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Technical Resources Bulletin

To: SMACNA Members
SMACNA Chapter Executives

From: Technical Resources Department

Subject: **Flat Lock Seam Soldered Copper Joints Study**

The International Training Institute (ITI) commissioned Simpson Gumpertz & Heger Inc. (SGH) to evaluate 1/2 inch wide flat lock seam soldered joints. The industry's current recommended widths are 5/8 inch wide flat lock seams (Architectural Sheet Metal Manual by SMACNA) and 3/4 inch wide flat lock seams (Copper and Common Sense by Revere Copper).

The study investigated the in-service cyclical thermal loads that flat seams typically experience, and to test varying levels of dressing extent, joint gaps, voids in solder, edge seam solder geometry, and solder extent, to help analyze the minimum requirements for meeting the intended service life of 75 years without failure in a 1/2 inch wide flat lock seam.

Study - Physical Testing

All the specimens tested were 1/2 inch wide seams.

The analysis used multi-geographical formats to gather thermal cycling and the amplitude applied to specimens simulating 75 years of in-service of flat seam roof panels. The analysis evaluated stresses on copper roof seams due to thermal expansion and contraction. Seventy-one 16 oz. copper specimens were subjected to this cyclic testing **all** with varying degrees of dressing extent, joint gaps, voids in solder, edge seam solder geometry, and solder extent. No common specimens were tested.

A hydraulic tester was used to apply loads to the specimens according to thermal cycles simulating 75 years or until the specimen failed. There were 5 groups tested in 2 phases.

Phase 1 consisted of three preparation methods:

- Method 1 – pre-tinning of the front and backside of the 1/2 copper pieces, turning them 180 degrees to form hooks, applying flux to the inside of the hook seam on both pieces, hook both pieces and flatten, applying flux to the outside of the seam and then soldering the joint on the side with flux only to sweat solder completely through the joint
- Method 2 – no pre-tinning was done, but otherwise the same actions were followed
- Method 3 – no pre-tinning was done and they "Apply solder to seam at a slightly faster travel pace using approximately 20 to 25 percent less solder."

Phase 2 consisted of two preparation methods:

- Method 4 – pre-tinning of one side of the 1/2 copper pieces, turning them 180 degrees to form hooks, applying flux to the inside of the hook seam on both pieces, hook both pieces and flatten, applying flux to the outside of the seam and then soldering the joint on the side with flux only to sweat solder completely through the joint

- Method 5 – was the same as Method 4 with one exception: "Apply solder to seam at a slightly faster travel pace in order to sweat partially through joint"

Study - Findings

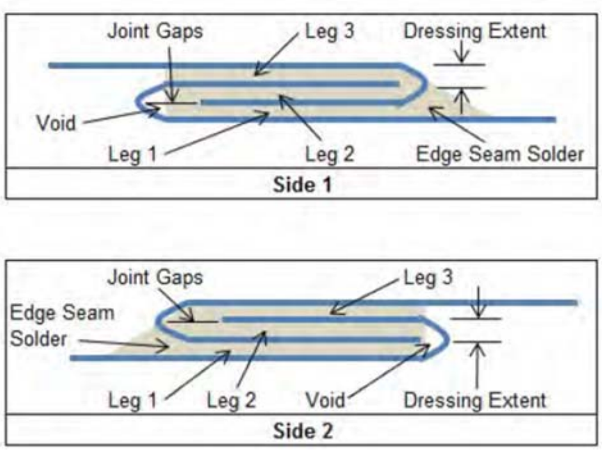
- Method 1 – 10 specimens tested: All completed 75 cycles of testing
- Method 2 – 12 specimens tested: 5 completed 75 cycles, 1 completed 73 cycles, 4 ranged from 37 to 65 completed cycles, and 1 failed at 19 cycles
- Method 3 – 10 specimens tested: 1 completed 75 cycles, 1 completed 61 cycles, 6 ranged from 20 to 45 completed cycles, and 2 failed at less than 20 cycles
- Method 4 – 17 specimens tested: 13 completed 75 cycles, and 4 failed at less than 30 cycles
- Method 5 – 23 specimens tested: All failed at less than 17 cycles

Study - Summary

Two variables were determined to have a direct effect on the in-service life and failure mode of flat soldered copper seams. Based on their testing, solder extent and edge solder geometry both contribute to the ability of the seam to withstand cyclic thermal loading.

Every seam with any degree of solder present in the third leg achieved the 75-year in-service life benchmark. These specimens varied in dressing extent, number of voids in the solder within the seam, and edge solder geometry. Figure 1 shows the four parameters used to evaluate the flat seam solder joints.

Figure 1: Four Parameters for Evaluating Flat-Seam Solder Joints



Twenty-two out of twenty-three specimens with solder present in the third leg achieved the 75-year service life. One specimen that was sweated 90% into the third leg failed during the seventy-fifth cycle. Not all specimens that achieved a 75-year service life had solder present in the third leg.

The specimens had various degrees of dressing extent, voids in the solder within the seam, and edge solder geometry, yet a common characteristic among the seams was a moderate to high amount of edge seam solder present (see Figure 1). The edge seam solder provided additional stiffness to a soldered seam and may extend the life of a seam.

The specimens in Groups 2, 3, and 5 had similar joint evaluation parameters aside from the amount of edge seam solder present. The specimens in Groups 2 and 3 had a moderate to high amount of edge seam solder, and the specimens in Group 5 had no edge seam solder present. The specimens in Groups 2 and 3 completed an average of fifty-nine and thirty-seven cycles, respectively, while the specimens in Group 5 completed an average of ten cycles. The specimens that did not have any edge seam solder present failed after one third fewer cycles than the specimen with edge seam solder present.

While edge seam solder may extend the life of a seam, it cannot be depended upon to provide a reliable soldered seam. The average life of a partially sweated joint with a moderate to high amount of edge seam solder is 48 years. The standard deviation for this set of data was 23 years, indicating that results are highly variable and inconsistent.

<u>Study - Conclusion</u>

Based on analysis and cyclical load testing, the following are recommendations for flat locked soldered copper seams:

1. In seams that are 1/2 inch in width, solder must be sweated into all three legs of the flat lock seam to provide appropriate service life, regardless of the extent of solder into the third leg.
2. In seams that are 1/2 inch in width, soldering only into the second seam leg is not sufficient to provide a long-lasting solder joint. Only 2% of the seams tested with solder in the first two legs achieved the 75-year service life without failure.
3. In seams that are 1/2 inch in width, small voids in the solder at seam bends have marginal effect on service life.
4. In seams that are 1/2 inch in width, within the variances of the samples received, the dressing extent has little to no effect on service life. The majority of the samples received were fully dressed or nearly fully dressed. The worst sample had a dressing measurement of 0.07 in. (1.78 mm).

The prequalification of architectural sheet metal workers per the criteria outlined in the Architectural Sheet Metal Manual published by SMACNA and AWS B2.3 Specification for Soldering Procedure and Performance Qualification, is critical in ensuring a quality, long-lasting flat lock seam installation as the test data proves the most important factor in determining quality of a copper solder seam is the extent of the solder sweated through the seam.

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