Alloy 617- an Option for High Temperature Nuclear and Conventional Power Plants

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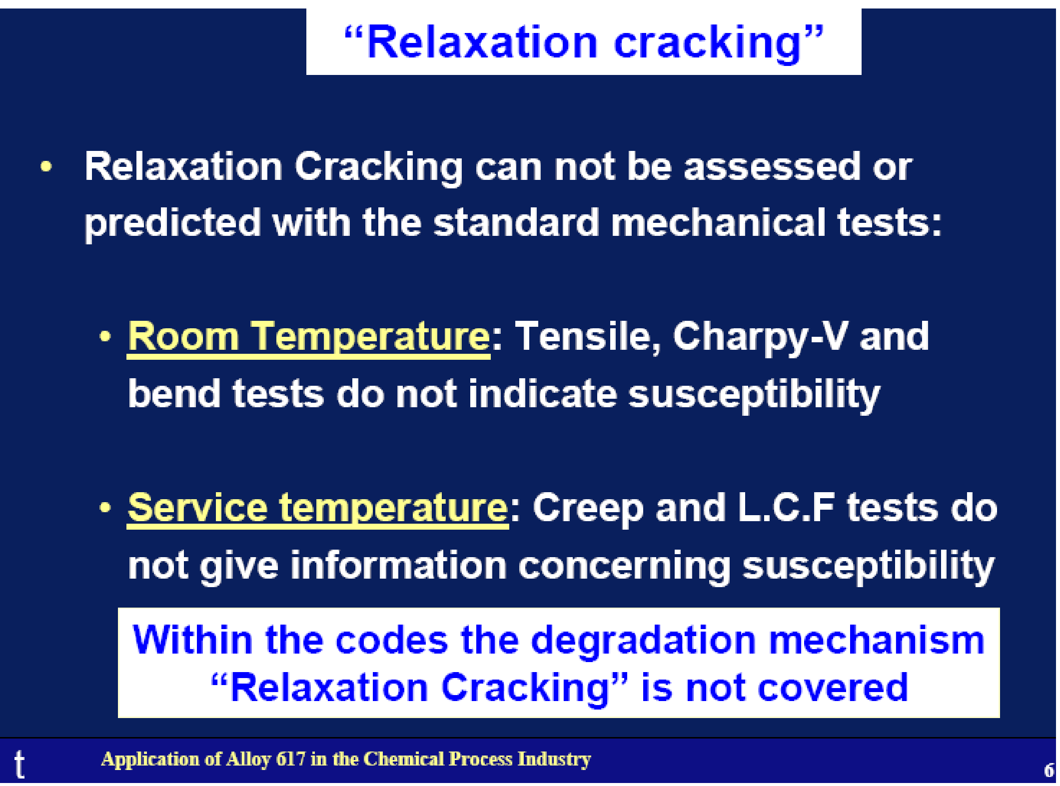
Limitation of Standard Tests

Some effects can only be found in components under multi-axial stress conditions, the real environment of a plant and materials technology under real manufacturing conditions



Other examples:

Hydrogen induced cracking

Type IV cracking

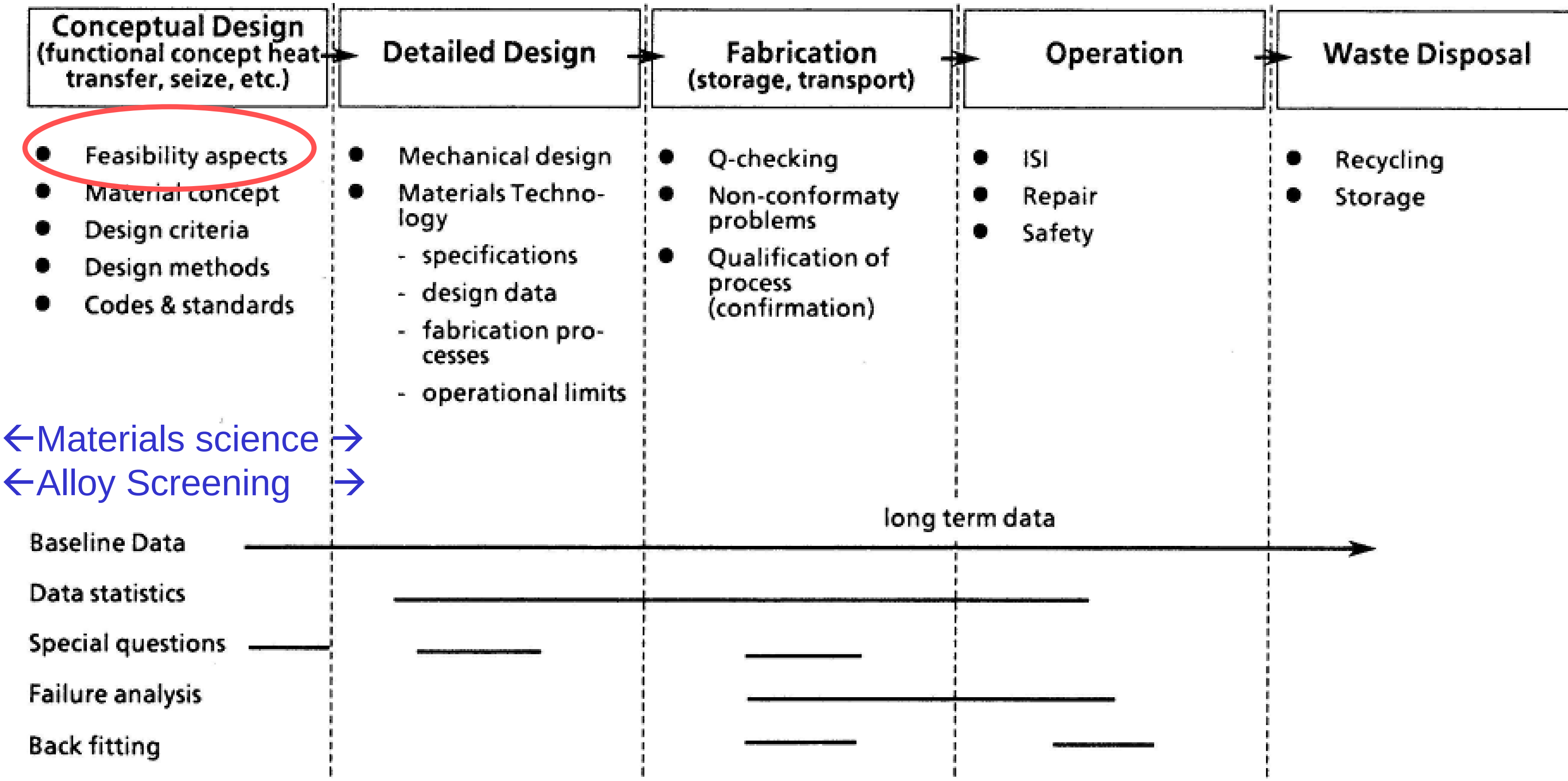
vanWortel, 2007

Objectives

This Conference: Development of new structural materials for advanced fission and fusion reactor systems and advanced conventional power plants

- To show the extend of qualification necessary for code and fabrication development (example A617)
- Survey the experiences from the previous HTR program (the resources are distributed over various places in different forms e.g. MatDB, reports,.. ...)
- Fabrication of components and other challenges on the way to a 700°C power plant

Product cycle



Aspects of Material Selection / Qualification - Data for Design

- Thermo physical Properties (stress factor)
- Ductility irradiated/aged
- Tensile strength
- Swelling /irradiation creep
- Creep strength
- Resistance to crack propagation
- Toughness /DBTT
- Hardness
- Corrosion
- Ductility/uniform elong.
- Stress corrosion cracking
- Fatigue resistance, TMF
- Reduced activation and radiological properties

Weldment data are a general problem (relaxation cracking, creep, effect of internal stresses , Q, → corrosion, relaxation, ...)

