National Transportation Safety Board
Office of Research and Engineering
Washington, DC 20594

HWY22MH003

MATERIALS LABORATORY

Factual Report 23-034

April 17, 2023

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A. ACCIDENT INFORMATION

Location: Pittsburgh, Pennsylvania
Date: January 28, 2022
Vehicle: Fern Hollow Bridge
Investigator: Dennis Collins (HS-22)

B. COMPONENTS EXAMINED

Portion of the bottom of leg B1R from the Fern Hollow Bridge.

C. EXAMINATION PARTICIPANTS

Specialist — Adrienne Lamm
National Transportation Safety Board
Washington, D.C.

D. DETAILS OF THE EXAMINATION

1.0 Introduction and Structure Terminology

On Friday, January 28, 2022, about 6:37 a.m. eastern standard time, the Fern Hollow Bridge, which carried Forbes Avenue over the north side of Frick Park, in Pittsburgh, Allegheny County, Pennsylvania, experienced a structural failure. As a result, the 447-foot-long bridge fell approximately 100 feet into the park below.

The bridge superstructure was a frame-floorbeam-stringer system with two parallel lines of rigid "K" frames. Each frame was comprised of three-span, continuous welded I-shaped steel girders, and two inclined, welded steel I-shaped legs. The structure was unique in that the legs were bolted to I-girders. The entire superstructure was made from uncoated weathering steel plates. The ends of the girders rested on reinforced concrete caps on stone masonry abutments, and each leg rested atop reinforced concrete thrust blocks. The bents of the bridge referred to the legs and thrust blocks, taken together with their associated cross bracing.

Figure 1 shows a plan view composite photo of the collapsed structure with the locations of the legs underneath the structure outlined and labeled. The bridge legs were individually labeled according to bent number and bridge side. The first index of the naming convention is “B” for bent. The second index is the numeric “1” or 2”, meant to indicate the first and second bent away from the near abutment. The final index is the letter “L” or “R”, representing left or right when looking east from the near abutment. Thus, B1R refers to the leg in bent 1 on the right side of the bridge.

In Figure 1, the plan view composite photo is compared to schematics in plan view and elevation view orientations, with the components of the bridge labeled

consistent with the latest bridge inspection report.[1] Figure 2 shows the plan view composite photo of the collapsed structure relative to the elevation view schematic, with each leg identified.

The bridge legs were a built-up I-shape cross-section configuration of web plate bracketed by flanges. The width of the bridge legs tapered slightly from the top down, with a second, sharper taper resulting in a trapezoidal-shaped shoe at the bottom of the leg. The width of the flanges was oriented perpendicular to the direction of the girders, with the web plate perpendicular to the width of the flanges. A schematic showing the outward facing side of a leg mating with a girder with all structural elements labeled is shown in Figure 3. A schematic showing a detailed view of the labeled structural elements in the bottom of a leg is shown in Figure 4.

2.0 Leg B1R

During the collapse, most of leg B1R separated into two large pieces, along with several small fragments of web and stiffeners that were not identifiable in the collapse debris. One large piece consisted of the bottom half of the leg including the shoe, a portion of the web and stiffeners, and approximately half of the span 1 side flange. The other large piece consisted of the top half of the leg including the top half of the span 1 side flange and the mating web and stiffeners, and all the span 2 side flange. The bottom half of the span 2 side flange had rolled up on the outward facing side of the leg.

The exact position post-collapse and the recovery of leg B1R is detailed in NTSB Materials Laboratory Factual Report 23-009. Photos of the two pieces of leg B1R are shown in Figure 5. The pieces are cross-referenced to a schematic of a leg colored to illustrate the portion of leg that comprised each piece. The bottom of leg B1R containing the span 1 side flange and the mating web and stiffeners, and the bottom of the rolled span 2 side flange were retained for further examination.

3.0 Tie Plates

The only drawings of the Fern Hollow bridge available were the original design plans. No shop drawings completed by the bridge fabricator were discovered. The original design plans indicated a groove weld symbol between the tie plate and leg flange but did not clearly indicate that complete joint penetration was required. The construction plans listed in Steelwork General Notes that "All welding shall be performed in accordance with AWS D2.0-69…" In review of AWS D2.0-69, welding symbols "…shall be those shown in the latest edition of Standard Welding Symbols AWS A2.0." Review of AWS A2.0 found a statement that "The size of groove welds

[1] "2021 Routine Bridge Safety Inspection Report, City of Pittsburgh, Allegheny County, Forbes Avenue over Fern Hollow and Nine Mile Run" by Gannett Fleming, Inc.

with no specified root penetration shall…extend completely through the member or members being joined."[2] Thus, the original design intent is interpreted to be the welds between the tie plates and the flanges should have complete joint penetration.

3.1 Leg B1R Tie Plates

The shoe was sectioned from the remainder of the span 1 side leg B1R piece for stability and to facilitate necessary handling. The location of the torch cut is shown in Figure 6. The removal of the shoe fully exposed the tie plates located between the shoe and panel 1. Schematics showing the outward and inward facing sides of the bottom of leg B1R with the tie plates highlighted in yellow are shown in Figure 7 and Figure 8, respectively. The ends were secured to the mating spans using welds on either side of the tie plates. The welds on the tie plate ends were thus labeled as shoe side and panel 1 side welds, as shown in the schematics in Figures 9 and 10.

The ends of the tie plates that separated from the span 2 side flange are encircled by the green dotted lines in Figures 11–12 and shown in more detail in Figures 13–14. Figure 13 shows the end of the tie plate on the inward facing side of the leg. The inward facing side tie plate had extensive corrosion damage and had thinned down to a razor's edge. Figure 14 shows the end of the tie plate on the outward facing side of the leg; the outward facing side tie plate appeared largely intact, with some weld material still joined to the plate faces (white arrows).

The top half of leg B1R with the separated span 2 side flange rolled up on the outward facing side of the leg is shown in Figure 15; the yellow dotted line encircles the location on the internal surface of the span 2 side flange that mated with the tie plates. The retained portion of the span 2 side flange is shown in Figure 16. Figure 17 shows close-up photos of where the tie plates mated to the span 2 side flange. The white arrows point to fractured areas on the weld metal still joined to the flange surface. The orange arrows point to fragments of unfused weld flux joined to the base of the weld. A portion of tie plate approximately 2 inches in height was still adhered to the inward facing side weld; the tie plate had pulled completely away from the weld on the outward facing side.

The segment that mated with the tie plates was sectioned from the span 2 side flange for further analysis. After sectioning, the span 2 side flange segment was soaked in Evapo-Rust® (CRC Industries, Horsham PA) heavy duty rust remover then rinsed with methanol. Photos of plan and profile views of the sectioned span 2 side flange segment are shown in Figure 18. The tie plate piece on the inward side of the span 2 flange is shown in Figures 19 and 20. The tie plate piece adjacent to the web at the center of the flange had a fracture surface with features consistent with ductile

[2] AWS A2.0-68, "Welding Symbols", AWS Committee on Definitions and Symbols, American Welding Society, Inc., New York, NY, 1968.

overstress (red arrows). The remainder of the tie plate piece had thinned to a razor's edge (yellow arrows) due to corrosion, with rub damage resulting from the collapse observed on a portion of tie plate curled over near the flange end.

Figures 21 and 22 show the weld metal still joined to the outward side of the span 2 flange. The white arrows point to fractured portions of the shoe side weld. The orange arrows point to fragments of unfused weld metal and flux joined to the base of the shoe side weld. The fragments of unfused weld metal and flux were not well adhered, and some pieces broke loose and were lost during cleaning. On the opposite face of the tie plate, the panel 1 side weld, encircled by a yellow dotted line, appeared largely intact, with a smooth surface where the weld mated to the tie plate (green arrows).

Cross-sections were prepared through the weld metal still joined to the span 2 side flange at the outward and inward facing side tie plates, as shown in Figures 23 and 24, respectively. The cross-sections were polished and etched to reveal the microstructure. Montage digital microscope images of the cross-sections are compared in Figure 25.

On the inward facing side, the tie plate was not flush with the flange and there was a gap between them resulting from the offset. The gap was filled with unfused weld metal and flux, as indicated by the orange arrows in Figures 24 and 25. The portions of the welds below the tie plates and adjacent to the gap were smooth and not fused to the tie plates, as indicated by the white brackets. The amount of weld metal comprising the panel 1 side weld appeared to be less than the amount of metal on the shoe side weld. For the shoe side weld, approximately half of the fillet weld present was above the gap and had fusion with the tie plate. The fusion was visible on the intact inward facing tie plate and apparent from the fractured portion of weld on the outward facing tie plate (indicated by the red bracket in Figure 25). For the panel 1 side weld, none of the remaining weld metal on the outward side showed fusion. The specified complete joint penetration was not observed in the welds between the Leg B1R tie plates and the span 2 side flange. Measurements of the weld throats[3] on the tie plates are shown in Figure 26.

3.2 Leg B2L Tie Plates

The "K" frame configuration of the bridge legs resulted in one span side located uphill and the other span side located downhill. For leg B1R, the span 1 side was uphill and the span 2 side was downhill. The tie plate thinning at the joint with the span 2 side flange was thus on the downhill side. For comparison, a tie plate on the uphill side of a leg was examined. The tie plates on the uphill side of leg B1R were affected by specimen extraction for mechanical testing (detailed in NTSB Materials

[3] The throat is the minimum distance from the real root to the real face of a weld.

Laboratory Factual Report 23-036) and thus not available for examination. The uphill side tie plates from leg B2L had not been affected by mechanical testing specimen extraction and were chosen for examination.

A schematic showing the inward facing side of the bottom of leg B2L with the tie plate highlighted in yellow is shown in Figure 27. A schematic compared to a photo of the bottom portion of leg B2L are shown in Figure 28. The ends of the tie plates that mated with the span 3 side flange on the uphill side of the leg are encircled by the green dotted lines in Figure 28.

Cross-sections were prepared through the tie plates to span 3 side flange joints on the inward and outward facing sides of the leg. The cross-sections were polished and etched to reveal the microstructure, as shown in Figure 29. The sectioning and preparation of the cross-sections through the leg B2L tie plates were completed by Federal Highway Administration (FHWA).

Like the leg B1R tie plate to flange joint, the leg B2L tie plates were not flush with the span 3 side flange and there was a gap between them resulting from the offset. The gaps in the leg B2L joint were smaller than the one seen in the leg B1R joint. Also, while not filled like the gap in leg B1R, unfused weld metal and flux was observed in some areas of the leg B2L gaps, as indicated by the orange arrows. The portions of the welds below the tie plates and adjacent to the gaps were smooth and not fused to the tie plates, as indicated by the white brackets in Figure 30. Fusion with the weld metal was observed on both tie plates, and again the amount of metal comprising the panel 1 side weld was less than that on the shoe side weld. The specified complete joint penetration was not observed in the welds between the Leg B2L tie plates and the span 3 side flange. Measurements of the weld throats on the tie plates are shown in Figure 30.

4.0 Leg B1R Span 2 Side Flange

A schematic showing the outward facing side of the bottom of leg B1R is shown in Figure 31. In the figure, the joint between the top of the toe and the bottom of the span 2 side flange is encircled in yellow. Schematics identifying the two main welds at this joint as the outer and inner welds are shown in Figure 32.

The joint on the shoe of leg B1R where the bottom of the span 2 side flange separated from the toe is identified by dotted green circles in Figure 33. Close-up photos of the weld metal still joined to the bottom of the shoe on the outward and inward facing sides are shown in Figures 34 and 35, respectively. The orange arrows point to remnants of the inner weld where the toe, flange end, and bearing stiffener mated. The green arrows point to remnants of the outer weld where the toe and flange end mated.

The bottom of the rolled span 2 side flange while it was still attached to the leg on-scene is shown in Figures 36 and 37. Again, the orange arrows point to remnants of the inner weld where the toe, flange end, and bearing stiffener mated and the green arrows point to remnants of the outer weld where the toe and flange end mated. On the exposed end face of the flange without overlaid weld metal, vertical lines were observed consistent with machining of the flange plate.

Approximately 2.5 inches were sectioned off the end of the rolled span 2 side flange for further examination of the welds. The outer weld visible on the end face of the flange is shown in Figures 38–40. The outer weld was continuous across the full length of the flange width and appeared to consist of 2 passes, as indicated by the two green brackets in Figure 40. The thinner second pass on top of the thicker first one had transverse lines visible on the fracture surface likely related to shrinkage of the weld metal during cooling. The total thickness of the outer weld measured approximately 0.75 inches.

The inner weld visible on the inner face of the span 2 side flange is shown in Figures 41–43. The inner weld was discontinuous and not consistent in thickness along the length. In addition, numerous large pores were observed within the weld metal. The inner weld had fusion with the flange and did fracture through the weld metal when the flange separated during the collapse.

5.0 Leg B1R Span 1 Side Flange

A schematic showing the outward facing side of the bottom of leg B1R is shown in Figure 44 with the joint between the top of the toe and the bottom of the span 1 side flange encircled in yellow. Schematics identifying the two main welds at this joint as the outer and inner welds are shown in Figure 45. The sectioning and preparation of the cross-sections through the leg B1R toe were completed by Federal Highway Administration (FHWA).

The toe and the mating joints with the span 1 and span 2 side flanges were sectioned through on the inward and outward facing sides. The joint on the shoe of leg B1R where the bottom of the span 1 side flange mated with the toe is identified by dotted green circles in Figure 46. The cross-sections through the joint were polished and etched to reveal the microstructure.

The cross-section through the span 1 side flange joint on the inward facing and outward facing sides are shown in Figures 47 and 48, respectively. In both cross-sections, the inner weld appeared to be a partial penetration bevel weld. The design plans specified a bevel weld in this location, but neither the size of the weld nor level of penetration (full or partial) was specified. The outer weld had appeared to be a partial penetration bevel weld on the outer surface, with a fillet weld observed

between the inner surface of the flange and the bearing stiffener. The J-groove weld listed on the design drawings for this location was not observed.

A schematic showing the outward facing side of the bottom of leg B1R is shown in Figure 49 with the joint between the top of the toe and the bottom of the span 2 side flange encircled in yellow. Schematics identifying the two main welds at this joint as the outer and inner welds are shown in Figure 50.

The toe and the mating joints with the span 1 and span 2 side flanges were sectioned through on the inward and outward facing sides. The joint on the shoe of leg B1R where the bottom of the span 2 side flange mated with the toe is identified by dotted green circles in Figure 51. The cross-sections through the joint were polished and etched to reveal the microstructure.

The cross-section through the span 2 side flange joint on the inward facing and outward facing sides are shown in Figures 52 and 53, respectively. In both cross-sections, the inner weld appeared to be a partial penetration bevel weld. As before, this was compared to the design plans that listed a bevel weld of unspecified size and level of penetration (full or partial) in this location. Most of the outer weld had separated with the span 2 side flange; however, what remained showed evidence of a partial penetration weld on the outer surface, with a fillet weld observed between the inner surface of the flange and the bearing stiffener. The J-groove weld listed on the design drawings for this location was not observed.

Submitted by:

Adrienne V. Lamm
Materials Engineer

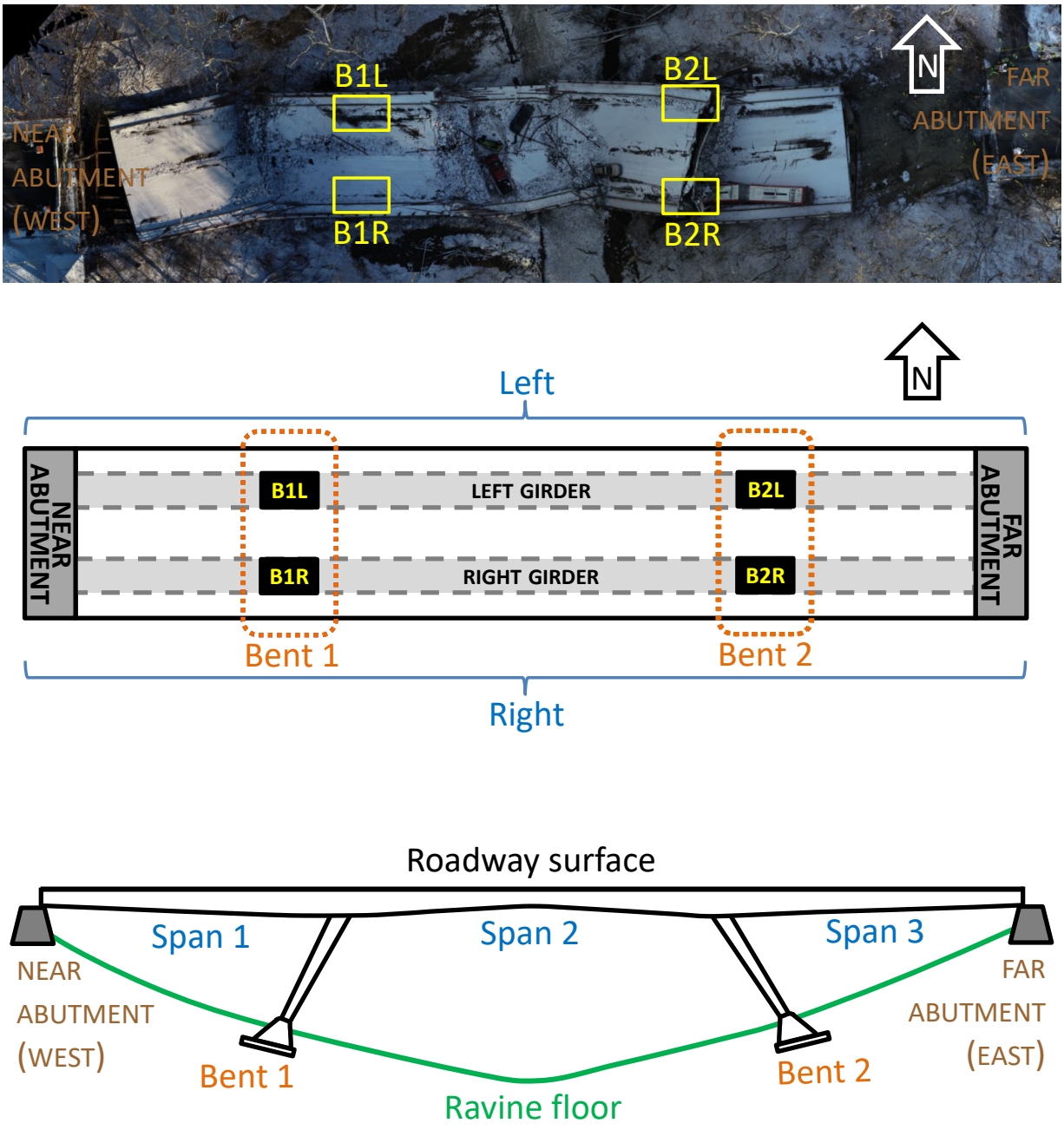


Figure 1. Plan view composite photo (top) compared to schematics in plan view and elevation view orientations (middle and bottom, respectively).

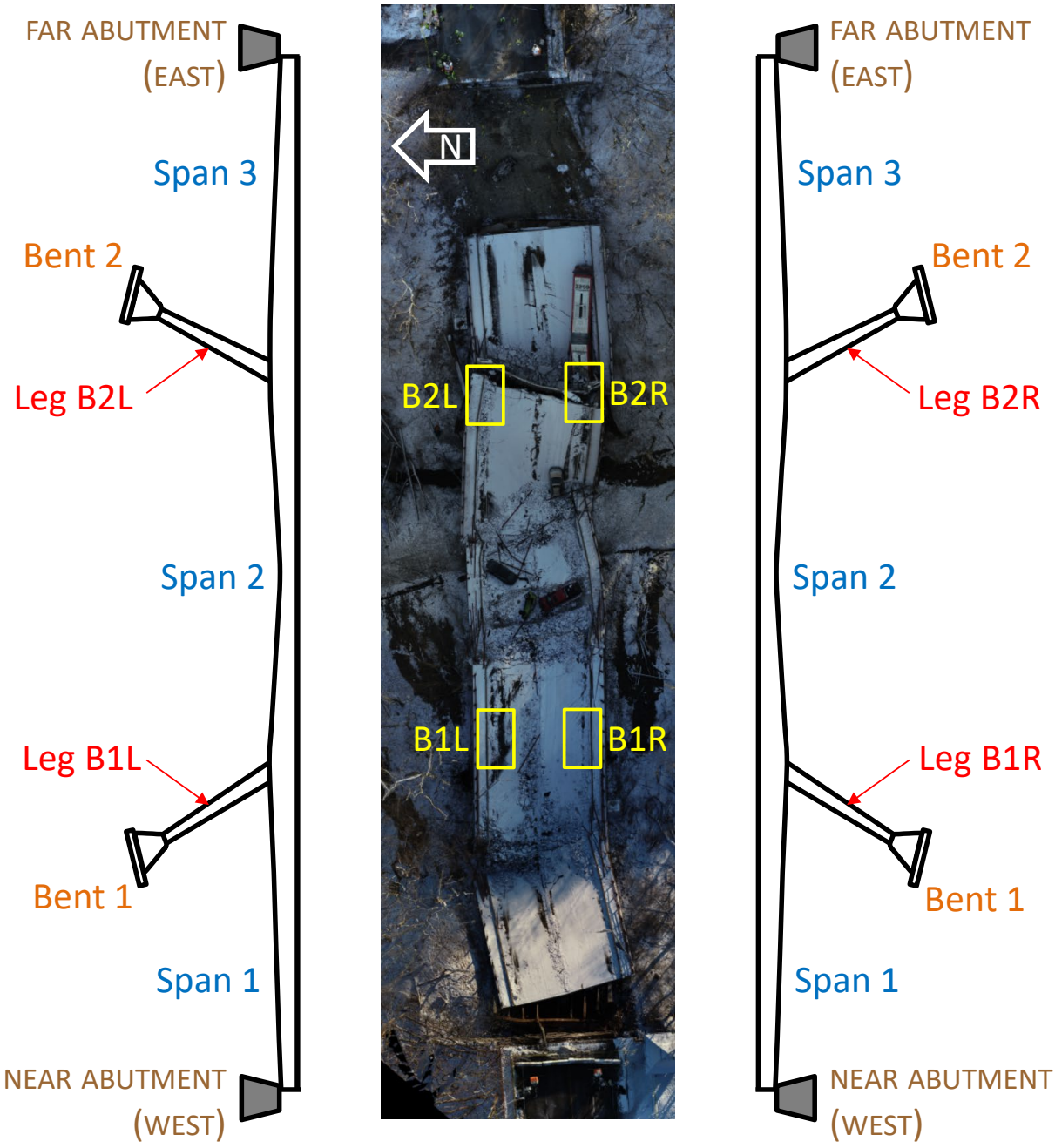


Figure 2. Plan view composite photo of the collapsed structure relative to the elevation view schematics.

