

DESIGN OF LOAD-TO-FAILURE TESTS OF HIGH-VOLTAGE ELECTRIC INSULATION BREAKS FOR ITER'S CRYOGENIC NETWORK

*S.A.E. Langeslag, E. Rodriguez Castro, I. Aviles Santillana,
S. Sgobba, A. Foussat*

*CERN, CH-1211 Genève – Switzerland
Stefanie.Langeslag@cern.ch*



ENGINEERING
DEPARTMENT



china eu india japan korea russia usa

Introduction

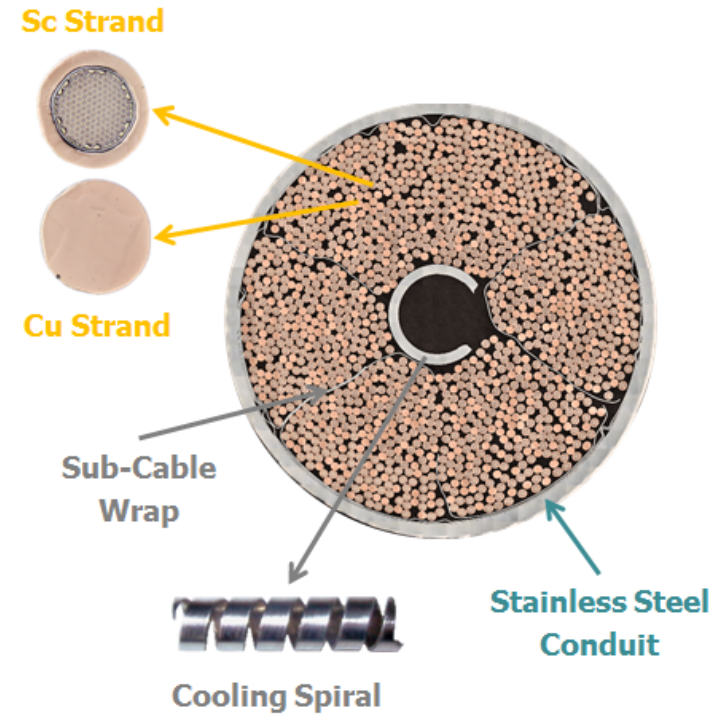
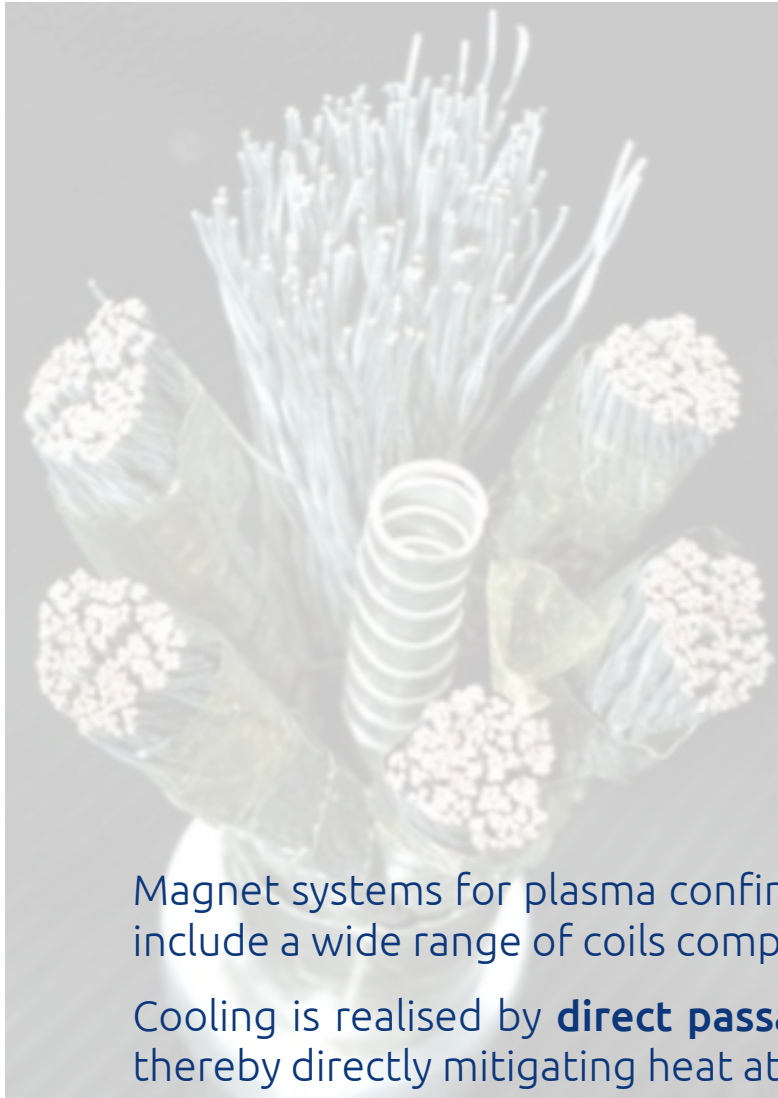


Figure 1: cross-section of one of the many types of CICCs implemented in the ITER experiment

Magnet systems for plasma confinement, in fusion energy experiments such as ITER, include a wide range of coils composed of **cable-in-conduit conductors (CICCs)**.

Cooling is realised by **direct passage of supercritical helium** through the conduits, thereby directly mitigating heat at the superconducting strands.

[illegible]

High-voltage **insulation breaks (IBs)** provide the required electrical isolation between the CICC and the helium supply lines.

IBs consist of stainless steel end-fittings, hermetically connected via a **glass reinforced resin composite body** of sufficient length, to prevent electrical discharge during magnet operation.

[illegible]

The cryogenic insulation system does not only rely on the electrical, but also the **structural properties** of the individual IBs.

A **binary test setup** was designed, manufactured and commissioned, allowing for an extensive assessment of the structural reliability of currently produced IBs.