Aspects of Material Selection&Qualification
- Data for Procurement Specifications -

- Chem. comp (min/max and methods/standards)
- Tensile strength
- Toughness /DBTT (aged)
- Hardness
- Ductility/uniform elong.
- Corrosion (IGA,..)
- (Creep strength)
- (Fatigue resistance)

- Availability (qualified manufacturer)
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- Qualified fabrication routes (TMT)
- Weldability/joining
- Dimensional stability of components fabricated
- Non-destructive testing
- Costs

Applications of Alloy 617

- Welding large Gas turbine components
- Heating systems at very high temperature
- Research programs (HTR, PNP,...)
- Conventional Power Plant with an operating temperature of 700°C

➔ Qualified manufacturing technology available

➔ Technical specifications and data sheets as basic documents for manufacturing are available incl. a draft nuclear standard (KTA)

Chemical Composition of NiCr22Co12Mo

Chemical composition of **A617**mod for use in 700°C PP

	C	Si	Mn	P	S	N	Al	B	Co	Cr	Cu	Mo	Ti	Fe
min	0,05						0,8	0,002	11	21		8	0,3	
max	0,08	0,3	0,3	0,012	0,008	0,05	1,3	0,005	13	23	0,05	10	0,5	1,5

Chemical composition of A617 due to VDTÜV 485

	C	Si	Mn	P	S	N	Al	B	Co	Cr	Cu	Mo	Ti	Fe
min	0,05						0,6		10	20		8	0,2	
max	0,10	0,7	0,7	0,012	0,008		1,5		13	23		10	0,5	

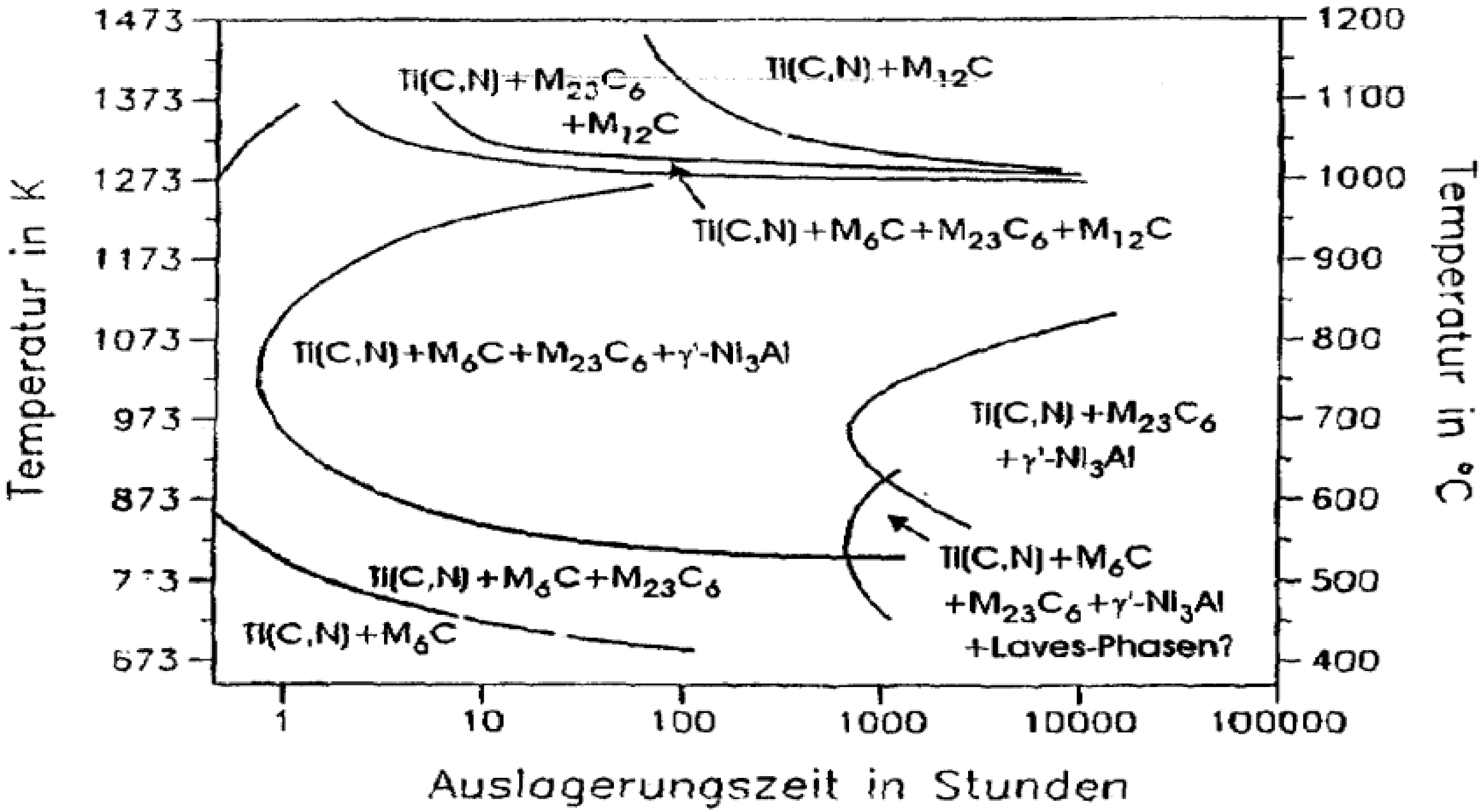
Higher Requirements of A617mod:

