



Design File

Pay Attention to Tack and Temporary Welds

Practical Ideas for the Design Professional by Duane K. Miller, Sc.D., P.E.

Introduction

Ever noticed how sometimes the smallest details can cause the biggest problems? This situation can be compounded when a variable or factor is considered insignificant and accordingly ignored. Such can be the case when tack welds and temporary welds are improperly made.

AWS A3.0 Standard Terms and Definitions defines a tack weld as: “A weld made to hold the parts of a weldment in proper alignment until the final welds are made.”

The term “temporary weld” is defined as: “A weld made to attach a piece or pieces to a weldment for temporary use in handling, shipping, or working on the weldment.”

The clear difference is that the tack weld joins “*the parts of a weldment*,” whereas the temporary weld joins “*a piece or pieces to a weldment*.” Thus, a temporary weld will always join to the weldment something foreign to the weldment proper.

The term implies, but the A3.0 definition does not actually mandate, that temporary welds have a limited life. Specifically, the definition does not require that the weld be removed after its function has been performed. However, the implication is that after the weld and the associated attachment have performed their function during “handling, shipping, or working on the weldment,” the attachment and the associated weld will be removed. Thus, the weld that joins a lifting lug onto a weldment could be either a permanent weld (if the lug was to remain in place for future handling of the weldment) or a temporary weld (if the lug was to be removed after handling the weldment). In these two situations, the welds may be otherwise identical, but they are called by different names.

Semantics and definitions aside, the important issue is this: both tack welds and temporary welds must be properly made. Since there are no secondary members in welded construction, improperly made tack or temporary welds

may create problems that result in the propagation of cracks into main members. Further, temporary welds may provide the metallurgical path for cracks (if present) in attachments to propagate through the weld, into the main member. Accordingly, these seemingly unimportant welds may be critical, especially in weldments subject to cyclic loading. Let’s look into the issues that should be considered when tack and temporary welds are designed and fabricated.

Same Quality Required

In general, the same quality requirements that would apply to final welds should apply to both tack and temporary welds. The *AWS D.1.1: 2002 Structural Welding Code—Steel* requires this in 5.18.1, which states “Temporary welds shall be subject to the same WPS requirements as the final welds.” For tack welds, 5.18.2 reads “Tack welds shall be subject to the same quality requirements as the final welds...” The provision goes on to list some exceptions, to be discussed below. But the basic starting point for tack and temporary welds is that they are to be of the same quality as the final welds.

More on Tack Welds

The A3.0 definition does not define the length or size of a tack weld, but rather addresses the purpose of the weld. This definition does not, nor should it, preclude the use of a continuous weld in the root of a joint. It does not, and again should not, mandate a certain maximum size for the tack weld. Colloquial usage would suggest, however, that a tack weld must be small, and intermittent. But as we will see, small intermittent welds may be undesirable in some circumstances.

Tack welds may be placed within the weld joint, and then subsequently welded over with the final weld. Alternately, tack welds may be made outside the weld joint. For welds made within the weld joint, the tack weld may be complete-

