ATF Fire Research Laboratory Technical Bulletin

ATFFRL-TB-190001
July 19, 2019

Arc Melting in Electrical Receptacles Research Photographs

Abstract

The purpose of this Technical Bulletin is to provide a selection of photographs of various receptacle failures as a reference for fire investigators and engineers. The arc melting was created by arc tracking as well as by fire impingement. This Bulletin should be used in conjunction with the paper published in the Fire & Arson Investigator to familiarize the reader with the evidence left after a potential arc tracking failure or arc melting caused by fire impingement [1].

As discussed in a paper published in the Fire & Arson Investigator, arc melting can be formed in receptacles both as a cause and the result of the fire [1]. Fire investigators should consider the following factors when arc melting is discovered in a receptacle:

- Was a load attached to the receptacle? (lamp, appliance, electrical device, etc.)
- What type of receptacle was it? (regular duplex, ground fault circuit interrupting, tamper-resistant)
- What type of plastic was used for the body of the receptacle? (thermoplastic, thermoset)
- Where was the arc melting located on the receptacle? What components were affected?
- What were the nearby fuels and where were they in relation to the receptacle?

These questions may help to determine cause versus effect, aiding in the analysis of potential ignition sources. This Bulletin includes selected photographs from research conducted at the Fire Research Laboratory (FRL) as a reference for investigators and engineers. This research was published in the July 2019 issue of the Fire & Arson Investigator [1]. For full details on the testing procedures and results, it is recommended that the reader refer to the full paper.

Attachment 1 includes pictures of receptacles and components that failed as a result of arc tracking or conducting through liquid in the receptacle, resulting in a spark and the activation of the circuit breaker. These failures occurred in receptacles that were made of both thermoset and thermoplastic materials. The arc tracking was induced by spraying the receptacles with water or a saline solution daily for nearly two years.

Attachment 2 consists of pictures of receptacle components that arced as a result of impingement by fire. After the primary arc tracking research was completed, the receptacles were exposed to a fire from a natural gas burner to see what artifacts may be created and if the fire would impact the evidence created by arc tracking. The artifacts created as a result of fire impingement were limited to receptacles made only of thermoplastic materials. This arc melting was the result of the plastic softening from fire impingement, allowing the components to shift and make contact. These are not all-inclusive, as many power rails fell from their respective locations and could not be matched to their original receptacle.

Recommendations

It is recommended that fire investigators do not eliminate a receptacle as an ignition source based only on the observation that no devices were attached. Receptacles may fail as a result of arc tracking or from a high resistance connection, regardless of the presence or absence of an attached load. However, arc melting may also be formed during fire impingement.

In order to properly visualize and document these failure modes, the investigator must look at the various components of the receptacle. This may entail the removal of the charred or melted plastic body to gain access to the power rails, ground yoke, and push-in terminals. Investigators are urged to seek out training on how to properly conduct this intrusive examination. It may also be beneficial for the investigator to practice on new receptacles, or receptacles from unaffected portions of the structure in question, in order to gain an understanding of how to access these components without causing unnecessary damage.

As a reminder, any hypothesized ignition scenario should include a discussion of what was the first fuel ignited. As a general rule the greater the distance a spark has to travel, the less energy the spark will retain for ignition. Therefore, fuels that are several feet away are unlikely to be ignited by all but the largest sparks. More research is needed to address these factors.

References

[1] Novak, C., Keller, M., Palmer, D., Gallagher, G. (2019). An Analysis of Electrical Arcing in Electrical Receptacles. *Fire & Arson Investigator*, Volume 70 (Issue 1), pgs. 26-35.

