FUNDAMENTALS OF THERMAL-HYDRAULIC CALCULATIONS OF HEAT EXCHANGE APPARATUSES OF NUCLEAR REACTORS

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Relevance: Why are thermal-hydraulic calculations Important in Nuclear Power Plants?

The aim of this hydraulic calculation review is to look at the fundamental underlaying calculations which help guide engineers working in the designing, constructing and maintaining of nuclear reactor oriented heat exchangers.

- Turning nuclear energy into usable power
- Keeping a reactor from melting down (in the Literal Sense)
- Boosting plant efficiency
- Barrier guards
- Decay heat removal

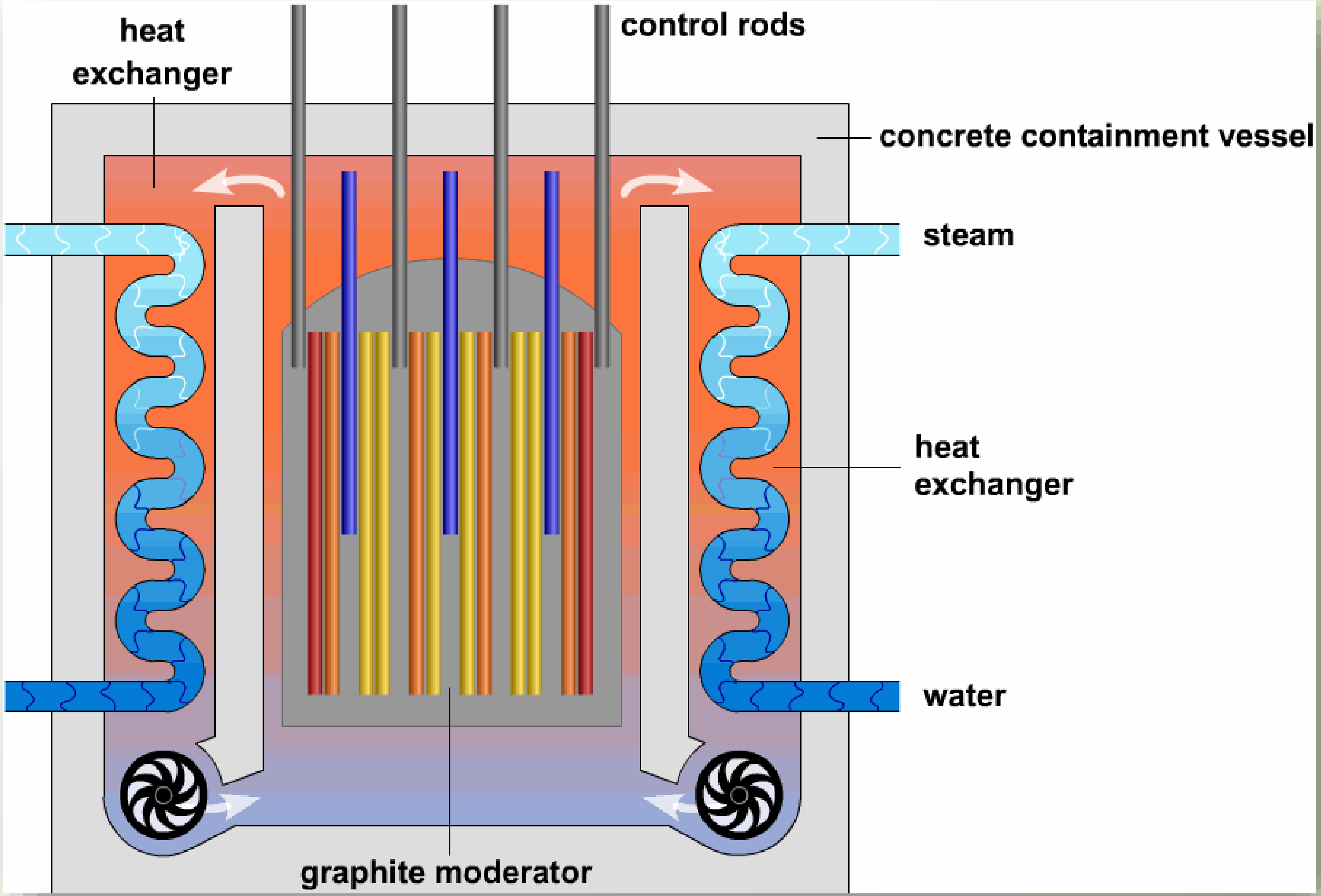


Diagram of a double-circuit power plant with a nuclear reactor Source: Yandex

Fundamentals of a heat exchanger suited for a NPP

- **The heat exchanger combines two passes with a common wall (each of length L) to make counter flow within the vessel.**
- **Flow areas AF and velocities that can be varied, dividing the length of a heat exchanger into different elements.**

