

K-3 Refractory Corrosion Test Results for the HS24 Matrix

August 2026

T Jin
L Le
NL Canfield
E Nienhuis

X Lu
JD Vienna
MA Hall



U.S. DEPARTMENT
of **ENERGY**

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor Battelle Memorial Institute, nor any of their employees, **makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights.** Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or Battelle Memorial Institute. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

PACIFIC NORTHWEST NATIONAL LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC05-76RL01830

Printed in the United States of America

Available to DOE and DOE contractors from
the Office of Scientific and Technical
Information,
P.O. Box 62, Oak Ridge, TN 37831-0062
www.osti.gov
ph: (865) 576-8401
fax: (865) 576-5728
email: reports@osti.gov

Available to the public from the National Technical Information Service
5301 Shawnee Rd., Alexandria, VA 22312
ph: (800) 553-NTIS (6847)
or (703) 605-6000
email: info@ntis.gov
Online ordering: <http://www.ntis.gov>

K-3 Refractory Corrosion Test Results for the HS24 Matrix

August 2026

T Jin
L Le
NL Canfield
E Nienhuis

X Lu
JD Vienna
MA Hall

Prepared for
the U.S. Department of Energy
under Contract DE-AC05-76RL01830

Pacific Northwest National Laboratory
Richland, Washington 99354

Abstract

This report summarizes the refractory corrosion data for a matrix of direct-feed high-level waste (DFHLW) glasses generated to expand glass property data into the high sulfur composition region. The design of the high sulfur glass matrix, HS24, was reported in Reiser et al. (2026). Fifty HS24 glasses were tested for the corrosion of Monofrax® K-3 refractory materials.

The corrosion of K-3 refractory materials in the HS24 glass melts was measured using a static crucible method. Two test conditions, 1150 °C for 7 days and 1200 °C for 7 days, were applied. The melt-line neck corrosion depth of the test coupons was measured by micro-computed tomography (micro-CT). The measured K-3 neck corrosion values were compared to predicted values using the EWG3.0 K-3 corrosion model (Lu et al. 2026). Proposed upper limits for K-3 neck corrosion, 0.04 in. (EWG2.5, Vienna et al. 2024) and 0.025 in. (EWG2.6, Vienna et al. 2025 and EWG3.0, Lu et al. 2026) were applied to evaluate the neck corrosion data of the HS24 matrix glasses. Two glasses of this HS24 matrix were designed as replicates of glasses previously tested by different laboratories. The inter-laboratory discrepancies of the test results were analyzed and are discussed. Future work will continue to investigate the consistency of K-3 corrosion data collected by different institutions, and incorporate these factors into future model development to better account for experimental variability and support more accurate and robust models.

Acknowledgments

The authors gratefully acknowledge the financial support provided by the U.S. Department of Energy Hanford Field Office Enhanced Waste Glass Project with technical oversight by Albert Kruger. The authors gratefully acknowledge Monofrax LLC for providing Monofrax® K-3 refractory material utilized in this work. We thank Dr. Richard Pokorný, Dr. Jaroslav Kloužek, and Radek Pezl of University of Chemistry and Technology, Prague for their support in preparing the Monofrax® K-3 refractory samples. The following Pacific Northwest National Laboratory staff members are acknowledged for their contributions: Alyssa Petersen and David MacPherson for quality assurance, Chrissy Charron and Cassie Martin for programmatic support during the conduct of this work, and Renee Russell and Will Eaton for project management.

Acronyms and Abbreviations

ASTM	ASTM International, formerly American Society for Testing Materials
CFR	<i>Code of Federal Regulations</i>
DFHLW	direct-feed high-level waste
DOE	Department of Energy
EWG	enhanced waste glass
HLW	high-level waste
LAW	low-activity waste
micro-CT	micro-computed tomography
NQAP	Nuclear Quality Assurance Program
PNNL	Pacific Northwest National Laboratory
SD	standard deviation
SI	International System of Units
SRNL	Savannah River National Laboratory
VSL	Vitreous State Laboratory at the Catholic University of America
WTP	Waste Treatment and Immobilization Plant

Contents

Abstract.....	iii
Acknowledgments.....	iv
Acronyms and Abbreviations	v
1.0 Introduction	1
1.1 Quality Assurance	1
2.0 Test Methods	2
2.1 Glass Fabrication	2
2.2 Refractory Corrosion Test	2
3.0 Results and Discussion	6
4.0 Conclusions.....	12
5.0 Bibliography	13
Appendix A – Photographs of Test Coupons.....	A.1
Appendix B – Micro-CT Results of the K-3 Refractory Corrosion Test	B.1
Appendix C – Original Data from Micro-CT Measurements.....	C.1

Figures

Figure 2.1.	K-3 corrosion test setup in a static glass melt showing general measurements for coupon size and positioning, glass depth, and coupon immersion depth. For convenience in the following discussion, the test coupon's dimensions were defined by the x-, y-, and z-axes. The x-y plane is the horizontal plane, and the z-axis is the vertical axis.	2
Figure 2.2.	Samples for micro-CT scanning.	3
Figure 2.3.	Procedure for measuring refractory corrosion using micro-CT scanning images. The brighter material is the K-3 phase, and the darker material is the glass remaining on the coupon surface after the test. (a) 3D view of an example coupon, HS24-09 1150 °C for 7 days. The outlines of the pre-test coupon (in cyan) and the post-test coupon (in red) are aligned and overlapped. The cropped scan volume for analysis is 12 mm × 12 mm (x-y plane) × 50 mm (along the z-axis). (b) Horizontal cross sections (slices of x-y plane) from different locations; the bounding rectangles (on the right) are drawn based on the outlines for dimensional measurement. (c) Dimensions measured on the bounding rectangles.	5
Figure 3.1.	K-3 refractory corrosion neck depth. (a) Neck corrosion depth data from Table 3.1. (b) Neck corrosion depth data of 1200 °C for 7 days, converted by an offset of 0.3654 ln[in.] to compare with the limit set based on the previous 1208 °C for 6 days bubbling test dataset.	9
Figure 3.2.	Measured and predicted (EWG3.0 model, Lu et al. 2026) K-3 refractory corrosion neck depth. The red line is the 1:1 line between the measured and predicted values. The uncertainties in the measured values are represented by the pooled SD reported in Lu et al. (2026).	10

Tables

Table 3.1.	K-3 refractory corrosion neck depth, d_{neck} , in inches. The symbol “-” means that neck corrosion was not observed on the post-test coupon.....	8
Table 3.2.	K-3 refractory corrosion neck depth, d_{neck} , in inches, of HS24-49.	11
Table 3.3.	K-3 refractory corrosion neck depth, d_{neck} , in inches, of HS24-50.	11

1.0 Introduction

Hanford glass melts are contained within their melters by Monofrax® K-3 refractories. K-3 corrosion – melt composition models are used in glass design to avoid excessive corrosion of these refractories (Jin et al. 2023). Initial models were found to be subject to higher than desired uncertainties and were valid over limited composition space compared to other models used in glass design (Vienna et al. 2025). To improve glass property models, a matrix of glasses was designed, fabricated, and tested for various properties (Reiser et al. 2026). Models will be developed in the future with these additional K-3 corrosion-glass composition data collected in this report to improve prediction performance and expand applicable composition region. This will help to improve loading of waste in glass, while reducing risk of unacceptable K-3 corrosion.

Glass matrix design was described in detail by Reiser et al. (2026) along with results from testing other properties of these glasses. The K-3 crucible scale test and characterization methodologies were developed and described by Jin et al. (2025). This report summarizes these methods in Section 2.0 and documents the testing and characterization results in Section 3.0. Section 4.0 offers conclusions drawn from the testing.

1.1 Quality Assurance

This work was performed in accordance with the Pacific Northwest National Laboratory (PNNL) Nuclear Quality Assurance Program (NQAP). The NQAP complies with Department of Energy (DOE) Order 414.1D, “Quality Assurance,” and Title 10 of the *Code of Federal Regulations* (10 CFR) Part 830, “Nuclear Safety Management,” Subpart A, “Quality Assurance Requirements.” The NQAP uses NQA-1-2012, *Quality Assurance Requirements for Nuclear Facility Application*, as its consensus standard and NQA-1-2012, Subpart 4.2.1, as the basis for its graded approach to quality.

The NQAP works in conjunction with PNNL’s laboratory-level Quality Management Program, which is based on the requirements as defined in DOE Order 414.1D and 10 CFR Part 830, Subpart A.

The work of this report was performed at a technology readiness level of 5.

2.0 Test Methods

This section describes how the K-3 corrosion was measured.

2.1 Glass Fabrication

The glass fabrication procedure and compositional analysis were reported in Reiser et al. (2026); the chemical analysis confirmed that the target glass compositions were met.

2.2 Refractory Corrosion Test

The Monofrax® K-3 refractory (Monofrax LLC, Falconer, NY) corrosion test was performed using a crucible-scale test method based on ASTM C621 (2022) with minor modifications to the crucible size and coupon size. Such modification is common in refractory corrosion research as the original ASTM standard is very specific; the data collected by the same modified setup are comparable and suitable for modeling. The setup, which has been used to collect K-3 refractory corrosion data to support research of Hanford glassed formulation (Russell et al. 2025 and Jin et al. 2025), is shown in Figure 2.1. K-3 test coupons were cut from K-3 refractory slabs into 1 cm × 1 cm × 11 cm coupons. A notch was cut on the top end of the coupons to denote face “A–A.” Each coupon was mounted with the crucible lid made by castable alumina (RESCOR™ CER-CAST CERAMIC 780, Cotronics Corp., Brooklyn, NY) with a 1 cm × 1 cm slot in the center. The K-3 test coupon was inserted into a Pt crucible with crushed glass. The loaded crucible was heated in a furnace, and the K-3 test coupon was submerged into a static glass melt at 1150 °C or 1200 °C for 7 days. Following the 7 days test, the K-3 coupons were removed from the glass melt for characterization.

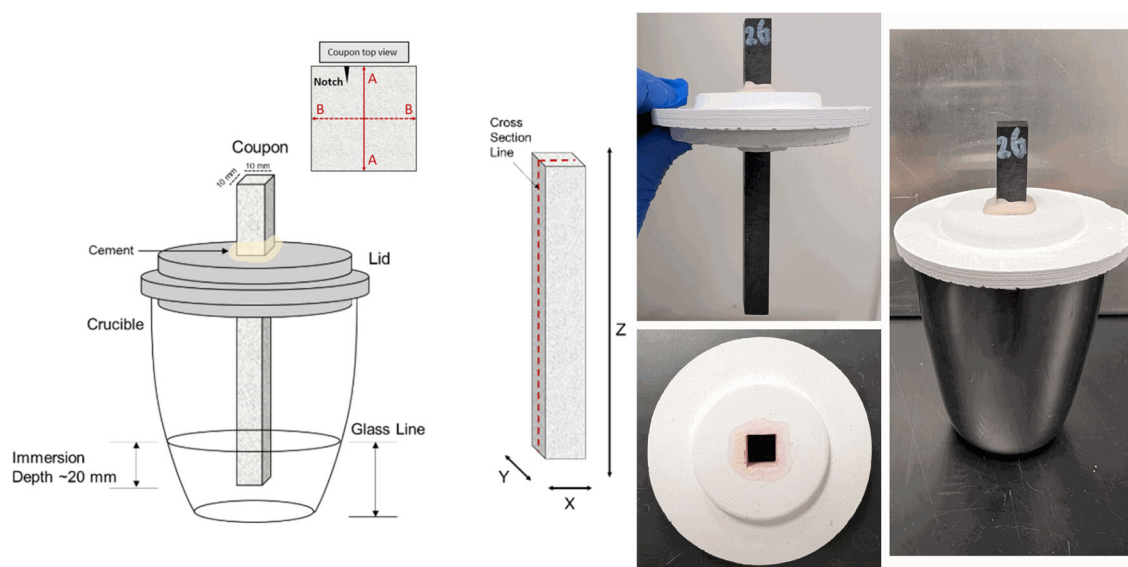


Figure 2.1. K-3 corrosion test setup in a static glass melt showing general measurements for coupon size and positioning, glass depth, and coupon immersion depth. For convenience in the following discussion, the test coupon's dimensions were defined by the x-, y-, and z-axes. The x–y plane is the horizontal plane, and the z-axis is the vertical axis.

Both pre-test and post-test coupons were scanned using Zeiss Xradia Versa 610 micro-computed tomography (micro-CT) (Carl Zeiss Microscopy GmbH, Jena, Germany). As shown in Figure 2.2, the coupons were mounted in 3D-printed plastic sample holders. Up to four coupons were bundled to fit in the scanning volume. Each single scan covered a cylindrical volume ~4 cm tall and 4 cm in diameter; three to five scans were conducted vertically to cover a 6–10 cm length. Single scans must be partially overlapped for image stitching. The voxel size was set to 0.04 mm. A certified volume standard was used to verify the voxel size of the micro-CT measurement.

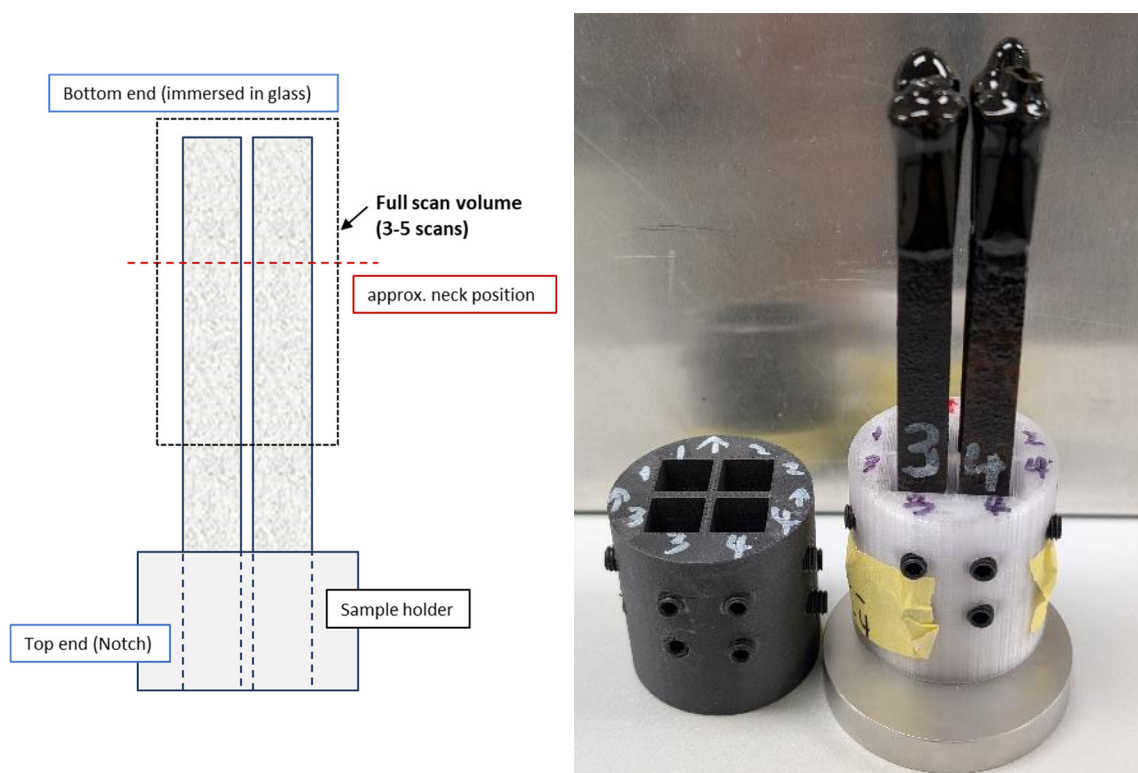


Figure 2.2. Samples for micro-CT scanning.

The K-3 corrosion was calculated by dimensional changes in the coupons after crucible tests in glass melts. As shown in Figure 2.3, the micro-CT scan produces a “stack” of X-ray images, which can be reconstructed to a 3D object for each sample. The 3D object can be sliced from different angles for analysis. The data from the pre-test and post-test K-3 coupons resulted in two stacks of images and were adjusted and aligned for analysis. Each image stack contains a 50-mm-long section of coupon ($1250 \text{ slices} \times 0.04 \text{ mm} = 50 \text{ mm}$; each slice is one voxel thick, 0.04 mm), with each slice set to $12 \text{ mm} \times 12 \text{ mm}$ (300×300 pixels, where the pixel size is the same as the voxel size for the 2D images). The pre-test and post-test image stacks of the same sample were aligned by matching the slices with visible features (grain sizes, pores, etc.), i.e., the same slice number in the pre- and post-test image stacks should have corresponded to the same position on the sample.

After adjusting and aligning, each slice was converted to a binary outline image and then a bounding rectangle of the outline. Adjustment of the contrast of the X-ray images was necessary to draw the outline of the post-test coupons to separate the glass and the K-3, which are of different brightness in the X-ray images. After generating the stack of outlines from the X-ray image stack, a stack of bounding rectangles was generated from the stack of outlines

(Figure 2.3). A dataset was generated by measuring the dimensions of the A–A and B–B directions of the bounding rectangles: $G_A(i)$ and $G_B(i)$, the dimensions of the A–A and B–B directions of the i th slice of the pre-test stack; $g_A(i)$ and $g_B(i)$, the dimensions of the A–A and B–B directions of the i th slice of the post-test stack ($i = 1-1250$). The dimensional change or corrosion depth ($d_{\text{corr},i}$) of each slice was calculated as follows:

$$d_{\text{corr},A}(i) = \frac{G_A(i) - g_A(i)}{2} \quad (2.1)$$

$$d_{\text{corr},B}(i) = \frac{G_B(i) - g_B(i)}{2} \quad (2.2)$$

The maximum corrosion depth along the coupon is the neck corrosion depth ($d_{\text{neck},A}$ and $d_{\text{neck},B}$), and the average neck corrosion (d_{neck}) of the A and B sides was calculated using

$$d_{\text{neck},A} = \text{MAX}[d_{\text{corr},A}(i)] = \text{MAX}\left[\frac{G_A(i) - g_A(i)}{2}\right] \quad (2.3)$$

$$d_{\text{neck},B} = \text{MAX}[d_{\text{corr},B}(i)] = \text{MAX}\left[\frac{G_B(i) - g_B(i)}{2}\right] \quad (2.4)$$

$$d_{\text{neck}} = \frac{d_{\text{neck},A} + d_{\text{neck},B}}{2} \quad (2.5)$$

The results are discussed in Section 3.0.

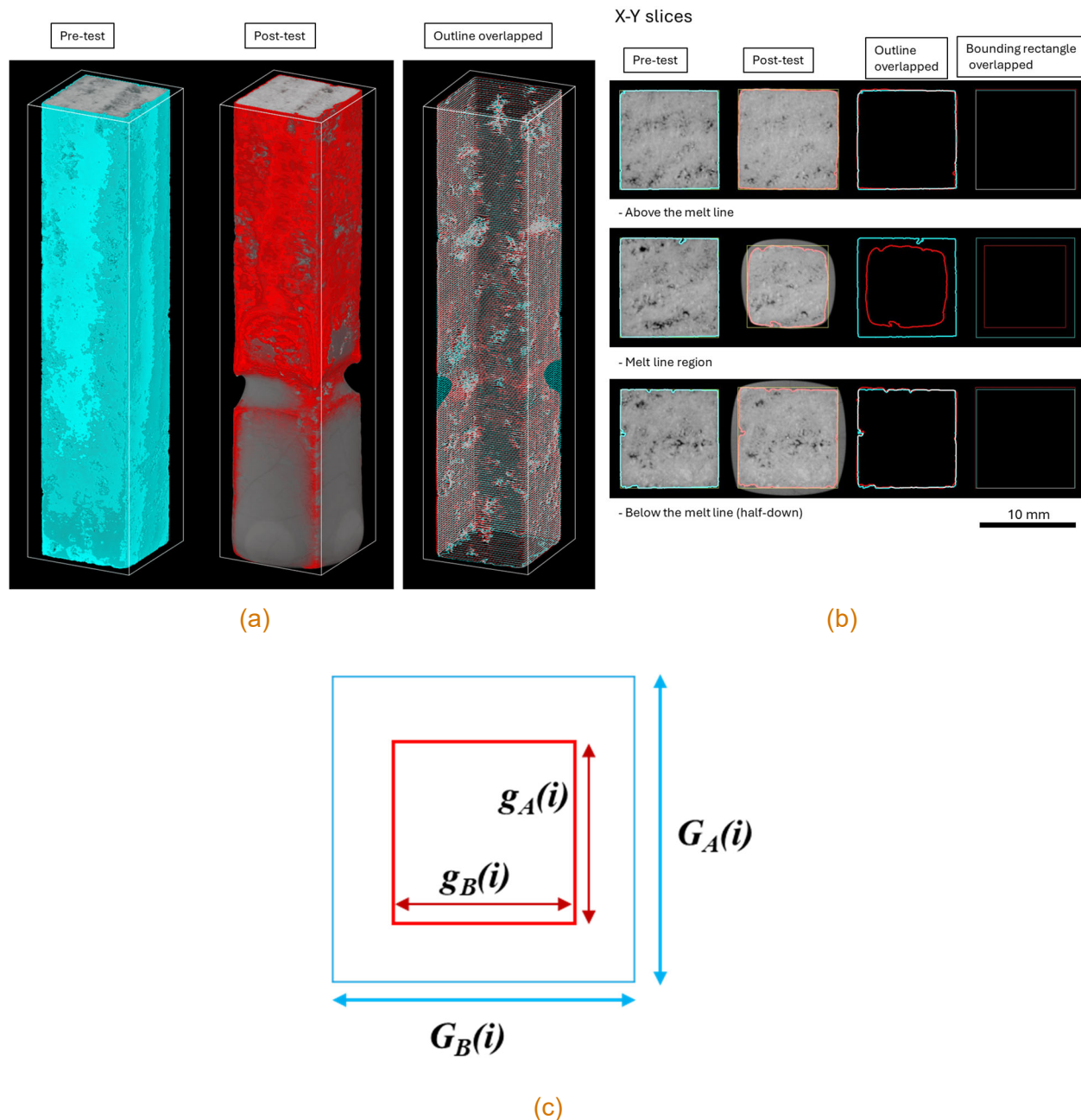


Figure 2.3. Procedure for measuring refractory corrosion using micro-CT scanning images. The brighter material is the K-3 phase, and the darker material is the glass remaining on the coupon surface after the test. (a) 3D view of an example coupon, HS24-09 1150 °C for 7 days. The outlines of the pre-test coupon (in cyan) and the post-test coupon (in red) are aligned and overlapped. The cropped scan volume for analysis is 12 mm × 12 mm (x-y plane) × 50 mm (along the z-axis). (b) Horizontal cross sections (slices of x-y plane) from different locations; the bounding rectangles (on the right) are drawn based on the outlines for dimensional measurement. (c) Dimensions measured on the bounding rectangles.

3.0 Results and Discussion

Table 3.1 and Figure 3.1 summarize the measured neck depths of the HS24 glass corroded K-3 coupons. Each glass was tested under two different conditions: 1150 °C for 7 days and 1200 °C for 7 days. For the combined modeling dataset, the corrosion depth values are converted to non-SI units of inches in the tables and plots in this section. The original measured values in SI units of millimeters can be found in the appendices. Test coupon photos are shown in Appendix A, micro-CT scan images are shown in Appendix B, and the original measured corrosion data are shown in Appendix C. For each coupon, the neck depth was measured in two perpendicular directions, as discussed in Section 2.2. The average values of the two measurements are reported with the standard deviation (SD). During the micro-CT measurement, setting the threshold to outline the scanned materials can lead to a measurement uncertainty of ~1 to 3 voxels (0.0016 to 0.0047 in.).

In this HS24 matrix, 15 glasses showed low corrosivity on the K-3 coupons without forming a distinguishable neck at either 1150 °C or 1200 °C after 7 days. The coupons without a distinguishable neck for the corrosion depth measurement are marked in Table 3.1. For another nine glasses, HS24-03, HS24-10, HS24-11, HS24-12, HS24-14, HS24-33, HS24-34, HS24-40, and HS24-48, the corrosion neck was only observed on the coupons after the 1200 °C for 7 days test but not after the 1150 °C for 7 days. The other glasses had distinguishable neck corrosion on the K-3 test coupons with the necks generally deeper after the 1200 °C for 7 days test. Four glasses, HS24-13, HS24-31, HS24-44, and HS24-50, showed equivalent corrosion at 1150 °C for 7 days and 1200 °C for 7 days test conditions (differences were less than estimated uncertainty of ~3 voxels or ~0.0047 in.). There is only one glass, HS24-09, that clearly showed a deeper neck on the 1150 °C for 7 days K-3 test coupon compared to the 1200 °C for 7 days K-3 test coupon, the cause of which is currently unknown, but could be attributed to factors such as reaction layer formation, the presence of pores or pre-existing cracks, or glass viscosity; further investigation is warranted.

Based on data from a previous 1208 °C for 6 days bubbling crucible test (Muller et al. 2018), two values were proposed as the upper limits for K-3 neck corrosion, 0.04 in. and 0.025 in. A limit of 0.04 in. was used in EWG2.5 (Vienna et al. 2024), based on the EWG-LAW constraint (Vienna et al. 2022). A more conservative limit of 0.025 in. was subsequently adopted, which has been used since EWG2.6 (Vienna et al. 2025) and retained in EWG3.0 (Lu et al. 2026). An offset of 0.3654 ln[in.] was estimated based on previous data from the 1208 °C for 6 days bubbling test and 1200 °C for 7 days static test (Lu et al. 2026). By applying the offset to the 1200 °C for 7 days measured data [Equation (3.1)], the transferred results are comparable with the limits of the 1208 °C for 6 days bubbling data. As shown in Figure 3.1(b), only one of the 50 glasses, HS24-49, had a neck corrosion depth on the K-3 test coupons exceeding the 0.04 in. limit, and four, HS24-04, HS24-05, HS24-25, and HS24-49, had neck corrosion deeper than the more restrictive limit of 0.025 in.

$$\ln(d_{\text{neck},1208/6\text{d}/\text{bubbling}}) = \ln(d_{\text{neck},1200/7\text{d}/\text{static}}) - \text{offset} \quad (3.1)$$

Figure 3.2 shows the measured neck depth of the 1200 °C for 7 days test samples plotted against the model predictions from Lu et al. (2026). The y-axis error bars are the uncertainty in the predicted values calculated by the model, and the x-axis error bars are applied using a fixed value of 0.3976 ln[in.] which is a pooled SD reported in Lu et al. (2026). The model prediction improves when the overall K-3 neck corrosion is deeper. This is attributed to the relatively high

inaccuracies in the measured data when the corrosion damage to the test coupons is minimal, but still above limits of detection of the micro-CT method (0.0016 in., 1 voxel).

Table 3.1. K-3 refractory corrosion neck depth, d_{neck} , in inches. The symbol “-” means that neck corrosion was not observed on the post-test coupon.

Glass ID	1150 °C for 7 days	1200 °C for 7 days	Glass ID	1150 °C for 7 days	1200 °C for 7 days
HS24-01	0.0012 ± 0.0006	0.0035 ± 0.0006	HS24-26	-	-
HS24-02	0.0193 ± 0.0006	0.0307 ± 0.0033	HS24-27	0.0154 ± 0.0017	0.0220 ± 0.0011
HS24-03	-	0.0035 ± 0.0006	HS24-28	0.0051 ± 0.0006	0.0091 ± 0.0006
HS24-04	0.0370 ± 0.0011	0.0480 ± 0.0000	HS24-29	0.0142 ± 0.0000	0.0193 ± 0.0006
HS24-05	0.0283 ± 0.0000	0.0398 ± 0.0006	HS24-30	-	-
HS24-06	-	-	HS24-31	0.0043 ± 0.0006	0.0020 ± 0.0006
HS24-07	0.0043 ± 0.0006	0.0079 ± 0.0000	HS24-32	-	-
HS24-08	-	-	HS24-33	-	0.0012 ± 0.0006
HS24-09	0.0394 ± 0.0022	0.0260 ± 0.0011	HS24-34	-	0.0020 ± 0.0006
HS24-10	-	0.0024 ± 0.0011	HS24-35	-	-
HS24-11	-	0.0020 ± 0.0006	HS24-36	0.0008 ± 0.0000	-
HS24-12	-	0.0016 ± 0.0011	HS24-37	0.0043 ± 0.0006	0.0102 ± 0.0011
HS24-13	0.0075 ± 0.0006	0.0067 ± 0.0006	HS24-38	-	-
HS24-14	-	0.0016 ± 0.0000	HS24-39	-	-
HS24-15	0.0075 ± 0.0006	0.0142 ± 0.0000	HS24-40	-	0.0016 ± 0.0011
HS24-16	0.0004 ± 0.0006	0.0067 ± 0.0017	HS24-41	0.0059 ± 0.0017*	0.0098 ± 0.0006
HS24-17	-	-	HS24-42	-*	-
HS24-18	0.0106 ± 0.0006	0.0146 ± 0.0017	HS24-43	-*	-
HS24-19	-	-	HS24-44	0.0051 ± 0.0006*	0.0047 ± 0.0000
HS24-20	0.0185 ± 0.0006	0.0276 ± 0.0011	HS24-45	0.0016 ± 0.0022	0.0035 ± 0.0017
HS24-21	-	-	HS24-46	0.0020 ± 0.0006	0.0035 ± 0.0006
HS24-22	-	-	HS24-47	0.0024 ± 0.0000	0.0087 ± 0.0011
HS24-23	-	-	HS24-48	-	0.0008 ± 0.0000
HS24-24	0.0059 ± 0.0028	0.0063 ± 0.0011	HS24-49	0.0374 ± 0.0006	0.0646 ± 0.0011
HS24-25	0.0291 ± 0.0011	0.0390 ± 0.0006	HS24-50	0.0118 ± 0.0011	0.0098 ± 0.0006

* The crucible was cooled once during the 7 days test due to a furnace breakdown; the test duration was compensated after reheating to the target temperature.

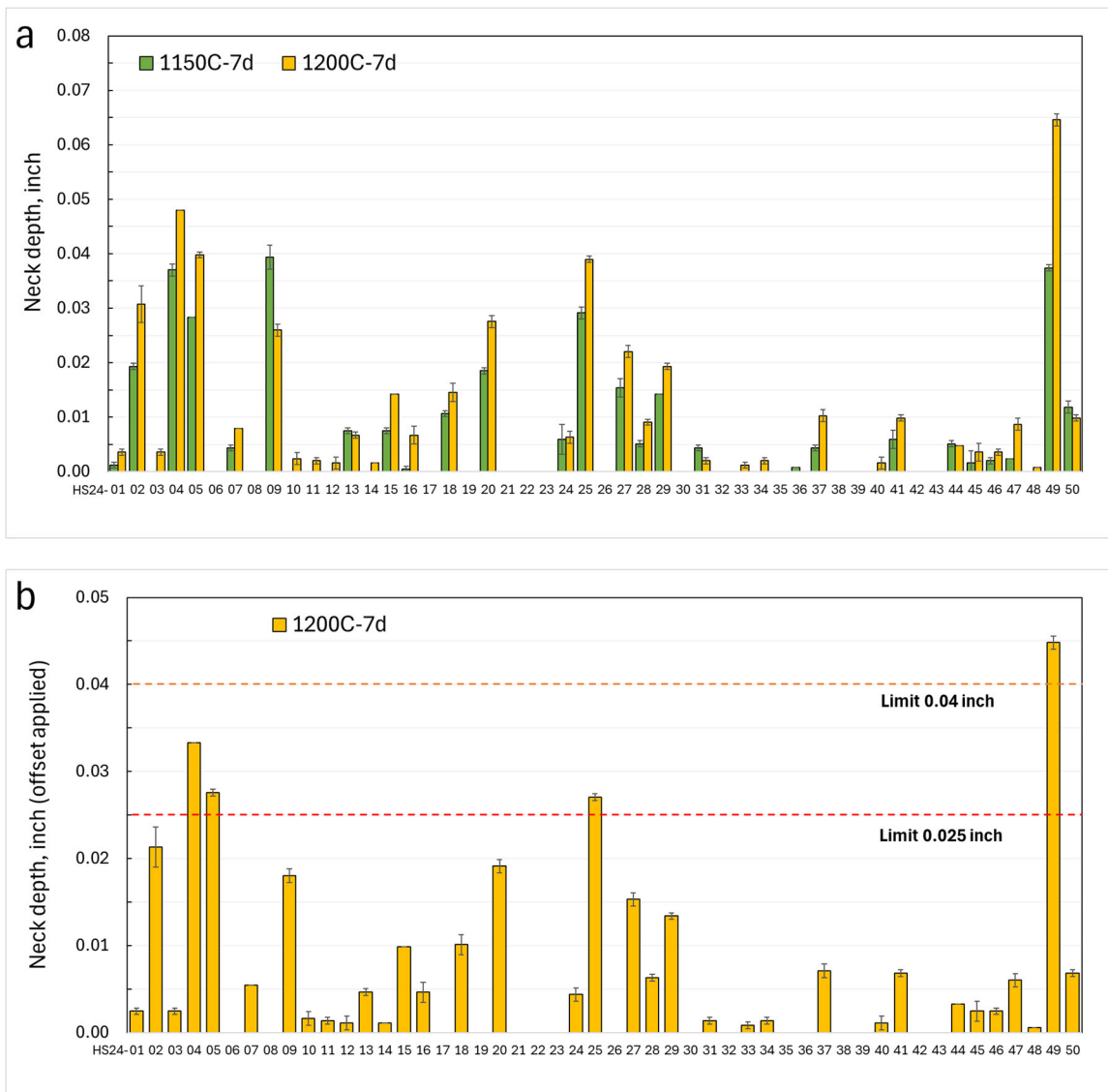


Figure 3.1. K-3 refractory corrosion neck depth. (a) Neck corrosion depth data from Table 3.1. (b) Neck corrosion depth data of 1200 °C for 7 days, converted by an offset of 0.3654 ln[in.] to compare with the limit set based on the previous 1208 °C for 6 days bubbling test dataset.

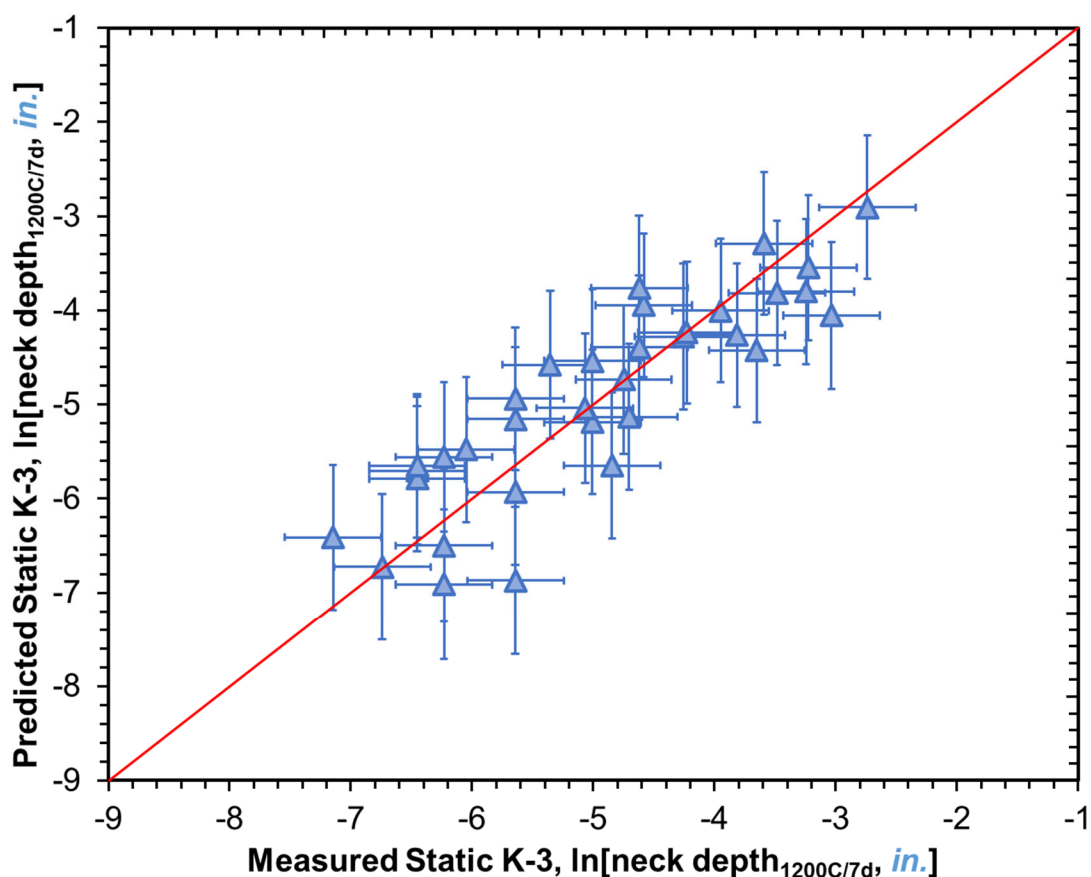


Figure 3.2. Measured and predicted (EWG3.0 model, Lu et al. 2026) K-3 refractory corrosion neck depth. The red line is the 1:1 line between the measured and predicted values. The uncertainties in the measured values are represented by the pooled SD reported in Lu et al. (2026).

Two of the HS24 glasses were designed as replicates from previous work: HS24-49 is a replicate of ORPLG27 (Muller et al. 2010, 2018), and HS24-50 is a replicate of HLW-APPS-05 (Gervasio et al. 2023; Page et al. 2026). The results are shown in Table 3.2 and Table 3.3 for comparison.

The results for the HS24-49/ORPLG27 glass, including three data points for 1200 °C for 7 days, are listed in Table 3.2. The two replicates done by PNNL match very well; however, the value reported by the Vitreous State Laboratory (VSL) is significantly lower compared with the PNNL data converted by Eq. (3.1). The cause of this difference is likely due to the limited set of data used to calculate the offset. Additionally, it should be noted that the experimental errors of the results of this work and from literature are different. In this work, each data point includes the SD calculated by two measurements from two perpendicular directions (see Figure 2.3(c)) on one K-3 test coupon. On the other hand, two K-3 test coupons were measured for the average and SD for the data from Muller et al. (2018), which could also attribute to differences in the reported data. Additional work is planned to evaluate the data offset across a larger data set and to determine a pooled SD for the PNNL test methodology and resulting neck loss data.

Table 3.2. K-3 refractory corrosion neck depth, d_{neck} , in inches, of HS24-49.

Glass ID		1200 °C for 7 days	1208 °C for 6 days (PNNL data converted by Eq. 3.1 for comparison)	Reference
HS24-49	HS24-49 (PNNL)	0.0646 ± 0.0011	0.0448 ± 0.0008	This work
	OPRLG27 (PNNL)	0.0614 ± 0.0011	0.0426 ± 0.0008	Unpublished data
	OPRLG27 (VSL)	N/A	0.029 ± 0.0071	Muller et al. (2018)

For the HS24-50/APPS-05 glass results, the neck corrosion depths measured by this work are compared with those measured by Savannah River National Laboratory (SRNL) in Table 3.3. Three different analysis methods were used by SRNL (the details can be found in Page et al. (2026)). The SRNL results obtained by the maximum method are comparable with the image analysis method used in this work (Figure 2.3). SRNL's 1150 °C for 7 days data are significantly higher than those from this work, while the 1200 °C for 7 days data from both PNNL and SRNL are similar. Apart from the expected experimental error, the difference may be related to the characterization and image analysis methods. More comparison experiments will be conducted to investigate the origins in data discrepancy when evaluating data collected at the two laboratories.

Table 3.3. K-3 refractory corrosion neck depth, d_{neck} , in inches, of HS24-50.

Glass ID		1150 °C for 7 days	1200 °C for 7 days	Reference
HS24-50	HS24-50	0.0118 ± 0.0011	0.0098 ± 0.0006	This work
	APPS1-05 (average of midpoint method)	0.0239	0.0135	Page et al. (2026)
	APPS1-05 (maximum method)	0.0220	0.0096	
	APPS1-05 (midpoint method)	0.0235	0.0131	

4.0 Conclusions

This report documents the results of the refractory corrosion tests of a high S matrix (HS24) of simulated DFHLW glasses. Each glass was tested using a static crucible setup at two test conditions: 1150 °C and 1200 °C for 7 days. The corrosion depth at the melt line, i.e., the neck corrosion depth data, was measured by scanning the K-3 coupons before and after testing with micro-CT. From the 50 HS-24 glasses, 15 did not show distinguishable neck corrosion after testing at either temperature condition. For another nine glasses, the corrosion neck was only observed on the coupons after the 1200 °C for 7 days test condition but not after the 1150 °C for 7 days. There are six glasses that had deeper neck corrosion on the test coupons after being tested at 1150 °C for 7 days than after being tested at 1200 °C for 7 days. The reason for this behavior may be attributed to the experimental error related to the defects of the K-3 coupons and the limit of the measurement but should be subject to further investigation to rule out other causes.

The measured neck corrosion depth data were compared with model predicted values from the latest EWG3.0 K-3 refractory corrosion neck loss model (Lu et al. 2026). The measured and predicted values agreed well; however, the prediction is better when the neck corrosion is deeper. After applying a 0.3654 ln[in.] offset to the 1200 °C for 7 days data (the offset in the model equation was to make the static crucible test data comparable with the limits based on bubbling crucible test data), one glass of the 50 glasses, HS24-49, failed the nominal 0.04 in. neck corrosion limit, and four glasses, HS24-04, HS24-05, HS24-25, and HS24-49, failed the more restrictive 0.025 in. limit.

Two glasses, HS24-49 and HS24-50, were designed as replicates of previously tested glasses, ORPLG27 and APPS1-5. The 1200 °C for 7 days results for HS24-49 (ORPLG27) showed consistency between two replicates (static test, measured neck depths of 0.0646 in. and 0.0614 in. respectively) performed by PNNL; on the other hand, VSL's results (bubbling crucible test, Muller et al. 2018) were lower than PNNL's (after conversion with an offset for comparison, 0.029 in. vs. 0.0426-0.0448 in.). For HS24-50 (APPS-05), both SRNL and PNNL tested K-3 coupons using a static crucible setup, at the same temperatures (1150 °C and 1200 °C), and for a 7-day test duration. For the 1150 °C for 7 days test, PNNL's results were lower than SRNL's; however, for the 1200 °C for 7 days test, the results were consistent between laboratories. The inter-laboratory differences of K-3 corrosion data are attributed to variations in test conditions and characterization methods. Future work will investigate these factors to better understand the observed discrepancies and experimental uncertainty. Quantifying and reducing experimental uncertainty can improve data quality, help identify potential model overfitting, and ultimately support more accurate and robust model development.

5.0 Bibliography

10 CFR 830. 2020. Nuclear Safety Management. Office of Environment, Health, Safety and Security, Department of Energy.

ASTM C621-09. 2022. *Standard Test Method for Isothermal Corrosion Resistance of Refractories to Molten Glass*. ASTM International. West Conshohocken, PA.

DOE O 414.1D Chg. 2 (LtdChg). 2020. Quality Assurance. Department of Energy.

Gervasio, V., X. Lu, J. T. Reiser, M. Peterson, N. L. Canfield, J. B. Lang, J. C. Rigby, J. L. George, D. A. Cutforth, J. M. Westman, R. Brown, J. M. Oshiro, B. T. Boehnke, E. A. Cordova, J. V. Crum, N. A. Lumetta, J. D. Vienna, J. W. Amoroso, M. Page, N. Rod, and M.C. Hsieh. 2023. *Direct Feed High-Level Waste APPS Model Glass Testing (DFHLW APPS) Matrix*. PNNL-35503, Rev. 0. Pacific Northwest National Laboratory Richland, WA.
<https://www.osti.gov/biblio/3024080>.

Jin T., M. A. Hall, J. D. Vienna, W. C. Eaton, J. W. Amoroso, B. J. Wiersma, W. Li, A. W. Abboud, D. P. Guillen, and A. A. Kruger. 2023. Glass-contact refractory of the nuclear waste vitrification melters in the United States: a review of corrosion data and melter life. *Int Mater Rev.* 2023;68(8):1135–1157. <https://doi.org/10.1080/09506608.2023.2211469>.

Jin T., L. Q. Le, N. L. Canfield, K. C. Bryce, E. T. Nienhuis-Marcial, X. Lu, and J. D. Vienna. 2025. K-3 Refractory Corrosion Test Results, HAL24M2. PNNL-37964, Rev. 0. Pacific Northwest National Laboratory, Richland, WA. <https://www.osti.gov/biblio/2584612>.

Lu, X., J. D. Vienna, P. Ferkl, D. Kim, J. Marcial, J. Bai, D. Wang, J. V. Crum, J. J. Neeway, and N. A. Lumetta. 2026. *Glass Property-Composition Models Update for use in Direct Feed High-Level Waste Flowsheet Development: EWG3.0*. PNNL-38953, Rev. 0. Pacific Northwest National Laboratory, Richland, WA.

Muller, I. S., K. S. Matlack, H. Gan, I. Joseph, and I. L. Pegg. 2010. *Waste Loading Enhancements for Hanford LAW Glasses*. VSL-10R1790-1, Rev. 0, ORP-48578, Rev. 0. Vitreous State Laboratory, The Catholic University of America, Washington, DC.
<https://www.osti.gov/biblio/1004083>.

Muller, I. S., K. Gilbo, M. Chaudhuri, I. L. Pegg, and I. Joseph. 2018. *K-3 Refractory Corrosion and Sulfate Solubility Model Enhancement (Final Report)*. VSL-18R4360-1, Rev. 0, ORP-63490, Rev. 0. Vitreous State Laboratory, The Catholic University of America, Washington, DC.
<https://www.osti.gov/biblio/1513833>.

NQA-1-2012. 2013. *Quality Assurance Requirements for Nuclear Facility Applications*. American Society of Mechanical Engineers. New York, NY.

Page, M., J. W. Amoroso, and N. A. Rod. 2026. *Corrosion Testing of Refractory in Contact with Molten Glasses Designed for Waste Vitrification - APPS1 Matrix Glasses*. SRNL-STI-2024-00055, Rev. 3. Savannah River National Laboratory, Aiken, SC.
<https://www.osti.gov/biblio/3023100>.

Reiser, J. T., R. L. Russell, X. Lu, V. Gervasio, S. Chong, J. Bai, L. M. Seymour, J. J. Neeway, N. A. Lumetta, J. L. George, and J. D. Vienna. 2026. *Testing of High S Matrix Glasses to Expand DFHLW Glass Compositional Ranges*. PNNL-36617, Rev. 1. Pacific Northwest National Laboratory, Richland, WA. <https://www.osti.gov/biblio/3031189>.

Russell, R. L., V. Gervasio, X. Lu, S. Chong, J. T. Reiser, N. L. Canfield, J. L. George, J. N. A. Lumetta, J. J. Neeway, L. M. Seymour, T. Jin, M. A. Hall, E. T. Nienhuis-Marcial, and J. D. Vienna. 2025. *Direct Feed High-Level Waste APPS Model Glass Testing (DFHLW APPS) Matrix, Phase 2*. PNNL-37506, Rev. 0. Pacific Northwest National Laboratory, Richland, WA. <https://www.osti.gov/biblio/3018519>.

Vienna, J. D., A. Heredia-Langner, S. K. Cooley, A. E. Holmes, D. Kim, and N. A. Lumetta. 2022. *Glass Property-Composition Models for Support of Hanford WTP LAW Facility Operation*. PNNL-30932, Rev. 2. Pacific Northwest National Laboratory, Richland, WA. <https://www.osti.gov/biblio/1862823>.

Vienna J. D., X. Lu, P. Ferkl, L. L. Gunnell, A. Heredia-Langner, N. A. Lumetta, T. Jin, J. T. Reiser, and V. Gervasio. 2024. *Glass Property-Composition Models Update for use in Direct Feed High-Level Waste Flowsheet Development*. PNNL-35884, Rev. 1. Pacific Northwest National Laboratory, Richland, WA.

Vienna J. D., X. Lu, P. Ferkl, D. Kim, J. Marcial, J. Bai, and J. V, Crum. 2025. *Glass Property-Composition Models Update for use in Direct Feed High-Level Waste Flowsheet Development: EWG2.6*. PNNL- 37762. Pacific Northwest National Laboratory, Richland, WA.

Appendix A – Photographs of Test Coupons

The photographs in this appendix show the K-3 refractory coupons after corrosion testing with HS24 glasses. Note that the coupons are upside down in the photos; the top of each coupon is the section immersed in the glass melt.



Figure A.1. K-3 coupons HS24-01 through HS24-06 after the refractory corrosion test.



Figure A.2. K-3 coupons HS24-07 through HS24-12 after the refractory corrosion test.



Figure A.3. K-3 coupons HS24-13 through HS24-18 after the refractory corrosion test.



Figure A.4. K-3 coupons HS24-19 through HS24-24 after the refractory corrosion test.



Figure A.5. K-3 coupons HS24-25 through HS24-30 after the refractory corrosion test.



Figure A.6. K-3 coupons HS24-31 through HS24-36 after the refractory corrosion test.



Figure A.7. K-3 coupons HS24-37 through HS24-43 after the refractory corrosion test.



Figure A.8. K-3 coupons HS24-44 through HS24-50 after the refractory corrosion test.

Appendix B – Micro-CT Results of the K-3 Refractory Corrosion Test

This appendix presents the X-ray images used for the dimensional measurements of the K-3 refractory coupons tested for corrosion with the HS24 glasses. Each figure shows the results of one test coupon, including cross-sectional view (x - z and y - z) images, top-view images (x - y) with outlines and bounding rectangles, and plots of the corrosion depth measured based on the bounding rectangles. For each figure, (a) shows the cross-sectional view of the post-test coupon at the center from both the A-A and B-B directions with the neck marked by red arrows. Plots of the corrosion depth along the coupon are also shown in (b). For samples with a distinguishable neck for measurement, (c) shows the micro-CT images of the x - y plane at the neck locations with the pre-test image outline and bounding rectangle in cyan and the post-test image outline and bounding rectangle in red. For each coupon, the neck corrosion depth and neck locations measured from the A-A and B-B directions are not exactly the same (see Appendix C) since the pores and uneven distribution of the different phases can affect the corrosion damage on different faces.

