

Ciência para o Desenvolvimento Sustentável



Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2009 Tele Atlas
© 2009 Europa Technologies
© 2009 DMapas
41°03'55.54" S 11°18'34.74" O elev -9569 pés

©2009 Google

Altitude do ponto de visão 7462.67 mi

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Composição da atmosfera (amostra isenta de água), por volume

ppmv: partes por milhão por volume (nota: a fração de volume é igual à fração molar para apenas em gases ideais)

Gás	Volume
Nitrogênio (N ₂)	780.840 ppmv (78,084%)
Oxigênio (O ₂)	209.460 ppmv (20,946%)
Argônio (Ar)	9.340 ppmv (0,9340%)
Dióxido de carbono (CO ₂)	390 ppmv (0,0390%) ^[2]
Neônio (Ne)	18,18 ppmv (0,001818%)
Hélio (He)	5,24 ppmv (0,000524%)
Metano (CH ₄)	1,79 ppmv (0,000179%) ^[3]
Criptônio (Kr)	1,14 ppmv (0,000114%)
Hidrogênio (H ₂)	0,55 ppmv (0,000055%)
Óxido nitroso (N ₂ O)	0,3 ppmv (0,00003%)
Monóxido de carbono (CO)	0,1 ppmv (0,00001%)
Xenônio (Xe)	0,09 ppmv (9x10 ⁻⁶ %)
Ozônio (O ₃)	0,0 a 0,07 ppmv (0% a 7x10 ⁻⁶ %)
Dióxido de nitrogênio (NO ₂)	0,02 ppmv (2x10 ⁻⁶ %)
Iodo (I)	0,01 ppmv (10 ⁻⁶ %)
Amônio (NH ₃)	traços
Gases não incluídos na alta atmosfera (amostra isenta de água):	
Vapor de água (H ₂ O)	~0.40% em toda a atmosfera, normalmente entre 1%-4% na superfície

http://pt.wikipedia.org/wiki/Atmosfera_terrestre

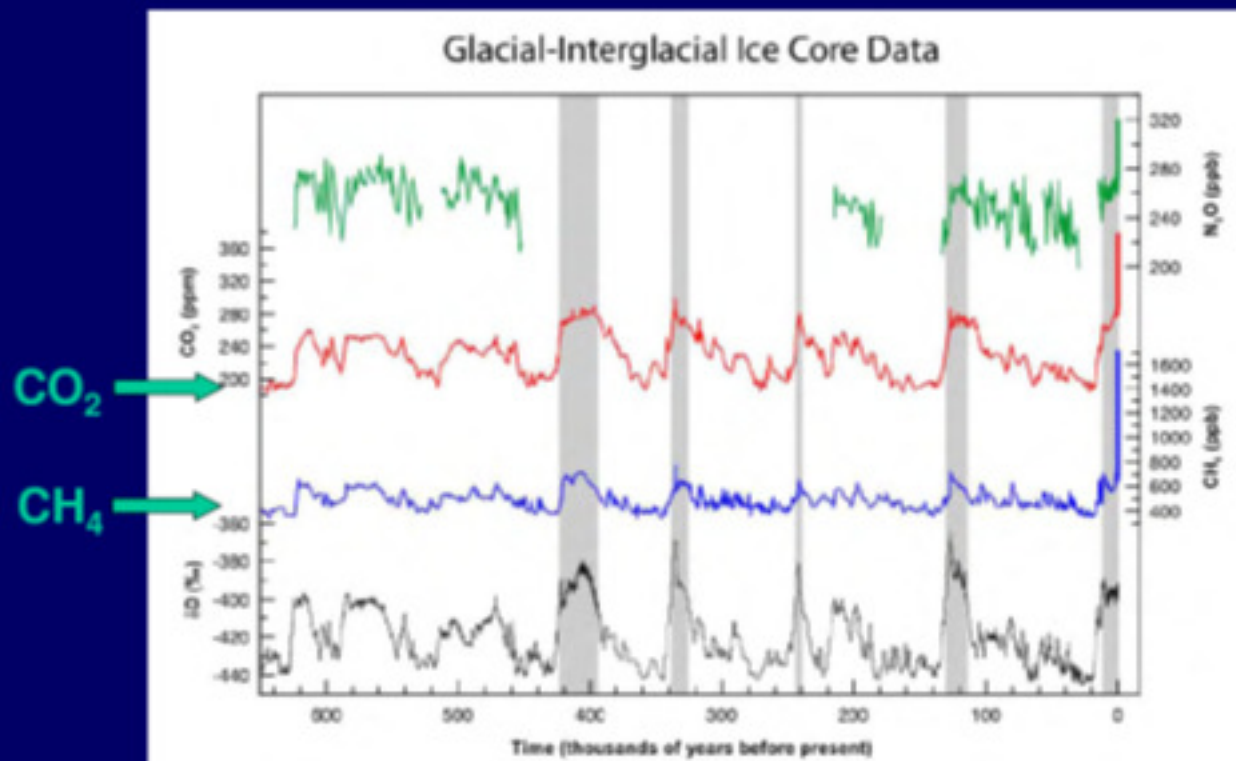
The 21st Century changes

Four distinctive characteristics:

- They are **cumulative**
- The effects are **irreversible**
- Large time lags – **today's actions are tomorrow's problems**
- They are **global**

<http://www.ipcc.ch/pdf/presentations/pre-cop-warsaw-2-10-2008/pres-warsaw-climate%20-botagaj-1.pdf>

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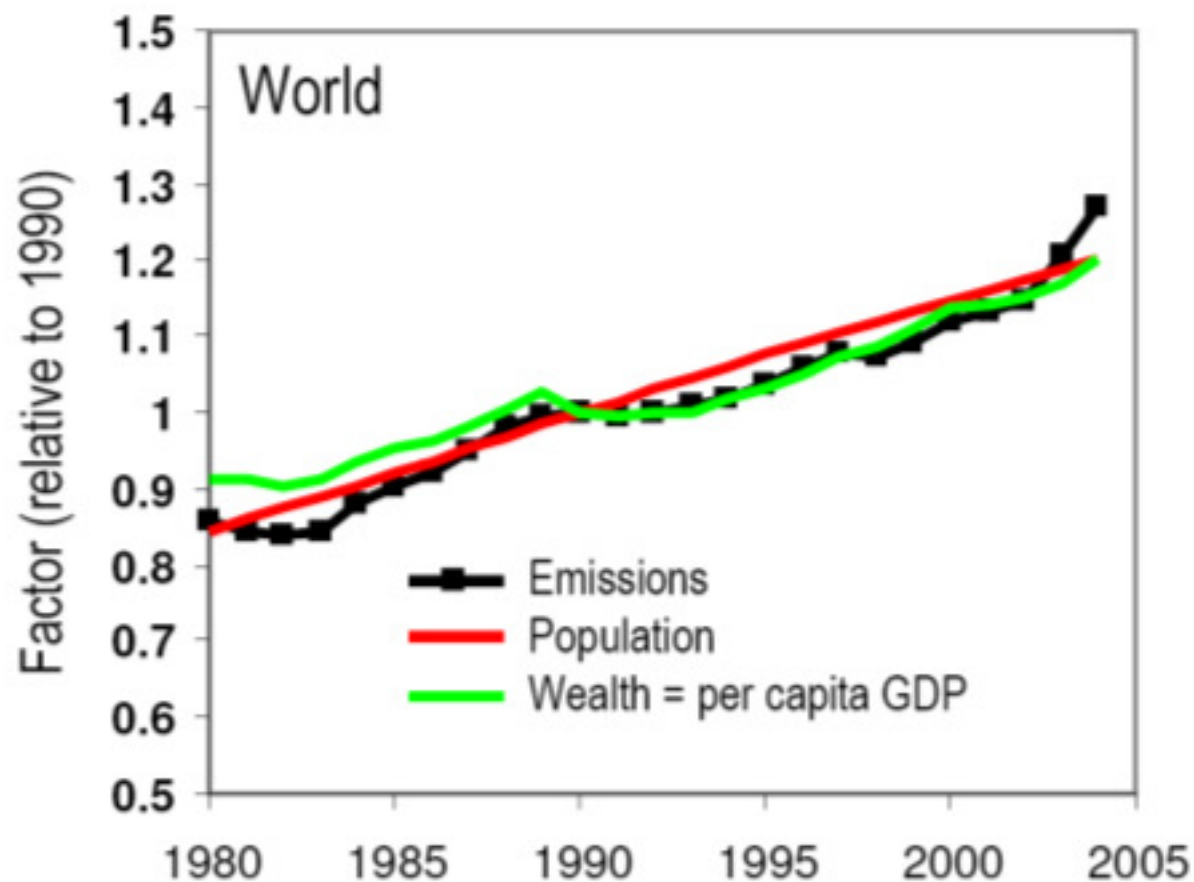


The atmospheric concentration of CO₂ and CH₄ in 2005 exceeds by far the natural range of the last 650,000 years

<http://www.ipcc.ch/pdf/presentations/pre-cop-warsaw-2-10-2008/pres-warsaw-climate%20-botagaj-1.pdf>

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Drivers of Anthropogenic Emissions



<http://www.ipcc.ch/pdf/presentations/pre-cop-warsaw-2-10-2008/pres-warsaw-climate%20botagaj-1.pdf>

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Curiosidades

Variação populacional mundial por dia:

Morrem 150.000

Nascem 211.000

Saldo 61.000 (uma cidade de quase 2 milhões de habitantes por mês)

Fonte: diversas (<http://www.un.org/>), (<http://wikipedia.org/>), etc.

Disponibilidade de água:

Somente 0,007% da água doce disponível é própria para o consumo humano e encontra-se em rios, lagos e pântanos. Estes 0,007% estão ainda divididos da seguinte forma: Agricultura 70%, Indústria 22%, Individual 8% (clubes; hospitais; residências; etc)

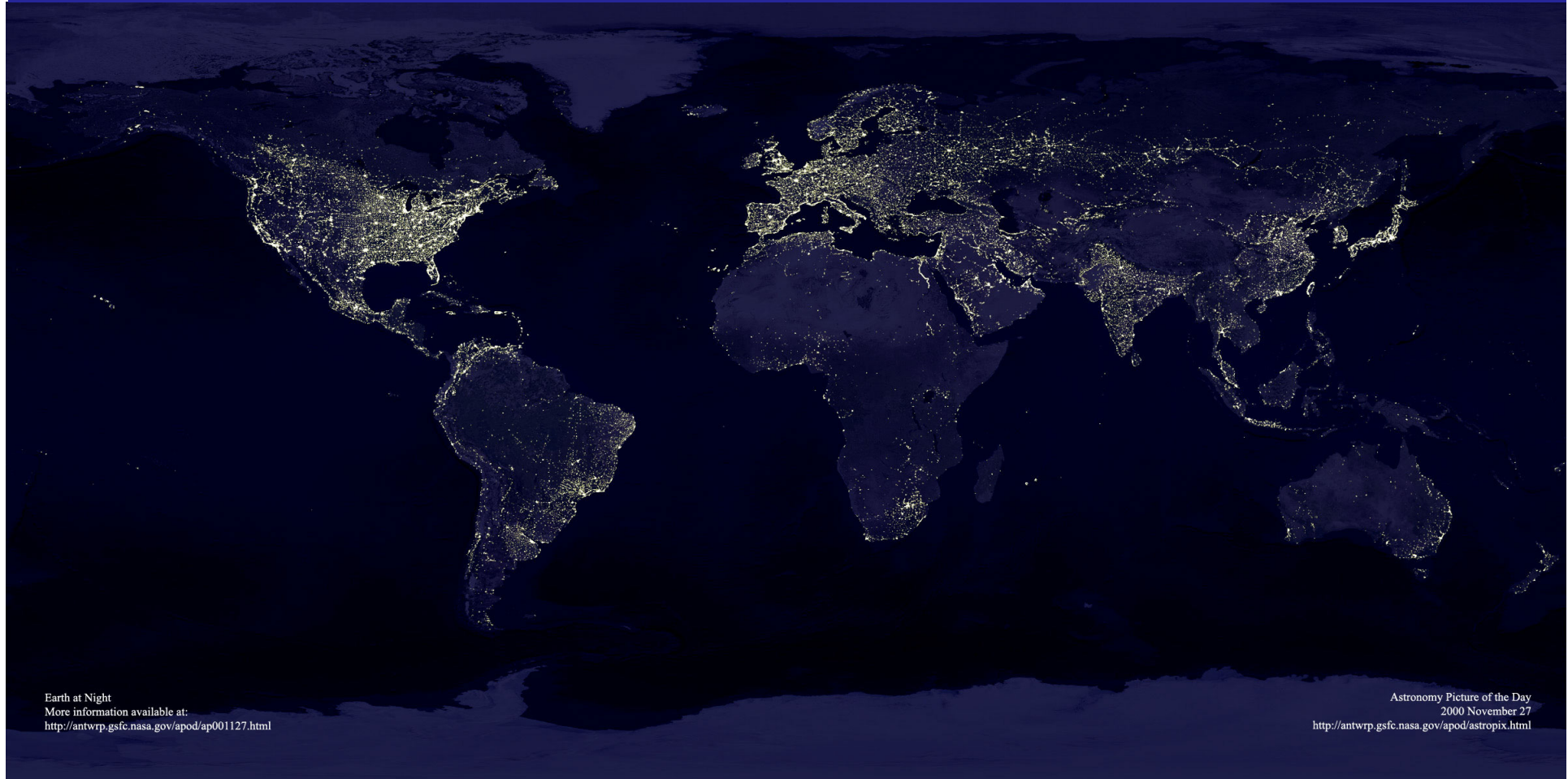
Fonte: http://www.altoqi.com.br/suporte/hydros/duvidas_usuais/Utilizacao/Consumo_agua_uso_racional.htm

Crescimento econômico: ...

Consumo de energia: ...

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Imagem de satélite da terra à noite



Earth at Night
More information available at:
<http://antwrp.gsfc.nasa.gov/apod/ap001127.html>

Astronomy Picture of the Day
2000 November 27
<http://antwrp.gsfc.nasa.gov/apod/astropix.html>

http://apod.nasa.gov/apod/image/0011/earthlights2_dmisp_big.jpg

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Scenario characteristics

(34 scenarios, IPCC/WEC)

	1800	2000	Δf	2050	Δf
Population (billion)	1	6	x6	10	x1.6
GDP (trillion 1990 \$)	0.3	30	x100	85-110	<x3-x4
Primary energy (EJ)	13	420	x30	600-1,040	x1.5-x2.5
CO ₂ emissions (GtC)	0.3	6.4	x20	5-15	<x1-x3
Mobility (km/person/day)	0.04	40	x1,000	120-160	x3-x4

<http://www.ipcc.ch/pdf/presentations/pre-cop-warsaw-2-10-2008/pres-warsaw-climate%20-botagaj-1.pdf>

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Muir Glacier, Alaska, August 13, 1941, photo by W.O. Field



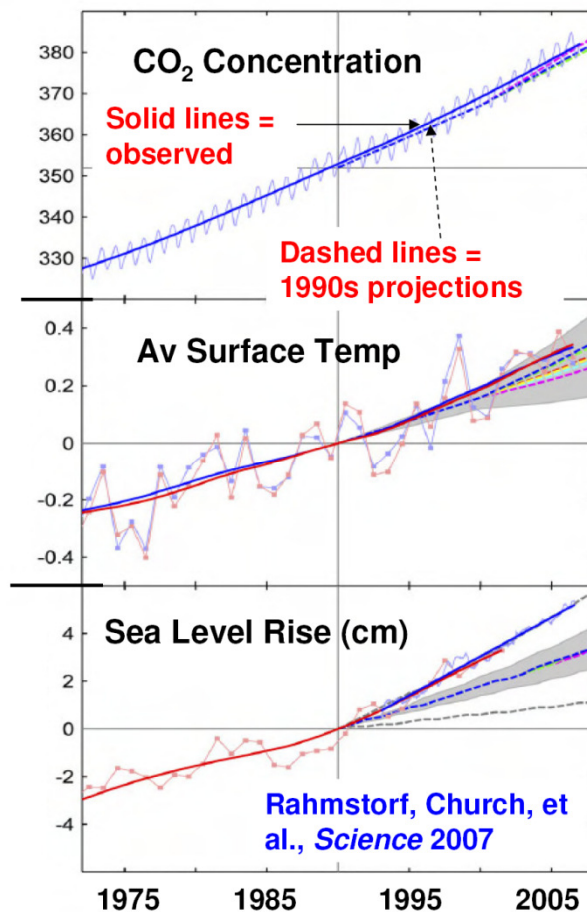
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<http://www.ipcc.ch/pdf/presentations/pre-cop-warsaw-2-10-2008/pres-warsaw-climate%20-botagaj-1.pdf>

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Climate Change: Faster than expected in 1990s

IPCC 4 (2007) was limited to science published by early 2006

Subsequent research shows increasing rates of:

Global GHG emissions

3.3% p.a. in 2000s, vs 1.3% p.a. in 1990s

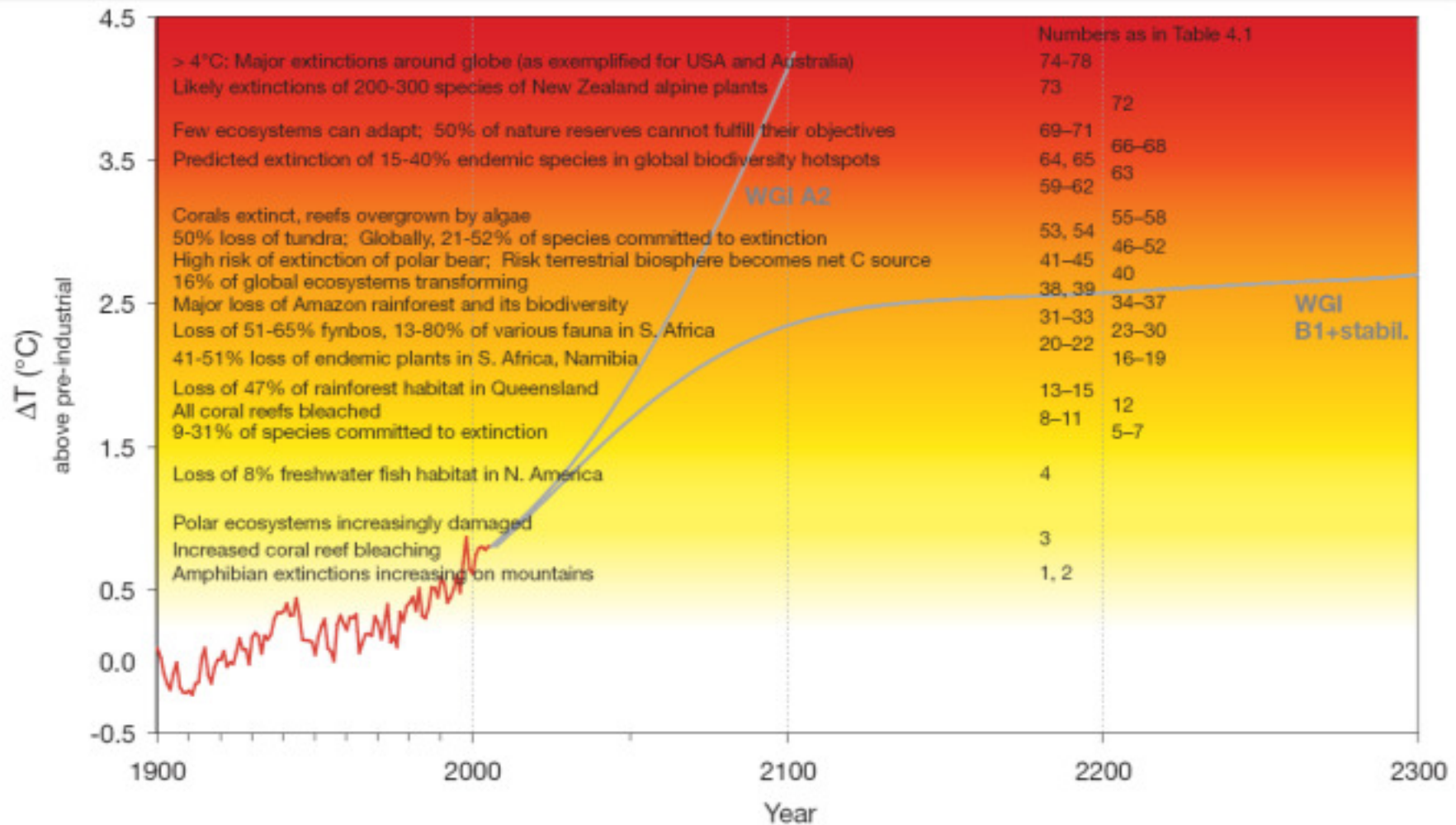
Temperature rise

especially in polar regions

Ice melt (Arctic: 40% loss since 1980, accelerating 2006-07)

