

Chapter 8. Preheating and Postweld Heat Treating

For certain base metals and weld joints, preheating and postweld heat treating are mandatory in order to produce sound welded assemblies. These requirements should be spelled out in the applicable welding procedure specifications and must be followed during production welding.

Preheating

Heating the weld joint prior to welding may be desirable and may in some cases also be required.

A drying operation is desirable for most metals and is designed to remove surface condensate and other forms of moisture that otherwise could cause porosity or weld cracking. Such a drying operation requires only that the surface be heated to evaporate the surface moisture prior to starting a welding operation.

When preheating is specified, the entire weld joint area should be heated through the metal thickness to the desired minimum temperature. To obtain a uniform temperature through the metal thickness, it is desirable to locate the heating sources on one surface of the metal and to measure the metal temperature on the opposite surface. Whenever heating and temperature measurement must be done from the same surface, the inspector must assure himself that more than just the surface has been heated; the heat must have soaked through the entire material thickness.

In addition to establishing a preheat temperature, an interpass temperature limitation may need to be considered for many materials. These data should be shown in the procedure governing the welded fabrication. Depending upon the metallurgical or mechanical properties of the weldment, or both, preheat and interpass temperature may be specified as follows:

- (1) Minimum temperature only (i.e., mild carbon steel without special requirements)
 - (2) Maximum temperature only (i.e., aluminum and nickel alloys)
 - (3) Minimum and maximum temperatures (i.e., low alloy steels with impact requirements)
- In situations where a preheat temperature has been specified but neither range nor interpass temperatures have been spelled out, it is usually safe to consider the preheat temperature as a minimum preheat and interpass temperature.

When an interpass temperature is specified, the weld area must be checked prior to depositing the next bead. (It does not apply to the temperature at or near a just completed bead.) Welding may not continue if the measured temperature exceeds the maximum interpass conditions specified in the applicable welding procedure; the area must be permitted to cool to the specified upper limit. Accelerated cooling is sometimes authorized for non-air-hardenable alloys such as austenitic stainless steel and high nickel alloys. However, such accelerated

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cooling is not acceptable when welding air-hardenable materials such as the low alloy chromium-molybdenum steels.

While furnace preheating is sometimes employed (as for cast iron), local heating sources, including flames, resistance elements, induction coils, exothermic kits, infrared systems, and quartz lamps, are selected for most preheating operations. When properly employed, all these sources are capable of achieving acceptable results; the selection is usually based on the shape of the component, the number of welds involved, the geographic location of the work, the availability of equipment, and the cost of the operation.

The inspector can evaluate the efficiency of these heating processes by monitoring the process with temperature indicating crayons, paints, or pellets that melt or change color at predetermined temperatures. Some welding procedures, processes, and applications require that such indicators be applied adjacent to the welding groove or be removed prior to depositing the next bead to avoid contaminating the weld. Other tools available for that purpose include thermocouples and surface pyrometers.

Postweld Heat Treating (PWHT)

While PWHT operations can affect the weldment in many ways, the two most frequent requirements involving PWHT are tempering and stress relieving.

In a tempering treatment, the hard areas in the weld and adjacent metal are softened. This can involve a complete softening operation using an annealing cycle during which the metal is heated above its transformation temperature (for steel, about 1650° F [900° C]). This must be followed by slow cooling. Since partial tempering is acceptable for most applications, a subcritical PWHT of about 1150° to 1350° F (620° to 730° C) is most frequently used for carbon and alloy steels.

In stress relieving treatment, the residual stresses created by localized heating and cooling associated with welding are reduced by creep or plastic deformation. Any weld can be expected to retain localized residual stresses equal to the room temperature yield strength of the material. When the equipment designer or

the applicable code considers the retention of such stresses unacceptable, the situation can be corrected by heating the weldment to a temperature at which the yield strength is considerably reduced. At such elevated temperatures, the residual stresses will dissipate or equalize with time to a level equal to a yield strength of the material at that temperature. Thus, the effectiveness or the completeness of the stress relieving operation is increased as the holding temperature or holding time, or both, are increased. To prevent the re-establishment of high residual stresses, slow and uniform cooling is needed.

As indicated above, tempering and stress relieving depend primarily on the holding temperature selected for the PWHT operation. Other factors may contribute to the success of any such operation, including the following:

(1) Holding time must be of sufficient length, since neither temperature nor stress relieving occurs instantaneously. Holding one hour per inch of thickness with a minimum of one hour appears to be a safe concept when no other instructions are available.

(2) The heating area is of special concern during local PWHT. Since spot PWHT causes high localized stresses, the heating of a wide area or a circumferential band is desirable and usually mandated by the applicable code.

(3) Heating of the weld can be very fast, but it should be uniform over the entire area to be treated. A few specifications restrict the maximum heating rate, but the need for such a requirement has not found general acceptance and has not been clearly demonstrated.

(4) Cooling rates and the uniformity of the cooling operation should be specified in detail and executed with care. To achieve specific properties in some metals, accelerated cooling is desirable, but for most components, slow cooling maximizes tempering and minimizes residual stresses. Many PWHT operations have failed to meet their objective due to improper cooling rates.

Applicable codes and specifications, job requirements, and qualification test results govern the specific PWHT cycle. The adequacy of a PWHT operation of carbon and low alloy steels can often be measured by hardness testing. Such

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a procedure is mandated by a few specifications (e.g., ANSI B31.3).

In addition to full furnace PWHT operations, local PWHT equipment is frequently employed. The same processes used for preheating and mentioned earlier in this chapter can be successfully employed for this purpose. However, the use of flame heating is generally undesirable for PWHT operations since uniformity is difficult if not impossible to achieve. A detailed discussion of each process, together with relative advantages and disadvantages, has been presented in AWS D10.10, Local Heat Treatment of Welds in Piping and Tubing.

Cautions

In all heating operations care is needed to assure that the heat sources and the temperature

indicating tools do not adversely affect the weldment. Items of special concern involve:

- (1) Copper, lead, and mercury (this applies to most metals)
- (2) Chlorides and zinc (this applies especially when using stainless steels)
- (3) Sulfur in small quantities (this applies especially when using nickel alloys)
- (4) Sulfur in large quantities (this applies to most metals)

The aforementioned contaminants can deteriorate the weld and adjacent area properties or accelerate the corrosion process. The most severe deterioration will occur when an accidental arc strike or a scheduled welding operation melts the contaminant. Such molten materials can attack or destroy the grain boundaries, resulting in cracks in the weld or the base metal.