Why do we need a European Standard on Shell and Tube Heat Exchangers?

When I started working for an important Italian Pressure Vessel and Heat Exchangers manufacturer (around 50 years ago) **I only knew that a shell and tube heat exchanger was some kind of metallic container, generally filled with tubes, with two fluids coming into it: a cold fluid, which should come out less cold, and a hot fluid, which should come out less hot**. Of course, making a walk into the shop, my ideas about the subject began to be less approximated; nevertheless, it took some time before I could understand that **the tubes are generally grouped together into a tube bundle, and attached to one or two discs completely filled with holes, called tubesheets**; and it took some more time before I could understand **the meaning of those funny groups of characters (AES, BEM, BEU, AKT, etc.)** which are **a compact description of the internal arrangement of the exchanger**, capable of giving the designer some more information about its characteristics (straight tubes or U-tubes, removable bundle or fixed bundle, etc.). But every time I asked the old engineers sitting in the Design department some technical question about shell and tube heat exchangers, the answer was always **the same: "Look in the TEMA standard"**. Well, this was really the usual way in which old designers liked to transmit their experience to young engineers: in fact, when my questions were concerning other types of pressure vessels, or specific vessel components like shells, flanges, domed or flat ends, the usual answer was: **"Look in the ASME code"**. So I started to understand two different things: first of all, that, **at that time, all pressure vessel and heat exchanger technology could only be found in American standards**; and secondly, that in the Design department of a pressure vessel manufacturer **people are too busy to transmit their experience to young engineers** (by the way, today this situation remains still unchanged, except for the fact that most manufacturers have simply disbanded their design departments, thus preferring to buy calculations and drawings elsewhere).

In any case, **at that time Pressure Vessel technology In Italy, in France, in Benelux, in Spain and in Portugal was really based on American sources**, although different alternative methods were developed in German speaking countries (Germany, Austria and Switzerland): but certainly, **the chemical and petrochemical industry had exported to Europe most chemical processes, so imposing the use of American standards** for the construction of new plants. Moreover, **the use of English as standard communication language in Europe made easier the diffusion of all American pressure vessel standards**. The result was that the various national pressure vessel laws and standards, although with different inspection and certification procedures, were all based on the same American sources. However, **the coming into force of the Pressure Equipment Directive (PED) and the effort made by the European Commission to promote the use of the harmonized European standards has progressively changed this situation**: so that the relatively new European Unfired Pressure Vessel standard EN 13445 has largely taken into consideration calculation and inspection methods based on European sources (including in these sources also the experience made in the former East Germany and other Eastern European countries). It should also be noted that **the Pressure Equipment directive is based on safety criteria that are completely different from those used in USA**: just to simplify the problem, in **USA the safety is based on the punctual respect of all the minimum details of the standard**, while **the PED doesn't make reference to any standard (not even the harmonized one), but always requires a risk analysis** taking into account all the conditions in which the equipment will find itself during its entire service life (service, testing, transport, erection, maintenance, exceptional, etc.).

However, even if it is now progressively increasing in Europe the number of contracts where users and engineering companies are specifying to manufacturers (together with the PED, which is imposed by law) the relevant harmonized standards, **for shell and tube heat exchangers also the TEMA standard (TEMA = Tubular Exchanger Manufacturers' Association, now arrived at its 10th Edition) is always specified**, although the present situation is substantially different from the situation existing 50 years ago: **50 years ago in the ASME code there was nothing about the calculation of heat exchanger**

tubesheets, while now all modern national pressure vessel standards contain a suitable ad-hoc method (and therefore **the TEMA method is now contained in a non-mandatory appendix**, whose residual presence in the standard is justified by the following sentence: "***The following rules have been included as a design method for tubesheets for heat exchangers that are not designed per ASME Code. It is not intended that these rules be used in addition to ASME design rules***". In other words: if your design has to be made according to ASME, you are sufficiently safe, but in the opposite case you have better to follow this appendix, which is certainly more reliable than any other design method contained in non-American standards.

All modern European Pressure Vessel standards also contain rules for the calculation of expansion joints, while according to ASME VIII division 1 these components may be designed according to a mandatory Appendix (26), based on another well-known American standard **(EJMA = Expansion Joint Manufacturer's Association)**, however **applicable only for plate thicknesses not above 0,2 inches (5 mm)**; well, **the TEMA standard, which always makes reference to the ASME code for the mechanical calculation of all heat exchanger components, for the particular case of expansion joints which are outside the limits imposed by Appendix 26, provides 17 pages of detailed instructions for a FEM analysis of the joint**: and note that, in theory, if TEMA is specified this FEM analysis should be mandatory.

TEMA provides also **mechanical calculation of supports (saddles, brackets) or lifting lugs**. However, at the end, even in the cases where in a heat exchanger subject to the PED also TEMA is imposed**, it is generally agreed that only the harmonized standard (or possibly another European national standard specified by the user in order to comply with the Essential Safety Requirements of the PED) must be followed for the case of tubesheets, expansion joints and supports**. Some additional calculation prescriptions generally not contained neither in the ASME code nor in any other European Pressure Vessel standard still remain in the TEMA standard: for example, the **calculation of floating head backing devices, or the calculation of channel pass partition plates subject to the pressure drop** of the tube side fluid from the inlet to the outlet.