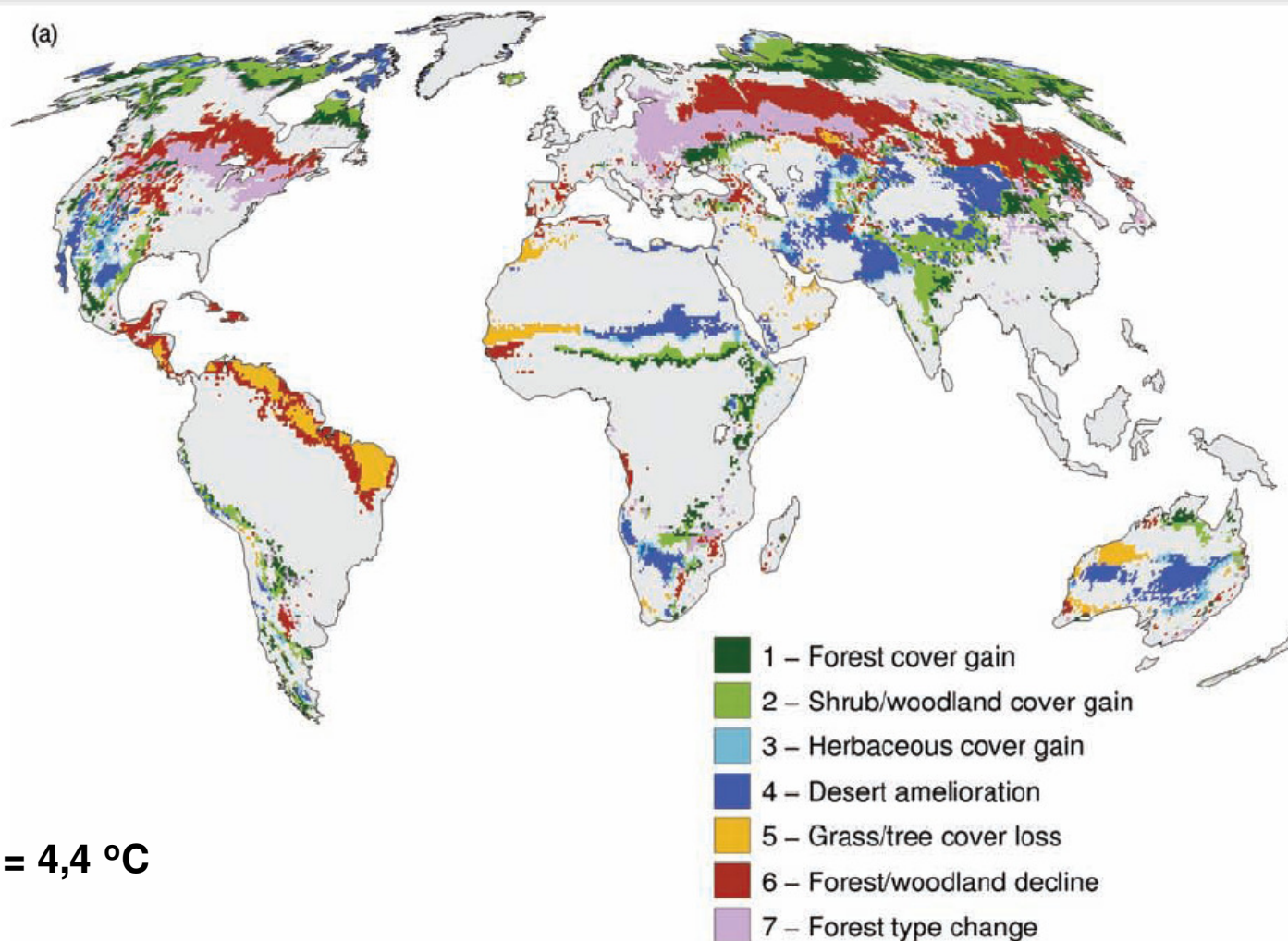
<http://www.ipcc.ch/pdf/presentations/pre-cop-warsaw-2-10-2008/pres-warsaw-climate%20-botagaj-1.pdf>

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<http://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4-wg2-chapter4.pdf>

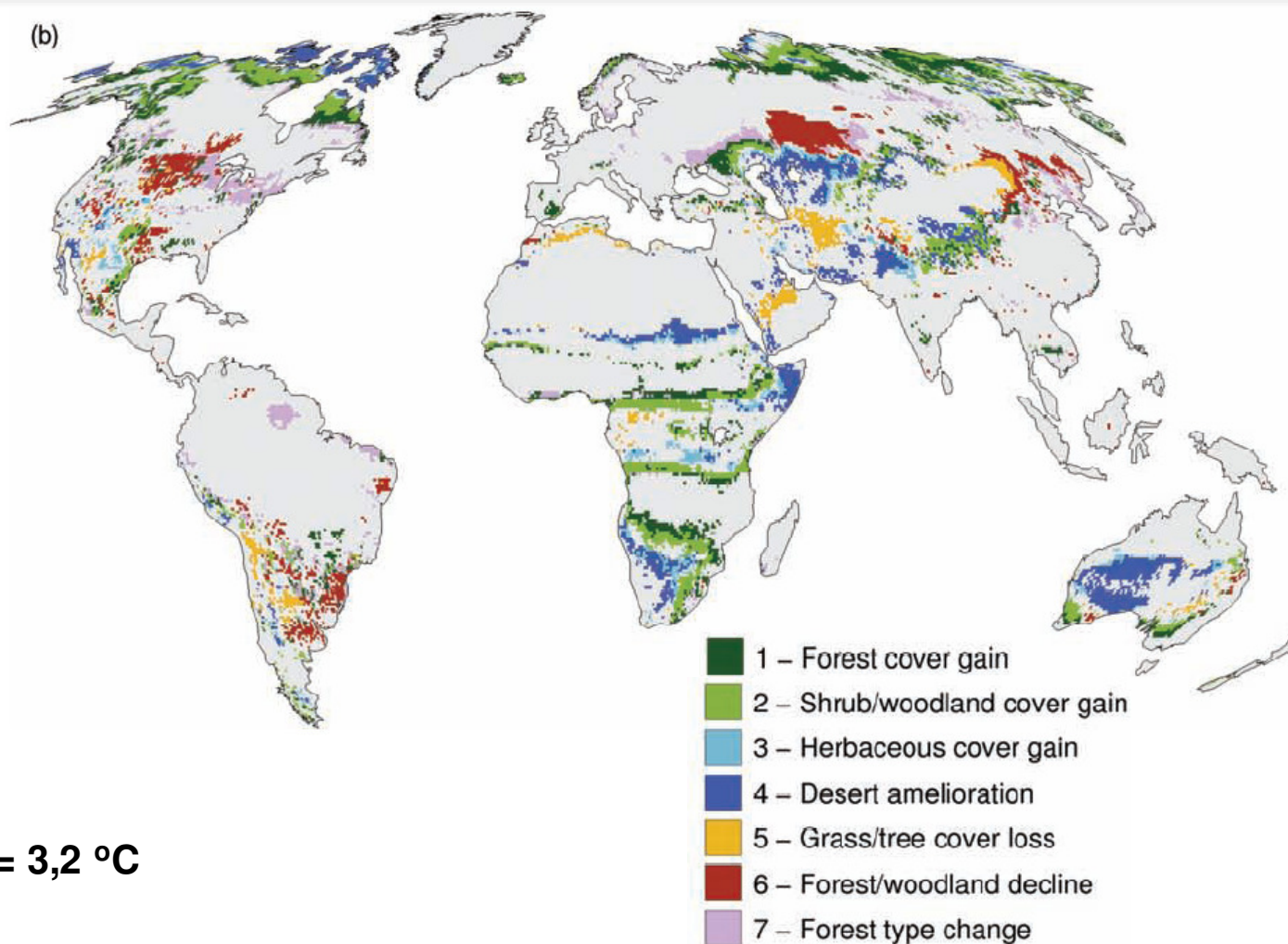
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$\Delta T_{2100} = 4,4 \text{ }^{\circ}\text{C}$

<http://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4-wg2-chapter4.pdf>

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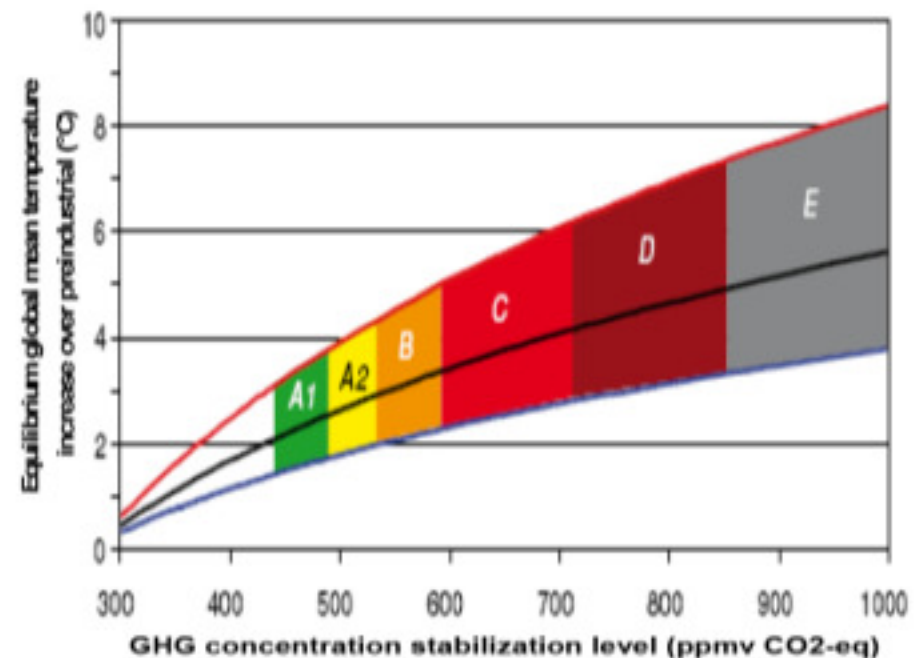
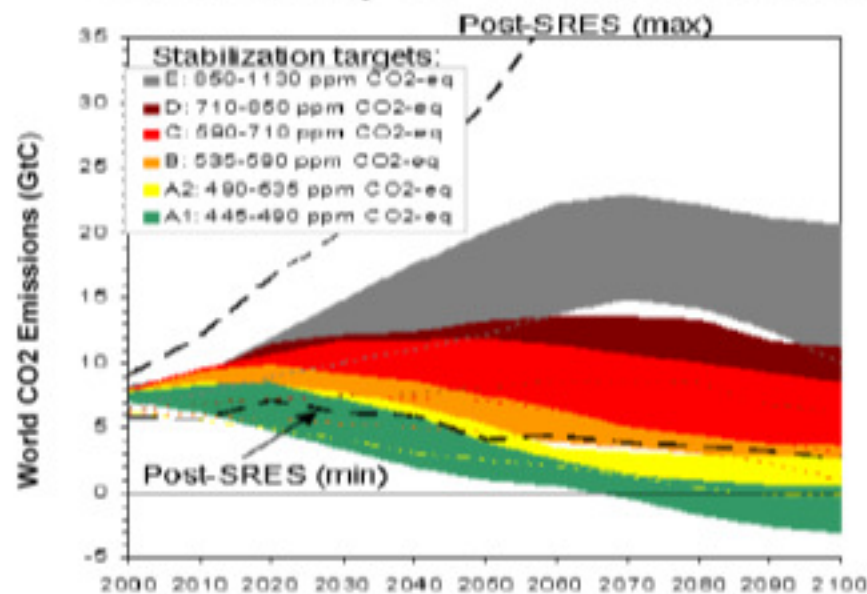


$\Delta T_{2100} = 3,2 \text{ }^{\circ}\text{C}$

<http://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4-wg2-chapter4.pdf>

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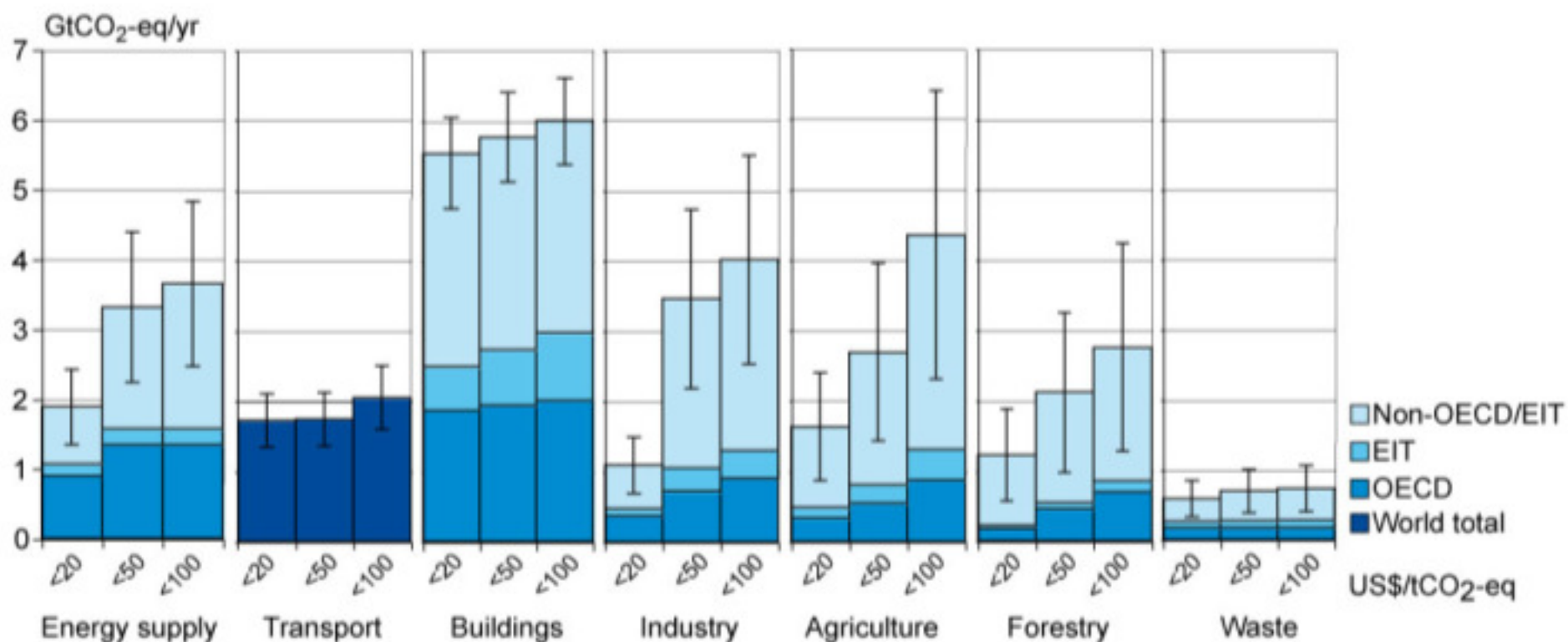
- Equilibrium temperatures reached after 2100
- Uncertainty of climate sensitivity important



<http://www.ipcc.ch/pdf/presentations/poznan-COP-14/ottmar-edenhofer.pdf>

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todos os setores e regiões têm potencial para contribuir

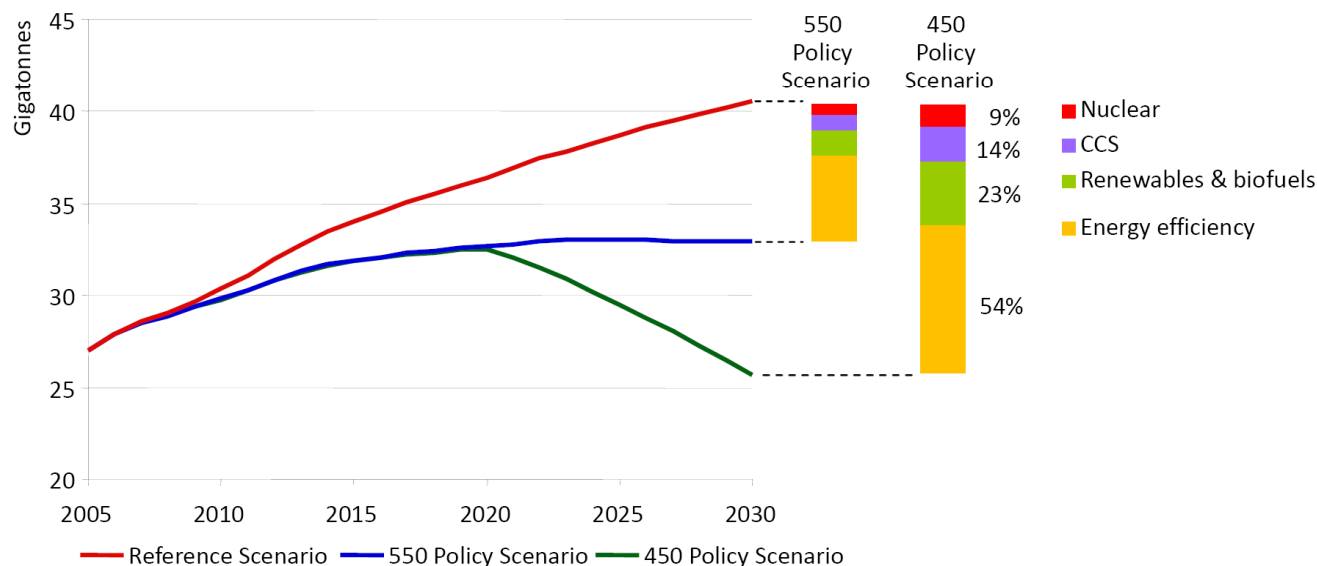


<http://www.ipcc.ch/pdf/presentations/poznan-COP-14/ottmar-edenhofer.pdf>

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Reductions in energy-related CO₂ emissions in the climate-policy scenarios



While technological progress is needed to achieve some emissions reductions, efficiency gains and deployment of existing low-carbon energy accounts for most of the savings

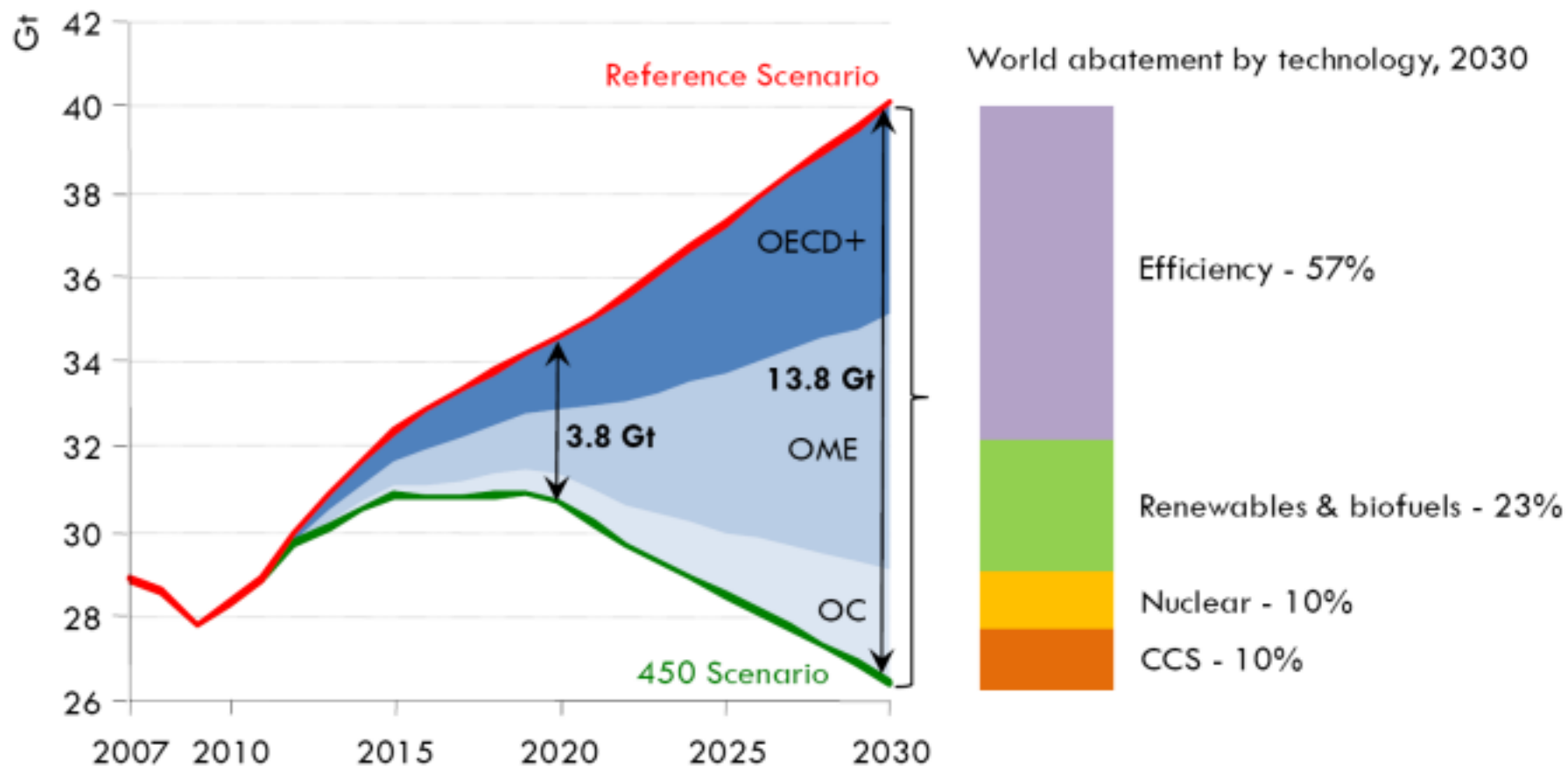
Slide 4

INTERNATIONAL ENERGY AGENCY

AGENCE INTERNATIONALE DE L'ENERGIE

http://www.iea.org/speech/2009/Tanaka/Tanaka_MEE.T.pdf

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http://www.iea.org/speech/2009/Birol_WEO2009_Rome.pdf

