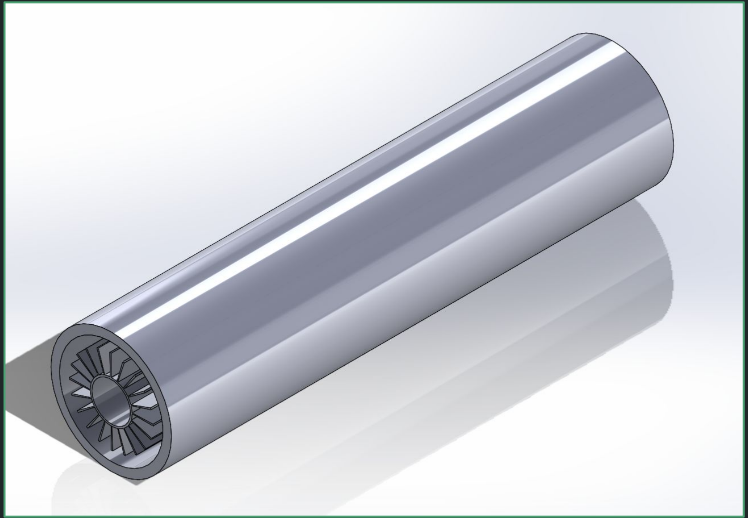
Parallel Flow Heat Exchanger

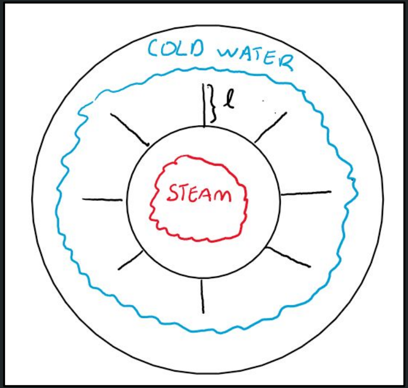
Faraz Iqbal, Ashrafur Rahman, Ted Yee

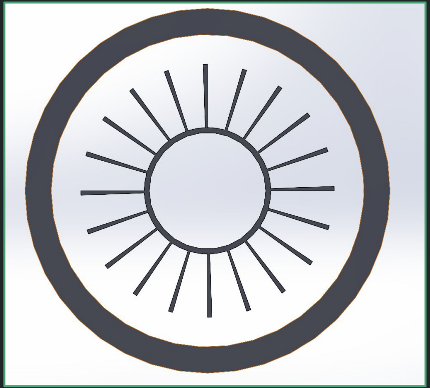
Current system

<u>Problem Definition</u>: Model the heat transfer from steam to cold water in a concentric pipe heat exchanger

- Concentric pipes
  - Inner pipe w/ fins
  - Adiabatic outer pipe
- Two fluids
  - Hot steam
  - Cold water

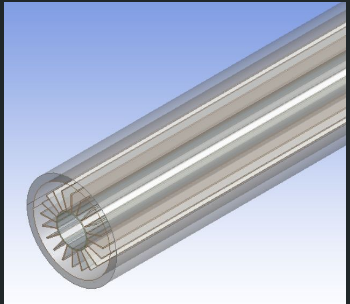


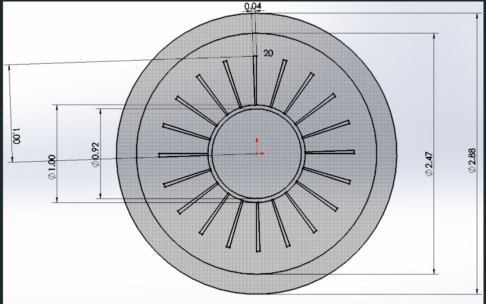




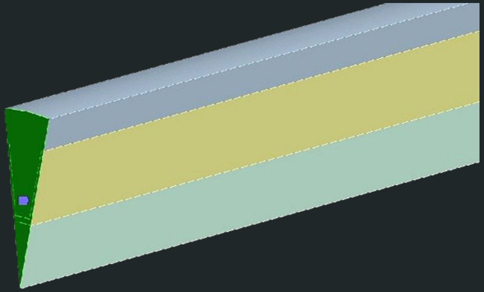
Modeled Elements - Full Revolution and Wedge

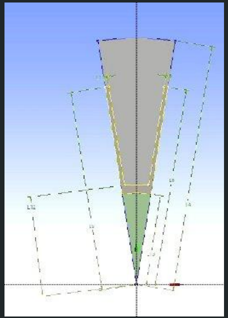
- Full Revolution
  - <u>Geometry</u>:
    - SolidWorks
    - 4 Bodies - Outer/Inner Pipe, Hot/Cold Fluid
  - <u>Variable</u>:
    - Flow Rate - cold water





- Wedge - Space between fins
  - <u>Geometry</u>:
    - Ansys DesignModeler
    - 3 Bodies - Inner Pipe, Hot/Cold Fluid
  - <u>Variable</u>:
    - Geometry - angle of fin / number of fins



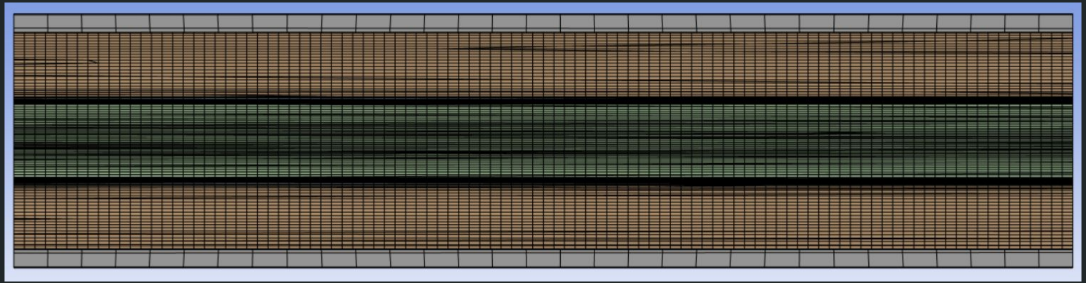


Mesh Convergence Study - Full Revolution: Sweep

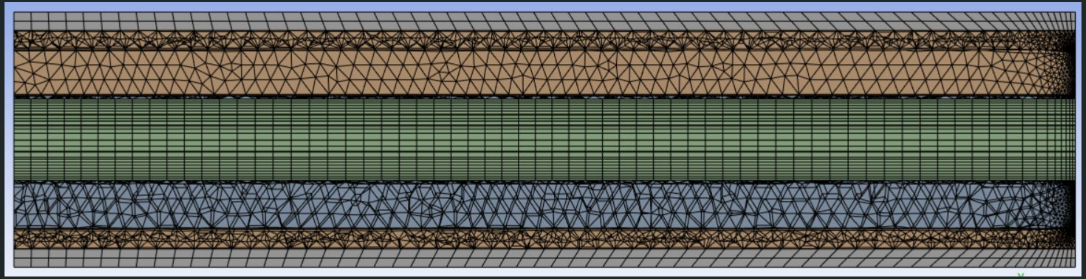
Sweep Settings:

- Inner pipe, hot and cold fluid bodies
- 100 divisions of constant size across length of pipe

Mesh with Sweep:



Mesh without Sweep:

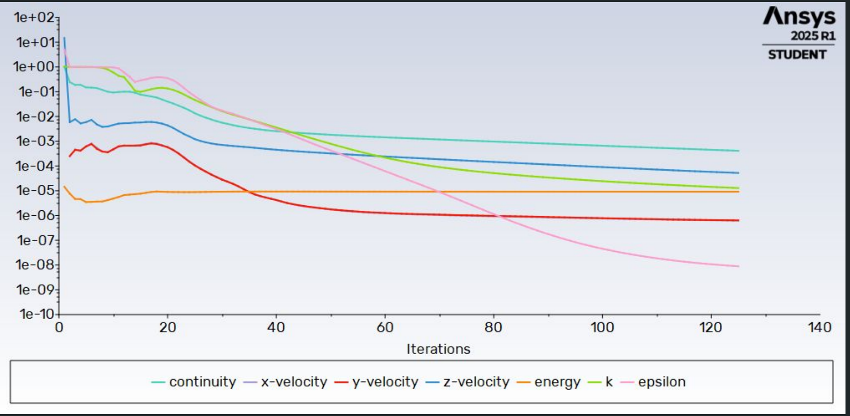


Sweep Settings:

- N/A

Mesh Convergence Study - Full Revolution: Residual Plot

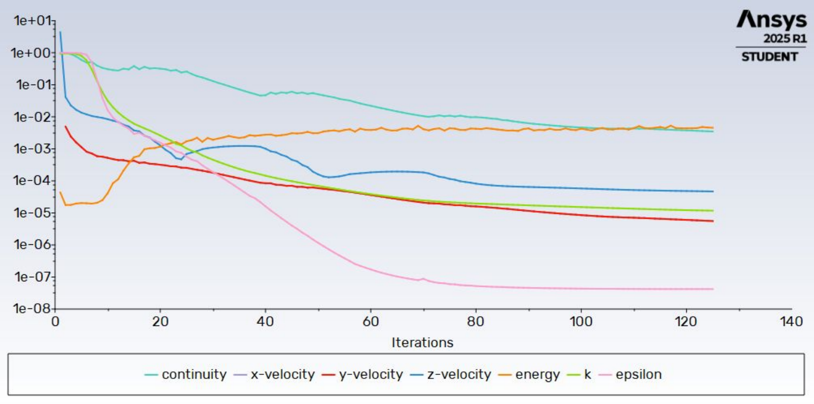
Mesh with Sweep:



Results:

- Better continuity and turbulence
- Energy residual is smoother
- Energy residual decreasing at end of iteration
- Negative slopes throughout

Mesh without Sweep:

