



TITANIUM BENEFITS

**Tony Terranova, Greg Dunn, and Charly Hulswitt,
Titanium Fabrication Corp, USA, discuss the
practical aspects and benefits of titanium surface
condensers for process plant steam turbines.**

Vendor engineers and plant users' process engineers need to work closely together if long term maintenance free cost effective designs are to be developed. This article examines the respective details that need to be considered for this to be achieved in the process sector condensers and reviews the general applications for steam surface condensers.

Steam surface condensers used in the power and process industry can be summarised but are not limited to the following:

- Power (both utility and cogeneration).
- Chemical processing/petroleum refining.
- Air conditioning.
- Sugar refining.

Typically, condensers fall into two basic categories, as shown in Figure 1. The differences are outlined in Table 1.

Impact of past specifications on operating life and maintenance

Over the past 50 years suppliers have provided a multitude of different condenser designs to plant operators. The possible variations on design, materials and construction are endless, and the following are but a few of the possible examples:

- Tubes, tubesheets and waterboxes in a variety of materials.
- Different types of tube to tubesheet joint arrangements.
- Anodic and cathodic protection in various materials.
- Single and multi pressure units (rectangular condensers only).

Table 1. Comparison of condenser types		
Type	Round (cylindrical) condensers	Rectangular condensers
Surface area	Typically maximum of 65 000 ft ²	65 000 - 200 000 ft ² for fossil fuel and nuclear power plants
Size	30 - 120 in. diameter and 30 - 60 ft long	Usually 20 ft wide x 20 ft long x 30 - 60 ft long
Power rating	Usually 35 - 50 MW turbines	75 - 200 MW (maximum) turbines for CCGT. Up to 1000 MW for fossil fuel and nuclear power plants
Application	These are attached to steam turbines that act as drivers for compressors and pumps	Used in fossil fuels, gas, nuclear plants. The condenser collects steam and many condensed drains during both operation and startup

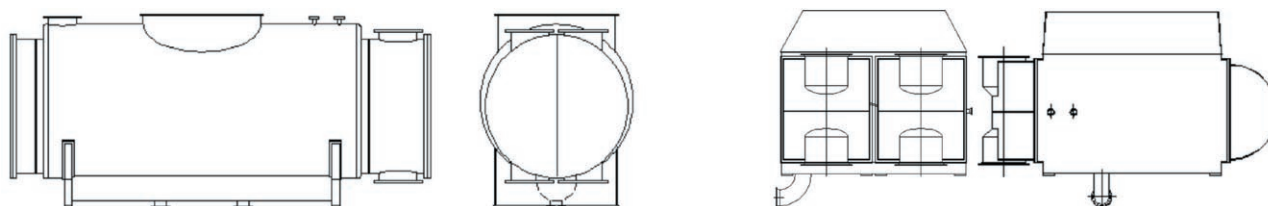


Figure 1. Typical round steam surface condenser for process service (left). Typical rectangular steam surface condenser for power plant service (right).

- Hotwells use any of the following geometries: bathtub, rectangular, and cylindrical pots.
- Steam dump systems with varying capacities.

Over the years many advances in condenser technology have been made by designing condensers using:

- Titanium and austenitic and ferritic stainless steels tubes.
- Titanium and SS and special alloy AL-6XN tube sheets.
- Special clad tubesheets.
- Advanced and new methods of fixing the tubes to the tubesheets.
- Specialist online tube cleaning equipment.

The objective has been to construct new or rebuild existing condensers that have a high availability and maintainability to reduce downtime and expensive maintenance. The end result has been:

- Many old condensers have been retubed with the same or different tube materials.
- Many old condensers have been reconstructed with different tube, tubesheet and waterbox materials.
- It is now often difficult for the plant operator to assess a meaningful framework to create an optimum scope of supply for repair, refurbishment, or replacement of condensers, as there is a much wider range of material and design know-how to consider.

Engineering for low maintenance costs with no downtime

The design and material solutions illustrated in this article are primarily intended for process round surface condensers as some of the recommendations with respect to waterbox design are not economically practical for the larger rectangular condensers.

Steam turbine drives, and their associated condensers, will continue to be a major prime mover in the process sector for ethylene, methanol, PTA and many other plants. There are thousands of round surface condensers installed on steam turbines worldwide.