Materiais para aplicação em altas temperaturas: Turbinas aeronáuticas e para geração de energia

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GRUPO PHASE – Grupo de Diagrama de Fases e Termodinâmica Computacional

- **Membros do grupo:**
Prof. Gilberto Carvalho Coelho
Prof. Carlos Angelo Nunes
Prof. Paulo Atsushi Suzuki
- **Temas de pesquisa:**
Termodinâmica experimental (diagramas de fases)
Termodinâmica computacional (bases de dados)
Materiais para aplicação em altas temperaturas

ROTEIRO

- **Introdução**
- **Tipos de turbinas**
- **Superligas de níquel**
- **Novos materiais**
- **Conclusão**

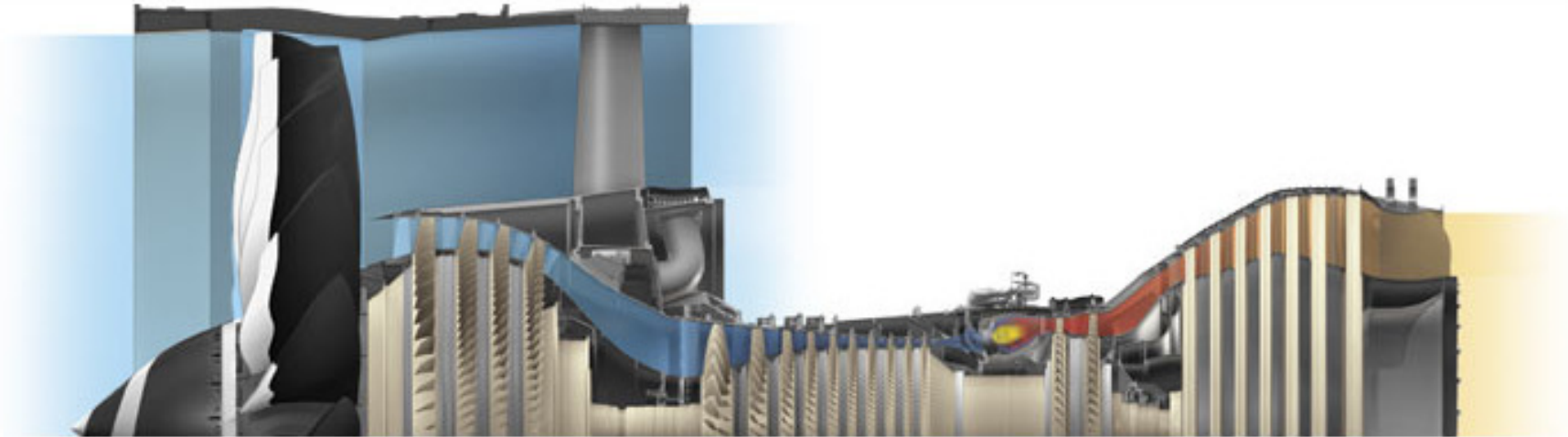
Tipos de Turbinas

Boeing 787 Dreamliner™



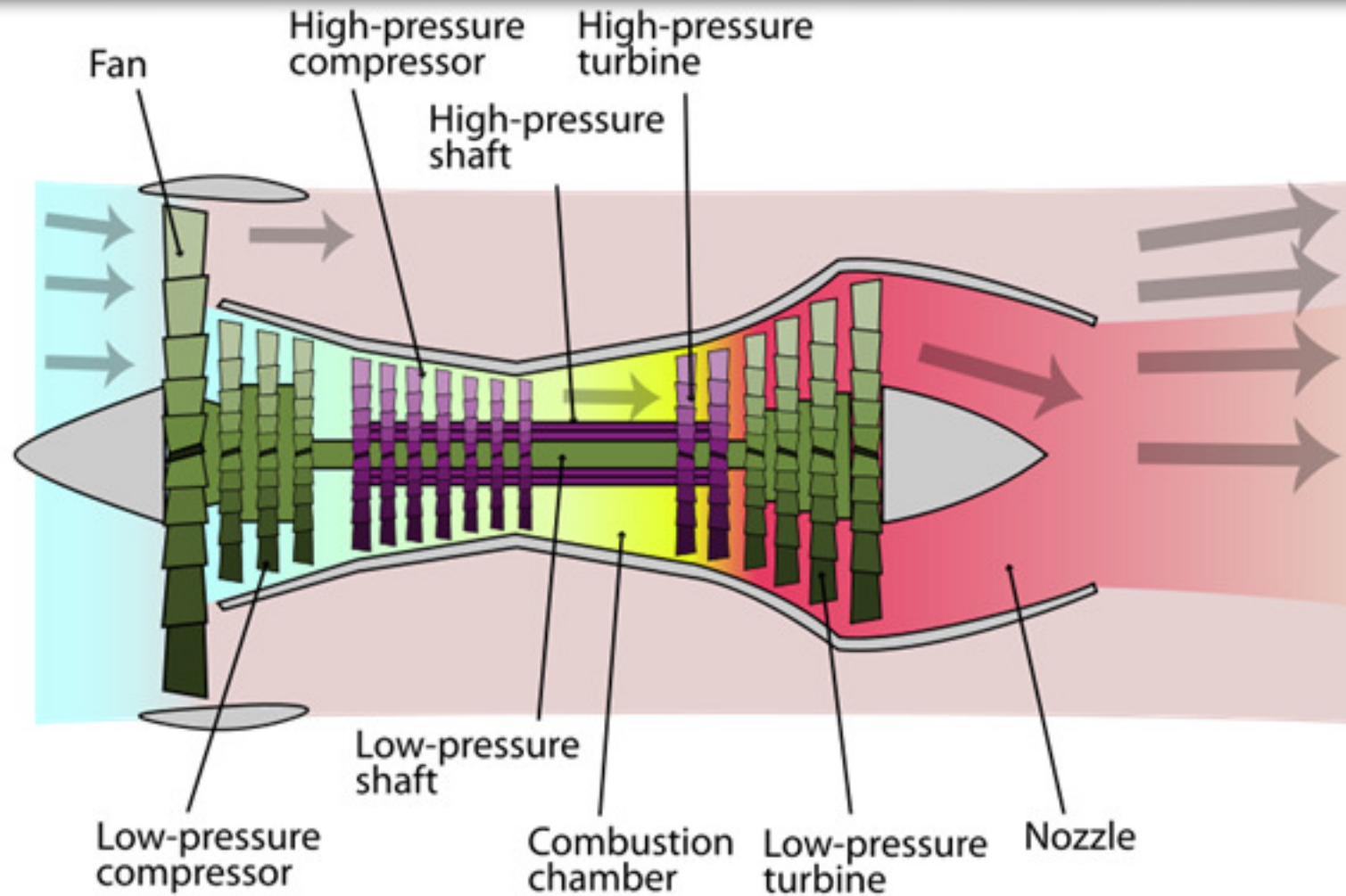
<http://www.geae.com/engines/commercial/genx/index.html>

Tipos de Turbinas



<http://www.geae.com/engines/commercial/genx/index.html>

Tipos de Turbinas

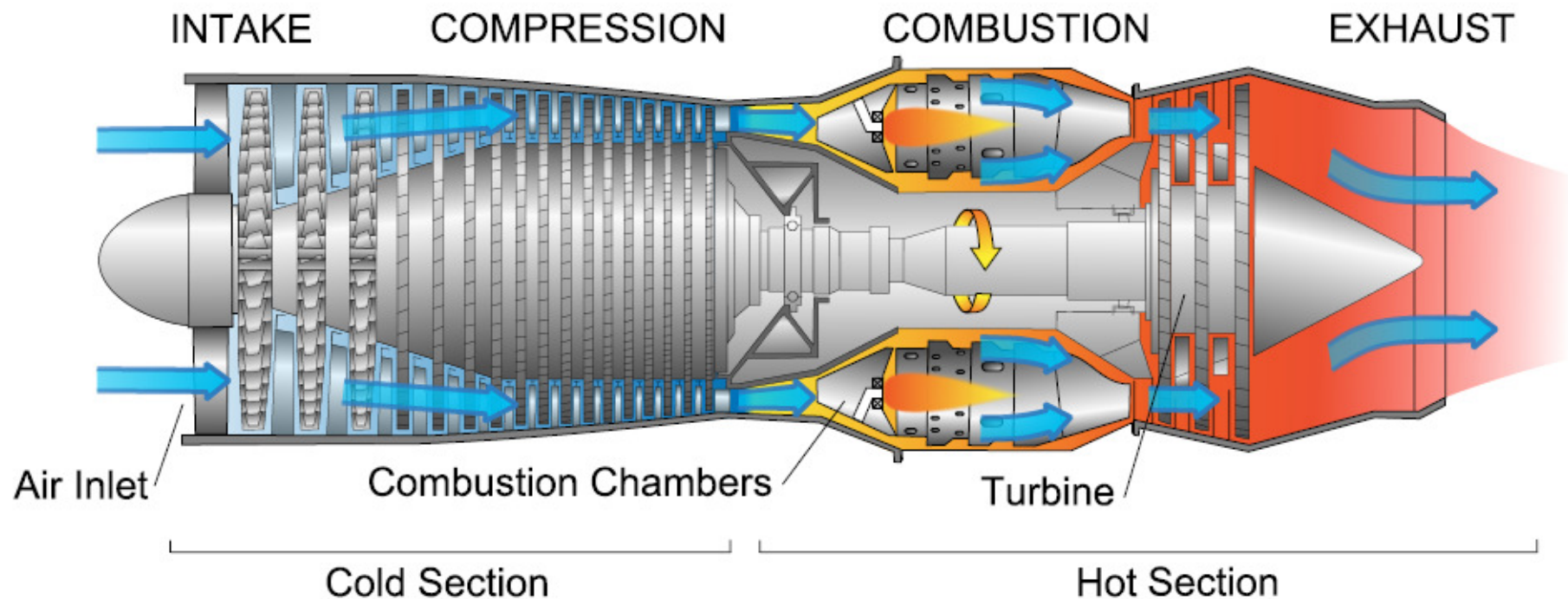


<http://en.wikipedia.org/wiki/Turbofan>

Tipos de Turbinas

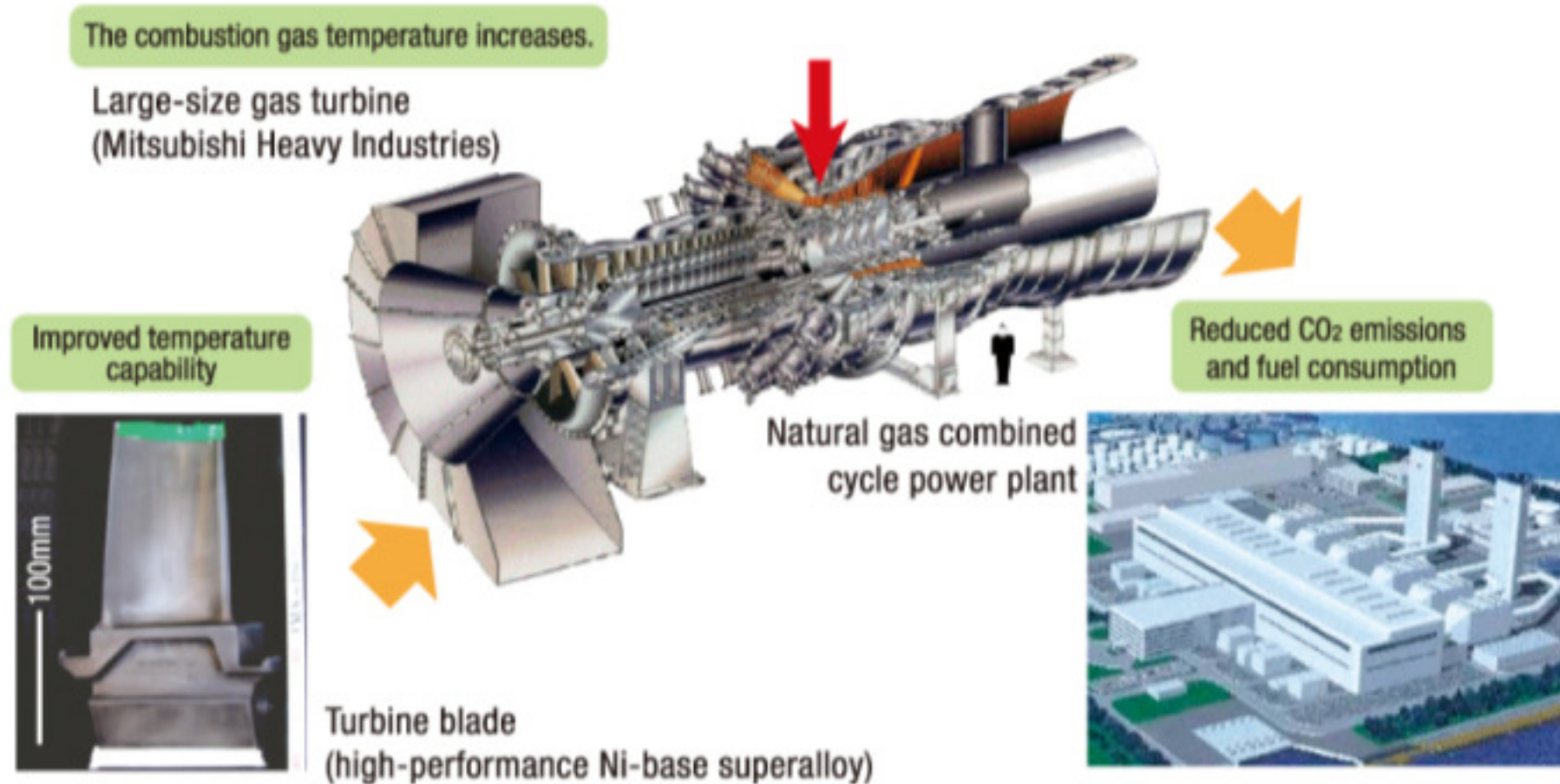


Tipos de Turbinas



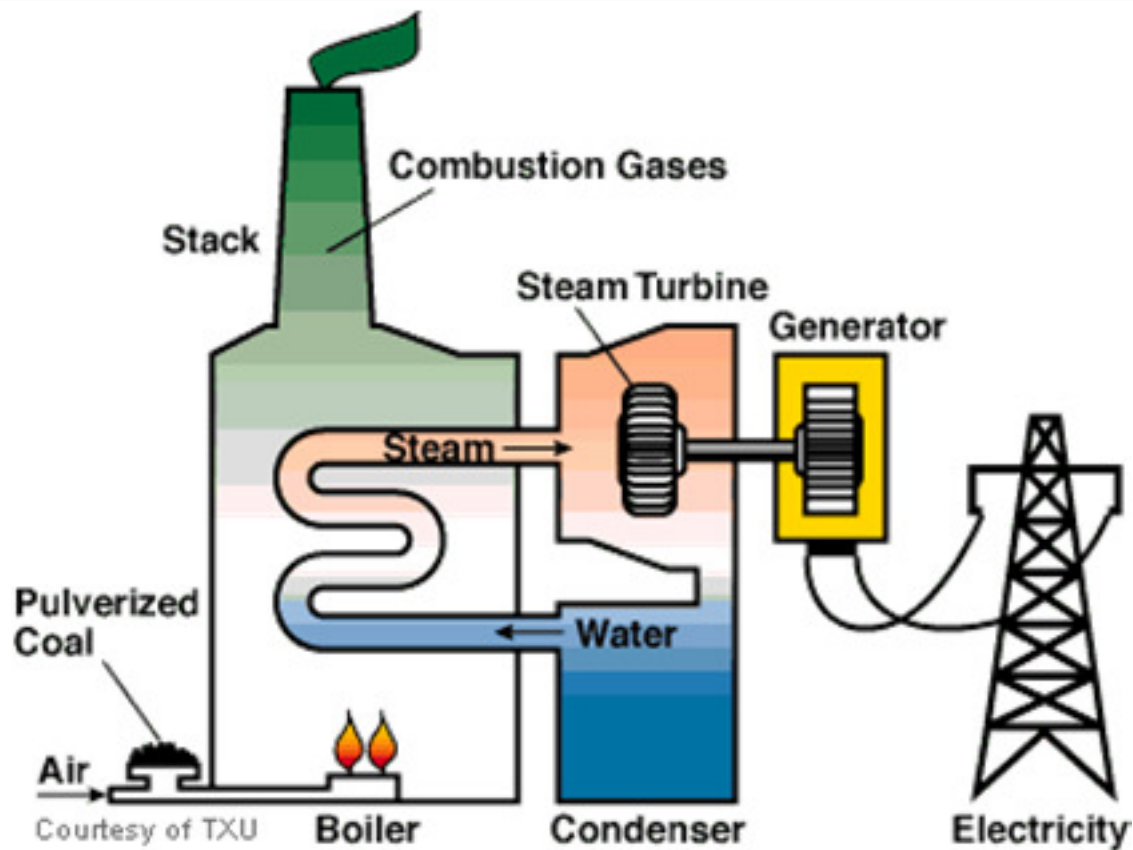
http://en.wikipedia.org/wiki/Gas_turbine

Tipos de Turbinas



H. Harada, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 604-614, 2010

Tipos de Turbinas



Cerca de 80% da energia elétrica no mundo é gerada usando turbinas a vapor

Propriedades dos materiais – aplicações em altas temperaturas

Requirement in design and service	Material property
Static strength	Tensile strength (UTS) 0.2 Yield Strength (0.2YS)
Long-term strength	Creep Rupture Strength (CRS) Creep elongation limits (CEL)
Toughness - short-term - long-term	Fracture toughness (K_{IC}) Creep rupture elongation Toughness values after long-term aging
Fatigue strength	Low Cycle Fatigue (LCF) High Cycle Fatigue (HCF) Creep Fatigue Interaction (CFI)
Crack tolerance	Static: Creep Crack Growth behaviour (CCG) Alternating: Fatigue Crack Growth (FCG)
Oxidation resistance	Steam oxidation behaviour
Erosion resistance	Erosion behaviour

