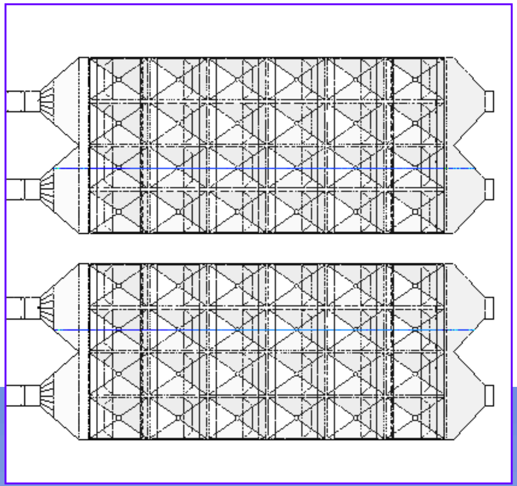
Flow separation after GD Screen

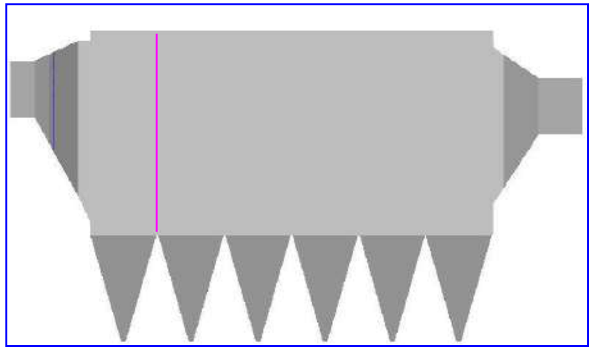


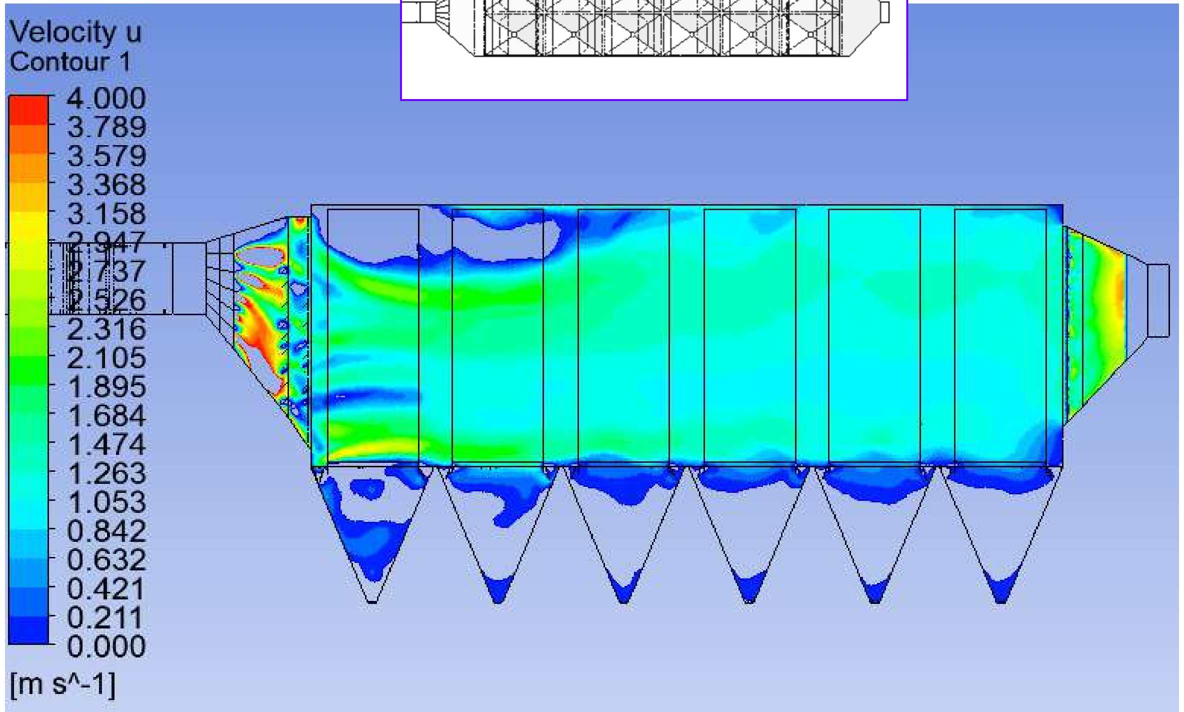
FLOW DIRECTION

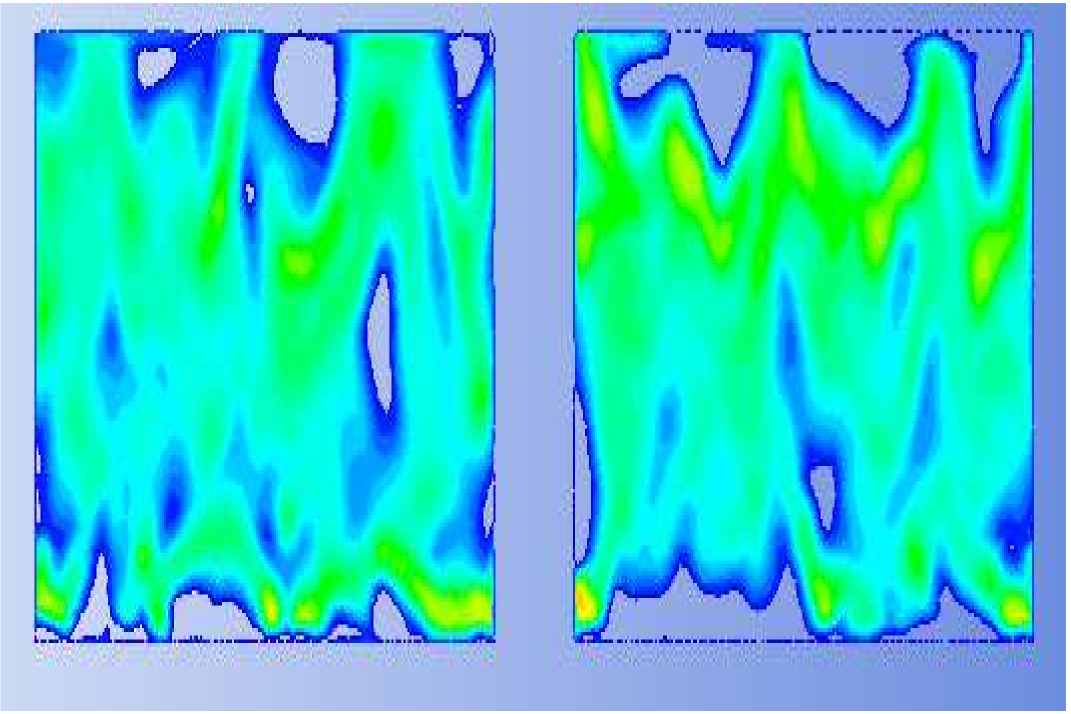


DETAIL OF RAMAGUNDAM ST-II ESP: Results- Flow in 1st/2nd fields



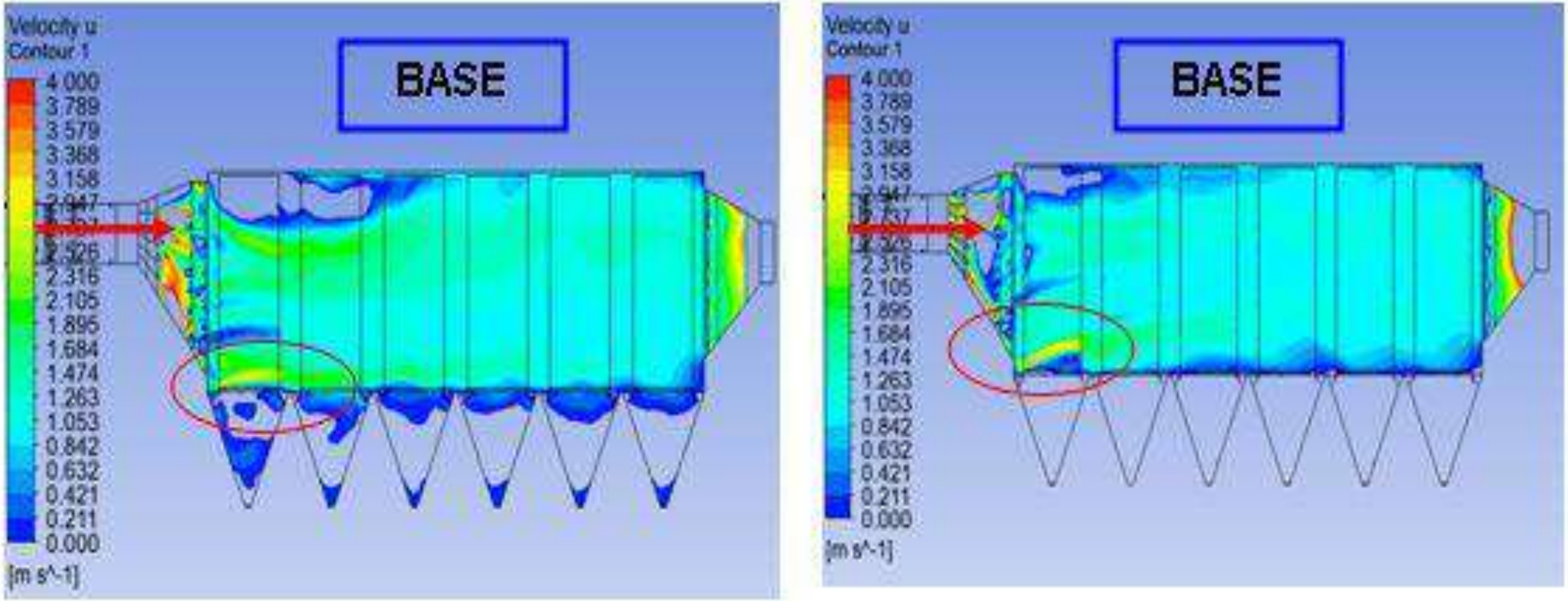






DETAIL OF RAMAGUNDAM ST-II ESP: Results-Flow in 1st /2nd Field

Recirculation zones and high velocity over first field hoppers



DETAIL OF RAMAGUNDAM ST-II ESP: Summary of CFD results

NTPC
A Maharatna Company
NETRA

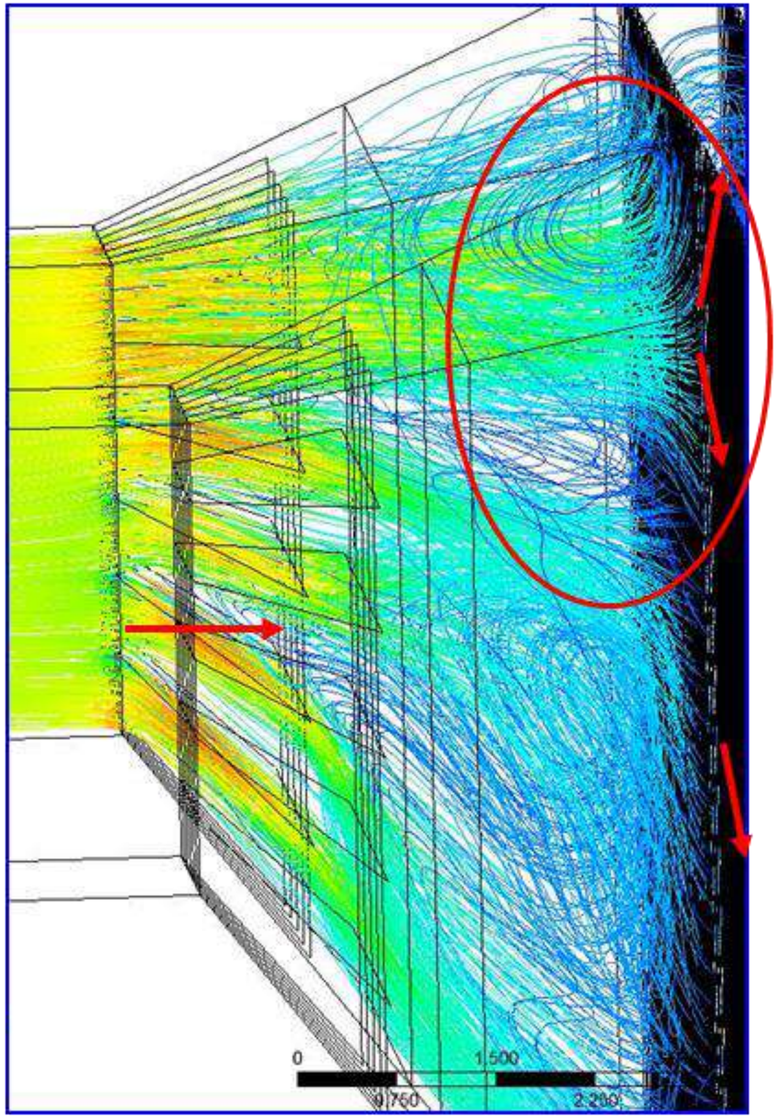
Summary of flow pattern inside ESP

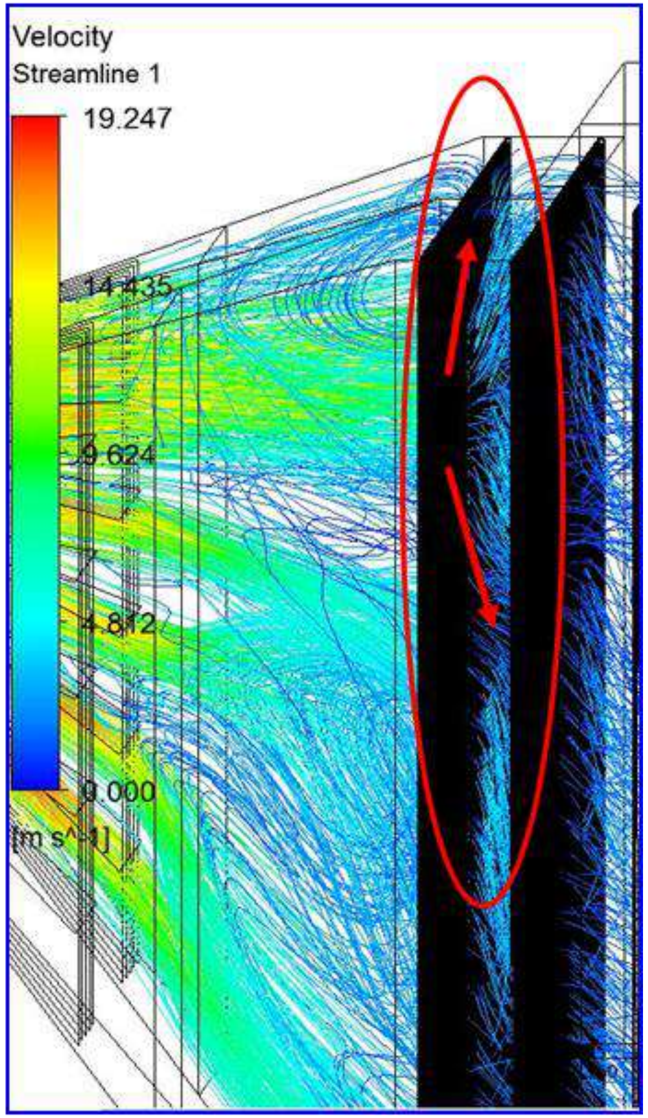
- Presence of stagnation zone after splitter/diffuser plate