PGV-1000M Steam generator

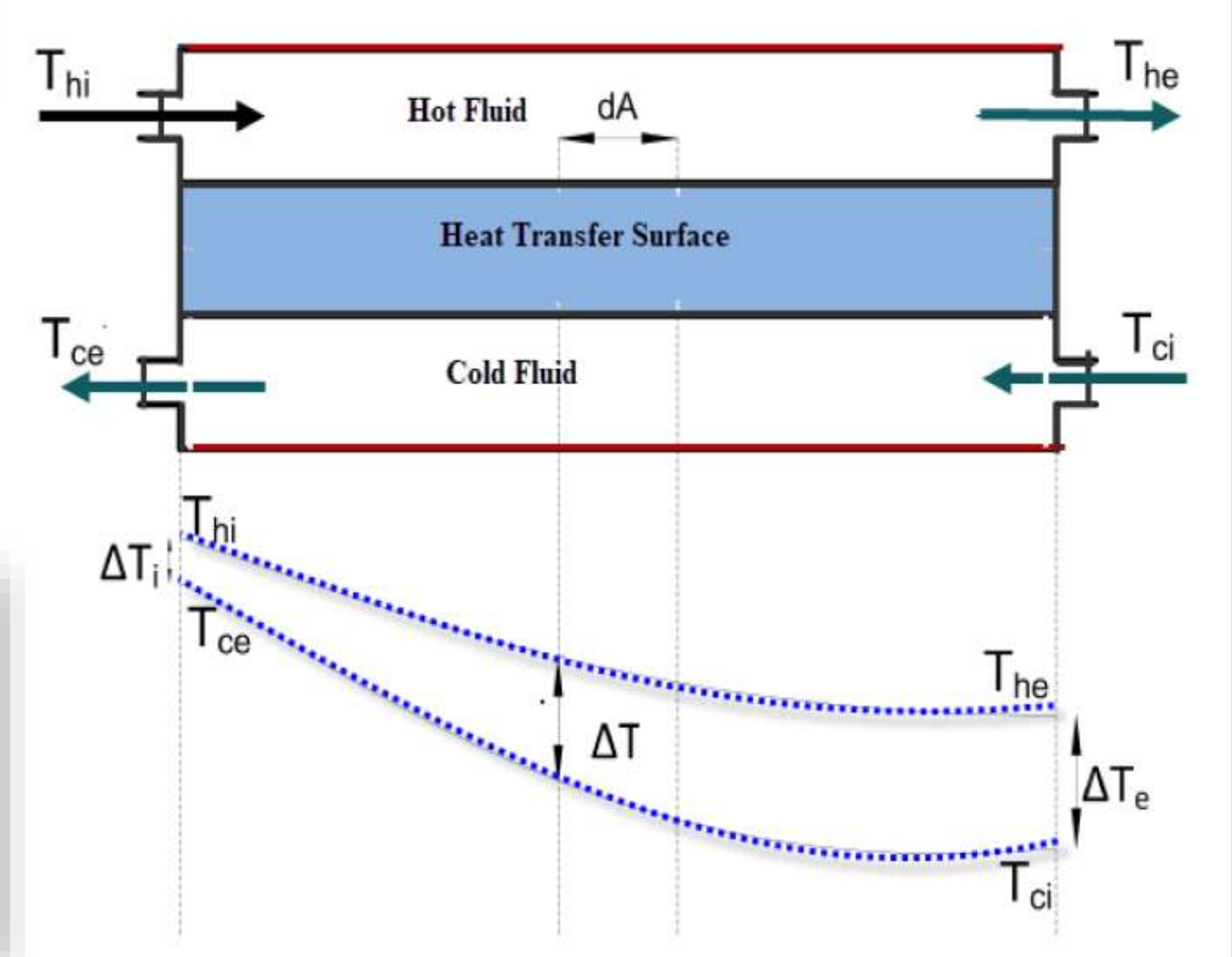


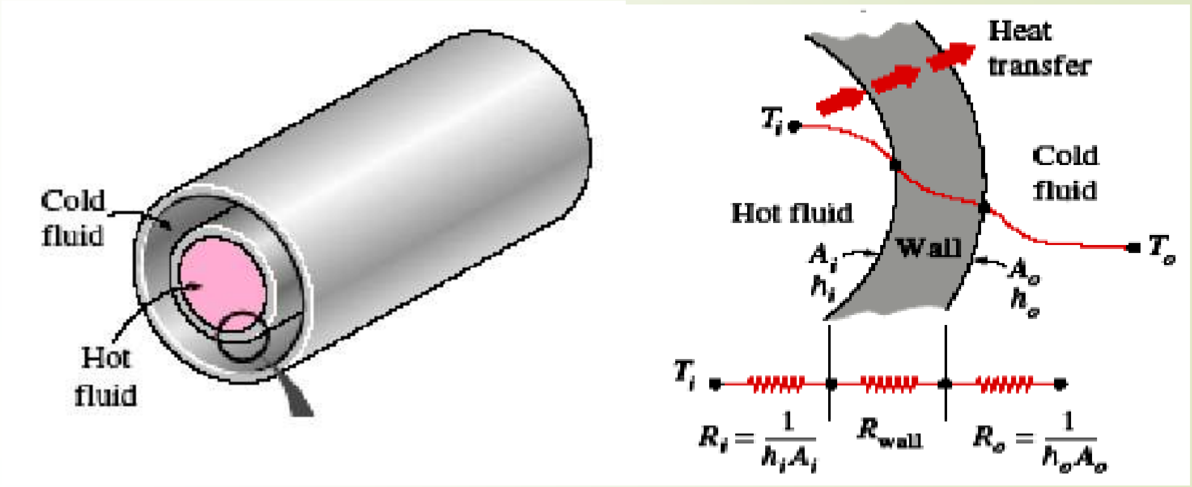
Diagram of the opposite fluid flow mechanism in heat exchangers, source: Yandex

Fluid flow and heat transfer

- q = UA∆T

The primary objective in the thermal design of heat exchangers is to determine the necessary surface area required to transfer heat at a given rate for given fluid temperatures and flow rates.

- The overall heat transfer coefficient – U
- $U_o = \dfrac{1}{\frac{1}{h_o}+\frac{r_o}{k}ln\left(\frac{r_o}{r_i}\right)+\left(\frac{r_o}{r_i}\right)\frac{1}{h_i}}$
- $U_i = \dfrac{1}{\left(\frac{r_i}{r_o}\right)\frac{1}{h_o}+\frac{r_i}{k}ln\left(\frac{r_o}{r_i}\right)+\frac{1}{h_i}}$
- UA = $U_oA_o = U_iA_i$
- q = UA∆T = $U_oA_o\Delta T = U_iA_i\,\Delta T$
- $\Delta T = \dfrac{\Delta T_2-\Delta T_1}{ln\left(\frac{\Delta T_2}{\Delta T_1}\right)} = \Delta T_{ln}$ the logarithmic mean temperature difference (LMTD).



