Post Weld Heat Treatment Of Welded Structures

The welding process generally involves melting and subsequent cooling, and the result of this thermal cycle is distortion if the welded item is free to move, or residual stress if the item is securely held. There comes a point when the amount of residual stress can create potential problems, either immediately or during the life of the welded structure, and it needs to be reduced or removed. Post weld heat treatment is the most widely used form of stress relieving on completion of fabrication of welded structures. The principle is that as the temperature is raised, the yield stress and the elastic modulus of the material fall. A point is reached when the yield stress no longer supports the residual stresses and some localised plastic deformation occurs.

Effect on Mechanical Properties

The general changes to expect from post weld heat treatment are:
- Yield strength is temporarily decreased slightly
- Tensile strength is decreased
- Ductility is increased and improved
- Hardness levels are reduced
- Toughness is slightly reduced at short times, but the effect can be significant over longer times
- Creep resisting material strength is fully developed

Other advantages include:
- Improved diffusion of hydrogen
- Improved toughness by softening the heat affected zone.
- Improved dimensional stability.
- Better resistance to stress corrosion cracking.
- Reduced effects of cold work.

When to Post Weld Heat Treat

For carbon-manganese steels, post weld heat treatment is mandatory at a thickness of 32-38mm. For alloy steels, that thickness is typically between 13-20mm.

Post weld heat treatment of structural steels and large machines used in the mining industry are almost never subjected to post weld heat treatment.

Most requirements for post weld heat treatment can be found in the fabrication standard to which the vessel is constructed. In Australia, most fabrication standards now refer to AS/NZS 4458 for manufacture, as well as post weld heat treatment.

How to Perform a Post Weld Heat Treatment

There are a variety of post weld heat treatment methods.

Fixed Furnace

Fixed furnaces can heat to approximately 1,200°C and can stress relieve, normalise and anneal. A fixed furnace is generally large, costly operation that has fixed thermocouples that measure the furnace atmosphere temperature rather than the temperature of the article being heat treated. It is usually satisfactory up to around 300°C. Care and observance of manufacturing cooling codes should be taken when using a fixed furnace.

Temporary Furnace

These are custom-built around a vessel, rather than transport a vessel to a fixed furnace. The idea is to minimise the air space between the vessel and furnace walls, and they allow for faster heating and cooling. The basic structure of the furnace should be creep resisting piping (if the pipes are to be continually re-used) with heat resistant materials attached to them. Heating can be through resistant heating mats placed on a concrete floor or via gas burners placed at each end.

Internal Firing

Vessels of suitable dimensions and arrangement of openings can be post weld heat treated by gas firing through nozzles or manways. Manways are large enough to accommodate the gas burners, but care needs to be exercised with the diameter and position of nozzles and expert opinion should be sought.

Care must also be taken to place deflector plates inside the vessel and opposite the burner entry points to avoid direct flame impingement on the shell. It is not advisable to post weld heat treat vessels that contain internals in this manner.

Local Heating

Circumferential weld seams can be post weld heat treated by heating a band around the weld. Although not specifically stated, such heating is essentially limited to resistance or induction heating, mainly because of the controls required on heated band width, width of insulation and temperature measurement requirements.

Thermocouples

The normal chromel-alumel thermocouples perform well for the temperature ranges in heat treatment. Insulated wire types are preferable because they can be attached directly to equipment being heat treated by capacitor discharge. The number and placement of thermocouples is, to an extent, regulated by Standard requirements which must be observed.

Test Pieces

The use of test pieces such as Production Test Plate (PTP) and Coupon Plate are only needed where local post weld heat treatment has been applied and therefore their use is limited to furnace heat treated vessels. Again there are Standards surrounding test piece usage and they must have a separate thermocouple attached.

Non-Destructive Testing

Standards require that all non-destructive testing be carried out after post weld heat treatment, unless the material is not sensitive to heat treatment cracking or it is not a high alloy steel.

Omission of Post Weld Heat Treatment

In a general sense, any alteration, modification or repair to an item of pressurised equipment that was originally post weld heat treated after fabrication needs to be post weld heat treated again after repair.