- Presence of stagnation zone in first two fields
- 38 % of cross-sectional having more than 1.4* Avg. velocity (ICAC Limit-1%)
- Higher velocity above hopper

Consequences:

- Low effective SCA
- Low precipitation efficiency
- High re-entrainment

DETAIL OF RAMAGUNDAM ST-II ESP: Results: Flow around GD screens





DETAIL OF RAMAGUNDAM ST-II ESP: Results

High Localized velocity

Flue gas velocity pattern at cross-section after the first field			
SN	Average velocity, V_{avg}	% Area <= 1.15*V_{avg}	% Area <= 1.40 V_{avg}
1	1.07	43.53	62.27

MODIFICATIONS STRATEGY FOR CORRECTING FLOW ABNORMALITY

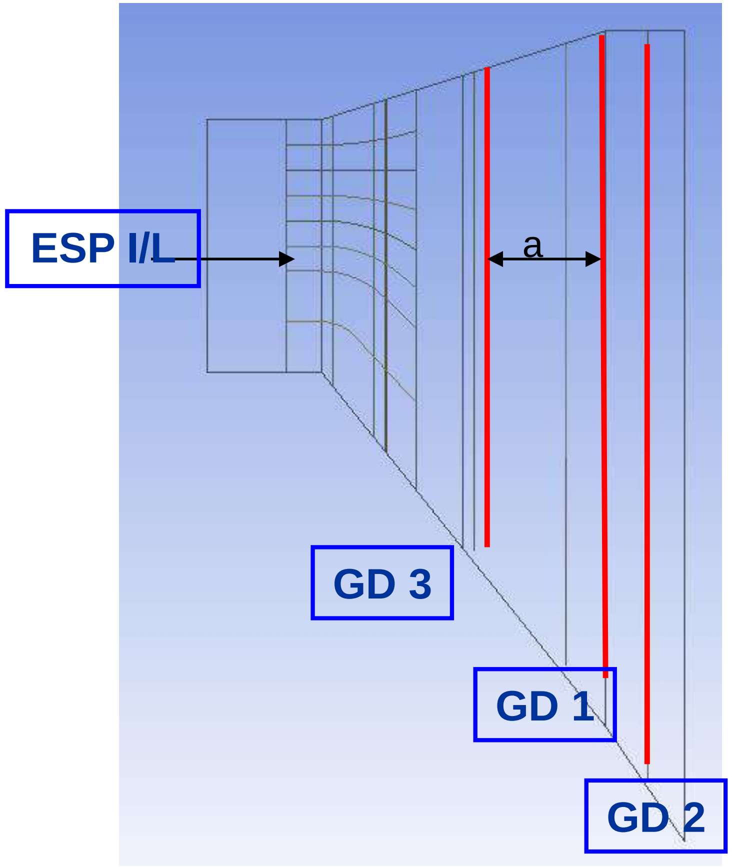
MODIFICATION STRATEGY FOR CORRECTING THE FLOW PATTERN t