Experimental setup; Design features

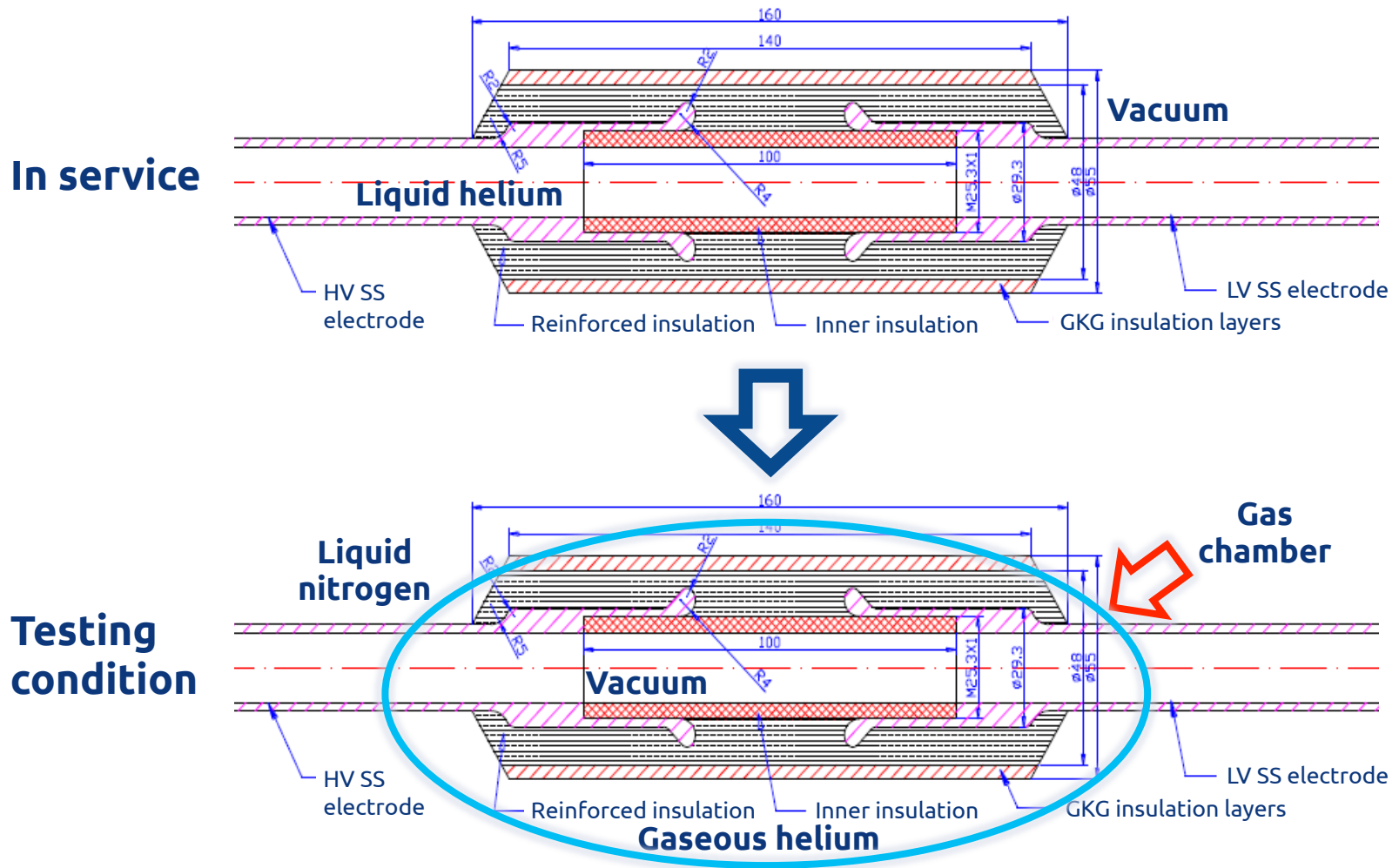
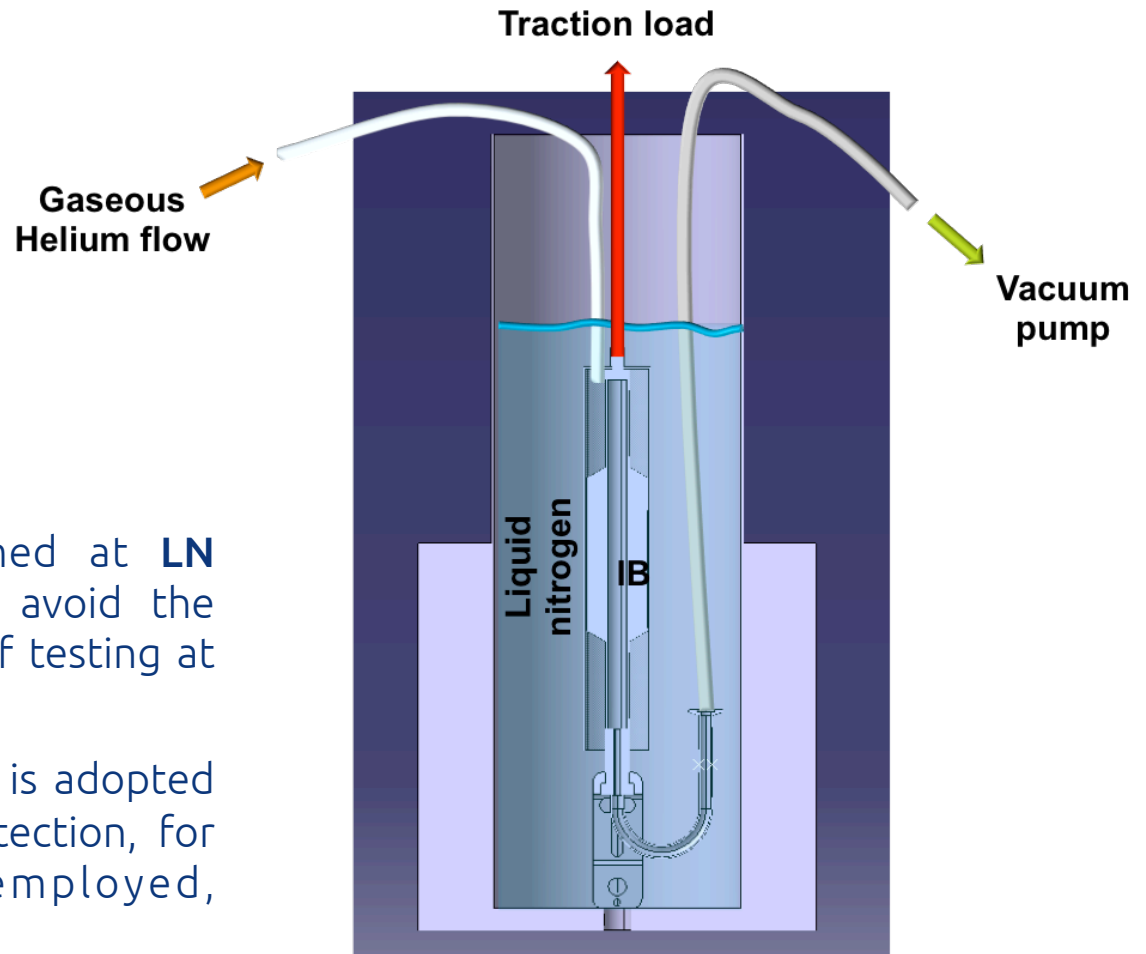


Figure 3: Schematic diagram of the IB in operating condition, versus the inverted cooling scheme in testing condition

Experimental setup; Design features



Measurements are performed at **LN temperature** (i.e. 77 K) to avoid the closed-circuit complications of testing at LHe temperature.

Low density **gaseous helium** is adopted as a flow agent for leak detection, for which a gas dome is employed, supported from the IB.

Figure 4: Schematic diagram illustrating the binary test setup design

Experimental setup; Sample adjustment

Modifications include:

- TIG-welding of a **thread** for load application
- Gyrolok® coupling via a **U-tube** for pumping

Bottom tooling is designed to grip around a **load bearing ring** on the bottom end, while allowing for the passage of the U-tube.

