

Unsolved problems of the material structure of the Doel 3 / Tihange 2 reactor pressure vessels.

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Overview

1. Construction of a nuclear reactor vessel.
2. Flaw map of the Doel3 lower core shell.
3. Hypothesis Electrabel.
4. Hydrogen balance.
5. Production: Casting and forging.
6. Summary

Vessel head top cap

Vessel head flange

Vessel flange

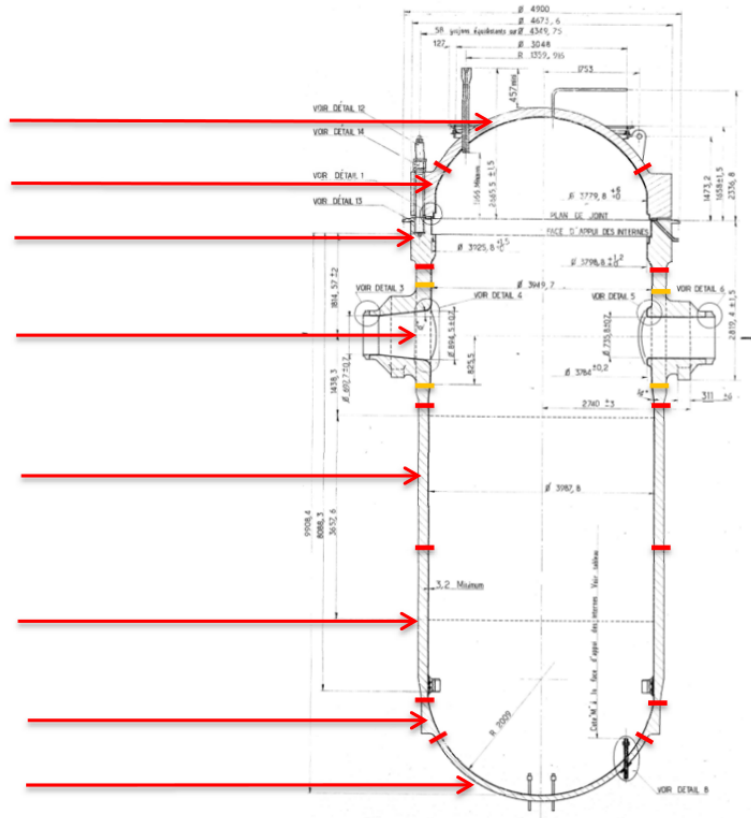
Nozzle shell
I/O nozzles

Core upper shell

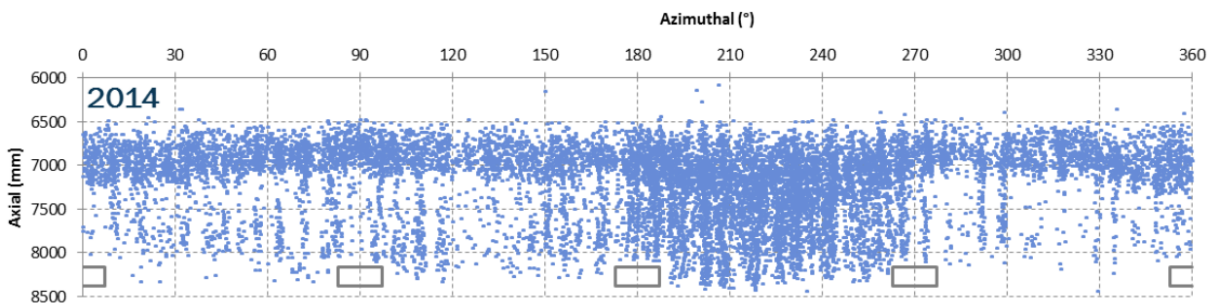
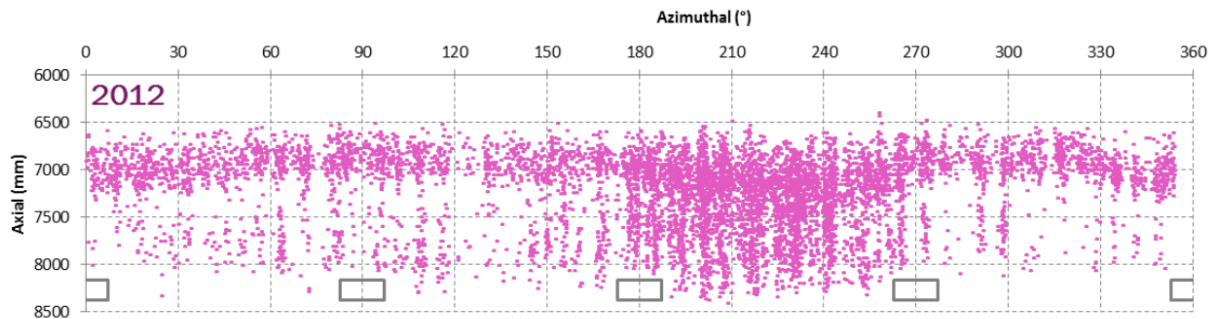
Core lower shell

