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Field welding of pin studs in black liquor recovery boilers

Scope

This Technical Information Paper (TIP) provides guidelines for achieving an acceptable level of weld quality in field application of pin studs in black liquor recovery boilers. Owners and applicators may agree to modify these guidelines as they deem necessary and reasonable in order to more closely meet the needs of their particular situation.

This document is divided into two sections: the first covers the welding of pin studs (or “studding”) on bare tubes (see NBIC Code Part 3, Section 3 “Examples of Repairs and Alterations” 3.3.2.b.), the second covers studding on existing studs or “nubbins” (which is not subject to ASME Code requirements).

Safety precautions

Job safety must always be made a top priority. Studding contractors and welders must be aware of and implement all relevant health and safety rules and procedures in effect for work in and around the recovery boiler. The contractor for studding work should have a written safety program and procedures covering all contractor employees. These should be reviewed by the recovery boiler safety or supervisory personnel.

Background

Pin studs are welded to tubes or membranes in the fireboxes of recovery boilers to promote formation of a thick, anchored frozen layer of smelt to protect the tube surfaces against corrosion. Field stud welding commonly involves arc-welding a solid carbon steel pin stud on a carbon steel boiler tube. Composite studs also are available. Appropriate weld quality is required in order to assure good heat transfer, which correlates to better performance, and to reduce damage to the tube surfaces during stud welding.

Maintenance of studs on recovery boiler tubes is a necessary and costly operation for which quality and procedure related guidelines can improve stud life and reduce the risk of some of the problems sometimes associated with the studding processes. A quality installation requires: weld procedure qualification, welder qualification, proper tube or existing stud surface preparation, mechanical testing and inspection. ASME or NBIC Code rules may apply in stud welding.

Studs and studding equipment

Stud dimensions

The most common cylindrical “pin” stud diameter for field welding is 9.3 mm (3/8 in.). Larger, 12.5 mm (½ in.) diameter studs that are shop applied using a resistance welding process are difficult to apply in the field. If they must be field welded, 12.5 mm (½ in.) diameter studs should be field welded to bare tube surfaces only after careful qualification of the specific welding conditions and welding procedures by the applicator. Studs typically are 19–31 mm (¾ in. to 1¼ in.) long.

Stud life is not linearly related to stud length because long studs soon burn back to a length defined by their

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temperature. Studs must be at least 19 mm (3/4 in.) long for most automatic field stud welding equipment.

Studs that are 9.3 mm (3/8 in.) in diameter have a less favorable mass/area ratio which results in short life cycle and expensive maintenance. A better choice for recovery boilers is to use 12.5-mm (1/2-in.) studs whenever possible.

Stud shapes

Studs are manufactured with three types of welded ends: flat, concave and convex (or spherical). It is important to use studs for their particular design purpose. The flat-end shape is preferable for both bare tubes and nubbins. Convex shape welded ends may be used for bare tubes. Concave studs are not designed for and therefore not recommended for use on bare tubes in recovery boilers. A small aluminum button in the weld end of a concave stud stabilizes the weld arc, but the concave shape mitigates the proper fusion of the button on bare tubes (or nubbins). Spherical or ball studs are unsuitable for recovery boiler tubes. Studs with proprietary designs such as ridges and spike tips are also available.

Stud materials

Studs are made from low carbon steel and Type 430 ferritic stainless steel. Composite and chromized steel studs are special variants. Low carbon steel studs are the most widely used because they are the lowest cost; conduct heat better than stainless steel and avoid weld zone brittleness of ferritic stainless steel. Chromized studs maintain the heat transfer characteristics of carbon steel, while the diffused chromized layer provides corrosion resistance.

Studding equipment

The manual, drawn-arc electric welding process is used to field weld large numbers of pin studs on recovery boiler tubes. This high speed process minimizes tube heating and maximizes weld fusion. The equipment consists of the stud gun, a control unit, studs, ferrules when applicable, and DC power source. Studs may be manually or automatically fed into the stud gun. Major welding variables are welding amperage, welding time, arc length, and plunge. These factors determine the amount of heat input and control weld quality for a properly aligned stud. Stud alignment in manual studding depends on the stud-gun operator's care and attention.