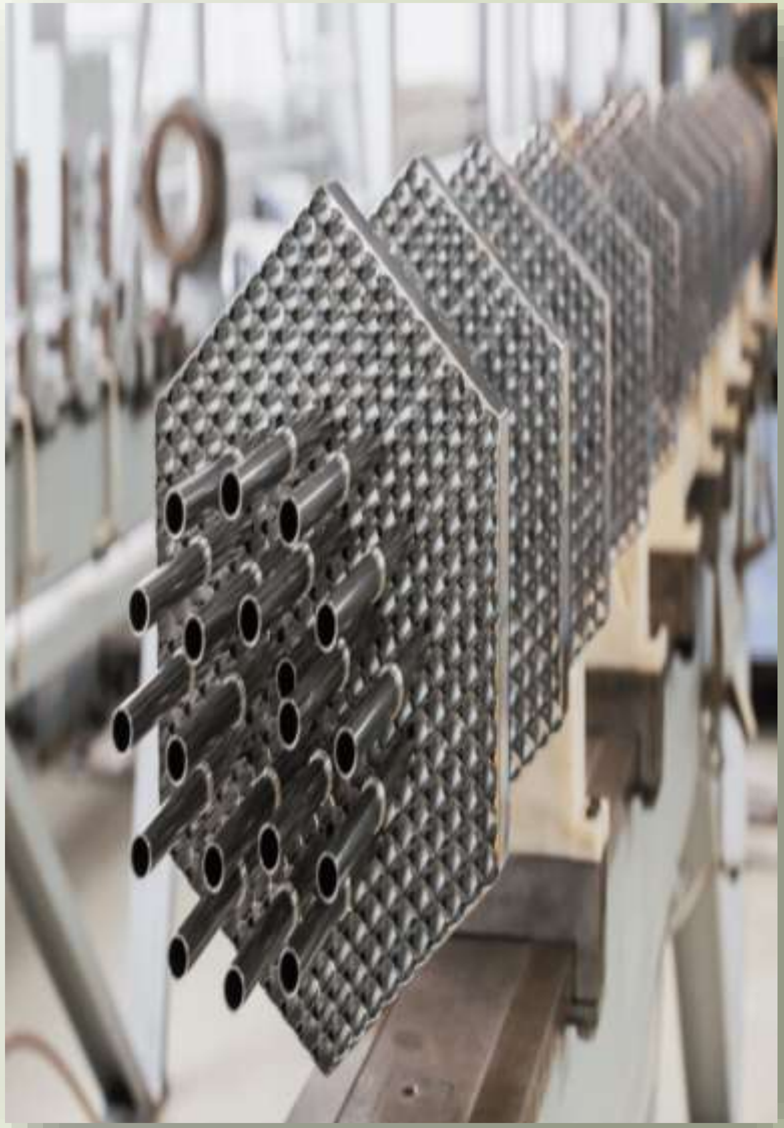
$\Delta P = f(L/D) *(\rho V^2) = \rho ghl$, The Darcy-Weisbach equation

Where:

- ∆P − Pressure Loss, N/m^2
- hl −frictional head loss, m
- L − pipe length, m
- D − pipe diameter, m
- V− average flow velocity of fluid (= Q/A), m/s
- g − acceleration due to gravity = 9.81 m/s^2
- f −friction factor, a dimensionless empirical factor that is a function of Reynolds Number (Re = DVρ/µ), where
- ρ −fluid density, kg/m^2