Transition ring

Vessel bottom cap



Construction Doel3 Reactor Vessel



Lower shell 2012:7200/2014:11600 Upper shell 2012:800/2014:1400

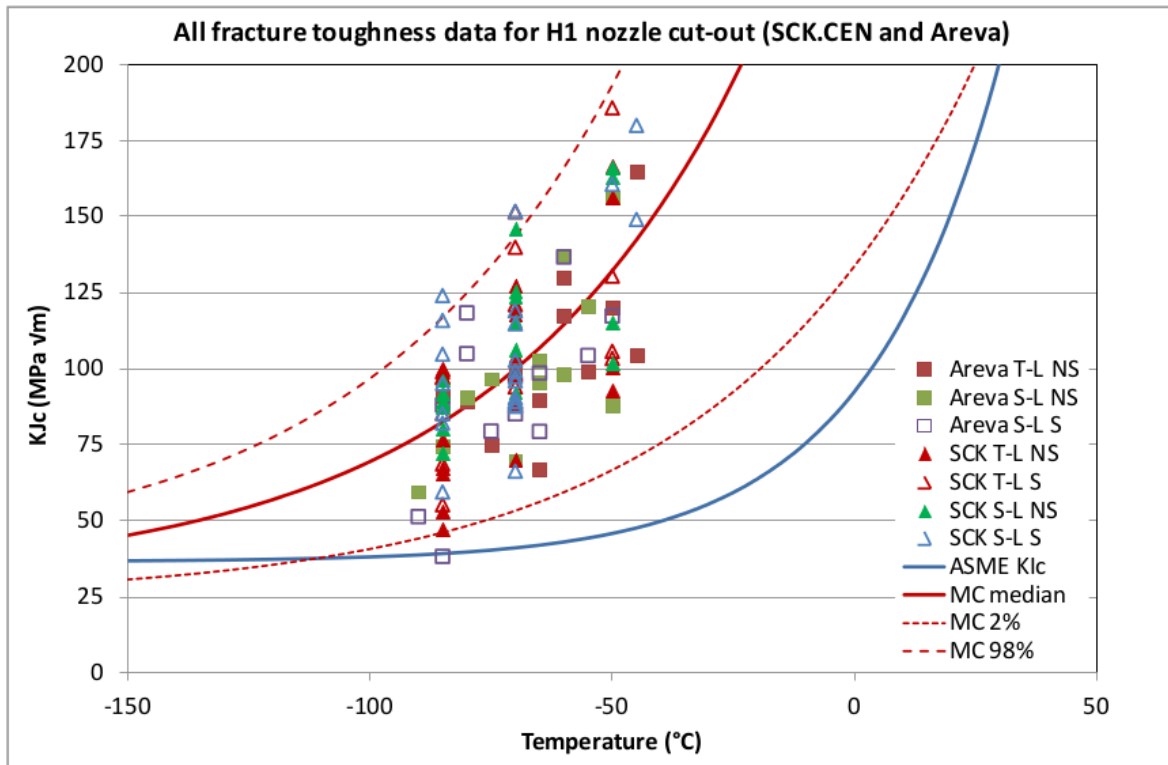
Flaws distribution in the circumference of the Doel 3 lower core shell.

Hyphothesis Electrabel:

