Sister Rod Destructive Examinations (FY23)

Appendix E2: Four-Point Bend Fractured Specimen Images

Spent Fuel and Waste Disposition

Prepared for
US Department of Energy

Spent Fuel and Waste Science and Technology

Oak Ridge National Laboratory
Rose Montgomery,
Darren Skitt,

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SUMMARY

This report documents work performed under the Spent Fuel and Waste Disposition's Spent Fuel and Waste Science and Technology program for the US Department of Energy (DOE) Office of Nuclear Energy (NE). This work was performed to fulfill Level 2 Milestone M2SF-24OR010201024, "FY23 ORNL Testing on Sibling Pins," within work package SF-24OR01020102 and is an update to the work reported in M2SF-23OR010201024, M2SF-22OR010201047, M2SF-21OR010201032, M2SF-19ORO010201026, and M2SF-19OR010201028.

As a part of the DOE NE High Burnup Spent Fuel Data Project, Oak Ridge National Laboratory (ORNL) is performing destructive examinations (DEs) of high burnup (HBU) (>45 GWd/MTU) spent nuclear fuel (SNF) rods from the North Anna Nuclear Power Station operated by Dominion Energy. The SNF rods, called *sister rods* or *sibling rods*, are all HBU and include four different kinds of fuel rod cladding: standard Zircaloy-4 (Zirc-4), low-tin Zirc-4, ZIRLO, and M5. The DEs are being conducted to obtain a baseline of the HBU rods' condition before they are sent to dry storage and are focused on gaining an understanding of overall SNF rod strength and durability. Composite fuel and defueled cladding will be tested to derive material properties. Although the data generated can be used for multiple purposes, one primary goal for obtaining the post-irradiation examination data and the associated measured mechanical properties is to support SNF dry storage licensing and relicensing activities by (1) addressing identified knowledge gaps and (2) enhancing the technical basis for post-storage transportation, handling, and subsequent disposition.

This report documents the status of the ORNL Phase 1 DE activities related to the mechanical testing of selected sister rods in Phase 1 of the sister rod test program.

This appendix provides images of the segments broken in four-point bending (4PB).

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ACKNOWLEDGMENTS

Many thanks to US Department of Energy Office of Nuclear Energy sponsor Ned Larson, along with the Spent Fuel and Waste Science and Technology storage and transportation program leadership, for their continued support. The sister rod project would not have been possible without the vision and support of the Electric Power Research Institute, Westinghouse, Framatome, and Dominion Energy.

We thank John Hunn for allowing us to use his photography set-up and the Irradiated Microsphere Gamma Analyzer (IMGA) facility.

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No tables.

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REVISION HISTORY

Date	Changes
10/31/2023	Initial issue.
1/31/2024	Document ID was updated to reflect the M2 status and the dates were updated.

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ACRONYMS

4PB	four-point bend
DE	destructive examination
DOE	US Department of Energy
FHT	full-length fuel rod heat treatment
HBU	high burnup
IFEL	Irradiated Fuels Examination Laboratory
IMGA	Irradiated Microsphere Gamma Analyzer
LT	low tin
MET	metallography
NE	Office of Nuclear Energy
ORNL	Oak Ridge National Laboratory
PWR	pressurized water reactor
RT	room temperature
SNF	spent nuclear fuel

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E2-1. Zircaloy-4 Clad Segments Broken in Four-Point Bend (4PB)

The segments from F35P17 were heat-treated prior to testing in 4PB (see Appendix A).

