

A Helical Blade Design for APEX-Dry Wall

Elsayed A. Mogahed

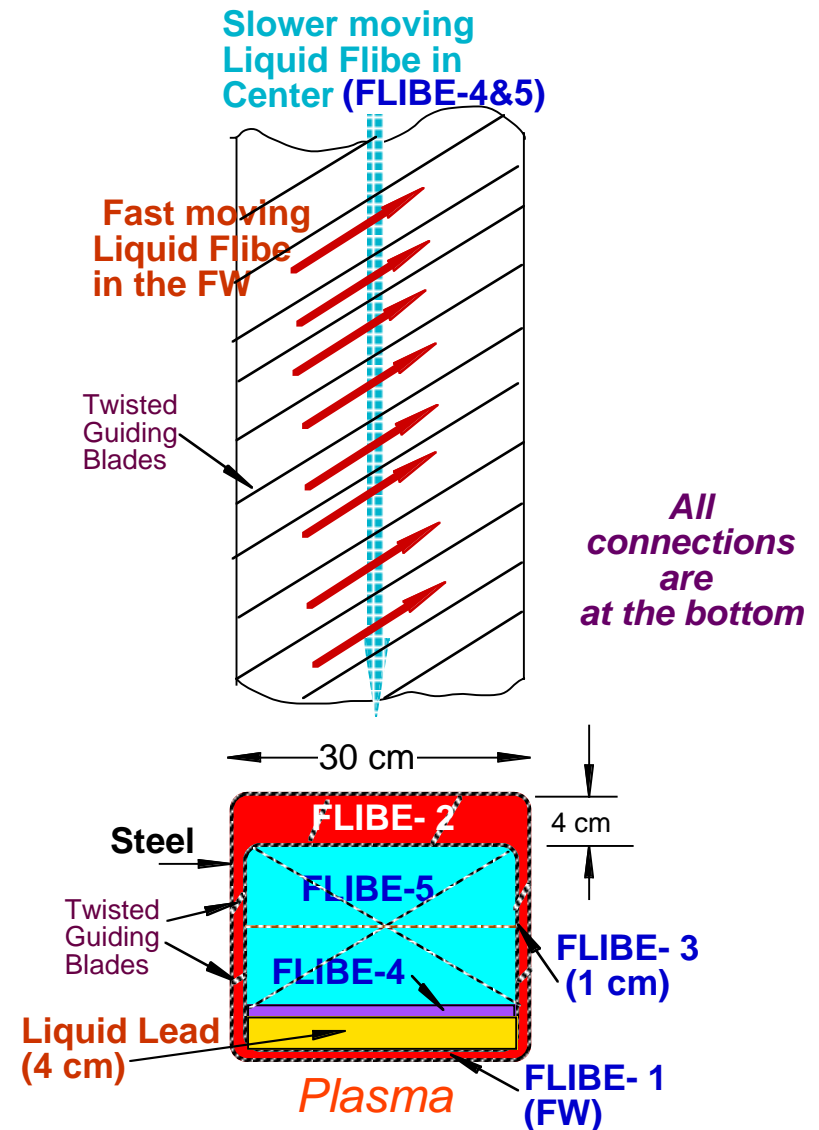
Fusion Technology Institute

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The Flat-Helical FLIBE/Liquid Lead /Dry Wall APEX Design