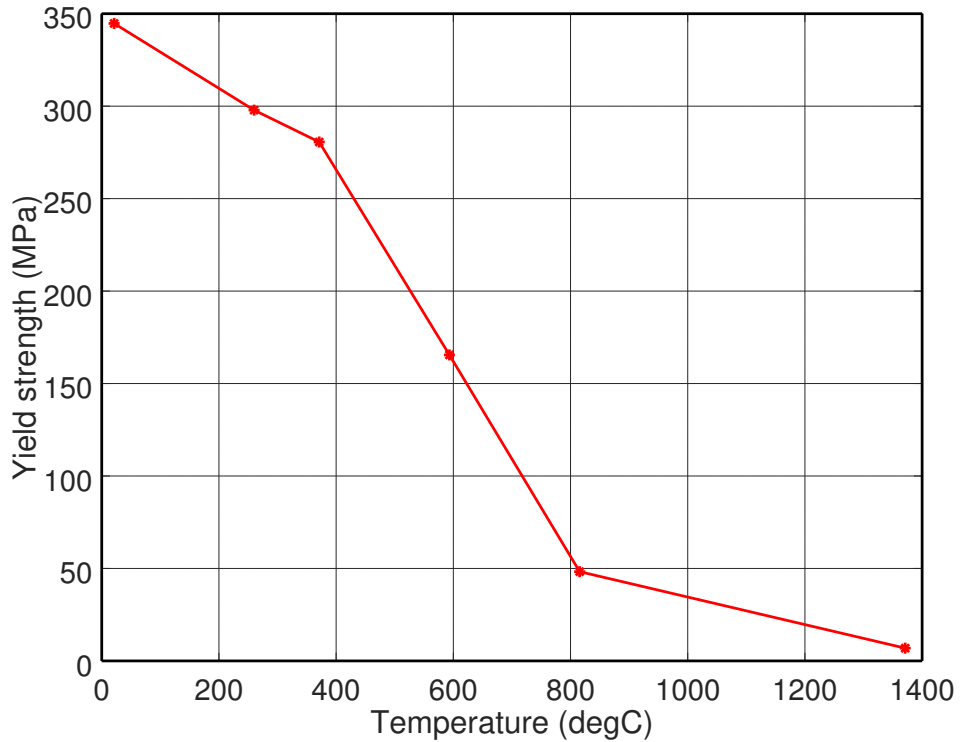
- The flaws are caused by hydrogen flaking during production.
- Consequently the flaws are stable, they do not grow.

Test hypothesis Electrabel:

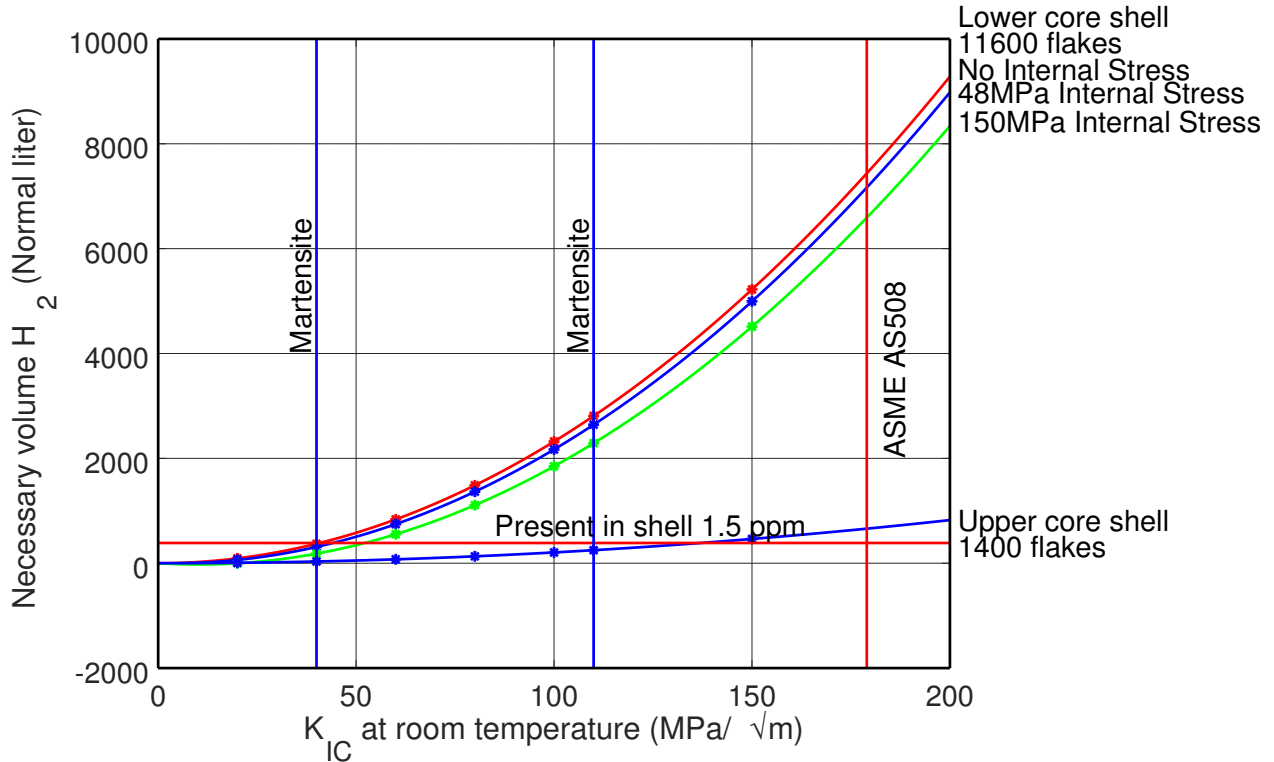
- Sufficient volume hydrogen.
- Material structure sensitive to flaking.
- Internal stresses perpendicular to the flakes.
- Flaking occurs during cooling below 200°C