- To prevent flow separation after the splitter/diffuser plates
  - Modified designed splitter plate to reduce erosion and flow separation
  - At what distance (x) from plates flow separate, how it can be prevented
  - A GD screen ?? But it will add pressure drop in the system
- To prevent flow separation after GD screen:
  - Different amount of flow arrives at different part of GD screen
  - Blocking plates in GD screen causing stagnation zones in 1st and 2nd field
  - Can flow be made uniform without blocking screen, Multi hole GD screen
- To prevent re-entrainment from hopper
  - Existing hopper plates not able to prevent re-entrainment from hopper
  - New designed hopper plate

FINAL MODIFICATIONS

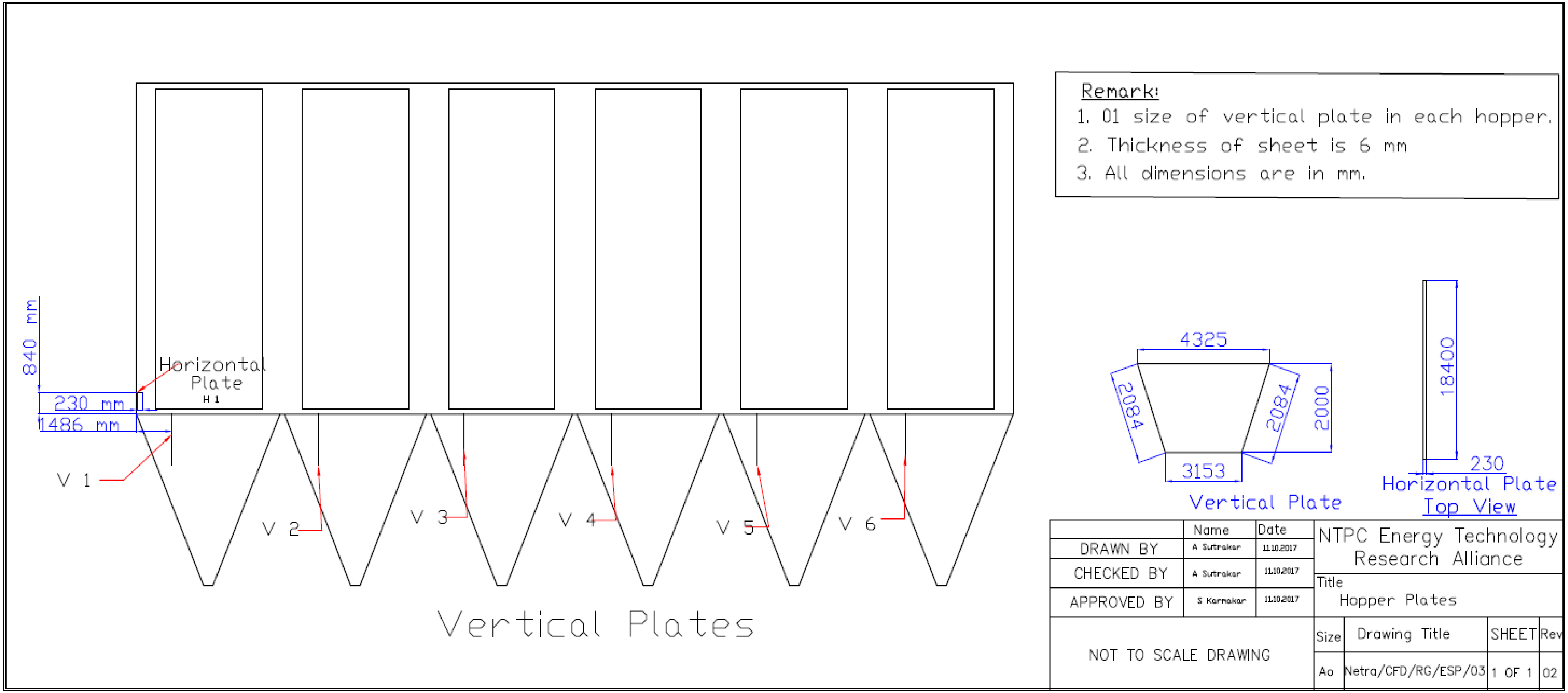
Modification proposed

- Modified Splitter Plate design-similar to
- Addition of 3rd GD screen after splitter plate
- Graded porosity in existing GD Screens
- Hopper plates at appropriate location
- Replacement of all worn-out internals
- Flow reduction, Temperature reduction

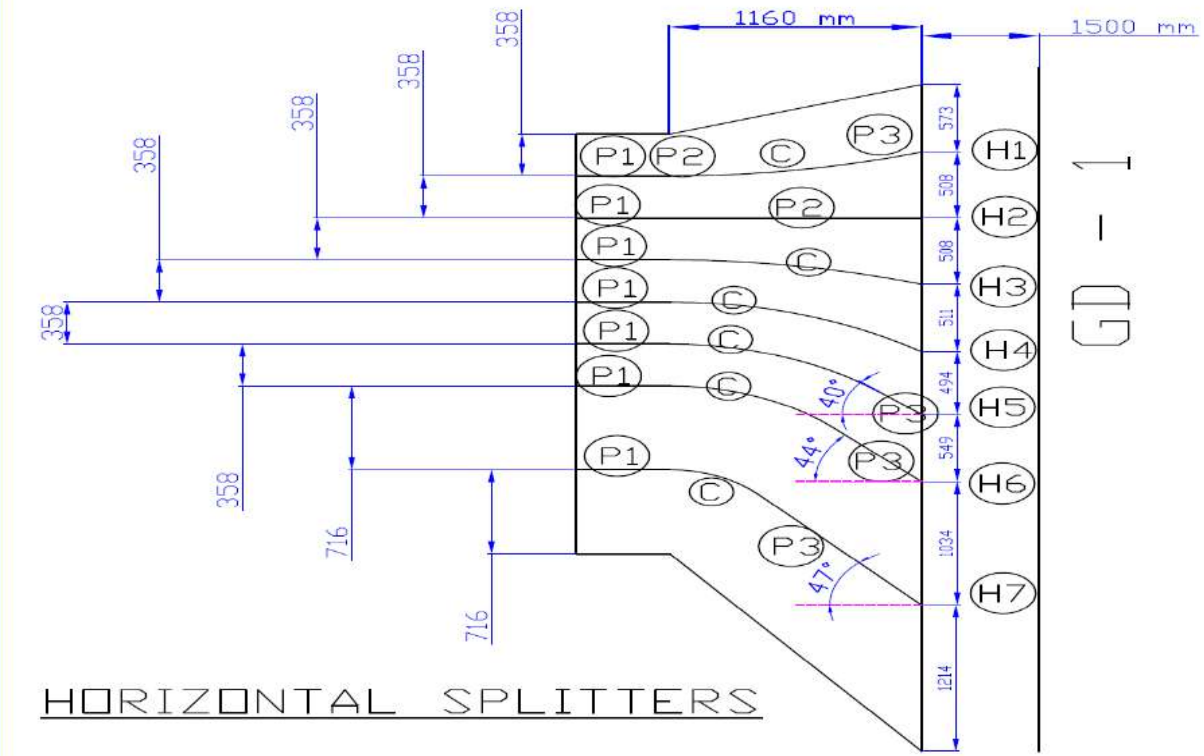


a- 1500 mm

FINAL MODIFICATIONS



FINAL MODIFICATIONS



Horizontal Splitter						
SL. NO	Horizontal		Radius	Cord Leng	Arc Length/Length	Thickness
1	H1	P1	-	-	As per site condition	6
		P2	-	-	-	
		C	4532	1366	1542	6
		P3	-	-	-	
2	H2	P1	-	-	As per site condition	6
		P2	-	-	1533	6
		C	-	-	-	
		P3	-	-	-	
3	H3	P1	-	-	As per site condition	6
		P2	-	-	-	6
		C	4532	1366	1542	6
		P3	-	-	-	
4	H4	P1	-	-	As per site condition	6
		P2	-	-	-	
		C	2367	1410	1573	6
		P3	-	-	-	
5	H5	P1	-	-	As per site condition	6
		P2	-	-	-	
		C	1749	1207	1575	6
		P3	-	-	43	6
6	H6	P1	-	-	As per site condition	6
		P2	-	-	-	
		C	1260	948	1234	6
		P3	-	-	462	6
7	H7	P1	-	-	As per site condition	6
		P2	-	-	-	
		C	643	514	668	6
		P3	-	-	1175	6

Note: All dimensions are in mm

Legends:

V	Vertical
C	Curved Baffles
P	Straight Plate

Remarks:

C1 to C5 is in increasing order of size.

Note: All dimensions are in mm

Legends:

V : Vertical

C : Curved Baffles

P : Straight Plate

C1 to C5 is in increasing order of size.

