

Introduction & Objective

- The capsules of the IFMIF-DONES High Flux Test Module (HFTM) are packed with Eurofer specimens, therefore a filling material is needed to fill any empty volume to improve the heat conduction and obtain uniform temperature distribution inside the capsule.
- The objectives are: (i) test the wettability of Eurofer and 316L stainless steel specimens by liquid sodium within 100°C to 430°C, and (ii) demonstrate a successful sodium filling process using a prototype capsule to have a better understanding of how well the specimens are wetted and the gaps are filled with sodium.

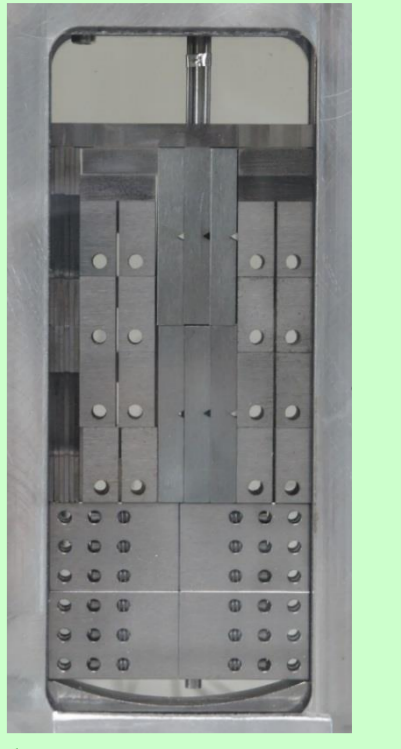


Fig.1. HFTM capsule.

Wettability Testing Setup

- The setup, in Fig. 2, consists of: (i) container made of 316L stainless steel, (ii) two parallel plates, (iii) four cartridge heaters, (iv) four thermocouples, (v) metallic ruler, and (vi) various supporting parts.
- The container has outer dimensions of 190×90×40 mm³ and its cavity (to contain sodium) is 80×80×20 mm³.
- The plates are clamped closely using two screws to form a channel which is adjusted to 0.3 mm by inserting a steel spacer (with dimensions of 30×25 mm²) between the plates.
- All experiments are performed inside a glovebox filled with dry argon to maintain an oxygen-free and moisture-free atmosphere where both the oxygen and water amounts were kept less than 0.1 ppm.
- The sodium capillary rise is determined using a digital camera and the metallic ruler located next to the plates.