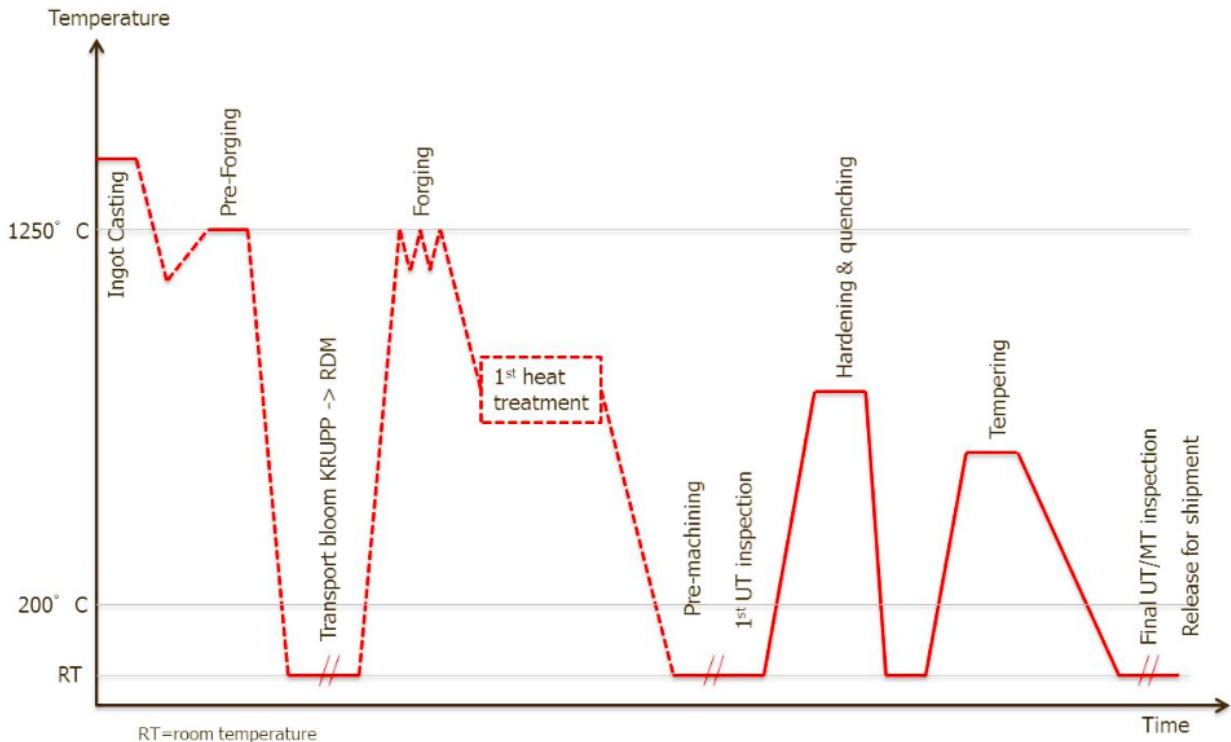
RT-curve AS508.



Yield strength AS508.

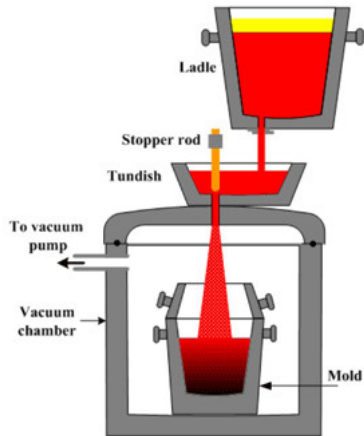


Required volume hydrogen to form all measured flakes.