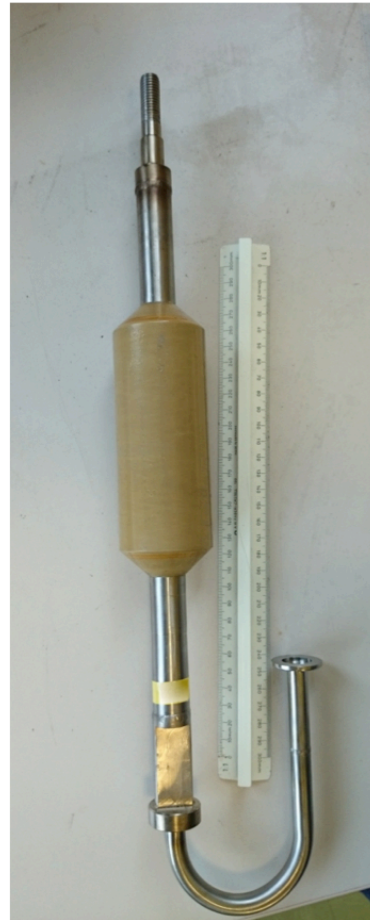


Figure 5: Adjusted IB

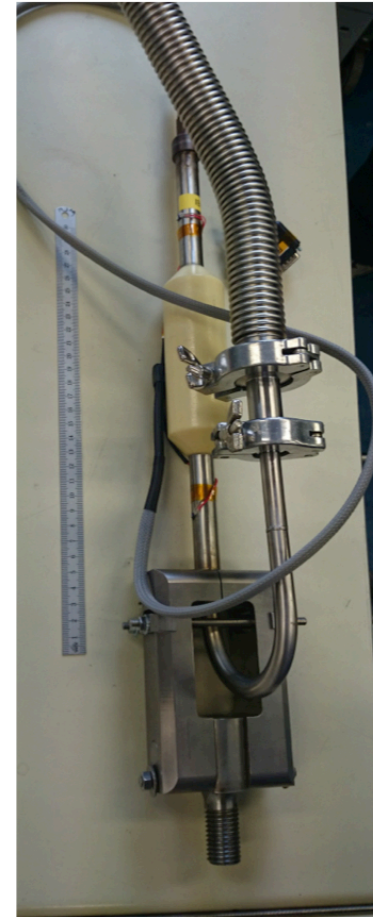


Figure 6: Adjusted IB including tooling for load and vacuum application



Figure 7: Adjusted IB including tooling for load application and gas dome

Discussion of selected test results

IB30kV1; primary measurement at 77 K

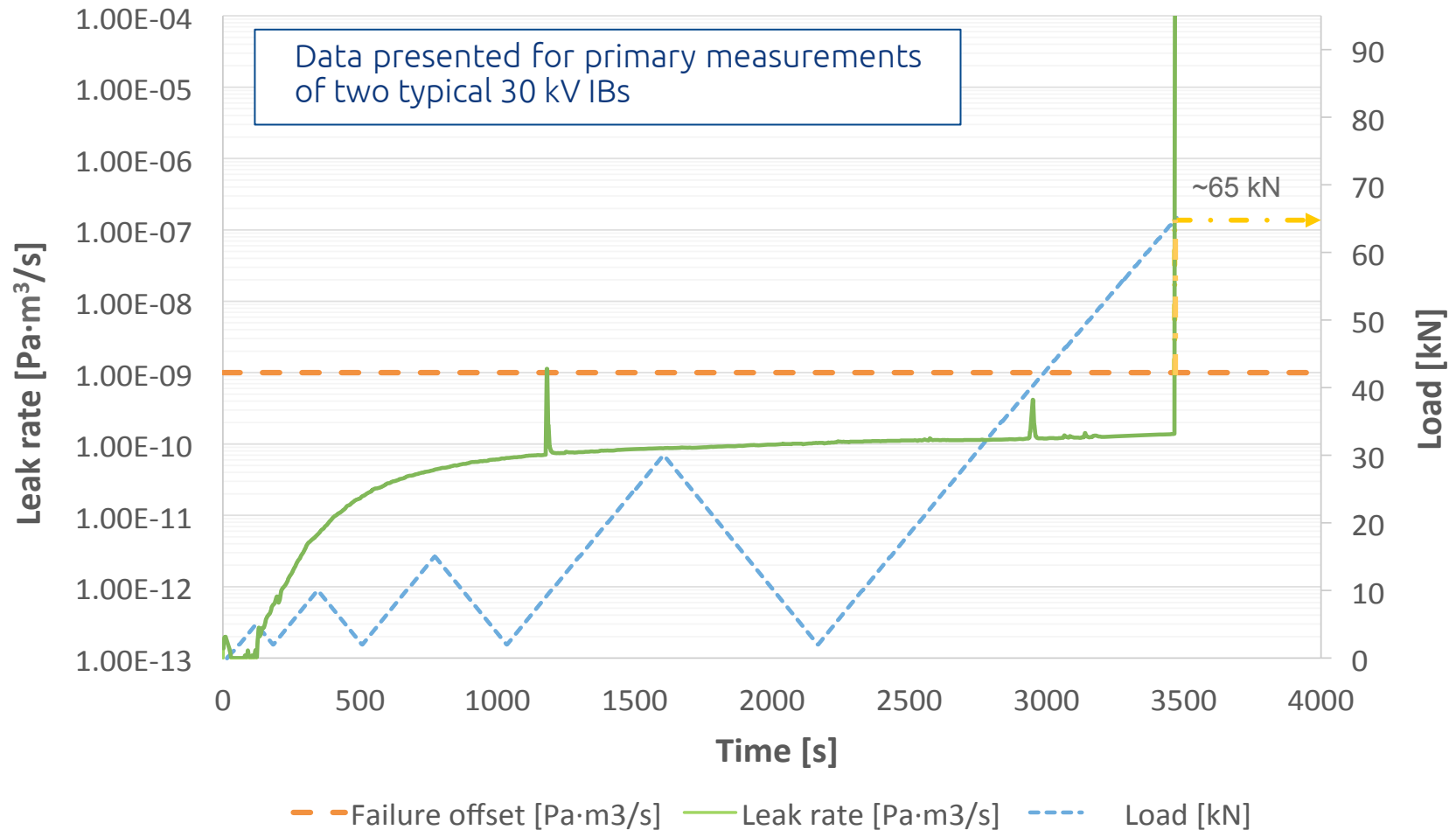


Figure 8: Diagram showing leak rate and applied load over time for the primary load-to-failure test of **IB30kV1** at 77 K

Discussion of selected test results

IB30kV1; primary measurement at 77 K

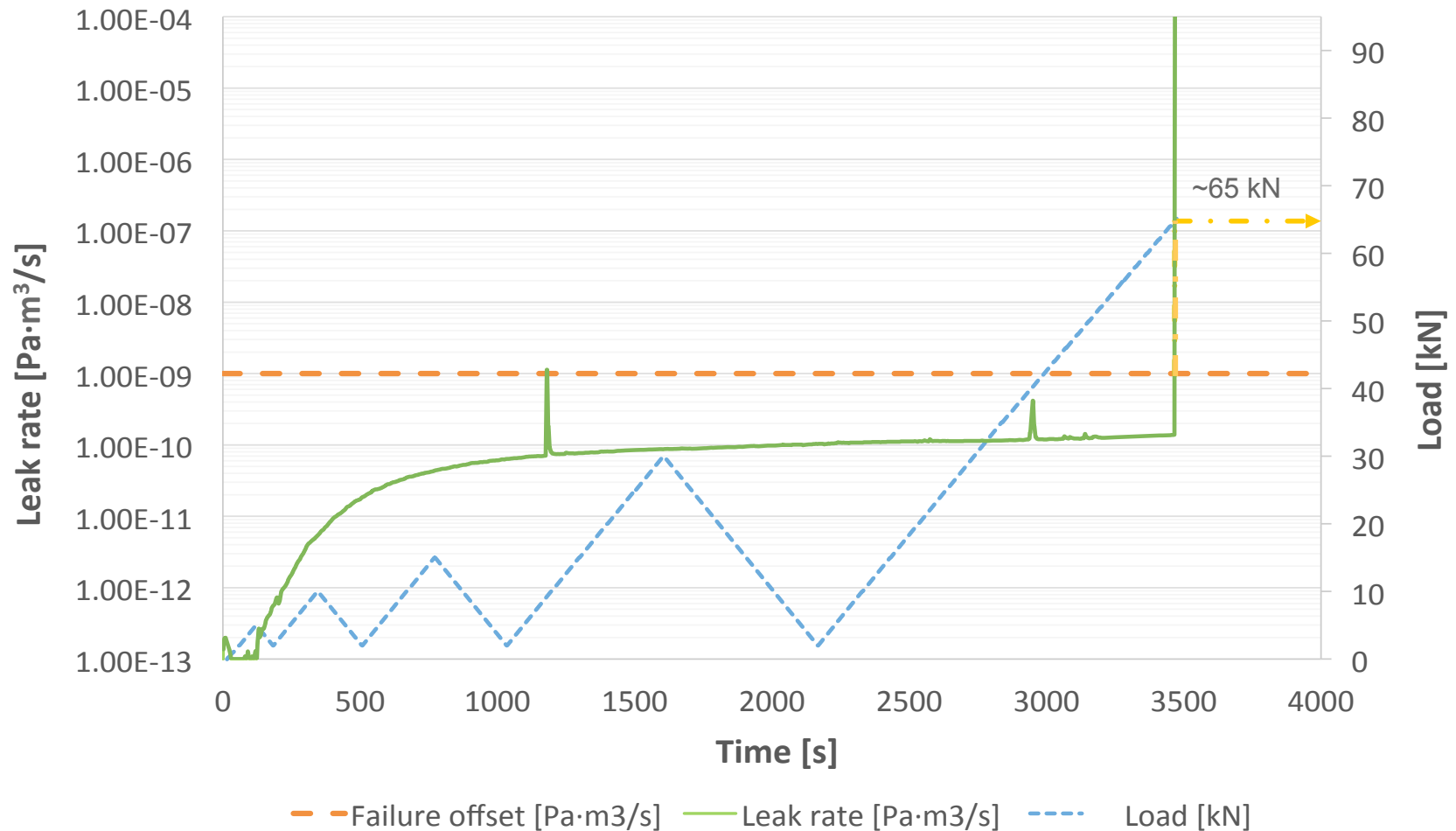


Figure 8: Diagram showing leak rate and applied load over time for the primary load-to-failure test of **IB30kV1** at 77 K