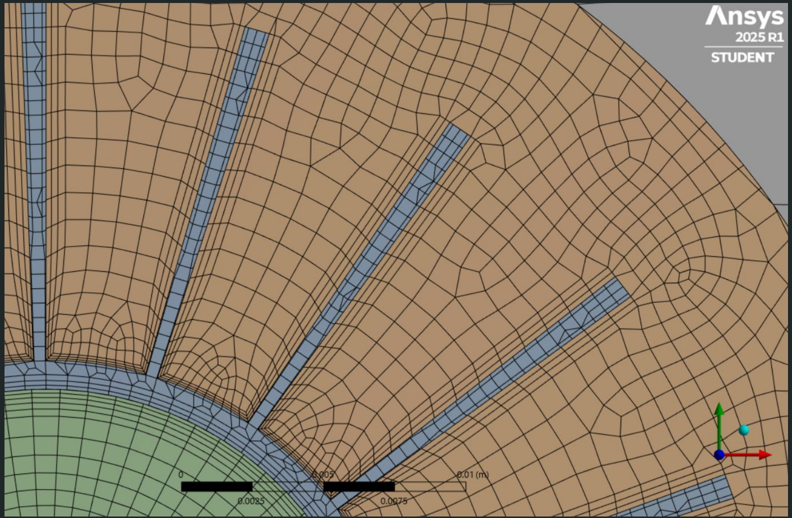


Results:

- Energy residual rising over iterations
- Energy residual oscillations
- Early fluctuations in the z velocity residuals
- Still rising energy residual values at end of iteration

Mesh Convergence Study - Full Revolution: Inflation

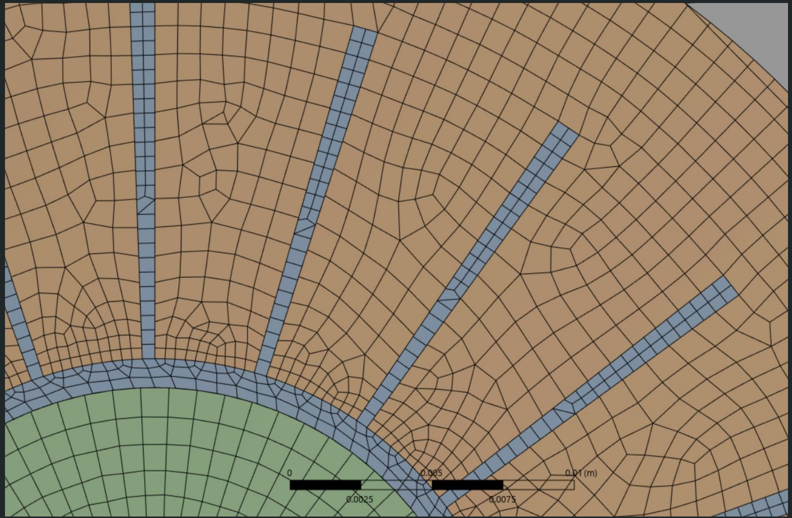
Mesh with Inflation:



Inflation Settings:

- 3 layers around fins and base of inner pipe
- 1 layer on inside of each fin
- 5 layers on steam face
- 3 layers on inner surface of inner pipe

Mesh without Inflation:

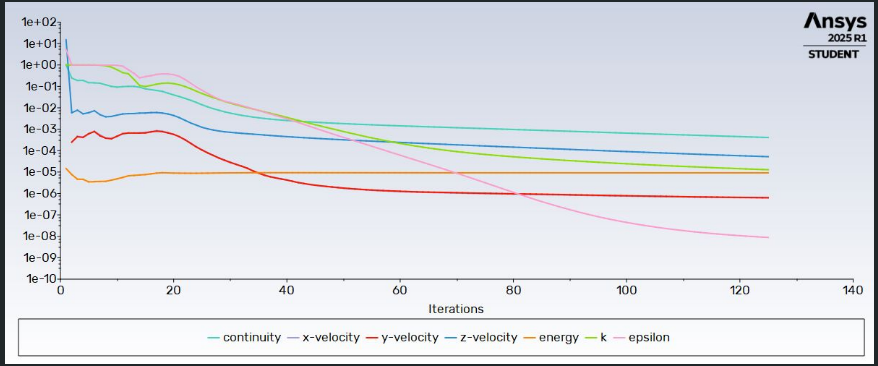


Inflation Settings:

- N/A

Mesh Convergence Study - Full Revolution: Residual Plot

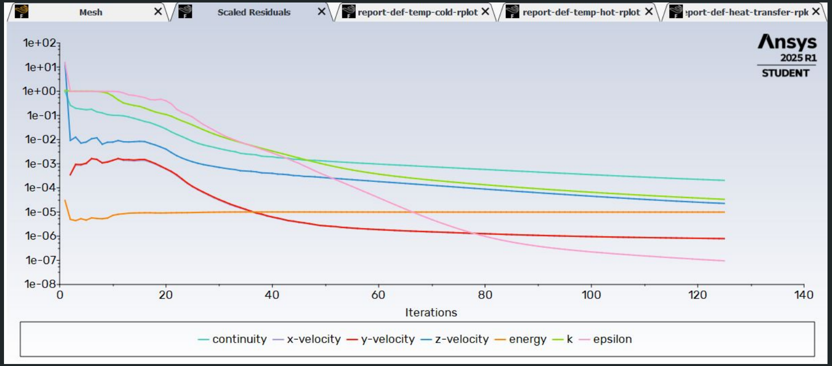
Mesh with Inflation:



Results:

- Better continuity and turbulence
- Energy residual is smooth

Mesh without Inflation:

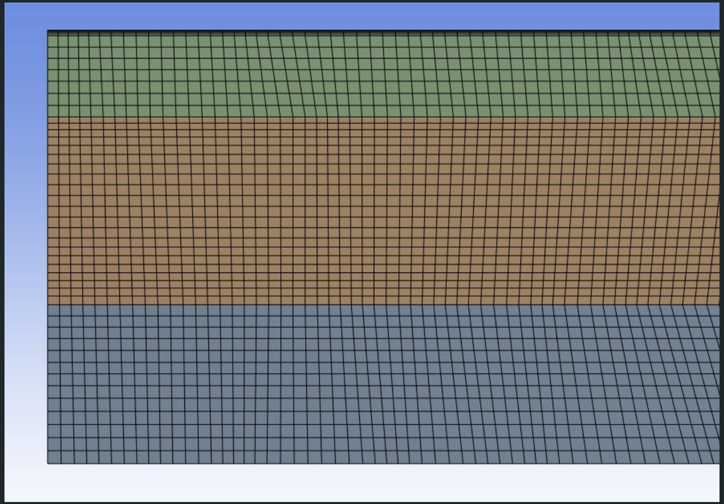


Results:

- Ends at higher residual magnitudes
- Energy residual curve is rough towards beginning

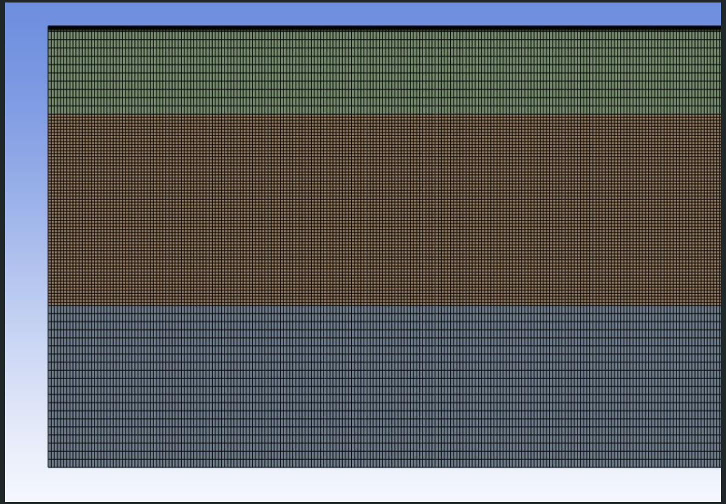
Mesh Convergence Study - Wedge: Mesh (Body Sizing)

Standard Mesh (Default Growth):



Body Sizing Settings
- Element Size: **Default (1.5328e-2)**
- Growth Rate: **Default (1.2)**

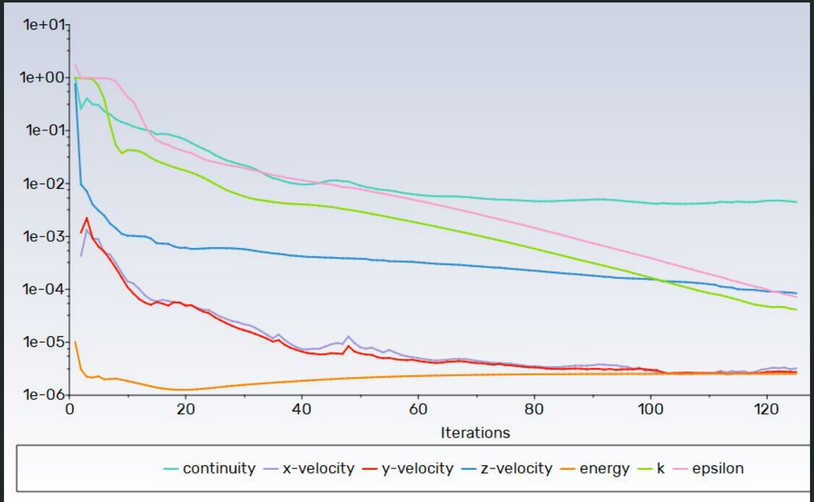
Uniform Mesh Size:



Body Sizing Settings
- Element Size: **1e-3**
- Growth Rate: **1.0**

Mesh Convergence Study - Wedge: Residual Plot (Body Sizing)

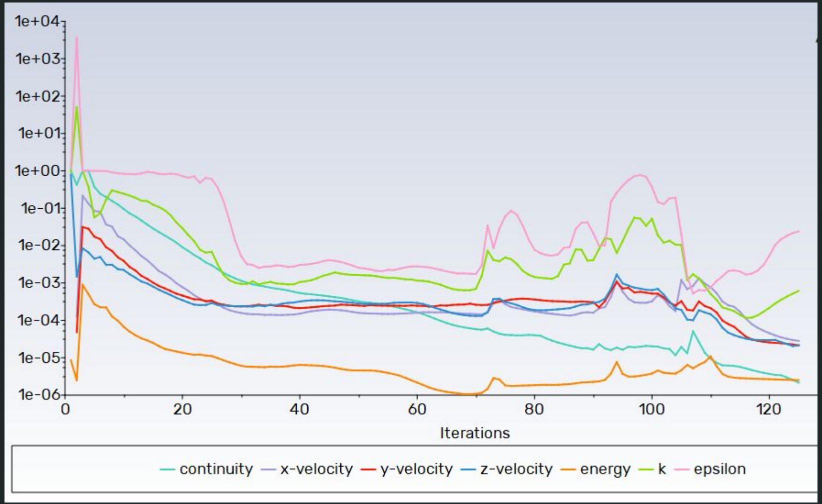
Standard Mesh (Default Growth):