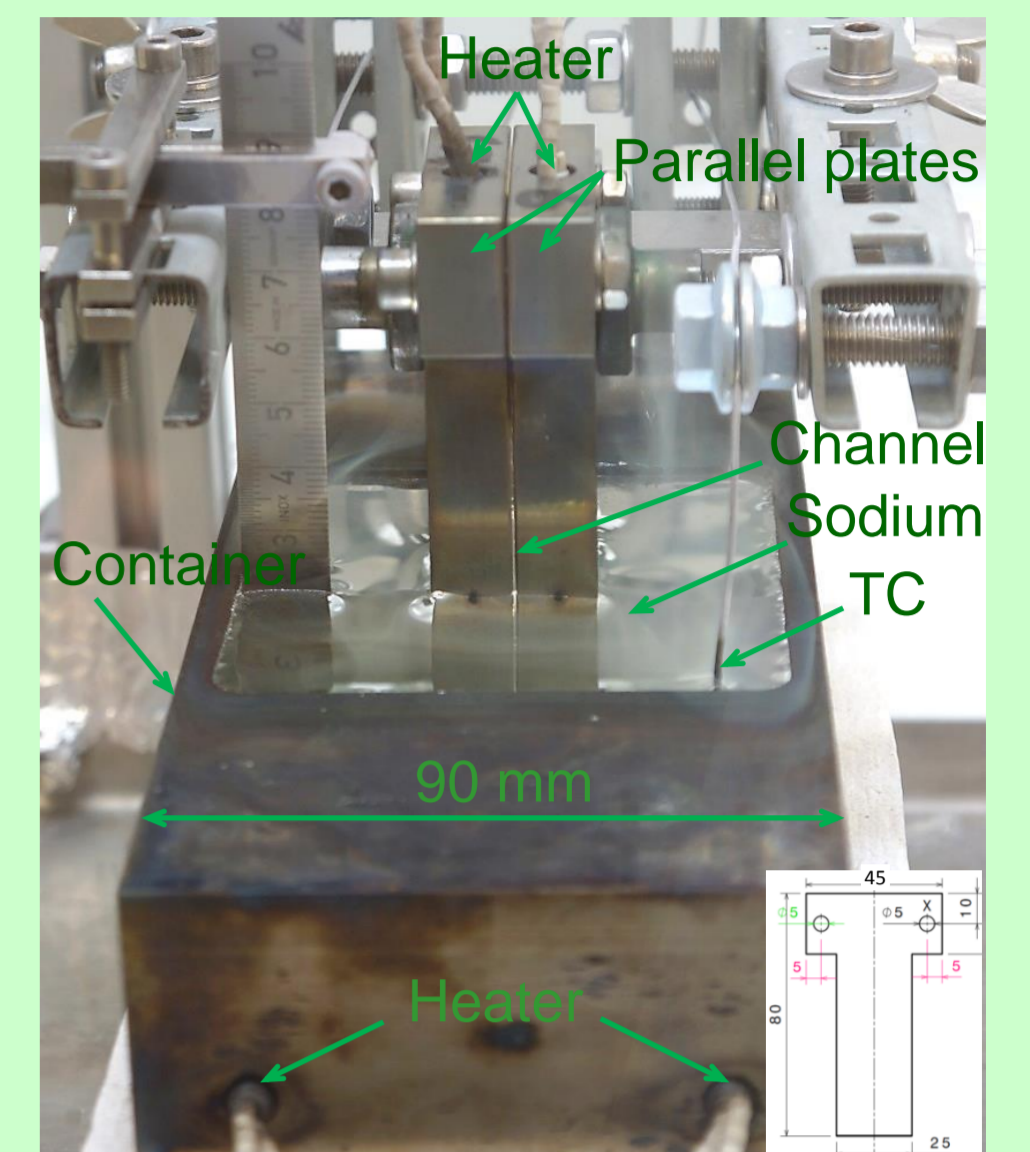


Fig.2. Wettability testing setup.

Wettability Results I

	Plate 1	Plate 2	Plate 3	Plate 4	Plate 5	Plate 6
Material	Eurofer	Eurofer	Eurofer	Eurofer	316L SS	316L SS
Surface finish	spark erosion	spark erosion	grinding	grinding	milling	milling
Ra (μm)	0.30	0.32	0.70	0.83	1.16	0.69

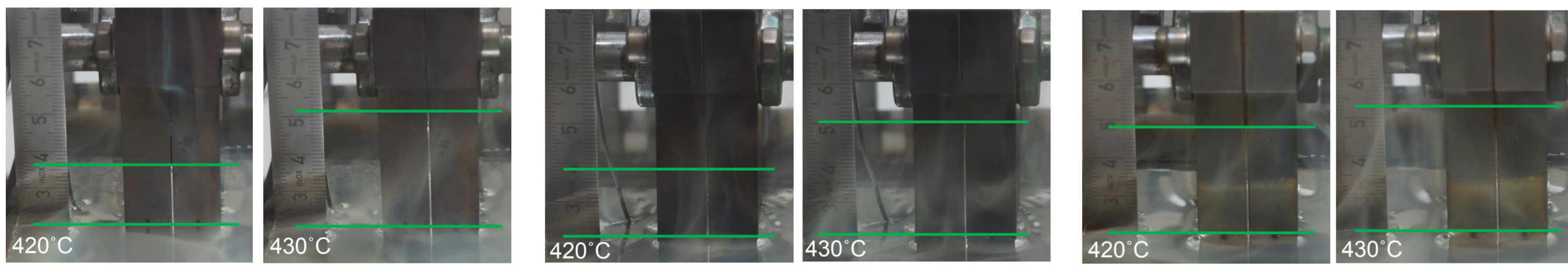


Fig.3. Sodium rise for plates 1 & 2. Fig.4. Sodium rise for plates 3 & 4. Fig.5. Sodium rise for plates 5 & 6.

- Sodium does not wet the steel surfaces within 100°C to 380°C.
- Approaching 390°C, sodium starts to wet the sides of the plates.
- Reaching 415°C, sodium starts to make a complete wetting of the plates surfaces and also rise in the channel between the plates.
- From 420°C to 430°C, the sodium rise increases with temperature.