Discussion of selected test results

IB30kV1; primary measurement at 77 K

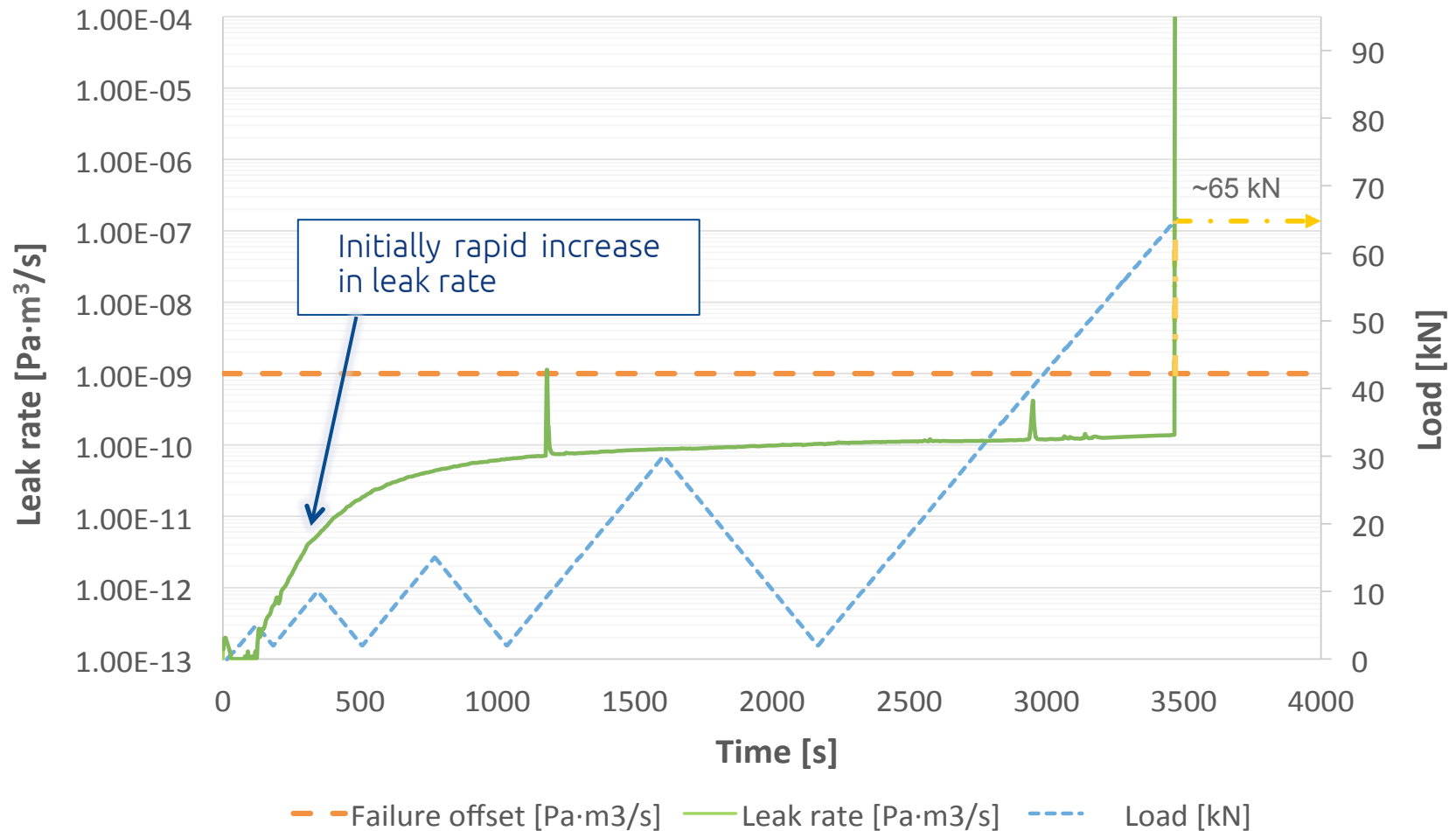


Figure 8: Diagram showing leak rate and applied load over time for the primary load-to-failure test of **IB30kV1** at 77 K

Discussion of selected test results

IB30kV1; primary measurement at 77 K

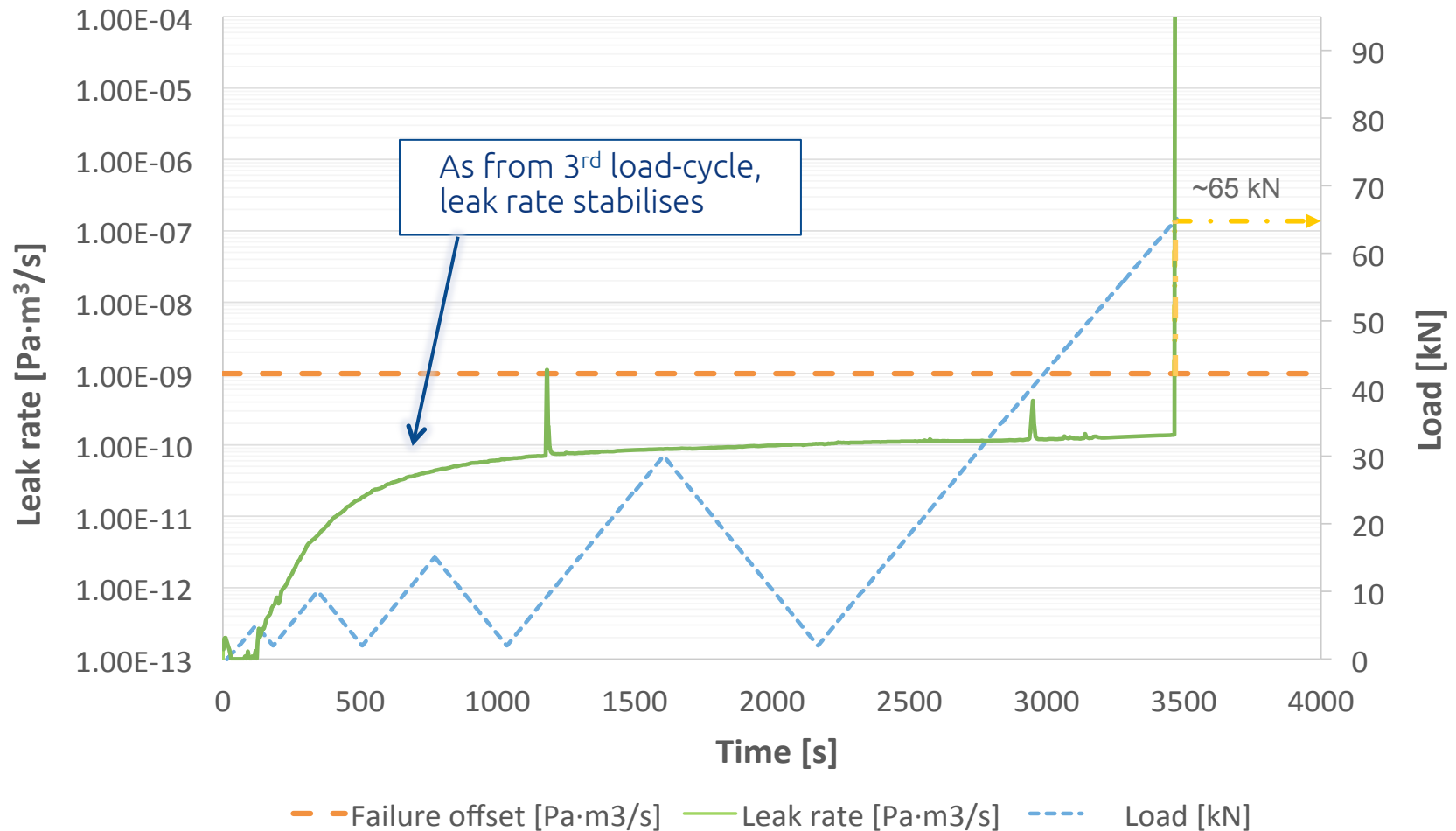


Figure 8: Diagram showing leak rate and applied load over time for the primary load-to-failure test of **IB30kV1** at 77 K