Results:

- Most residuals decrease
- Energy residual slightly increases

Uniform Mesh Size:

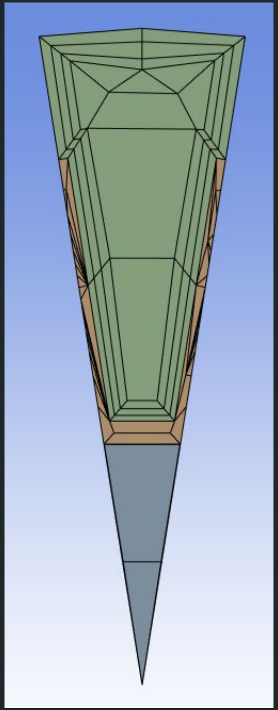


Results:

- Same range of values
- Fluctuations in energy and turbulence

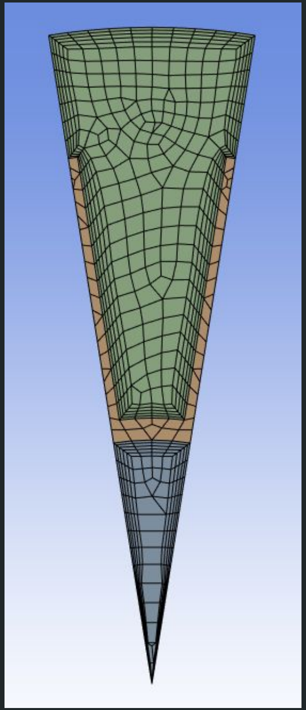
Mesh Convergence Study - Wedge: Mesh (Face Sizing)

Standard Mesh (Less Inflation):



Face Sizing
- Maximum Layers: **3**
- Element Size: **0.01**

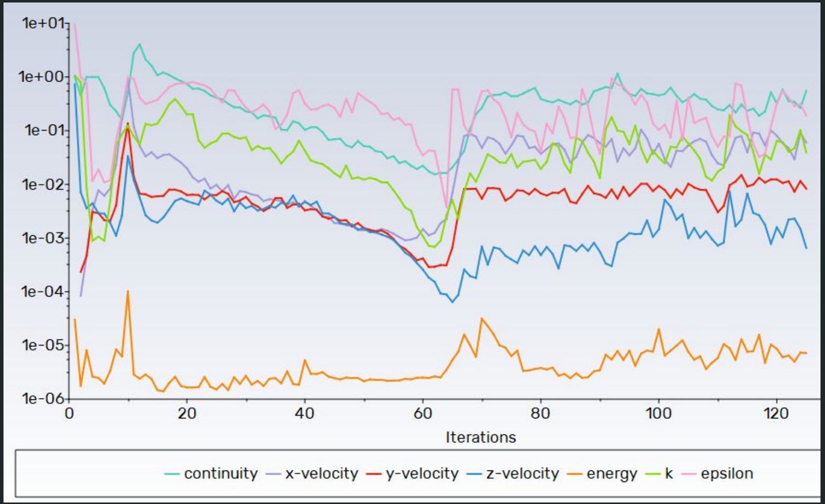
Mesh with Increased Inflation:



Face Sizing
- Maximum Layers: **5**
- Element Size: **0.001**

Mesh Convergence Study - Wedge: Residual Plot (Face Sizing)

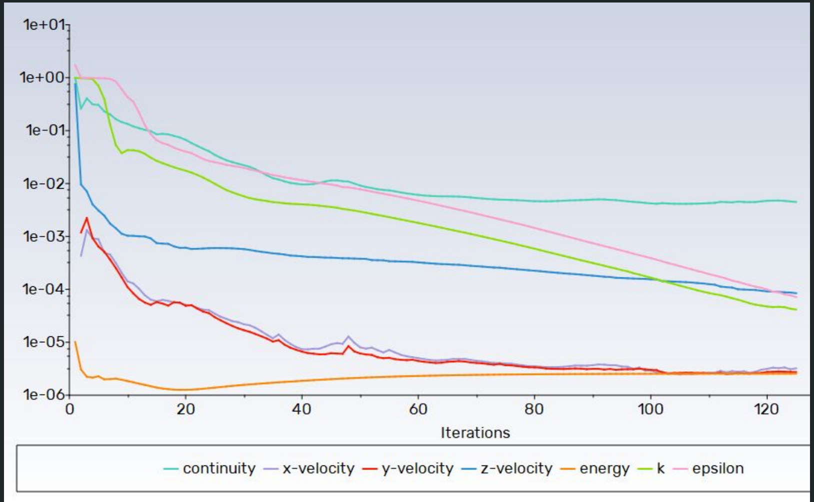
Standard Mesh (Less Inflation):



Results:

- High fluctuations in residuals
- No noticeable decrease

Mesh with Increased Inflation:



Results:

- Same range of values, but smooth residuals and decrease

Final Mesh Settings - Both Simulations

➢ Full Revolution

Inflation Settings:
- 3 layers around fins and base of inner pipe
- 1 layer on inside of each fin
- 5 layers on steam face
- 3 layers on inner surface of inner pipe

Edge Sizing
- Divisions along edges of fins, base, and interfaces between fluids and pipes

Sweep
- 100 divisions across pipe axis (both fluids + inner pipe)

➢ Wedge

Body Sizing
- Element Size: Default (1.5328e-2)
- Growth Rate: Default (1.2)

Face Sizing
- Maximum Layers: 5
- Element Size: 0.001

Model setup - Both Simulations

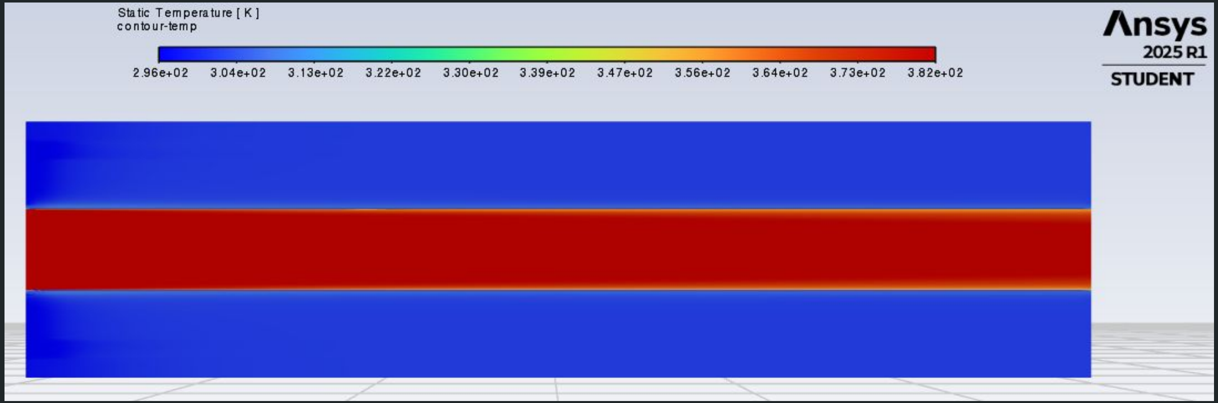
Boundary Conditions

- Heat flux = 0 across outer pipe (adiabatic wall condition)
- Inlet
  - Steam = 5 psi (pressure inlet type)
  - Cold water = 1.324 kg/s (mass flow inlet type)

Model

- Turbulent (k-epsilon)
- Steady state

Results - Full Revolution Configuration



Simulation over 1 foot → 303.175 K to 303.320 K

Difference of 0.145 K

Inlet: 295.87 K + (0.145 * 41) = **301.82 K final temperature of outlet of cold water** (linear extrapolation)

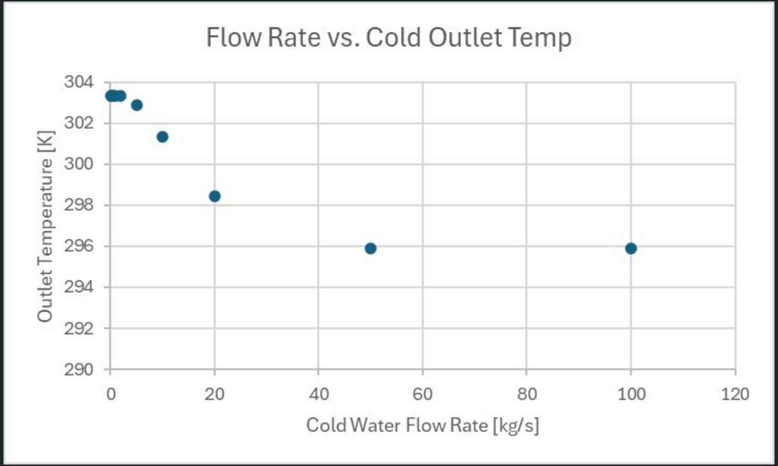
Lab data = 310.483 K final temperature of outlet of cold water

Results - Full Revolution Configuration Parameter Sweep

Swept Cold Water Flow Rate

1. Flow Rate vs. Cold Outlet Temp
2. Flow Rate vs. Hot Outlet Temp
3. Flow Rate vs. Heat Transfer Rate

1.



