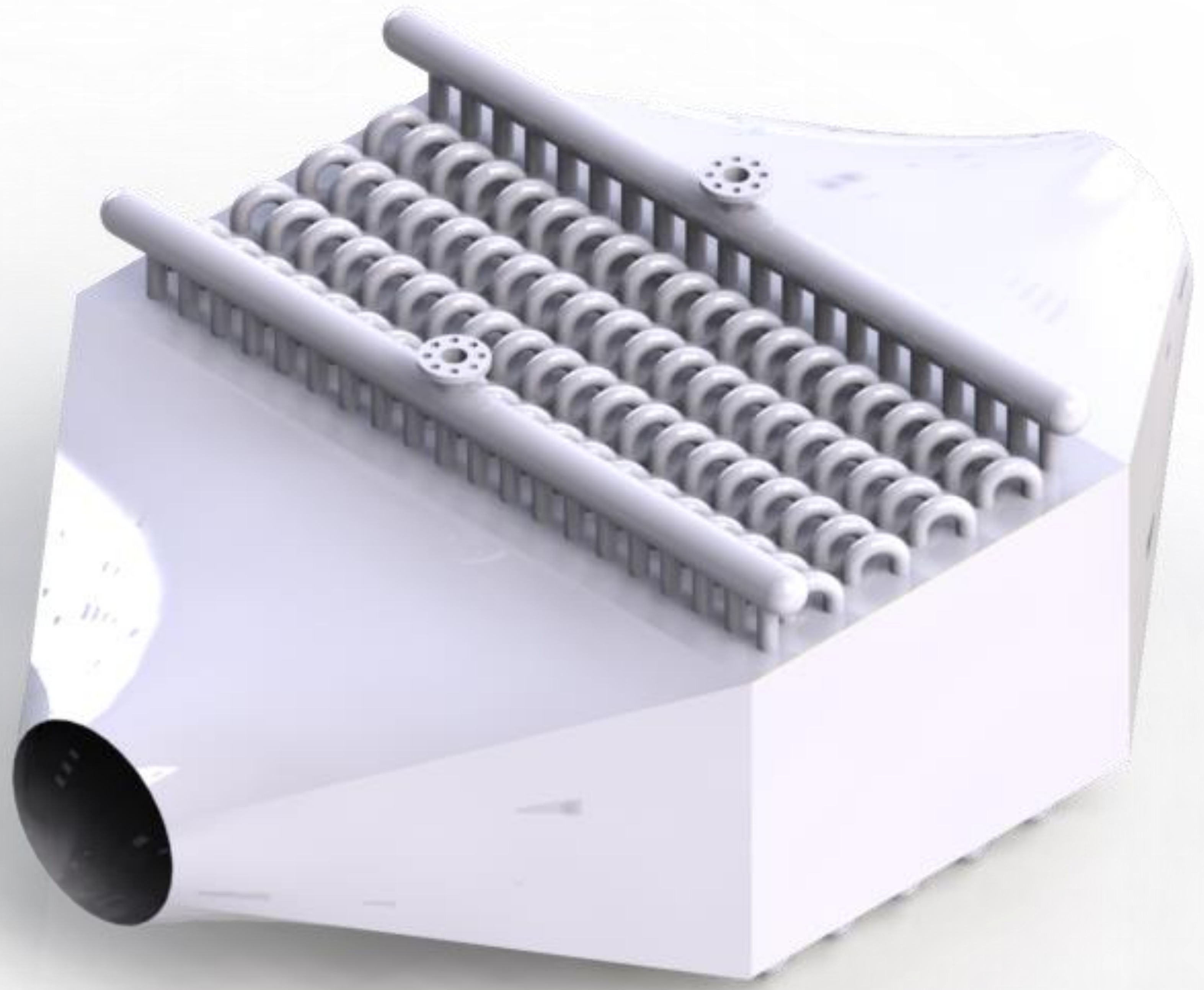
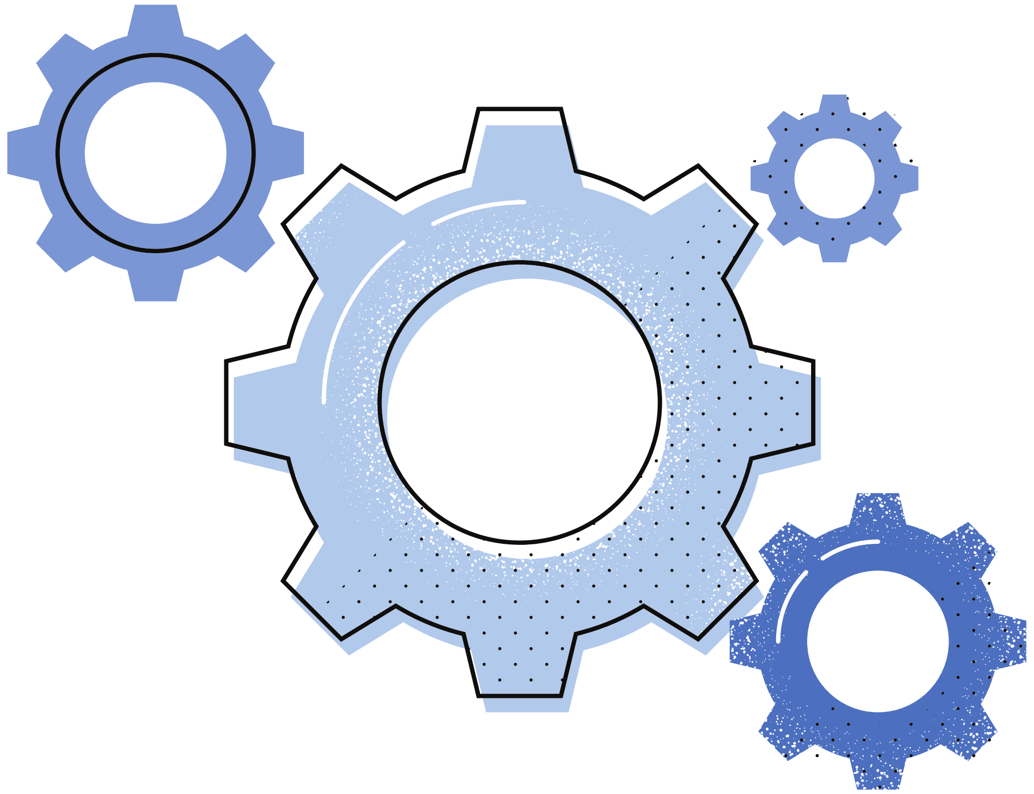
Non-condensing Economizer



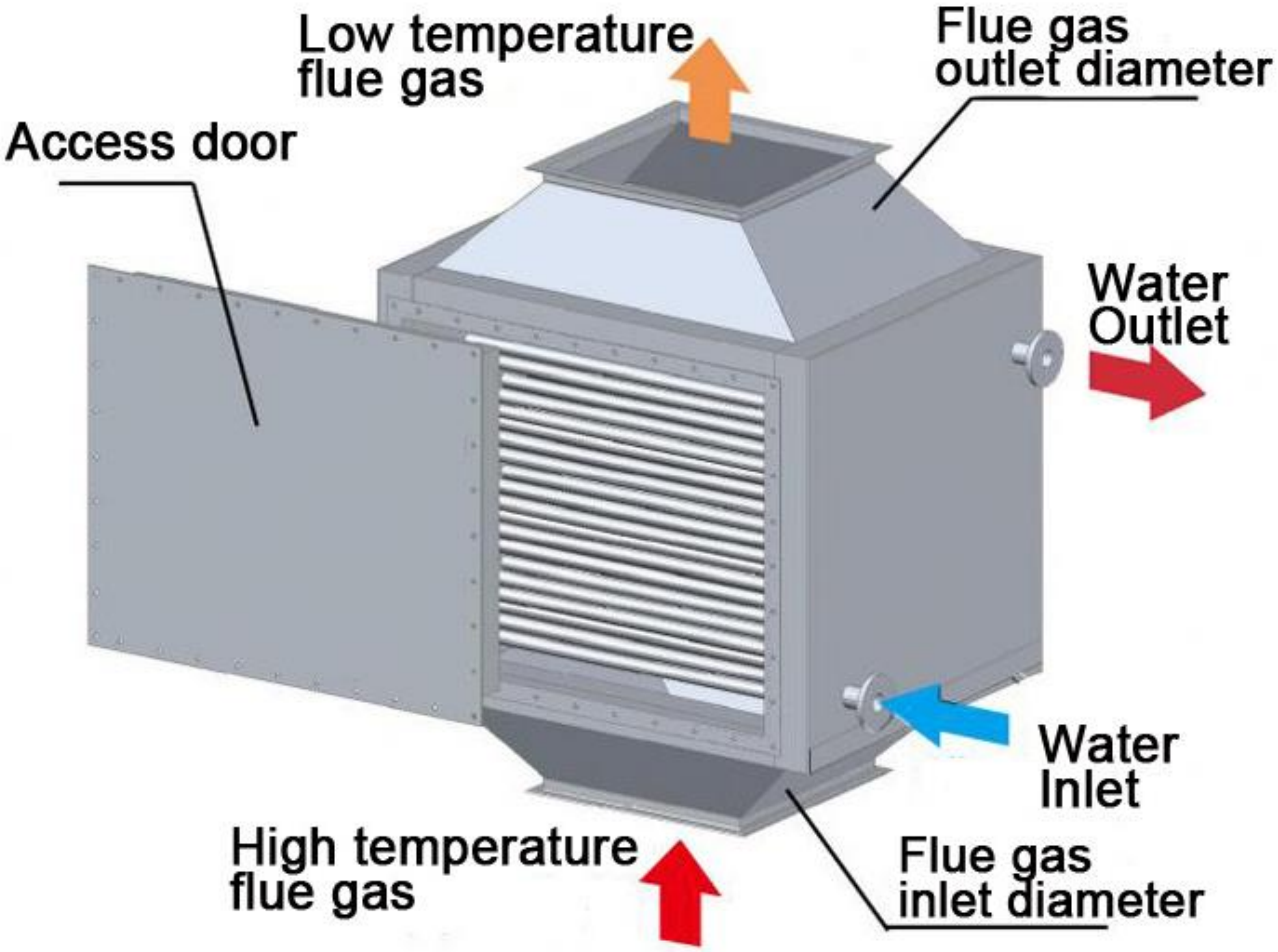
Group A12

Md Jawarul moresalein (1710002)
Shouvik Sarker (1710017)
Sadib Fardin (1710019)
Md Fuad Amin Jarif (1710020)



- To create a mathematical model of the economizer
- To design this model by CAD software
- To validate this model by ANSYS & HTRI Exchanger-Suite
- To manufacture this model by practical market study & cost analysis
- To analyze the overall efficiency & practicality of this model

What Is An Economizer



- Mechanical device intended to reduce energy consumption.
- To perform useful functions such as preheating a fluid

Benefits of having one:

- Improves the boiler efficiency.
- Reduces the losses of heat with the flue gases.
- Reduces the consumption of fuel
- Reduces thermal stresses in the boiler

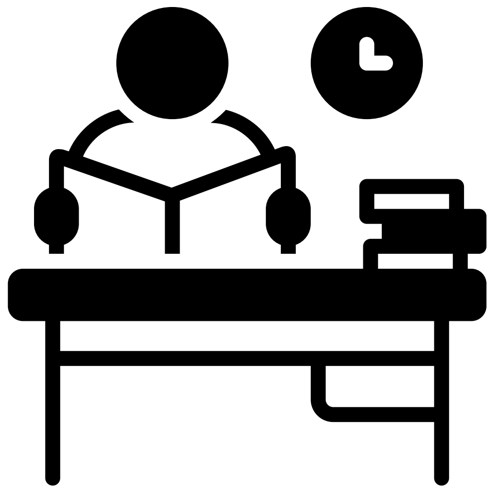
PROJECT FEATURES

- Cross flow heat exchanger
- Tubes in staggered position
- Improved efficiency, Improved ventilation
- Simple Structure, Easy Installation
- Improved Fin Structure To Increase Efficiency
- Non-Condensing Economizer