Note:- The length of Straight plate P1 is to be taken as per the space available between end of the expansion joint and starting point of the funnel

Remark:
All dimensions are in mm.

LEGENDS:
Dimension Line
Reference Line

	Name	Date
DRAWN BY		
CHECKED BY	A.K.Sutrakar	11.10.2017
APPROVED BY	S.Karmakar	11.10.2017

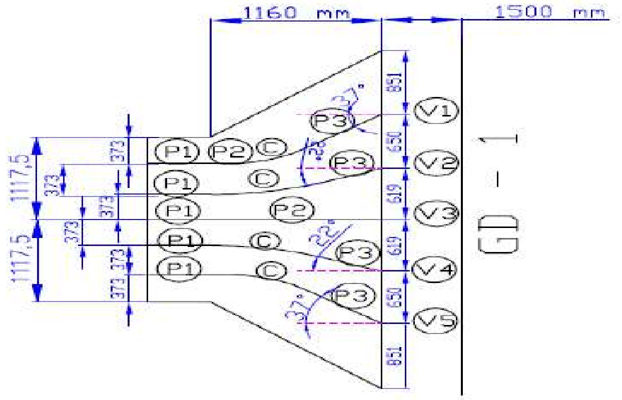
NOT TO SCALE DRAWING

NTPC Energy Technology Research Alliance

Title: Horizontal Splitters

Size	Drawing Title	SHEET	Rev
Ao	Netra/CFD/RG/ESP/01d	1 OF 1	02

FINAL MODIFICATIONS



VERTICAL SPLITTERS

Vertical Splitter						
SL. NO	Vertical		Radius	Cord Length	Arc Length/Length	Thickness
1	V1	P1	-	-	As per site condition	6
		P2	-	-	162	6
		C	964	612	649	6
		P3	-	-	548	6
2	V2	P1	-	-	As per site condition	6
		P2	-	-	-	
		C	2427	937	986	6
		P3	-	-	270	6
3	V3	P1	-	-	As per site condition	6
		P2	-	-	1224	6
		C	-	-	-	
		P3	-	-	-	
4	V4	P1	-	-	As per site condition	6
		P2	-	-	-	
		C	2427	937	958	6
		P3	-	-	297	6
5	V5	P1	-	-	As per site condition	6
		P2	-	-	162	6
		C	964	612	649	6
		P3	-	-	548	6

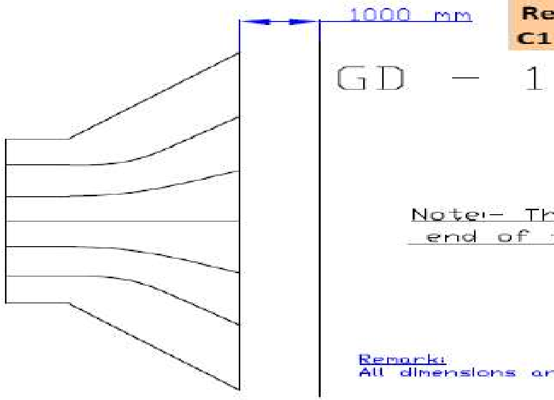
Note: All dimensions are in mm

Legends:

V	Vertical
C	Curved Baffles
P	Straight Plate

Remarks:

C1 to C5 is in increasing order of size.



Note: All dimensions are in mm
Legends:
V : **Vertical**
C : Curved Baffles
P : Straight Plate
C1 to C5 is in increasing order of size.

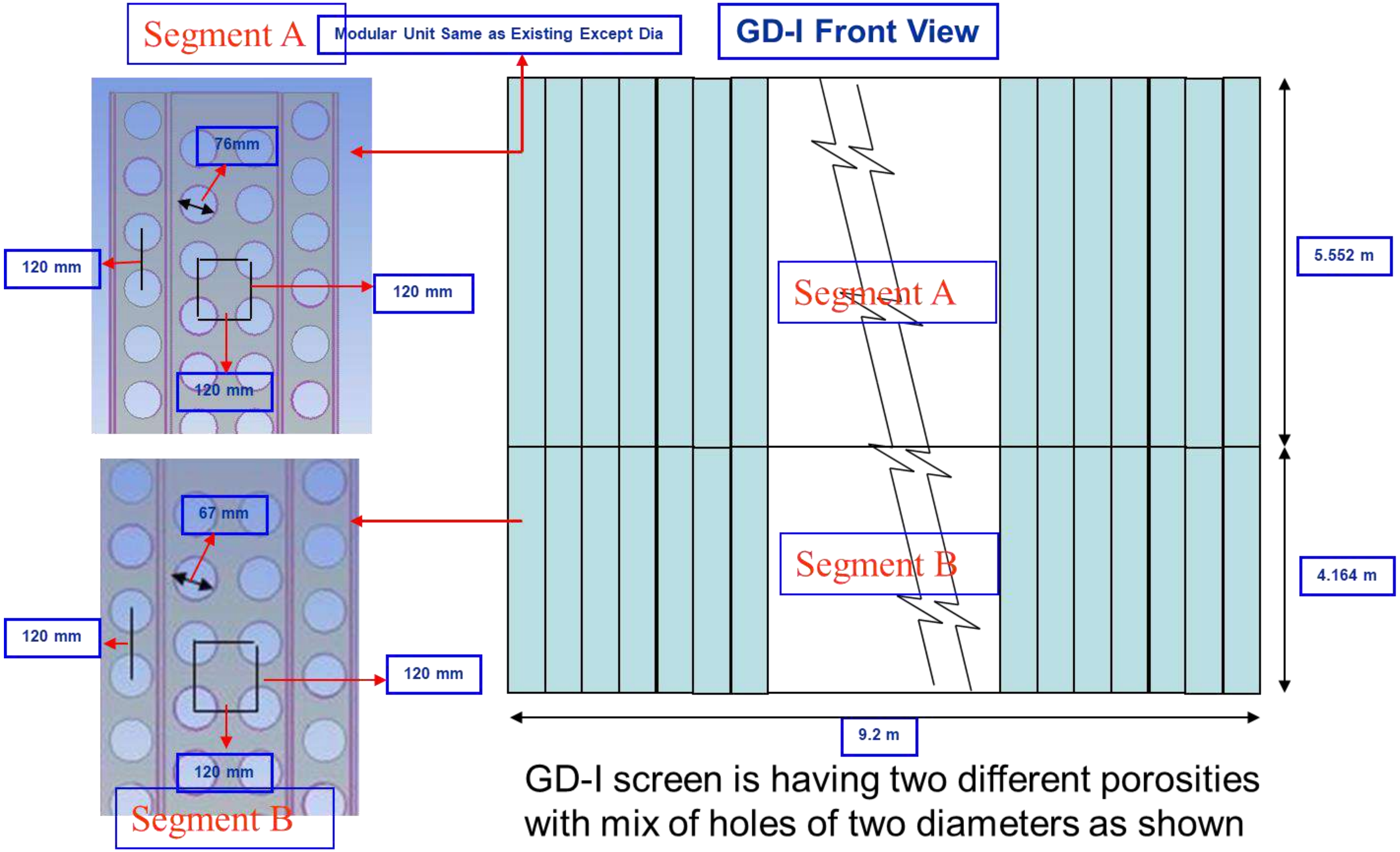
Note:- The length of Straight plate P1 is to be taken as per the space available between end of the expansion joint and starting point of the funnel

Remark:
All dimensions are in mm.