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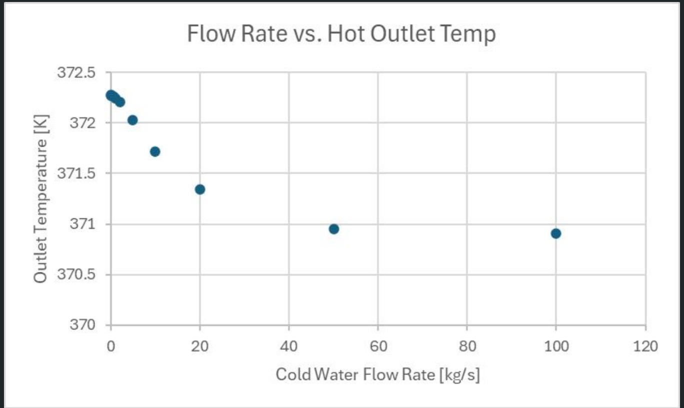
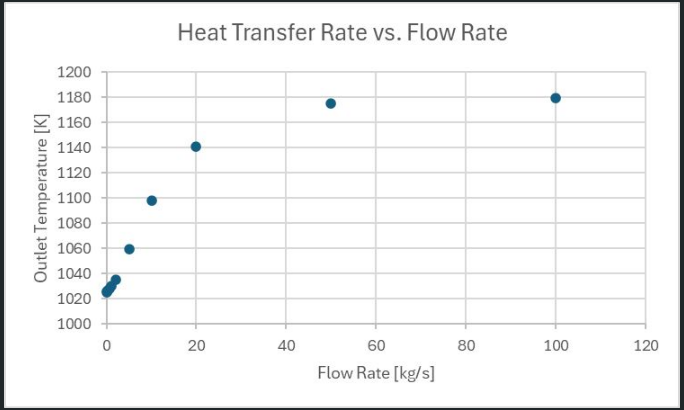
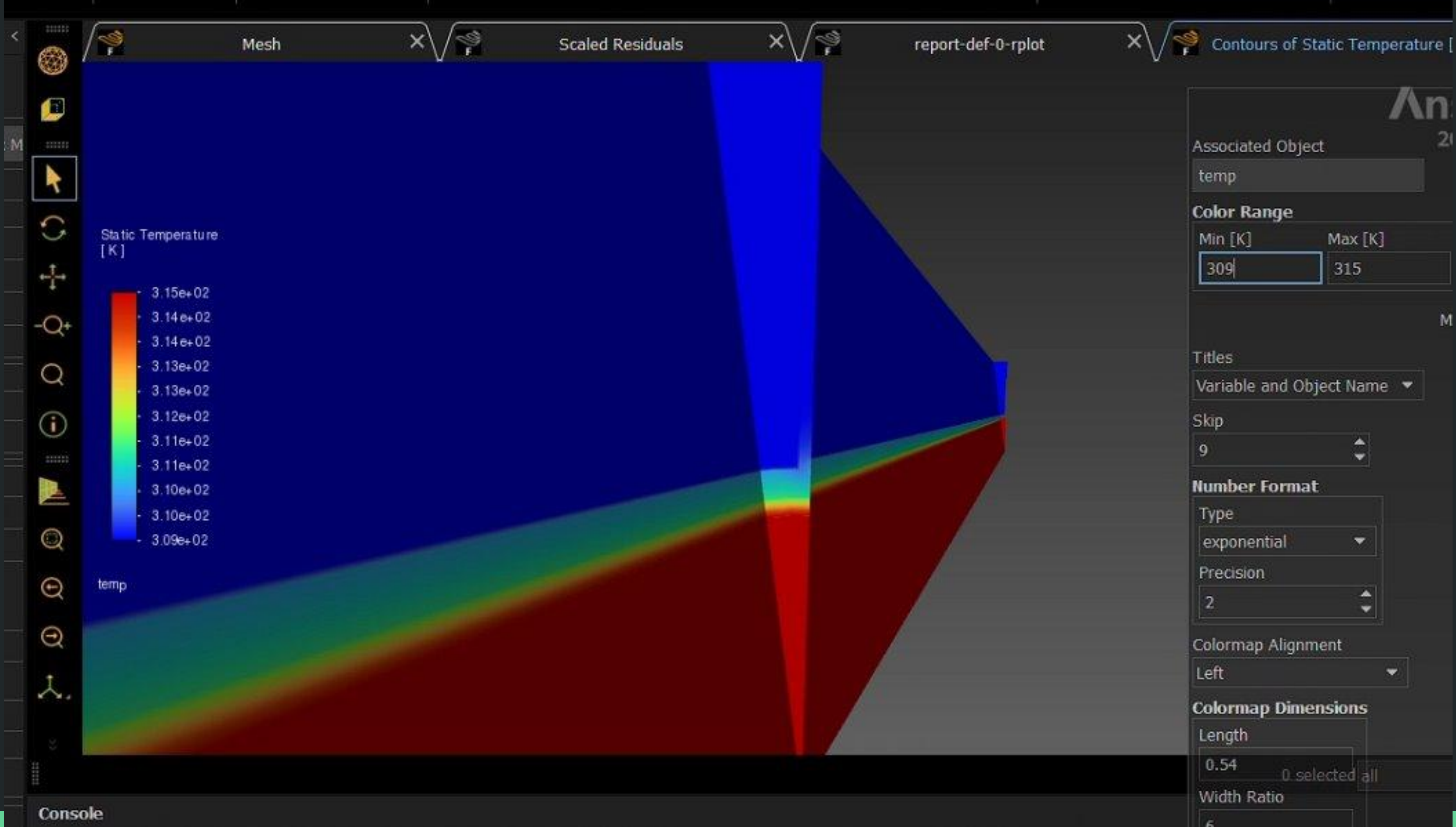


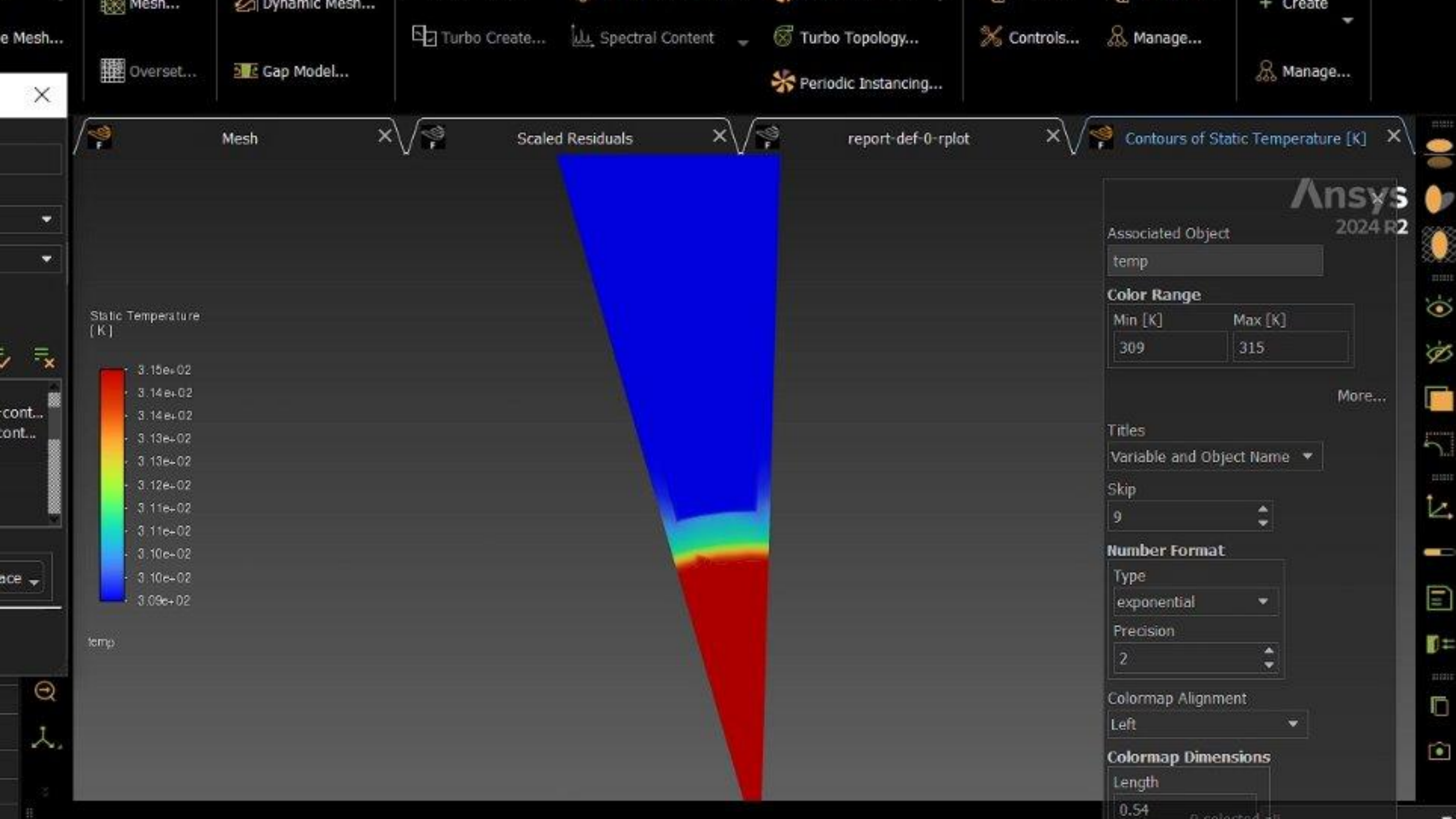
3.