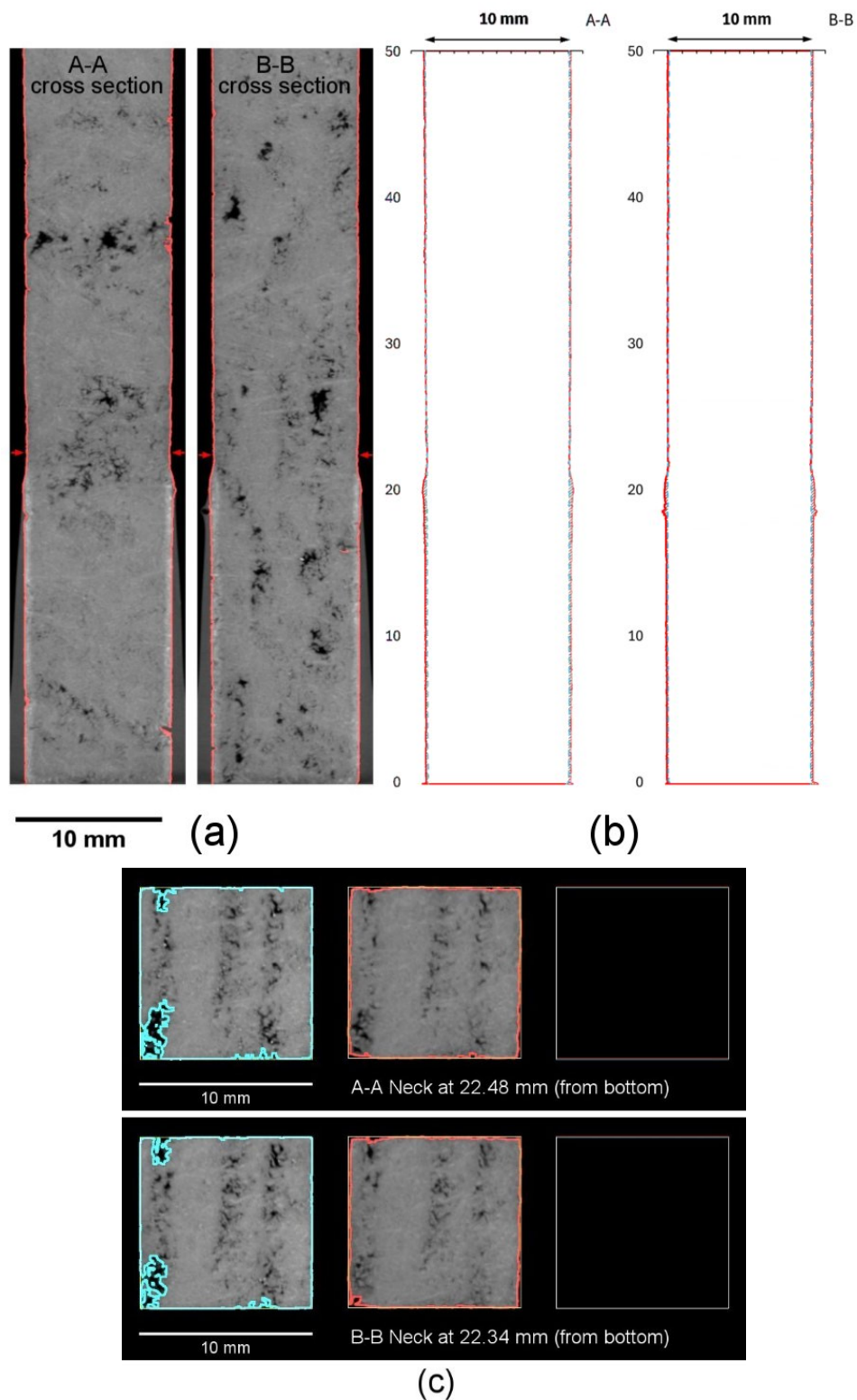


Figure B.1. Micro-CT results of the K-3 refractory corrosion test, HS24-01_1150C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

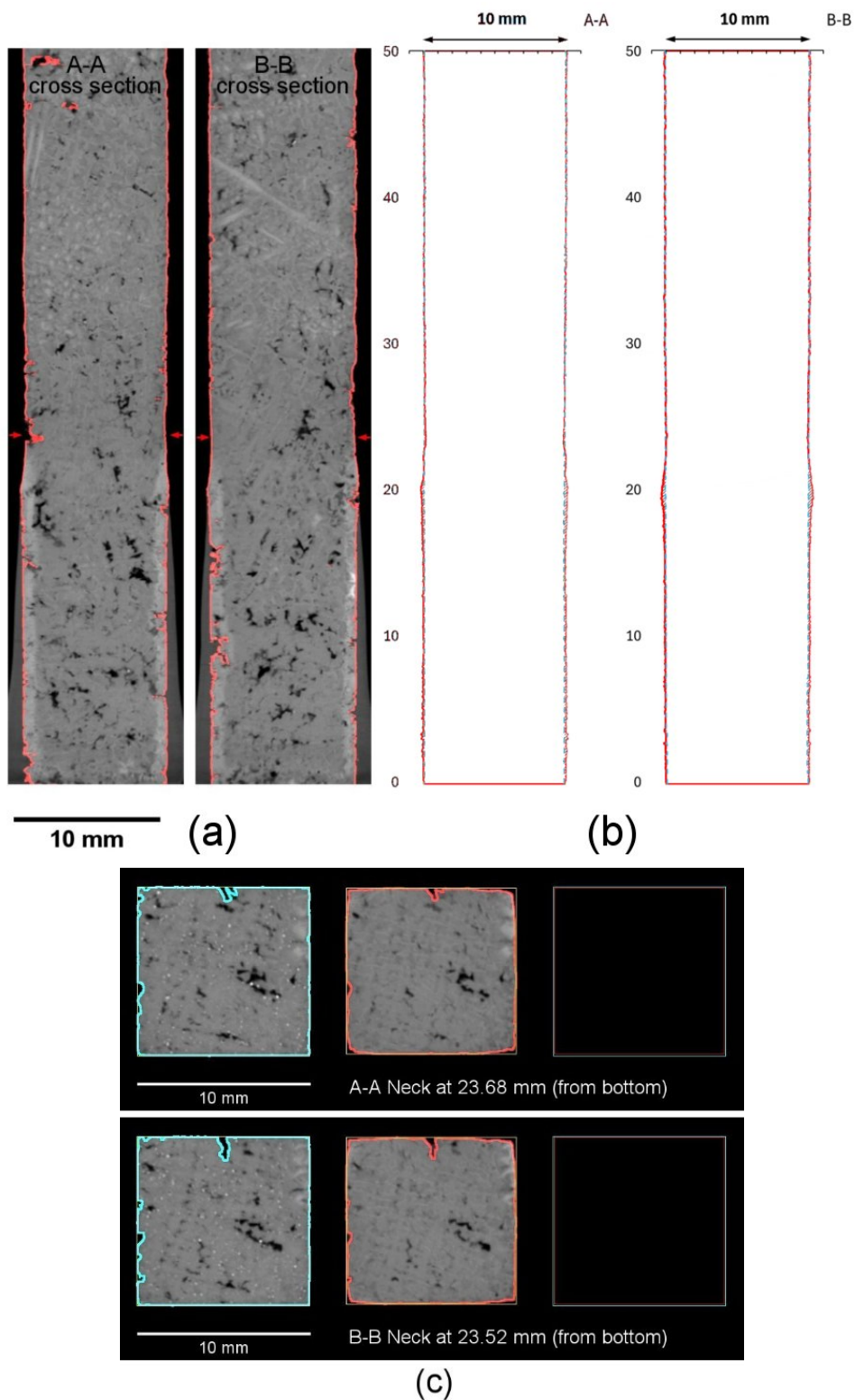


Figure B.2. Micro-CT results of the K-3 refractory corrosion test, HS24-01_1200C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

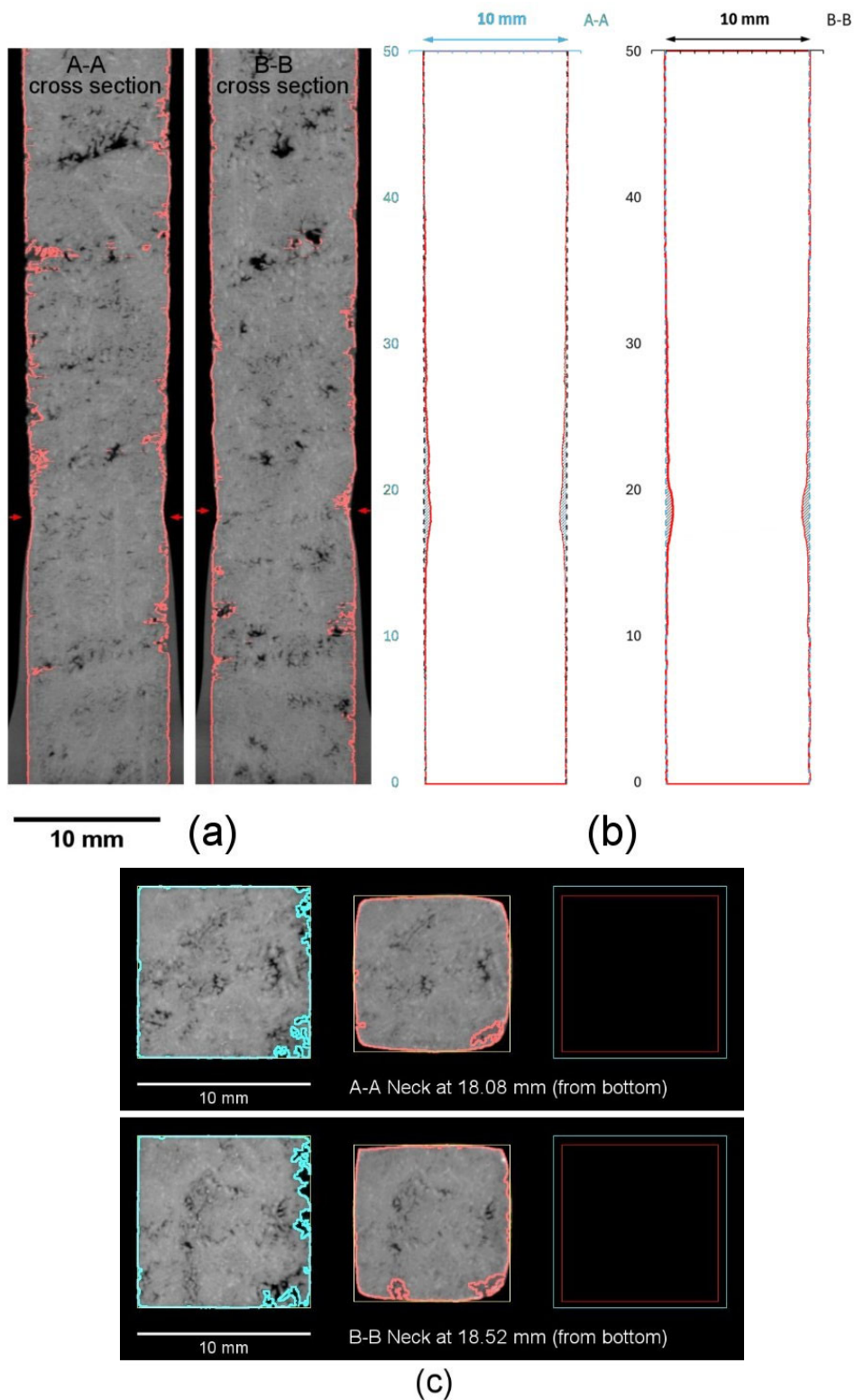


Figure B.3. Micro-CT results of the K-3 refractory corrosion test, HS24-02_1150C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

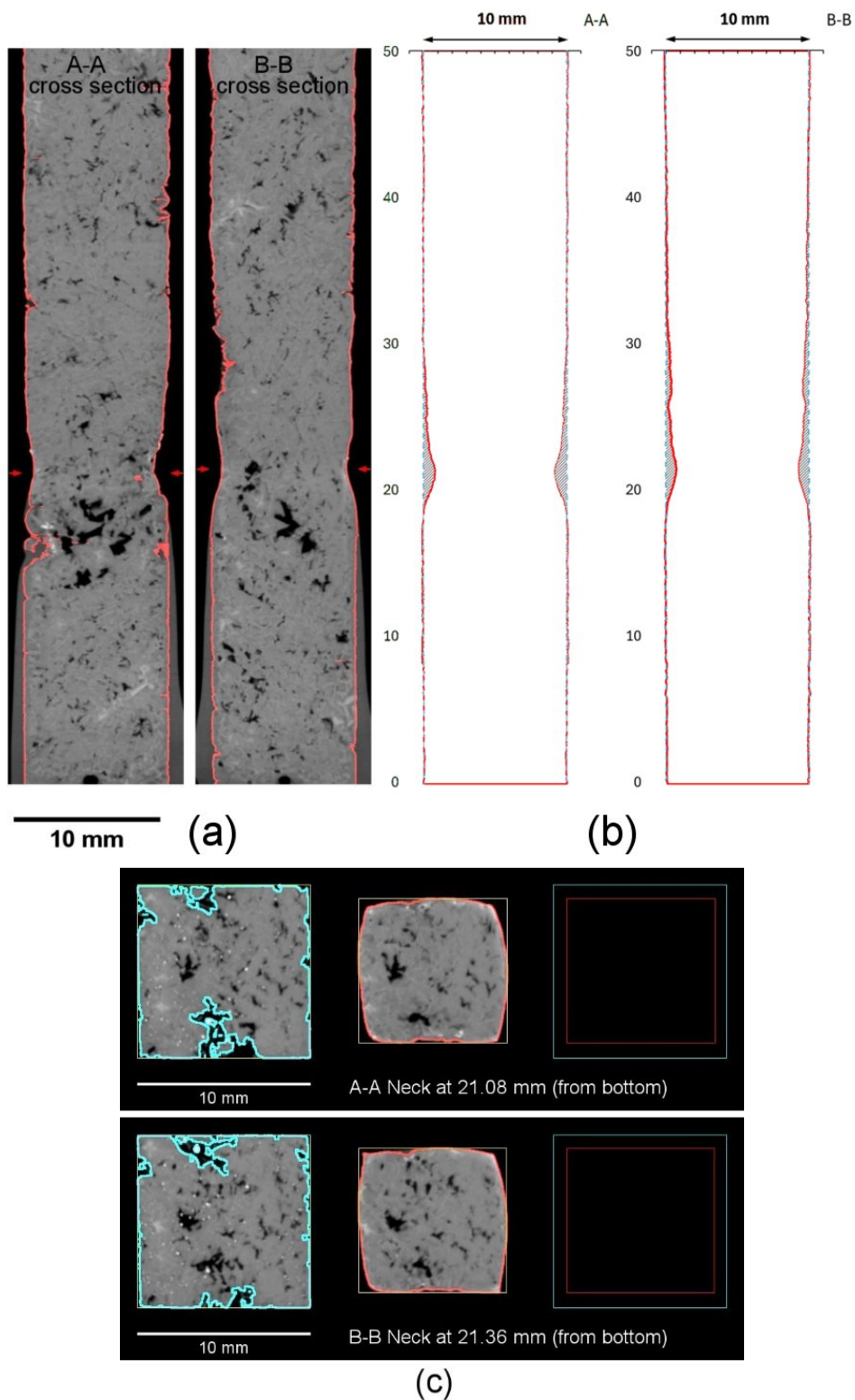


Figure B.4. Micro-CT results of the K-3 refractory corrosion test, HS24-02_1200C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

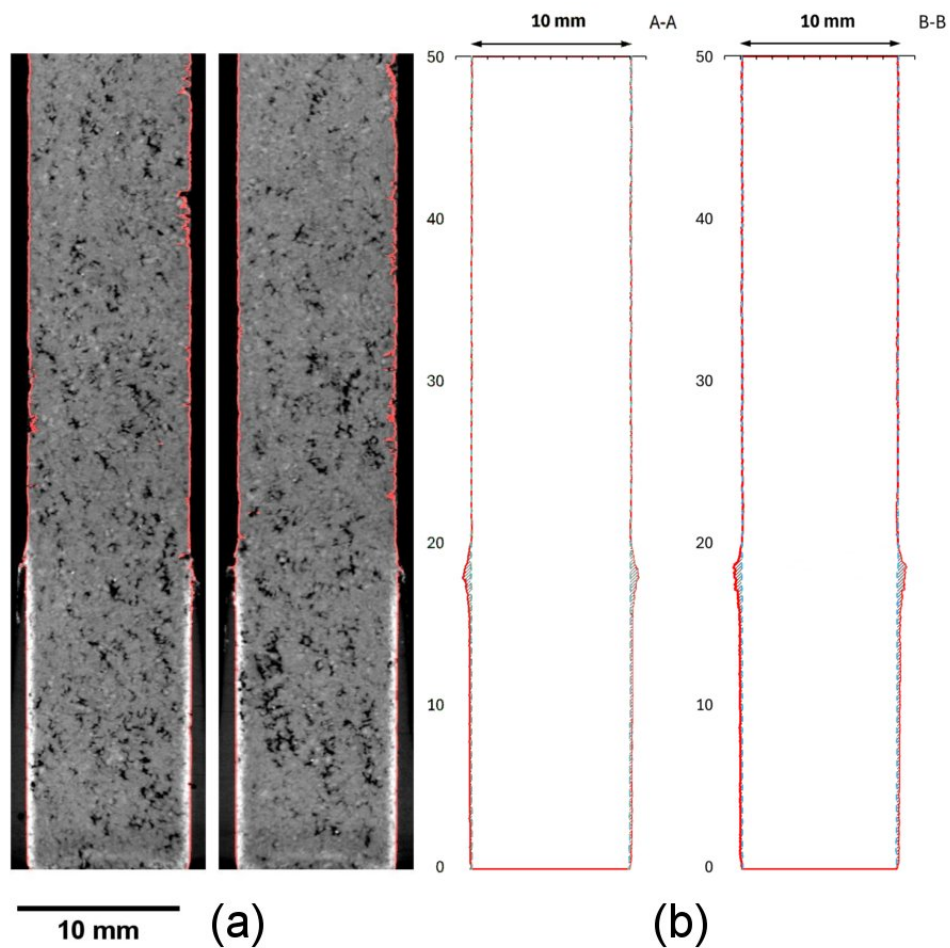


Figure B.5. Micro-CT results of the K-3 refractory corrosion test, HS24-03_1150C-7d. (a) Micro-CT images of the cross section at the center. (b) Corrosion depth plots, no distinguishable neck.

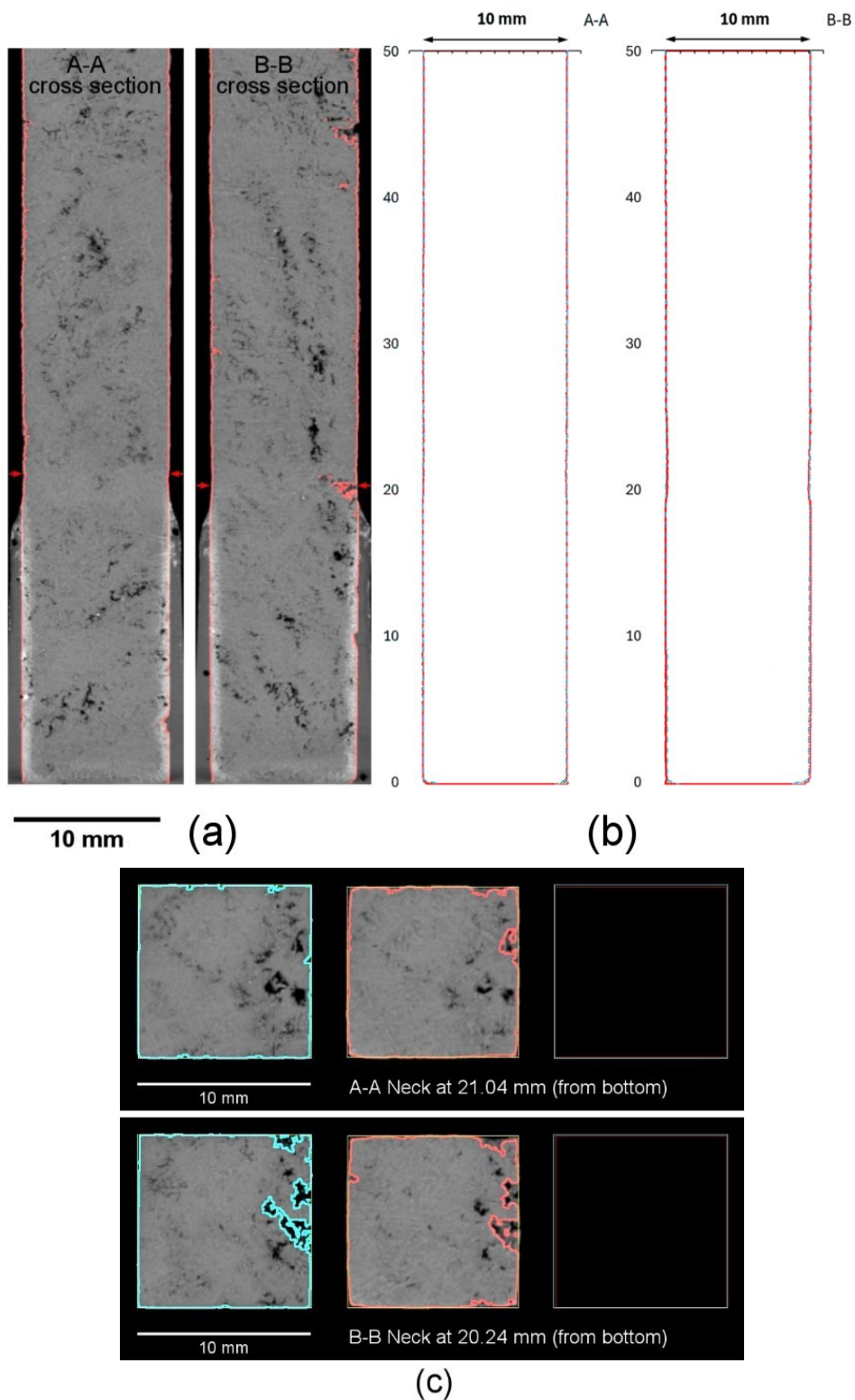


Figure B.6. Micro-CT results of the K-3 refractory corrosion test, HS24-03_1200C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

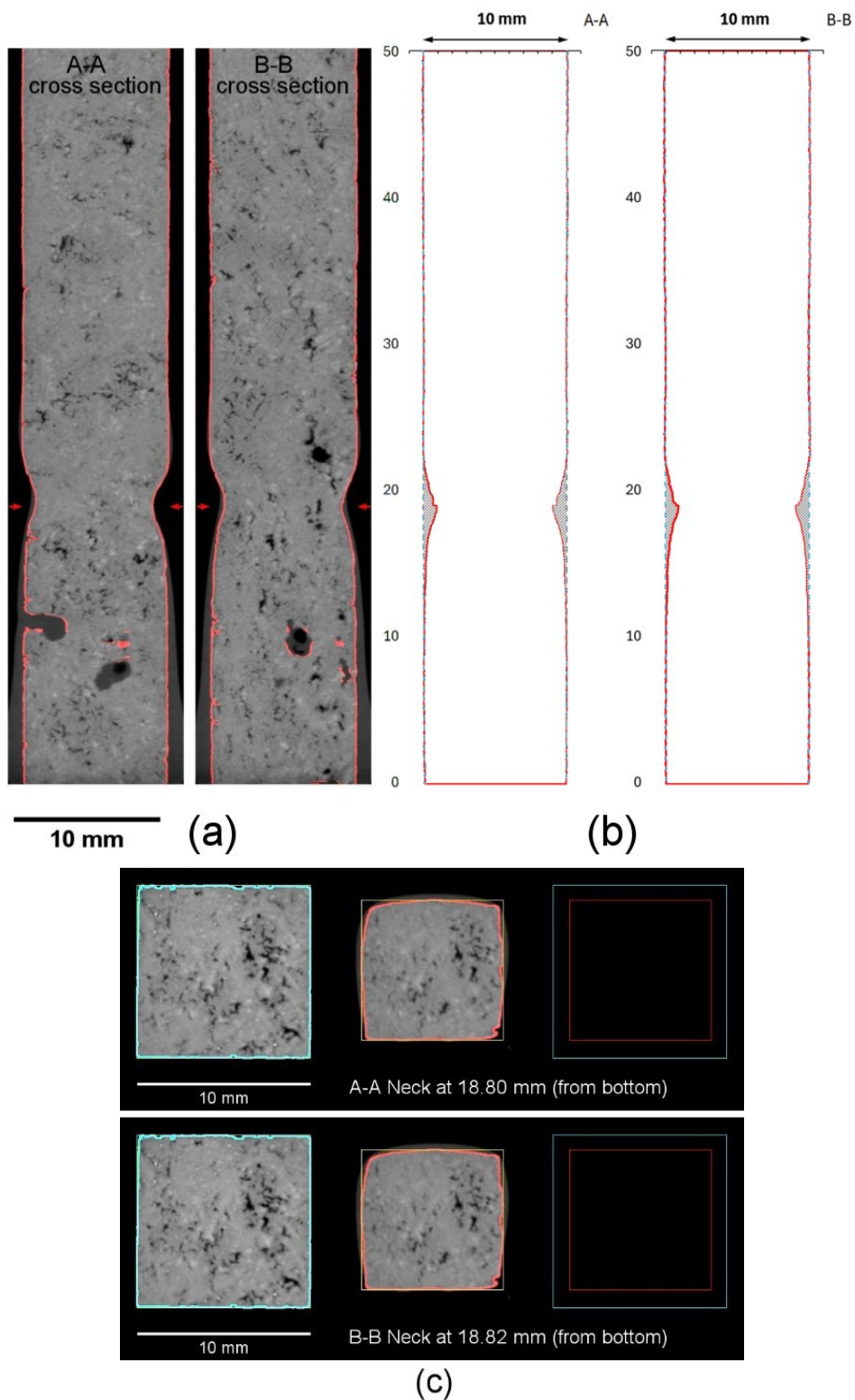


Figure B.7. Micro-CT results of the K-3 refractory corrosion test, HS24-04_1150C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

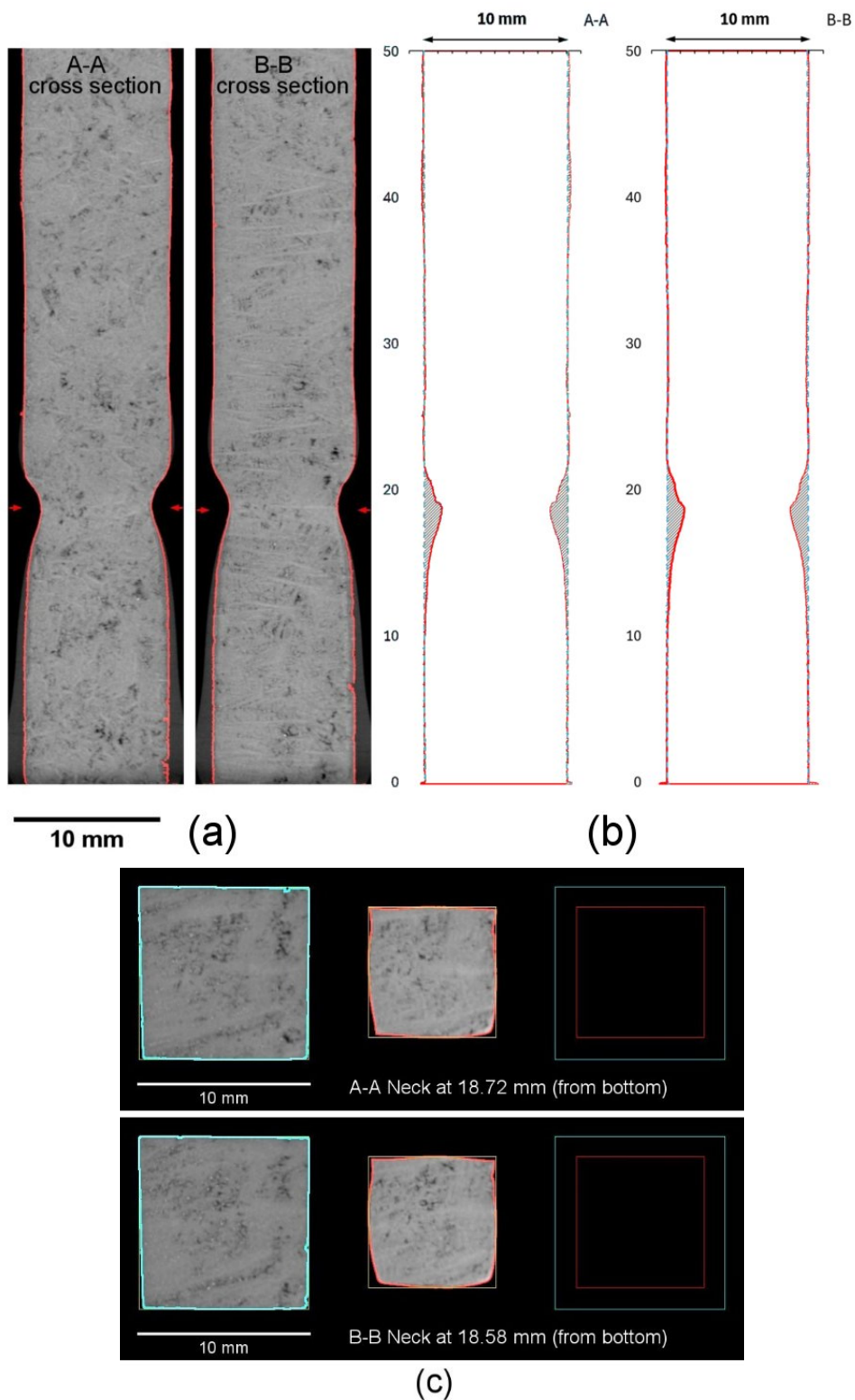


Figure B.8. Micro-CT results of the K-3 refractory corrosion test, HS24-04_1200C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of x-y plane with the outline and bounding rectangles at the neck locations.

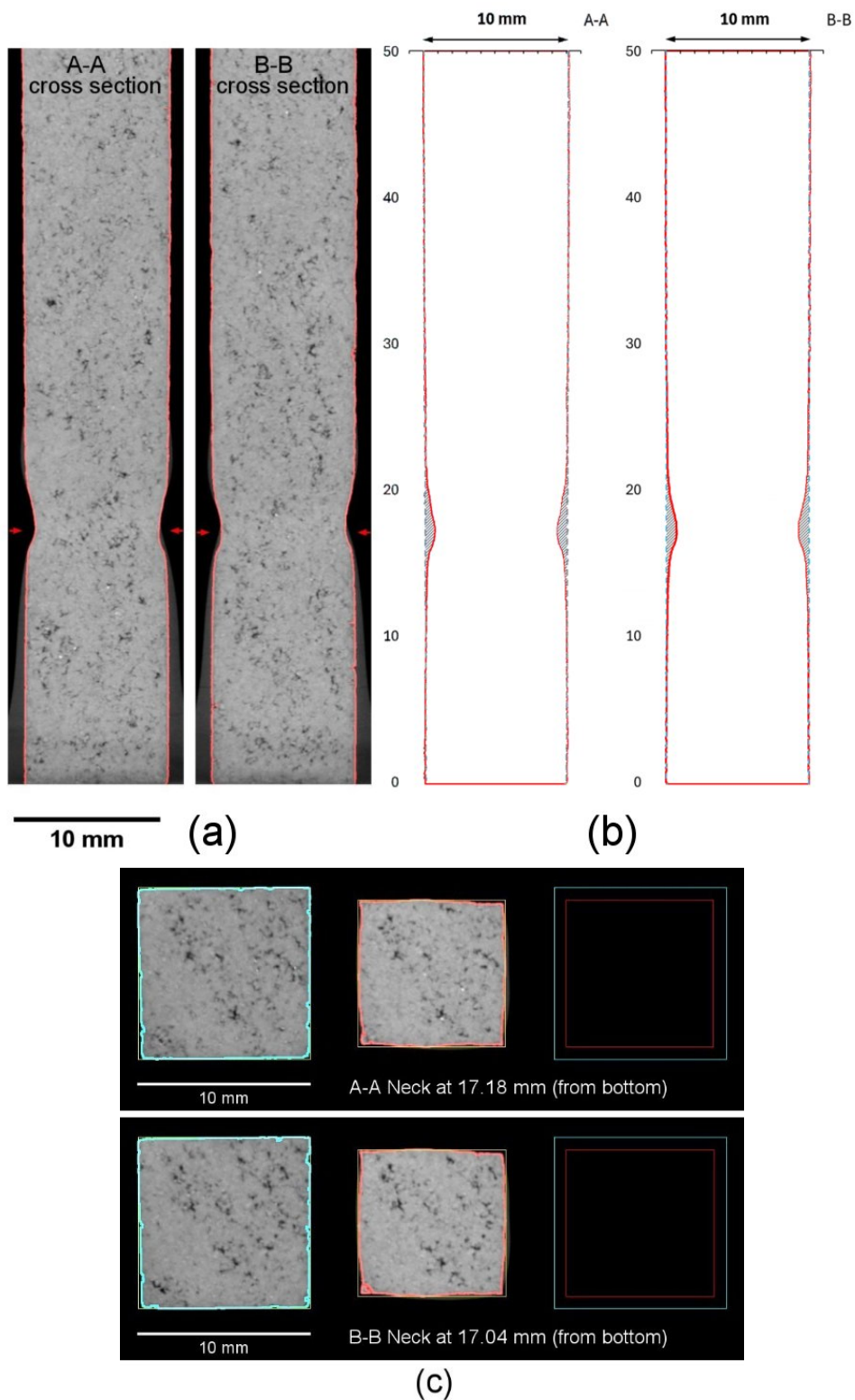


Figure B.9. Micro-CT results of the K-3 refractory corrosion test, HS24-05_1150C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

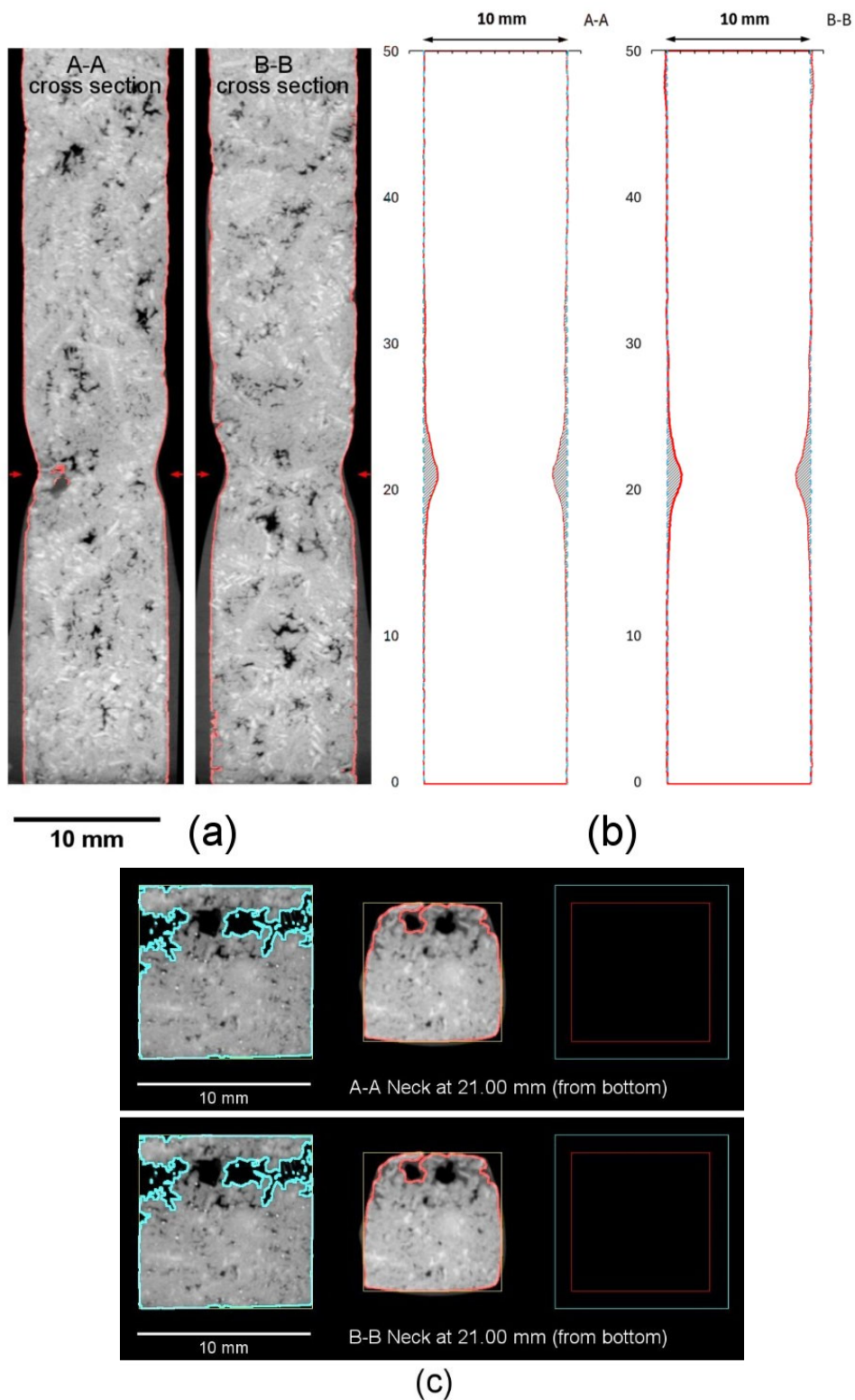


Figure B.10. Micro-CT results of the K-3 refractory corrosion test, HS24-05_1200C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

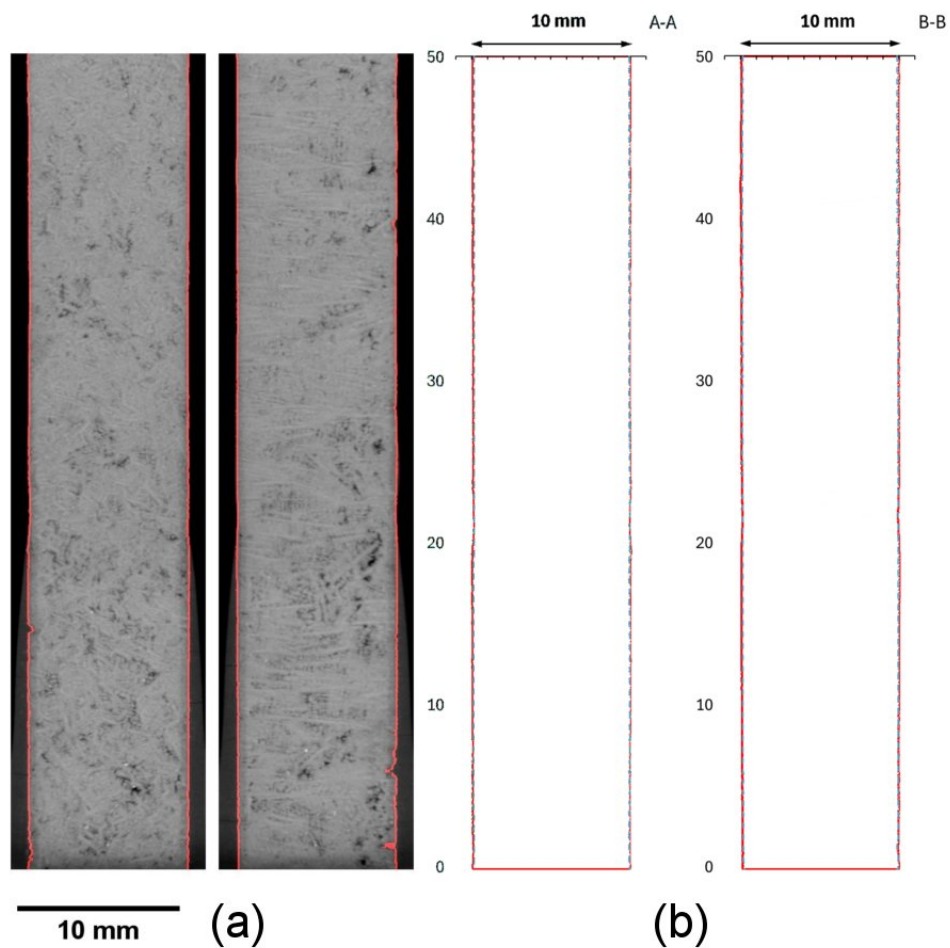


Figure B.11. Micro-CT results of the K-3 refractory corrosion test, HS24-06_1150C-7d. (a) Micro-CT images of the cross section at the center. (b) Corrosion depth plots, no distinguishable neck.

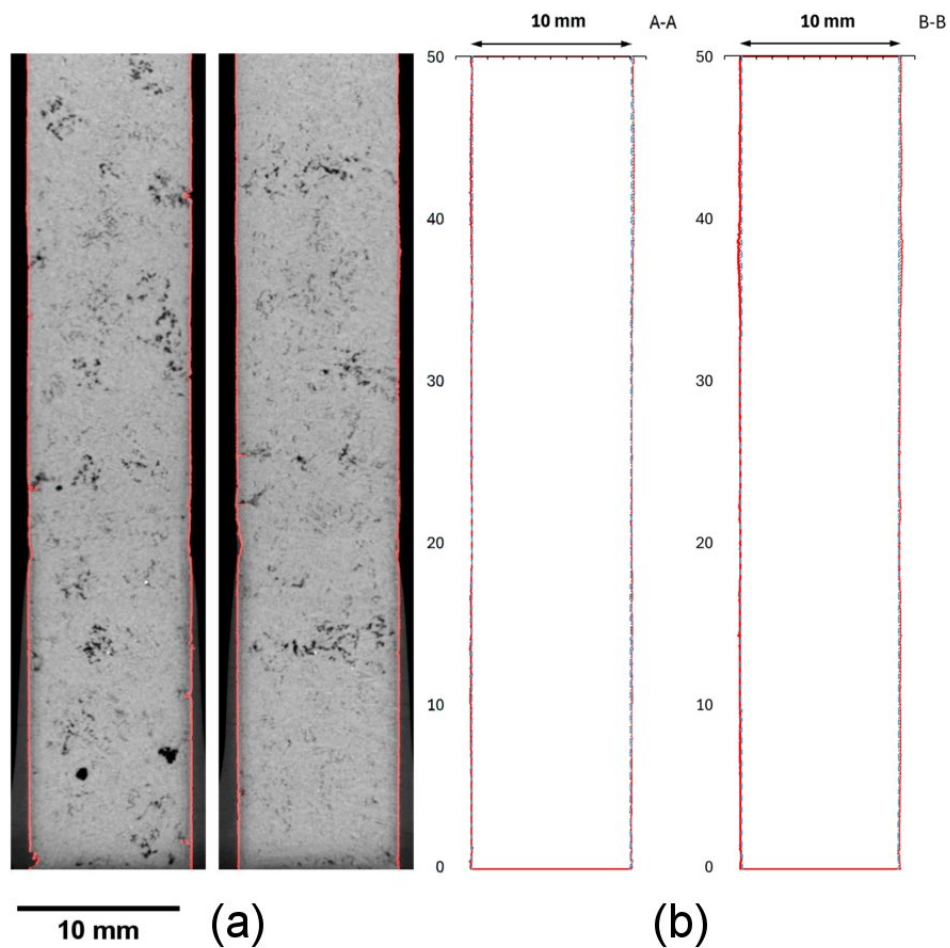


Figure B.12. Micro-CT results of the K-3 refractory corrosion test, HS24-06_1200C-7d. (a) Micro-CT images of the cross section at the center. (b) Corrosion depth plots, no distinguishable neck.

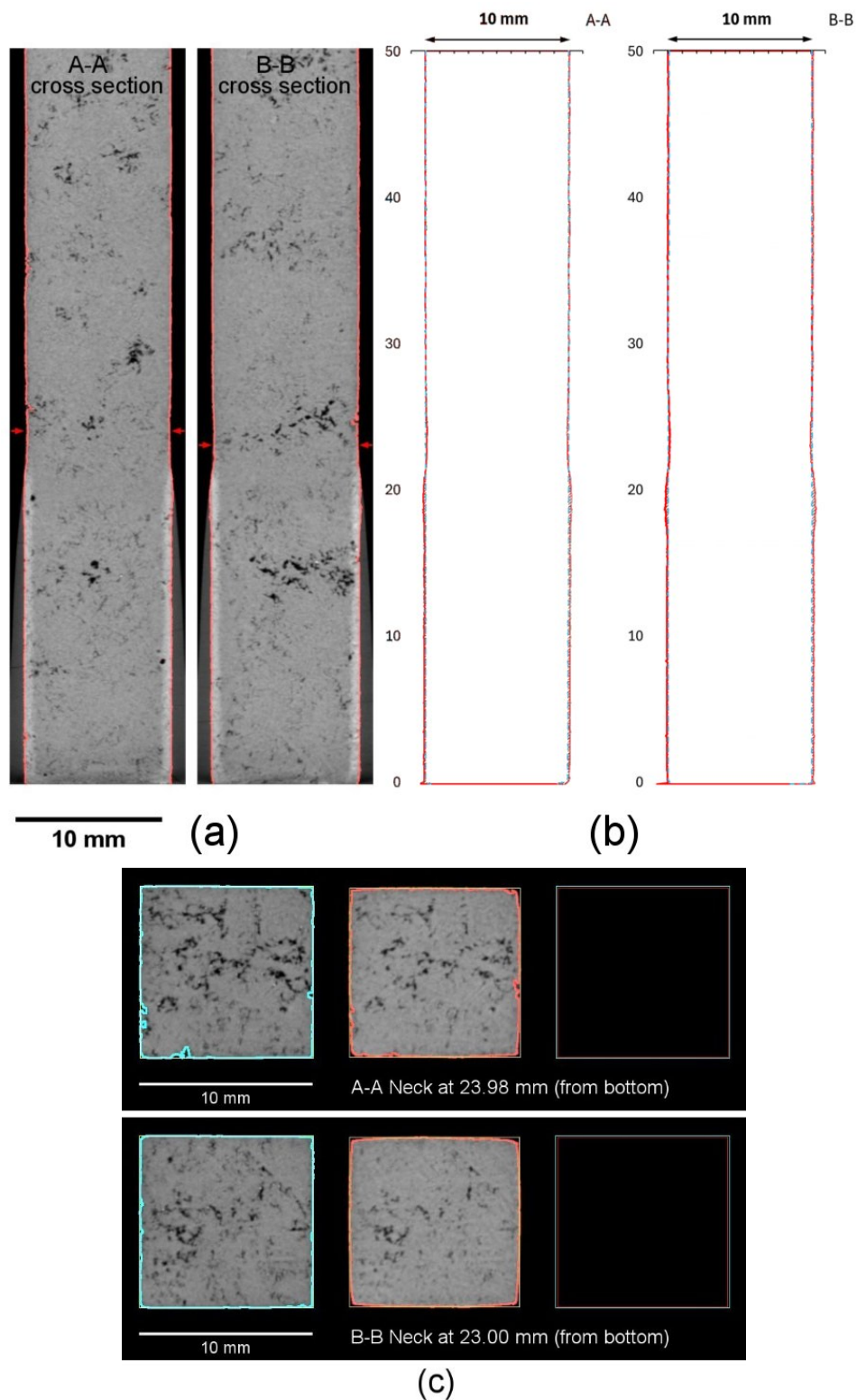


Figure B.13. Micro-CT results of the K-3 refractory corrosion test, HS24-07_1150C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

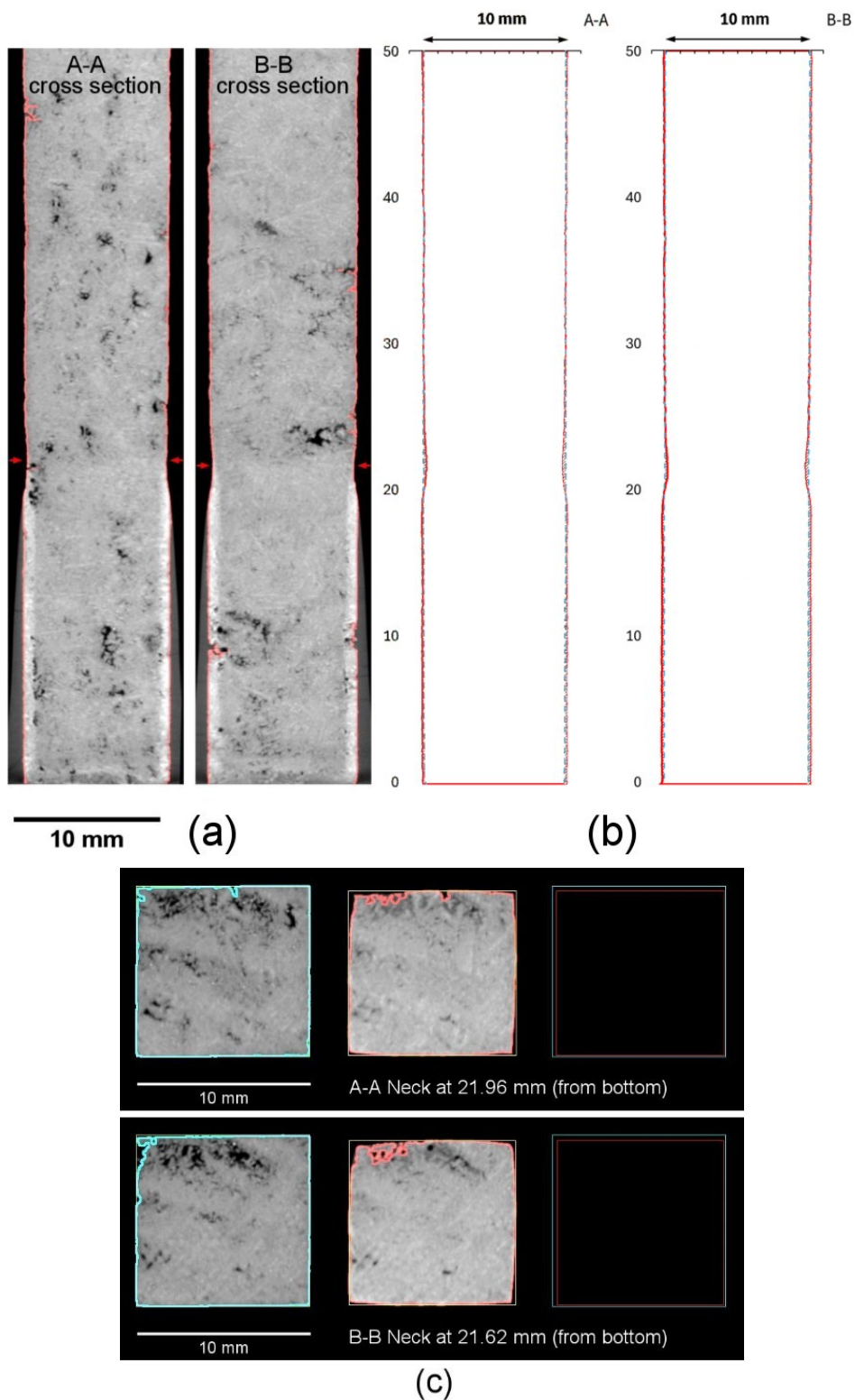


Figure B.14. Micro-CT results of the K-3 refractory corrosion test, HS24-07_1200C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

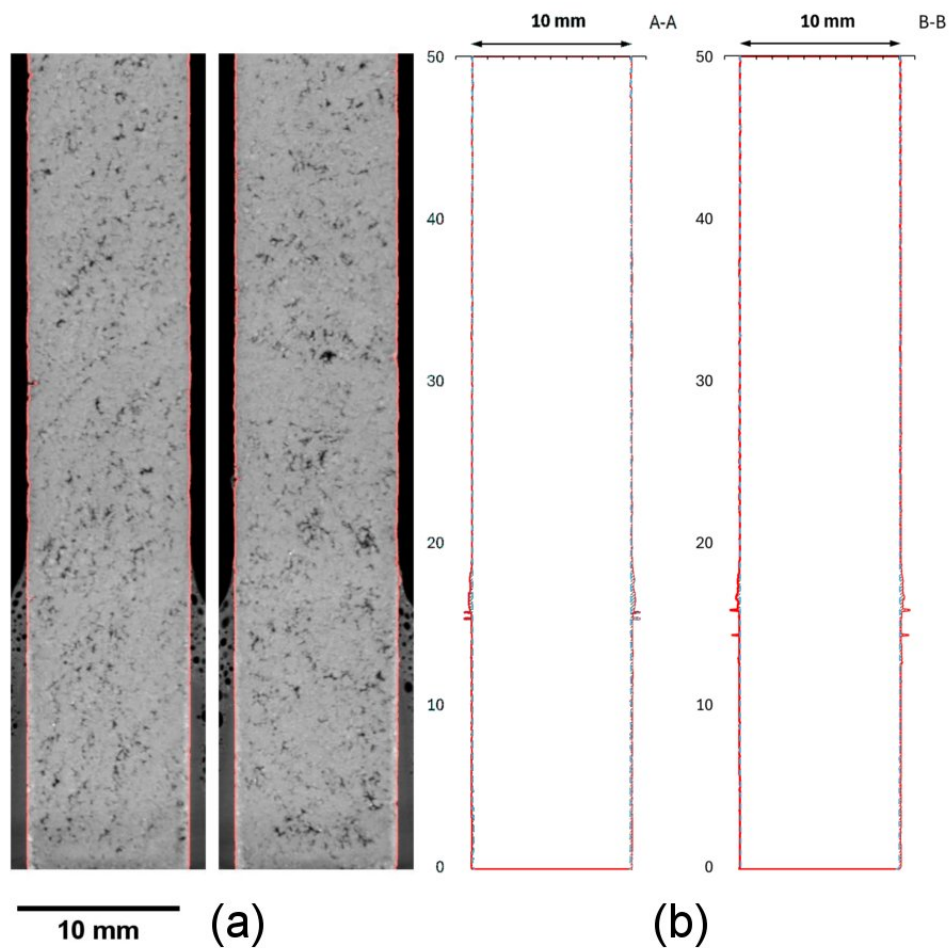


Figure B.15. Micro-CT results of the K-3 refractory corrosion test, HS24-08_1150C-7d. (a) Micro-CT images of the cross section at the center. (b) Corrosion depth plots, no distinguishable neck.