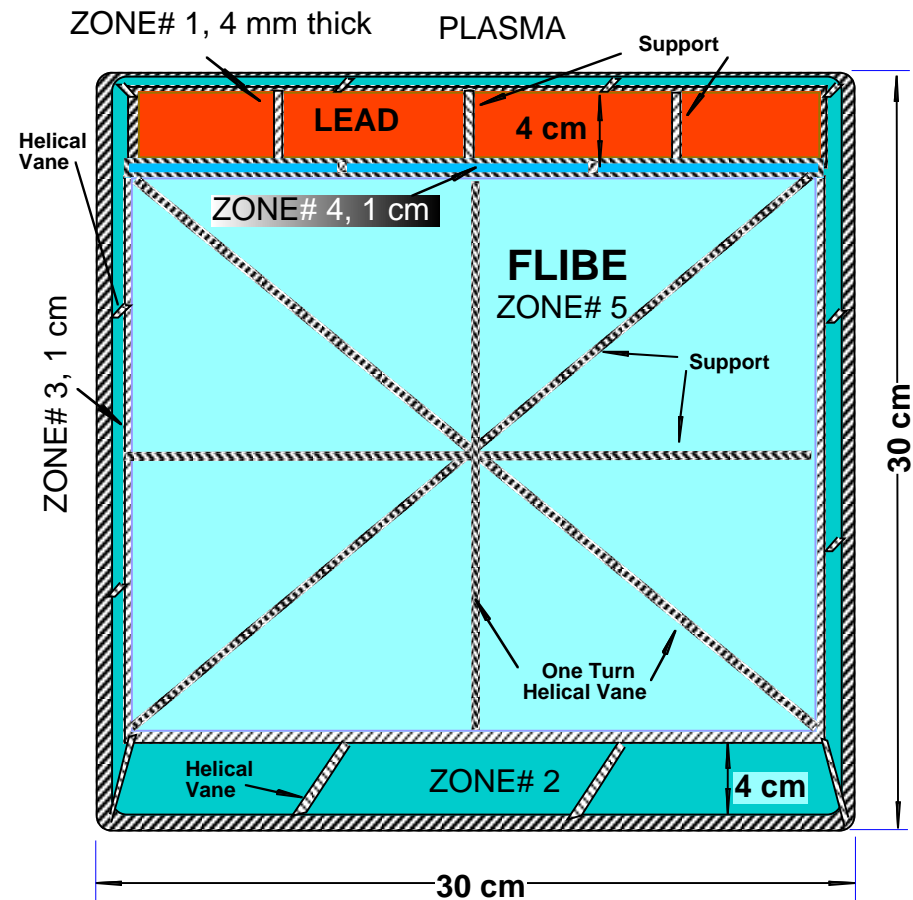
- A cross-section view at mid-plane of the suggested Dry Wall -APEX Design, which uses slow flowing lead as a multiplier and FLIBE as a breeder/multiplier coolant media.
- A fast FLIBE flows in the first wall in a helical fashion around the module.
- The supporting structure in Zone 5 is in a form of a **helix** with one turn in the poloidal direction.



Liquid Lead/FLIBE FW For APEX-Dry wall

The Flat-Helical FLIBE/Liquid Lead /Dry Wall APEX Design

- The coolant (FLIBE) high speed in the first wall is needed to carry away the surface heat flux and the high volumetric heating.
- The FLIBE flows at a slow speed in the side channels and even slower speed in the back channels to reduce the pressure drop associated with helical designs (longer path and more turns).