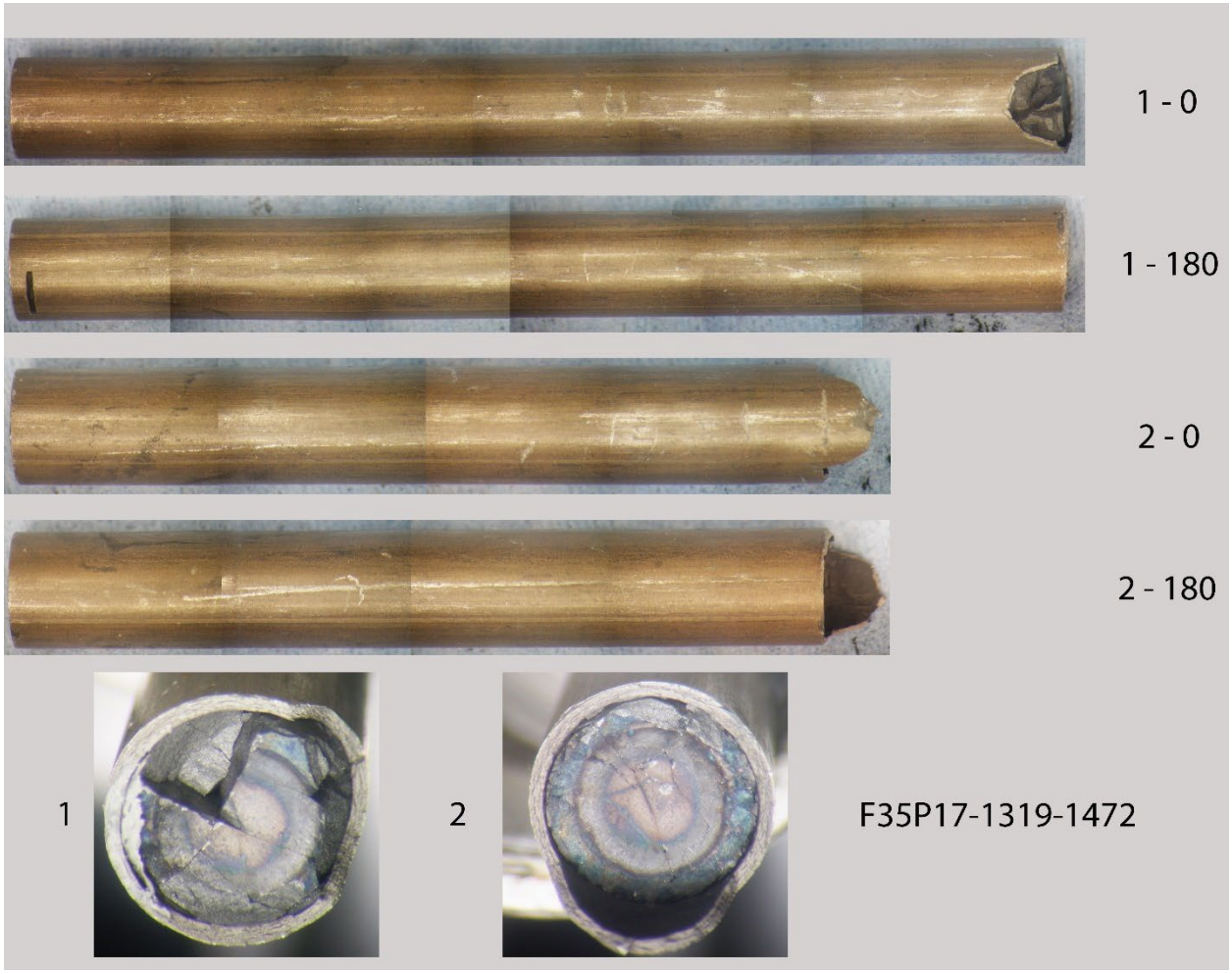

Figure E2- 1. F35P17-1319-1472.

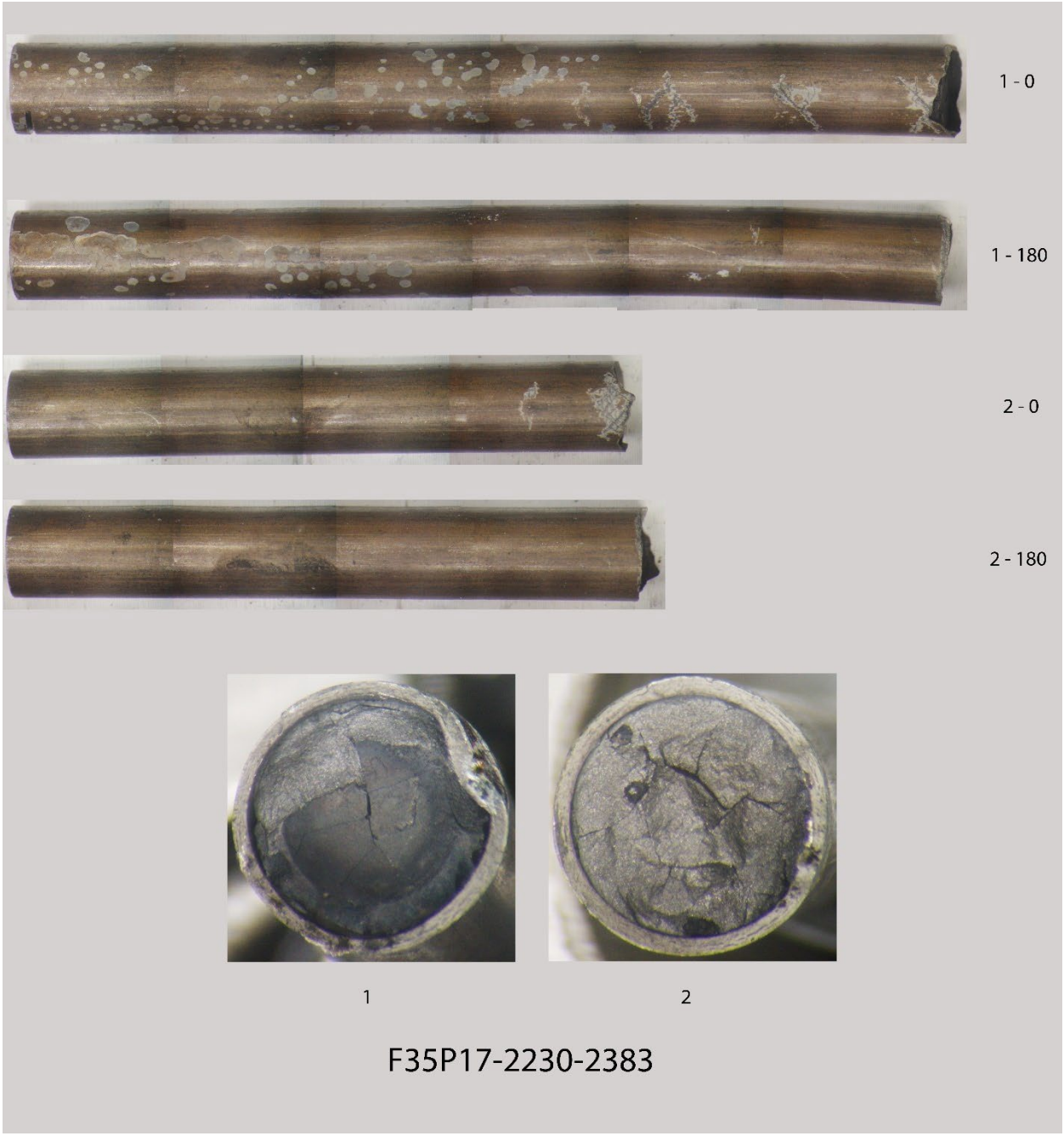

Figure E2- 2. F35P17-2230-2383.