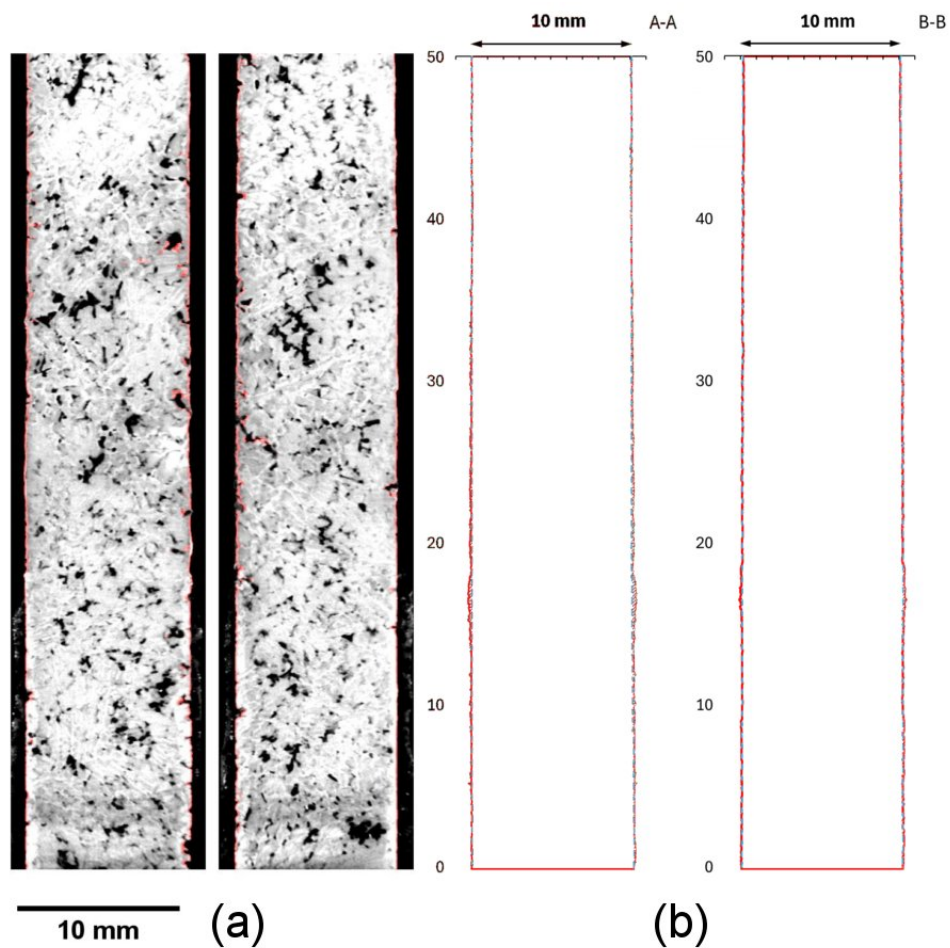


Figure B.16. Micro-CT results of the K-3 refractory corrosion test, HS24-08_1200C-7d. (a) Micro-CT images of the cross section at the center. (b) Corrosion depth plots, no distinguishable neck.

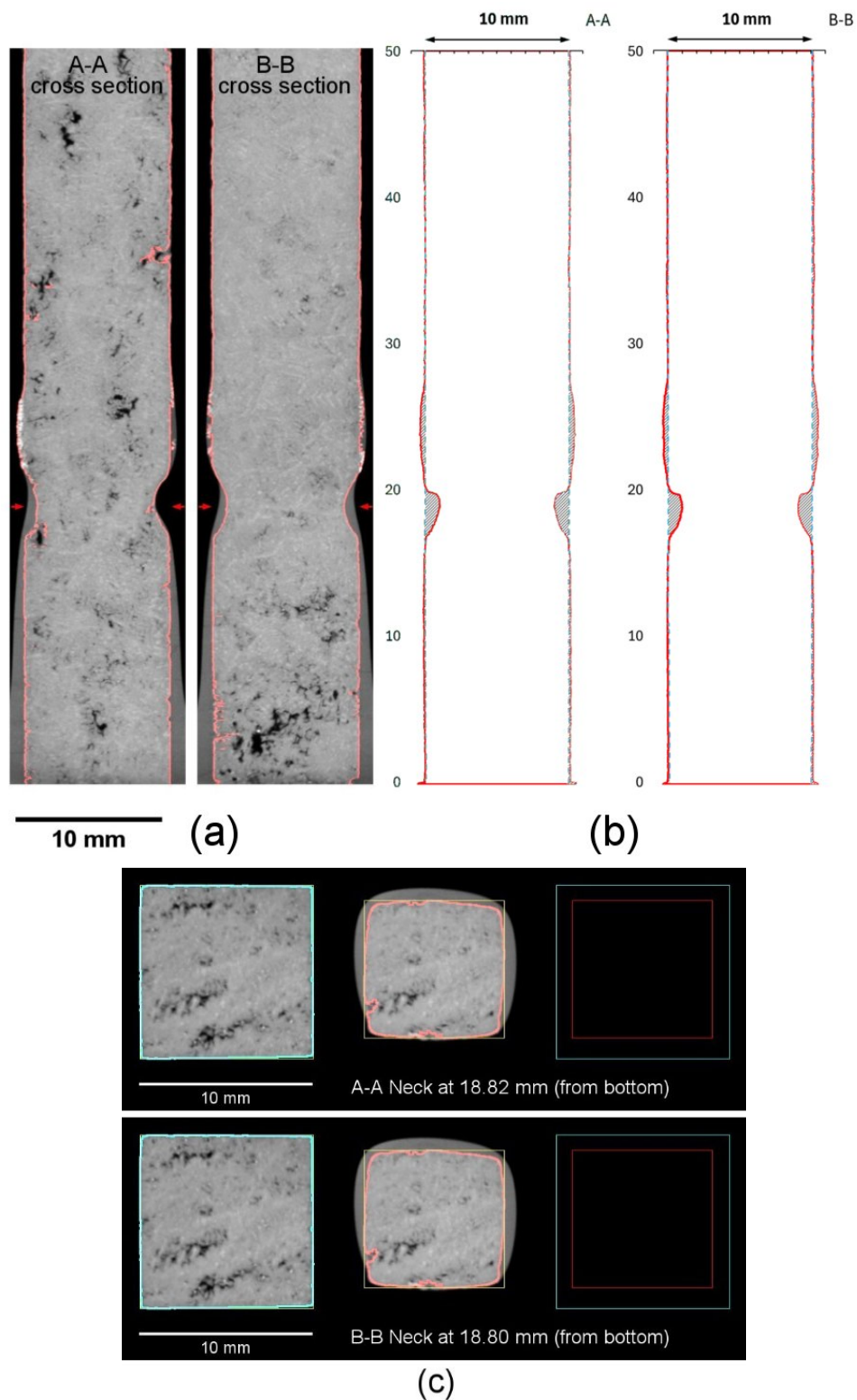


Figure B.17. Micro-CT results of the K-3 refractory corrosion test, HS24-09_1150C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

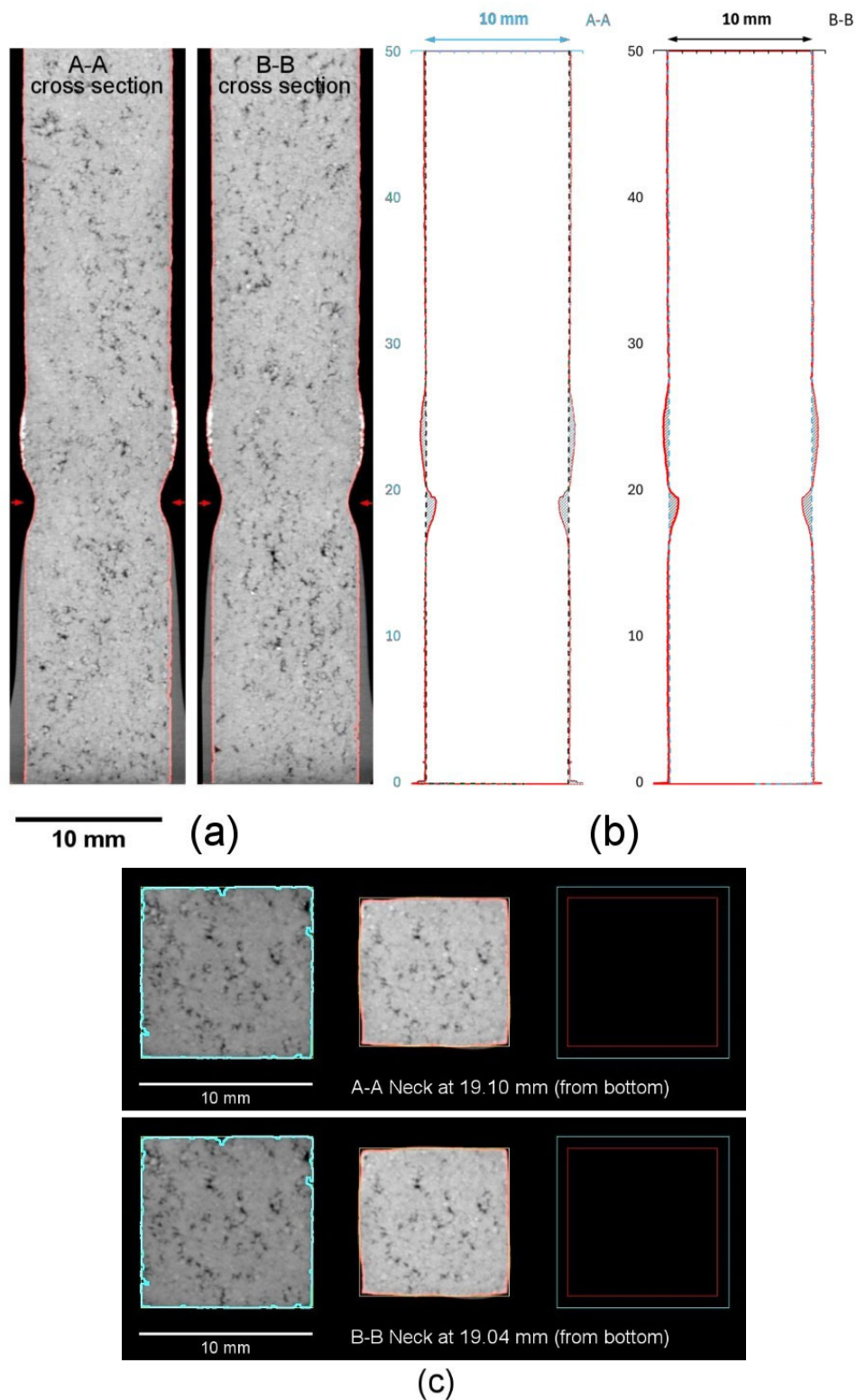


Figure B.18. Micro-CT results of the K-3 refractory corrosion test, HS24-09_1200C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

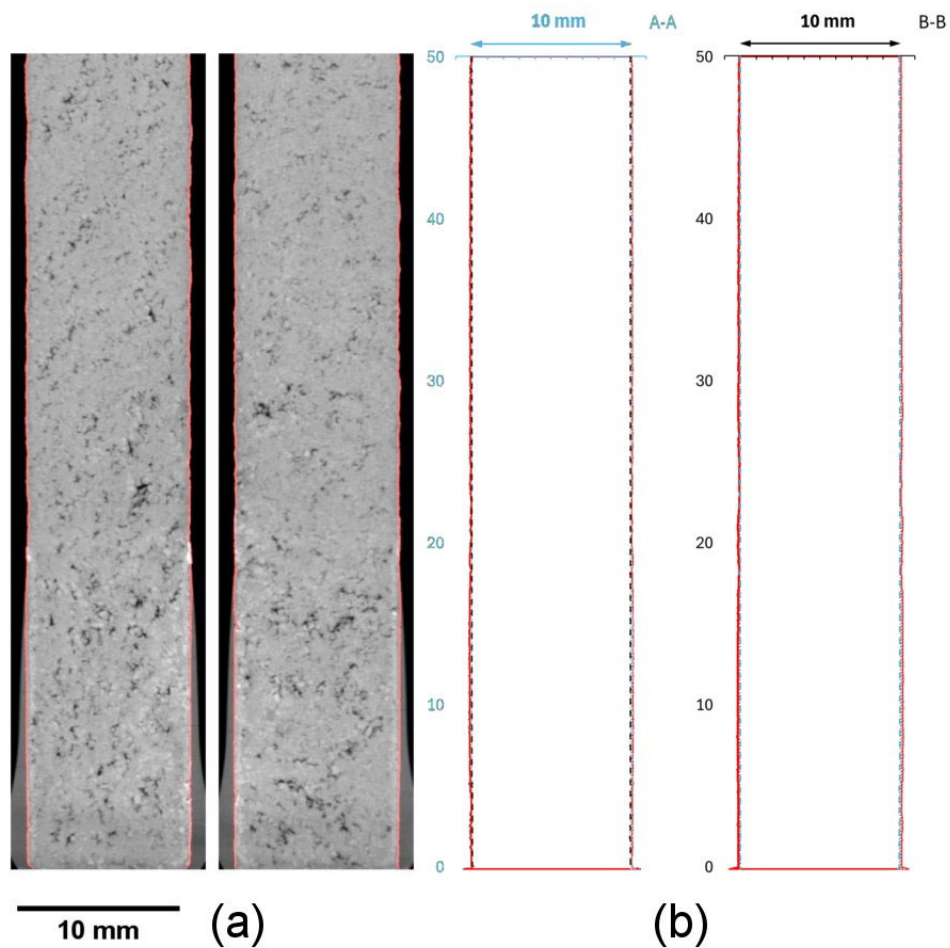


Figure B.19. Micro-CT results of the K-3 refractory corrosion test, HS24-10_1150C-7d. (a) Micro-CT images of the cross section at the center. (b) Corrosion depth plots, no distinguishable neck.

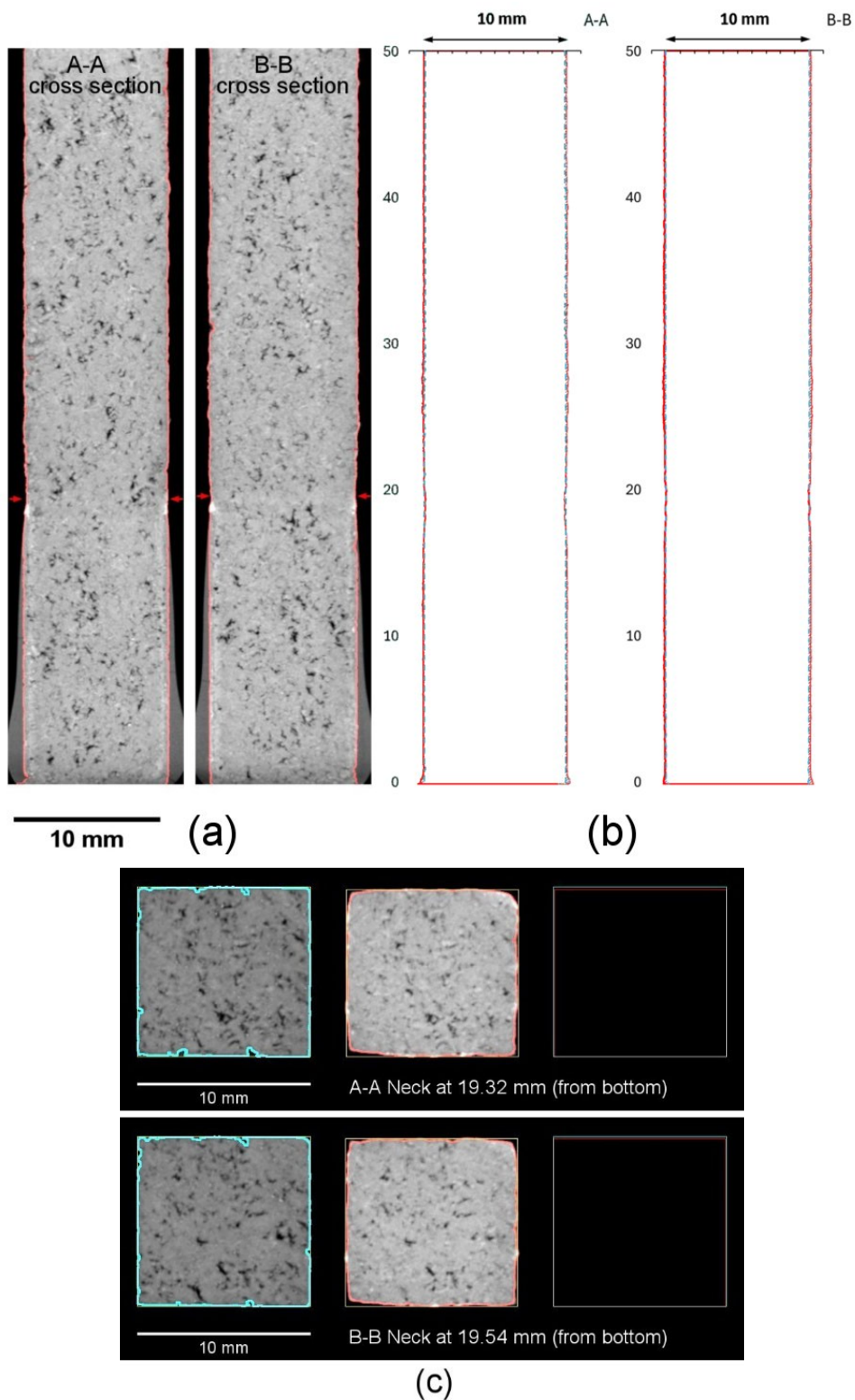


Figure B.20. Micro-CT results of the K-3 refractory corrosion test, HS24-10_1200C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

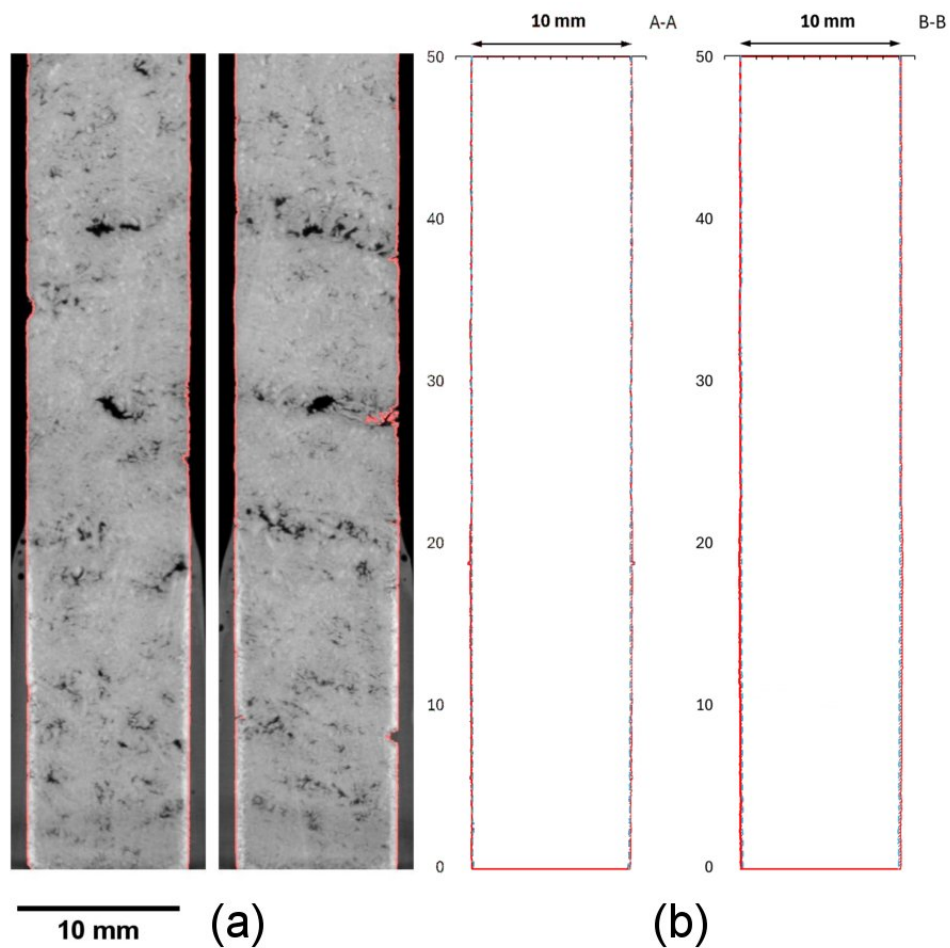


Figure B.21. Micro-CT results of the K-3 refractory corrosion test, HS24-11_1150C-7d. (a) Micro-CT images of the cross section at the center. (b) Corrosion depth plots, no distinguishable neck.

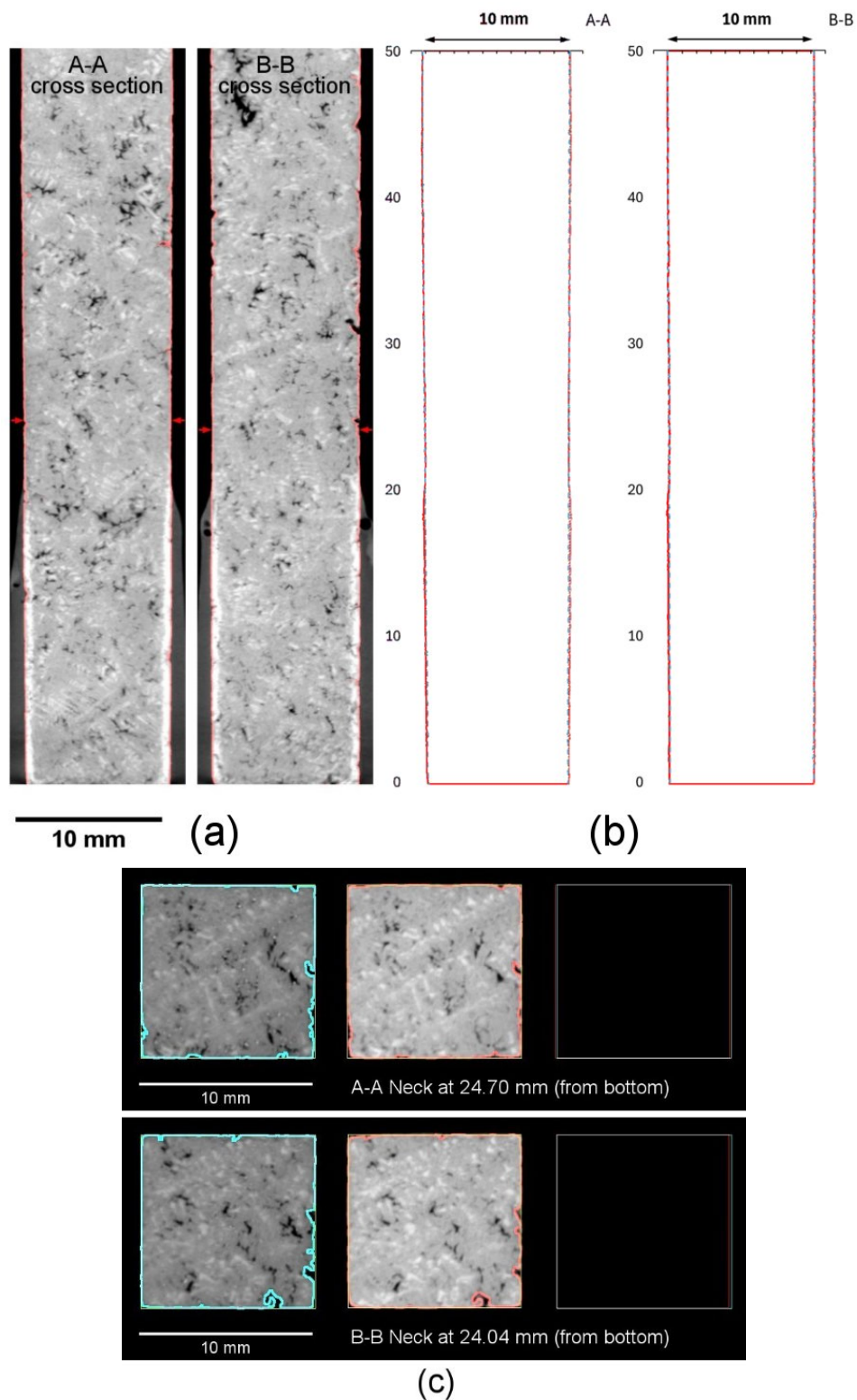


Figure B.22. Micro-CT results of the K-3 refractory corrosion test, HS24-11_1200C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

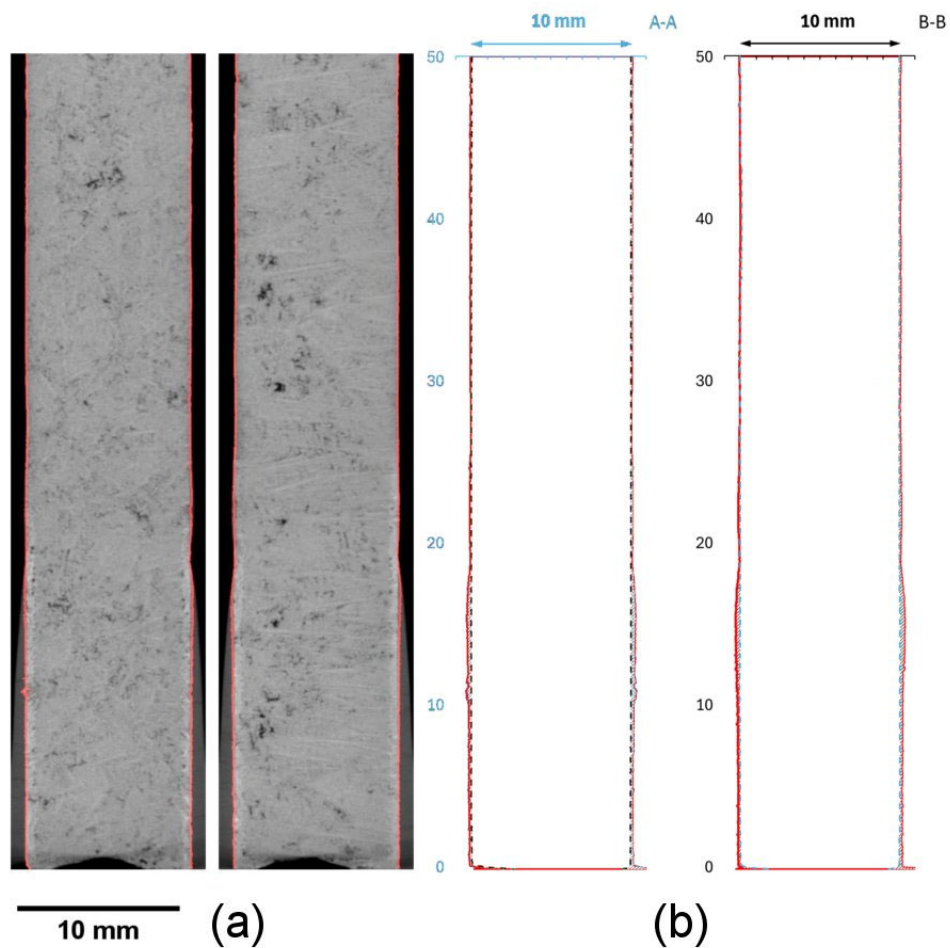


Figure B.23. Micro-CT results of the K-3 refractory corrosion test, HS24-12_1150C-7d. (a) Micro-CT images of the cross section at the center. (b) Corrosion depth plots, no distinguishable neck.

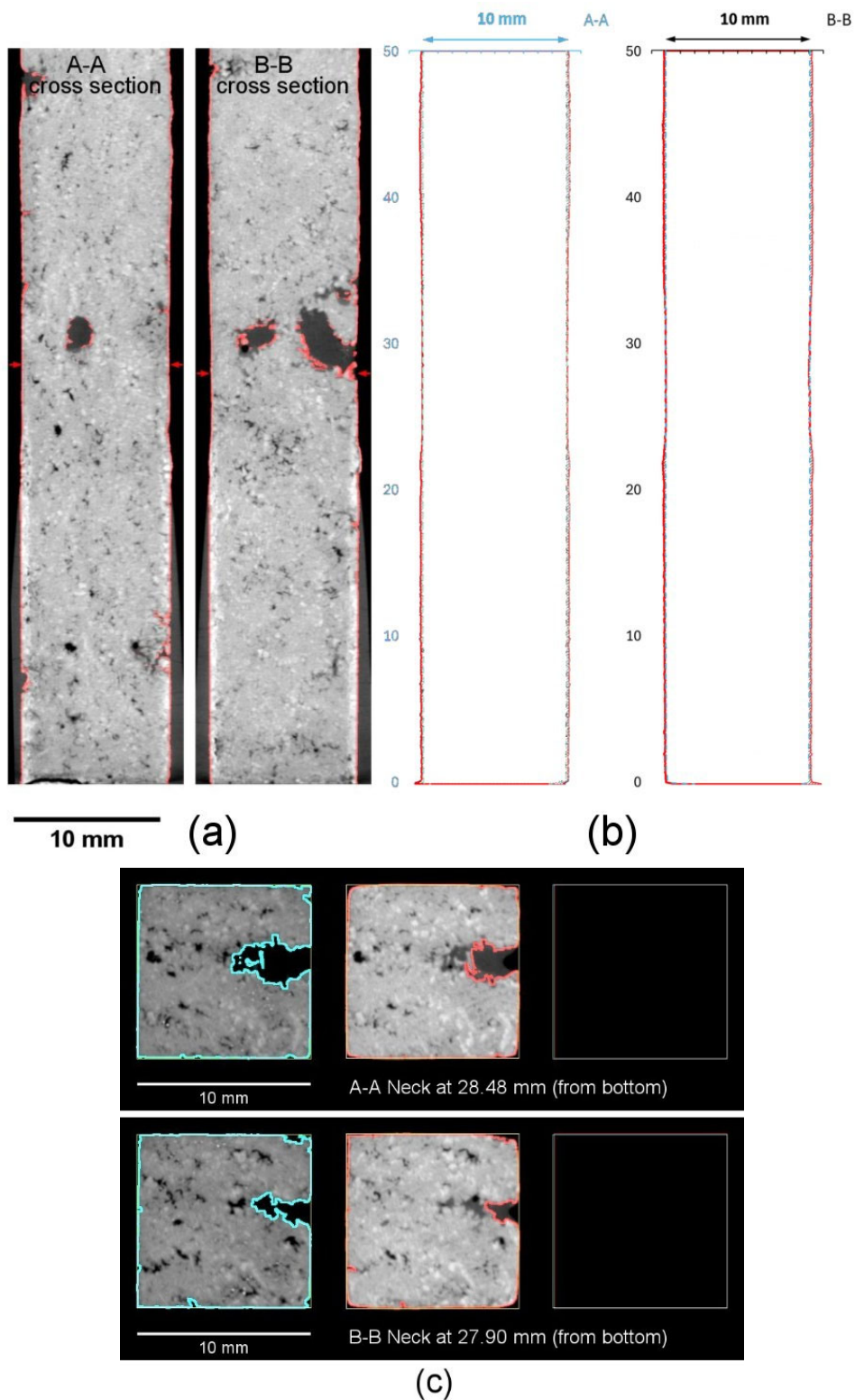


Figure B.24. Micro-CT results of the K-3 refractory corrosion test, HS24-12_1200C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

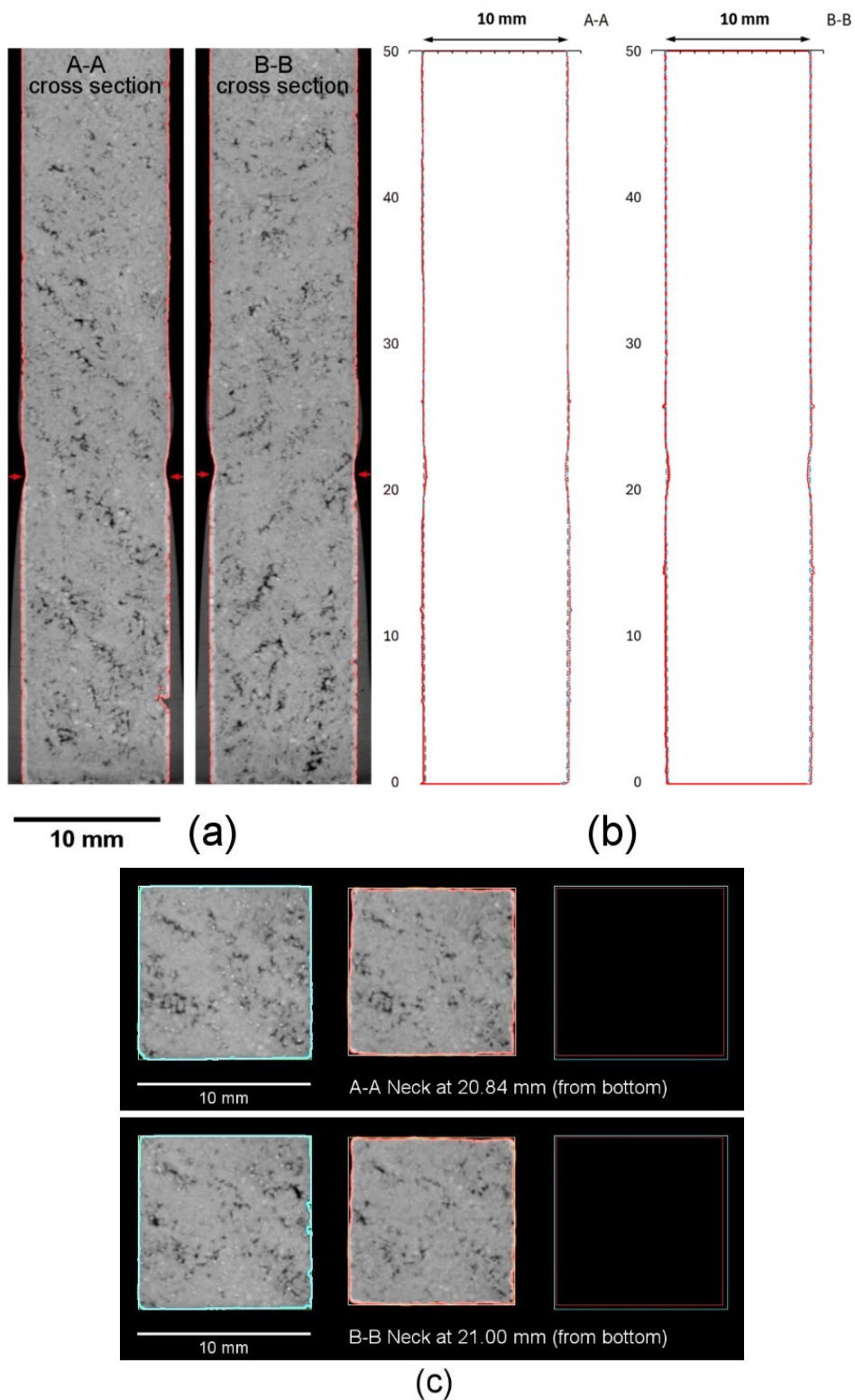


Figure B.25. Micro-CT results of the K-3 refractory corrosion test, HS24-13_1150C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

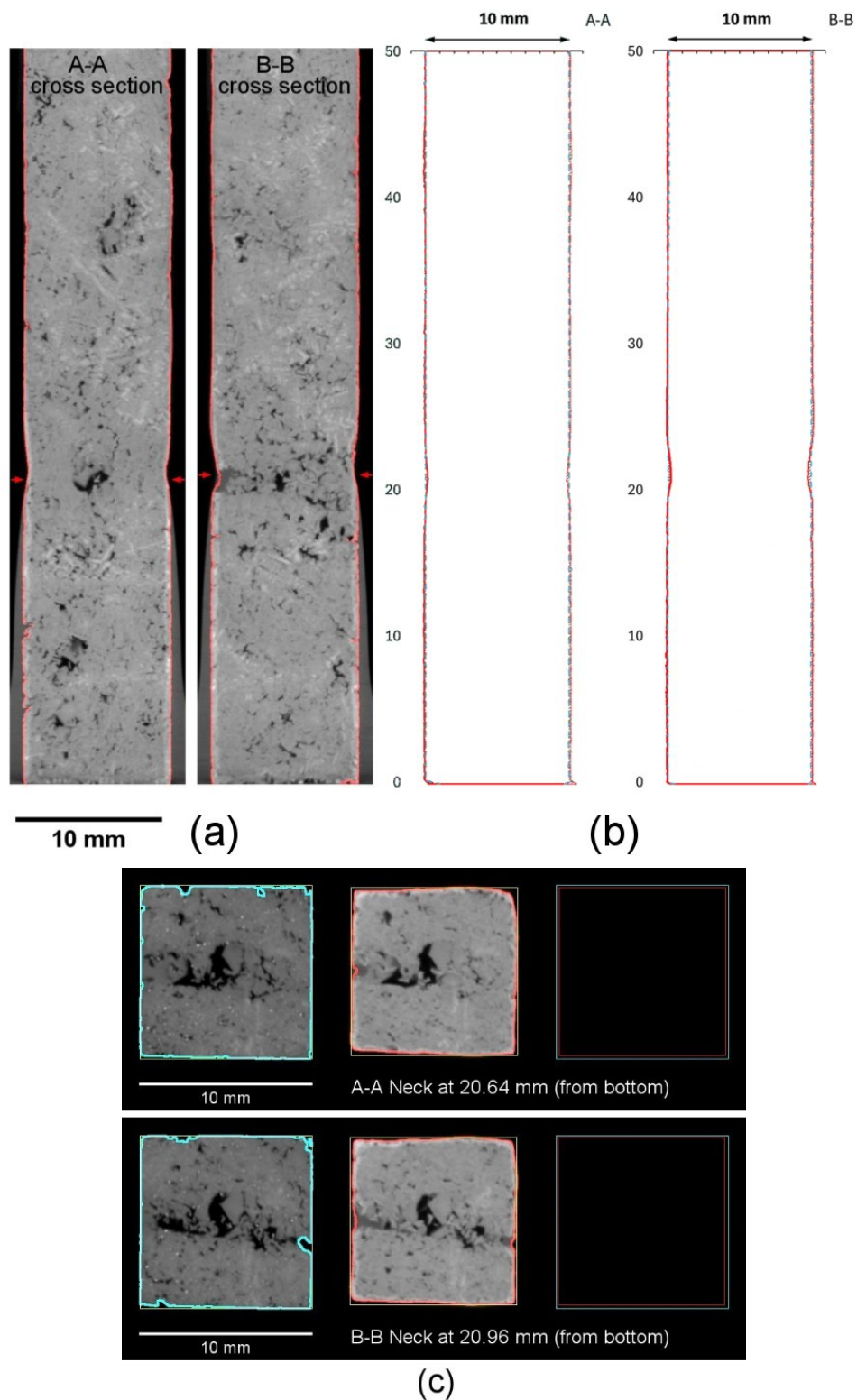


Figure B.26. Micro-CT results of the K-3 refractory corrosion test, HS24-13_1200C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

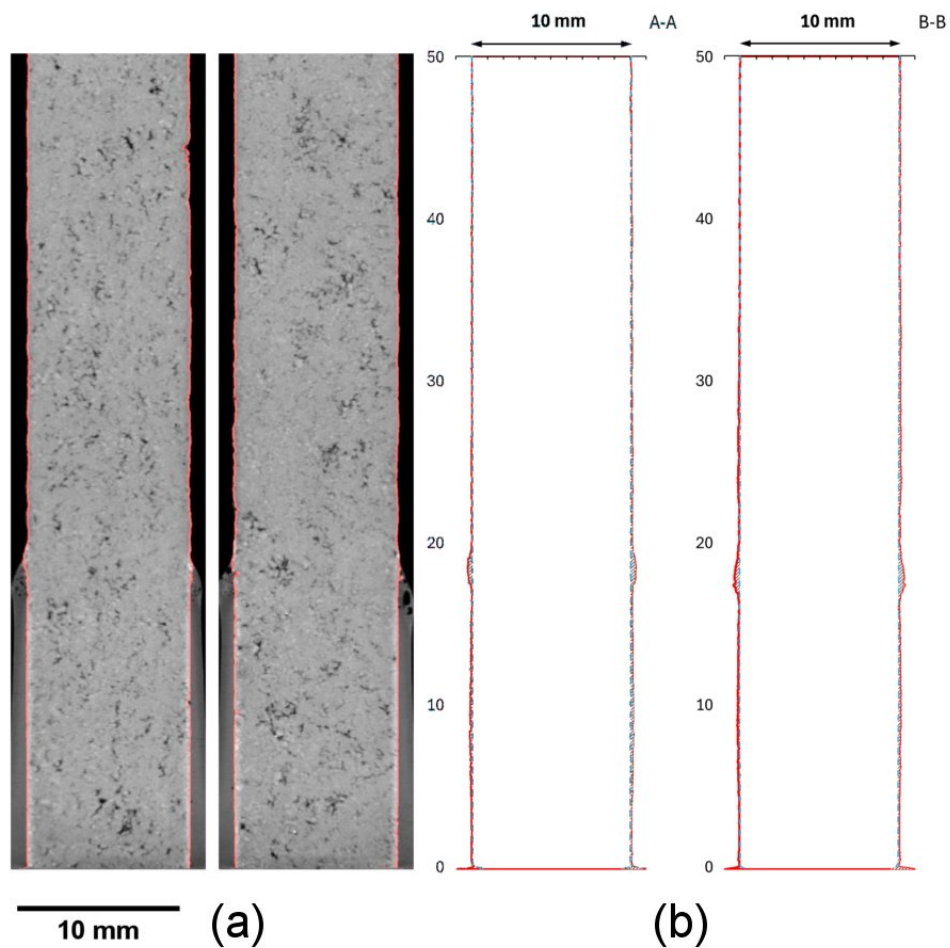


Figure B.27. Micro-CT results of the K-3 refractory corrosion test, HS24-14_1150C-7d. (a) Micro-CT images of the cross section at the center. (b) Corrosion depth plots, no distinguishable neck.

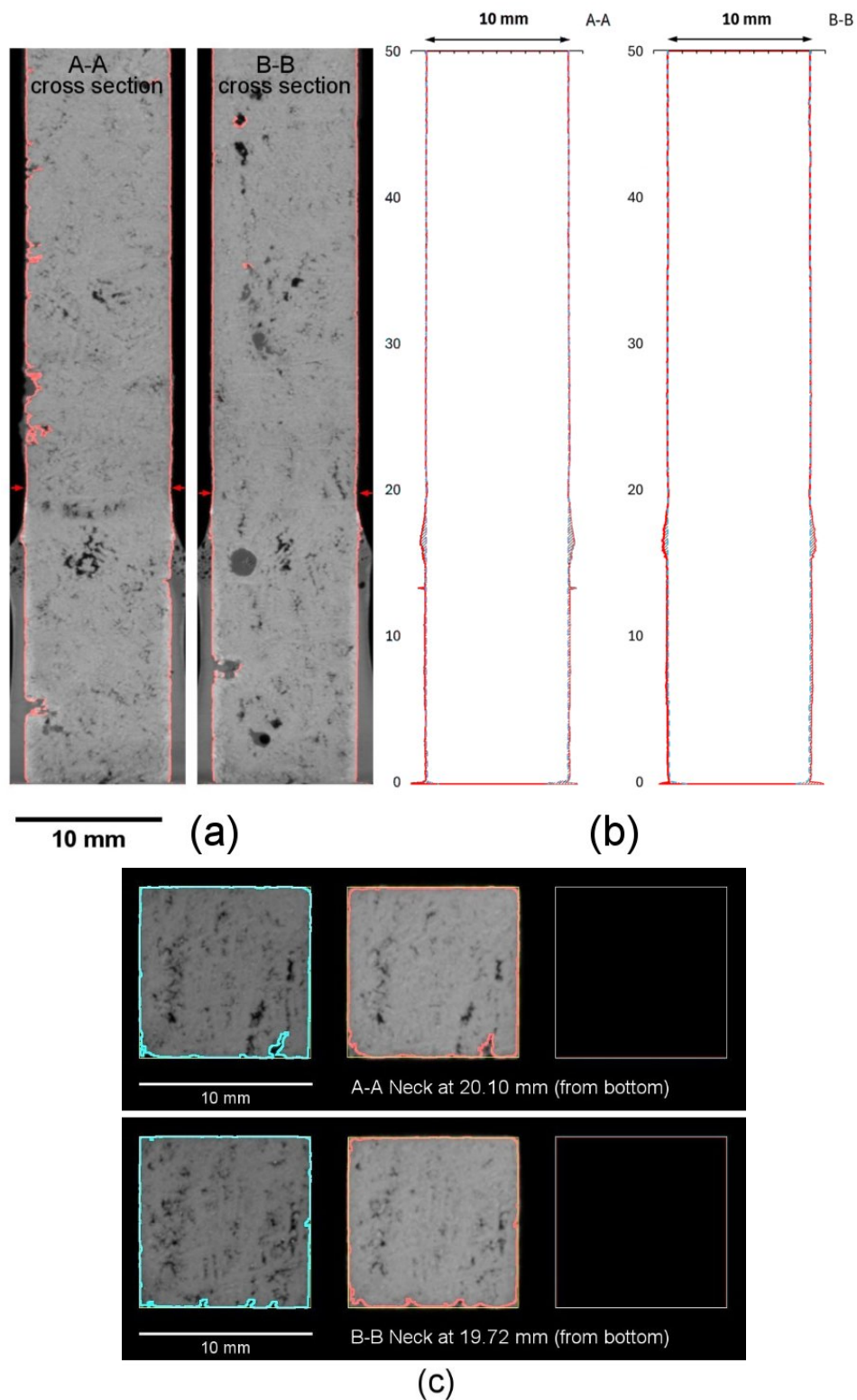


Figure B.28. Micro-CT results of the K-3 refractory corrosion test, HS24-14_1200C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

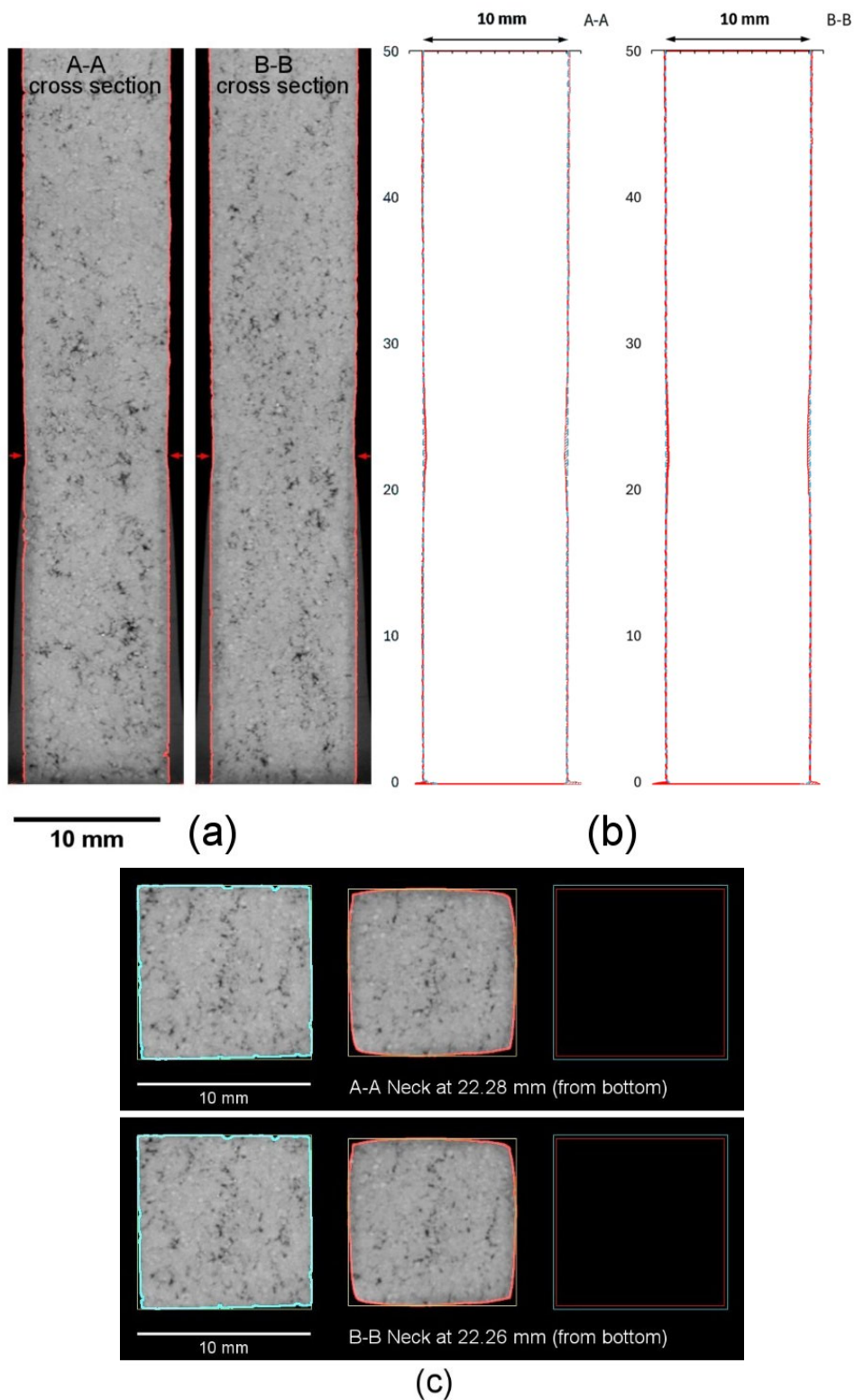


Figure B.29. Micro-CT results of the K-3 refractory corrosion test, HS24-15_1150C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