Discussion of selected test results

IB30kV1; primary measurement at 77 K

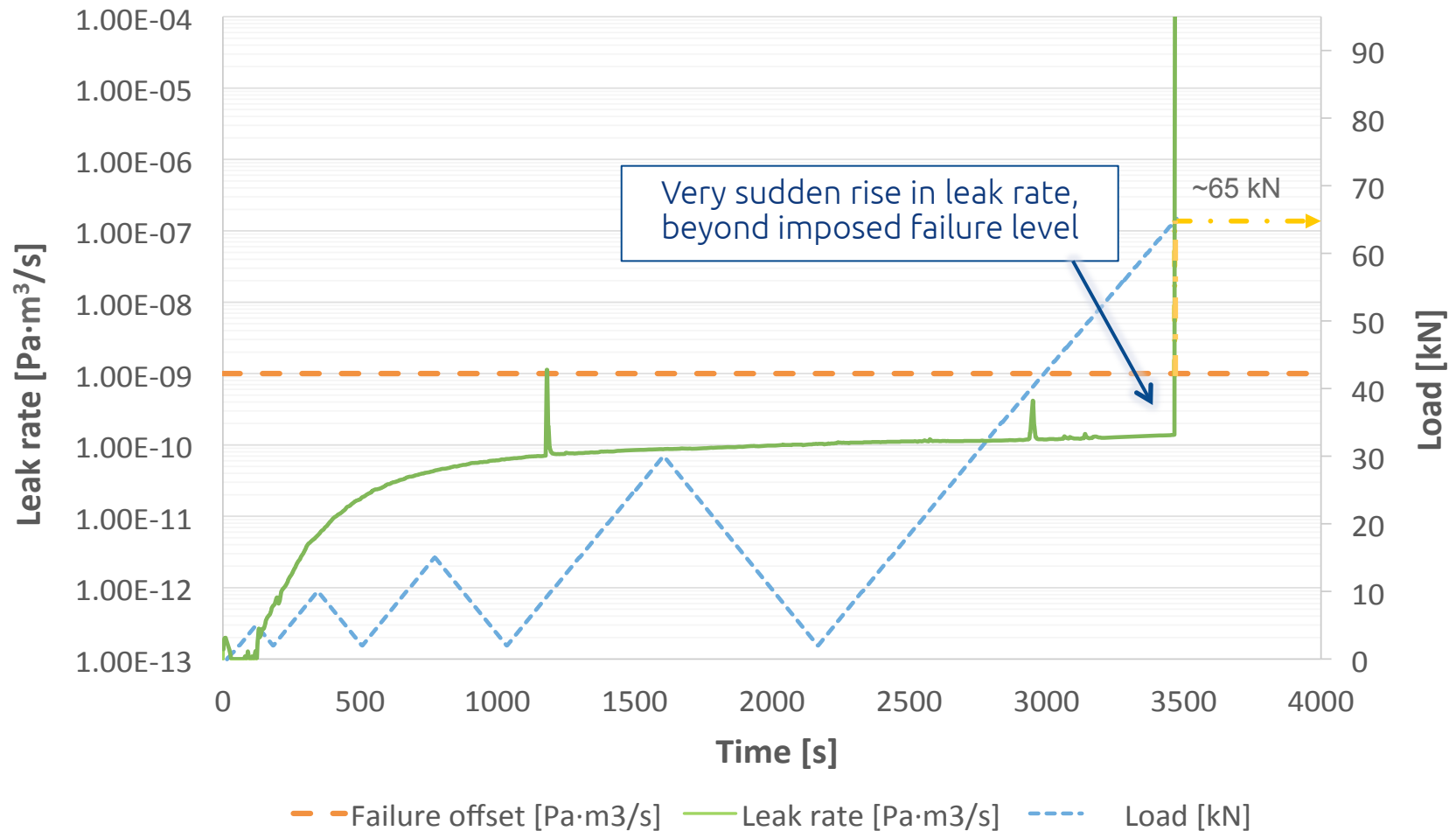


Figure 8: Diagram showing leak rate and applied load over time for the primary load-to-failure test of **IB30kV1** at 77 K

Discussion of selected test results

IB30kV2; primary measurement at 77 K

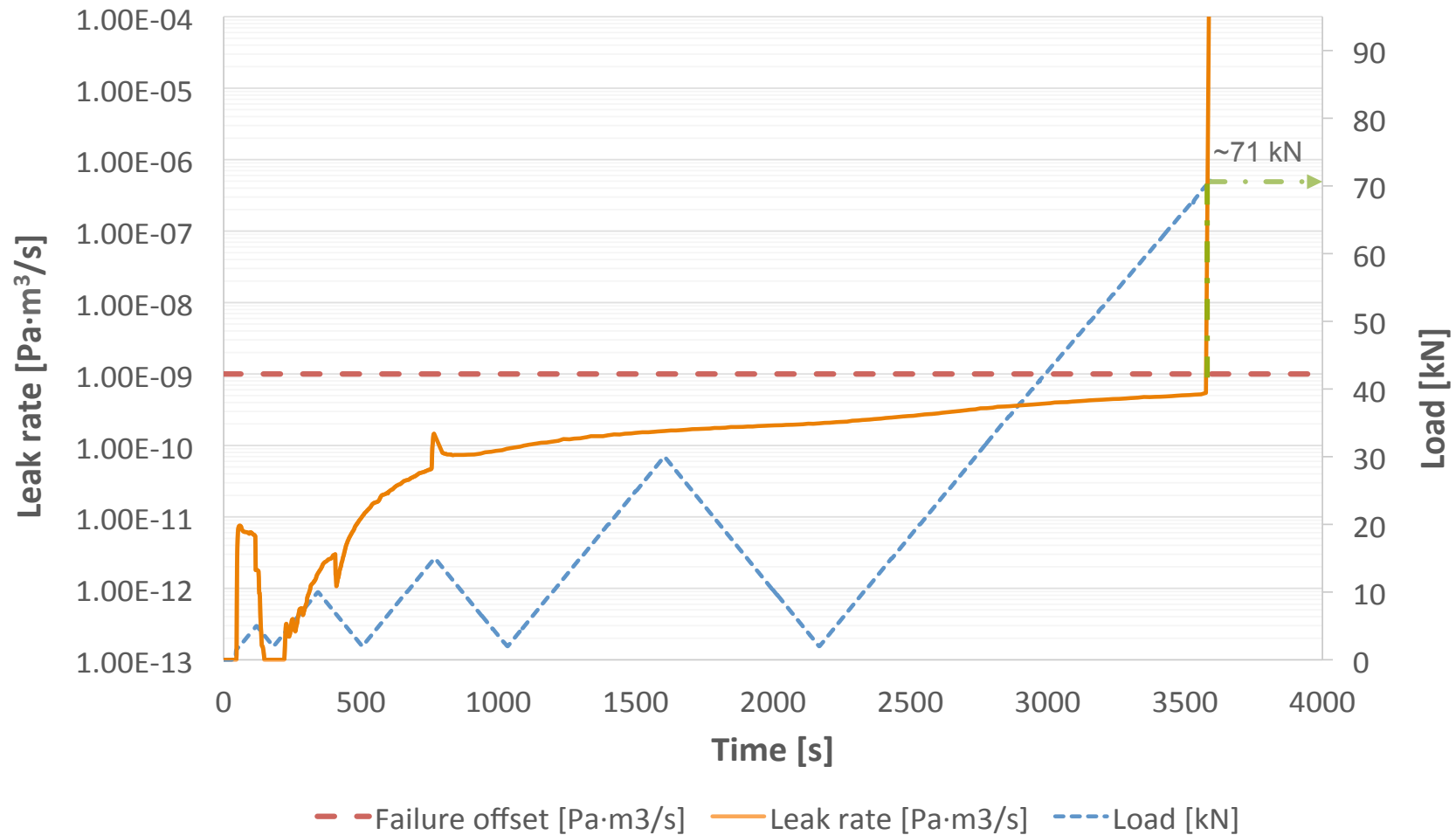


Figure 9: Diagram showing leak rate and applied load over time for the primary load-to-failure test of **IB30kV2** at 77 K