ATTACHMENT 1: ARC TRACKING FAILURES

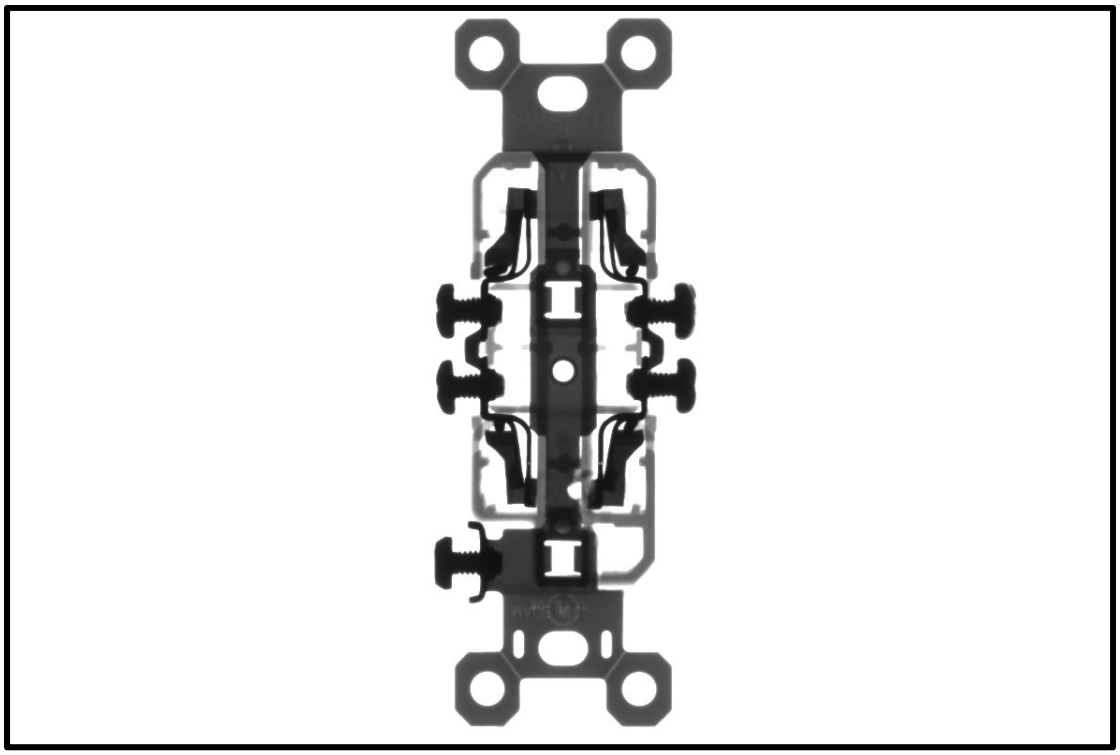

Figure 1. Radiographic (x-ray) image of receptacle 1-T

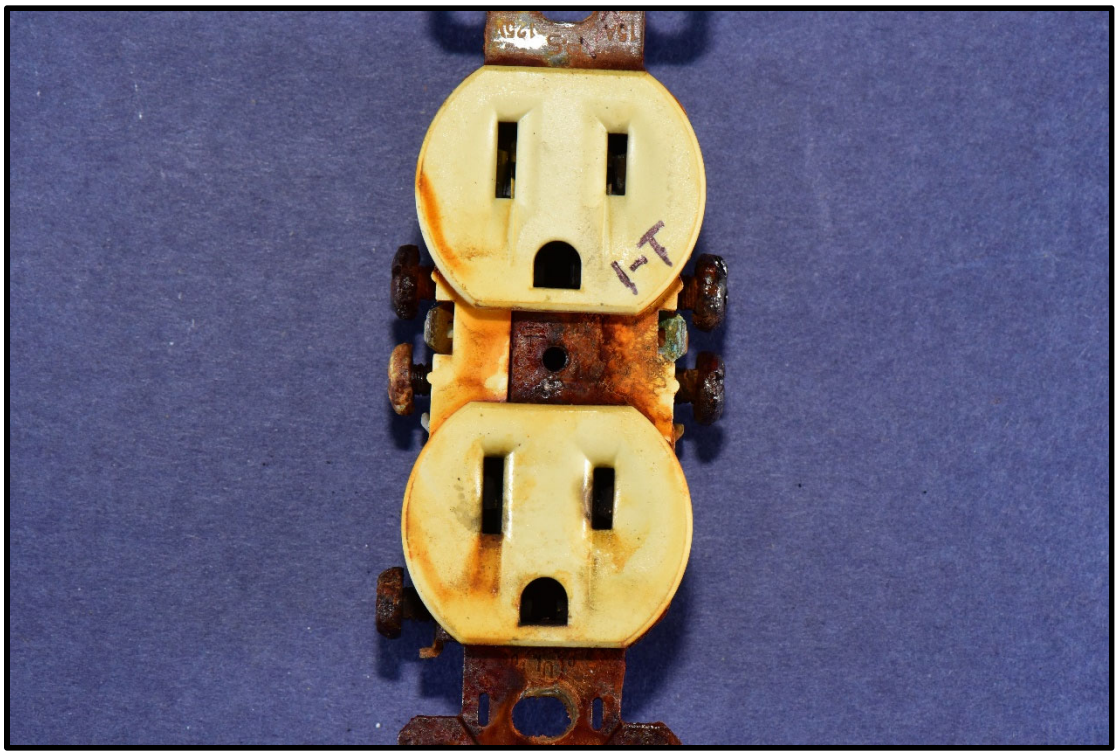

Figure 2. Receptacle 1-T

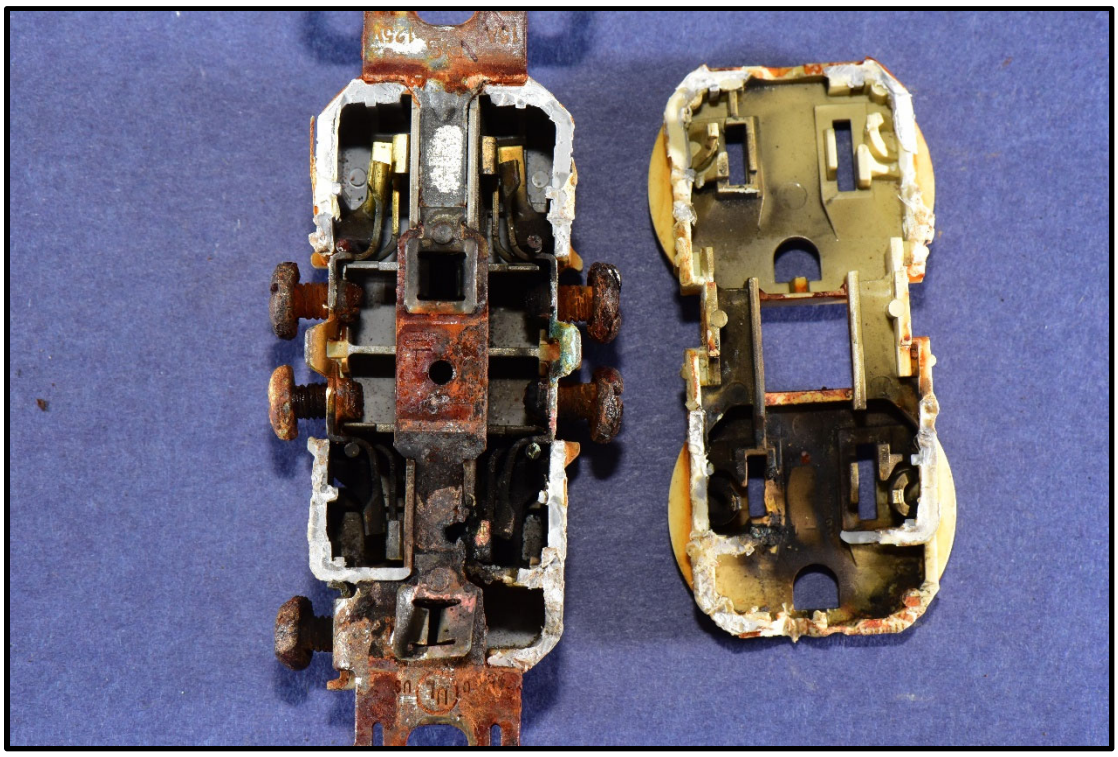

Figure 3. Receptacle 1-T

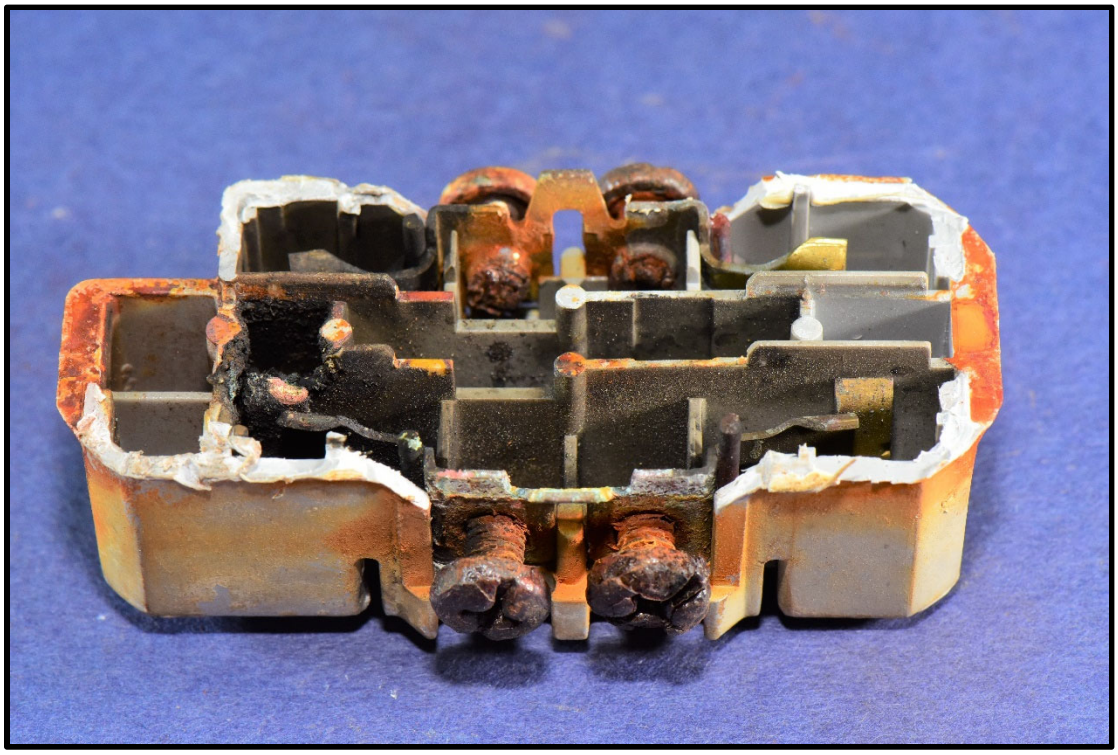

Figure 4. Receptacle 1-T

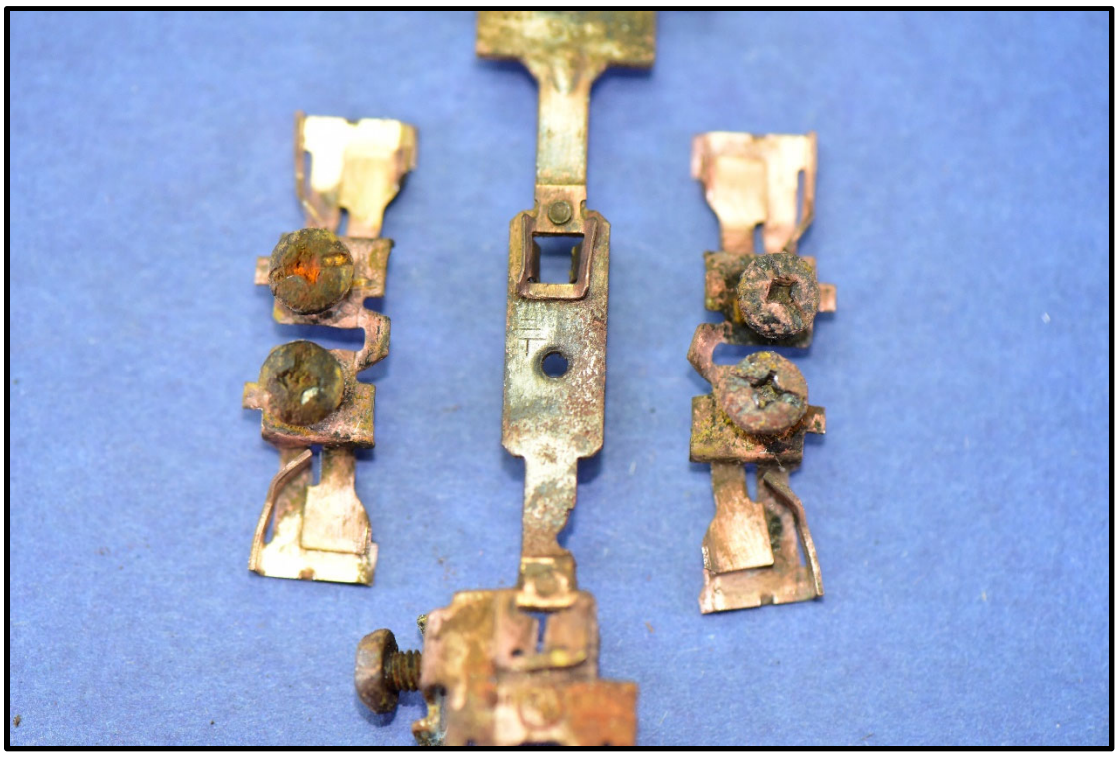

Figure 5. Receptacle 1-T power rails and ground yoke

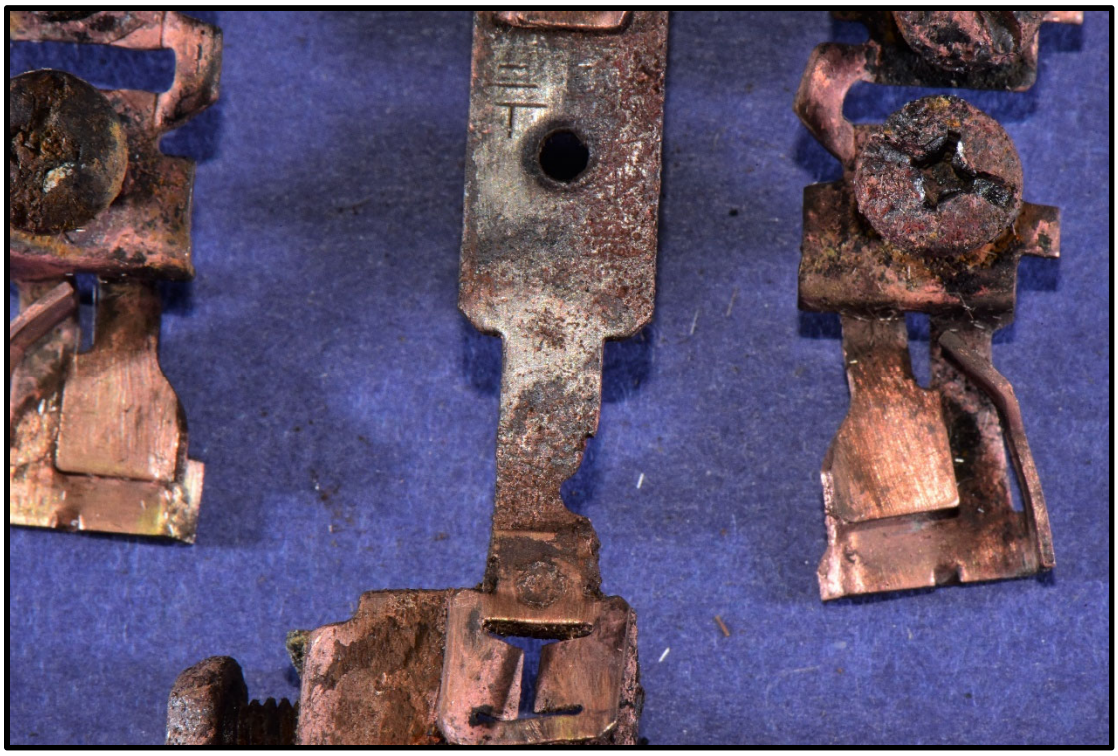

Figure 6. Receptacle 1-T power rails and ground yoke

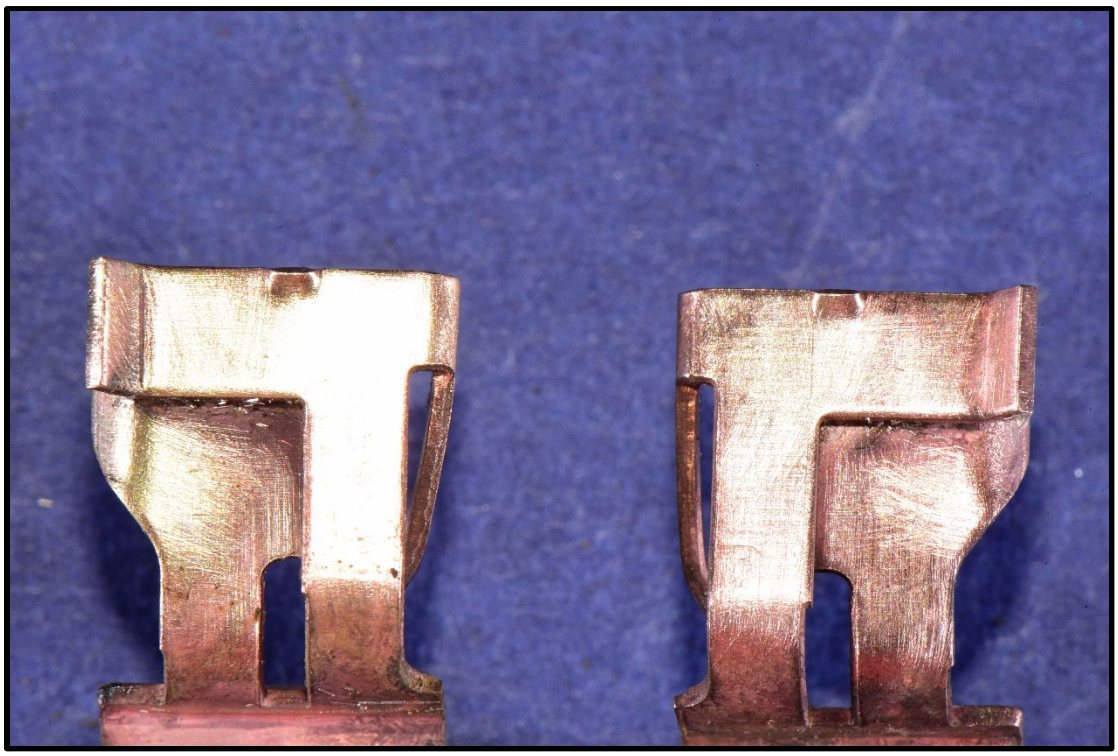

Figure 7. Top blade receptors for Receptacle 1-T

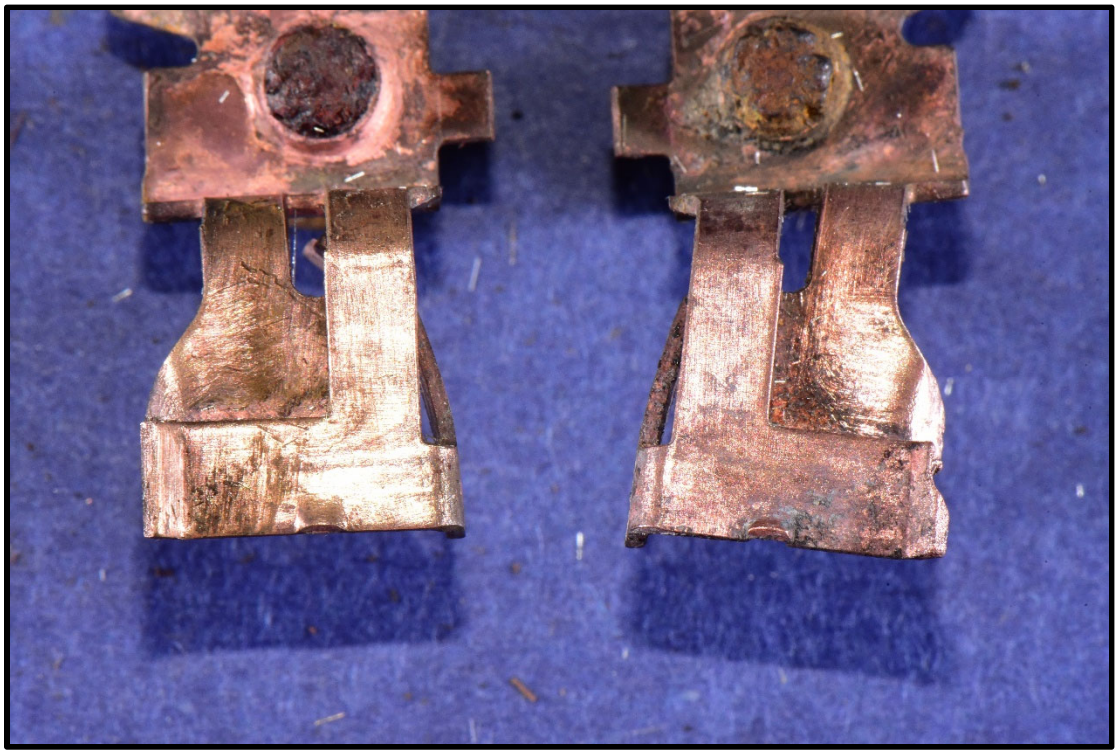

Figure 8. Bottom blade receptors for Receptacle 1-T

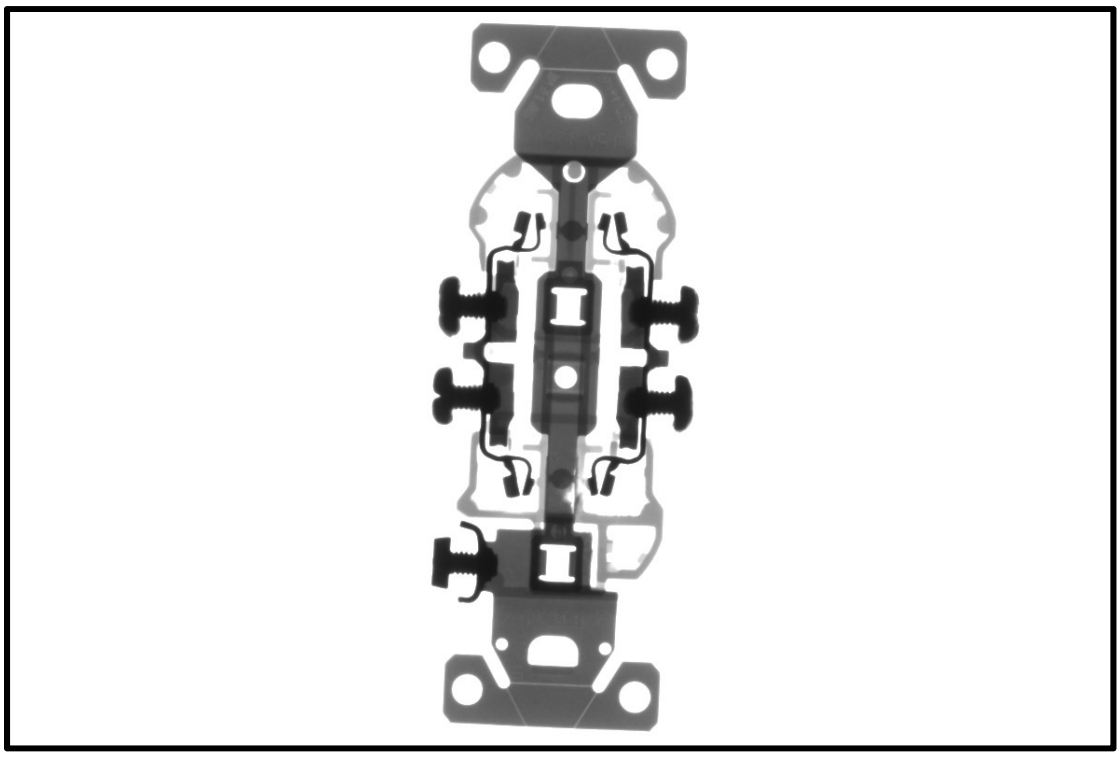

Figure 9. Radiographic (x-ray) image of Receptacle 2-O

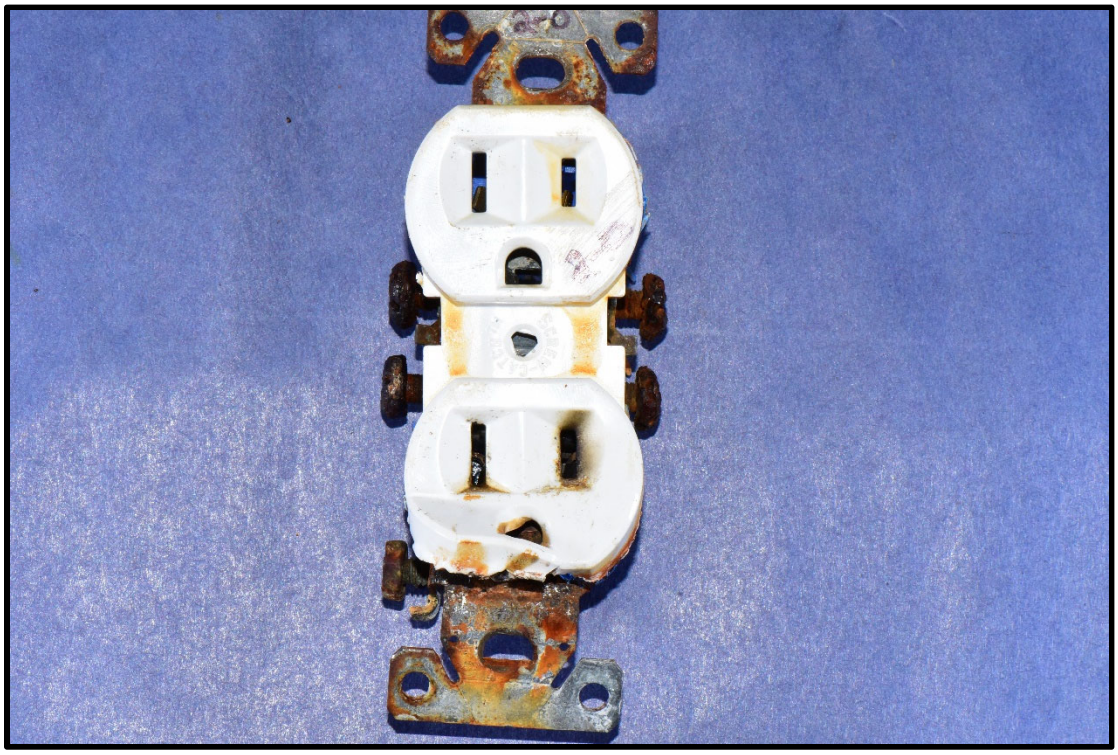

Figure 10. Receptacle 2-O

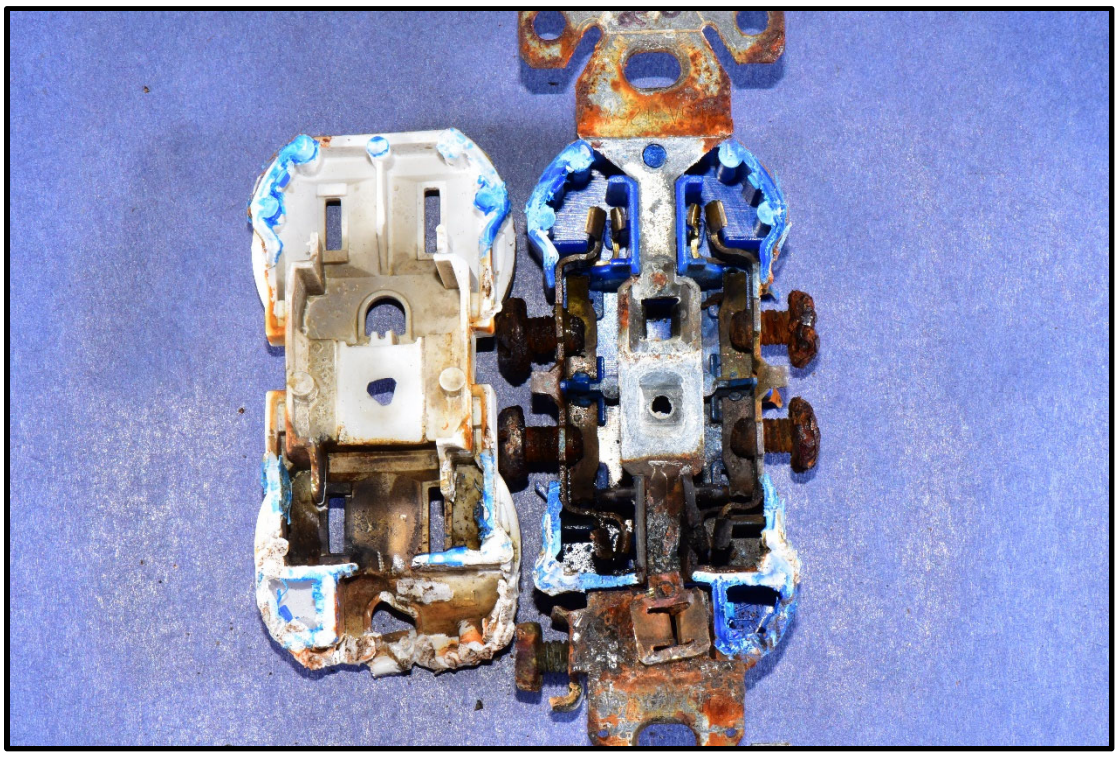

Figure 11. Receptacle 2-O

Figure 12. Receptacle 2-O

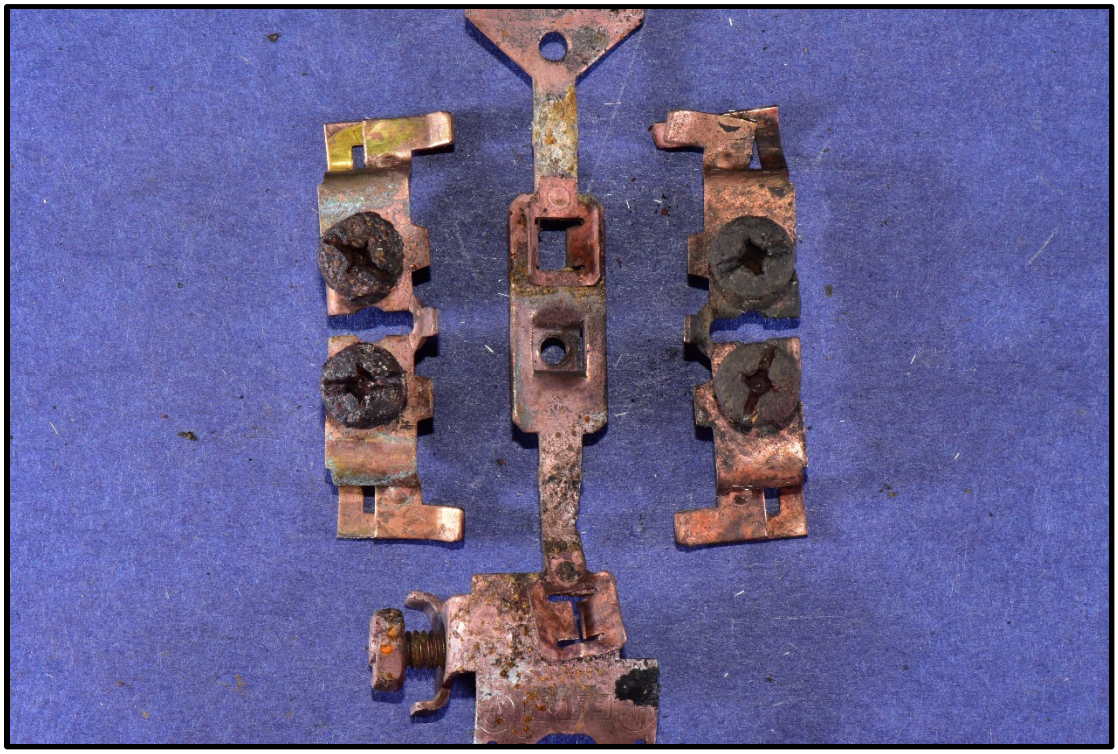

Figure 13. Power rails and ground yoke for Receptacle 2-O

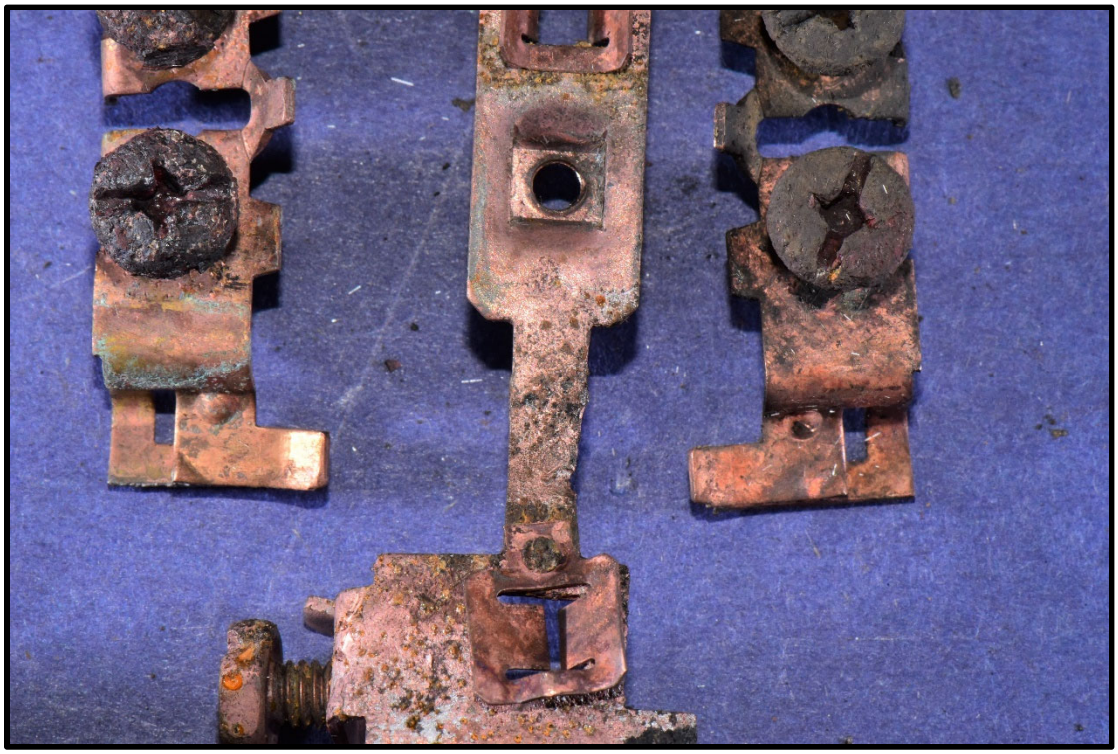

Figure 14. Power rails and ground yoke for Receptacle 2-O

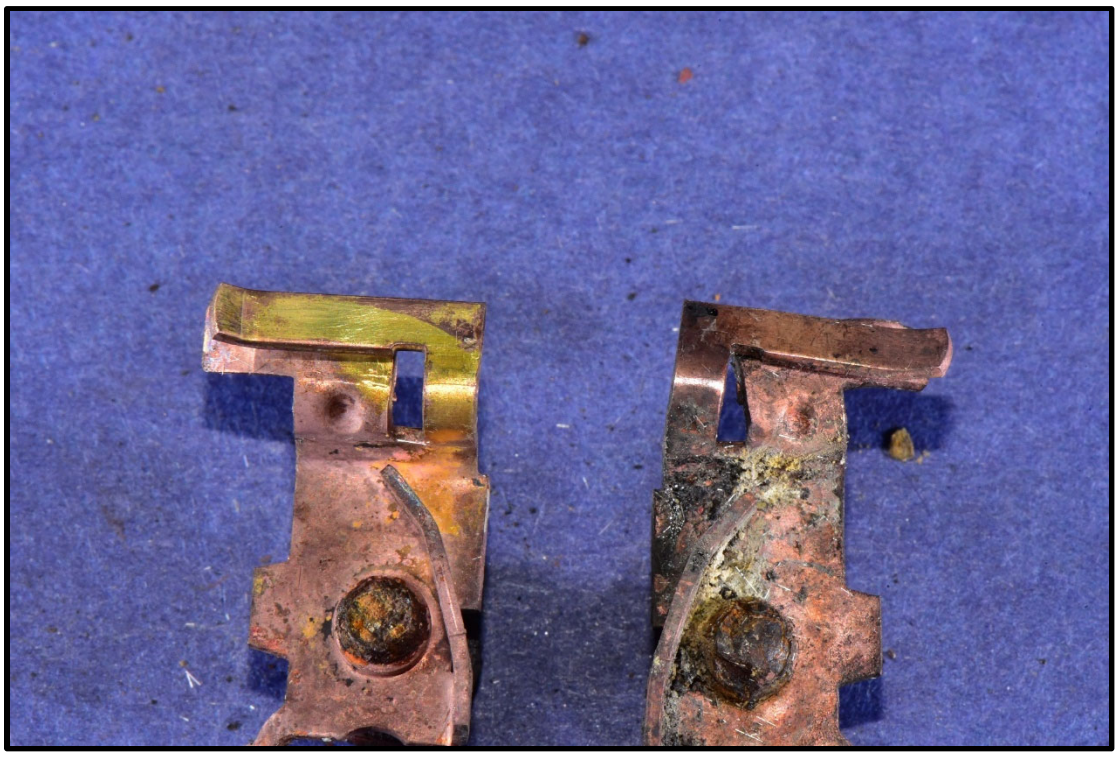

Figure 15. Top blade receptors from Receptacle 2-O

Figure 16. Bottom blade receptors from Receptacle 2-O

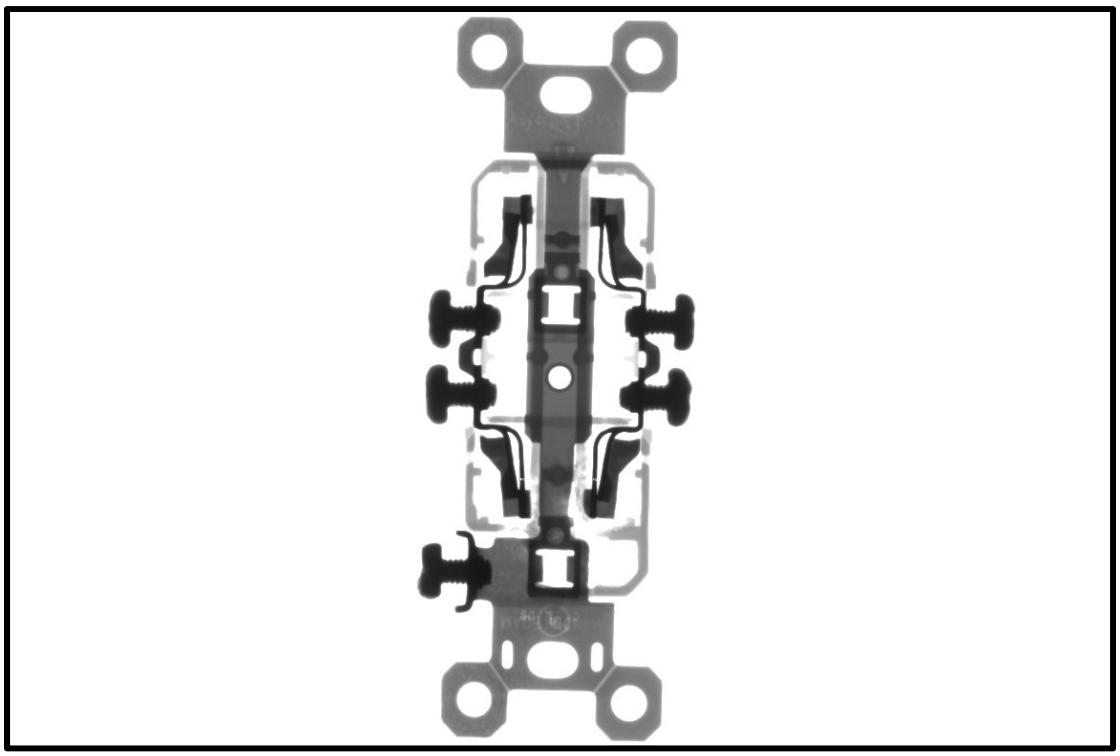

Figure 17. Radiographic (x-ray) image of Receptacle 10-Q

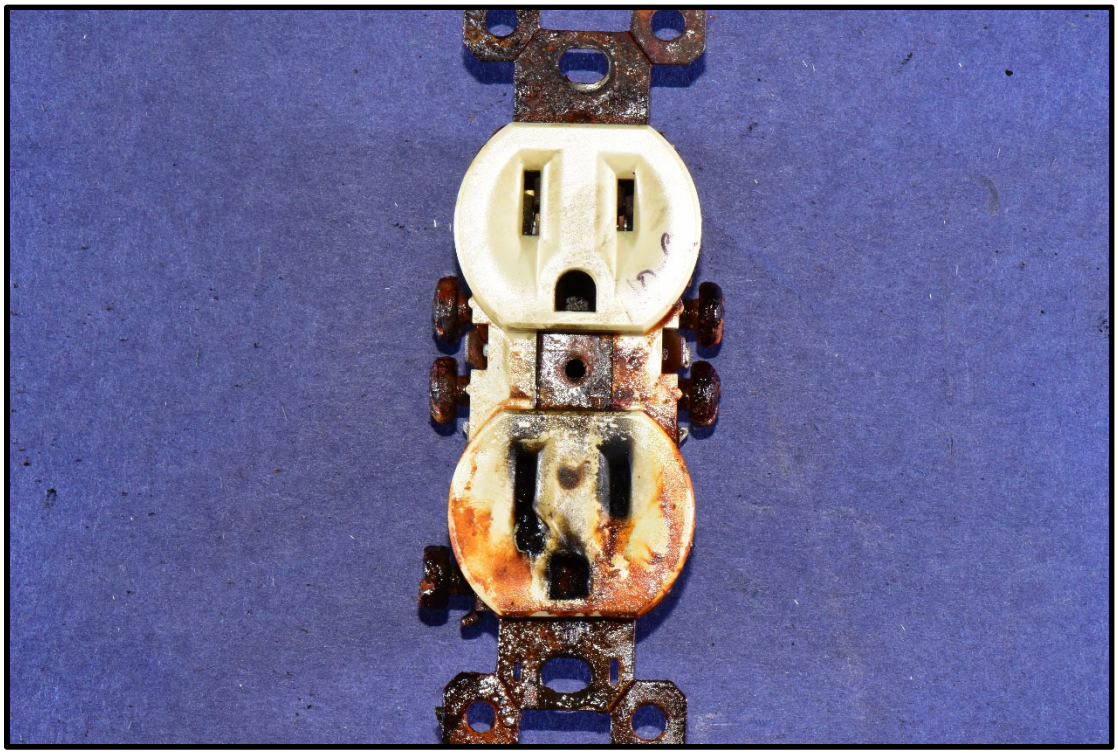

Figure 18. Receptacle 10-Q

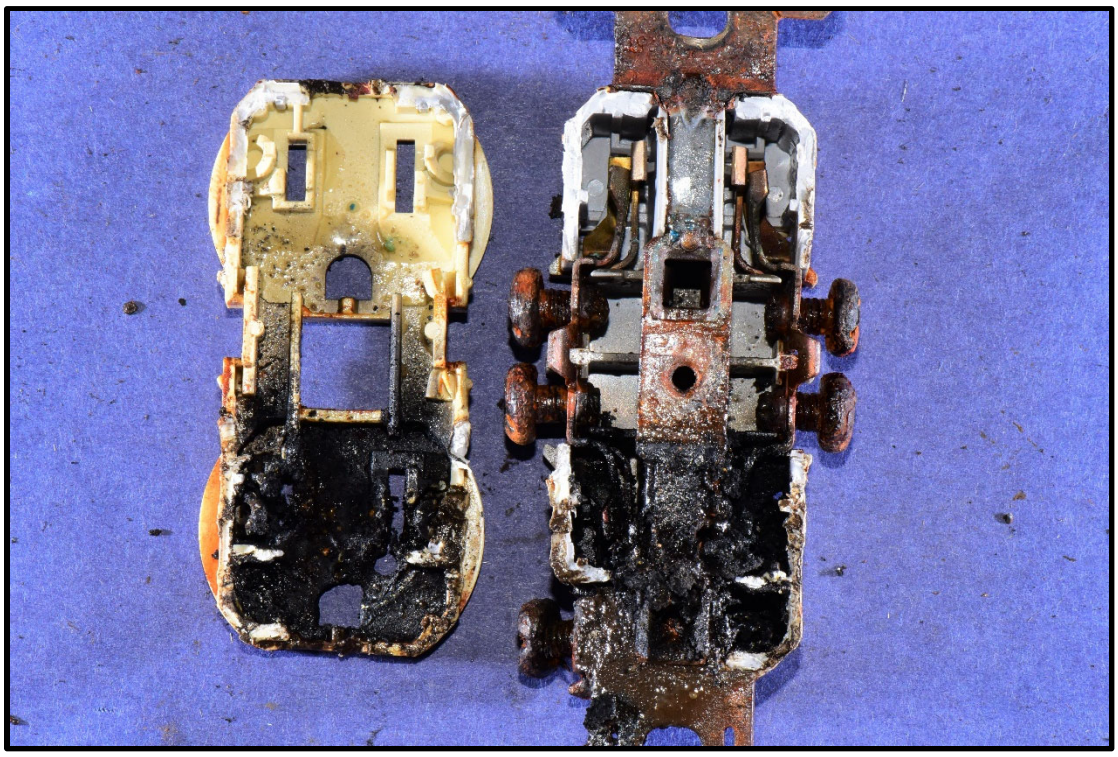