- Stronger limitations of elements → C, B, Cr, Ti, Fe, Si, Mn, …

- Solution Annealing: >1160°C

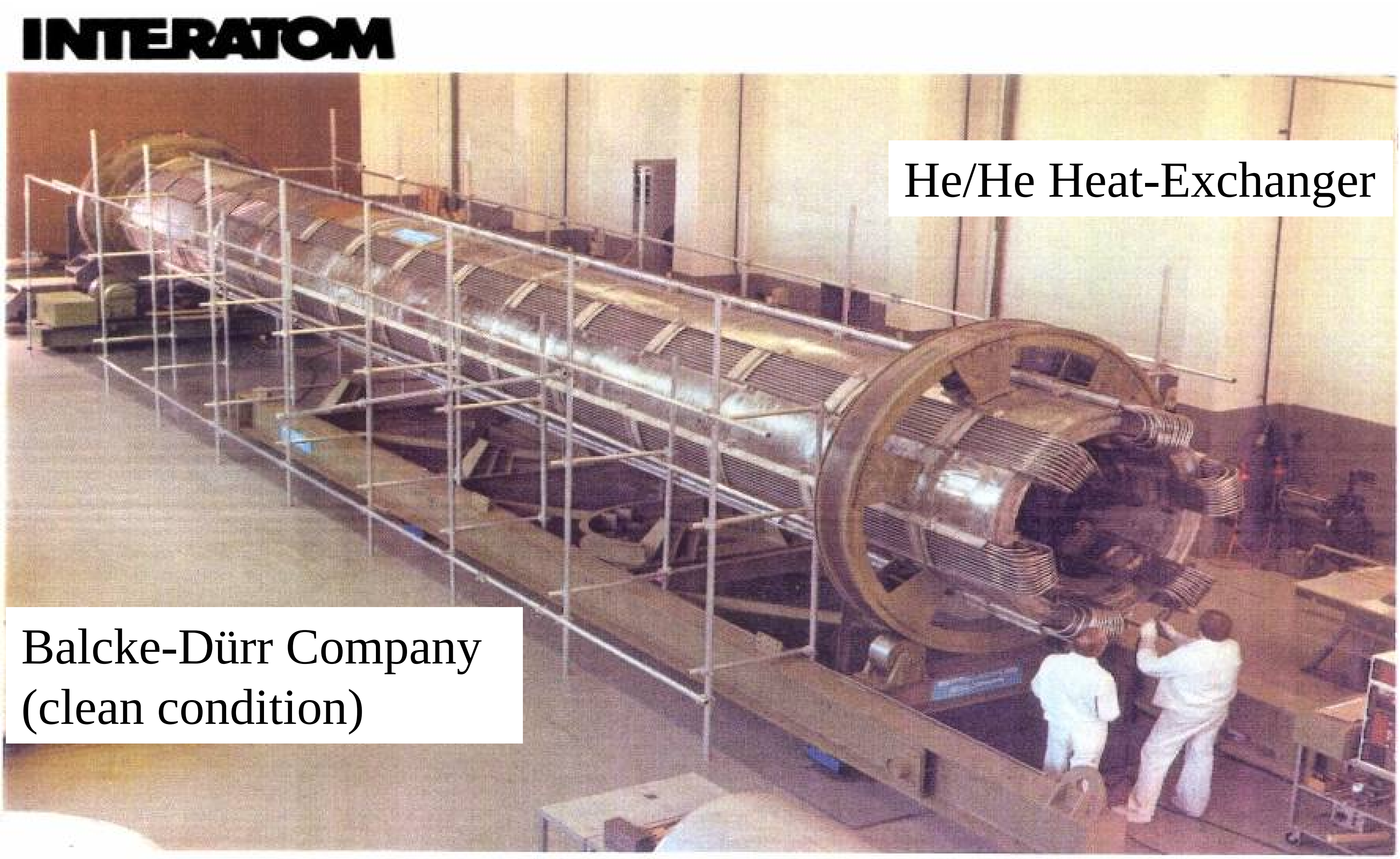
Source: VDTÜV data sheets

Precipitations in A617

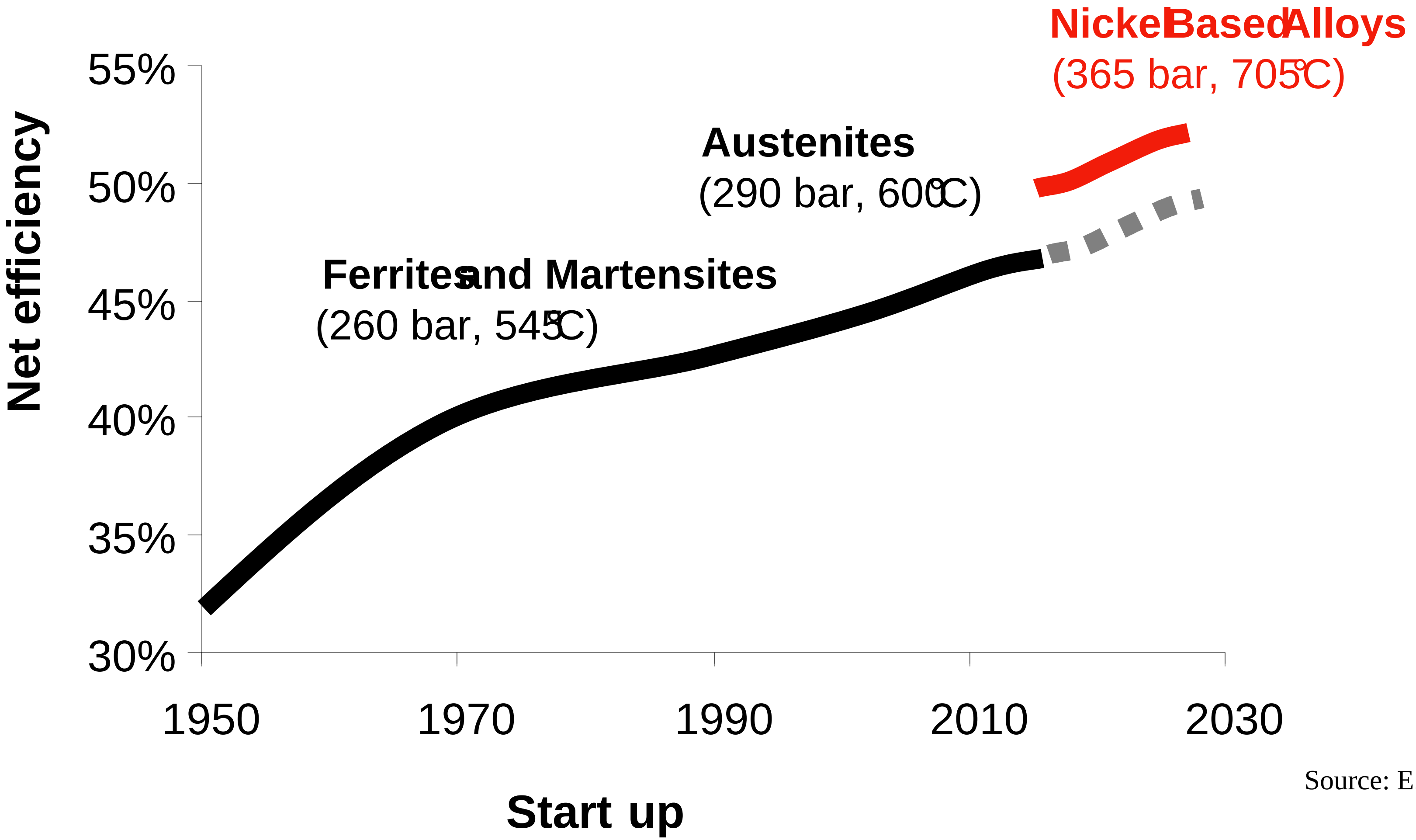


Components of A 617

Tests to Verify HTR Technology



Development of Efficiency in Coal Fired PP in Germany

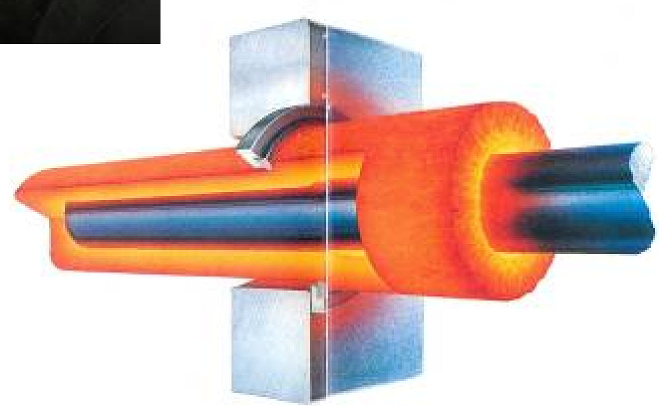


Source: E.ON

Challenging Components of a 700°C PP (1)

