DCLL He Thermal Hydraulics

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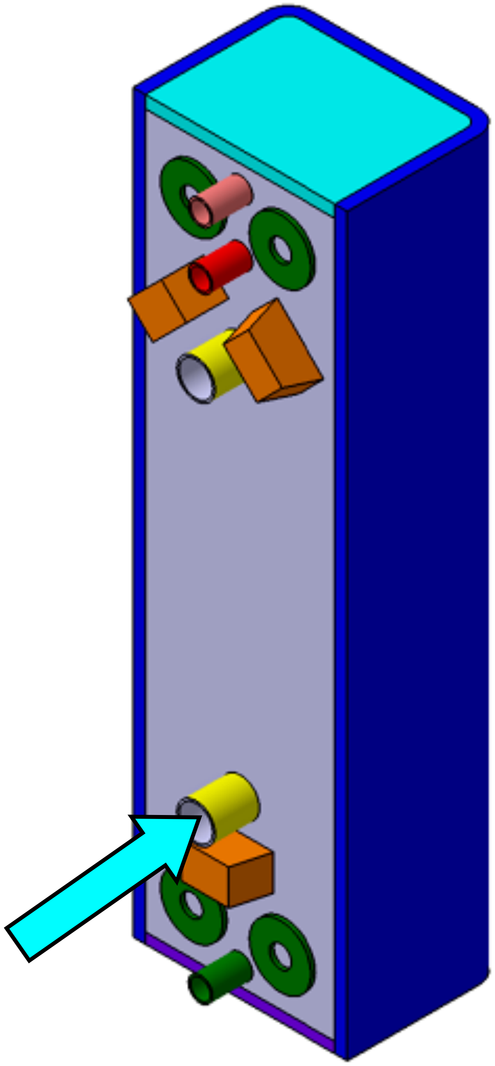
Outline

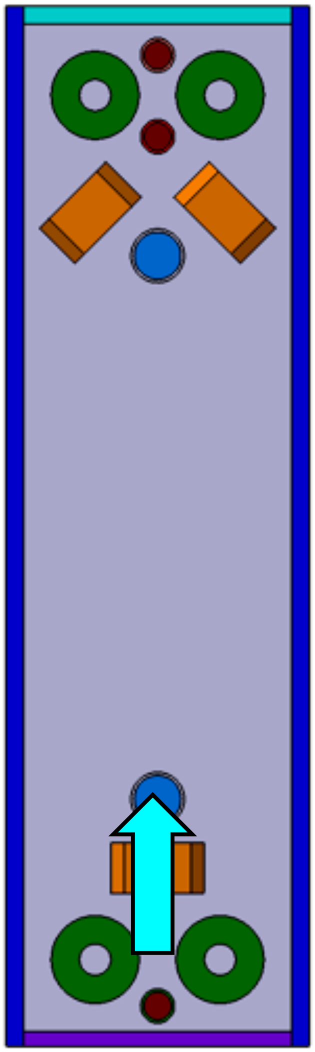
- Helium Flow Distribution
- Objectives
- Methodology

Helium Flow Distribution

US DCLL TBM



Step 1: Helium enters the back plate inlet.