Figure 19. Receptacle 10-Q

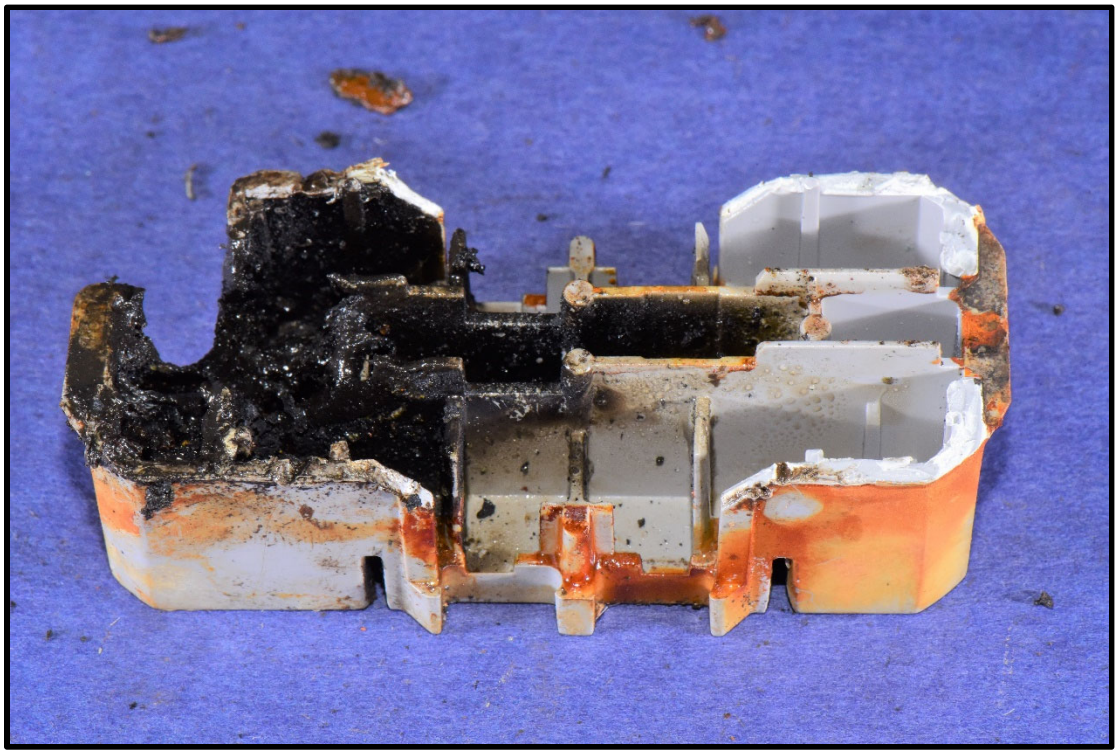

Figure 20. Receptacle 10-Q

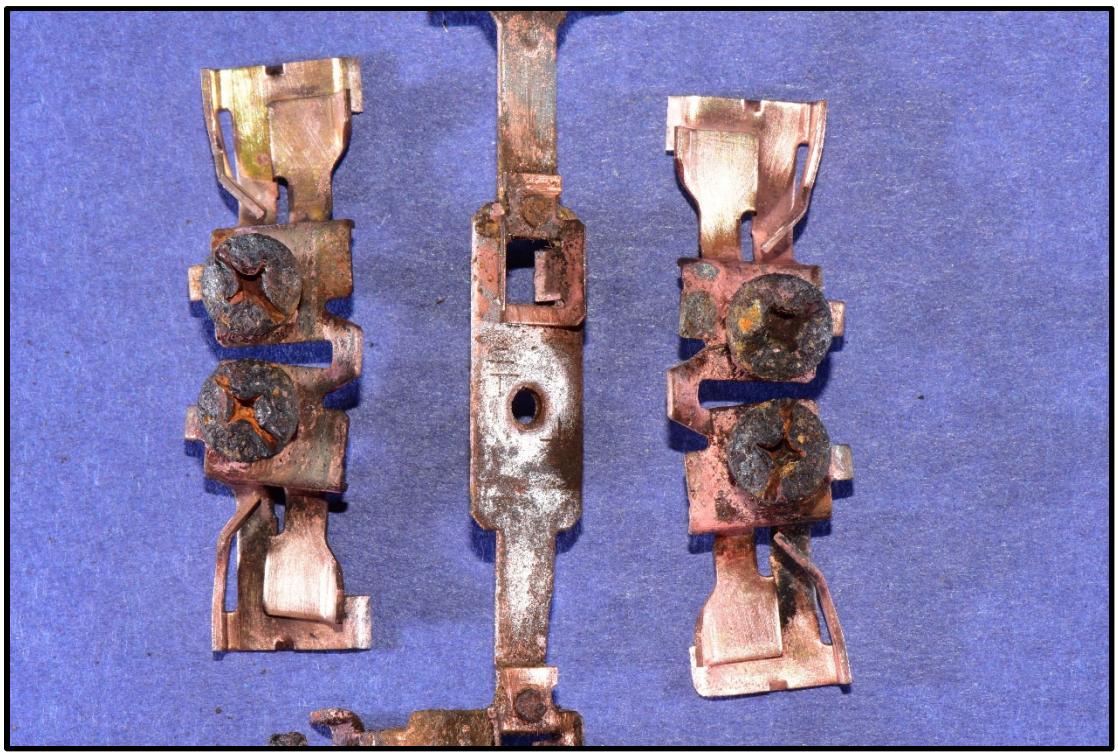

Figure 21. Power rails and ground yoke for Receptacle 10-Q

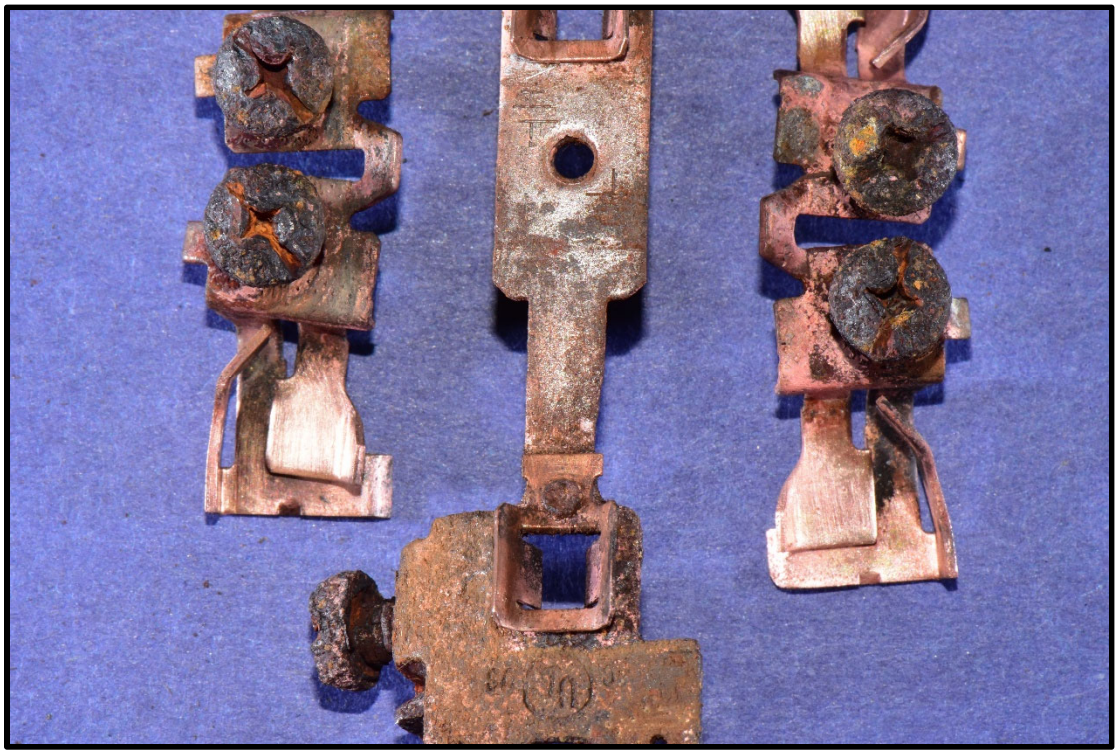

Figure 22. Power rails and ground yoke for Receptacle 10-Q

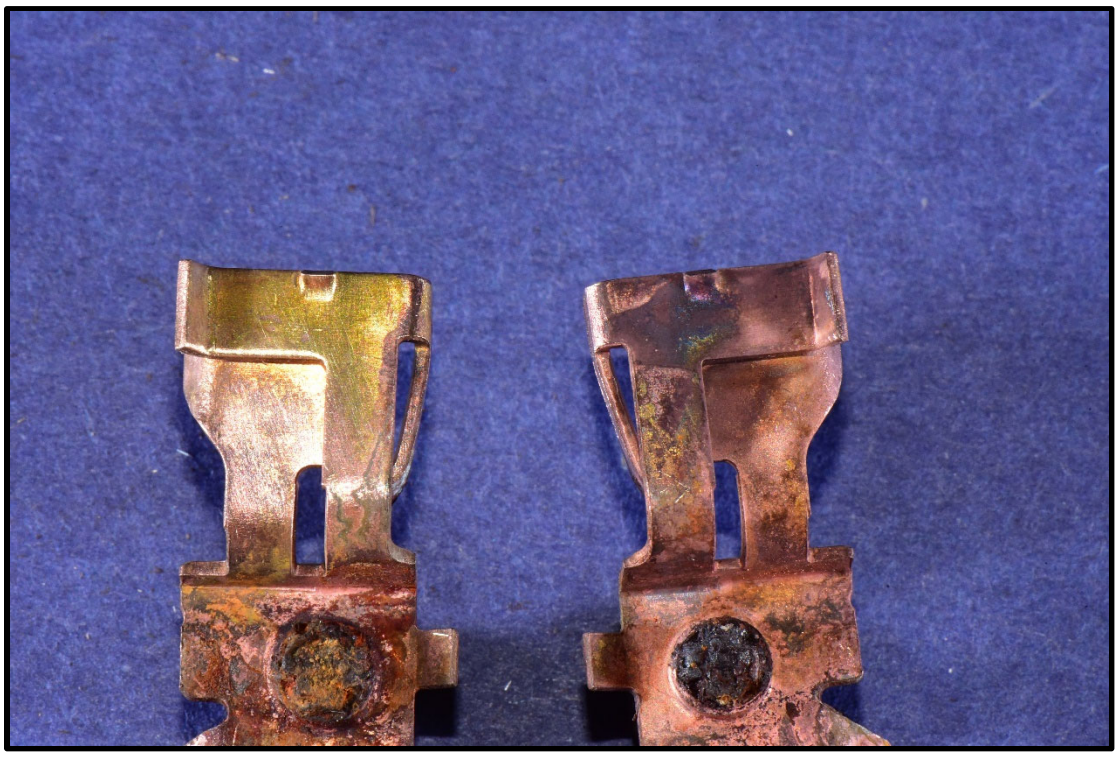

Figure 23. Top blade receptors for Receptacle 10-Q

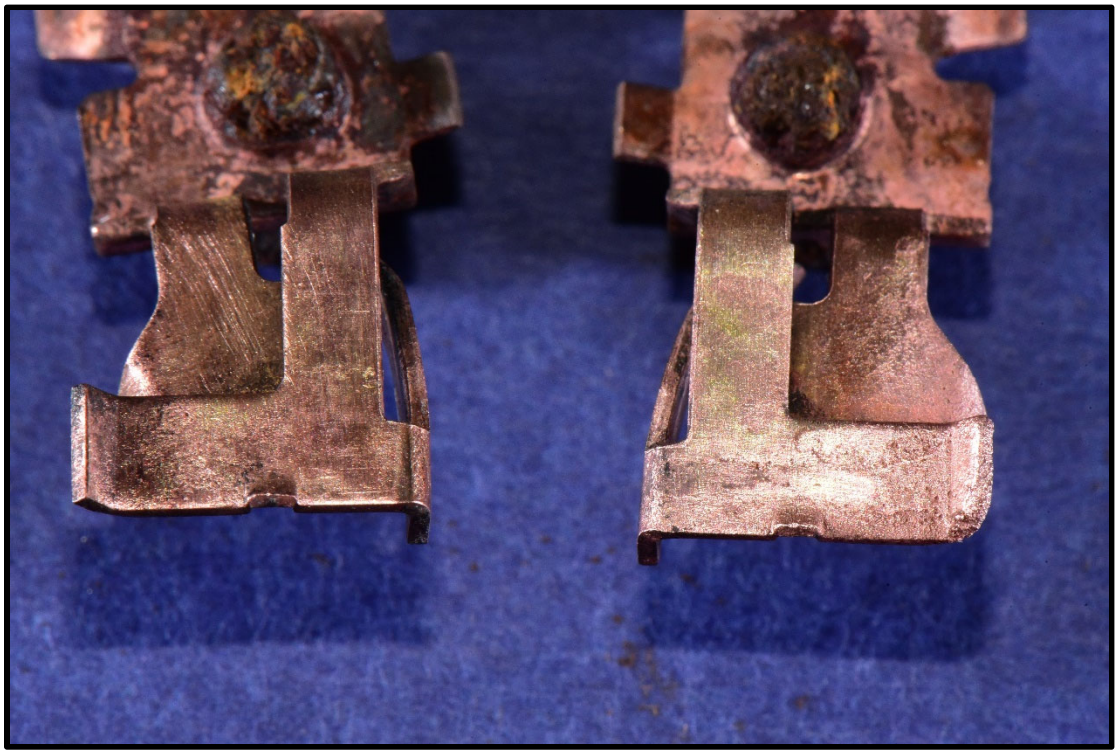

Figure 24. Bottom blade receptors for Receptacle 10-Q

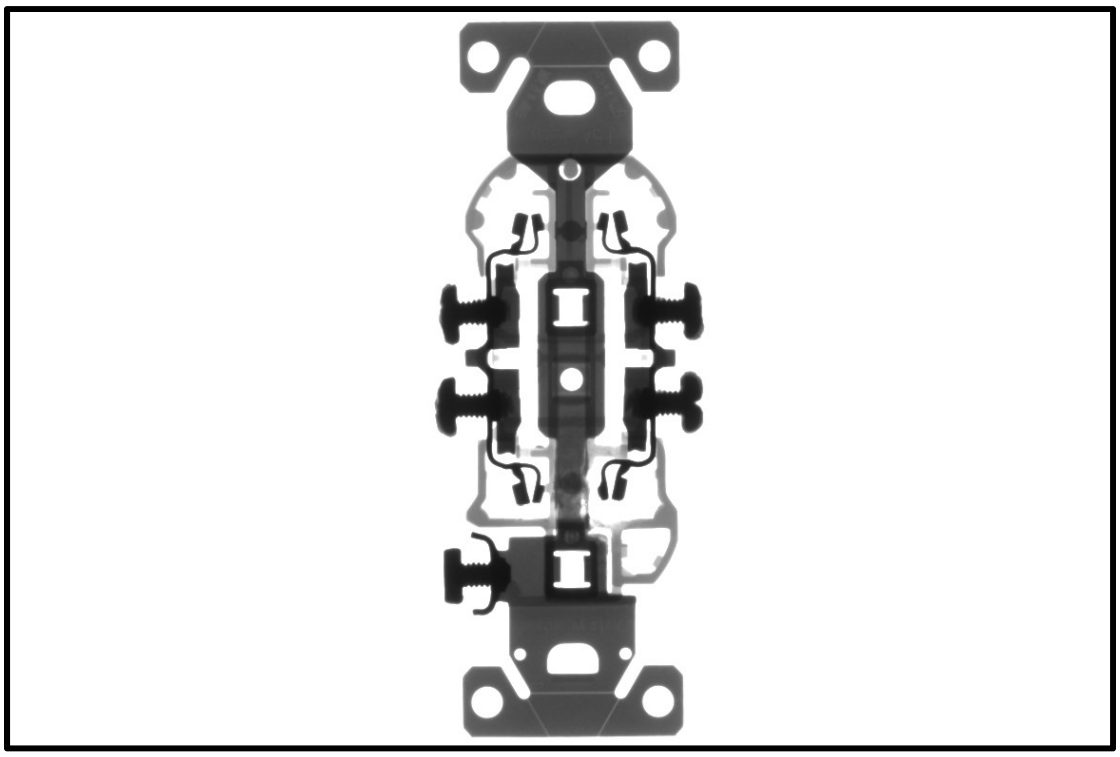

Figure 25. Radiographic (x-ray) image of Receptacle 11-R

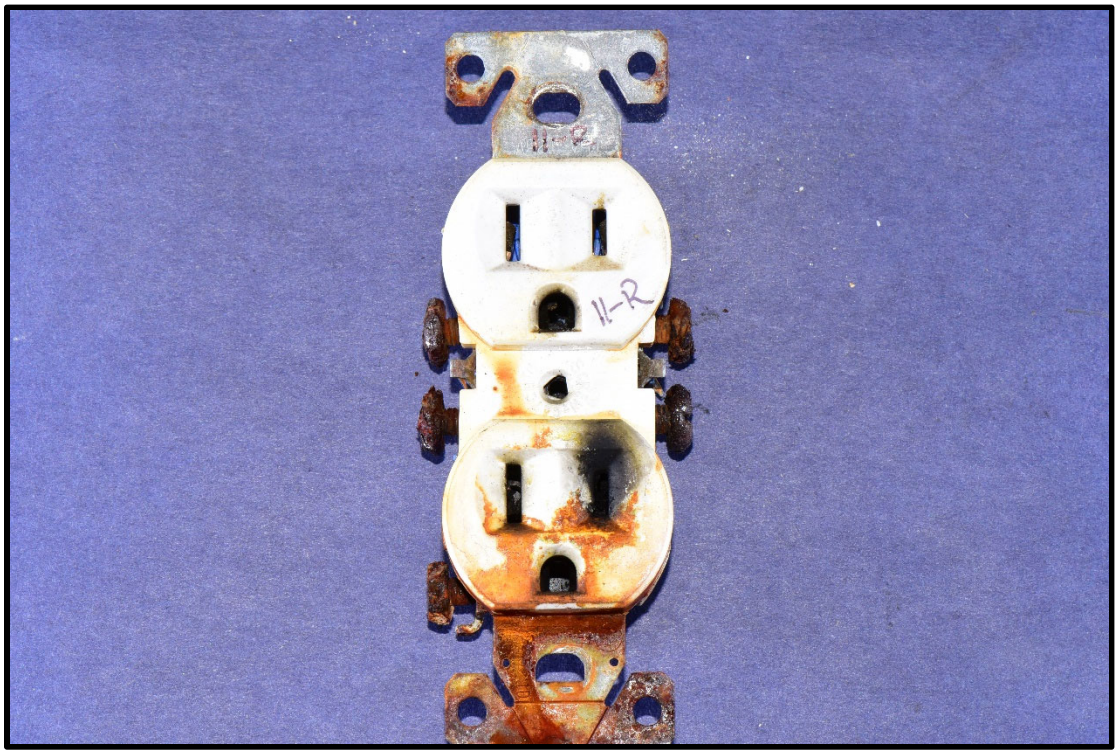

Figure 26. Receptacle 11-R

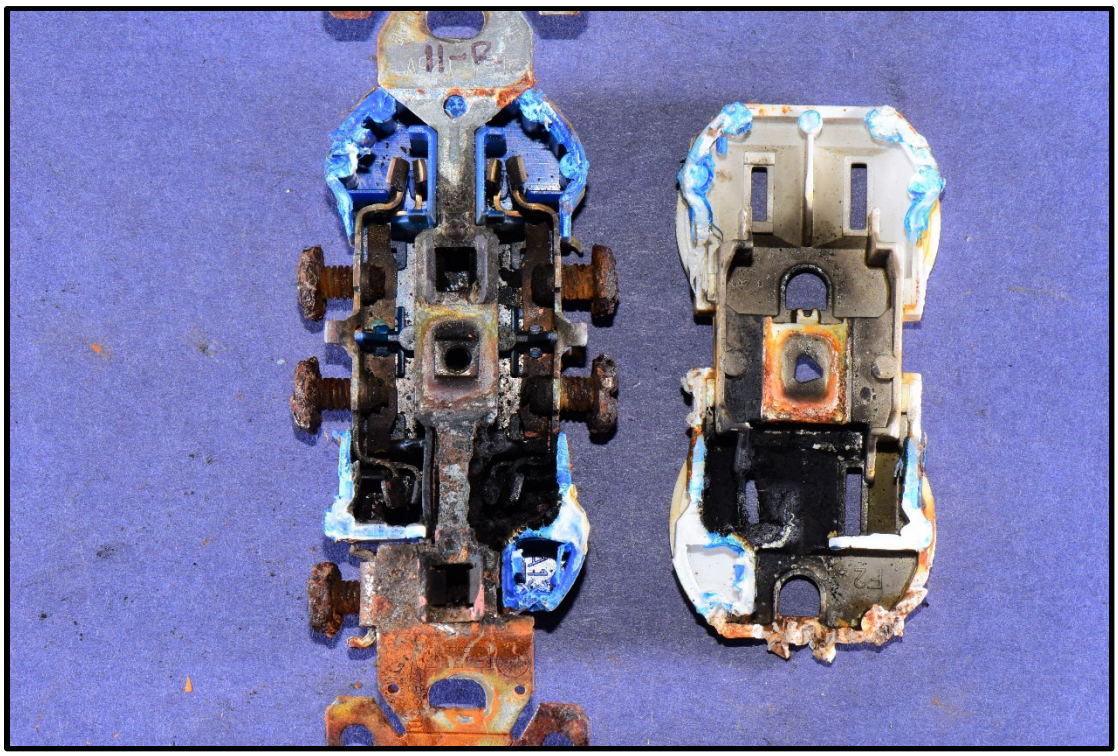

Figure 27. Receptacle 11-R

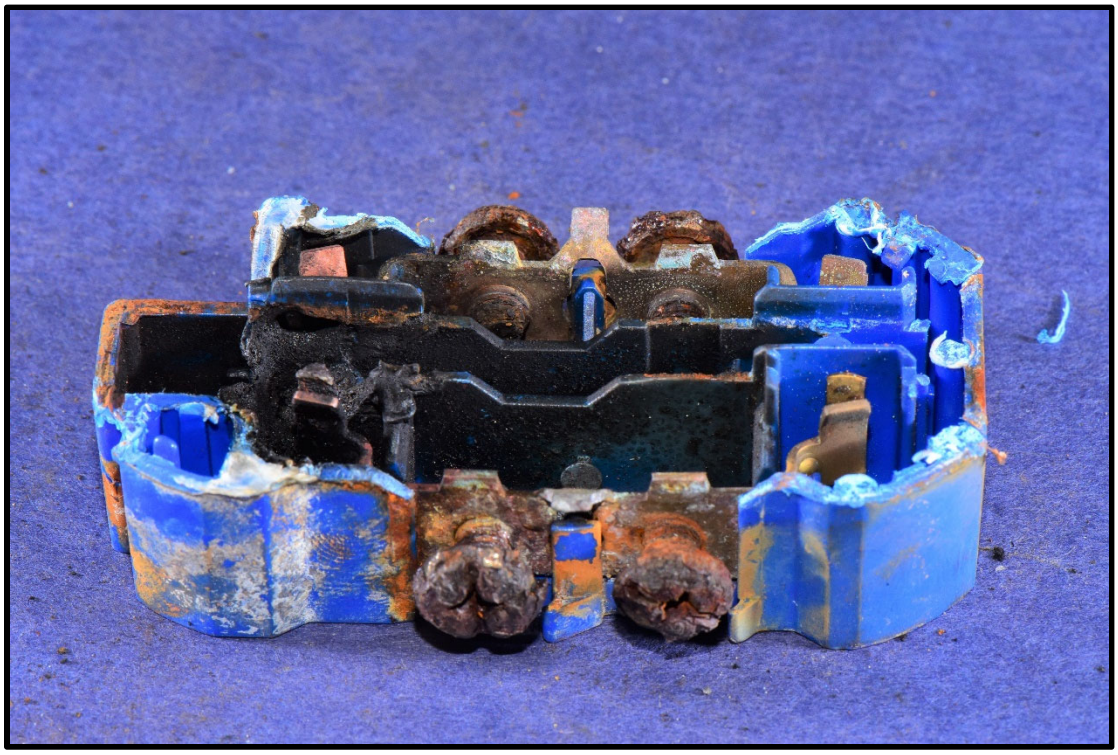

Figure 28. Receptacle 11-R

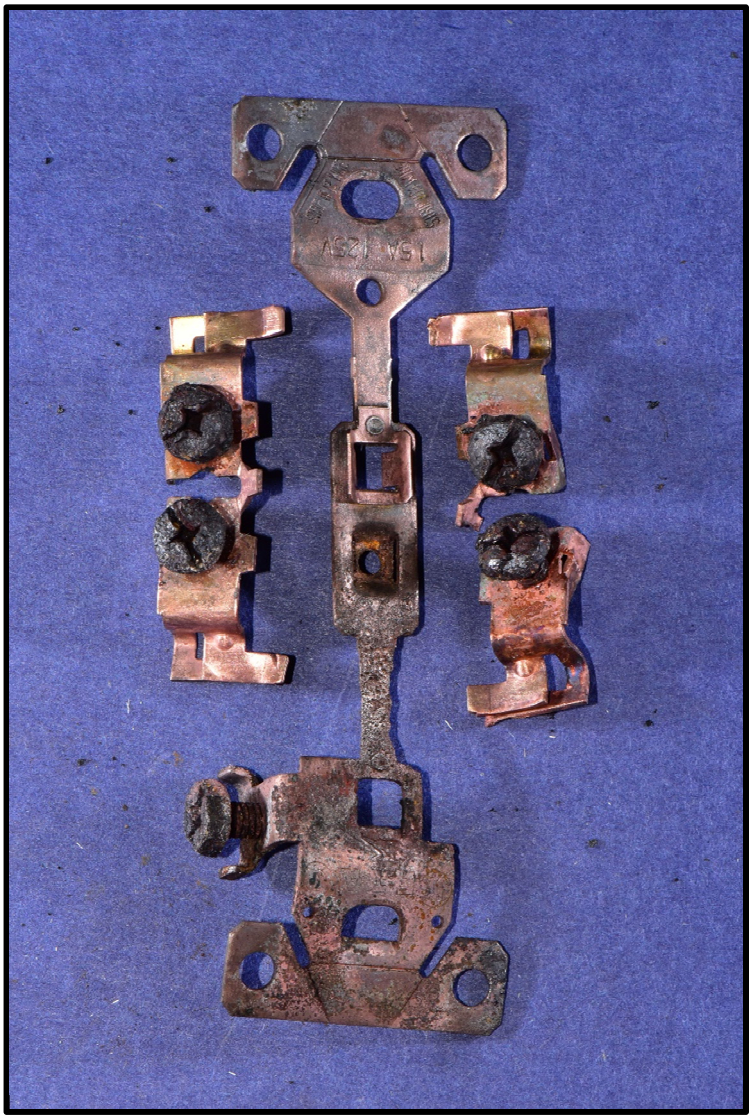

Figure 29. Power rails and ground yoke of Receptacle 11-R

Figure 30. Power rails and ground yoke of Receptacle 11-R

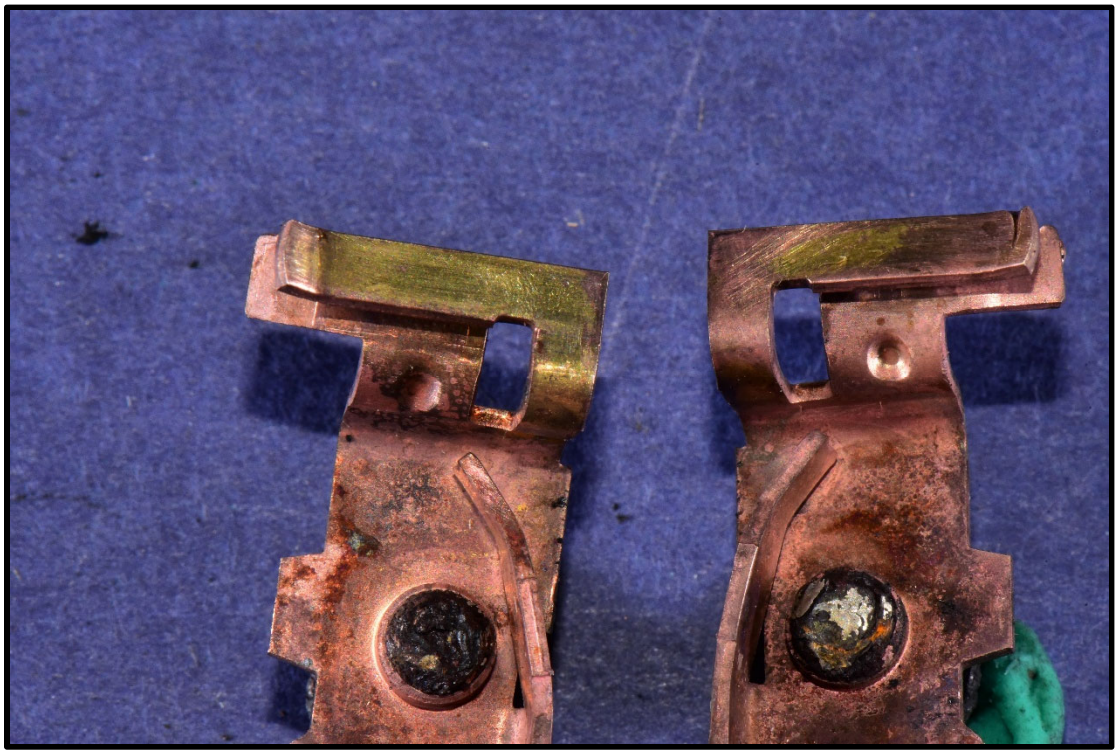

Figure 31. Top blade receptors of Receptacle 11-R

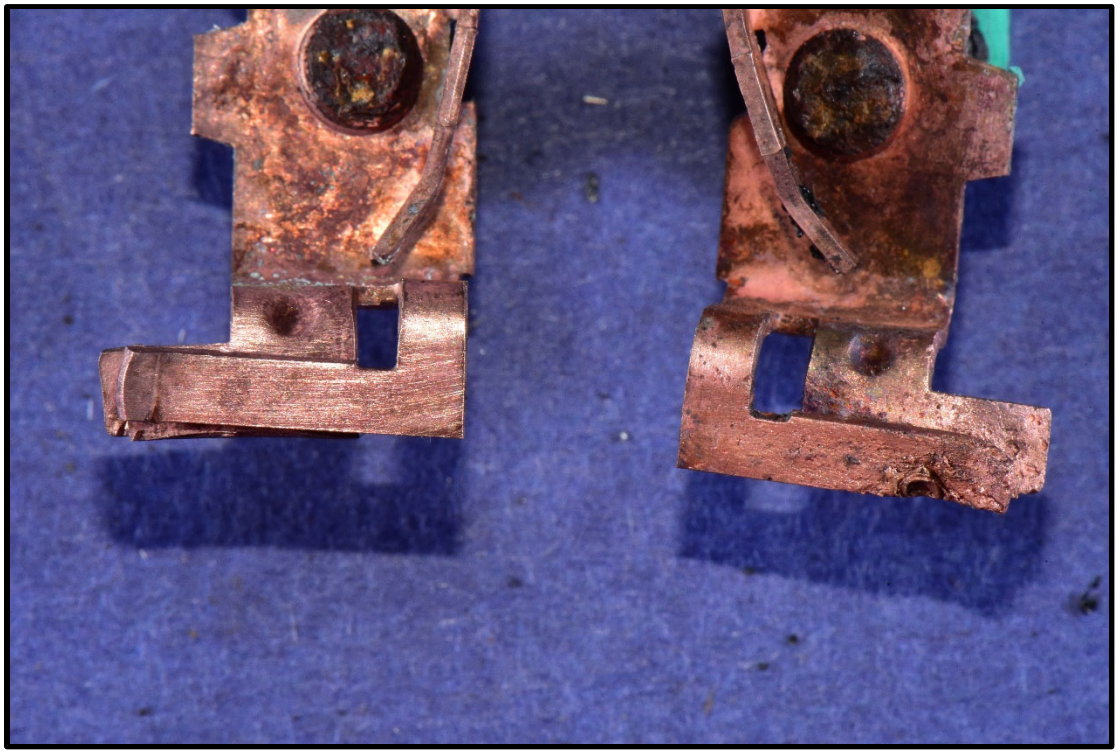

Figure 32. Bottom blade receptors of Receptacle 11-R

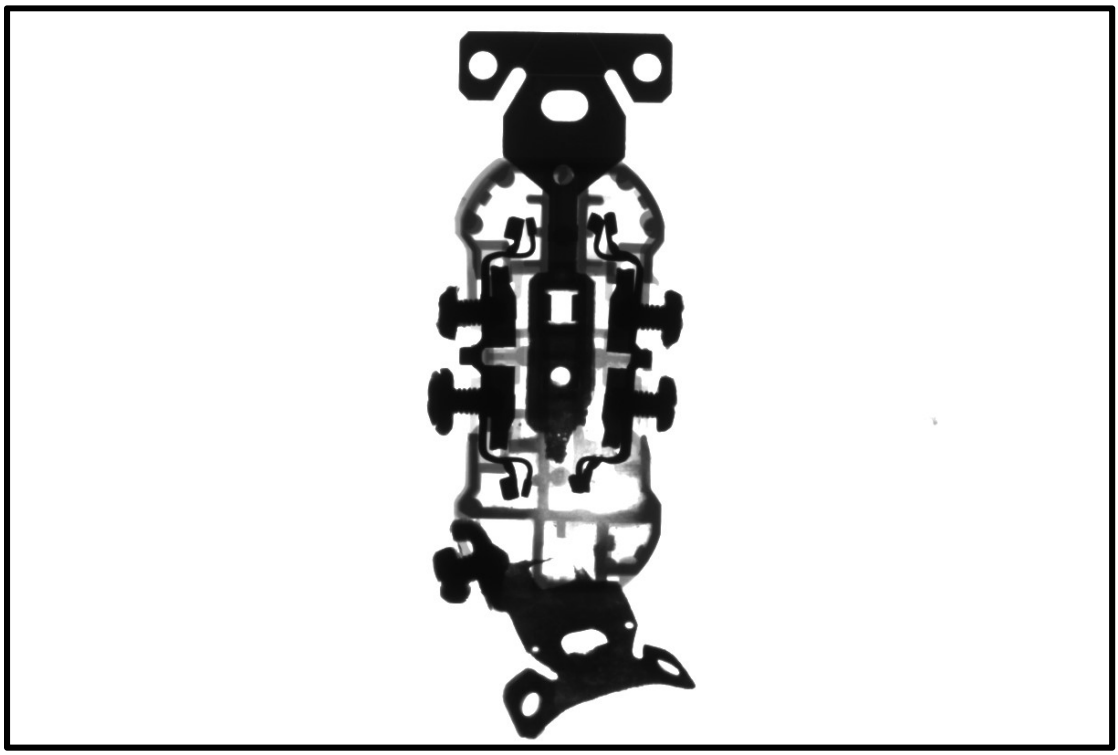

Figure 33. Radiographic (x-ray) image of Receptacle 11-U

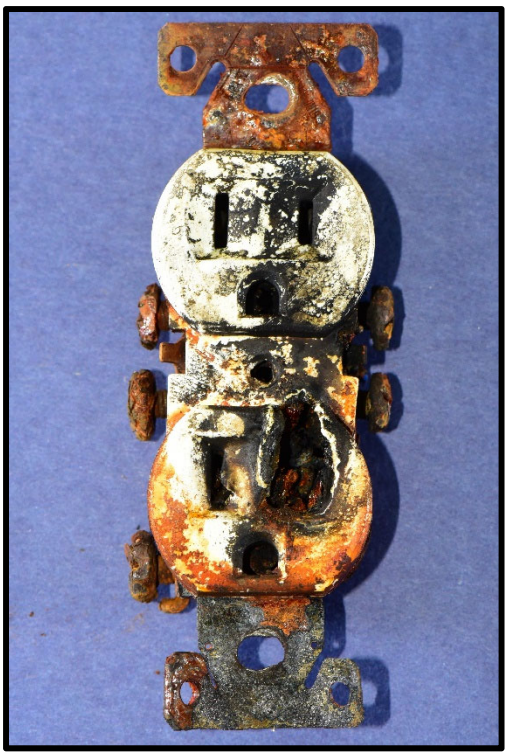

Figure 34. Receptacle 11-U

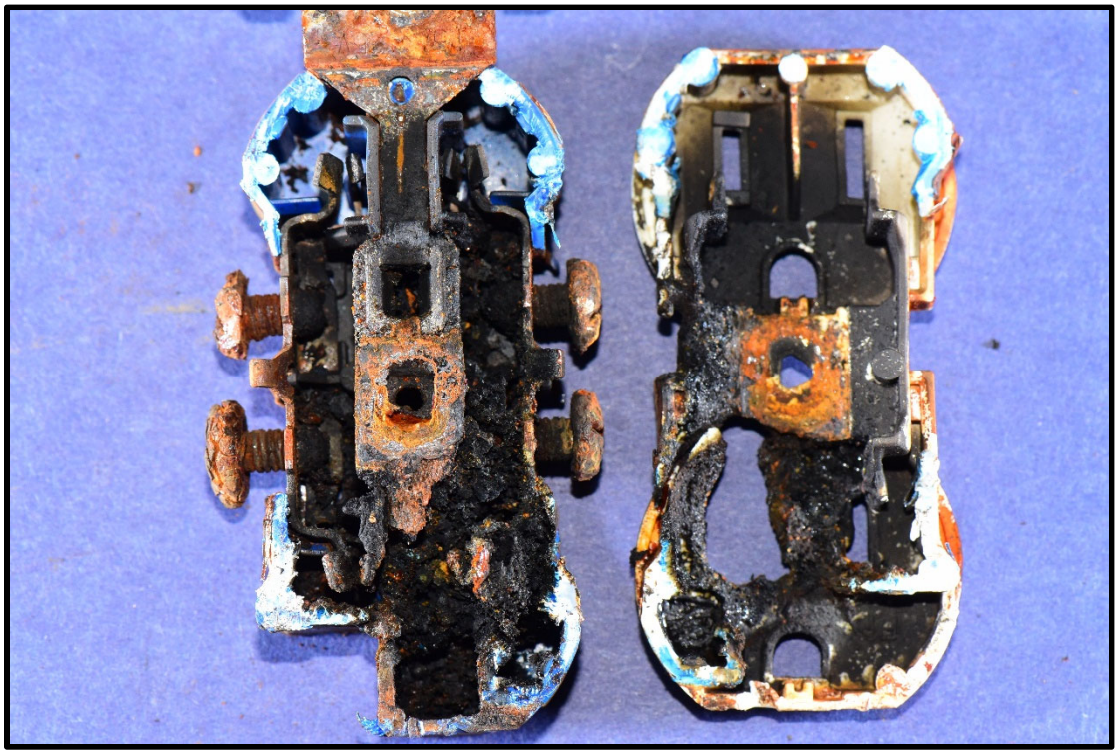

Figure 35. Receptacle 11-U

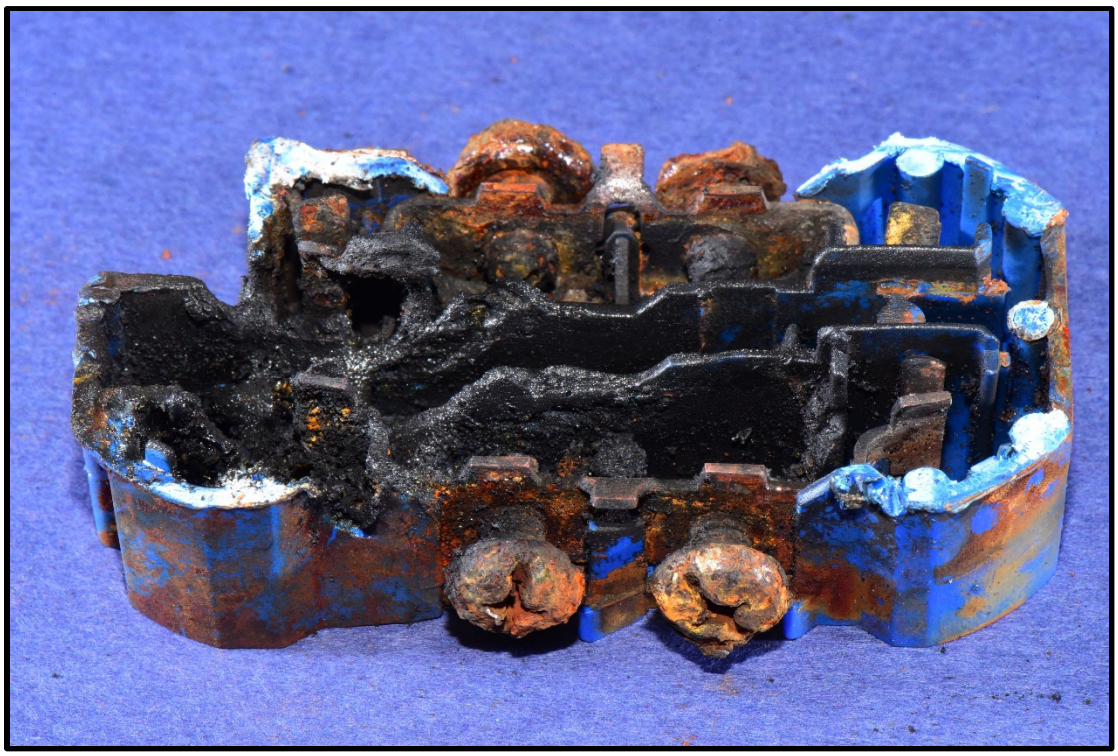

Figure 36. Receptacle 11-U

Figure 37. Remains of the bottom of the arc-severed ground yoke from Receptacle 11-U