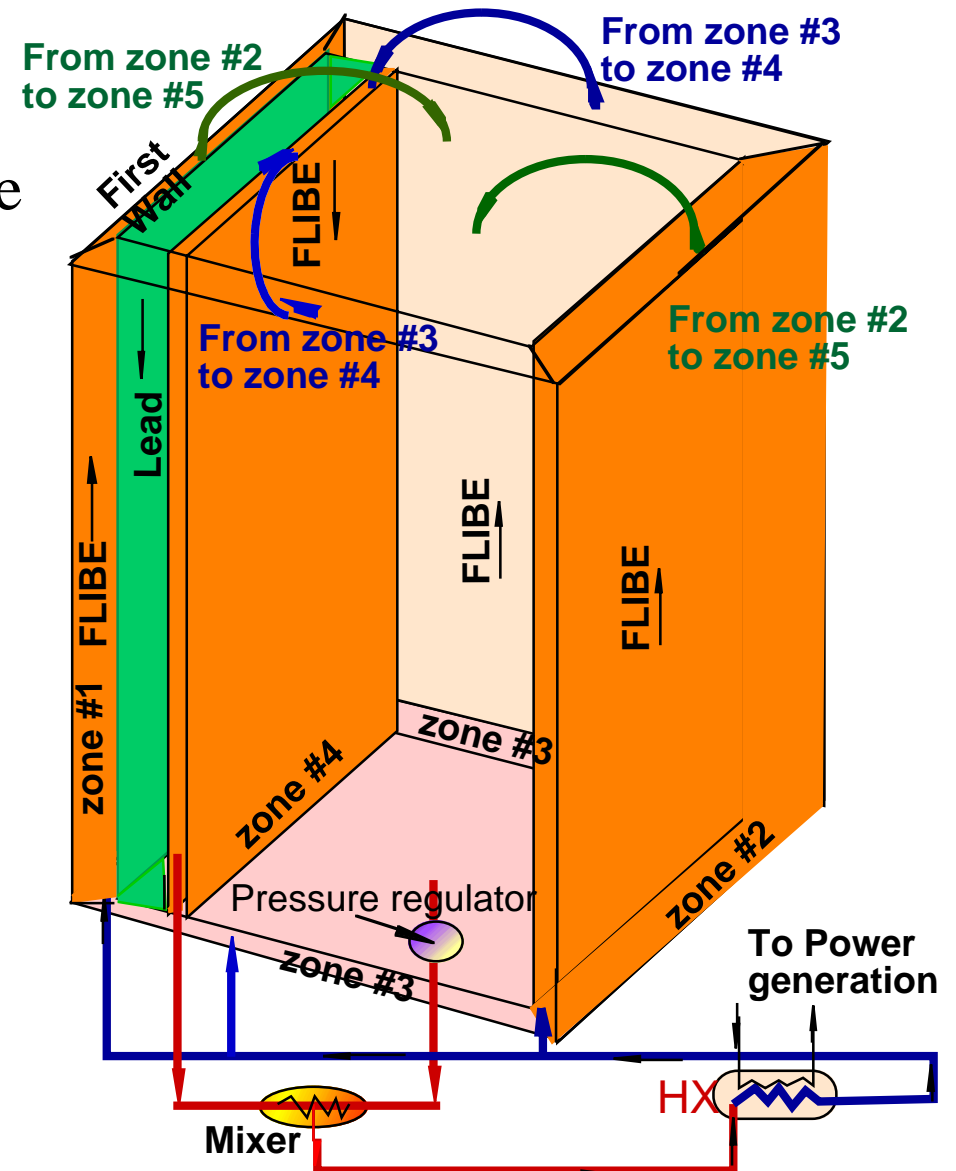
Cross section

APEX-Variable First Wall Coolant Area,
Helical Design

The Flat-Helical FLIBE/Liquid Lead /Dry Wall APEX Design

Coolant Routing:

- Coolant fed at the bottom of the module to Zones 1, 2, and 3.
- Coolant from Zone 3 feed into Zone 4.
- Coolant from Zones 1 and 2 feed into Zone 5.
- Coolant from Zones 4 and 5 feed into HX.



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Input Data:

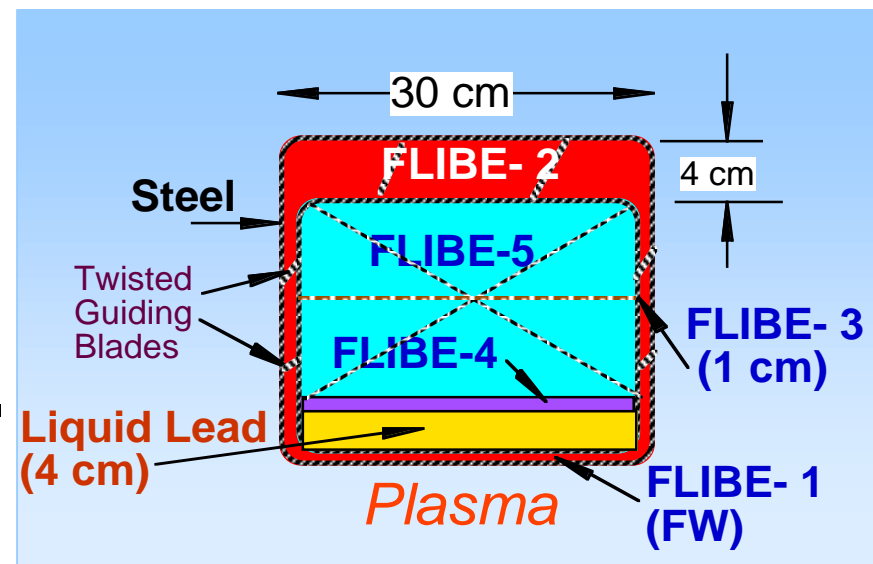
- Average neutron wall loading 5 MW/m^2
- Average surface heat flux 1 MW/m^2

Design Requirements:

- Maximum Steel temperature $\approx 800^\circ\text{C}$
- Maximum Steel/FLIBE interface temperature $\approx 700^\circ\text{C}$
- Maximum Steel/Lead interface temperature $?^\circ\text{C}$
- Inlet FLIBE temperature $> \approx 530^\circ\text{C}$

Design Criteria:

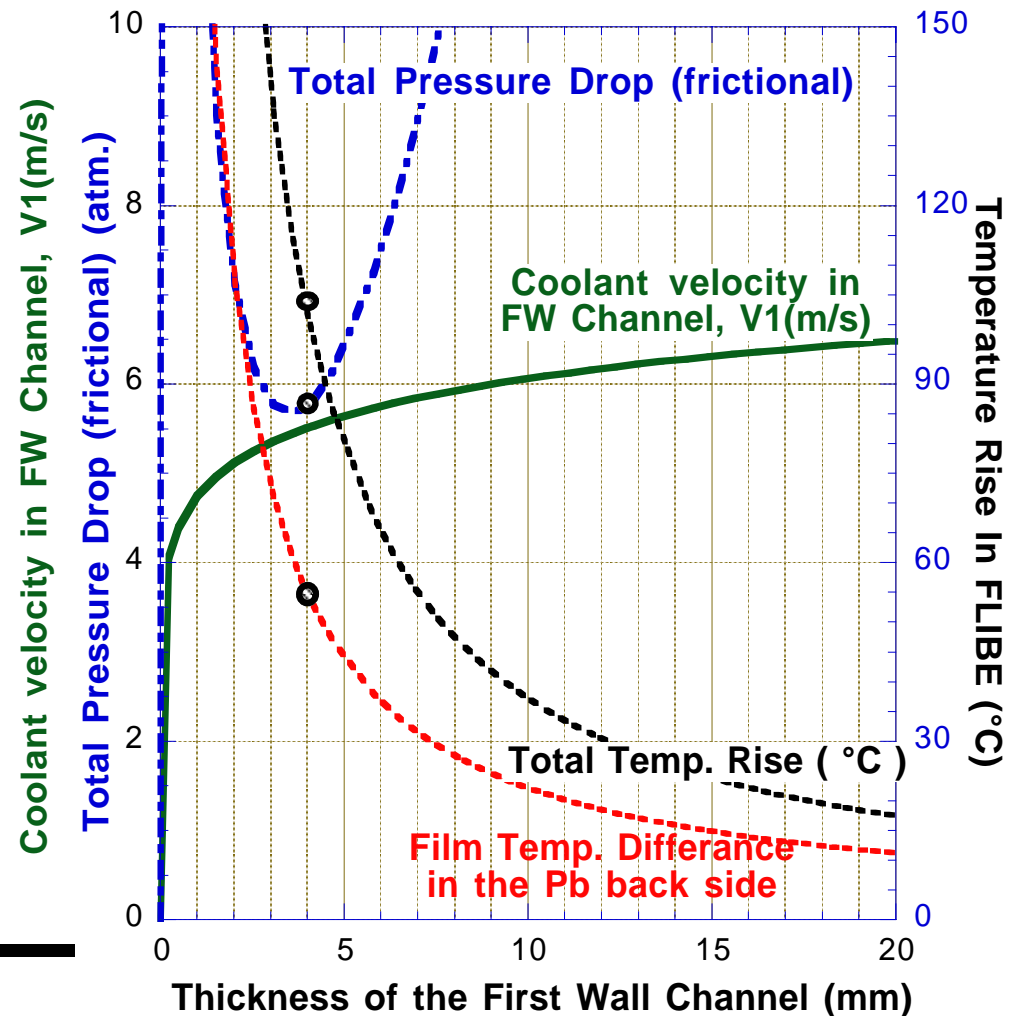
- Maximum outlet possible temperature
- Minimum coolant velocity
- Minimum pressure losses
- Minimum pressure driven stresses