Therefore **the main reason of specifying the TEMA standard in PED compliant heat exchangers has very little to do with calculations**: unless you consider, as part of the Heat Exchanger design, the prescriptions to avoid thermal or performance problems: that is, **inlet areas into shell and bundle to be provided in order to avoid tube erosion, correct spacing of sealing strips and other devices in order to prevent bypassing of the bundle, maximum kinetic energy of the streams flowing through the nozzles, tolerances between bundle and shell, between baffles and shell, and between tube holes in the baffles and tube outside diameter**. Note that **the thermal design, generally made by well-known ad-hoc software programs (HTRI, HTFS, etc.) is always based on the said tolerances**, which therefore must be respected in order to assure the thermal performance. And, **certainly the most important prescription, the calculation of tube natural frequencies in order to avoid tube vibrations**: the method given by TEMA, although slightly modified in the a.m. thermal design programs, is not contained in any Pressure Vessel standard, but it is of fundamental importance, considering that tube vibrations today are the most frequent cause of heat exchanger failures.

Other sections of TEMA are very important for the correct performance of the exchanger: for example the **mechanical tolerances to be considered for tubesheet drilling**; while the **tables giving the correct spacing to be provided around bolts** are the basis for an economic design of the main (non-standard) flanges, considering that flange dimensions are conditioned by such spacing.

However, it must not be forgotten **that TEMA is a standard (as the name itself says) elaborated by heat exchanger manufacturers: whose interest is certainly to provide safe and durable products; but of course, the attention is not completely addressed to reduce their cost**. Just an example: for a class R (=Refinery) exchanger, a shell of 39" ID (991 mm) made of Carbon or Low-alloy steel must have a minimum thickness of 11,1 mm, whichever is the pressure; while a shell of 40" ID (1016 mm) must have a minimum thickness of 12,7 mm; and for both of them the designer must provide a corrosion allowance od 3,2 mm, whichever is the fluid contained in the exchanger. Apart from the fact that the standard doesn't say anything about the minimum thickness of a shell with an ID of 1000 mm (11,1 mm, 12,7 mm or should we interpolate?), even considering a corrosion allowance of 3,2 mm and a joint efficiency of 0,85, at 250°C a thickness of 12,7 mm for a carbon steel shell in P265GH EN 10028.2 according to EN 13445.3 is adequate for a pressure of 19 bar, while for a pressure of 10 bar 8,32 mm are sufficient (note that replacing EN 13445.3 with ASME VIII division 1 and the EN material with the ASME equivalent SA 516.60 we get almost the same thickness).

In other words: **TEMA is very conservative and not completely adequate for the use in Europe**. This was the reason why **EPERC has proposed, in the recent program provided by the Commission for the preparation of new harmonized standards, the creation of an EN standard equivalent to TEMA**, based on EN 13445 and not on ASME, but including all the prescriptions of this standard (tube vibrations, tolerances, etc.) that are really valid in order to assure a correct mechanical design and also a correct thermal performance. **The new standard should possibly be prepared by a group of experts in which not only manufacturers, but also users, engineering companies and notified bodies should be represented.**

Well, the discussion with CEN and the Commission is already started. But I was really surprised in learning, during the discussion, that **an EN standard on shell and tube heat exchangers already exists: it is called EN ISO 16812, with the title "Petroleum, petrochemical and natural gas industries – Shell and Tube Heat Exchangers"**. The content of the standard (not more than 10 pages) is very simple, and could be summarized in the following statement, placed at the beginning: ***"This document supplements API Std 660, 9th edition (2015). The technical requirements of this document and API Std 660 used to be identical. In the meantime API Std 660 has been technically revised as API Std 660, 9th edition (2015). The purpose of this document is to bring it up to date, by referencing the current edition of API Std 660 and adding supplementary content."*** In other words: "*this standard is a carbon copy of the American standard API 660 (API = American Petroleum Institute). If you want to know something more, look at API 660*". Of course, it is not a scandal that an American standard has been converted into an ISO standard: it is remarkable that, in order to do this, **a cosmetic revision of the original API standard has been made, for example converting the original American "customary" units into SI units, and mentioning EN 13445, together with ASME VIII division 1 and 2, not in the normative references, but simply in the bibliography**. Except for this, **API 660 is full of normative references to other American standards (including TEMA)**, some of them also already converted into ISO standards. Moreover, **the prescriptions are generally more stringent than those contained either in TEMA or in EN 13445**.

But how is it possible that this American standard is now become an EN standard? This is because of the so called **"Vienna agreement", between CEN and ISO**, which provides that a standard made by any one of the two organizations can be automatically taken by the other one, of course after a specific decision of both organizations. I do not know the details of the decision taken in the specific case: I only know that **the matter was handled by CEN TC12 "Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries"**, which now has been interested to the possibility of preparing a new standard which may be in conflict with EN ISO 16812. In any case, **I really do not remember to have seen this standard among the specifications of any European contract for shell and tube heat exchangers**: on the contrary, as already said above, I have almost always seen the TEMA standard within the contract specifications (which, at the end, means that **the European industry considers the TEMA standard a better reference than API 660**).

Moreover, I wish to draw the attention of the responsible people to the fact that **the latest revision of the Vienna agreement between CEN and ISO was made in 2001, that is, before the coming into force of the**

Pressure Equipment Directive: therefore, in my opinion, any EN standard concerning pressure equipment should have been investigated for possible non-compliance with the Essential Safety requirements of the PED. This is particularly true for EN ISO standards, many times based on American standards.

Coming back to the proposed new EN standard for Shell and Tube Heat Exchangers, I think that **it is now urgent for CEN to resolve the conflict with EN ISO 16812**. Failure to do this, would make impossible for the Commission to consider the new standard in the program for the preparation of new harmonized standards.

I hope that the European industry (manufacturers, users, engineering companies and notified bodies) will assist in order to solve the problem, and will also give a positive contribution of their experts in the preparation of the new standard.

Milano, 7.10.2022 Fernando Lidonnici