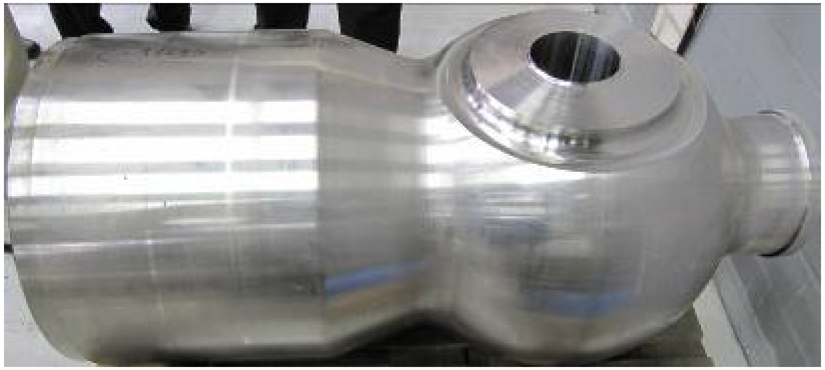
Section of a HR-pipe with a wall thickness of ca. 30mm

Manufacturing routes:
Piercen and Drawing →
performed by V&M



Source: V&M

Challenging Components of a 700°C PP (2)

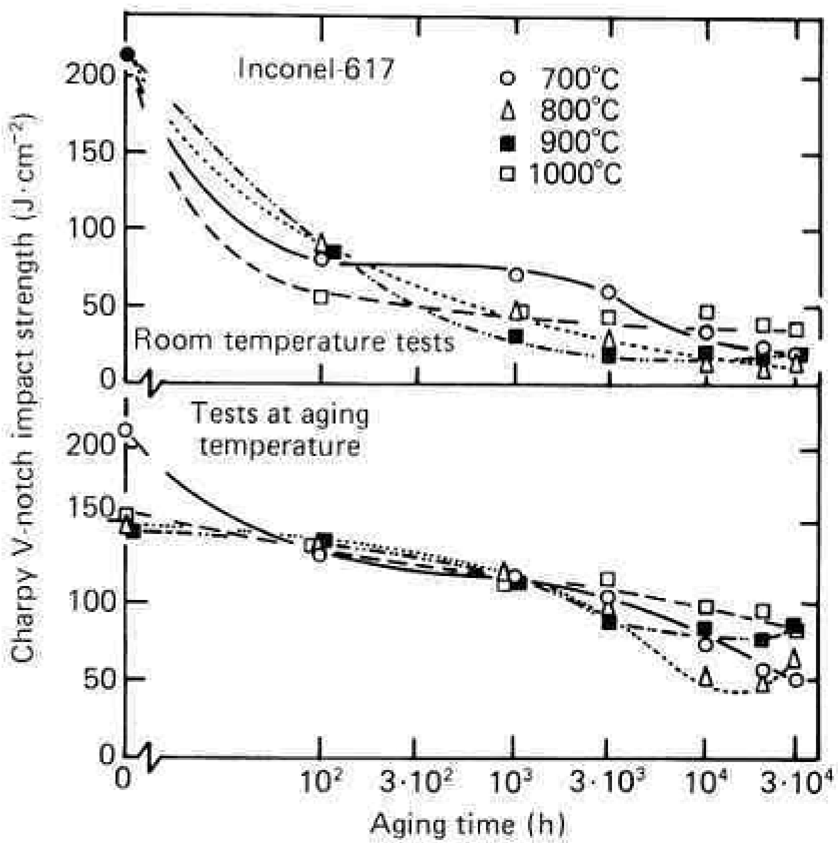


Machining status of an HP-bypass valve out of a forging of A617mod

Wall-thickness: ca. 85mm

Source: Hora; E.ON

Impact behaviour at RT and elevated temperature



Heat to heat variation significant

Minimum Values: tests at RT