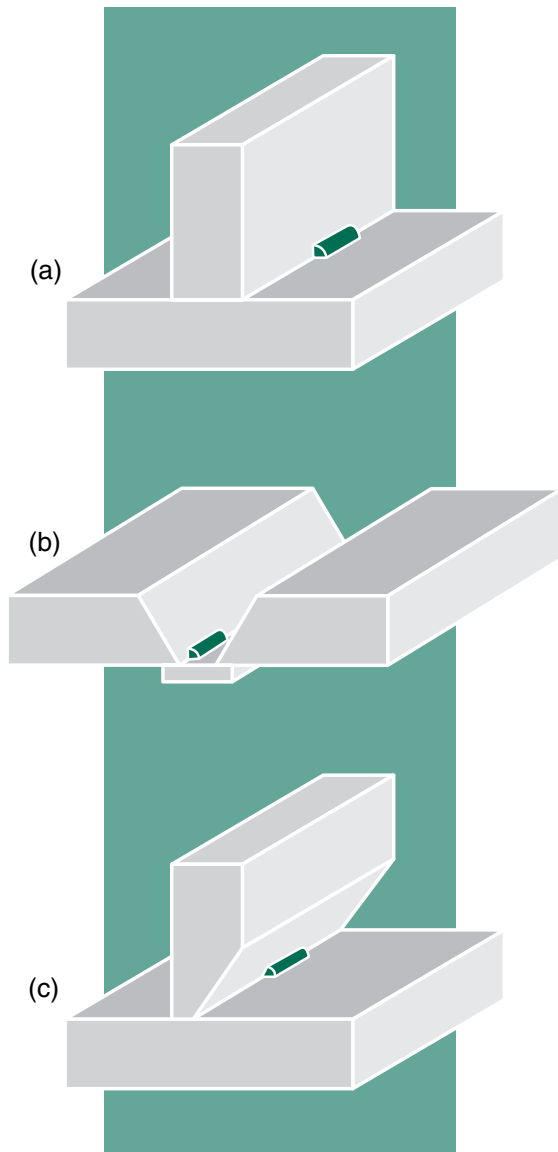


Figure 1. Tack welds in joints.

ly remelted and become part of the final weld. Alternatively, part or most of the tack weld may remain within the joint, and become part of the final weld. Tack welds made outside the joint may remain in place, and become part of the permanent weldment, or they may be removed after the joint has been partially or completely welded. The placement of the tack weld, its relationship to the fill passes in the weld, and the final disposition of the tack—all will affect how the tack weld is to be treated.

A tack weld must be sufficiently strong to resist the loads that will be transmitted through it. Some weldments have

individual components that are massive, and the weight of such parts may be transferred through tack welds while the weldment is handled during fabrication. Careful sizing of tack welds that are used for this purpose is essential. Tack welds are often required to hold parts in alignment while assemblies are being preheated for final welding. Thermal expansion, the corresponding strains, and resultant stresses may necessitate tack welds of significant strength. The strength of tack welds, like other welds, is proportional to the throat size, and the length. Thus, a stronger tack weld may be made by making it with a larger throat, or longer length, or both. In most cases, tack welds are intermittent, and the strength across the joint can be made greater by increasing the number of intermittent tack welds, even to the point of a continuous tack weld. Other factors, discussed below, should be considered when determining whether the tack weld should be made longer, or larger, when additional strength is required.

Tack Welds Within the Joint

Examples of tack welds within a joint, shown in Figure 1, would include:

- A tack weld in a T-joint that will receive a final fillet weld
- A tack weld in the root of a CJP groove weld preparation that attaches the steel backing
- A tack weld in the root of a PJP groove weld preparation

In each case, the final weld is placed over the tack weld. The subsequent weld passes may totally remelt the tack weld, and significantly reheat the surrounding heat affected zone (HAZ). Or, the following passes may partially melt the tack weld, and reheat the surrounding HAZ, but the reheating may be to a level such that the previous HAZ properties are not much changed. The first condition will be referred to as “remelted tack welds” and the second as “incorporated tack welds.” Fundamentally different approaches should be taken to remelted versus incorporated tack welds.

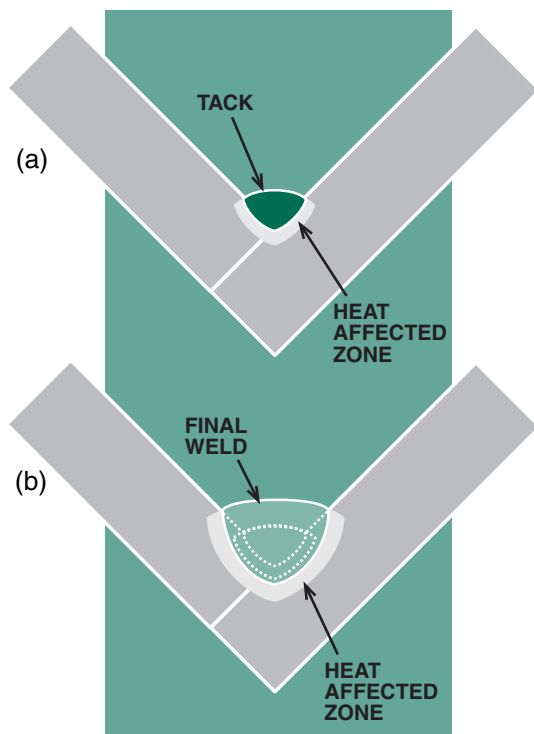


Figure 2. Remelted tack welds.