H. Tschaffon, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 20-28, 2010

Turbinas a vapor – tendências das condições de operação

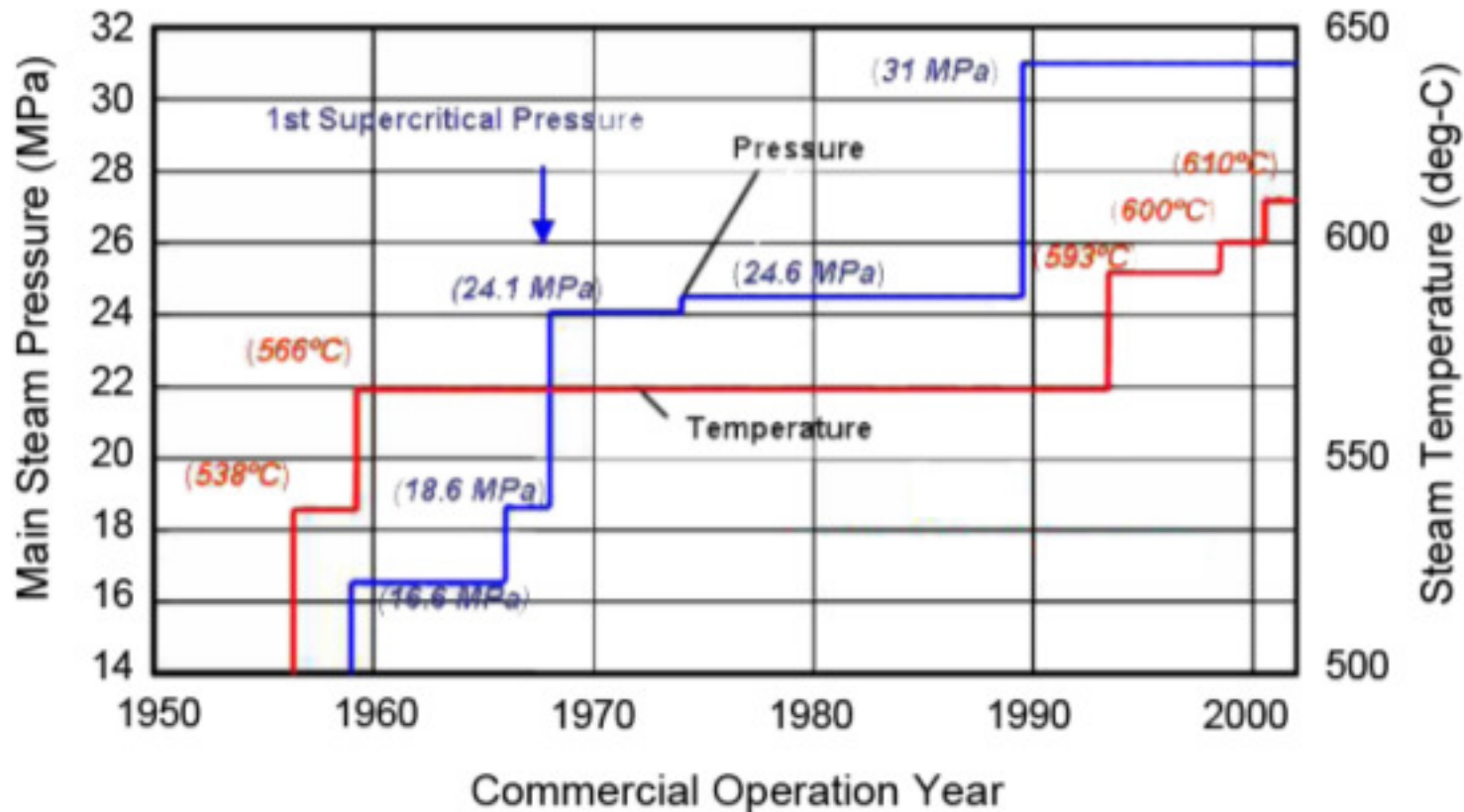


Figure 1 Trend of steam conditions in Japan

M. Fukuda, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 5-19, 2010

Turbinas a vapor – tendências das condições de operação

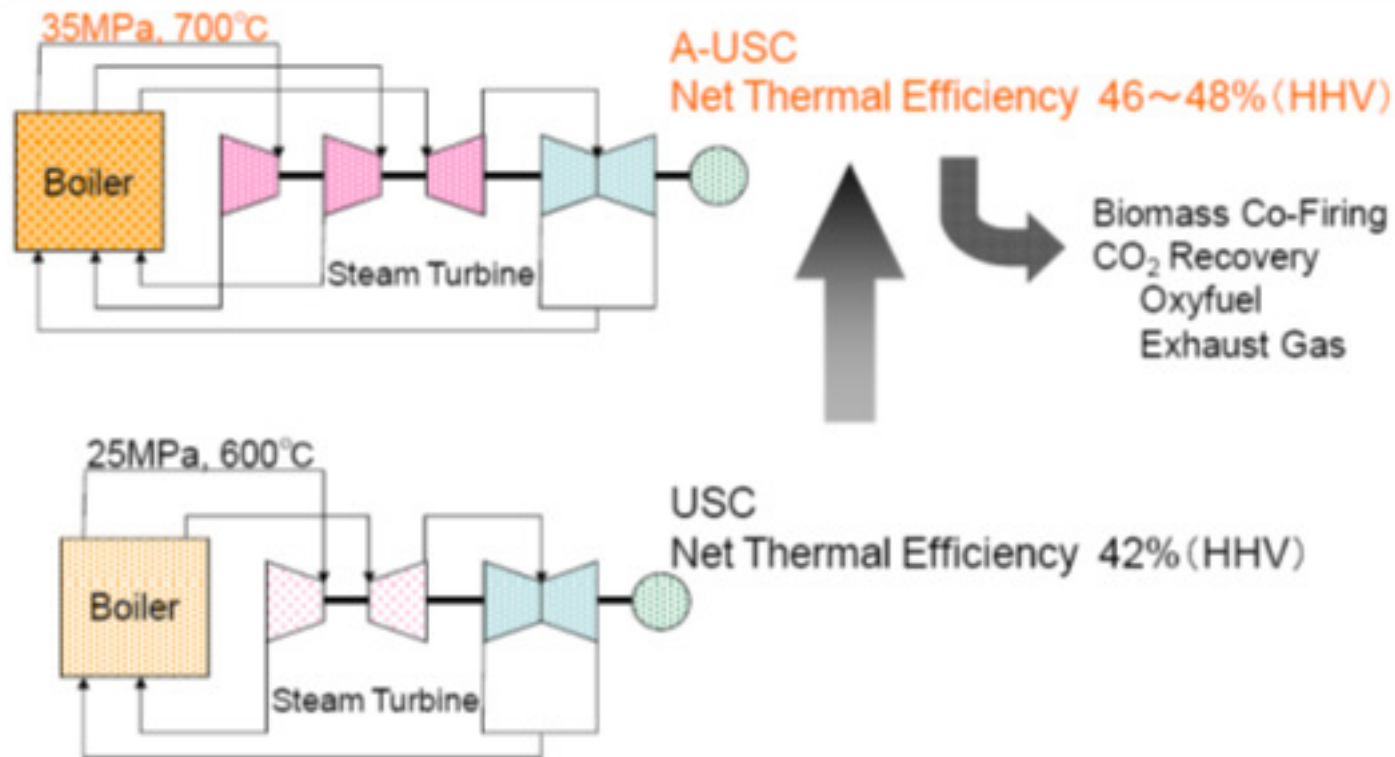
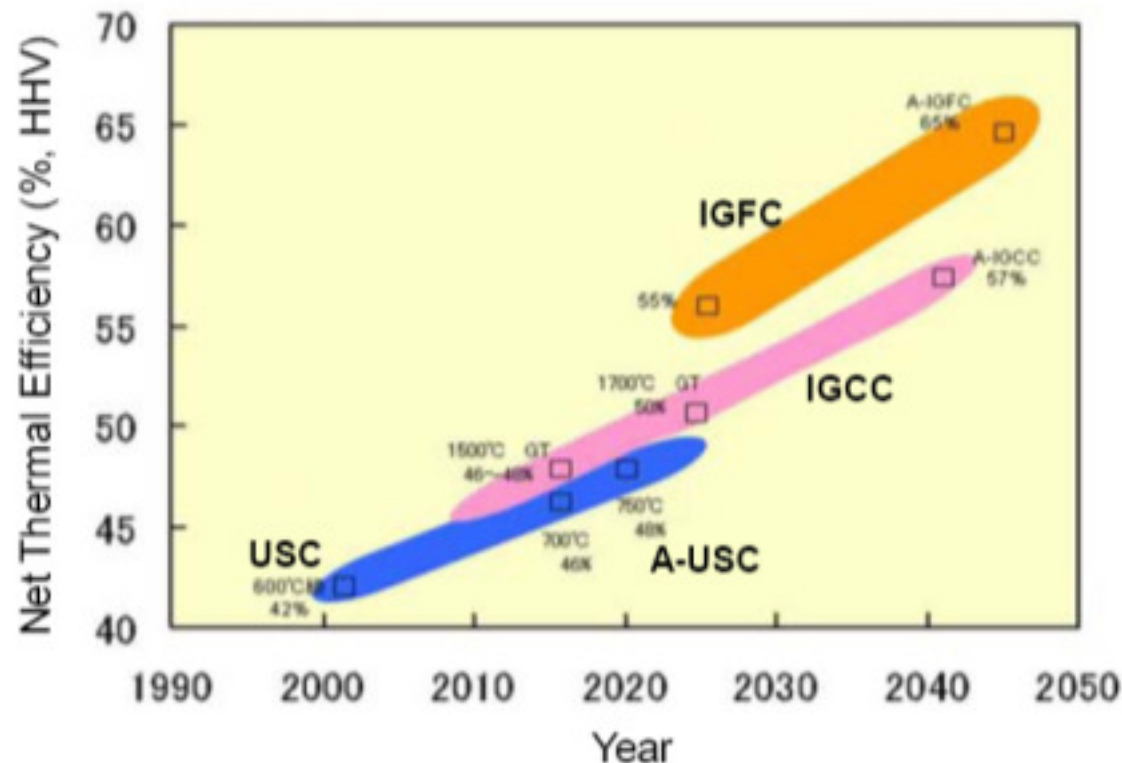


Figure 5 700deg-C class advanced USC (A-USC)

USC (Ultra Super-Critical steam condition)
A-USC (Advanced Ultra Super-Critical steam condition)
HHV (Higher Heating Value – poder calorífico superior)

M. Fukuda, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 5-19, 2010

Turbinas a vapor – tendências das condições de operação



- USC (Ultra Super-Critical steam condition)
- A-USC (Advanced Ultra Super-Critical steam condition)
- IGCC (Integrated coal Gaseification Combined Cycle)
- IGFC (Integrated coal Gaseification Fuel Cell Combined Cycle)

M. Fukuda, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 5-19, 2010

Turbinas a vapor – tendências das condições de operação

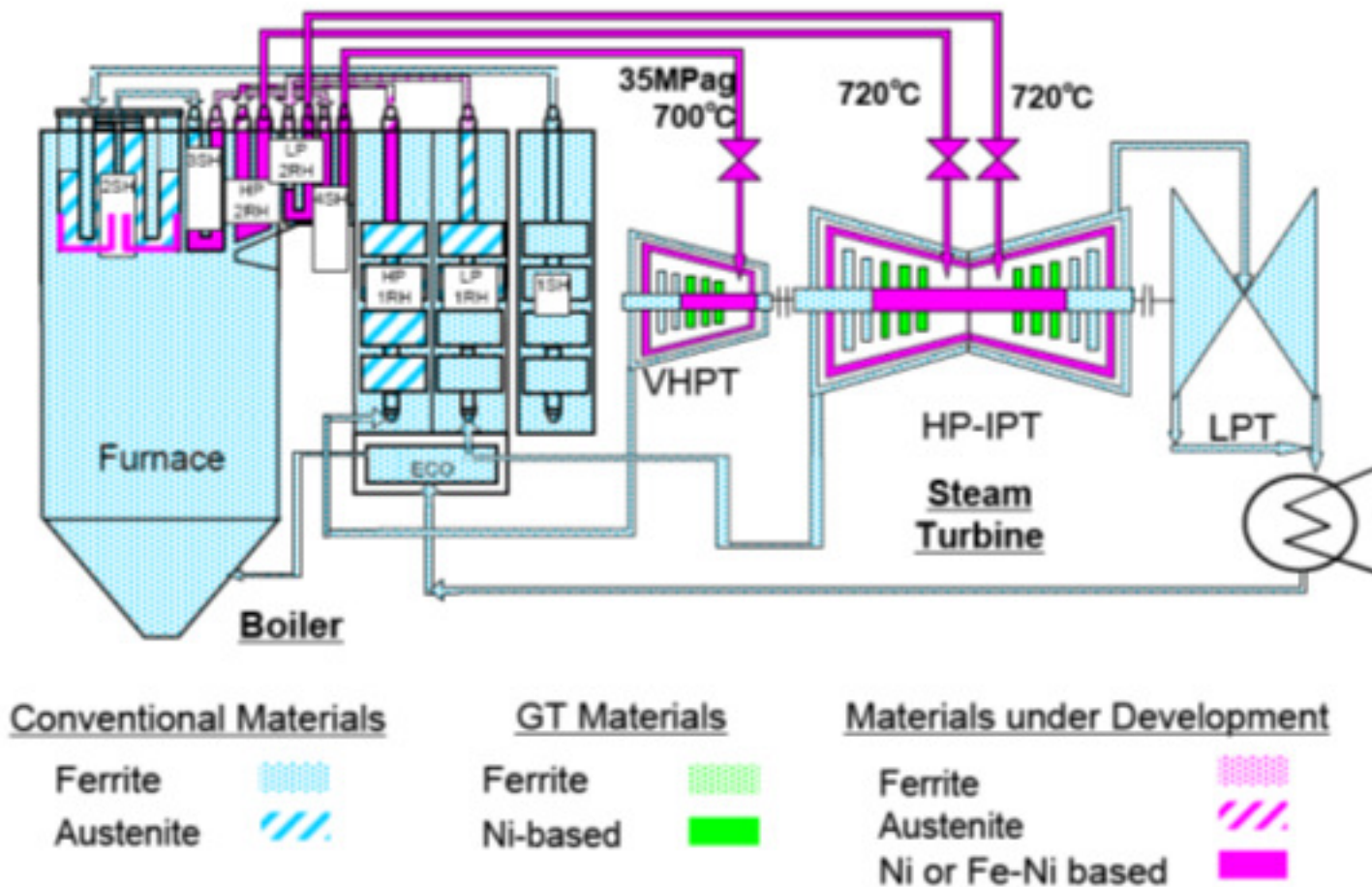


Figure 8 Selected materials for double reheat system

M. Fukuda, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 5-19, 2010

Turbinas a vapor – tendências das condições de operação

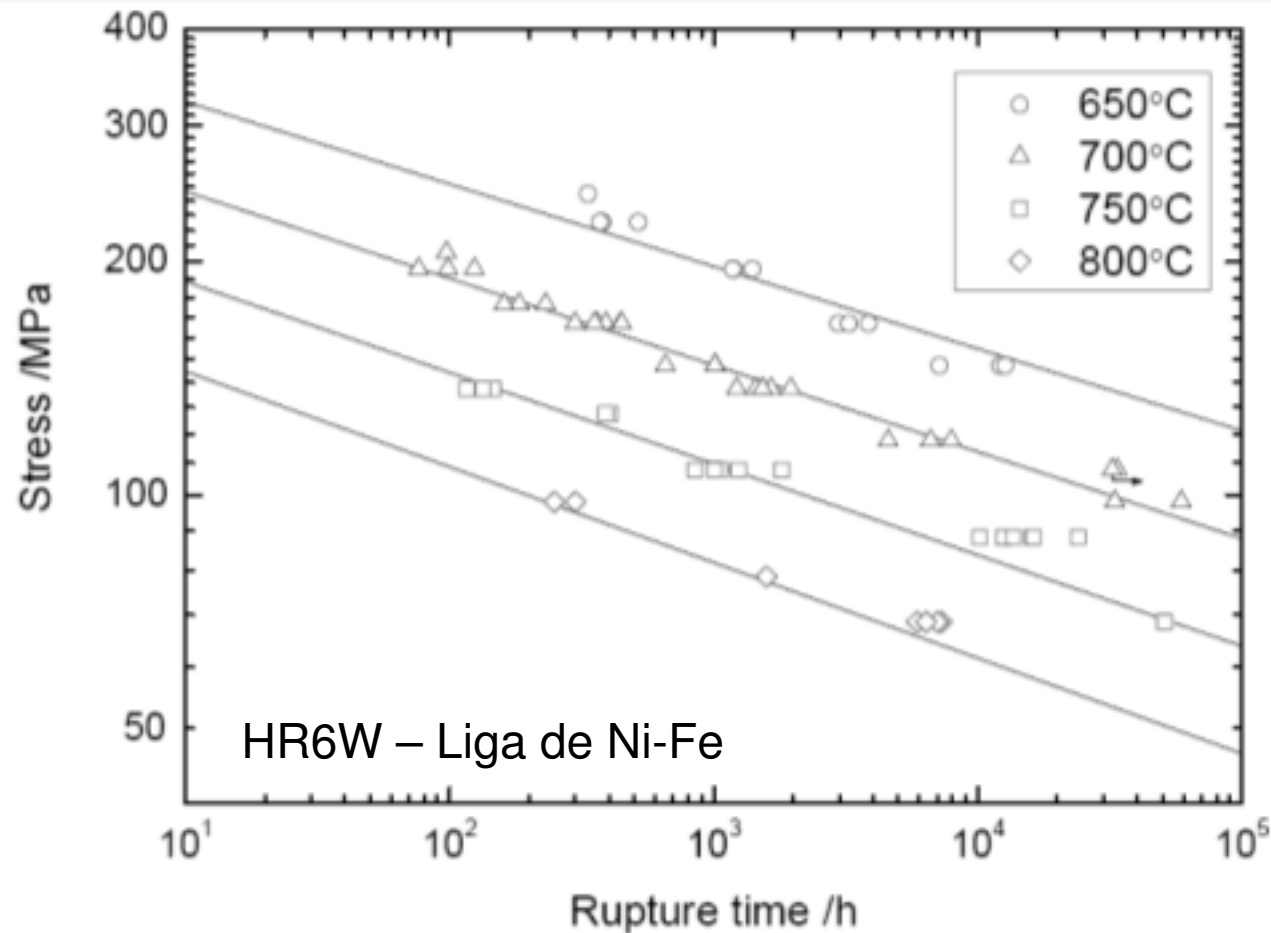
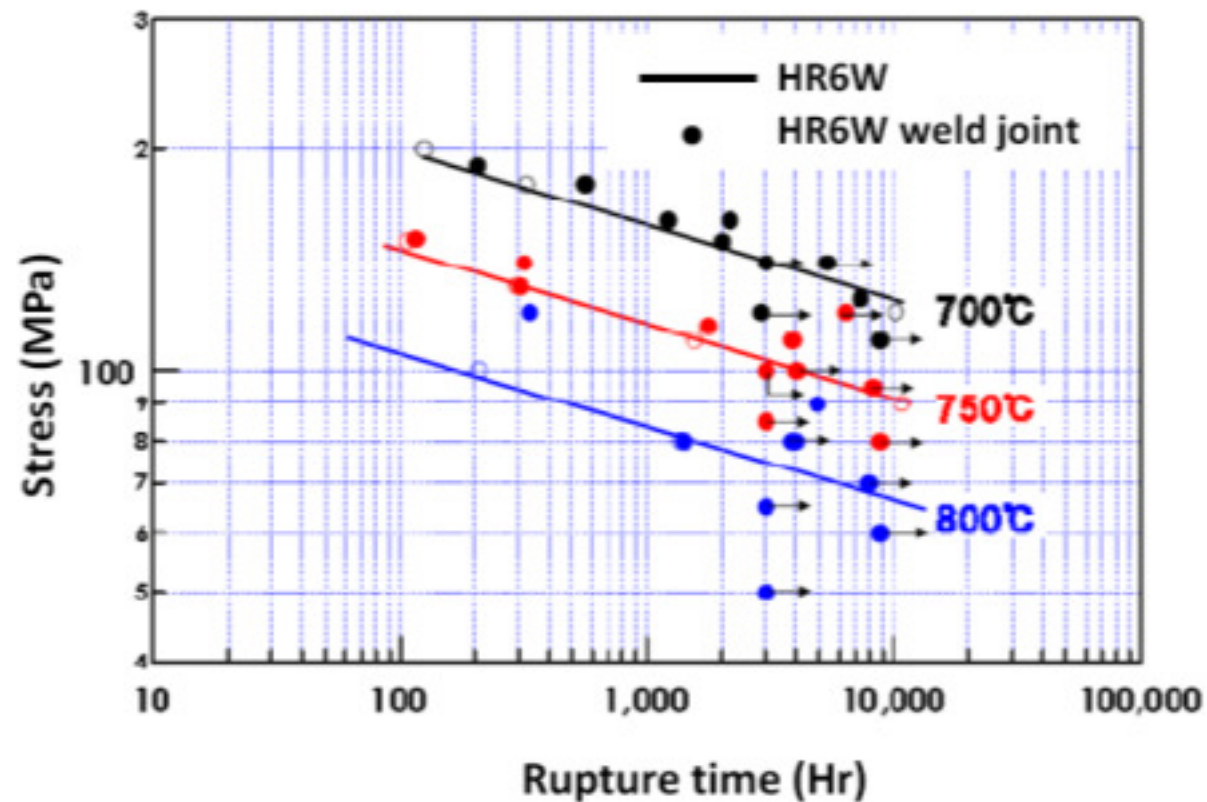


Figure 14 HR6W creep rupture strength (Courtesy of Sumitomo Metal Industries)

M. Fukuda, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 5-19, 2010

Turbinas a vapor – tendências das condições de operação



*Figure 15 Creep rupture strength of HR6W weld
(Courtesy of Babcock-Hitachi, IHI, Mitsubishi Heavy Industries)*