Project Timeline

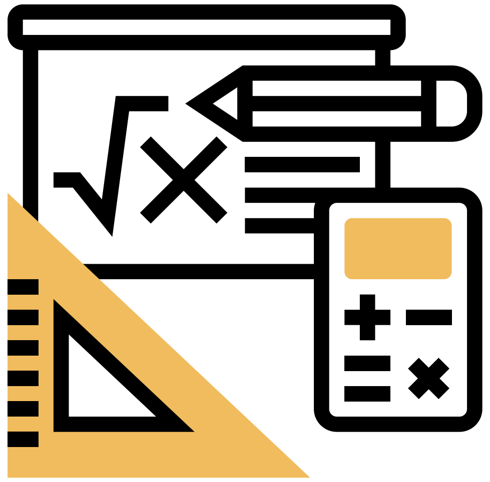
9TH WEEK

PROJECT STUDY



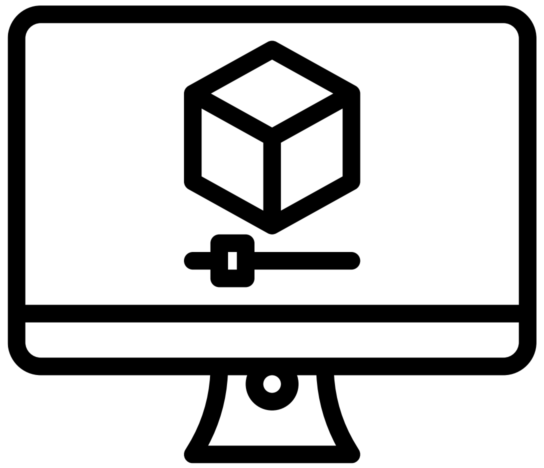
10TH WEEK

MATHEMATICAL MODEL CREATE



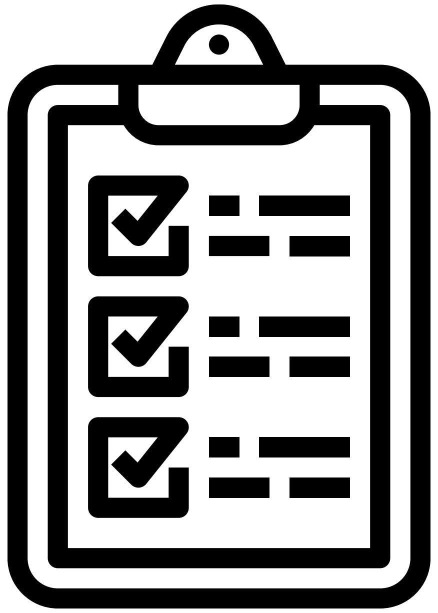
11TH WEEK

3D MODEL CREATE



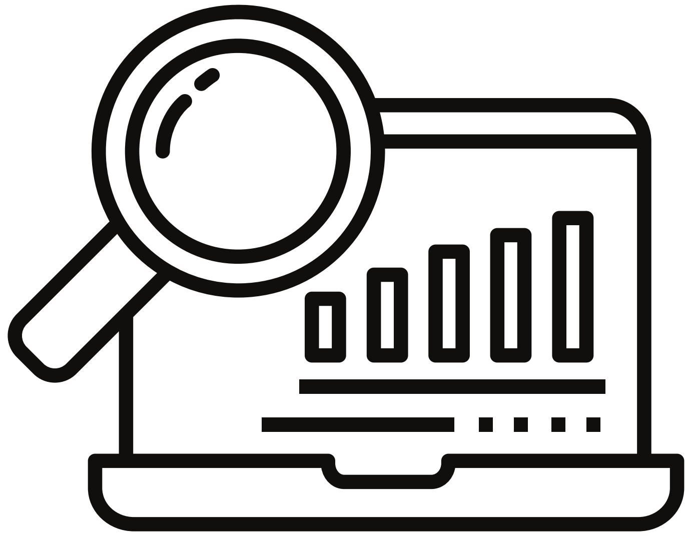
12TH WEEK

DESIGN VALIDATION



13TH WEEK

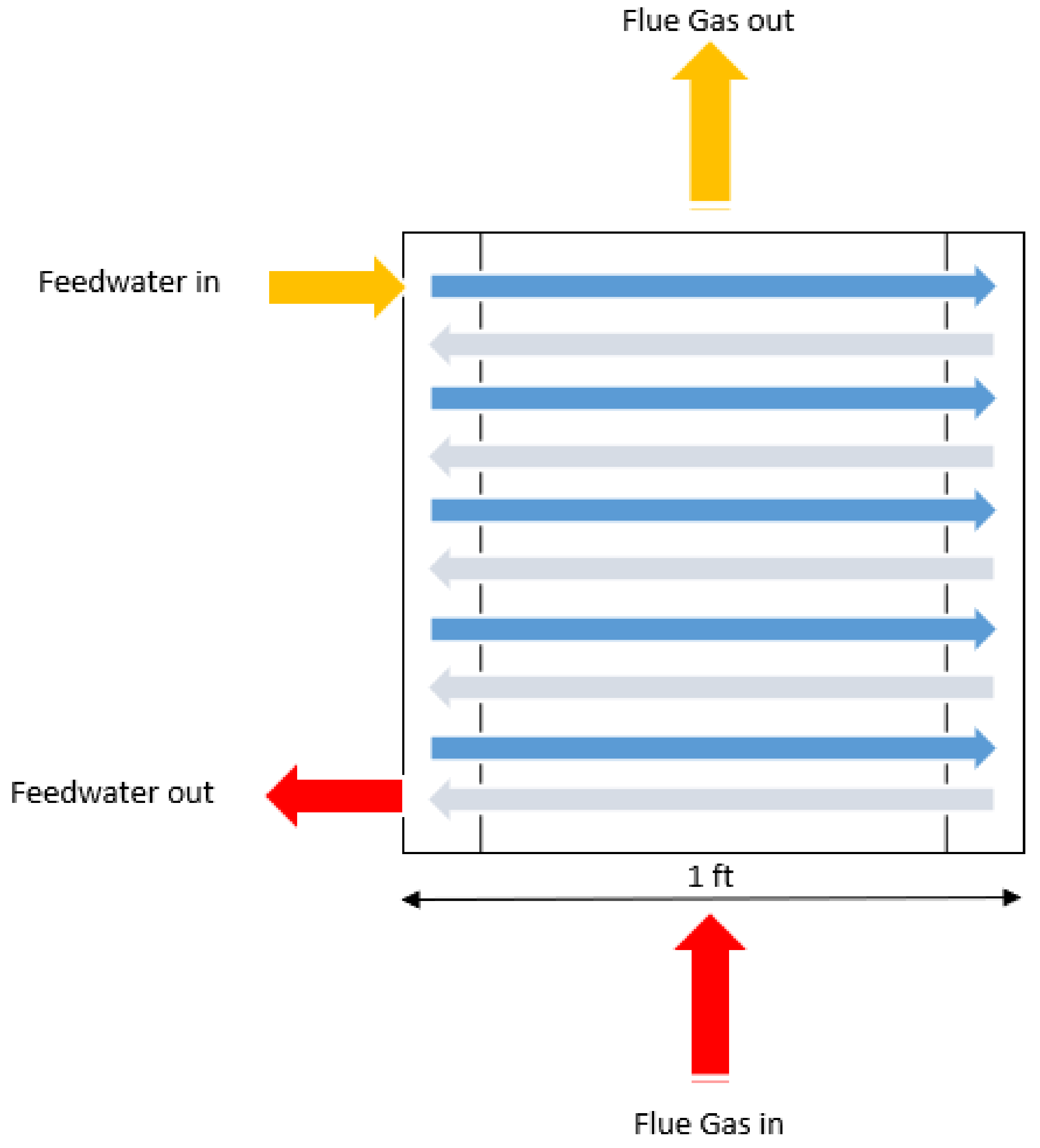
LITERATURE REVIEW AND RESULT STUDY



Components & costing

Component	Price(Taka)
Shell (Stainless steel)	4,000/-
Tube (Copper)	10,500/-
Fin (Aluminum)	2,500/-
Insulation	2,200/-
Additional Cost	2,000/-
Total	**21,200/-**

Problem statement



Hot fluid : Flue Gas

Position : Shell

Inlet temperature, $T_{h,in} = 180^\circ$ C

Outlet temperature, $T_{h,out}=120^\circ$ C

Mass flow rate, $\dot{m}_h = 60$ kg/hr

Uniform velocity, $U_\infty = 3$ m/s

Cold fluid : Feedwater

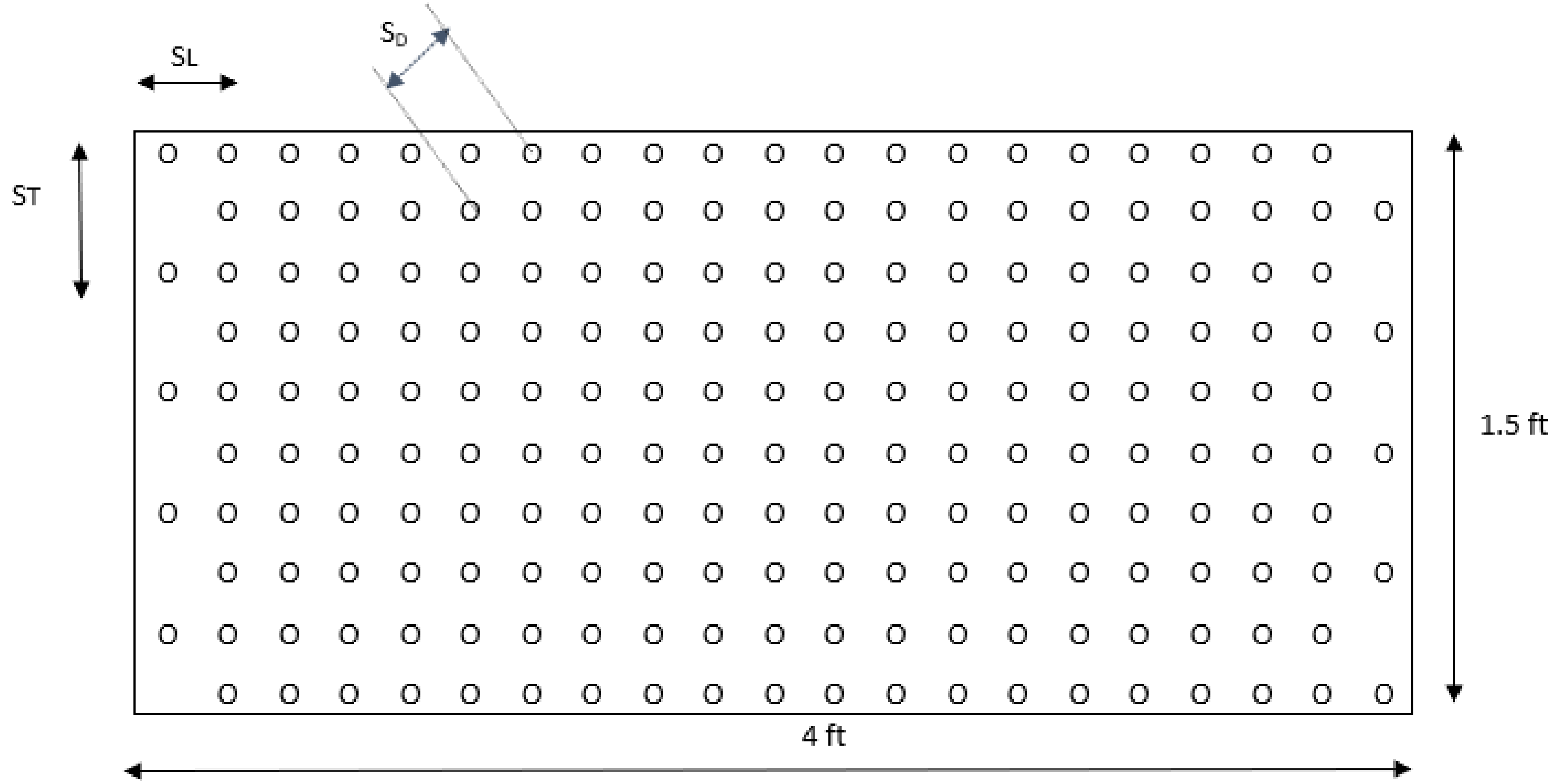
Position : Tubes

Inlet temperature, $T_{c,in} = 50^\circ$ C

Outlet temperature, $T_{c,out}=80^\circ$ C (assumed)

Mass flow rate, $\dot{m}_c = 6$ kg/hr

Physical dimensions



Length, L = 4 ft

Width, W = 1 ft

Height, H = 1.5 ft

Tangential pitch, S_T = 5 cm

Longitudinal pitch, S_L = 2.5 cm

Tube outer diameter, D = 2.5 cm

Tube inner diameter, d = 2.4 cm

Number of tubes in longitudinal distance, N_L = 20

Number of tubes in transverse distance, N_T = 10

Calculation

$$T_{avg} = \frac{180+120}{2}\,^\circ C = 150^\circ C$$

$$s_D = \sqrt{S_L^2 + \left(\frac{s_T}{2}\right)^2} = 3 \cdot 54 \text{ mm}$$

$$U_{max} = \max\left(U_\infty \left[\frac{S_T}{S_T - D}\right], U_\infty \left[\frac{S_T}{2(S_D - D)}\right]\right) = 7.2 \text{ ms}^{-1}$$

$$R_e = \frac{U_{max} \times D}{\nu} = 6313.57$$

Zukauskas co-relation for cross flow heat exchanger :

$$N_{u_m} = \frac{h_m D}{K} = C_1 \times R_{e_{D,max}}^m \times P_r^{0.36}$$

$h_m = 91.75 \text{ W/m}^2\text{-K}$

Flue gas properties @T_{avg}= 150° C

$\rho = 0.8068\ kg/m^3$

Cp = 1043 J/kg K

K = 0.03416 W/m K

μ = 2.3 x 10^-5 kg/m s

ν = 2.851 x 10^-5 m^2/s

Pr = 0.7025

C_1=0.40 & m = 0.60

Exit temperature, $T_{e,w} = 160 - (16050)\exp\left(-\frac{15.71 \times 91.75}{1.21 \times 4180}\right) = 77.28\ ^\circ C$

$$\therefore \text{error} = \frac{80 - 77.28}{80} = 3.40\%$$

So the assumption is correct.

Calculation

Here,

$$\frac{S_T}{S_L} = 1.41\ ;\ \frac{S_T}{D} = 2\ ;$$

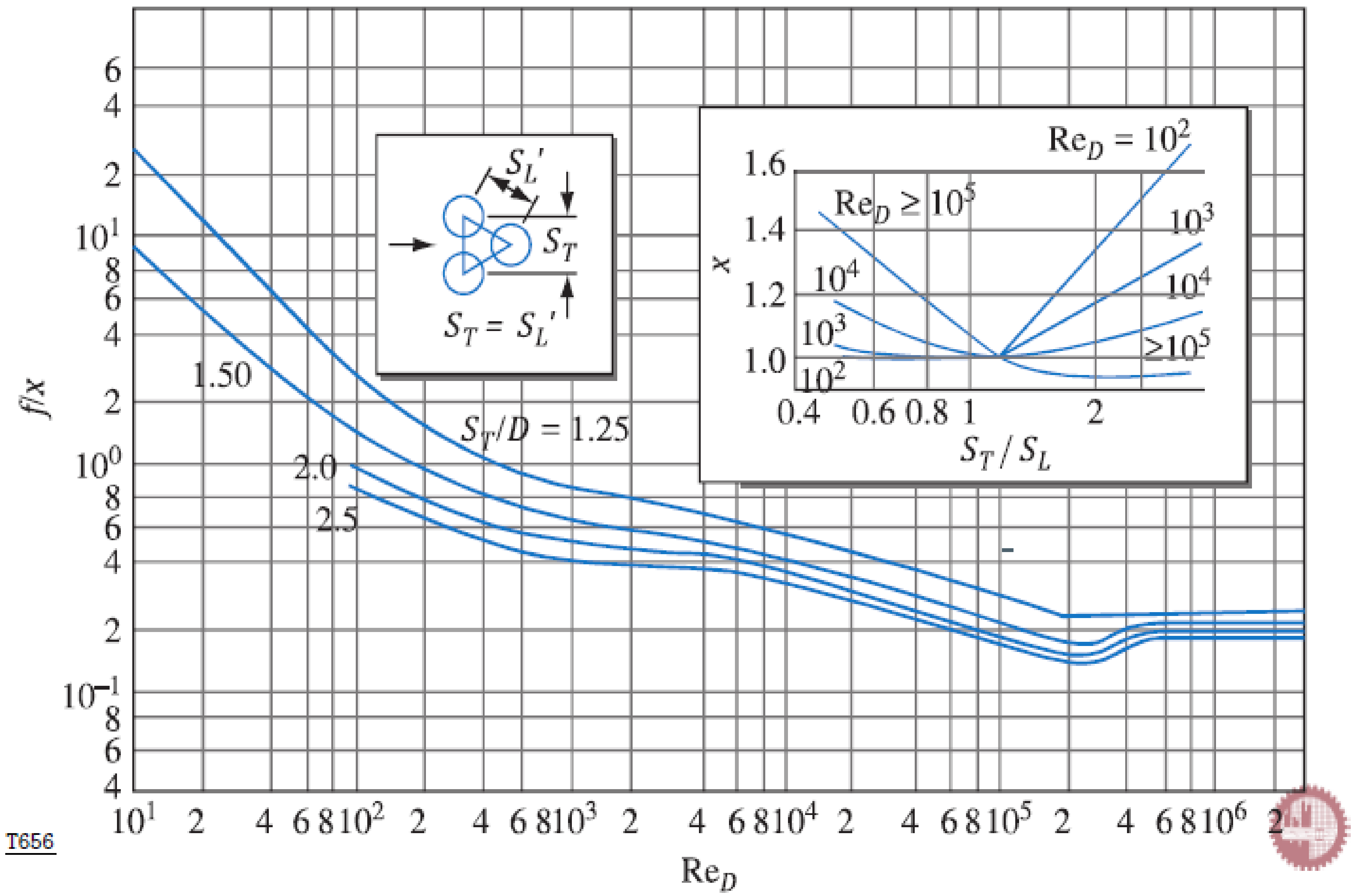
$$R_e = 67000\ \ (Feedwater\ velocity = 1\frac{m}{s}\ \ assumed)$$