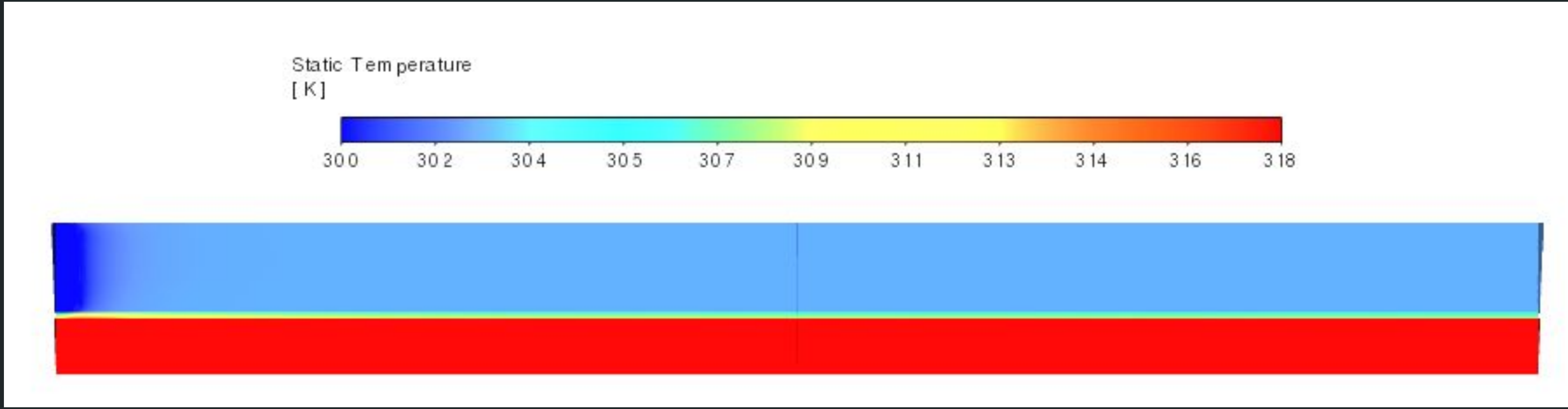
Results - Wedge Configuration

Number of Fins	Angle	Outlet Temp
40	9	300.03
20	18	301.07
8	22.5	300.43
4	45	300.36
3	60	301.21


Mesh
Scaled Residuals
report-def-0-rplot
Contours of Static Temperature
Static Temperature
[K]
3.15e+02
3.14e+02
3.14e+02
3.13e+02
3.13e+02
3.12e+02
3.11e+02
3.11e+02
3.10e+02
3.10e+02
3.09e+02
temp
Associated Object
temp
Color Range
Min [K]
309
Max [K]
315
Titles
Variable and Object Name
Skip
9
Number Format
Type
exponential
Precision
2
Colormap Alignment
Left
Colormap Dimensions
Length
0.54
0 selected
all
Width Ratio
Console

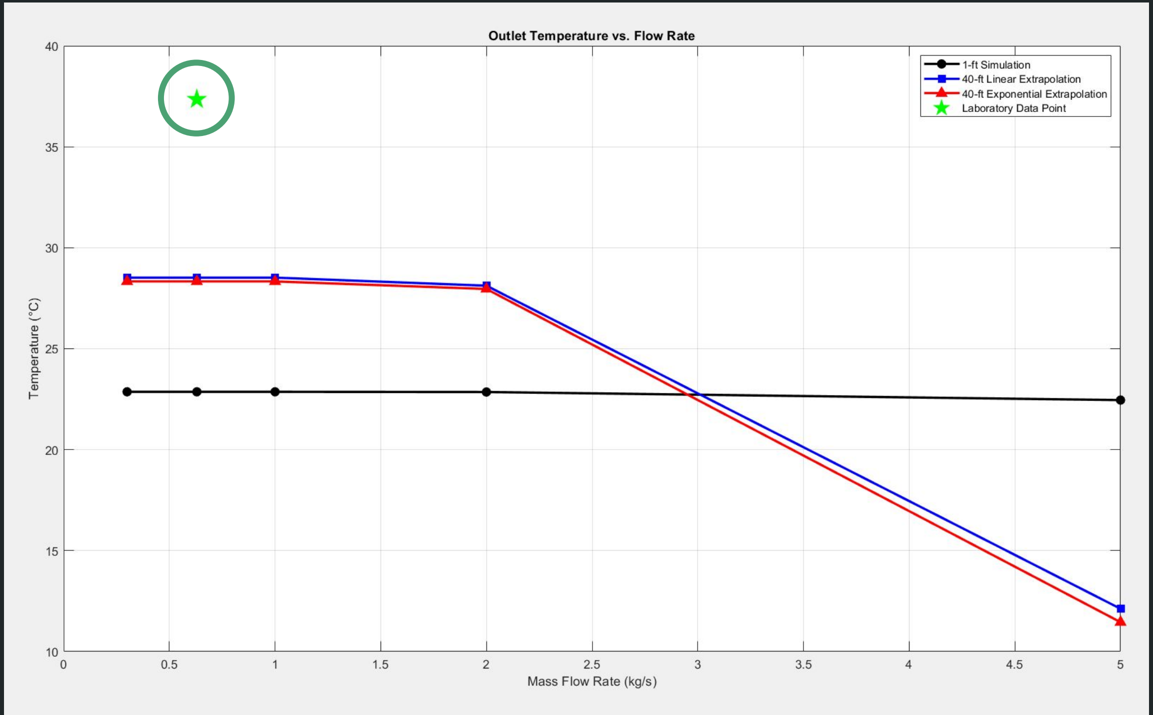

Turbo Create...
Spectral Content
Turbo Topology...
Periodic Instancing...
Controls...
Manage...
Overset...
Gap Model...
Mesh
Scaled Residuals
report-def-0-rplot
Contours of Static Temperature [K]
Ansys
2024 R2
Static Temperature
[K]
3.15e+02
3.14e+02
3.14e+02
3.13e+02
3.13e+02
3.12e+02
3.11e+02
3.11e+02
3.10e+02
3.10e+02
3.09e+02
temp
Associated Object
temp
Color Range
Min [K]
309
Max [K]
315
More...
Titles
Variable and Object Name
Skip
9
Number Format
Type
exponential
Precision
2
Colormap Alignment
Left
Colormap Dimensions
Length
0.54

Results - Wedge Configuration



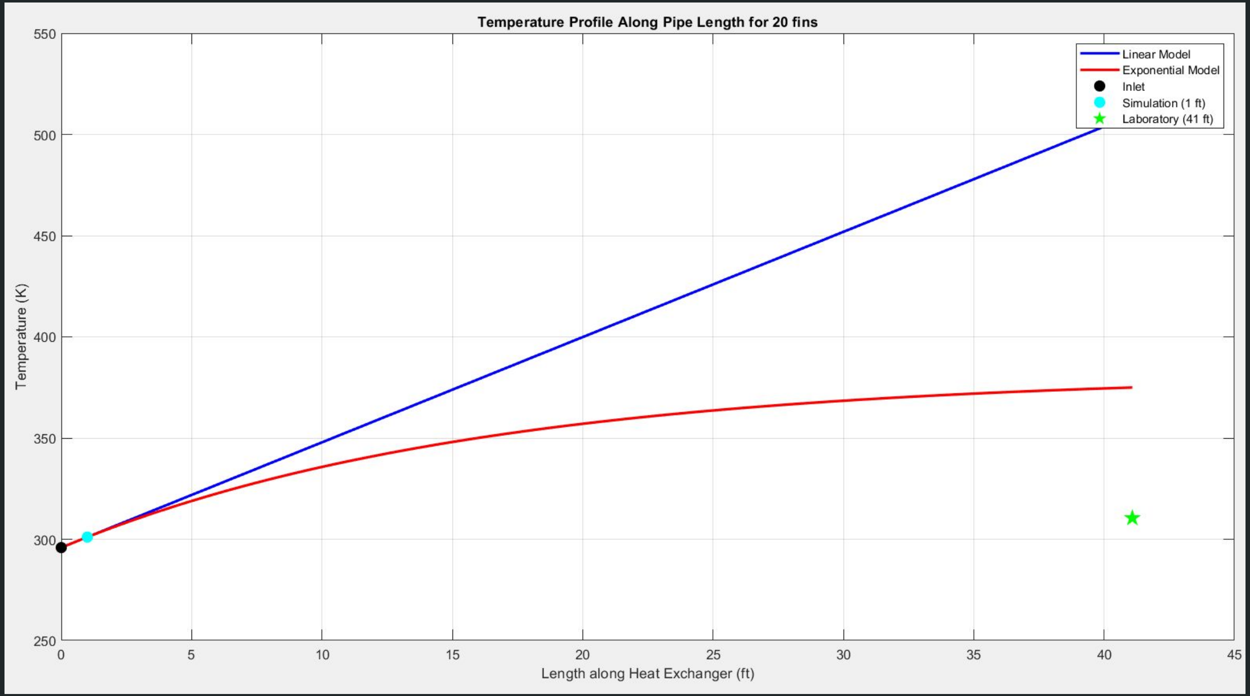
Ansys Simulation vs. Lab Data - Full Revolution

Extrapolating the 1 foot simulation data to match the 40 feet set up in the ChemE lab



Ansys Simulation vs. Lab Data

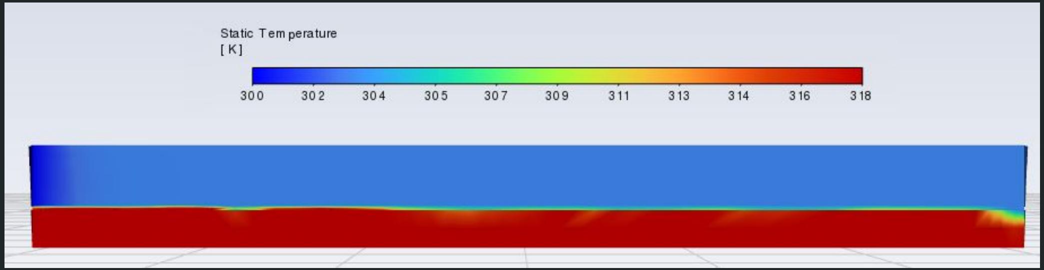
Extrapolating the 1 foot simulation data to match the 40 feet set up in the ChemE lab



