Choosing Materials of Construction for Pilot Plant Equipment and Piping

Published on April 4, 2017

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This demonstration-scale hydromet plant designed by Hatch and executed by Zeton had 13 different wetted materials of construction.

If you are in new process territory and corrosion service is a known risk, you cannot trust the charts or the experts. A corrosion metallurgist needs to know more about the composition and other conditions of each stream than you likely know at the outset of a pilot plant design project in order to give you reliable advice. From our hard experience, whenever possible we recommend accelerated corrosion testing done at the lab scale prior to making final materials selections for the pilot plant. If possible, select a material completely immune to the type of corrosion you may face in the pilot, so you can pursue the pilot program in safety and confidence. This is doubly true for mechanisms which may produce localized corrosion such as pitting, stress cracking or the like. The additional investment required to build pilot equipment from an alloy with known resistance is modest relative to the risk an uncontrolled corrosion-related failure.

Sometimes, the design life of the pilot equipment is short enough to make the corrosion risk of using a more standard material acceptable. The alternative to going to a truly resistant alloy may be periodic preventative replacement of pieces of equipment, which may be the best option for off-the-shelf equipment but can be a real problem when these items are custom built for purpose.

Be aware that the experience in your laboratory batch reactor may not accurately simulate the conditions experienced in all parts of a continuous pilot plant over the long term. The first compartment in a CSTR train, or the first few diameters downstream of a chemical injection point, encounter conditions continuously which might be experienced only for seconds to minutes in a batch. Your history of hundreds of batch runs may therefore have given you only a few hours of meaningful experience in those sections of the pilot plant.

Scaling Metallic Materials for a Pilot Plant

Keep in mind that the available selection of metallic materials for a pilot plant is more limited than for a commercial system. Similarly, it is a mistake to assume that a pilot plant must be made of the same material as the current commercial concept to give adequate risk-mitigation on scale-up. A special alloy that you may be thinking about for the commercial plant is probably not available in less than full mill runs of pipe or fittings, especially at the smaller sizes, and may not be available in tubing at all. This means that fittings or even pipe may have to be fabricated from bar stock. While there is always a justification for selecting "unobtainium" as a material of construction for your pilot plant, it is usually a mistake arising from inflexible thinking.

Any metallic material you select will be significantly more expensive and less readily available than the common grades of stainless steel at the pilot scale for valves, instruments and lines, and often for equipment as well. An example is the use of duplex or super-duplex grades of stainless steel or 6% molybdenum austenitic grades. These materials may be the right choice for even pilot equipment once it is beyond a certain size, and can offer great economic advantages relative to high nickel alloys or titanium at the commercial scale. But once you're down into tubing, the savings versus nickel alloys or titanium frequently evaporate.

In our experience, the relative cost factors found in commercial plant fabrication (and found in the cost comparison tables presented by vendors of alloys and pipe and fittings) dramatically underestimate the installed cost differences actually observed in pilot-plant fabrication. Figure 1 compares the historical, industry accepted, scoping-level commercial scale ratios of the cost of piping systems (Perry & Green, 1984, p. 106) versus those encountered in a pilot-plant design study from roughly 9 years ago. Clearly, the comparative cost between various candidate materials of construction is scale-dependent, and also varies with time as alloy constituent prices fluctuate.