Helium Flow Distribution

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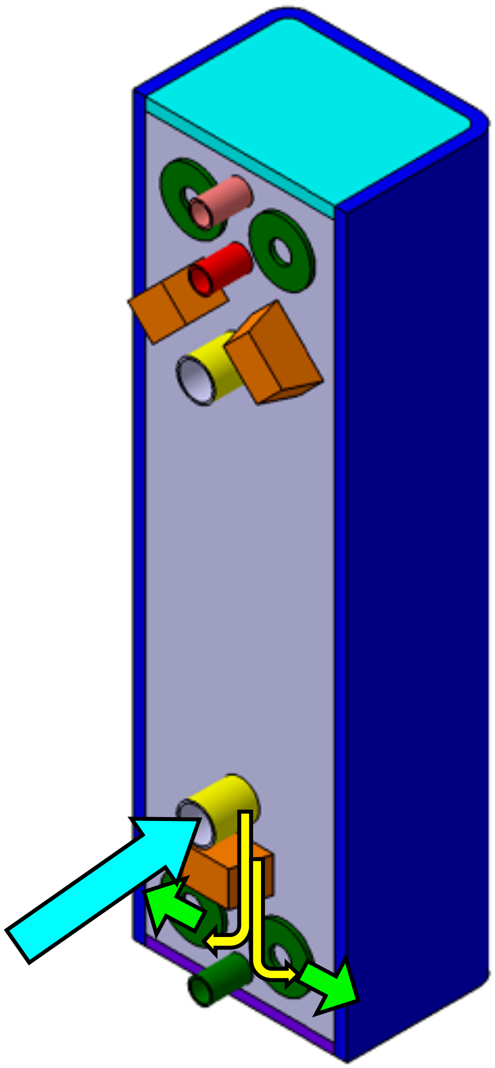
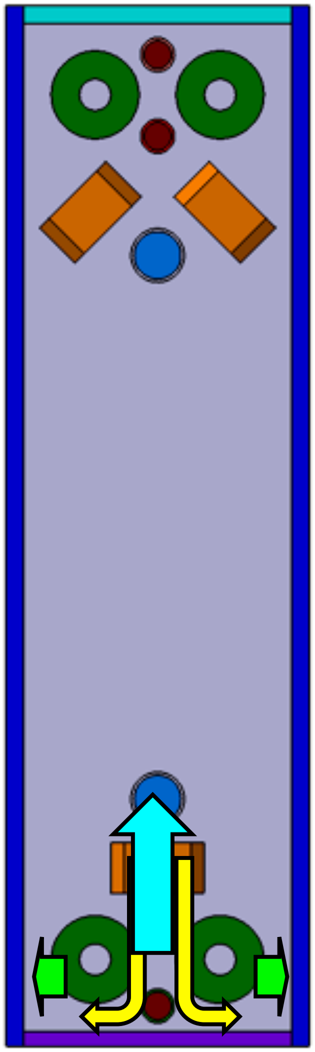
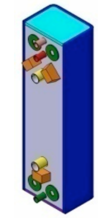


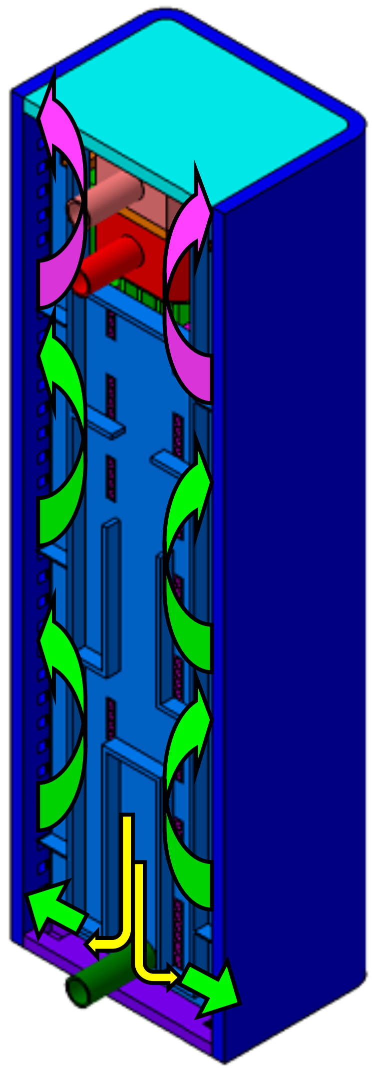
Step 1: Helium enters the back plate inlet.