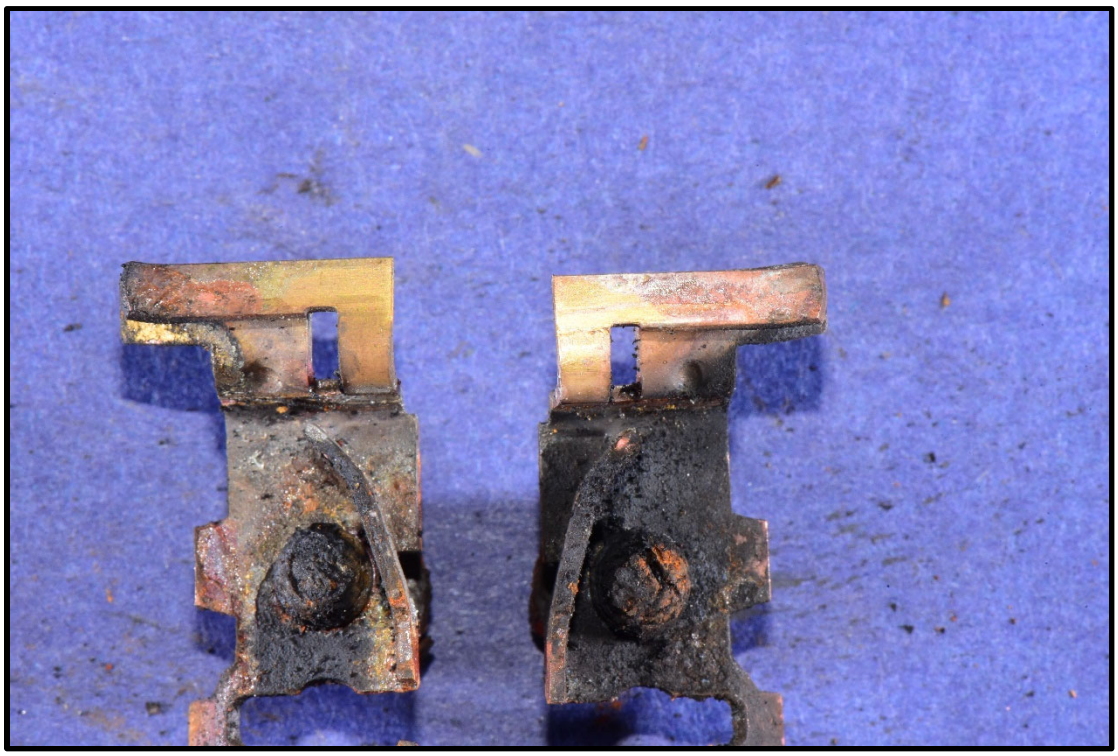

Figure 38. Top blade receptors from Receptacle 11-U

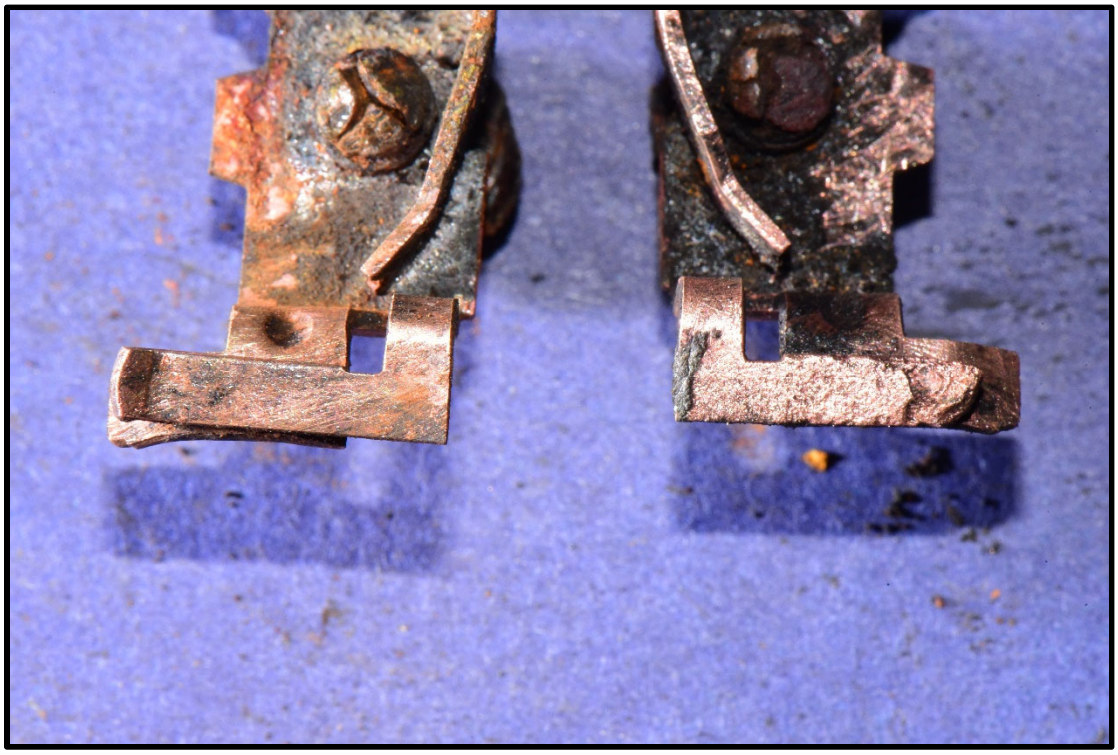

Figure 39. Bottom blade receptors from Receptacle 11-U

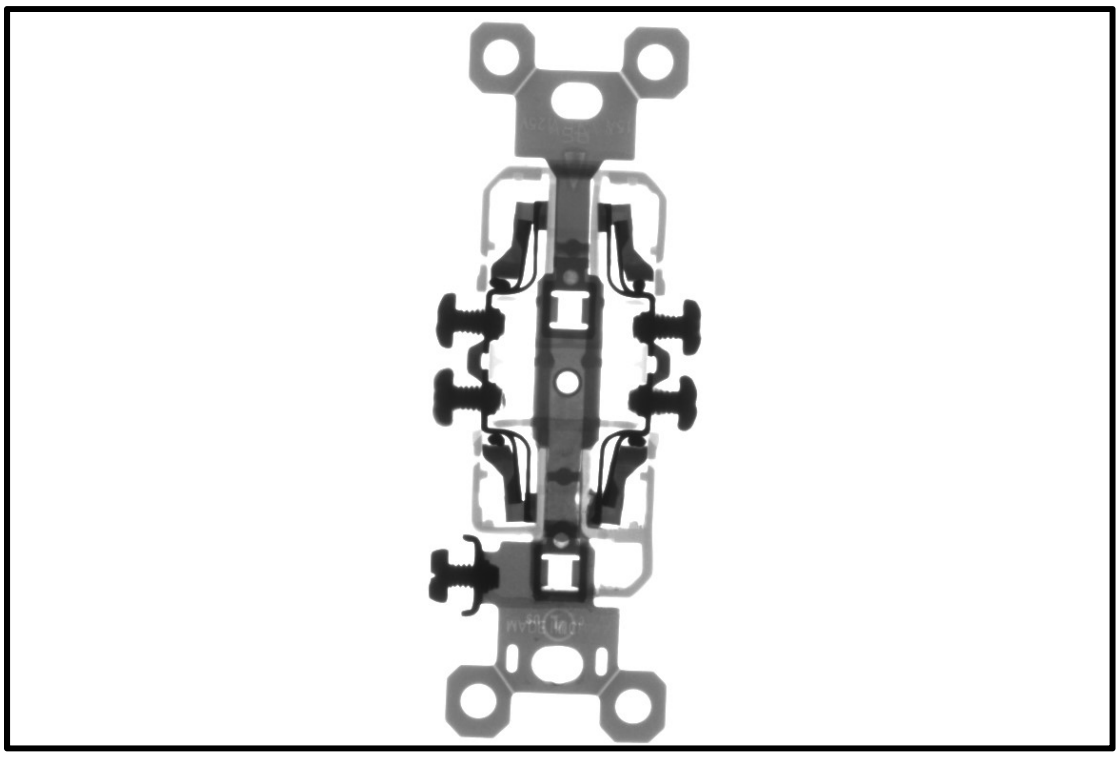

Figure 40. Radiographic (x-ray) image of Receptacle 13-S

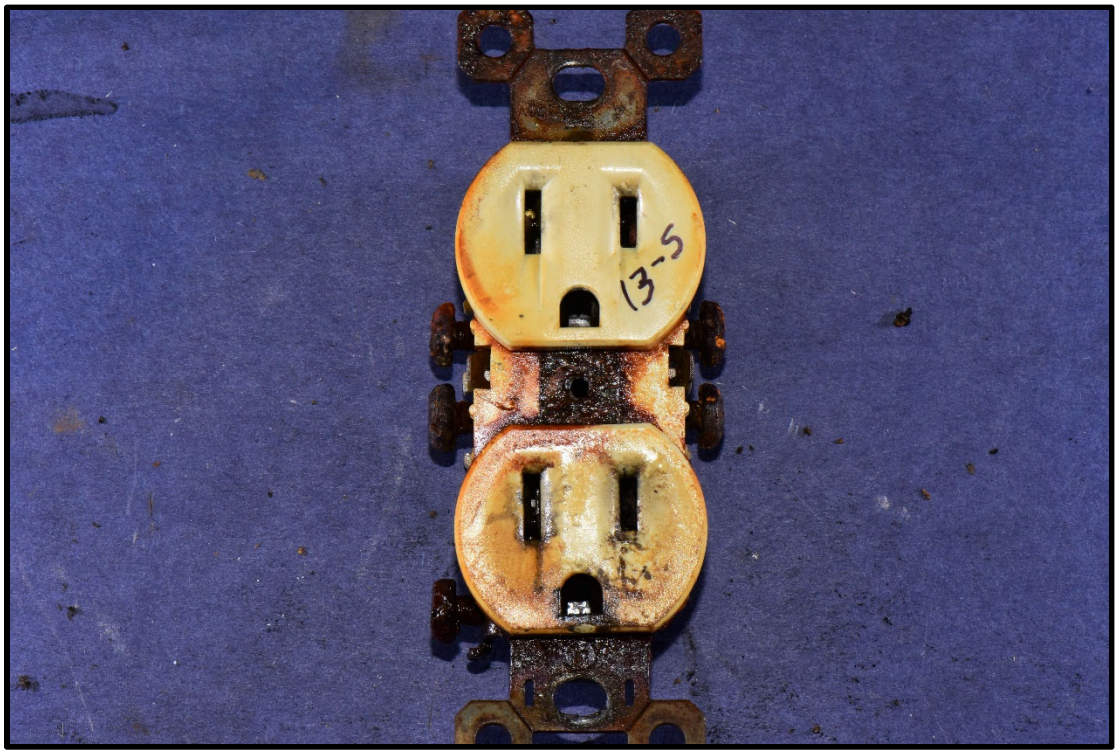

Figure 41. Receptacle 13-S

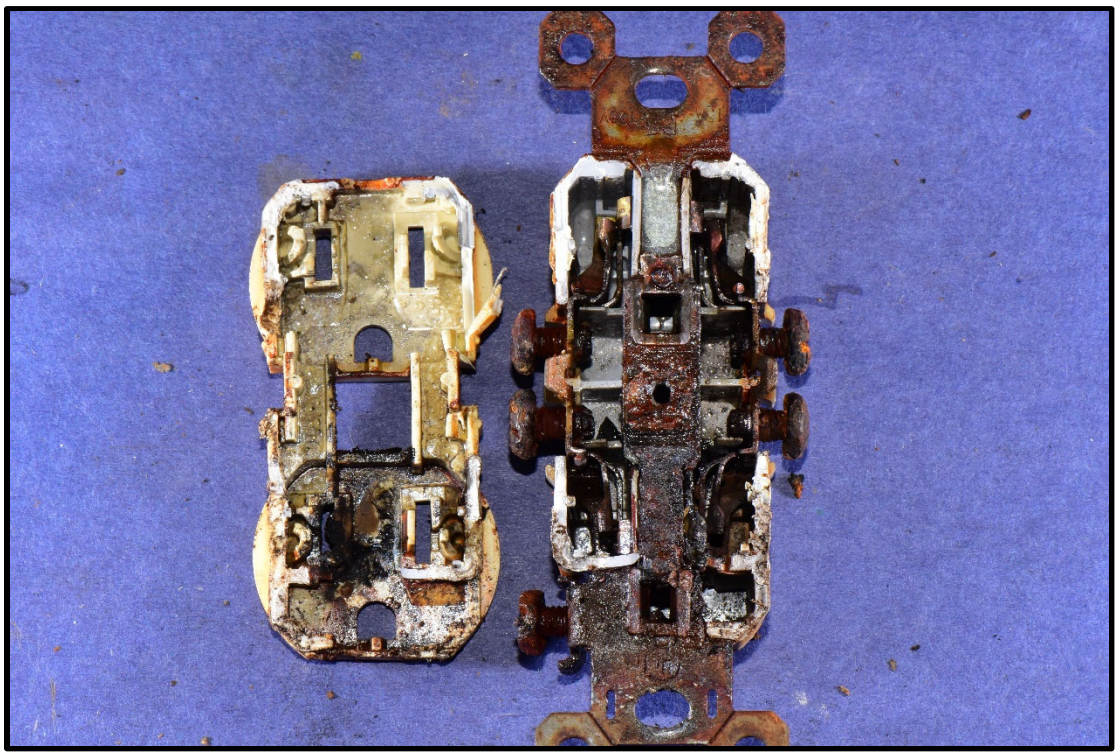

Figure 42. Receptacle 13-S

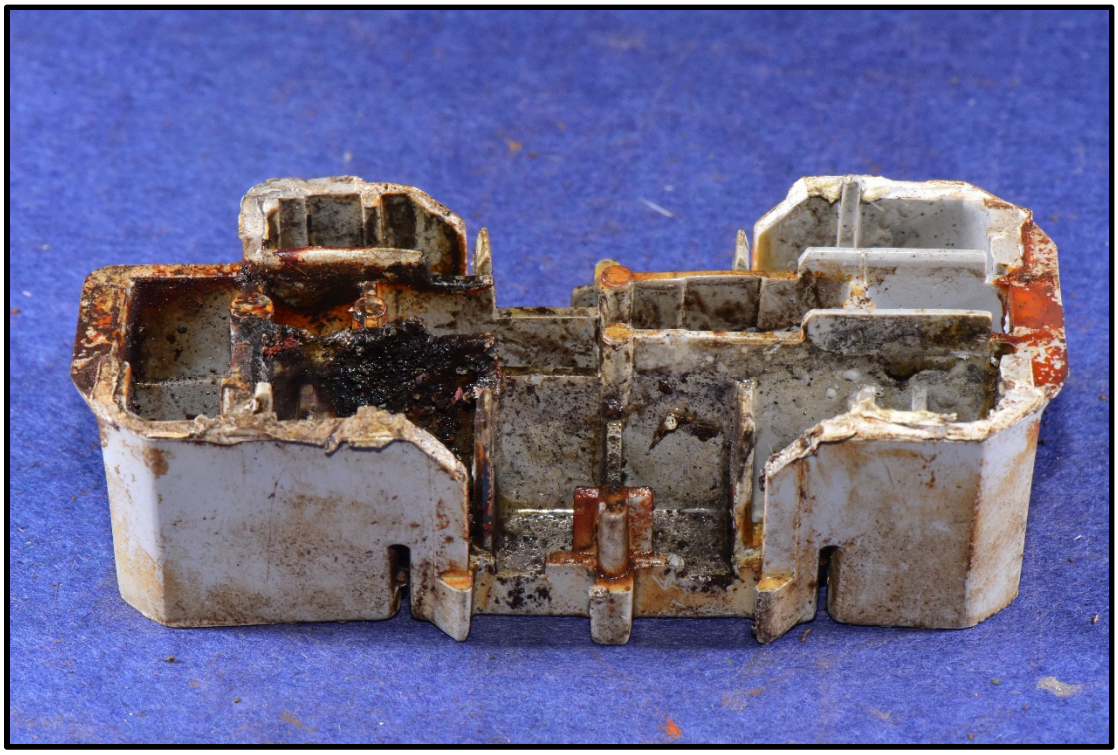

Figure 43. Receptacle 13-S

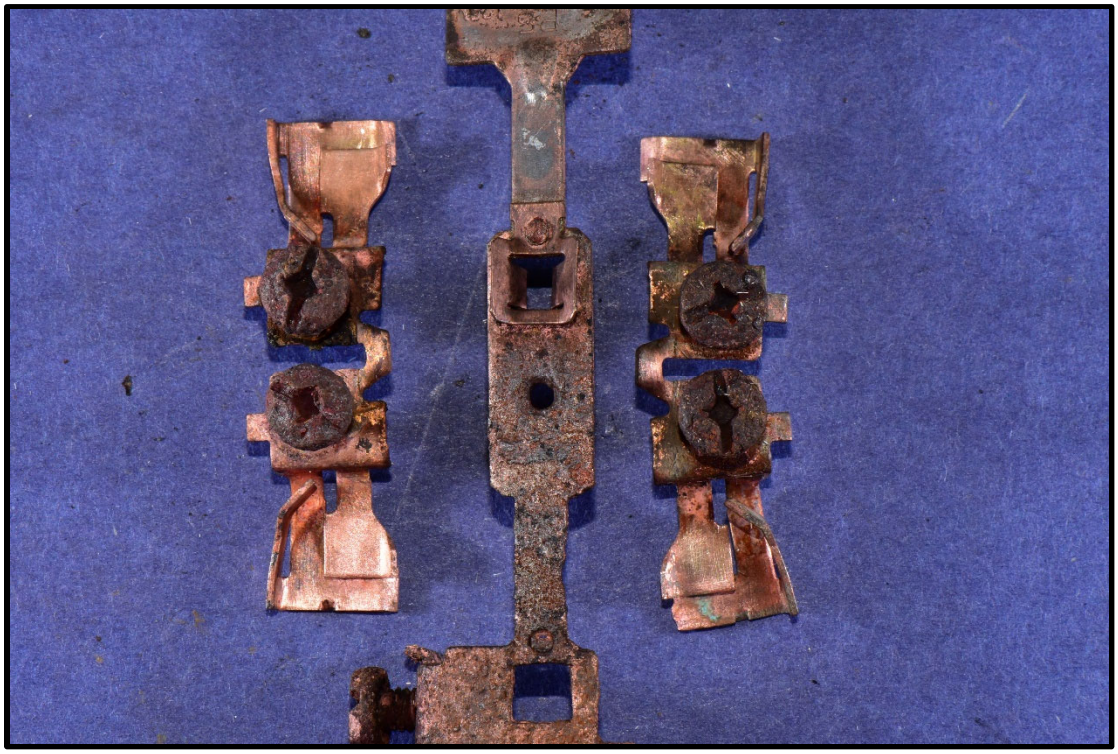

Figure 44. Power rails and ground yoke from Receptacle 13-S

Figure 45. Power rails and ground yoke from Receptacle 13-S

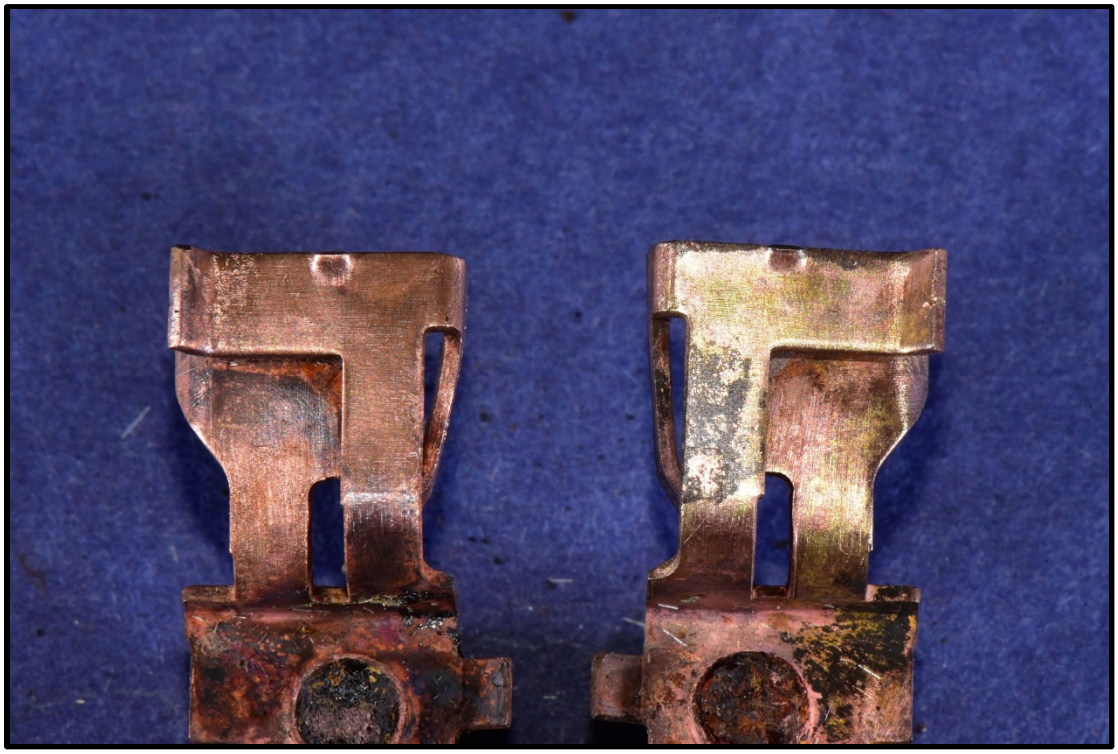

Figure 46. Top blade receptors from Receptacle 13-S

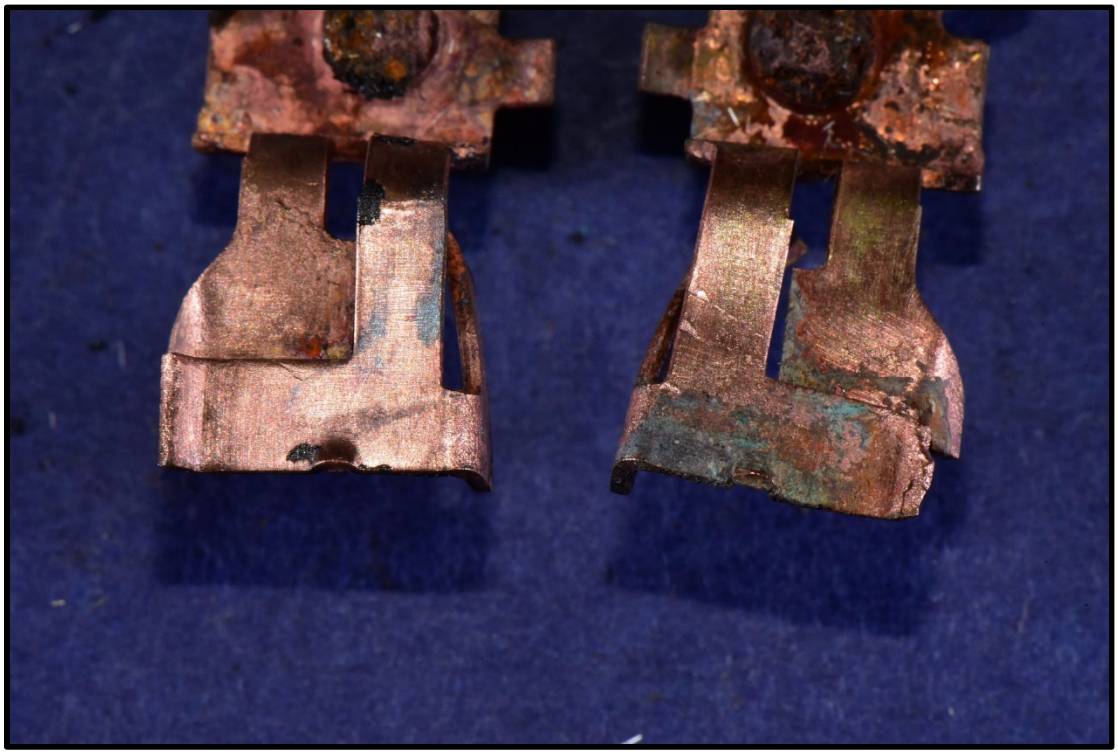

Figure 47. Bottom blade receptors from Receptacle 13-S

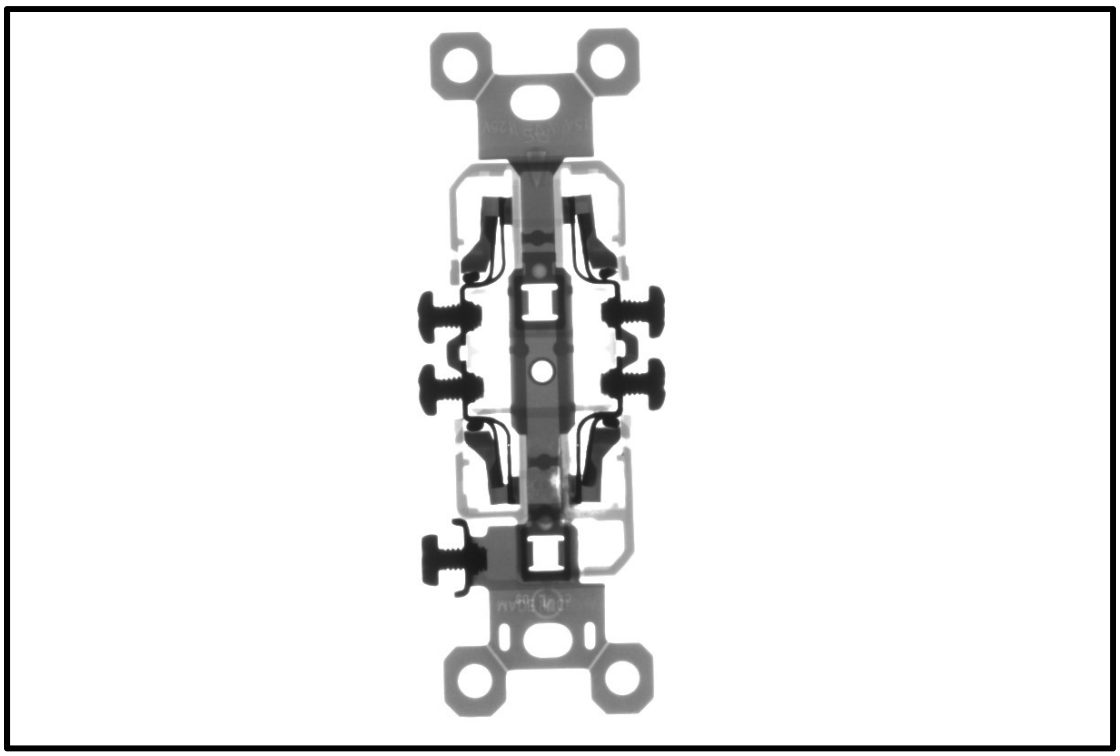

Figure 48. Radiographic (x-ray) image of Receptacle 13-U

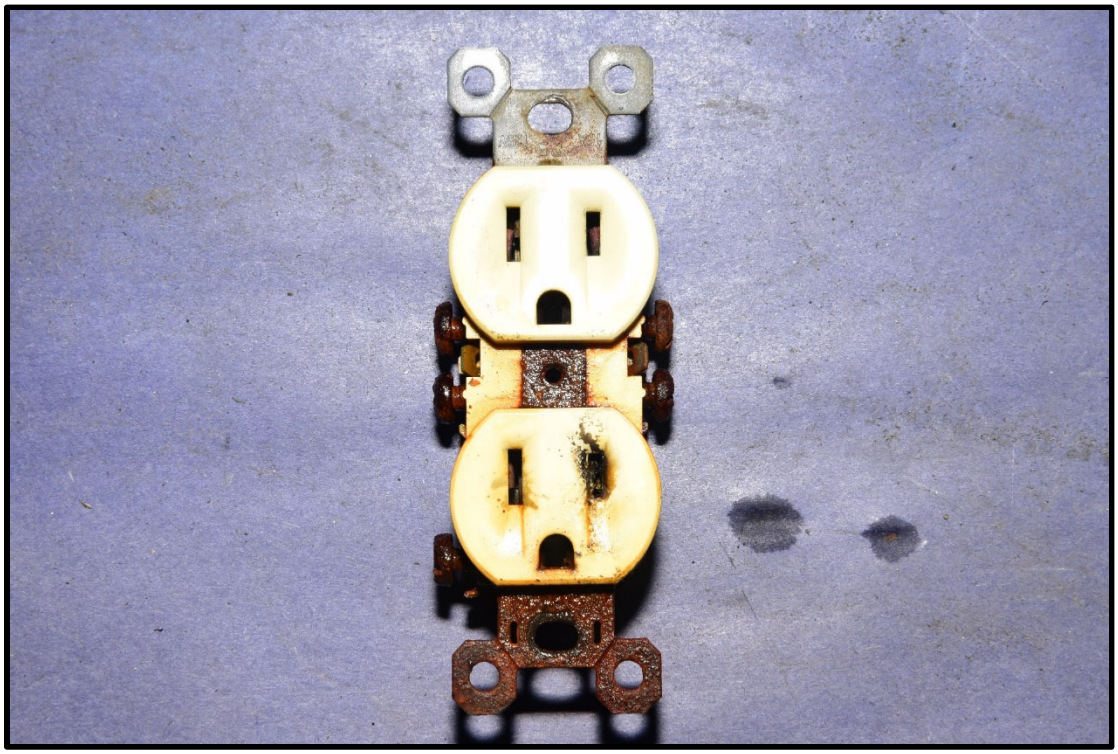

Figure 49. Receptacle 13-U

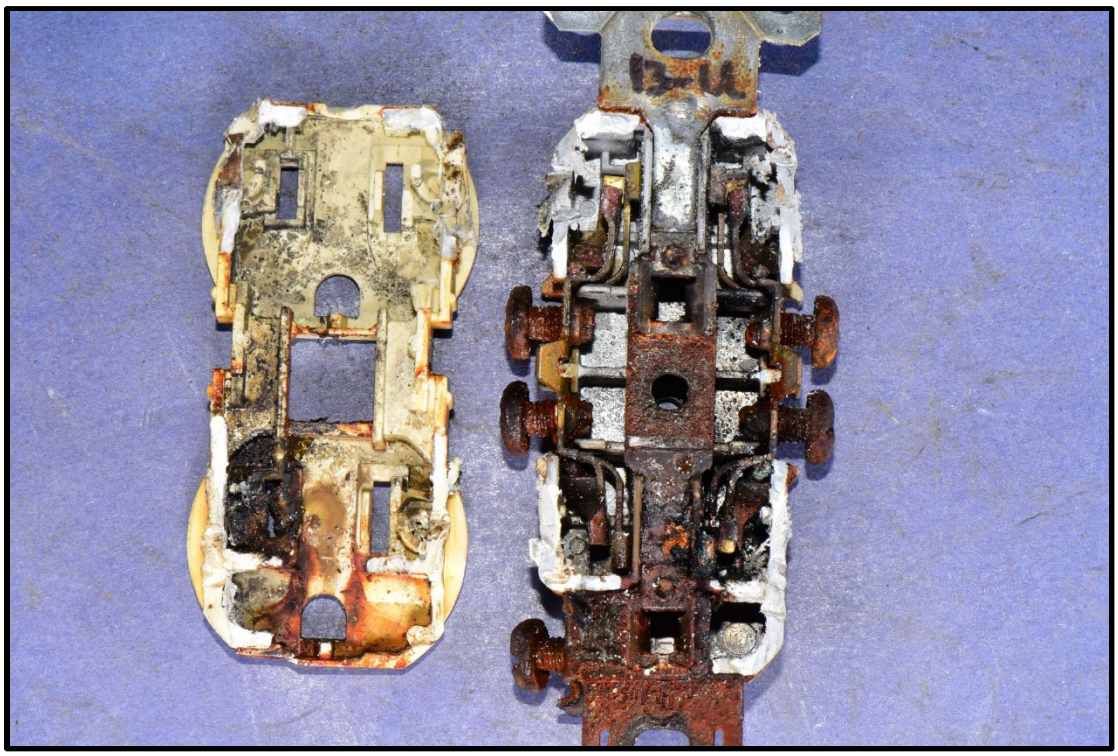

Figure 50. Receptacle 13-U

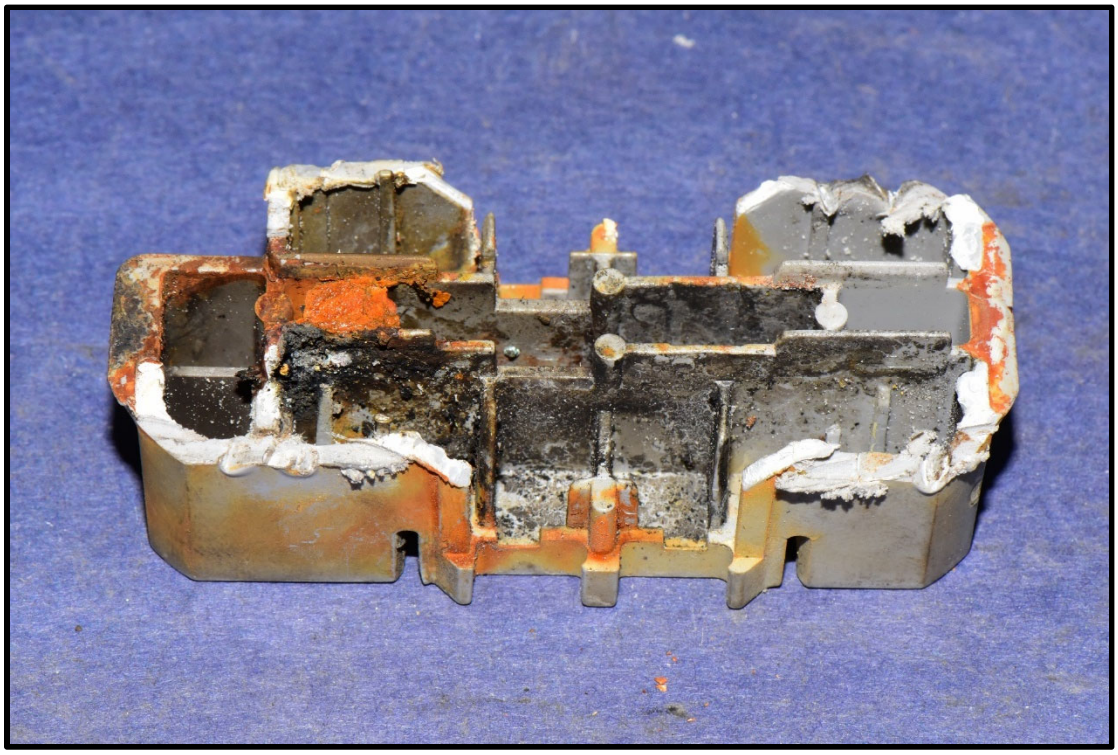

Figure 51. Receptacle 13-U

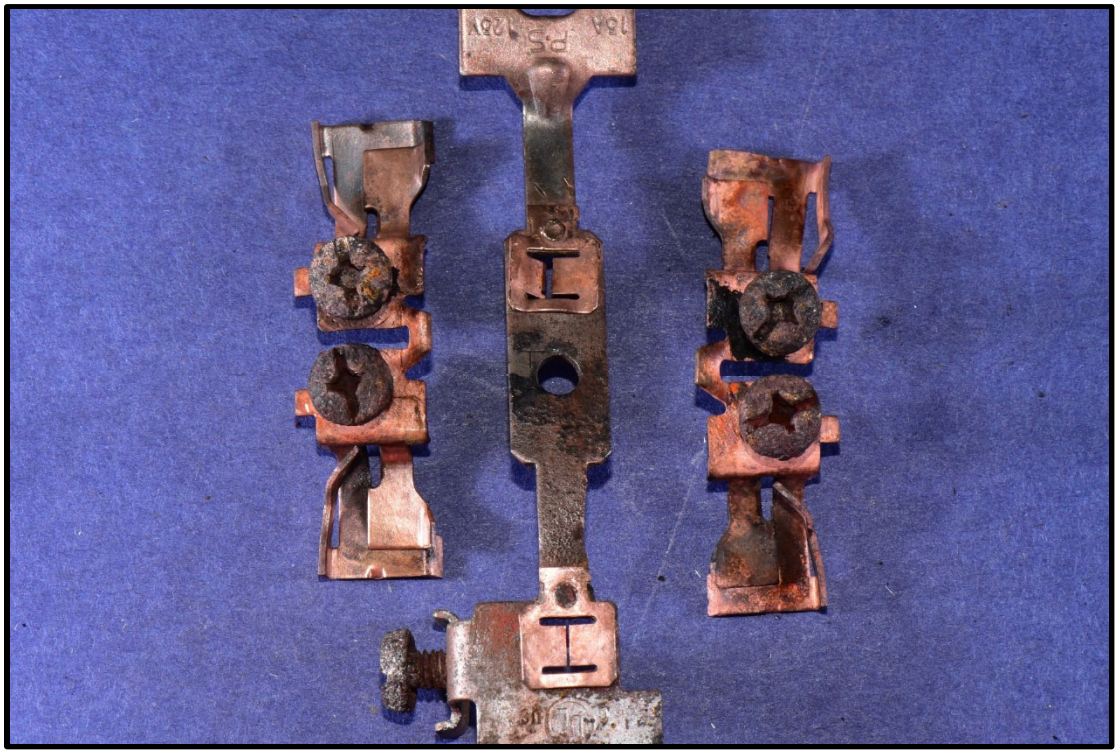

Figure 52. Power rails and ground yoke of Receptacle 13-U

Figure 53. Power rails and ground yoke of Receptacle 13-U