Wettability Results II

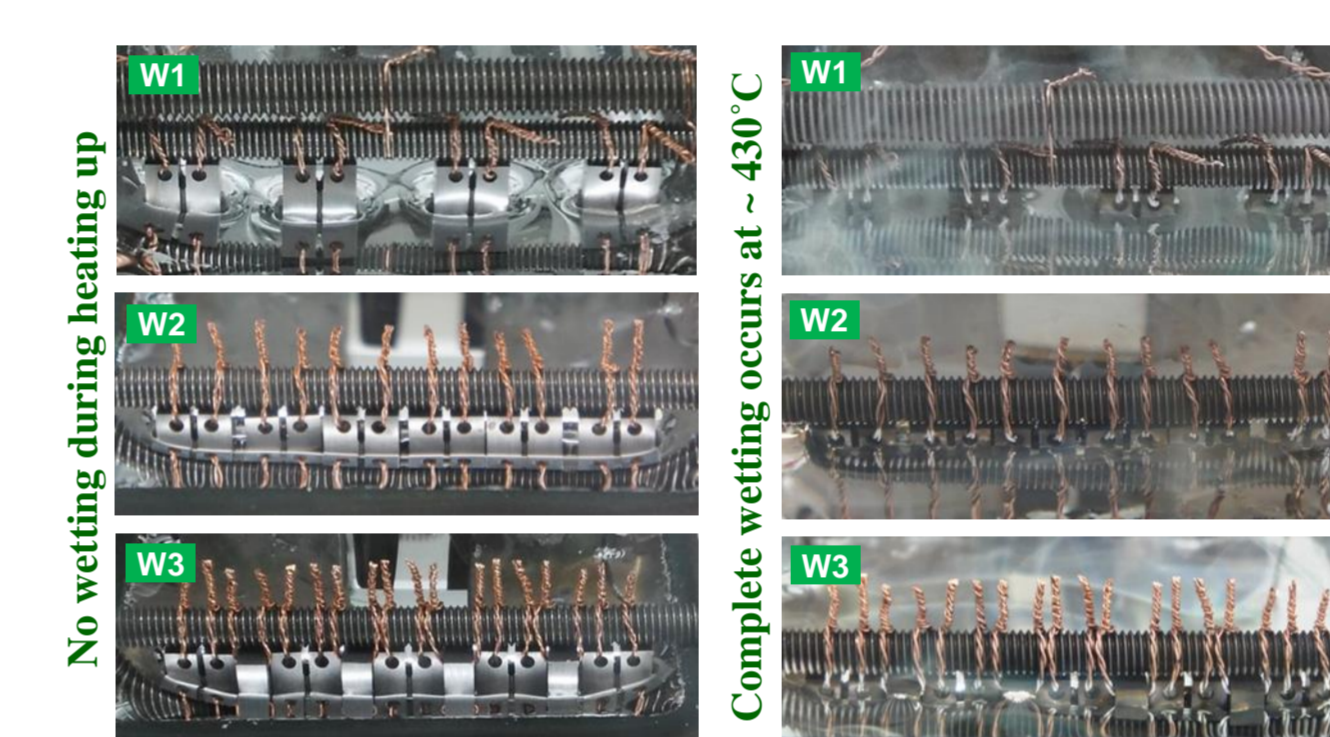


Fig.6. Runs W1-W3 results: no wetting (left column) during heating and wetting (right column) at 430°C.