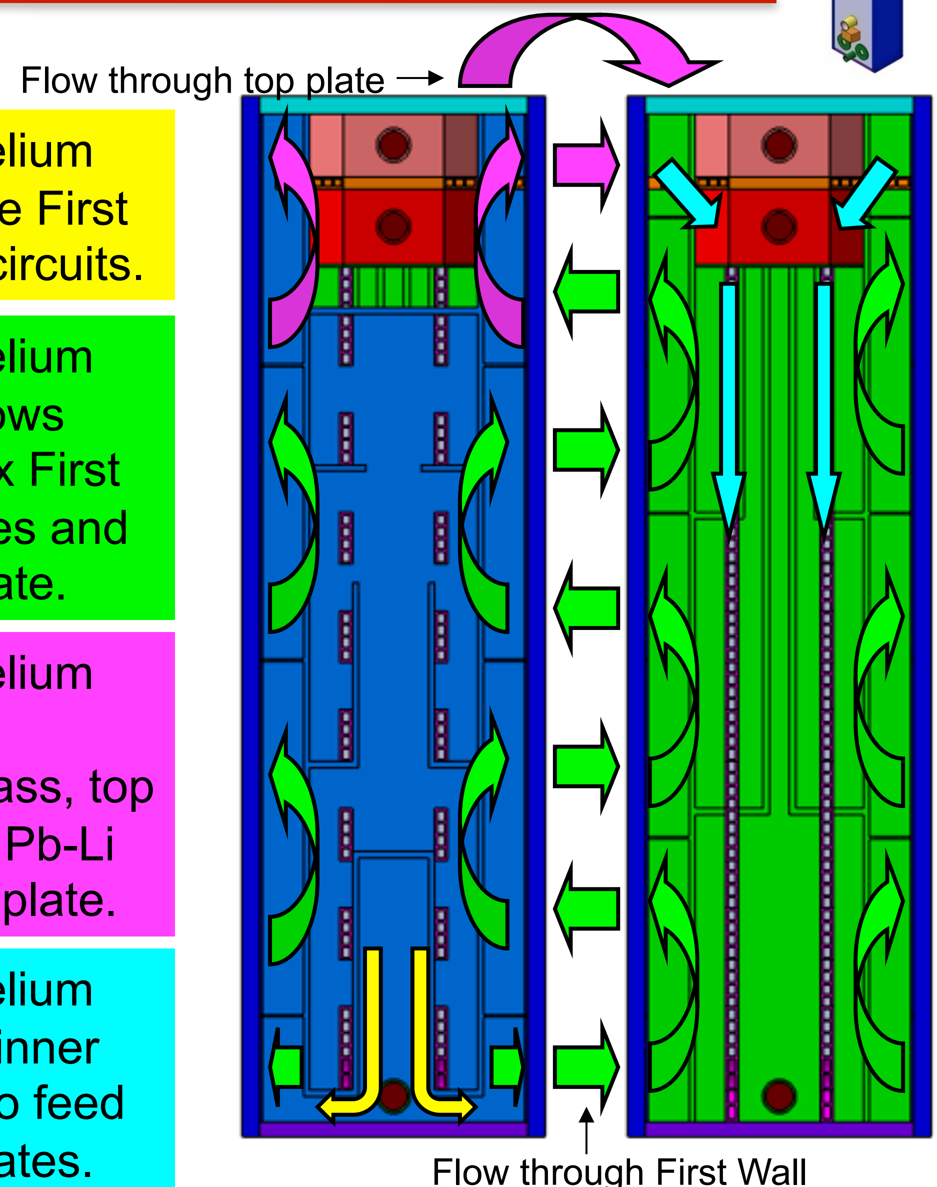
Step 3: Helium counter-flows through six First Wall passes and Bottom Plate.



Helium Flow Distribution







Step 2: Helium splits to the First Wall flow circuits.

Step 3: Helium counter-flows through six First Wall passes and Bottom Plate.

Step 4: Helium flows into seventh pass, top plate, and Pb-Li horizontal plate.

Step 5: Helium flows into inner chamber to feed the grid plates.