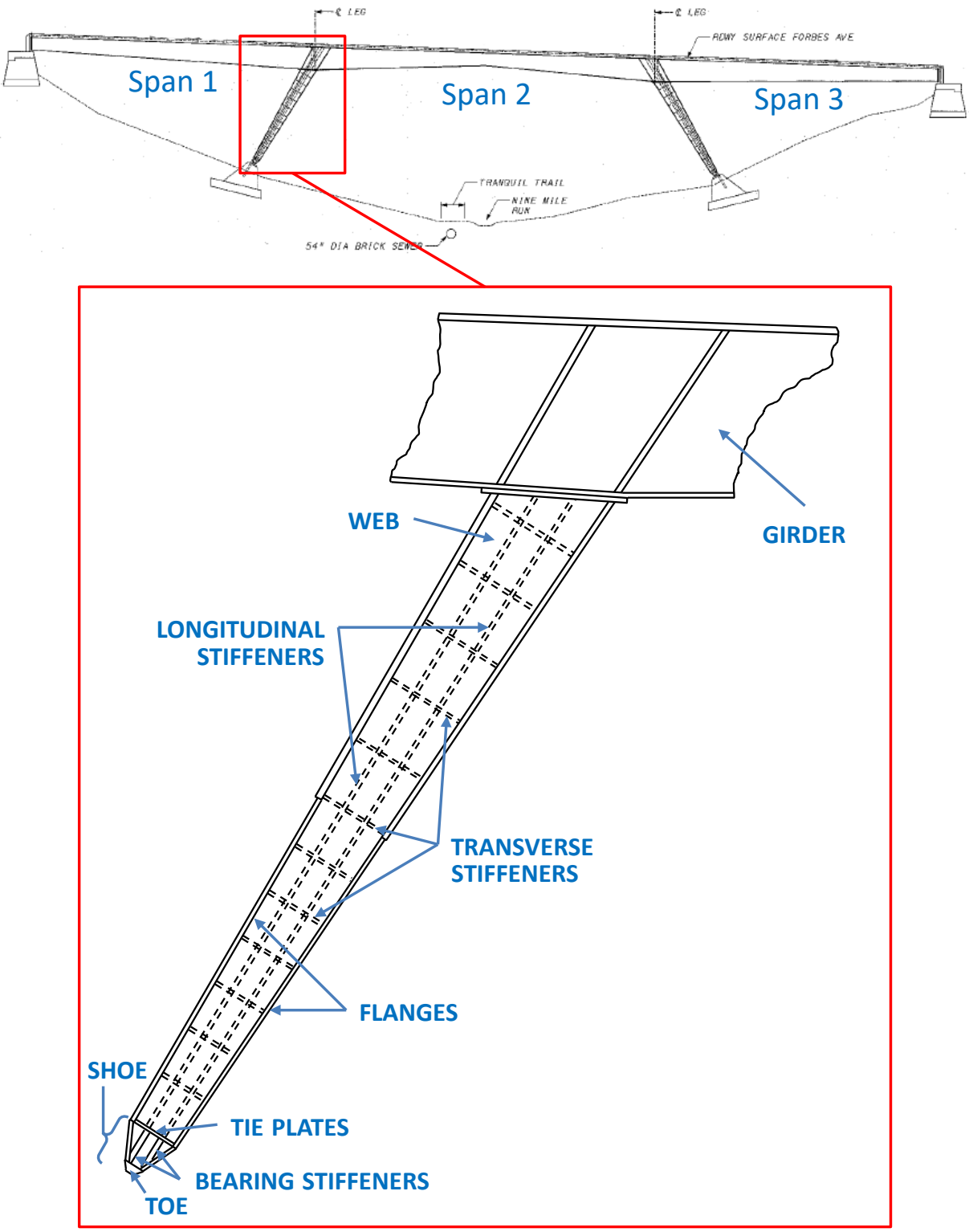


Figure 3. Schematic showing the outward facing side of a leg mating with a girder with all structural elements labeled. The dashed lines indicate components on the inward facing side of the leg. (Schematic not to scale)

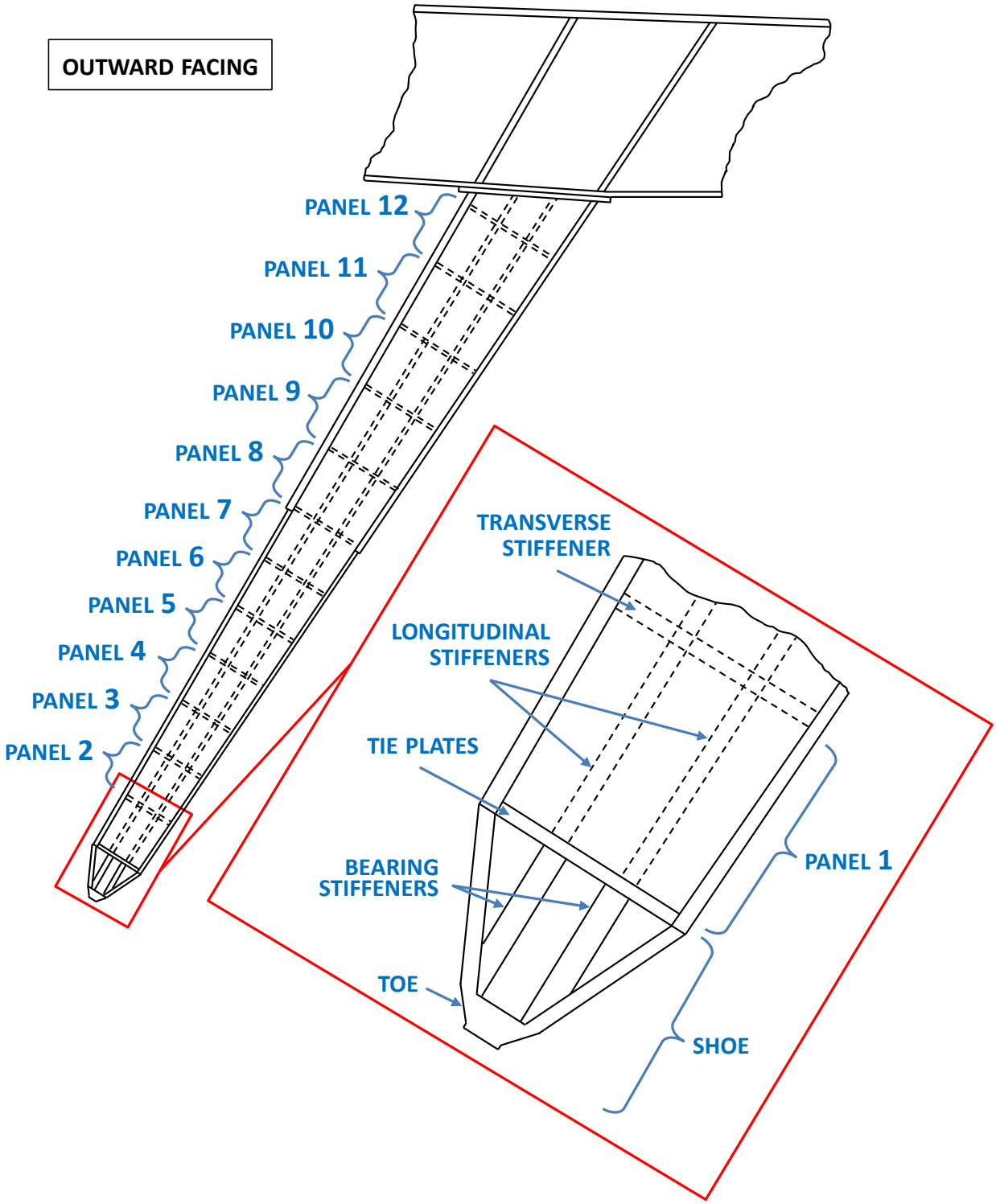


Figure 4. Schematic showing a detailed view of the labeled structural elements in the bottom of a leg. The dashed lines indicate components on the inward facing side of the leg. (Schematic not to scale)

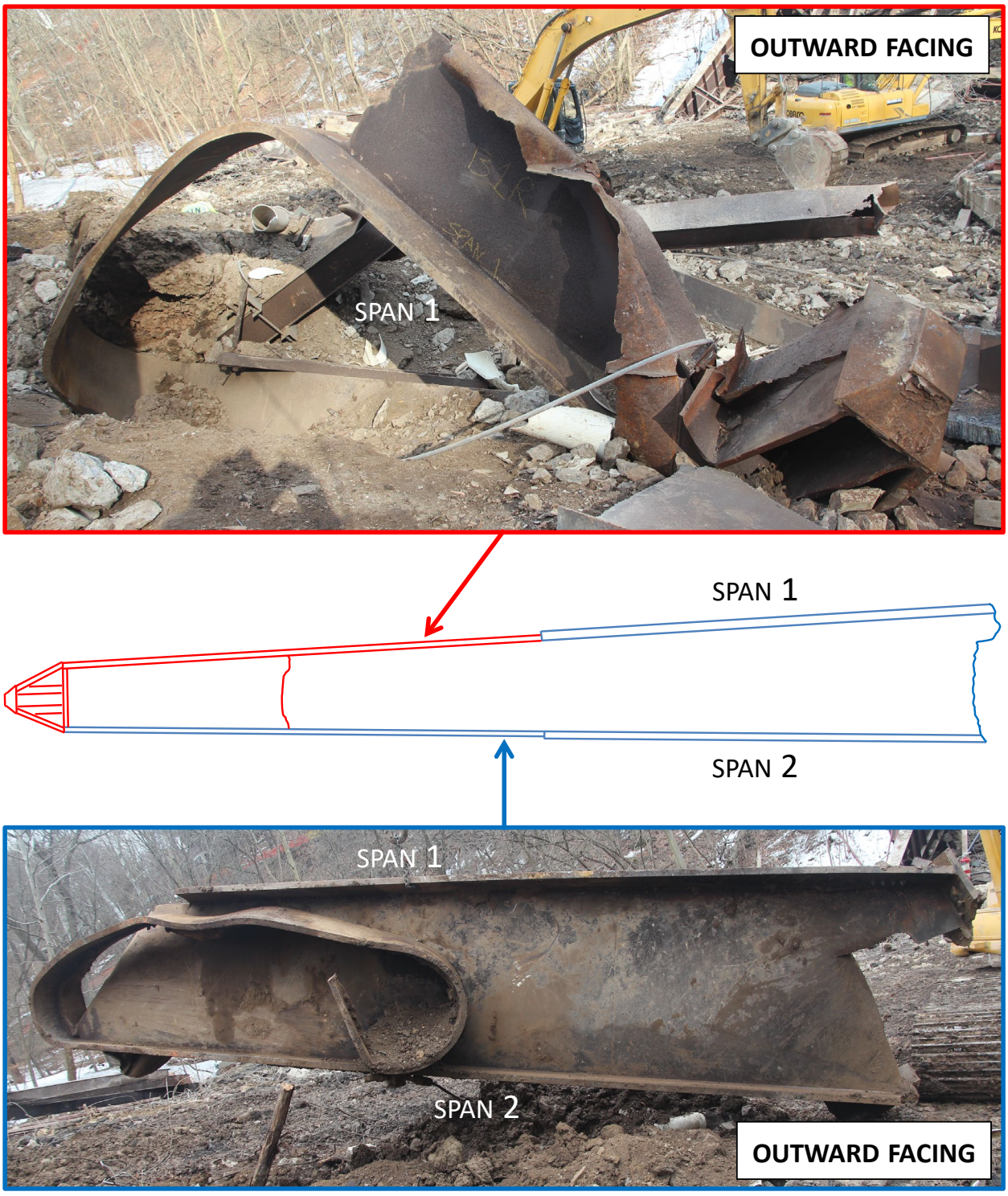


Figure 5. Photos of the two pieces of leg B1R compared to a schematic of a leg.

Figure 6. Photos showing the location of the torch cut that sectioned the shoe from the remainder of the span 1 side leg B1R piece.

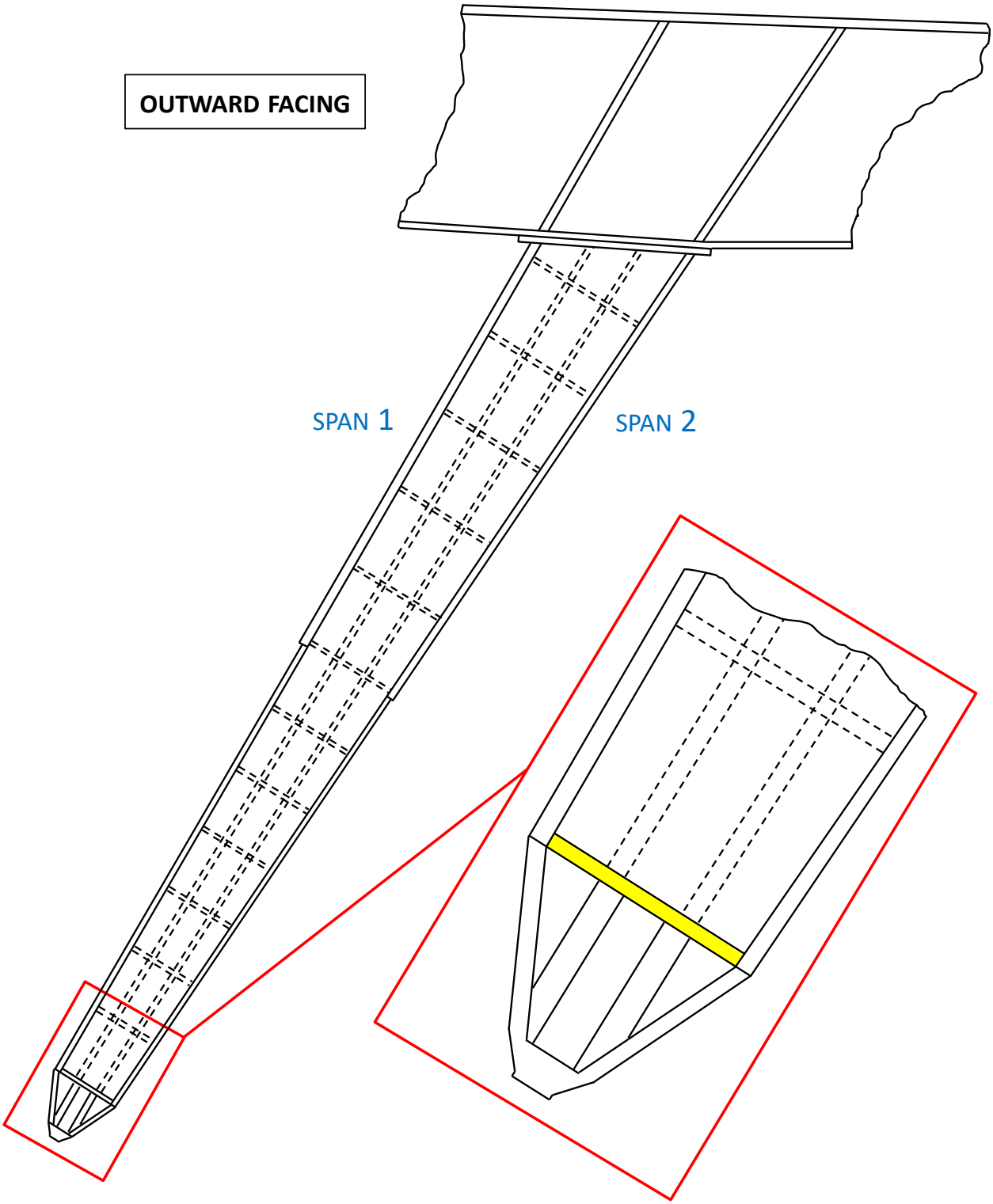


Figure 7. Schematic showing the outward facing side of the bottom of leg B1R with the tie plate highlighted in yellow. (Schematic not to scale)

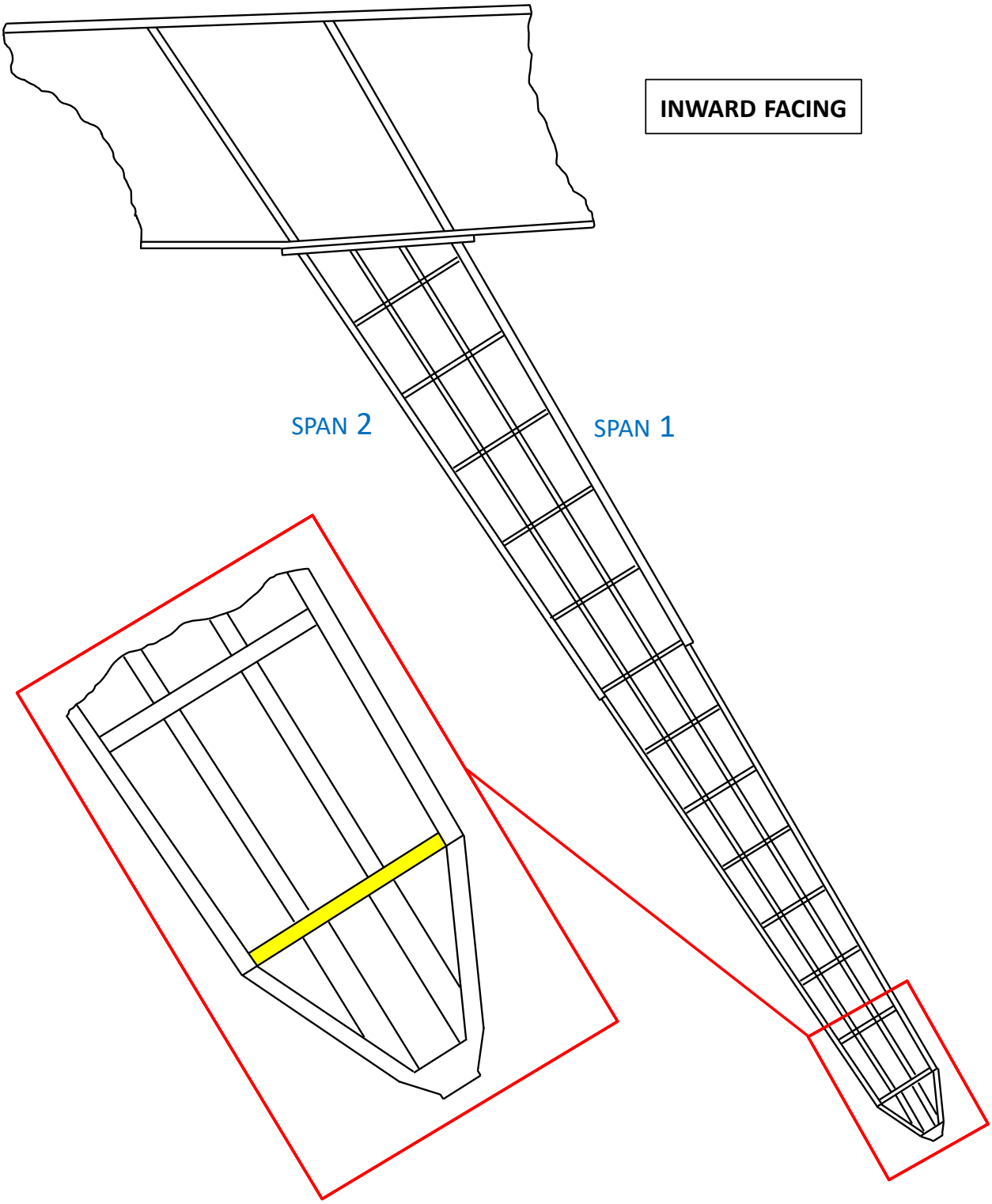


Figure 8. Schematic showing the inward facing side of the bottom of leg B1R with the tie plate highlighted in yellow. (Schematic not to scale)

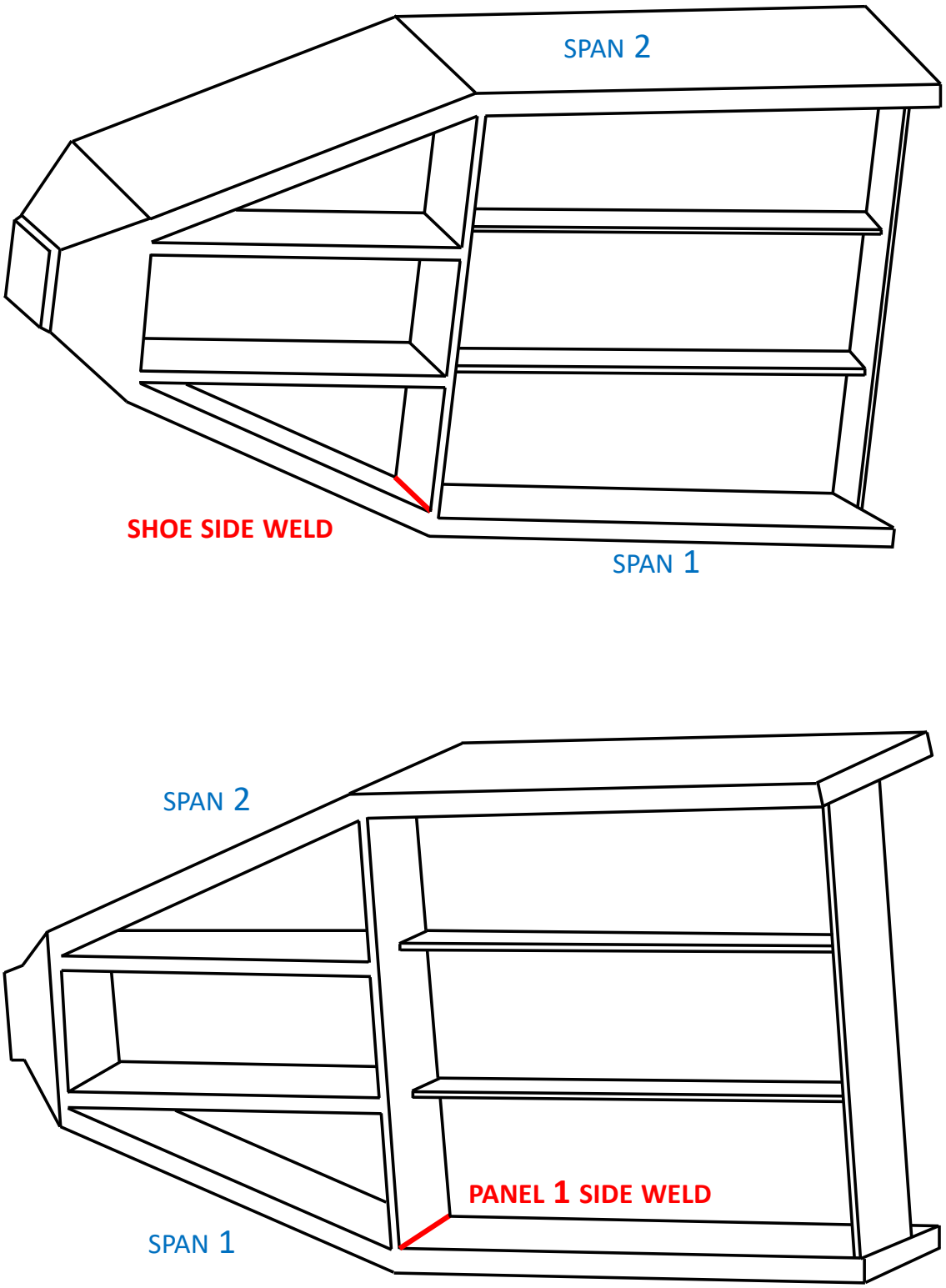


Figure 9. Schematics of leg B1R with the welds on either side of the tie plate mating to the span 1 side flange identified.

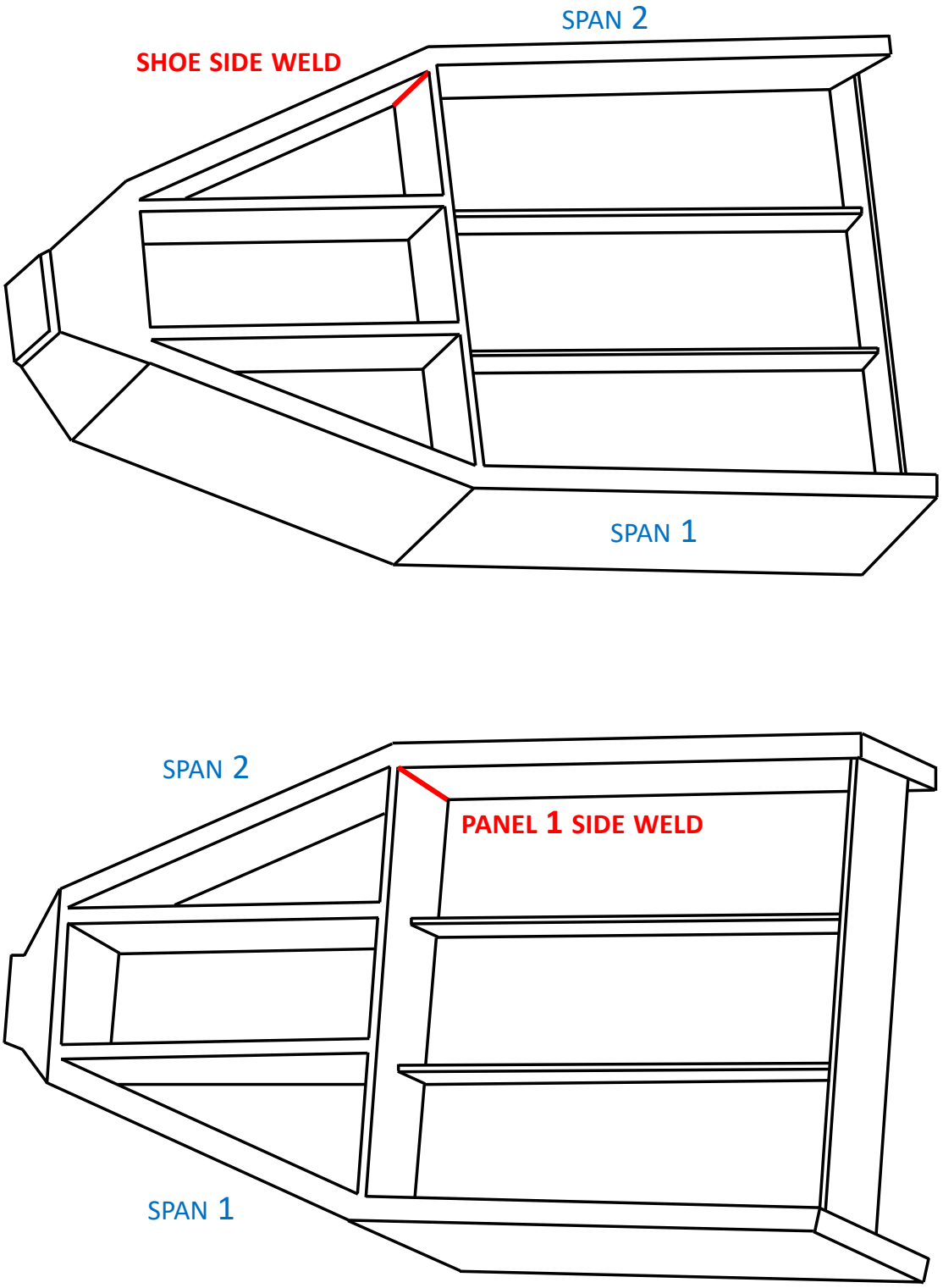


Figure 10. Schematics of leg B1R with the welds on either side of the tie plate mating to the span 2 side flange identified.