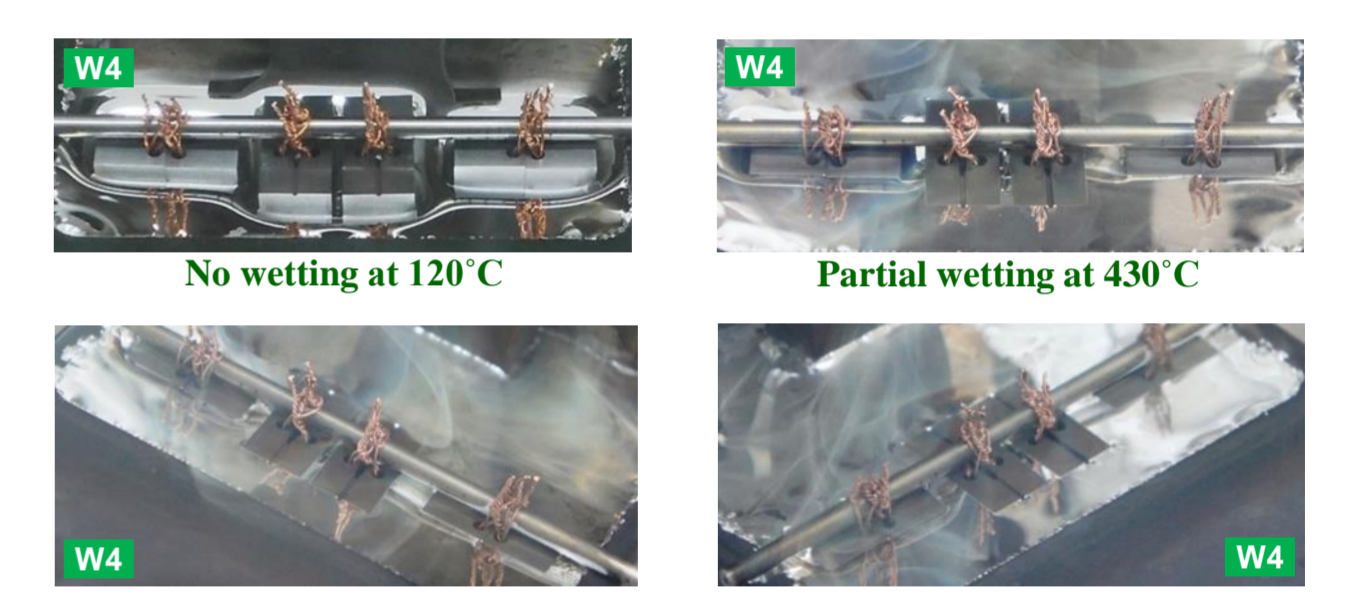


Fig.7. Wetting results of run W4.

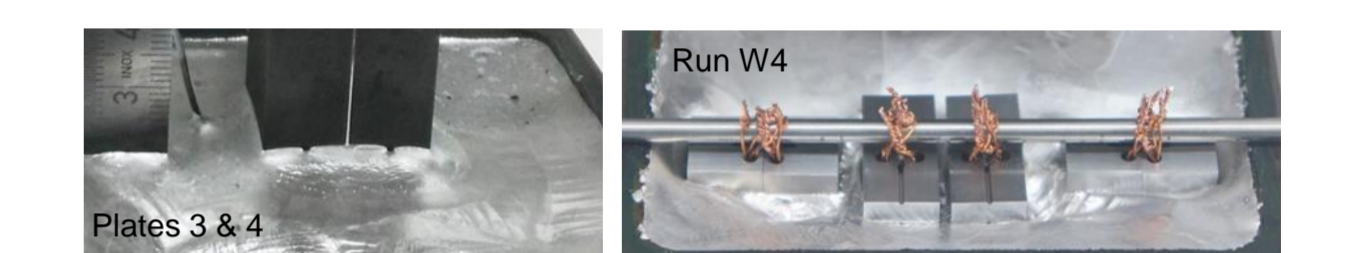


Fig.8. Hysteresis Effect: wetted specimens at 26°C.

- Tension crack growth specimens are tested in 4 runs (W1 to W4).
- W1: 4 specimens are aligned with inter-distance, ID = 10 mm.
- W2: 6 specimens are aligned with ID = 0.4, 0.7, 1.0, 1.7, 2.0 mm.
- W3: 9 specimens are arranged closely in two upright directions.
- W4: 8 specimens placed in 4 pairs, each has 2 adjacent specimens.
- At 420°C to 430°C, wetting was complete at all specimens' surfaces.

