Enhancement of Heat Transfer Performance of the FW of the re-circulating NCF/FLIBE concept

Elsayed Mogahed

Fusion Technology Institute

University of Wisconsin- Madison

The Need to Enhance Heat Transfer performance of the FW

- The need to maximize Neutron wall loading for solid FW concept and meet the NCF/FLIBE temperature requirements at the same time.
- The reduction in heat transfer coefficient due to MHD effect.
- The need to minimize pressure losses.

Options for FW heat transfer enhancement are explored.

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Enhancement techniques

A- Passive

• Special surface geometry provide enhancement by establishing a higher *hA* per unit base surface area.

• Three basic methods are employed to increase the *hA*.

1- Increase h without an appreciable area (*A*) increase.

2- Increase of *A* without appreciably changing *h*.

3- Increase of both *A* and *h*.

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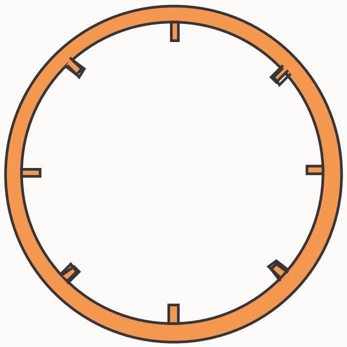
↘ Some techniques to achieve these methods:

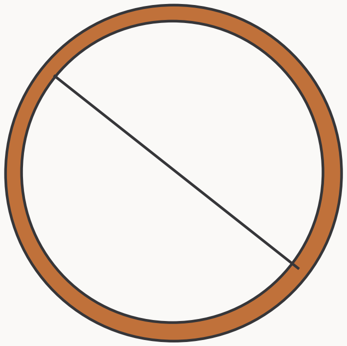
• Surface roughness or turbulent promoters.

• Internally/externally finned tubes with plain integrated fins.



• Internally/externally porous coating.

• Twisted tape insert on inner surface.



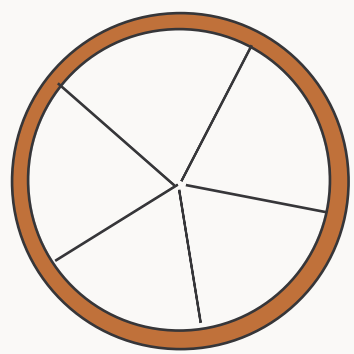
↘ Some Insert Devices:

• Wire coil inserts.

- It has been reported that the enhancement level in Nusselt number was between1.5 and 4.0. The friction increase was considerably less than the Nusselt number increase.

• Extended surface insert.

Not often used. Pressure drop and cost are unfavorable.



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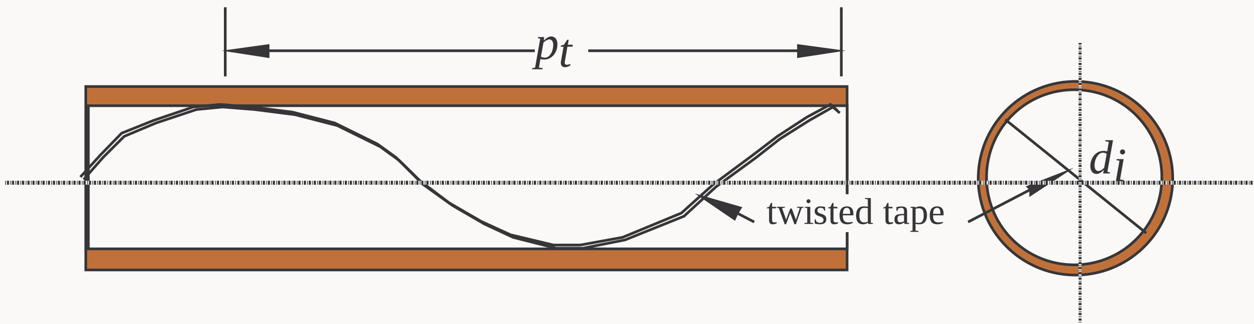
• Swirl-Flow insert devices:



Heat transfer enhancement may occur for three reasons:

1- The tape reduces the hydraulic diameter, which effects an increased heat transfer coefficient, even from zero tape twist.