E2-2. M5-Clad Segments Broken in 4PB

The segments from rod 30AE14 were heat-treated prior to testing in 4PB (see Appendix A).

Figure E2- 3. 30AE14-0825-0978.

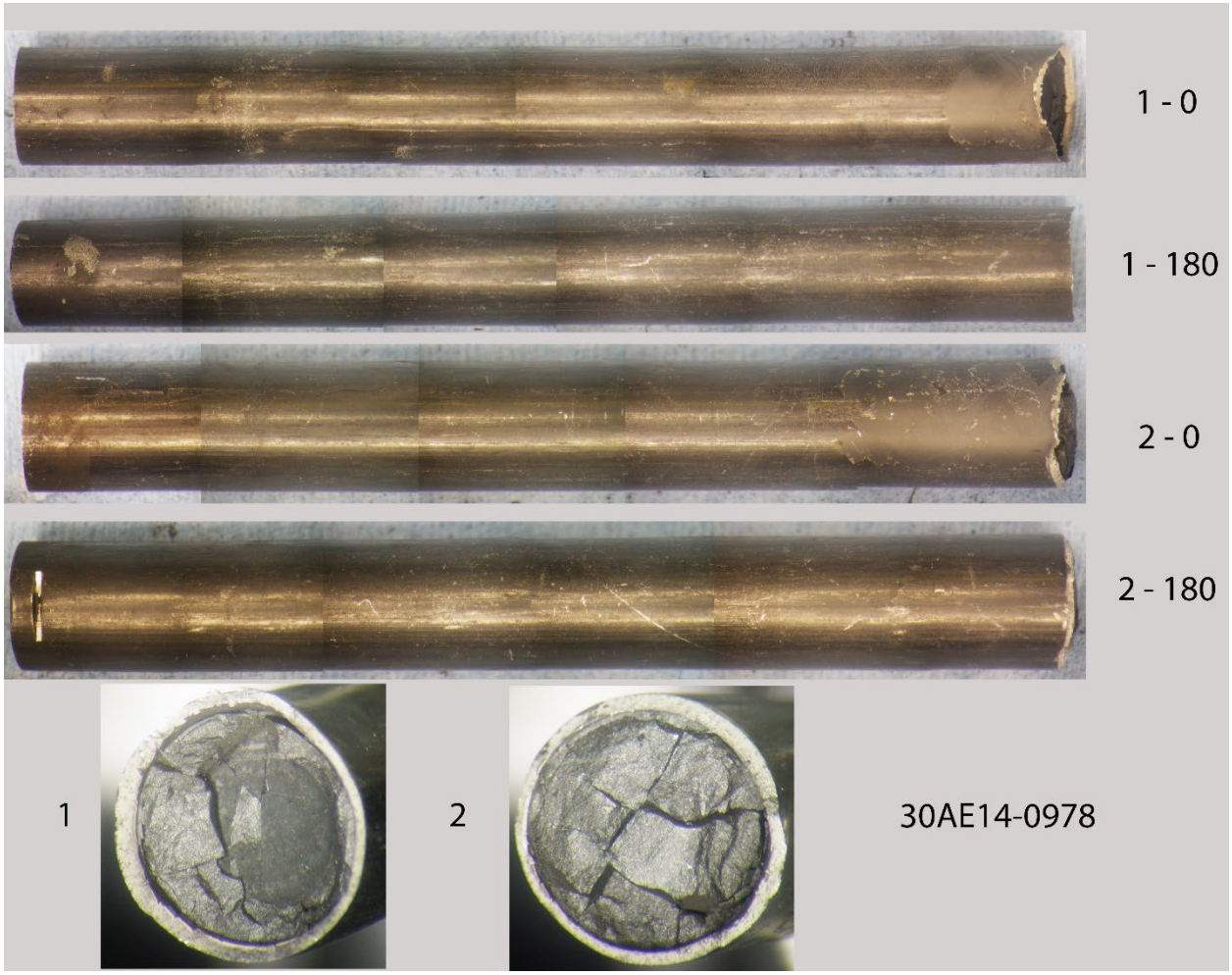

Figure E2- 4. 30AE14-0978-1130.