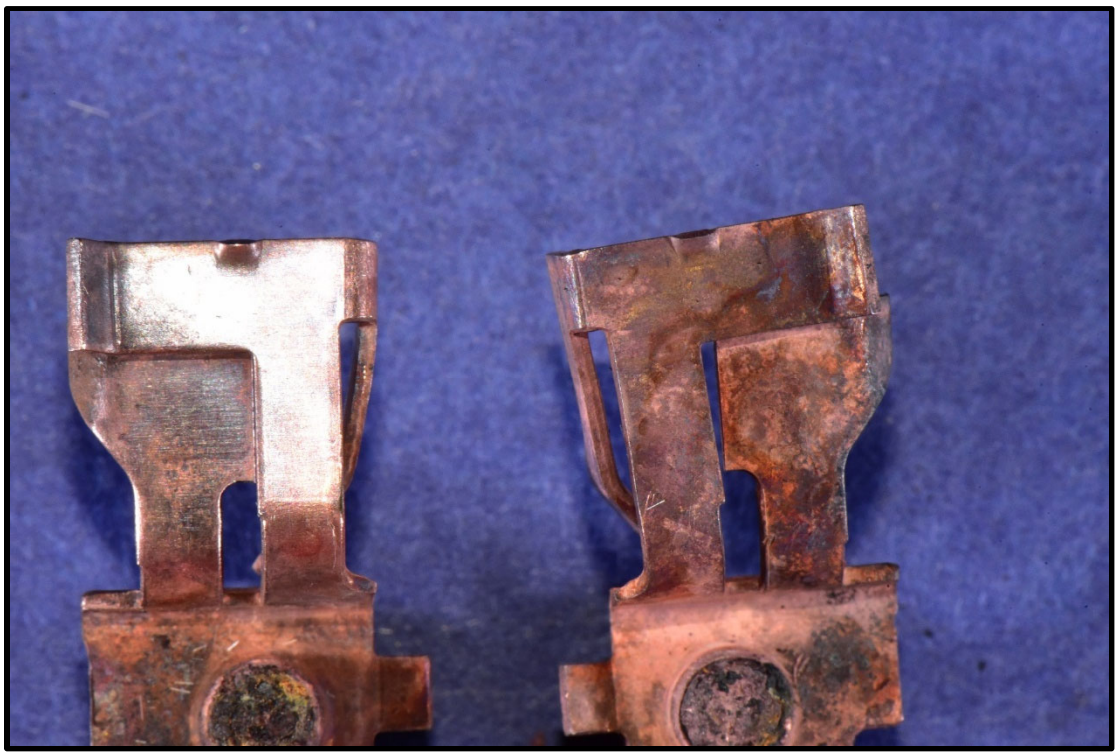

Figure 54. Top blade receptors from Receptacle 13-U

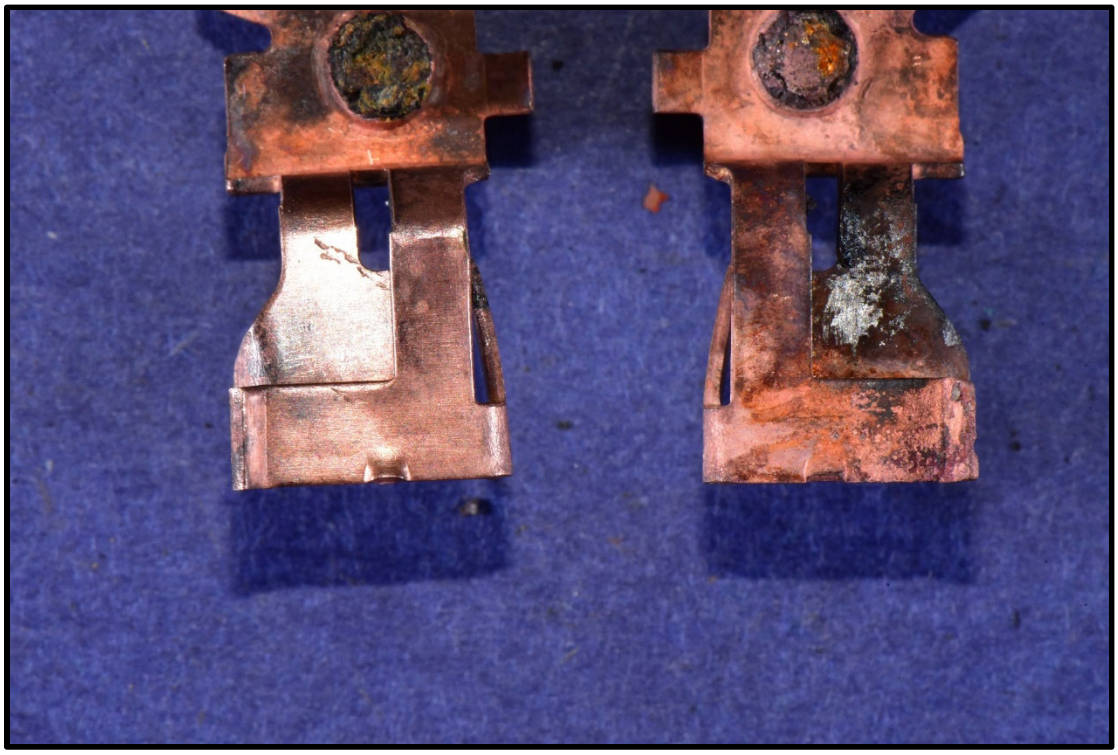

Figure 55. Bottom blade receptors from Receptacle 13-U

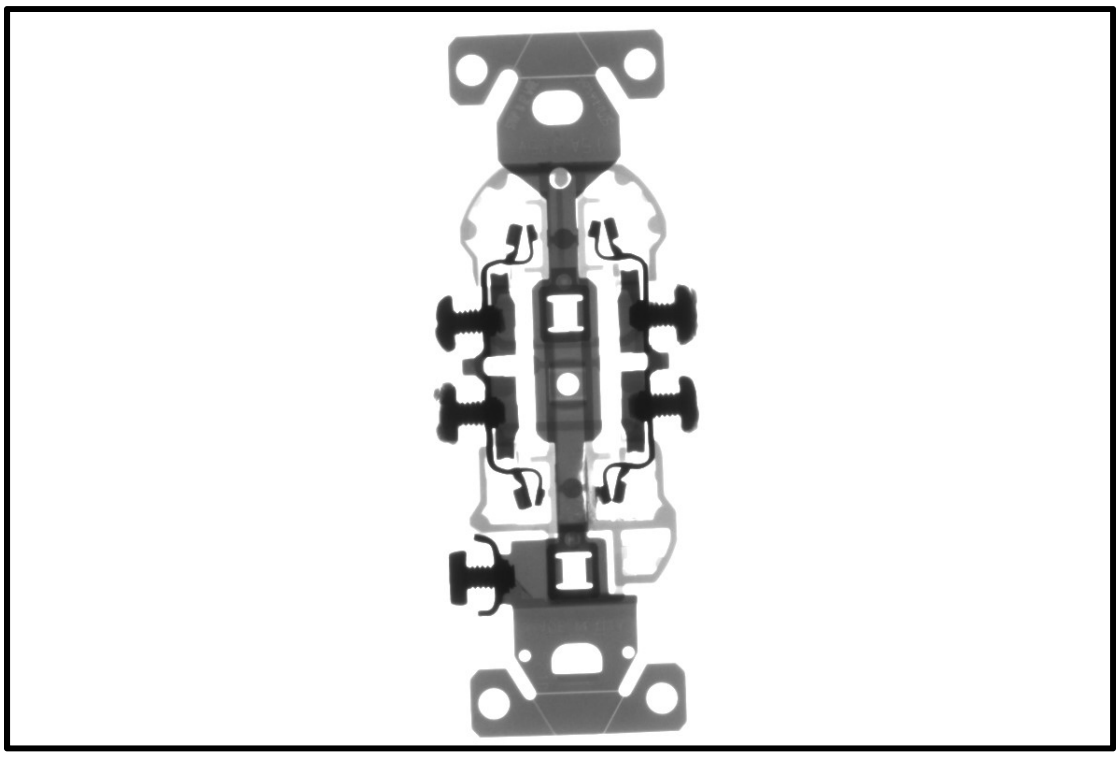

Figure 56. Radiographic (x-ray) image of Receptacle 17-S

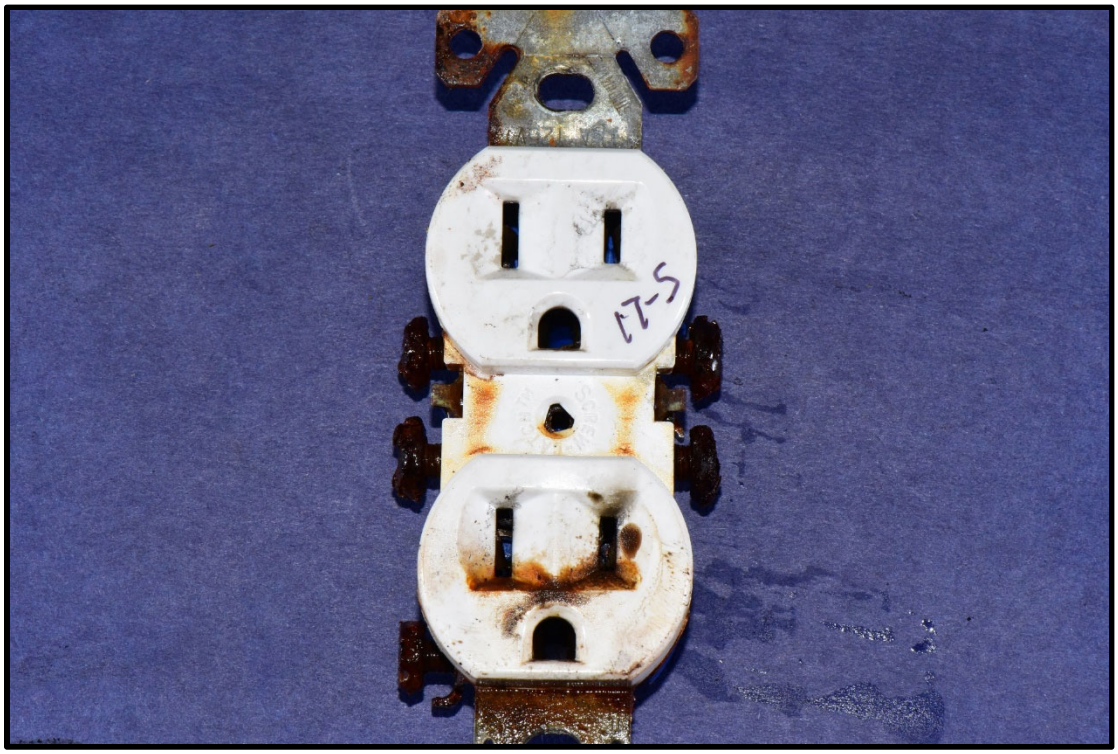

Figure 57. Receptacle 17-S

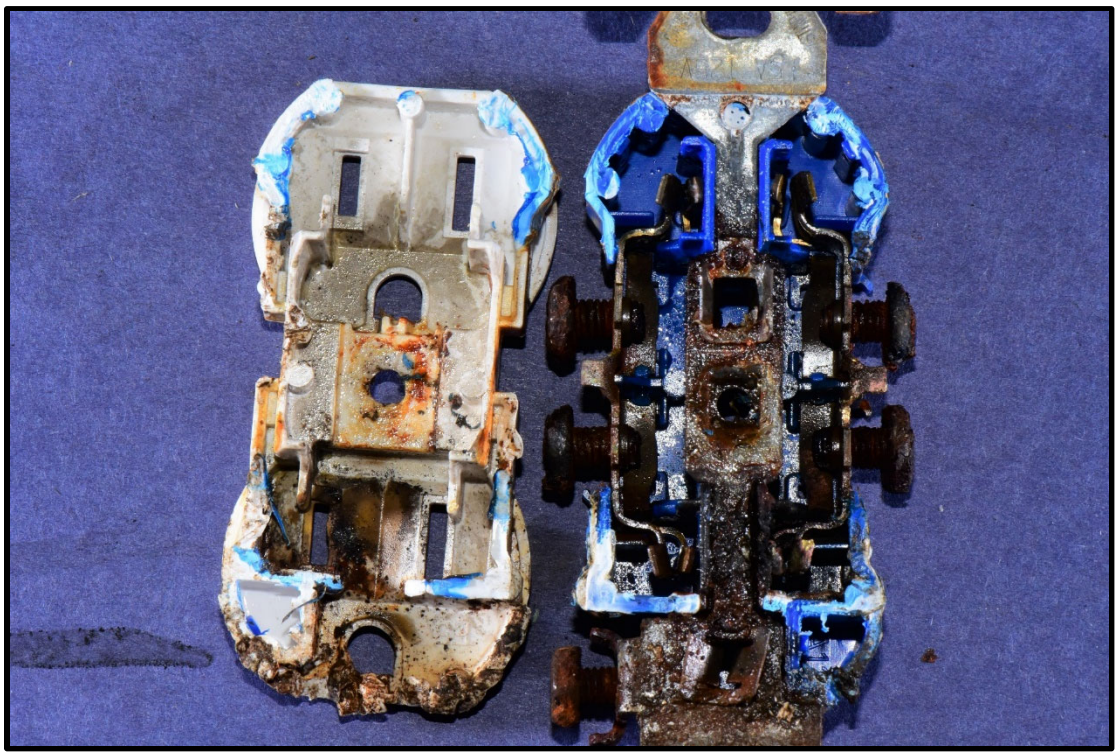

Figure 58. Receptacle 17-S

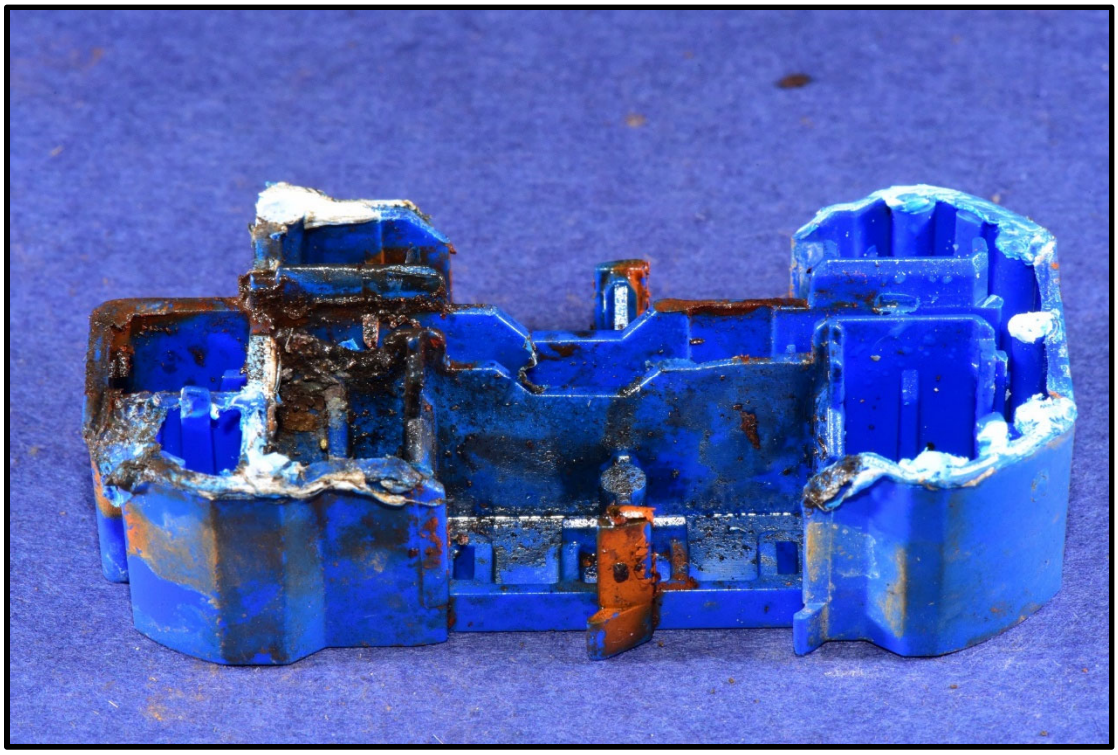

Figure 59. Receptacle 17-S

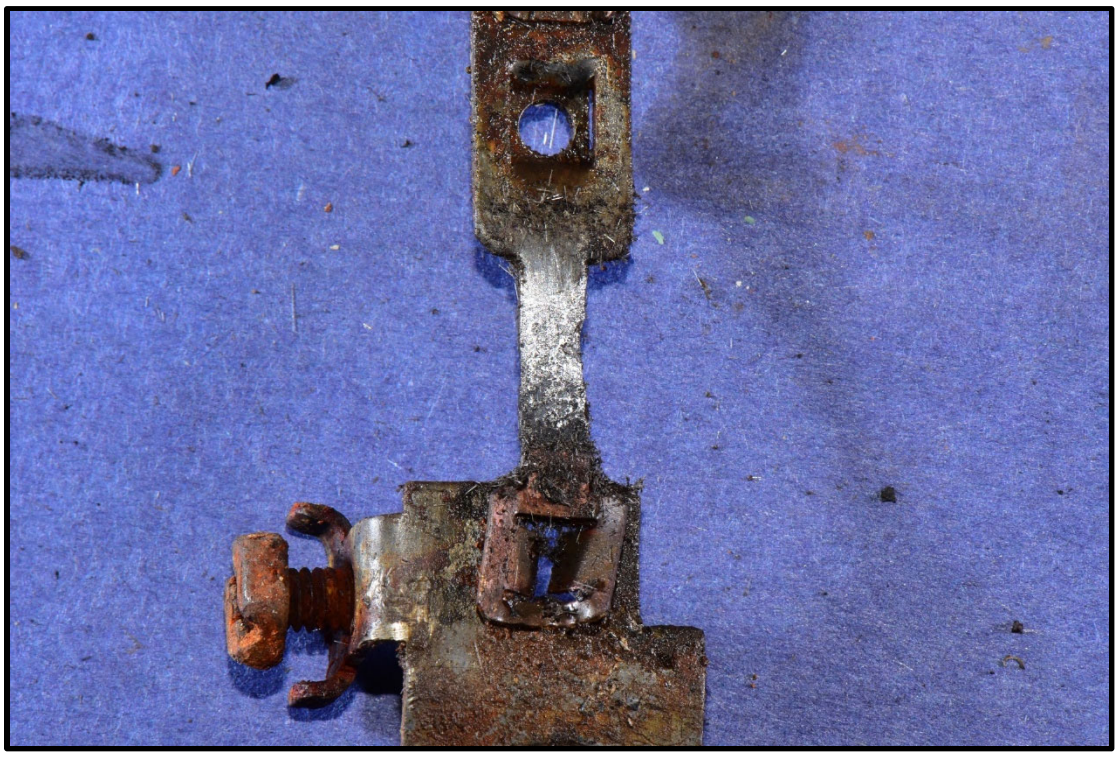

Figure 60. Ground yoke from Receptacle 17-S

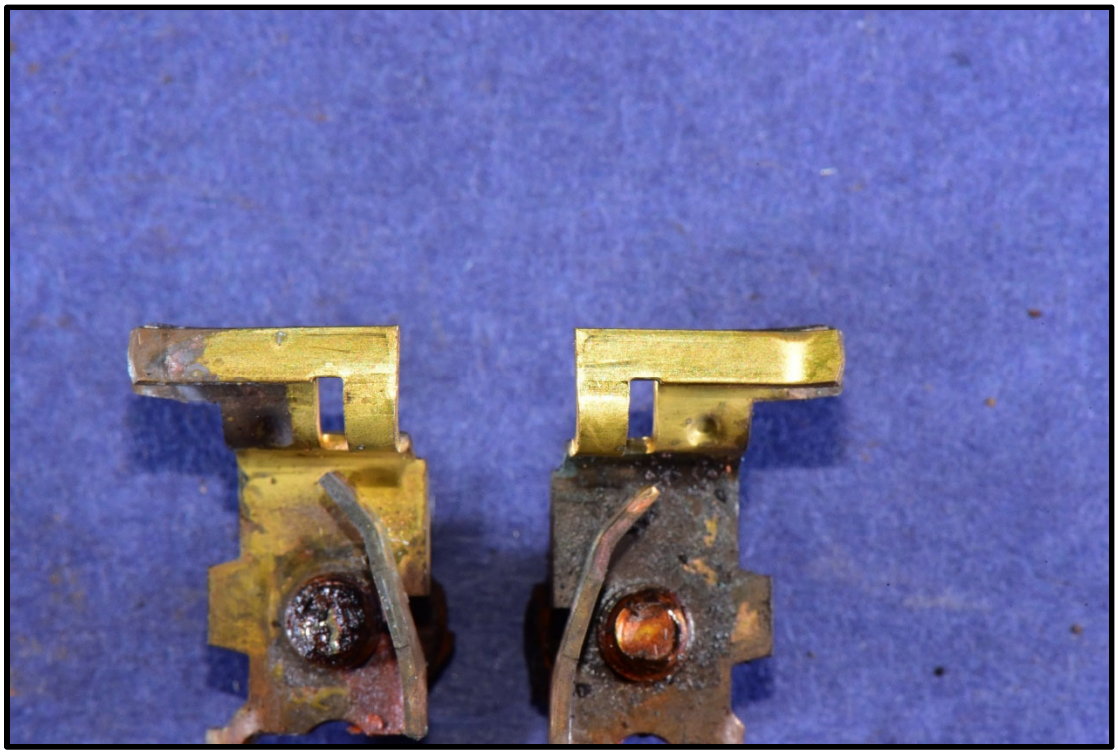

Figure 61. Top blade receptors from Receptacle 17-S

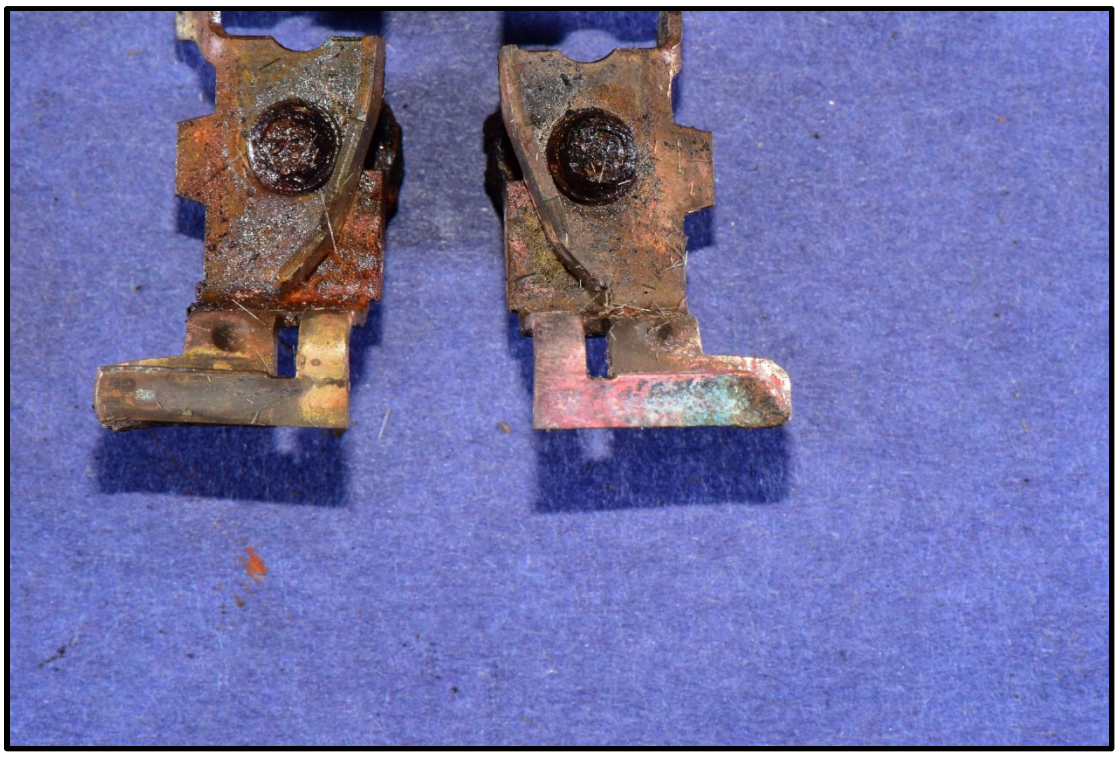

Figure 62. Bottom blade receptors from Receptacle 17-S

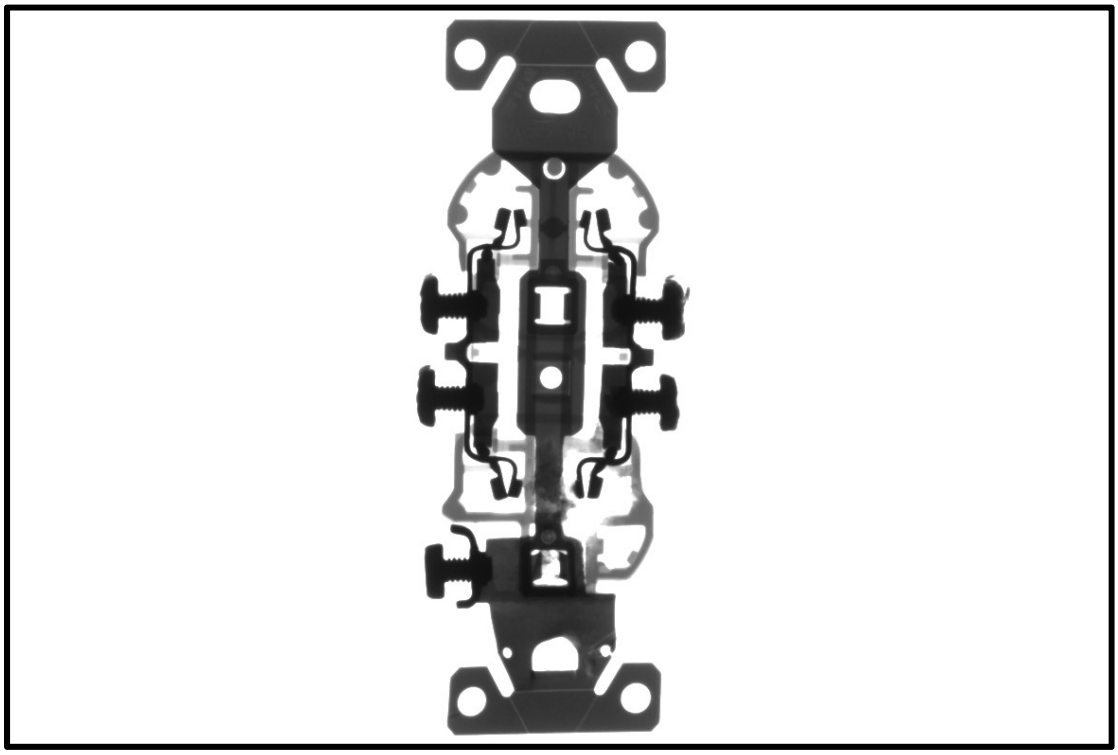

Figure 63. Radiographic (x-ray) image of Receptacle 17-T

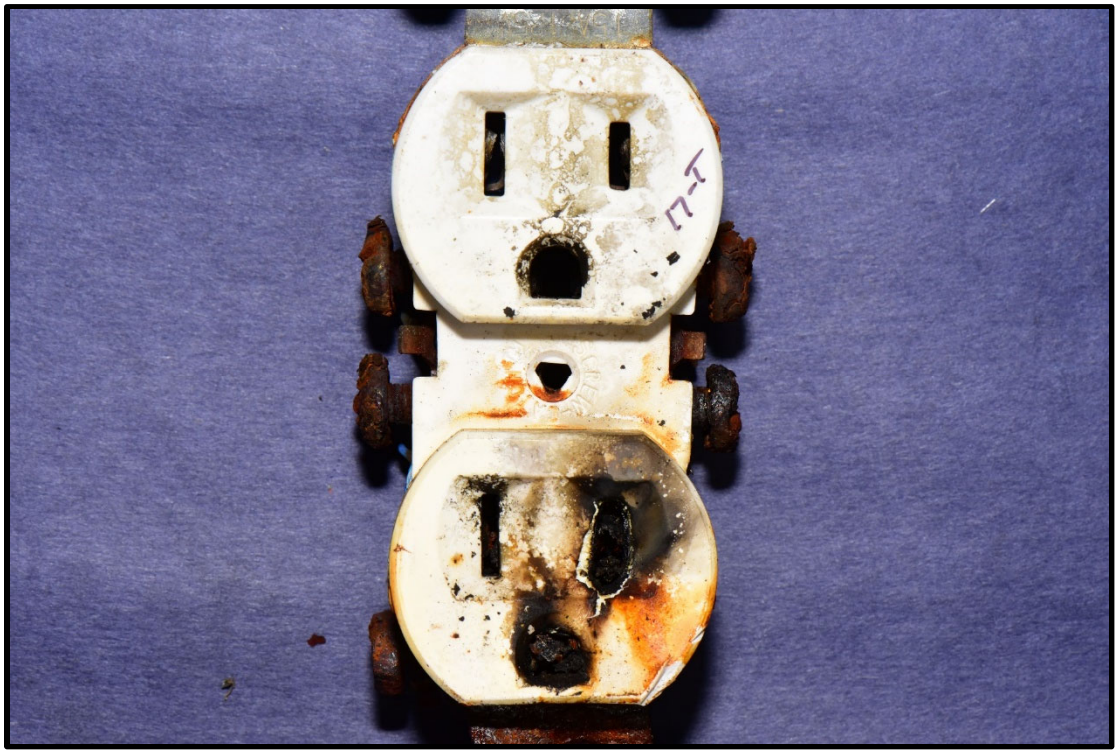

Figure 64. Receptacle 17-T

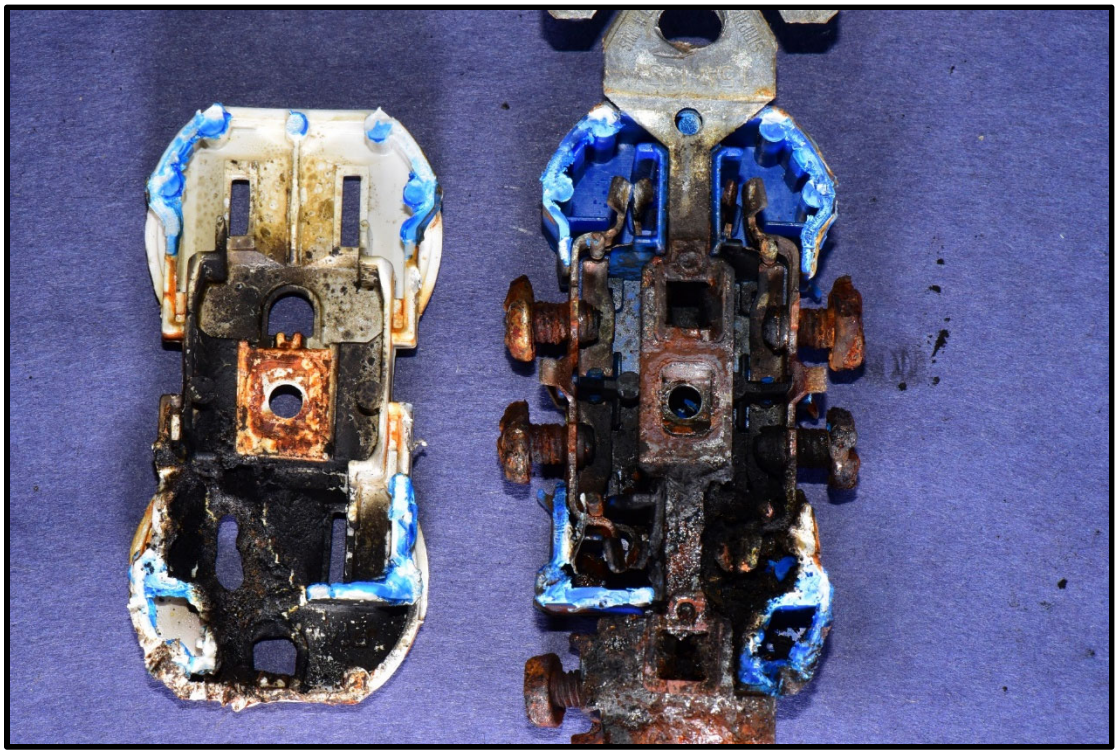

Figure 65. Receptacle 17-T

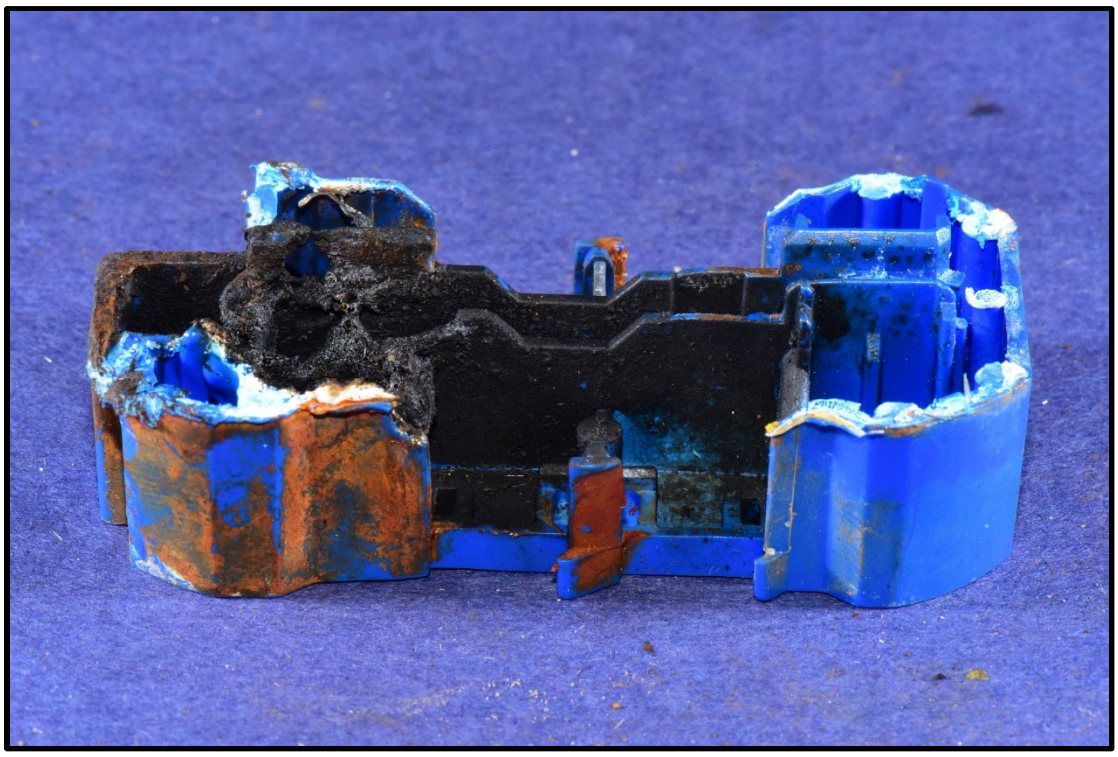

Figure 66. Receptacle 17-T

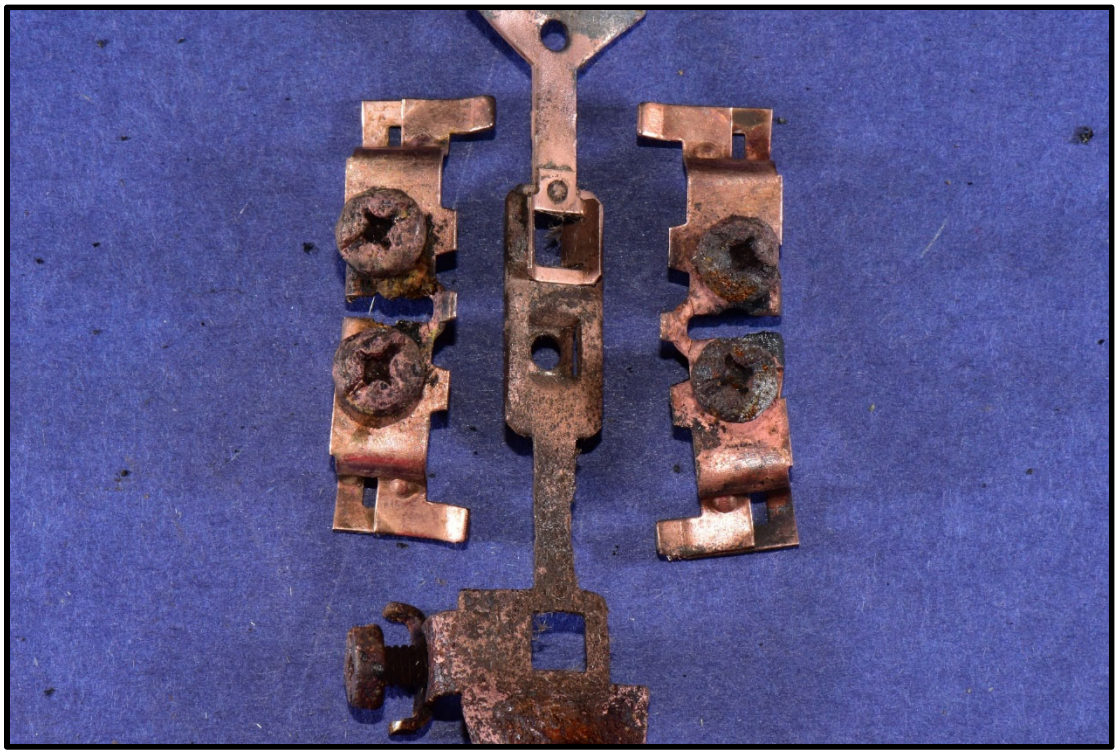

Figure 67. Power rails and ground yoke of Receptacle 17-T

Figure 68. Power rails and ground yoke of Receptacle 17-T

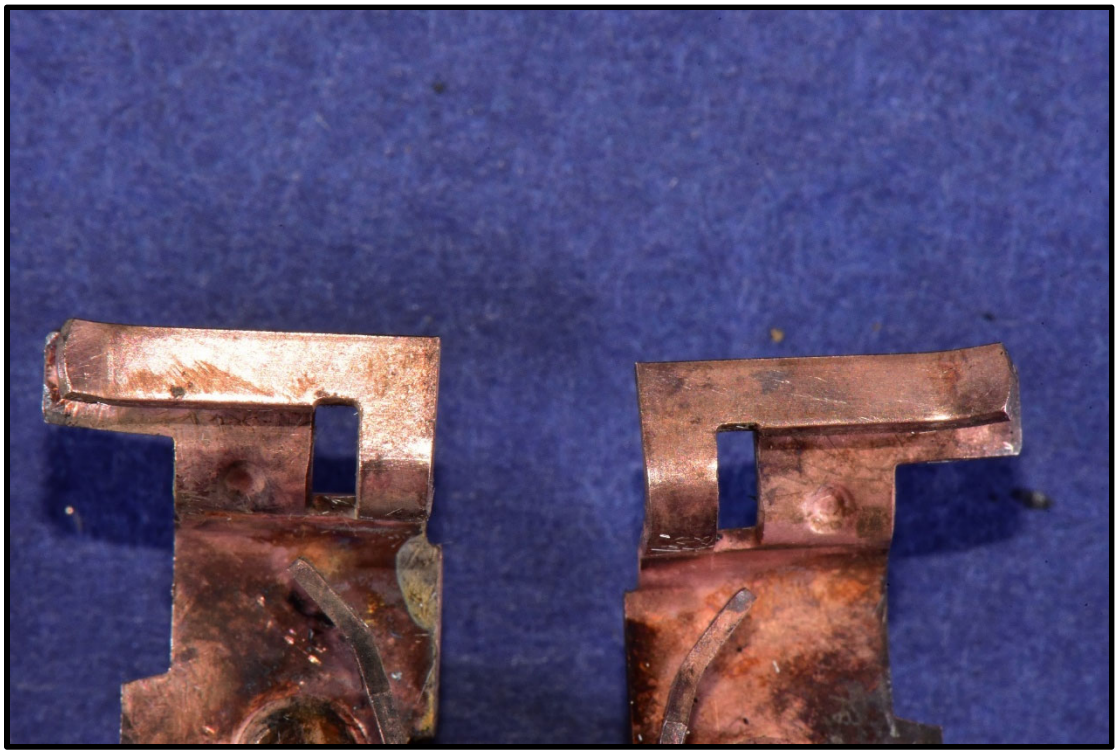