M. Fukuda, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 5-19, 2010

Turbinas a vapor – ensaio de corrosão

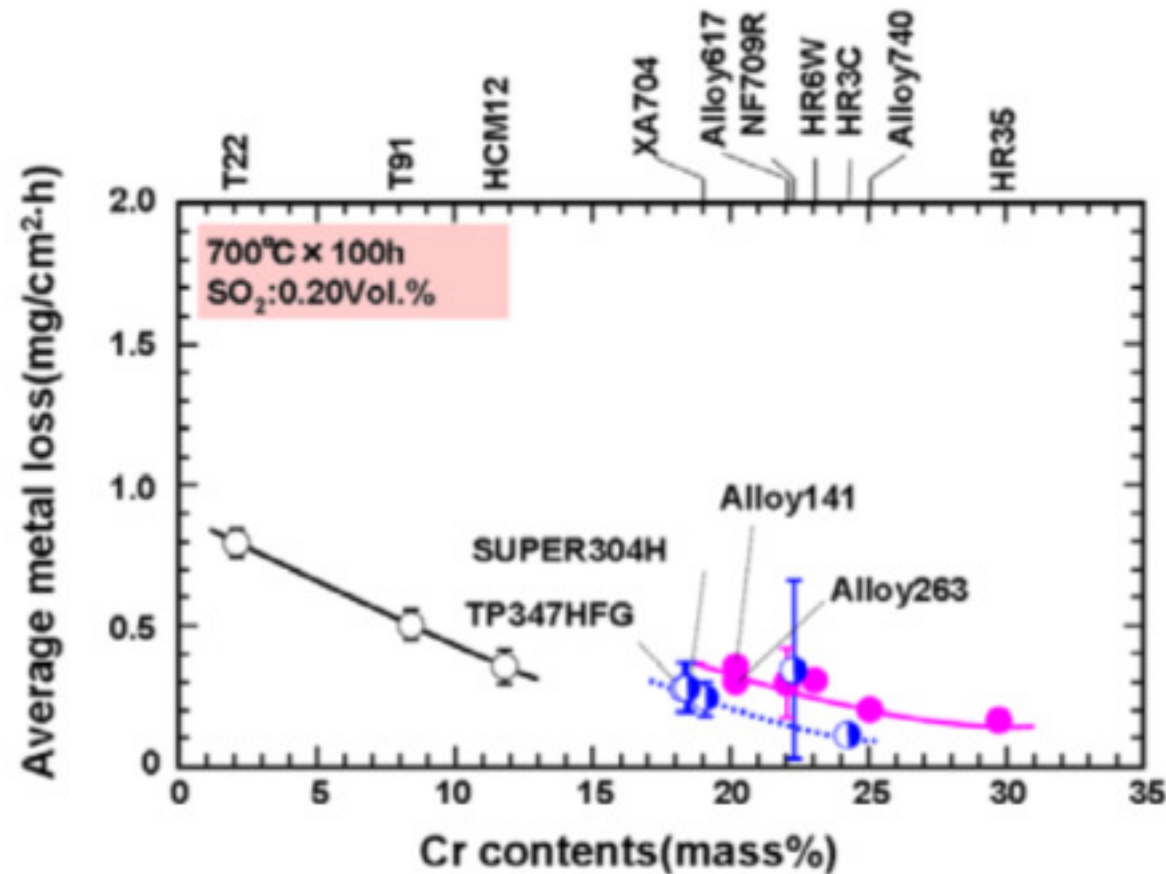


Figure 16 Hot corrosion test (Courtesy of Mitsubishi Heavy Industries)

M. Fukuda, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 5-19, 2010

Turbinas a vapor – ensaio de oxidação

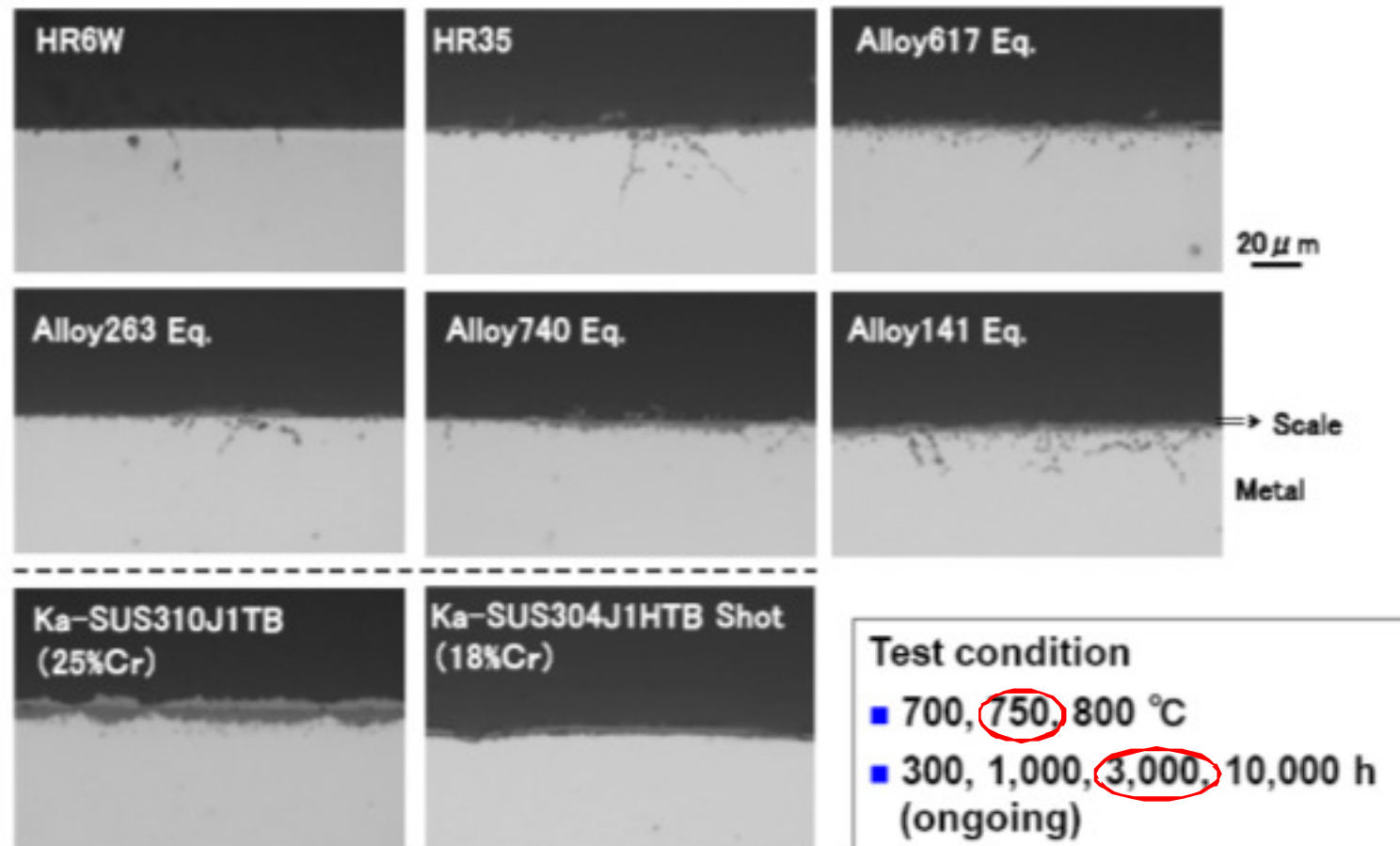


Figure 17 Steam oxidation test (Courtesy of Babcock-Hitachi)

M. Fukuda, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 5-19, 2010

Turbinas a vapor – desenvolvimento de processos (extrusão)

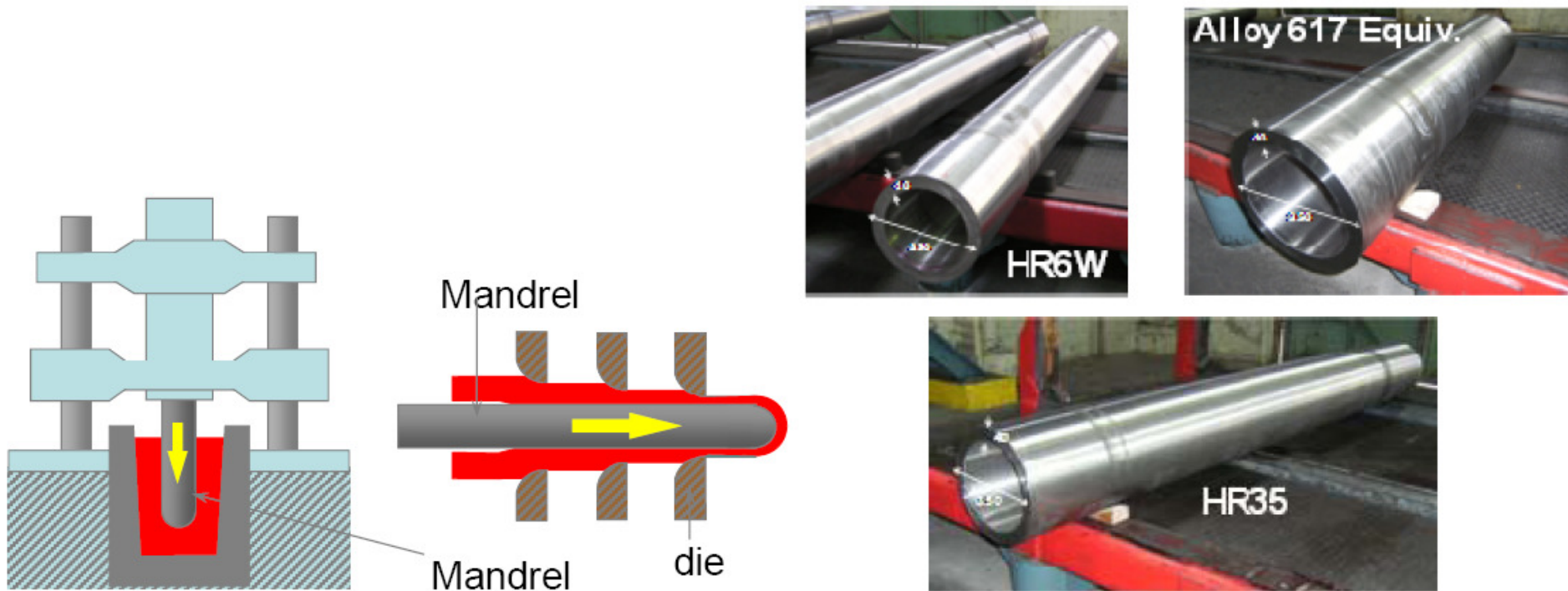


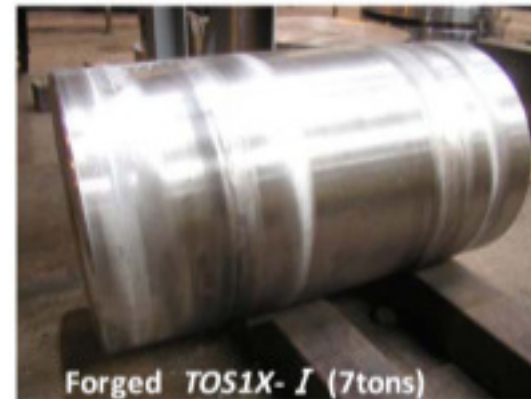
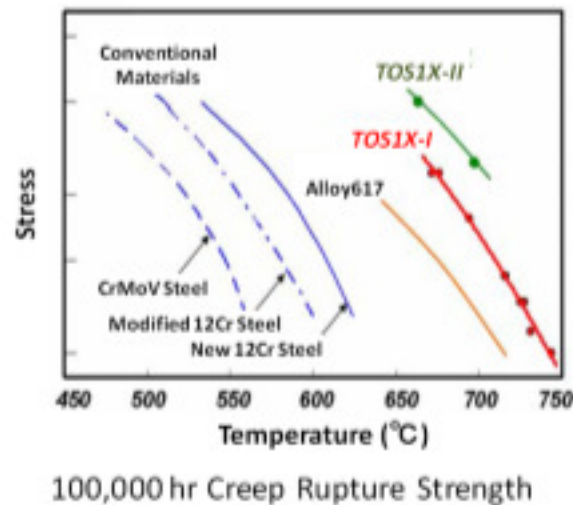
Figure 18 Pipes prepared for material test (Courtesy of Sumitomo Metal Industries)

M. Fukuda, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 5-19, 2010

Turbinas a vapor – desenvolvimento de ligas para forjamento



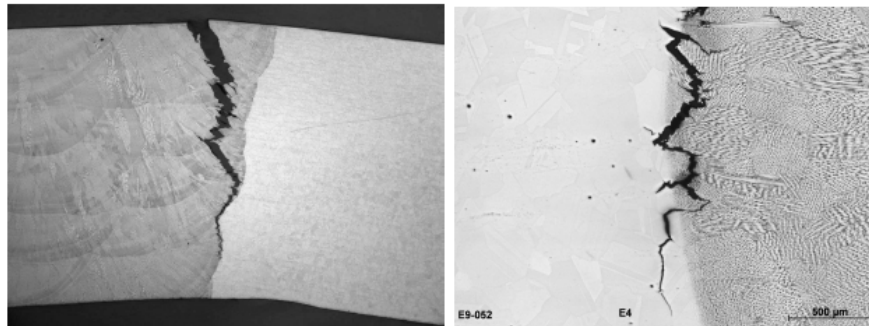
Figure 24 12Cr steel disc for welding test with LTES700R
(Courtesy of Mitsubishi Heavy Industries)



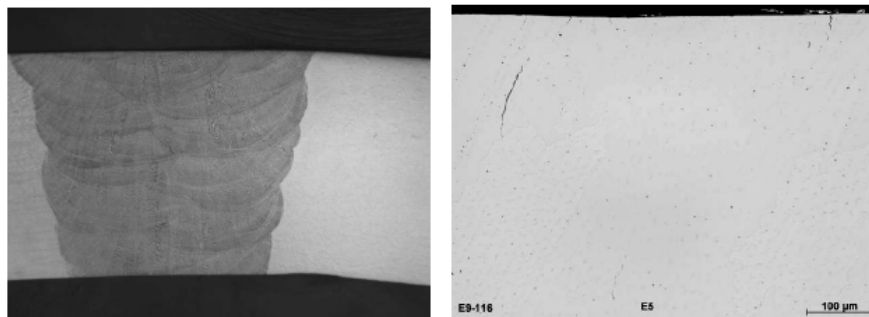
M. Fukuda, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 5-19, 2010

Turbinas a vapor – desenv. de processos (soldagem + T.T.)

Figure 6: TNO-test: Crack behaviour with and without heat treatment with 980°C, 3h



Without heat treatment: Interdendritic macro crack in the weld metal next to the fusion line propagating towards the HAZ



Nearly no cracks with heat treatment (high ductility of the material)

H. Tschaffon, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 20-28, 2010

Turbinas a vapor – tendências das condições de operação

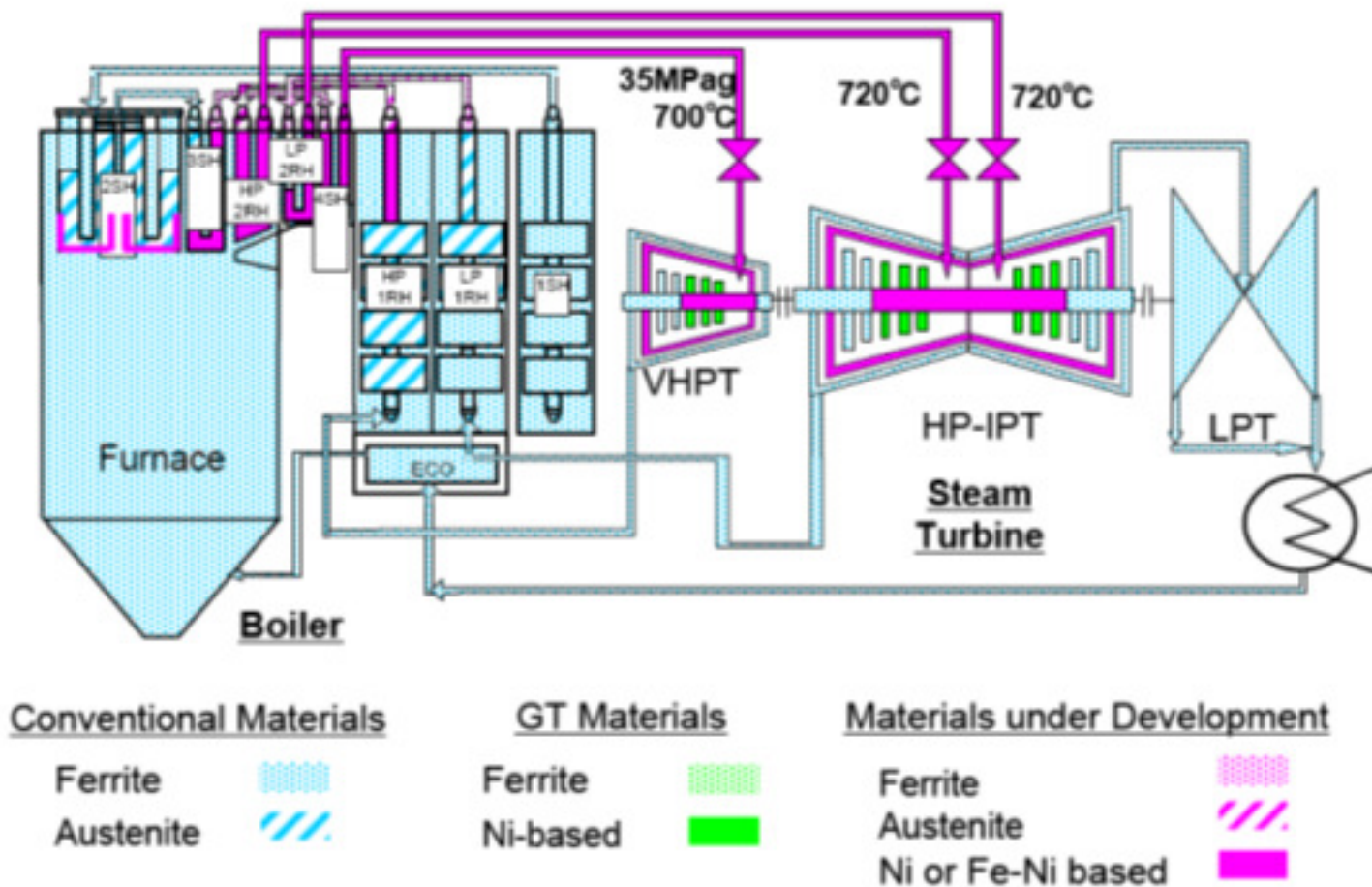
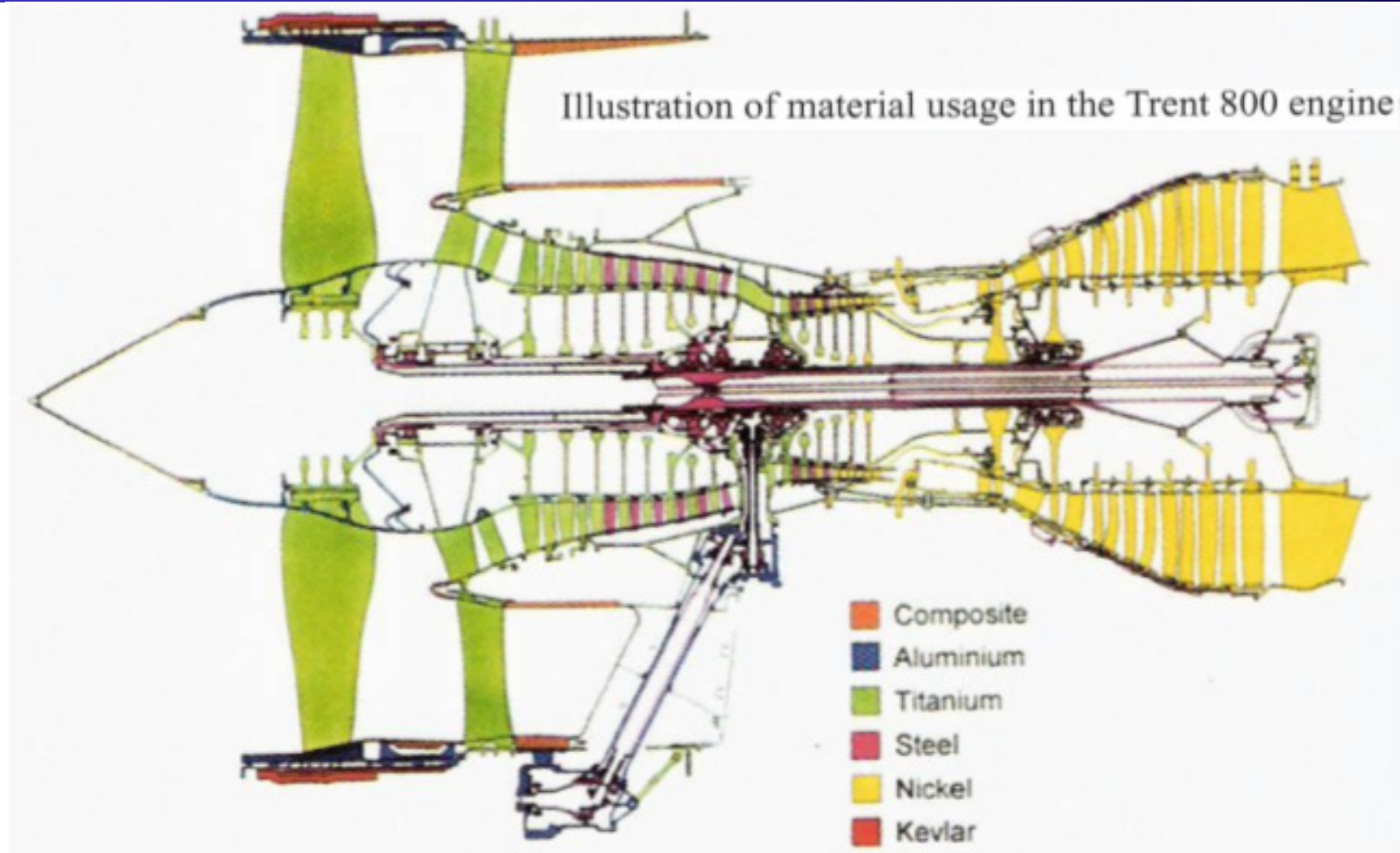