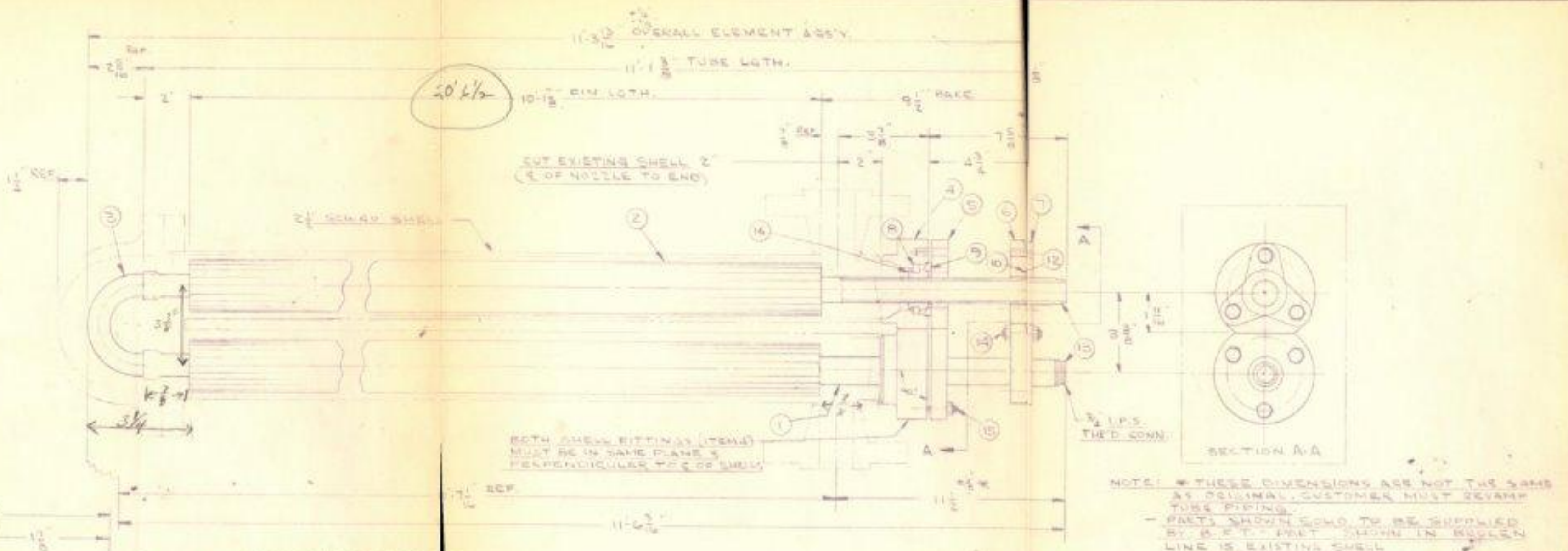
End

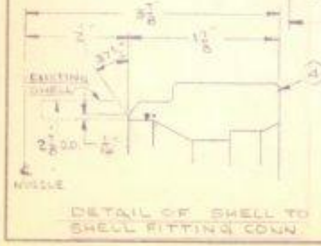
Mesh Contours - Wedge

Standard Mesh (Less Inflation):



Uniform Mesh Size:





CONVERSION PROCEDURE

1. DISASSEMBLE EXISTING UNIT & REMOVE ELEMENT.
2. CUT EXISTING SHELL AS SHOWN (WELD B.F.T. SHELL FITTING (ITEM 4) TO SHELL.
3. INSERT B.F.T. ELEMENT INTO EXISTING SHELL UNTIL FINTUBE FITTING (ITEM 16) EXTEN[DS] BEYOND FACE OF ITEM 4.
4. PLACE SPLIT RING (ITEM 8) IN GROOVE AS SHOWN & RETRACT ELEMENT UNTIL SPLIT RING S[EATS].
5. PLACE ITEM 9 IN POSITION AS SHOWN, FOLLOWED BY ITEM 5 & BOLT SHELLSIDE CLOSU[RE].
6. SLIDE ITEM 6 OVER FINTUBE END, POSITION SPLIT RING (ITEM 10) AS SHOWN & RETRACT ITEM 6 UNTIL SPLIT RING SEATS.
7. ASSEMBLE FINTUBE STUB END (ITEM 13) WITH GASKET (ITEM 12) & FLANGE (ITEM 7) AS SHOWN.
8. BOLT TUBESIDE CLOSURE.

NOTE: * THESE DIMENSIONS ARE NOT THE SAME AS ORIGINAL, CUSTOMER MUST REVAMP TUBE PIPING.
— PARTS SHOWN SOLID TO BE SUPPLIED BY B.F.T. - PART SHOWN IN BROKEN LINE IS EXISTING SHELL

USED ON S.O.	USED ON S.O.	USED ON S.O.
1951-1F		

LETTER	REVISION	BY	DATE

DRAWN BY		CHECKED BY		SCALE
H.S.	17-1-68	D.A.F.	17-1-68	1" = 1'-0"

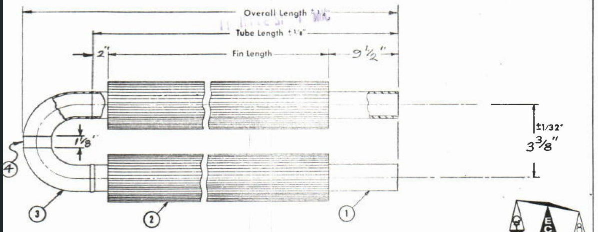
CONFIDENTIAL
PROPERTY OF
BROWN FINTUBE CO. ELYRIA, OHIO

CONVERSION PROCEDURE FROM GE TYPE AAA 12A TO BFT 80-10A18-310

DRAWING NUMBER C 24135

CONFIDENTIAL
PROPERTY OF
BROWN FINTUBE COMPANY

FINTUBE ASSEMBLY



ITEM	DESCRIPTION	PCS. PER SECT.	FINISHED PART DWG. No.	FINISHED PART REV.	ASSEMBLY DWG. No.	ASSEMBLY REV.	TOTAL PC'S.	MATERIAL CODE
1	TUBE - 1" O.D. x .083" MIN. WL. x 21'-8" (21'-6") LG.	2	SEE NOTE				4	439
2	FIN CHANN. 1/2" x .035" x 20'-6 1/2" LG. USE	20	SEE NOTE				40	401
3	RET. BEND 3/4" STD. WT. - 90° L.R.	2					4	493
4	3/4" SCH. 40 PIPE x 1 1/8" LG.	1					2	439
5								
6								
7								
8	NOTE: ITEM 1 - BEVEL 2" BARE END - OTHER END 9 1/2"							
9	BARE, SQ. CUT.							
10								
11	ITEM 2 - 20 FINS / TUBE - 822 FT. STRIP - 112#							
12								
13								
14	DOMESTIC CRATING.							

FIN LENGTH	TUBE LENGTH	OVERALL LGTH.	CUTTING LGTH.	ITEM No.	No. SECT.	SERIAL No.
20'-6 1/2"	21'-8"	21'-7 5/8"	21'-6"	1	2	—

MATERIAL CODE

000 CARBON STEEL, WELDABLE	055 SA-179 SML'S. MIN. WALL	124 YELLOW BRASS B-36 NO. 6
001 STEEL, C-1018, C-1015	060 SA-210A1 SML'S. MIN. WALL CD	180 ADMIRALTY SB-111-B, C OR D
002 STEEL, C-1015, C-1025	078 SA-214 R.W. MIN. WALL	268 SA-193-B7 & SA-194-2-H
005 SA-308 GR. 60 BAR STOCK	082 SA-105-II, 0.30% MAX. CARB.	401 SA-240-304
007 A-7 PLATE	083 SA-105-I, 0.35% MAX. CARB.	700 GARLOCK #7221
008 SA-306 GR. 70 BAR STOCK	084 SA-105-II, 0.35% MAX. CARB.	711 SOFT ST'L. DB'L. JKT'D. ASB.
012 SA-515 GR. 60 FIREBOX C-SI.	087 SA-181-I, 0.35% MAX. CARB.	720 SPR'L. NO. 304SS W/ASB. FILL
014 SA-515 GR. 70 FIREBOX C-SI.	092 A-234-WPB	727 SPR'L. NO. 304SS W/ASB. FILL CO
028 SA-285-C FIREBOX	095 SA-216-WCB.	750 SOLID ARMCO IRON
048 SA-53-B SML'S. AVG. WALL	122 NAVAL BRASS SB171 PLATE	752 SOLID COPPER, ANNEALED
053 SA-106-B SML'S. AVG. WALL	123 NAVAL BRASS B124 NO. 3	900 A-47 MALL. IRON