Discussion of selected test results

IB30kV2; primary measurement at 77 K

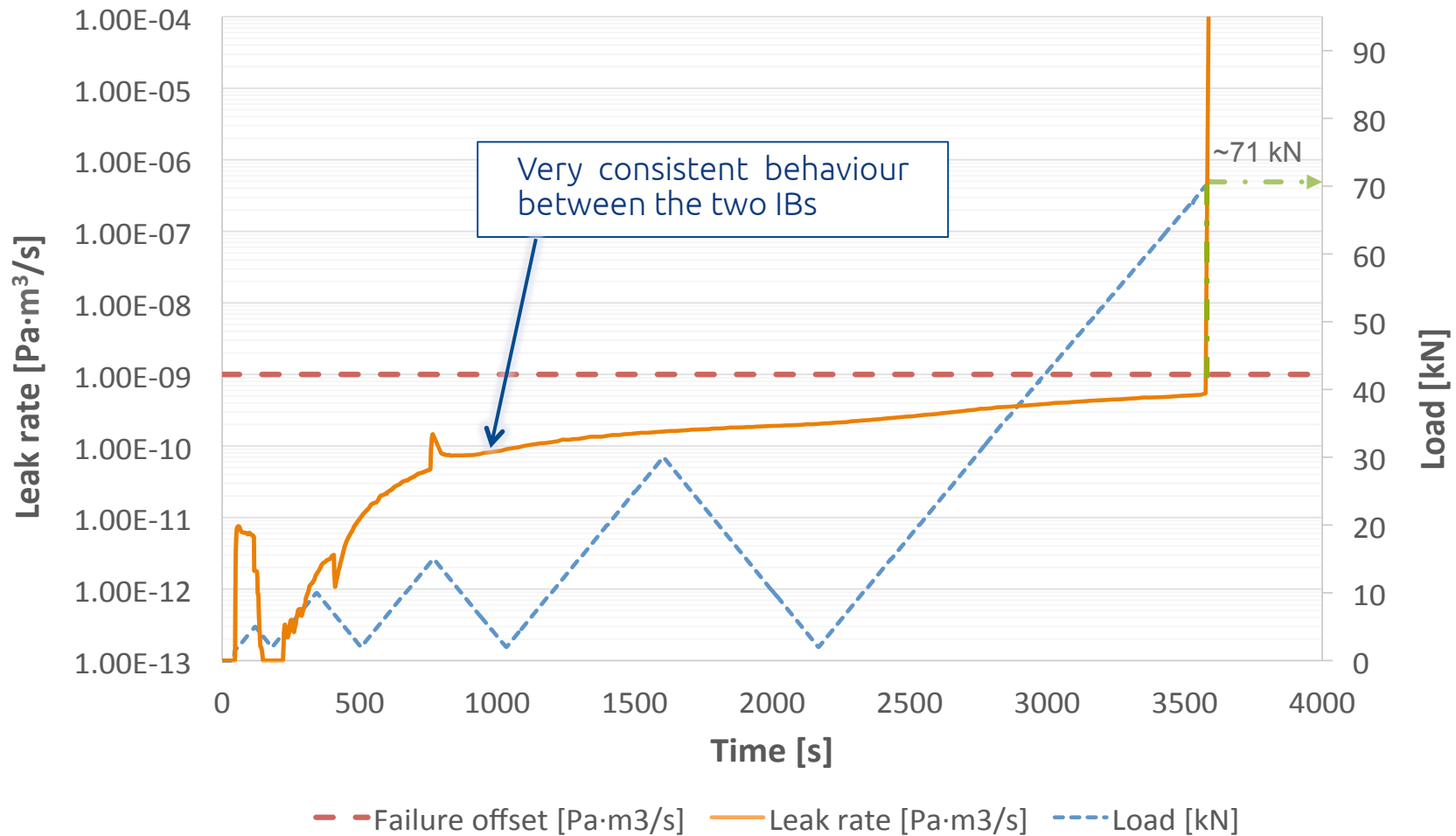


Figure 9: Diagram showing leak rate and applied load over time for the primary load-to-failure test of **IB30kV2** at 77 K

Discussion of selected test results

IB30kV2; primary measurement at 77 K

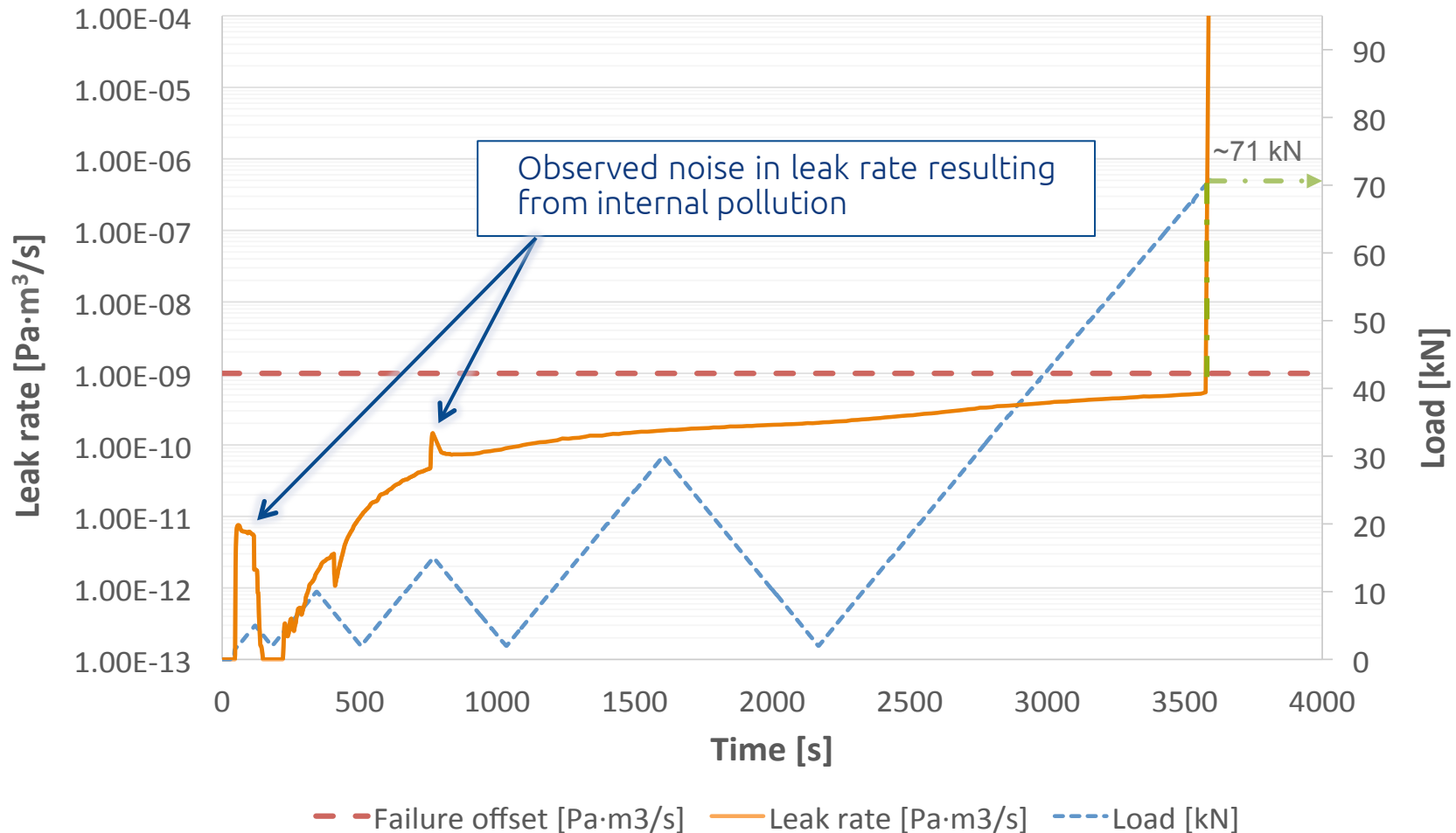


Figure 9: Diagram showing leak rate and applied load over time for the primary load-to-failure test of **IB30kV2** at 77 K