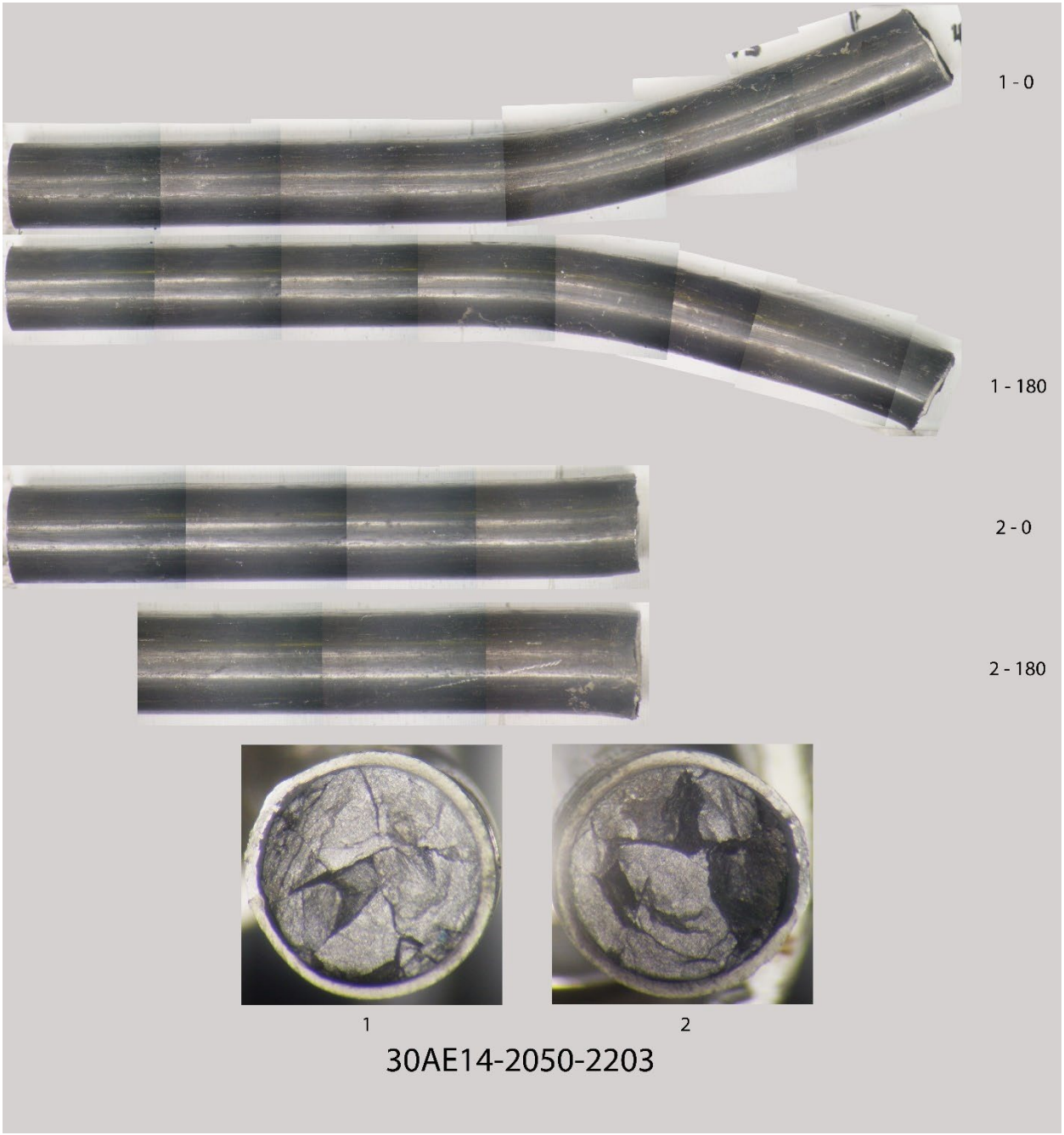

Figure E2- 5. 30AE14-2050-2203.