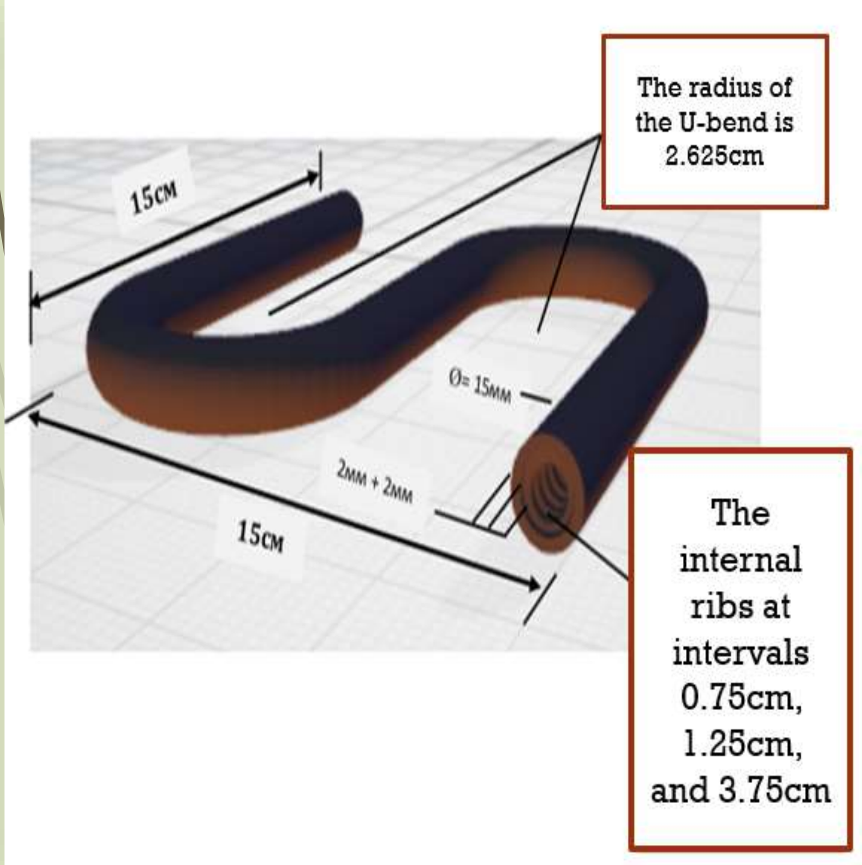
The heat exchanger effectiveness (NTU)

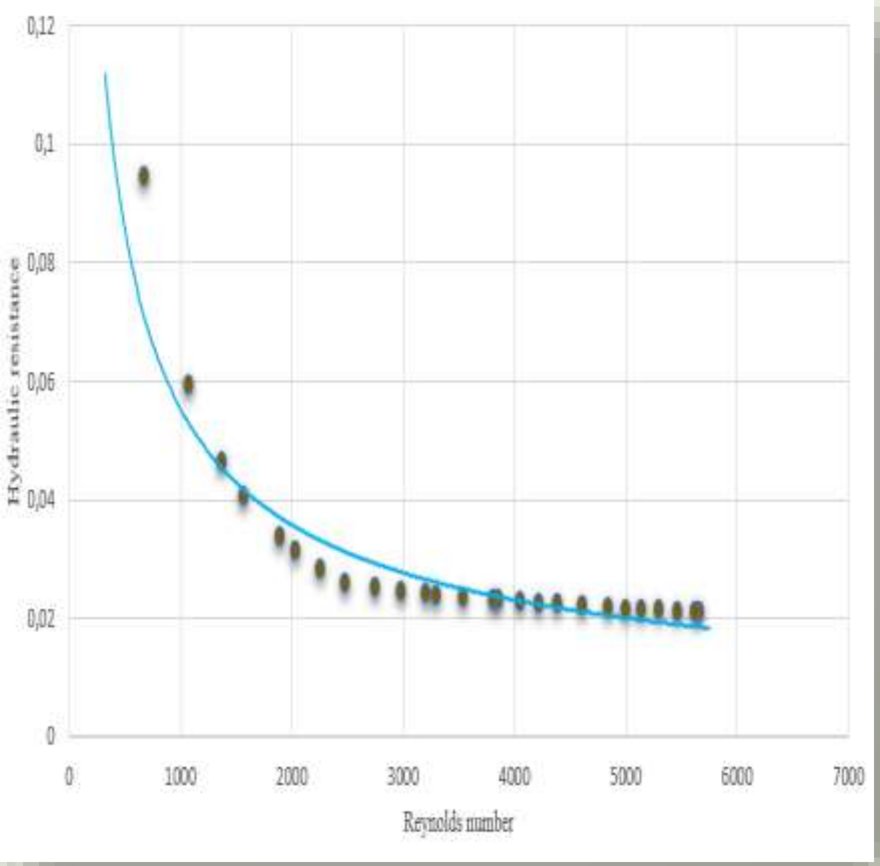
- $\varepsilon = \frac{q}{q_{max}}$
- Where: 0 ≤ ε ≤ 1 and ε = 0 (evaporation & condensation)
- q : Actual heat transfer
- q_{max} : maximum possible heat transfer is that which would result if one fluid underwent a temperature change equal to the maximum temperature difference (T_{hi}- T_{ci}).
- $\varepsilon = \frac{1-exp[-\left(\frac{UA}{C_{min}}\right)\left(1+\frac{C_{min}}{C_{max}}\right)]}{1+\frac{C_{min}}{C_{max}}}$
- Number of Transfer Units may be considered as a heat exchanger size factor:
- NTU = $\frac{UA}{C_{min}}$ **Kern Method, Bell Delaware's Method.**