Heat effected zone data very low: ~ 10 J

➔ tensile data acceptable, also fracture mechanics data

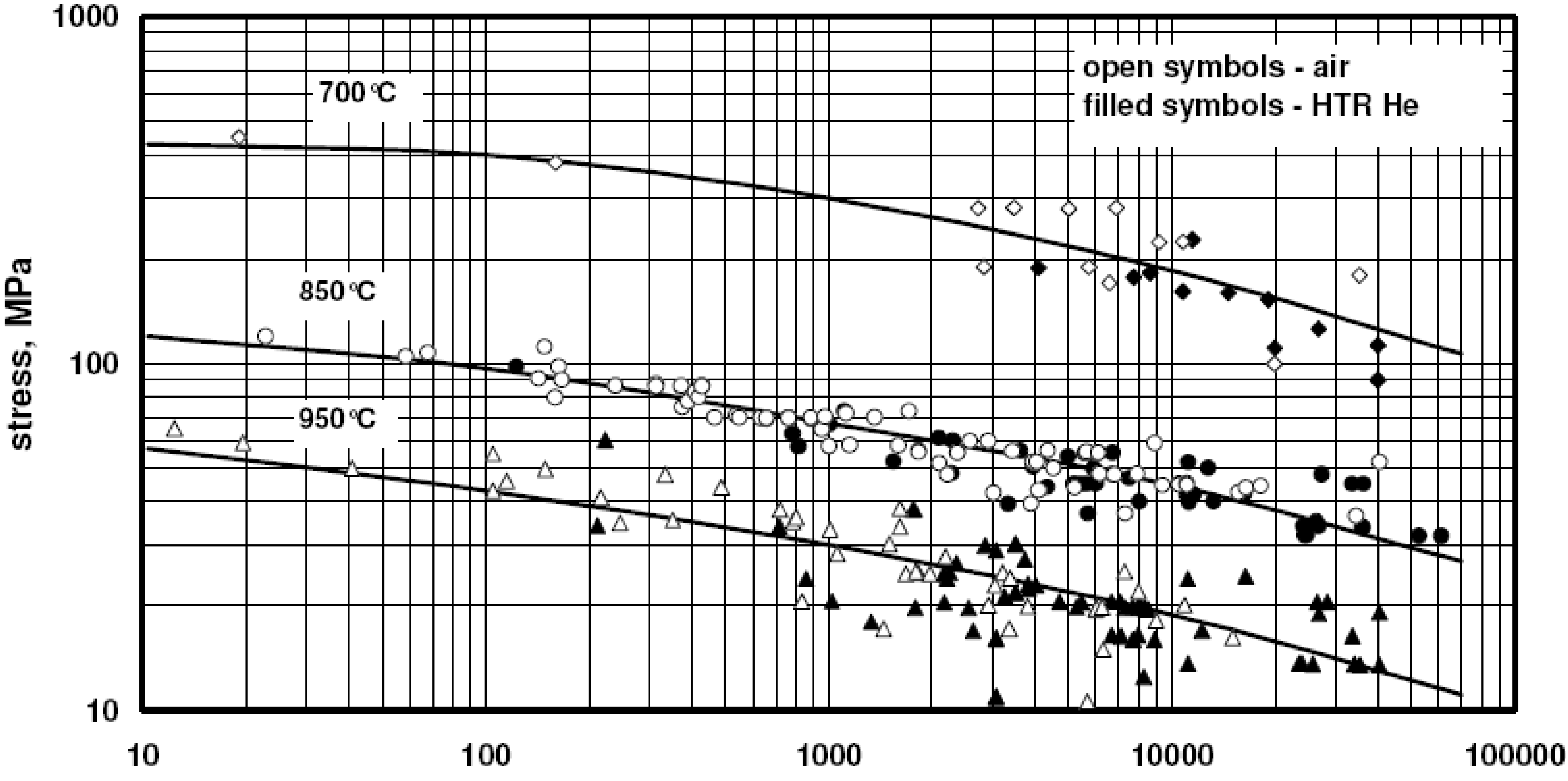
Precipitation diagram was determined

Stress Strain Behaviour at 750 and 950°C

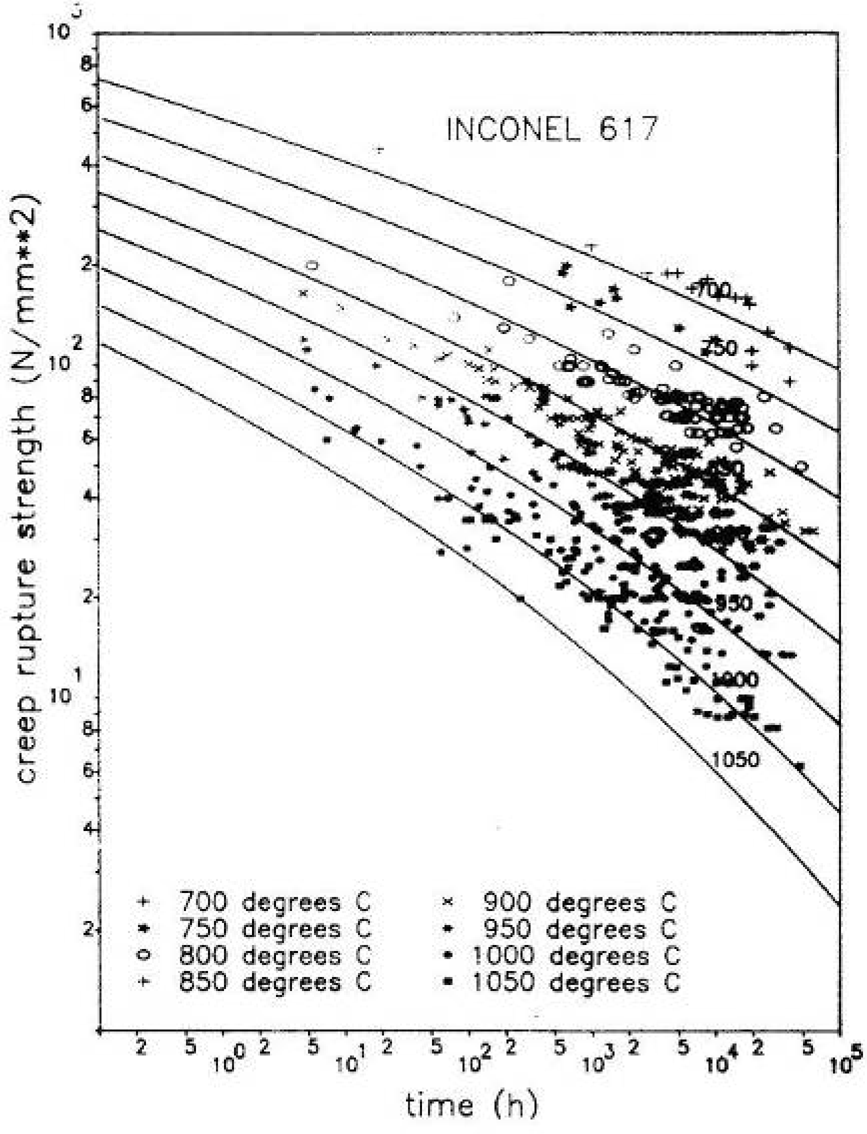
T (°C)	VR	*RP 0.2*	Ag
	(%/min)	*N/mm2*	*%*
750	0.08	235	3.2
	0.08	238	3.4
	0.5	233	8.83
	0.5	227	9.5
	5	226	23.47
	5	222	19.9
950	0.08	100	0.17
	0.08	98	0.15
	0.5	138	0.22
	0.5	139	0.3
	5	224	0.6
	5	*217*	0.55