Filling the Capsule with Sodium

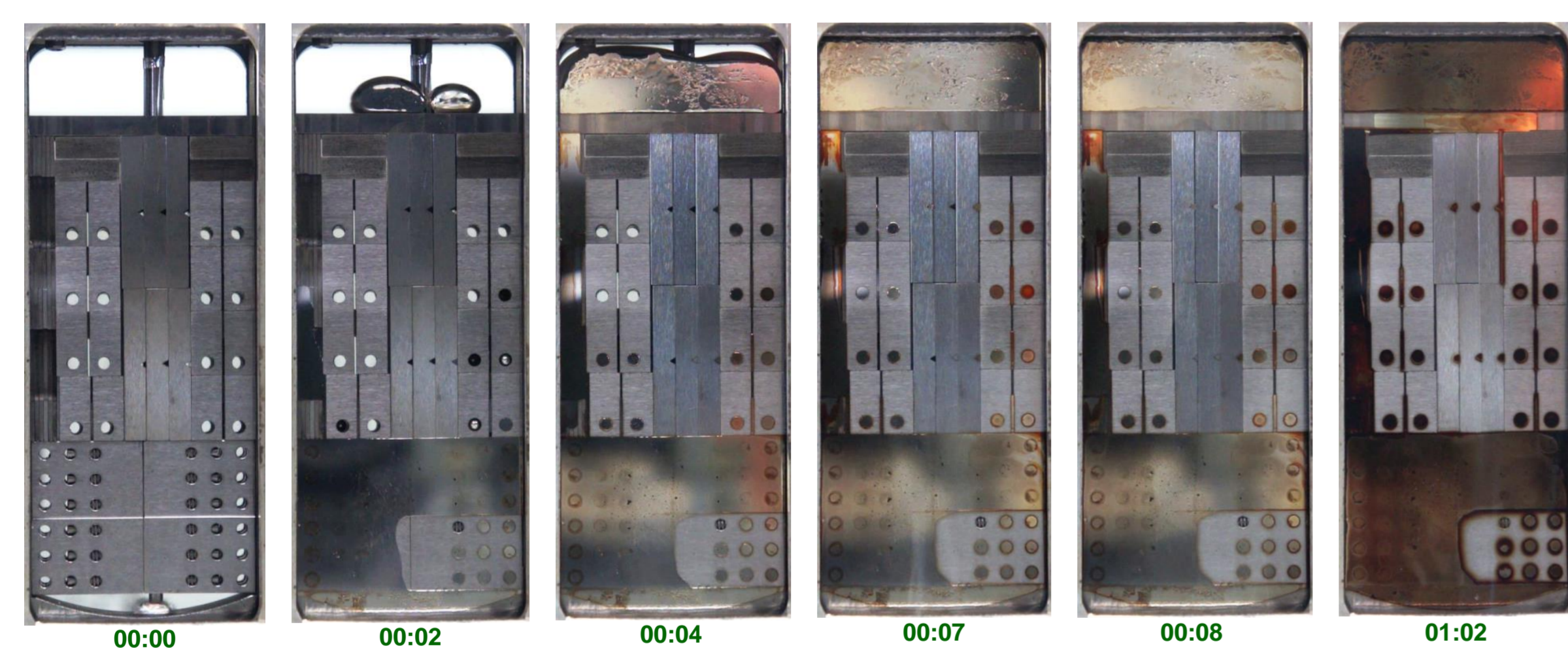


Fig.9. The filling sodium flow versus time (min:sec).



Fig.10. Capsule front (F) & back (B) views after cooling to RT.



Fig.11. The setup inside the glovebox.

- The setup and sodium were brought into the glovebox which is filled with dry argon.
- Digital camera was adjusted outside the glovebox for video recording of the filling process.
- The capsule's heaters were turned on to heat it to 430°C and when the capsule's TCs approached 400°C, the container's heater was turned on.
- The sodium pieces were put in the container when the highest and lowest temperatures inside the capsule were 430°C and 400°C respectively while the filling tube was ≈ 140°C and the container was ≈ 130°C.
- Sodium started to melt and about 4 minutes later it started to flow and fill the capsule.
- The filling process went smooth and fast (see Fig. 9), so it took the sodium 01 min : 02 sec to fill the capsule and penetrate through any gaps.
- Within 380°C to 330°C, sodium's color turned black, yet with more cooling, the color partially returned silver.