Using electrodes to apply studs to bare tubes should be avoided (as the weld solidifies it shrinks and creates a void at the weld interface) unless the procedure is qualified to achieve the desired results without harming the tube. Welding studs to bare tubes

Welding procedure qualification

Jurisdictional codes, e.g., ASME Boiler and Pressure Vessel Code and the National Board Inspection Code (NBIC), require use of qualified welding procedures by qualified welders. Operators involved in stud welding on bare boiler tubes shall be properly qualified under Section IX of the ASME code and demonstrate their ability to meet the weld quality specifications. Important elements in obtaining stud welds of acceptable quality include using qualified welding procedures; having equipment in good working order that is properly set up, and employing conscientious qualified operators under adequate supervision

Welder qualification

Before studs are applied to boiler tubes, each welder and stud gun combination must perform a qualifying test to ensure adequate weld quality is routinely obtained. Qualifying tests shall be done on separate tube samples or panels, NOT on the boiler tubes in the boiler. At least twenty (20) studs in a row should be installed covering all weld positions involved, for acceptable qualification. Qualifying tests shall be witnessed and inspected by the boiler owner's representative before welding to the boiler tube surfaces is authorized.

Tube thickness limitations

Studding should not be done on a tube surface thinner than 3.0 mm (0.12 in.) when welding 9.3 mm (3/8 in.) studs, and 4.0 mm (0.16 in.) for 12.5 mm (1/2 in.) studs. Minor surface roughness around these limits is permitted and tube thickness must be confirmed by ultrasonic testing.

Cleaning and surface preparation

Tube surfaces to be studded must be clean, dry and free of frozen smelt, rust, scale and other surface contamination, such as ultrasonic couplant. A typical sequence of events consists of:

- Regular water washing of the boiler tubes to remove as much smelt and salt cake as possible.
- Abrasive blasting to SSPC 6 (NACE SP 3) Commercial cleanliness.
- Removing excessively rough surface features deeper than 1.5 mm (1/16 in.) by careful grinding.

Abrasives for blast cleaning shall be low silica sand or other low dusting non-silicaceous abrasives. Other abrasives can be used if the specified cleanliness is achieved. Controlled abrasive blasting typically removes less than 0.1 mm (0.004 in.) of tube thickness. Power wire brushing is acceptable for preparing small areas for studding provided all surface contamination is removed.

Studs cannot be applied to surfaces having a thermal spray coating.

Prepared surfaces must be accepted by the stud installer before any studs are installed. Moderate rust bloom is not a problem but water and other surface contamination is not acceptable.

Stud welding practices

Ferrule welding

Most studs are welded to bare tube surfaces with a ceramic ferrule which contains the welding flash¹ around the base of the stud, and provides both a plunge² reference and physical shielding for consistent arc characteristics. Ferrules come in two basic lengths: short ferrules are used to weld pin studs to bare tube surfaces; long ferrules are used for welding studs to nubbins. Using the wrong ferrule in either situation may produce unacceptable welds. Gun plunge must be properly set for the nubbin and ferrule length and ferrules must be accurately positioned and properly seated for each weld.

Non ferrule welding

Non ferrule stud welding is a faster process but makes it harder to consistently obtain acceptable stud welds on bare tubes. However, ferrule-less welding of 12.5 mm (½ in.) diameter studs is not recommended.

Ferrules should be removed from the studs following application.

Inspection and testing

Visual inspection

Visual inspection confirms the proper stud pattern is achieved and that each stud weld is acceptable. Weld flash does not need to be of uniform height but the weld around the stud should be fully fused into the tube surface with no undercut. Voids in the flash may be due to lack of fusion. Undercut on the tube and voids in the flash must be repaired.

Studs should be aligned reasonably perpendicular to the tube surface. Physical restraints may make it impossible for every stud to be perpendicular to the tube centerline and tilted studs that are not fused around at least 90% of the base are unacceptable. (This may be a particular problem in the corners of the boiler).

At least 50% of the studs should be inspected and studs that do not pass visual inspection marked for mechanical testing, as described below.

¹ Flash is the visible weld metal around the base of a welded stud. This sometimes is referred to as the weld “fillet.”

² Plunge is the distance that the stud-gun retracts under spring pressure as the operator seats the ferrule just prior to initiating the weld sequence. This is normally set at approximately 3.2 mm (1/8 in.) and is critical to the proper formation of the flash. Improper flash formation may be the result of either too little or too much plunge.