The design of these systems is important in terms of both process economics and environmental impact. Design of the surface condenser is of particular importance. The condenser has a major influence upon the energy efficiency of the whole system. Choose the wrong condenser design/configuration and the operating costs incurred are in orders of magnitude greater than the capital price of the unit.

With the ever increasing cost of forced outages and pressure to maintain operating profits, it makes sense to consider using surface condensers that have been evaluated considering the long term cost benefits of virtually no maintenance.

Practical considerations

When a specification is developed for a steam surface condenser, the requirements of the process engineer are often encapsulated in the 'process specification' for the equipment. This is what the equipment vendor receives and what forms the basis for the subsequent equipment design. It is here that the engineering system falls down because the process engineer has usually made decisions without any reference to their impact upon the equipment design. It is at this grassroots stage of the project that the vendors' engineers and plant user's process engineers need to work closely together if long term maintenance free cost effective designs are to be developed.

Typical condenser specification scenarios

Condenser design is generally conducted against a process specification, including cooling water inlet

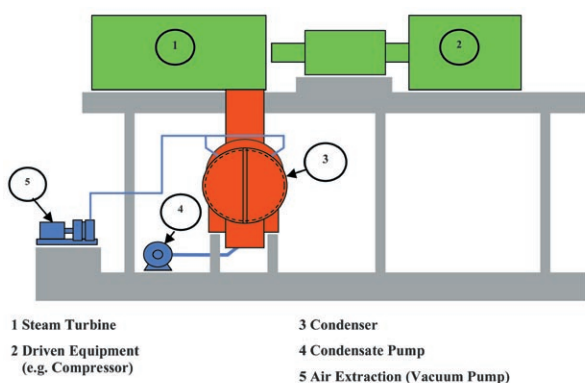


Figure 2. Typical steam surface condenser process application.

temperature, steam flowrate and cleanliness factor. Design is then conducted with the aim of condensing the required steam flow whilst achieving a specified vacuum. The steam flow and the vacuum achieved controls the power generation of the turbine.

While design is conducted for a specified operating condition, the actual plant will in reality rarely operate at this condition. The cooling water inlet temperature may be subject to seasonal variations and to fouling. The demands made for power will vary; and thus so will the flow of steam to the condenser. Changes in fouling resistance, cooling water temperature, steam flow (etc.) all affect the performance of the condenser. Once a condenser has been constructed the engineer can do little about the installed surface area or materials of construction. Furthermore, once the cooling water pumps have been purchased and installed the designer is restricted in what can be done regarding the cooling water flow. Therefore they will be locked into a design that may result in costly maintenance and downtime, simply because the original capital cost was evaluated as low (or acceptable to the purchaser's procurement department).

In addition, at this point the condenser may be far larger than it needs to be due to over specification of fouling factors as a result of having to limit the tube side velocity within the recommended range for the selected tubes. Table 2 illustrates typical velocity ranges for a variety of tubes. It is also well established that the minimum self cleaning velocity is 3 ft/s.

Fouling: the self fulfilling prophecy

Traditionally, steam surface condensers have been designed with a cleanliness factor of 75 - 85%. However, because many of these applications are now for process, these units are being viewed as standard heat exchangers and given exorbitant fouling factors for their design. The result is a condenser up to twice as large as necessary, and tubeside velocity is very low due to all the 'required' area. This large exchanger is likely to foul faster than the smaller unit with fewer tubes. The



Figure 3. Steam surface condensers for refineries.

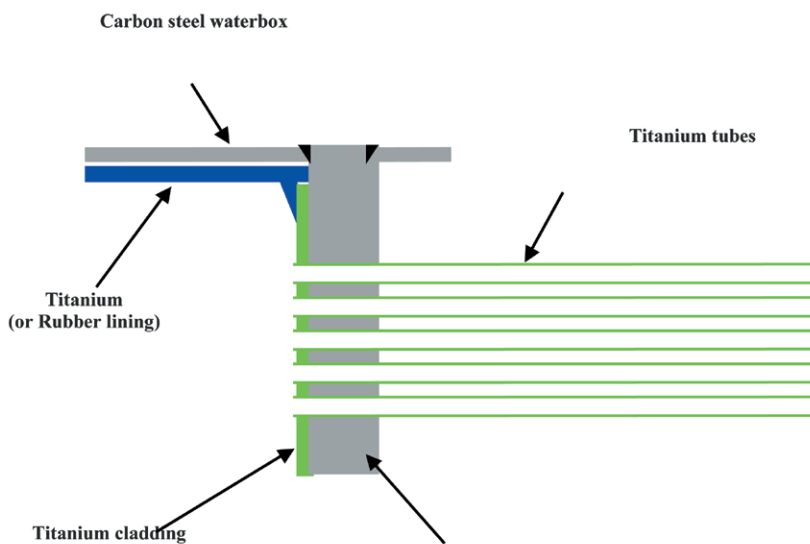


Figure 4. Illustration of typical CS/titanium explosively clad tubesheets.