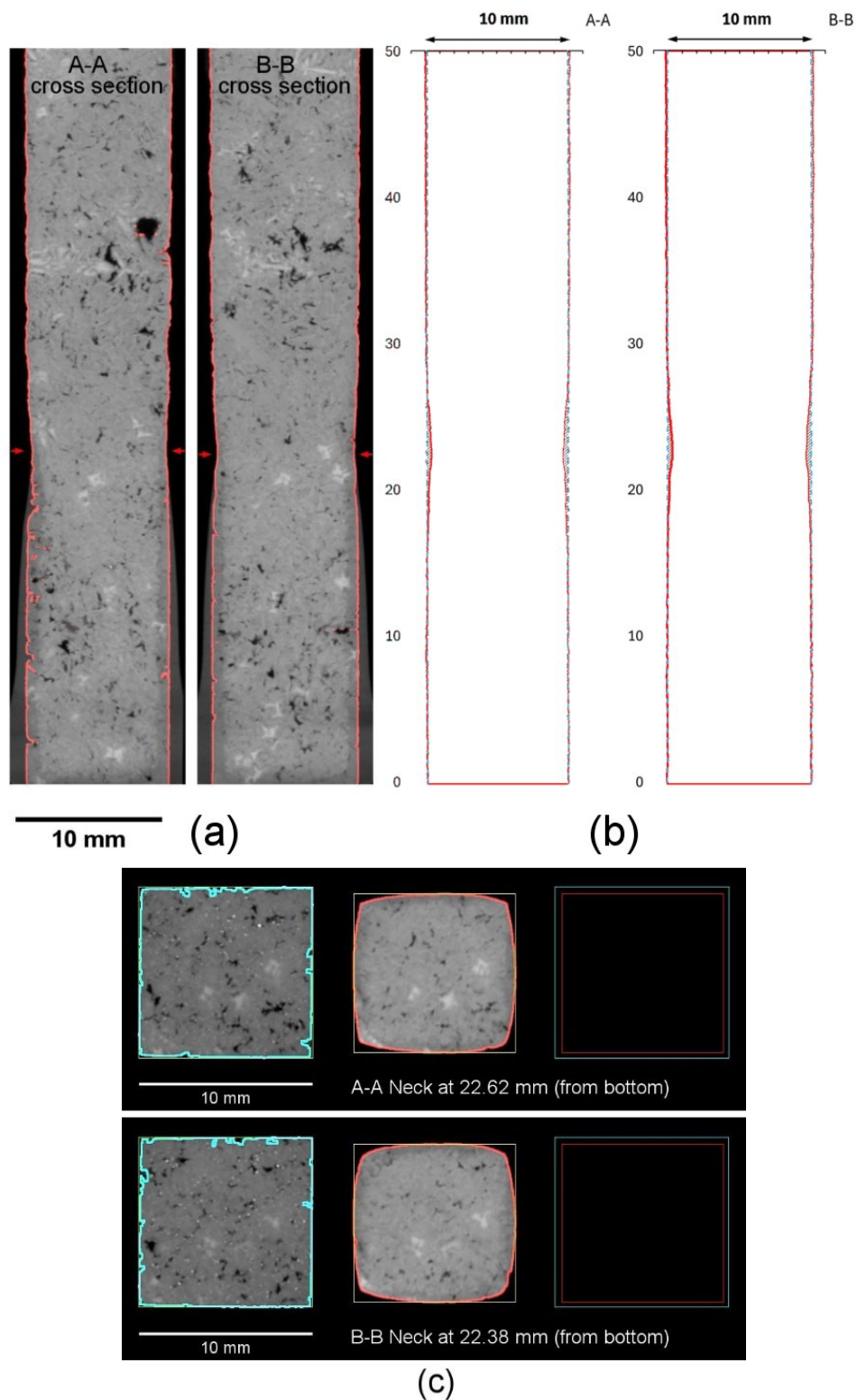


Figure B.30. Micro-CT results of the K-3 refractory corrosion test, HS24-15_1200C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

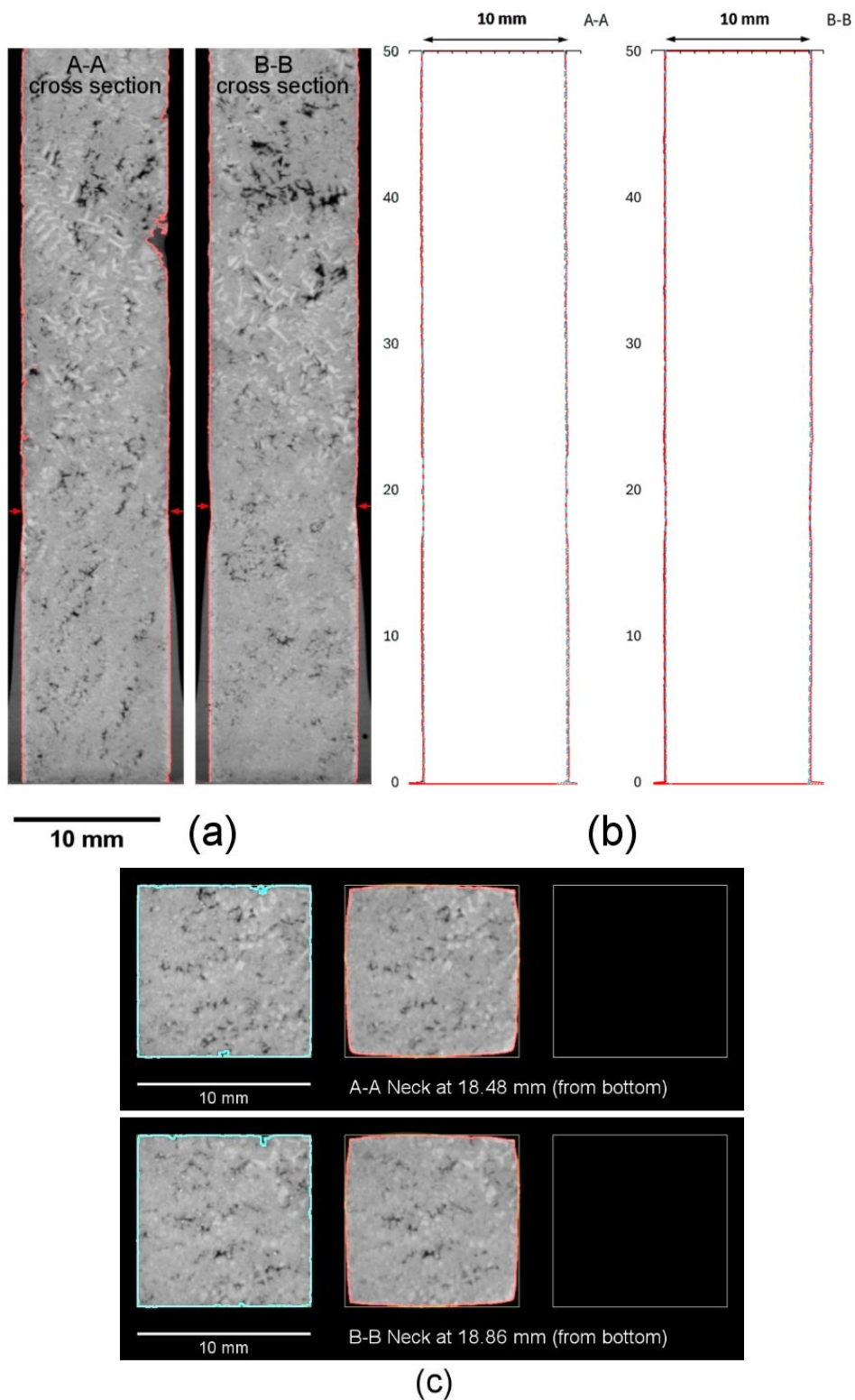


Figure B.31. Micro-CT results of the K-3 refractory corrosion test, HS24-16_1150C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

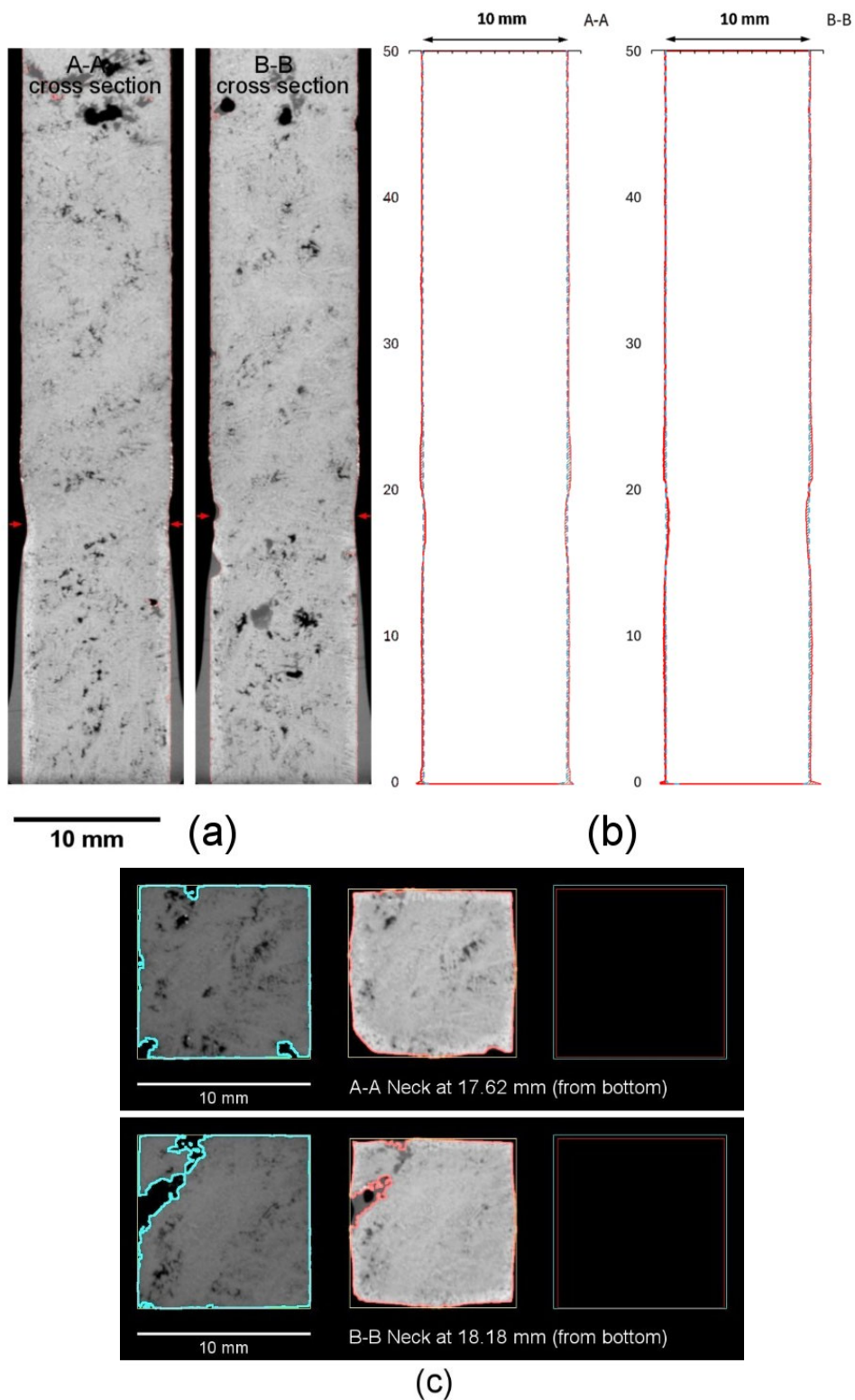


Figure B.32. Micro-CT results of the K-3 refractory corrosion test, HS24-16_1200C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

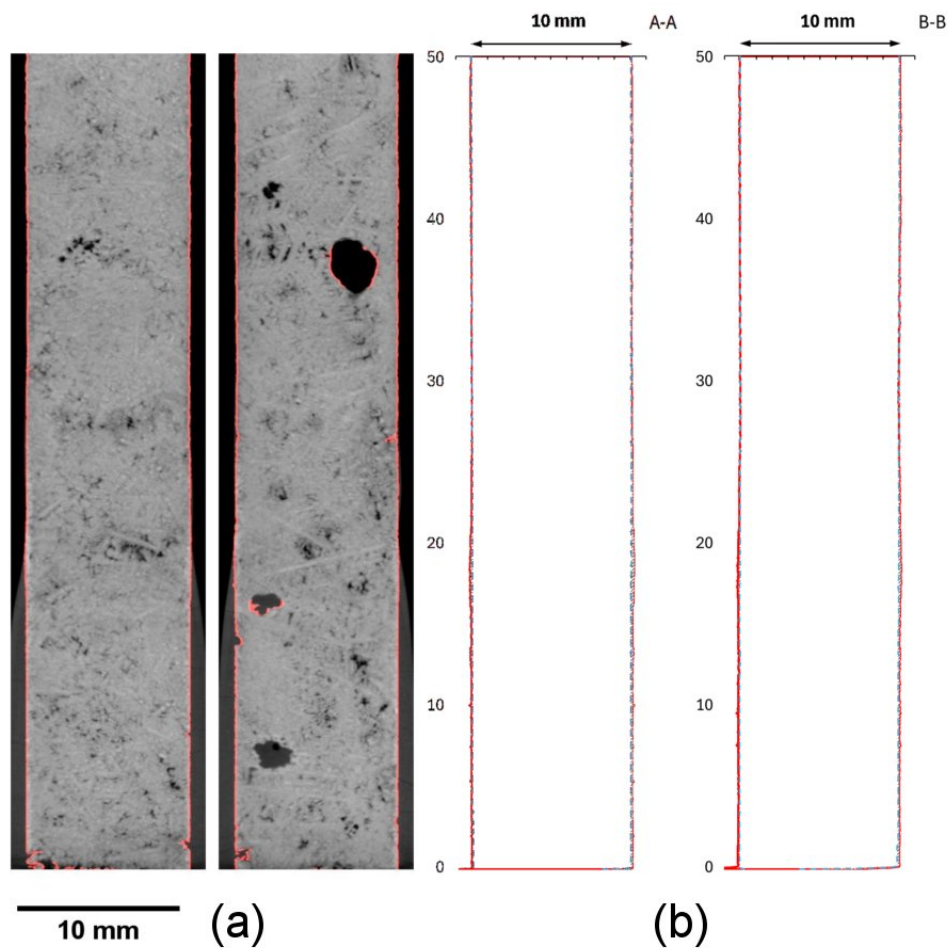


Figure B.33. Micro-CT results of the K-3 refractory corrosion test, HS24-17_1150C-7d. (a) Micro-CT images of the cross section at the center. (b) Corrosion depth plots, no distinguishable neck.

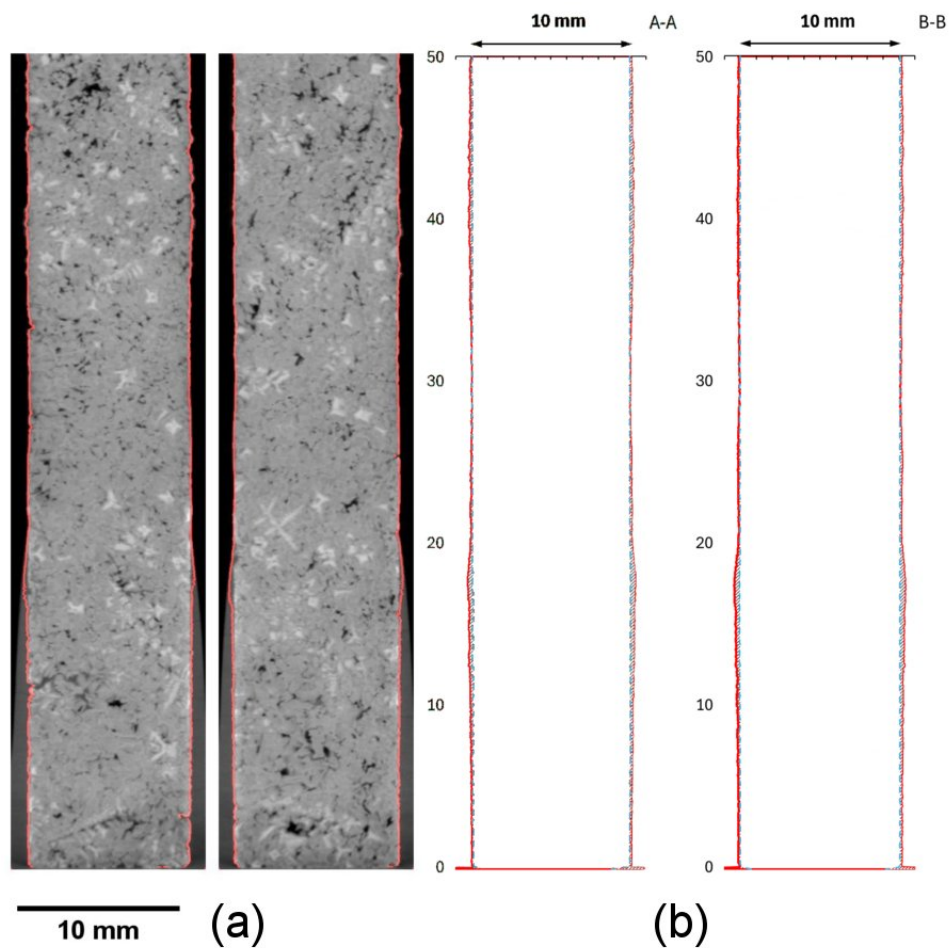


Figure B.34. Micro-CT results of the K-3 refractory corrosion test, HS24-17_1200C-7d. (a) Micro-CT images of the cross section at the center. (b) Corrosion depth plots, no distinguishable neck.

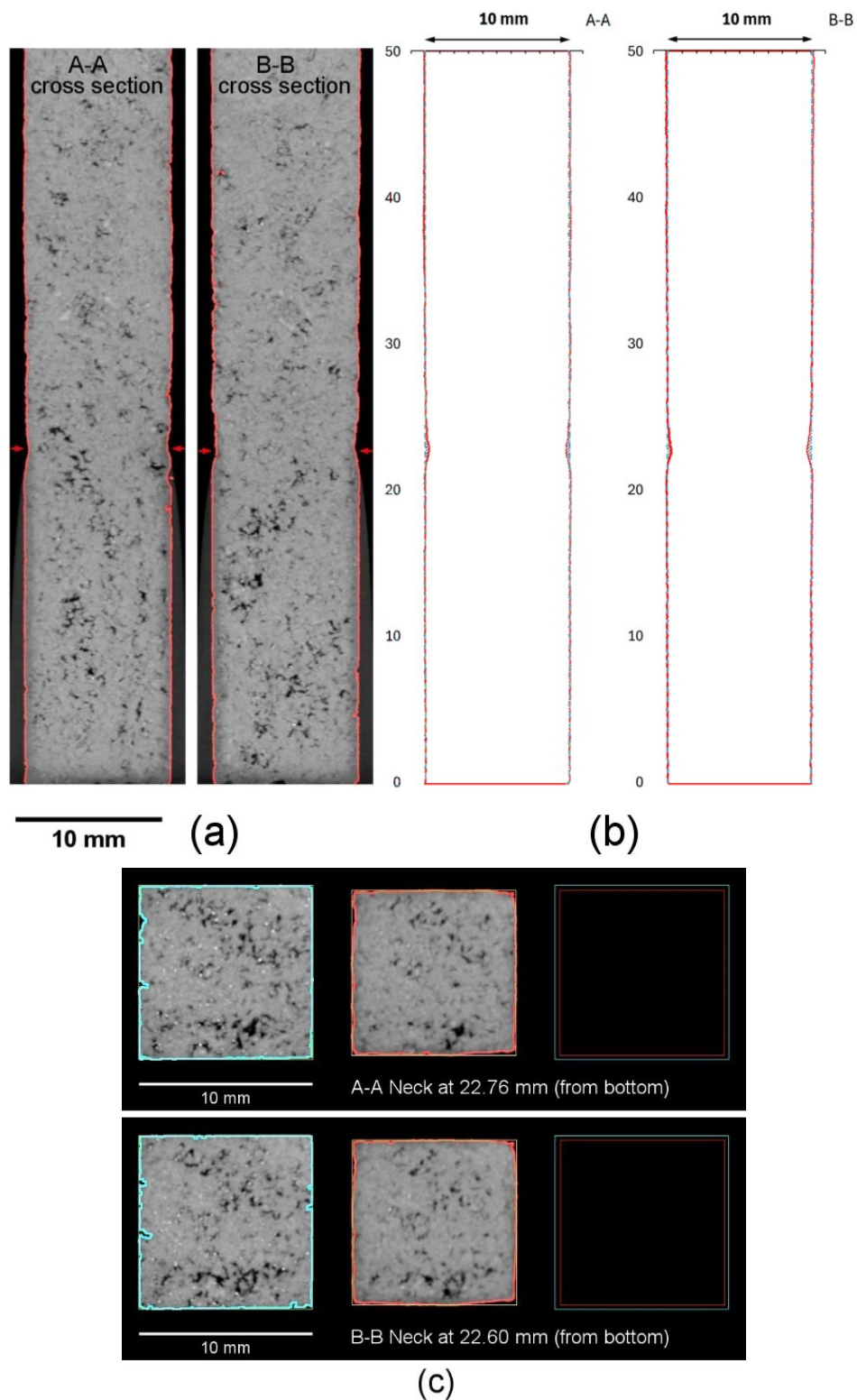


Figure B.35. Micro-CT results of the K-3 refractory corrosion test, HS24-18_1150C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

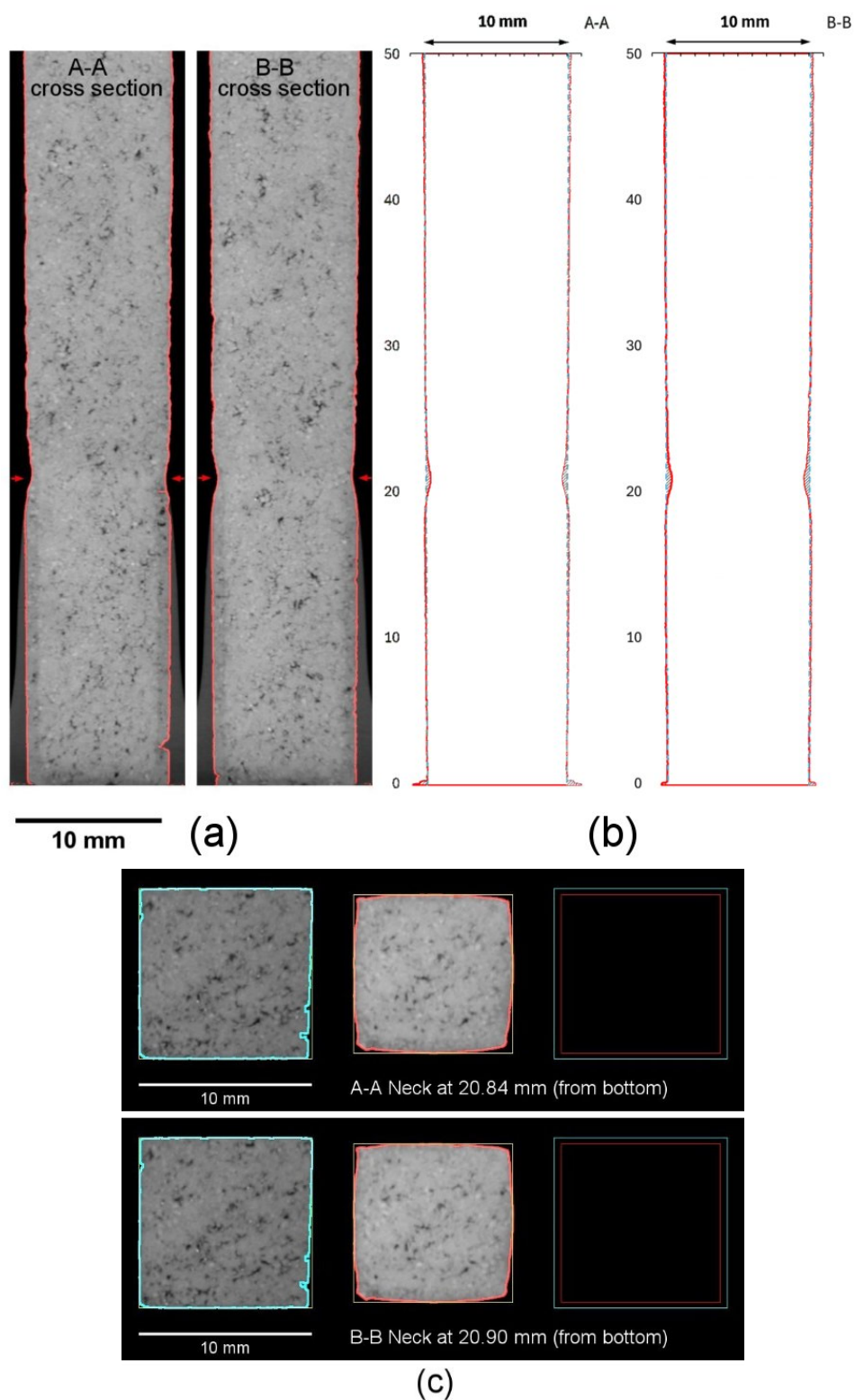


Figure B.36. Micro-CT results of the K-3 refractory corrosion test, HS24-18_1200C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

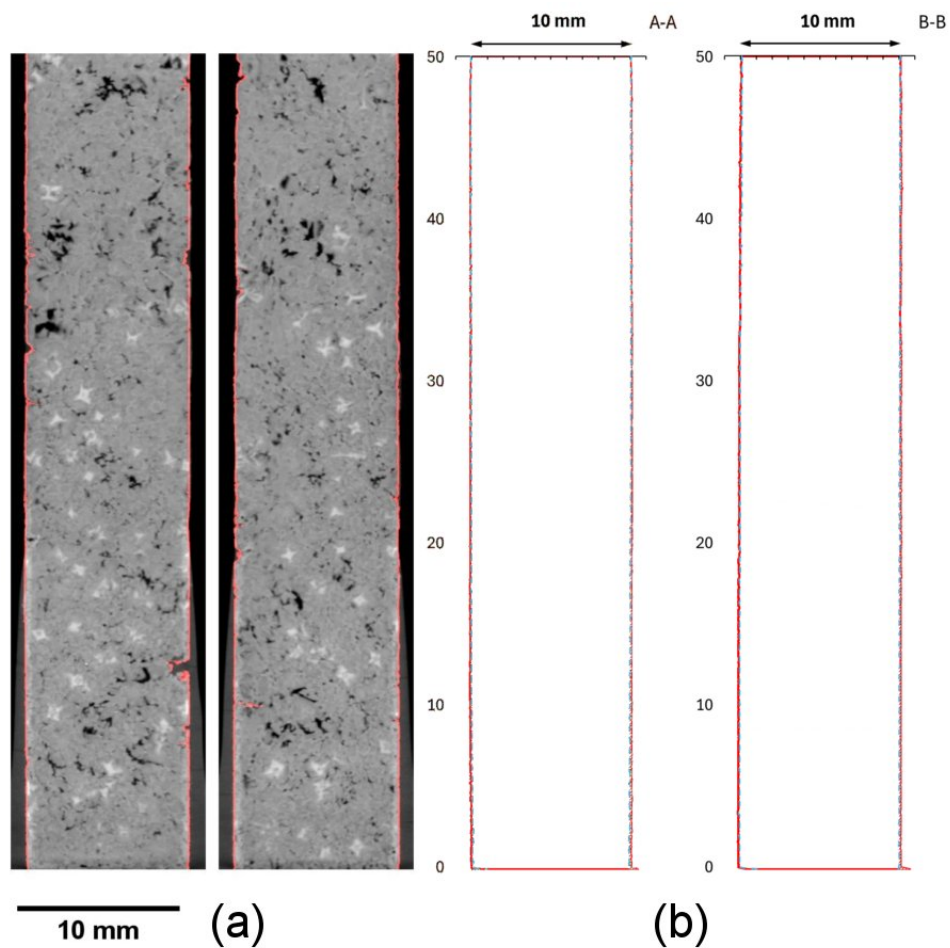


Figure B.37. Micro-CT results of the K-3 refractory corrosion test, HS24-19_1150C-7d. (a) Micro-CT images of the cross section at the center. (b) Corrosion depth plots, no distinguishable neck.

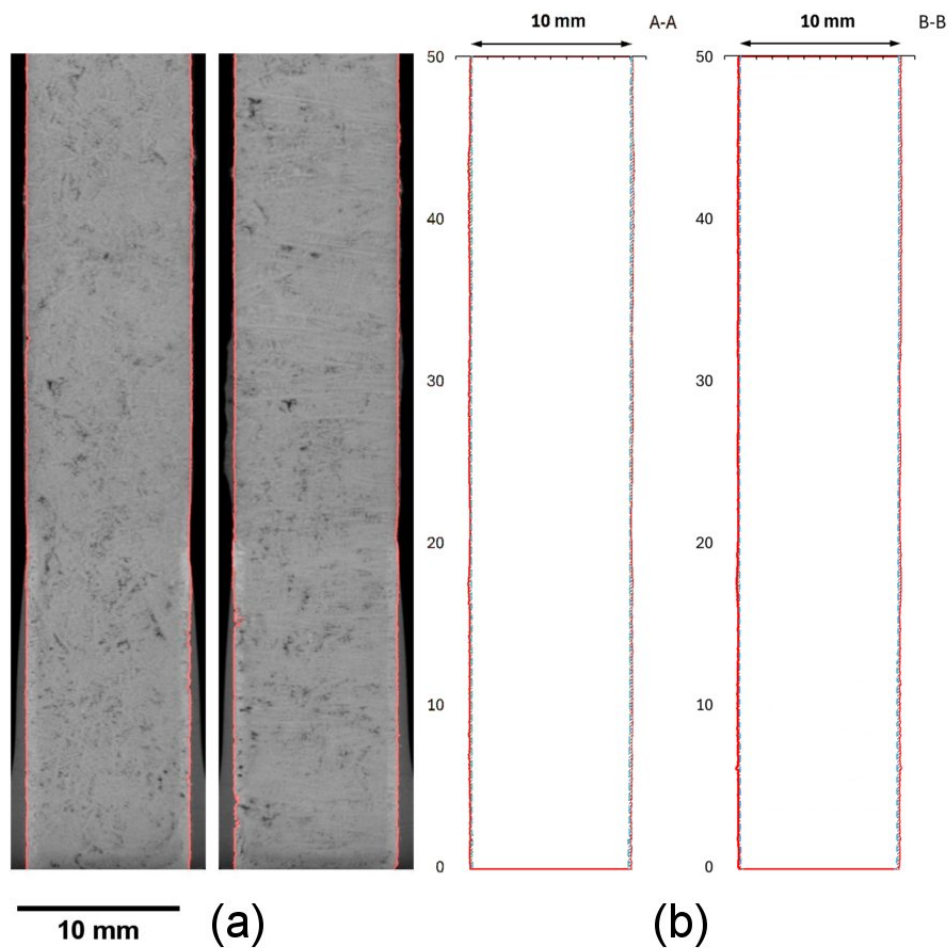


Figure B.38. Micro-CT results of the K-3 refractory corrosion test, HS24-19_1200C-7d. (a) Micro-CT images of the cross section at the center. (b) Corrosion depth plots, no distinguishable neck.

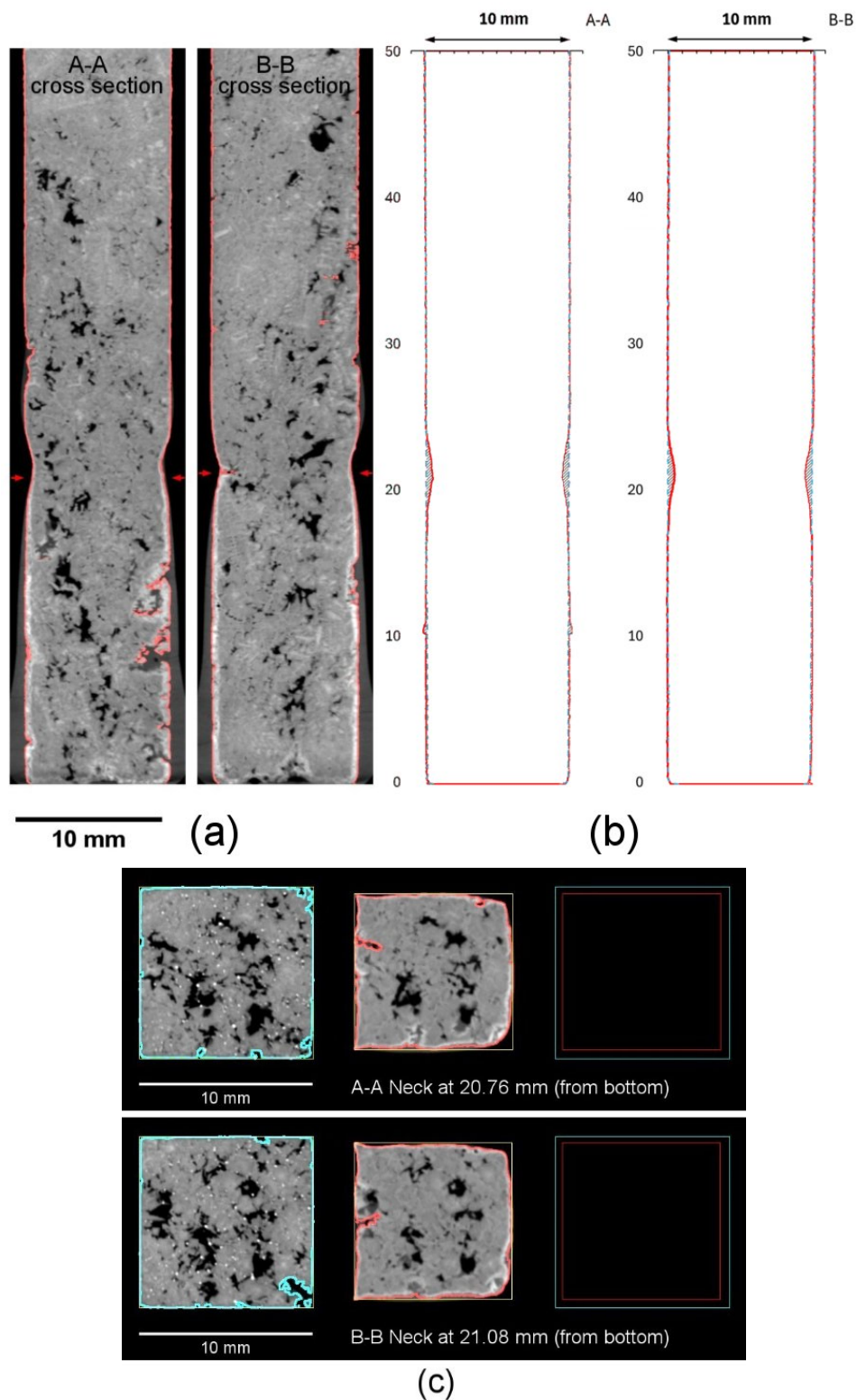


Figure B.39. Micro-CT results of the K-3 refractory corrosion test, HS24-20_1150C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

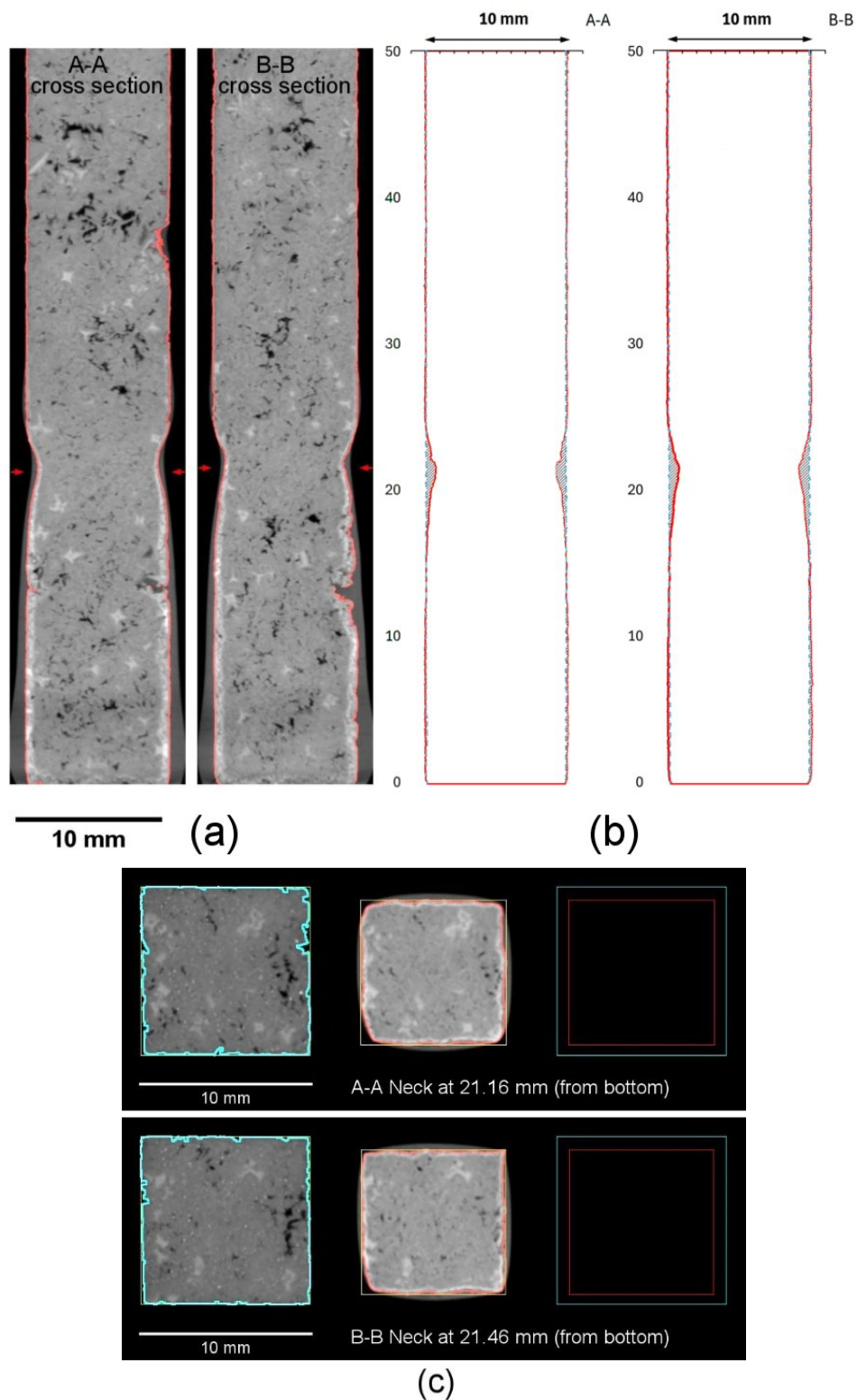


Figure B.40. Micro-CT results of the K-3 refractory corrosion test, HS24-20_1200C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

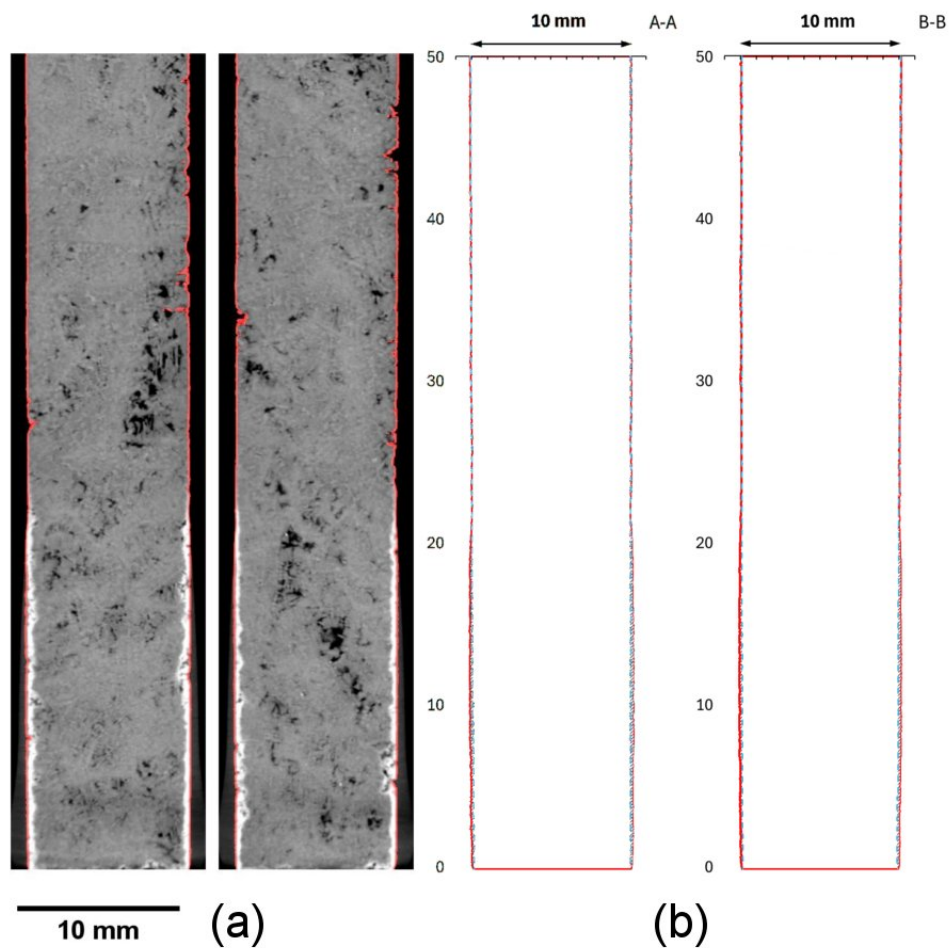


Figure B.41. Micro-CT results of the K-3 refractory corrosion test, HS24-21_1150C-7d. (a) Micro-CT images of the cross section at the center. (b) Corrosion depth plots, no distinguishable neck.

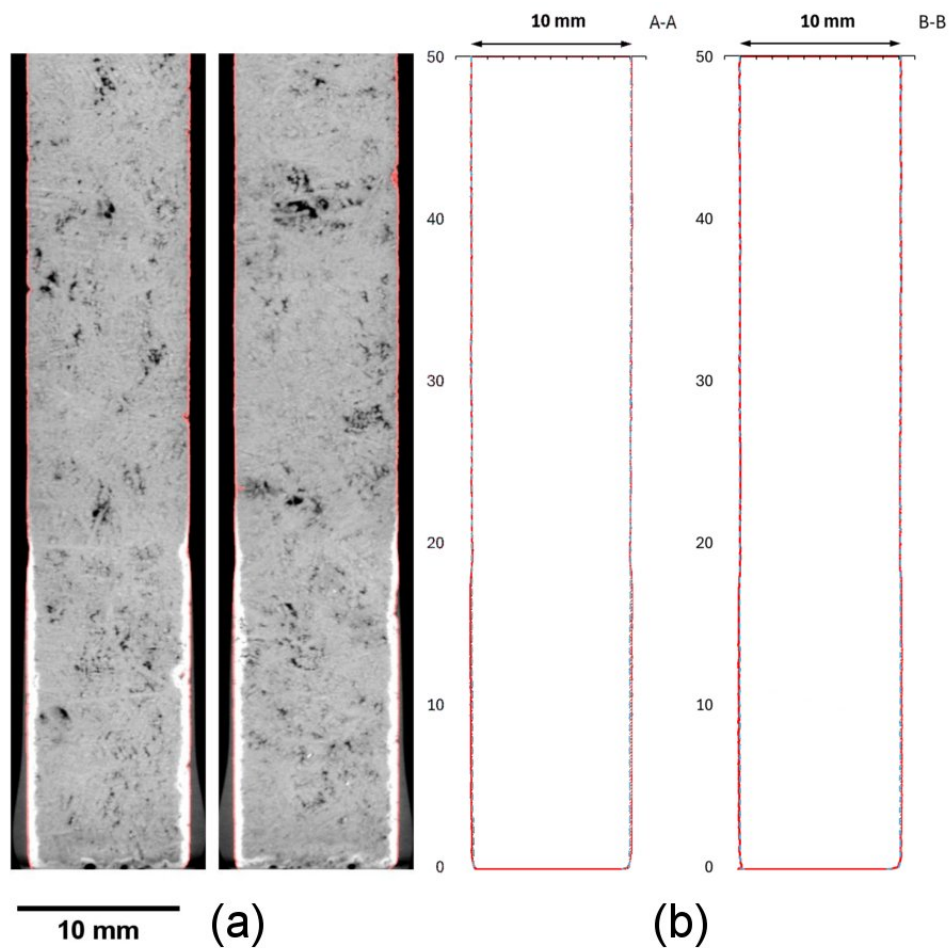


Figure B.42. Micro-CT results of the K-3 refractory corrosion test, HS24-21_1200C-7d. (a) Micro-CT images of the cross section at the center. (b) Corrosion depth plots, no distinguishable neck.

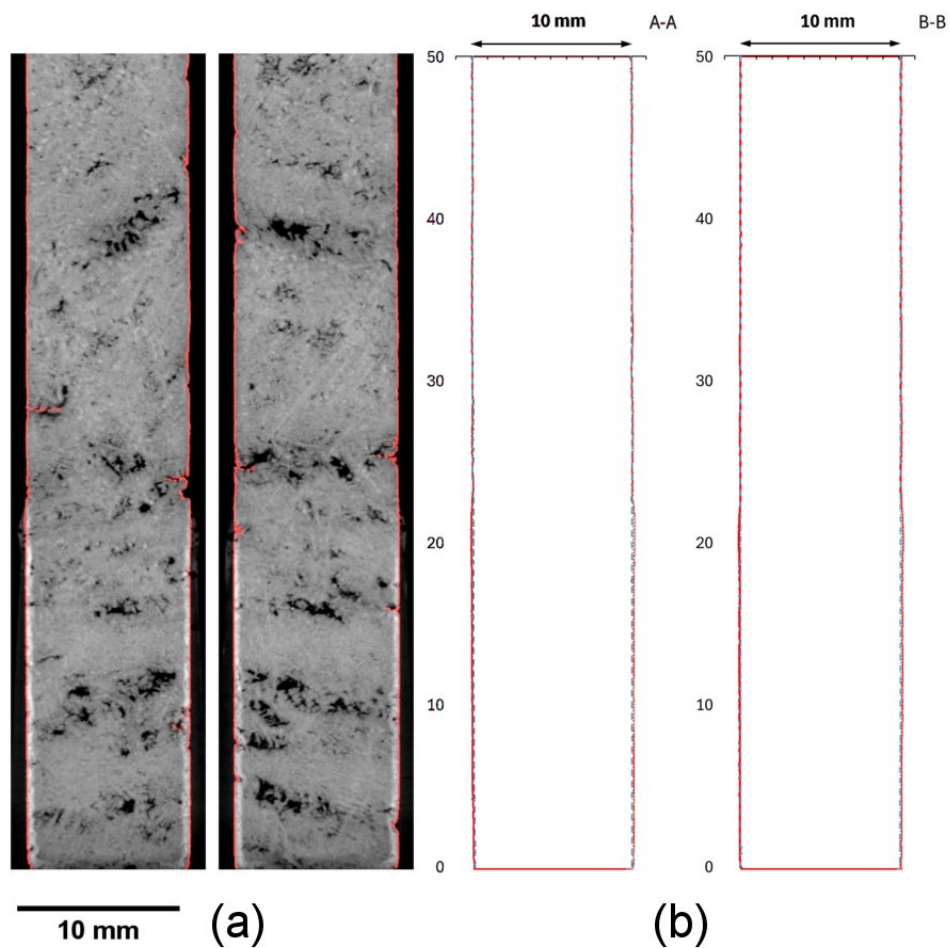


Figure B.43. Micro-CT results of the K-3 refractory corrosion test, HS24-22_1150C-7d. (a) Micro-CT images of the cross section at the center. (b) Corrosion depth plots, no distinguishable neck.

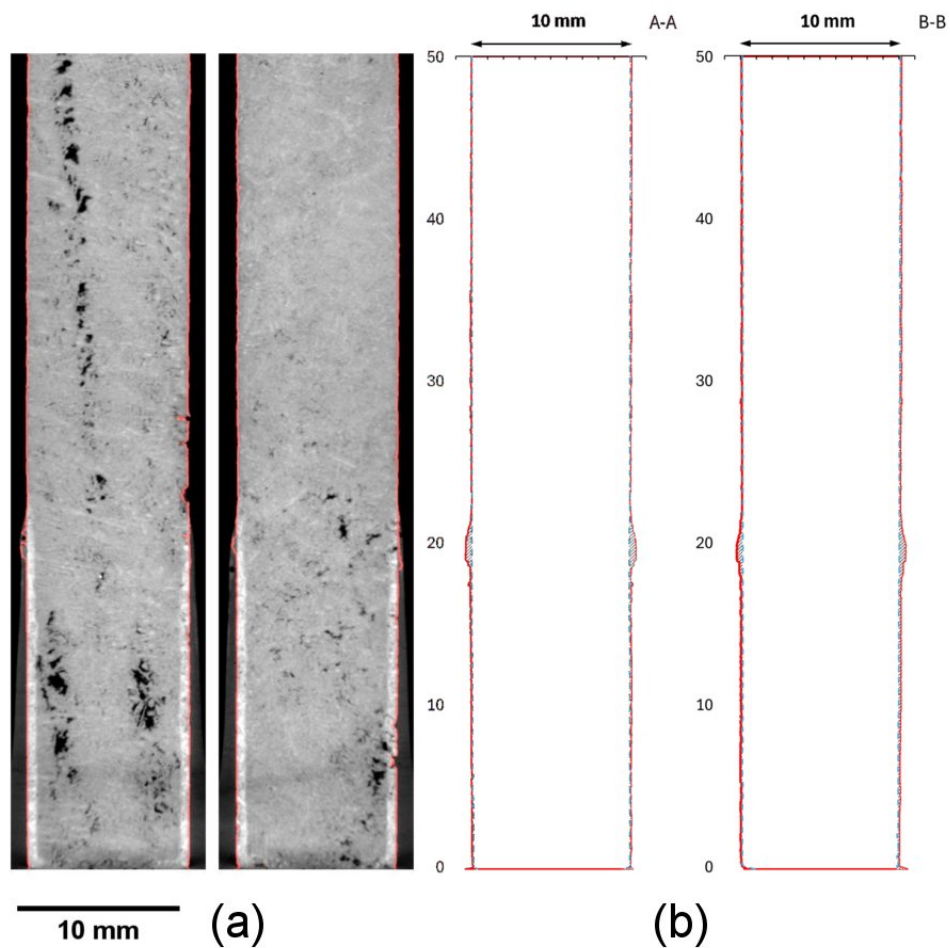


Figure B.44. Micro-CT results of the K-3 refractory corrosion test, HS24-22_1200C-7d. (a) Micro-CT images of the cross section at the center. (b) Corrosion depth plots, no distinguishable neck.