439 = SA-249-
TP 304 RES'S. W. MIN. WL
493 = SA-403-
WP-304

CUSTOMER NORTHEASTERN UNIV
P.O.# 32382-7MU
S.O.No. 757-971
SECT. REQ'D. 2
PRELIM.
FINAL 5-24-71

REMARKS: REFER S.O. 1552-1F & DWG. C-24135

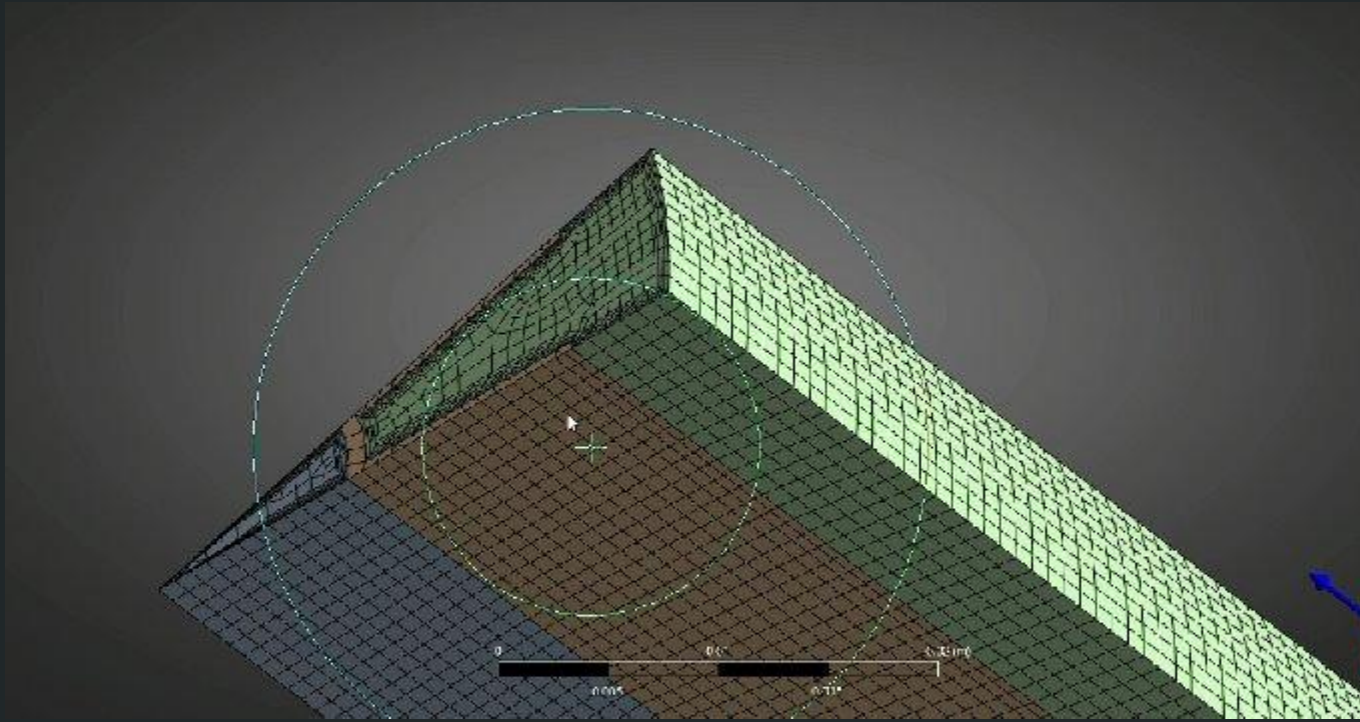
TEST 750 PSI

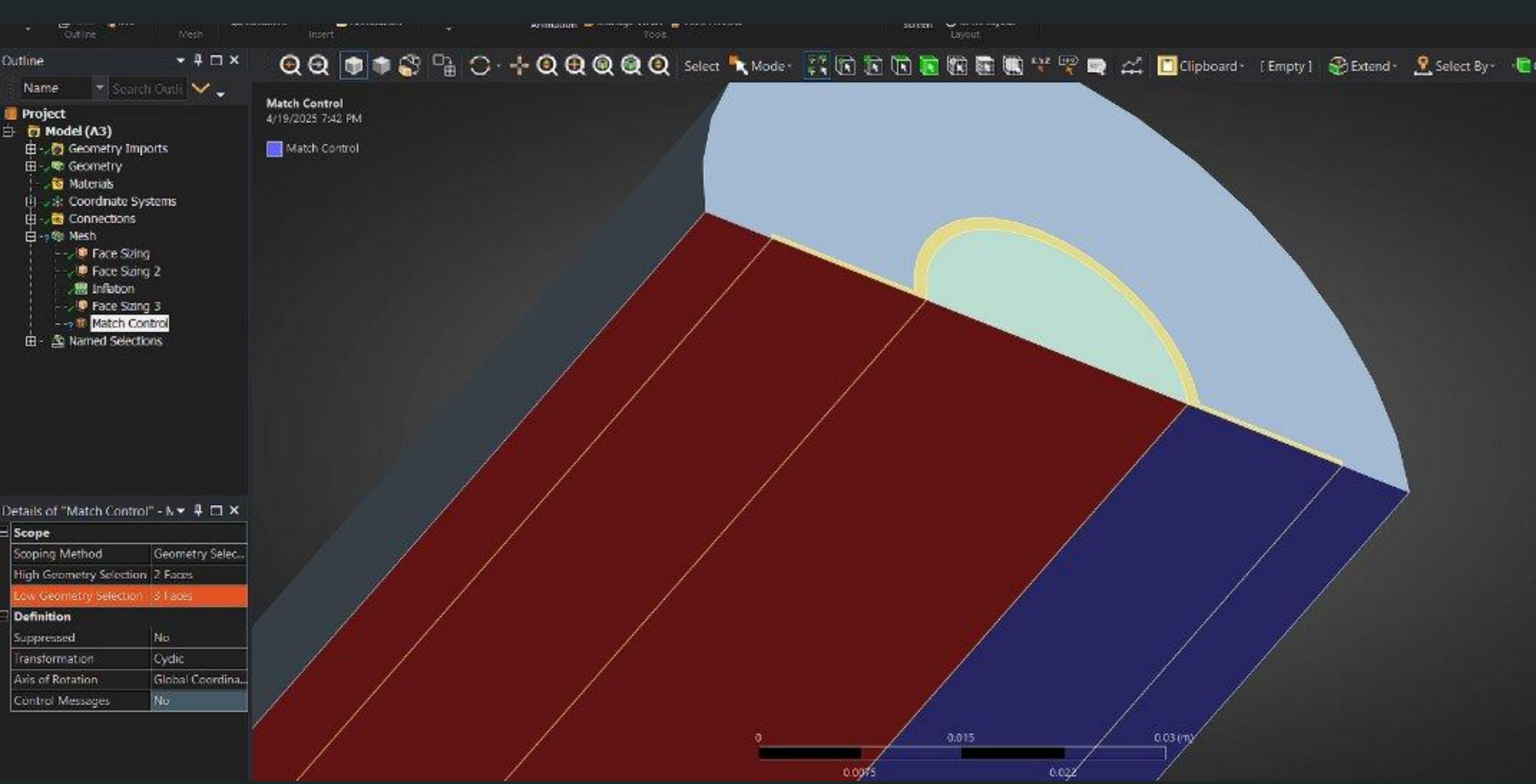
TYPE - REP'L. "U" TUBE

TA - 757-971

REF. 1 ACCT. 291 BY AC CK.