Figure 8 Selected materials for double reheat system

M. Fukuda, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 5-19, 2010

Superligas de níquel



R.C. Reed, The Superalloys – Fundamentals and Applications, Cambridge University Press, Cambridge, 2006

Superligas de níquel – Microestrutura

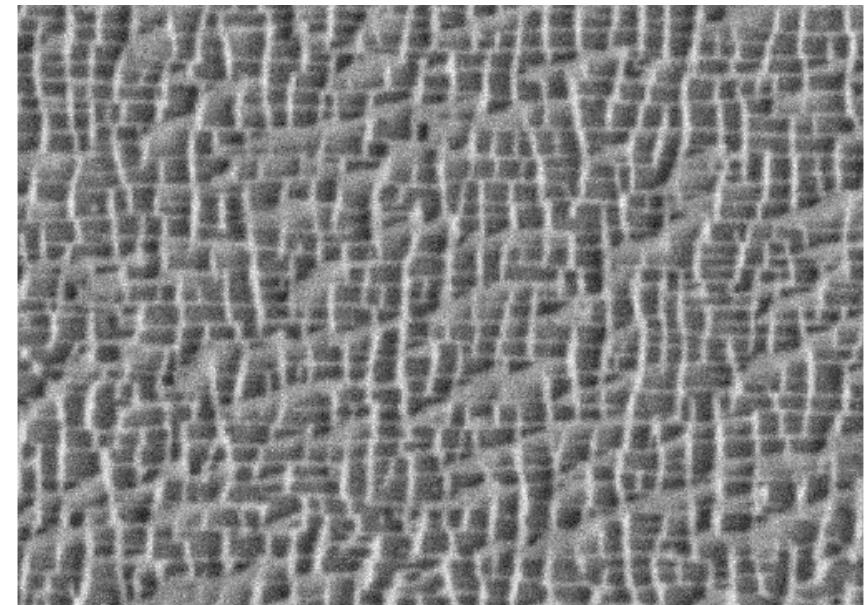
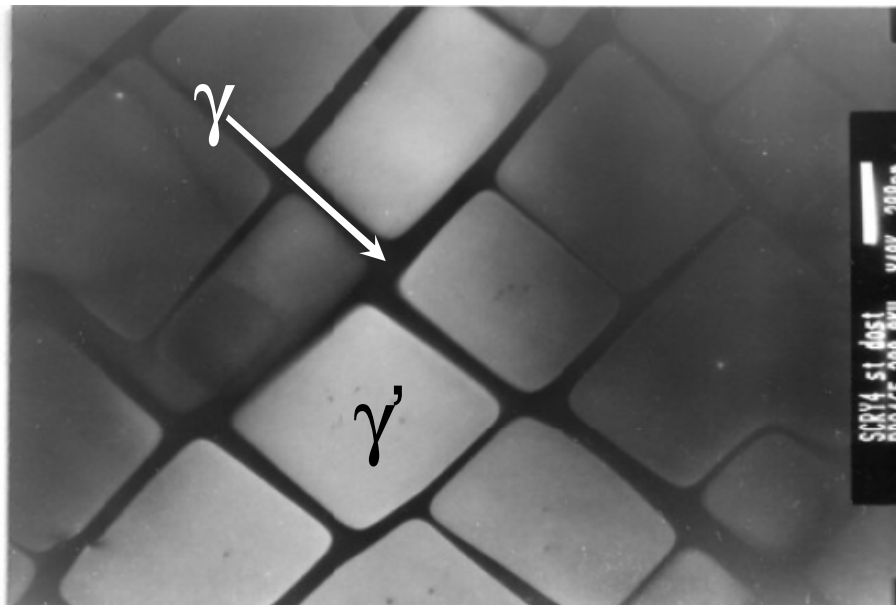
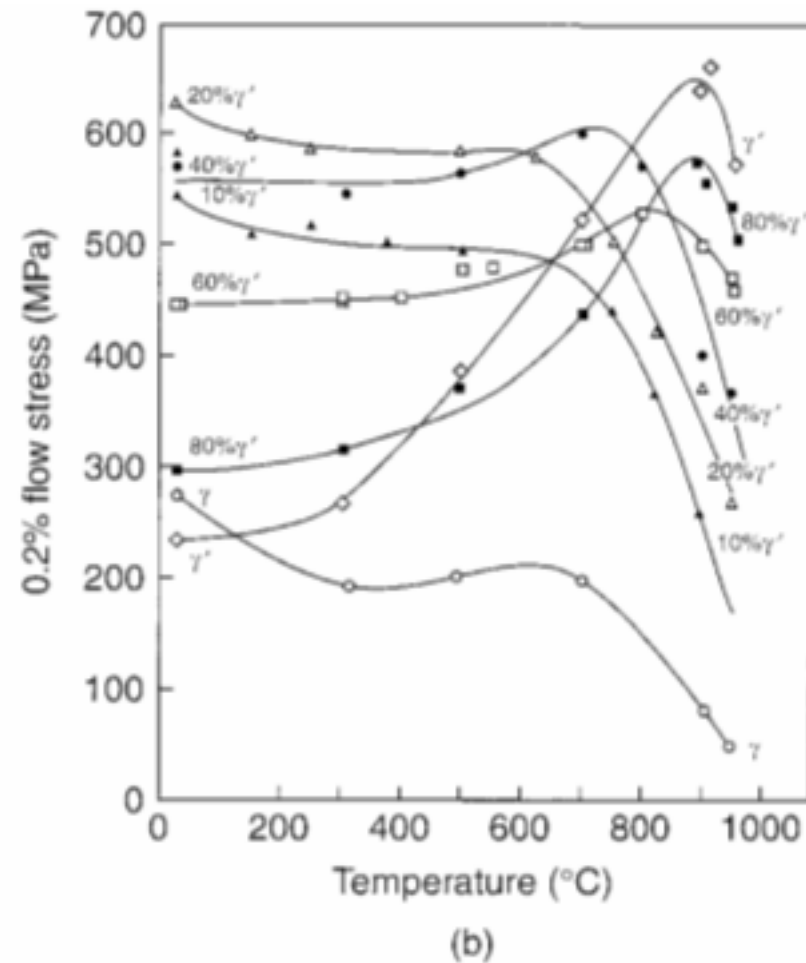
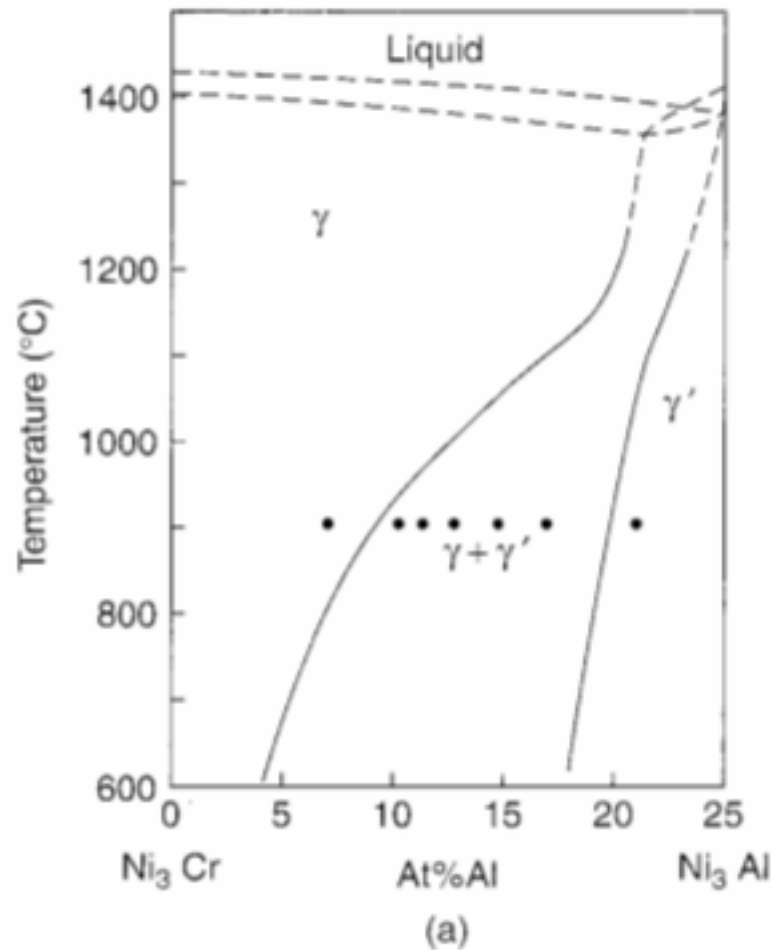


Figure 2: SEM dark field image of CMSX-4 microstructure (taken from γ' reflection), (left) & SEM image (right)

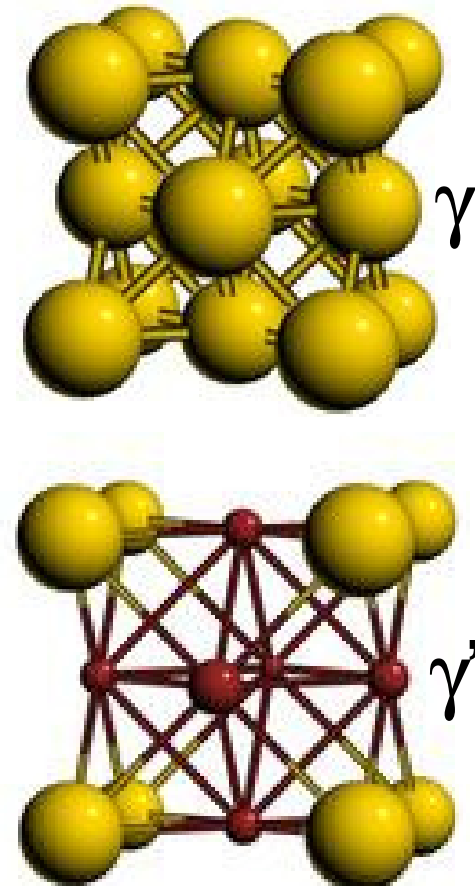
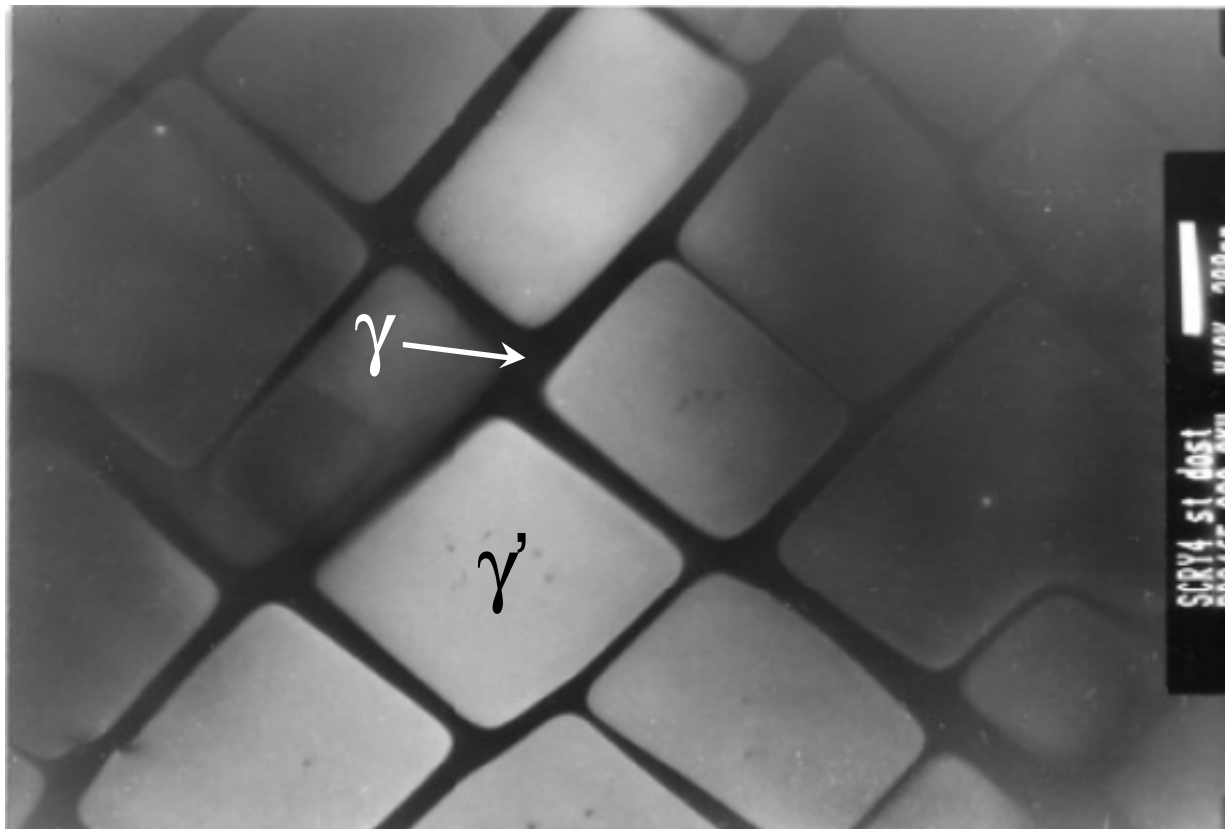
A. Scholz *et al.*, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 567-587, 2010

Superligas de níquel – Anomalia na tensão de escoamento



R.C. Reed, The Superalloys – Fundamentals and Applications, Cambridge University Press, Cambridge, 2006

Superligas de níquel – Microestrutura



A. Scholz *et al.*, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 567-587, 2010

Superligas de níquel – Estabilidade Microestrutural

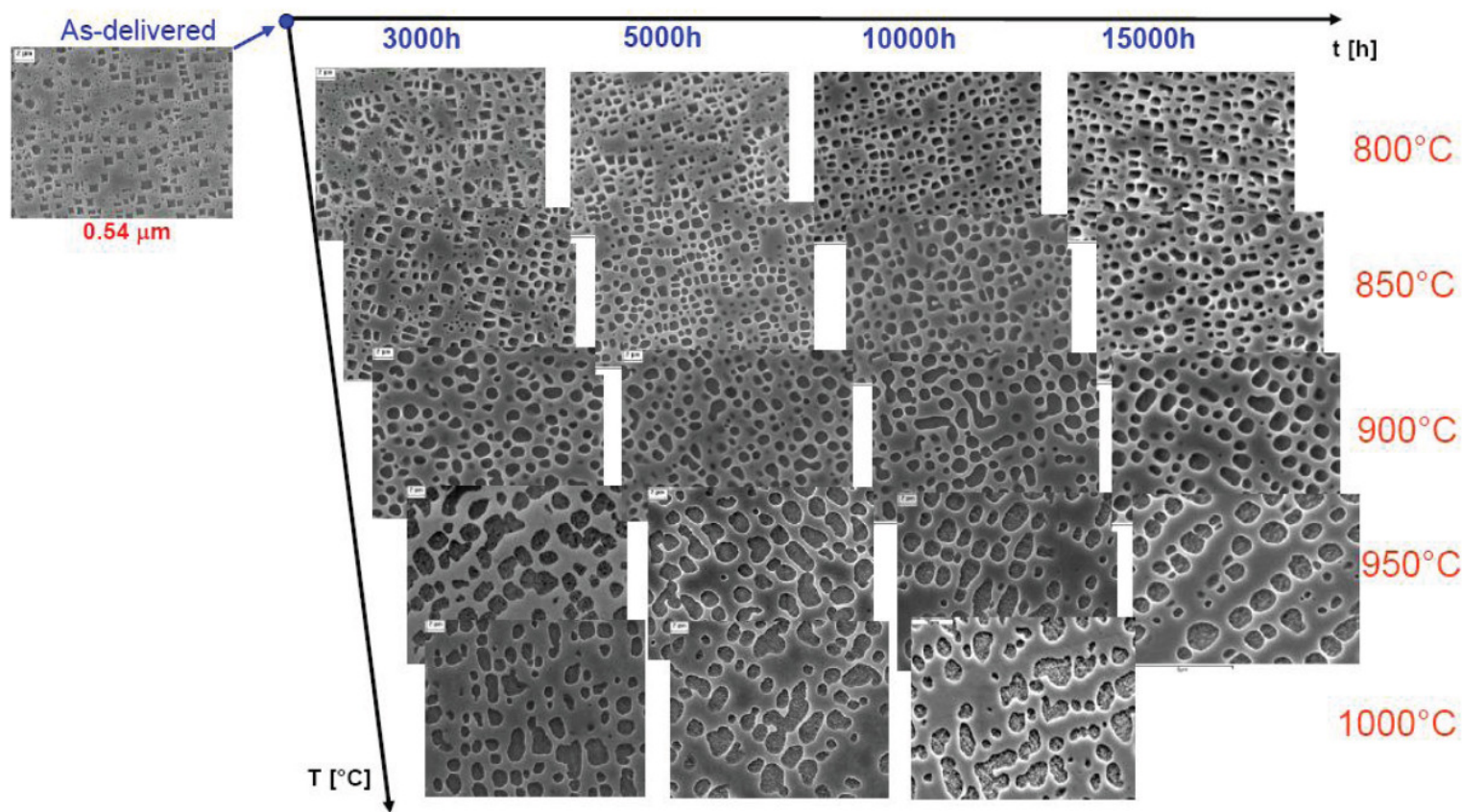


Figure 1: Microstructure evolution of primary γ' phase in IN738LC superalloys after isothermal exposure.

M. Mandeli *et al.*, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 707-716, 2010

Superligas de níquel – Estabilidade Microestrutural

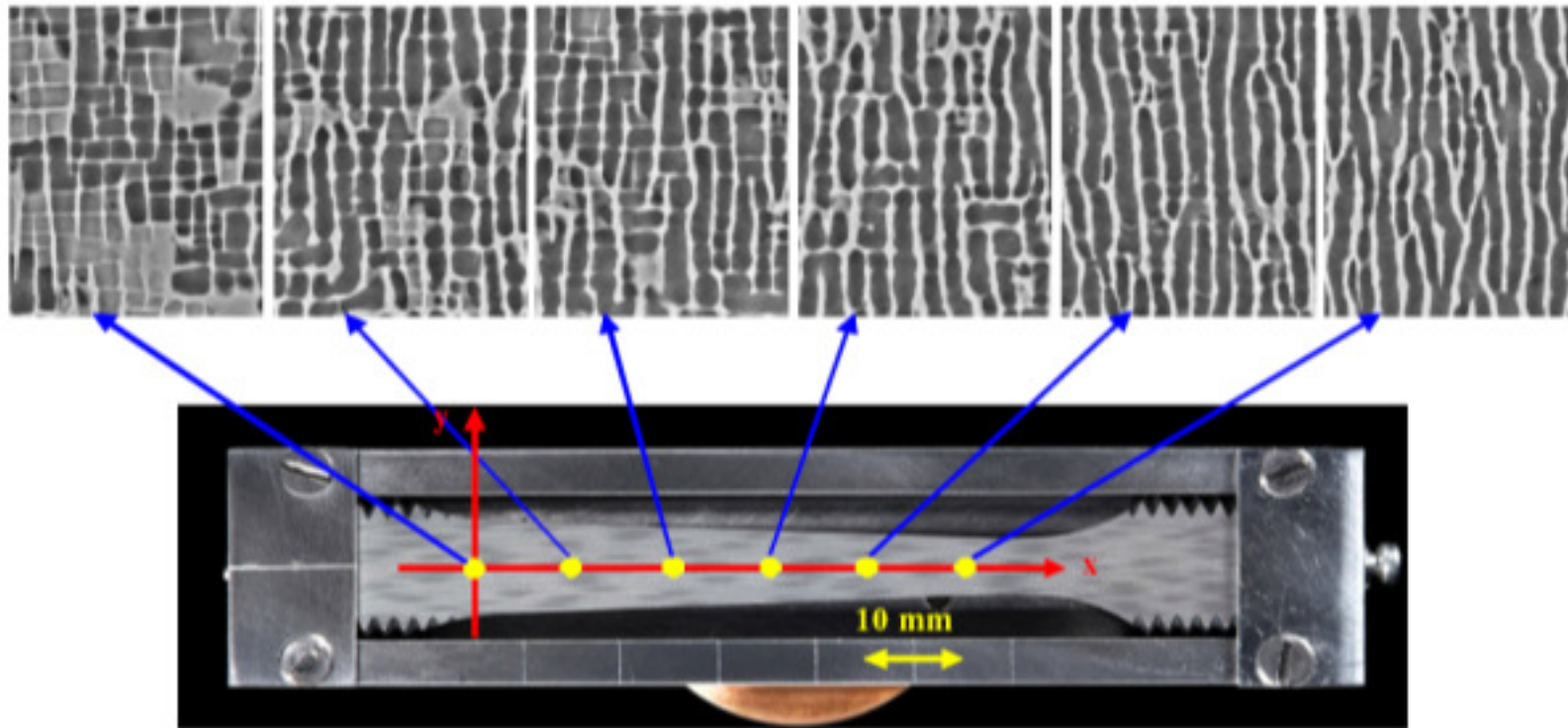


Figure 8: SEM holder with conical specimen degraded at 1050°C/175 h. Areas of analysis and SEM images correspond to the stress range 59 to 94 MPa [6]