Helium Flow Distribution

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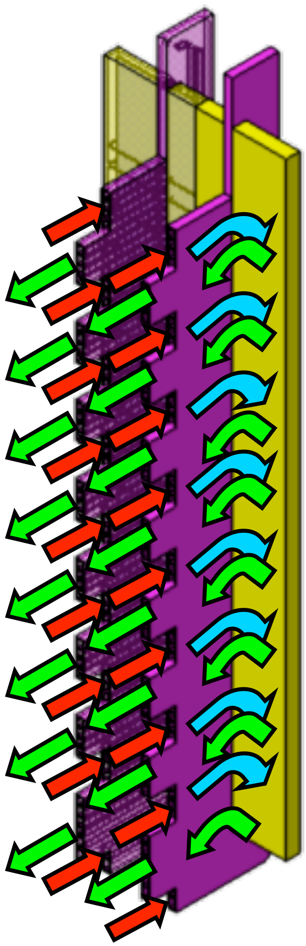
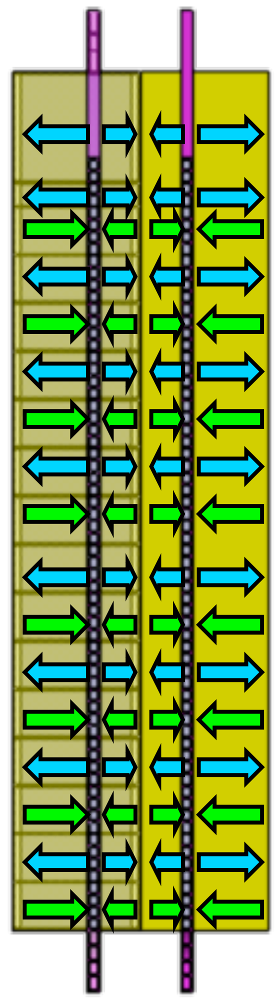
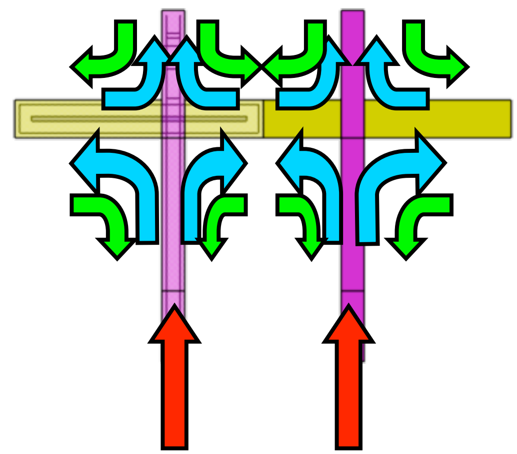


Step 6: Helium flows into grid plates from inner chamber.

Step 7: Helium splits to flow around divider plenum and re-enters grid plates.



Step 8: Helium u-turns along First Wall and returns through dividers, then to the outer Helium chamber.



Top View

Isometric View

View from Back Plate

Helium Flow Distribution

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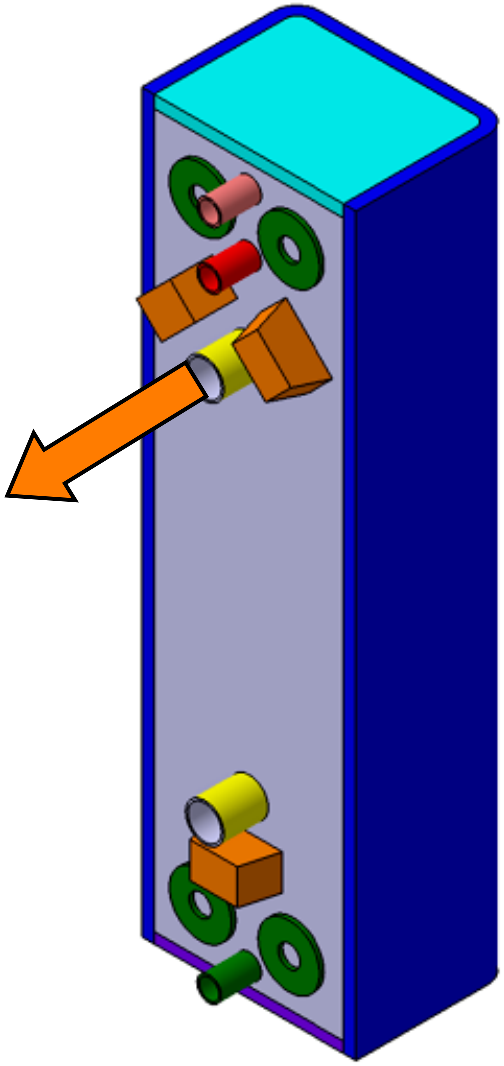
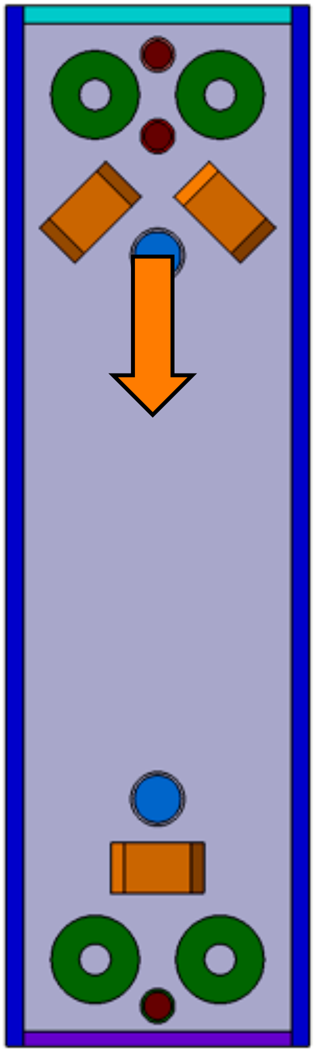
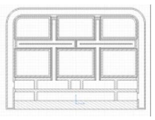
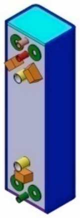