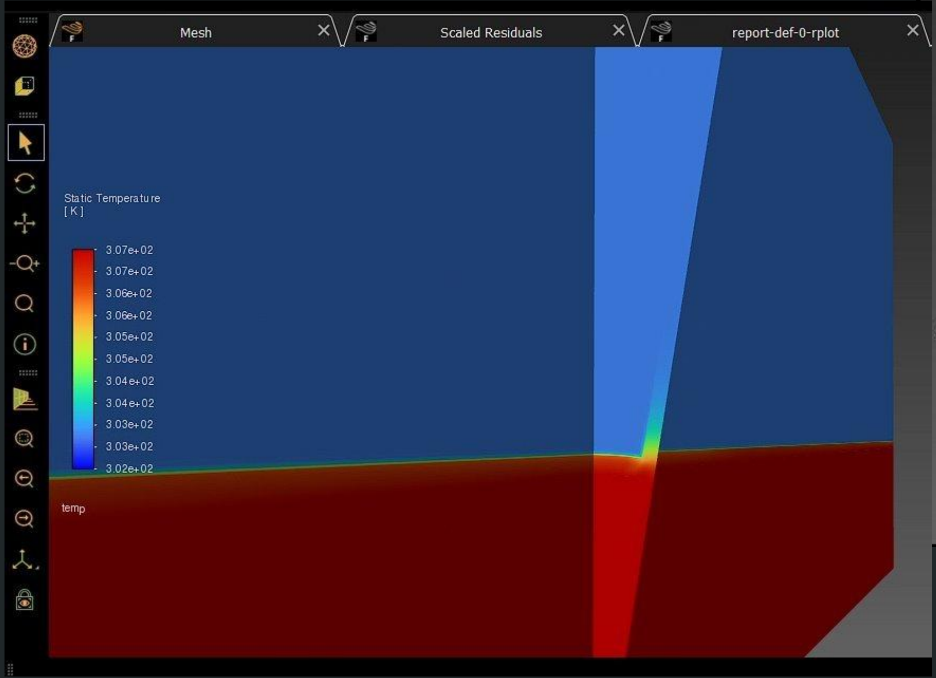

Mesh
Inflation
Named Selections
hot_fluid
cold_inlet
periodic_water_left

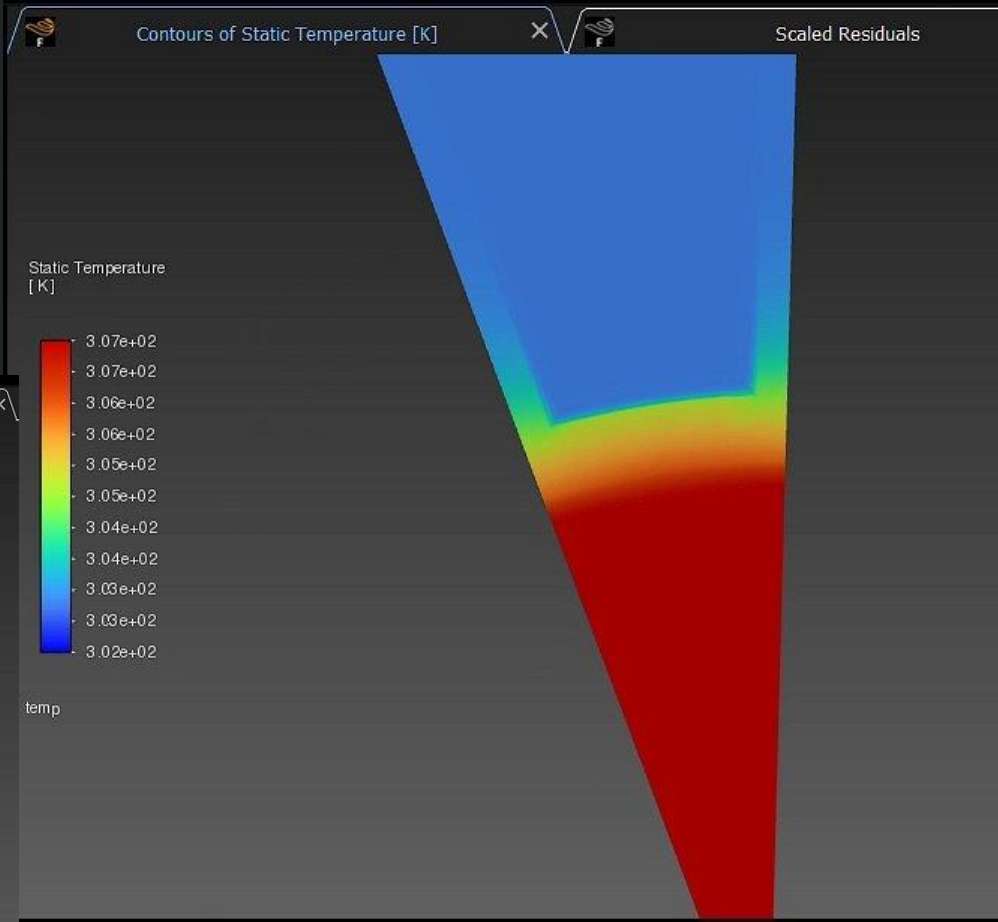


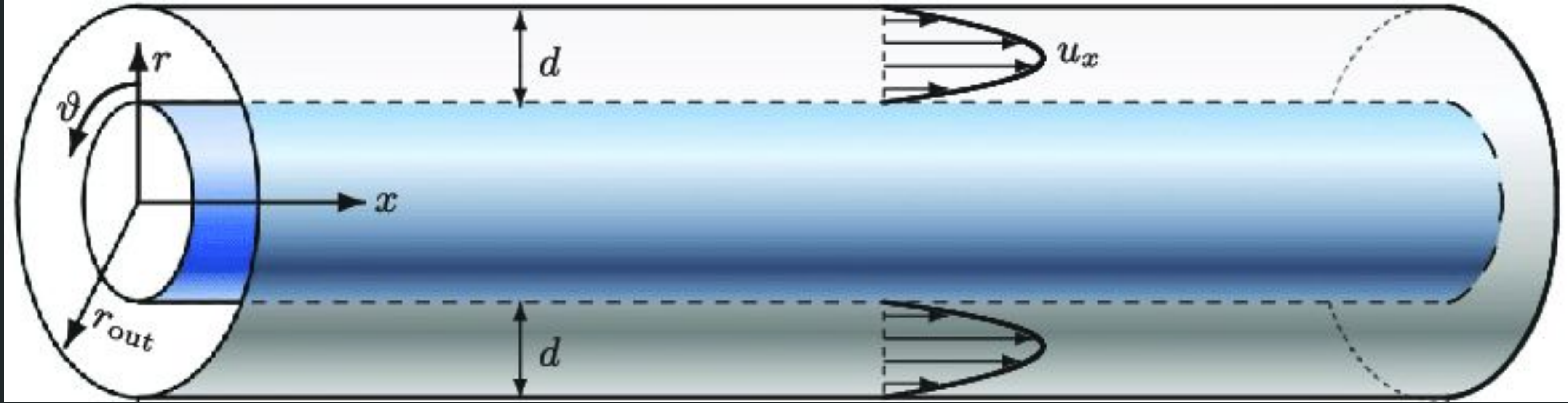


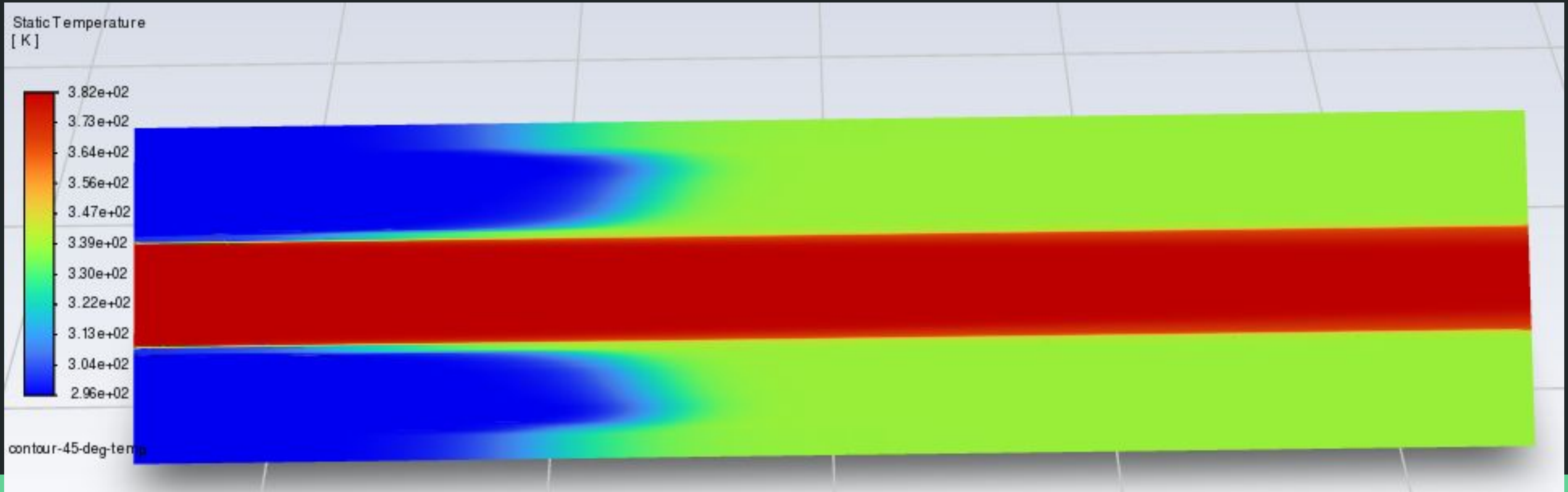
Outline
Name
Search Outli
Project
Model (A3)
Geometry Imports
Geometry
Materials
Coordinate Systems
Connections
Mesh
Face Sizing
Face Sizing 2
Inflation
Face Sizing 3
Match Control
Named Selections
Details of "Match Control" - M
Scope
Scoping Method
Geometry Selec...
High Geometry Selection
2 Faces
Low Geometry Selection
3 Faces
Definition
Suppressed
No
Transformation
Cyclic
Axis of Rotation
Global Coordina...
Control Messages
No
Select
Mode
Clipboard
[Empty]
Extend
Select By
Match Control
4/19/2025 7:42 PM
Match Control
0
0.015
0.03 (m)
0.0075
0.0225

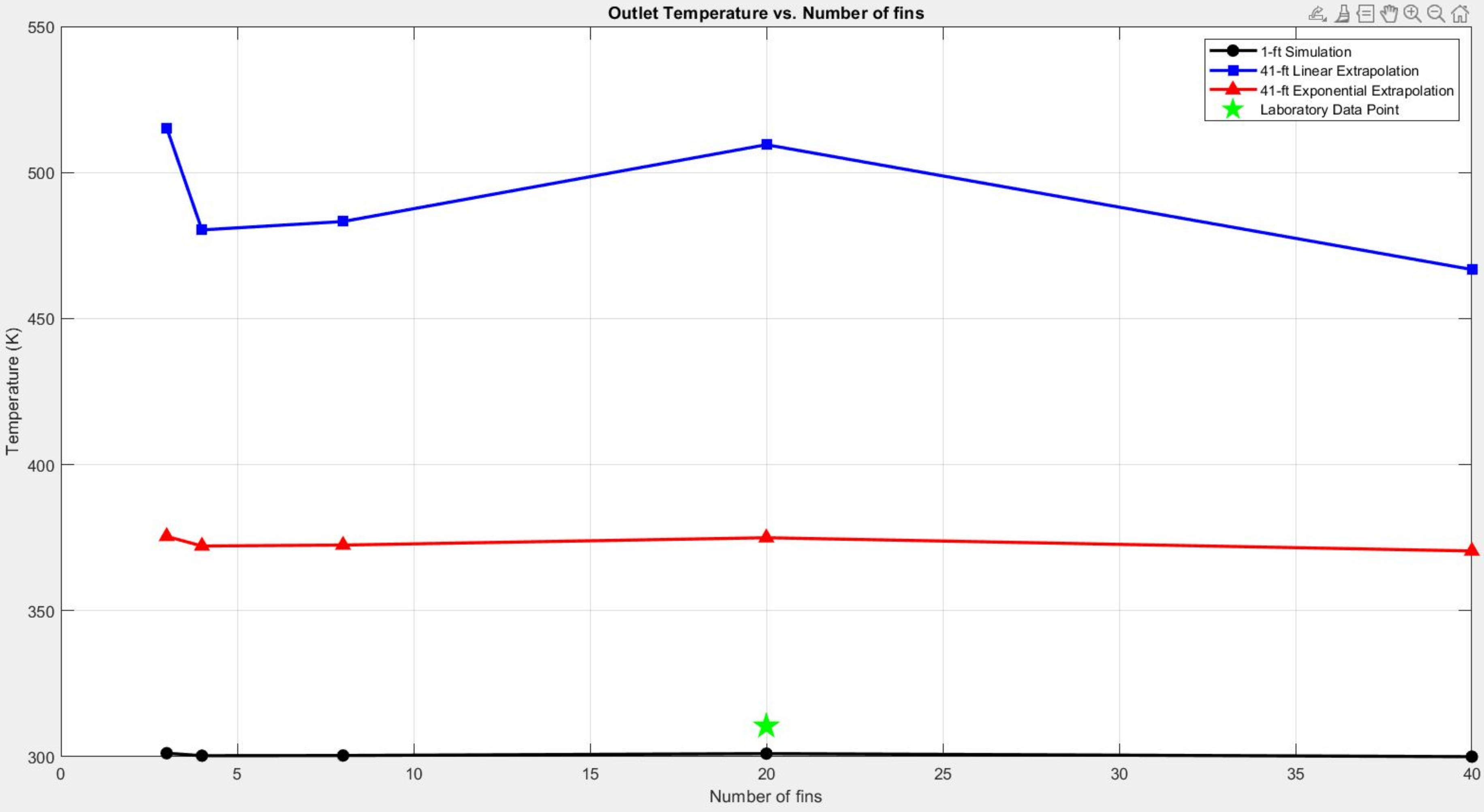
These were with the wrong dimensions but they're images of a slice midway through 1ft with 20fins






r
ϑ
d
u_x
x
r_{out}
d


Static Temperature
[K]
3.82e+02
3.73e+02
3.64e+02
3.56e+02
3.47e+02
3.39e+02
3.30e+02
3.22e+02
3.13e+02
3.04e+02
2.96e+02
contour-45-deg-temp



Outlet Temperature vs. Number of fins
1-ft Simulation
41-ft Linear Extrapolation
41-ft Exponential Extrapolation
Laboratory Data Point
Temperature (K)
Number of fins
550
500
450
400
350
300
0
5
10
15
20
25
30
35
40