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- The total frictional pressure drop shows a minimum at FW channel width of 3.5 mm.
- Unfortunately, it gives about a 70°C temperature difference in the FLIBE film at the Pb back coolant side.
- Working near the optimum at about 4 mm FW channel width gives a total temperature rise 102°C, and about 5.75 ATM total frictional pressure drop.

Performance of the APEX-dry Wall Helical-Blade Design

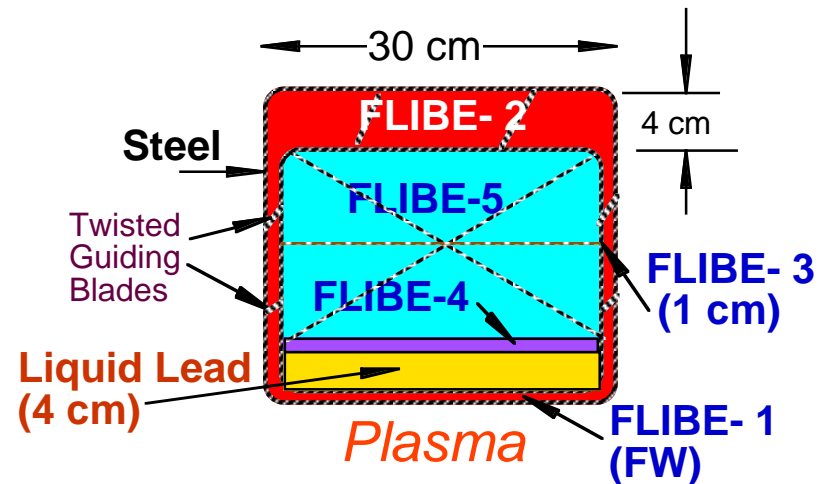


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Results Summary:

General --

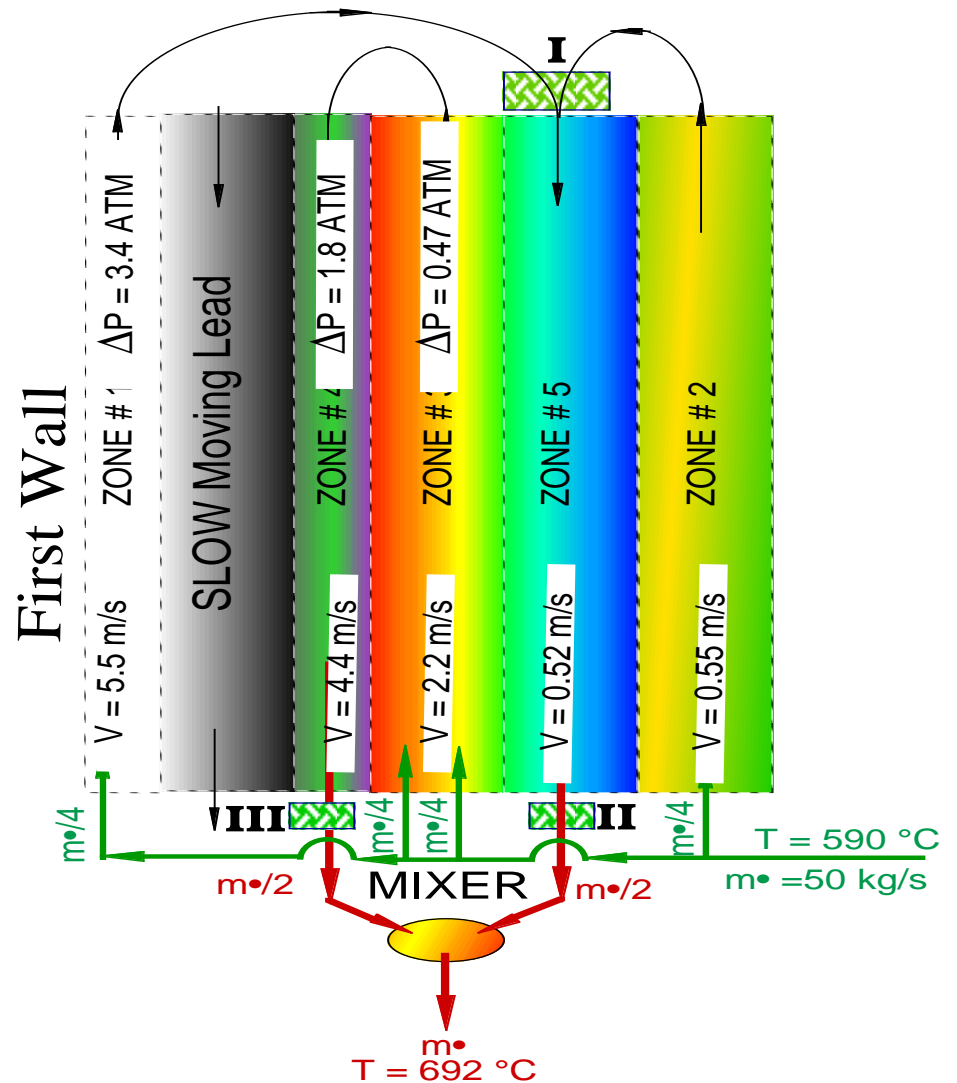
Mass flow rate (kg/s)	49.56
Temperature rise (°C)	102
Frictional pressure drop (ATM)	4
Width/length of one module (cm)	30/30
FW thickness (steel)(mm)	3.0
Helix pitch (m)	1.2



	<u>Zone 1</u>	<u>Zone 2</u>	<u>Zone 3</u>	<u>Zone 4</u>	<u>Zone 5</u>
Coolant channel width, (cm)	0.4	4.0	1.0	1.0	19
Coolant Speed, (m/s)	5.5	0.55	2.2	4.4	0.26
Heat transfer coefficient, (W/m ² K)	12,400	--	--	9,100	1,030
Temperature rise, (°C)	Total of 60		(20°C+63°C)= 42°C mixed		
Film Temp Difference, (T _{interface} -T _{bulk})	FWside 100/Lead side 37	Lead side 55		--	--
Coolant direction	up	up	up	down	down