A. Scholz *et al.*, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 567-587, 2010

Superligas de níquel – Microestrutura



Superligas de níquel – Propr. Mecânicas em Altas Temperaturas

Table 1. Chemical composition single crystal superalloy, wt.%

Al	Cr	Mo	W	Ta	Co	Re	Ru	Ni
6.0	3.3	4.0	4.0	5.0	7.0	6.5	4.0	basic

E, GPa

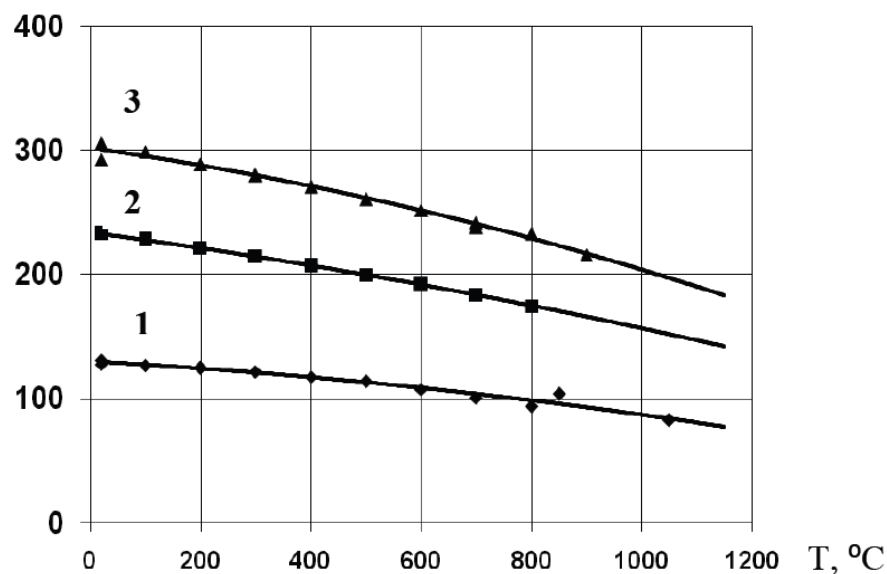


Fig. 1 Temperature dependence of Young modulus in single crystals of 1 - $\langle 001 \rangle$, 2 - $\langle 011 \rangle$, 3 - $\langle 111 \rangle$ orientations

I.L. Svetlov *et al.*, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 652-659, 2010

Superligas de níquel – Propr. Mecânicas em Altas Temperaturas

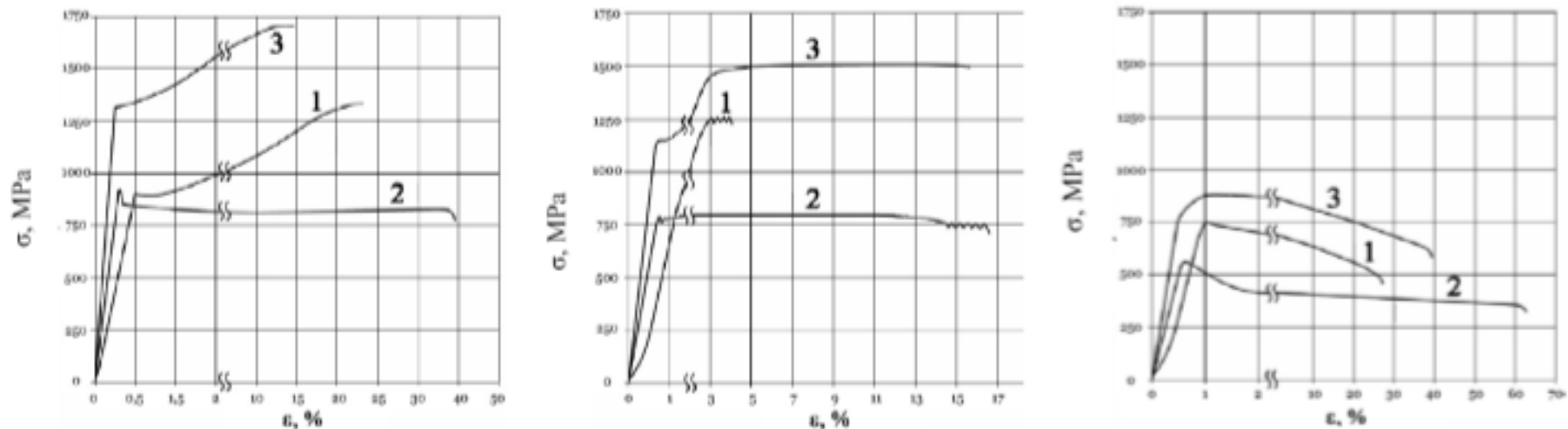


Fig. 2 Deformation diagrams of the investigated alloy with crystallographic orientations, close to $\langle 001 \rangle$, $\langle 011 \rangle$ and $\langle 111 \rangle$ at temperatures: 20 °C (a), 700 °C (b) and 1000 °C (c)

I.L. Svetlov *et al.*, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 652-659, 2010

Superligas de níquel – Propr. Mecânicas em Altas Temperaturas

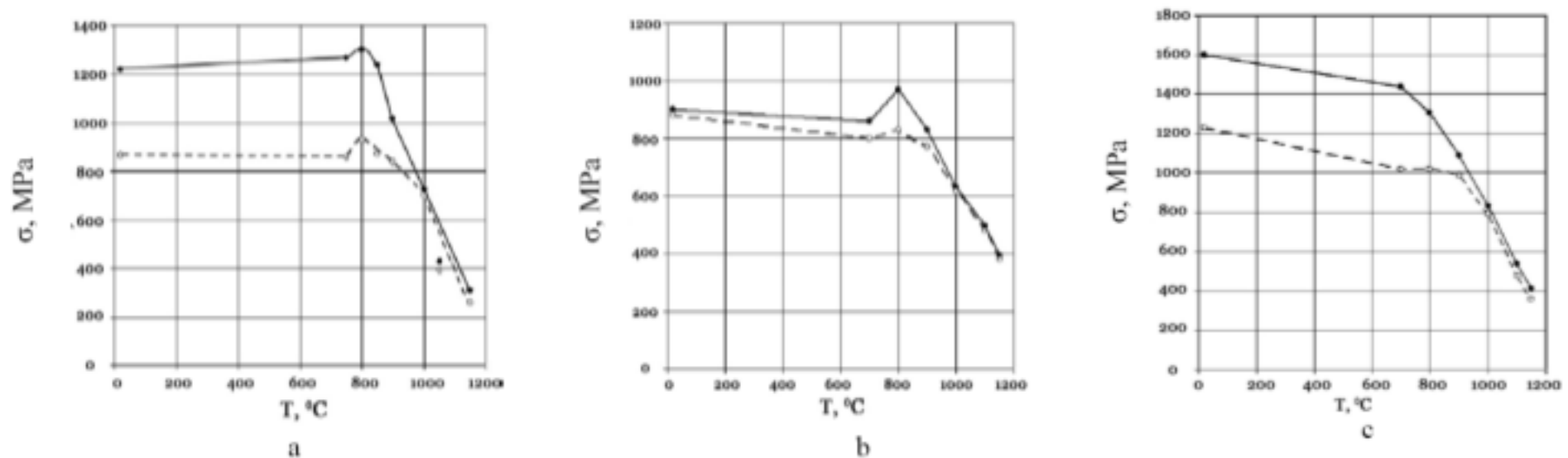
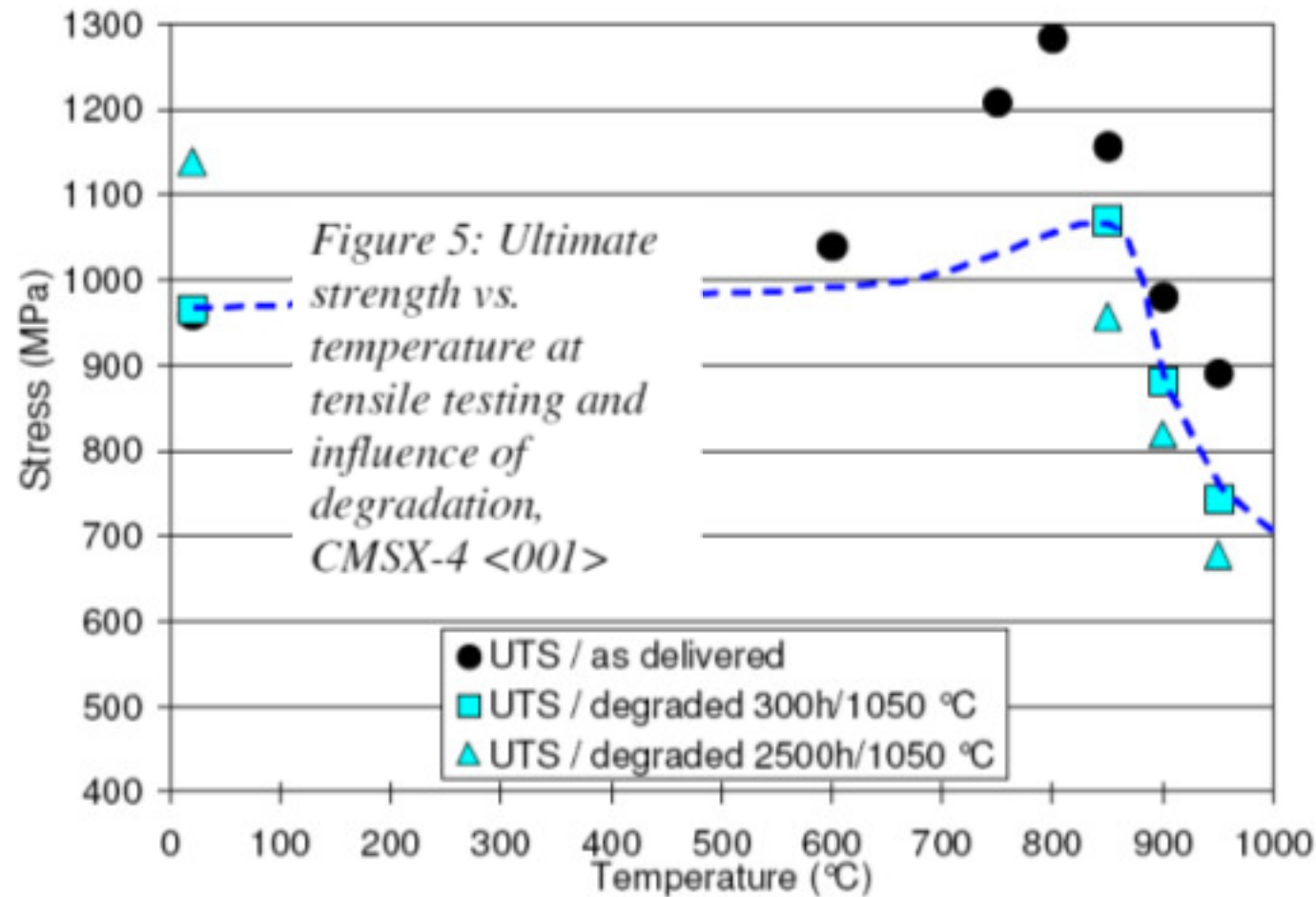


Fig. 3. Temperature and orientation dependence of yield and tensile strengths in the single crystals of investigated alloy. a - $\langle 001 \rangle$ orientation, b - $\langle 011 \rangle$ orientation, c - $\langle 111 \rangle$ orientation

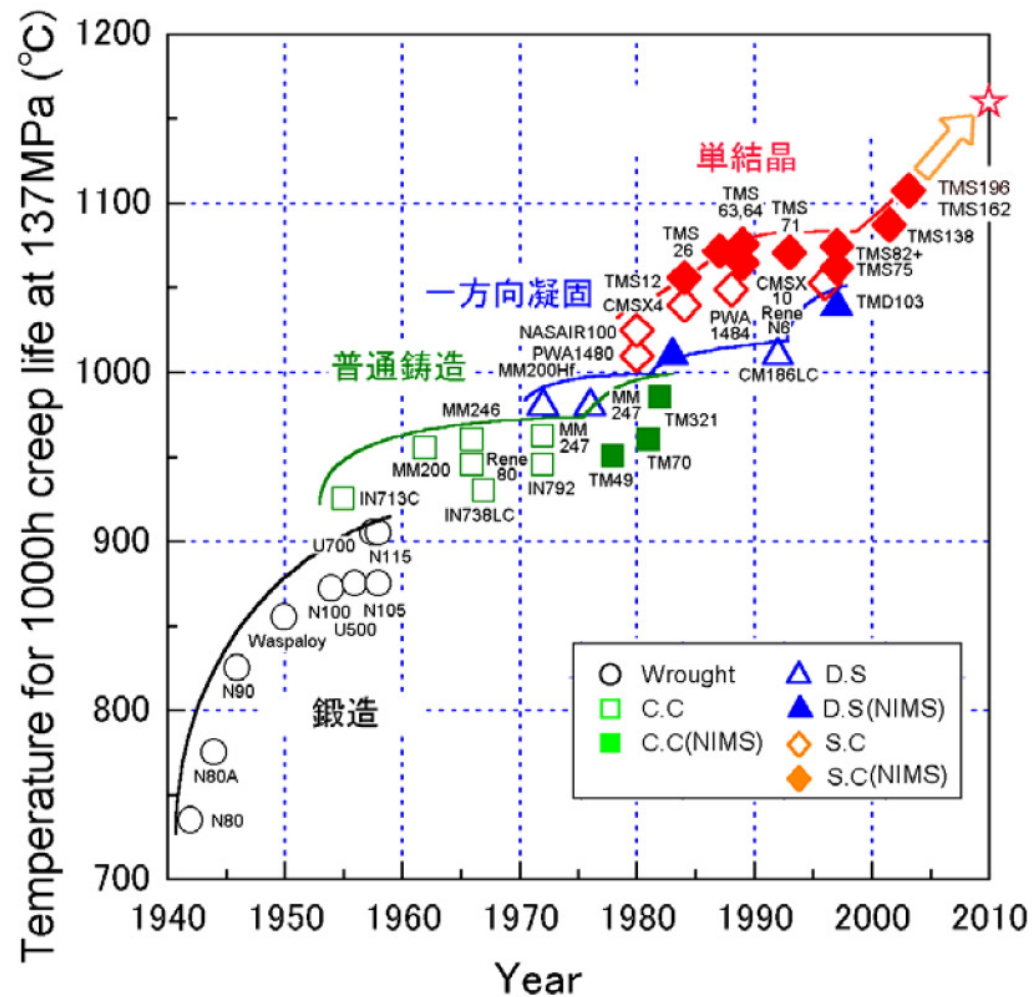
I.L. Svetlov *et al.*, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 652-659, 2010

Superligas de níquel – Propr. Mecânicas em Altas Temperaturas



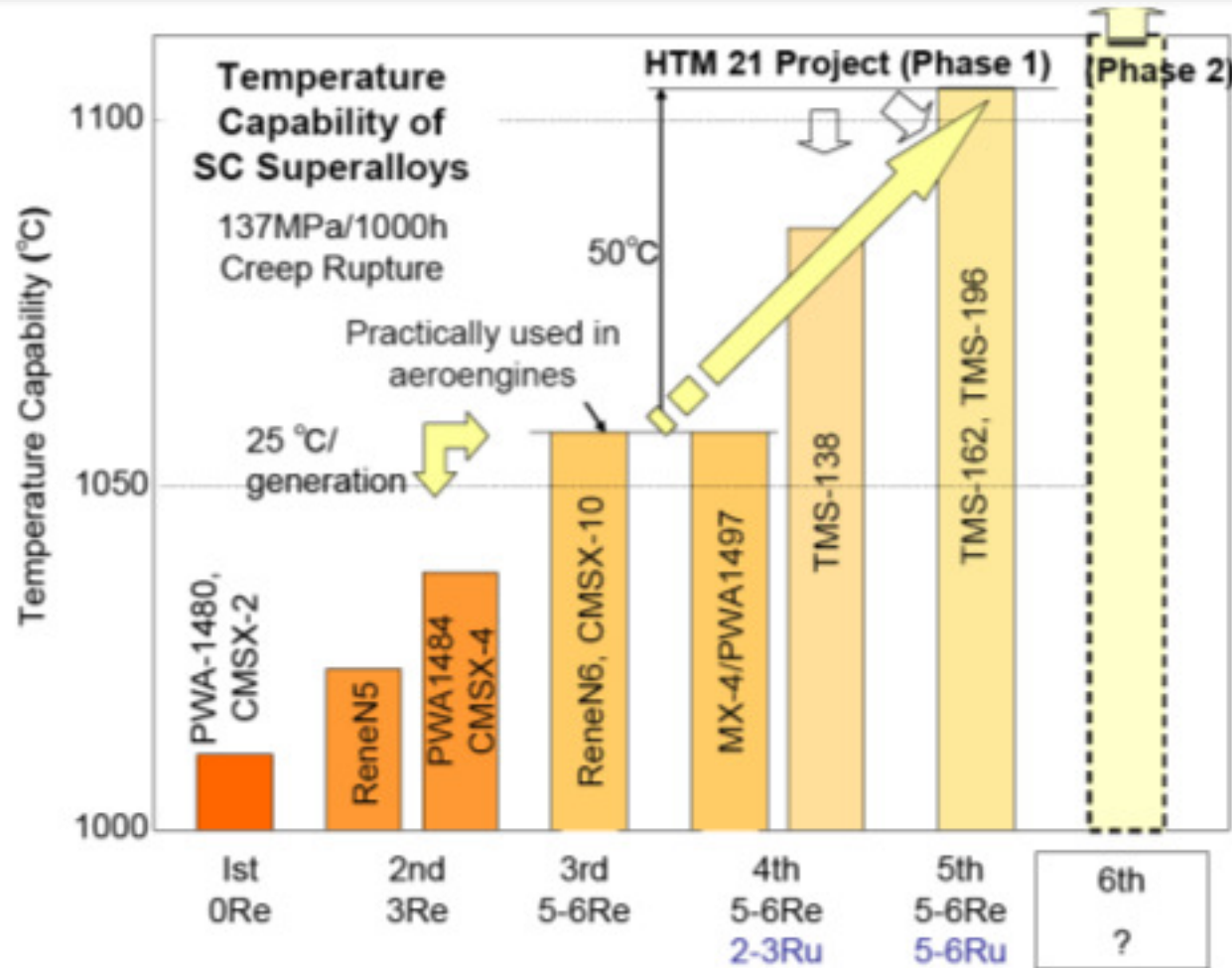
A. Scholz *et al.*, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 567-587, 2010

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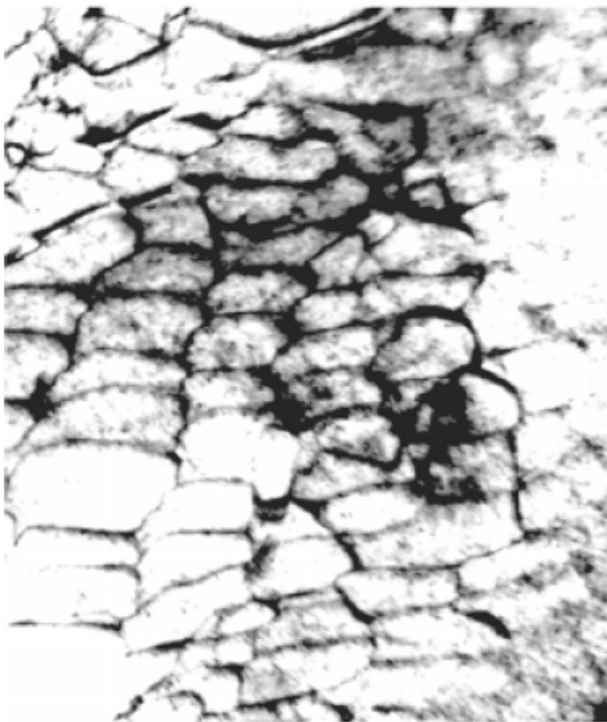
Superligas de níquel – Evolução Temperaturas de Aplicação



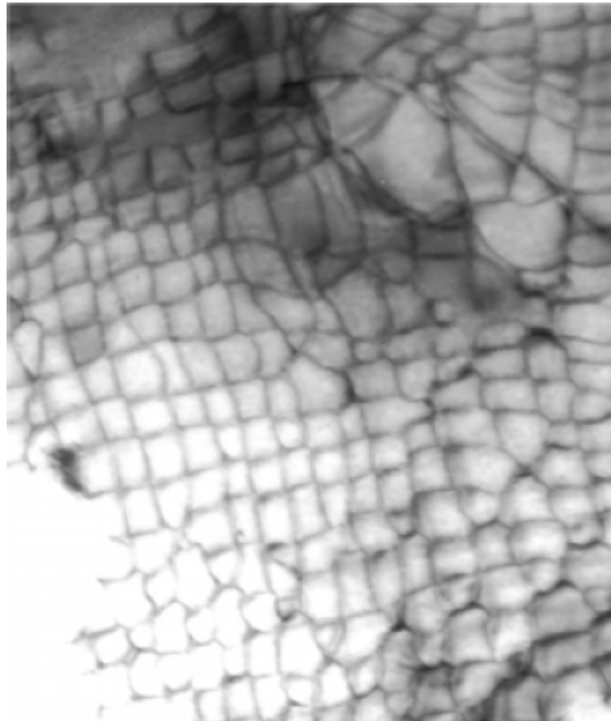
H. Harada, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 604-614, 2010

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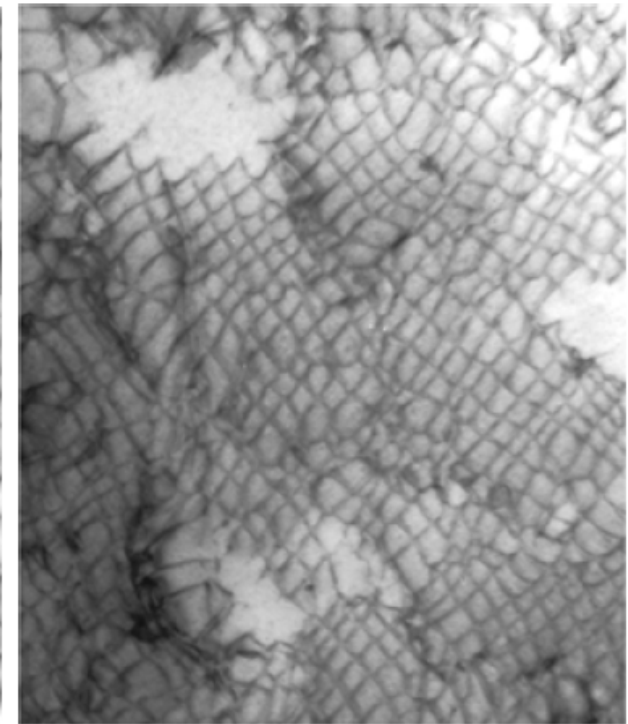
3rd Gen.