Step 9: Helium exits the back plate outlet from the outer Helium chamber.





What we want to learn



- Helium Flow Distribution.
  - Flow uniformity in channels
  - May lead to design changes
- Pressure Drops throughout the TBM.
- Heat Transfer of the Helium, output for structural temperature distribution modeling.

Design Areas to Analyze

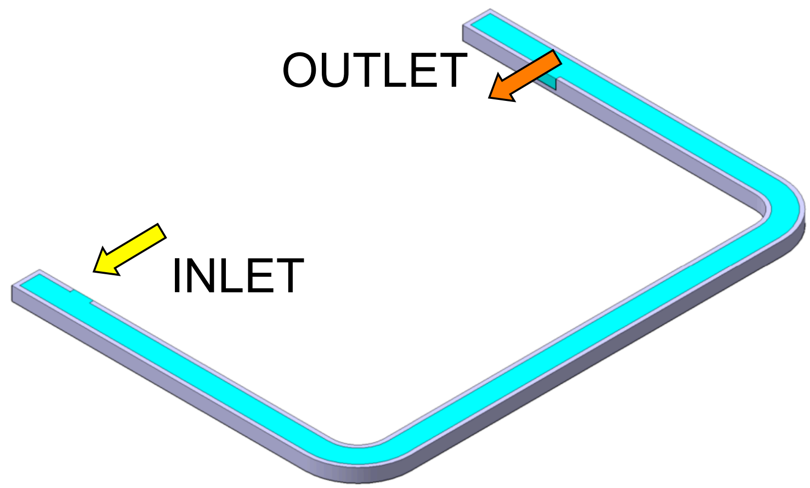
Several areas of the TBM design require special attention. These are areas of concern where the geometry presents complex features.

1. Individual Helium First Wall passes.
2. Helium First Wall “U-turn”
3. Grid Plate/Divider Regions

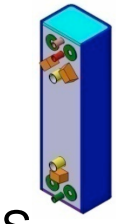
For each of these regions, a solid model has been built for analysis.

Analysis Area 1: Helium Channels

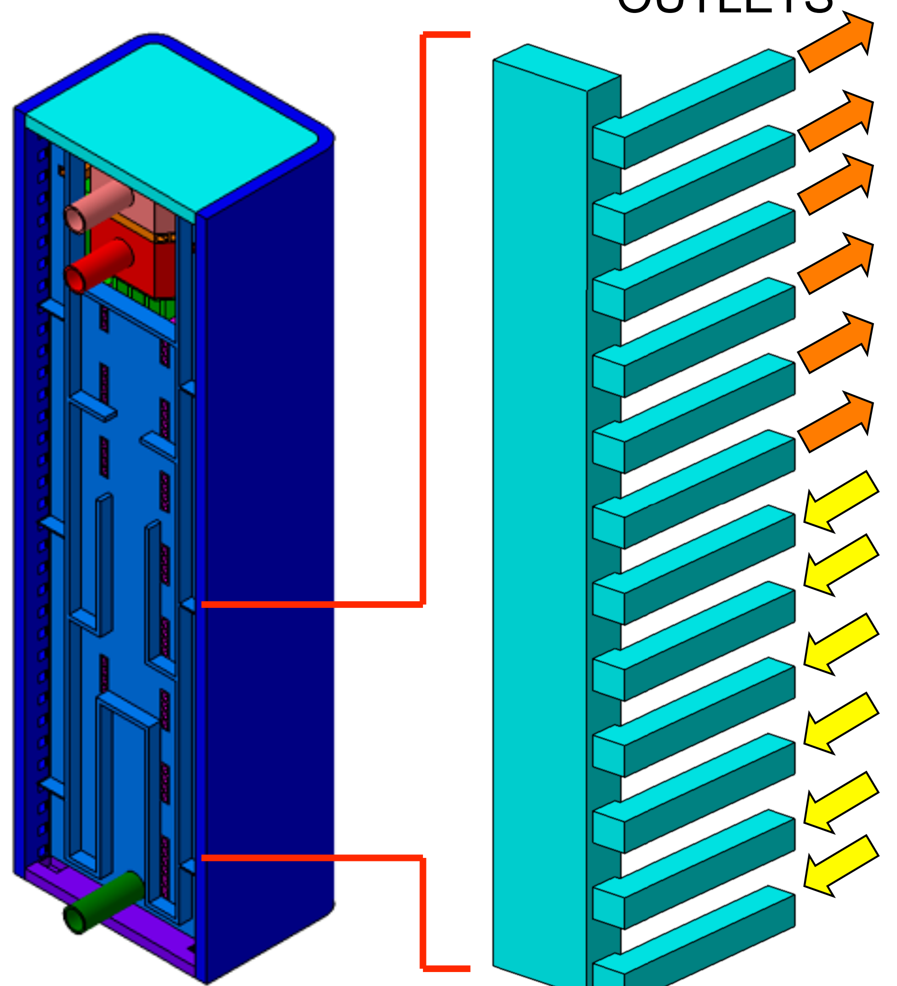
- Analysis for a single channel can be done analytically.
- One sided roughness of the first wall can be varied to provide necessary heat transfer enhancement.