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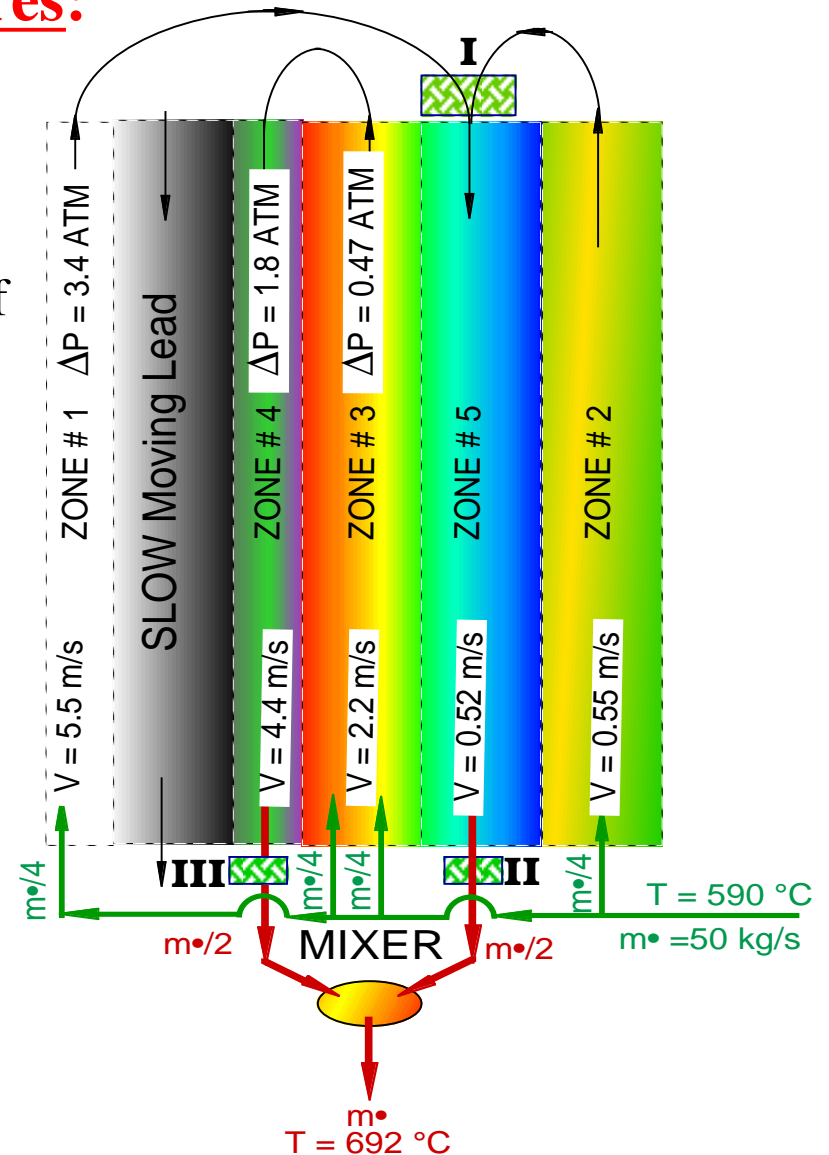
- The pressure and temperatures at point I is the same from both directions.
- The pressures and temperatures at point II and at point III are not equal. $T_{III} < T_{II}$, and $P_{III} > P_{II}$.
- Therefore, a pressure regulator and a mixer are needed before the two exit streams can be used in the power cycle. The pressure regulator could be at the inlet or at the exit of zone #5.



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Methods to regulate the exit pressures:

- Method 1:** A pressure dissipater could be inside the exit of zone 5 to deliver the the exact pressure as that at the exit of zone 4. This pressure dissipater could be a series of perforated plates at the exit or simply a series of valves.
- Method 2:** To design the supporting twisted plates in zone 5 to generate that pressure difference.
- Method 3:** Feeding the side zones (1 and 4) with a higher pressure ratio pump than the pump that feeds zones 1, 2 and 5.



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Conclusions:

- With a coolant loop of the shortest length (one upward and one downward) the **frictional pressure drop is minimal**.
- The coolant speed is **fast** where needed and **slow** where not needed.
- **Simplicity** in manufacturing a double wall with helical guiding blades.
- Design guide lines for temperatures are **satisfied**.
- However, interface temperature at lead/steel could reach 810°C , which is a concern.