LEGENDS:
——— Dimension Line
------ Reference Line

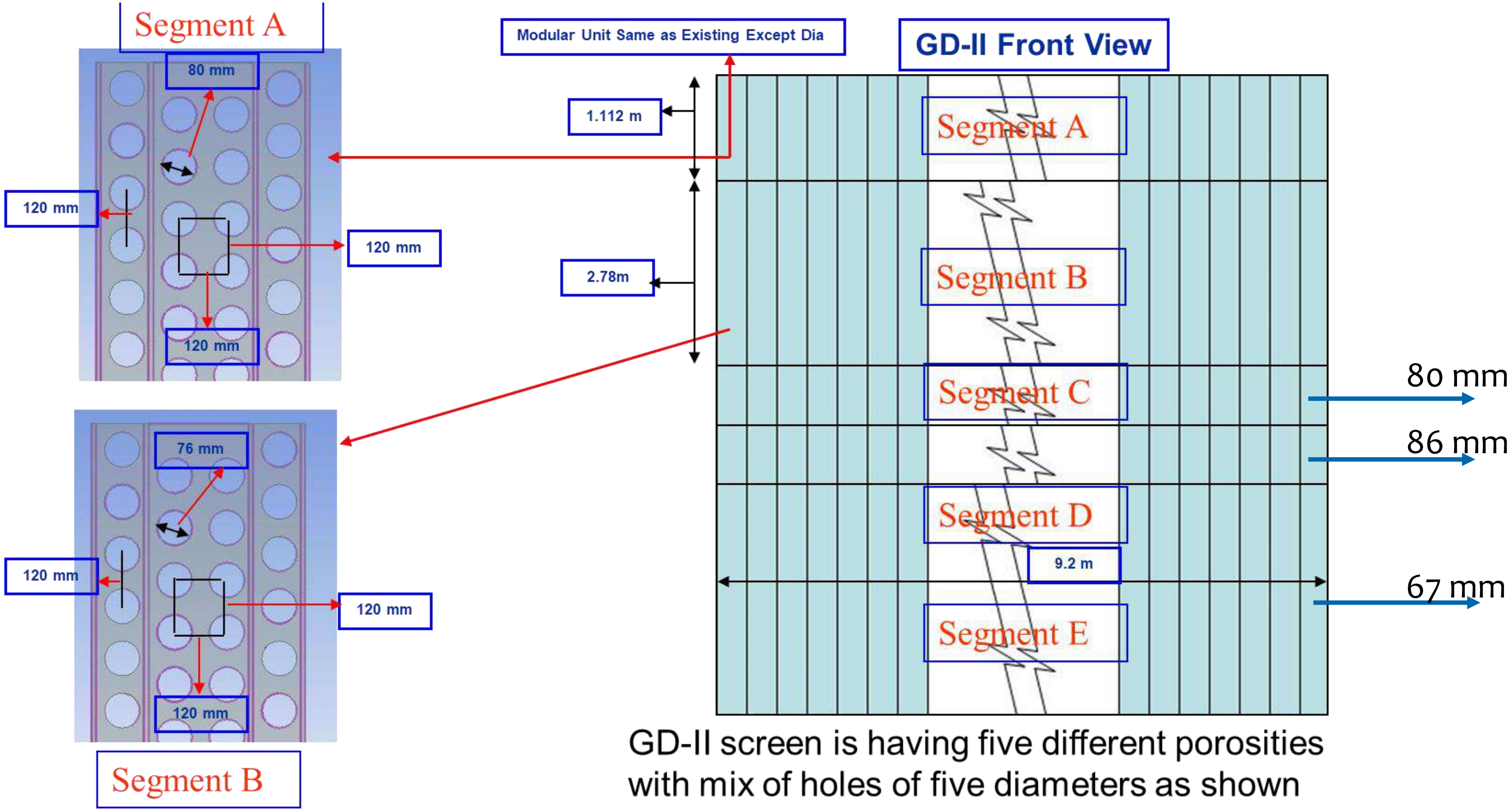
	Name	Date	NTPC Energy Technology Research Alliance			
DRAWN BY		11.10.2017	Title	Vertical Splitters		
CHECKED BY	A.K.Sutrakar	11.10.2017				
APPROVED BY	S.Karmakar	11.10.2017				
NOT TO SCALE DRAWING			Size	Drawing Title	SHEET	Rev
			Ao	Netra/CFD/RG/ESP/01c	1 OF 1	02

FINAL MODIFICATIONS: Graded porosity GD Screen 1



GD-I screen is having two different porosities with mix of holes of two diameters as shown

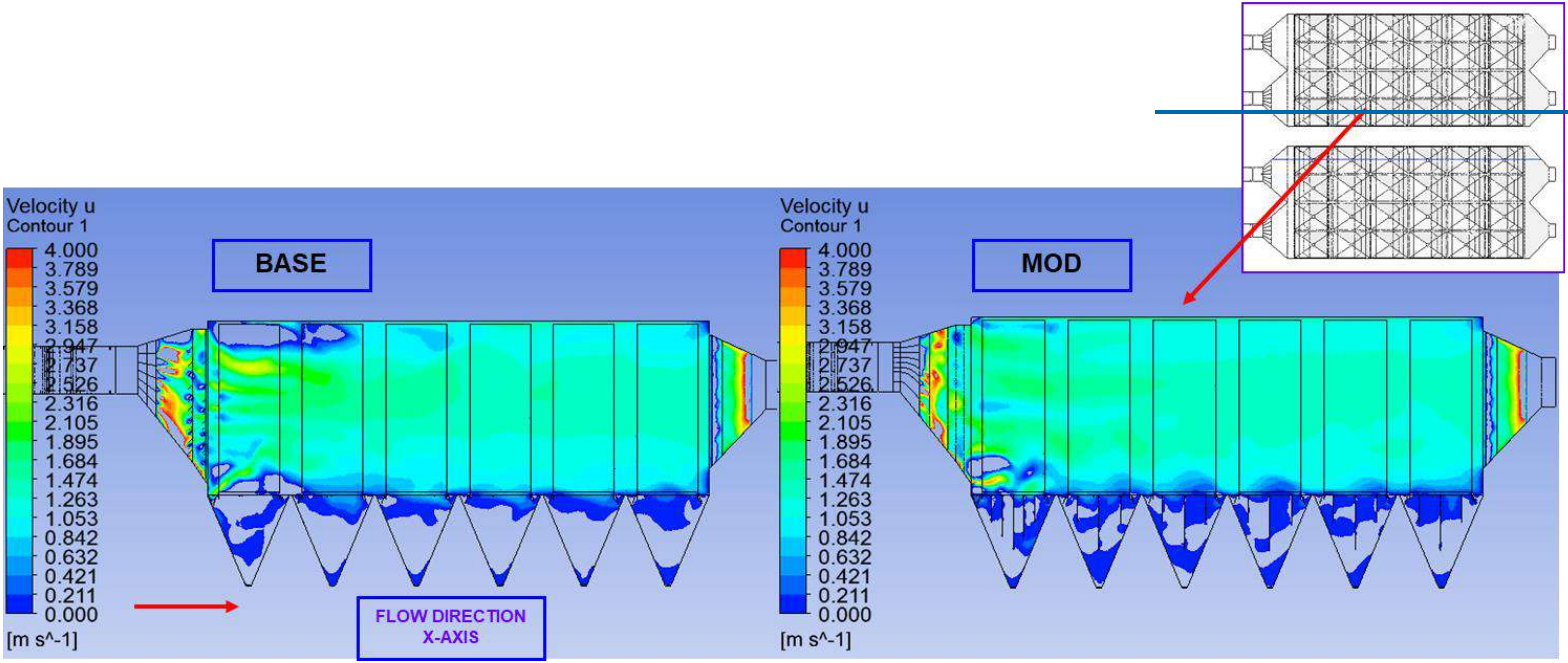
FINAL MODIFICATIONS: Graded porosity GD Screen 1



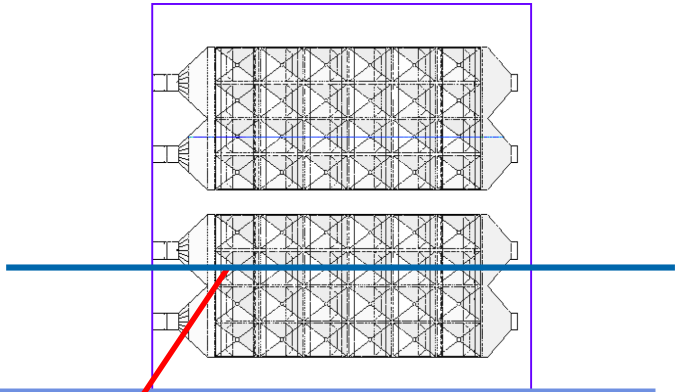
GD-II screen is having five different porosities with mix of holes of five diameters as shown