Effect of strain rate also seen in LCF Tests

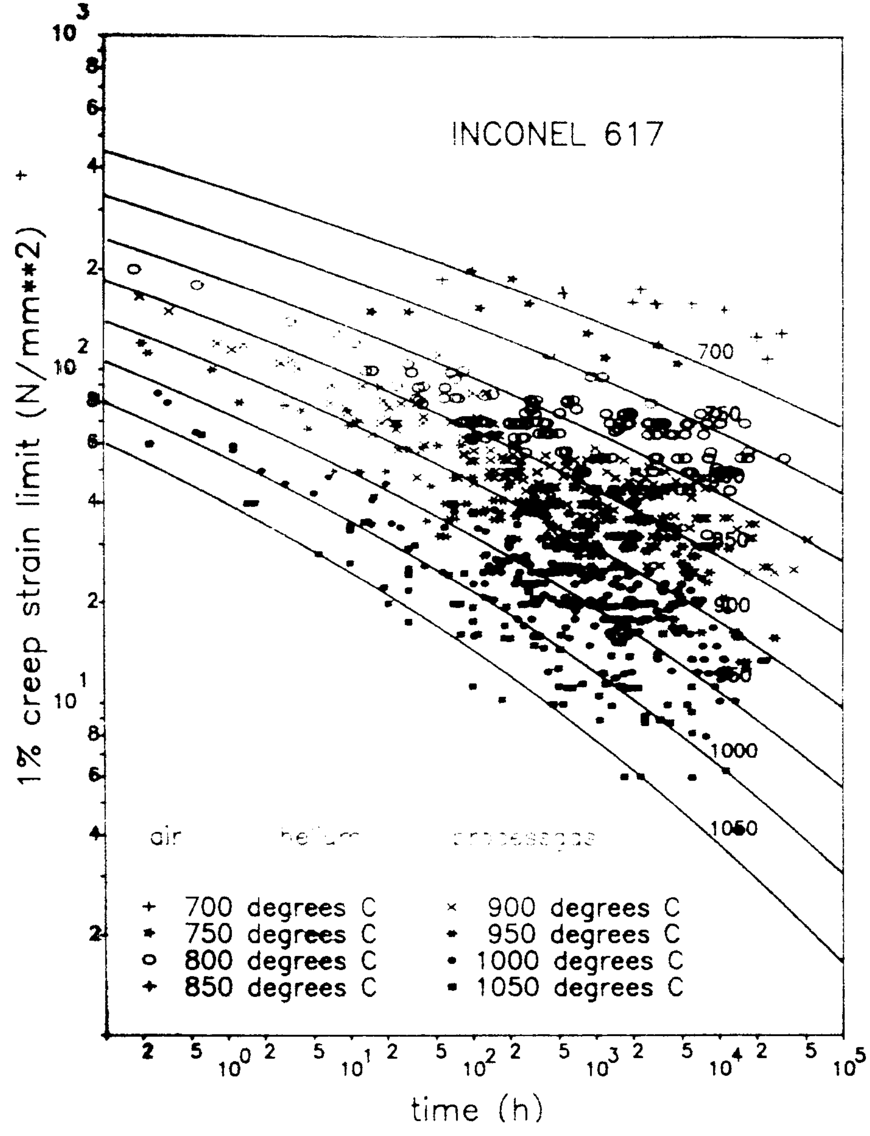
Creep Rupture Data & He/Air Effect



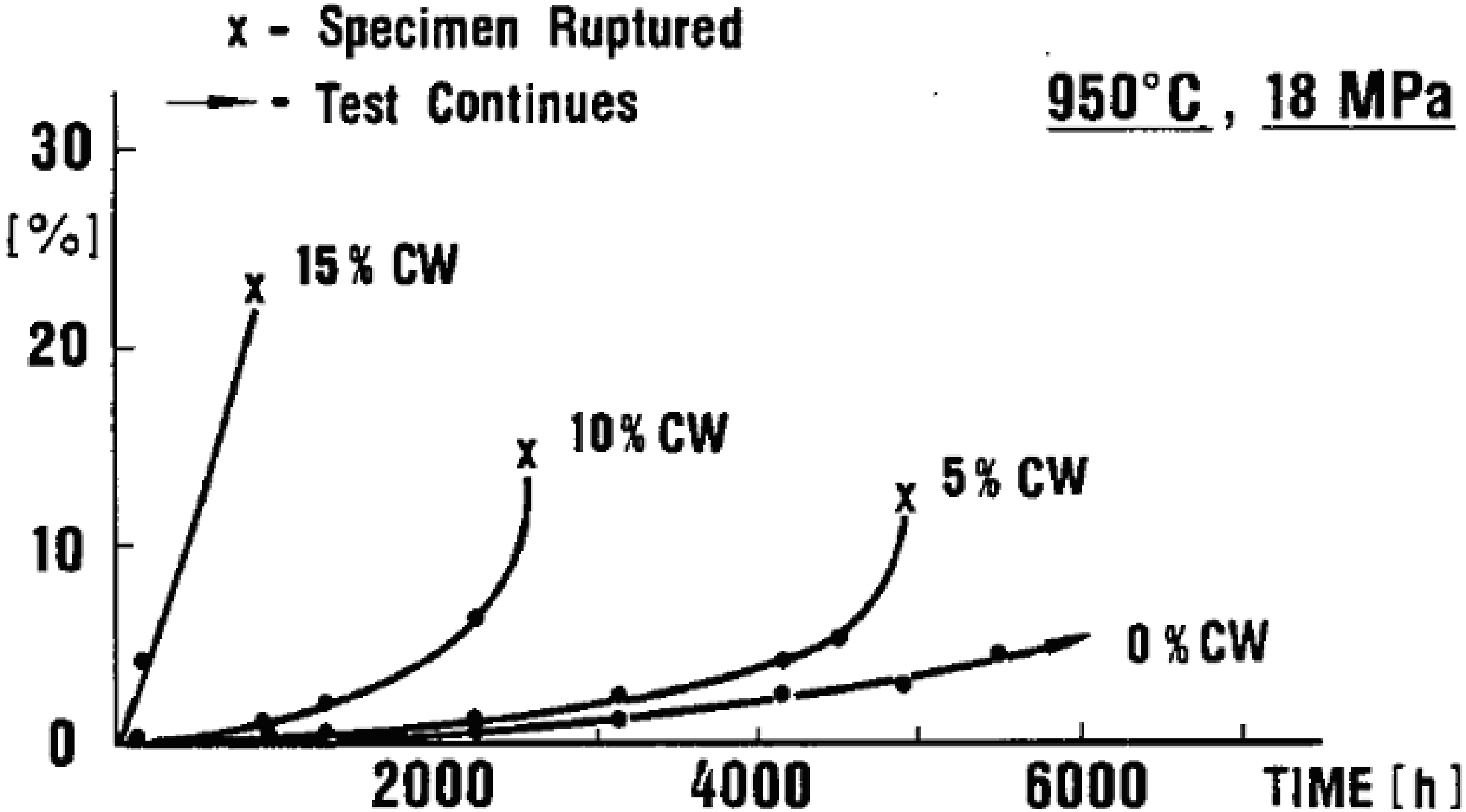
A617:All Creep Rupture Data HTR



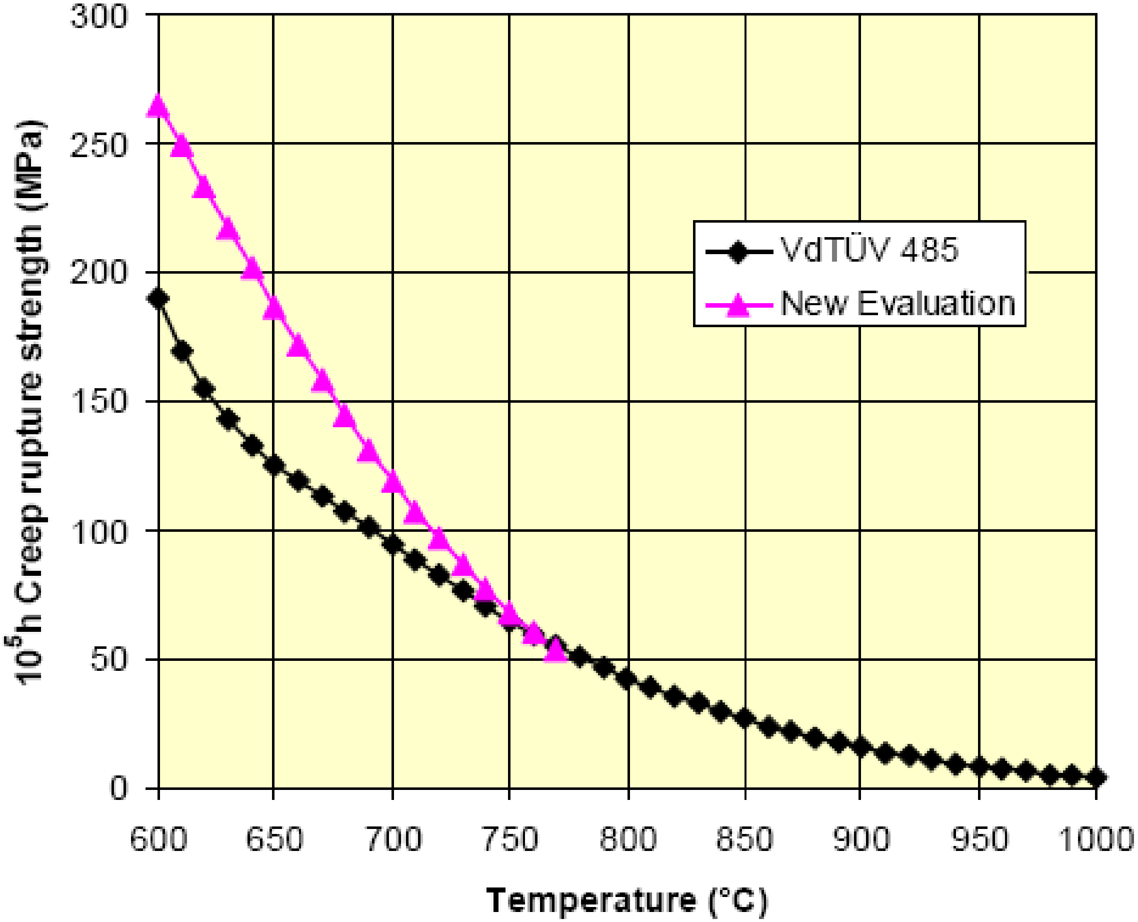
1% Creep Strain Limit: All Data



Coldwork Effect at 950°C



Effect of the New Specification on Creep Rupture Strength >> Alloy Tailoring



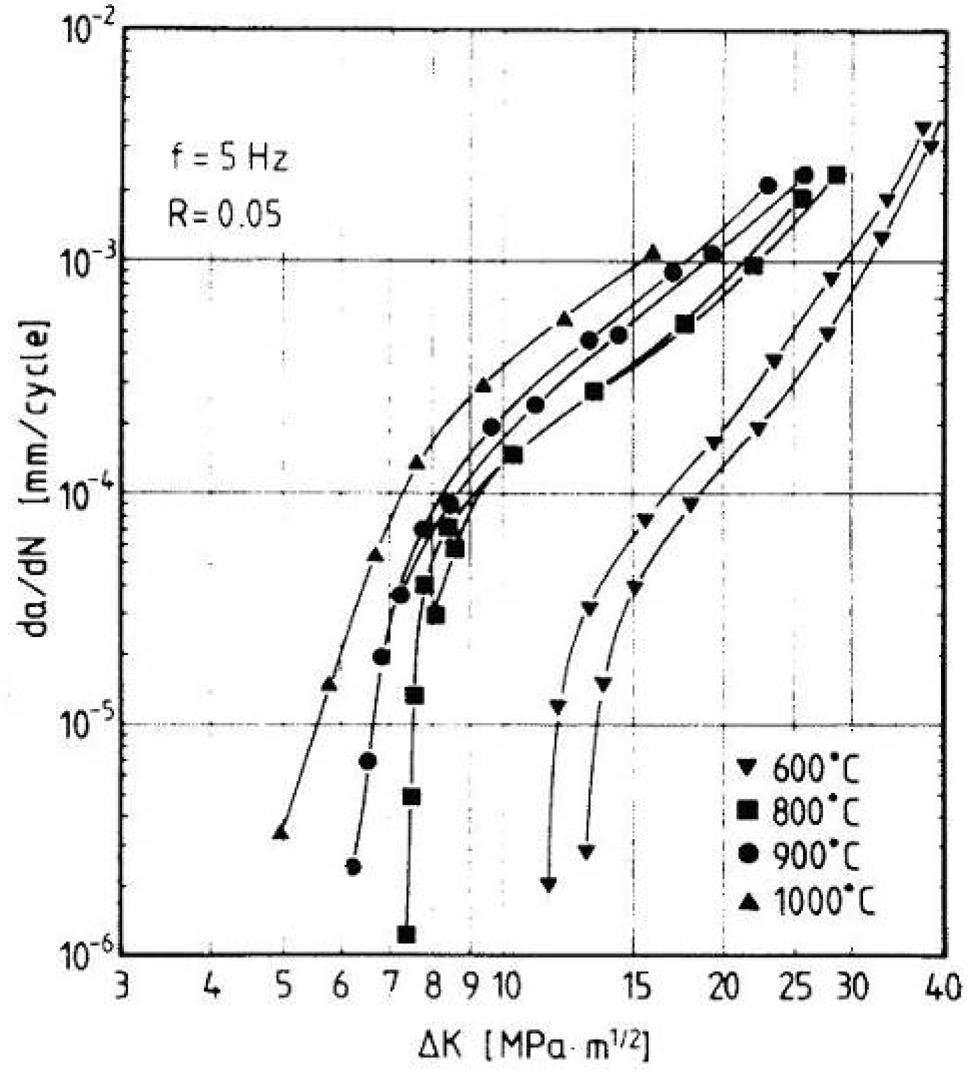
Fitness for purpose

WS A617/Bendik

Other Data Available

- Effect of cold work