Discussion of selected test results

IB30kV2; primary measurement at 77 K

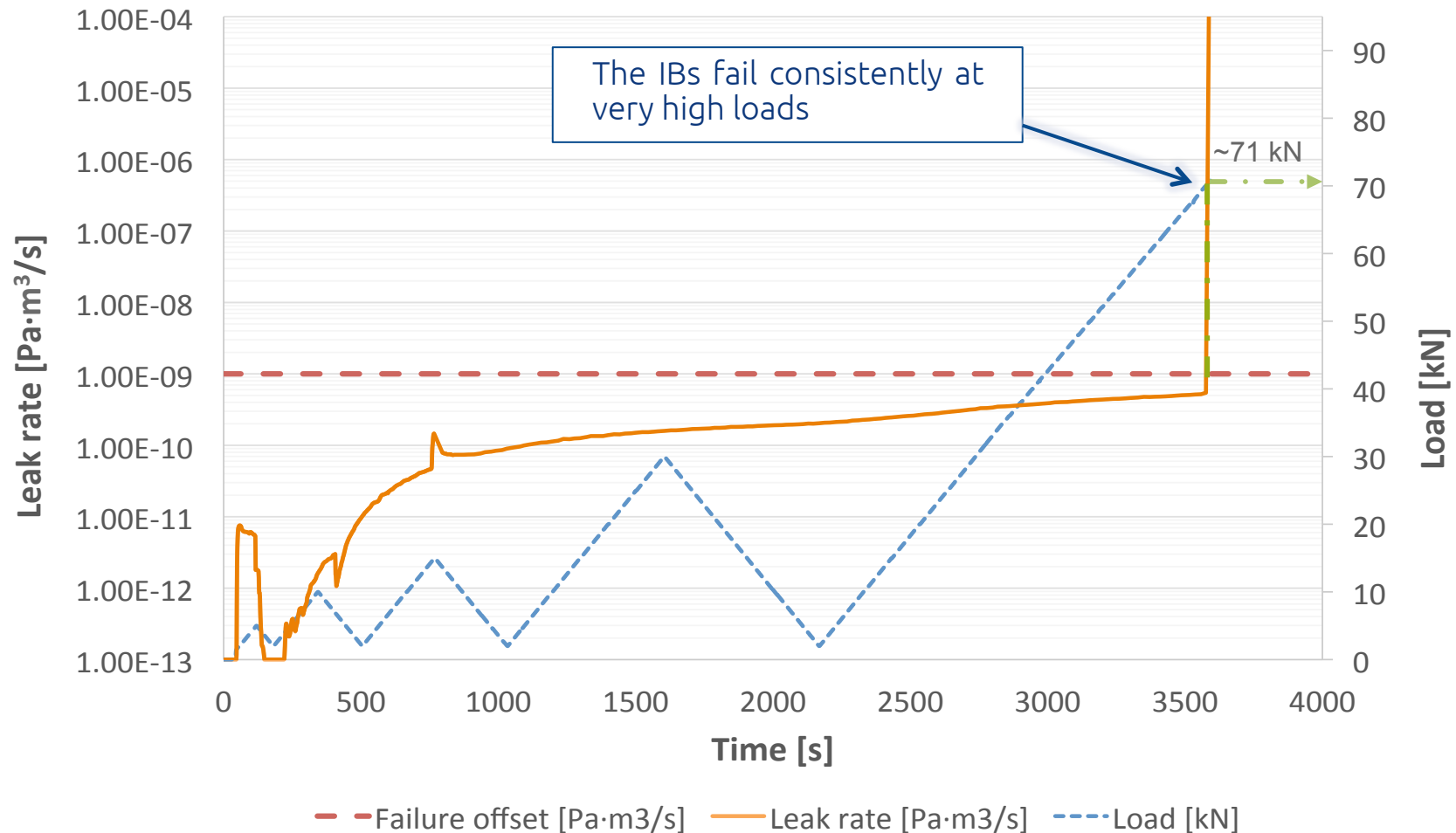


Figure 9: Diagram showing leak rate and applied load over time for the primary load-to-failure test of **IB30kV2** at 77 K

Discussion of selected test results

IB30kV1; secondary measurement at 77 K

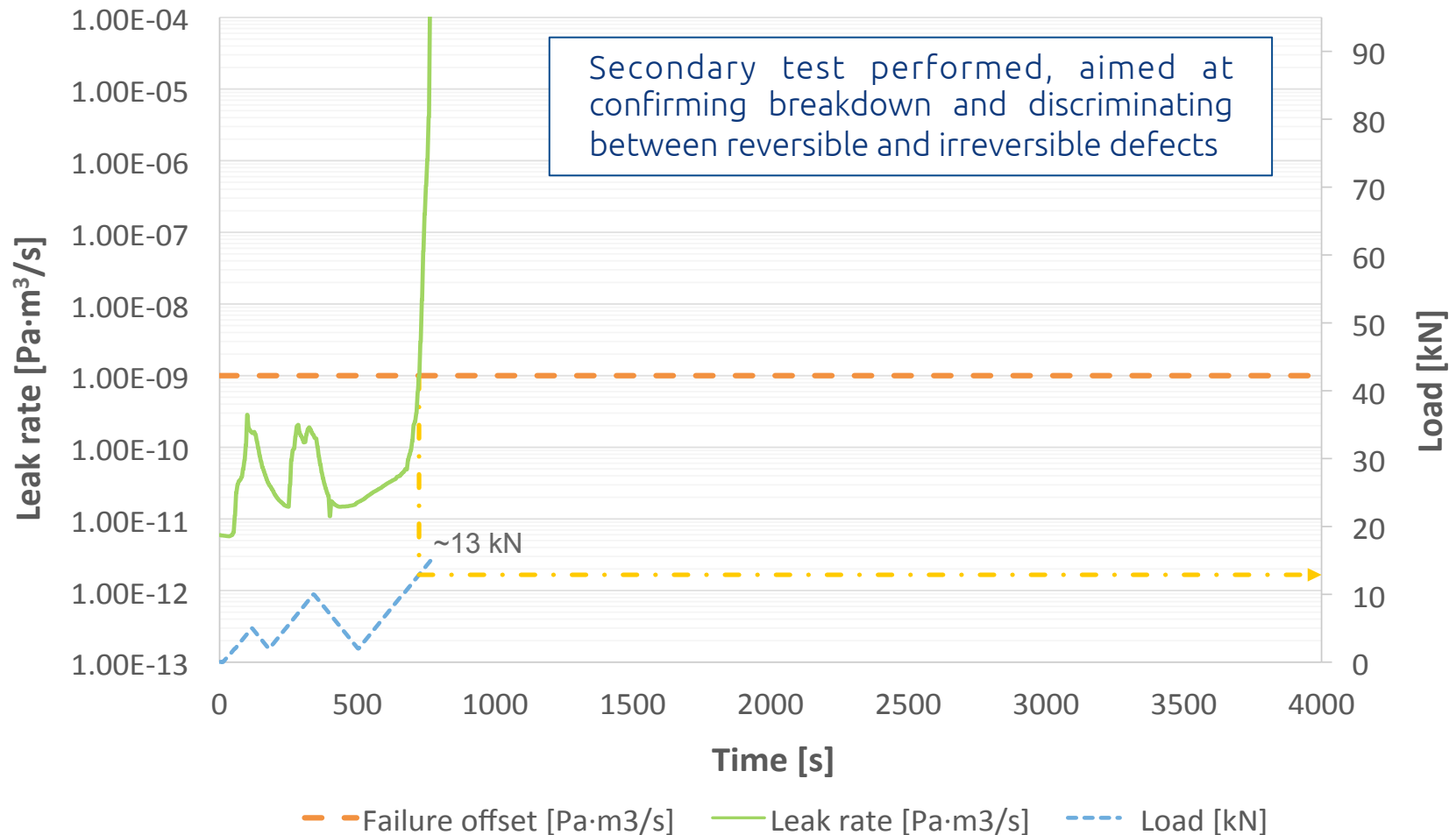


Figure 10: Diagram showing leak rate and applied load over time for the secondary test of **IB30kV1** at 77 K