$$From\ chart, x = 1\ \&\ \frac{f}{x} = 2\cdot 1\times 10^{-1}$$

$$\therefore\ \ x = 1.9\times 10^{-1}$$

$$\therefore Tubeside\ pressure\ drop,$$

$$\Delta P = f\left(\frac{1}{2}\times\rho\times v^2\right)N_L = 1356\ Pa$$



Fin analysis

Number of fins per tube, $N_{fin} = 35$

$r_1 = 2.5\ cm = 2.5 \times 10^{-2}\ m$
$r_2 = 3\ cm = 3 \times 10^{-2}\ m$
$t = 0.1\ cm = 1 \times 10^{-3}\ m$
$L = 0.5\ cm = 0.5 \times 10^{-2}\ m$

$$\therefore\ r_{2C} = r_2 + \frac{t}{2} = 3.05\ cm = 3.05 \times 10^{-2}\ m$$

$$L_C = L + \frac{t}{2} = 0.55\ cm$$

$A_P = L_C t = 0.055\ cm$

$A_{fin} = 2\pi\,(r_{2C}^2 - r_1^2) = 19.17 \times 10^{-4}\ m^2$

$$\xi = (L_C)^{\frac{3}{2}}\left(\frac{h}{kA_P}\right)^{\frac{1}{2}} = 0.10$$

$$\frac{r_{2C}}{r_1} = 1.22$$

From chart, $\eta_{fin} = 0.98$

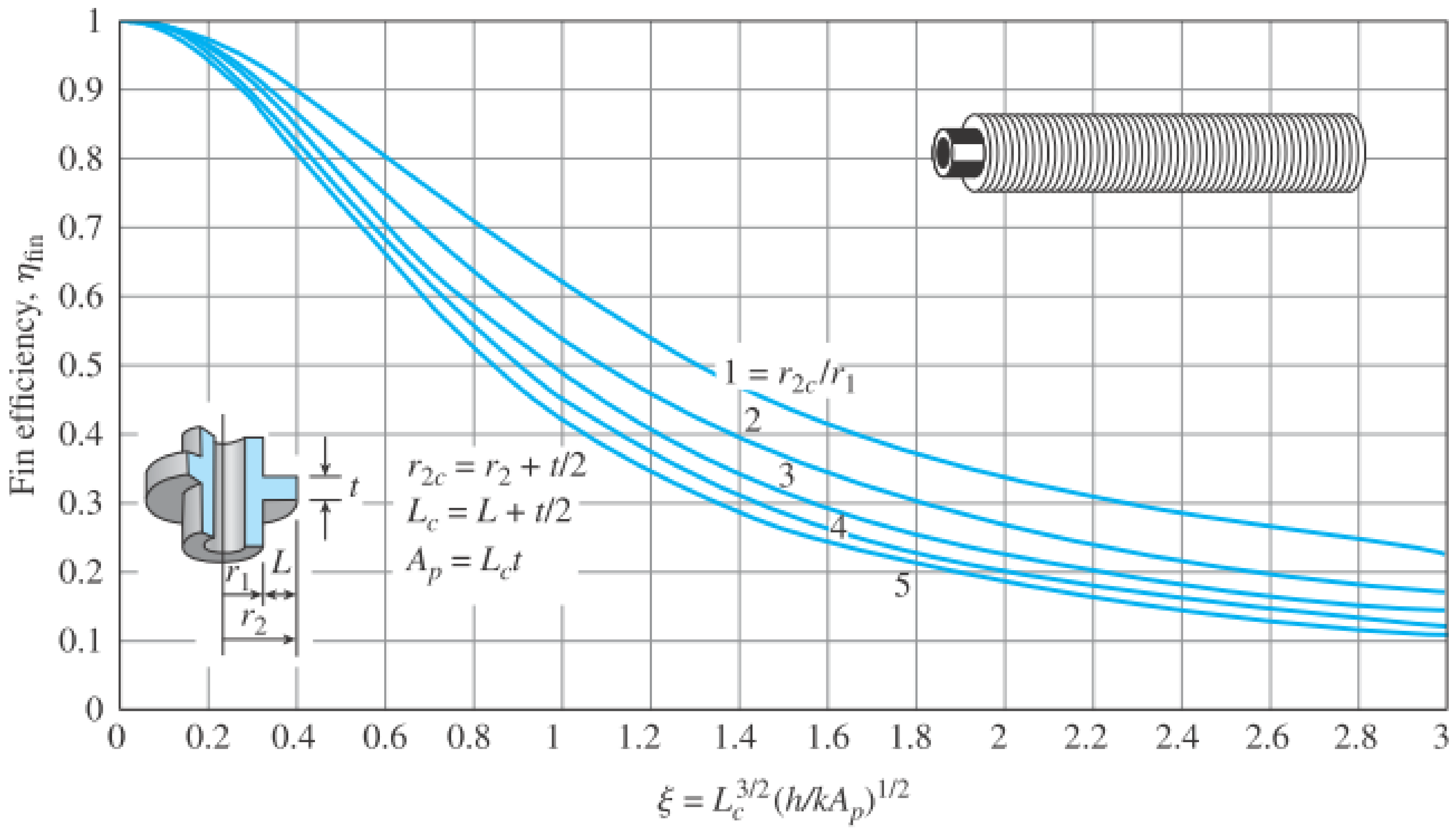


FIGURE 3–44
Efficiency of annular fins of constant thickness t.

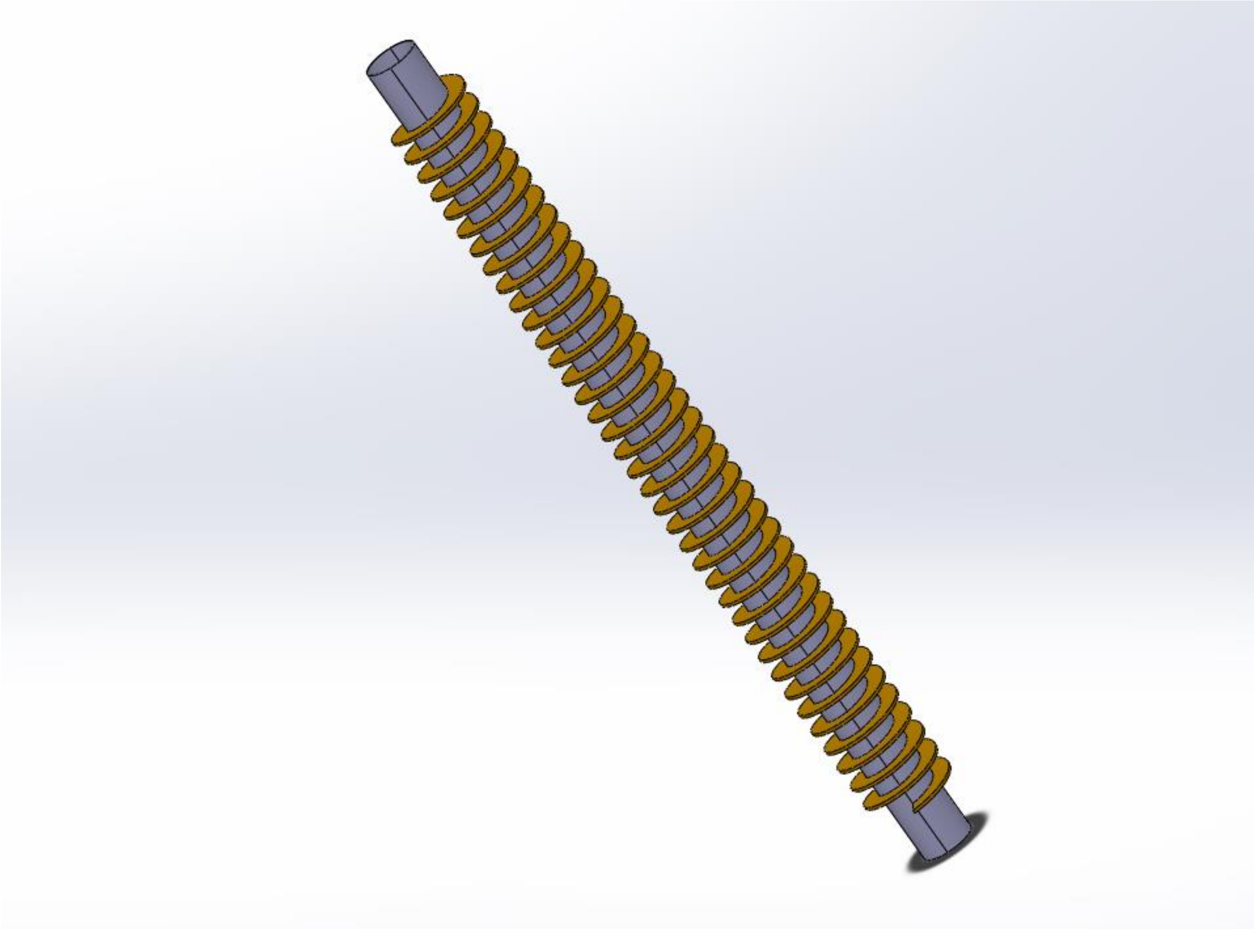
Fin analysis

$$\therefore A_t = NA_{fin} + \pi D(L - Nt) = 0.09\, m^2$$

$$\therefore \dot{Q} = hA_t\left[1 - \frac{NA_{fin}}{A_t}\left(1 - n_f\right)\right](T_S - T_\infty) = 81.34\, W$$

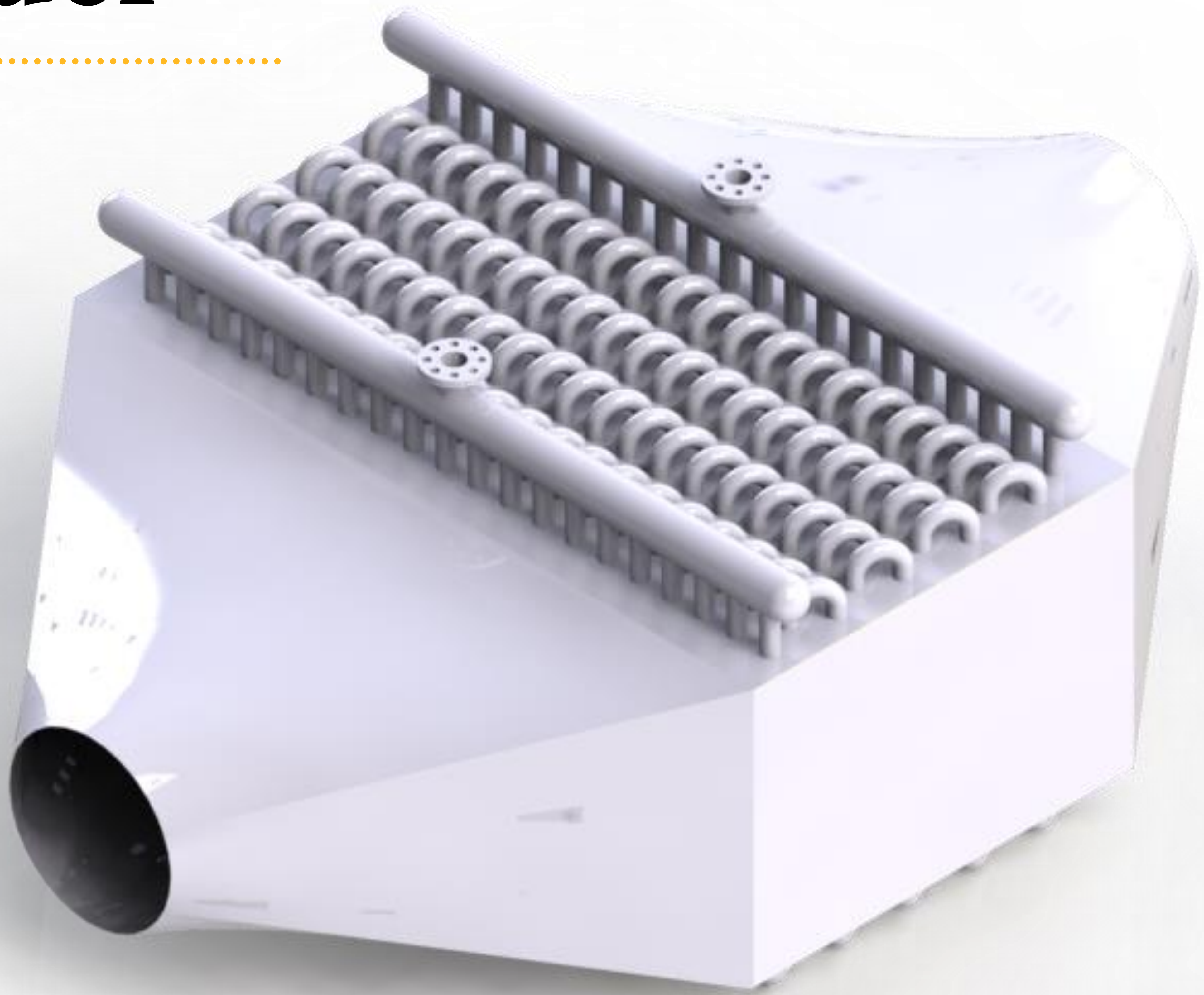
$$\dot{Q}_{no\ fin} = h\, A_b(T_S - T_\infty) = 25.22\, W$$

$$\therefore \boldsymbol{Effectiveness\ of\ fin, \epsilon = \frac{\dot{Q}}{\dot{Q}_{no\ fin}} = \frac{81.34}{25.22} = 3.23}$$

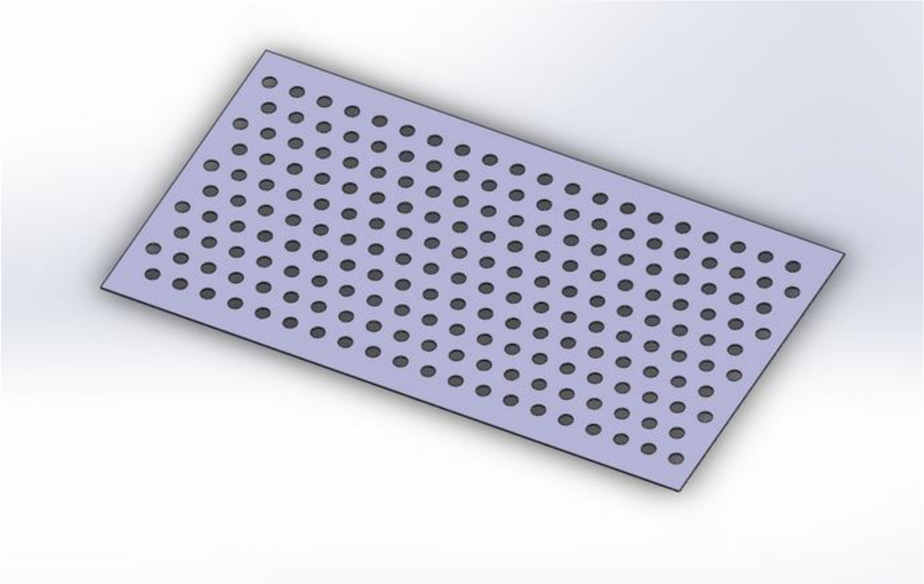


∴ There will be 35 fins per tube, which will increase overall efficiency of the economizer.