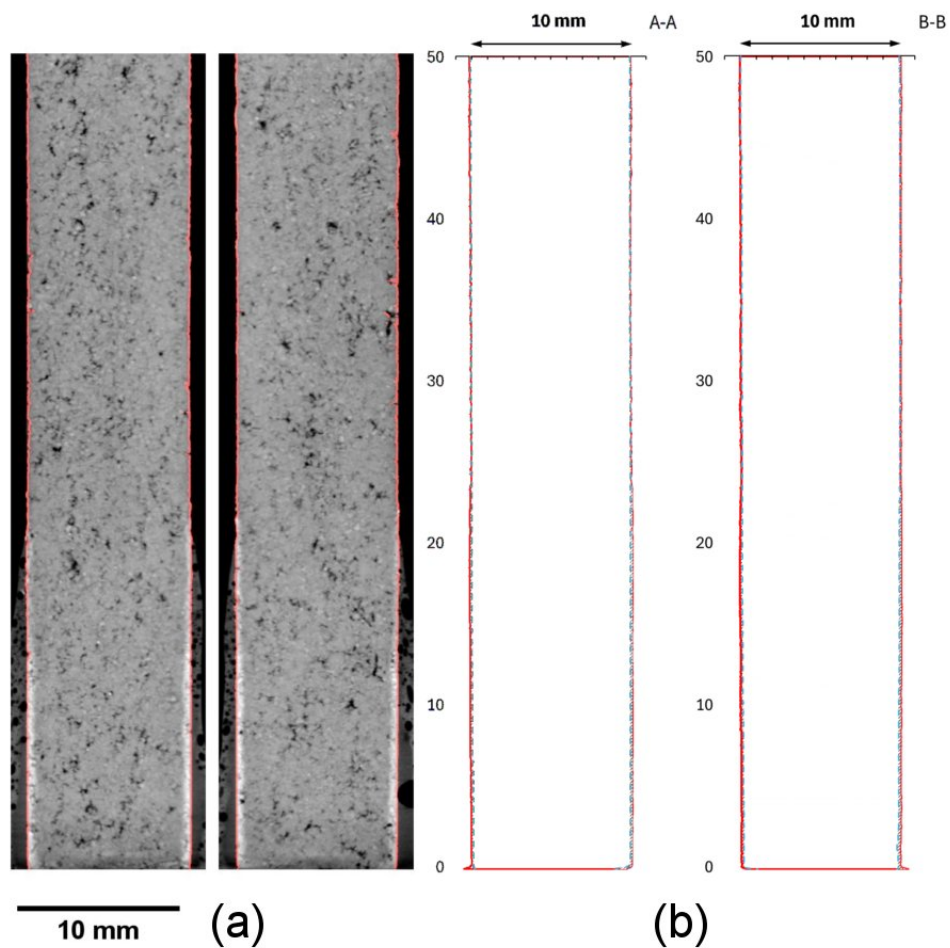


Figure B.45. Micro-CT results of the K-3 refractory corrosion test, HS24-23_1150C-7d. (a) Micro-CT images of the cross section at the center. (b) Corrosion depth plots, no distinguishable neck.

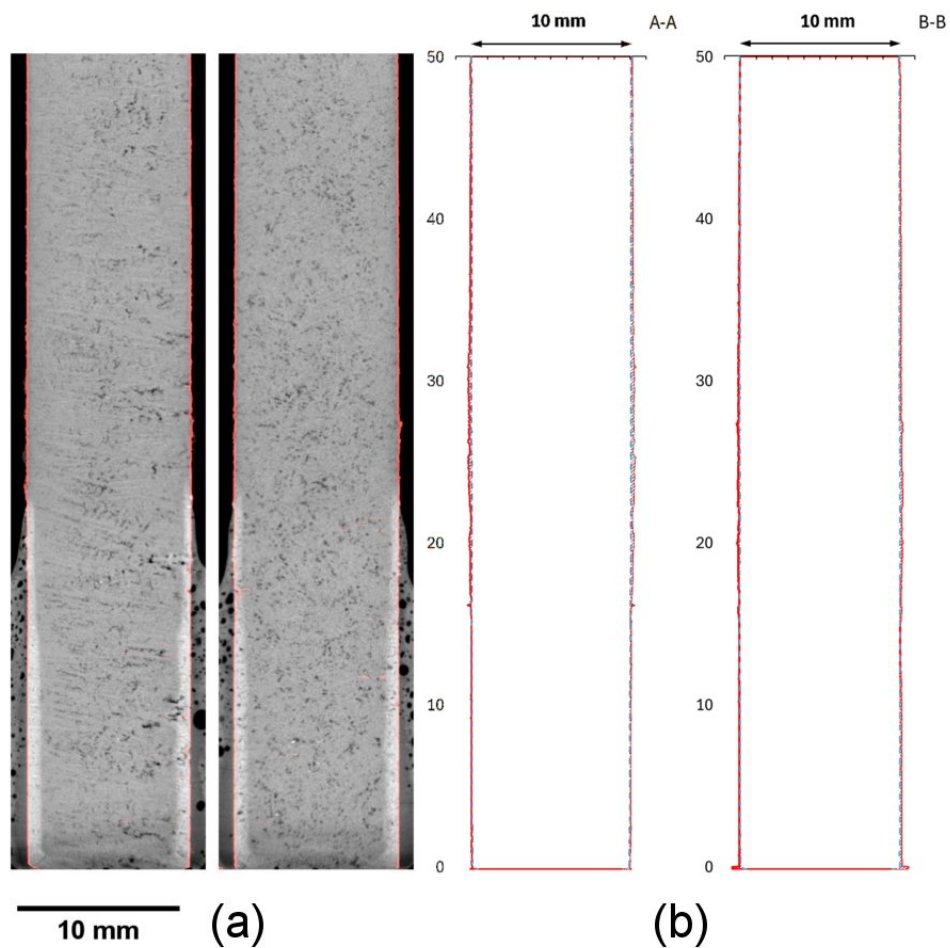


Figure B.46. Micro-CT results of the K-3 refractory corrosion test, HS24-23_1200C-7d. (a) Micro-CT images of the cross section at the center. (b) Corrosion depth plots, no distinguishable neck.

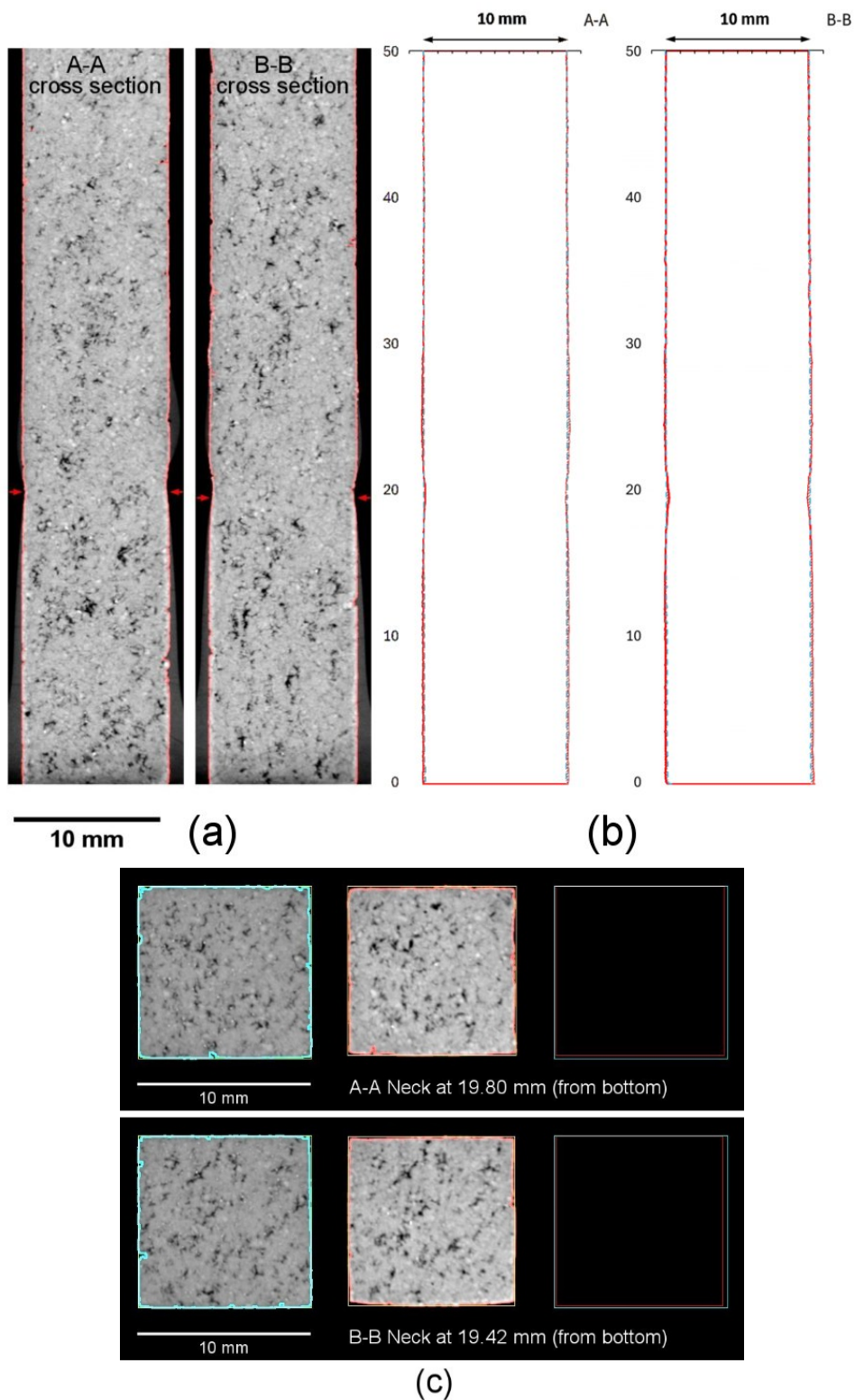


Figure B.47. Micro-CT results of the K-3 refractory corrosion test, HS24-24_1150C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

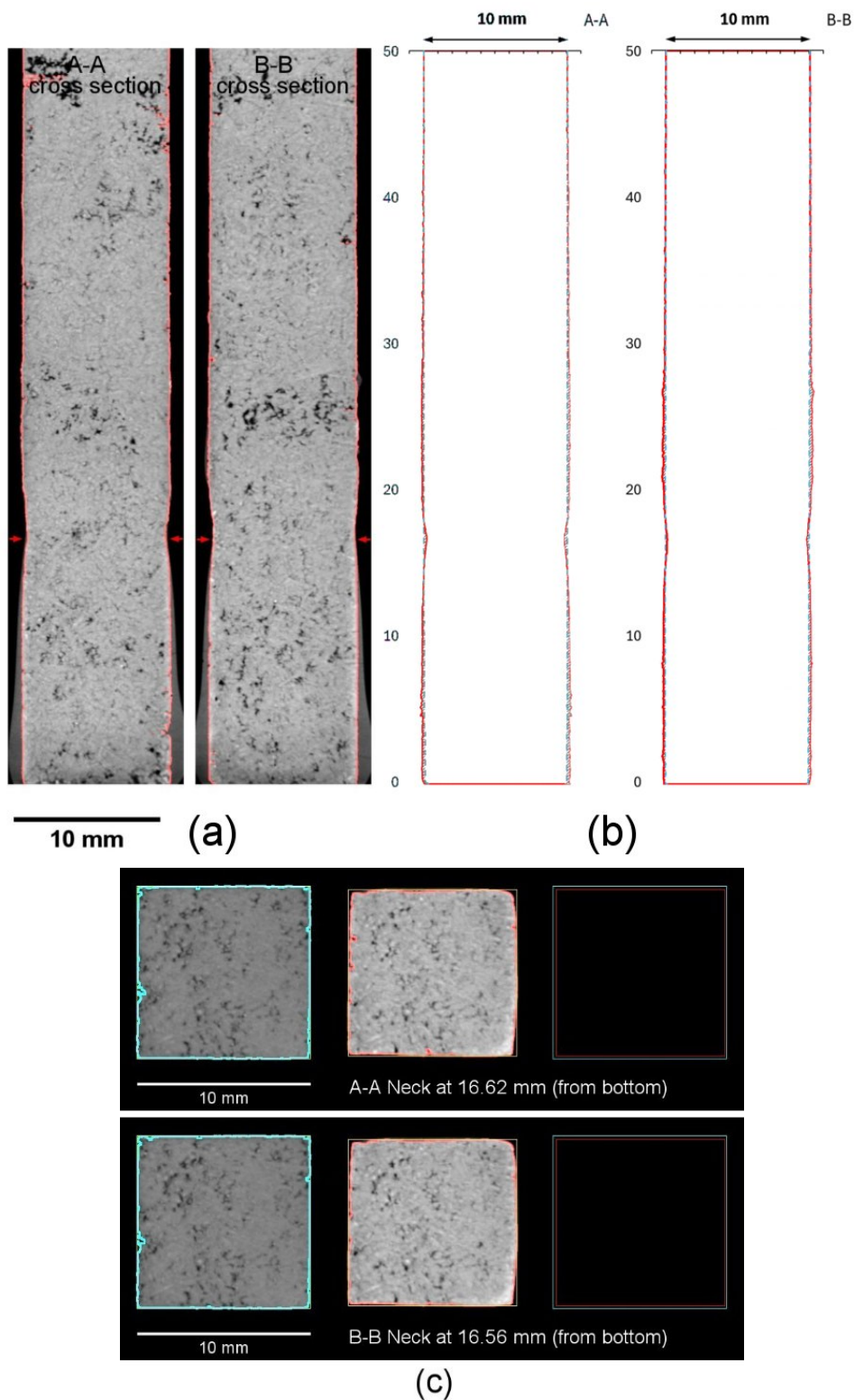


Figure B.48. Micro-CT results of the K-3 refractory corrosion test, HS24-24_1200C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

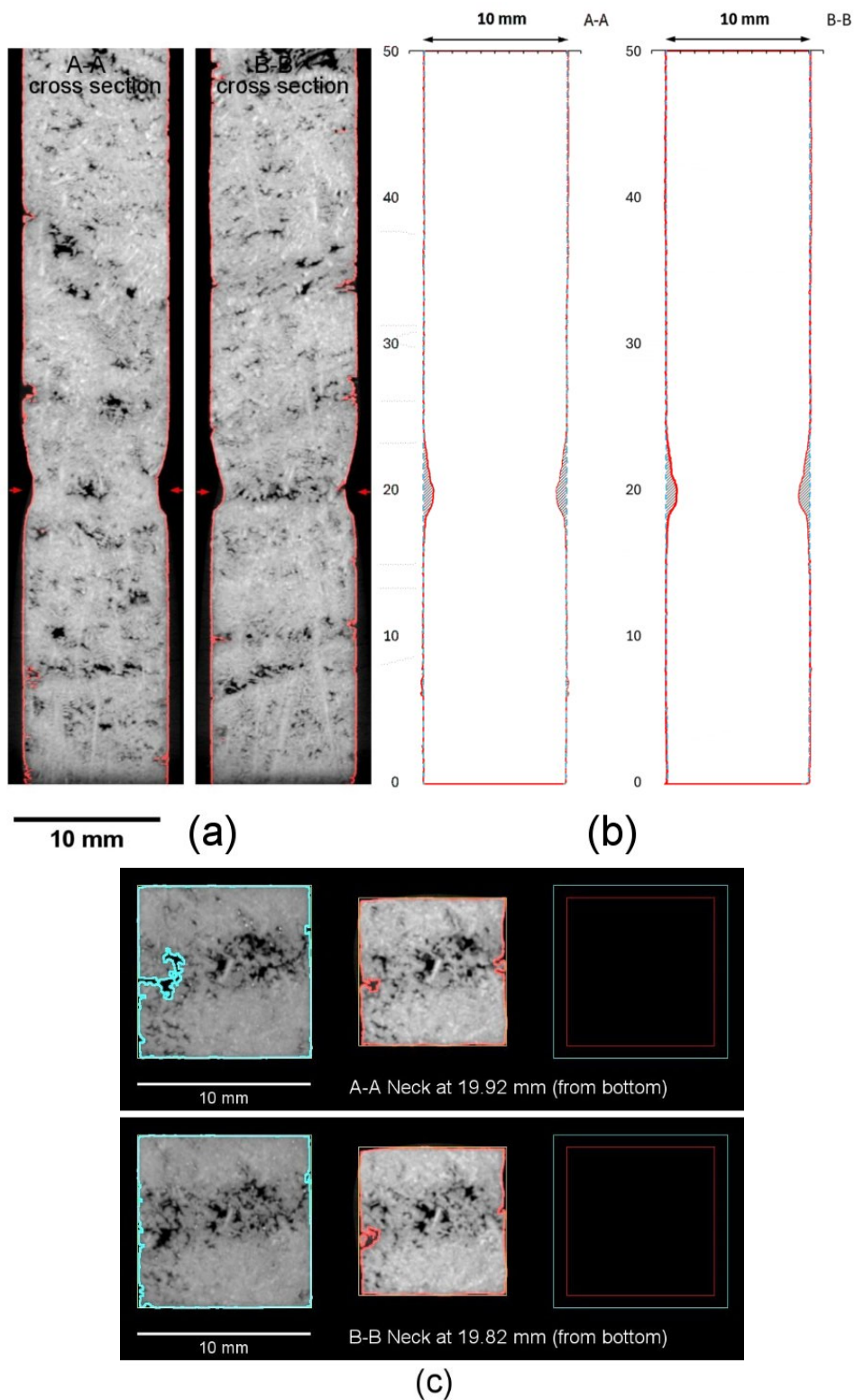


Figure B.49. Micro-CT results of the K-3 refractory corrosion test, HS24-25_1150C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

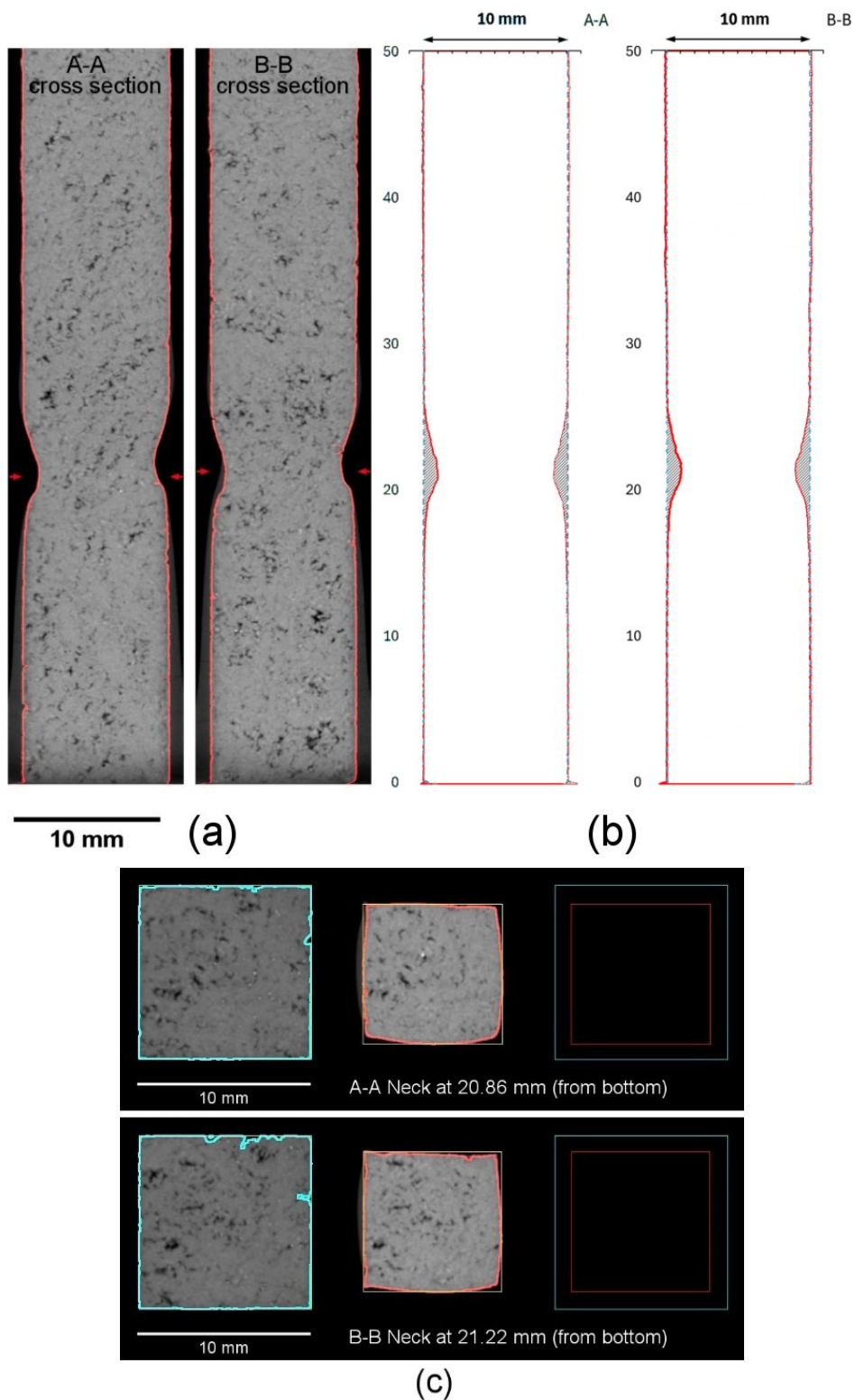


Figure B.50. Micro-CT results of the K-3 refractory corrosion test, HS24-25_1200C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

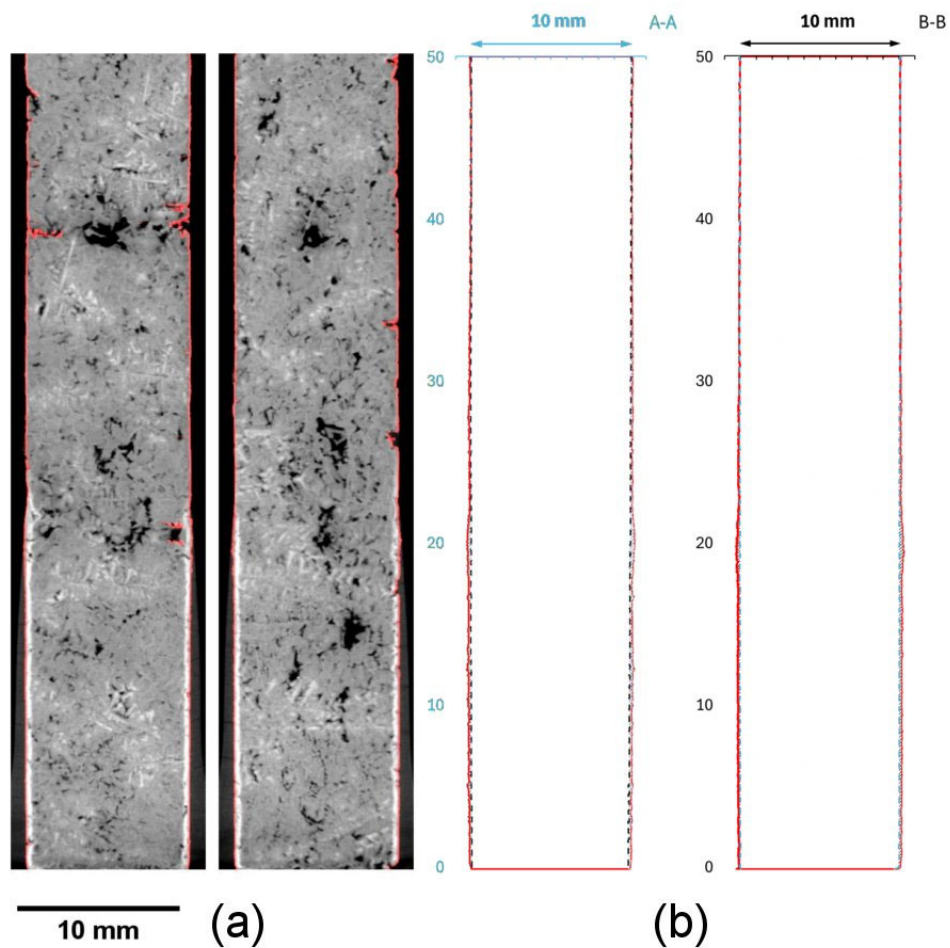


Figure B.51. Micro-CT results of the K-3 refractory corrosion test, HS24-26_1150C-7d. (a) Micro-CT images of the cross section at the center. (b) Corrosion depth plots, no distinguishable neck.

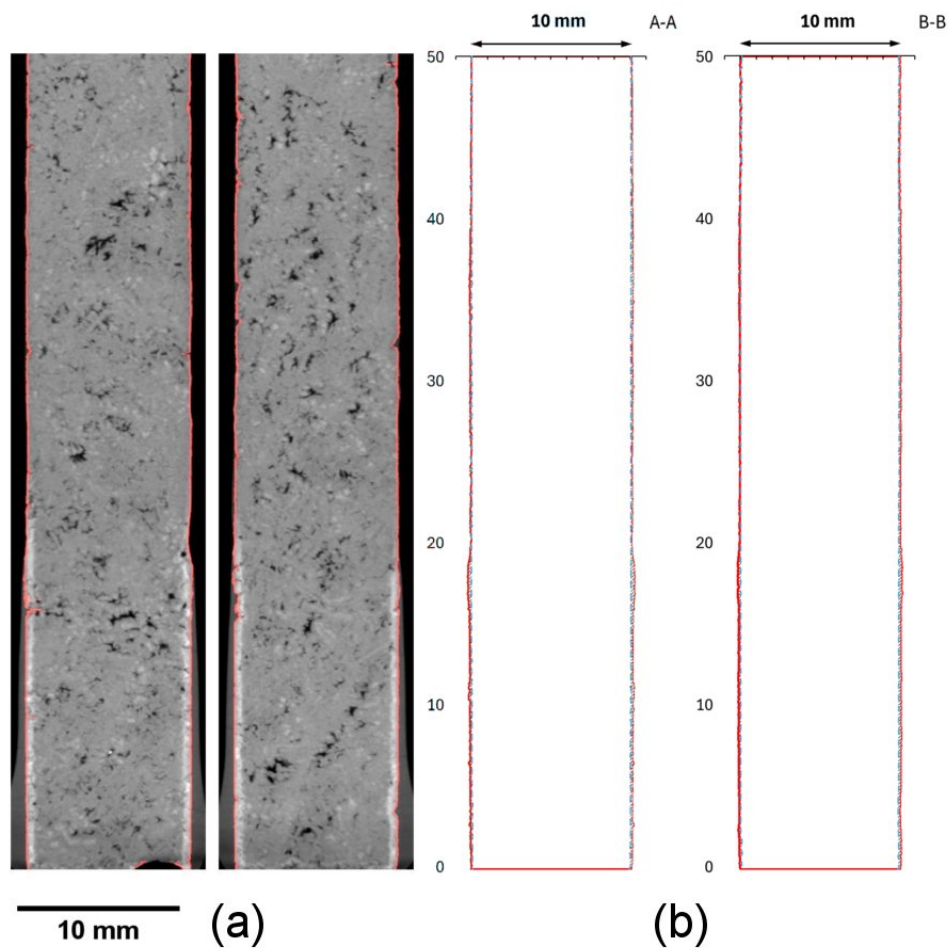


Figure B.52. Micro-CT results of the K-3 refractory corrosion test, HS24-26_1200C-7d. (a) Micro-CT images of the cross section at the center. (b) Corrosion depth plots, no distinguishable neck.

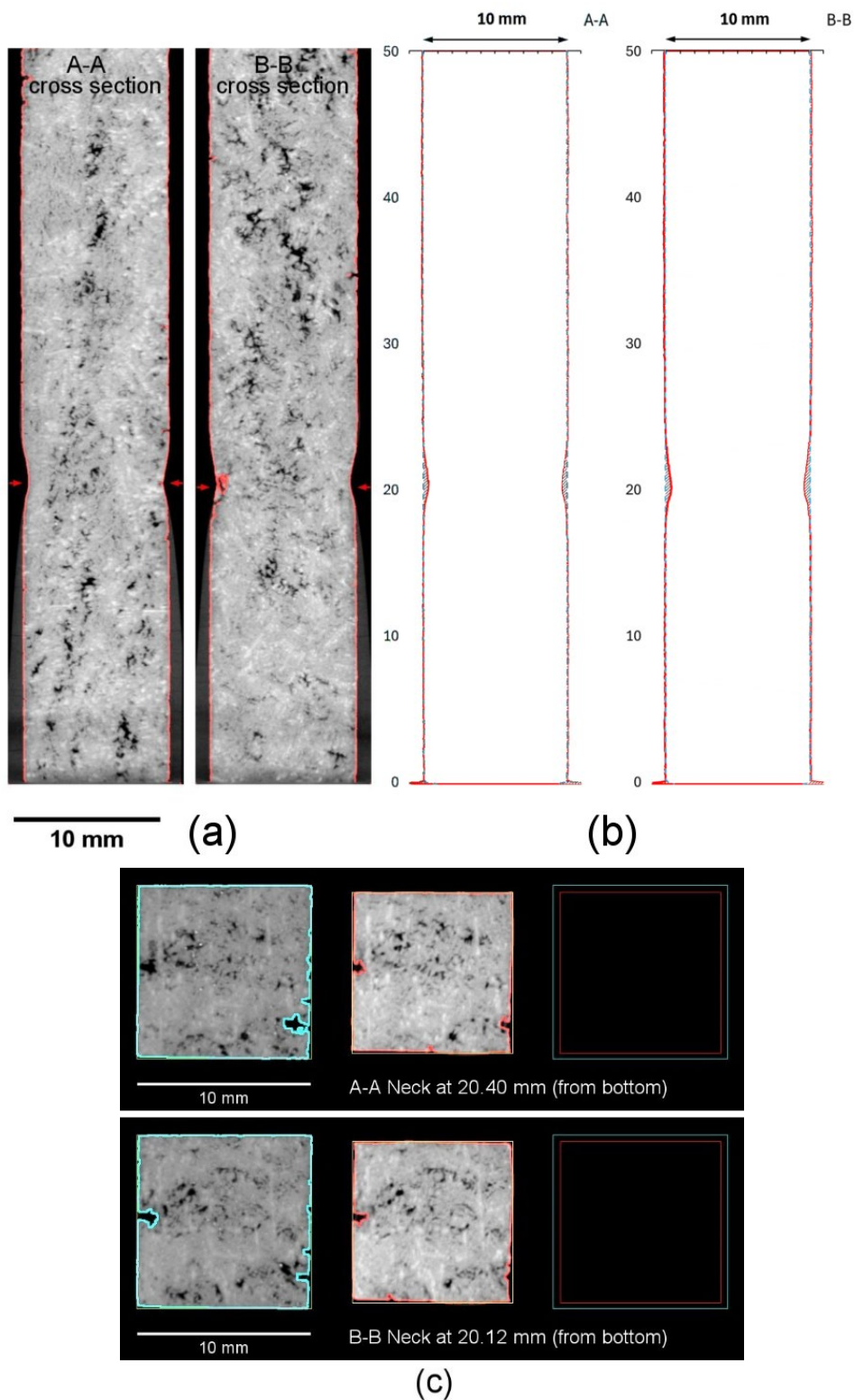


Figure B.53. Micro-CT results of the K-3 refractory corrosion test, HS24-27_1150C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

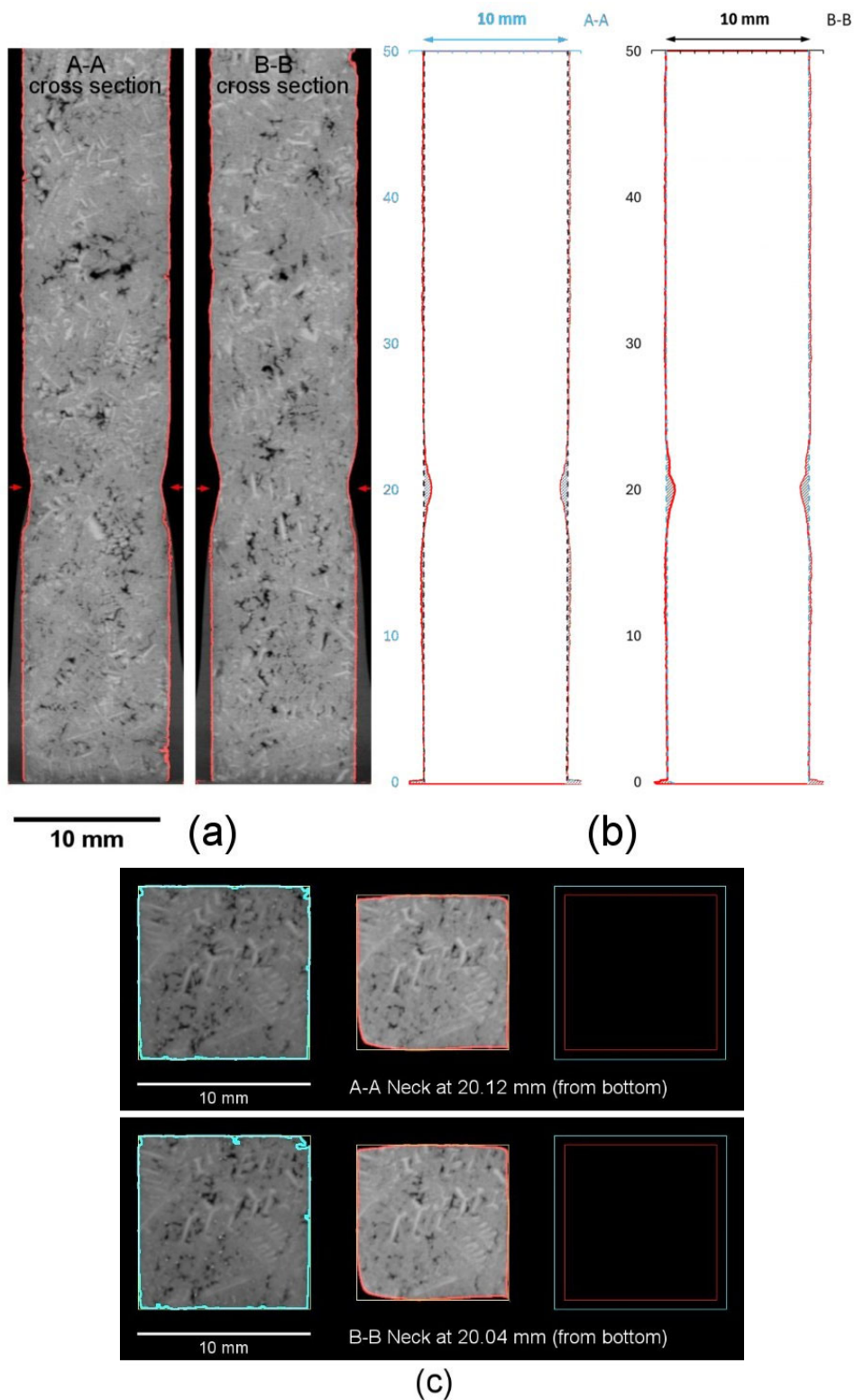


Figure B.54. Micro-CT results of the K-3 refractory corrosion test, HS24-27_1200C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

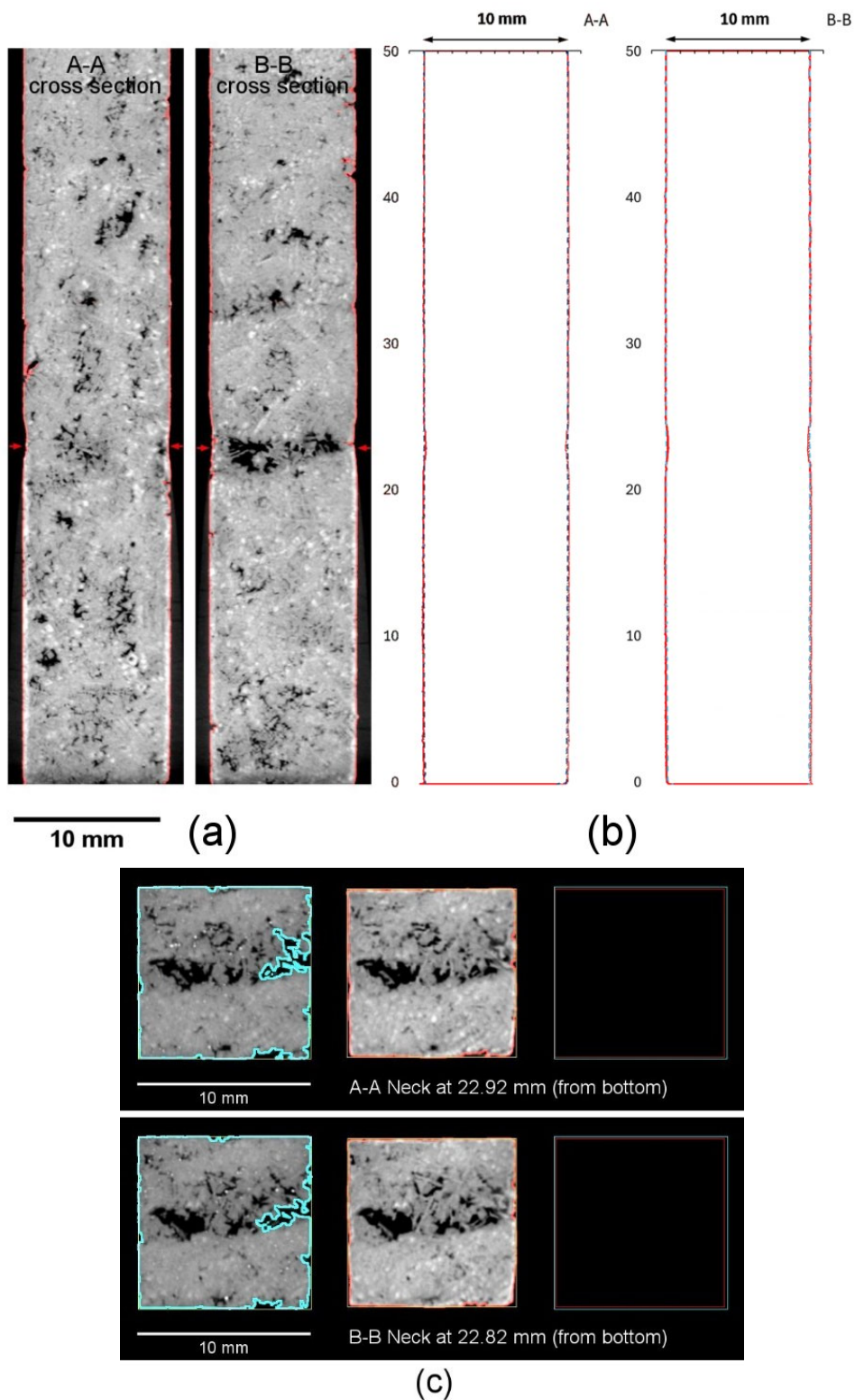


Figure B.55. Micro-CT results of the K-3 refractory corrosion test, HS24-28_1150C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

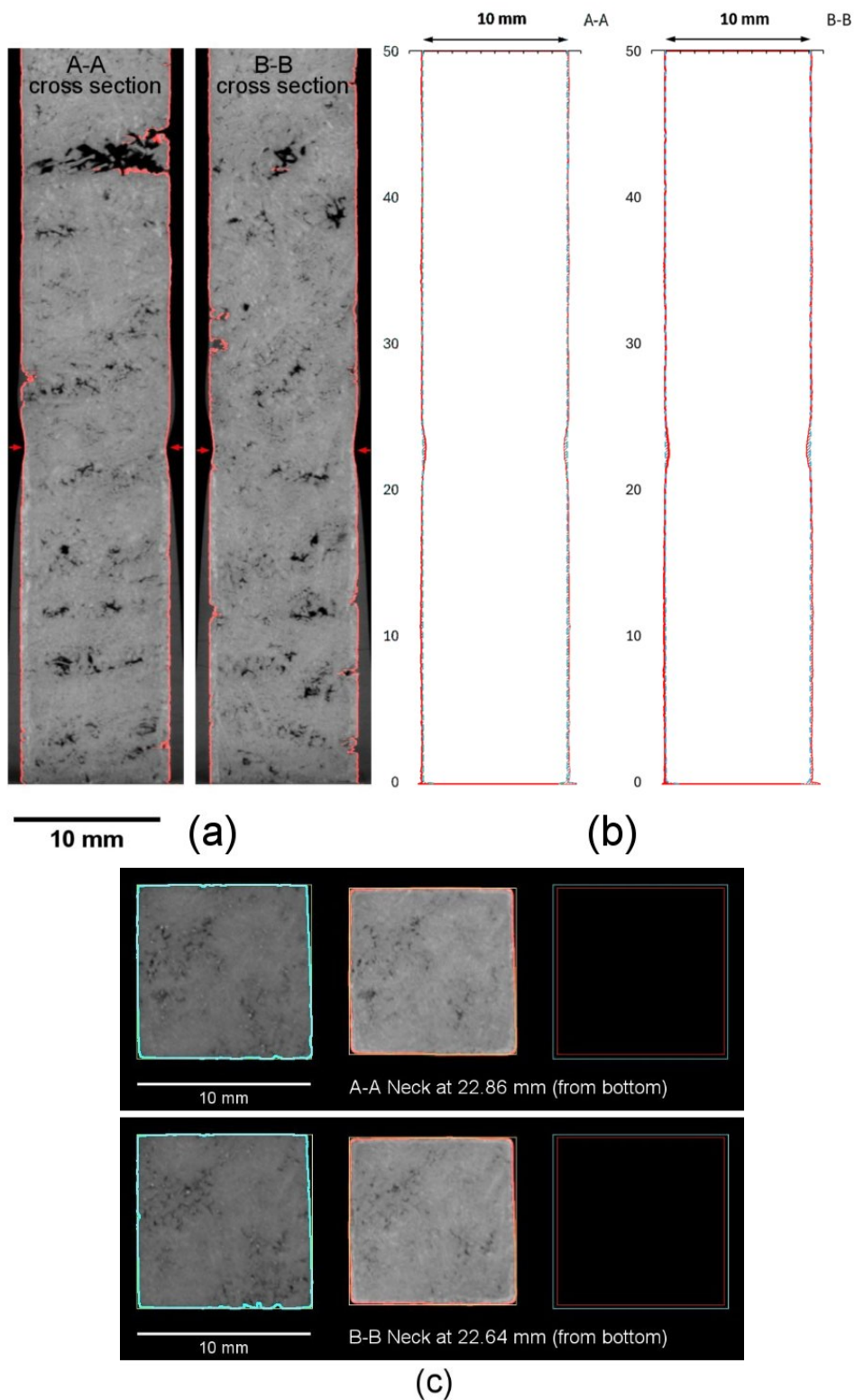


Figure B.56. Micro-CT results of the K-3 refractory corrosion test, HS24-28_1200C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

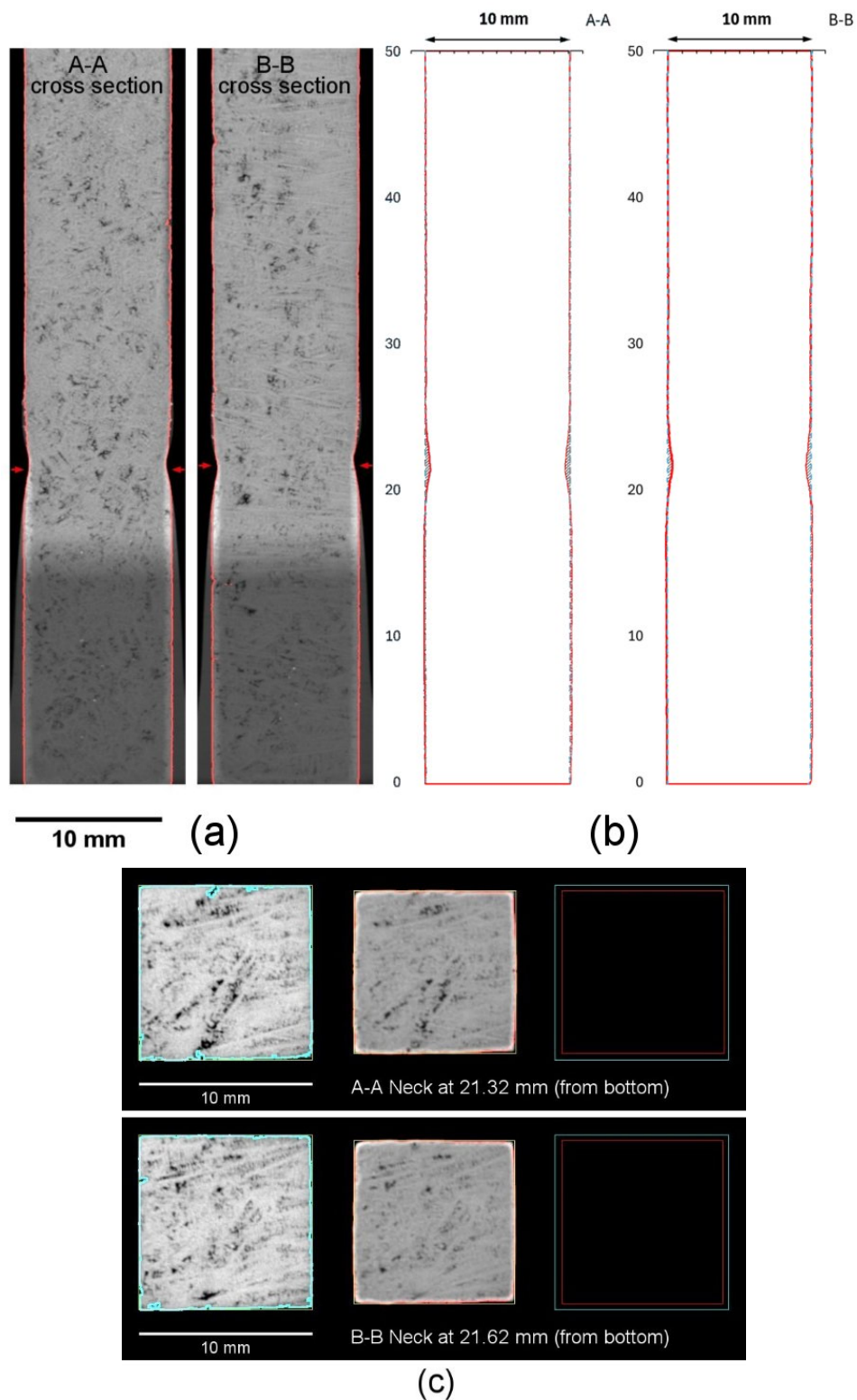


Figure B.57. Micro-CT results of the K-3 refractory corrosion test, HS24-29_1150C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

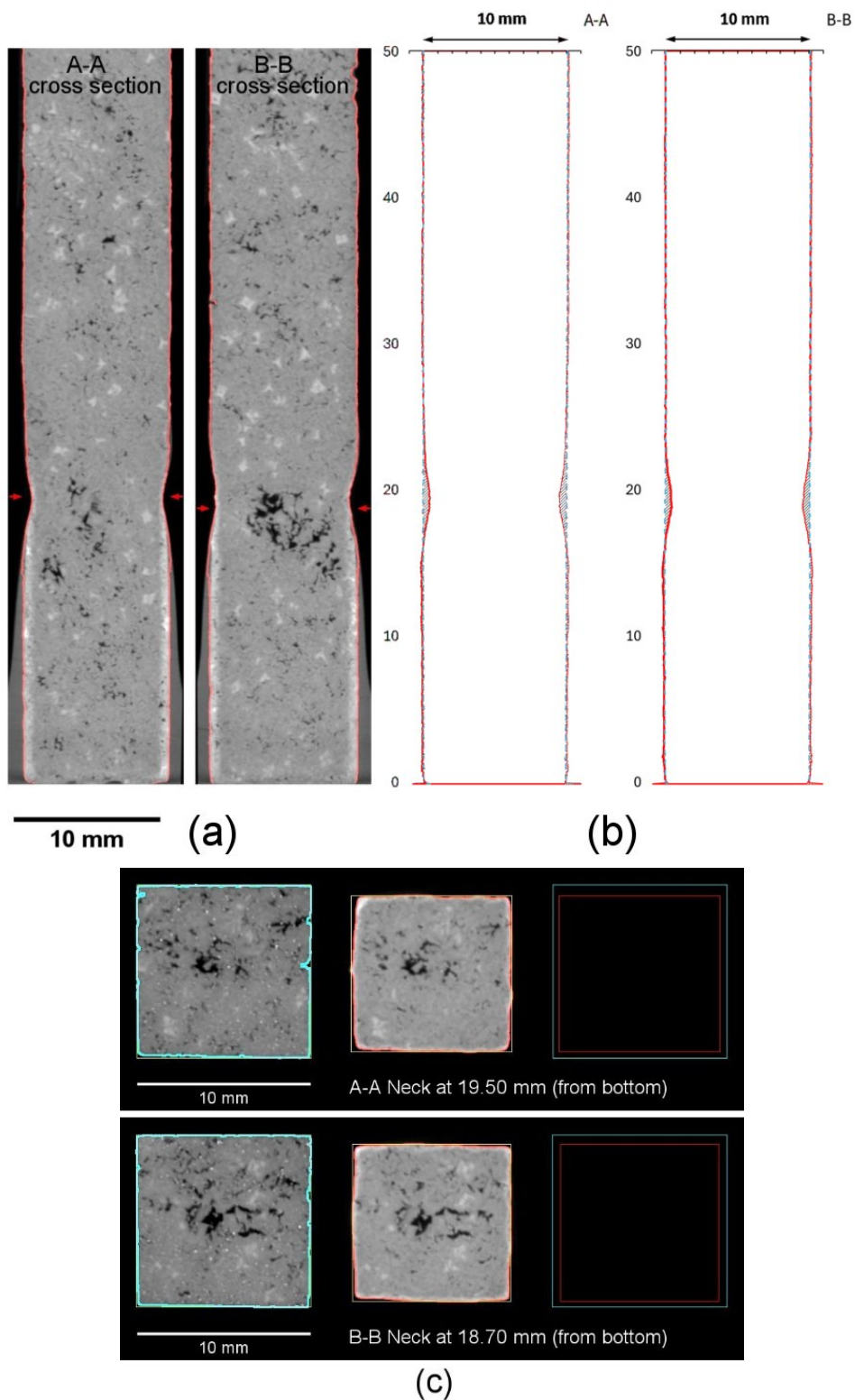


Figure B.58. Micro-CT results of the K-3 refractory corrosion test, HS24-29_1200C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

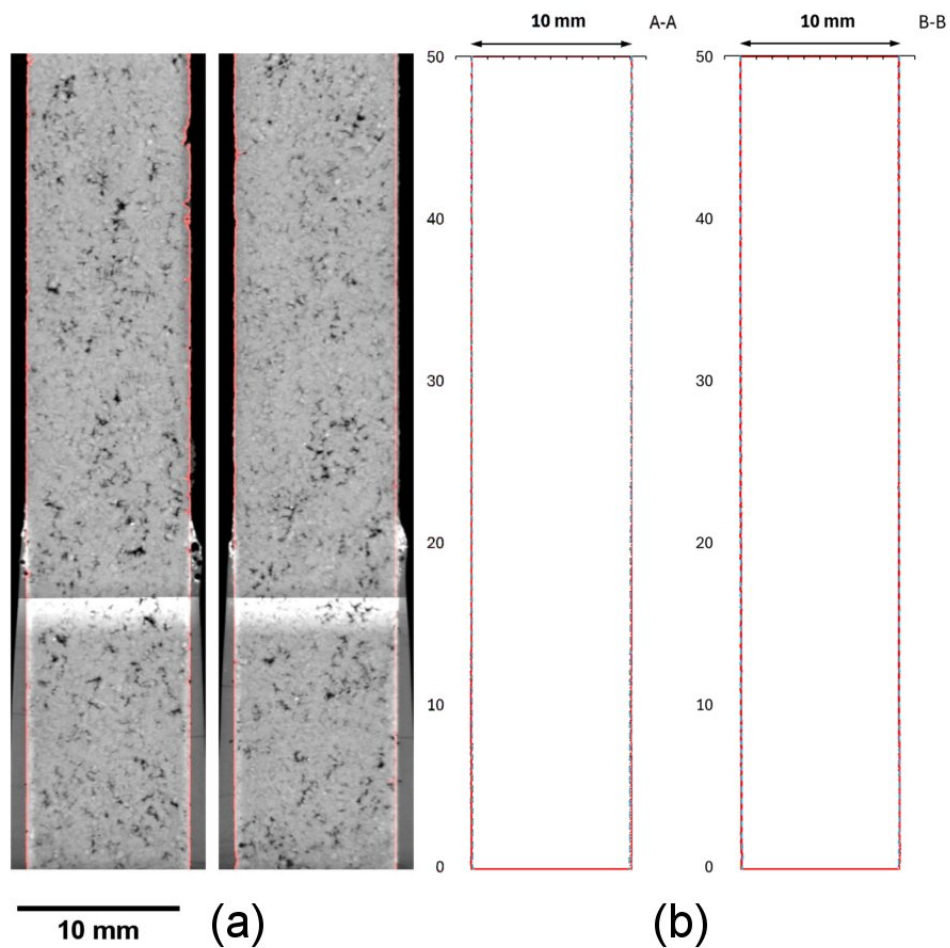


Figure B.59. Micro-CT results of the K-3 refractory corrosion test, HS24-30_1150C-7d. (a) Micro-CT images of the cross section at the center. (b) Corrosion depth plots, no distinguishable neck.