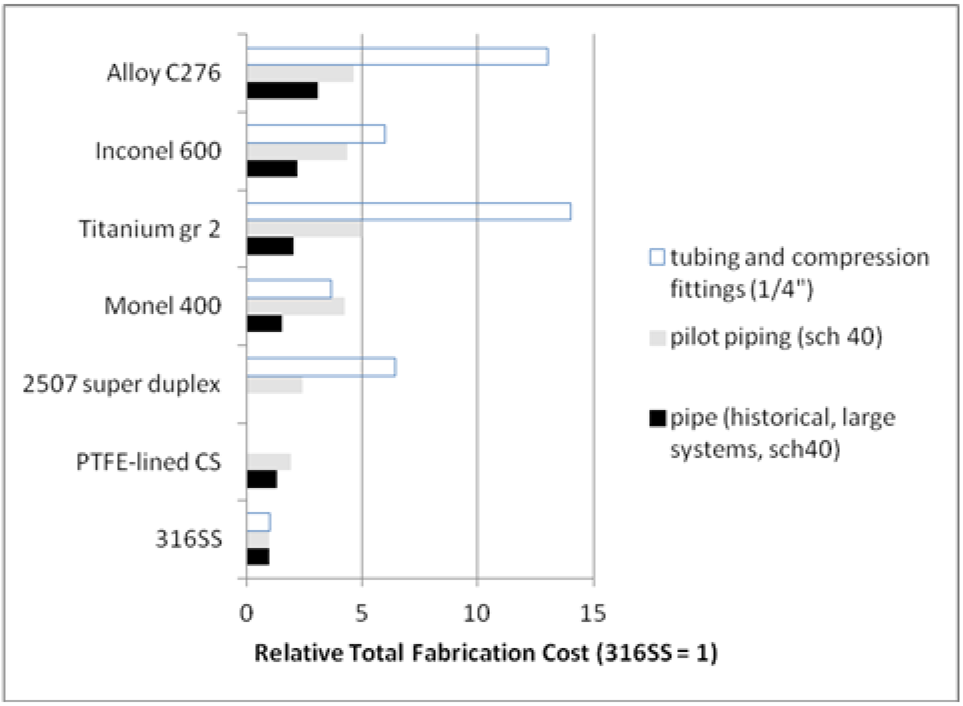

Figure 1. Comparison of total procurement and fabrication cost for various piping materials of construction

Corrosion Protection and Prevention in Pilot Plants

If a knowledge of the service life of materials of construction is key to the success of the pilot program, we recommend constructing the plant from the commercially-standard alloy that best suits the corrosion service requirements for the durability period of the plant and the use of corrosion coupons and/or electrically insulated test spools for materials testing.

Methods of corrosion protection, such as acid brick lining, exotic alloy cladding, electrochemical protection, and lined pipe, are also scale-sensitive methods, infeasible below a certain physical size for practical reasons. The use of solid resistant materials or alternative lining methods and materials must be pursued for pilot projects below a certain size out of physical necessity.

Pilot plant lines are frequently built in tubing, which offers significant advantages in terms of fabrication cost and operational flexibility relative to welded piping. However, in corrosion service, it is important to realize just how little meaningful corrosion allowance is available in a tubing line before rupture. This is another reason to consider selecting a more resistant alloy than you might ordinarily consider.

Special Considerations for Titanium

Titanium and its alloys are extensively used in pressure hydrometallurgical pilot plants, one of many areas of Zeton's practice in the chemical process industry. Among its various other properties, titanium in direct pressure-bearing service has a safe allowable stress that is strongly de-rated with increasing temperature to the code limit of 315 ˚C.

Figure 2 shows the strong temperature dependence of safe allowable stress (S) for commercially pure titanium. The saturation pressure for steam (P) is plotted alongside for comparison purposes. These factors combine such that modest changes in operation temperature can have significant effects on required wall thickness (proportional to the ratio P/S). The effect is most pronounced for pilot plants, where the use of titanium as a lining may be physically infeasible due to the small size of the vessels in question.

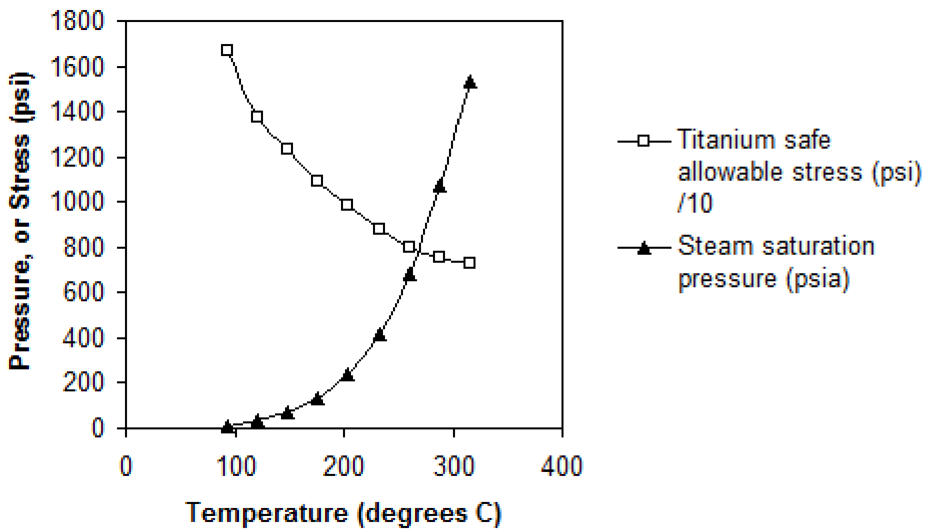

Figure 2. Titanium safe allowable stress (ASME B31.3) versus steam saturation pressure