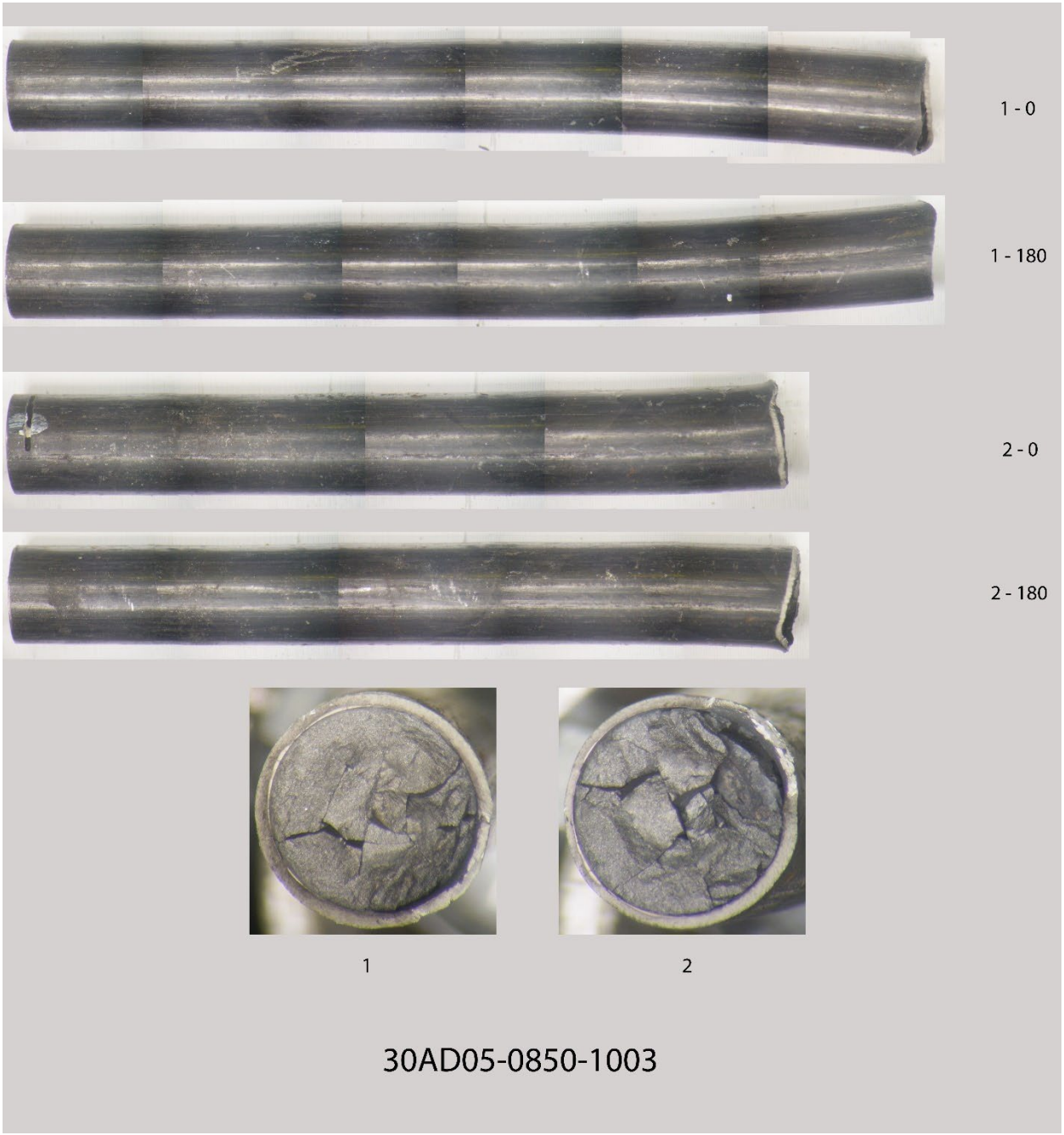

Figure E2- 6. 30AD05-0850-1003.

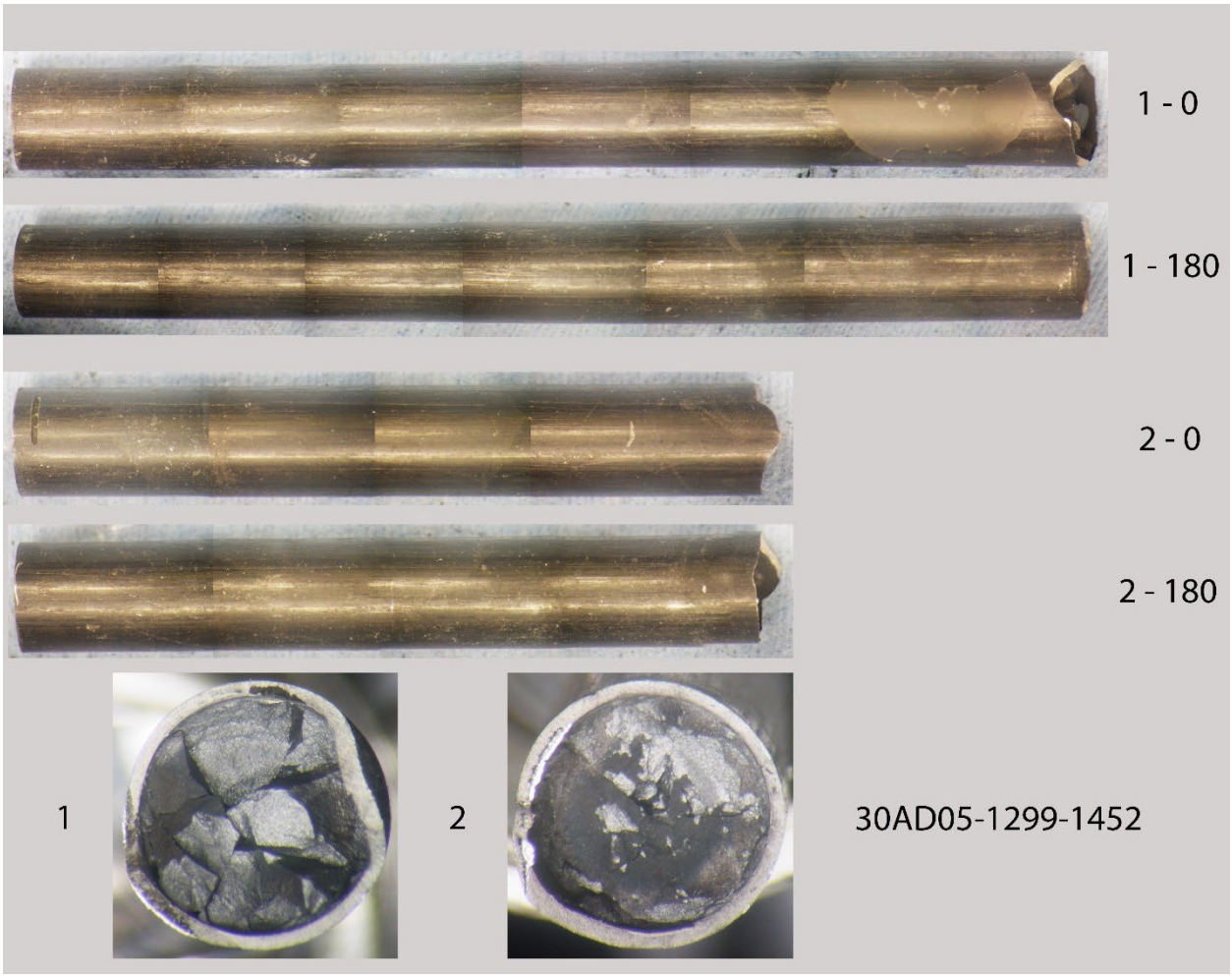

Figure E2- 7. 30AD05-1299-1452.

Figure E2- 8. 30AD05-1800-1953.

