BREDA

The utilization of Barsebäck NPP as host to enhance the RPV knowledge base

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Background

6 BWRs, 2 PWRs and 2 WWERs are preparing for operation beyond the original licensing period (LTO) in the Nordic countries

Necessary to distinguish the operational limiting factors

Can be assessed by a number of methodologies:

- IAEA Safety Report 57 presenting one such methodology (Safe Long Term Operation of NPPs)

Identification of TLAAs through a gross list suggested in IAEA iGALL (Safety report 82)

Reactor Pressure Vessel (RPV

The RPV was early on identified as an area that need special attention

Ageing of the component caused by both thermal and neutron irradiation induced embrittlement

Mechanical properties monitored by means of a ”surveillance program” consisting of a number of “capsules” installed in the RPV to be irradiated in a somewhat accelerated manner. Today lead-factors of 2-5 is considered “good practice”.

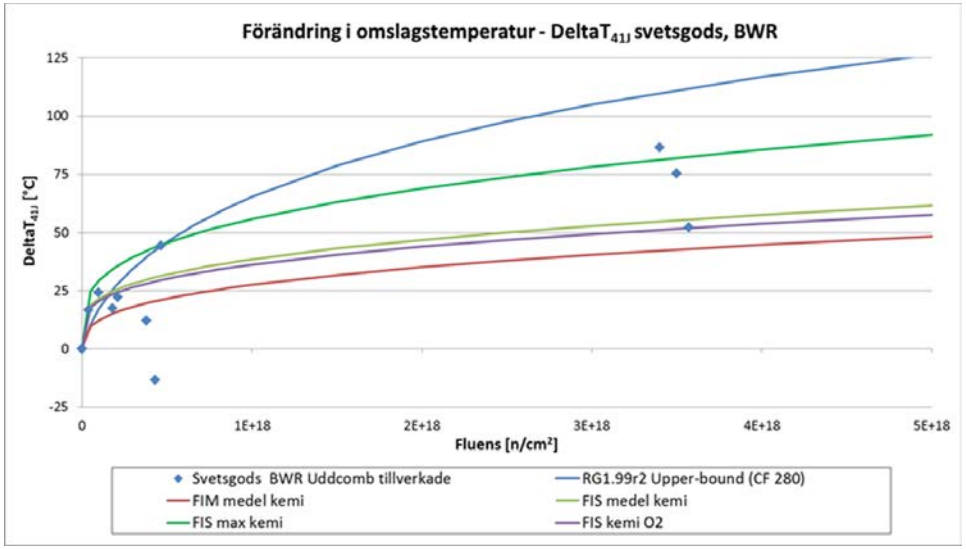
From ”Barsebäcks Kärnkraftverk, dokumentation, rapport 2006:57

Irradiation induced ageing and degradation

During service, the RPV is subjected to thermal and neutron induced ageing

The end-result is microstructural changes leading to hardening and a shift in a measure called ”DBTT”, or Ductile to Brittle Transition Temperature which is measure of the where the material exhibits a ductile behavior and thus prevents the on-set of brittle fracture

Has been measured at the NPPs since the beginning of operation and is to high extent regulated nationally



Specifics of the Uddcomb-RPVs

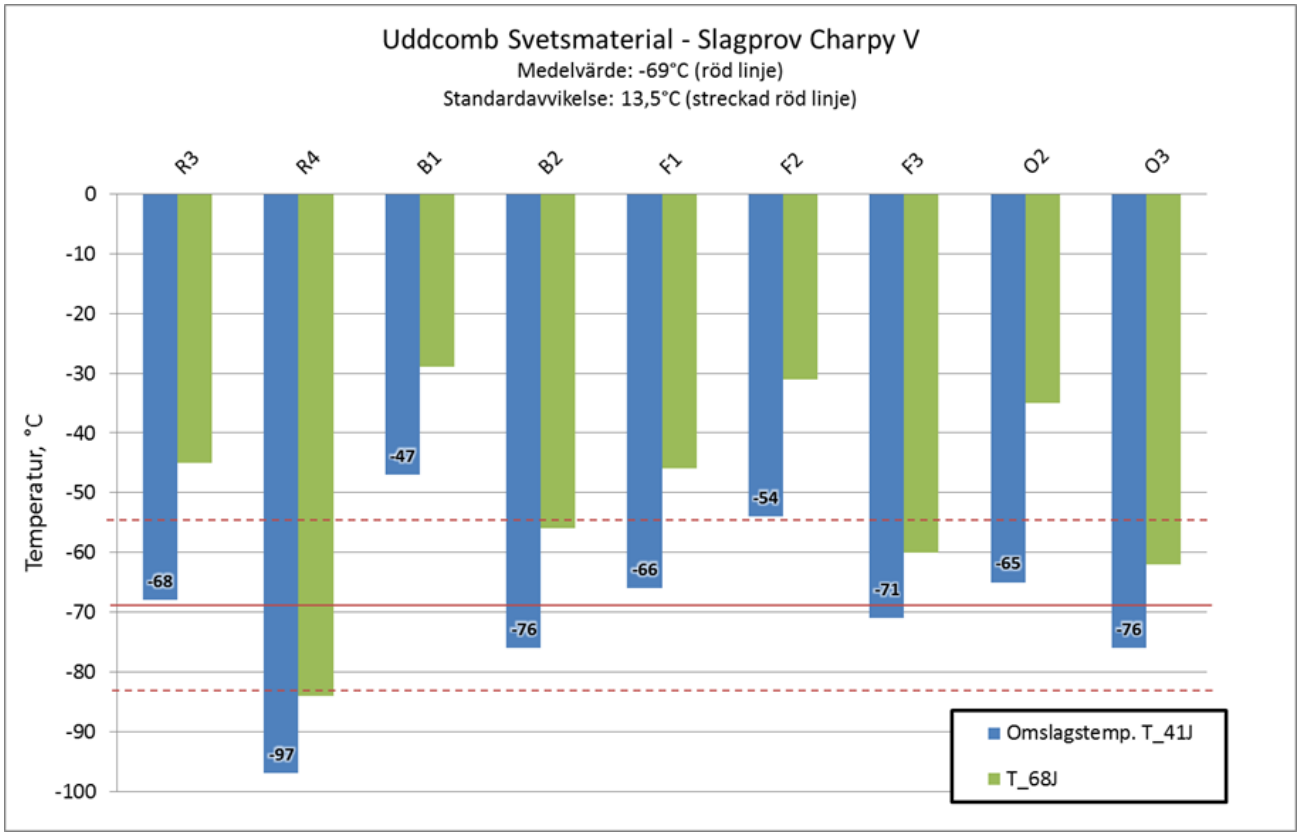
Weld-metal contains relatively high Ni- and Mn-content