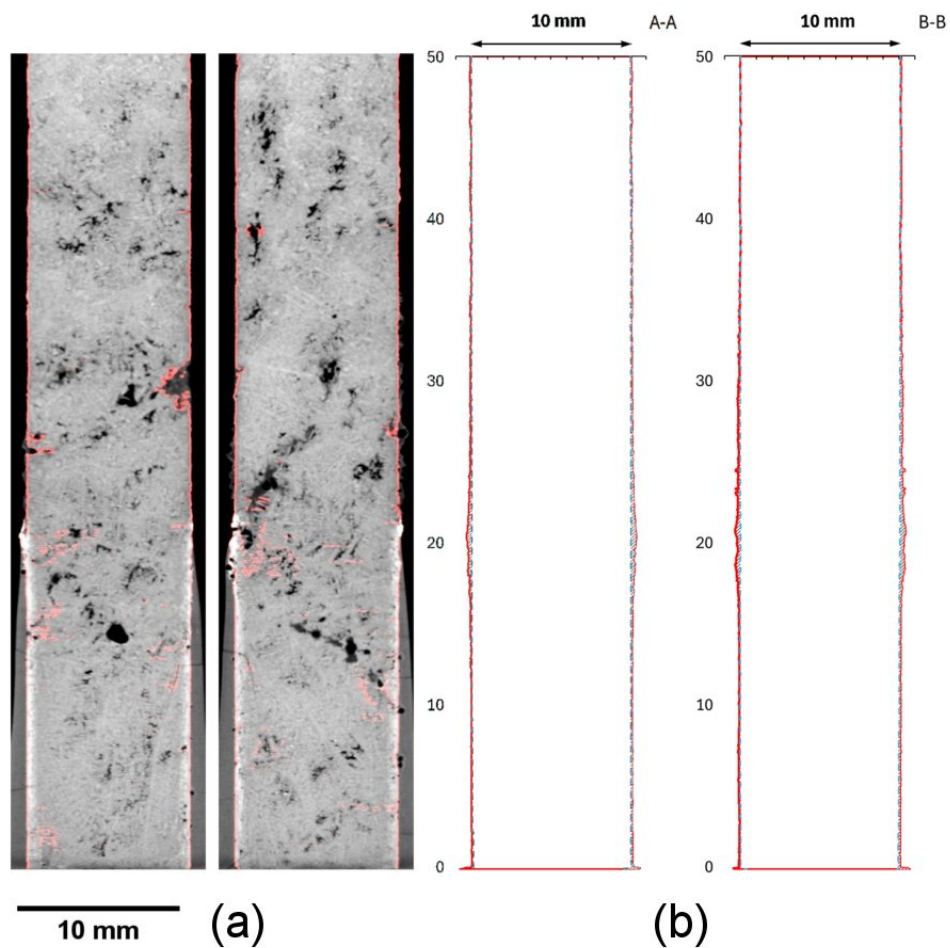


Figure B.60. Micro-CT results of the K-3 refractory corrosion test, HS24-30_1200C-7d. (a) Micro-CT images of the cross section at the center. (b) Corrosion depth plots, no distinguishable neck.

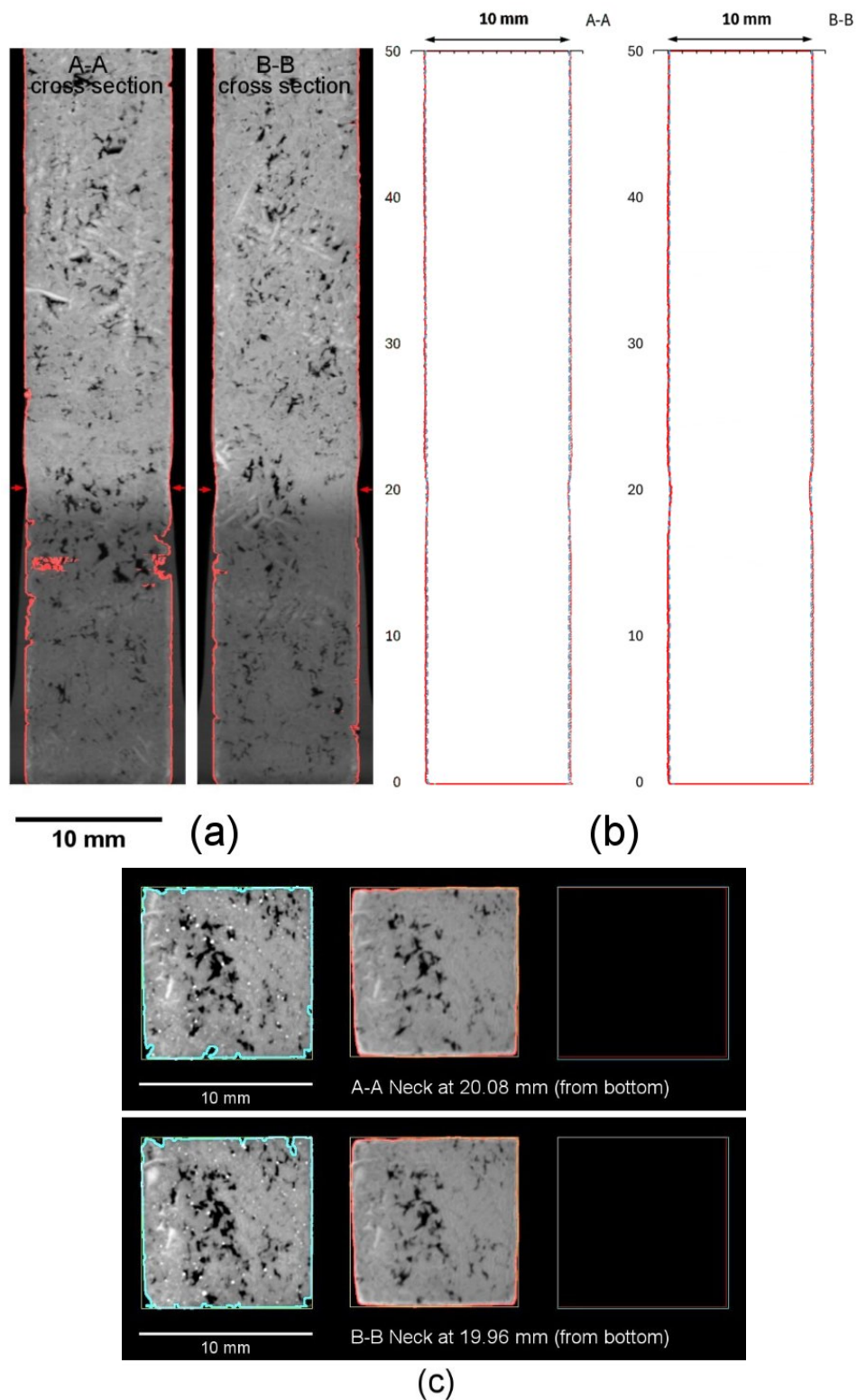


Figure B.61. Micro-CT results of the K-3 refractory corrosion test, HS24-31_1150C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

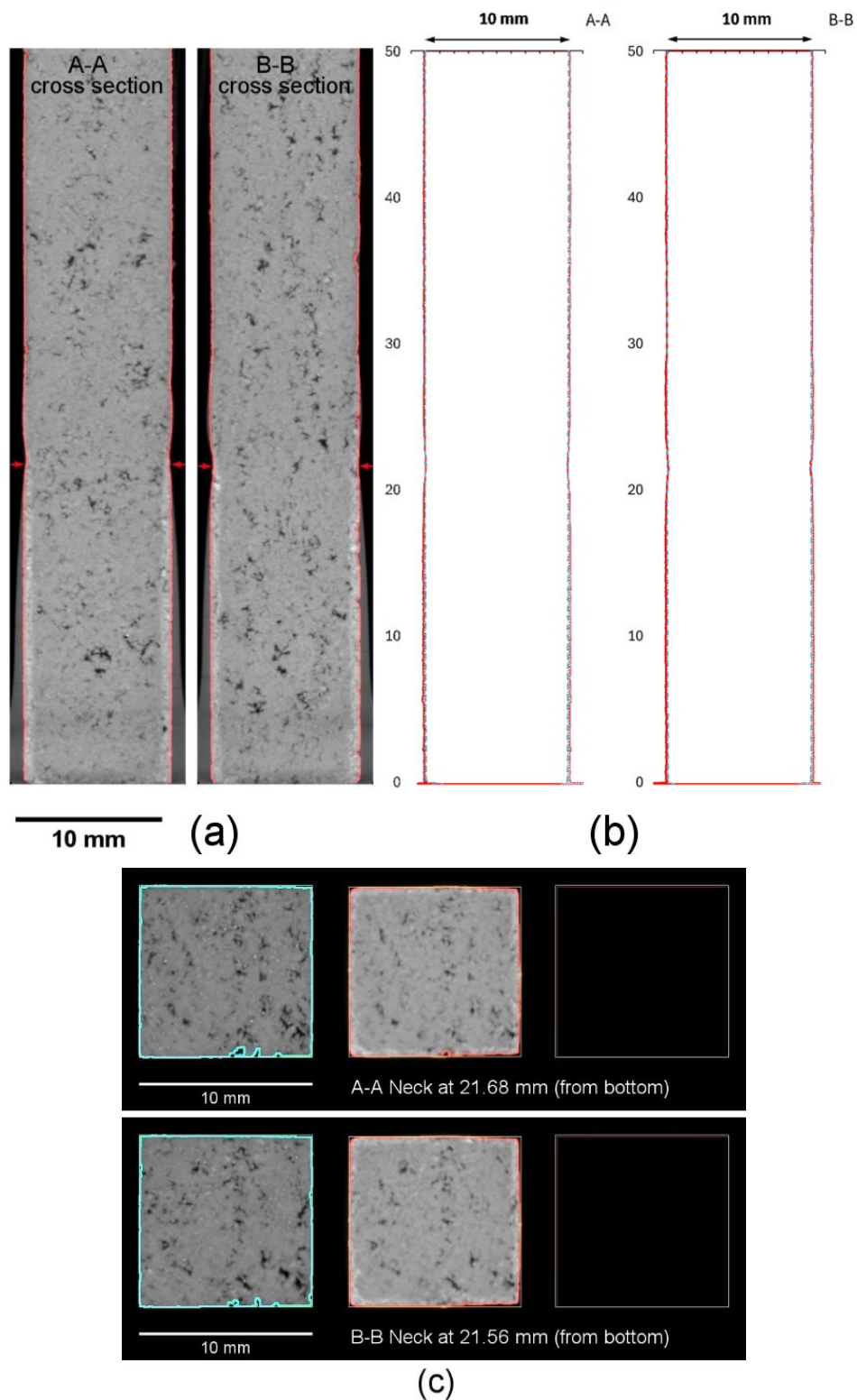


Figure B.62. Micro-CT results of the K-3 refractory corrosion test, HS24-31_1200C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

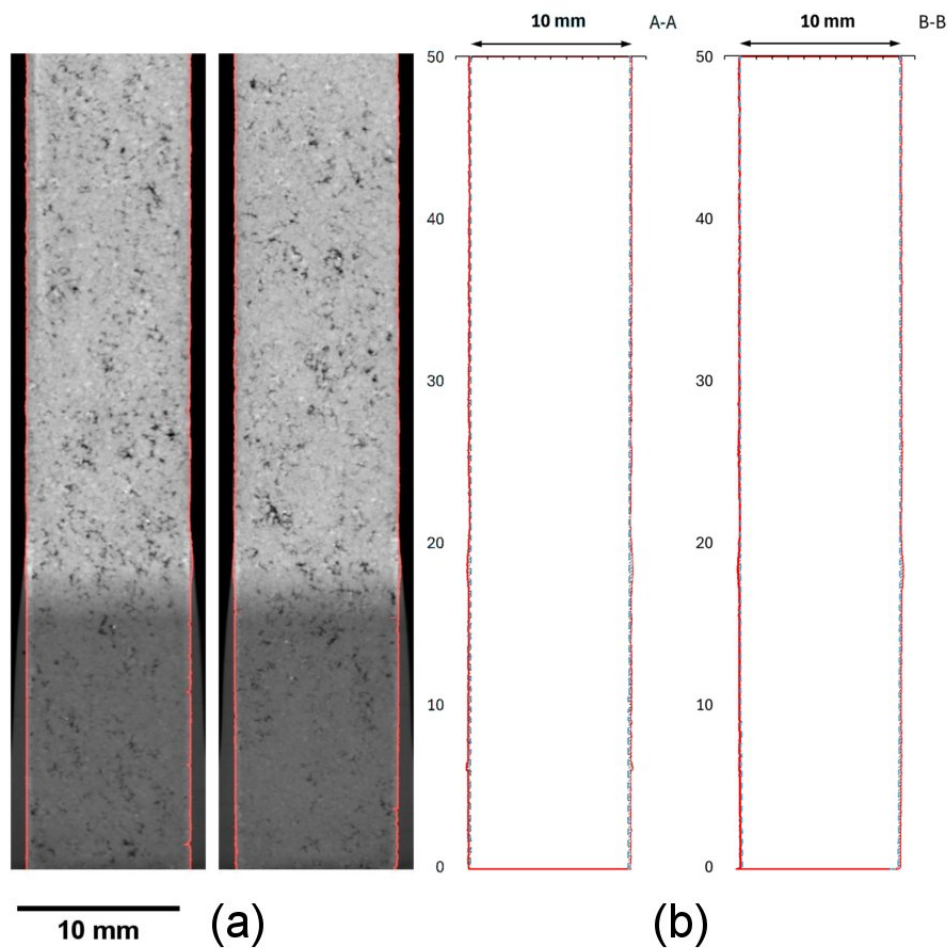


Figure B.63. Micro-CT results of the K-3 refractory corrosion test, HS24-32_1150C-7d. (a) Micro-CT images of the cross section at the center. (b) Corrosion depth plots, no distinguishable neck.

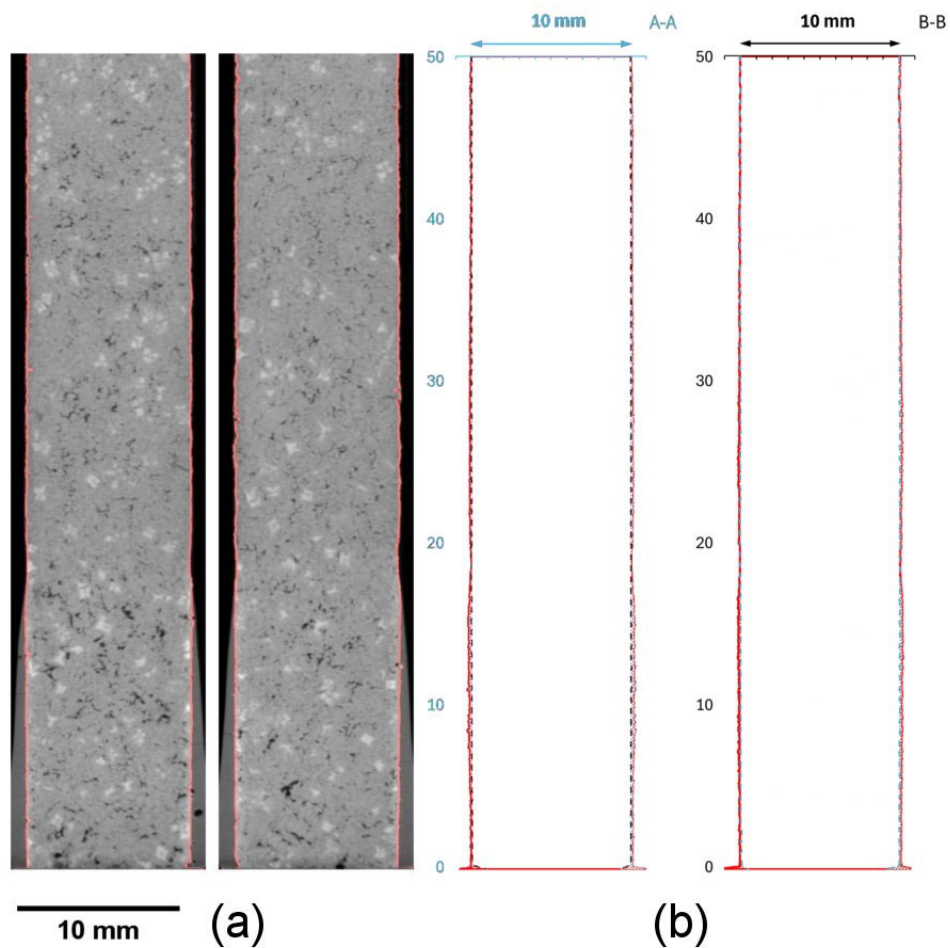


Figure B.64. Micro-CT results of the K-3 refractory corrosion test, HS24-32_1200C-7d. (a) Micro-CT images of the cross section at the center. (b) Corrosion depth plots, no distinguishable neck.

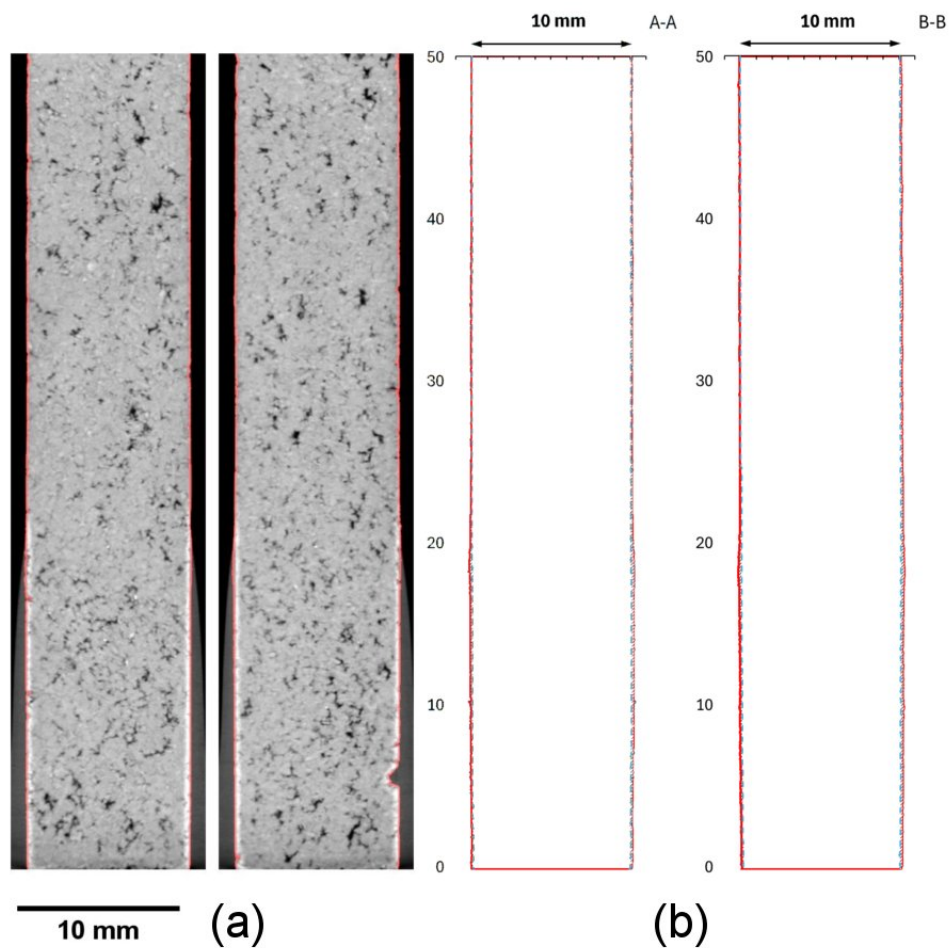


Figure B.65. Micro-CT results of the K-3 refractory corrosion test, HS24-33_1150C-7d. (a) Micro-CT images of the cross section at the center. (b) Corrosion depth plots, no distinguishable neck.

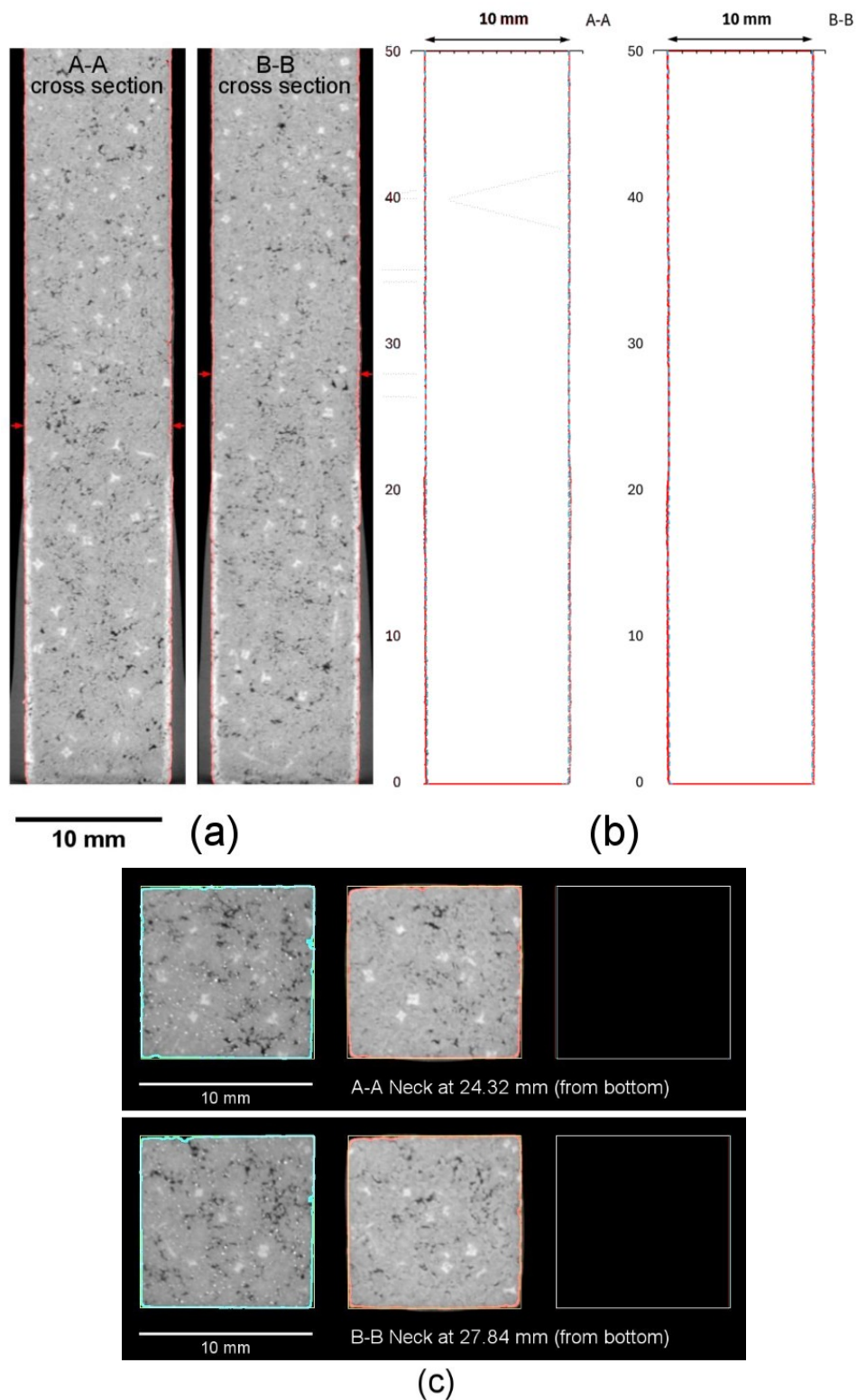


Figure B.66. Micro-CT results of the K-3 refractory corrosion test, HS24-33_1200C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

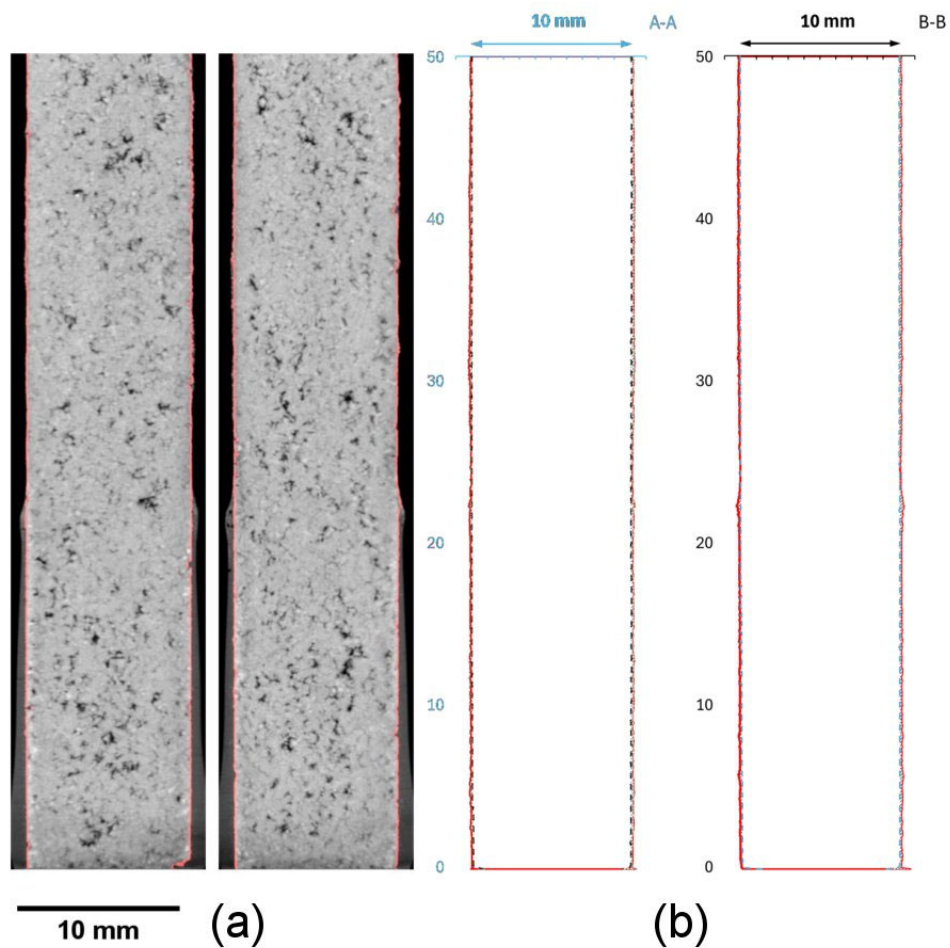


Figure B.67. Micro-CT results of the K-3 refractory corrosion test, HS24-34_1150C-7d. (a) Micro-CT images of the cross section at the center. (b) Corrosion depth plots, no distinguishable neck.

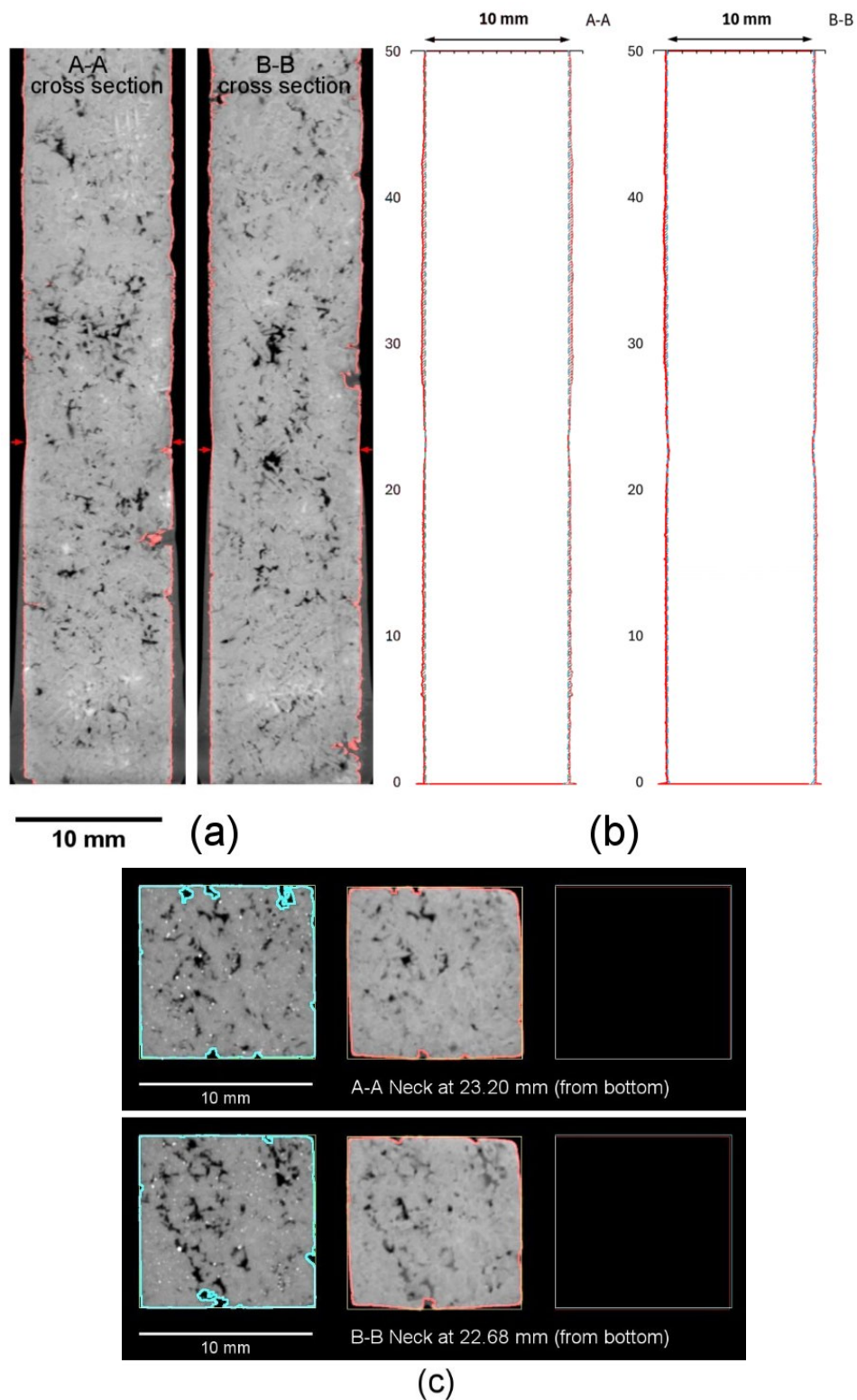


Figure B.68. Micro-CT results of the K-3 refractory corrosion test, HS24-34_1200C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

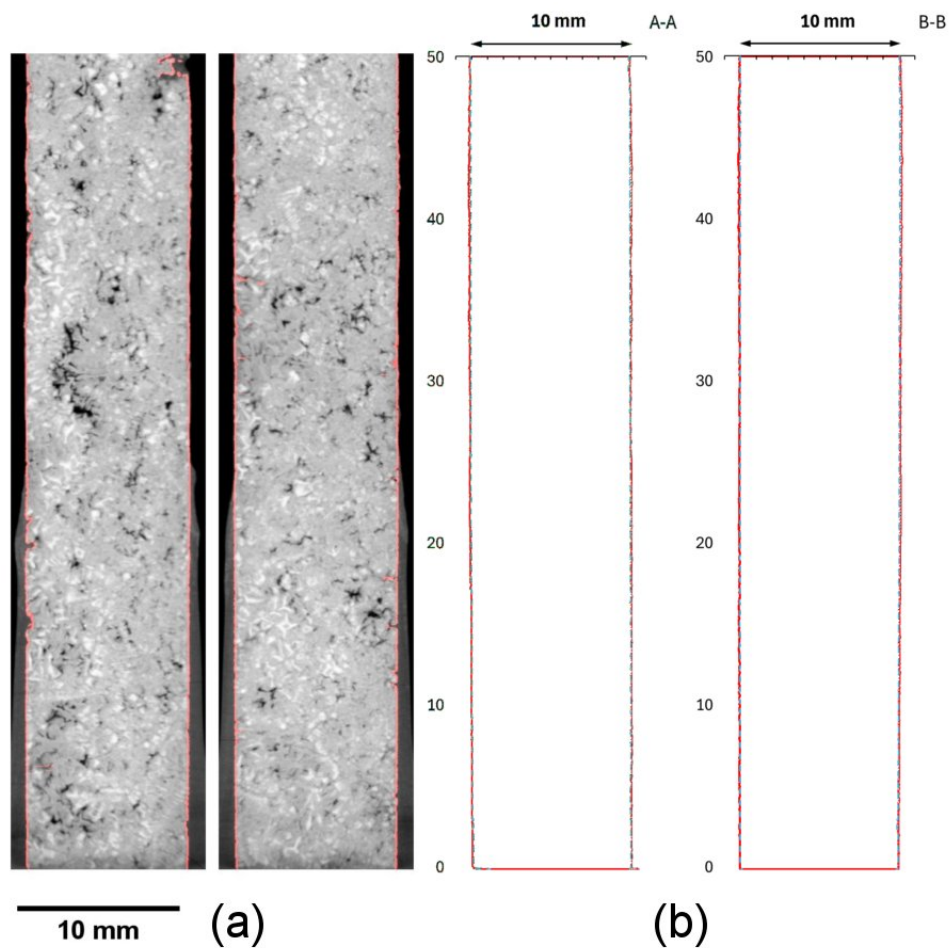


Figure B.69. Micro-CT results of the K-3 refractory corrosion test, HS24-35_1150C-7d. (a) Micro-CT images of the cross section at the center. (b) Corrosion depth plots, no distinguishable neck.

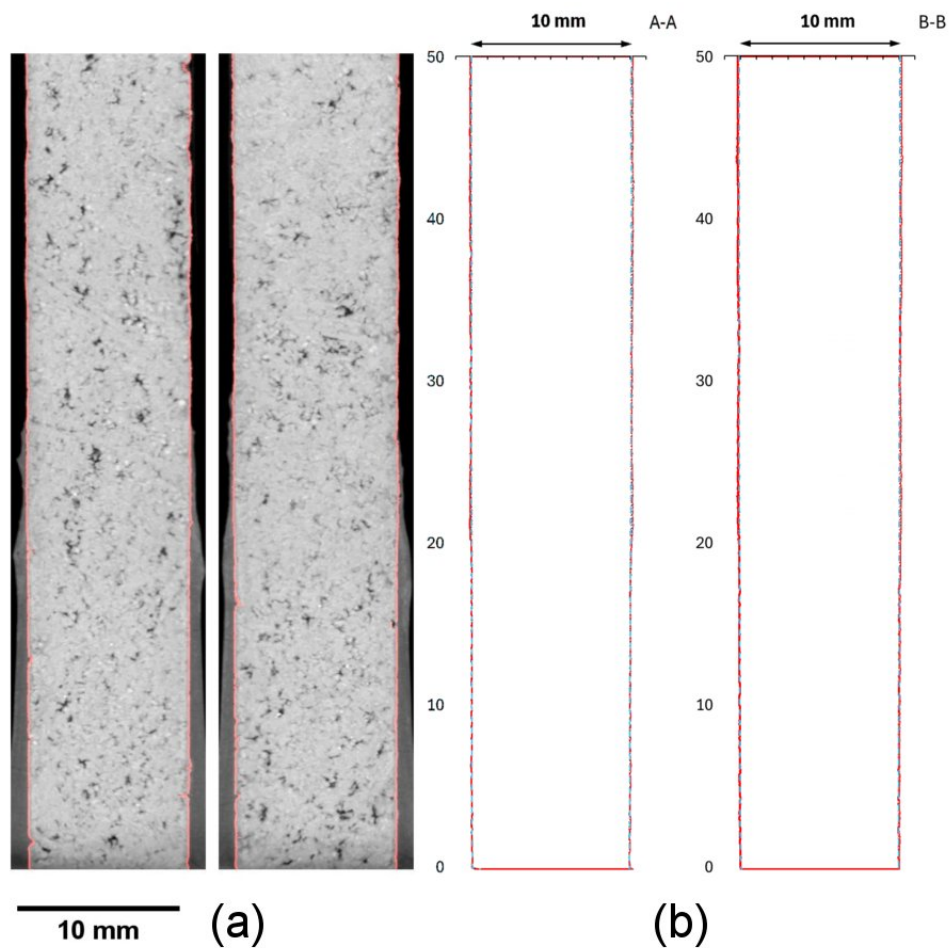


Figure B.70. Micro-CT results of the K-3 refractory corrosion test, HS24-35_1200C-7d. (a) Micro-CT images of the cross section at the center. (b) Corrosion depth plots, no distinguishable neck.

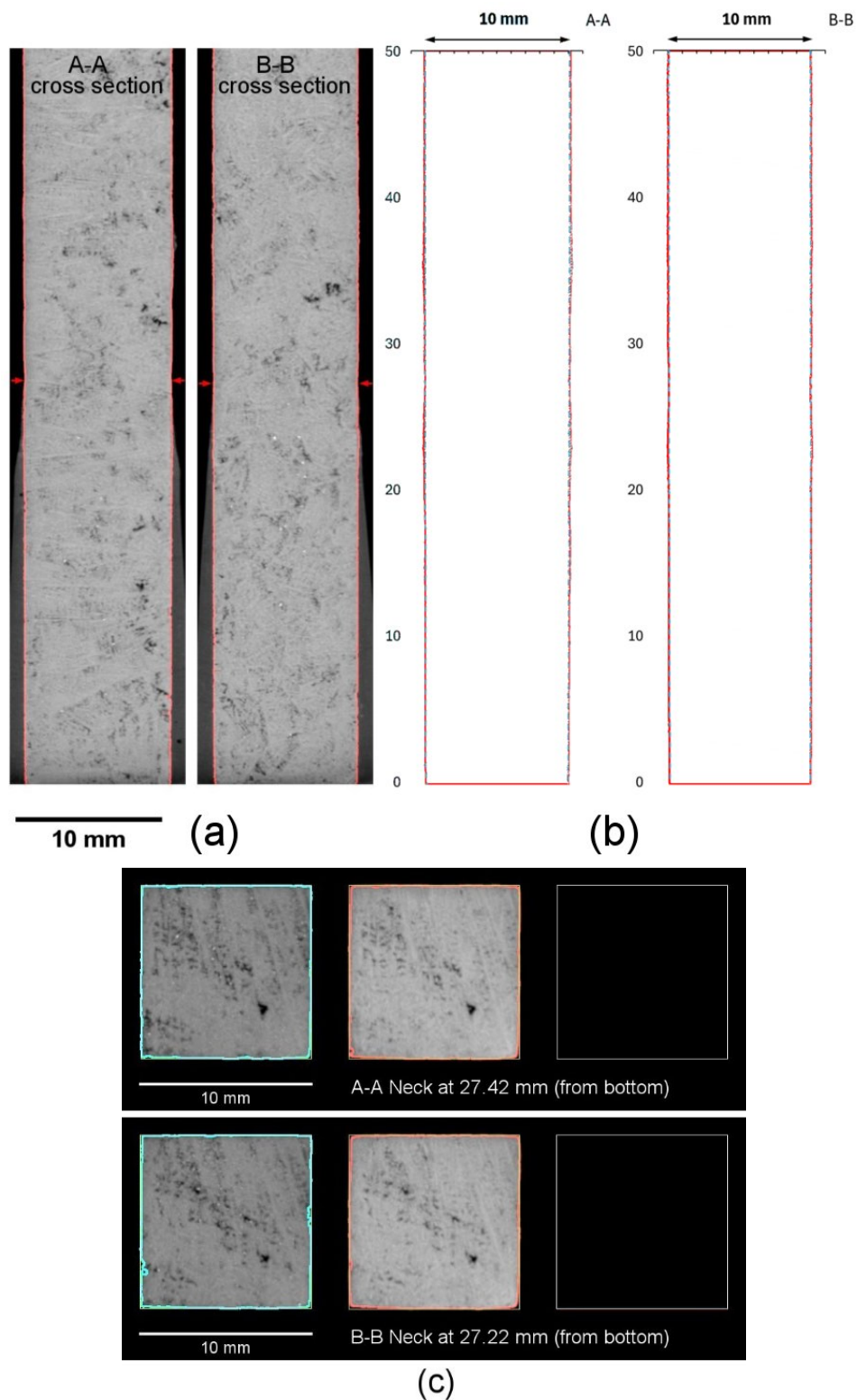


Figure B.71. Micro-CT results of the K-3 refractory corrosion test, HS24-36_1150C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

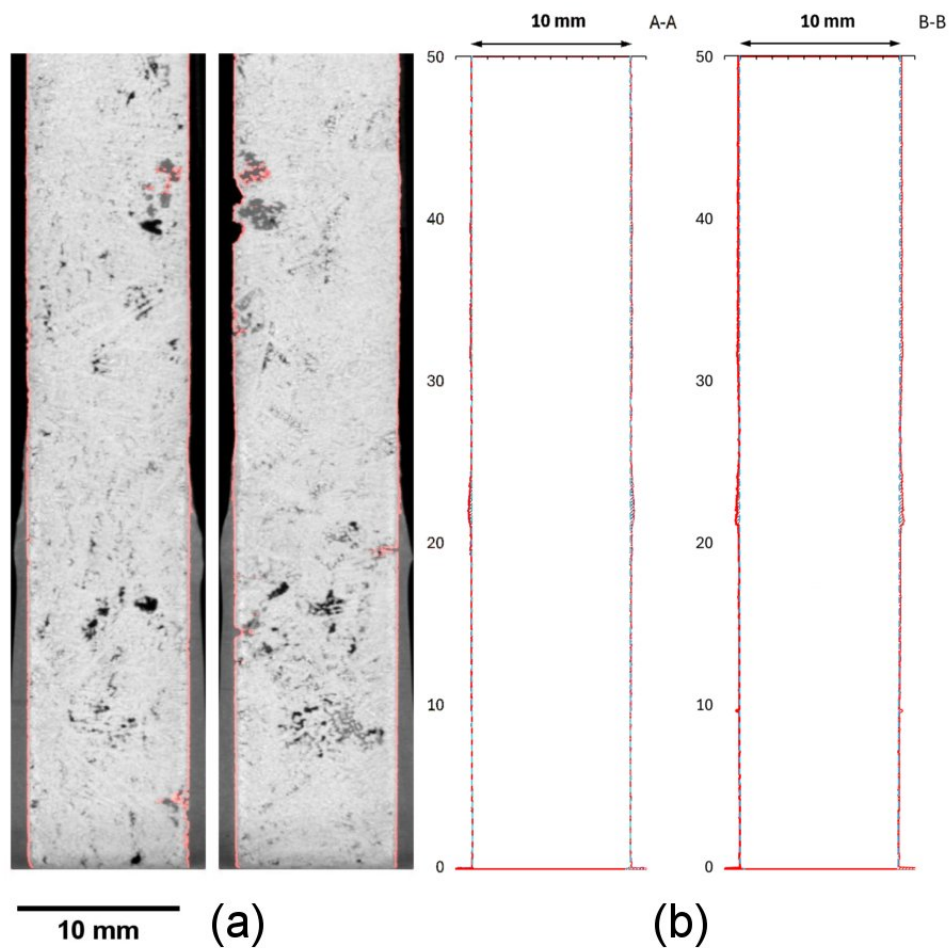


Figure B.72. Micro-CT results of the K-3 refractory corrosion test, HS24-36_1200C-7d. (a) Micro-CT images of the cross section at the center. (b) Corrosion depth plots, no distinguishable neck.

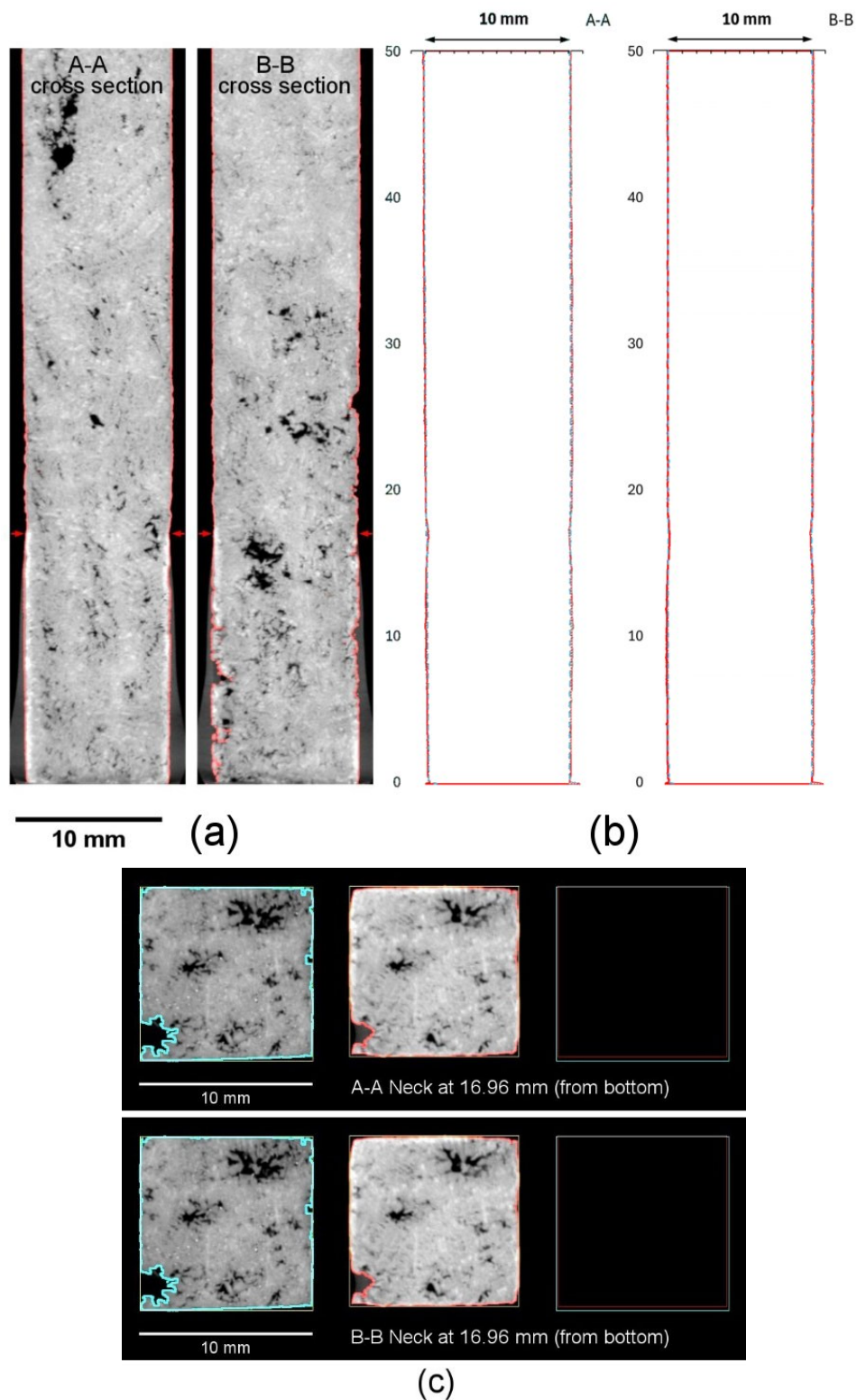


Figure B.73. Micro-CT results of the K-3 refractory corrosion test, HS24-37_1150C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

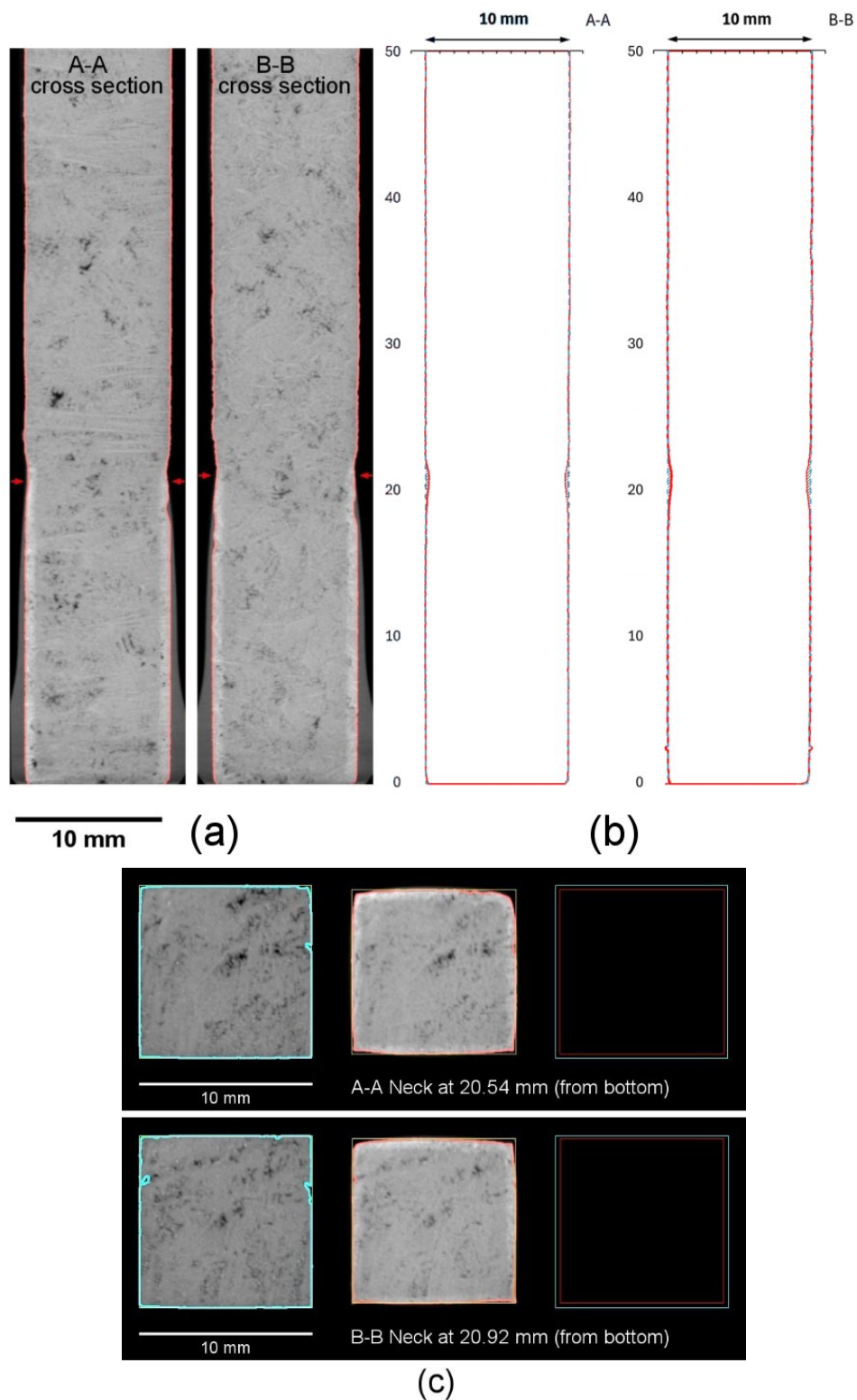


Figure B.74. Micro-CT results of the K-3 refractory corrosion test, HS24-37_1200C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

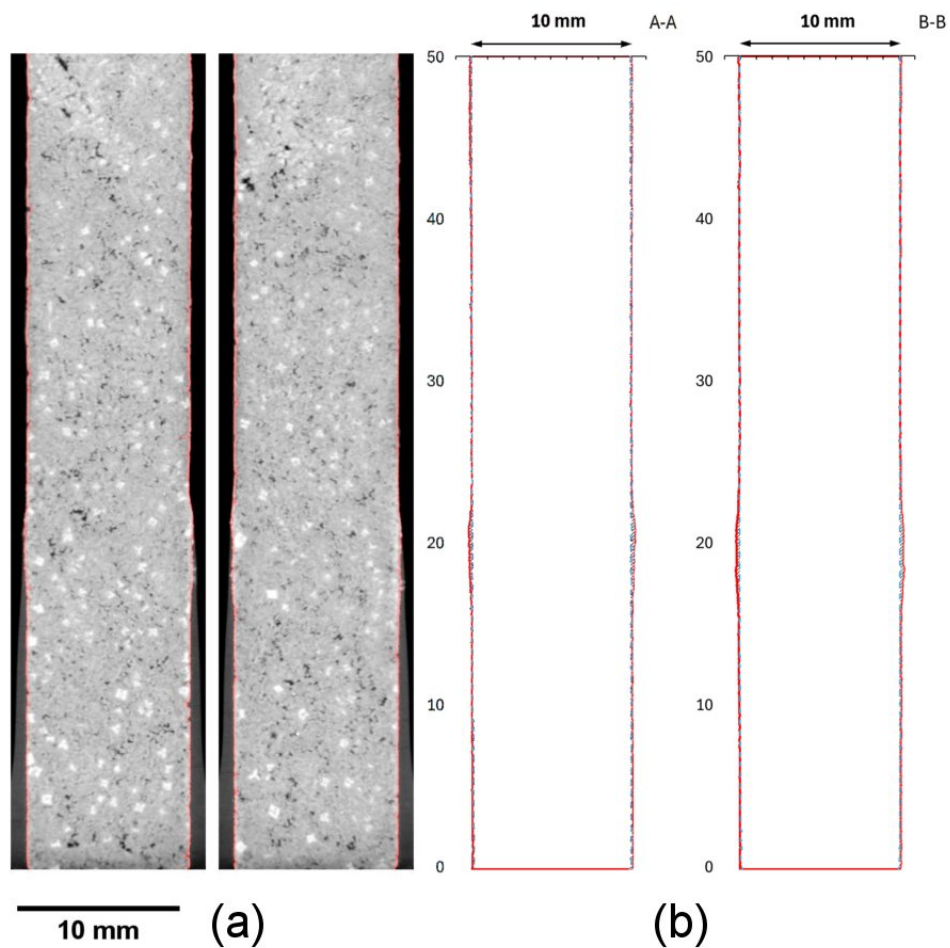


Figure B.75. Micro-CT results of the K-3 refractory corrosion test, HS24-38_1150C-7d. (a) Micro-CT images of the cross section at the center. (b) Corrosion depth plots, no distinguishable neck.