- Recrystallization behaviour
- Stress strain curves >> strain rate effect
- Fatigue behaviour >> hold time effect
- Weldment qualification
- Corrosion, etc.
- Data in a Data Base (→ MatDB in Petten)

Fatigue Crack Growth



Weld strength reduction factors

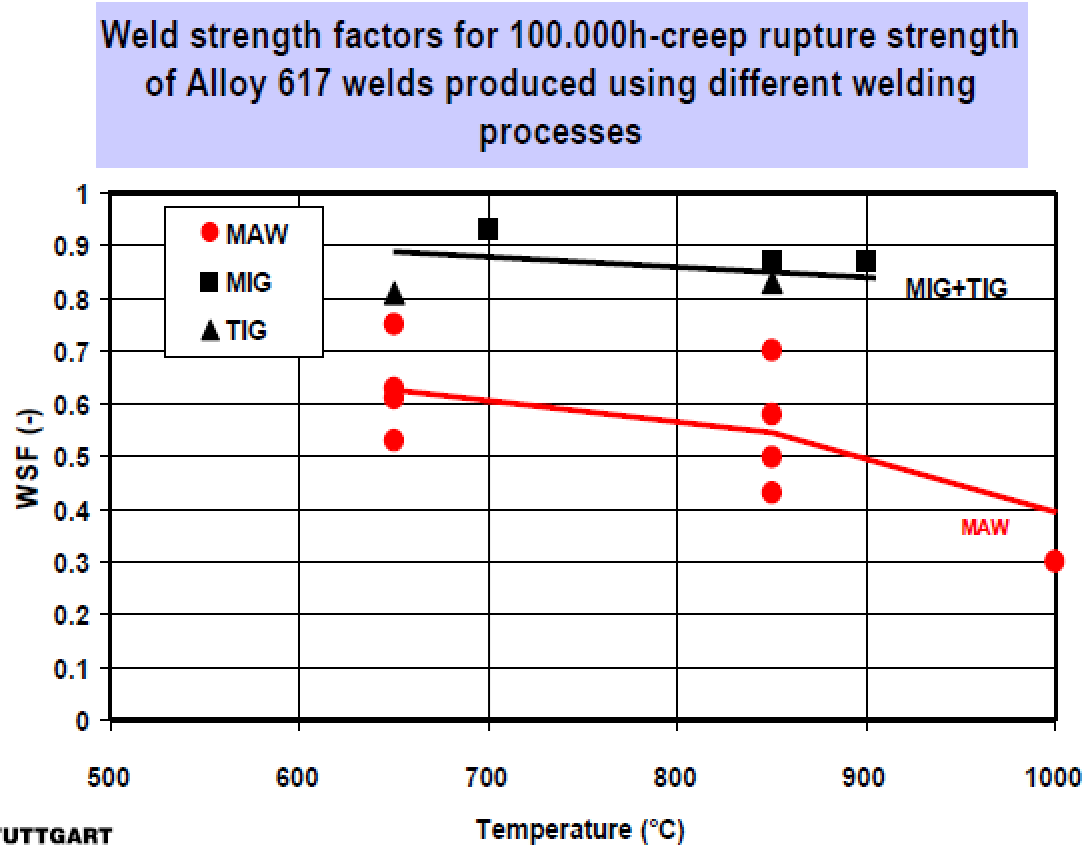
Influence on weld strength reduction

- Welding procedure and weld metal

Significant influences:

weld metal

welding process e.g. due to change in chemical composition of weld metal during welding