Remelted Tack Welds

The basic concept behind remelted tack welds is that the subsequent weld passes will effectively eliminate all evidence that the tack weld ever existed (see Figure 2). Accordingly, it is reasonable that quality criteria associated with tack welds that will be remelted would be more relaxed than for the situation where the tack welds become part of the completed weld. This is reflected in D1.1 as follows:

5.18.2 General Requirement for Tack Welds. Tack welds shall be subject to the same quality requirements as the final welds, with the following exceptions:

- (1) Preheat is not required for single-pass tack welds which are remelted and incorporated into continuous SAW welds.
- (2) Removal of discontinuities, such as undercut, unfilled craters, and porosity before the final SAW is not required.

The two exceptions apply only for the conditions of (a) remelting and incorporation, and (b) subsequent welding by SAW (submerged arc welding).

It should not be assumed that remelting will automatically occur when SAW is used. With the high amperage levels typically associated with larger electrode diameters, remelting may routinely occur. However, SAW may be performed with smaller diameter electrodes, composite (cored) versus solid electrodes, DC- polarity, long contact tip to work distances, lower current levels, and other conditions that may inhibit the ability of the SAW process to remelt tack welds.

Nor is it appropriate to assume that other welding processes cannot remelt tack welds. Electroslag (ESW) and electro-gas (EGW) are obvious examples of deep penetrating processes where tack welds are expected to be remelted. While D1.1 does not permit the consideration of other welding processes for remelting tack welds, for work not governed by codes with such a restriction, the capability of other processes could be evaluated. The AWS/AASHTO Bridge Welding Code D1.5: 2002, for example, recognizes the remelting capability of ESW and EGW and extends the exception to these processes as well (D1.5: 2002, 3.3.7.1[1]).

Heavy sections of steel, and higher strength steels with their corresponding higher carbon and/or alloy levels, typically require preheat. Maintenance of WPS (welding procedure specification) preheat levels is required for tack welds, unless the exception conditions are met. Even though a small tack weld on non-preheated thicker sections may result in a hard, crack sensitive heat affected zone around the tack weld, the high heat input levels of SAW passes that remelt the tack welds will also reheat the HAZ. If the HAZ created by the tack weld is heated above the transformation temperature, and permitted to slowly cool, the hard, crack sensitive HAZ will be softened. Discontinuities in the tack weld that will be remelted are not a concern, as the remelting process eliminates the discontinuities as well.

If the intent is to remelt the tack weld, then the tack weld should be made with a geometry that is conducive to remelting. Remelting is facilitated when the tack weld is relatively small. Large tack welds are more difficult to remelt, and excessively large tack welds will not be remelted even with high energy SAW procedures. Thus, to gain the required joint strength with tack welds that will be remelted, emphasis should be placed on making small welds that are longer in length. Not only will this encourage remelting of the tack weld, it also minimizes the tendency to disrupt the surface appearance of the final weld.

Incorporated Tack Welds

When tack welds are placed within the joint and not remelted, they are automatically incorporated into the subsequent final weld (see Figure 3). When this is the case, the tack weld should be treated in a manner much like the root pass of a final weld: everything associated with an incorporated tack weld should be the same as would apply to the weld root pass. The preheat, filler metal selection, WPS parameters, weld size, heat input, and the quality of deposit should meet the same standards as would apply to the root pass. In terms of quality, this would include undercut levels, porosity limits, bead shape criteria, and the absence of cracks. Remember: these tack welds will be incorporated, and therefore, will be part of the final weld.