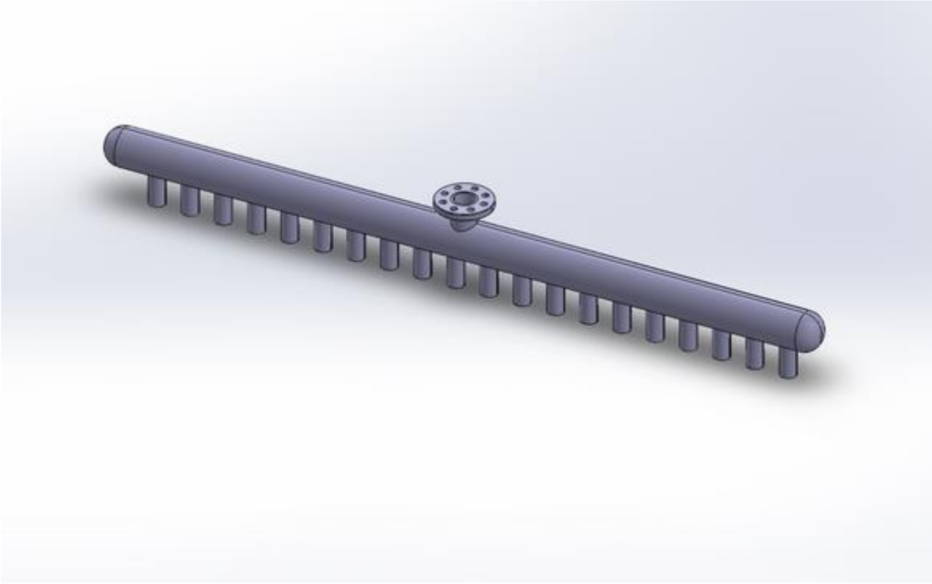
CAD Model



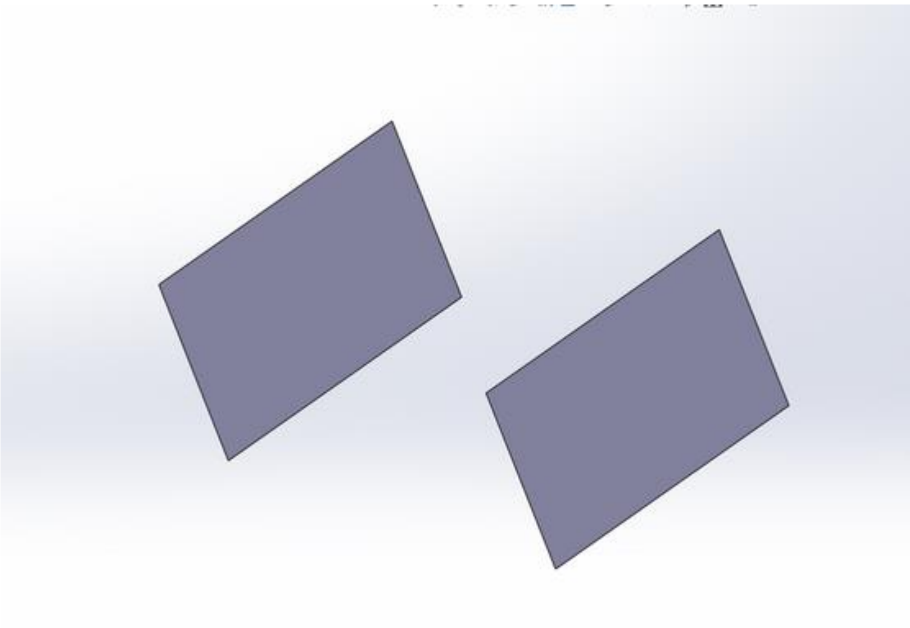
Parts of the CAD Model



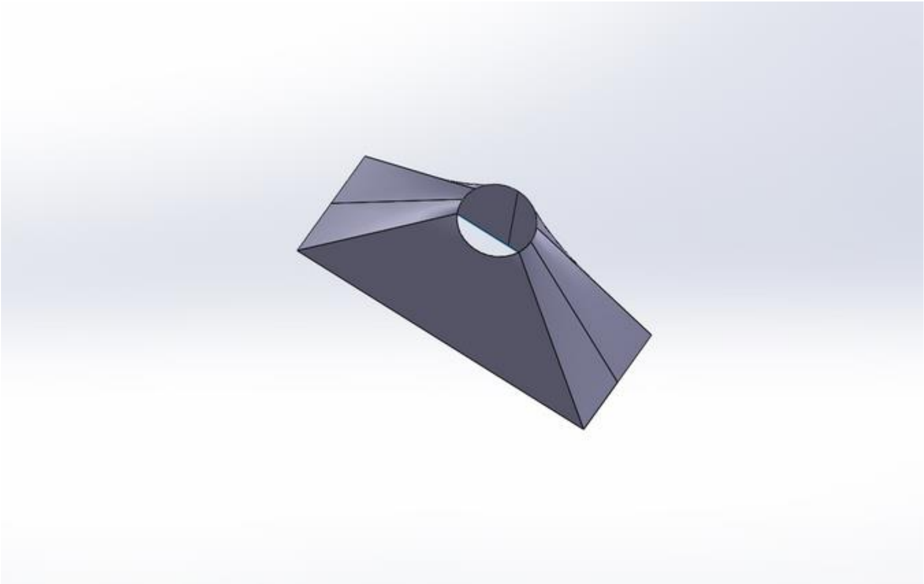
Base plate



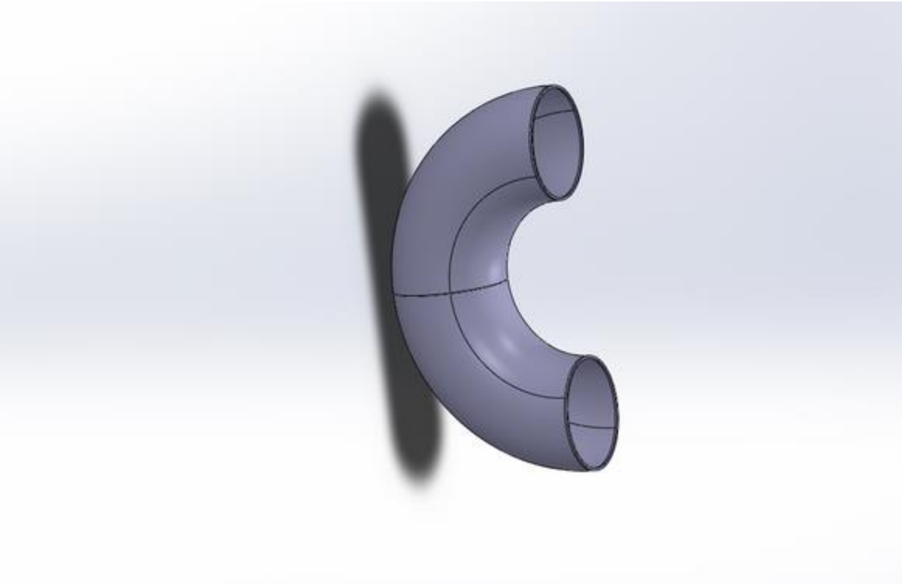
Feed water inlet-outlet



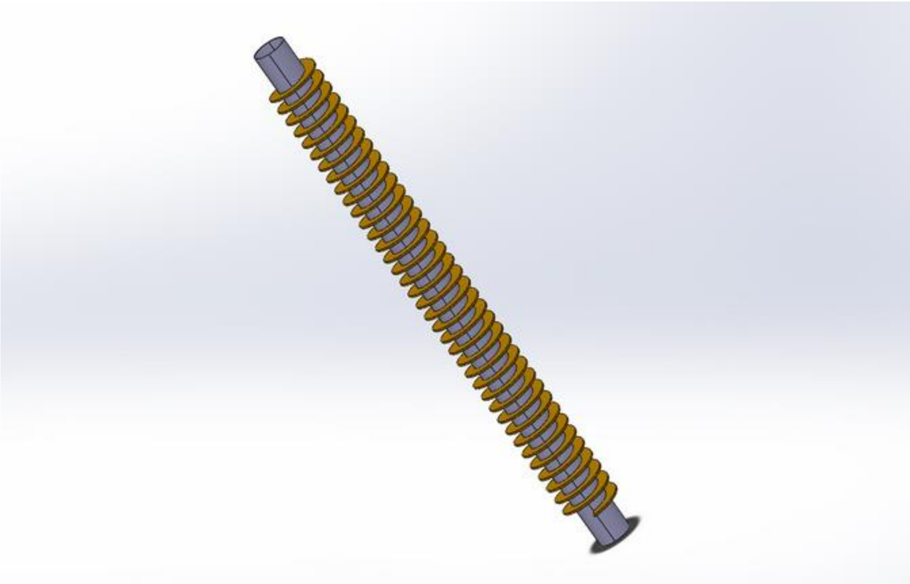
Cage



Flue gas inlet-outlet

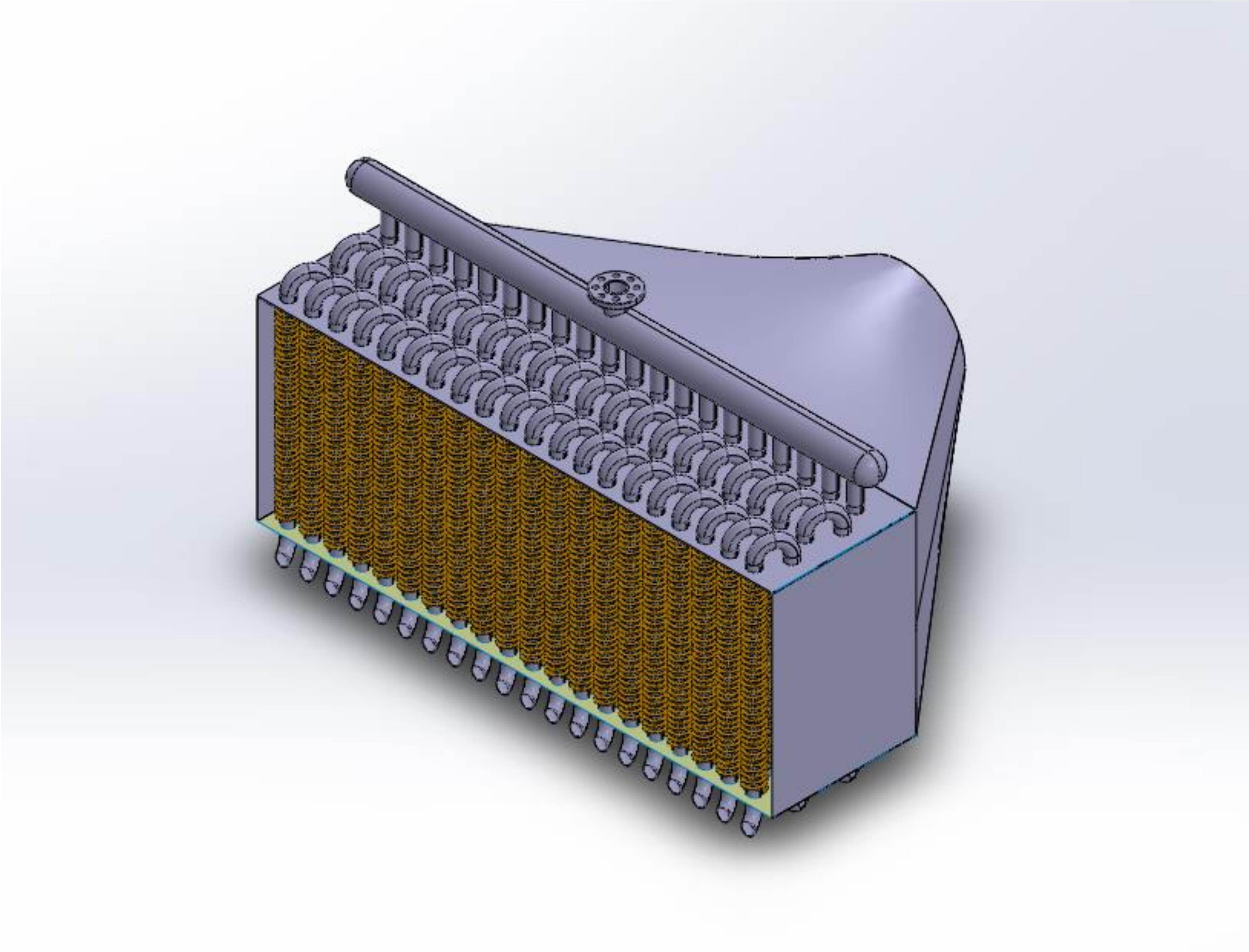


Pipe fitting

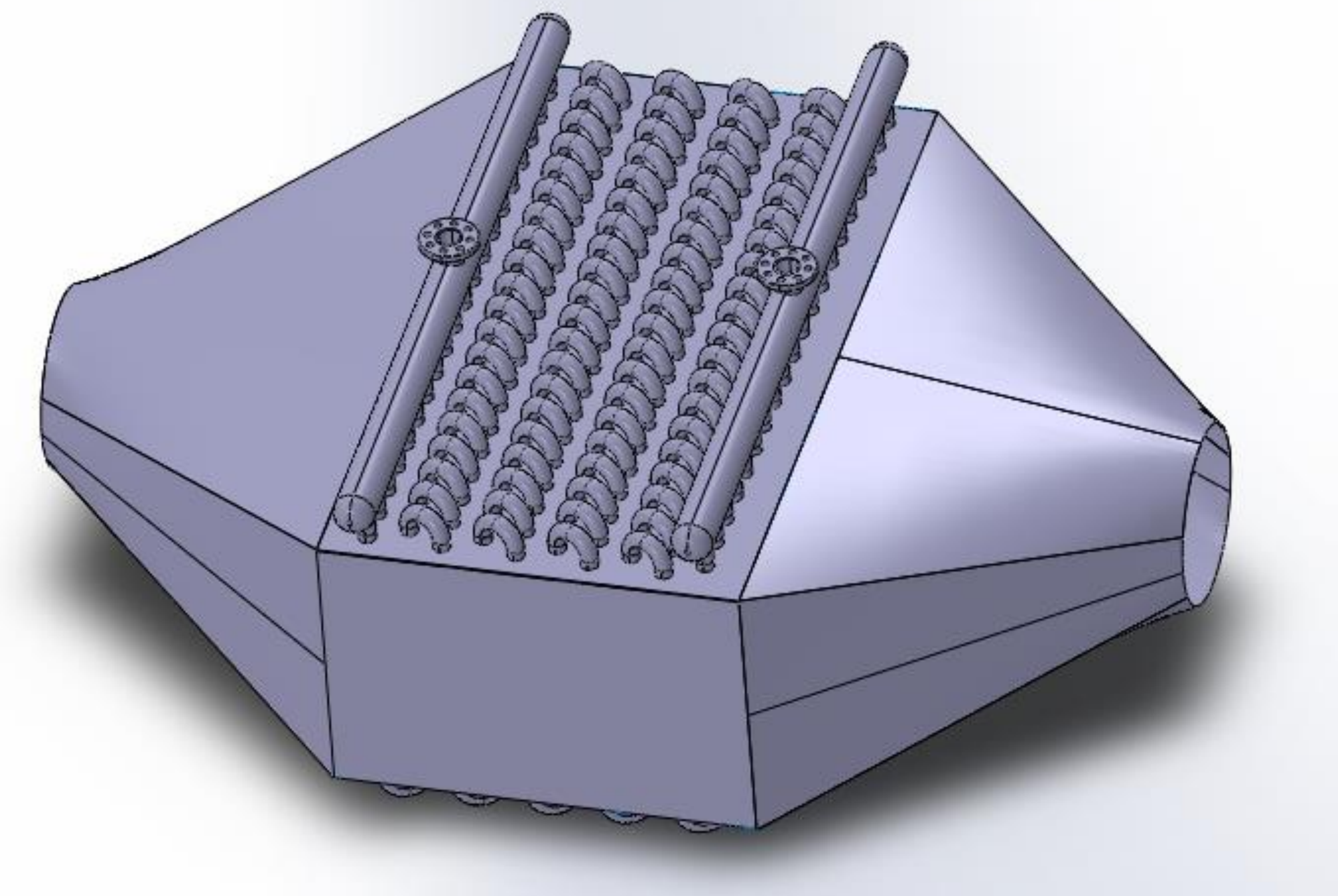


Finned tube

Sectional View & Complete Assembly

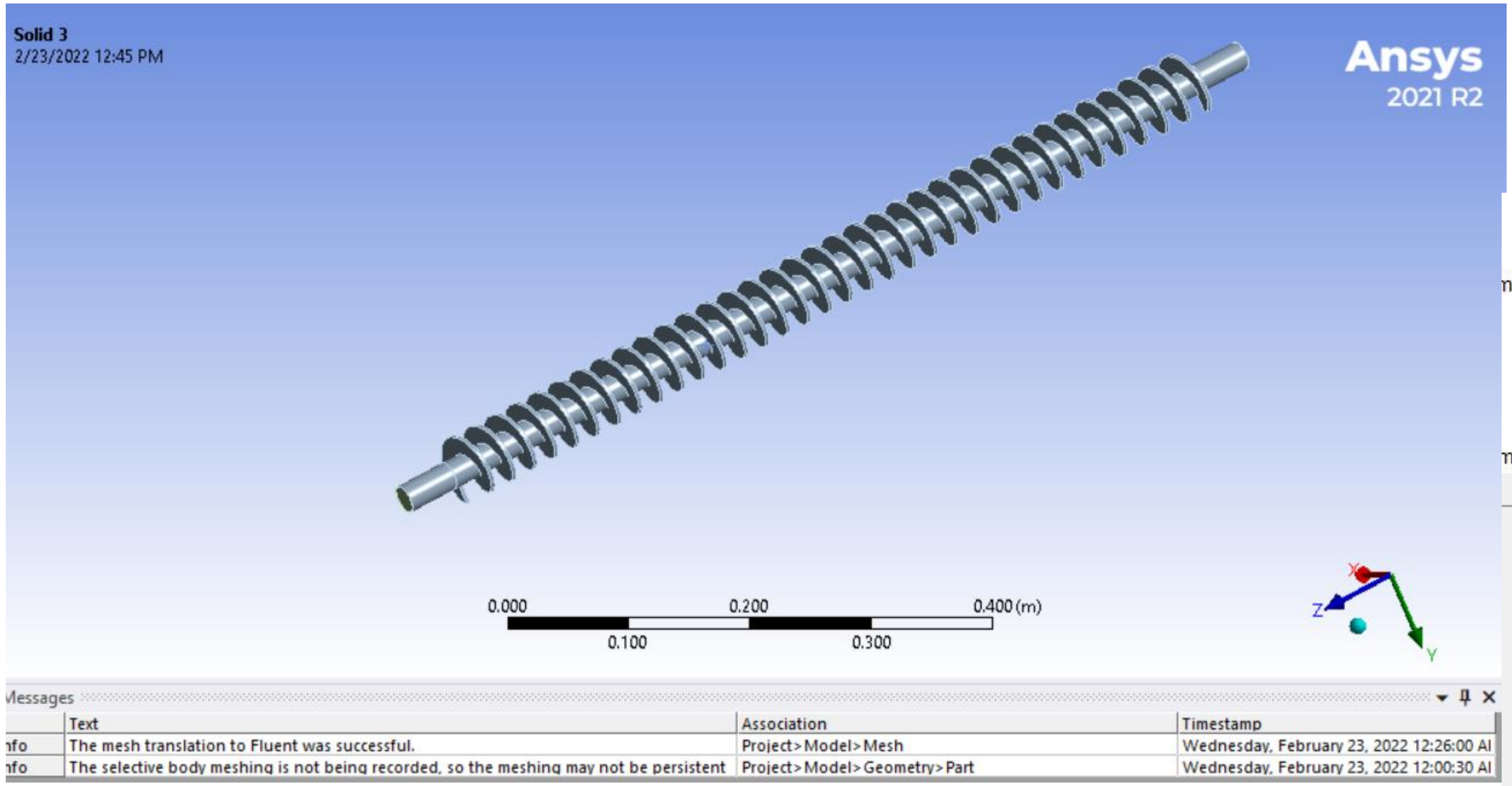


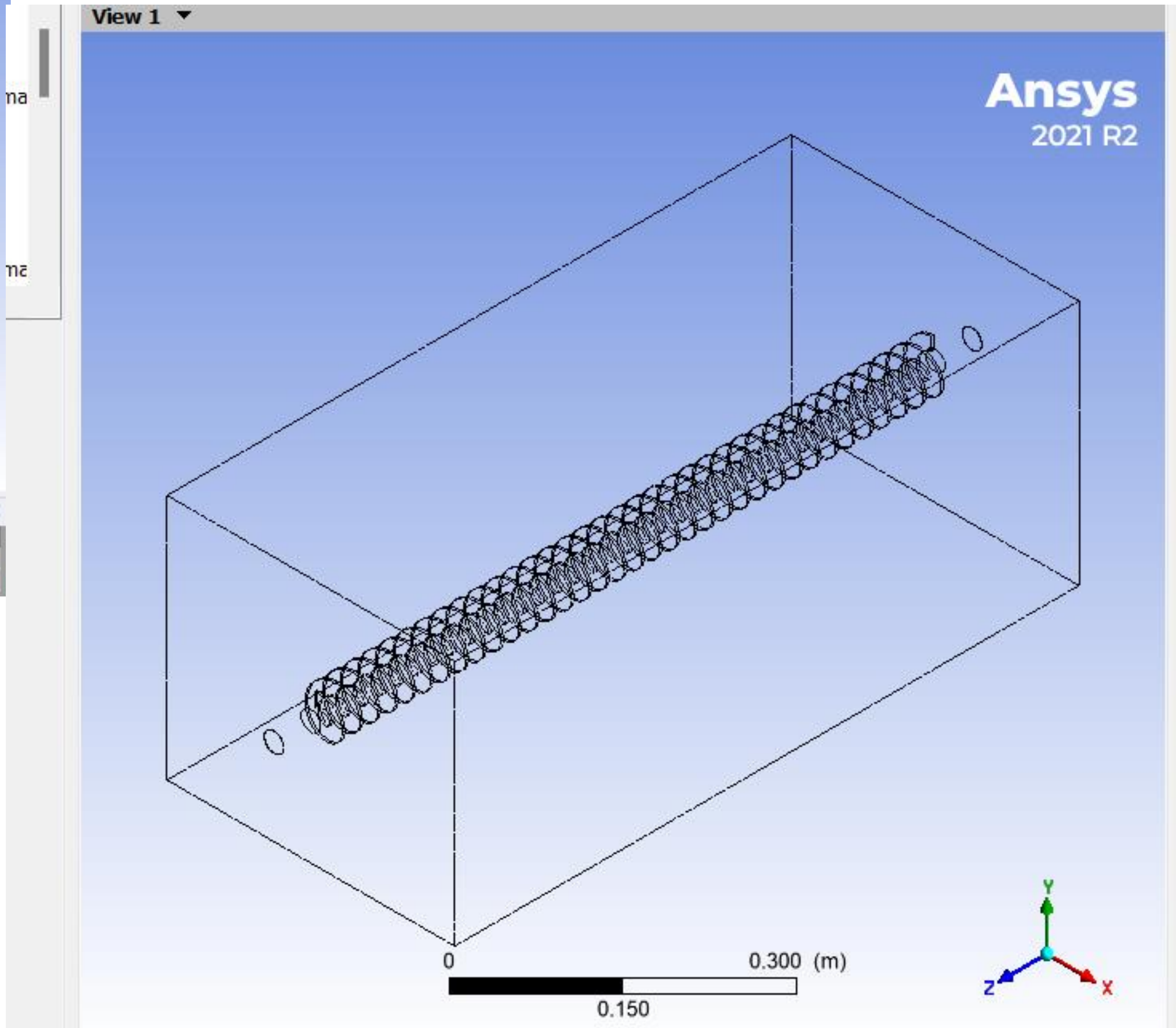