Analysis Area 2: Helium "U-turn"

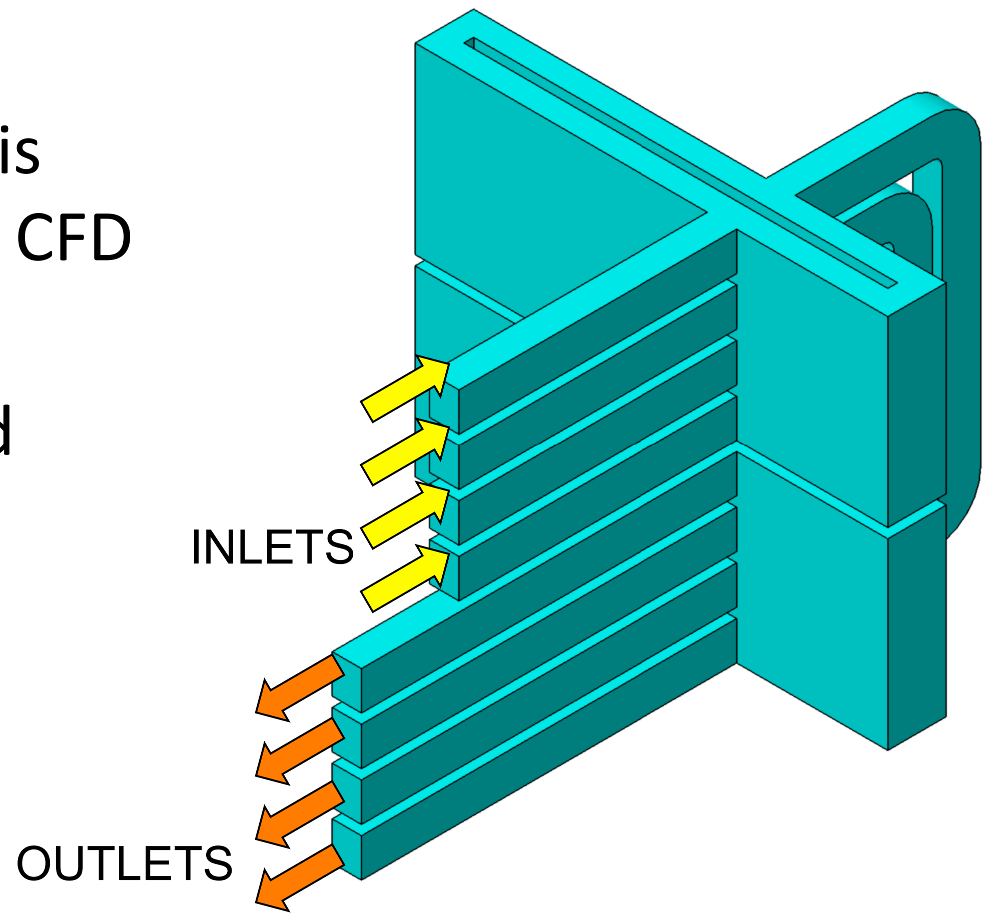


- This area will be analyzed to aid in the visualization of flow.
- Also, it will be determined if each channel has uniform flow distribution and similar pressure drop.
- Pressure drop and temperature change will be analyzed.