Discussion of selected test results

IB30kV1; secondary measurement at 77 K

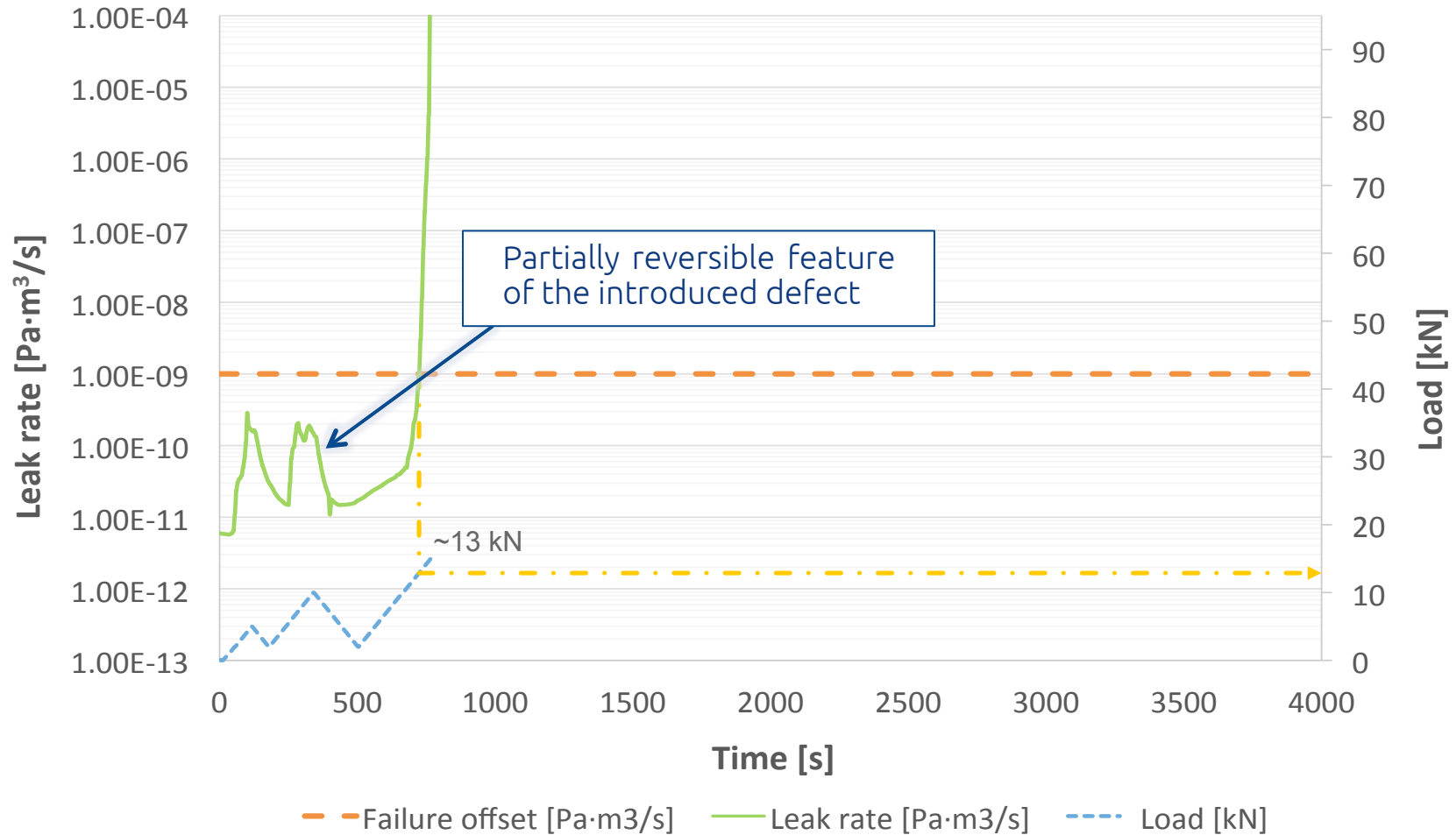


Figure 10: Diagram showing leak rate and applied load over time for the secondary test of **IB30kV1** at 77 K

Discussion of selected test results

IB30kV1; secondary measurement at 77 K

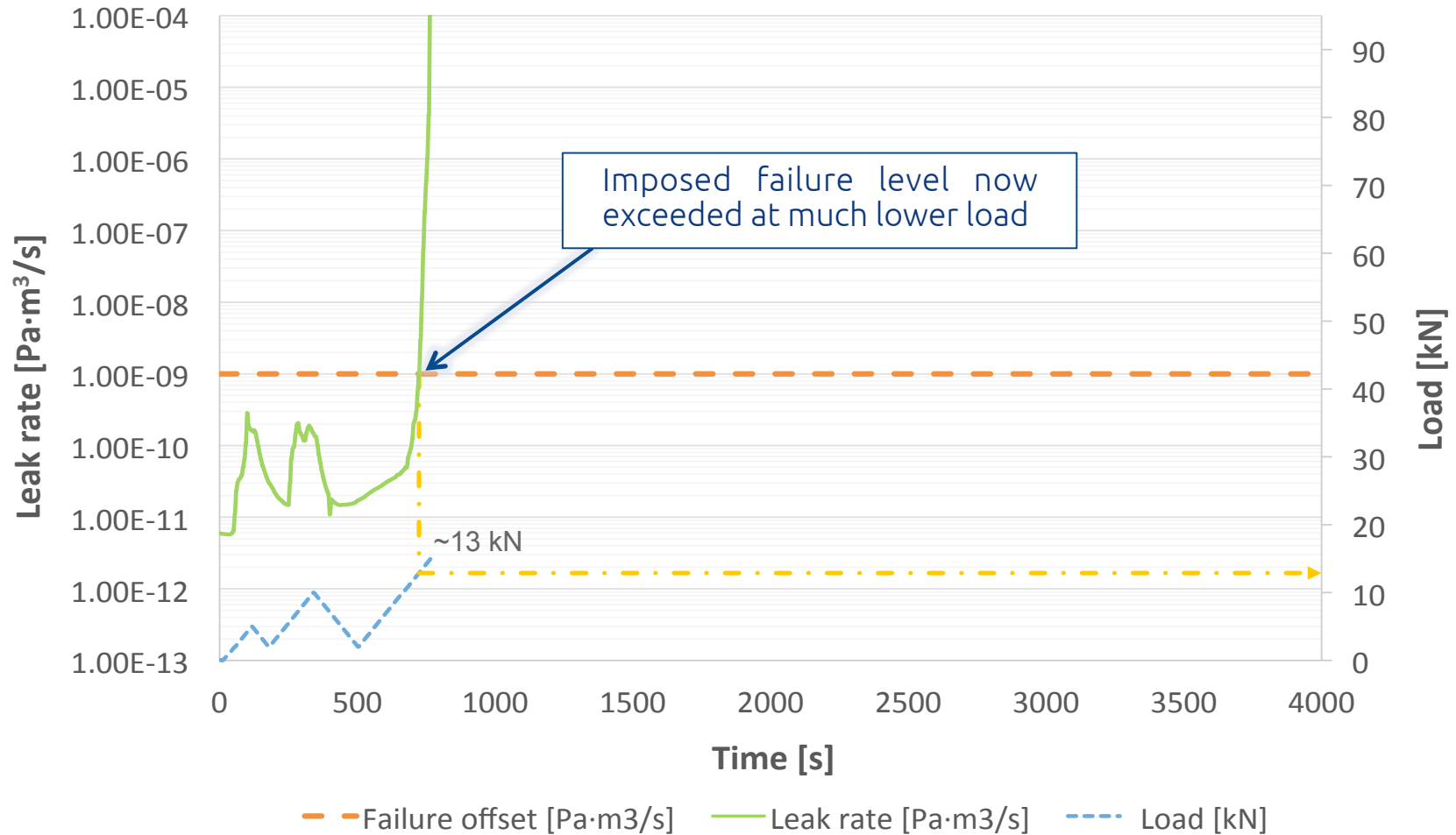


Figure 10: Diagram showing leak rate and applied load over time for the secondary test of **IB30kV1** at 77 K

Discussion of selected test results

Observed defects

primarily at:

- **Interface** between end-fittings and first glass-resin layer.
- Amidst the glass-resin layers; **interlayer** fashion.

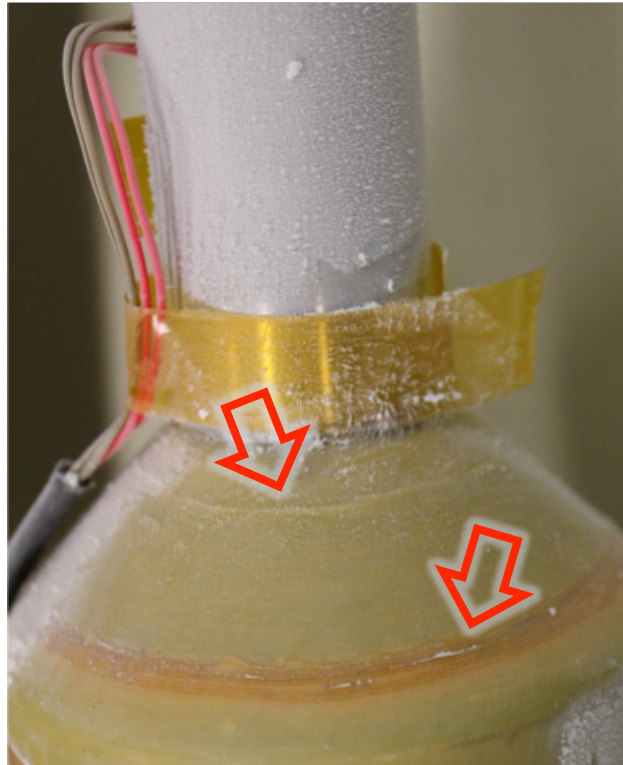


Figure 11: Defective regions observed on the as-tested IB30kV2, by visual inspection



Figure 12: Observation of defective regions on IB30kV2, revealed by the application of liquid penetrant

Concluding remarks

- A binary test setup was successfully designed, developed and commissioned for **low temperature load-to-failure tests of axial insulation breaks**.
- A **good test reproducibility** was obtained for all the tests performed.
- During primary load-to-failure tests, the **insulation breaks fail** consistently at **high loads**.
- Failure is accompanied by **extensive damage** of the insulation break.
- Secondary tests, implemented to examine the nature of the damage, have demonstrated that the damage consists of a **reversible and irreversible** part.

The above conclusions arise from a limited sample basis, hence they cannot be considered as sufficiently exhaustive to guarantee the performance of the axial insulation breaks at operating conditions, i.e. at supercritical helium and in a repeated loading condition.

'The views and opinions expressed herein do not necessarily reflect those of the ITER Organization.'



ENGINEERING
DEPARTMENT



china eu india japan korea russia usa

Thank you for your kind attention!