Sectional view



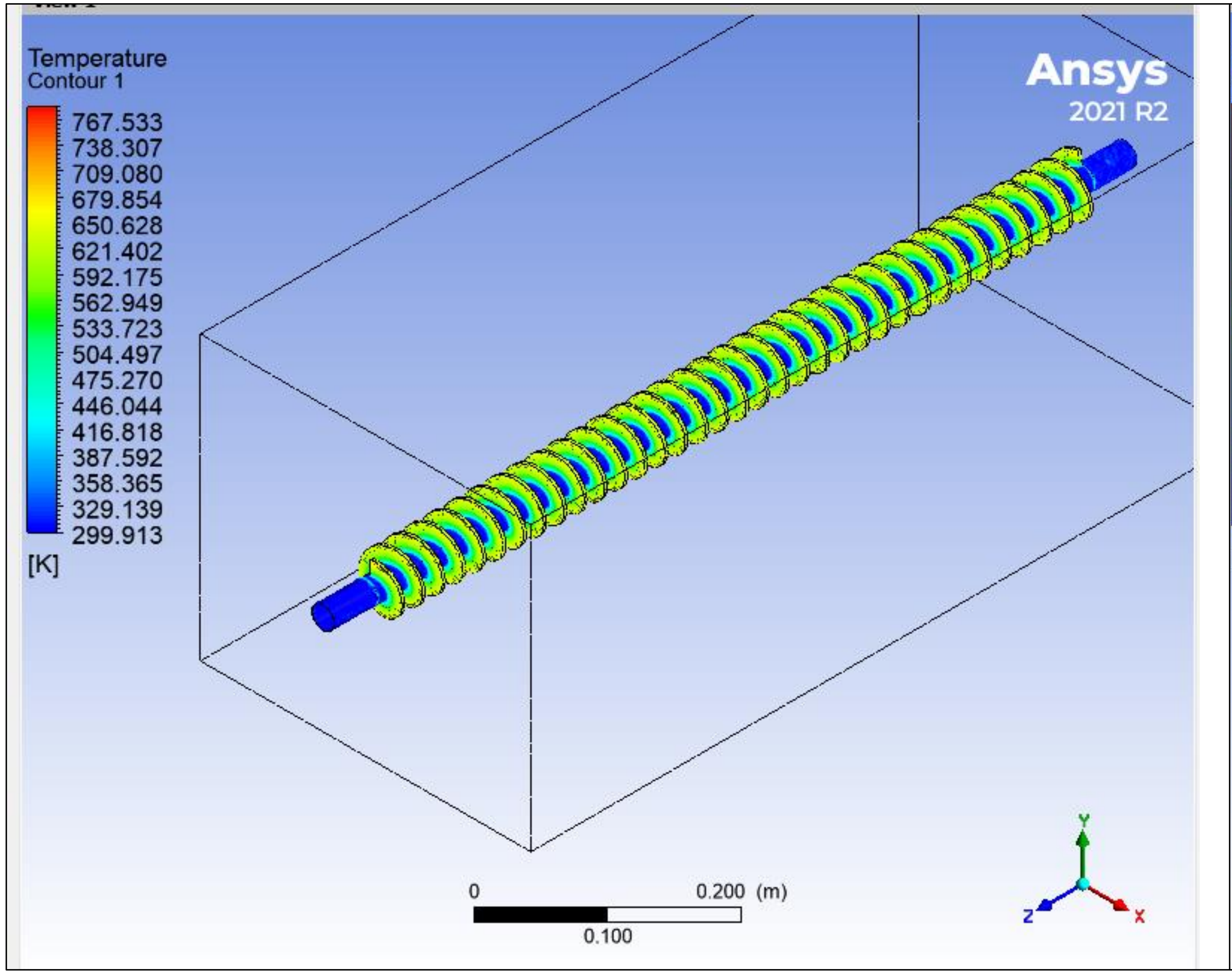
Complete assembly

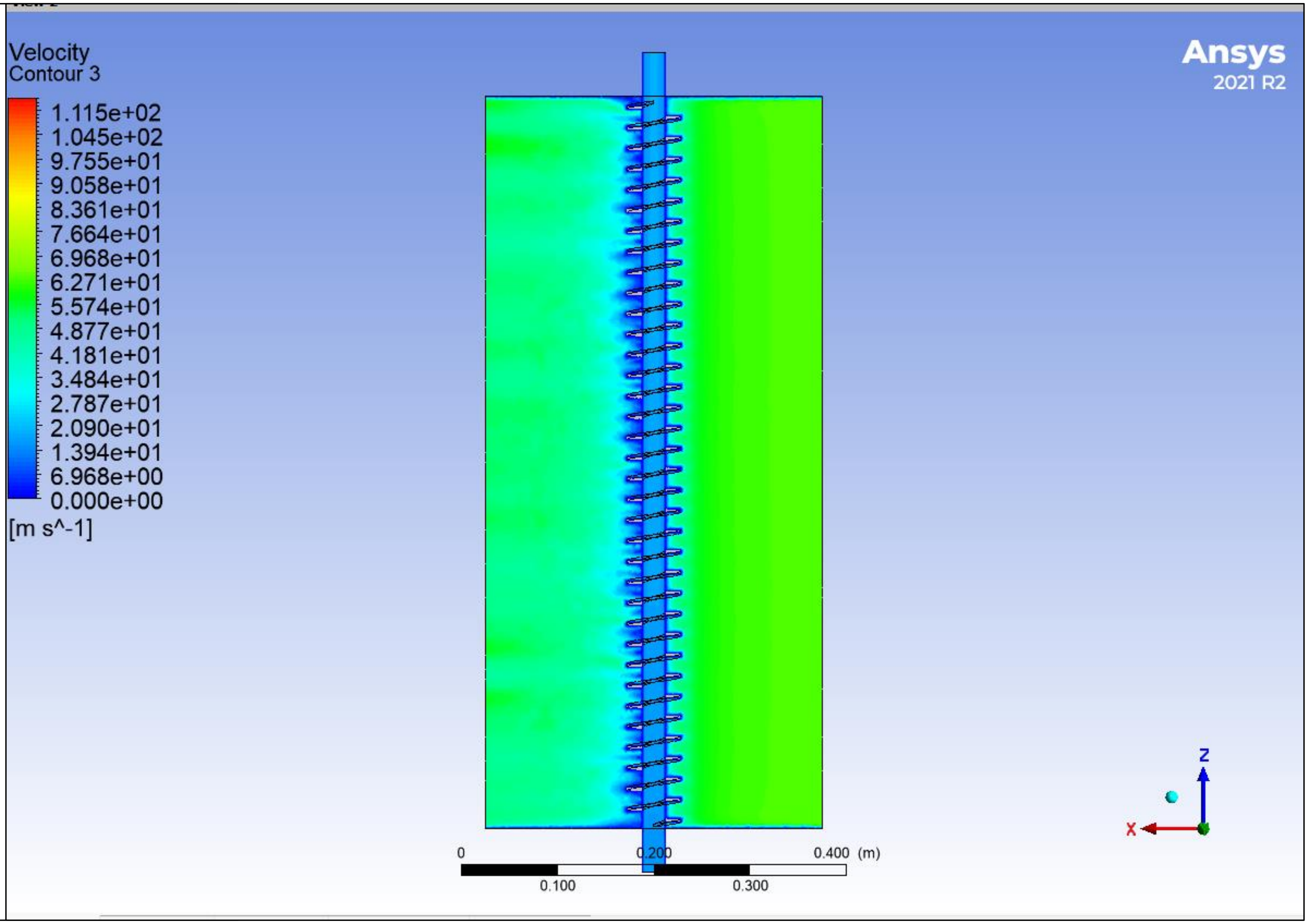
ANSYS Simulation



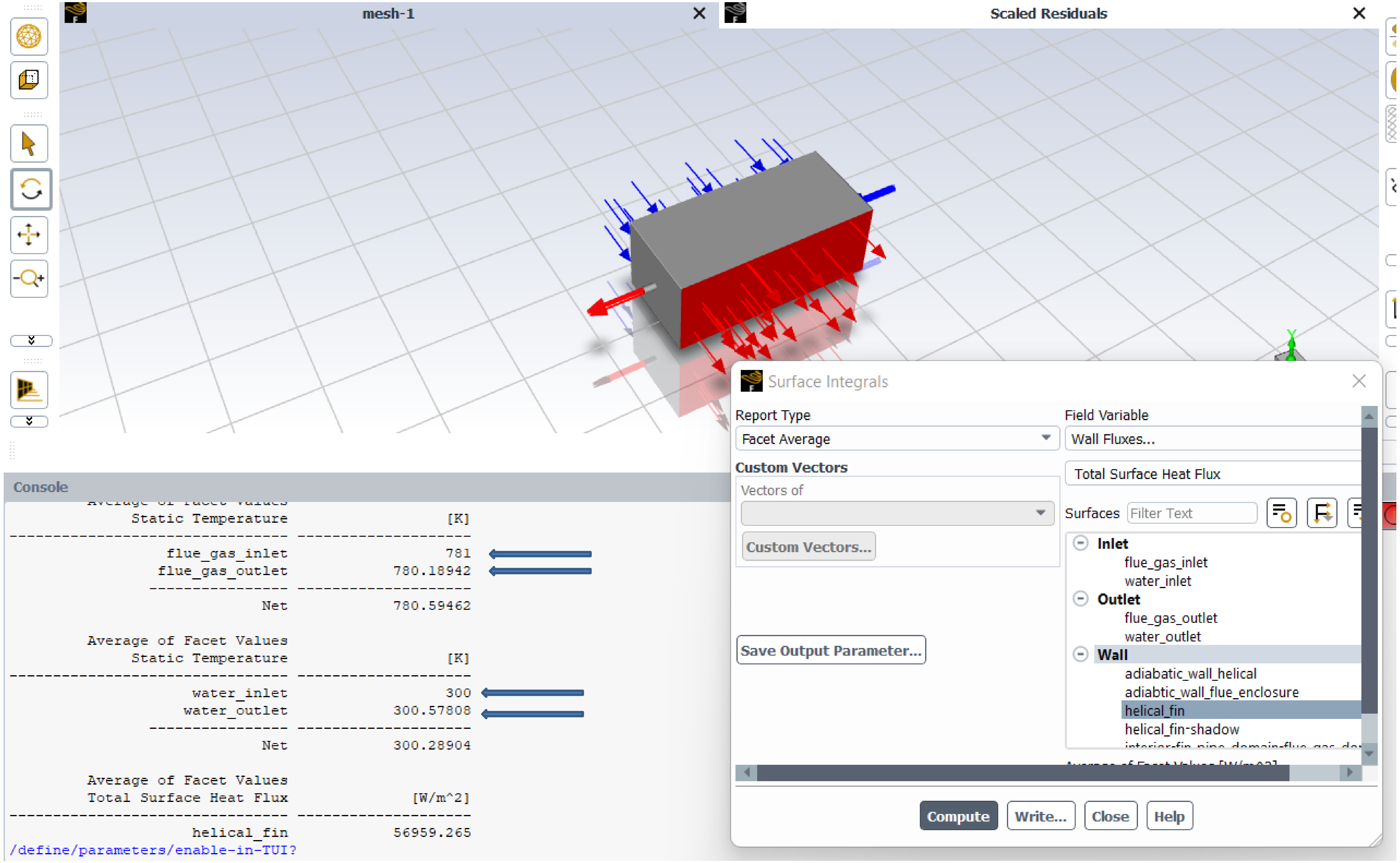


ANSYS Simulation

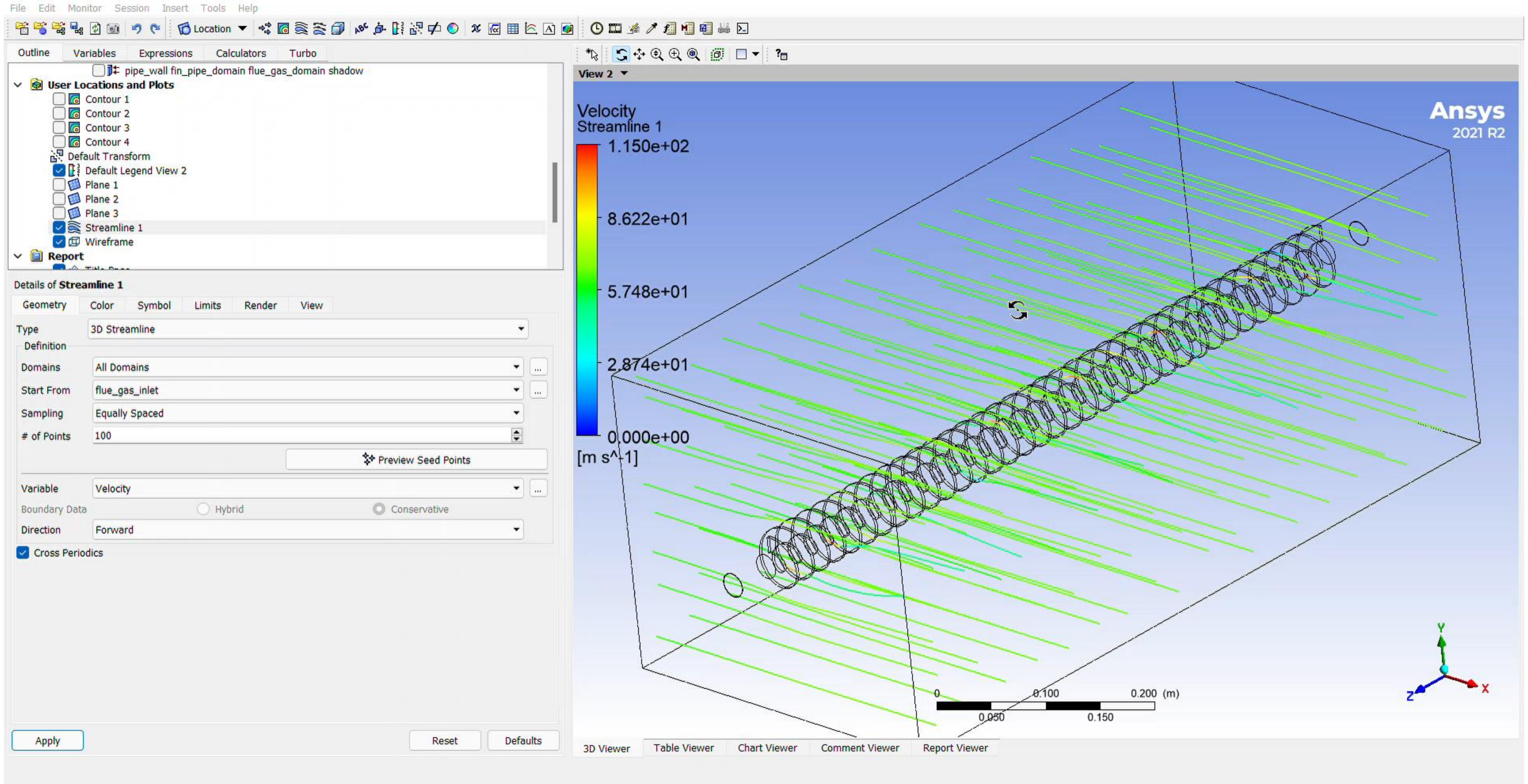




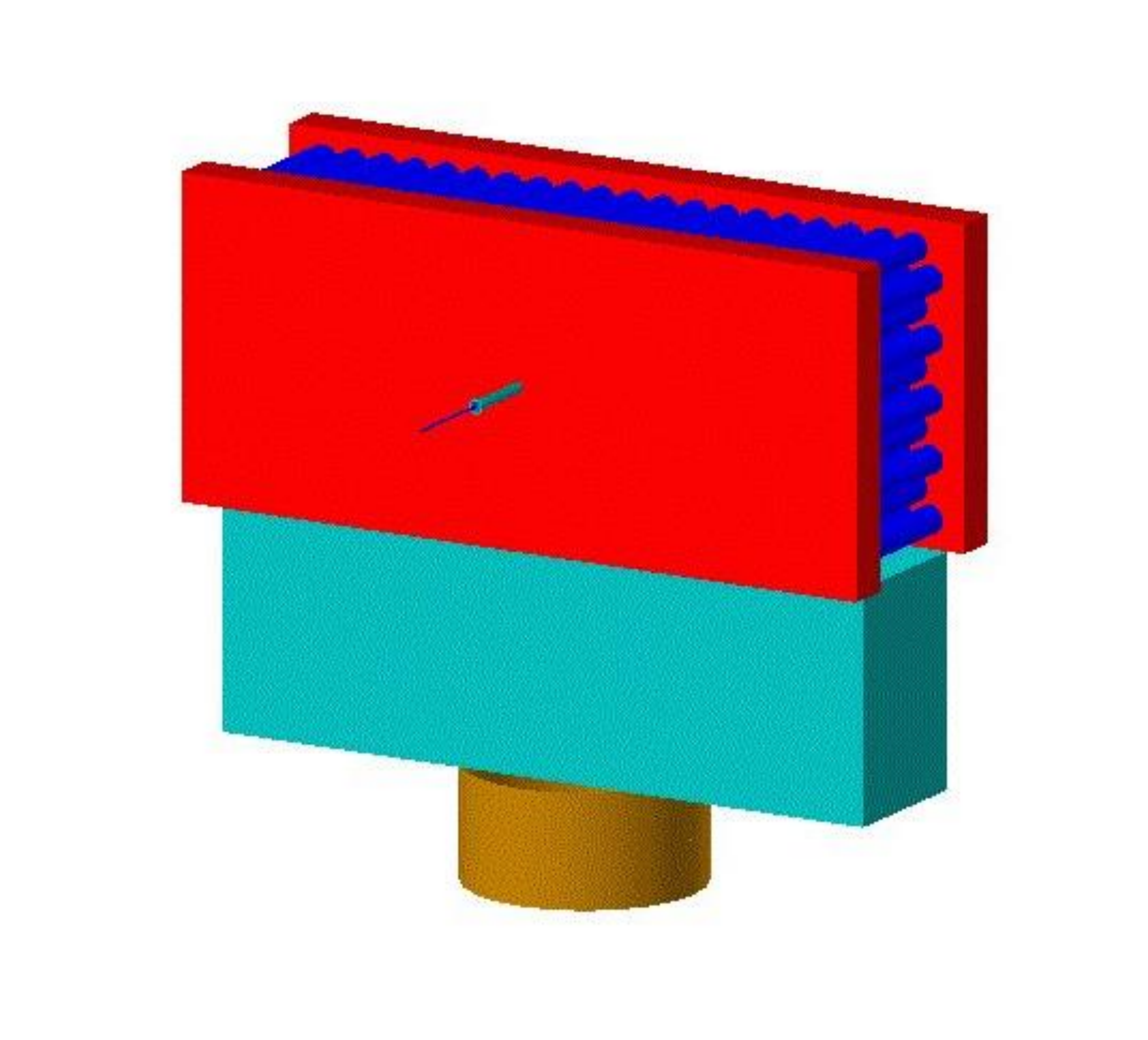
ANSYS Simulation



ANSYS Simulation



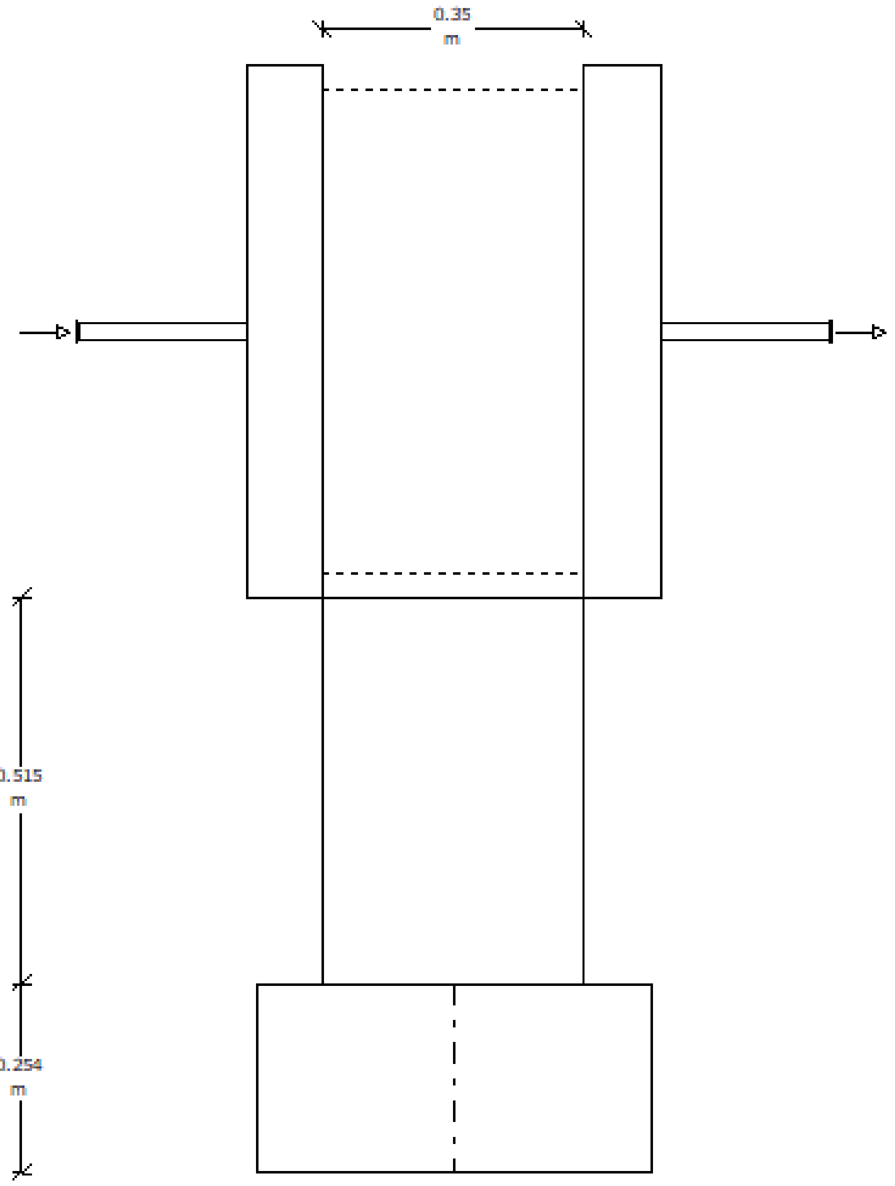
HTRI Modeling & Validation



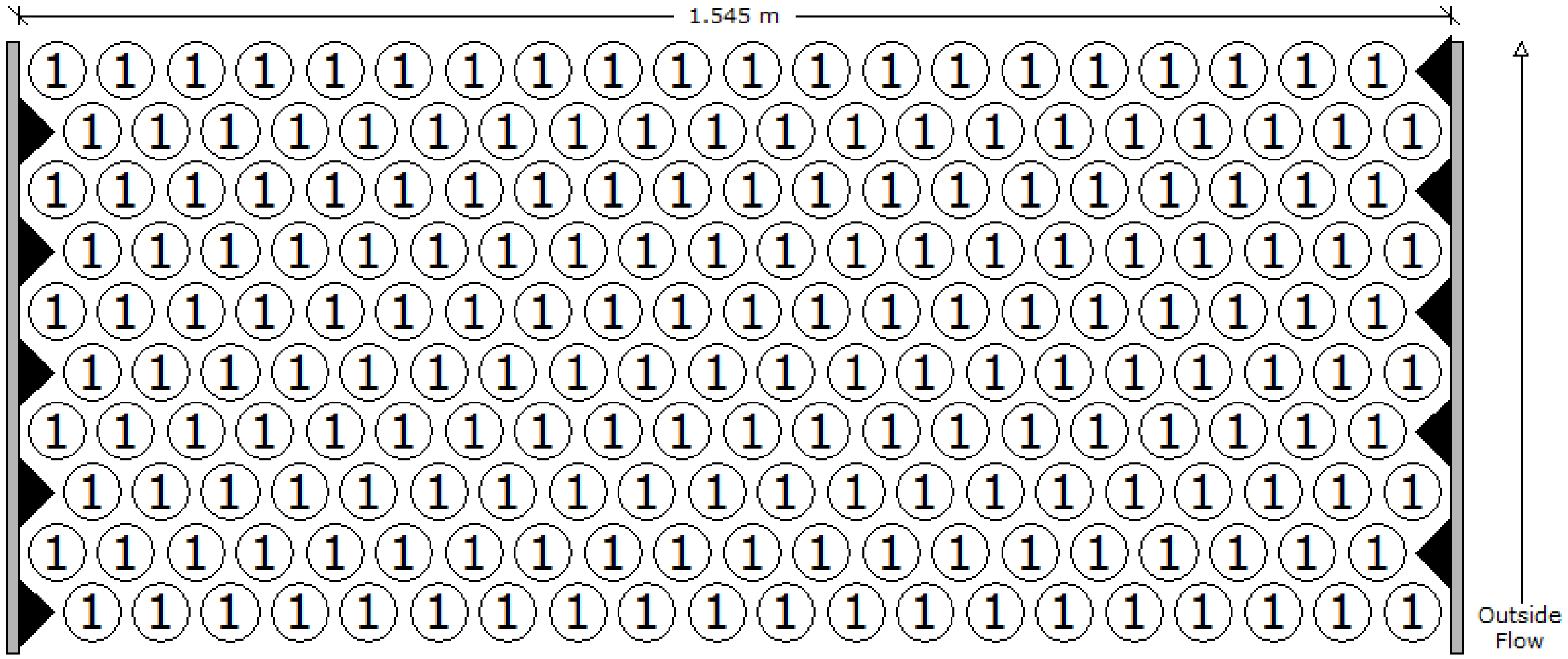
3D model generated from HTRI

2D View & tube layout

Bay Width	1.628 m	Single bundle weight	2520 kg