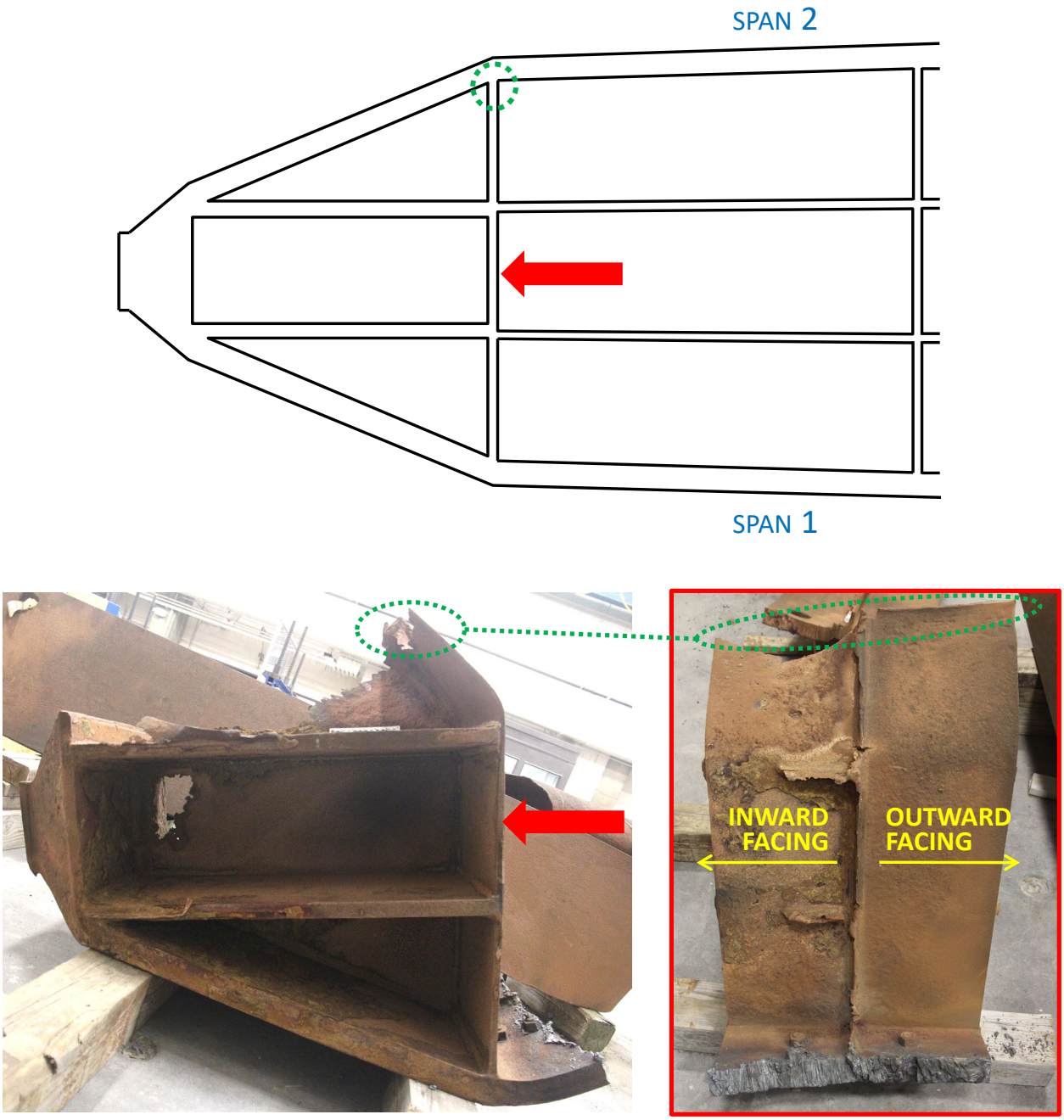
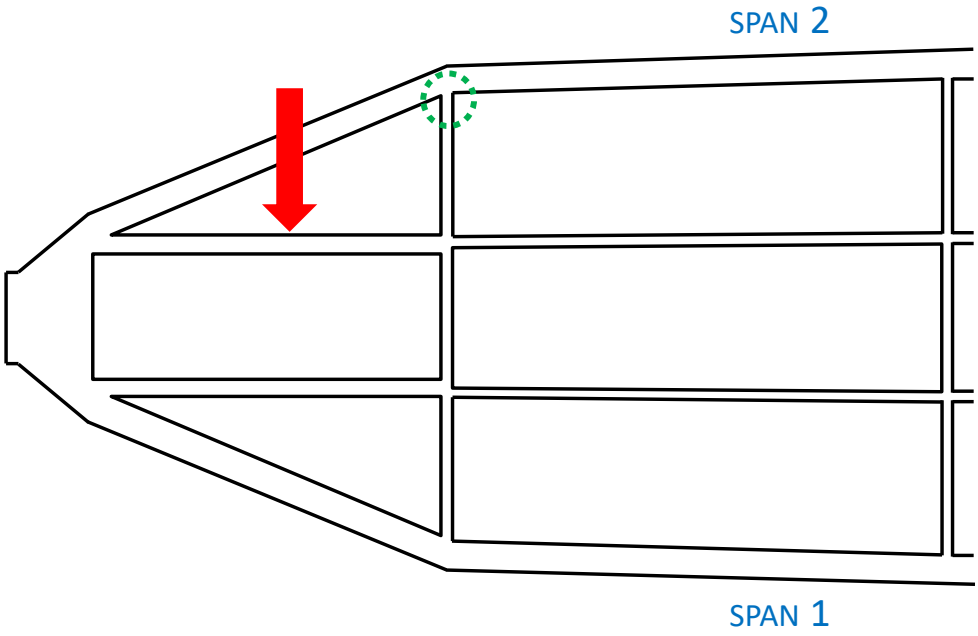


Figure 11. Schematic and photo of leg B1R as viewed from the inward facing side (top and bottom left, respectively). The bottom right photo shows the tie plates as viewed when looking in the direction of the red arrow. The green dotted lines encircle the ends of the tie plates that separated from the span 2 side flange.



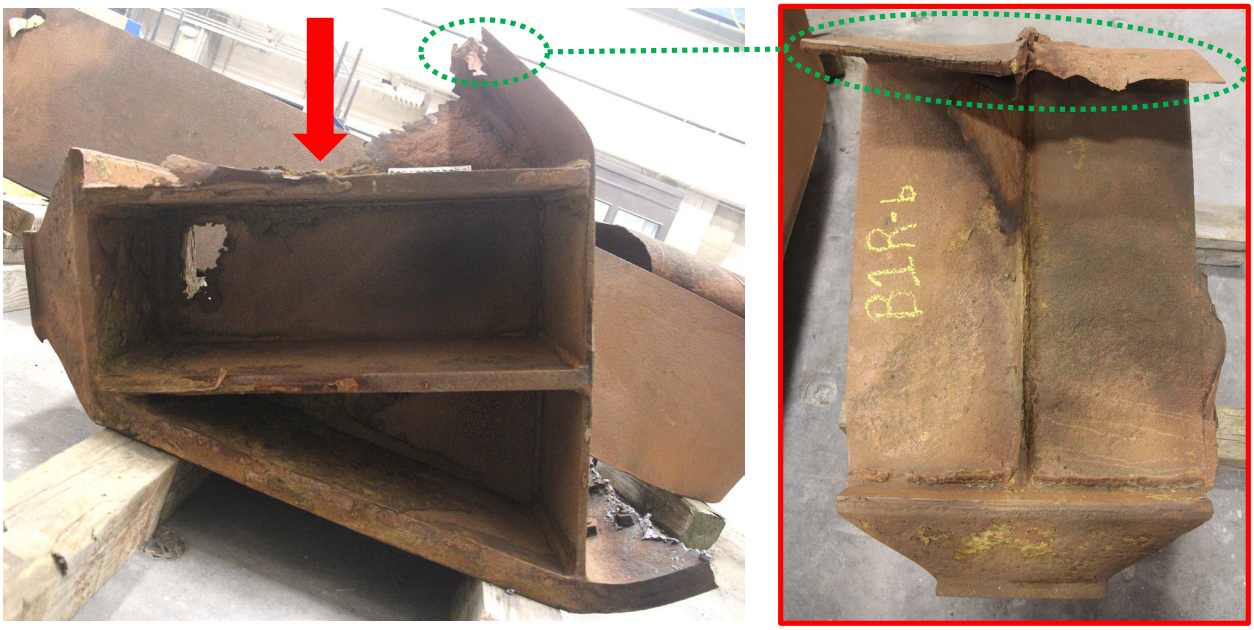


Figure 12. Schematic and photo of leg B1R as viewed from the inward facing side (top and bottom left, respectively). The bottom right photo shows the ends of the tie plates that separated from the span 2 side flange (green dotted lines).

Figure 13. Photos of the end of the tie plate that separated from the span 2 side flange on the inward facing side of the leg.

Figure 14. Photos of the end of the tie plate that separated from the span 2 side flange on the outward facing side of the leg. The white arrows point to weld material still joined to the plate faces.

Figure 15. Photos showing the top half of leg B1R with the separated span 2 side flange rolled up on the outward facing side of the leg. The yellow dotted line encircles the location on the internal surface of the span 2 side flange that mated with the tie plates.

Figure 16. Photos of the retained portion of the span 2 side flange. The red arrow in the top photo points in the direction of the view in the bottom photo.

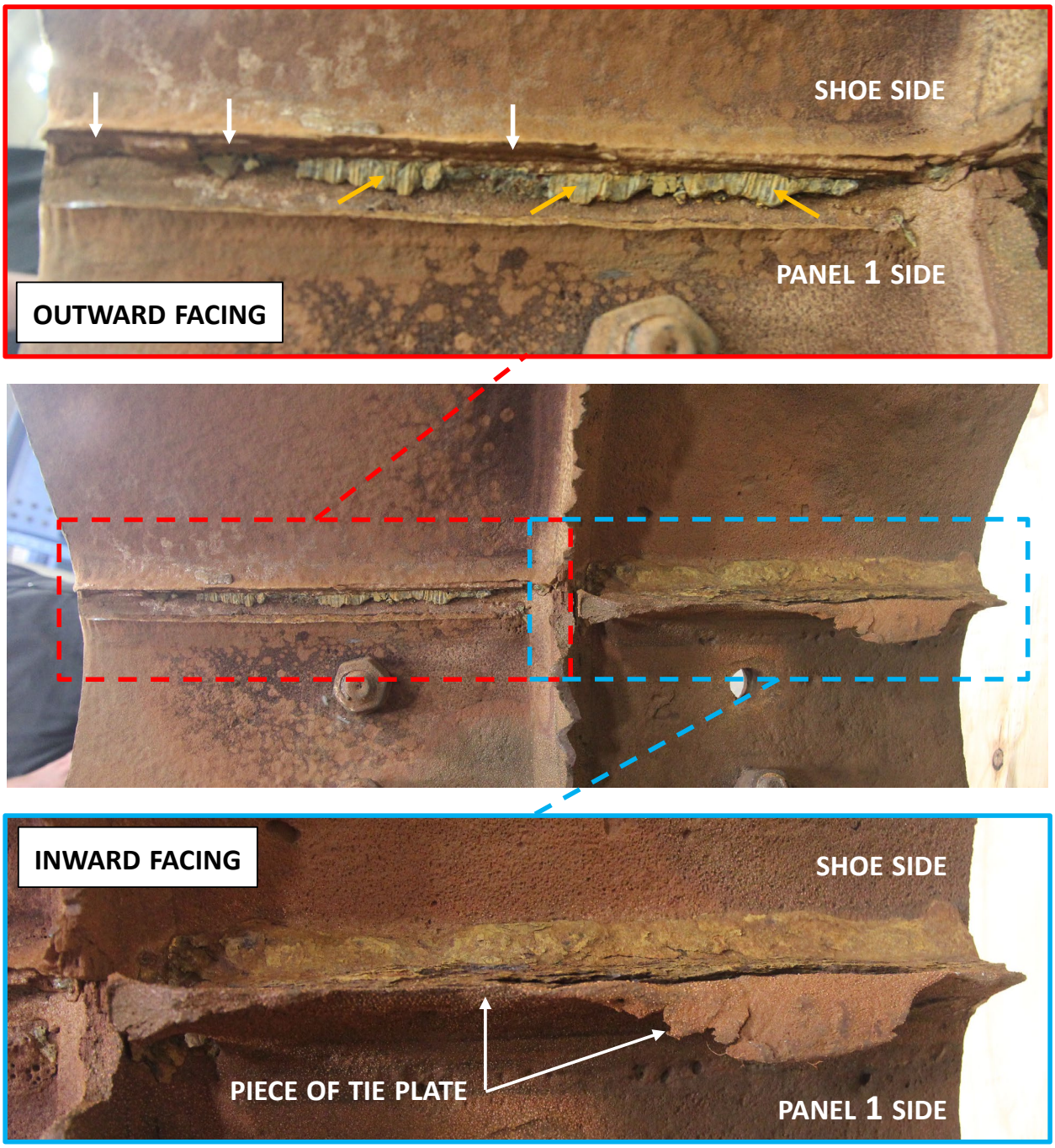


Figure 17. Close-up photos of where the tie plates mated to the span 2 side flange. The white arrows point to fractured areas on the weld metal still joined to the flange surface. The orange arrows point to fragments of unfused weld flux joined to the base of the weld.

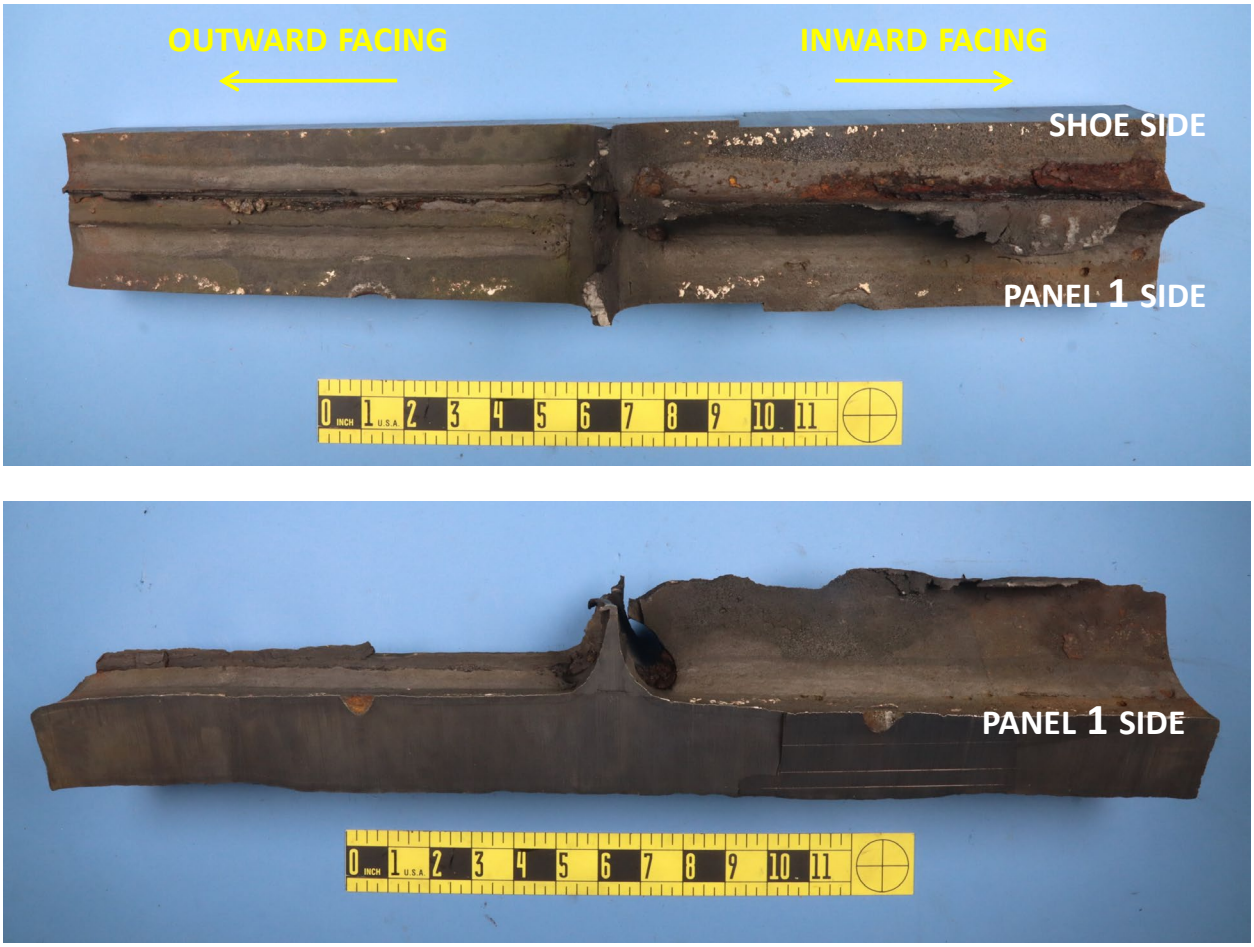


Figure 18. Photos showing the plan and profile views of the sectioned span 2 side flange segment.

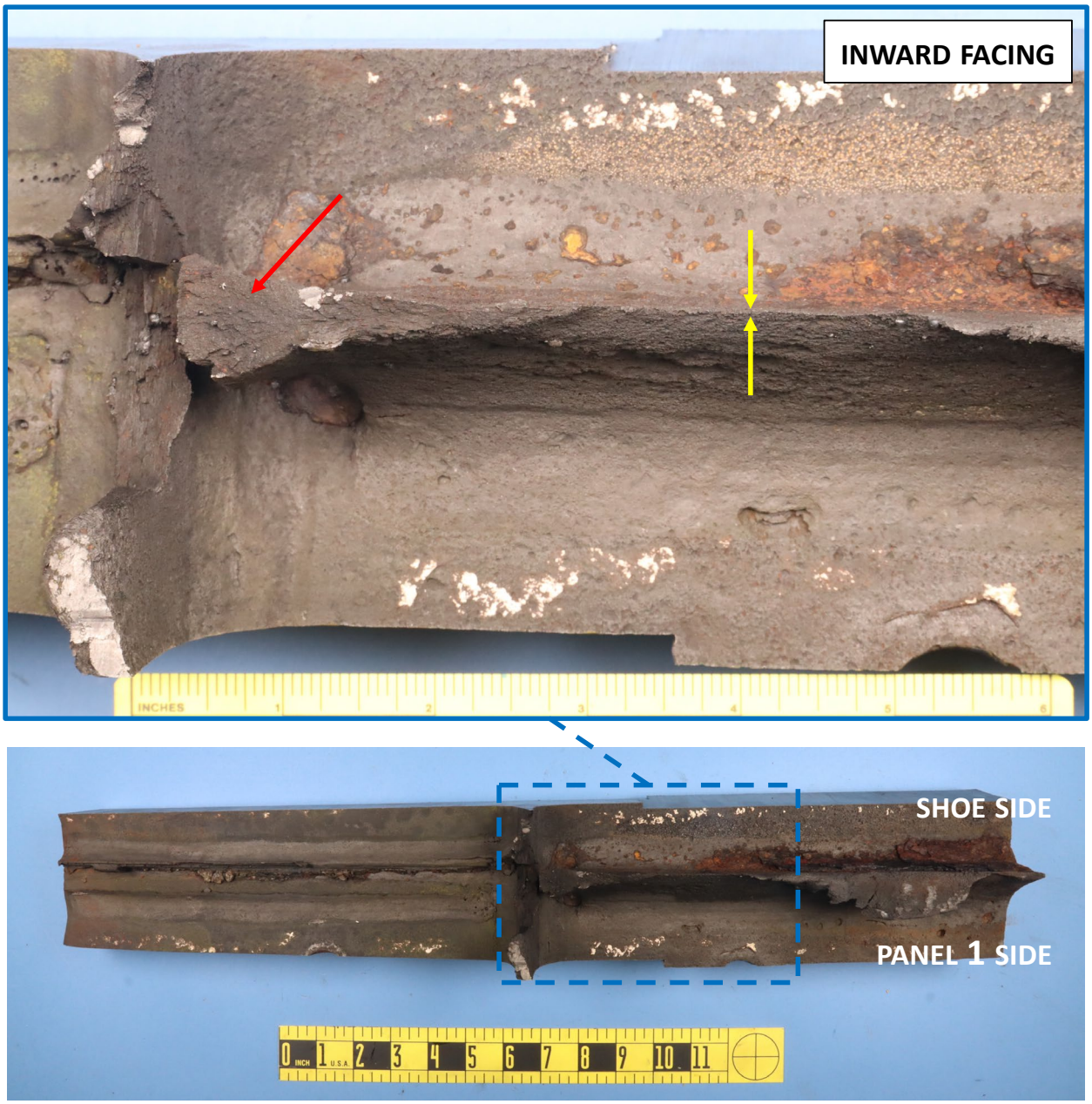


Figure 19. Plan view photos showing the tie plate piece on the inward side of the span 2 flange. The red arrow points to ductile overstress on the tie plate piece adjacent to the web at the center of the flange. The yellow arrows indicate the remainder of the tie plate piece had thinned to a razor's edge.

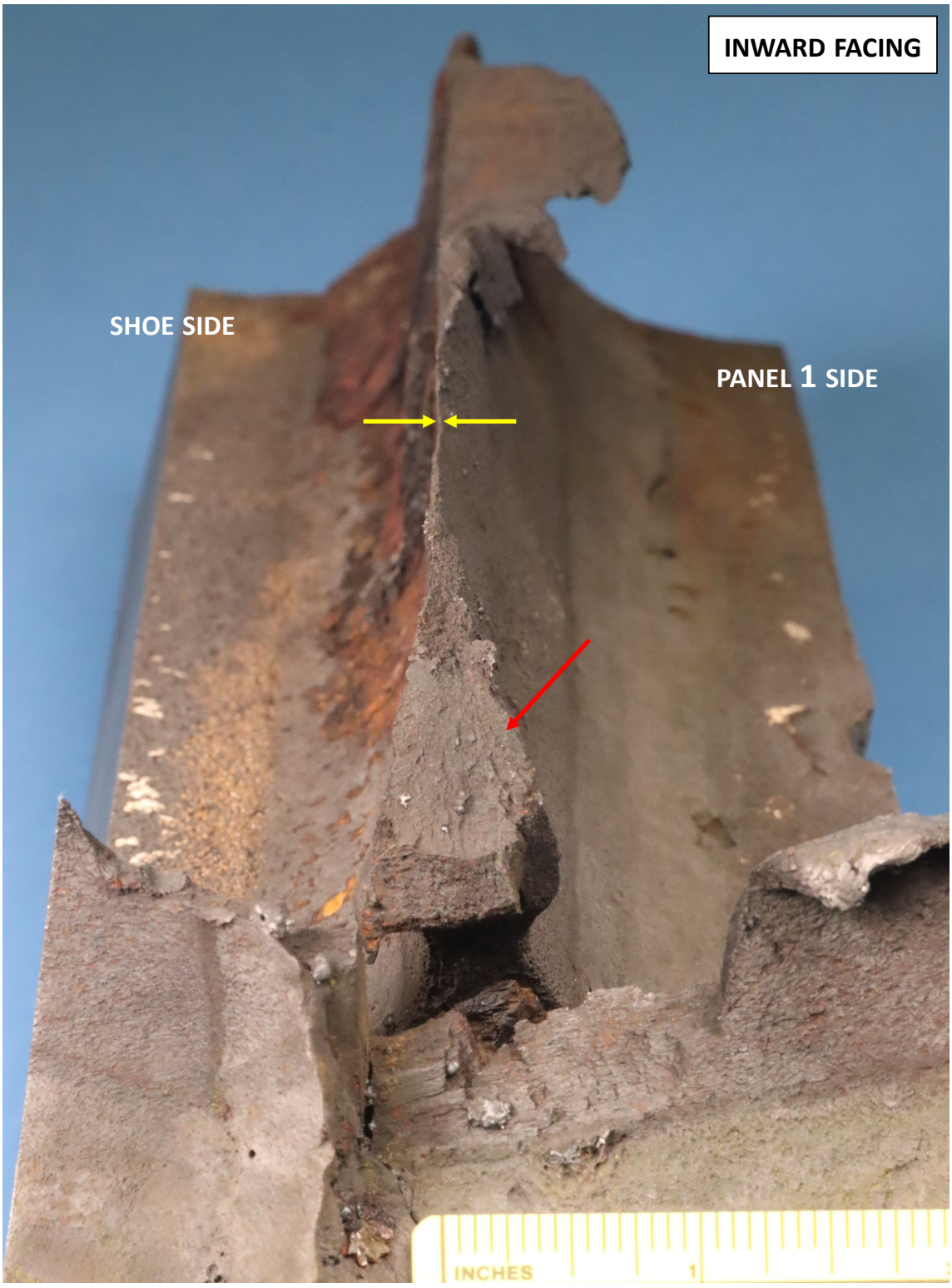


Figure 20. Oblique view photo showing the tie plate piece on the inward side of the span 2 flange. The red arrow points to ductile overstress on the tie plate piece adjacent to the web at the center of the flange. The yellow arrows indicate the remainder of the tie plate piece had thinned to a razor's edge.