Figure 69. Top blade receptors from Receptacle 17-T

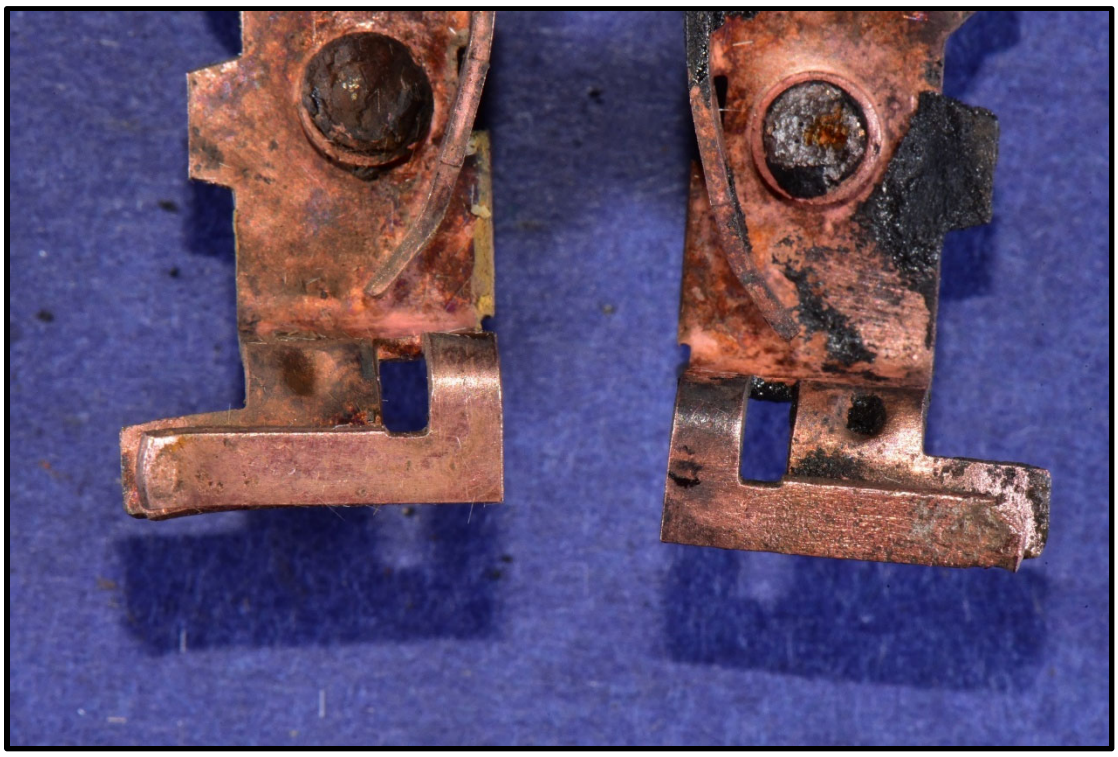

Figure 70. Bottom blade receptors from Receptacle 17-T

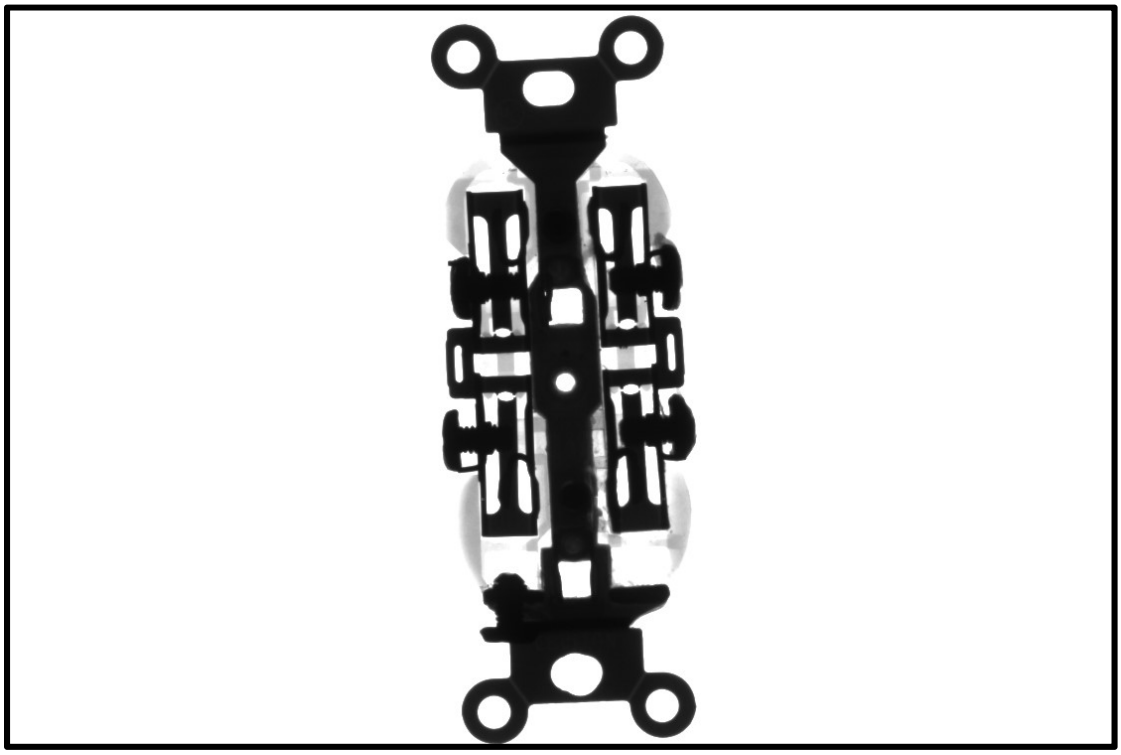

Figure 71. Radiographic (x-ray) image of Receptacle 22-R

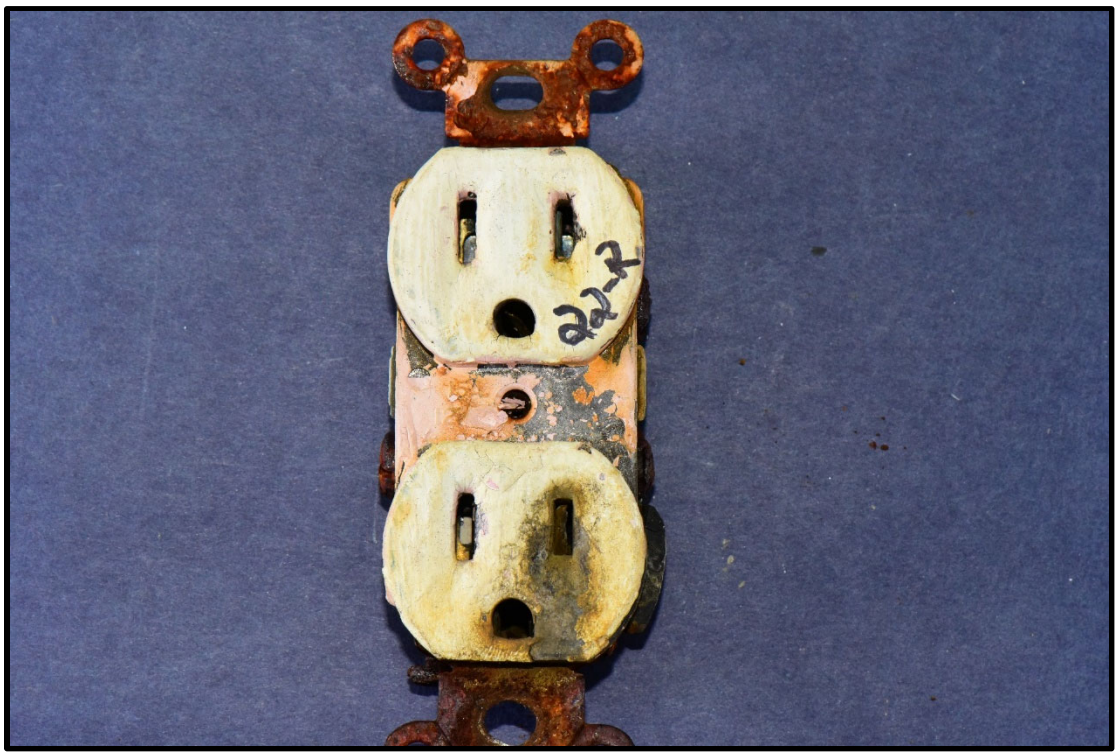

Figure 72. Receptacle 22-R

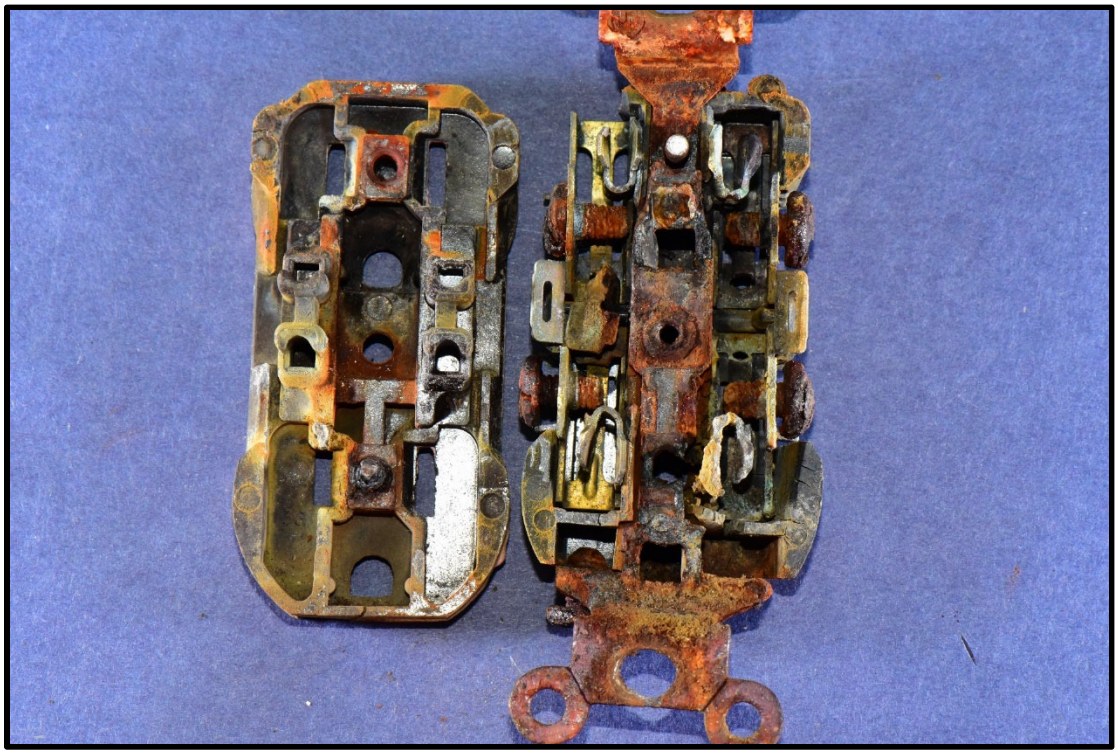

Figure 73. Receptacle 22-R

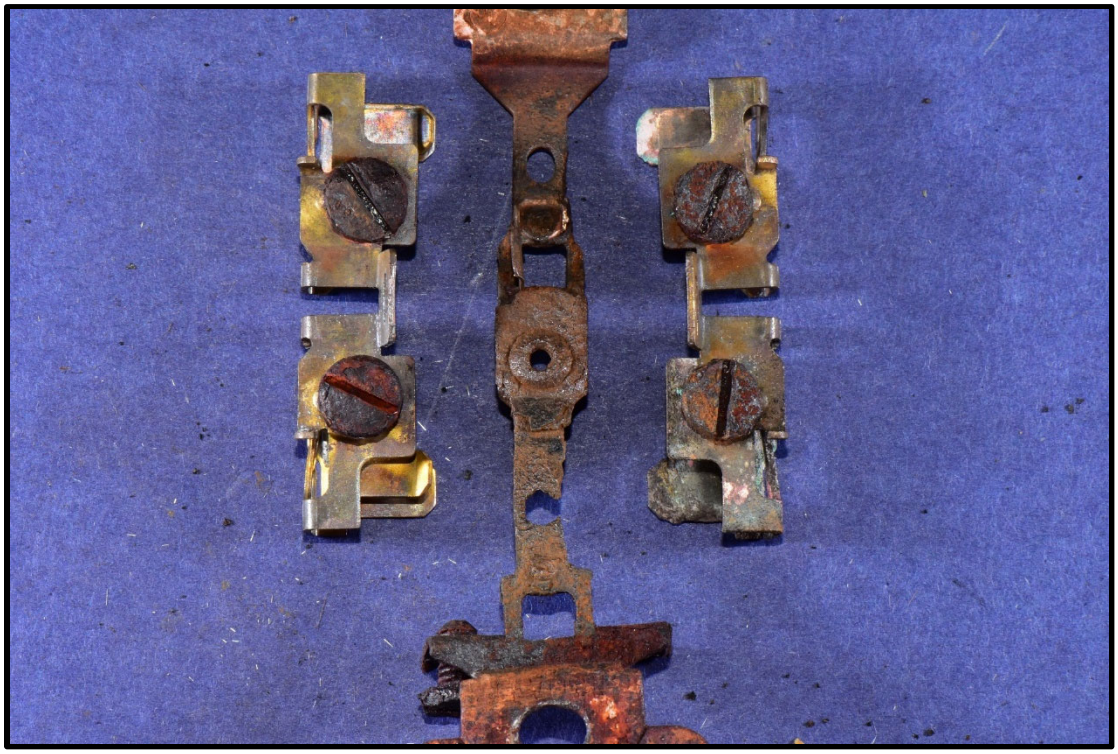

Figure 74. Power rails and ground yoke from Receptacle 22-R

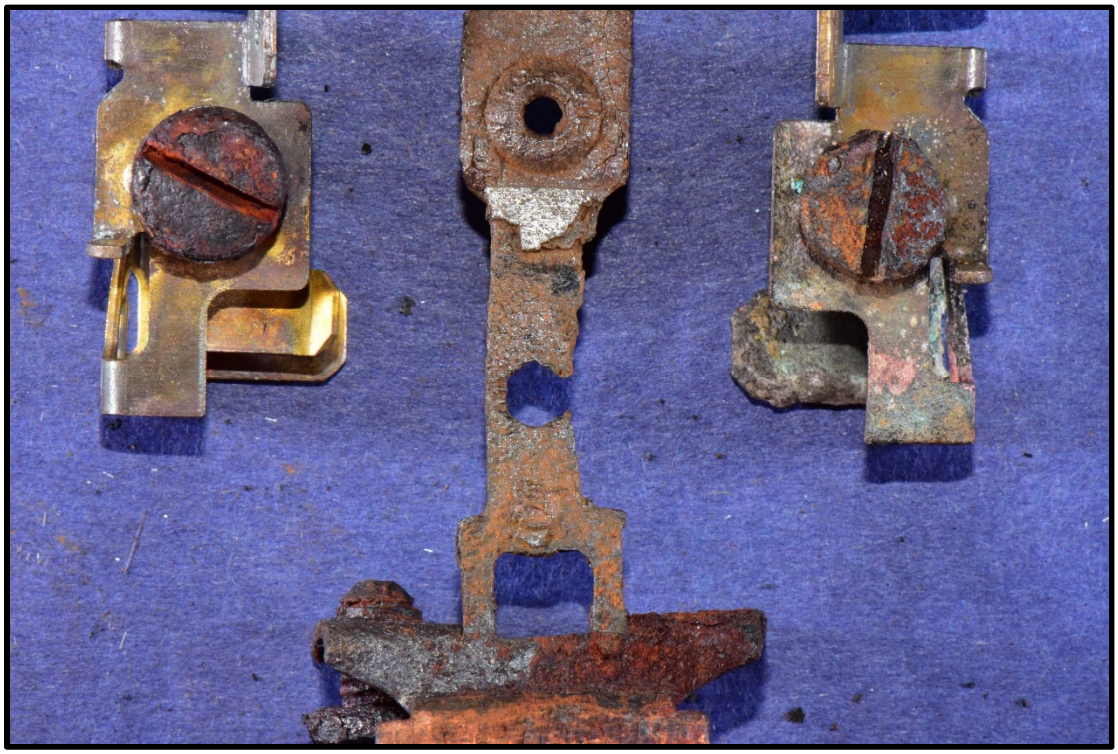

Figure 75. Power rails and ground yoke from Receptacle 22-R

Figure 76. Top blade receptors from Receptacle 22-R

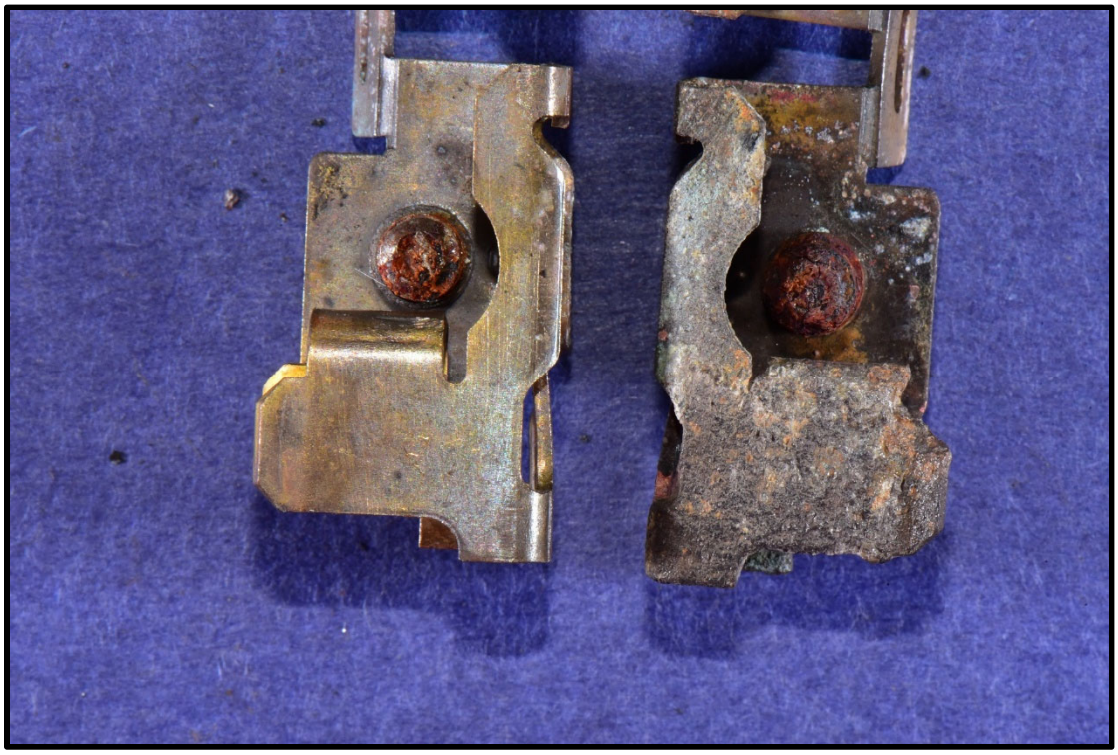

Figure 77. Bottom blade receptors from Receptacle 22-R

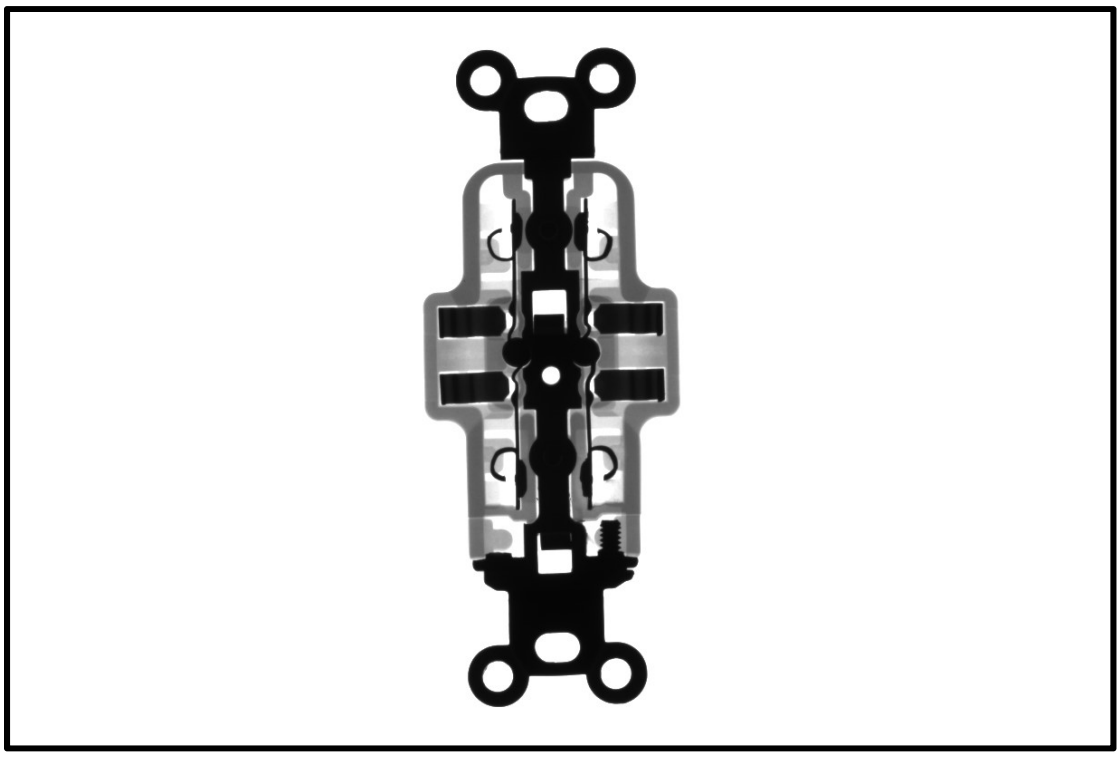

Figure 78. Radiographic (x-ray) image of Receptacle 23-T

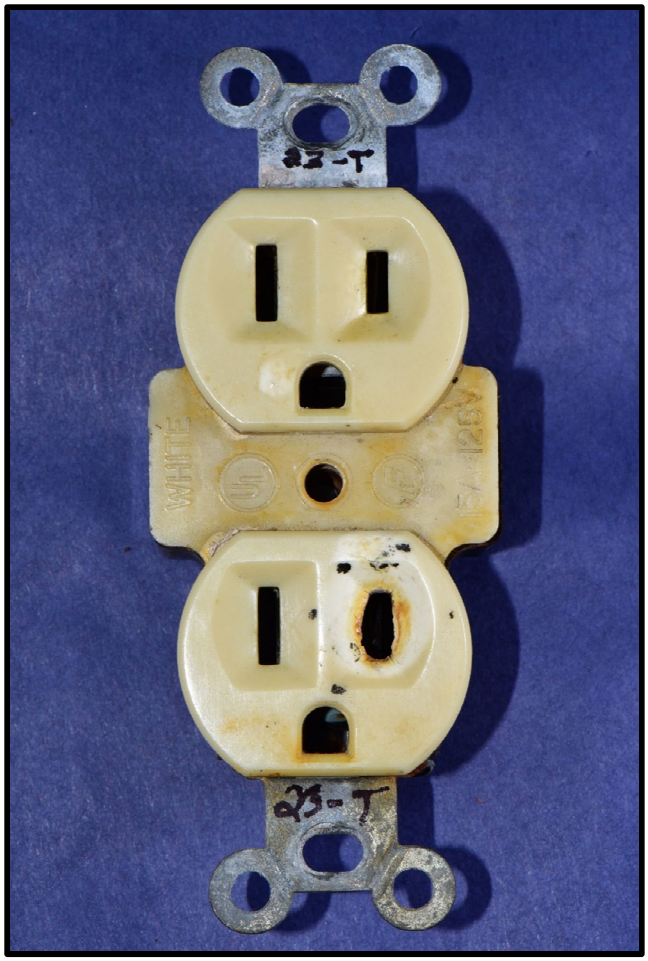

Figure 79. Receptacle 23-T

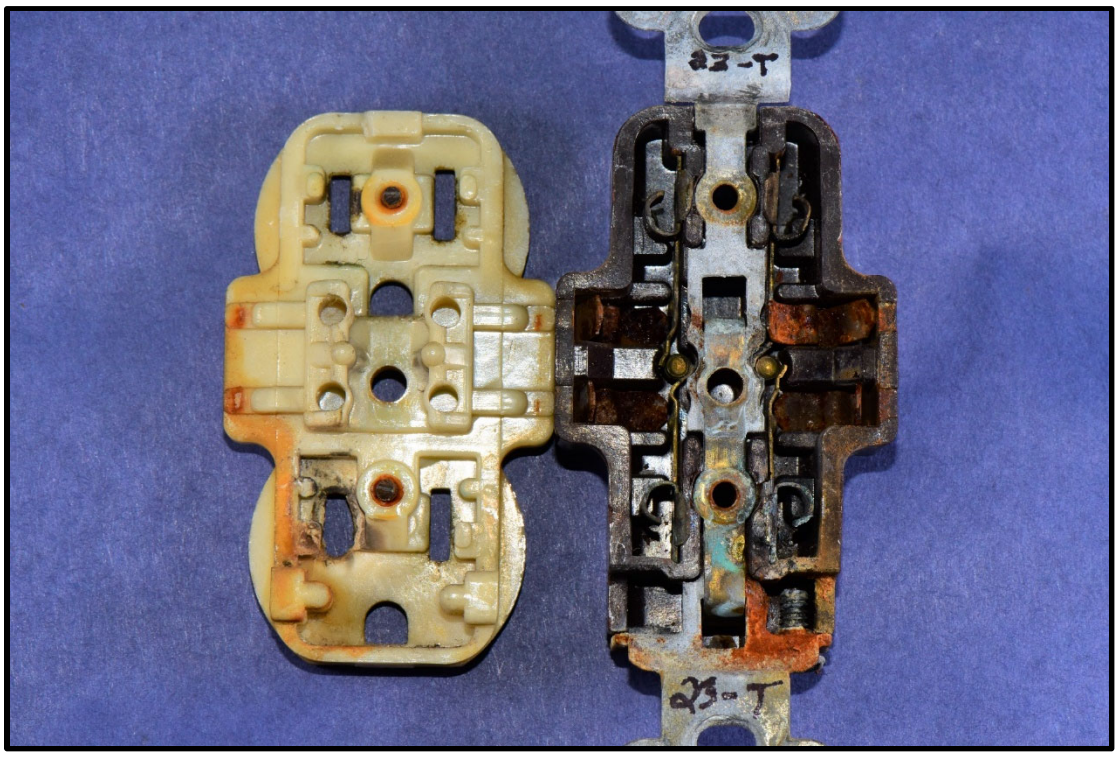

Figure 80. Receptacle 23-T

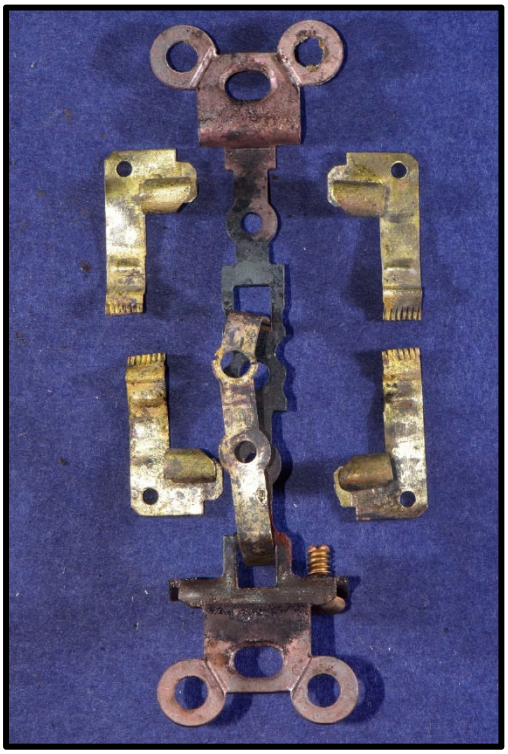

Figure 81. Power rails and ground yoke from Receptacle 23-T

Figure 82. Top blade receptors from Receptacle 23-T

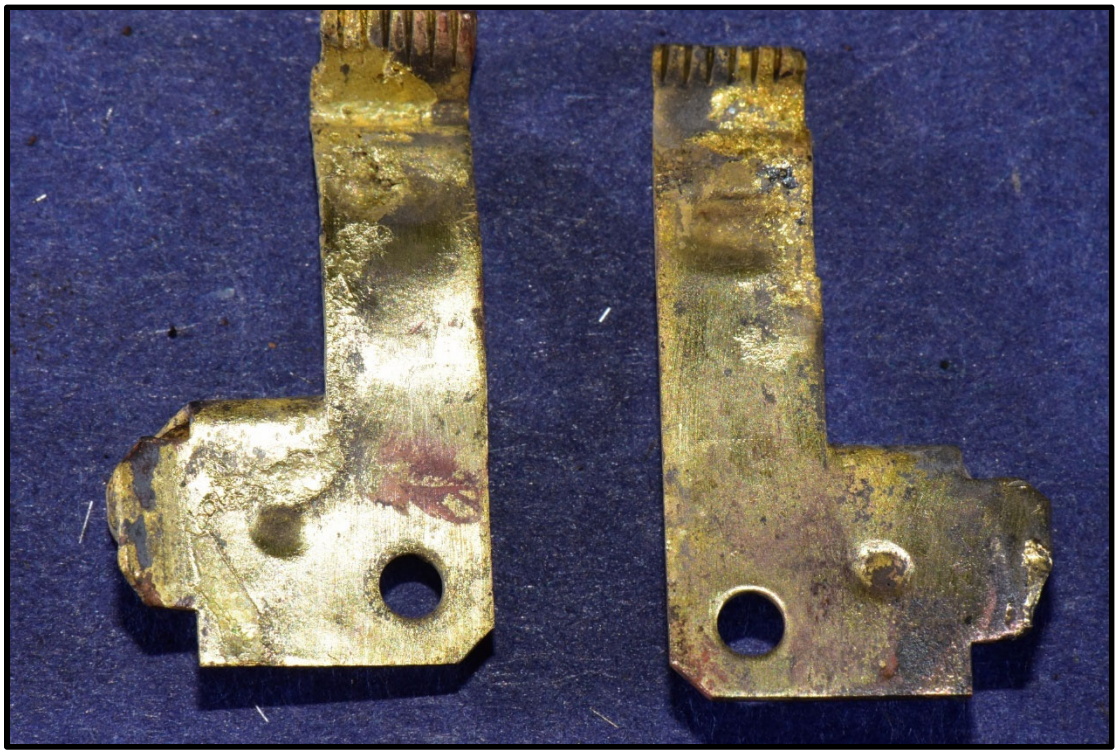

Figure 83. Bottom blade receptors from Receptacle 23-T

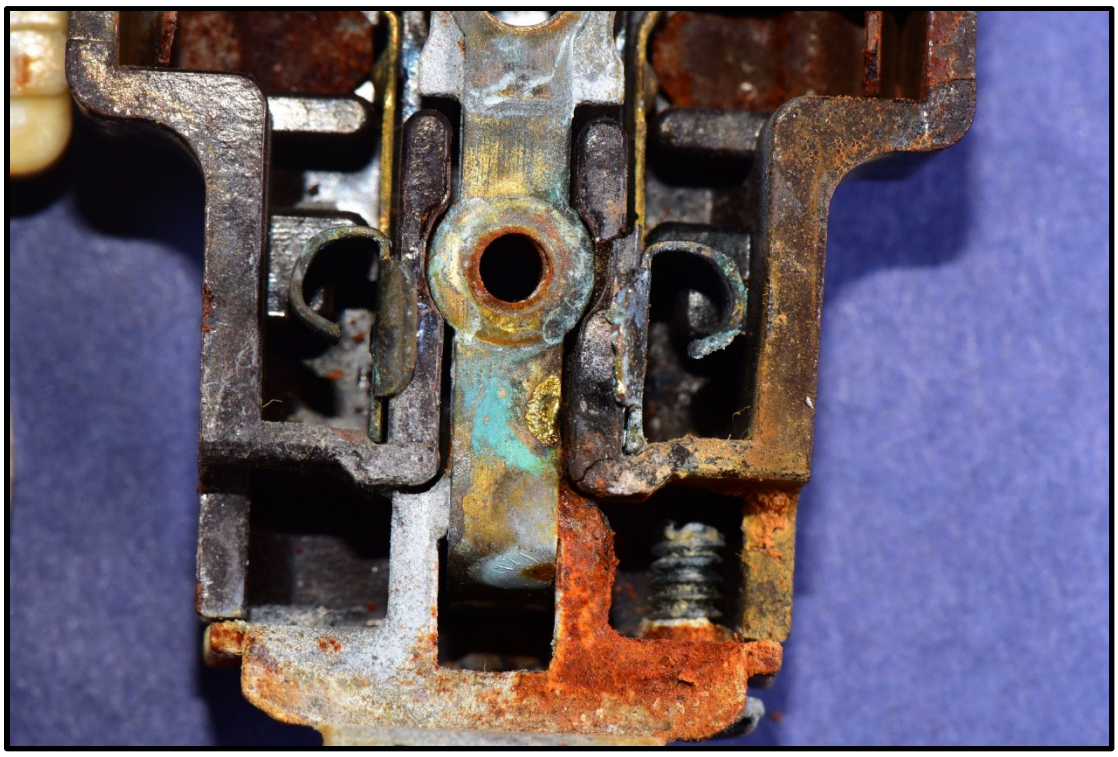

Figure 84. Power rails and ground yoke of Receptacle 23-T