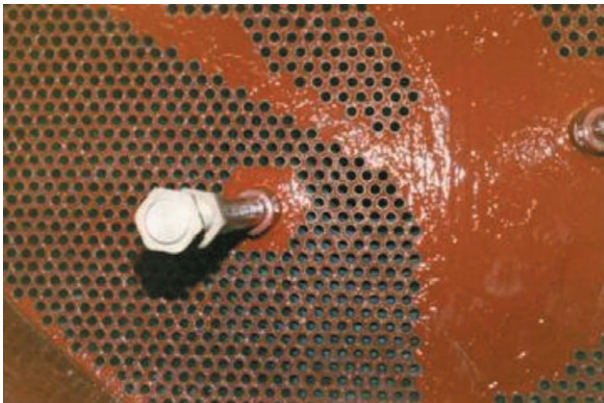


Figure 5. Conventional epoxy coating.

high fouling factor essentially created the fouling. An experienced surface condenser supplier will be able to identify such issues during design. This can usually only be changed at the early stages of the project however, and only with good communication between user and supplier.

Considerations when designing low maintenance surface condensers

Gaining familiarity with designs will provide the condenser designer with the ability to understand the effect of each parameter on the overall size, estimated capital cost, and the impact that material selection has on future maintenance requirements. Some examples include:

- The tube side cooling water velocity for process plants should be 6 - 8 ft/s and higher. Lower tube velocities can result in higher degrees of fouling from deposits. Excessively high velocities can result in tube side erosion and normally unacceptable pressure drops.
- The length of the tubes (longer tubes result in smaller shell diameters and lower cost units).
- The diameter of the tubes and tube gauge (the thinner the tubes the smaller the unit).

- The type of tube material (best to use materials that provide greatest resistance to erosion).
- The cooling water flow rate (best to use the highest flowrate possible to maximise velocity).
- The steam load to be condensed (this is specified by the steam turbine supplier).
- The steam inlet flow to the condenser shell (radial costs less to fabricate than axial entry).
- The number of passes (least number of passes is best for maintenance and capital cost).
- Divided or non-divided waterbox (divided allows cleaning one side with other side in operation, but it is more expensive to fabricate).

Low maintenance materials

Titanium is generally perceived to be an expensive material, which often leads the process engineer to specify what a 'more economical' alternative. However, the superior resistance of titanium to both corrosion and erosion allows for the use of very thin walled tubing. In addition, the maximum velocity that the cheaper material will accommodate is much lower than that permitted with titanium. The result of using lower cost material can be a larger and heavier condenser and one that may be more prone to problems such as:

- Tubeside fouling.
- Tube failures due to erosion and corrosion.
- Tube to tubesheet joint failures.
- Tubesheet pitting and erosion.
- Waterbox or tube/tubesheet failures due to galvanic corrosion.

The choice of cheaper material may result in both a more expensive unit and much greater lifetime costs with many costly forced outages. Correctly designed systems can only be achieved if process engineers and equipment vendor designers work together in an effective and efficient manner.

Recognising this, Titanium Fabrication Corporation (Ti-Fab) has used its extensive experience in the fabrication of titanium equipment and inhouse experienced engineers to develop new and replacement condensers using Ti-Fab design software programs to ensure:

- The most cost effective designs are achieved.
- Low cost maintenance is designed for.
- Proper system flexibility is achieved.

Case history

The gas compressor steam surface condenser shown in Figure 3 handles steam from a coking unit steam turbine at the Motiva Enterprises refinery in Delaware City, Delaware. The unit is cooled with Lower Delaware River water, which has varying levels of salinity depending on rainfall and tidal effects. The refinery was originally built in 1956 and made extensive use of both 90:10 and

Table 2. Industry standard tube velocities as a function of tube material

Tube material	Range	Typical maximum
Admiralty	7 - > 8 ft/s	8 ft/s
Cu Ni	7 - >10 ft/s	10 ft/s
Stainless steel	8 - >10 ft/s	10 ft/s
Titanium	10 - > pressure drop limit	12 ft/s

70:30 copper nickel tubing, aluminium brass and similar materials, which at the time were the refinery industry standard for combating corrosion in saline waters.