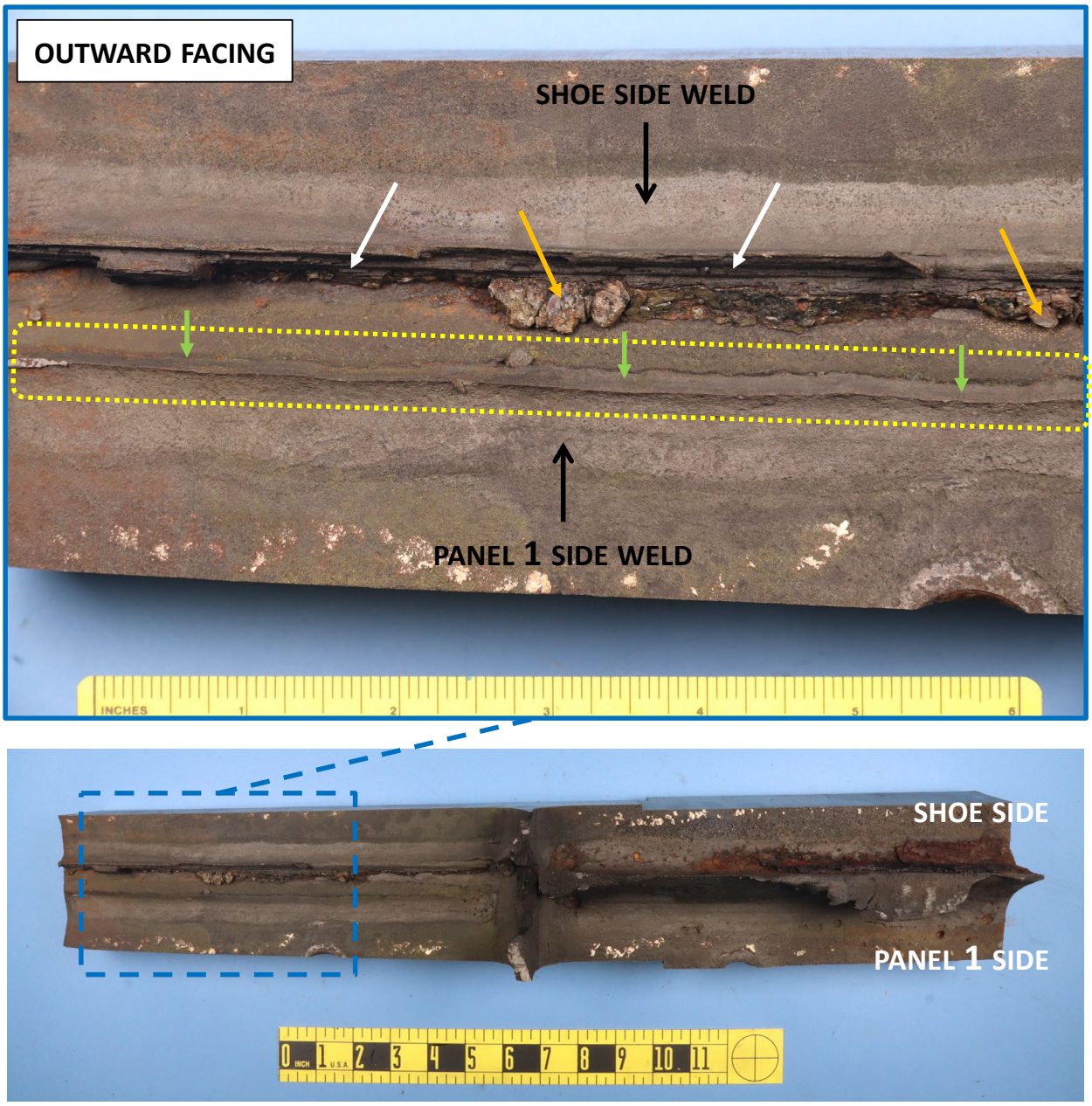


Figure 21. Plan view photos showing the tie plate piece on the outward side of the span 2 flange. The white arrows point to fractured portions of the shoe side weld. The orange arrows point to fragments of unfused weld metal and flux joined to the base of the shoe side weld. The green arrows point to the smooth surface on the panel 1 side weld (yellow dotted line) where the weld mated to the tie plate.

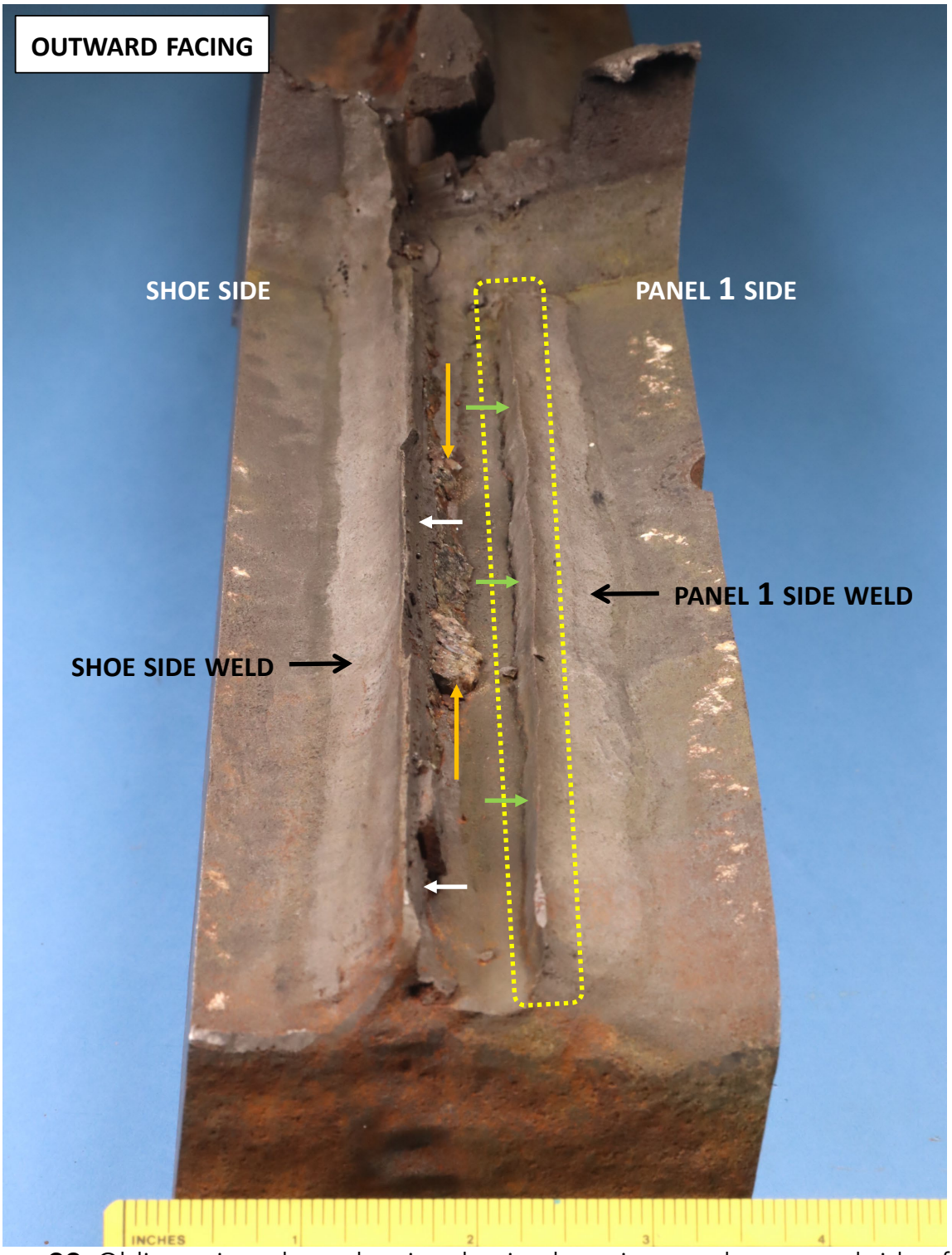


Figure 22. Oblique view photo showing the tie plate piece on the outward side of the span 2 flange. The white arrows point to fractured portions of the shoe side weld. The orange arrows point to fragments of unfused weld metal and flux joined to the base of the shoe side weld. The green arrows point to the smooth surface on the panel 1 side weld (yellow dotted line) where the weld mated to the tie plate.

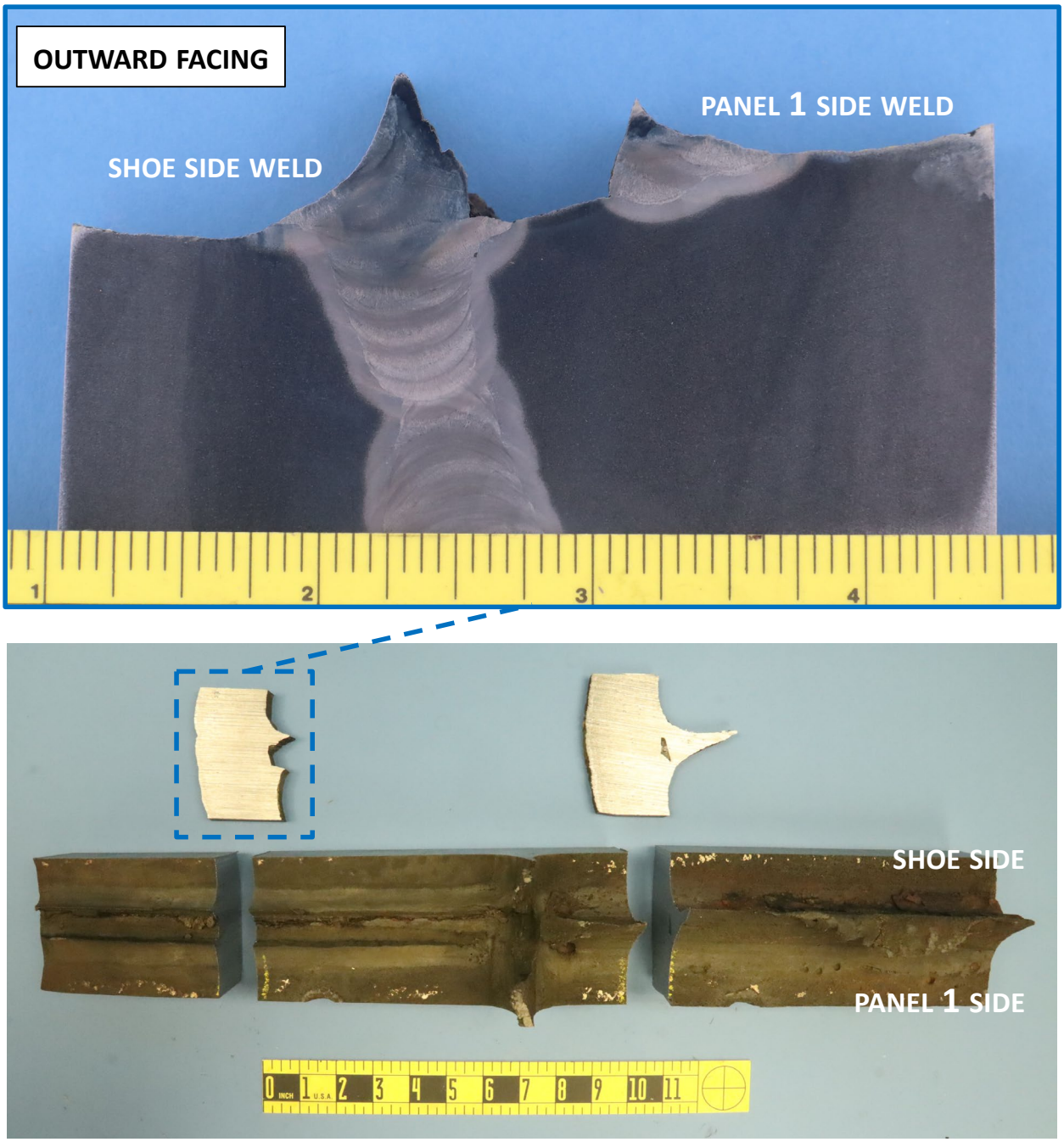


Figure 23. Photos showing cross-sections through the weld metal still joined to the span 2 side flange at the outward facing side tie plate. (Top photo etchant: 5% nital)

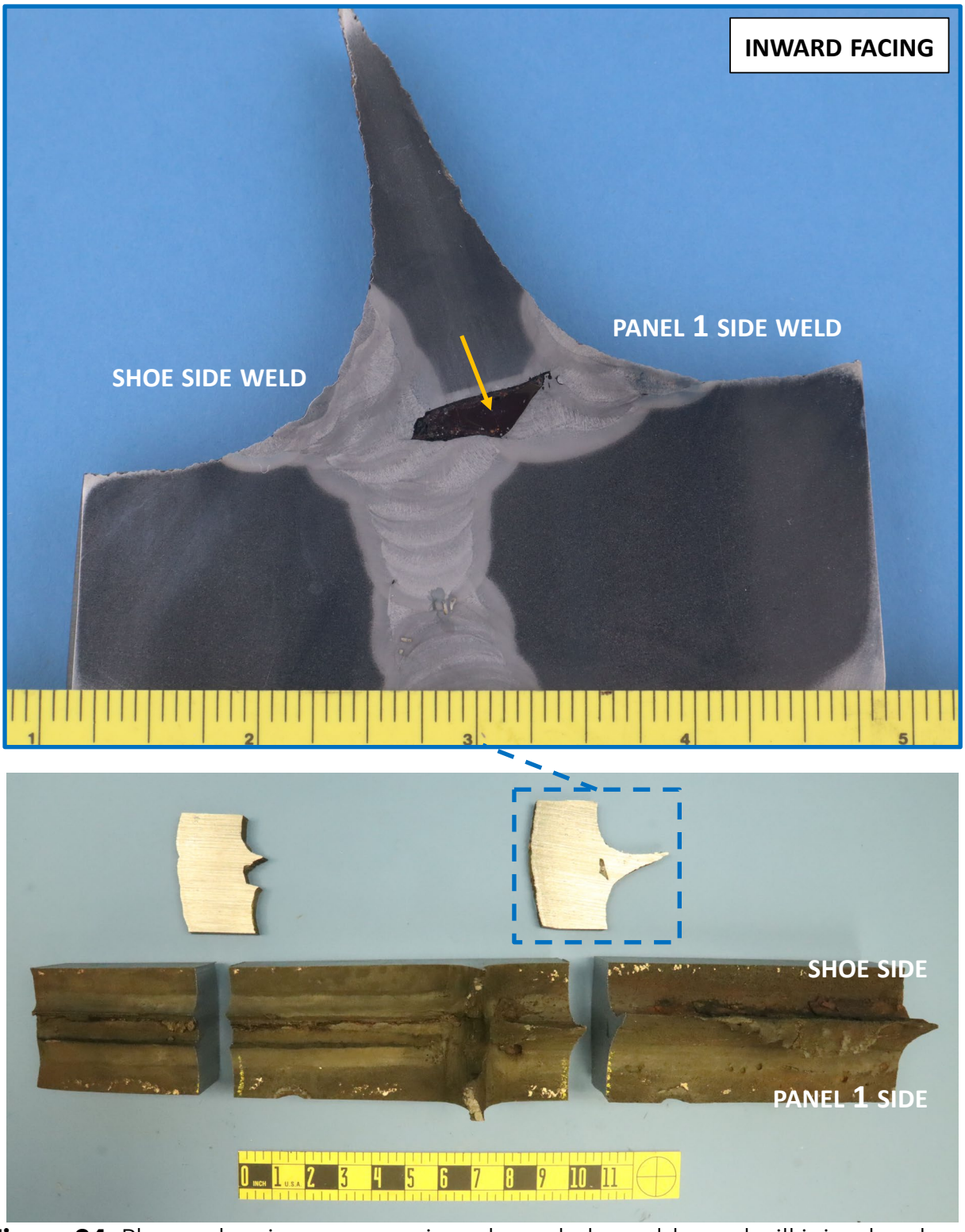


Figure 24. Photos showing cross-sections through the weld metal still joined to the span 2 side flange at the inward facing side tie plate. The orange arrow points to unfused weld metal and flux. (Top photo etchant: 5% nital)

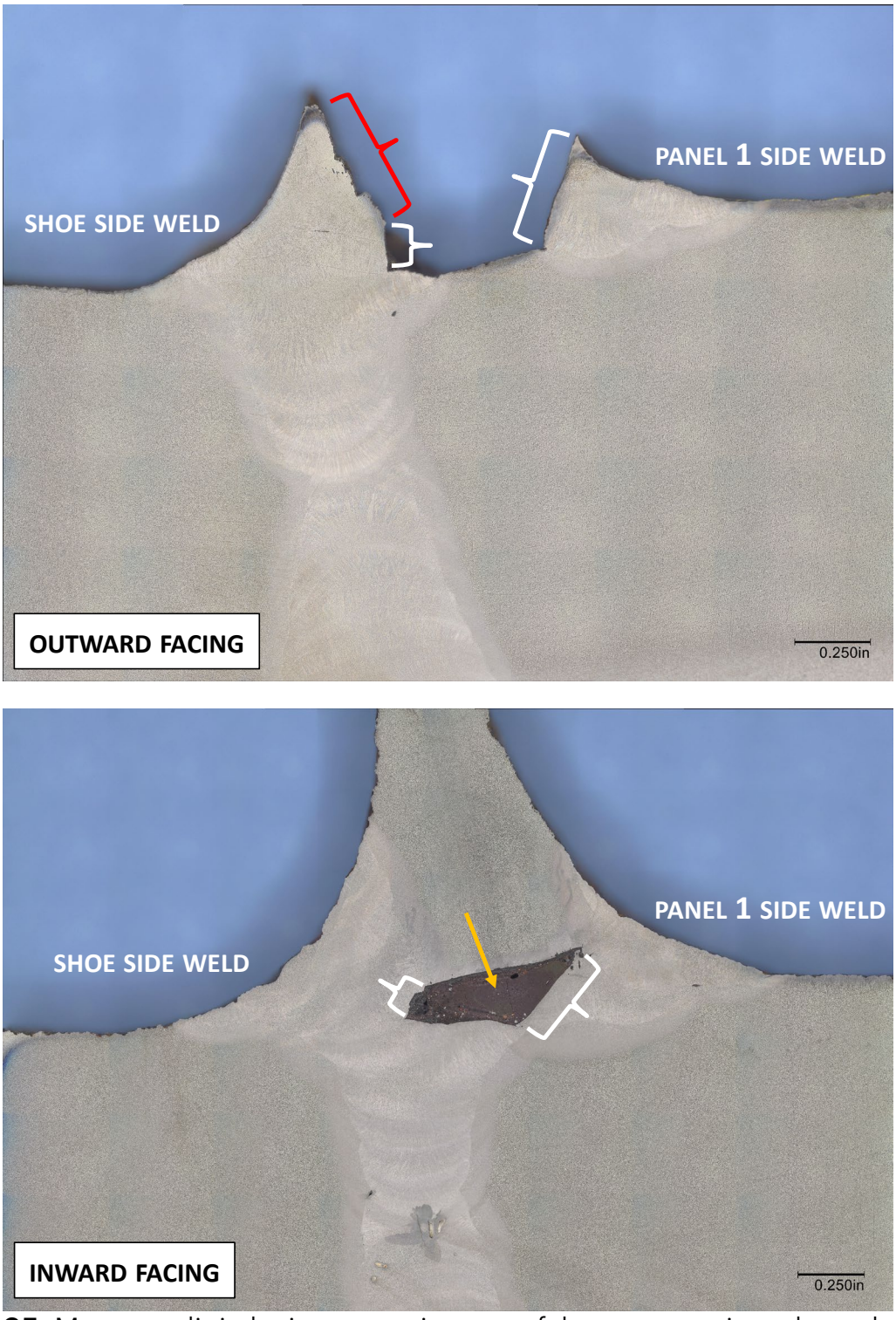


Figure 25. Montage digital microscope images of the cross-sections through the weld metal still joined to the span 2 side flange at the tie plates. The orange arrow points to unfused weld metal and flux. The red bracket indicates fractured weld metal. The white brackets indicate smooth portions of the welds that did not fuse to the tie plates. (Etchant: 5% nital)

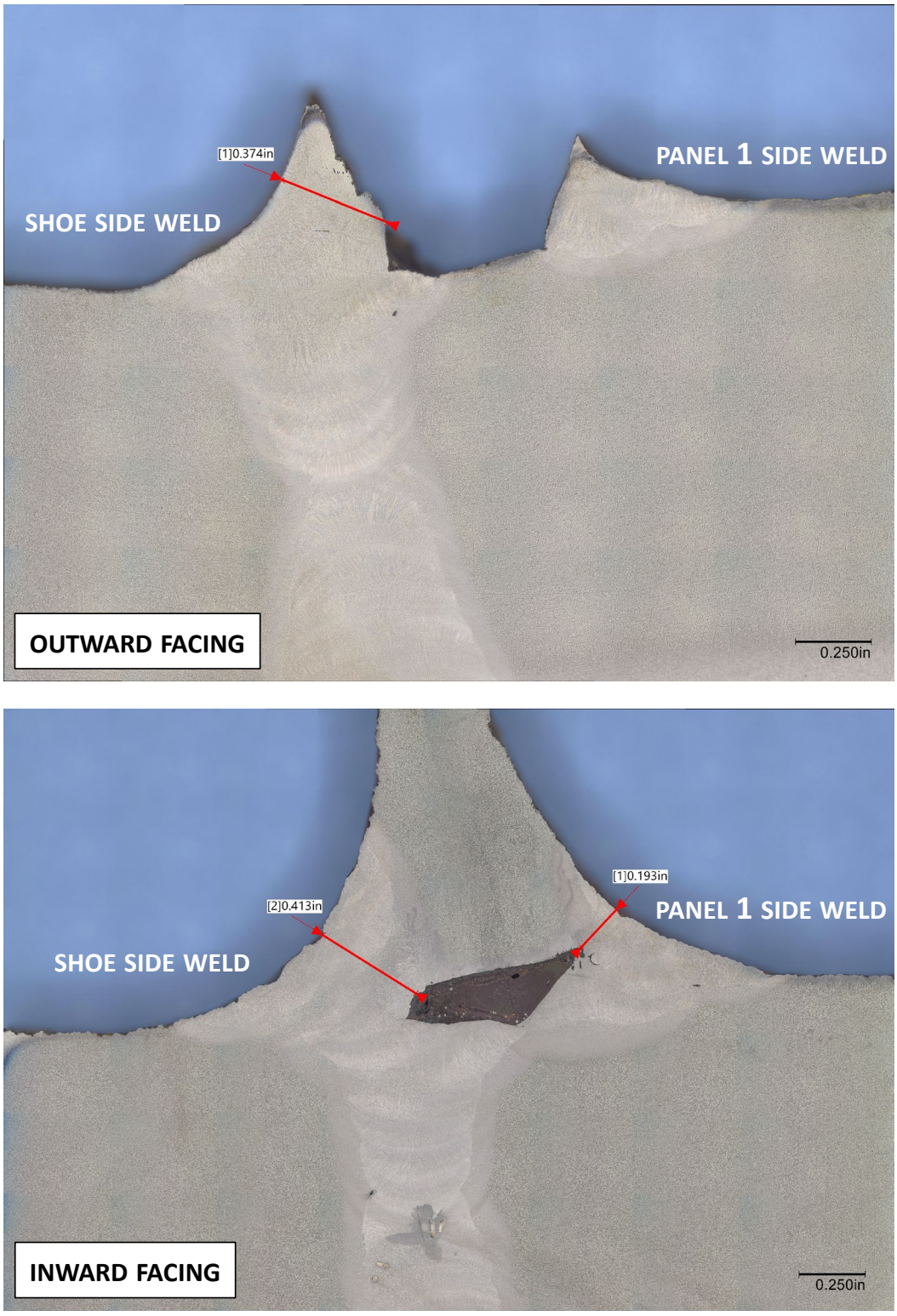


Figure 26. Montage digital microscope images of the cross-sections through the weld metal still joined to the span 2 side flange at the tie plates. Measurements of the weld throats (red arrows) are shown. (Etchant: 5% nital)