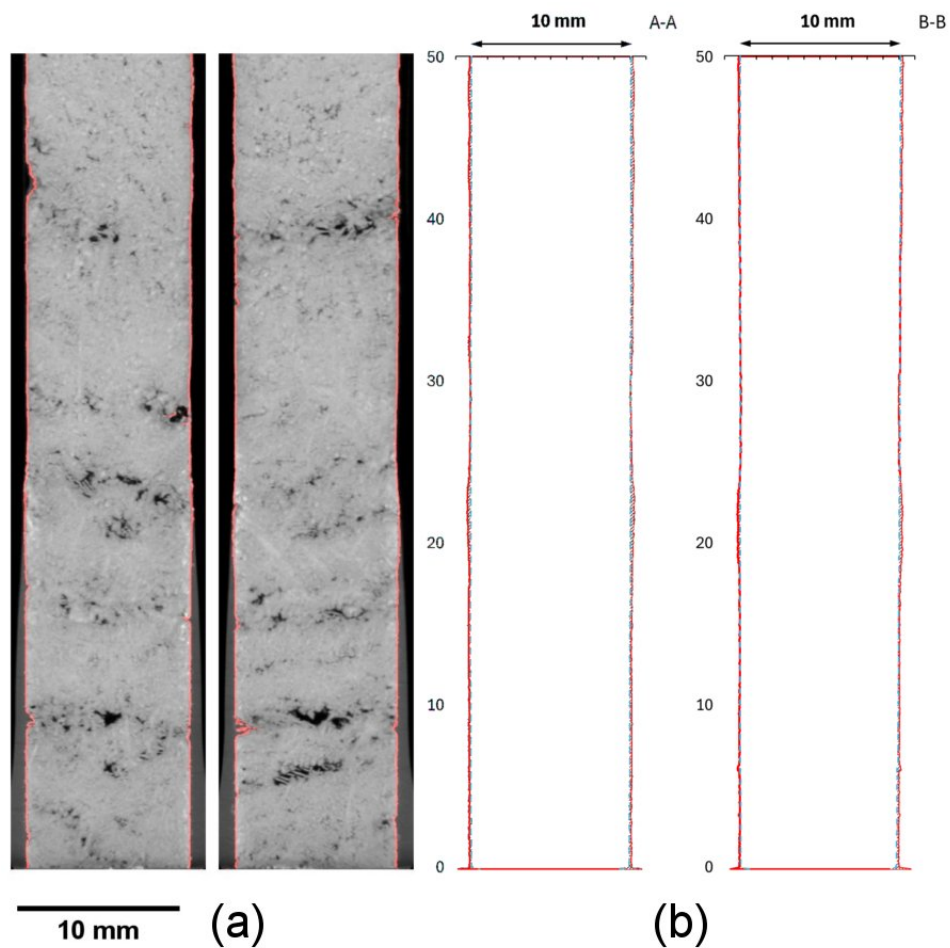


Figure B.76. Micro-CT results of the K-3 refractory corrosion test, HS24-38_1200C-7d. (a) Micro-CT images of the cross section at the center. (b) Corrosion depth plots, no distinguishable neck.

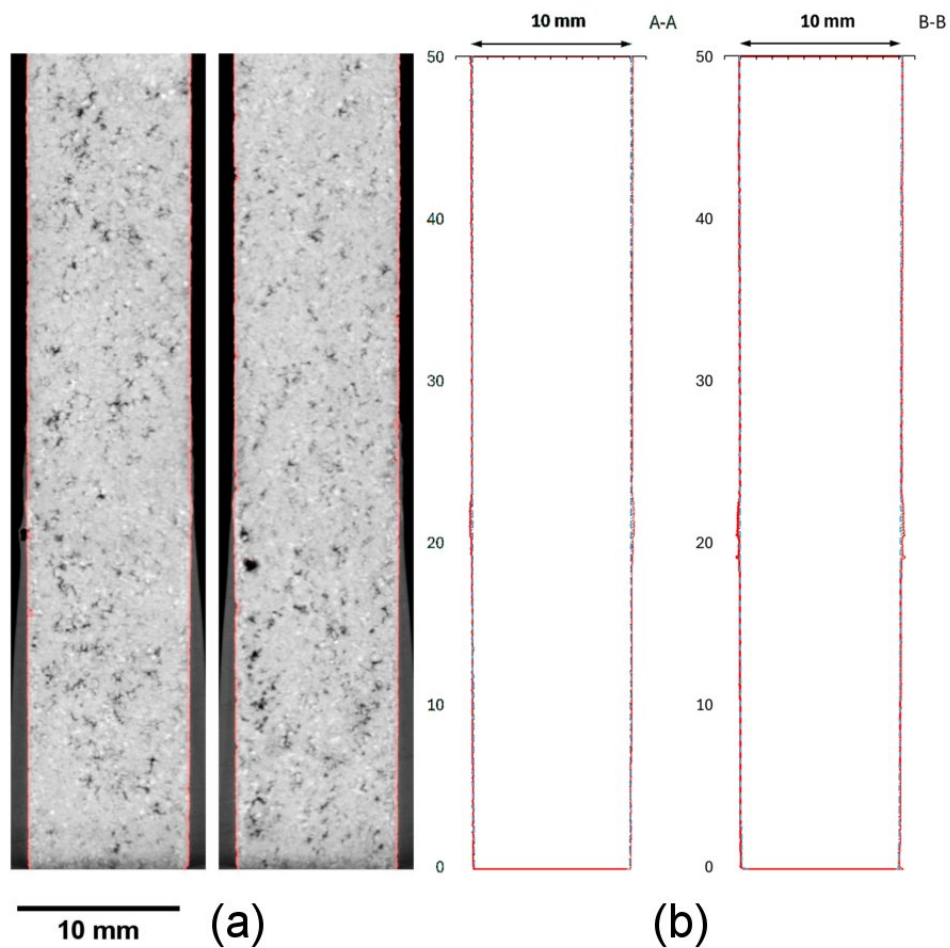


Figure B.77. Micro-CT results of the K-3 refractory corrosion test, HS24-39_1150C-7d. (a) Micro-CT images of the cross section at the center. (b) Corrosion depth plots, no distinguishable neck.

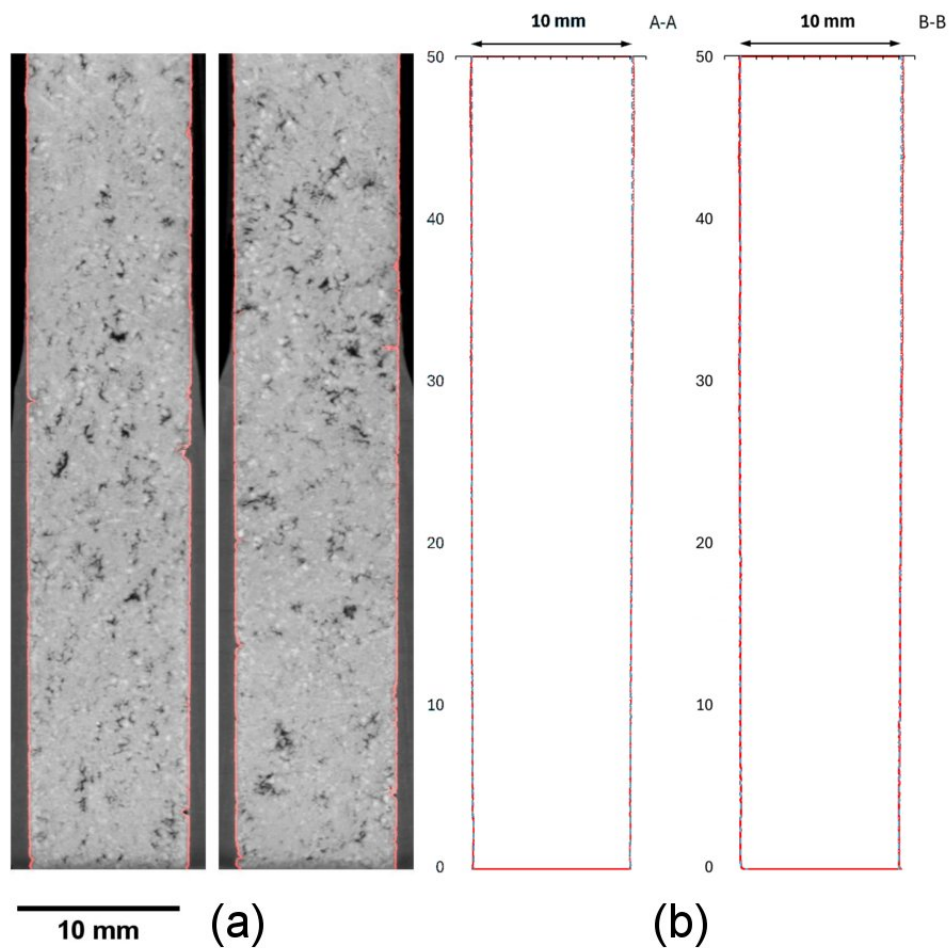


Figure B.78. Micro-CT results of the K-3 refractory corrosion test, HS24-39_1200C-7d. (a) Micro-CT images of the cross section at the center. (b) Corrosion depth plots, no distinguishable neck.

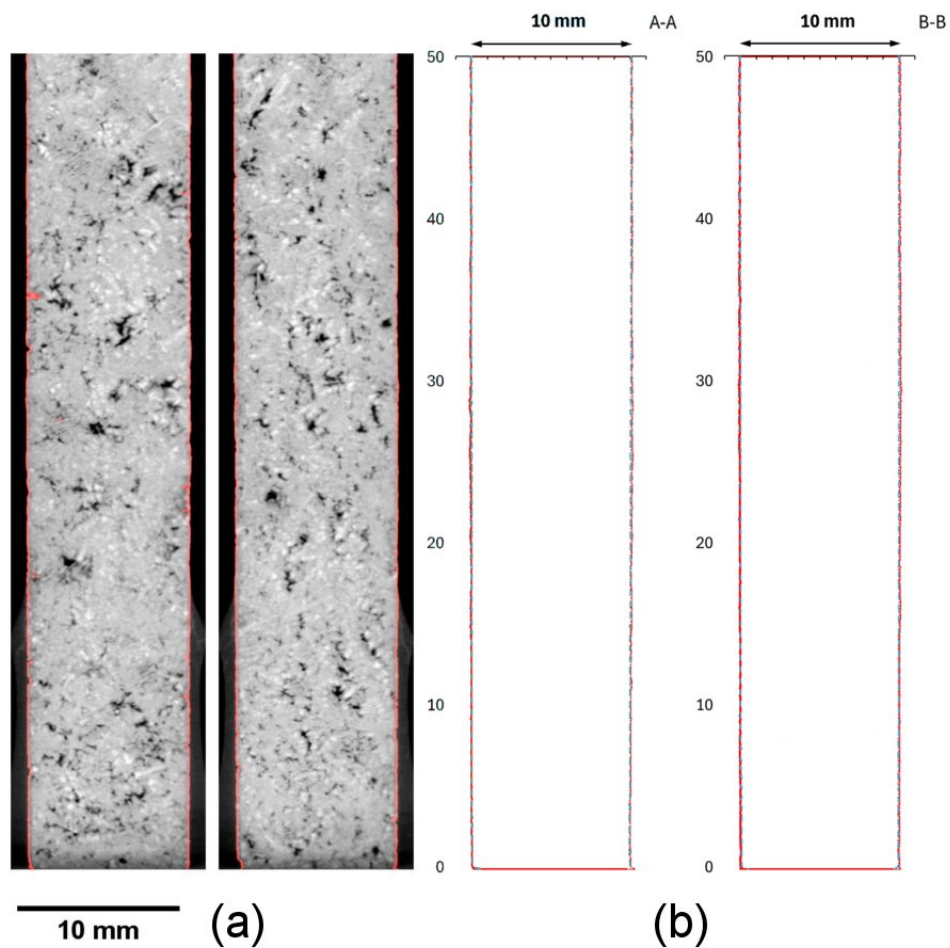


Figure B.79. Micro-CT results of the K-3 refractory corrosion test, HS24-40_1150C-7d. (a) Micro-CT images of the cross section at the center. (b) Corrosion depth plots, no distinguishable neck.

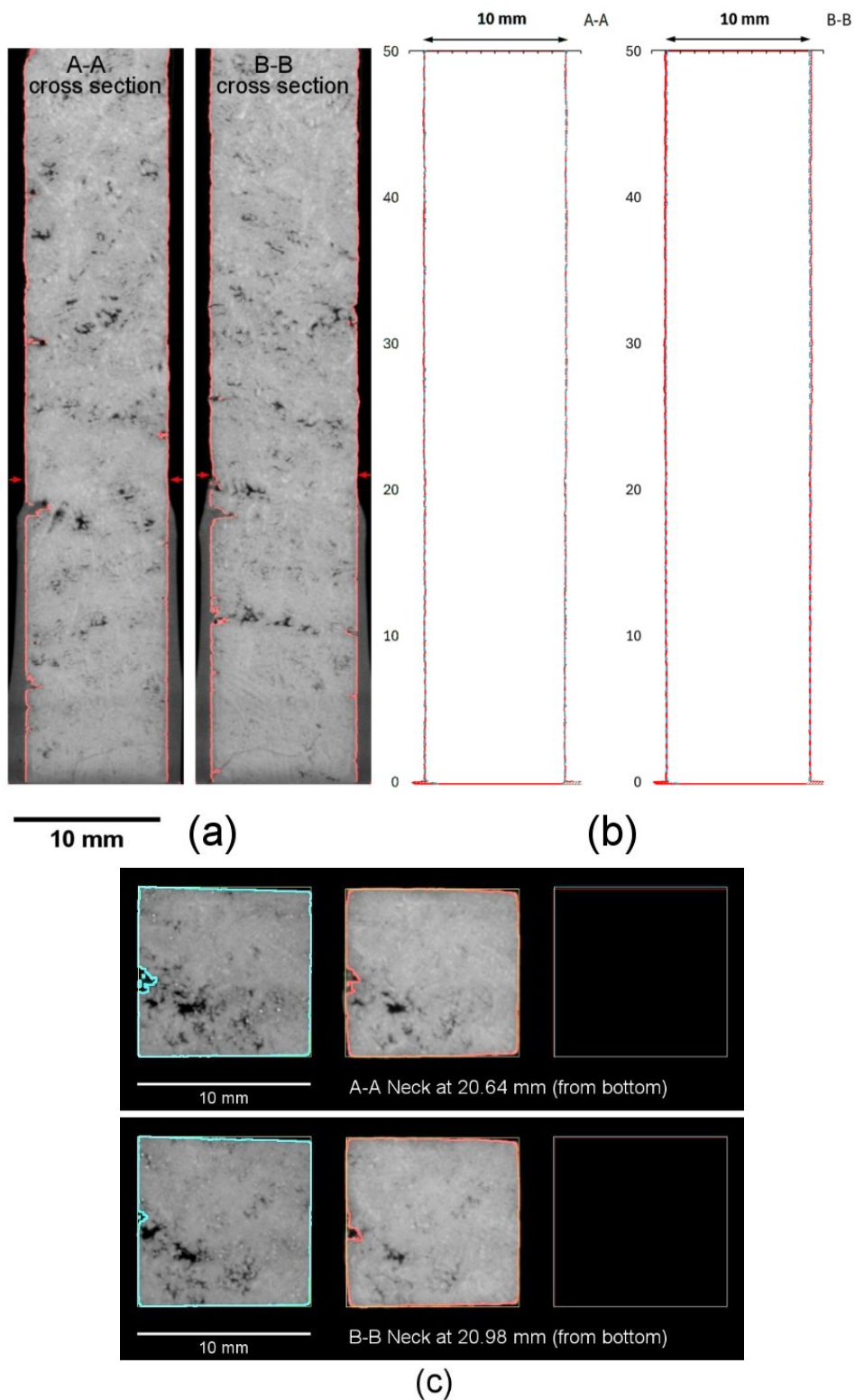


Figure B.80. Micro-CT results of the K-3 refractory corrosion test, HS24-40_1200C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

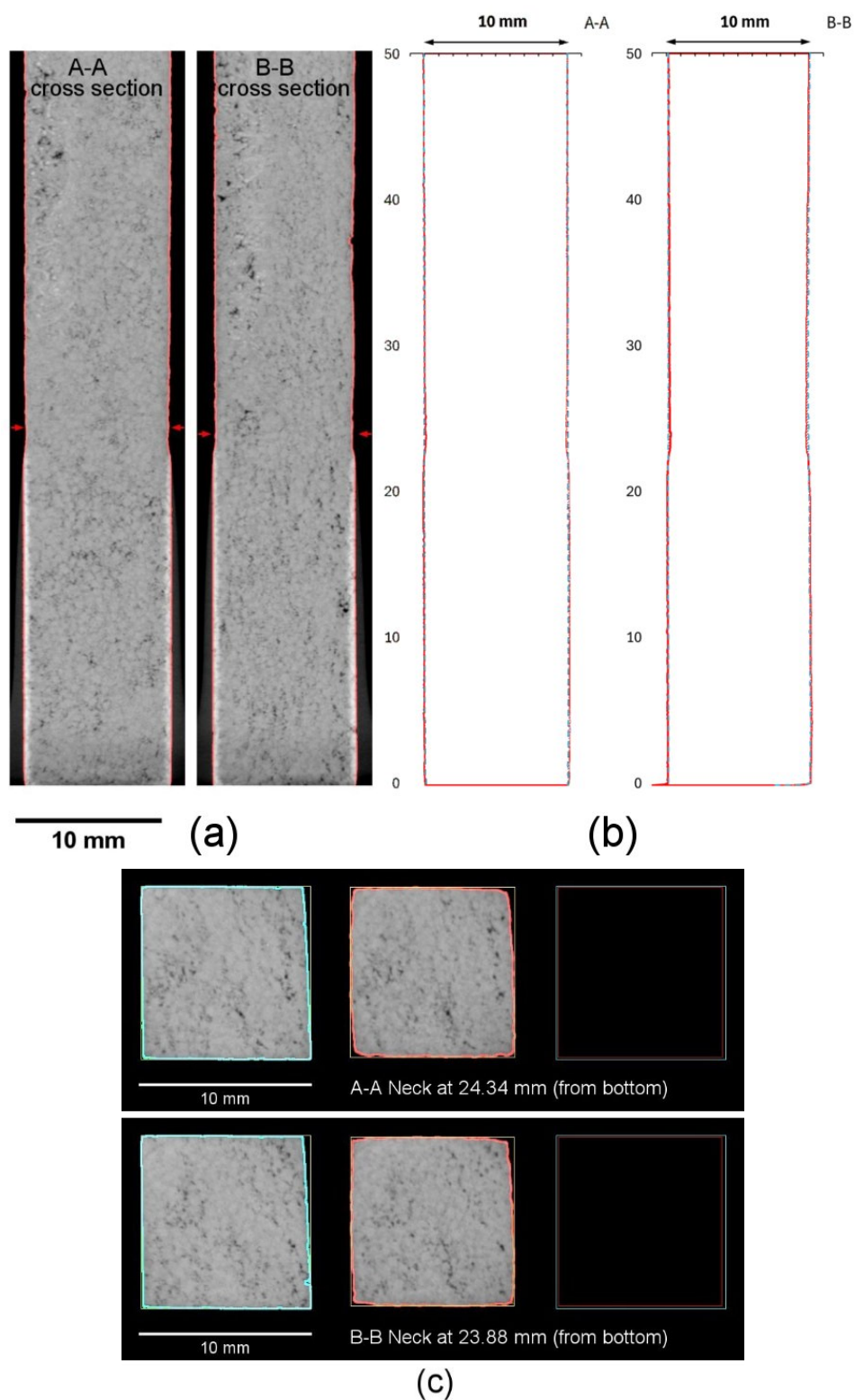


Figure B.81. Micro-CT results of the K-3 refractory corrosion test, HS24-41_1150C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

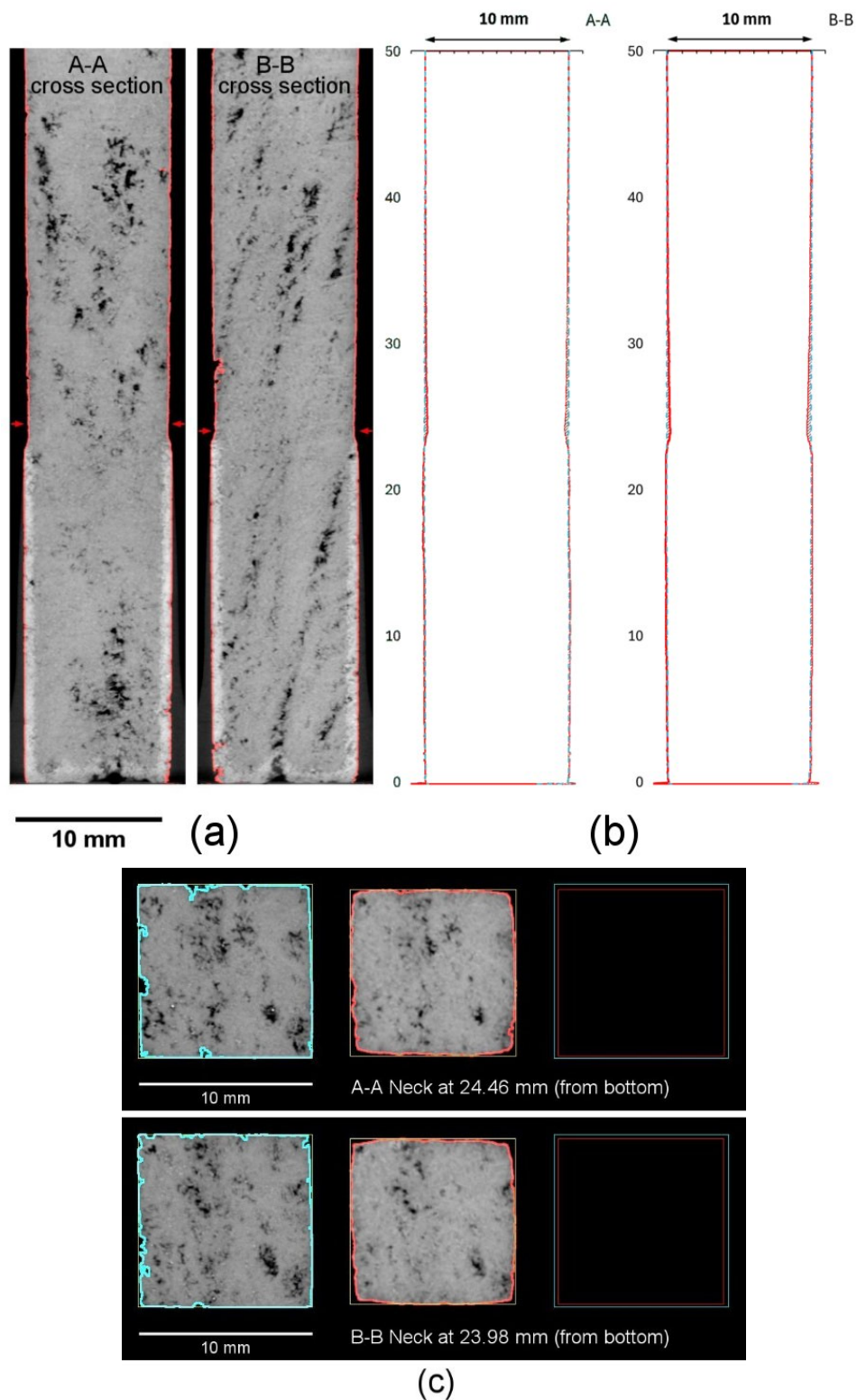


Figure B.82. Micro-CT results of the K-3 refractory corrosion test, HS24-41_1200C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

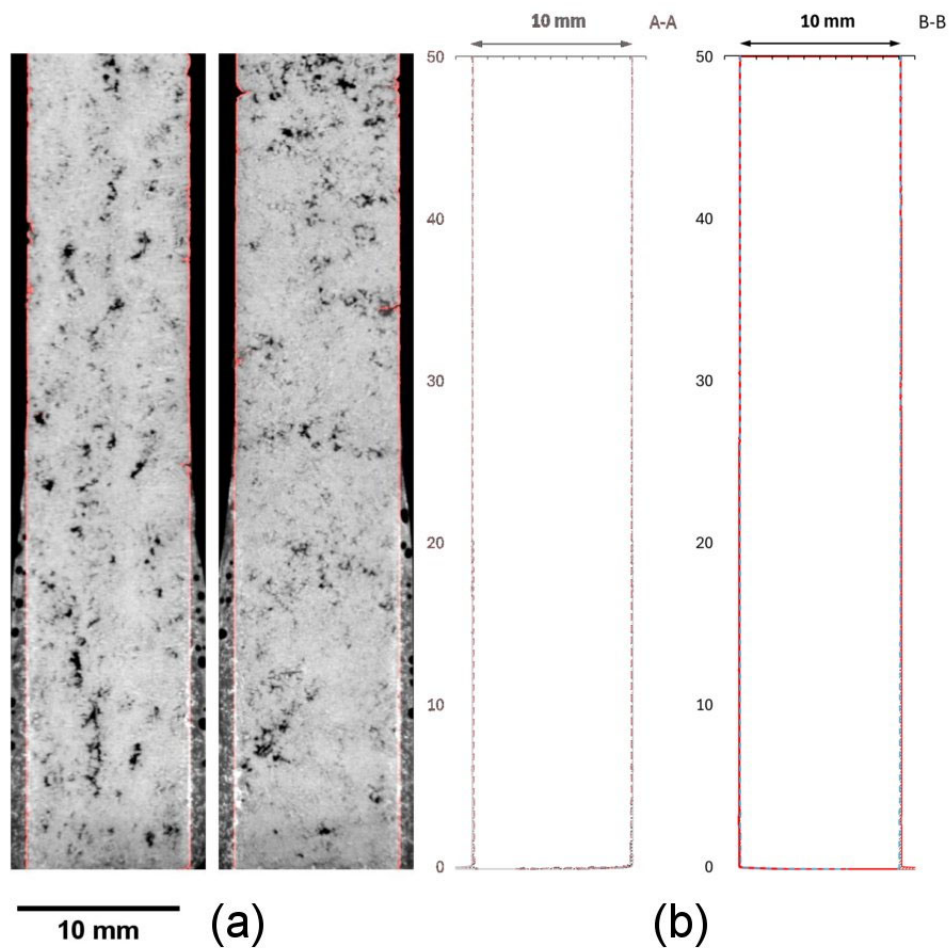


Figure B.83. Micro-CT results of the K-3 refractory corrosion test, HS24-42_1150C-7d. (a) Micro-CT images of the cross section at the center. (b) Corrosion depth plots, no distinguishable neck.

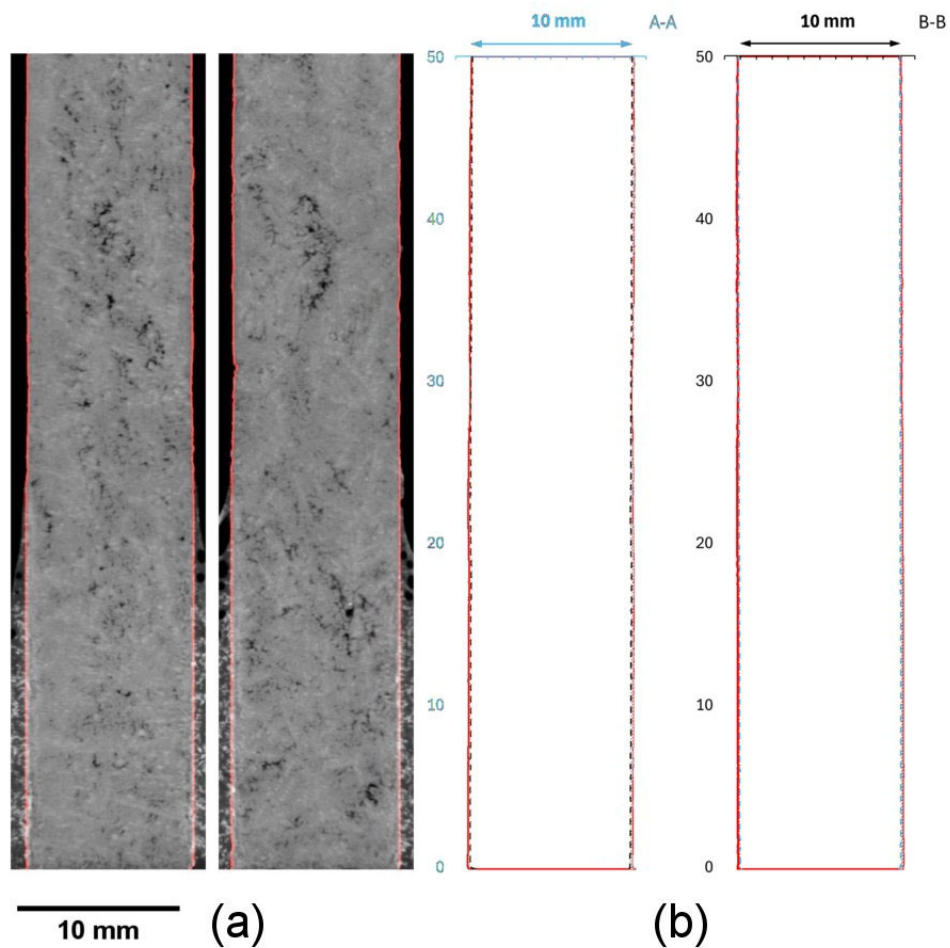


Figure B.84. Micro-CT results of the K-3 refractory corrosion test, HS24-42_1200C-7d. (a) Micro-CT images of the cross section at the center. (b) Corrosion depth plots, no distinguishable neck.

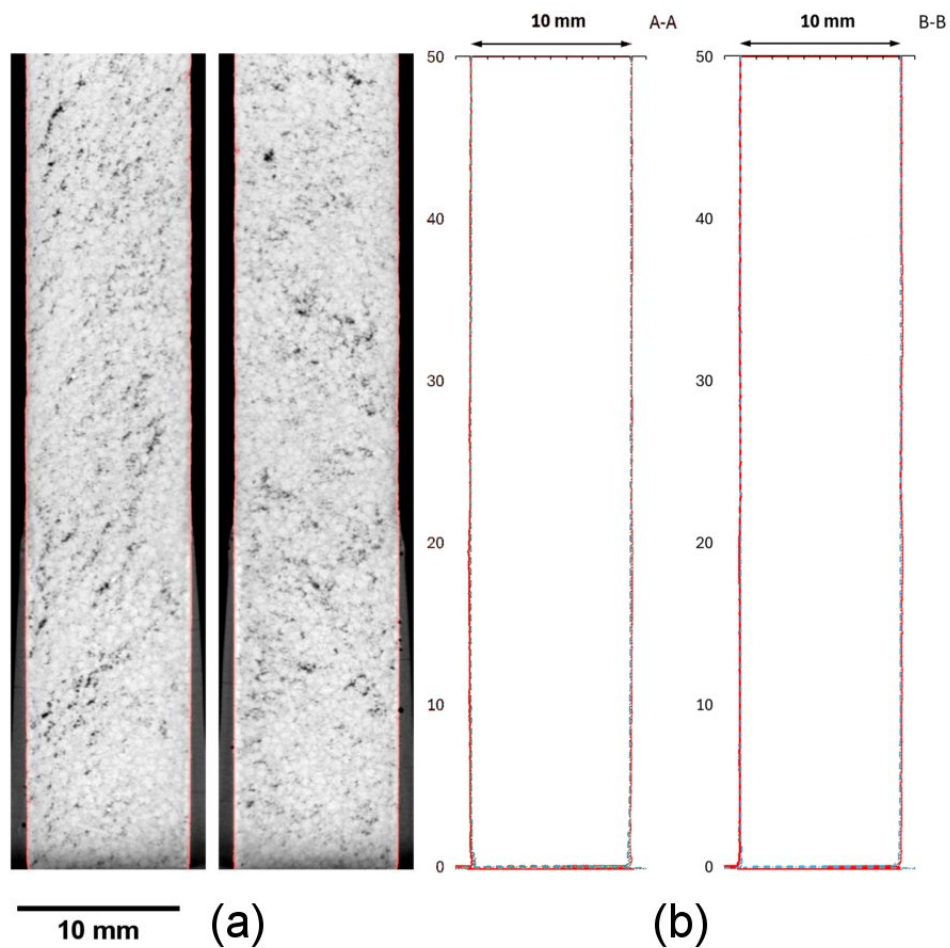


Figure B.85. Micro-CT results of the K-3 refractory corrosion test, HS24-43_1150C-7d. (a) Micro-CT images of the cross section at the center. (b) Corrosion depth plots, no distinguishable neck.

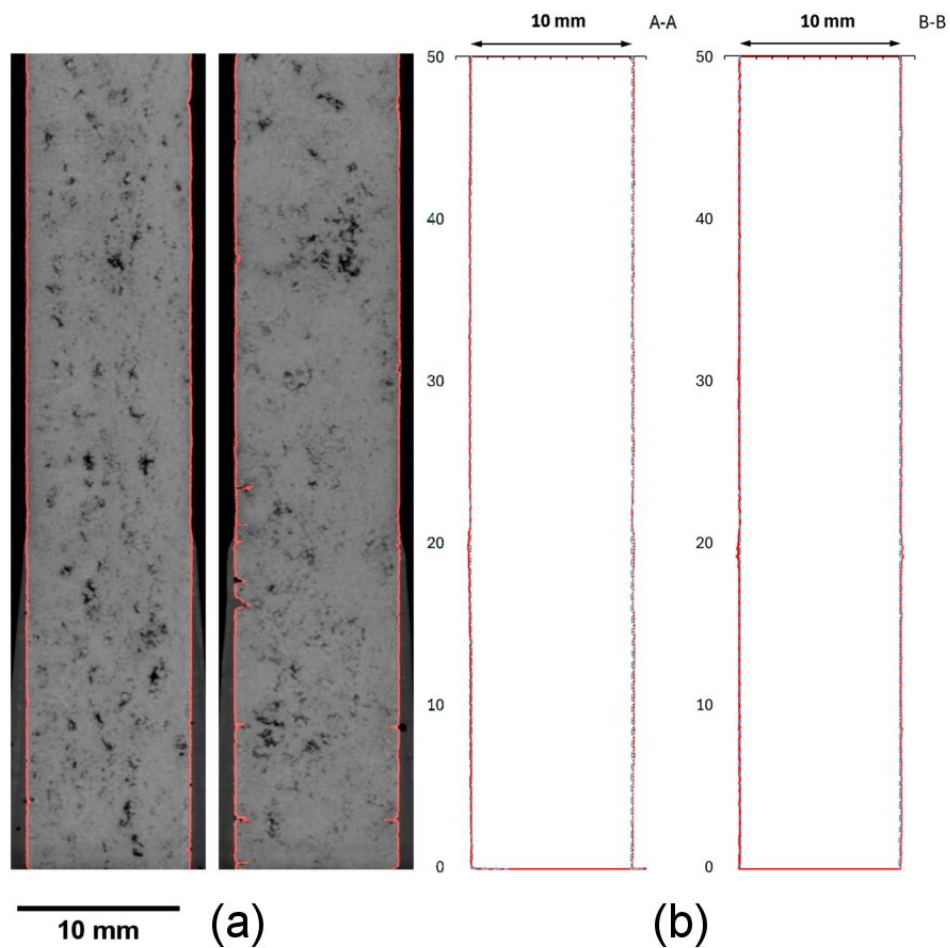


Figure B.86. Micro-CT results of the K-3 refractory corrosion test, HS24-43_1200C-7d. (a) Micro-CT images of the cross section at the center. (b) Corrosion depth plots, no distinguishable neck.

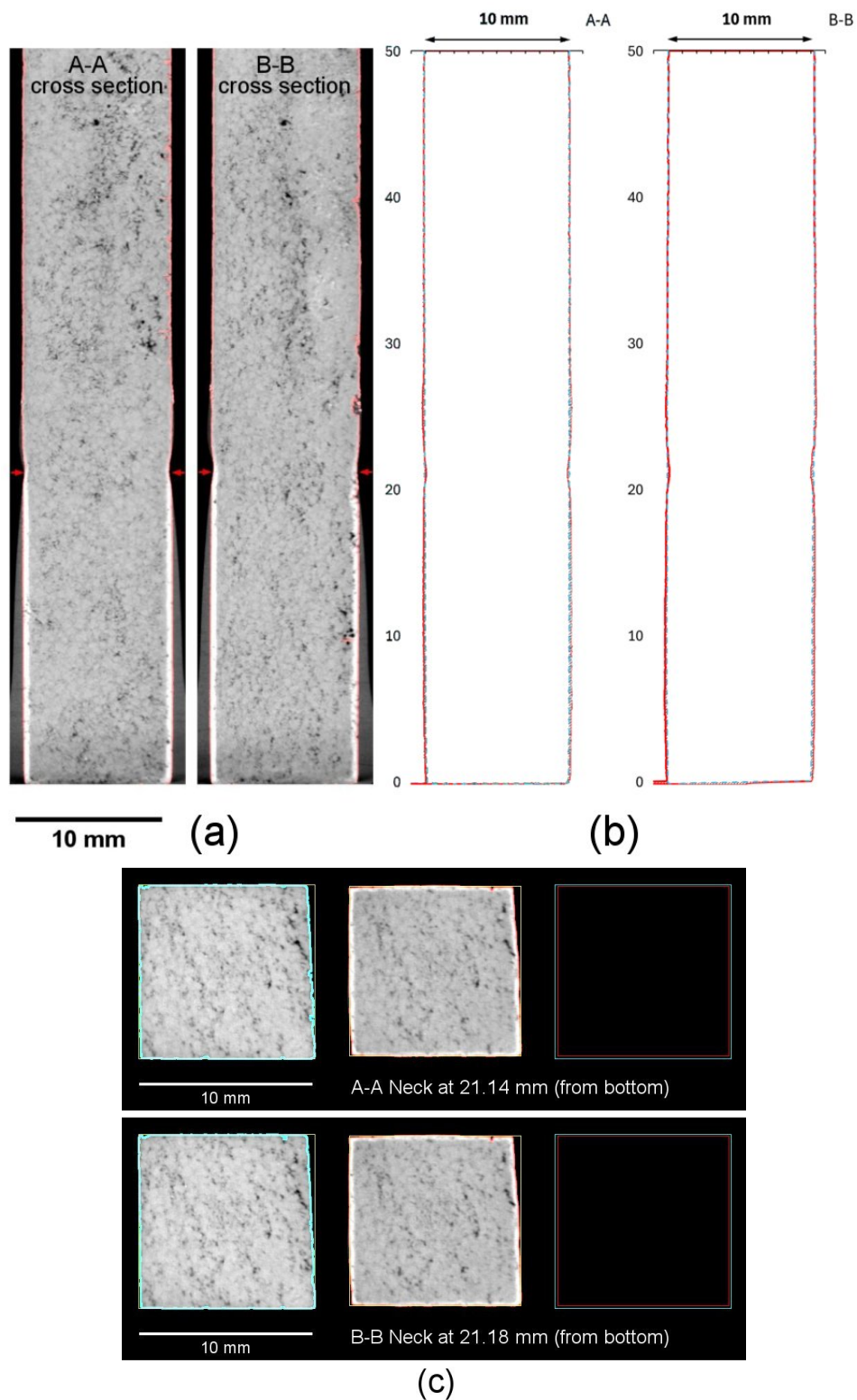


Figure B.87. Micro-CT results of the K-3 refractory corrosion test, HS24-44_1150C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

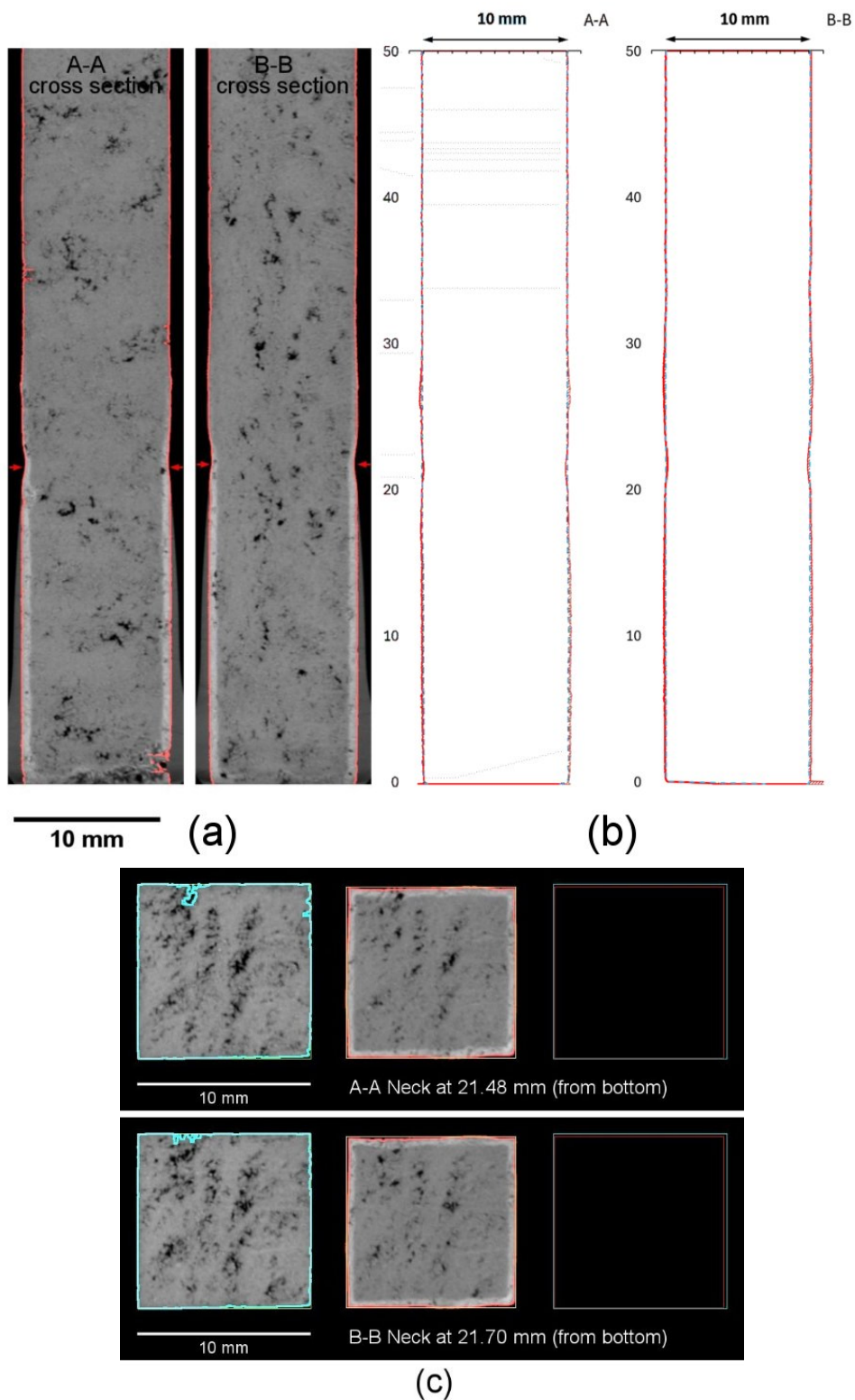


Figure B.88. Micro-CT results of the K-3 refractory corrosion test, HS24-44_1200C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

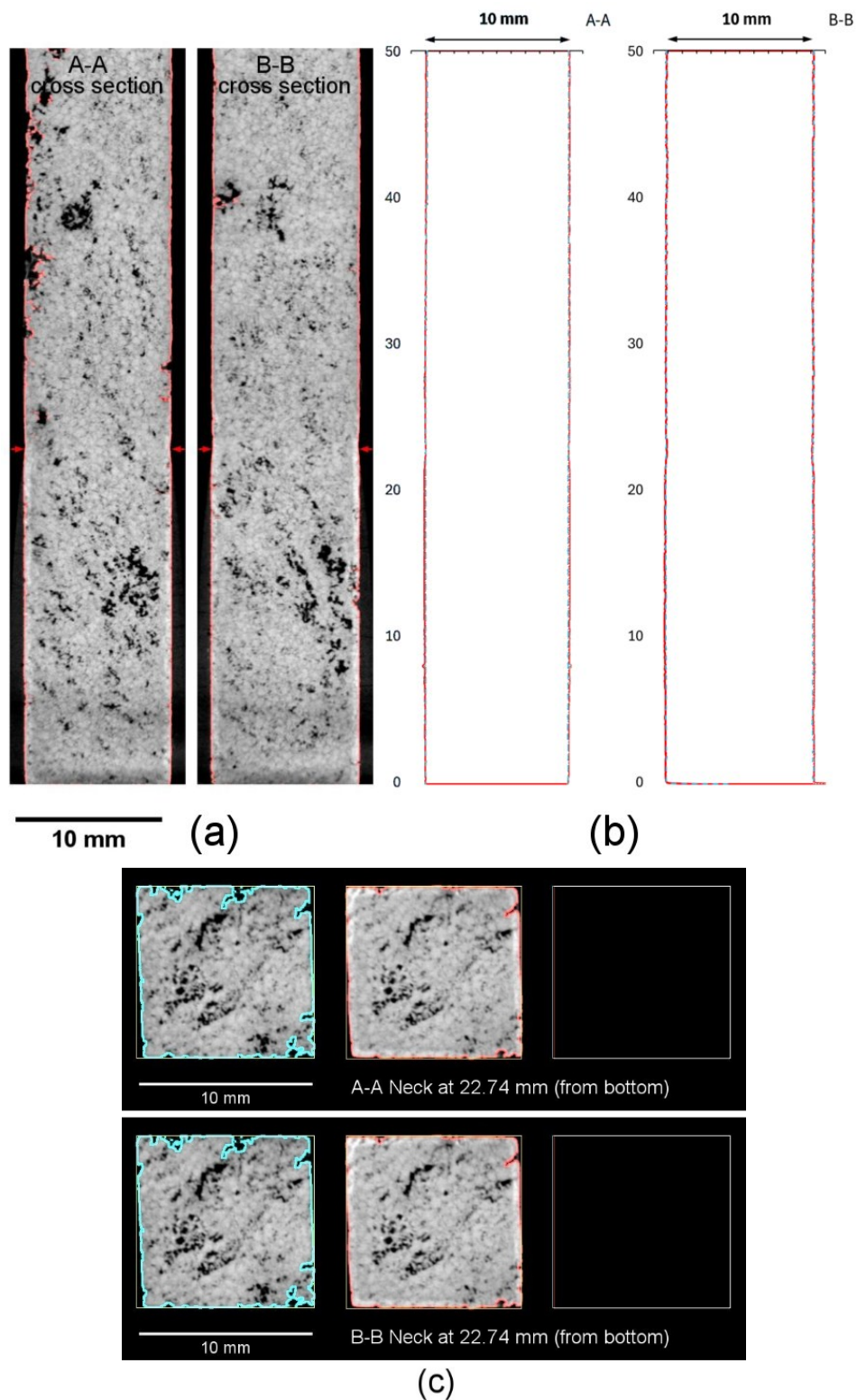


Figure B.89. Micro-CT results of the K-3 refractory corrosion test, HS24-45_1150C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