ATTACHMENT 2: FIRE-CAUSED ARC MELTING

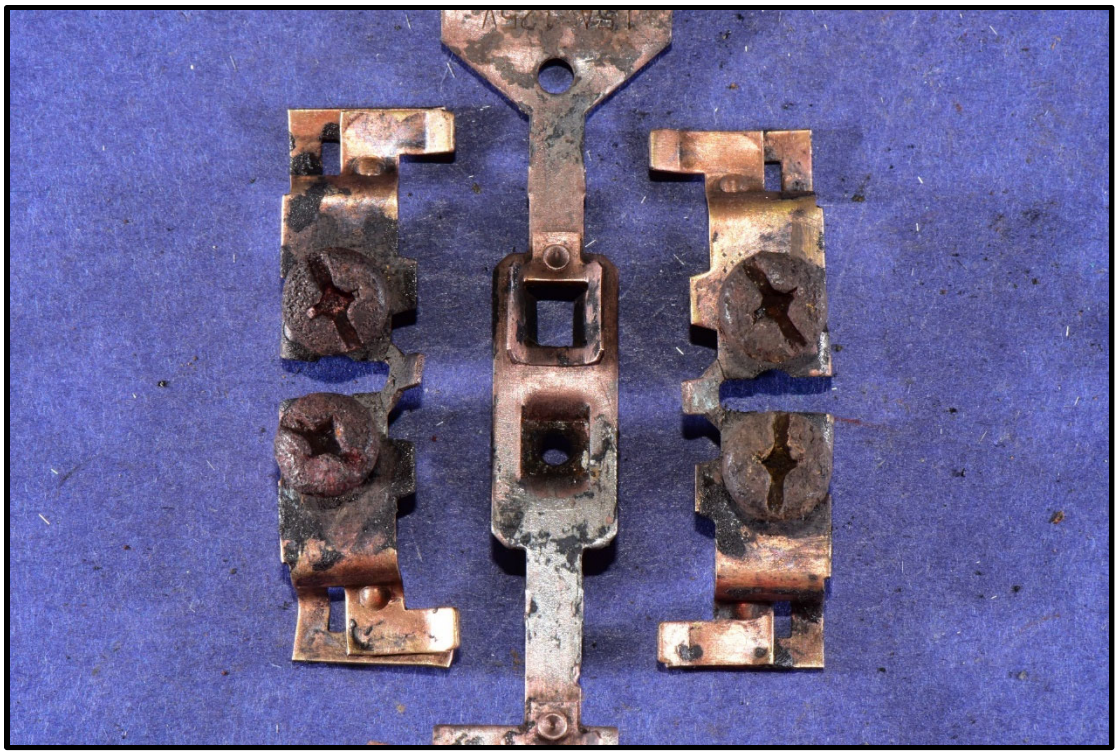

Figure 85. Power rails and ground yoke from Receptacle 2-D

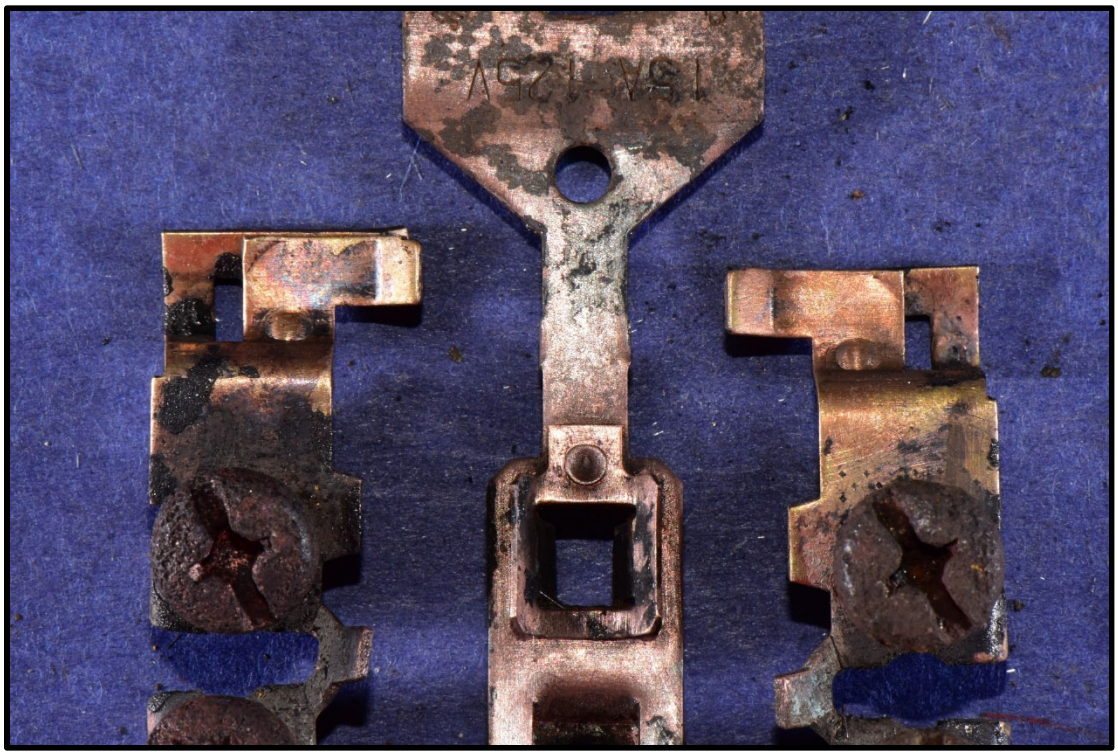

Figure 86. Power rails and ground yoke from Receptacle 2-D

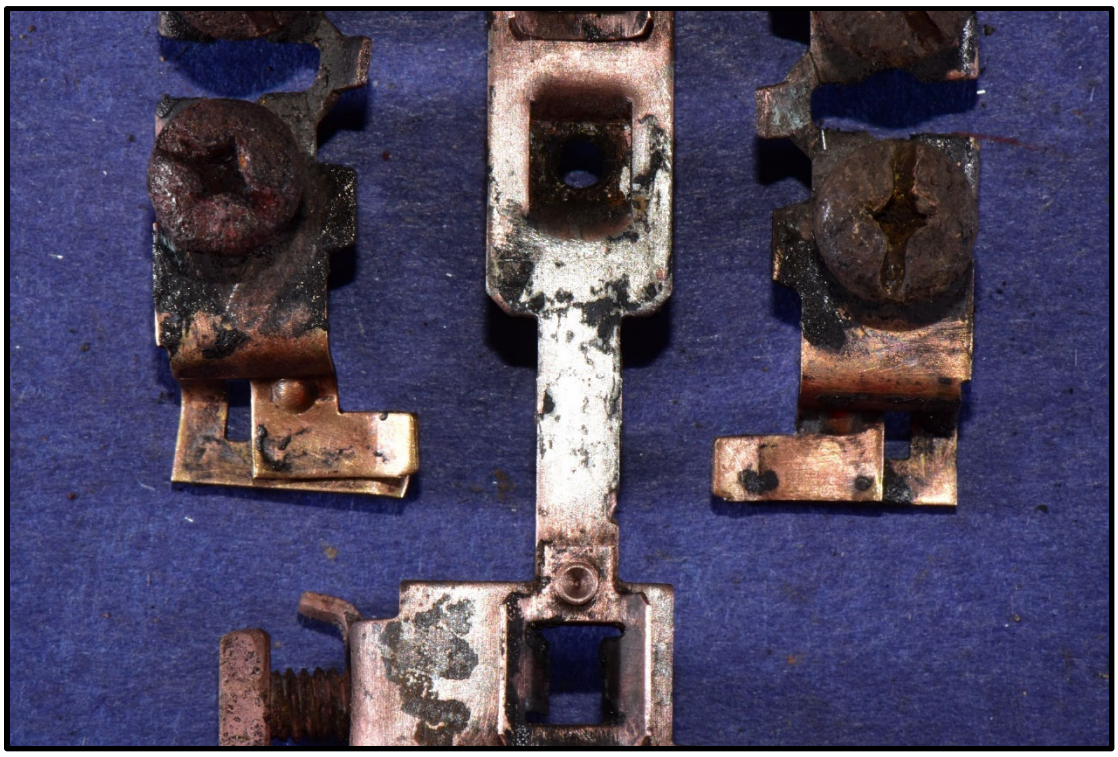

Figure 87. Power rails and ground yoke from Receptacle 2-D

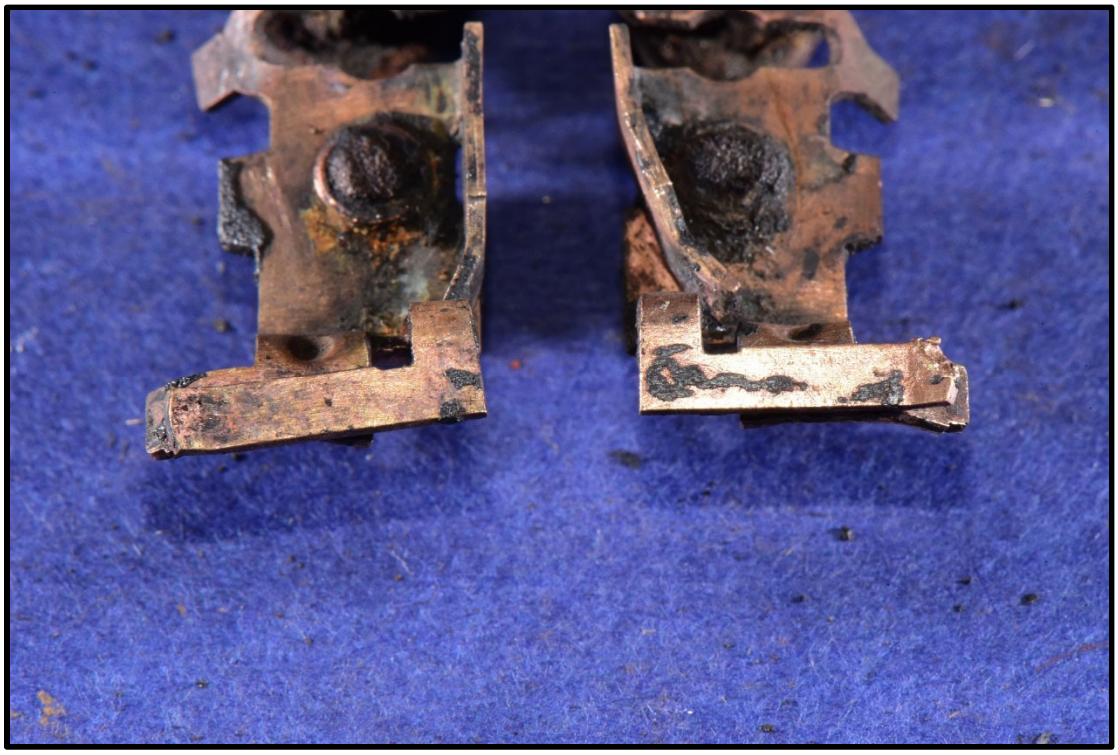

Figure 88. Bottom blade receptors from Receptacle 2-D

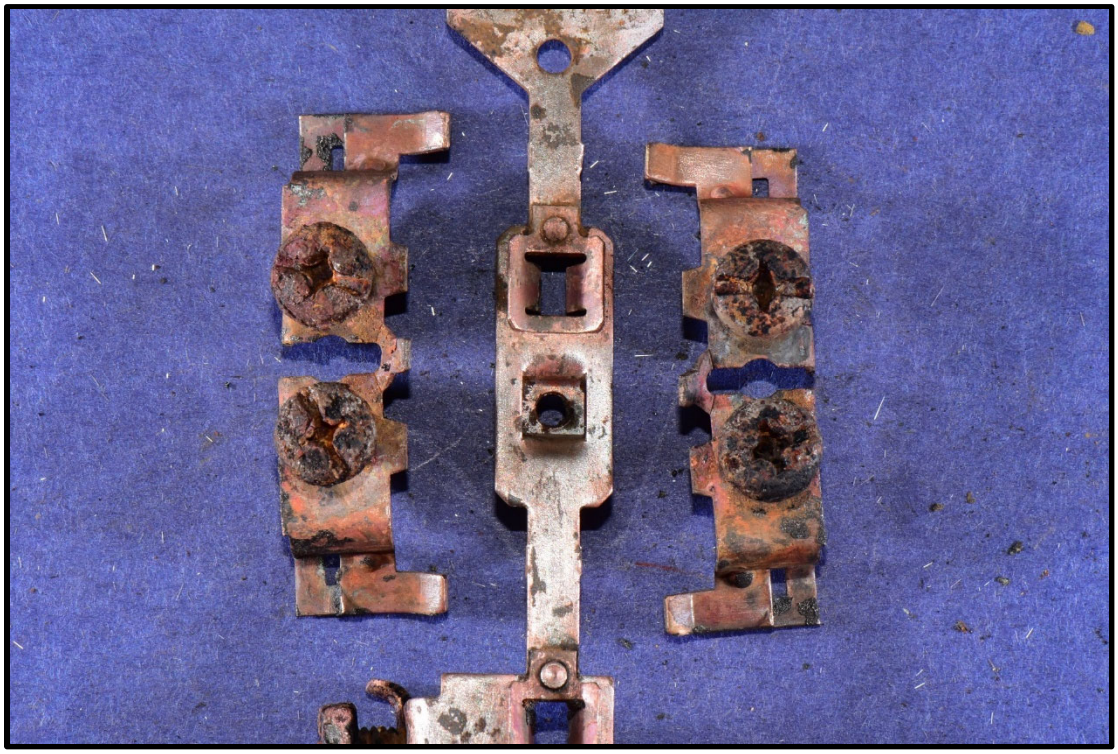

Figure 89. Power rails and ground yoke from Receptacle 11-B

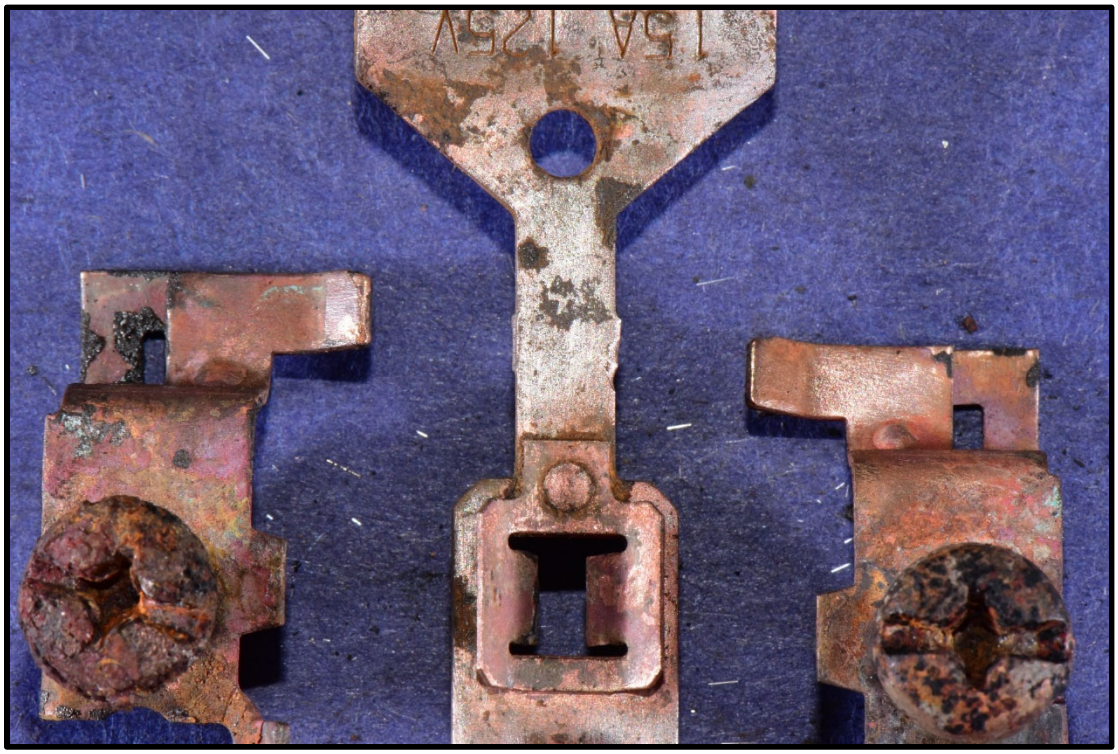

Figure 90. Power rails and ground yoke from Receptacle 11-B

Figure 91. Power rails and ground yoke from Receptacle 11-B

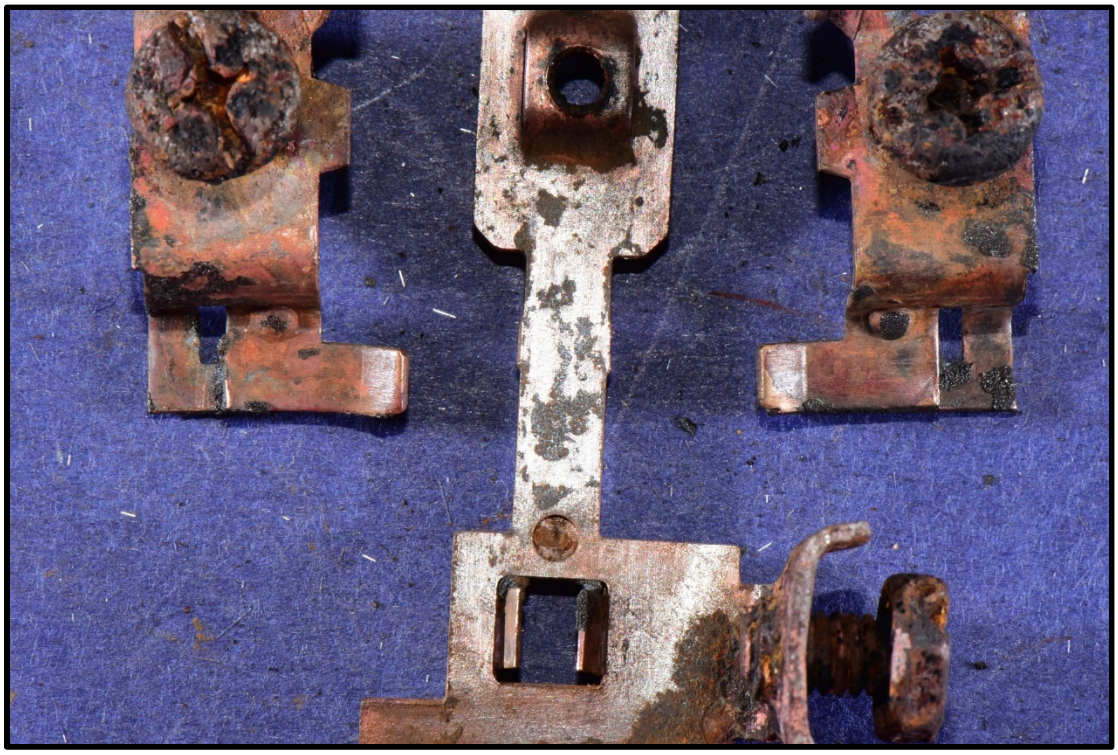

Figure 92. Power rails and ground yoke from Receptacle 11-B

Figure 93. Top blade receptors from Receptacle 11-B

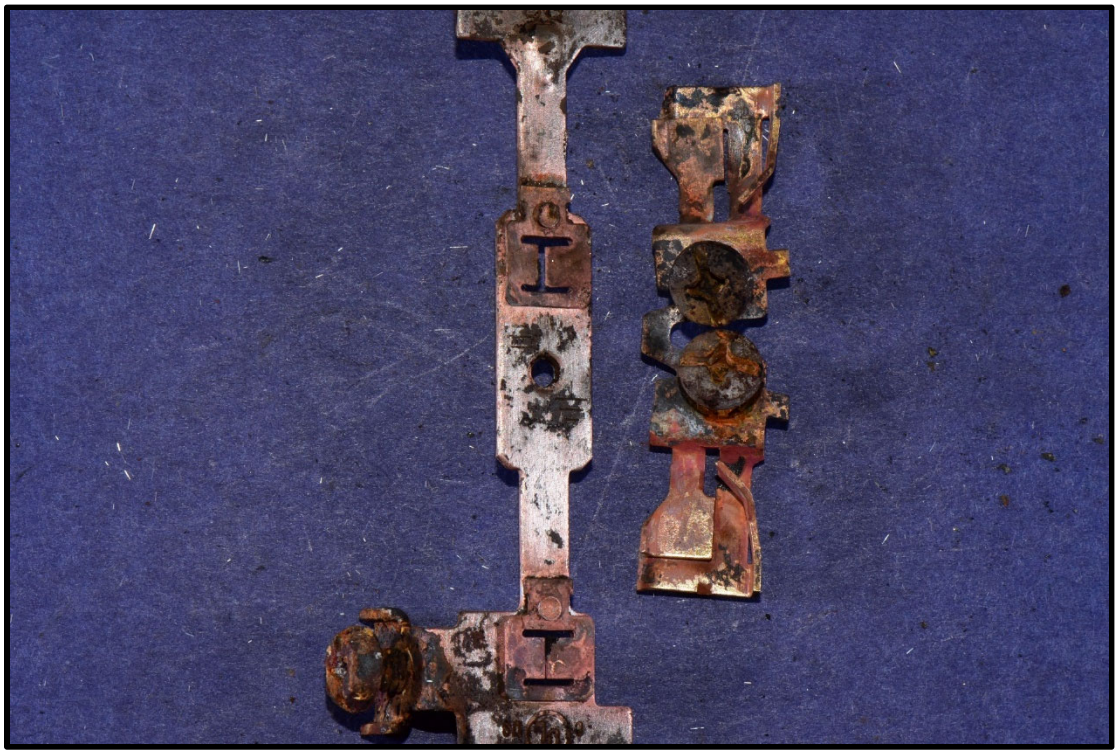

Figure 94. Power rail and ground yoke from Receptacle 13-B

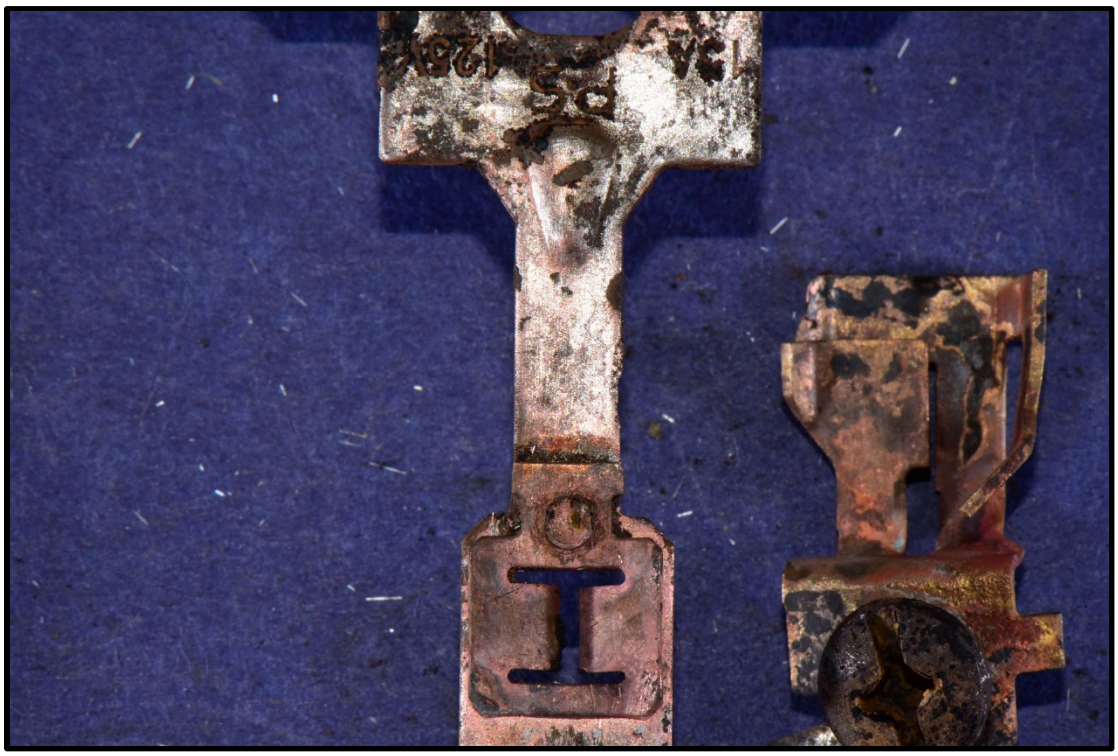

Figure 95. Power rail and ground yoke from Receptacle 13-B

Figure 96. Power rail and ground yoke from Receptacle 13-B

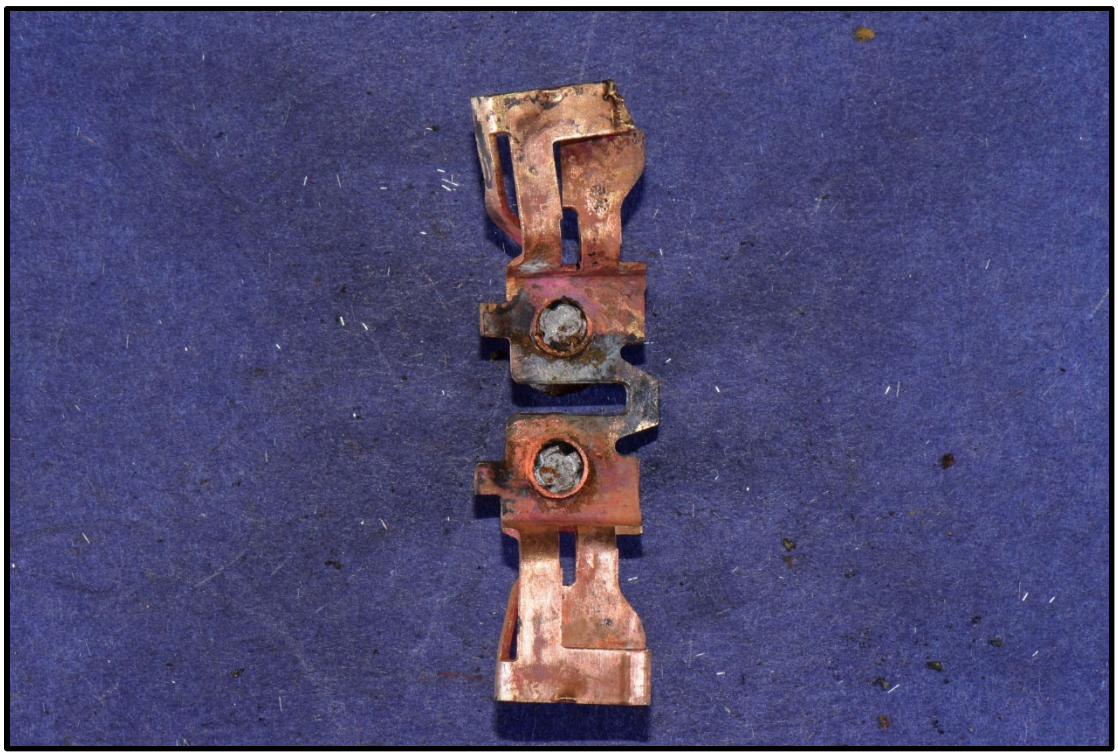

Figure 97. Power rail from Receptacle 13-B

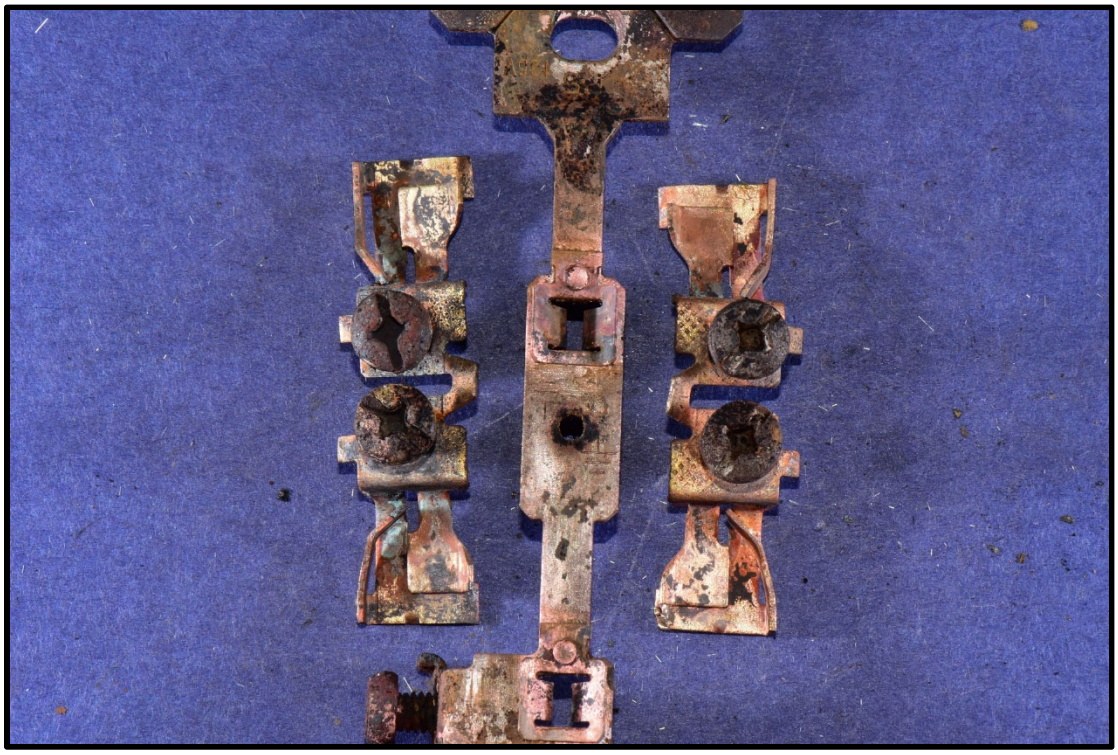

Figure 98. Power rails and ground yoke from Receptacle 16-A