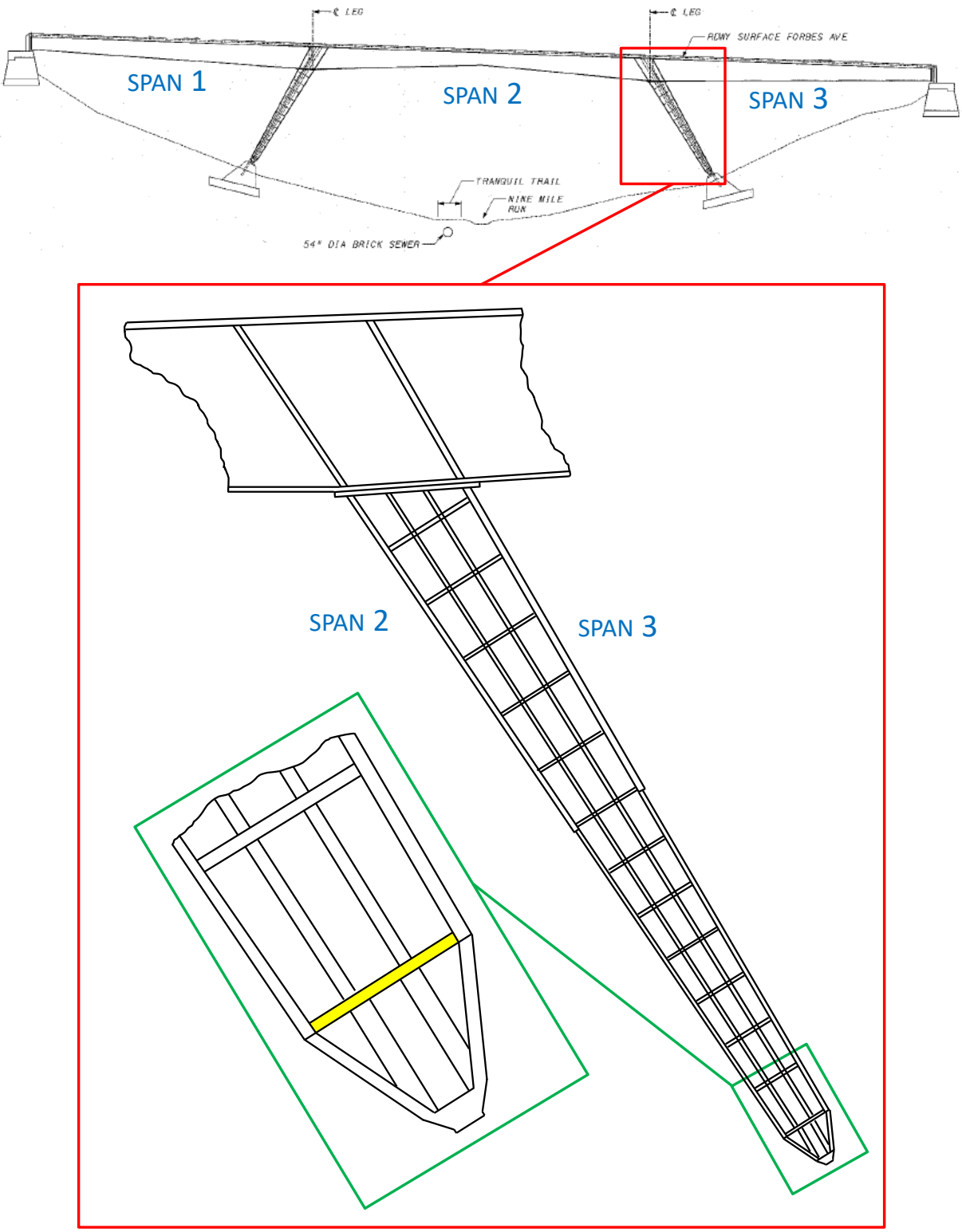


Figure 27. Schematic showing the inward facing side of the bottom of leg B2L with the tie plate highlighted in yellow. (Schematic not to scale)

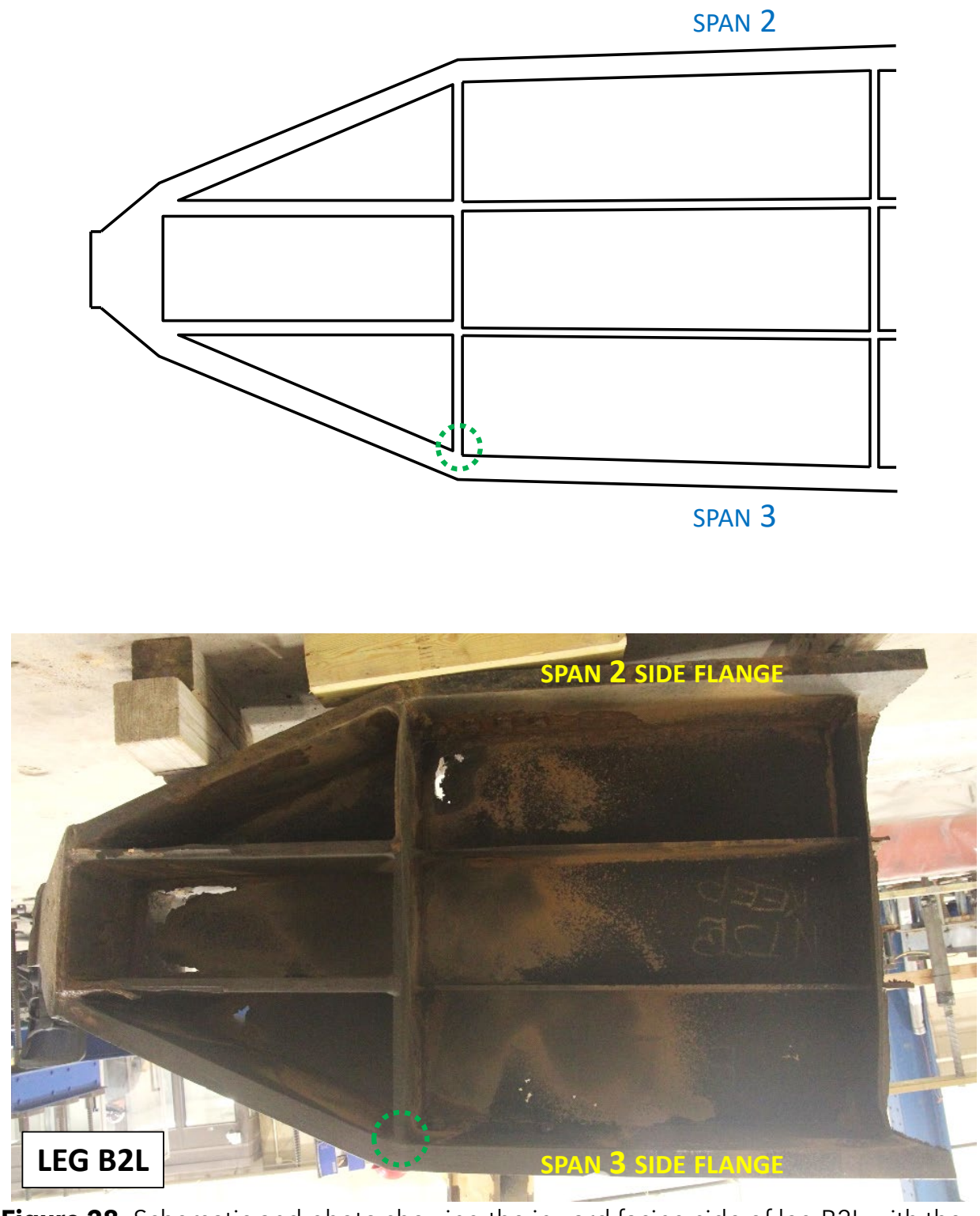


Figure 28. Schematic and photo showing the inward facing side of leg B2L with the ends of the tie plates that mated with the span 3 side flange on the uphill side of the leg encircled by the green dotted lines.

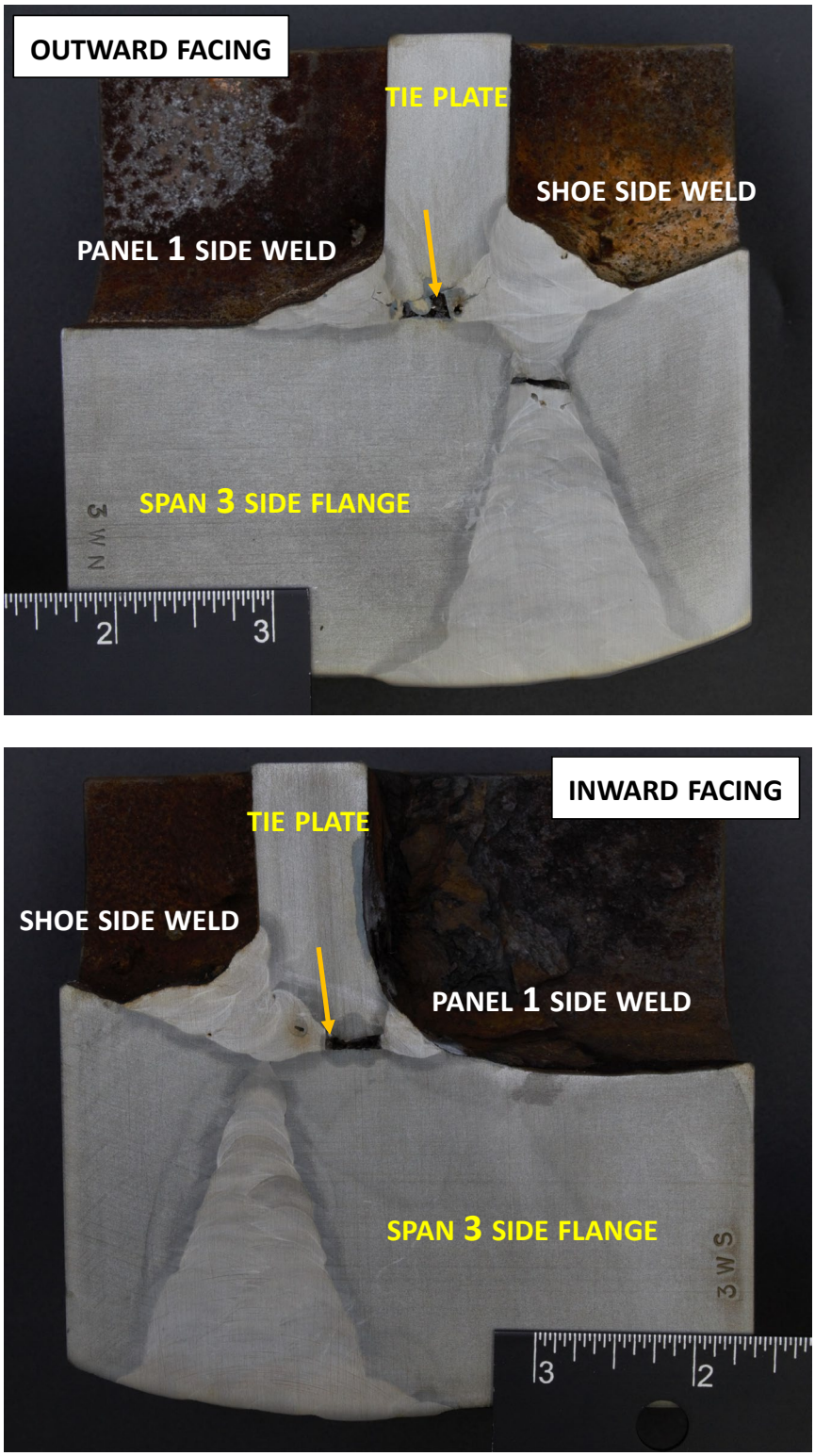


Figure 29. Photos of the cross-sections through the span 3 side flange at the tie plates on leg B2L. The orange arrows point to unfused weld metal and flux. (Etchant: 5% nital) (Photos by FHWA)

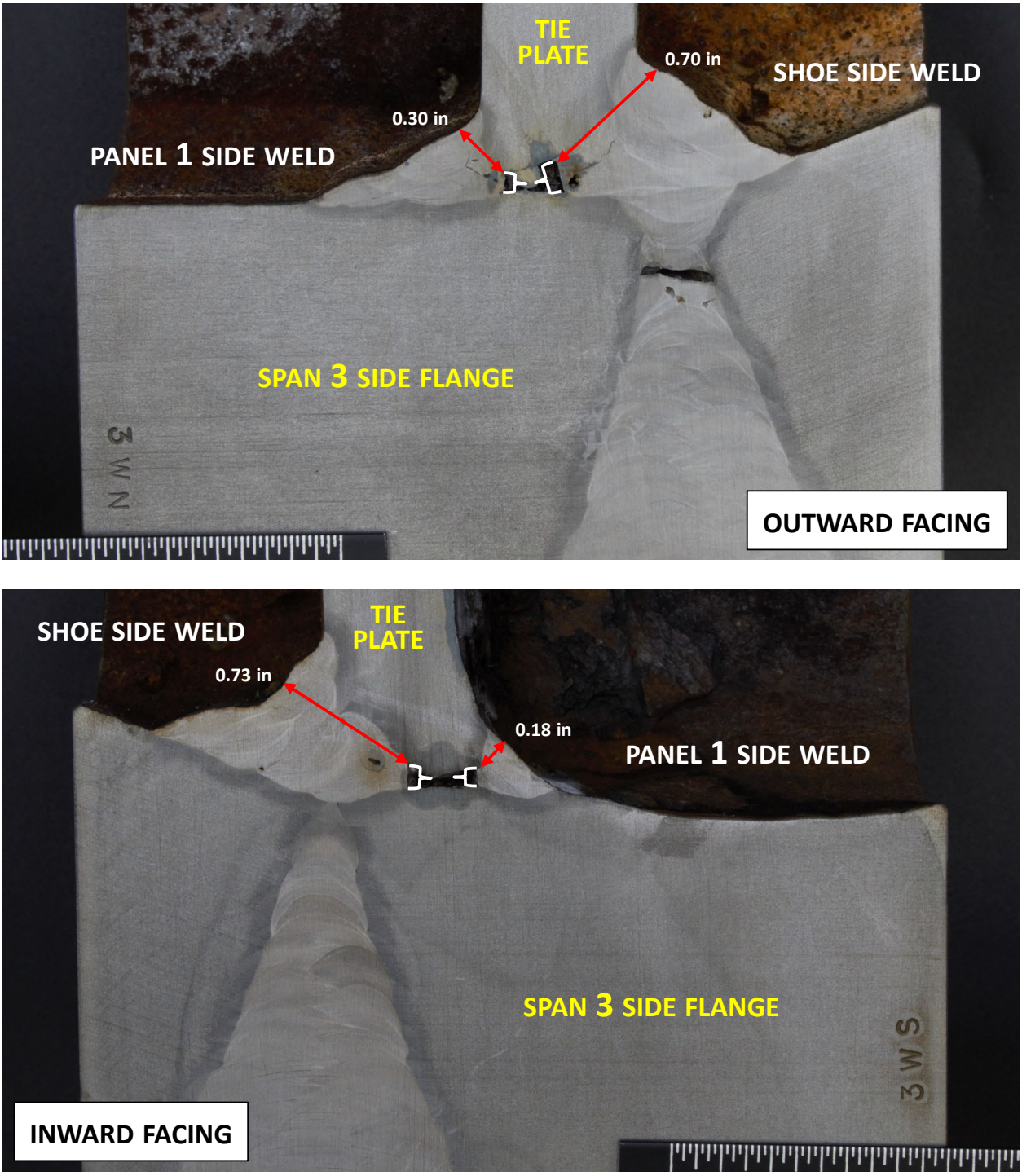


Figure 30. The Photos of the cross-sections through the span 3 side flange at the tie plates on leg B2L with measurements of the weld throats (red arrows) shown. The white brackets indicate smooth portions of the welds that did not fuse to the tie plates. (Etchant: 5% nital) (Photos by FHWA)

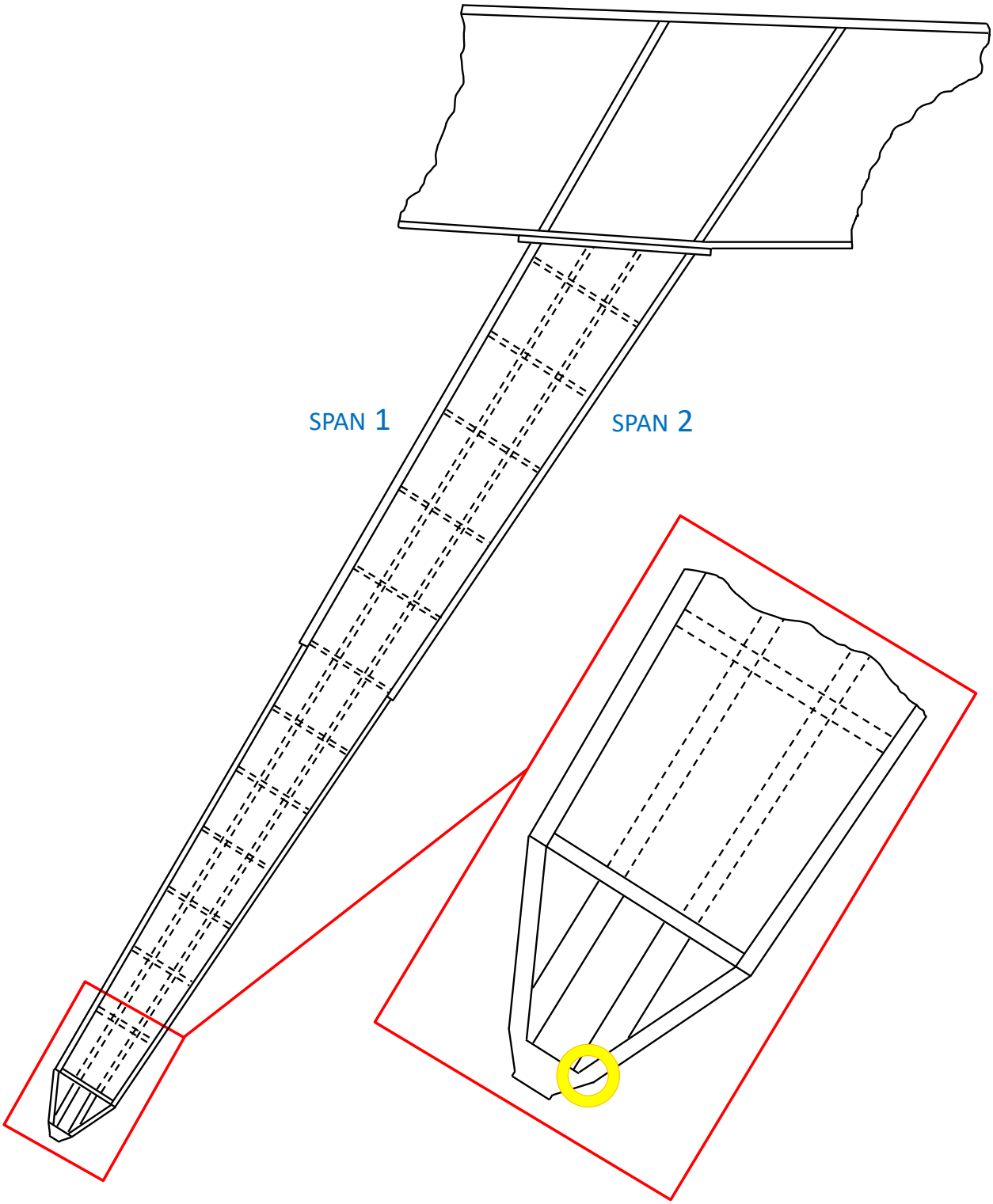


Figure 31. Schematic showing the outward facing side of the bottom of leg B1R with the joint between the top of the toe and the bottom of the span 2 side flange is encircled in yellow. (Schematic not to scale)

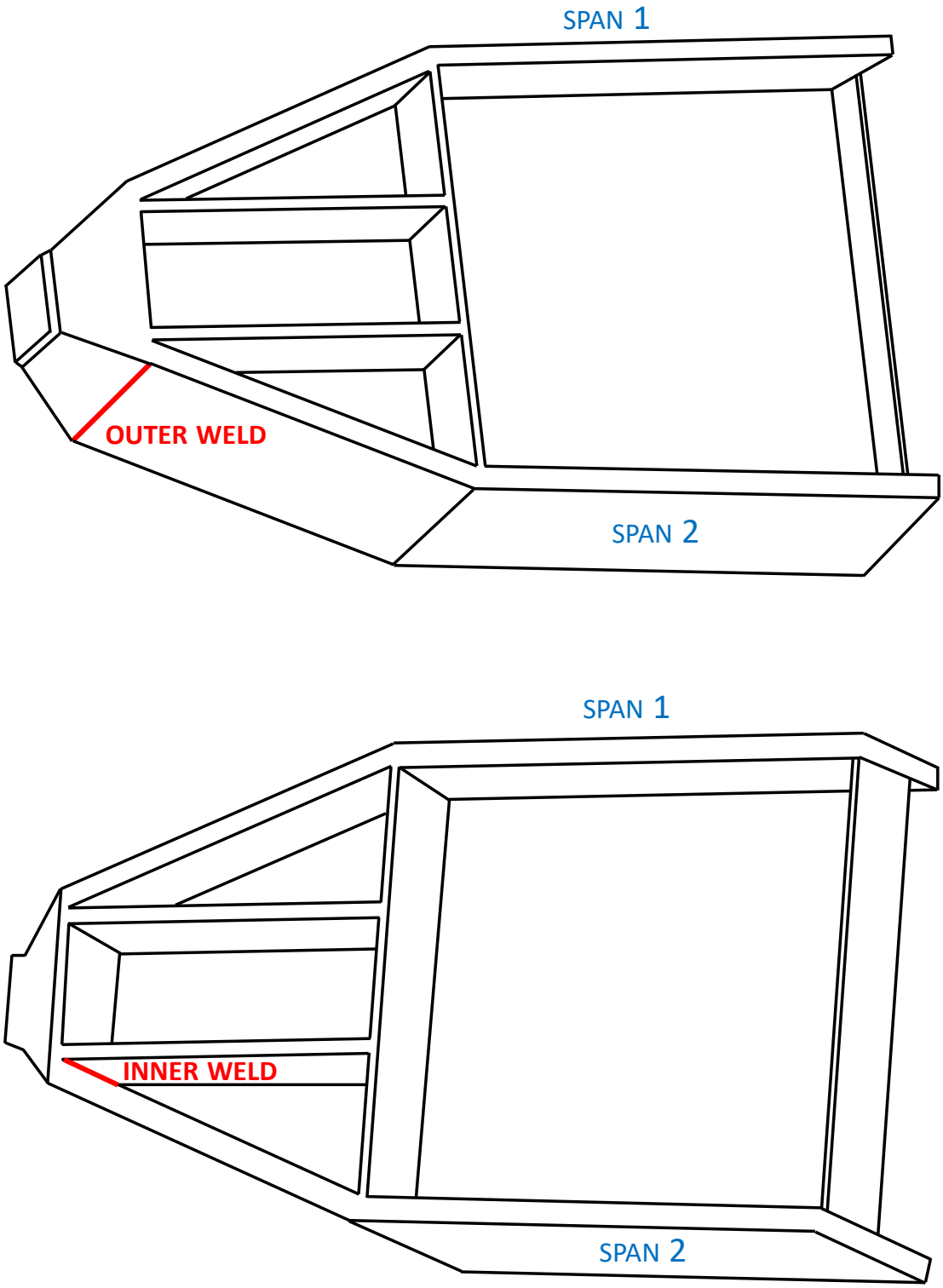


Figure 32. Schematics identifying the two main welds at the joint between the top of the toe and the bottom of the span 2 side flange as the outer and inner welds.