2- The twist of the tape causes a tangential velocity component. Hence, the speed of the flow is increased near the wall. The heat transfer enhancement is a result of increased shear stress at the wall. Also heat transfer is enhanced by mixing fluid from the core region (cold) with fluid in the wall region (hot).

3- There may be heat transfer from the tape.

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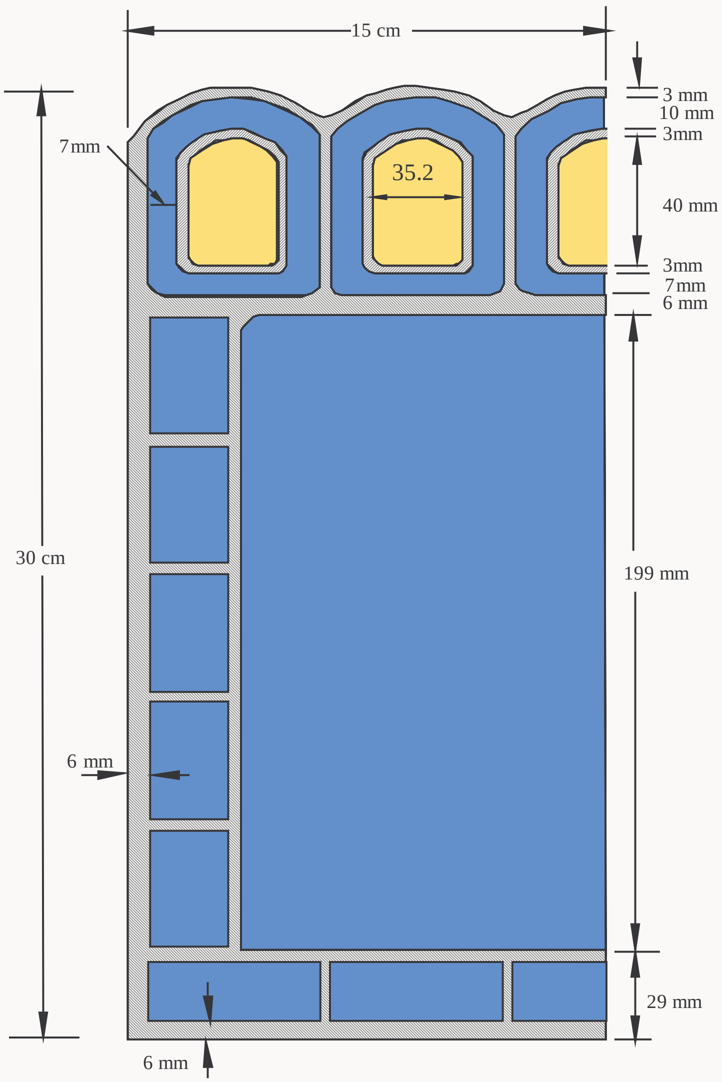
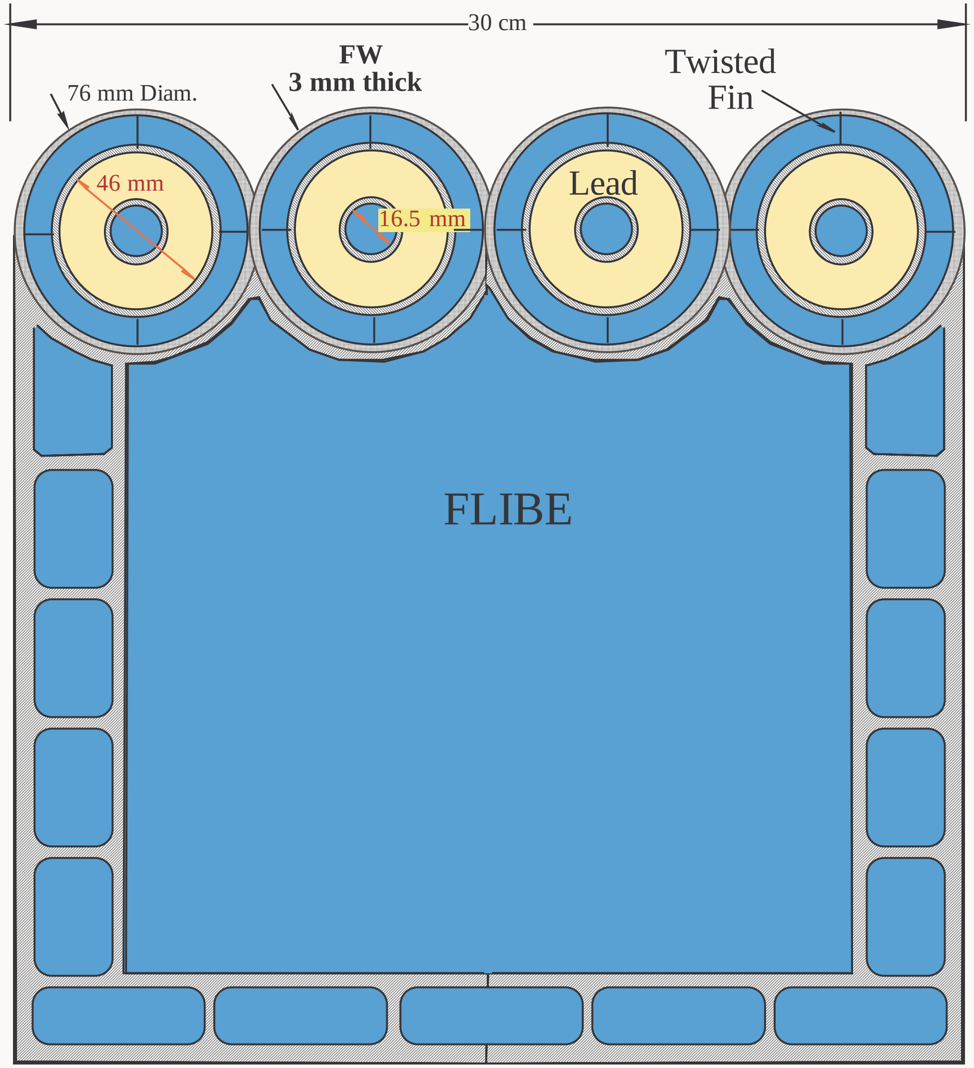