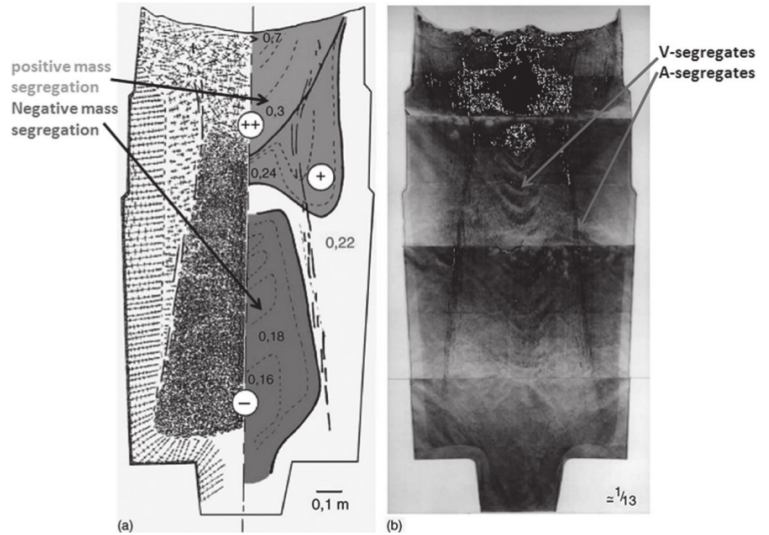
Production time about 1 to 1.5 years.

Production time line of the reactor vessel shells.



Component	C [%]	S [%]	Mn [%]	H [ppm]
Vessel head flange	0.21	0.009	1.27	1.170
Vessel flange	0.22	0.008	1.28	1.450
Nozzle shell	0.23	0.010	1.26	1.000
Core upper shell	0.23	0.012	1.34	1.400
Core lower shell	0.21	0.010	1.25	1.500
Transition ring	0.23	0.011	1.30	1.500

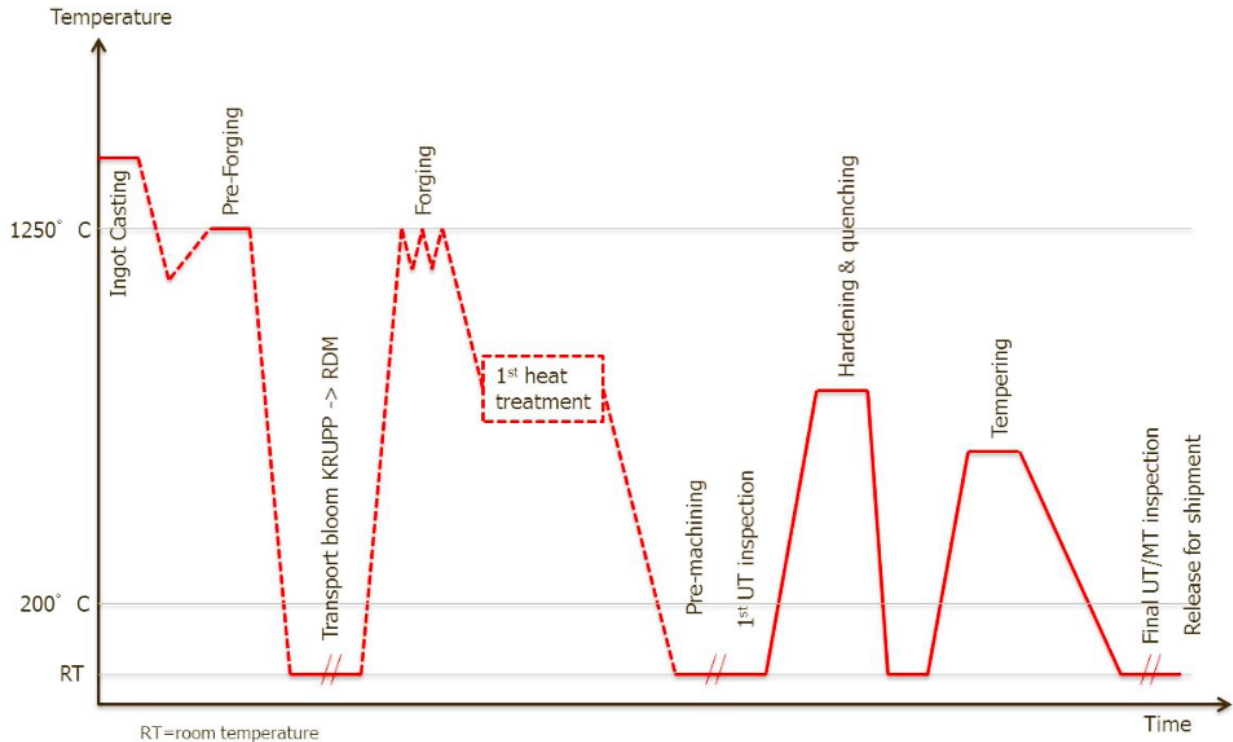
Vacuum casting.