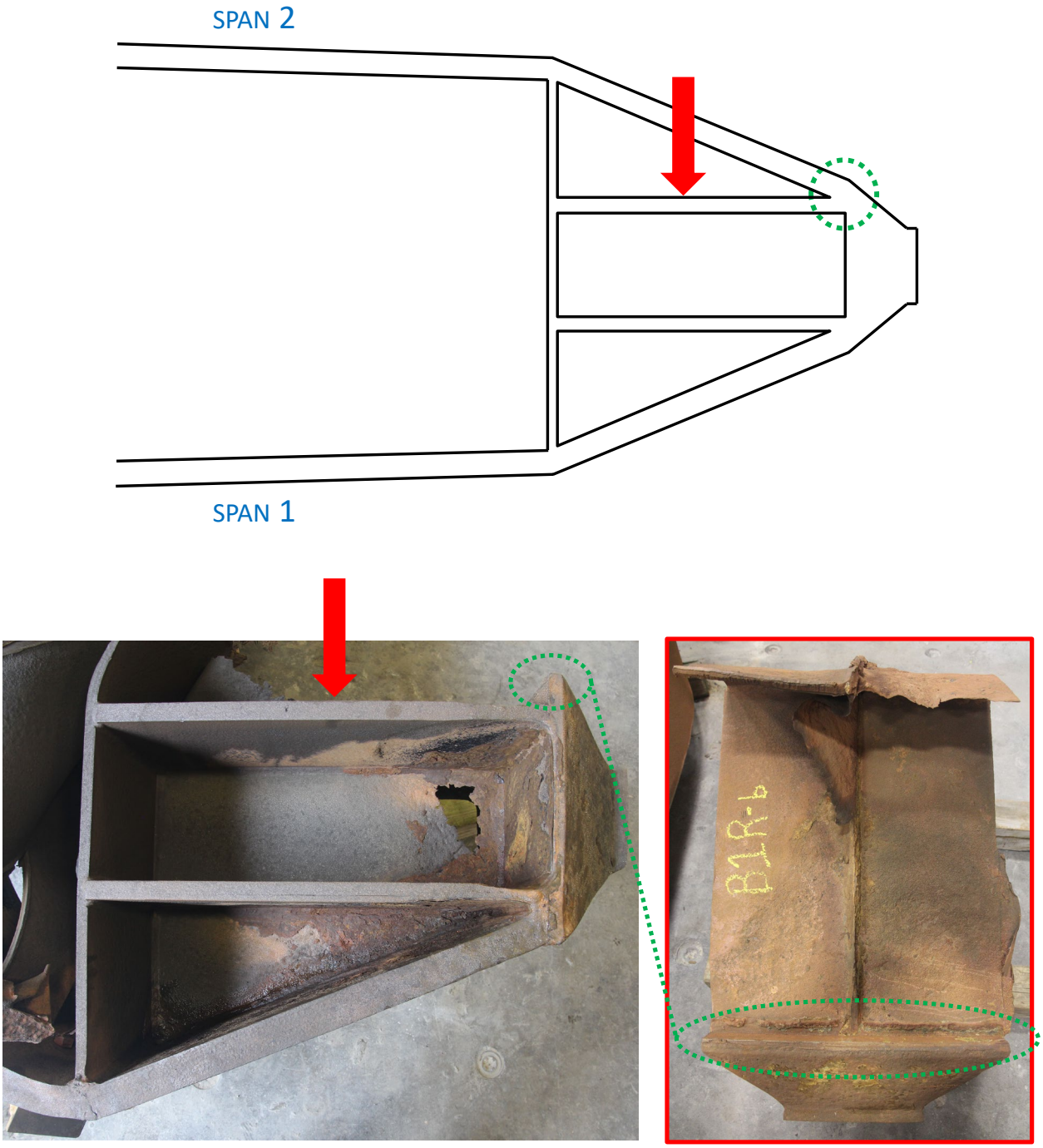


Figure 33. Schematic and photo of the outward facing side of leg B1R are shown in the top and bottom left, respectively. The bottom right image of the shoe is viewed in the direction of the red arrows. The joint between the top of the toe and the bottom of the span 2 side flange is encircled by the green dotted lines.

Figure 34. Close-up photos of the joint between the top of the toe and the bottom of the span 2 side flange on the outward facing side. The orange arrows point to remnants of the inner weld where the toe, flange end, and bearing stiffener mated and the green arrows point to remnants of the outer weld where the toe and flange end mated.

Figure 35. Close-up photos of the joint between the top of the toe and the bottom of the span 2 side flange on the inward facing side. The orange arrows point to remnants of the inner weld where the toe, flange end, and bearing stiffener mated and the green arrows point to remnants of the outer weld where the toe and flange end mated.

Figure 36. Photos of the bottom of the rolled span 2 side flange while it was still attached to the leg on-scene. The yellow dotted line encircles the flange end.

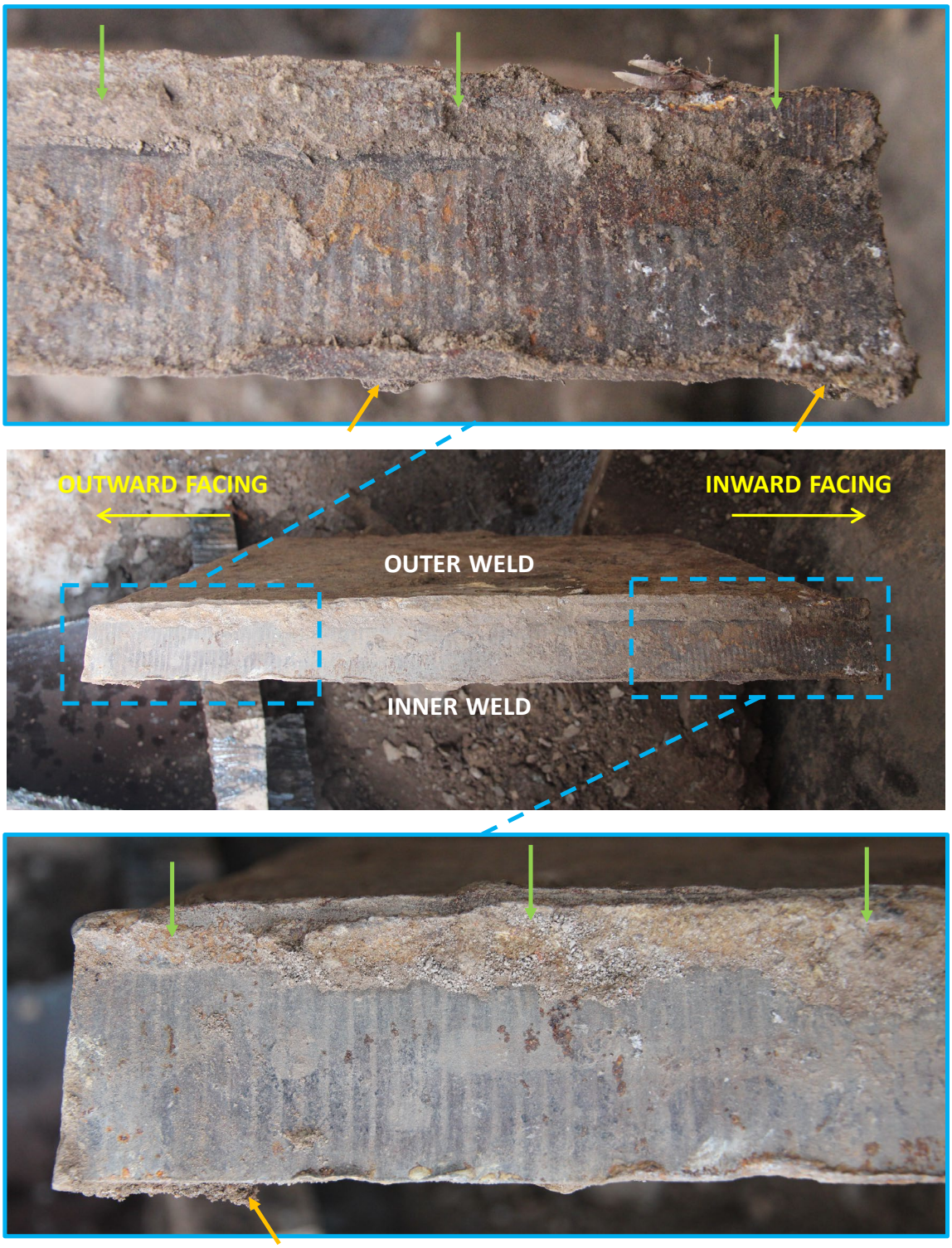


Figure 37. Close-up photos of the flange end on the bottom of the rolled span 2 side flange while it was still attached to the leg on-scene. The orange arrows point to remnants of the inner weld where the toe, flange end, and bearing stiffener mated and the green arrows point to remnants of the outer weld where the toe and flange end mated.

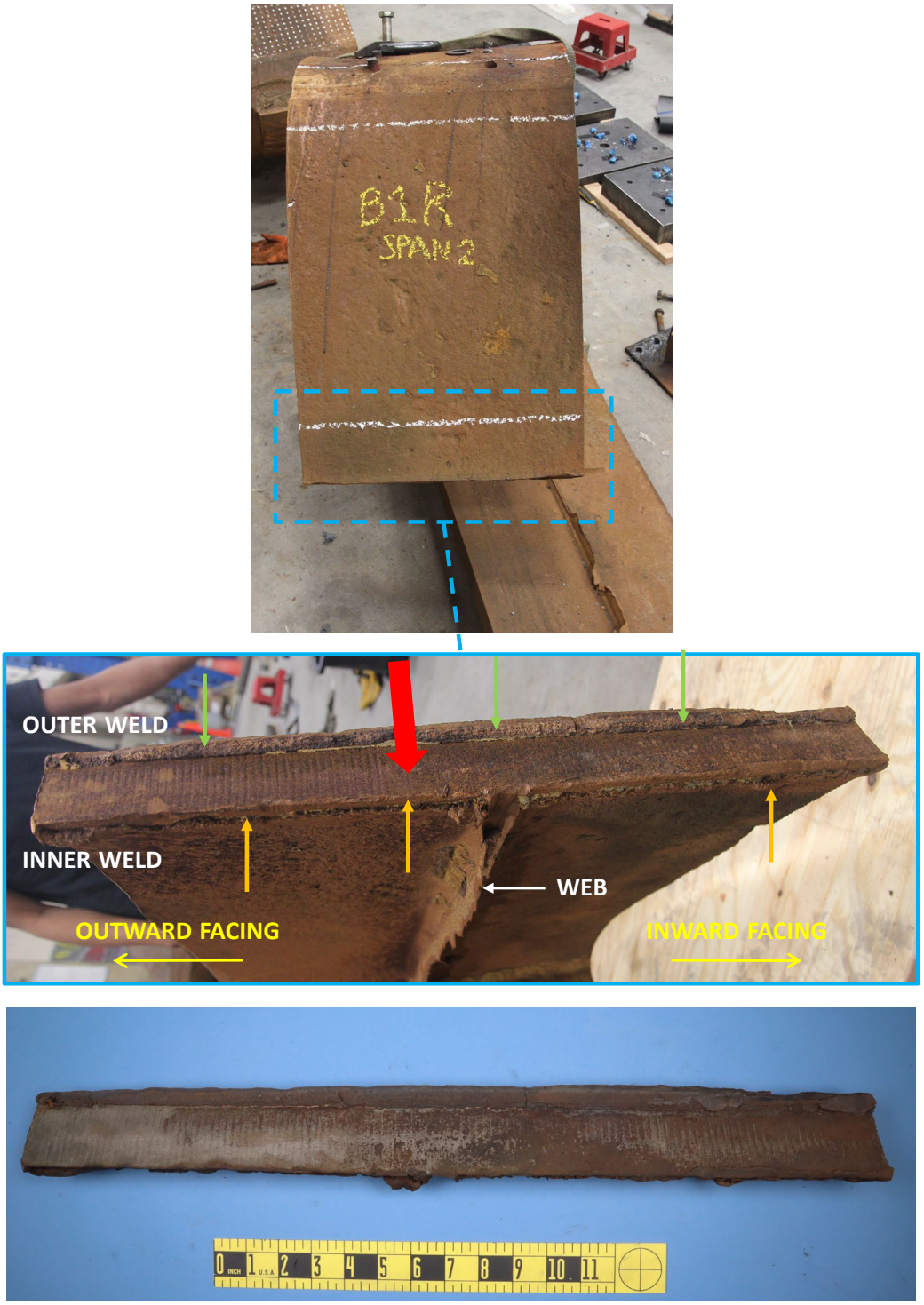


Figure 38. The top and middle photos show the end of the rolled span 2 side flange while still attached, and the bottom photo shows the flange end after sectioning. The red arrow points to the view of the flange piece shown in the bottom photo. The orange arrows point to remnants of the inner weld where the toe, flange end, and bearing stiffener mated and the green arrows point to remnants of the outer weld where the toe and flange end mated.

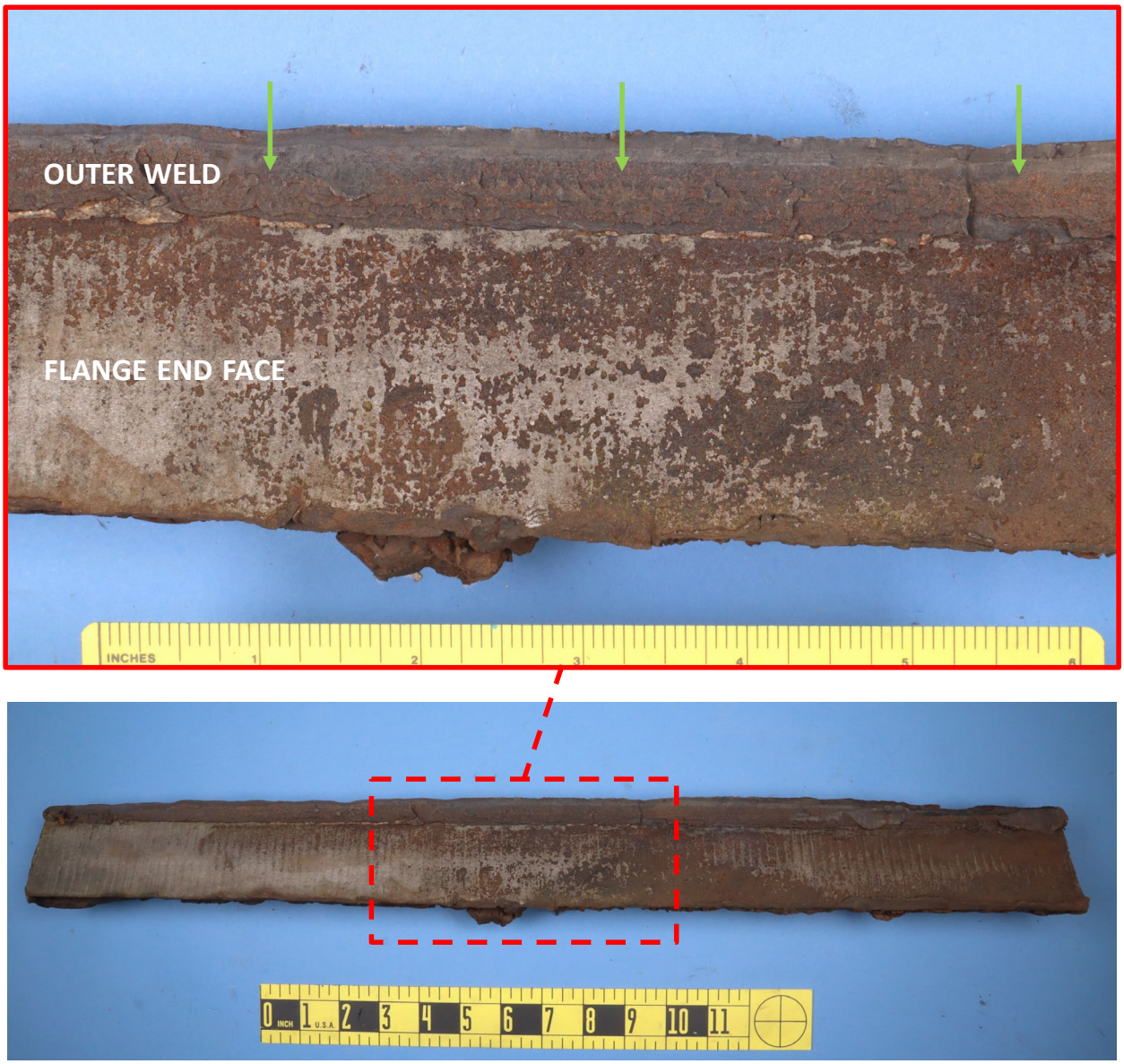


Figure 39. Overall photo (bottom) and close-up photo (top) showing the end of the rolled span 2 side flange. The green arrows green arrows point to remnants of the outer weld where the toe and flange end mated.

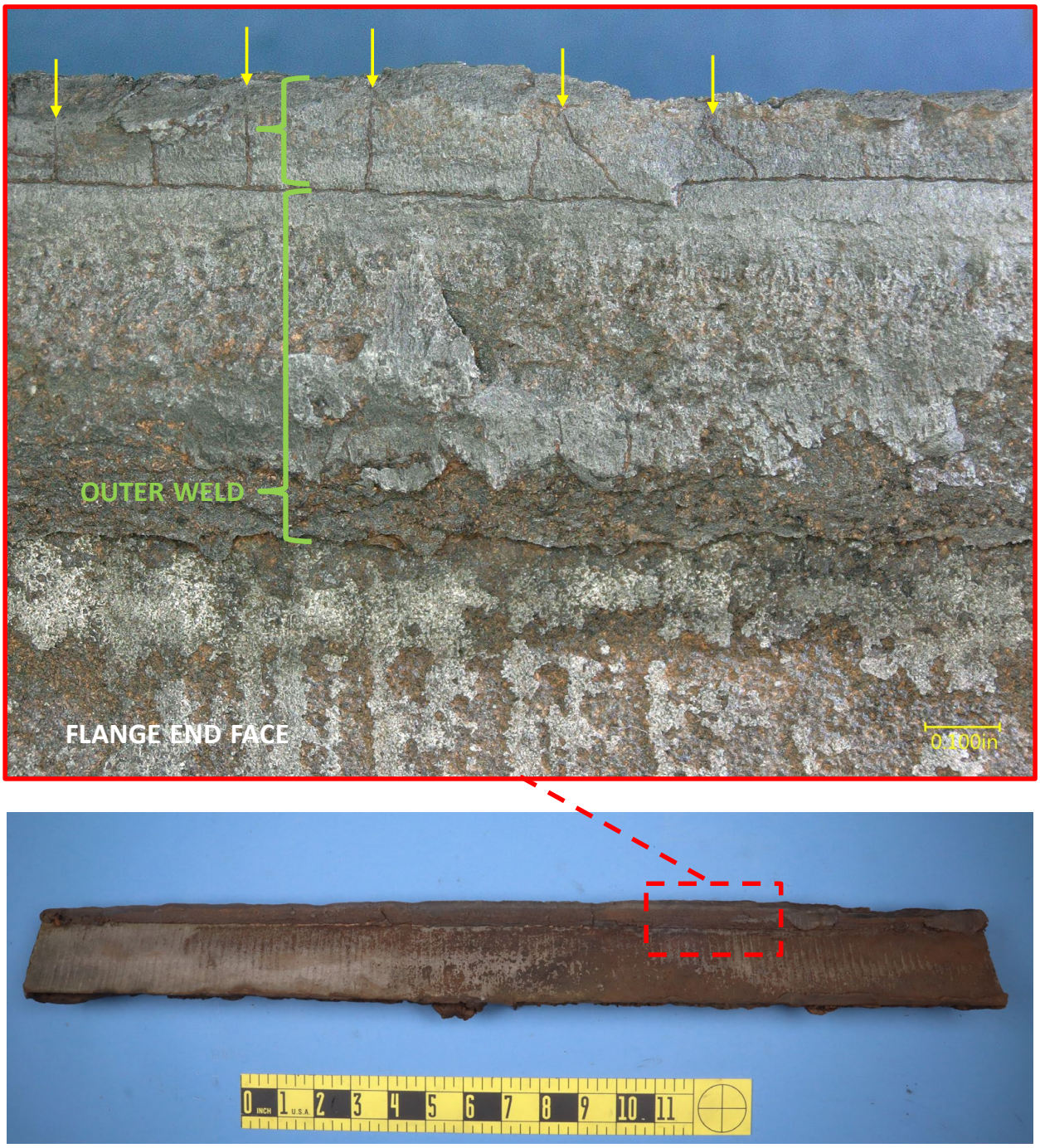


Figure 40. Overall photo (bottom) and digital microscope image (top) showing the end of the rolled span 2 side flange. The green brackets indicate the two passes of the outer weld where the toe and flange end mated. The yellow arrows point to transverse lines visible in the top weld pass.

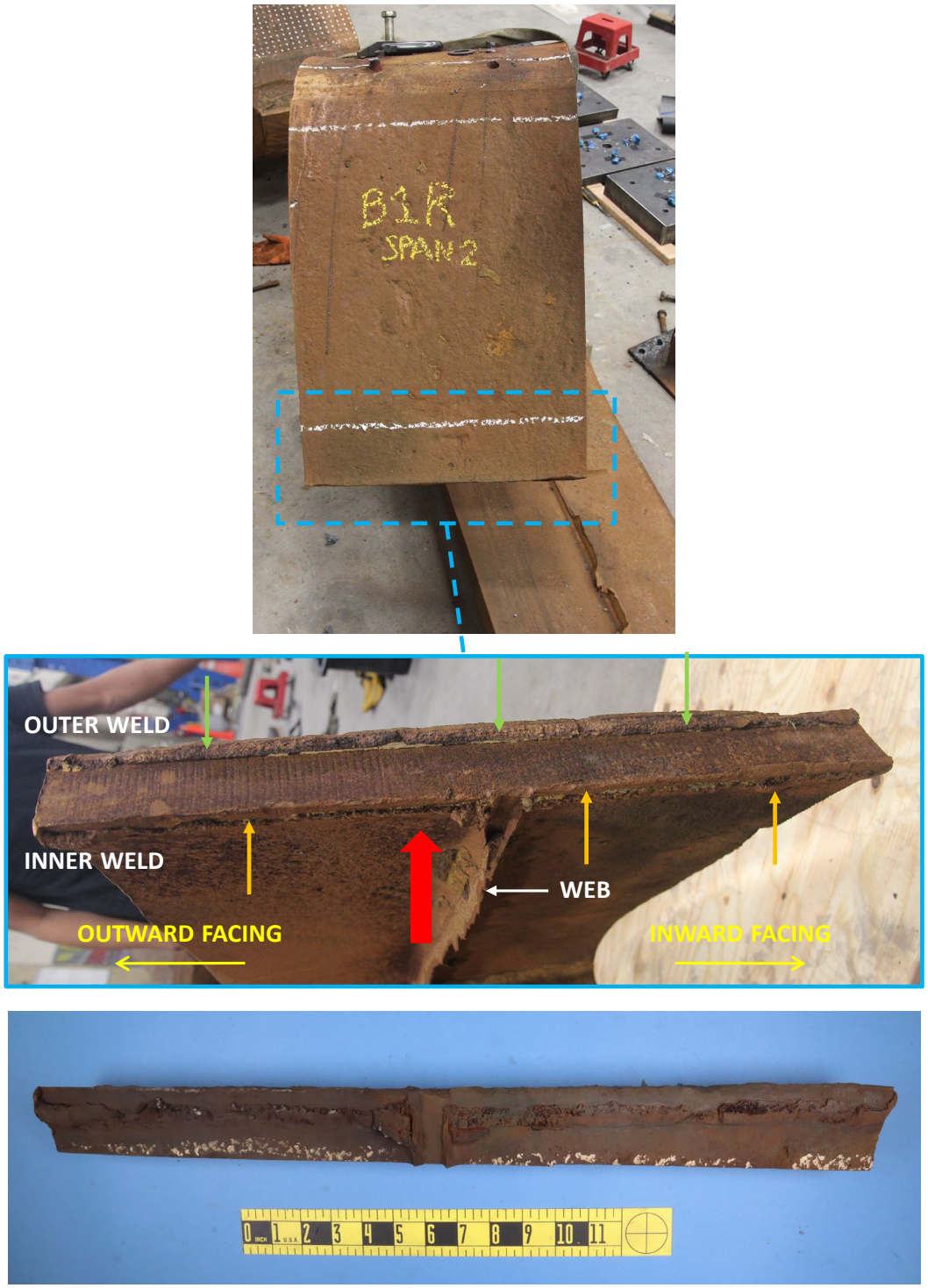


Figure 41. The top and middle photos show the end of the rolled span 2 side flange while still attached, and the bottom photo shows the flange end after sectioning. The red arrow points to the view of the flange piece shown in the bottom photo. The orange arrows point to remnants of the inner weld where the toe, flange end, and bearing stiffener mated and the green arrows point to remnants of the outer weld where the toe and flange end mated.