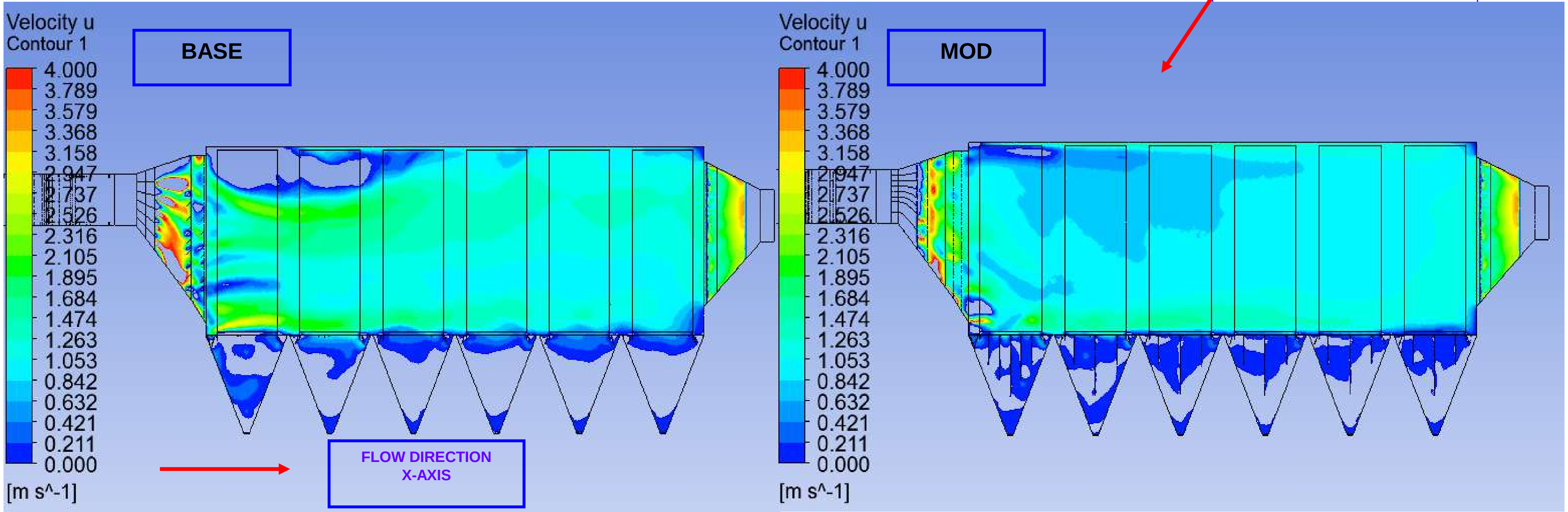
EFFECT OF MODIFICATION ON FLOW & ESITMATED MODIFIED EFFICIENCY

EFFECT OF MODIFICATIONS ON FLOW PATTERN



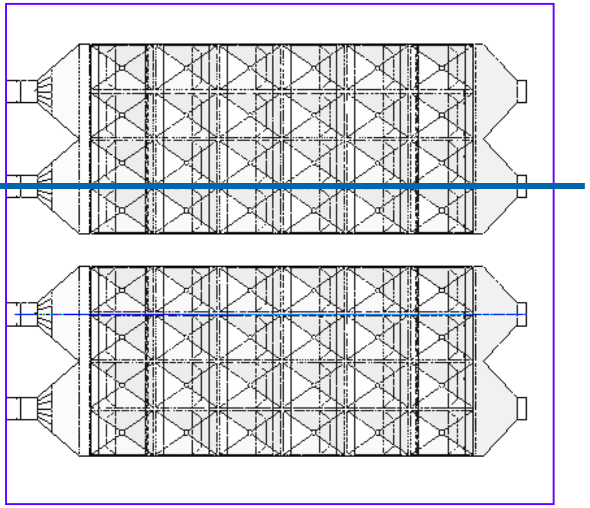
EFFECT OF MODIFICATIONS ON FLOW PATTERN





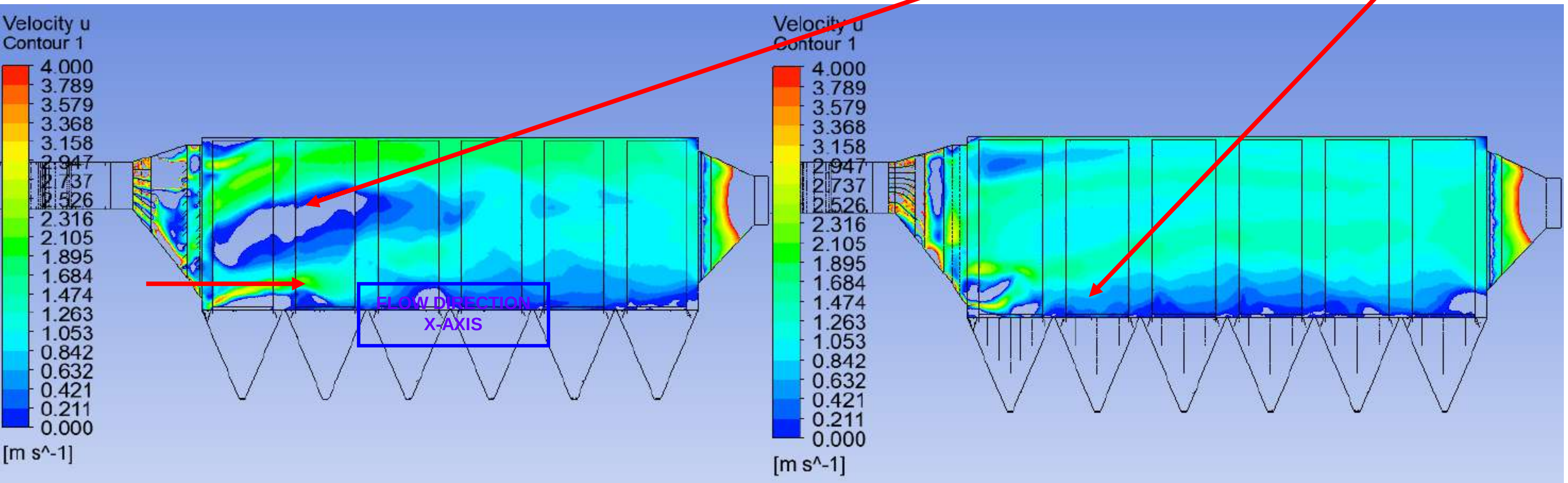
EFFECT OF MODIFICATIONS ON FLOW PATTERN

VERTICAL PLANES INSIDE ESP



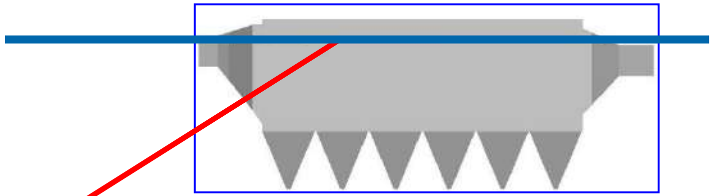
BASE

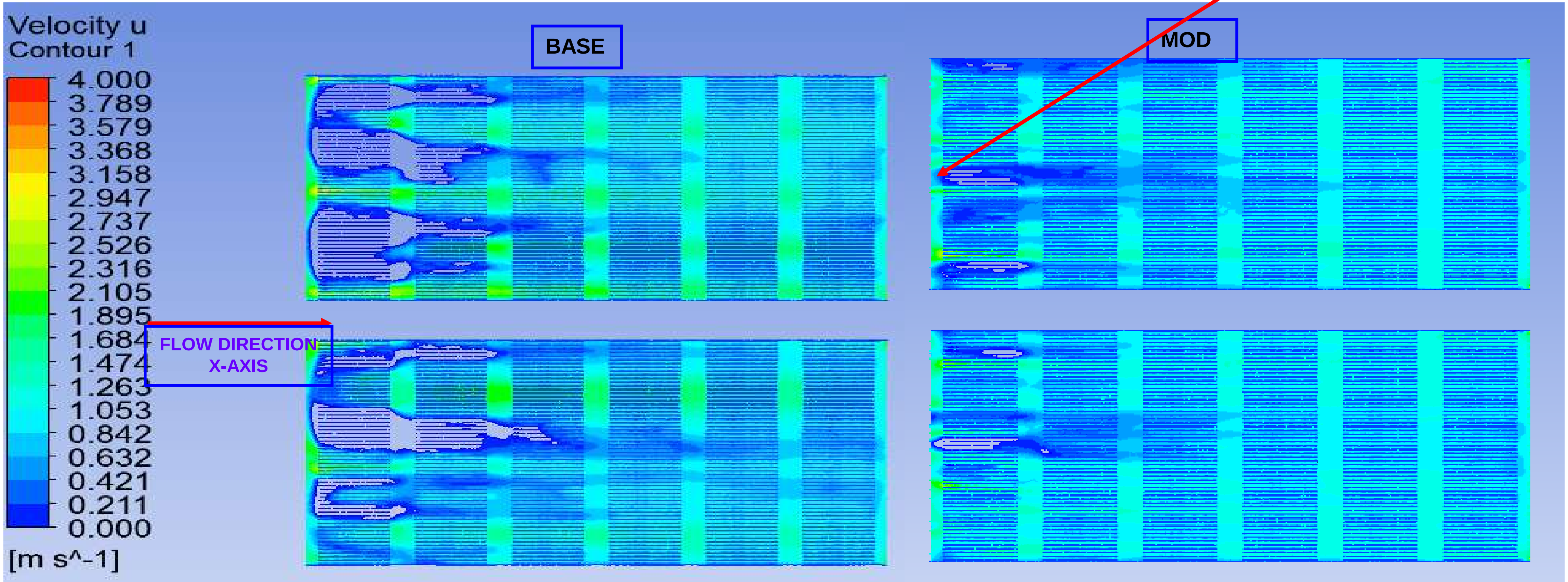
MOD



EFFECT OF MODIFICATIONS ON FLOW PATTERN

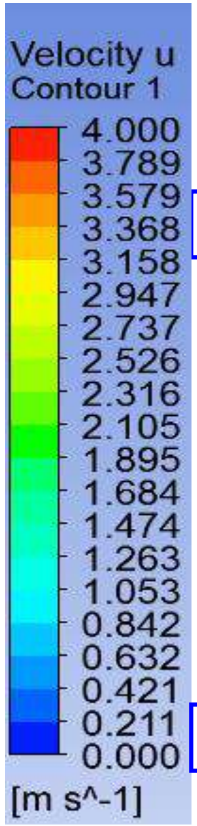
HORIZONTAL PLANES CLOSE TO ESP TOP





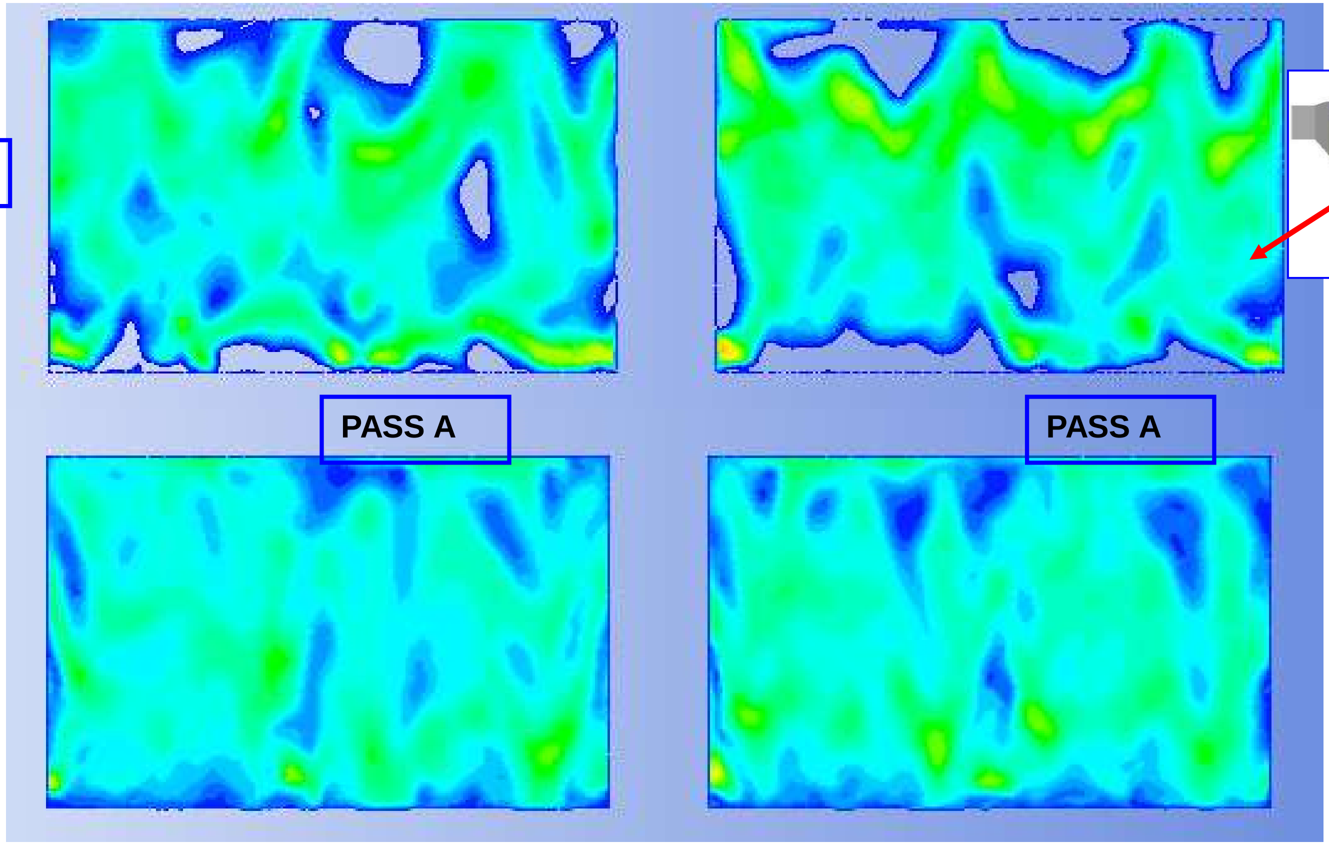
EFFECT OF MODIFICATIONS ON FLOW PATTERN

CROSS-SECTION AFTER FIRST FILELD



BASE

MOD

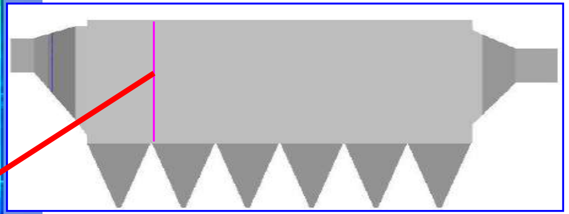


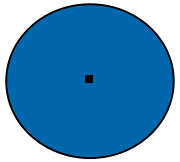
PASS A

PASS A

PASS B

PASS A



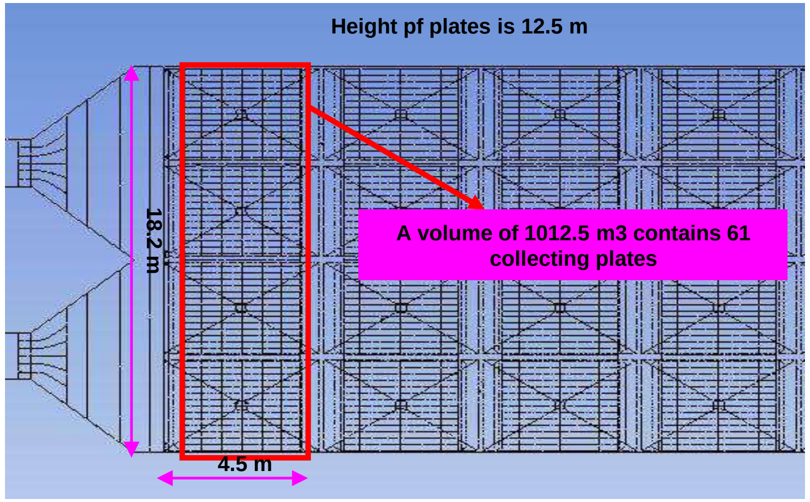


FLOW DIRECTION
OUT OF PLANE

EFFECT OF MODIFICATIONS ON FLOW PATTERN : SUMMARY

Increase in Available Collecting Area of Plates

- **Recirculation/stagnation zones eliminated in modified case: 1000 m3**
- **Additional collection area being made available: 6750 m^2**
- **Equivalent to adding one field in one pass**
  - 1000 m3 of swept volume ~60 collecting plates