Bays in parallel	2	Total bundle weight	--
Bundle width	1.545 m	Structure weight	--
Bundles in parallel	1	Walkway ladder weight	--
Fan diameter	0.527 m	Dry weight	5040 kg
Fans per bay	1	Wet weight	5862 kg
Ground clearance	--		
Plenum height	0.515 m		
Tube length	0.35 m		



2D View



ID	Name	Type	Outer Diameter (mm)	Wall Thickness (mm)	Transverse Pitch (mm)	Longitudinal Pitch (mm)	Fin Height (mm)
T1	TubeType1	Plain	63.5000	1.0000	75.0001	64.9501	n/a

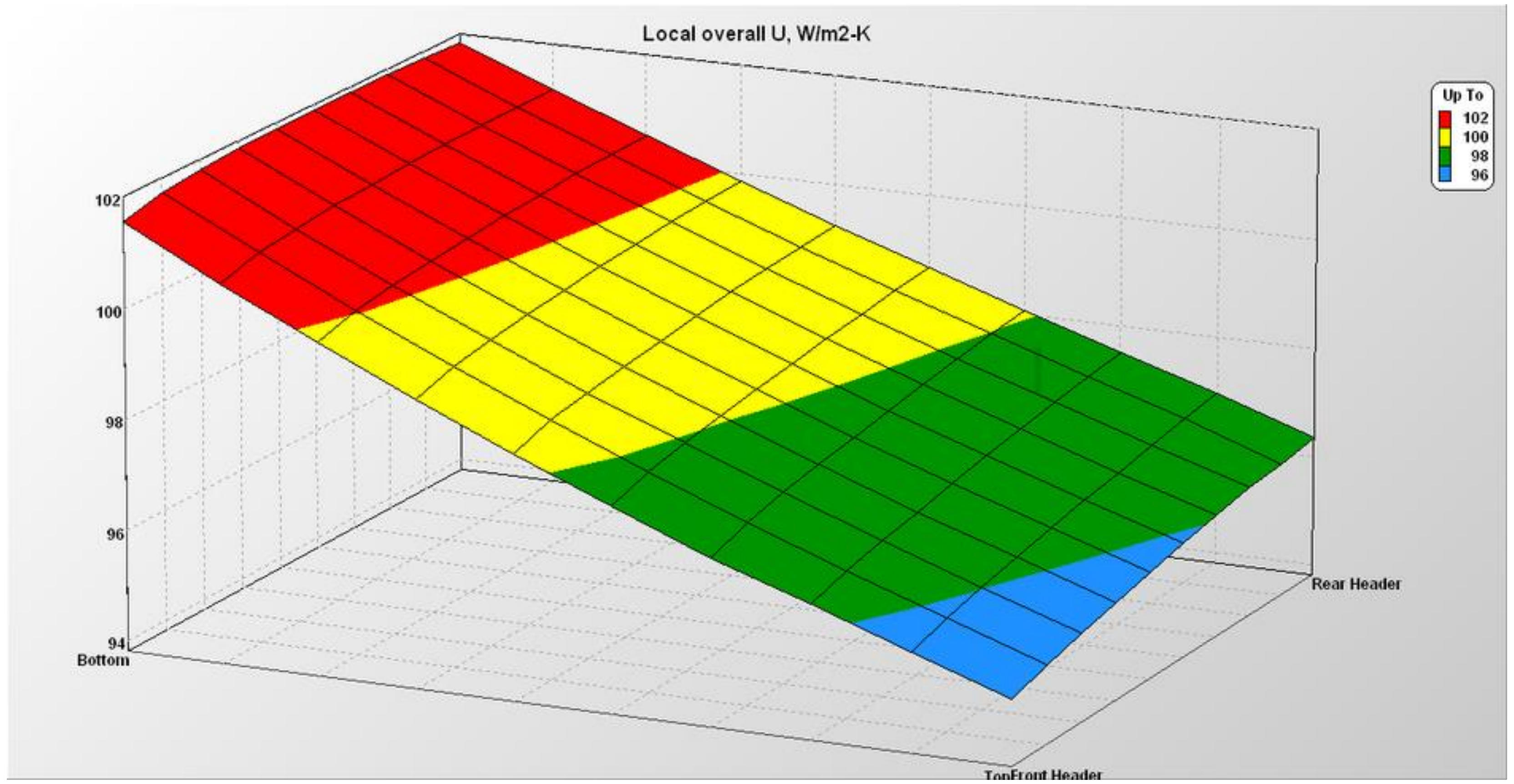