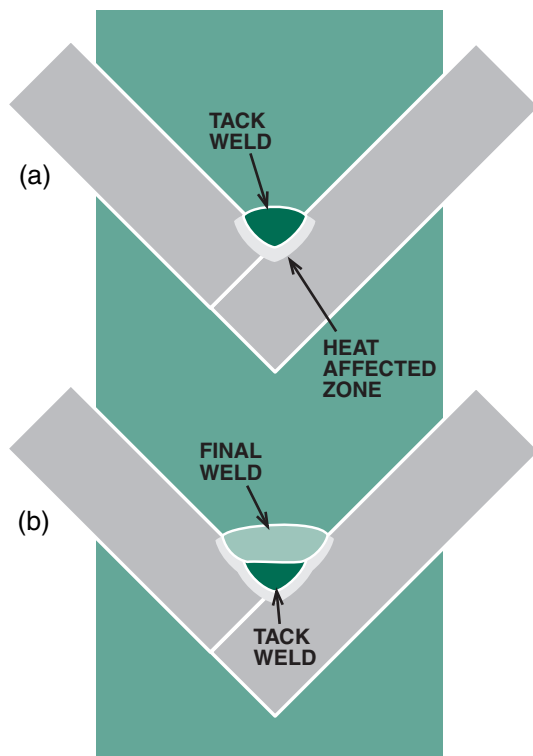


Figure 3. Incorporated tack welds.

A major shift in thinking is required when tack welds are to be incorporated, as compared to the remelted alternative. For example, incorporated tack welds should be made of a size, and with a heat input level, that will ensure good fusion. These welds should meet the minimum size requirements that would be imposed on any final weld. This will naturally result in larger sized tack welds than was encouraged for remelted tack welds. Thus, for a required joint strength, incorporated tack welds will be larger in size, but perhaps shorter in length, as compared to the remelted option.

Large, intermittent tack welds may require that the gaps between the tack welds be completely welded before the subsequent layers are made. Welding over large tack welds may disrupt the arc, or may affect the appearance of the subsequent final weld. The ends of the tack weld may be points where fusion into the weld root is difficult to achieve. Thus, the acceptable geometry of the tack weld is dependent on the ability of the final weld procedure to properly incorporate the tack weld into the final weld. This is the reason, for example, that 5.18.2.1 of D1.1 requires that multipass tack welds have cascaded ends.

Considerations for Both Types of Tack Welds

Irrespective of whether the tack weld will be remelted or incorporated, the interaction of the tack weld and the final weld must be considered. Tack welds are often made with

a different welding process, or even when the same process is used, with a different filler metal than will be used for the final weld. Chemical interactions between the two types of materials should be considered.

Some self shielded flux cored arc welding (FCAW-S) filler metals will have slag removal problems when welding over tack welds made with certain shielded metal arc welding (SMAW) electrodes. The electrode manufacturer can be contacted for a list of compatible electrodes.

A second type of interaction that must be considered is the potential effect of intermixed weld metals on mechanical properties. The Charpy V-notch toughness of subsequent final passes of normally tough welds may be reduced due to negative interaction with tack welds made with welding processes using a different shielding system. The typical combination that should be investigated is when FCAW-S is used to tack weld under non-FCAW-S deposits, such as SAW, or gas shielded FCAW. This does not mean that all combinations are unacceptable. However, these should be investigated on a case-by-case basis. The James F. Lincoln Foundation publication *The Fabricator's and Erector's Guide to Welded Construction*, available as a free PDF download from www.jlff.org, addresses a variety of combinations.

Tack Welds Outside the Weld Joint and Temporary Welds

When tack welds are placed outside the weld joint, and for all temporary welds, other factors must be considered. Simply put, these welds too should be treated as any final weld. They should be made with materials, procedures, techniques and quality levels that would be acceptable for final welds. Tack welds outside the weld joint fit into two categories: permanent, and removed. Temporary welds, by definition, will be removed.

Permanent Tack Welds Outside the Weld Joint

Tack welds outside the weld joint must be evaluated to determine if they can remain in place without causing unintended consequences. Of necessity, D1.1 places this responsibility on the Engineer as follows:

5.18.2.3 Nonincorporated Tack Welds. Tack welds not incorporated into final welds shall be removed, except that, for statically loaded structures, they need not be removed unless required by the Engineer.