Current research on an S-ribbed heat exchanger

Prediction of hydraulic resistance curves of an S-KR heat exchangers using the generalized analysis method.





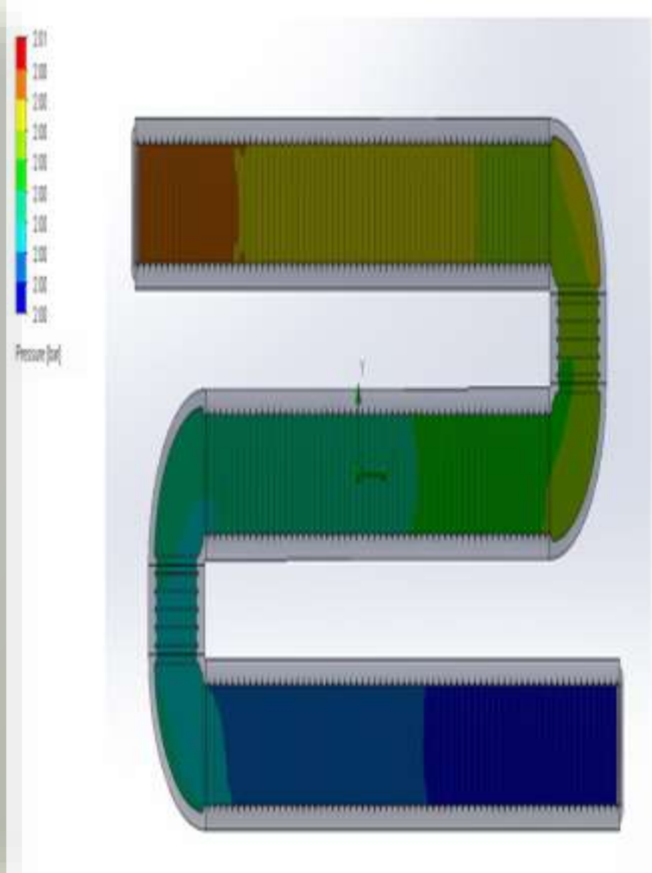


Illustration of the pressure distribution in an S-Ribbed heat exchanger

Current research on an S-ribbed heat exchanger

Nuclear engineering lab - NNSTU

Conclusion

Analysis of the design of nuclear reactor heat exchangers must indicate that the wall temperature that decreases with increasing time constant of the wall temperature. While the variation of secondary wall temperature increases with increasing time at various fluid heat transfer time constants. Moreover, the variation of the secondary wall temperature with time at various perimeters has to be studied and analyzed.

Thank you for your attention

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