E2-3. ZIRLO-Clad Segments Broken in 4PB

Segments from rod 3F9N05 were heat-treated prior to testing in 4PB (see Appendix A).

Figure E2- 9. 3F9N05-0872-1025.

Figure E2- 10. 3F9N05-1910-2063.

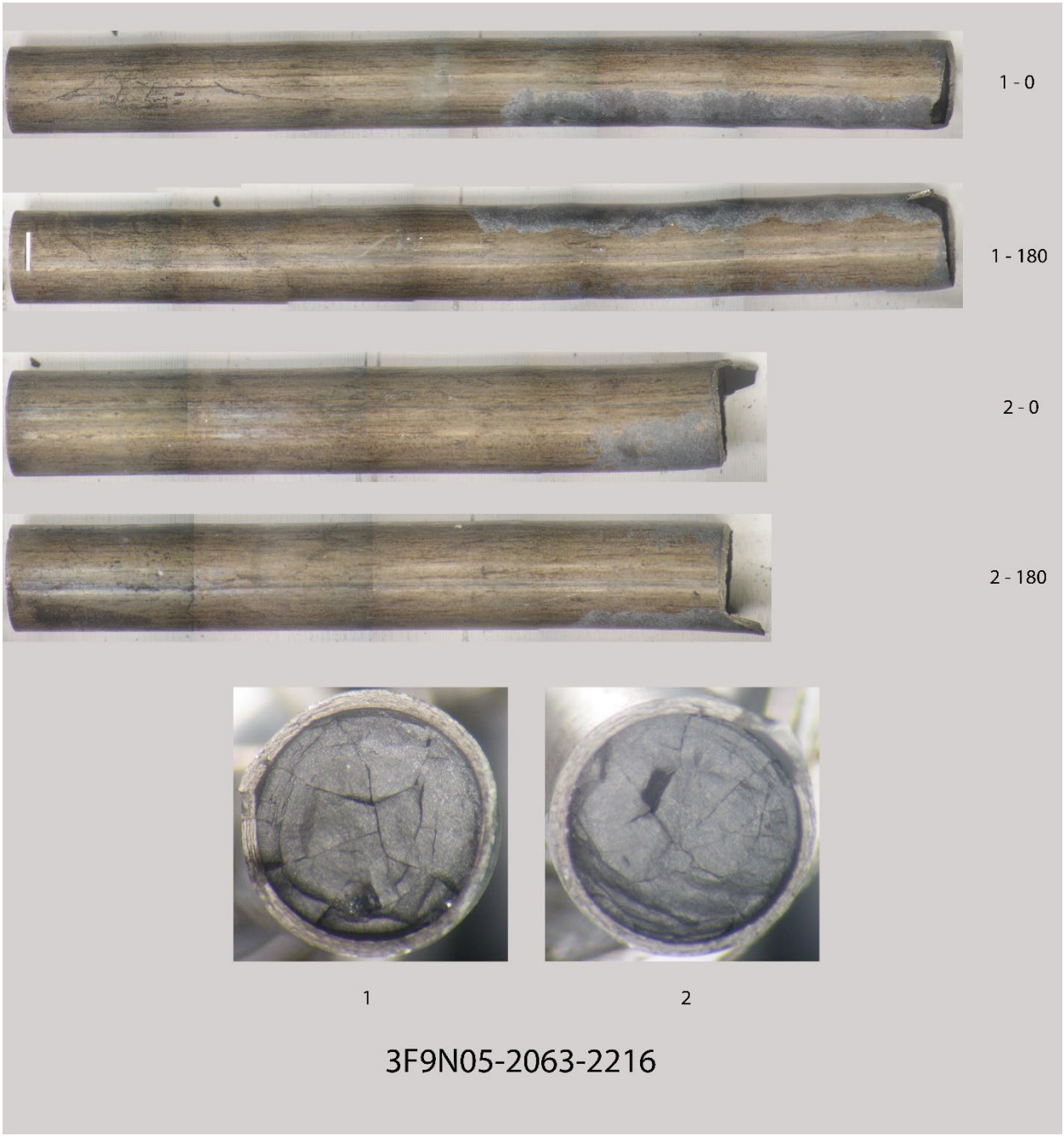

Figure E2- 11. 3F9N05-2063-2216.

Figure E2- 12. 3D8E14-0872-1025.