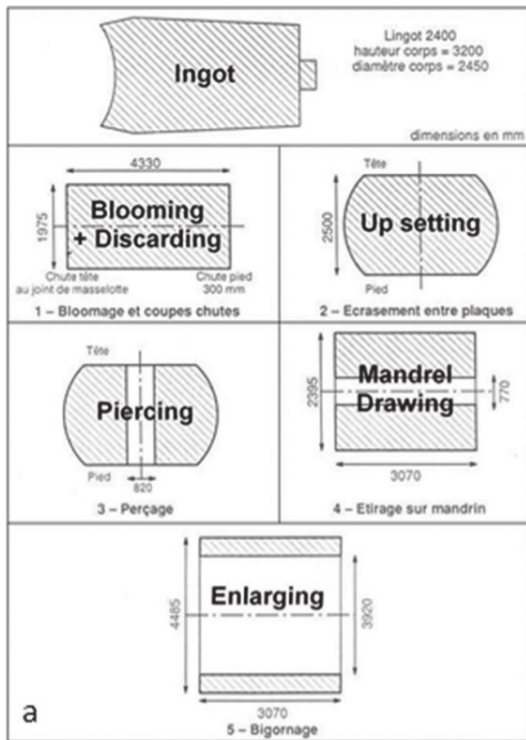
Segregations in ingot.



Preforging to bloom 110 ton.



Production time line of the reactor vessel shells.



Forging steps at RDN.



Forging steps at RDN: Up setting.

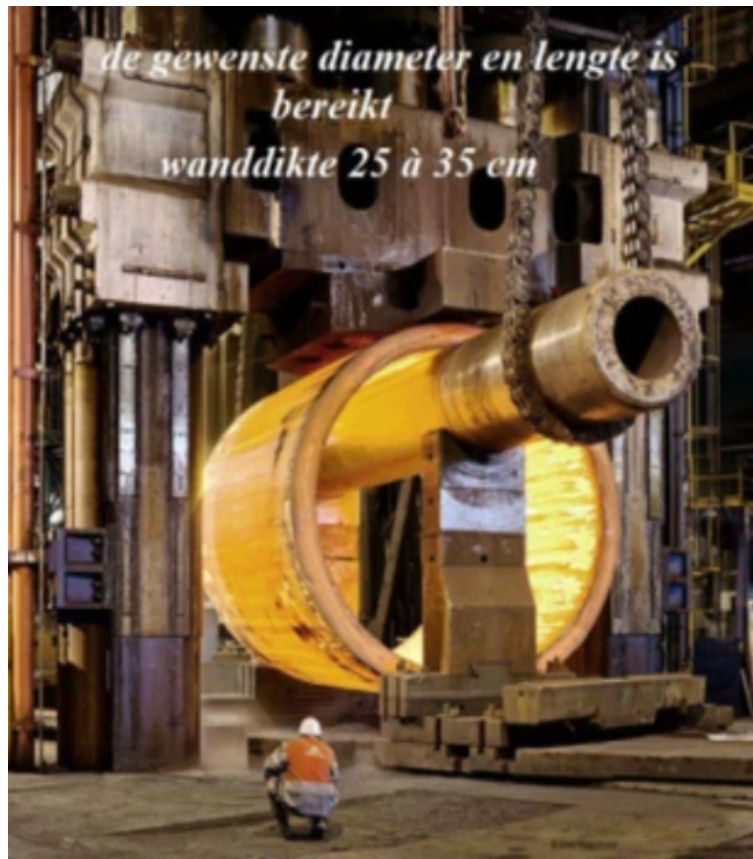


By piercing removal of impurities in center of the bloom.

Forging steps at RDN: Piercing.



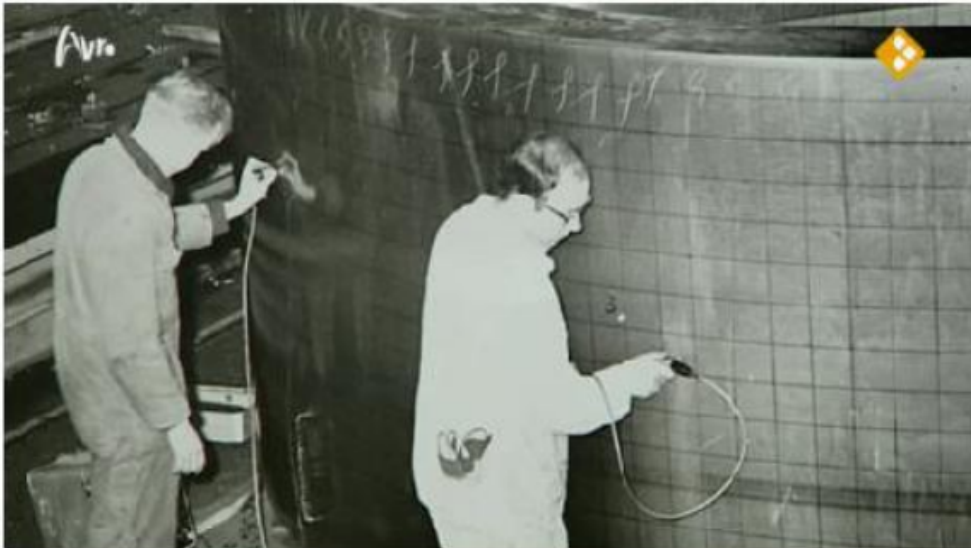
Forging steps at RDN: Pierced cylinder.