  - Additional Collecting area equivalent to 1000 m3 ~ 6750 m^2
  - (2 side of plate*60 plates*12.5 m height of each plate*4.5 m width of each plate)



Equivalent to adding one field in any one pass

EFFECT OF MODIFICATIONS ON FLOW PATTERN : SUMMARY

Decrease in Average velocity increasing residence time

SN	Case	% Area <=1.15 V_{avg}	% Area <=1.40 V_{avg}
1	As built	43.53	62.27
2	Modified	62.51	86.59

Velocity measurement plane: After First Field

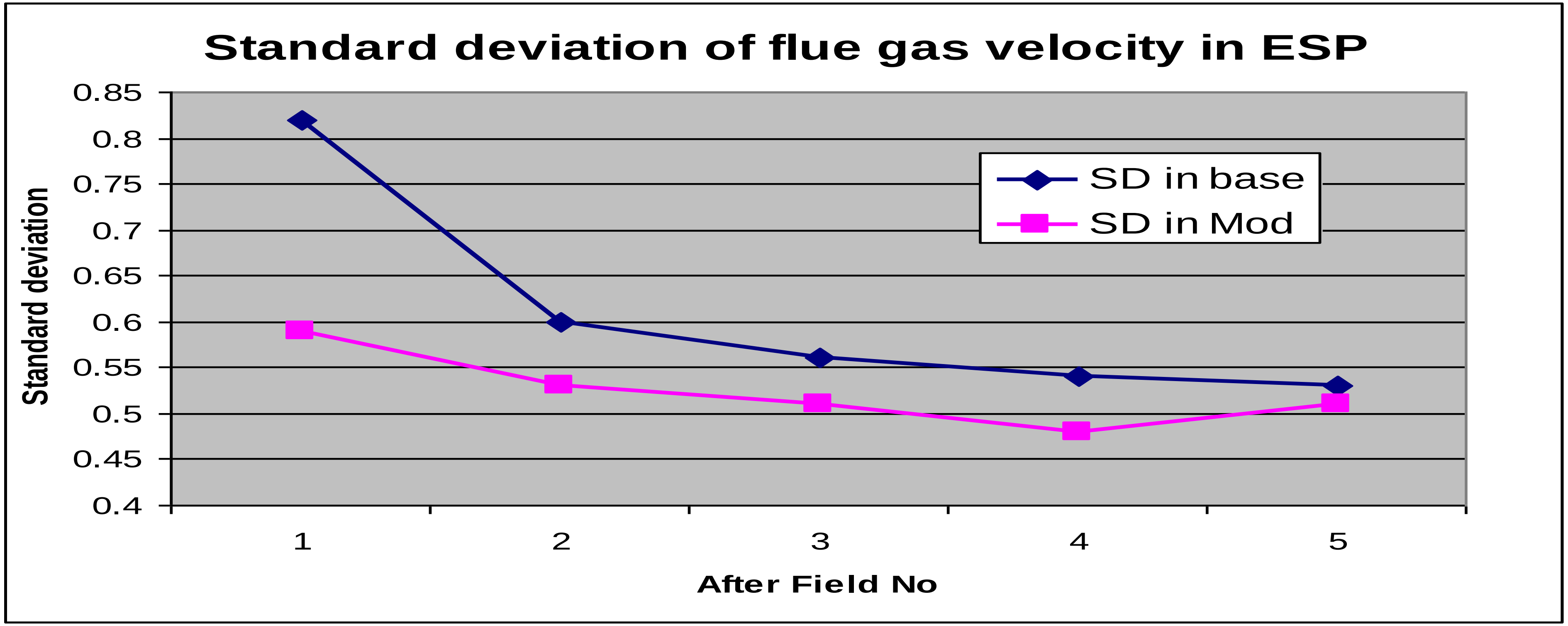
The ICAC guidelines of publication EP-7 requires

"Within the treatment zone near the inlet and outlet faces of the precipitator collection chamber, the velocity pattern shall have

85 % of the velocities not more than 1.15 times the average velocity, and
99 % of the velocities not more than 1.40 times the average velocity"

EFFECT OF MODIFICATIONS ON FLOW PATTERN : SUMMARY

Standard Deviation of Velocity decreases in proposed modification



- In proposed modification standard deviation decreases, i.e., velocity uniformization
- Flow gets settled after second field both in Base and Modified case
- Weak effect of velocity subsequent first field on the overall efficiency of the ESP.