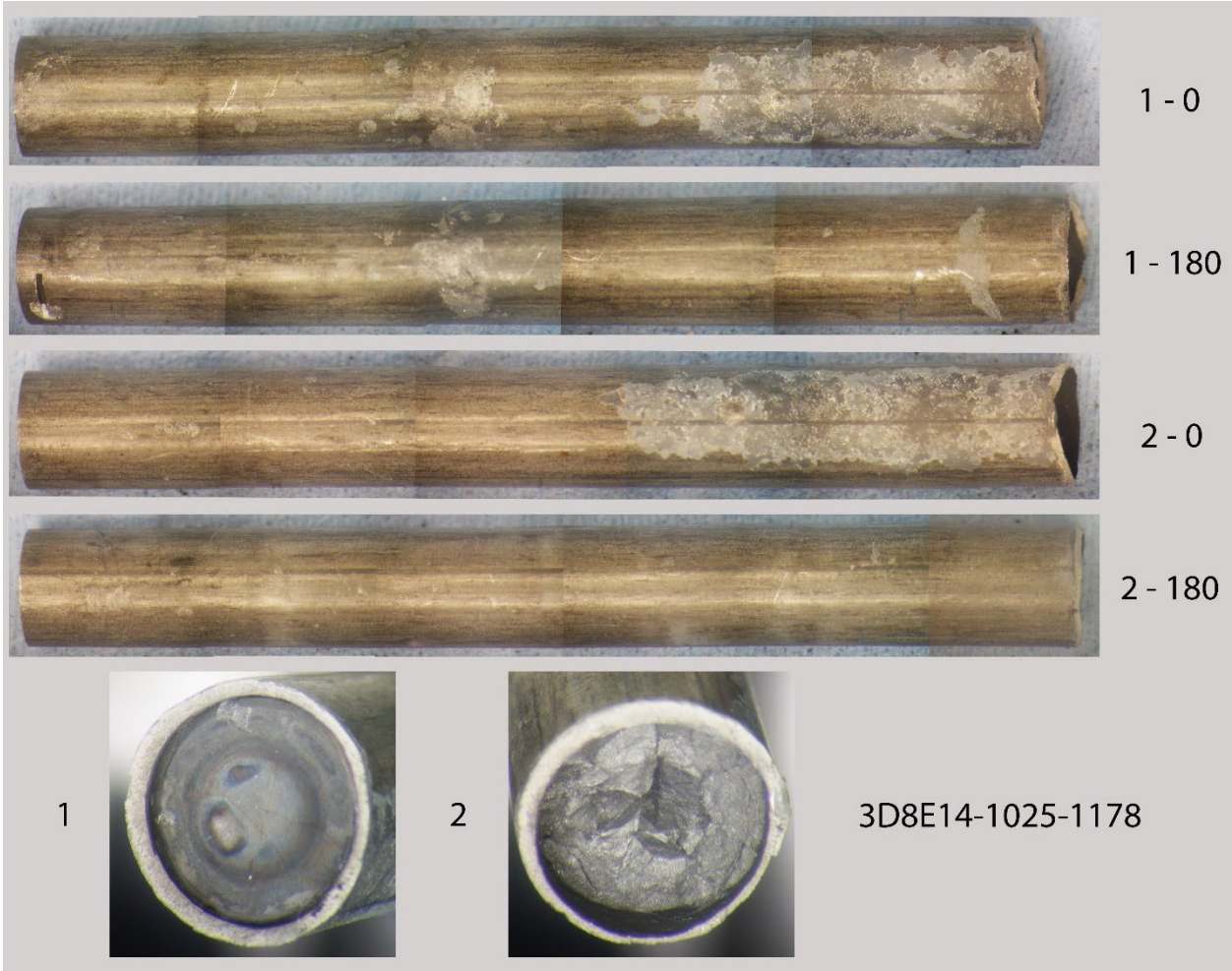

Figure E2- 13. 3D8E14-1025-1178.

