**New short-cut methods for the heat transfer in shell and tube heat exchangers**

My name is Hansjürg Sigrist. I was born in 1943 and grew up in Visp (Switzerland), a village in the German speaking part of the Rhone valley, not far away from the highest snow-covered peaks of the Swiss Alps. After my school-leaving examination I enrolled at the Technical High School (ETH) in Zurich where I got my diploma at the Institute for Process Engineering in 1969. At that time the institute was still under the leadership of its founder, Professor Peter Grassmann.

For my first job I joined Sandoz in Basel (Switzerland), where I was mainly responsible for process evaluation and pilot tests for the dyestuffs division. In 1981, I changed to Lonza, also domiciliated in Basel. The company’s largest production site is in Visp where I had grown up. Founded in 1897 as a producer of fertilizers, Lonza’s main activity today is in the production of fine chemicals and active pharmaceutical ingredients. I was a project leader for new multipurpose production plants for pharmaceuticals and agrochemicals. My major responsibilities included: developing concepts, organizing detailed engineering, supervising cost, meeting deadlines, and, last but not least, preparing the technical performance acceptance tests before the start-up with chemicals.

In my professional career I got the opportunity to deal with problems relating to heat transfer, my favorite subject. When we had asked for offers, the size of the heat exchangers often diverged very much. In such cases it was indispensable to carry out our own estimates to come to the right decision. Due to time constraints we had to focus on simple calculations; sometimes we even were forced to invent new short-cut procedures.

It had always been my intention to try and update one or the other of the methods created by myself in order to improve the practicability and to publish the results. After my early retirement I found enough time to investigate this subject further. Thanks to some dedicated work I am pleased to present new heat transfer theories for two very different applications:

- A short-cut method to obtain estimates of shell-side heat transfer coefficients of shell and tube heat exchangers for liquids, both for bundles with and without baffles.
- A calculation method which allows to deal with condensation processes where the condensable vapours contain non-condensable inert gases. The latter components in the gaseous mixture are the reason why the capacity of a condenser is significantly reduced already at low inert gas concentrations.

In the reports the methods are described in detail and documented by several layout examples for each configuration. Both theories are unconventional and easy to use. Relatively few inputs are required. The adjacent abstracts offer additional information. You may also contact me under hjuerg.sigrist@bluewin.ch.

After a credit transfer of EUR 200.– I will send hardcopies of the two reports to your postal address, either in German or English.

Heat transfer on the shell-side of liquid/liquid shell and tube heat exchangers

One of the author’s aim was to find a new short-cut method for the thermal dimensioning of shell and tube heat exchangers. The novel idea was to carry out estimates of shell-side heat transfer coefficients for liquid/liquid-applications on the basis of proven equations which originally had been designed for the heat transfer inside tubes. The concept works, if one multiplies the non-dimensional Reynolds-number Re by a correction factor, named Do.

For the factor Do an equation with Re as only variable could be established. Do includes the fact that in the range of low turbulent or laminar fluid flowing conditions the heat transfer on the shell-side is getting better and better compared to the transfer rate in a straight circular tube, thanks to the higher complexity of the shell-side geometry.

The result of Do-Re is decisive, whether the flowing conditions are either laminar (Do-Re<1000) or turbulent (Do-Re>4000). To compute the non-dimensional Nusselt-number Nu for each range a well-proven equation was selected; a formula of E. Schlinnder for laminarity and one of H. Hansen for turbulent conditions. As already mentioned, these formulas had been designed for the heat transfer inside tubes. To use it also for the shell-
side, Do-Re has to be employed in the equations instead of just Re. In the transition range \(1000<\text{Do-Re}<4000\), \(\text{Nu}\) has to be calculated with the lever principle.

Finally, the heat transfer coefficient \(\text{Alpha}\) has to be multiplied by another factor, called \(Z\), to include also the influence on the heat transfer by different geometric parameters. \(Z\) does not base upon experiments, but it reflects the anticipated trends. Should particular tests give reason to adaptations, these will presumably not have a mayor effect.

On this basis two calculation methods could be established which are analogue as far as possible. One refers to tube bundles with segmental baffles, the other to bare bundles. The physical properties and the throughput of the fluid must be known. Additionally just 6 geometric dimensions for bundles with baffles, respectively 5 for bare bundles, are needed to achieve good estimates for liquids of the shell-side heat transfer coefficient.

Within the range which was systematically checked (relevant fluid velocity max. 2m/s; Prandtl-number 3\(<\text{Pr}<500\)), mean variances of about +/-6% for bundles with baffles (reference method: E.E. Ludwig) respectively about +/-9% for bare bundles (reference method: D.A. Donahue) were found.

**Condensation of vapours, especially under the presence of inert gases**

In a second report a calculation method is presented which allows to deal with condensation processes, notably condensation of vapours containing non-condensable inert gases. Yet low concentrations of inerts cause significant reductions of the heat transfer capacity.

The new method is based upon the assumption that the degree of the heat transfer reduction can be reproduced by just two variables, i.e. the velocity of the gaseous phase and the concentration of inerts in the vapour/gas-mixture.

At the beginning one has to elaborate the mass and energy balances over the whole temperature range of the condensation process. This will allow to calculate the energy which has to be removed in each temperature increment. By the way, this is by far the most complex step of the whole procedure.

After that the first assumption of the expected size of the heat exchanger has to be taken.

Then the heat transfer coefficient \(\text{Alpha}\) as it would be without inerts has to be computed. To this Nusselt’s film theory is appropriate for the condensation both on horizontal and vertical surfaces, in as well as outside the tubes. It turned out to be sufficiently accurate applying the physical properties of just the main fraction of the condensable vapours.

Afterwards the predefined temperature range has to be subdivided into an adequate number of increments. Using a specifically designed equation with just the two above mentioned parameters it is possible to evaluate factor \(K\). This factor expresses the reduction of the heat transfer coefficient \(\text{Alpha}\) as it was evaluated for pure vapours.

Considering also the additional relevant terms to evaluate the overall heat transfer coefficient \(k\) such as heat transfer coefficient of cooling medium, heat resistance of tubes and fouling-factors, the required area per section can be calculated. The overall size of the heat exchanger follows from the addition of all sectional areas.

The procedure has to be iterated, if the resulting transfer area deviates too much from the assumed exchanger size.

In the report the new calculation method is described step by step. A couple of examples show that the obtained results are in good accordance with the respective literature.

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**Summary**

The new short-cut methods allow the user to carry out thermal layouts of shell and tube heat exchangers for liquid/liquid applications and for condensation tasks. The author would like to put a special highlight on the method to design condensers for vapours containing inert gases. All calculation procedures are transparent and easily programmable on personal computers.