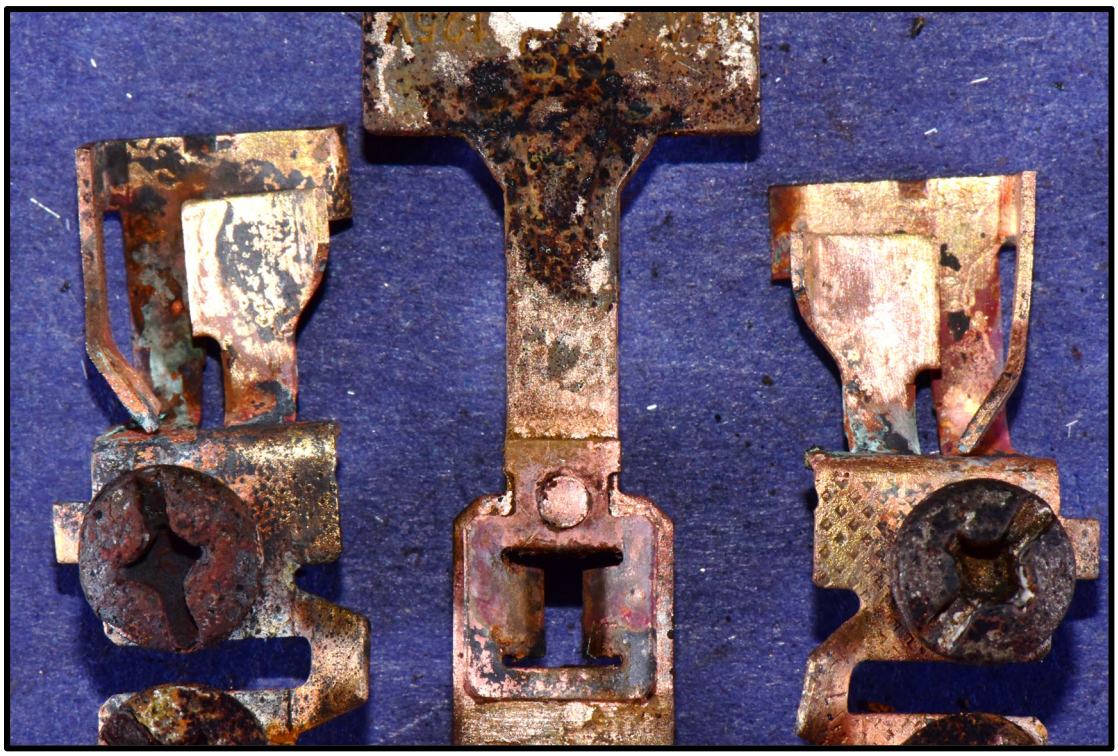

Figure 99. Power rails and ground yoke from Receptacle 16-A

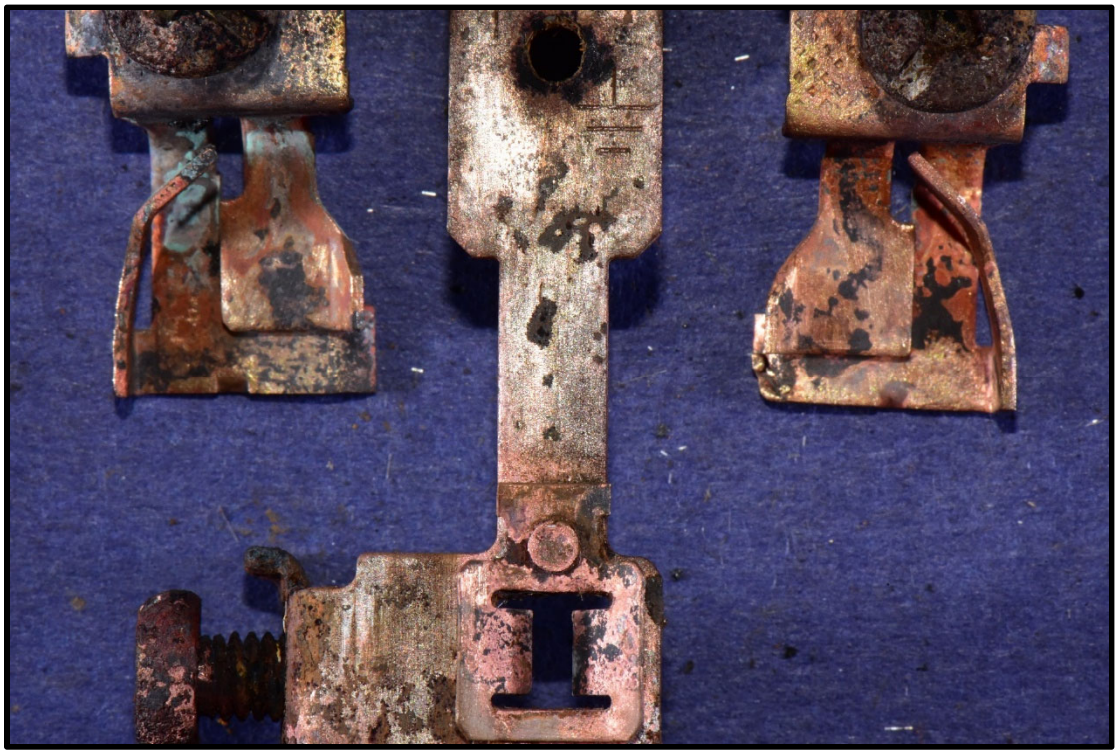

Figure 100. Power rails and ground yoke from Receptacle 16-A

Figure 101. Bottom blade receptors from Receptacle 16-A

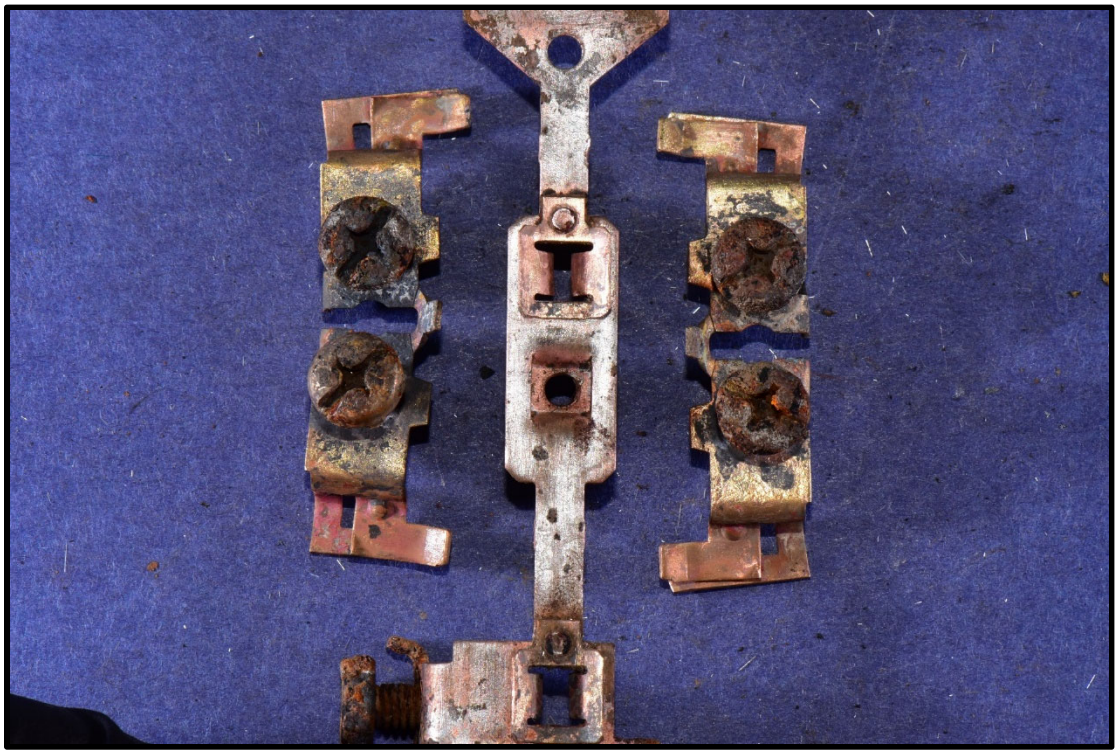

Figure 102. Power rails and ground yoke from Receptacle 17-B

Figure 103. Power rails and ground yoke from Receptacle 17-B

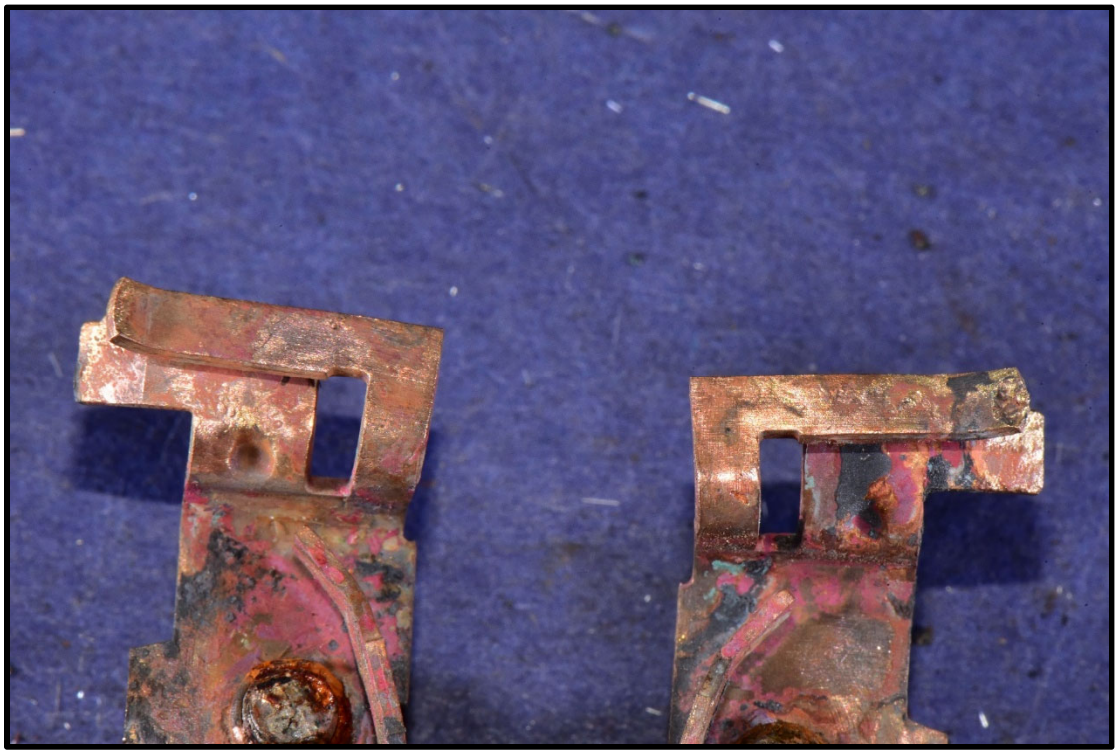

Figure 104. Top blade receptors from Receptacle 17-B

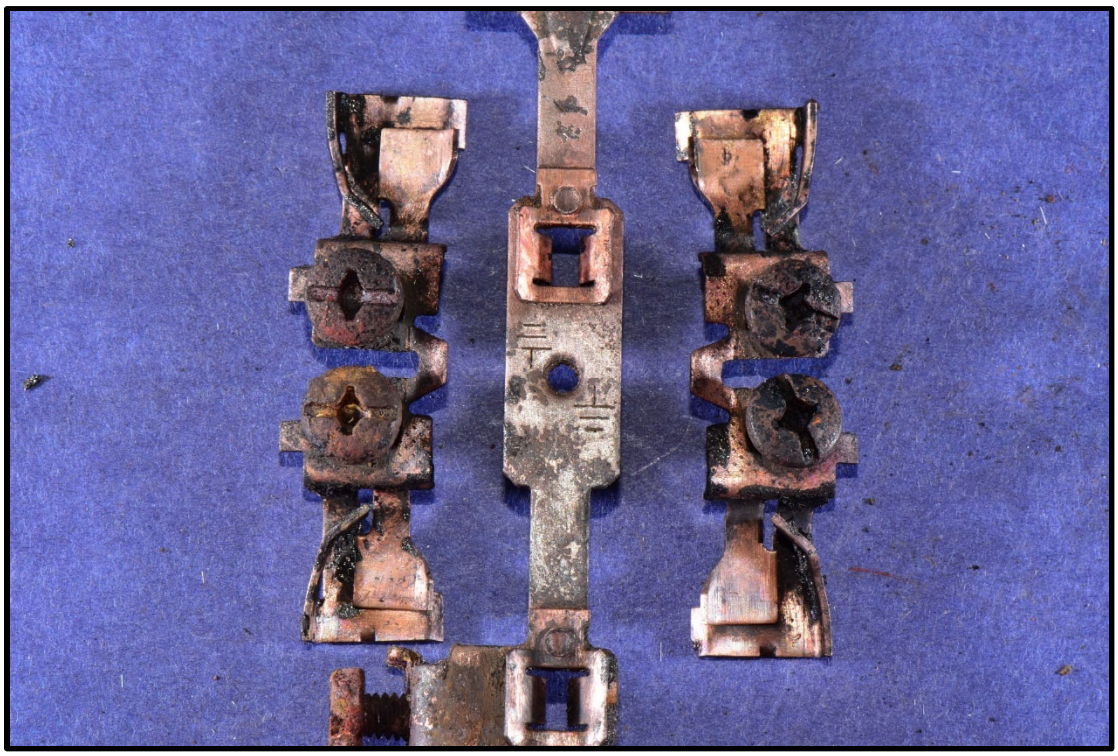

Figure 105. Power rails and ground yoke from Receptacle 4-C

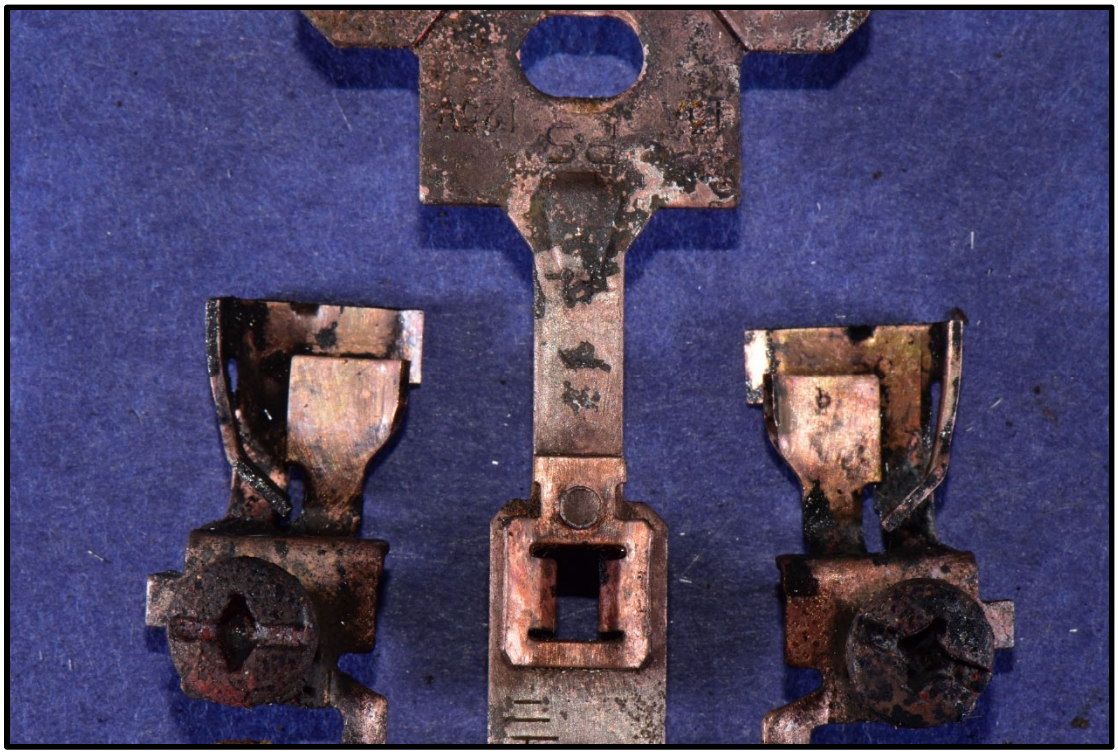

Figure 106. Power rails and ground yoke from Receptacle 4-C

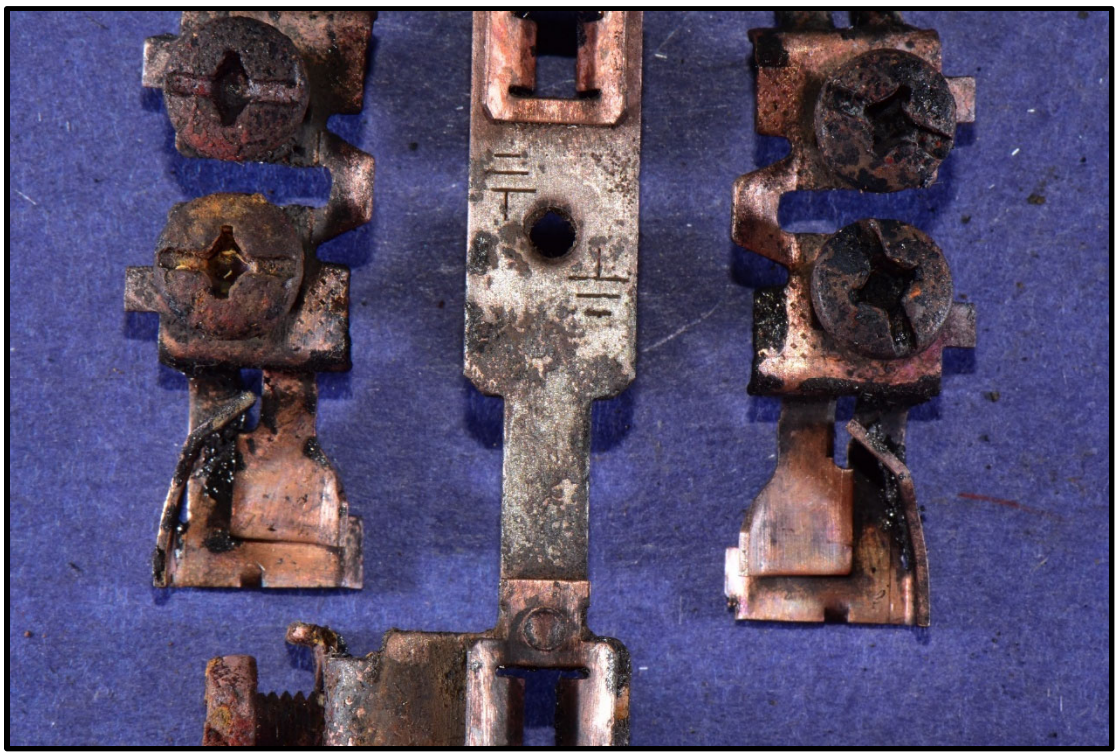

Figure 107. Power rails and ground yoke from Receptacle 4-C

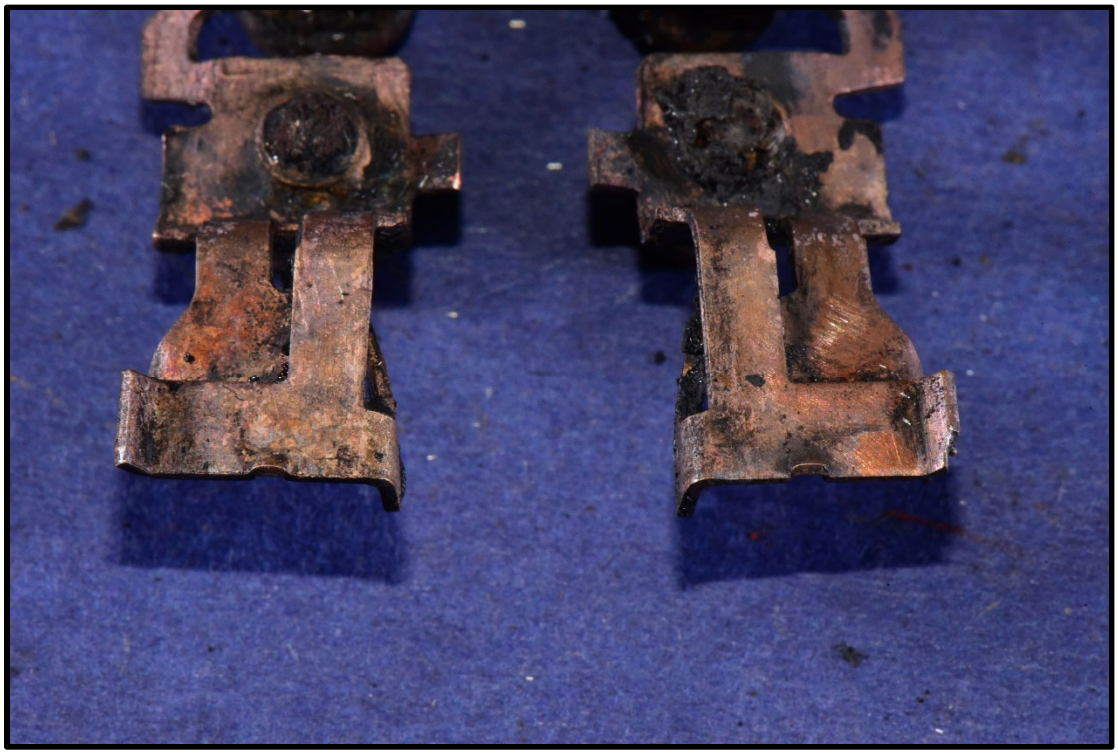

Figure 108. Bottom blade receptors from Receptacle 4-C

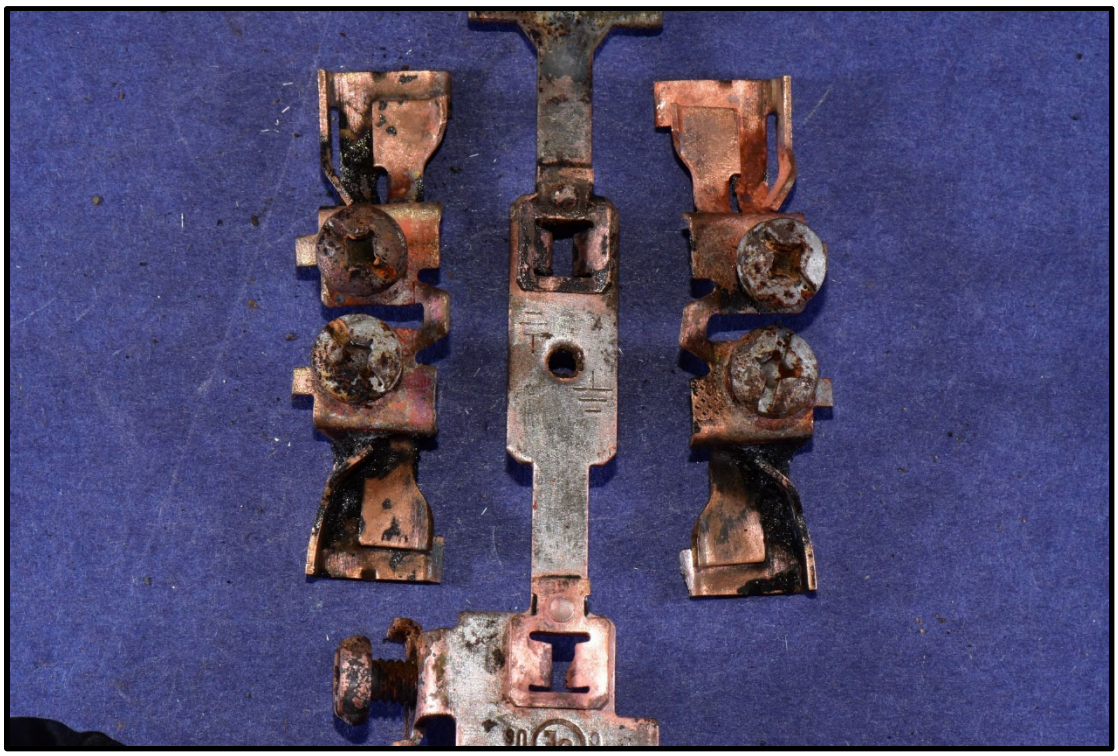

Figure 109. Power rails and ground yoke from Receptacle 7-A

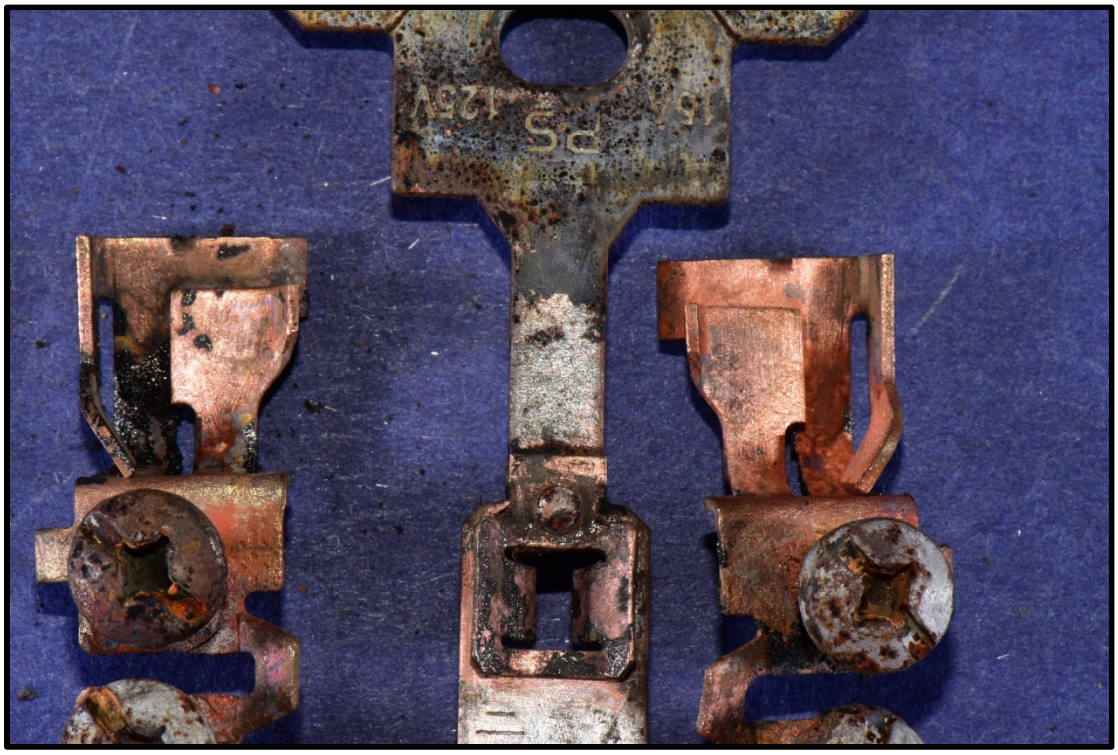

Figure 110. Power rails and ground yoke from Receptacle 7-A

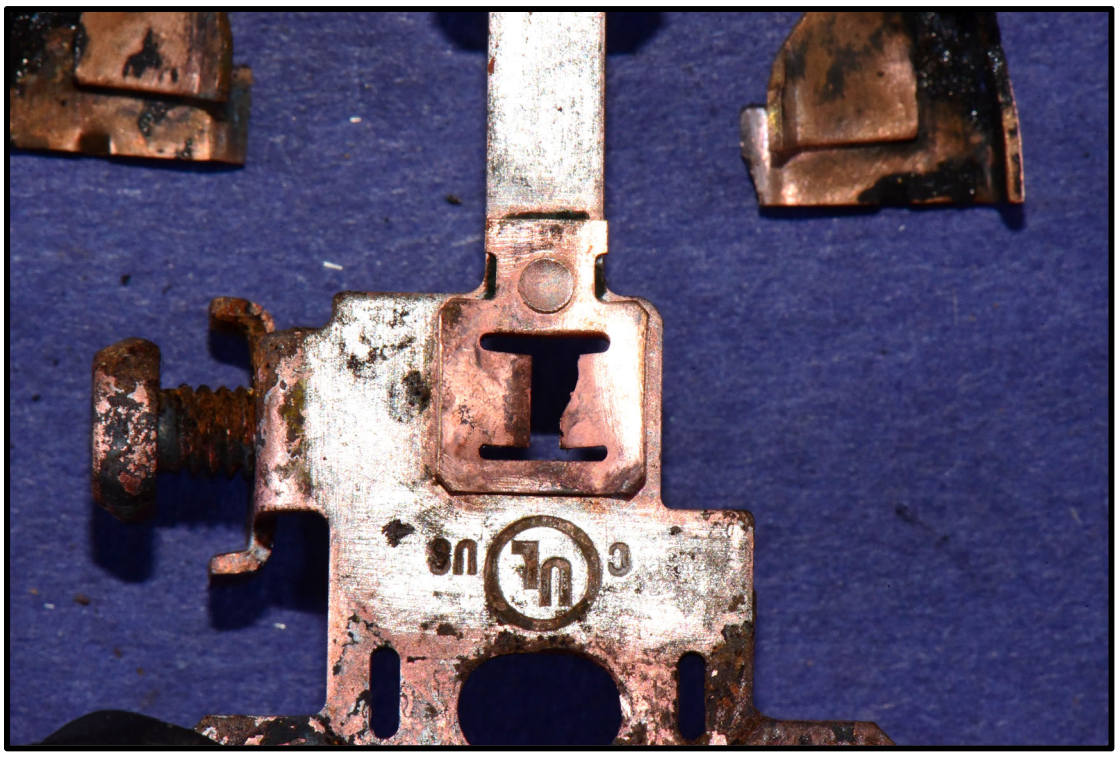

Figure 111. Power rails and ground yoke from Receptacle 7-A

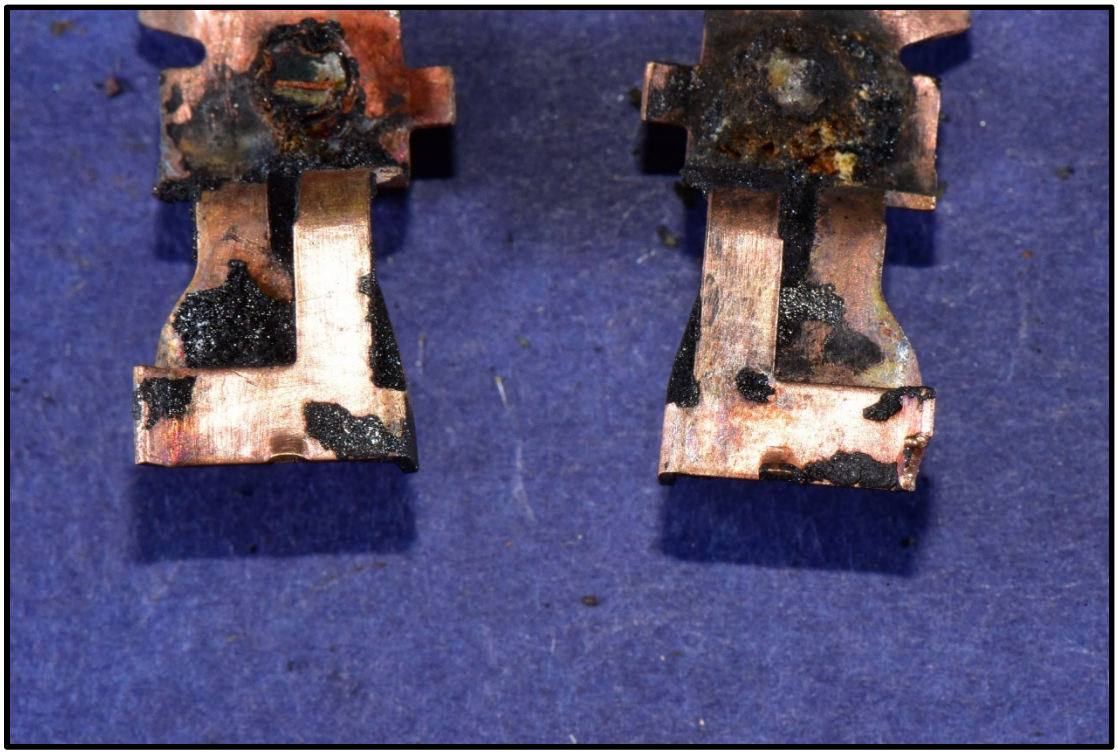

Figure 112. Bottom blade receptors from Receptacle 7-A