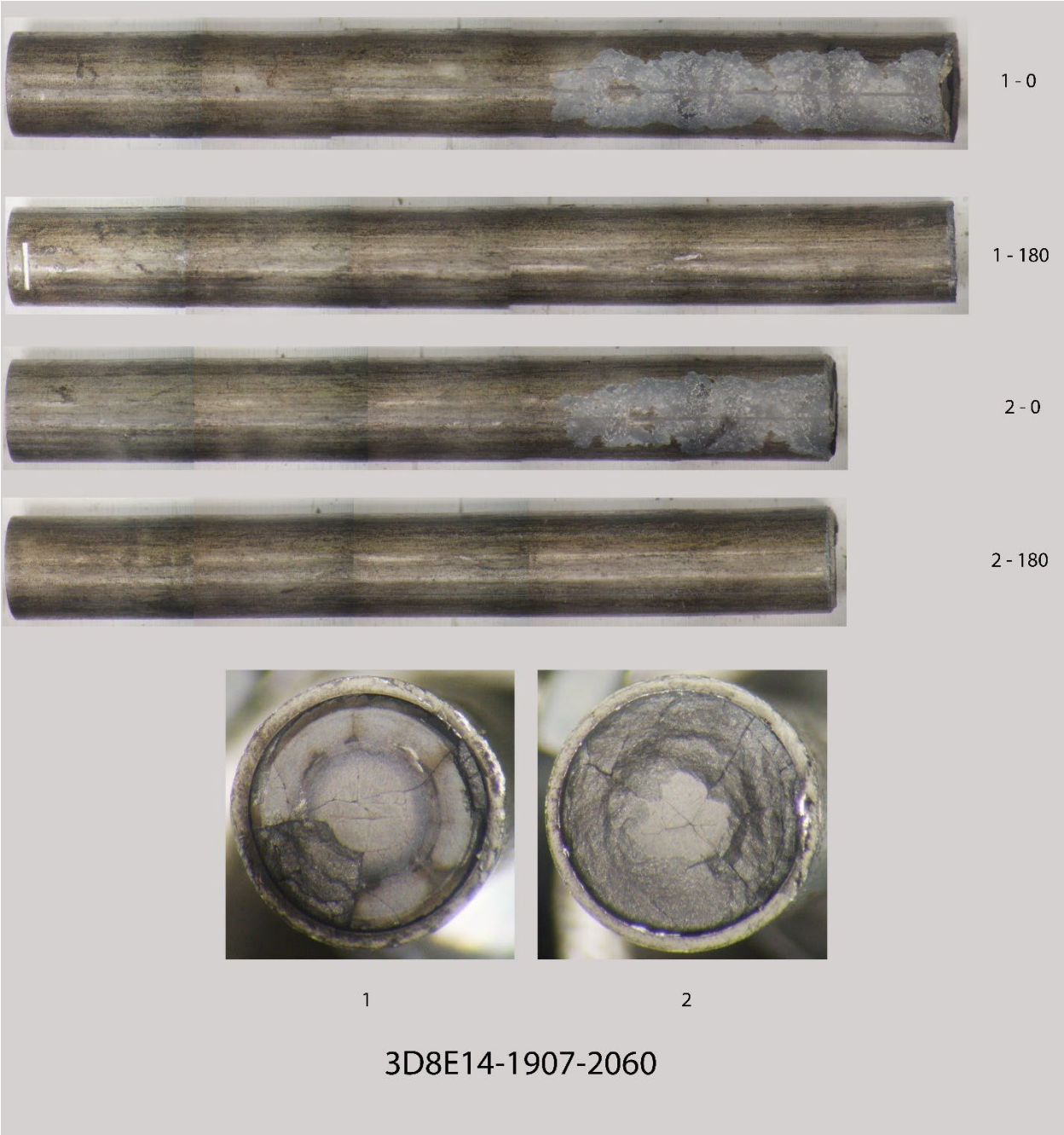

Figure E2- 14. 3D8E14-1907-2060.

Figure E2- 15. 3D8E14-2810-2963.

E2-4. Low-Tin Zircaloy-4-clad Specimens Broken in 4PB

Figure E2- 16. 3A1F05-2230-2383.

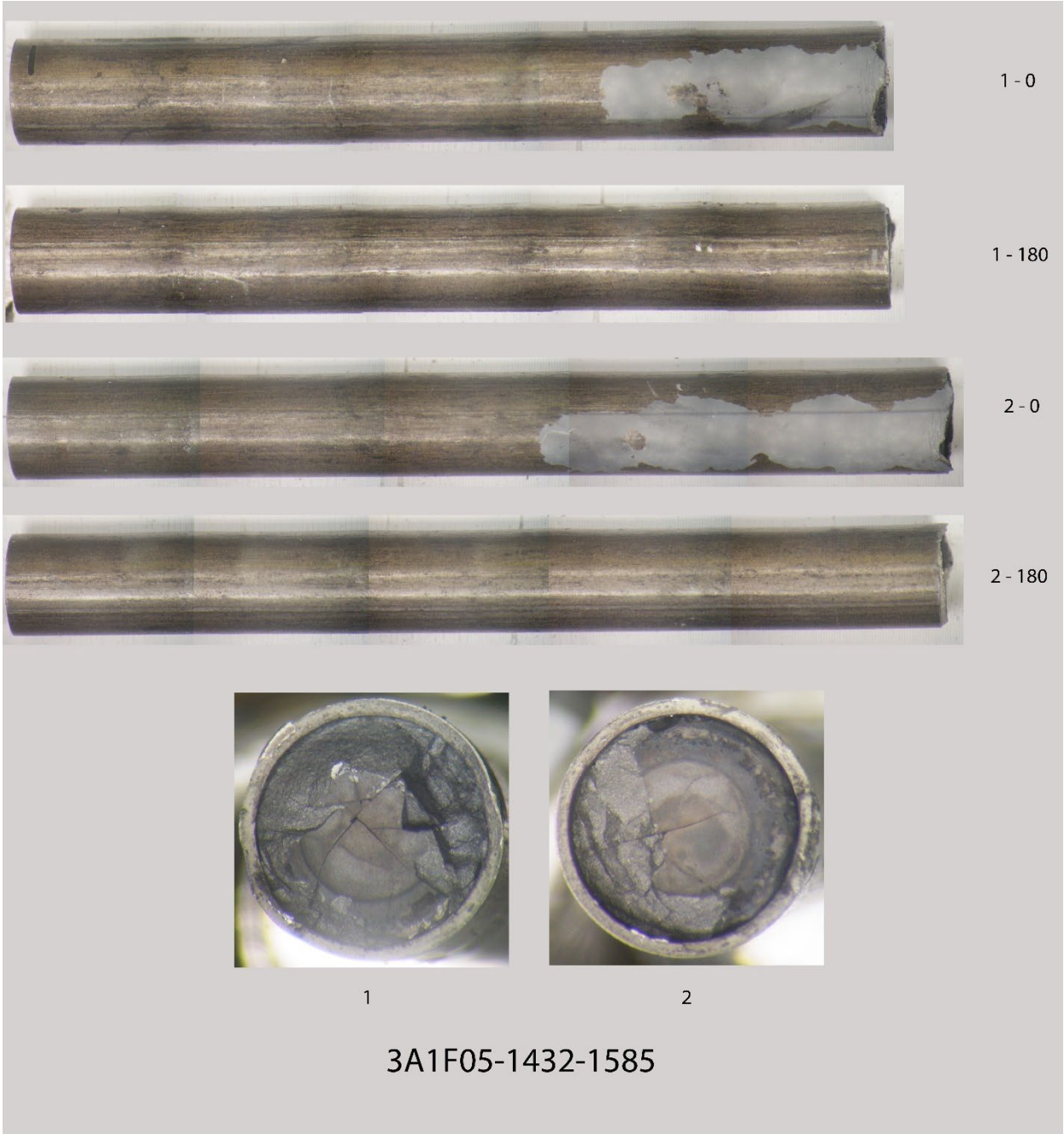

Figure E2- 17. 3A1F05-1432-1585.

Figure E2- 18. 3A1F05-1279-1432.