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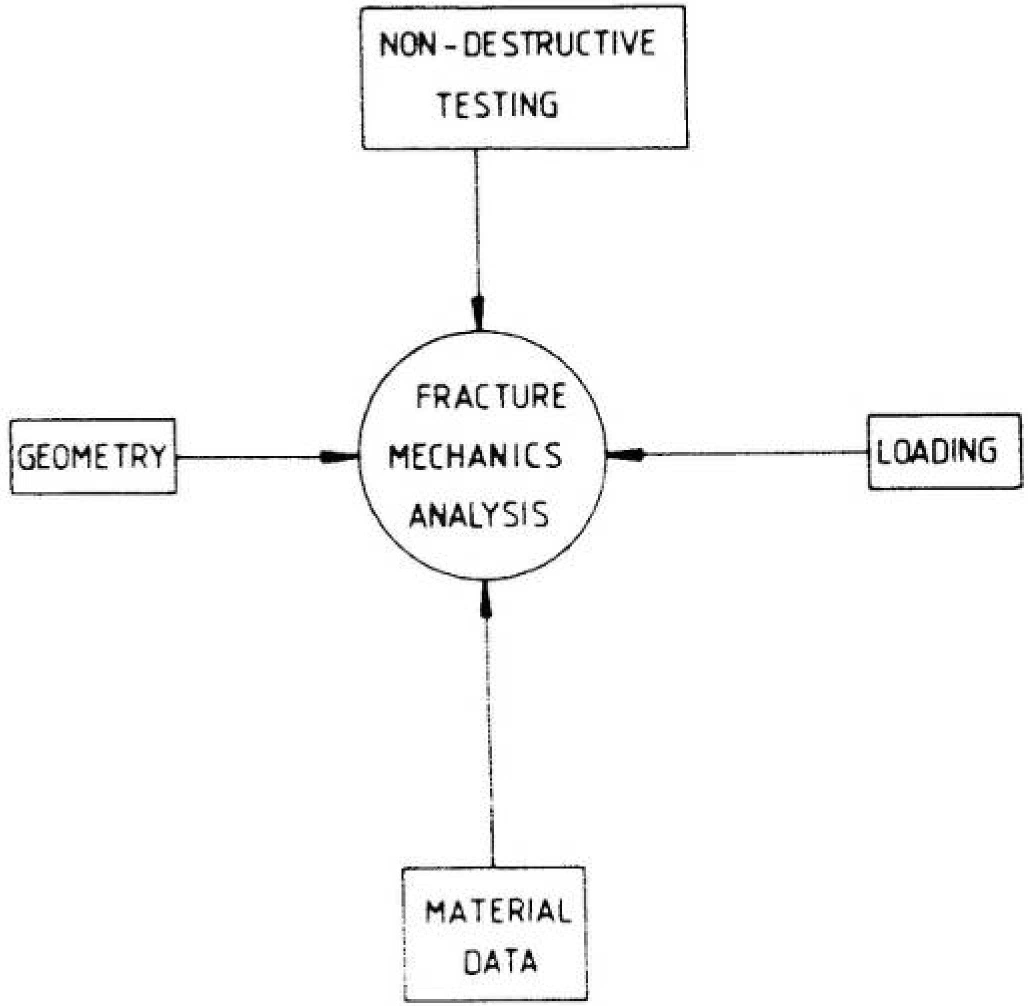
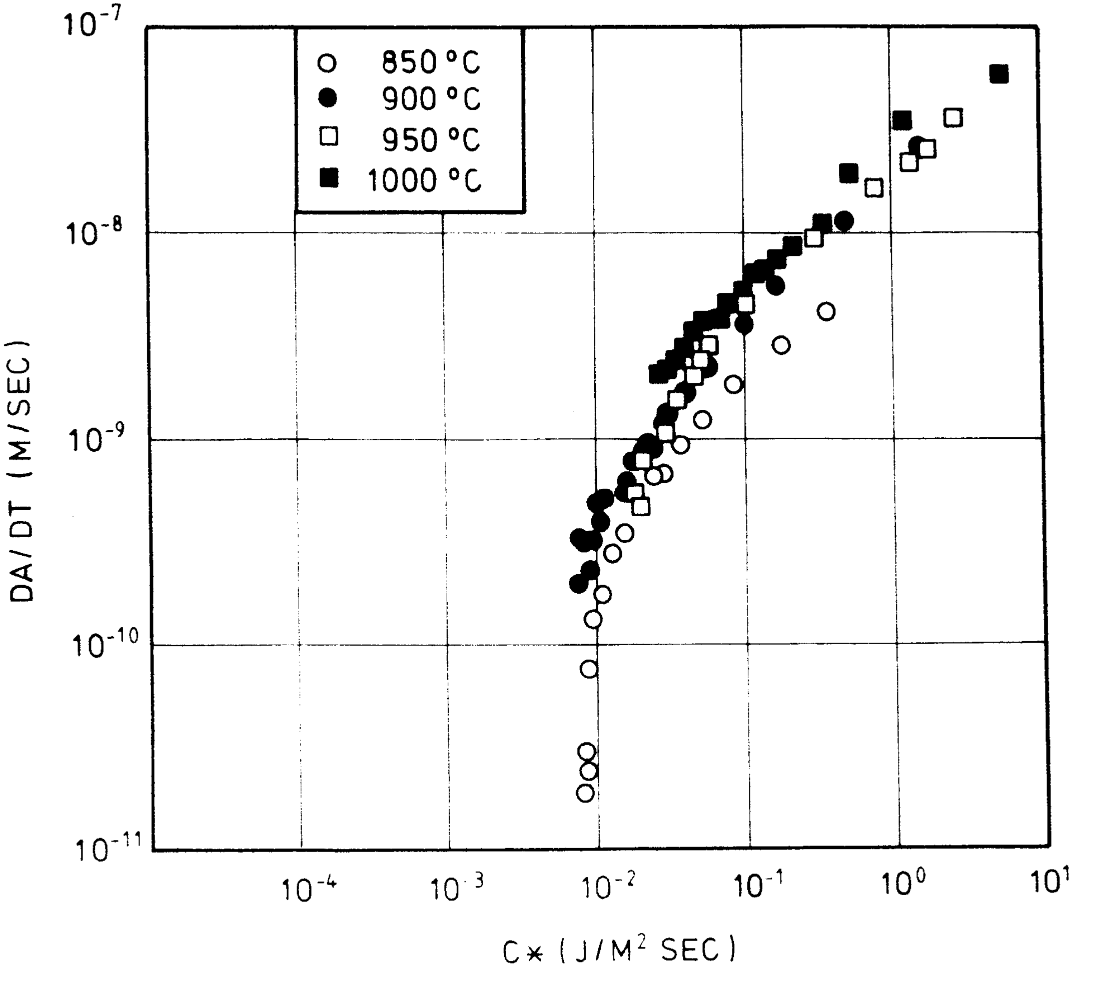
Fracture Mechanic Concept



Creep Crack Growth



Summary and Conclusion /1

- An extensive data base is available from the HTR materials research projects (see e.g. MatDB) :
- → still some open questions for design (LCF, FM)
- Experience in the manufacture of a wide range of product forms provides an excellent knowledge base for the mechanical properties and microstructure of Alloy 617, especially for the temperature range 800 – 1000 °C.
- The applications in other technologies provide a know how for the fabrication of future HTR components

Summary and Conclusion /2

- Since 2005 components for a 700°C Power plant are extensively tested in the European program COMTES700
- Manufacturing of A617 components challenging due to increase of hardness and machining
- Welding of thick-walled A617 components can lead to high residual stresses – PWHT needed
- At 700°C A617 has its minimum of ductility
- Not all the experience of the HTR-program can be transferred to the 700°C power-plant – new material programs are being started