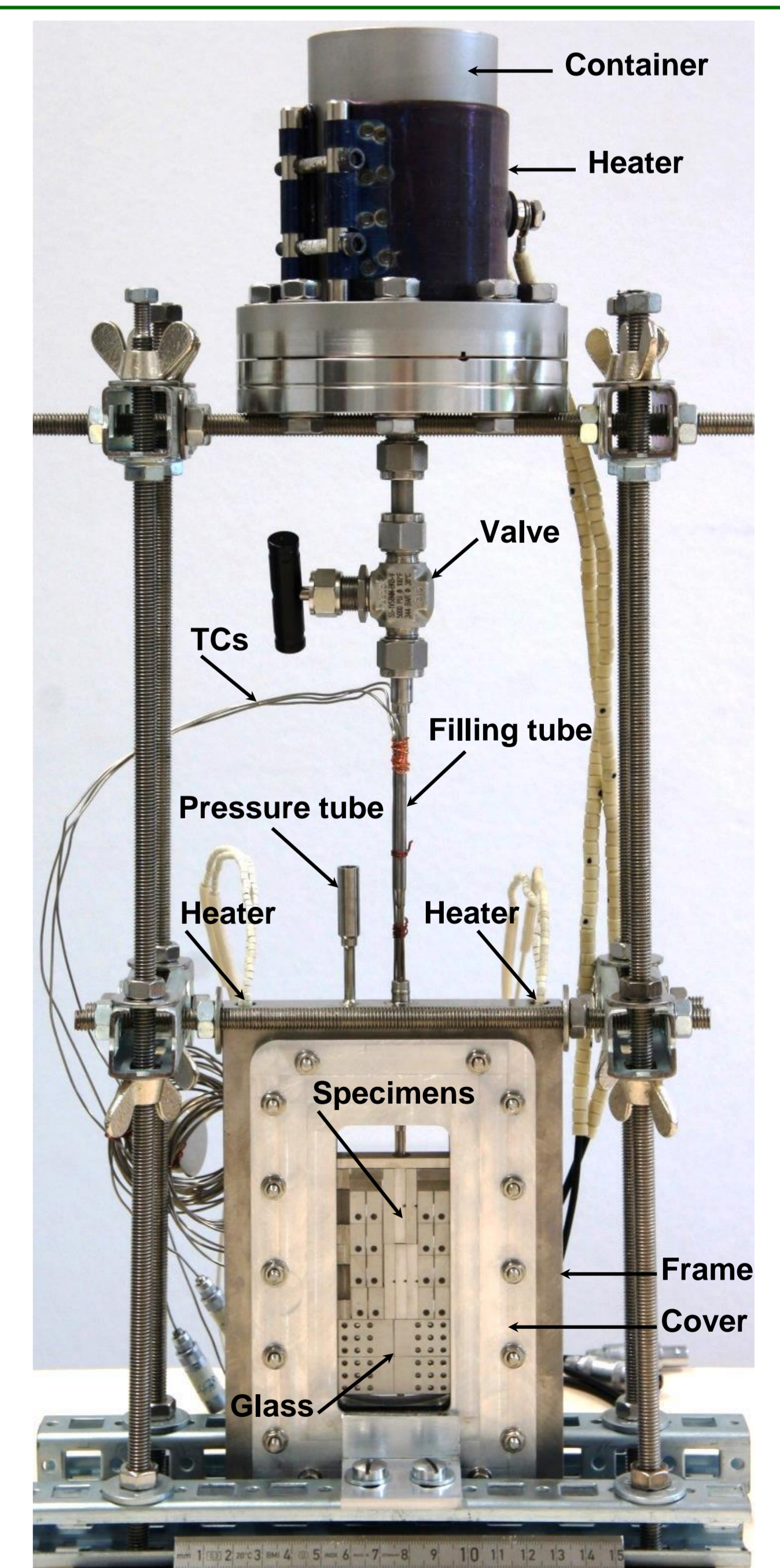


Fig.12. The sodium filling setup.

Summary

- Sodium was studied experimentally as a new filling material for the capsules of the IFMIF-DONES HFTM.
- Efficient wetting of Eurofer and 316L stainless steel by liquid sodium can be assured when the sodium-steel system temperature is ≥ 430°C.
- Successful sodium filling of the capsule was demonstrated as specimens were wetted effectively and empty volumes were filled with sodium.
- The objective of proof-of-principle testing of capsule filling and operational experience was achieved.