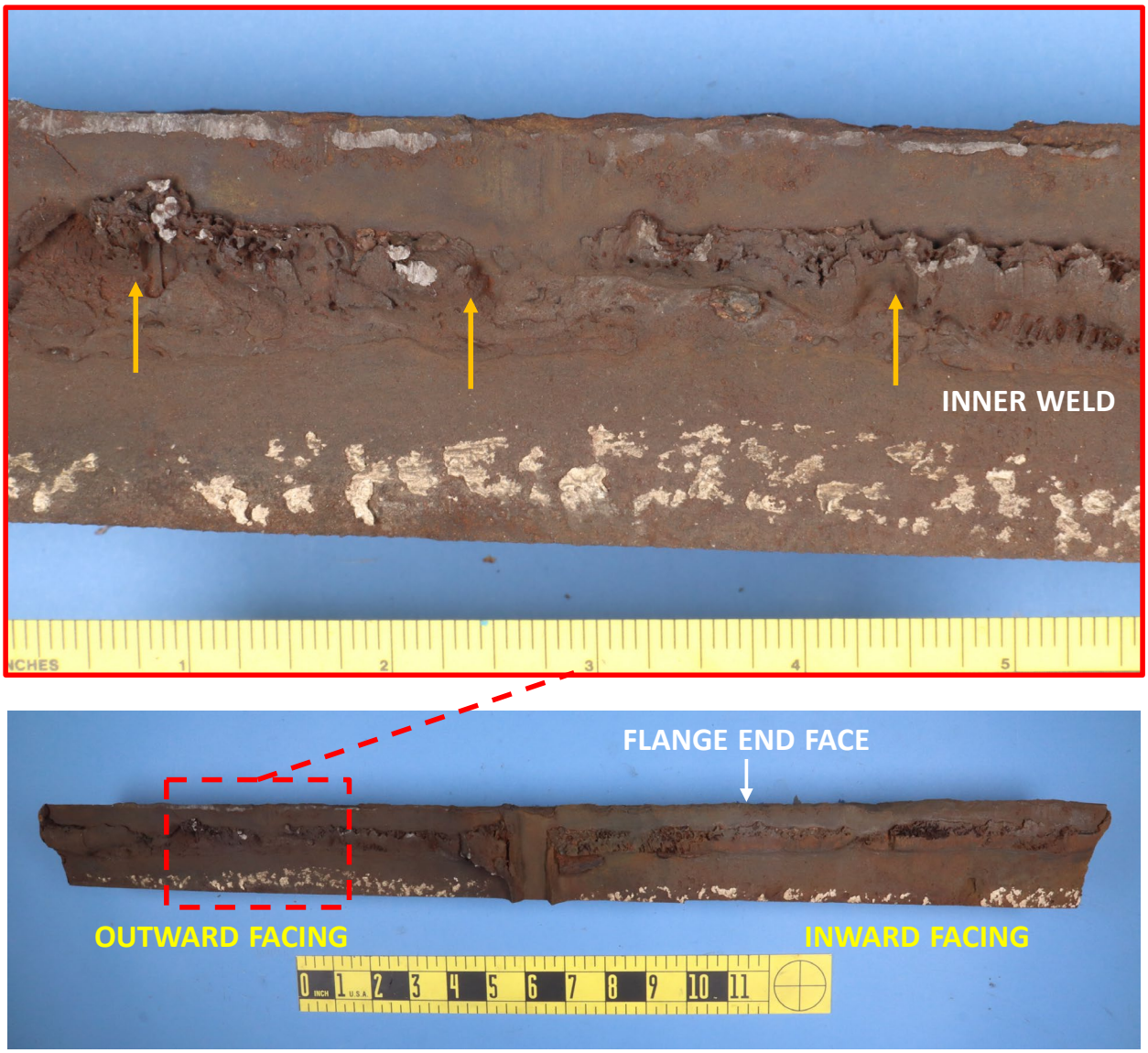


Figure 42. Overall photo (bottom) and close-up photo (top) showing the inner face of the rolled span 2 side flange. The orange arrows point to remnants of the inner weld where the toe, flange end, and bearing stiffener mated.

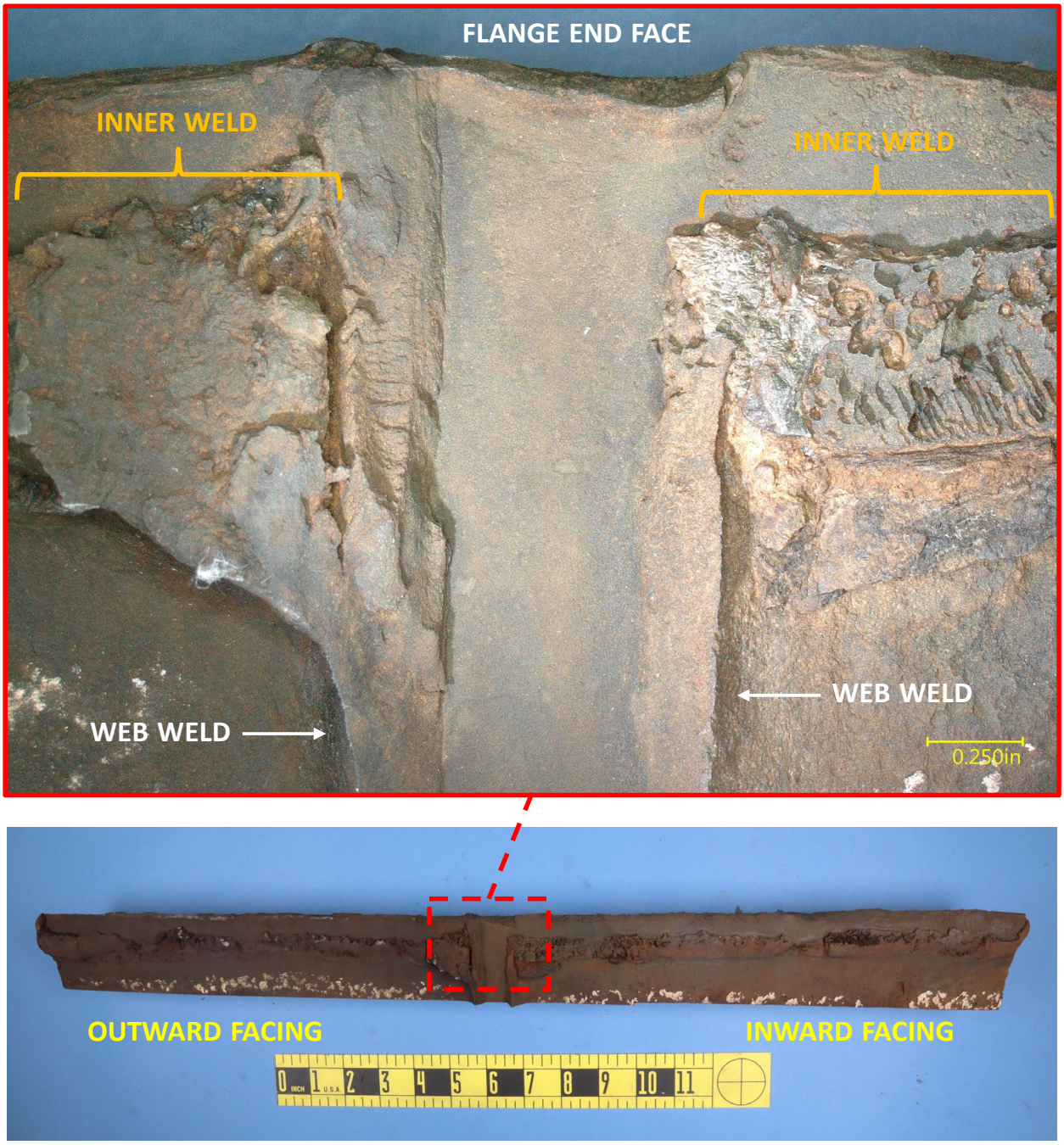


Figure 43. Overall photo (bottom) and close-up photo (top) showing the inner face of the rolled span 2 side flange. The orange brackets indicate remnants of the inner weld where the toe, flange end, and bearing stiffener mated.

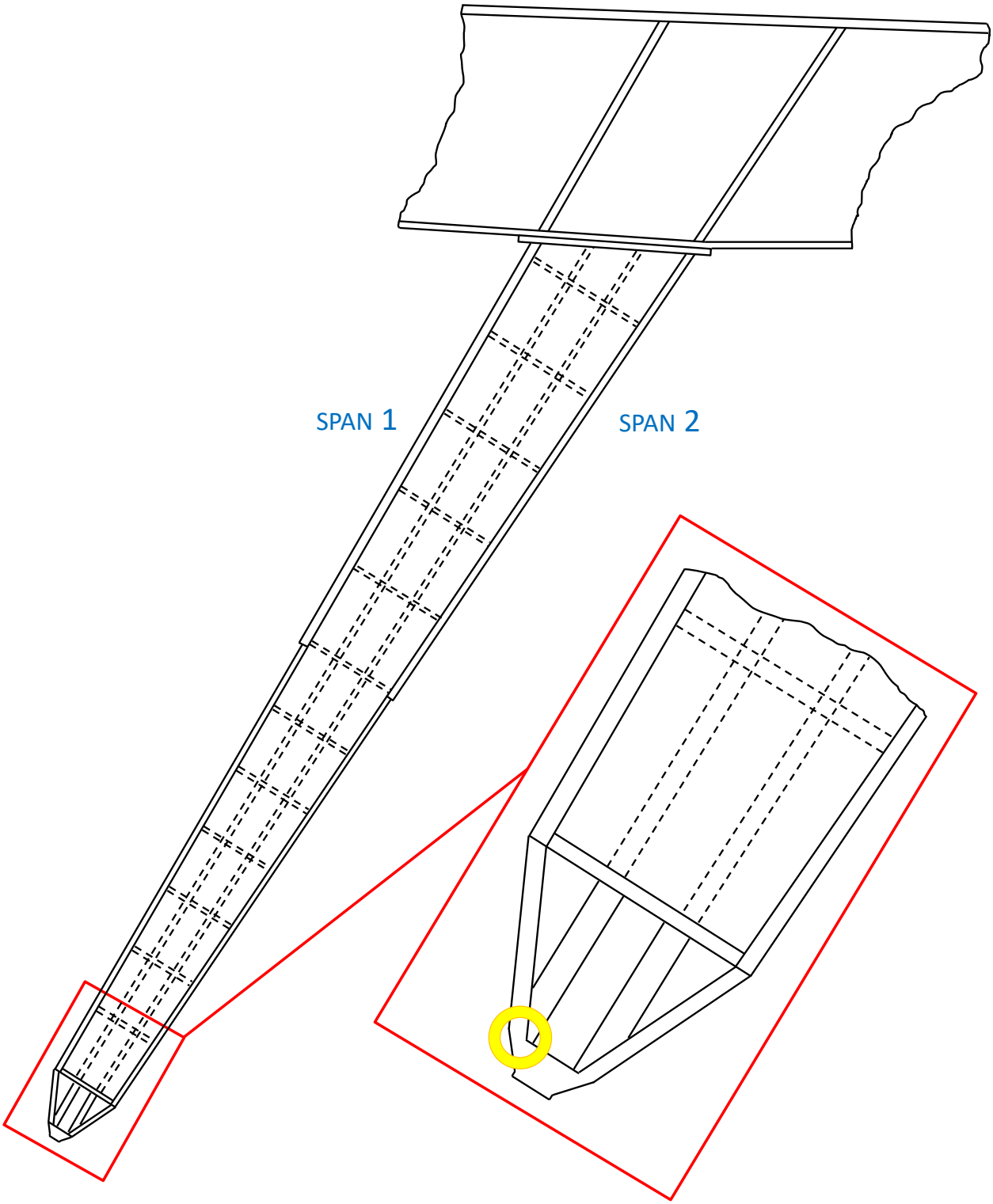


Figure 44. Schematic showing the outward facing side of the bottom of leg B1R with the joint between the top of the toe and the bottom of the span 1 side flange encircled in yellow. (Schematic not to scale)

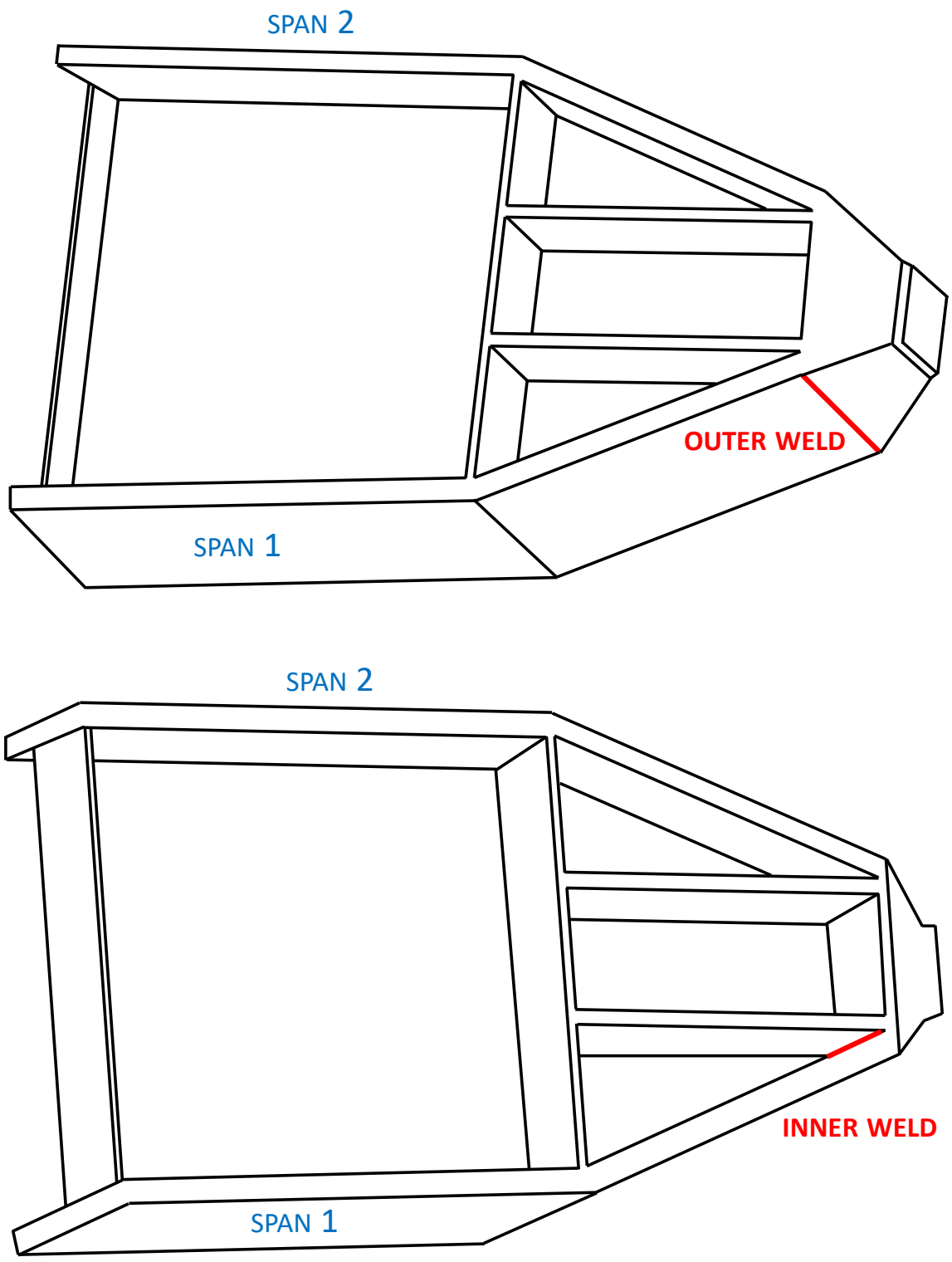


Figure 45. Schematics identifying the two main welds at the joint between the top of the toe and the bottom of the span 1 side flange as the outer and inner welds on leg B1R.

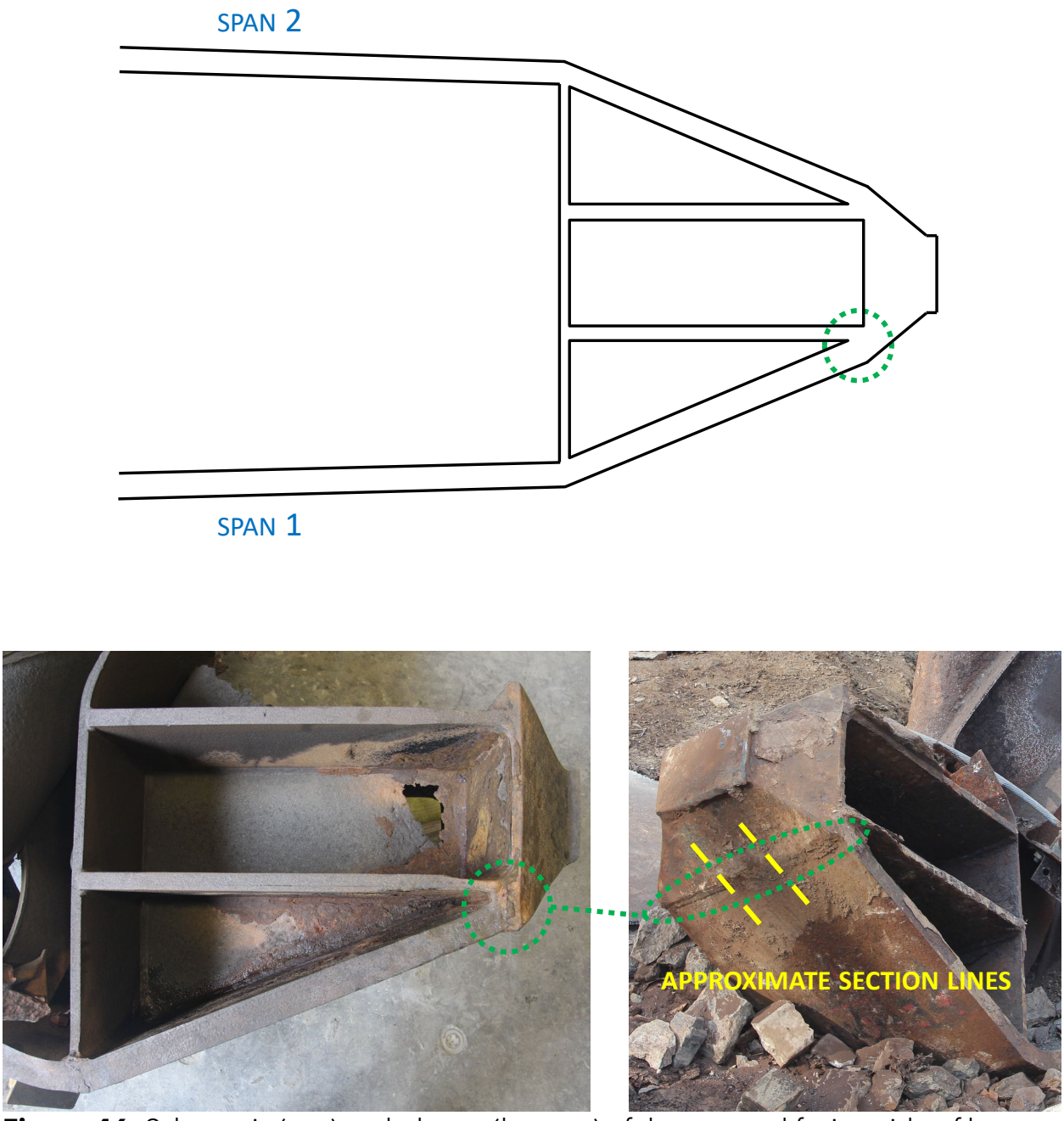


Figure 46. Schematic (top) and photos (bottom) of the outward facing side of leg B1R. The joint on the shoe where the bottom of the span 1 side flange mated with the toe is identified by dotted green circles.

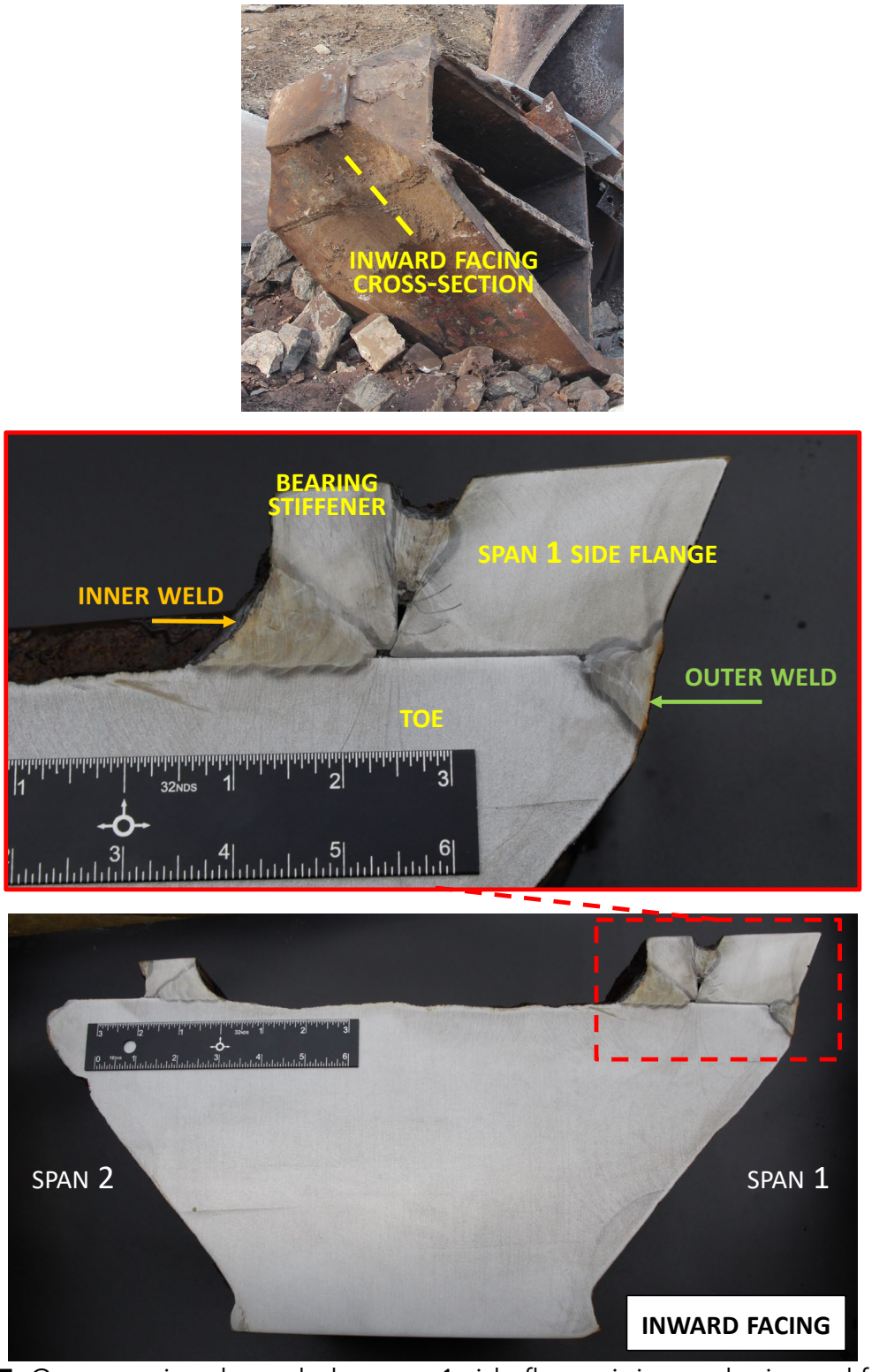


Figure 47. Cross-section through the span 1 side flange joint on the inward facing side. (Etchant: 5% nital) (Bottom two photos by FHWA)