NCF/FLIBE FW/Blanket Concept



Suggested FW Configuration

Advantages of the round concentric tubular FW

1- Can withstand higher pressure (only hoops stresses).

2- Thinner walls than flat sided channels for the same mechanical loads.

3- Thickness of lead channel is half that of the base design, cooled from both sides that reduces the maximum lead temperature rise by 50%.

4- Ease in manufacturing. Made of rounded tubes that attached together 4 in row, and then attached to a conformed back.

5- Allow Swirl-flow insert devices, like twisted tapes, to enhance the heat transfer performance.

6- FlIBE tubes (outside and central) have the same hydraulic diameter as the base configuration. This results in the same frictional pressure drop.

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7- The hydraulic diameter of the central tube (16.5 mm) is the same as the hydraulic diameter of the outer ring coolant tube, that results in the same pressure drop in both channels.

8- The following presented data shows an enhancement level in Nu about 300% over the smooth-tube value.

9- The friction factor for the range of $5000 < Re < 70{,}000$ and twist angle up to 46° is proposed to be:

$$f = f_p \left(y/(y-1)\right)^m$$

Where:

f_p is the friction factor in a plain tube, given by

$$f_p = 0.046\, Re_d^{-0.2}$$

$y =$ twist ratio $p_t/(2\, d_i)$

$m = 1.15 + 0.15\,(70{,}000 - Re)/65{,}000$

Ref., Handbook of Single-Phase Convective Heat Transfer, Kakac, Shah, and Aung, Wiley-Interscience, 1987. (Chapter 17; Enhancement of Single-Phase Heat Transfer, Ralph L. Webb.