Analysis Area 3: Grid Plate & Divider

- This area involves complex flow that is best analyzed with CFD software.
- Pressure drops and temperature distribution will be analyzed.



Analysis Methodology

Two main methods exist to perform the necessary analysis:

1. Analytic options for simpler geometry regions like "Analysis Area 1: Helium Channels."

2. Computational Fluid Dynamics (CFD) Software such as Fluent, SC/Tetra Cradle, or ANSYS CFX for complicated geometry.

Overall Analysis Methodology

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- The first analysis will be done using the high performance DT phase of ITER operation (case 3.d.1).
- This case will be used to set up the problem, provide a vehicle for assessing the design, and suggesting design changes should they become necessary.
- The second case to study would be the case with Multifaceted Asymmetric Radiation From the Edge (MARFE) (case 3.d.2).
- Both of these cases will be used to create required boundary and initial conditions for analysis.

Analytical Options

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- It is planned to utilize the heat transfer spreadsheet created by Greg Sviatoslavsky for heat transfer and pressure drop on the first wall helium channels.
- Changes will be made to reflect the new geometry.

	A	B	C	D	E	F	G	H	I	J
1	Helium Properties				FS Properties				(m^2)	
2	Density	6.1	kg/m^3		Density	7700	kg/m^3	Pass 1 manifold A	0.0025	
3	Specific Heat	5200	j/kg-K		Specific Heat			single channel A	0.000392	
4	Thermal Conductivity	0.253	W/m-k		Thermal Conductivity	33	W/m-k	triple channel A	0.001176	
5	Viscosity	3.50E-05	kg/m-s					uniform flow no. channels	2.1	
6										
7	Channel Parameters									
8	width	0.02	m		Environmental Parameters					
9	height	0.0196	m		Pressure	8	Mpa			
10	length	0.484	m		Heat Flux-ss	0.3	MW/m^2	300000	W/m^2	
11	Flow Area	0.000392	m^2		Heat Flux (max)	0.5	MW/m^2	500000	W/m^2	
12	Surface Area	0.009486	m^2		Nuclear Heating	7.54	MW/m^3	7540000	W/m^3	
13	Perimeter	0.0792	m		FW Q (flux)	0.241	MW	241032	W	
14	Hydraulic Diameter	0.019798	m		total FW & SW Q (NH)	0.118	MW	118125	W	
15	Wall Thickness	0.004	m		Max Total FW flux	0.530	MW/m^2	530160	W/m^2	
16	Radial depth length	0.307	m		Qtot - FW - ss	0.382	MW	382308	W	
17	no. channels	70	channels		Nuclear Heating					
18	TBM height	1.66	m		Component	top plate		bottom plate		gr
19					Nuclear Heating	5253	W	5253	W	17
20	FW Flow Conditions				Required Passes					
21	Max FW temp @ 2mm	520	C		Pass	m-dot (kg/s)	v-dot (m^3/s)	Inlet Temp (C)	chans	velocity (m/s
22	Pr	0.72			1	0.48	0.079	350.0	4	50.7
23	Required m-dot	1.29	kg/s		2	0.65	0.106	357.7	6	45.0
24	Required v-dot	0.21	m^3/s		3	0.65	0.106	367.4	6	45.0
25	T - inlet	350	C		4	0.65	0.106	377.2	5	54.0
26	T-Outlet	408	C		5	0.65	0.106	385.3	5	54.0
27	Delta T	58	C		6	0.65	0.106	393.4	5	54.0
28					7	0.65	0.106	401.5	4	67.5
29								**Total chans**	35	
30	Max FW temp @ 2mm	520	C		lambda/Dh	0.0038		lambda (grain-height)	0.00007	m
31	Local bulk He temp	solid ΔT	film ΔT	h(req'd)	Nu(req'd)	friction factor	X	Re(req'd)	v (req'd)	no. channels/p
32	(C)	(C)	(C)	(w/m^2-K)					(m/s)	
33	350	31.2	138.8	3820	299	0.0275	0.923200731	111602	32.3	6
34	355	31.2	133.8	3963	310	0.0275	0.923200731	115773	33.6	8
35	360	31.2	128.8	4117	322	0.0275	0.923200731	120268	34.9	8
36	365	31.2	123.8	4283	335	0.0275	0.923200731	125126	36.3	7
37	370	31.2	118.8	4463	349	0.0275	0.923200731	130393	37.8	7
38	375	31.2	113.8	4659	365	0.0275	0.923200731	136123	39.5	7
39	380	31.2	108.8	4874	381	0.0275	0.923200731	142380	41.3	7
40	385	31.2	103.8	5108	400	0.0275	0.923200731	149239	43.3	6