Thus, for statically loaded structures, the normal practice will be to leave such tack welds in place, unless otherwise indicated by the Engineer. For dynamically loaded structures, such nonincorporated tack welds would be removed.

Removing Tack and Temporary Welds

Consider the potential tack welds that could be used to attach longitudinal backing under a CJP groove weld. One option would be to tack weld the backing in the root of the joint as shown in Figure 1b. This may pose some practical problems, prompting the need to tack weld the backing outside the joint. Intermittent tack welds would be sufficient to hold the material in place, as shown in Figure 4a. This would be an acceptable option under D1.1 for statically loaded members. However, if the same member was put into a cyclic loading situation, the intermittent tack welds would behave as Category E fatigue details, greatly limiting the allowable stress range. An acceptable alternative (although not one specifically given in 5.18.2.3 of D1.1) is to make a continuous tack weld, which would behave as a Category B detail, much like the longitudinal CJP groove weld (Category B) shown in Figure 4b.

It is good to remember the adage “There are no secondary members in welded design” when evaluating the suitability of leaving in place tack welds that are made outside the weld joint.

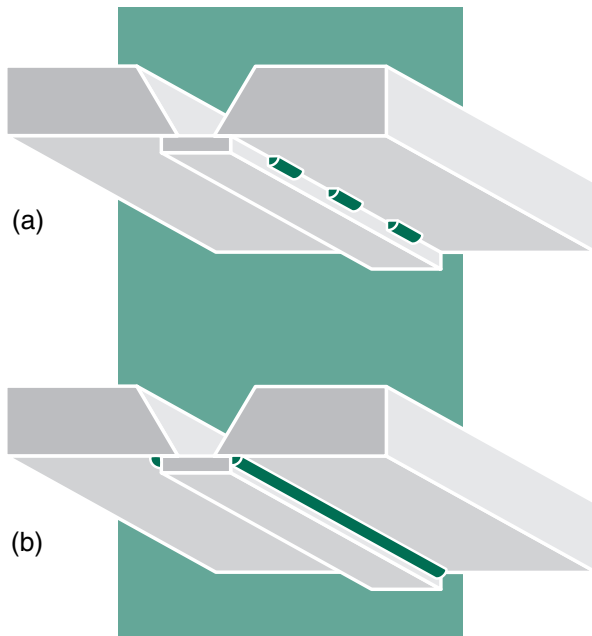


Figure 4. Non-incorporated, intermittent (a) and continuous (b) tack welds.

When tack welds are required to be removed, and when temporary welds are removed, it is important that the weld be fully removed *without damaging the base metal*. A typical approach is to thermally cut the weld or attachment off (using air arc gouging, oxy fuel cutting, or plasma cutting), and follow up with grinding. When cutting is performed too close to the final surface, one may inadvertently gouge the base metal.

The procedure described above assumes, however, that the tack weld, or the temporary weld, was properly made in the first place. Consider the improper procedure wherein a tack weld is placed outside the joint, but the weld is made without preheat, or the needed minimum heat input, or with an improper electrode. Such a procedure could result in an underbead crack, an excessively hard HAZ, or other weld defects. Simple removal of weld metal from the surface of the steel will not automatically remove the defect that may reside in the base metal. This can result in performance problems for the weldment, particularly when subject to cyclic loading.

In the case of Fracture Critical Members (FCMs), D1.5 requires that, when weld removal is required, the weld plus 1/8 in. [3mm] of adjacent metal be removed. The surfaces are faired in at a slope not steeper than 1 in 10 on the surface (see D1.5: 2002, 12.13.3). This conservative provision ensures that the whole weld, plus any affected base metal, is completely removed, along with any unacceptably hard or cracked material.

Summary

Neither tack welds nor temporary welds should be viewed as inconsequential, secondary welds, particularly when applied to cyclically loaded weldments. Whether the tack weld is to be made in the joint or not will affect the overall approach to the weld. If it is made in the joint, whether the tack weld is to be remelted or incorporated will determine the ideal configuration for that tack weld. For tack welds and temporary welds that will be removed, care must be taken to protect the base metal. There are plenty of opportunities to make tack and temporary welds improperly. Fortunately, it is not difficult to make them correctly. ✨