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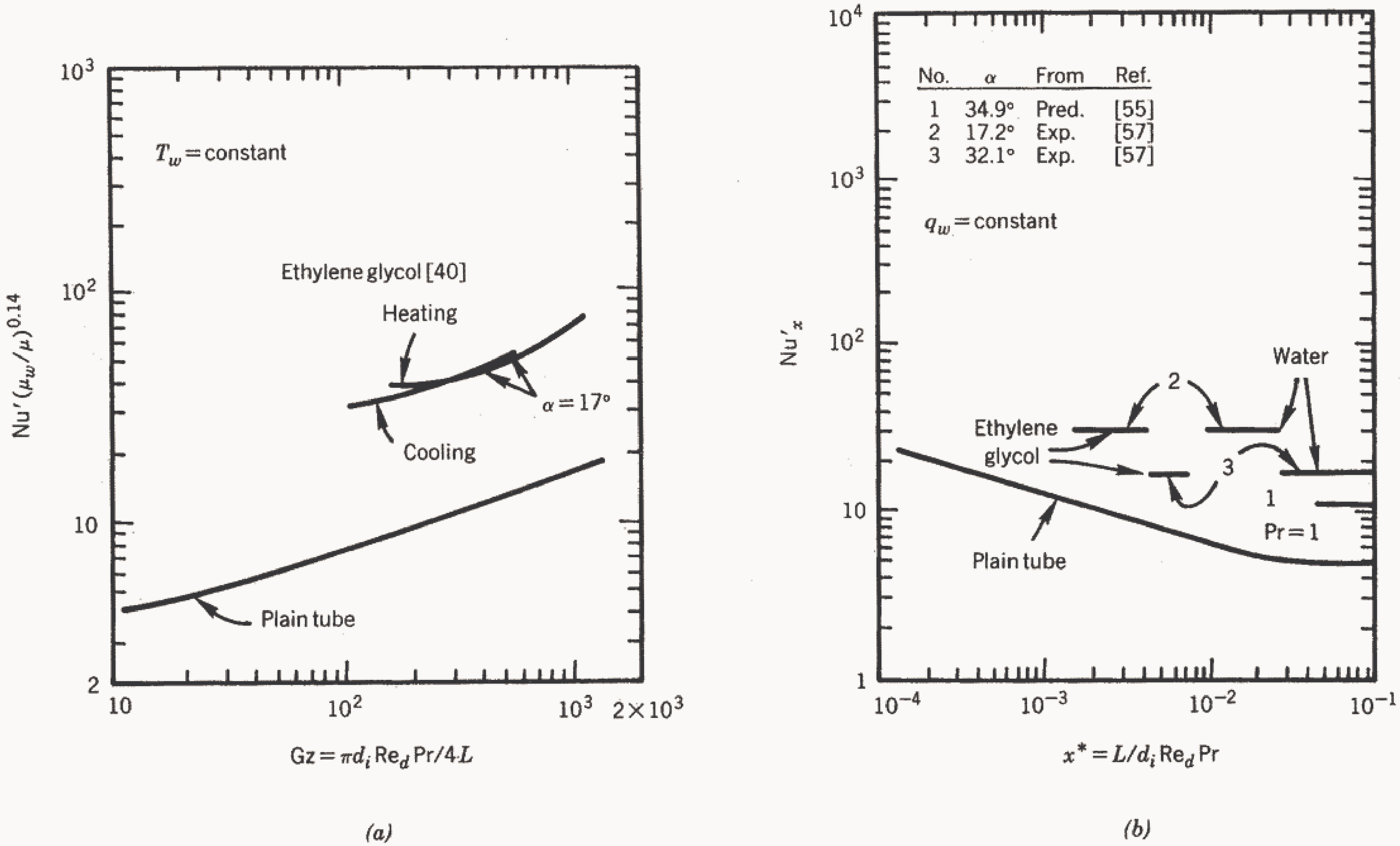

Figure 17.25. Nusselt number for laminar flow in tubes with twisted tape insert [44]: (a) constant wall temperature, (b) constant heat flux.

Ref., Handbook of Single-Phase Convective Heat Transfer, Kakac, Shah, and Aung, Wiley-Interscience, 1987. (Chapter 17; Enhancement of Single-Phase Heat Transfer, Ralph L. Webb.

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The Impact of the round concentric tubular FW

- Increase the structural material content in the FW by about 10%.
- May result in changing the T_2 breeding ratio.
- Increase pressure drop if we have a twist in the inserted tape.

Conclusions

- There are too many possible ways to enhance the heat transfer performance of an existing design.
- Enhancement of heat transfer coefficient always comes with a price (increase the pressure drop).
- Optimization analysis is needed to select the best options.

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