CFD Options

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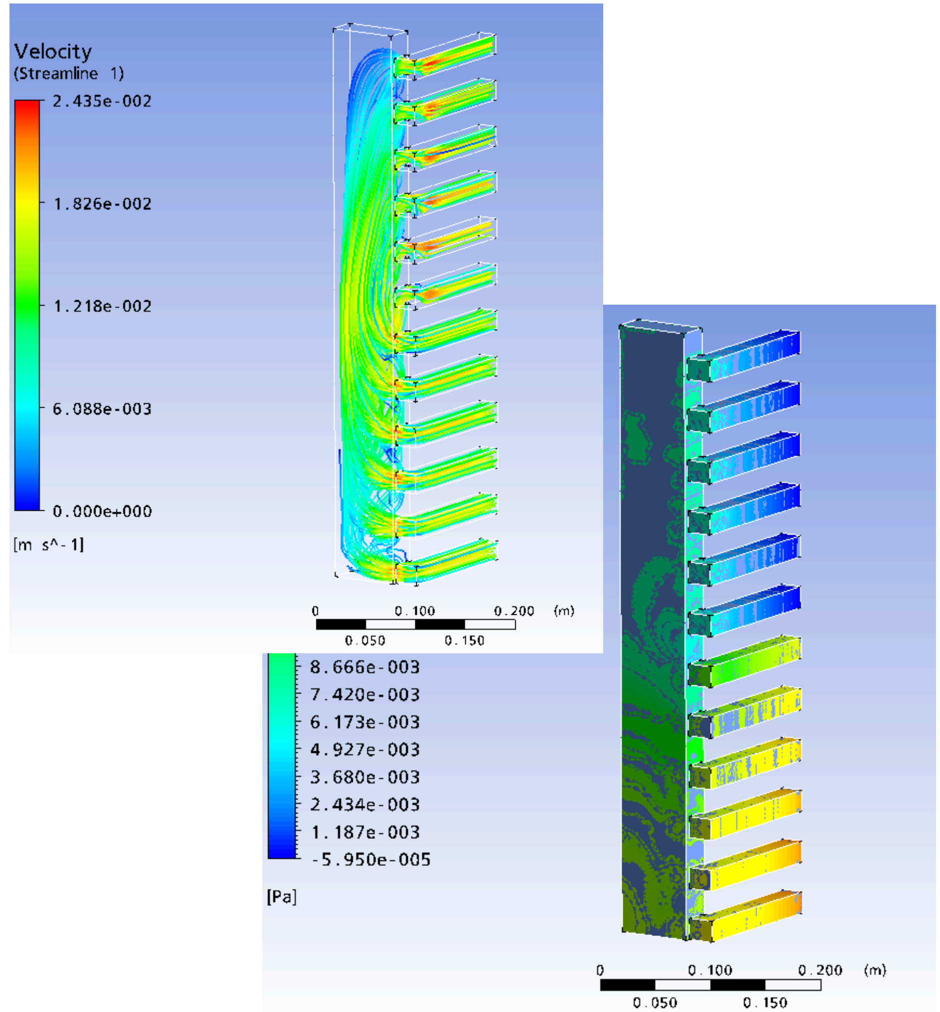
- We plan to use ANSYS CFX to analyze different helium flow regions.
- Care will be taken on necessary input and suitable boundary conditions.
- Results shown at right are examples.
- Detailed design changes may be needed to get flow uniformity in all regions.



Thanks, questions?