- Excellent BOL properties
- All RPVs are (more of less) manufactured to the same specifications

Can be considered a sub-group of RPVs

- Possibility for an integrated surveillance program allowing for optimized capsule withdrawal

Beginning of Life (BOL) properties of the Swedish Uddcomb manufactured RPVs



Current state of the art knowledge

All Uddcomb RPVs appear to follow similar trend curves with respect to neutron dose

Negligible influence of thermal ageing on the resulting shift in mechanical properties

The number of remaining surveillance capsules is in the low end of the acceptance band for operation beyond 60 years

Areas of improvement

Mechanical testing of the current fleet of reactors is primarily based on drop weight tests, where-as current SOA proposes direct measurement of fracture toughness

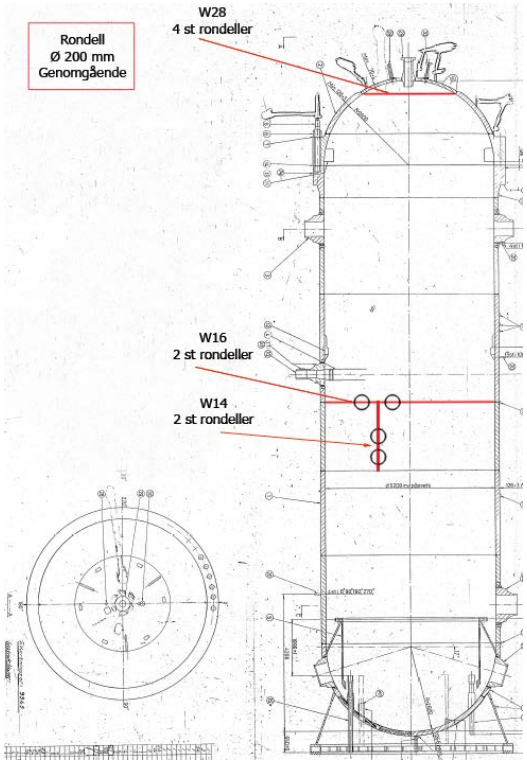
An ever on-going debate on the effect of constraint (i.e. the apparent difference between small specimen tests and actual components that can be simulated by ingenious specimen preparation)

Coupling between the surveillance program results and actual outcome in the RPV

Influence of attenuation (i.e. damping) of irradiation effects through the thickness of the RPV wall