EFFECT OF MODIFICATIONS ON FLOW PATTERN : SUMMARY

Estimated improvement in SPM after modifications

- With respect to increased SCA, the calculated SPM after modification ~ 100 mg/Nm3
- With pressure drop reduction due to improved flow ~ 6 mm WC

Modifications carried out:

- Carried out in major overhauling of U#4 in Jan 2018
- BHEL supplied the modified GD Screens
- Measurement was carried out by M/s SGS in June 2018
- Total cost of Modification including supply and services ~2.5 Cr

ESP performance efficiency improvement by CFD modeling: CONCLUSIONS

- Flow abnormality exists at ESP inlets with unequal flow in passes (was not there in this case)
- Existing splitter plates not able to prevent separation and stagnation of flow
- Existing design GD screen do uniformize the flow but creates a stagnation zone in 1^{st} and 2^{nd} field
- The above flow abnormality decreases the effective SCA decreasing the capture efficiency
- CFD modeling is an ideal tool to predict and correct these flow abnormalities
- The cost of rectification based on CFD modeling is comparatively cheaper with respect to adding SCA by adding fields or passes
- CFD based modifications may be implemented before taking ESPs into R&M
- CFD modeling analysis may also be taken as design tool for finalizing SCA in new ESPs

THANK YOU

CFD MODELING ASSUMPTIONS

- The flue gas flow has been considered to be single phase, steady and incompressible.
- No energy transfer has been considered across duct's and ESP's walls hence density and viscosity remains constant.
- Constituent species of the flue gas have not been considered.
- Mass flow distribution across the model inlet boundary is uniform.
- All the existing guide vanes and braces have been modeled as zero thickness wall.

CFD MODELING MATHEMATICAL APPROACH

- Conservation of mass

$$Mass: \quad \frac{\partial \rho}{\partial t} + div(\rho\, \mathbf{u}) = 0$$

- Conservation of momentum

Turbulent flow - Reynolds equations

$$x-momentum: \quad \frac{\partial(\rho U)}{\partial t} + div(\rho U \mathbf{U}) = -\frac{\partial P}{\partial x} + div(\mu\, grad\, U) + S_{Mx}$$
$$+\left[-\frac{\partial(\rho \overline{u'^2})}{\partial x} - \frac{\partial(\rho \overline{u'v'})}{\partial y} - \frac{\partial(\rho \overline{u'w'})}{\partial z}\right]$$

$$y-momentum: \quad \frac{\partial(\rho V)}{\partial t} + div(\rho V \mathbf{U}) = -\frac{\partial P}{\partial y} + div(\mu\, grad\, V) + S_{My}$$
$$+\left[-\frac{\partial(\rho \overline{u'v'})}{\partial x} - \frac{\partial(\rho \overline{v'^2})}{\partial y} - \frac{\partial(\rho \overline{v'w'})}{\partial z}\right]$$

$$z-momentum: \quad \frac{\partial(\rho W)}{\partial t} + div(\rho W \mathbf{U}) = -\frac{\partial P}{\partial z} + div(\mu\, grad\, W) + S_{Mz}$$
$$+\left[-\frac{\partial(\rho \overline{u'w'})}{\partial x} - \frac{\partial(\rho \overline{v'w'})}{\partial y} - \frac{\partial(\rho \overline{w'^2})}{\partial z}\right]$$

- Standard ķ - ε model has been used for the closure of turbulent momentum equations

DETAIL OF RAMAGUNDAM ST-II ESP-Assumption

- All four ESP passes are geometrically similar and hence only one pass has been considered for modeling
- Zero thickness of collecting electrode plates.
- Six collecting plates in a row of a field have been merged in single plate as the gap is very small.
- Primary and secondary GD screen modeled as porous jump.
- Emitting electrode not modeled.
- Mass flow at the inlet is uniform.
- Support structure of the electrodes/rapping arrangements omitted from the model.

DETAIL OF RAMAGUNDAM ST-II ESP-Ash Resistivity

ALS Coal

Milling & Combustion Evaluation of Indian Steaming Coals: Ramagundam

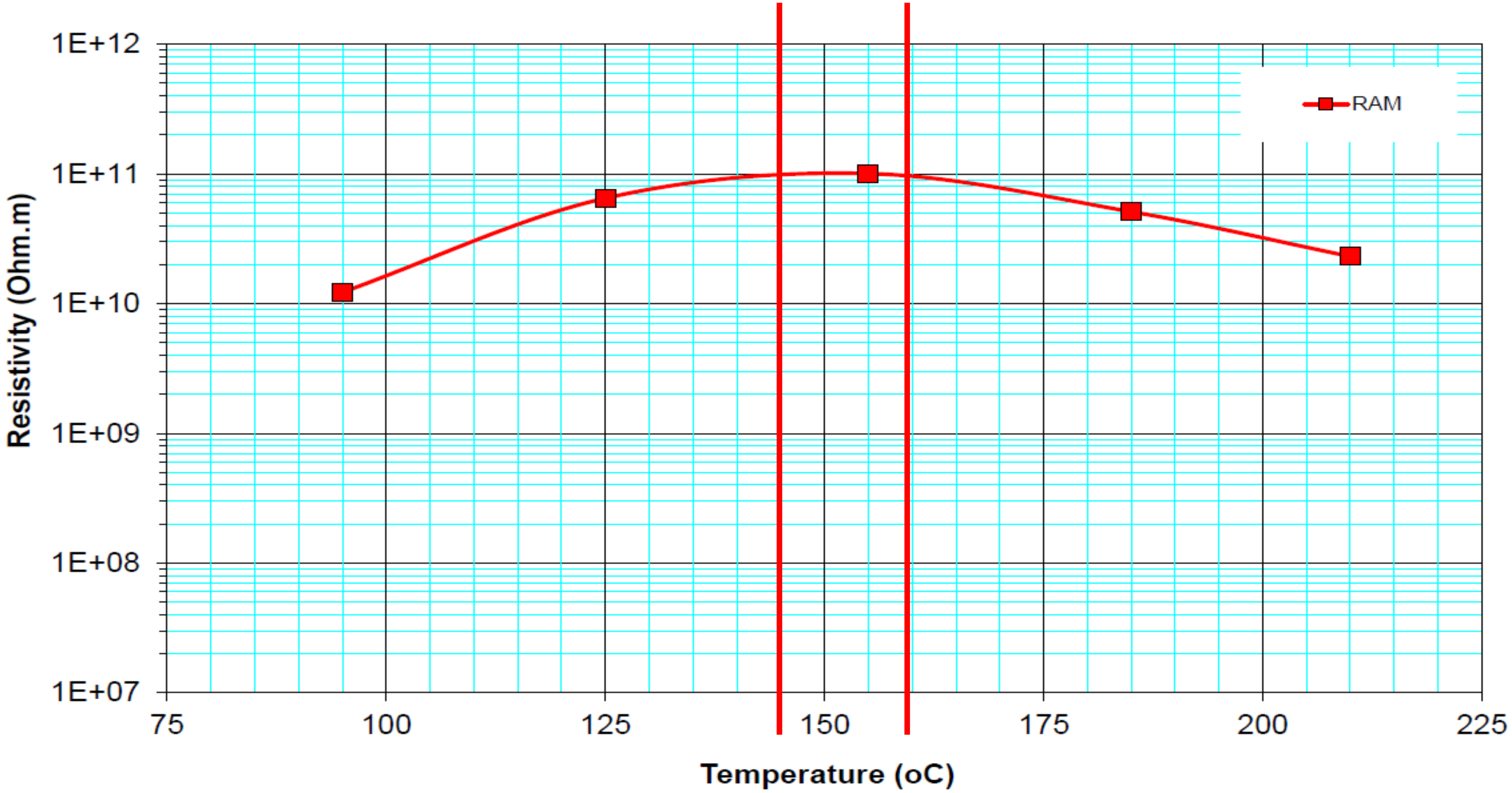


Fig. 6.3: Resistivity of RAM Fly Ash