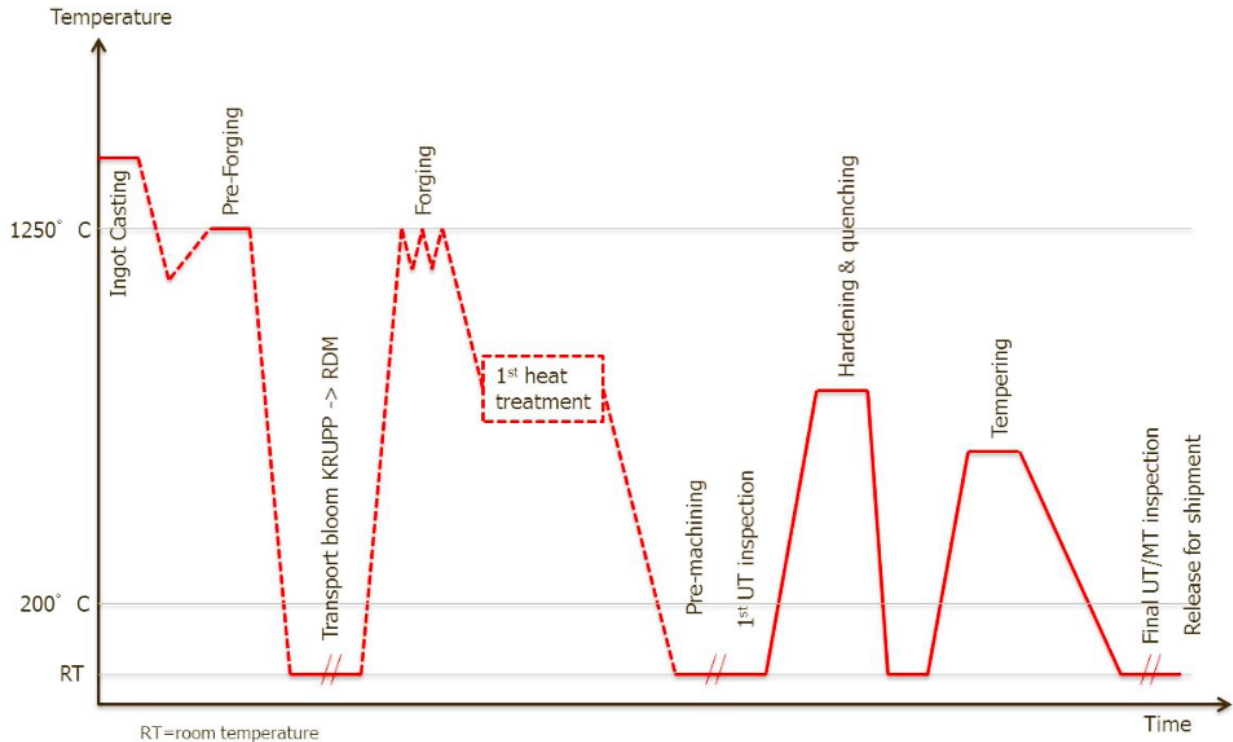
Forging steps at RDN: enlarging shell.



First turning cylinder.



First ultrasonic test: not obligated, no results known.



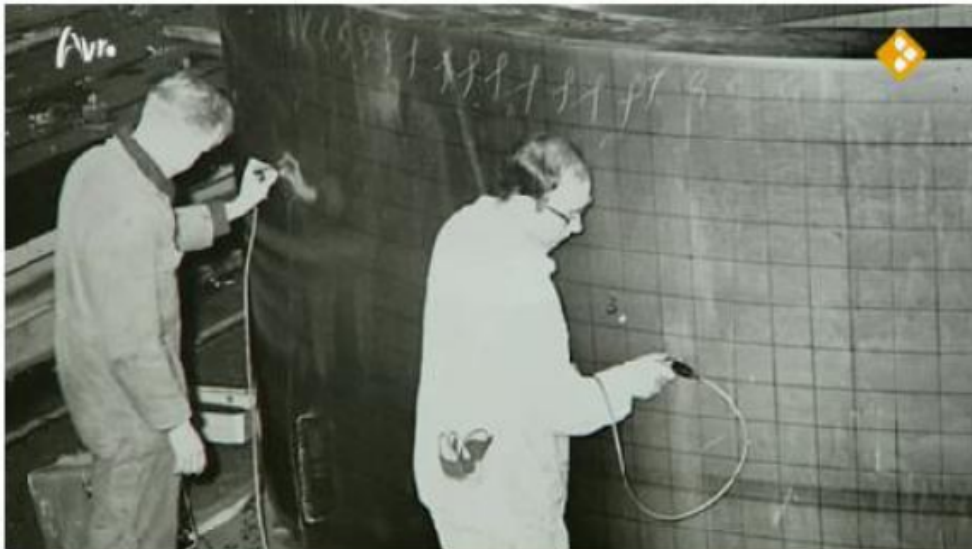
Production time line of the reactor vessel shells.