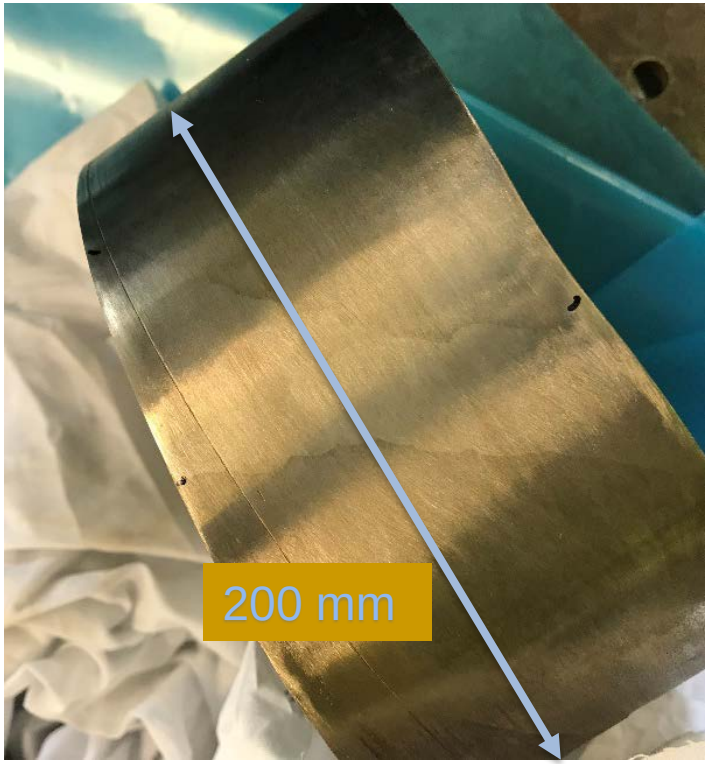
Long term effects of thermal ageing on the structural integrity of the RPV

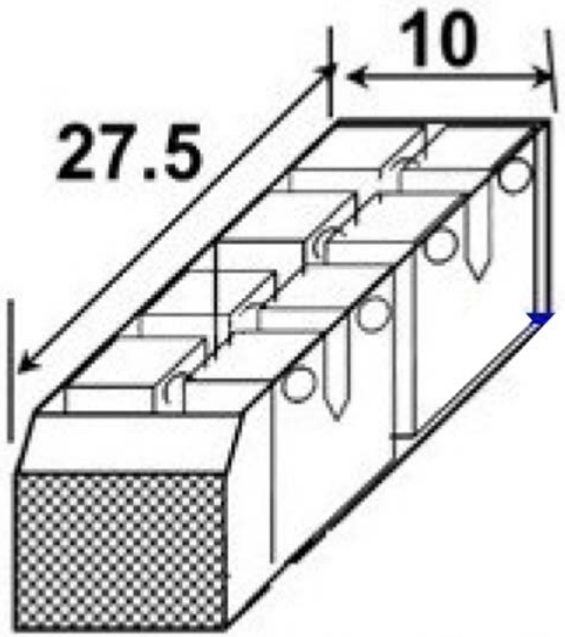
Extraction of trepans



Overview and drill with harvested sample

Testing on trepan, surveillance and additionally irradiated materials; unique and important





NKS work is a part of a large entity

NKS funding for KTH, Chalmers University and VTT

KTH: modelling the effect of constraint (Magnus Boåsen)

Chalmers: Atom probe tomography for mechanistic understanding of embrittlement (Kristina Lindgren, thesis defence December 11th, 2018)

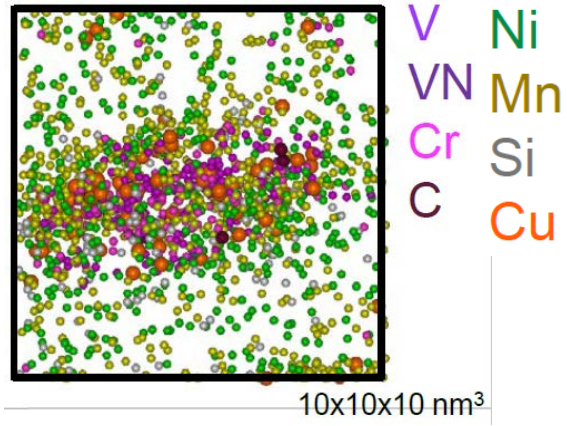
VTT: Mechanical testing on non-irradiated B2 material and microstructural investigations thereof (Jari Lydman)

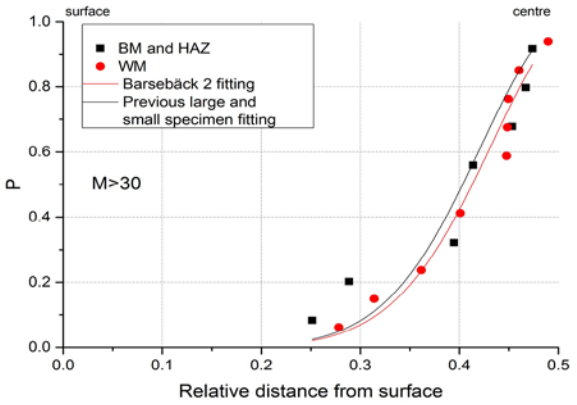
Examples of results

Single edge notched specimens are capable of producing loss of constraint and will be used in the testing campaign

Clusters containing Ni, Mn, Si and Cu are formed both due to irradiation and thermal ageing, but have different characteristics (https://research.chalmers.se/en/publication/506088)

The cumulative initiation location in B2 material is similar to other RPV materials





Conclusions

The support of BREDA/BRUTE by NKS has been a vital part of the formation of a broad Nordic network to enable both critical information to support LTO for the Nordic LWRs and knowledge build-up and transfer to allow for long term engineering support to the active NPPs

Material has been harvested and documented from the RPV of Barsebäck 2 which has laid the foundation for a successful project implementation for the near future