# Appendix B
# Temper Bead Welding

Temper bead welding is used to reduce the detrimental effects of exposure to the very high temperatures associated with the welding process. Using temper bead welding creates a weld that has a reduced hardness and lower residual stresses compared with welds created using conventional welding processes.[1] Reducing hardness improves resistance to brittle fracture, stress corrosion, and fatigue. Temper bead welding does not reduce residual stresses in a welded joint as well as full postweld heat treatment. However, if postweld heat treatment cannot be performed, some of its benefits can be obtained by using the temper bead welding technique.

In a typical weld bead, grain coarsening occurs in the parent metal[2] next to the weld, while the parent metal slightly beyond experiences grain refining. The temper bead welding method was developed to reduce or eliminate the coarse-grain regions in the parent metal. Coarse-grained structures have poor resistance to fracture. Coarse-grained structures in the weld metal also reduce toughness, but not to the same extent as in the parent metal.

In the temper bead welding method, first a layer of small weld beads with low heat input is laid to ensure minimum penetration of the parent metal. The technique entails using small electrodes, welding in the horizontal position, and adjusting the angle of the electrode or torch to minimize penetration, taking care to avoid cracking the metal from exposure to hydrogen and lack-of-fusion defects (incompletely fused spots). Successively larger weld beads are placed on top of smaller ones, such that the refined zone overlaps the coarse areas created by the original runs. Sometimes the first layer is slightly ground so that the refined zones of the successive layers line up correctly. The use of successive layers not only refines the grain structure of the parent metal, but each successive layer of weld beads tempers the previous weld bead. Often the top layers above the parent layer are ground off.

The author of the "Gowelding" website states, "Unfortunately, whilst this may appear easy in theory, in practice it can be difficult to achieve. It requires the production of many test weld simulations and metallographic examinations, before sufficient confidence can be gained to perform the actual production weld." According to the Navy repair manual,[3]

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[1] Further information on temper bead welding is found on the "Gowelding" website, which is maintained by a welding professional <www.gowelding.com/met/ temper.htm>, and also on the website of the Welding Technology Institute of Australia <wtia.com.au/>.

[2] The metal of parts to be welded is referred to as the "parent metal."

[3] Navy Technical Manual S9221-C1-GTP-010, 0910-LP-331-5300, "Repair and Overhaul Main Propulsion Boilers," vol. 1, revised February 1991, section 1-4.5.5, p. 1-6.

Whenever stress relief is required by MIL-STD-278, the proper application of stress relief procedures will produce weld metallurgical properties superior to those resulting from the stringer bead or temper bead procedures allowed by this manual for some of the welding on boilers. Repair activities should also be aware that, considering the requirements for temper bead procedure qualification and welder mock up trials, stress relief may in some cases be the more cost effective and timely alternative.

The Navy's temper bead welding procedure for low-carbon steel material up to 1.5 inches thick (weld repair thickness 0.25 to 0.5 inch) is described in its technical manual (chapter 5) as follows:

- Preheat joint to 350° F.

- Use temper bead method, where no postweld heat treatment is required. If the repair area is over 6 inches in length, special approval is required. The procedure is as follows (see figure):

  *Step 1*: Perform first pass using 3/32-inch electrodes over entire joint that was ground and grind welds to produce smooth layer.

  *Step 2*: Deposit second full layer with 1/8-inch rods.

  *Step 3*. Deposit third and subsequent layers with 5/32-inch rods, making sure not to overlap tie-in points.

  *Step 4*: Grind off reinforcement until flush.

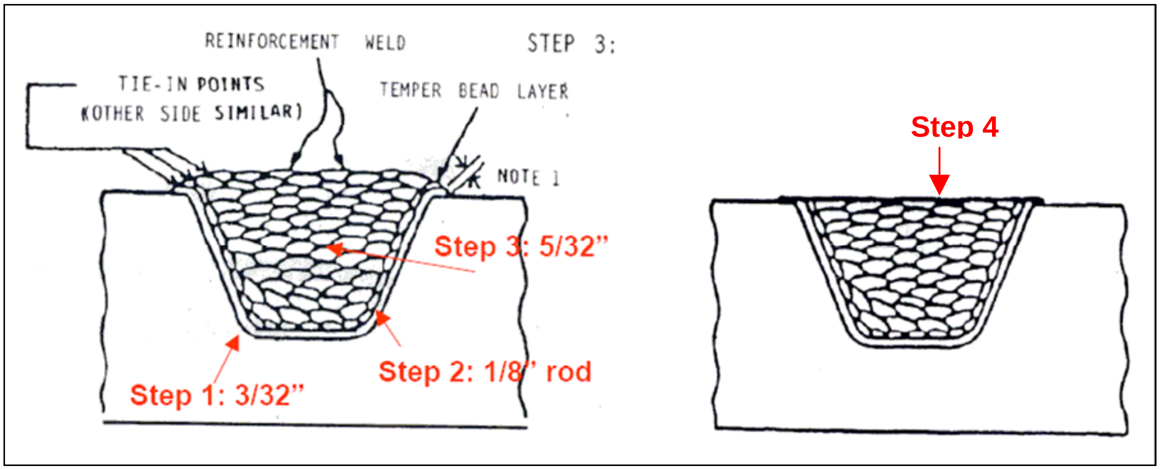


**Figure.** Navy's temper bead welding procedure, steps 1-3 (left), step 4 (right).

According to Lloyd Werft working instructions dated October 26, 1987, the weld procedure used on the *Norway*'s boilers was as follows:

The area of weld and a surrounding area of at least the drum wall thickness to be preheated to approximately 150° C [302 °F]. Such preheating will be done by

> means of resistance heating. Temperature control will be effected with thermocouples at inner side of drum.
>
> Welding additive will be a welding rod "E Mo B" to DIN 8575 of the trade mark "SH Schwarz 3 MK." Welding to be done in string layers.
>
> Once the prepared area has been filled up, so-called hardening layers will be welded using material different from the base metal. These hardening layers will subsequently be worked off again.

The Lloyd Werft procedure does not mention the size of the rods, the heat input, or how the layers are to be deposited. Further, there is no indication that a qualification plan was used to show that the welders were capable of welding the boiler geometry, or that actual weld coupons were made to show that the welders could do the job. By comparison, when the boiler tubes were welded in place (in 1999 and 2002), the weld procedures were very specific, with evidence that qualifications trials were performed and passed. No evidence or substantiation of a welding procedure was found to show that repair welds 11 feet long were acceptable and would not affect the life of the boiler. (According to the Navy's procedure, repair welds exceeding 6 inches in length require special approval.) Although the headers of boiler Nos. 21, 22, and 23 were welded, only header 21 appeared to have been ground flush.