The original surface condenser unit's 70:30 copper nickel tubes and aluminium brass water boxes provided a long service life, but tube failures were creating a capacity problem, and frequent unscheduled repair of corrosion of the waterboxes and impairment of boiler feedwater quality necessitated replacement.

Due to the critical nature of the equipment, the refinery needed a replacement that would solve these problems as well as minimise the downtime required for replacement. The refinery elected to build an exact replacement unit, and after consideration of various materials of construction, selected titanium both for tubing and for the waterboxes. Ti-Fab provided adaptive engineering to devise design details utilising a combination of solid titanium, explosive clad, and loose lined construction to provide an integral waterbox.

Tubesheets are explosive clad 5/8 in. Grade 1 Titanium on SA-516-70 carbon steel plate. Joints are grooved for added pullout strength, and seal welded for optimum reliability. The only modification on the shellside was utilisation of close tolerance baffle holes and a reduction of baffle spacing to minimise risk of tube vibration induced by the high cross flow steam velocity.

Figures 5 and 6 illustrate conventional epoxy lined brass tubesheets with aluminum brass tubes compared to the high resistance and low maintenance of CS/Ti clad tubesheets with castellated weld preps with seal welded 22 BWG titanium tubes.

Conclusion

The advantages of using titanium for all the wetted tubeside parts on a condenser are:

- The ability to achieve higher tubeside velocity, resulting in reduced fouling (and smaller fouling factors will result in smaller designs if the reduced effects of fouling are considered at design stage).
- Welded tubes to tubesheet require no maintenance as they are leak free.
- New welding technologies make it possible to weld tubes as thin as 0.016 in. which reduces the required surface areas when using titanium.
- Condensers are lighter requiring smaller support structures at site.
- Titanium tubes, tubesheet and waterbox lining result in no galvanic corrosion.
- No waterbox lining maintenance or repairs are necessary as pin holes and defects that appear in conventional linings do not occur on titanium clad waterboxes.



Figure 6. Example coating failure on condenser tubesheet and waterbox.

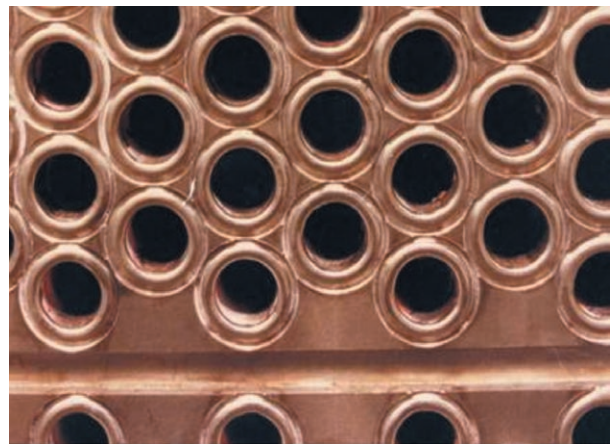


Figure 7. CS/titanium explosively clad tubesheets welded to titanium tubes.

- Reduced tubeside flushing and cleaning requirements as the higher velocities permissible with titanium tubes promote a self cleaning phenomenon at certain velocities.
- There are no erosion or corrosion concerns with titanium.

The use of titanium tubes and CS/titanium clad tubesheet is well established for large (rectangular) and smaller (round) condensers with excellent field experience. However, the application of titanium linings for inside the condenser waterboxes is only practical for round surface condensers. The larger condensers use a wide range of internal linings and coatings which are noted but not limited to epoxy coatings, phenolic coatings, glass flake coatings, and rubber lining.

Protective coatings on the larger condensers have been used for corrosion control. They provide little or no structural strength, but do protect other materials and preserve their strength and integrity. There are currently many excellent coating systems and companies that provide this technology. This article accepts that these technologies have a lot to offer on large condensers due to economic considerations. However, on the smaller process sector condensers there exists the practical option of using a maintenance free titanium liner for the waterbox fabrication. 