Hardening and tempering.

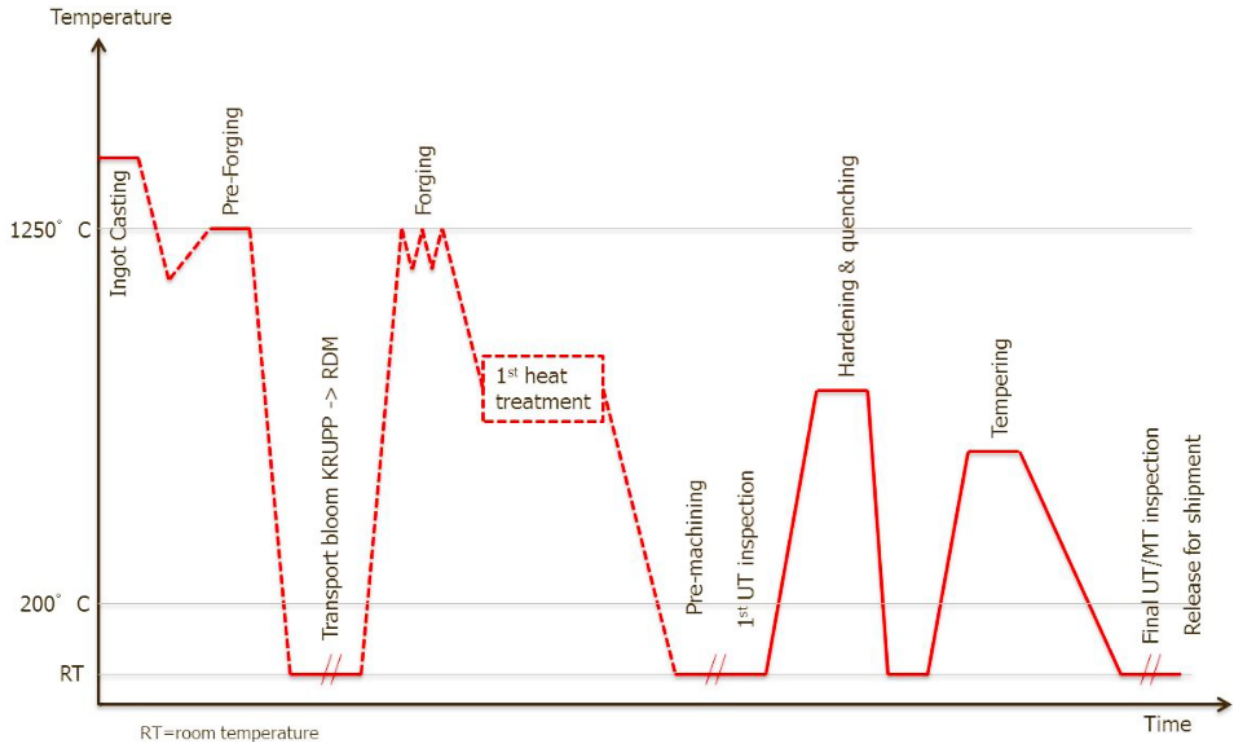


Turning cylinder to final dimensions.



Upper core shell: reported zone with acceptable flakes.
Lower core shell: no reportable flakes.

Final ultrasonic test.



Production time line of the reactor vessel shells.

Summary

1. Volume of hydrogen present during the production phase can explain maximum 1500 flakes in the shell.
2. Volume of hydrogen present during the production phase can NOT explain 11600 flakes in the lower core shell.
3. None of the four cooling cycles during production provides the conditions to form 11600 flakes in the lower core shell.
4. The hydrogen balance is not investigated by Electrabel.
5. It is absolutely necessary that the hydrogen balance must be investigated by Electrabel using the data they have at their disposal.

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