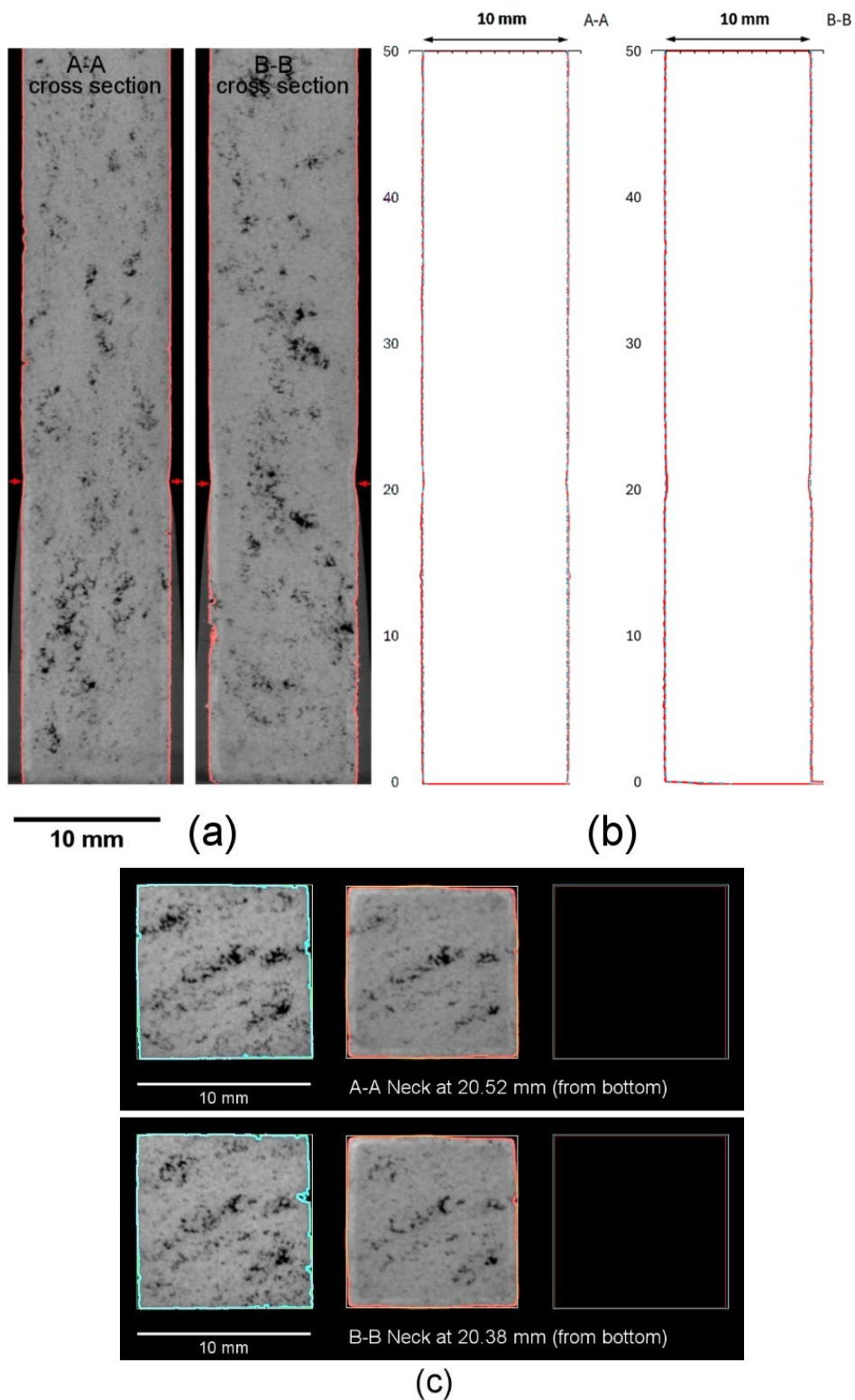


Figure B.90. Micro-CT results of the K-3 refractory corrosion test, HS24-45_1200C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

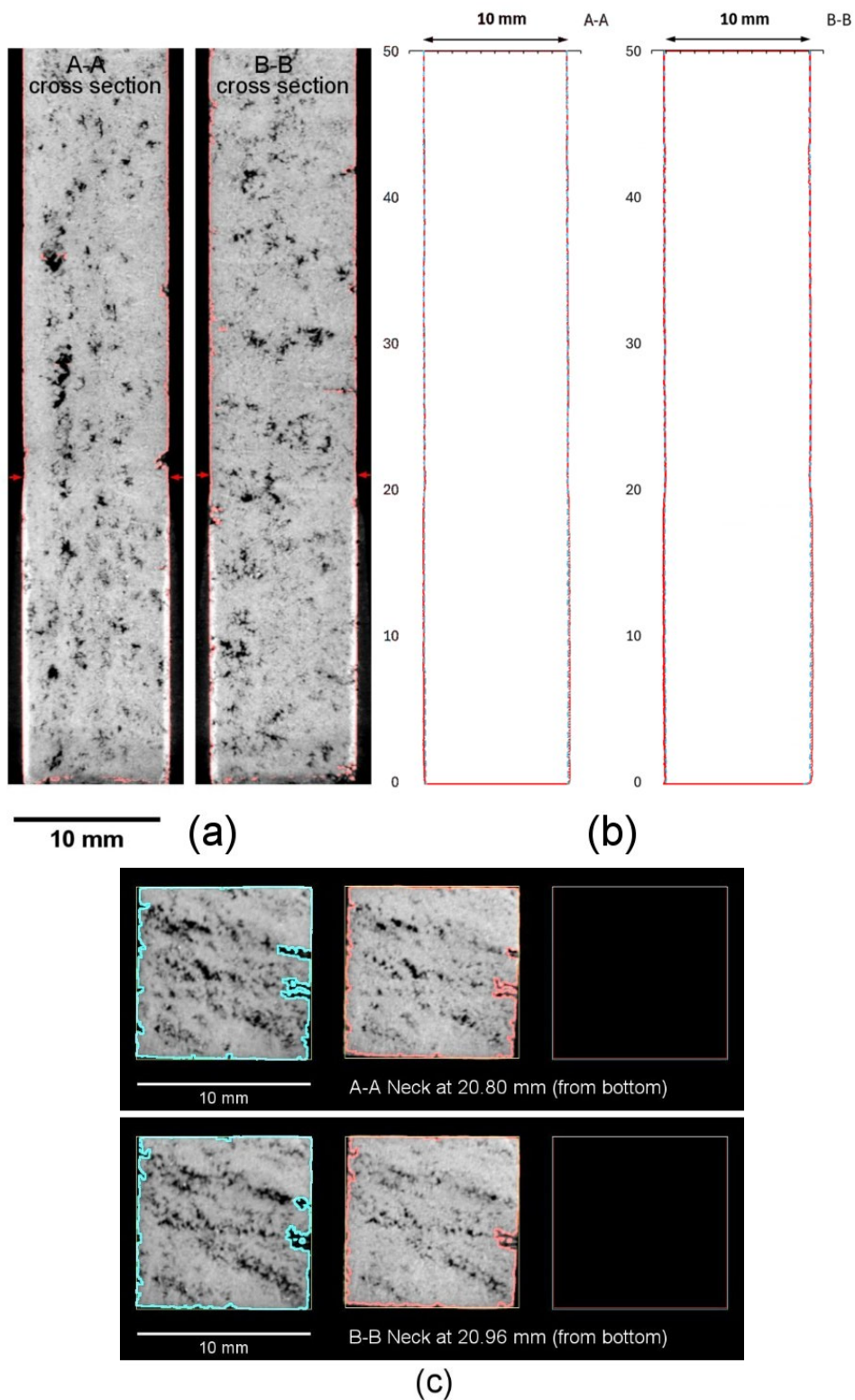


Figure B.91. Micro-CT results of the K-3 refractory corrosion test, HS24-46_1150C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

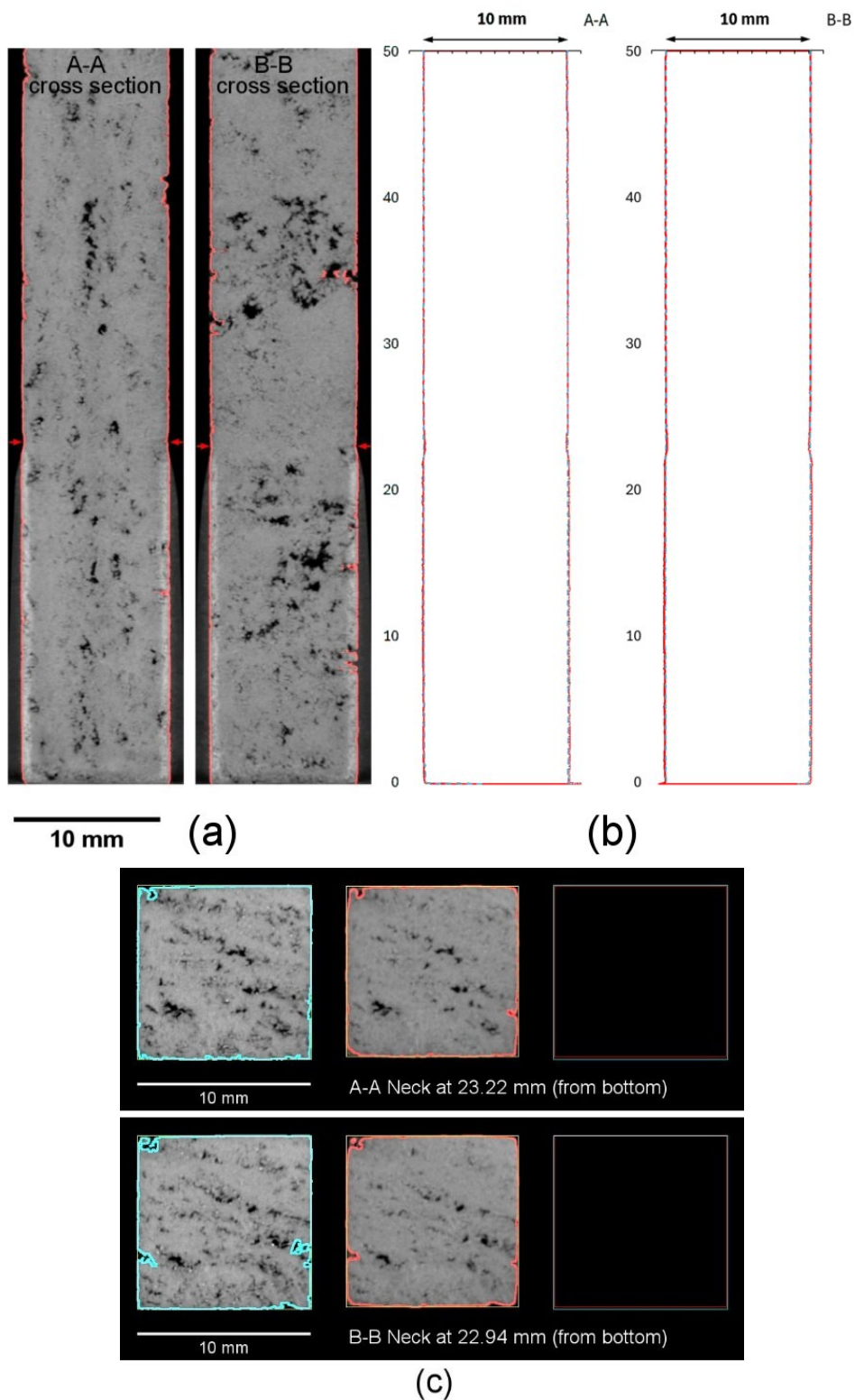


Figure B.92. Micro-CT results of the K-3 refractory corrosion test, HS24-46_1200C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

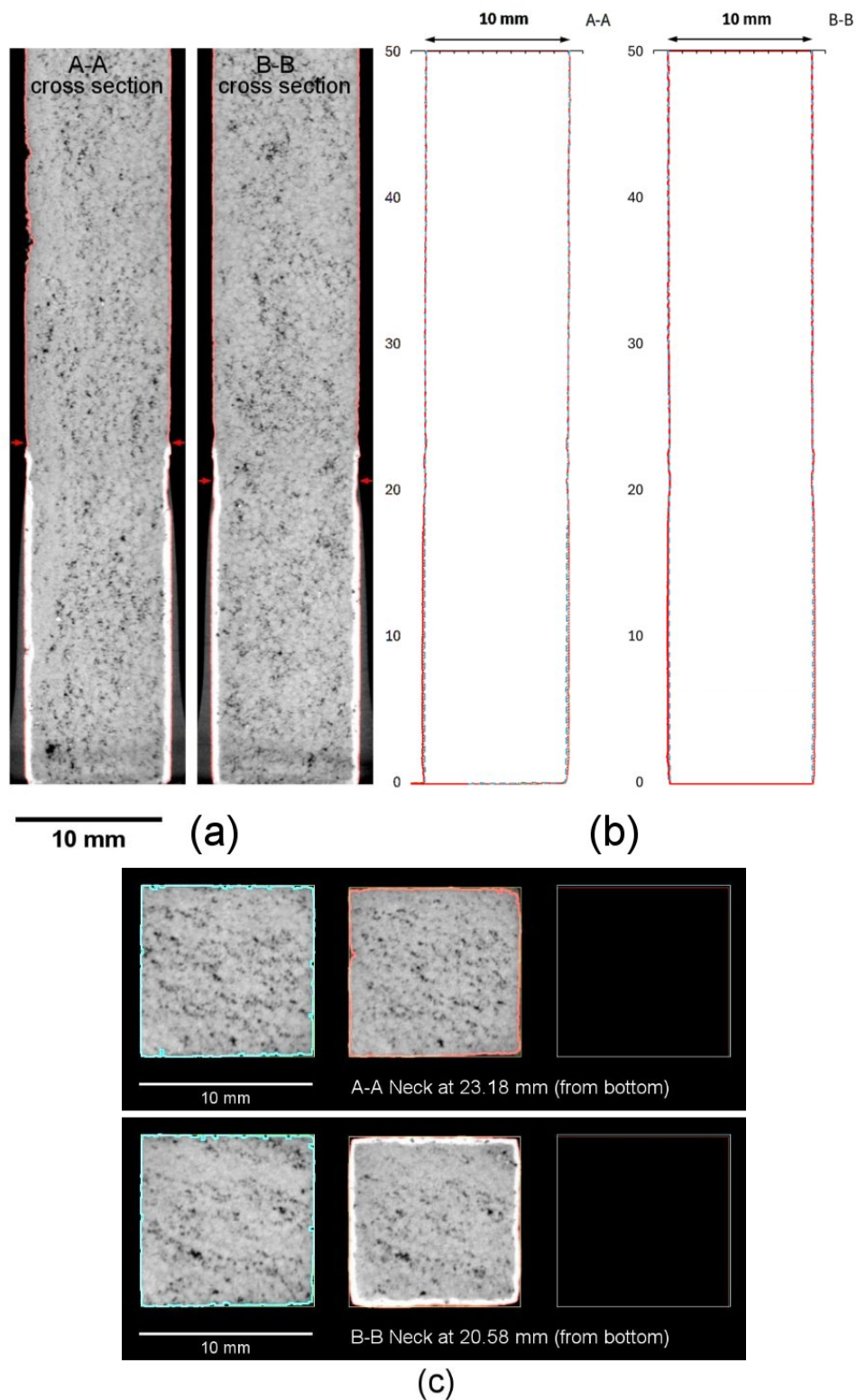


Figure B.93. Micro-CT results of the K-3 refractory corrosion test, HS24-47_1150C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

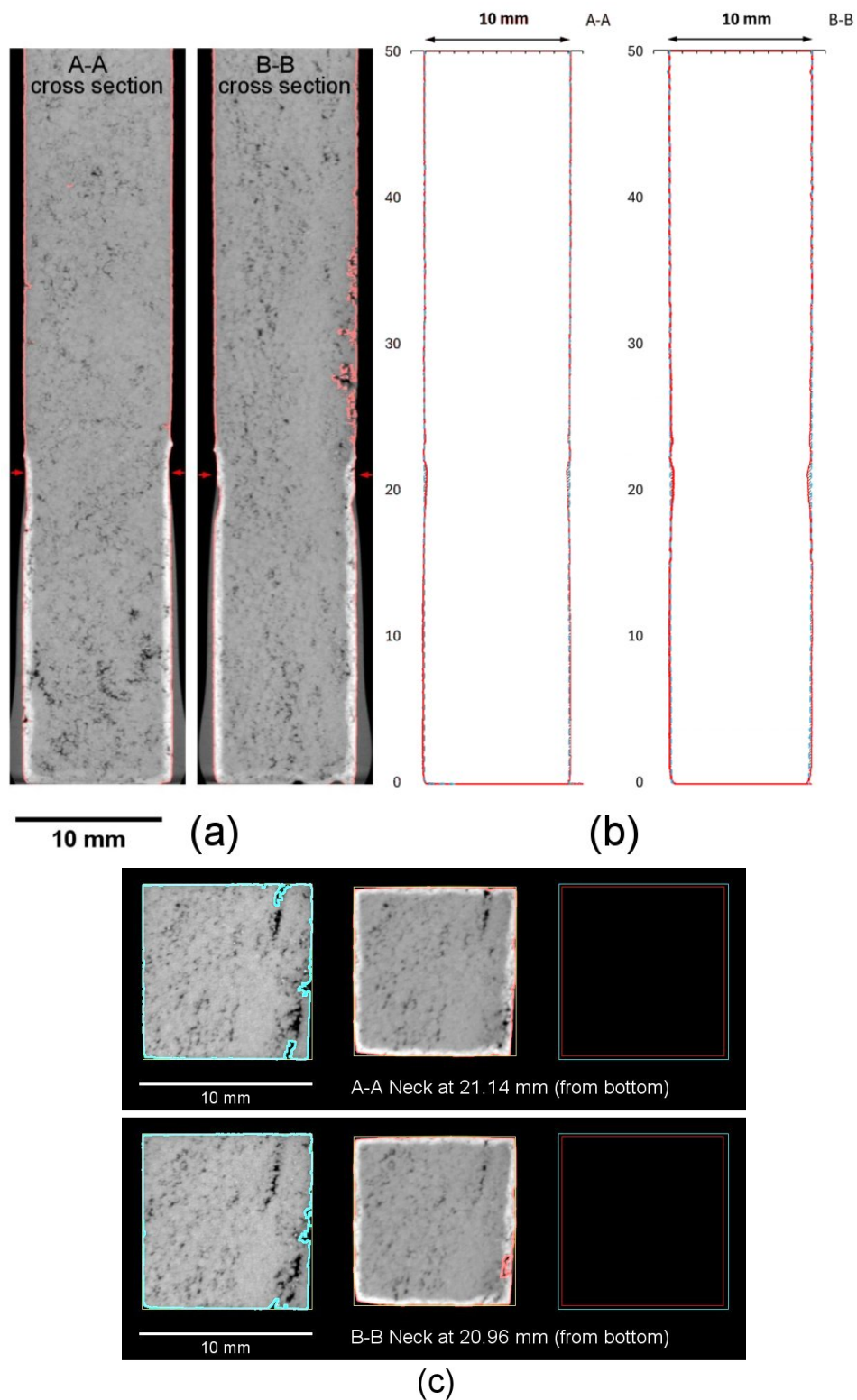


Figure B.94. Micro-CT results of the K-3 refractory corrosion test, HS24-47_1200C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

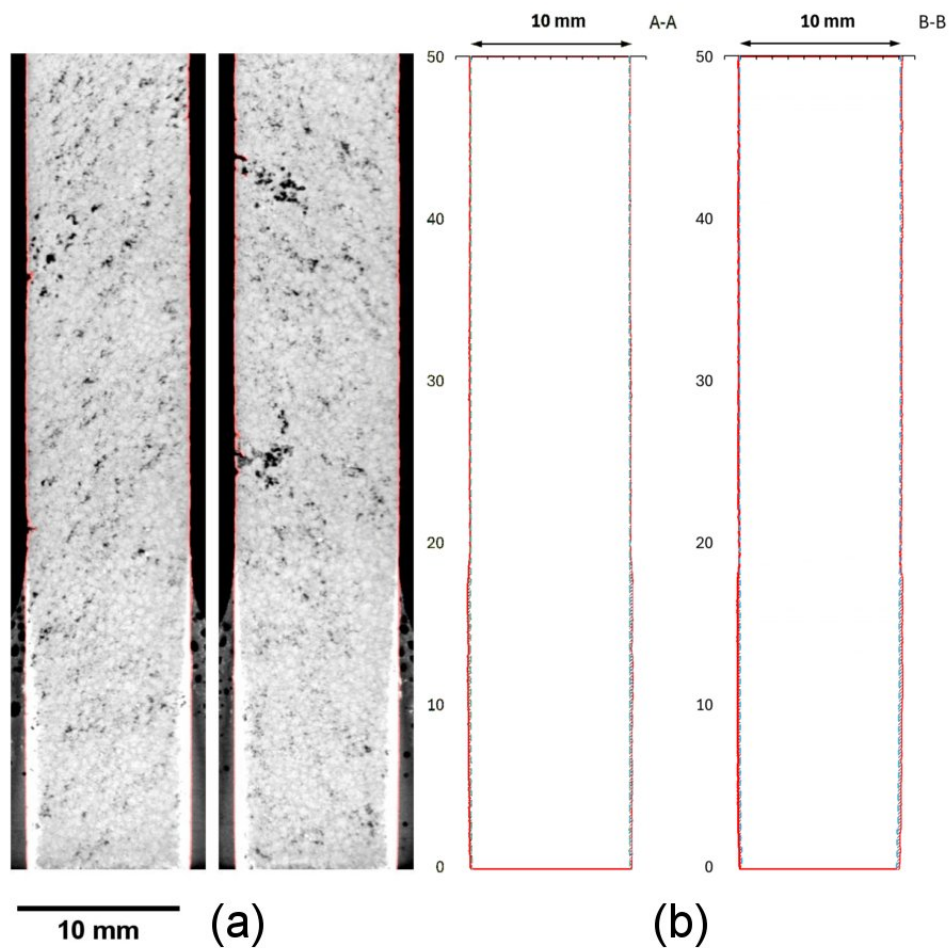


Figure B.95. Micro-CT results of the K-3 refractory corrosion test, HS24-48_1150C-7d. (a) Micro-CT images of the cross section at the center. (b) Corrosion depth plots, no distinguishable neck.

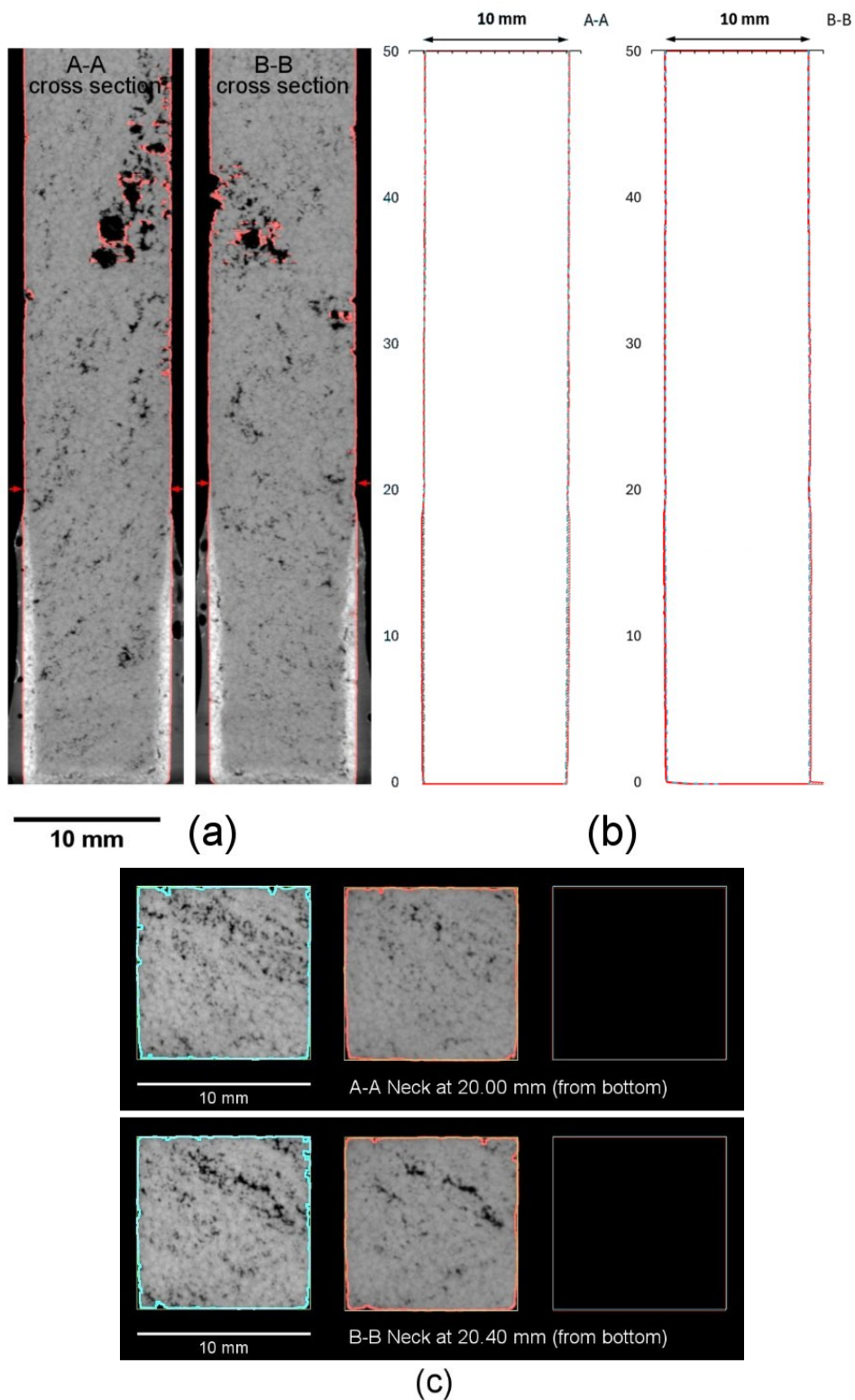


Figure B.96. Micro-CT results of the K-3 refractory corrosion test, HS24-48_1200C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

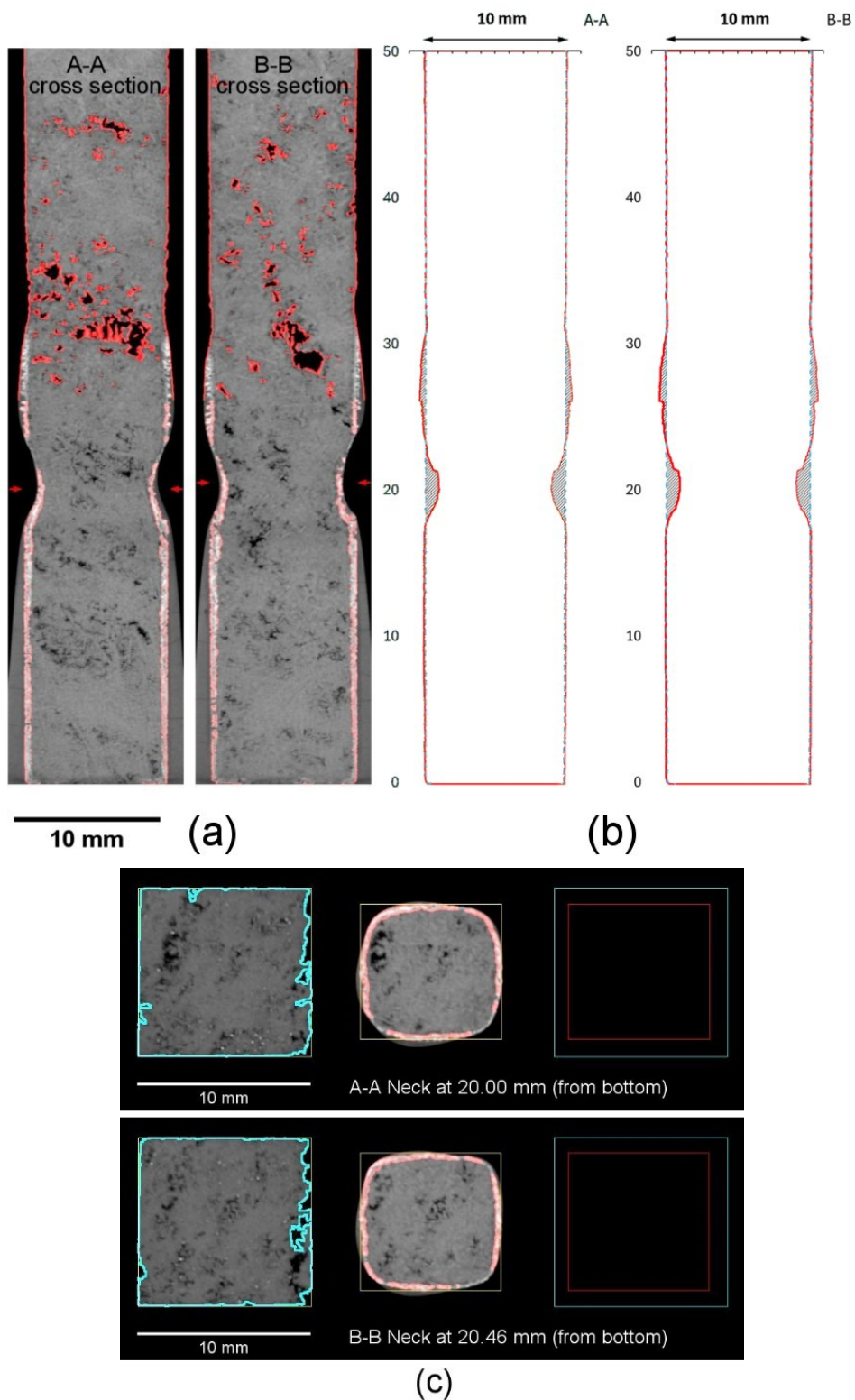


Figure B.97. Micro-CT results of the K-3 refractory corrosion test, HS24-49_1150C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

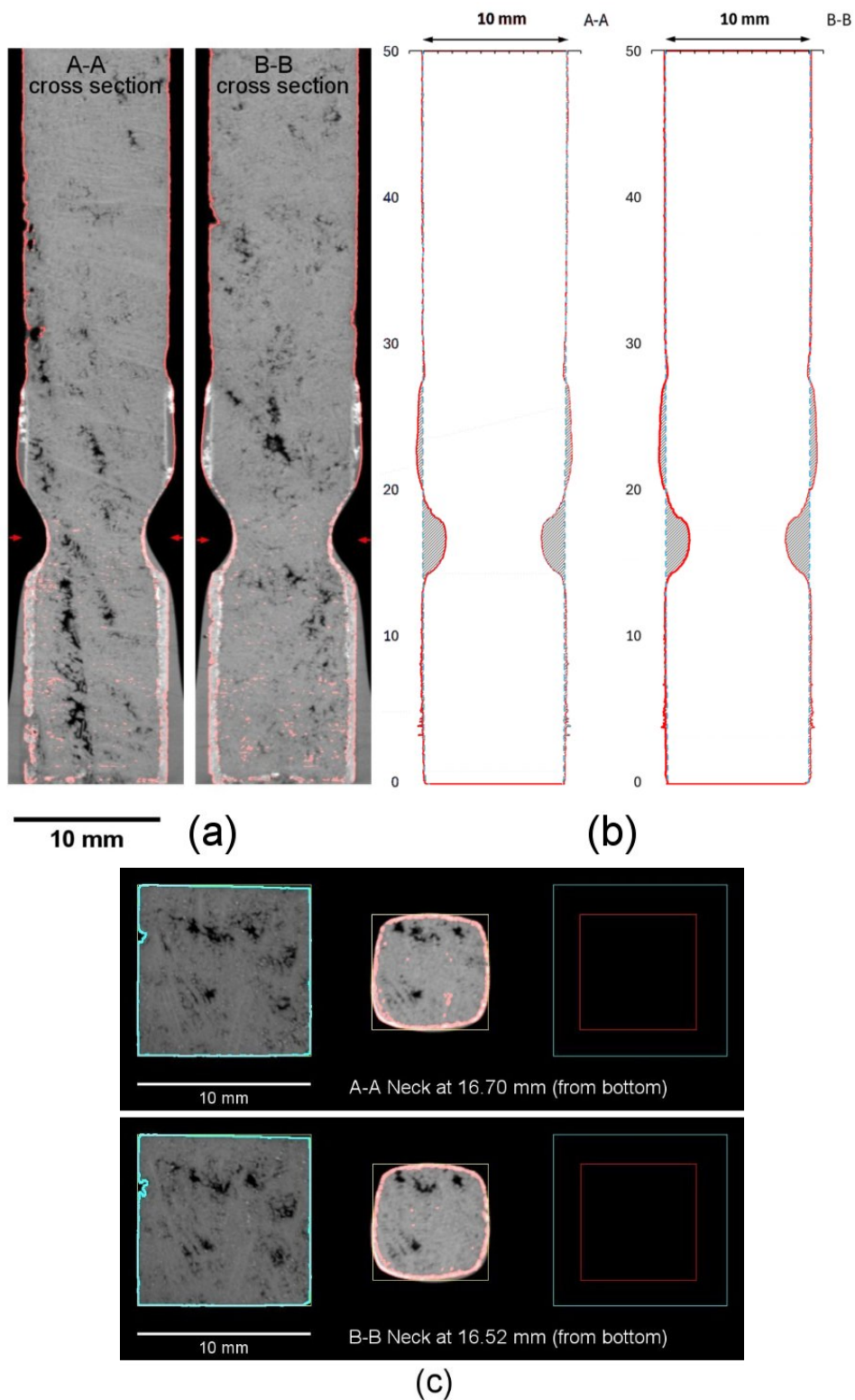


Figure B.98. Micro-CT results of the K-3 refractory corrosion test, HS24-49_1200C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

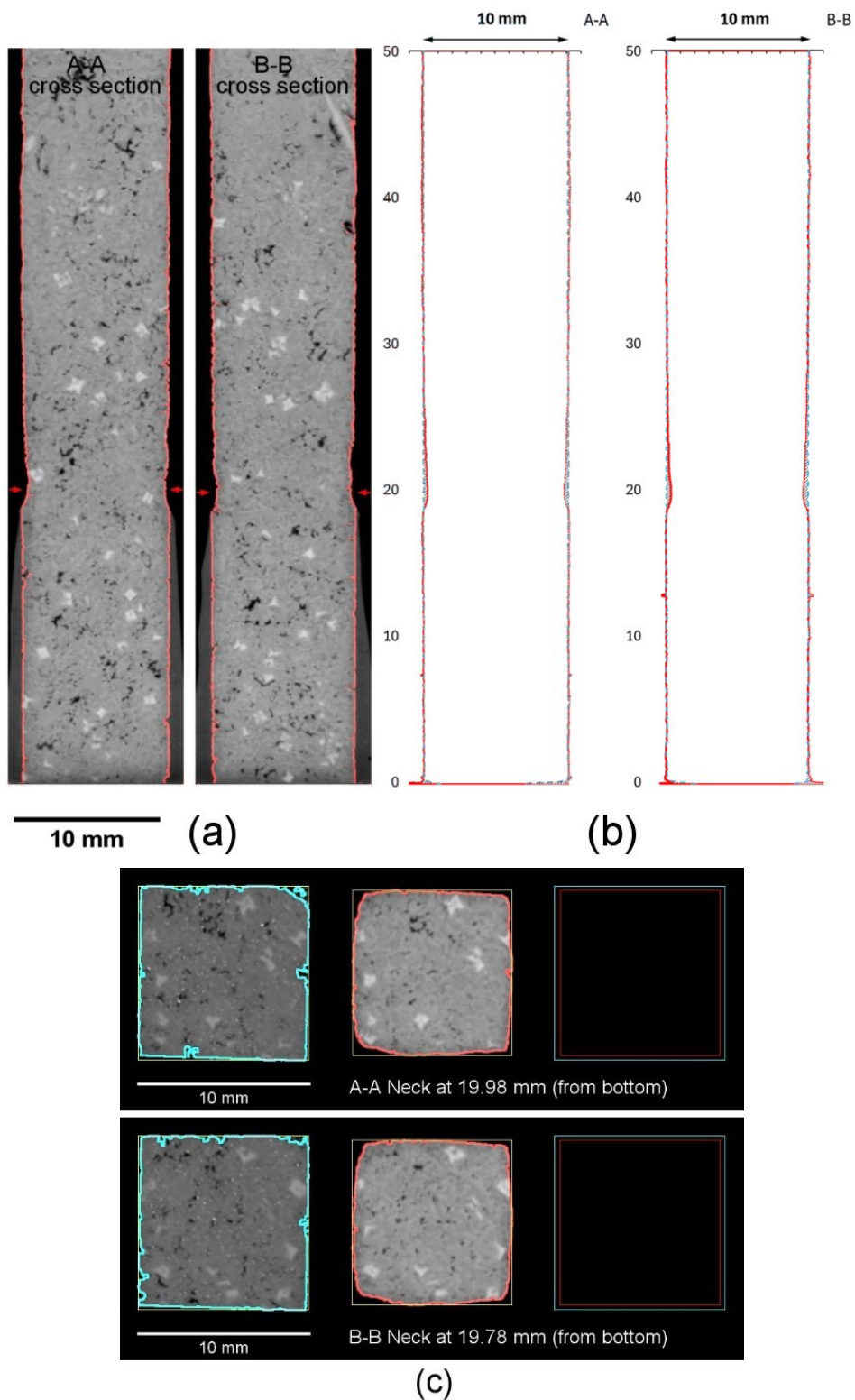


Figure B.99. Micro-CT results of the K-3 refractory corrosion test, HS24-50_1150C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

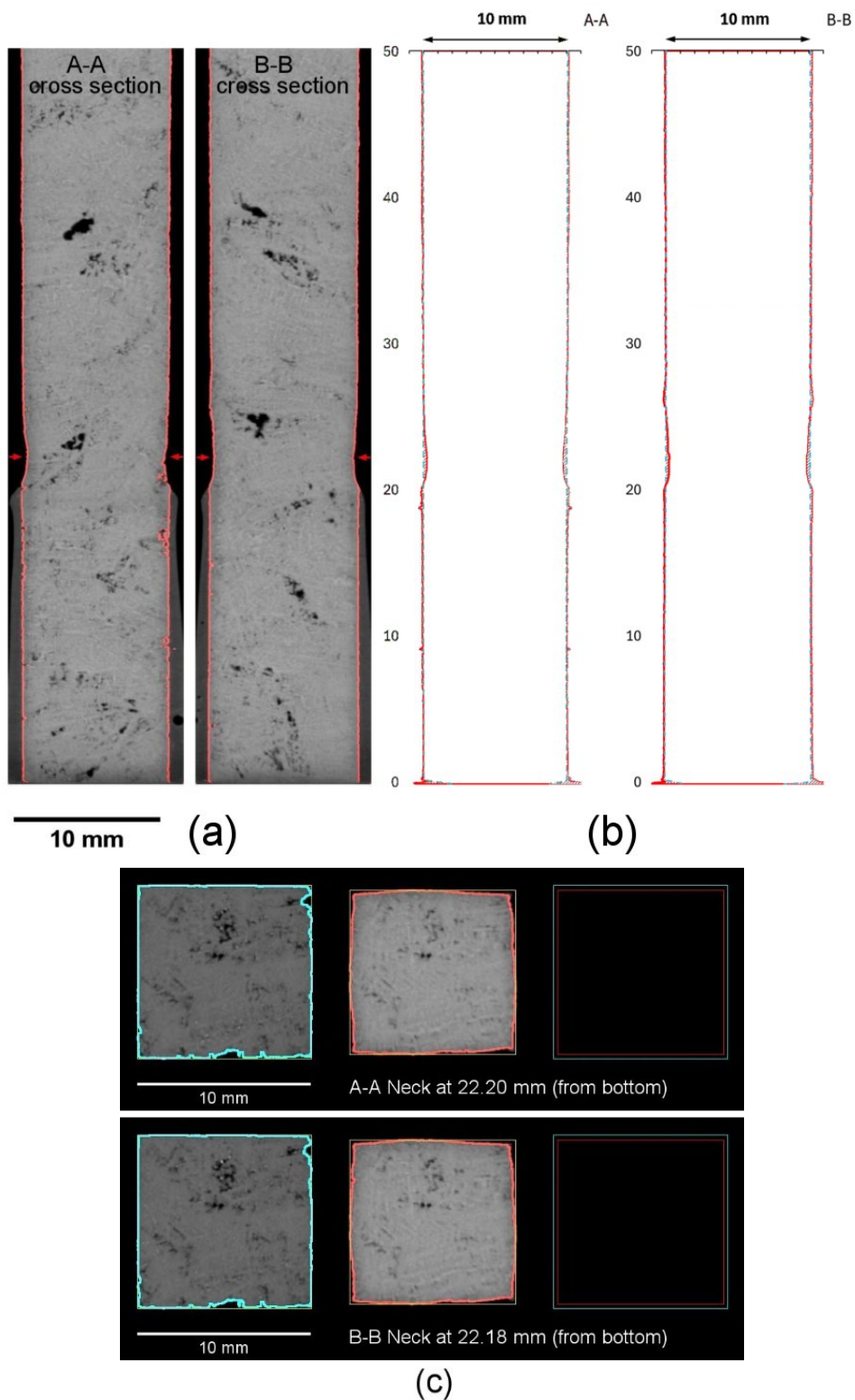


Figure B.100. Micro-CT results of the K-3 refractory corrosion test, HS24-50_1200C-7d. (a) Micro-CT images of the cross section at the center with the neck position marked by arrows. (b) Corrosion depth plots. (c) Micro-CT images of the x-y plane with the outline and bounding rectangles at the neck locations.

Appendix C – Original Data from Micro-CT Measurements

This appendix presents the original dimensional data measured by micro-CT, including the neck corrosion depth (d_{neck}) and the neck location (h_{neck} , the height of the identified neck from the bottom of the coupon) from directions A and B. The average neck corrosion depth values ($d_{\text{neck avg}}$) and the standard deviations (SDs) were calculated. In this appendix, all original data are reported in millimeters. Note that some neck corrosion depth values are zero or negative; the possible causes include the low corrosivity of some glass melts, slight expansion due to interfacial reactions, and experimental errors. The test coupons that do not show distinguishable neck corrosion are marked in the table below. The neck depths reported in Section 3.0 (Table 3.1) have been converted to inches. In Section 3.0, the data measured from coupons without a distinguishable neck are considered below the detection limit and disregarded.

Table C.1. Neck corrosion depth and the neck location of the 1150 °C for 7 days tested coupons, HS24-01 through HS24-25. All values are in millimeters.

Sample ID	$d_{\text{neck,A}}$	$h_{\text{neck,A}}$	$d_{\text{neck,B}}$	$h_{\text{neck,B}}$	$d_{\text{neck avg}}$	SD
HS24-01_1150C-7d	0.02	22.48	0.04	22.34	0.03	0.014
HS24-02_1150C-7d	0.48	18.08	0.5	18.52	0.49	0.014
HS24-03_1150C-7d*	0.04	25.56	0.08	21.92	0.06	0.028
HS24-04_1150C-7d	0.96	18.8	0.92	18.82	0.94	0.028
HS24-05_1150C-7d	0.72	17.18	0.72	17.04	0.72	0.000
HS24-06_1150C-7d*	0.02	21.06	0	21.62	0.01	0.014
HS24-07_1150C-7d	0.1	23.98	0.12	23	0.11	0.014
HS24-08_1150C-7d*	0	25.08	0	28.66	0.00	0.000
HS24-09_1150C-7d	1.04	18.82	0.96	18.8	1.00	0.057
HS24-10_1150C-7d*	-0.04	20.3	-0.04	21.46	-0.04	0.000
HS24-11_1150C-7d*	0.02	26.2	-0.02	24.76	0.00	0.028
HS24-12_1150C-7d*	-0.02	26.82	-0.02	25.66	-0.02	0.000
HS24-13_1150C-7d	0.18	20.84	0.2	21	0.19	0.014
HS24-14_1150C-7d*	-0.04	25.28	-0.02	20.08	-0.03	0.014
HS24-15_1150C-7d	0.2	22.28	0.18	22.26	0.19	0.014
HS24-16_1150C-7d	0.02	18.48	0	18.86	0.01	0.014
HS24-17_1150C-7d*	0	31.12	0.02	28.96	0.01	0.014
HS24-18_1150C-7d	0.26	22.76	0.28	22.6	0.27	0.014
HS24-19_1150C-7d*	0	33.96	0	33.72	0.00	0.000
HS24-20_1150C-7d	0.46	20.76	0.48	21.08	0.47	0.014
HS24-21_1150C-7d*	0.04	26.5	0.02	24.84	0.03	0.014
HS24-22_1150C-7d*	0.02	29.96	0	28.76	0.01	0.014
HS24-23_1150C-7d*	0.02	32.98	-0.02	29.78	0.00	0.028
HS24-24_1150C-7d	0.1	19.8	0.2	19.42	0.15	0.071
HS24-25_1150C-7d	0.72	19.92	0.76	19.82	0.74	0.028

* No distinguishable neck corrosion.

Table C.2. Neck corrosion depth and the neck location of the 1150 °C for 7 days tested coupons, HS24-26 through HS24-50. All values are in millimeters.

Sample ID	$d_{\text{neck,A}}$	$h_{\text{neck,A}}$	$d_{\text{neck,B}}$	$h_{\text{neck,B}}$	$d_{\text{neck avg}}$	SD
HS24-26_1150C-7d*	-0.06	30.02	0	31.22	-0.03	0.042
HS24-27_1150C-7d	0.36	20.4	0.42	20.12	0.39	0.042
HS24-28_1150C-7d	0.12	22.92	0.14	22.82	0.13	0.014
HS24-29_1150C-7d	0.36	21.32	0.36	21.62	0.36	0.000
HS24-30_1150C-7d*	0	27.98	0.04	27.54	0.02	0.028
HS24-31_1150C-7d	0.1	20.08	0.12	19.96	0.11	0.014
HS24-32_1150C-7d*	-0.06	25.92	-0.02	31.3	-0.04	0.028
HS24-33_1150C-7d*	-0.04	28.62	-0.04	27.56	-0.04	0.000
HS24-34_1150C-7d*	-0.04	24.96	-0.02	24.84	-0.03	0.014
HS24-35_1150C-7d*	-0.02	24.08	-0.02	24.32	-0.02	0.000
HS24-36_1150C-7d	0.02	27.42	0.02	27.22	0.02	0.000
HS24-37_1150C-7d	0.12	16.96	0.1	16.96	0.11	0.014
HS24-38_1150C-7d*	0.02	28.96	0.02	28.42	0.02	0.000
HS24-39_1150C-7d*	-0.02	24.28	0	28.84	-0.01	0.014
HS24-40_1150C-7d*	-0.02	25.32	-0.02	18.8	-0.02	0.000
HS24-41_1150C-7d	0.12	24.34	0.18	23.88	0.15	0.042
HS24-42_1150C-7d*	0	31.36	0	28.66	0.00	0.000
HS24-43_1150C-7d*	0	23.56	0	23.88	0.00	0.000
HS24-44_1150C-7d	0.12	21.14	0.14	21.18	0.13	0.014
HS24-45_1150C-7d	0	22.74	0.08	22.74	0.04	0.057
HS24-46_1150C-7d	0.04	20.8	0.06	20.96	0.05	0.014
HS24-47_1150C-7d	0.06	23.18	0.06	20.58	0.06	0.000
HS24-48_1150C-7d*	0	19.88	-0.02	19.24	-0.01	0.014
HS24-49_1150C-7d	0.96	20	0.94	20.46	0.95	0.014
HS24-50_1150C-7d	0.28	19.98	0.32	19.78	0.30	0.028
* No distinguishable neck corrosion.						

Table C.3. Neck corrosion depth and the neck location of the 1200 °C for 7 days tested coupons, HS24-01 through HS24-25. All values are in millimeters.

Sample ID	$d_{\text{neck,A}}$	$h_{\text{neck,A}}$	$d_{\text{neck,B}}$	$h_{\text{neck,B}}$	$d_{\text{neck avg}}$	SD
HS24-01_1200C-7d	0.1	23.68	0.08	23.52	0.09	0.014
HS24-02_1200C-7d	0.84	21.08	0.72	21.36	0.78	0.085
HS24-03_1200C-7d	0.08	21.04	0.1	20.24	0.09	0.014
HS24-04_1200C-7d	1.22	18.72	1.22	18.58	1.22	0.000
HS24-05_1200C-7d	1	21	1.02	21	1.01	0.014
HS24-06_1200C-7d*	0	26.62	0	23.22	0.00	0.000
HS24-07_1200C-7d	0.2	21.96	0.2	21.62	0.20	0.000
HS24-08_1200C-7d*	0.02	31.78	0.06	19	0.04	0.028
HS24-09_1200C-7d	0.68	19.1	0.64	19.04	0.66	0.028
HS24-10_1200C-7d	0.08	19.32	0.04	19.54	0.06	0.028
HS24-11_1200C-7d	0.04	24.7	0.06	24.04	0.05	0.014
HS24-12_1200C-7d	0.02	28.48	0.06	27.9	0.04	0.028
HS24-13_1200C-7d	0.16	20.64	0.18	20.96	0.17	0.014
HS24-14_1200C-7d	0.04	20.1	0.04	19.72	0.04	0.000
HS24-15_1200C-7d	0.36	22.62	0.36	22.38	0.36	0.000
HS24-16_1200C-7d	0.14	17.62	0.2	18.18	0.17	0.042
HS24-17_1200C-7d*	0	28.38	0	28.46	0.00	0.000
HS24-18_1200C-7d	0.34	20.84	0.4	20.9	0.37	0.042
HS24-19_1200C-7d*	-0.06	20.78	-0.06	23.14	-0.06	0.000
HS24-20_1200C-7d	0.68	21.16	0.72	21.46	0.70	0.028
HS24-21_1200C-7d*	0.06	19.52	0.06	24.22	0.06	0.000
HS24-22_1200C-7d*	-0.02	22.7	-0.04	27.94	-0.03	0.014
HS24-23_1200C-7d*	-0.02	15.42	-0.02	15.04	-0.02	0.000
HS24-24_1200C-7d	0.18	16.62	0.14	16.56	0.16	0.028
HS24-25_1200C-7d	0.98	20.86	1	21.22	0.99	0.014
* No distinguishable neck corrosion.						

Table C.4. Neck corrosion depth and the neck location of the 1200 °C for 7 days tested coupons, HS24-26 through HS24-50. All values are in millimeters.

Sample ID	$d_{\text{neck,A}}$	$h_{\text{neck,A}}$	$d_{\text{neck,B}}$	$h_{\text{neck,B}}$	$d_{\text{neck avg}}$	SD
HS24-26_1200C-7d*	0	24.48	-0.02	32.24	-0.01	0.014
HS24-27_1200C-7d	0.54	20.12	0.58	20.04	0.56	0.028
HS24-28_1200C-7d	0.22	22.86	0.24	22.64	0.23	0.014
HS24-29_1200C-7d	0.5	19.5	0.48	18.7	0.49	0.014
HS24-30_1200C-7d*	-0.02	33.08	-0.02	33.2	-0.02	0.000
HS24-31_1200C-7d	0.06	21.68	0.04	21.56	0.05	0.014
HS24-32_1200C-7d*	0	18.74	0	18.28	0.00	0.000
HS24-33_1200C-7d	0.02	24.32	0.04	27.84	0.03	0.014
HS24-34_1200C-7d	0.04	23.2	0.06	22.68	0.05	0.014
HS24-35_1200C-7d*	0.02	17.58	0.02	15.48	0.02	0.000
HS24-36_1200C-7d*	-0.02	22.52	0	26.94	-0.01	0.014
HS24-37_1200C-7d	0.24	20.54	0.28	20.92	0.26	0.028
HS24-38_1200C-7d*	0.04	28.92	0.04	27.94	0.04	0.000
HS24-39_1200C-7d*	0	21	0.02	17.32	0.01	0.014
HS24-40_1200C-7d	0.06	20.64	0.02	20.98	0.04	0.028
HS24-41_1200C-7d	0.24	24.46	0.26	23.98	0.25	0.014
HS24-42_1200C-7d*	-0.02	29.88	-0.02	32.08	-0.02	0.000
HS24-43_1200C-7d*	0	21.86	-0.02	21.36	-0.01	0.014
HS24-44_1200C-7d	0.12	21.48	0.12	21.7	0.12	0.000
HS24-45_1200C-7d	0.06	20.52	0.12	20.38	0.09	0.042
HS24-46_1200C-7d	0.1	23.22	0.08	22.94	0.09	0.014
HS24-47_1200C-7d	0.2	21.14	0.24	20.96	0.22	0.028
HS24-48_1200C-7d	0.02	20	0.02	20.4	0.02	0.000
HS24-49_1200C-7d	1.62	16.7	1.66	16.52	1.64	0.028
HS24-50_1200C-7d	0.26	22.2	0.24	22.18	0.25	0.014
* No distinguishable neck corrosion.						

Pacific Northwest National Laboratory

902 Battelle Boulevard
P.O. Box 999
Richland, WA 99354

1-888-375-PNNL (7665)

www.pnnl.gov