Row From Top	Number of Tubes	Tube Type Name	Wall Clearance (mm)	Row From Top	Number of Tubes	Tube Type Name	Wall Clearance (mm)
1	20	TubeType1	9.5250	6	20	TubeType1	47.0251
2	20	TubeType1	47.0251	7	20	TubeType1	9.5250
3	20	TubeType1	9.5250	8	20	TubeType1	47.0251
4	20	TubeType1	47.0251	9	20	TubeType1	9.5250
5	20	TubeType1	9.5250	10	20	TubeType1	47.0251

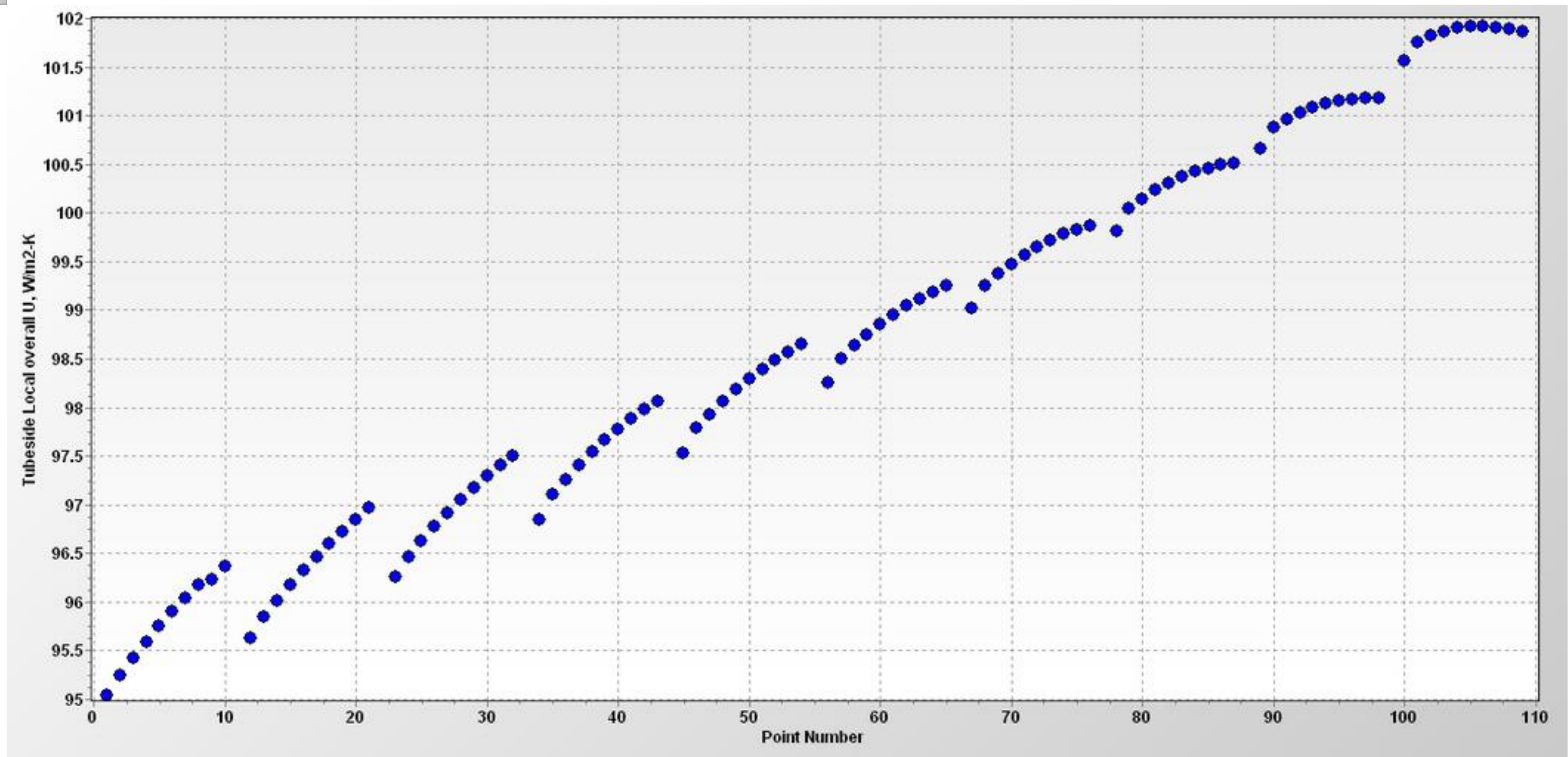
Bundle Information

Bundle width	1.545	m
Number of tube rows	10	
Number of tubes	200	
Minimum wall clearance		
Left	9.5250	mm
Right	9.5250	mm
Number of tubes per pass		
Tubepass # 1:	200	