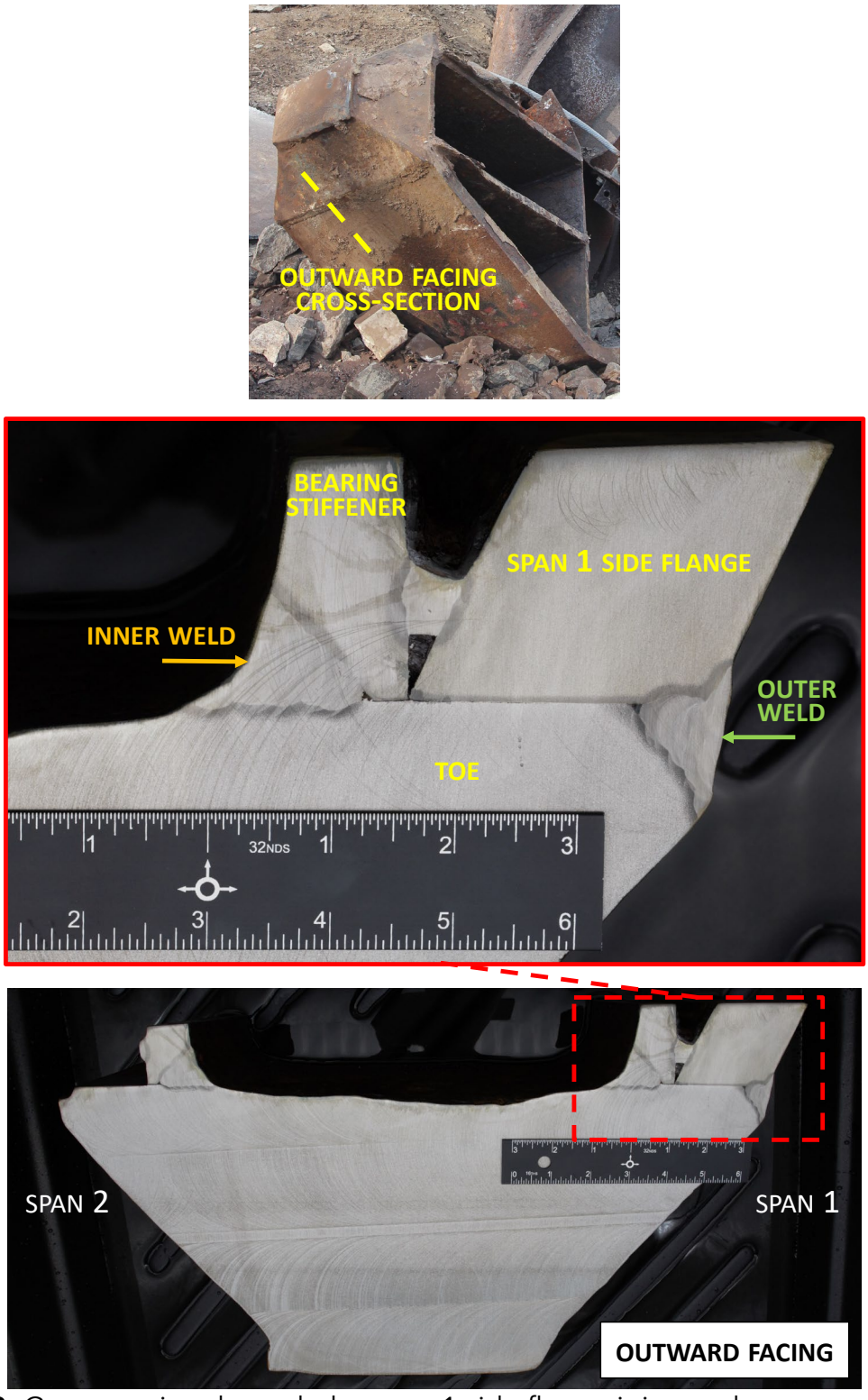


Figure 48. Cross-section through the span 1 side flange joint on the outward facing side. (Etchant: 5% nital) (Bottom two photos by FHWA)

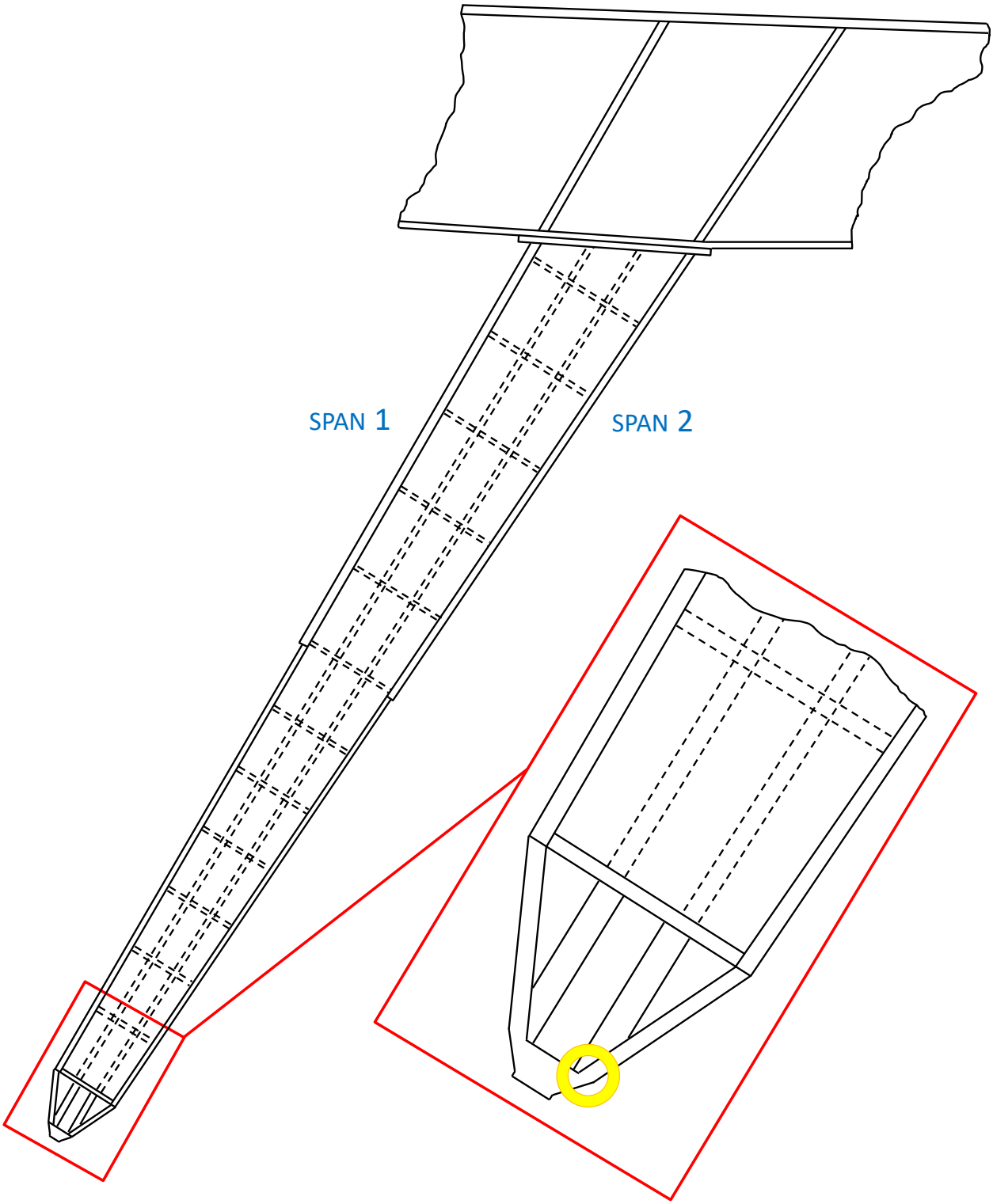
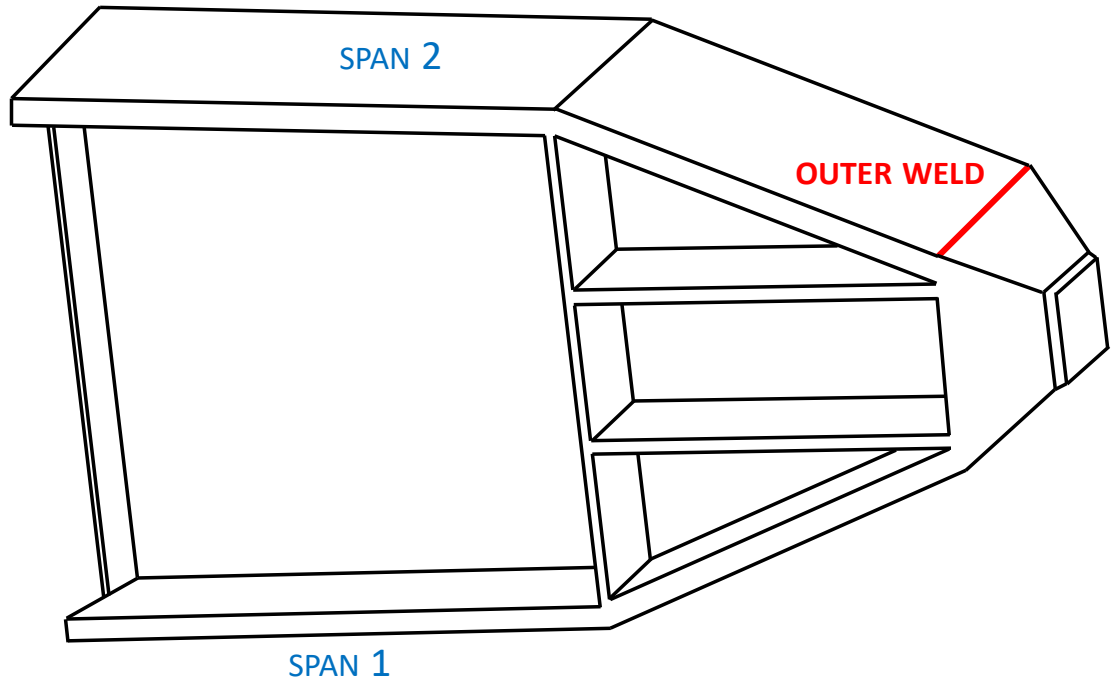


Figure 49. Schematic showing the outward facing side of the bottom of leg B1R with the joint between the top of the toe and the bottom of the span 2 side flange encircled in yellow. (Schematic not to scale)



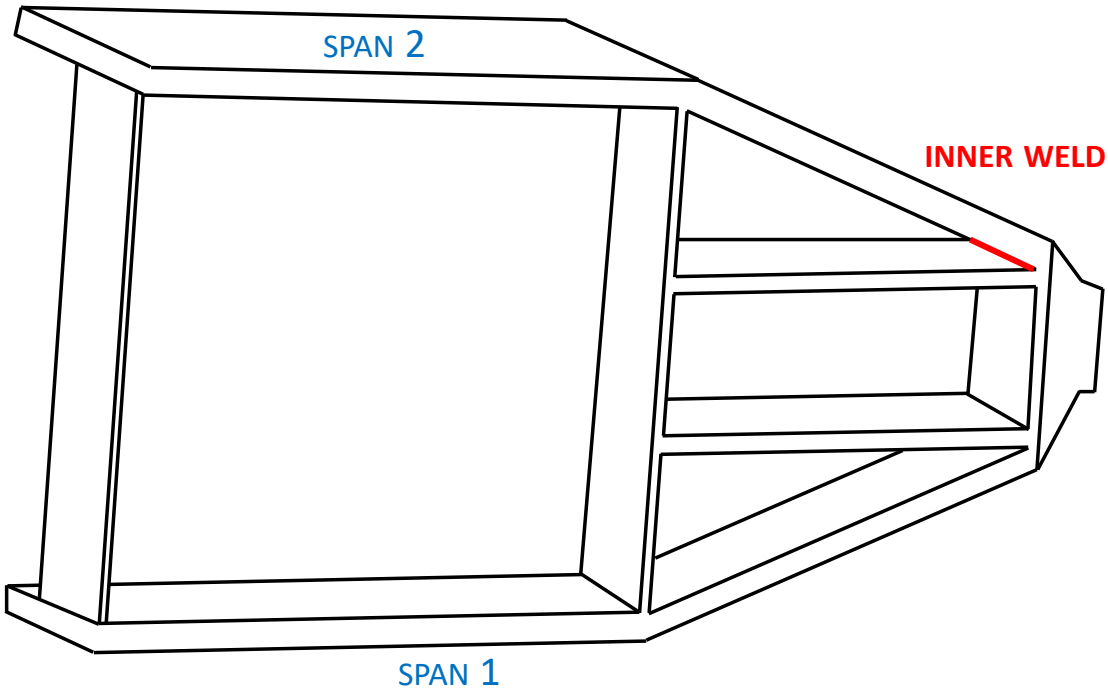


Figure 50. Schematics identifying the two main welds at the joint between the top of the toe and the bottom of the span 2 side flange as the outer and inner welds on leg B1R.

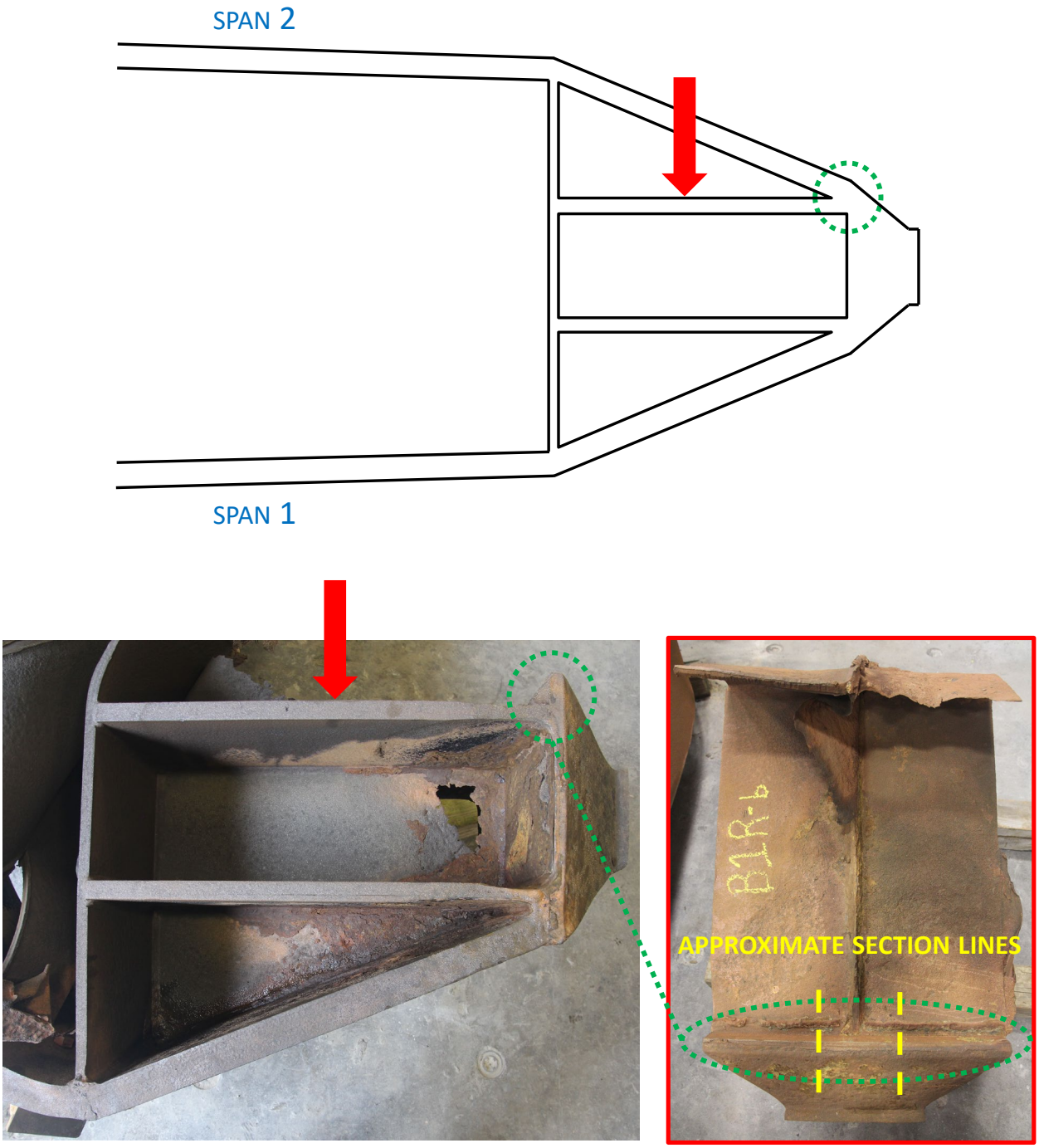


Figure 51. Schematic and photo of the outward facing side of leg B1R are shown in the top and bottom left, respectively. The bottom right image of the shoe is viewed in the direction of the red arrows. The joint between the top of the toe and the bottom of the span 2 side flange is encircled by the green dotted lines.

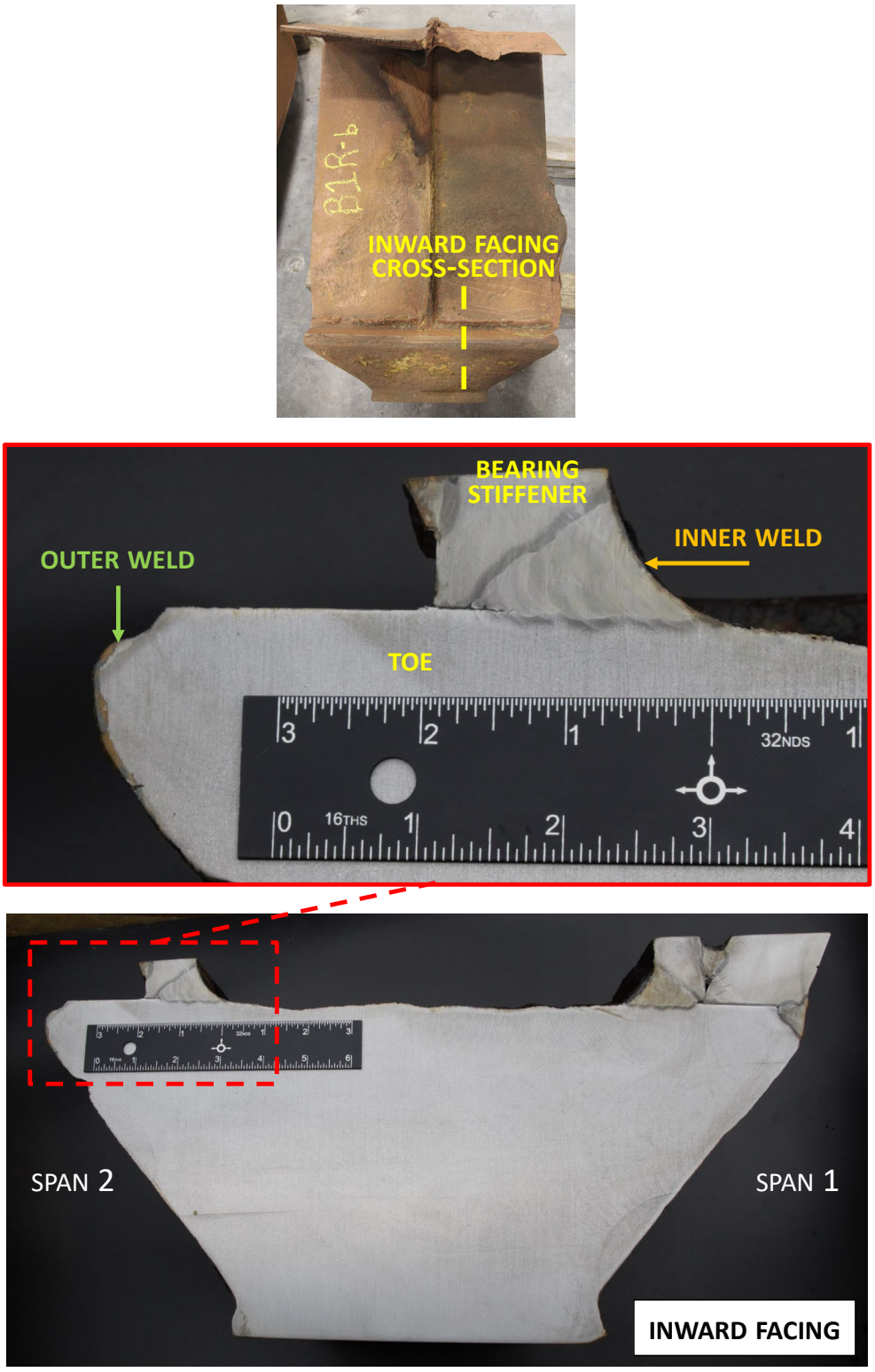


Figure 52. Cross-section through the span 2 side flange joint on the inward facing side. (Etchant: 5% nital) (Bottom two photos by FHWA)

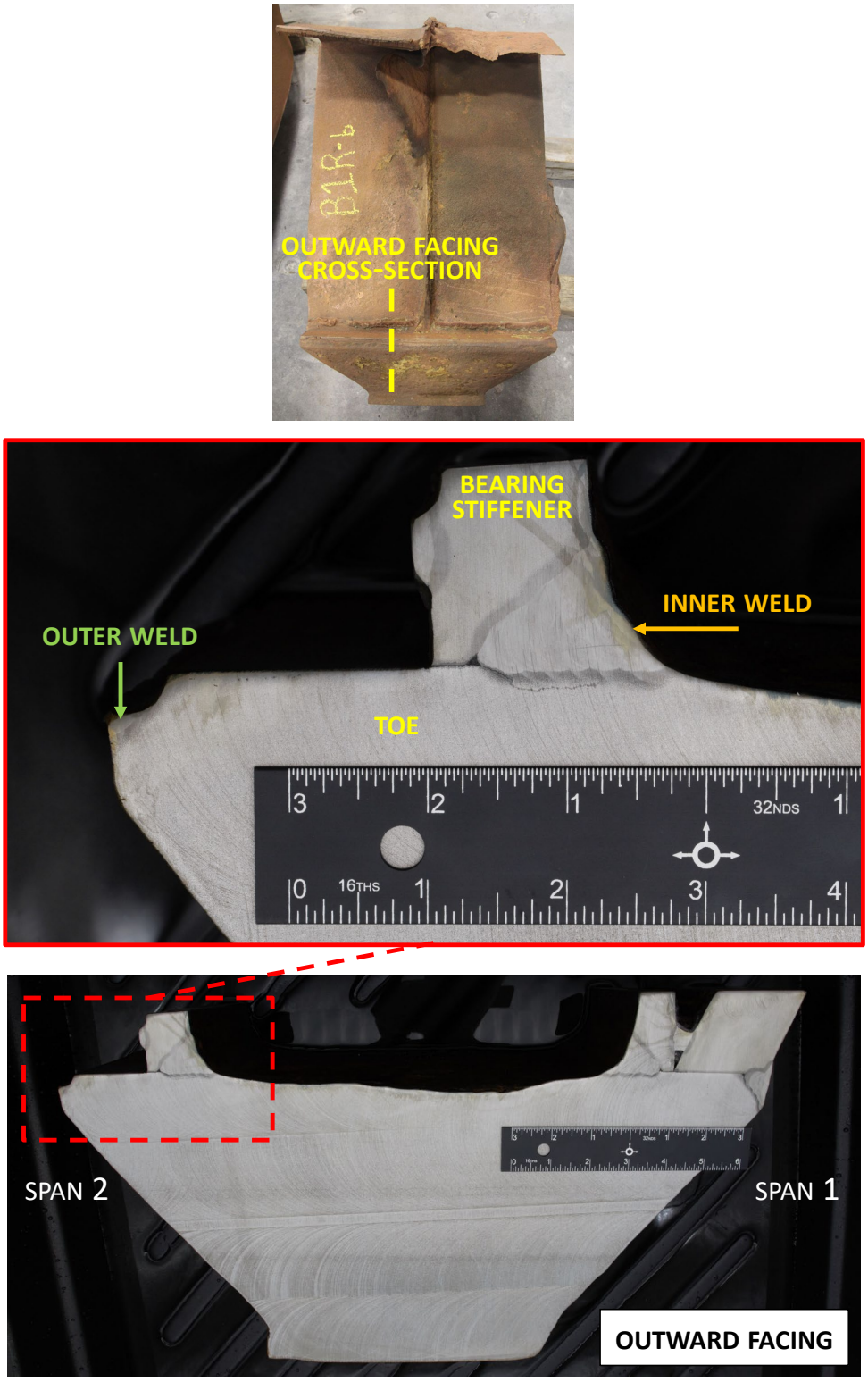


Figure 53. Cross-section through the span side flange joint on the outward facing side. (Etchant: 5% nital) (Bottom two photos by FHWA)