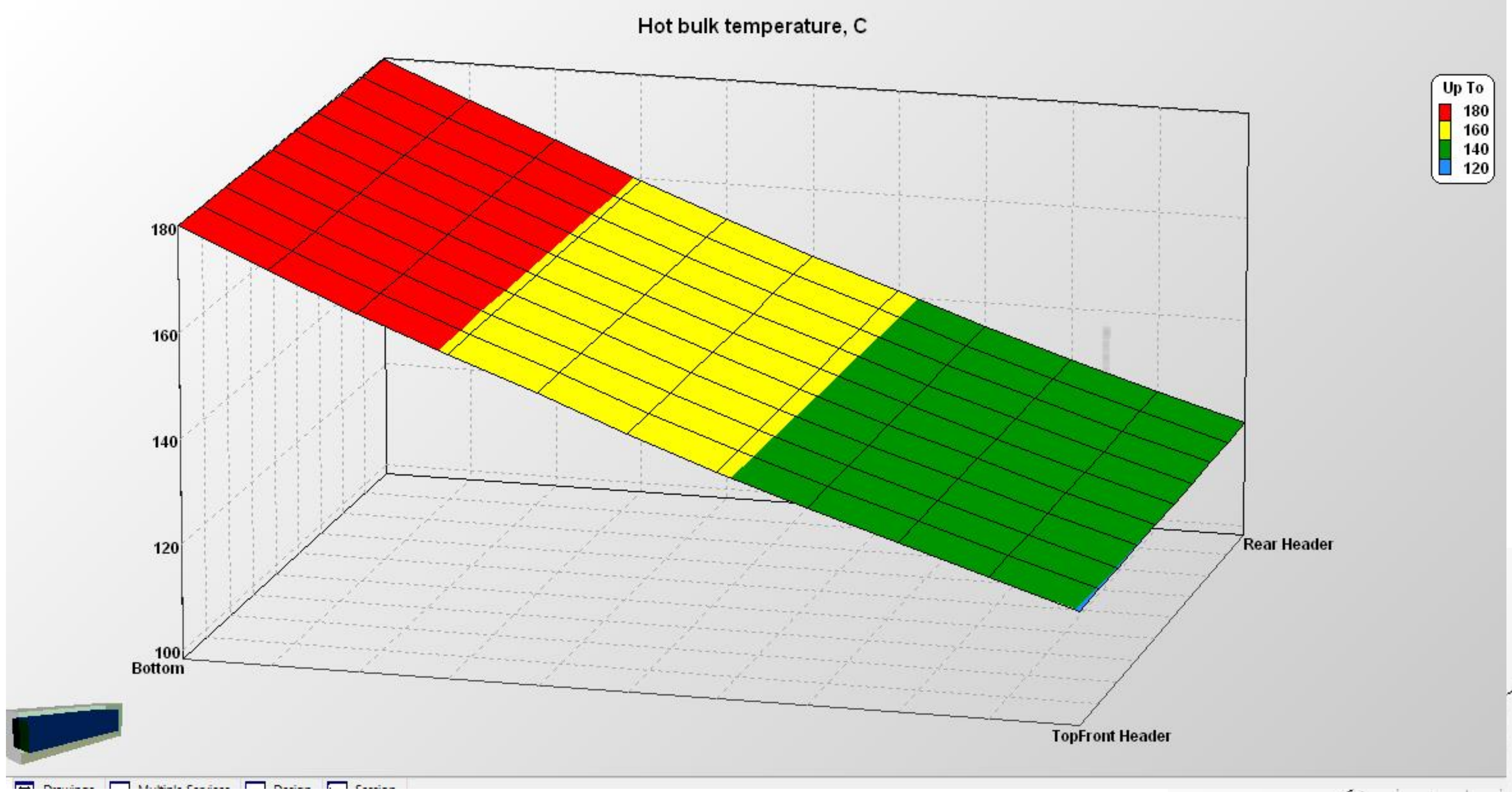
Tube layout

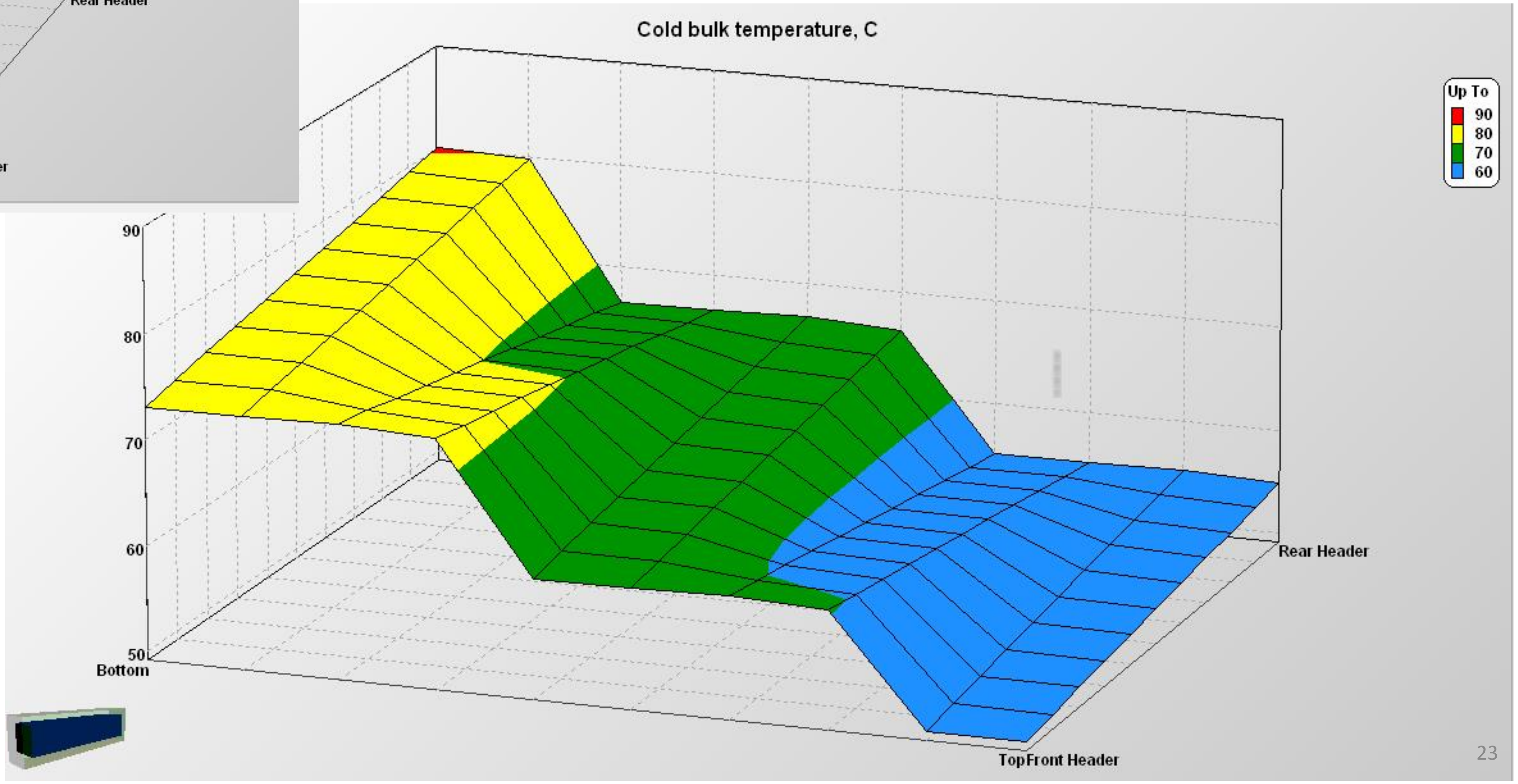
Local overall heat transfer co-efficient



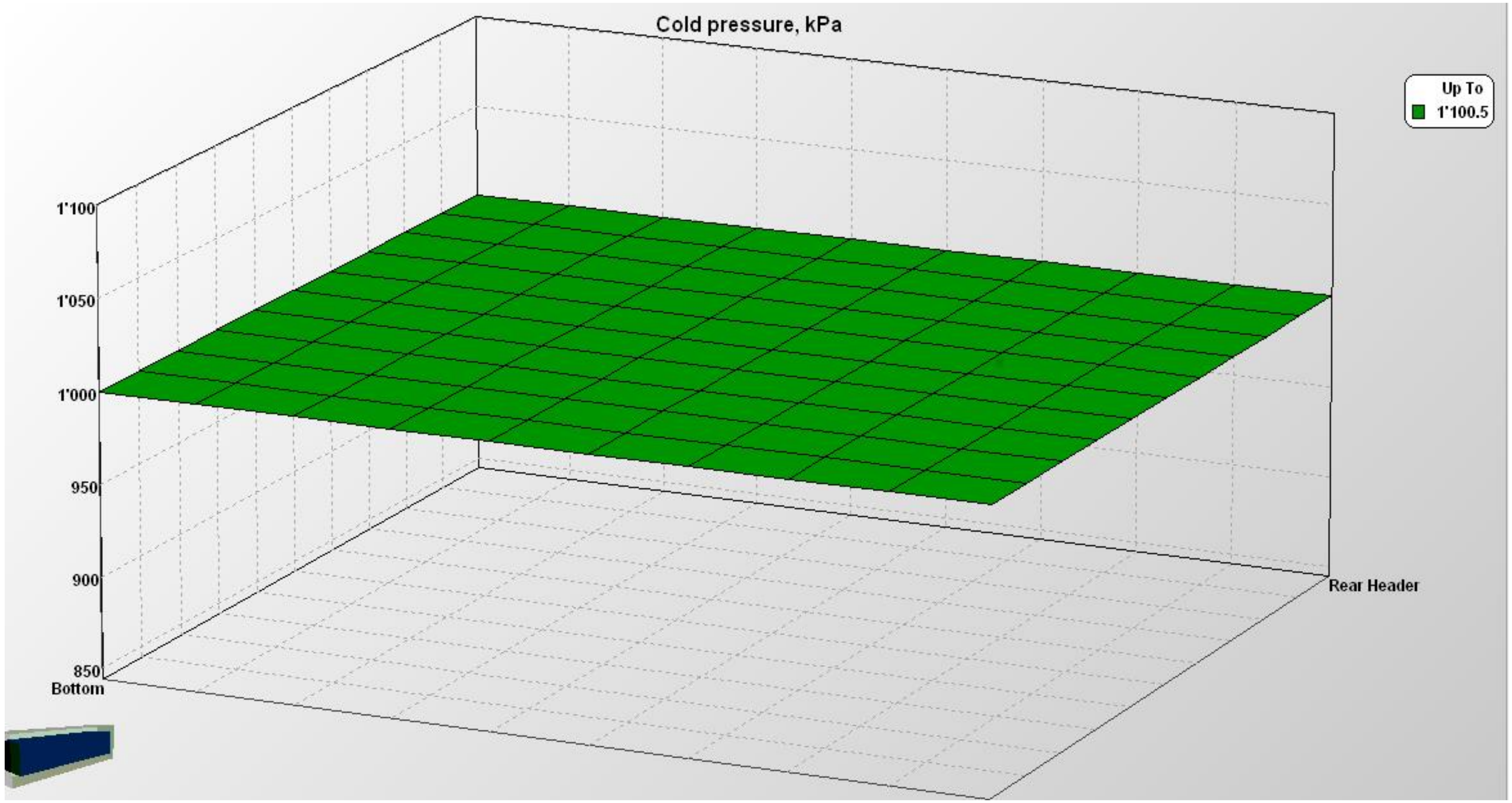


Temperature distribution





Pressure drop verification



From the mathematical model described previously, $tubeside\ pressure\ drop\ \Delta P = 1356\ Pa$

Economic Analysis

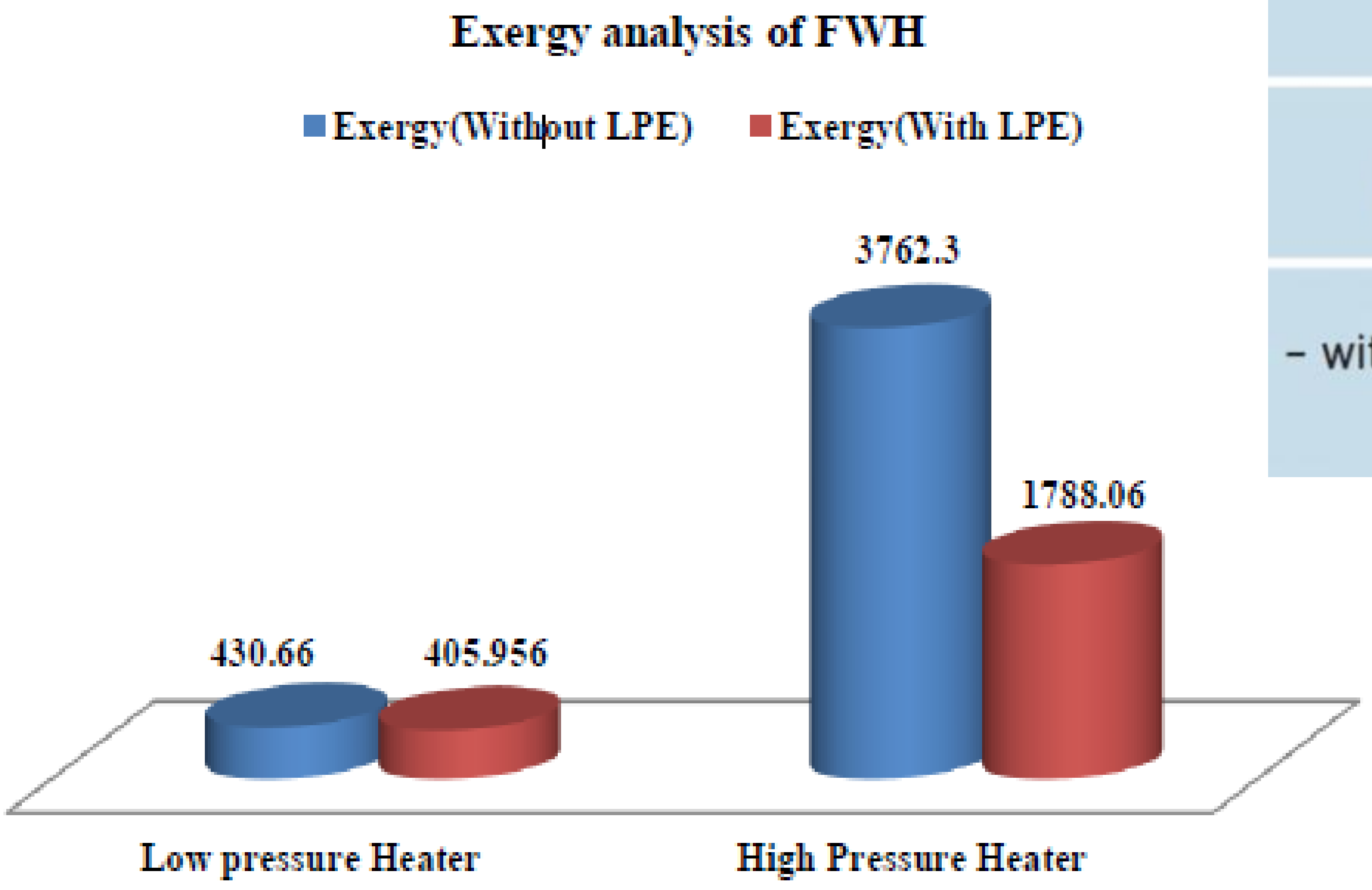
Key takeaways:

- Base Material : Stainless Steel
- Insulation Material : 1000MF Board Type III (Wool)
- Economic Thickness : Single Layer 25 mm
- Payback Period = 3.51 years
- Surface Temperature = 45˚ C

Future plans

1. Market study
2. COMPLETION OF THE WHOLE PROJECT
3. Market Launching
4. Expansion of the Project
5. FURTHER RESEARCH
6. Overall Efficiency improvement

Data Analysis



System	Combustion Efficiency @ 4% Excess O^2 (%)	Stack Gas Temperature °F
Boiler	78 to 83%	350 to 550°
– with Feedwater (FW) Economizer	84 to 86%	250 to 300°
– with FW and Condensing Economizer	92 to 95%	75 to 150°

BOILER EFFICIENCY OF CONDENSING ECONOMIZER

EXERGY ANALYSIS OF FEED WATER HEATER

REFERENCES

- *Campbell Survey*
- *Design & Analysis of Low-Pressure Economizer Based Waste-Heat Recovery System for Coal- Fired Thermal Power Plant 1*
- *Textbook - Heat Transfer : A Practical Approach 5th edition Edition by Yunus A. Cengel.*
- *Theory lectures of ME 307 course by Professor Dr. Md. Zahurul Haq, Dept. of Mechanical Engineering, BUET.*
- *Theory lectures of ME 307 course by Professor Dr. Md. Nasim Hasan, Dept. of Mechanical Engineering, BUET.*