4th Gen.



5th Gen.



100 nm

H. Harada, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 604-614, 2010

Superligas de níquel – Evolução Temperaturas de Aplicação

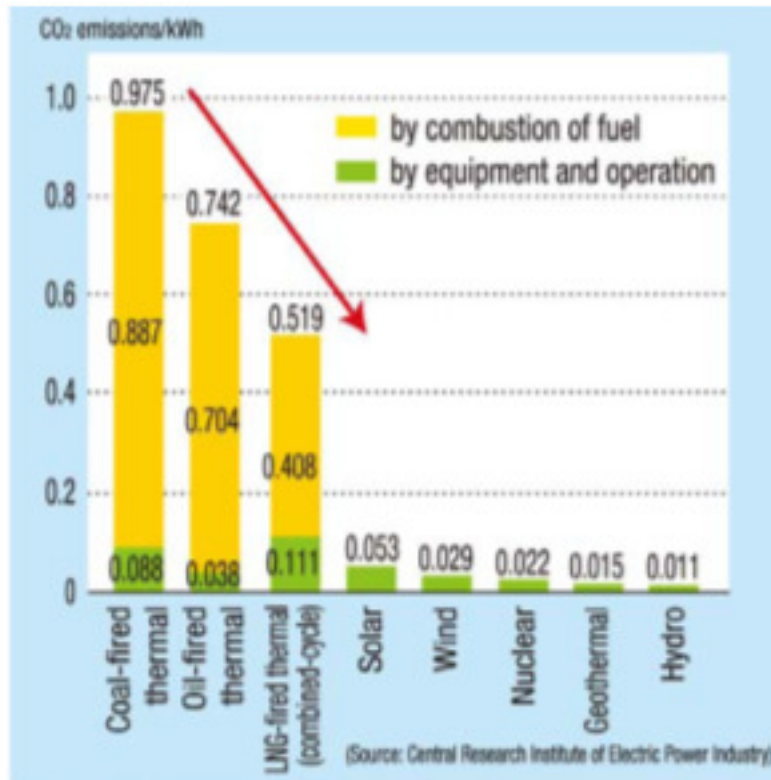


Fig. 1 CO₂ emissions by electric power source.

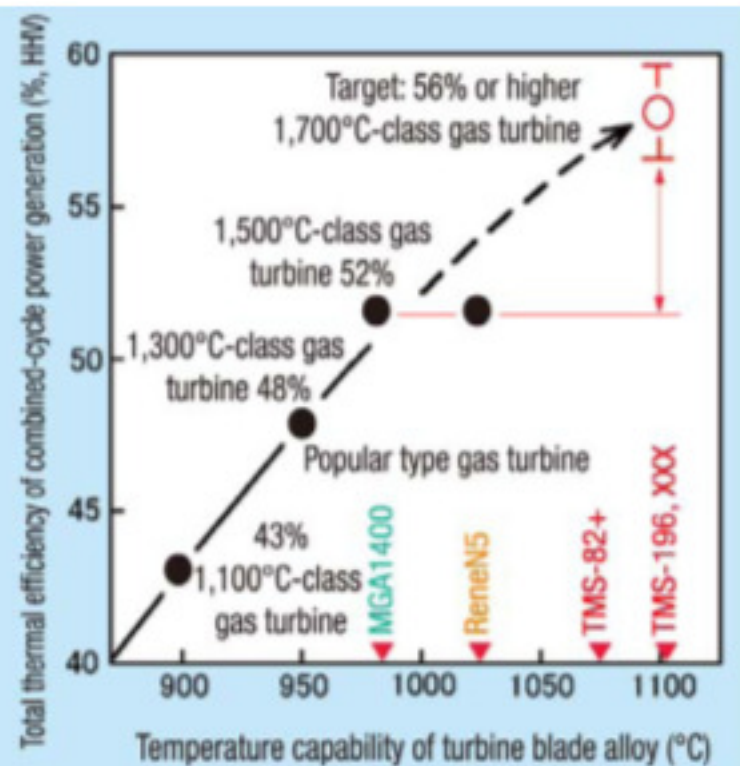


Fig. 2 Relationship between the temperature capability of turbine blade superalloys and power generation efficiency.

H. Harada, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 604-614, 2010

Superligas de níquel – Tecnologia de Revestimentos

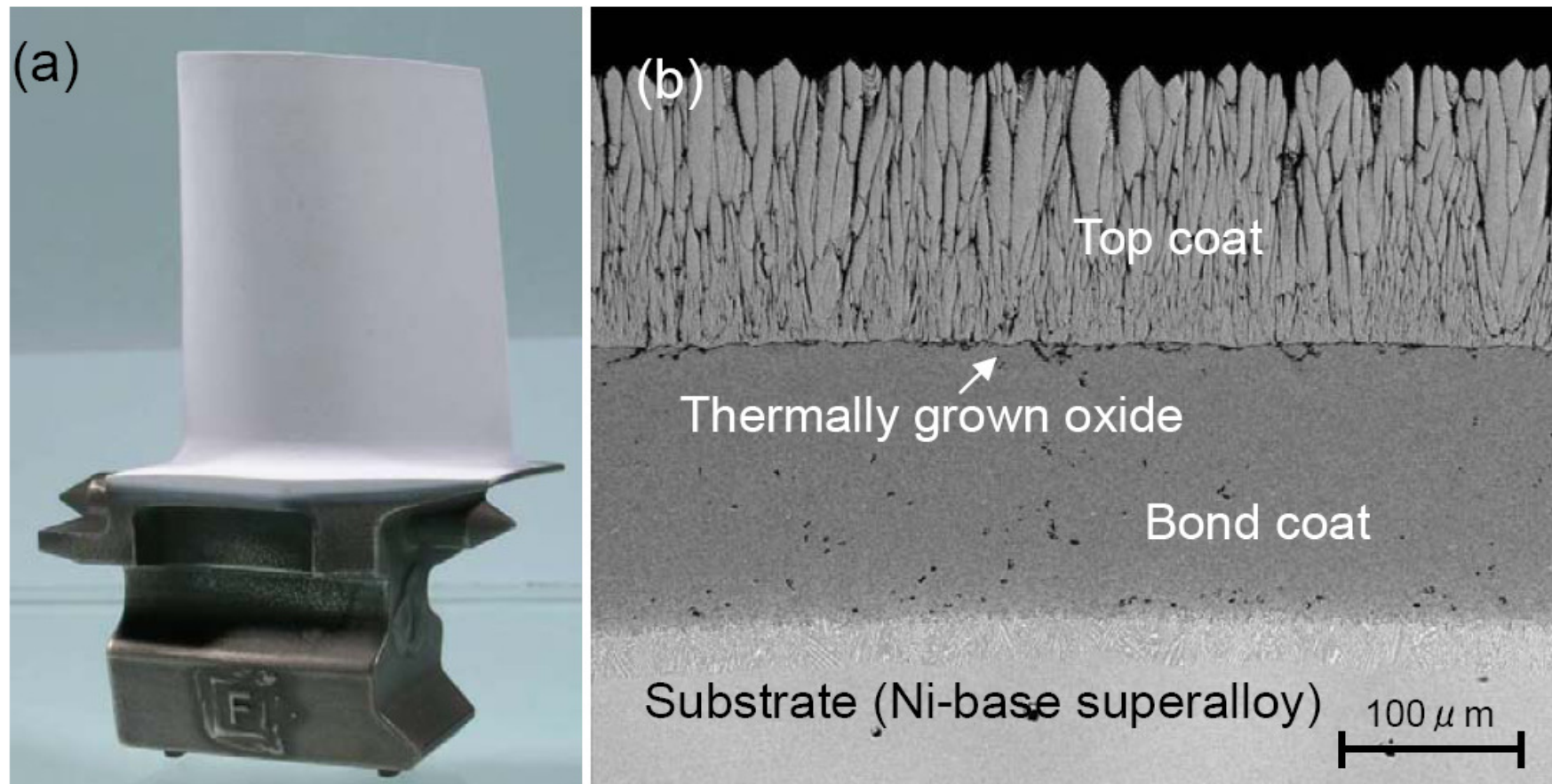


Fig.6 (a) Turbine blade with thermal barrier coating, (b) cross section of coating layer.

H. Harada, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 604-614, 2010

Superligas de níquel – Tecnologia de Revestimentos

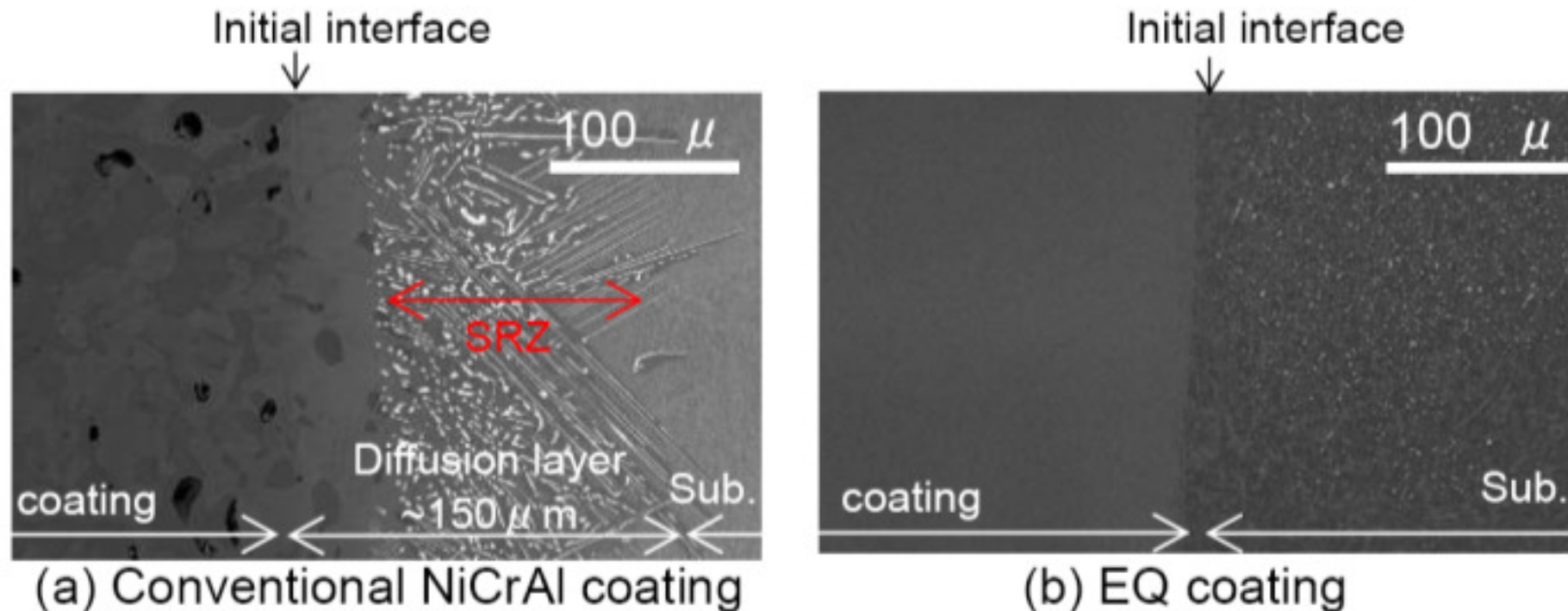


Fig. 7 Cross section of bond coat/substrate interface after 1,100°C for 300 hours exposure [8].

H. Harada, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 604-614, 2010

Superligas de níquel – Tecnologia de Refrigeração

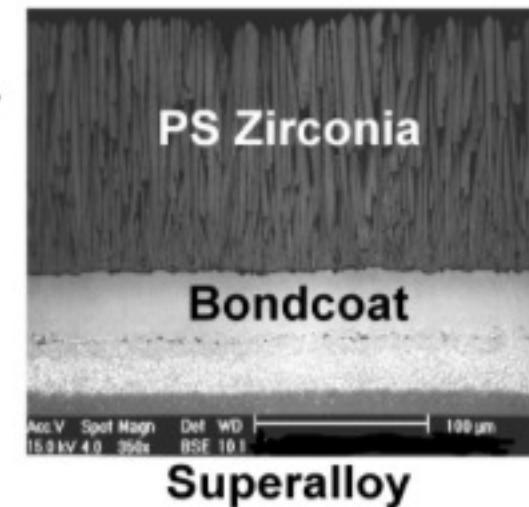
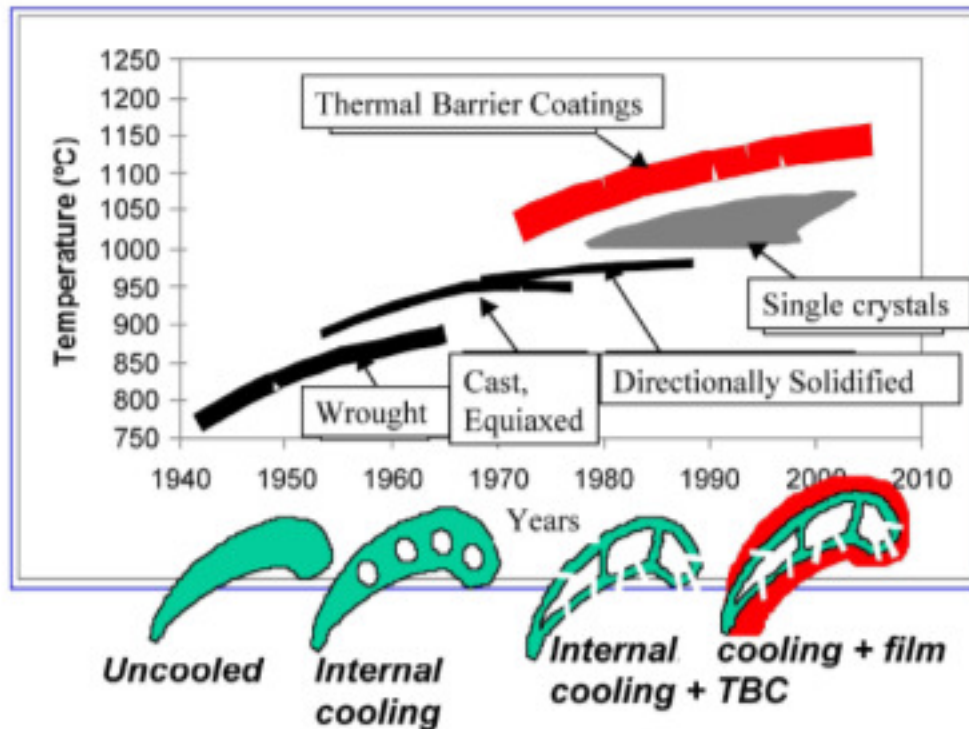
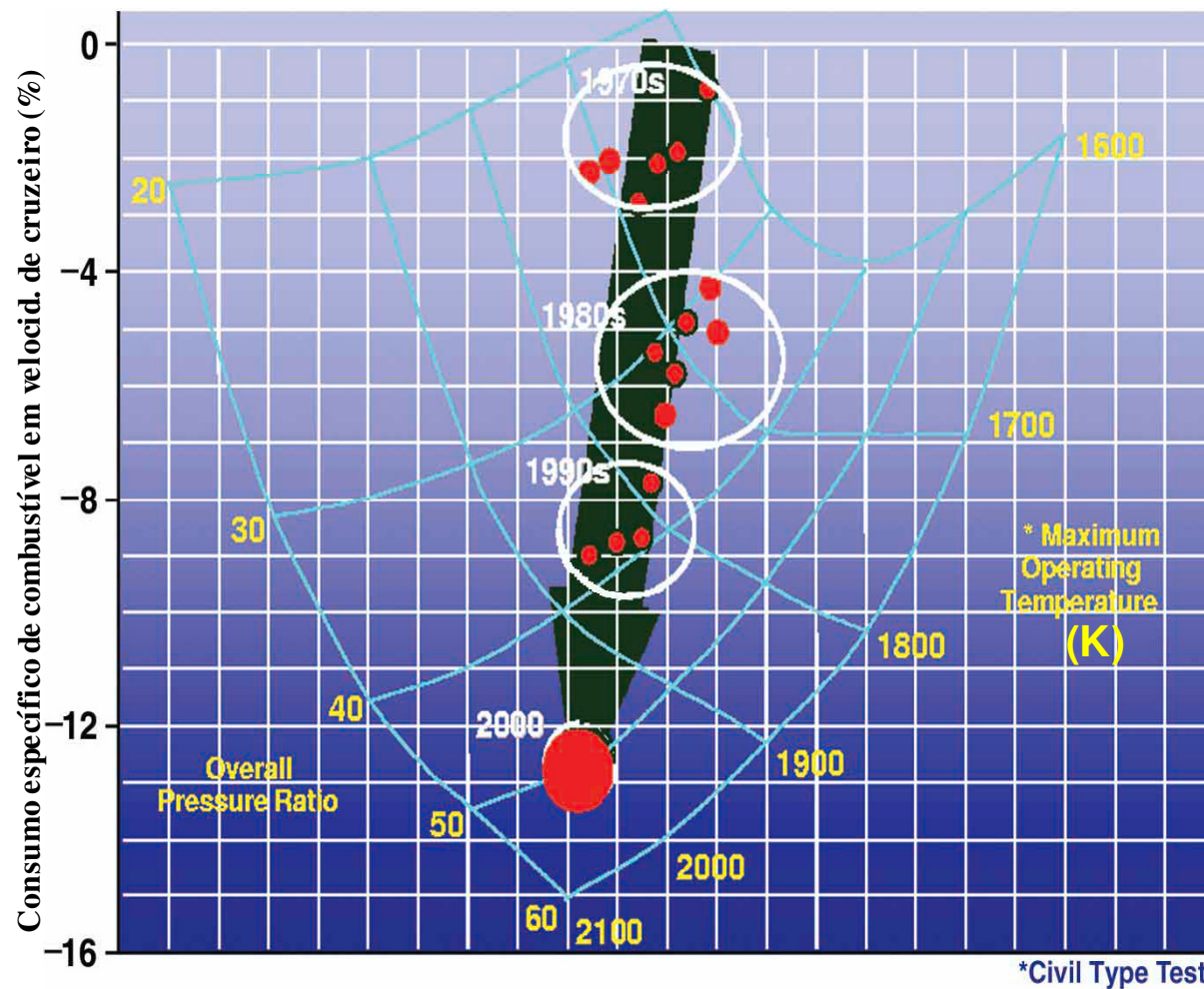


Figure 7: Variation of maximum blade temperature with years and evolution of materials and cooling technologies (left); Turbine blade coated by TBC and scanning electron microscope observation of various layers in the TBC (right).

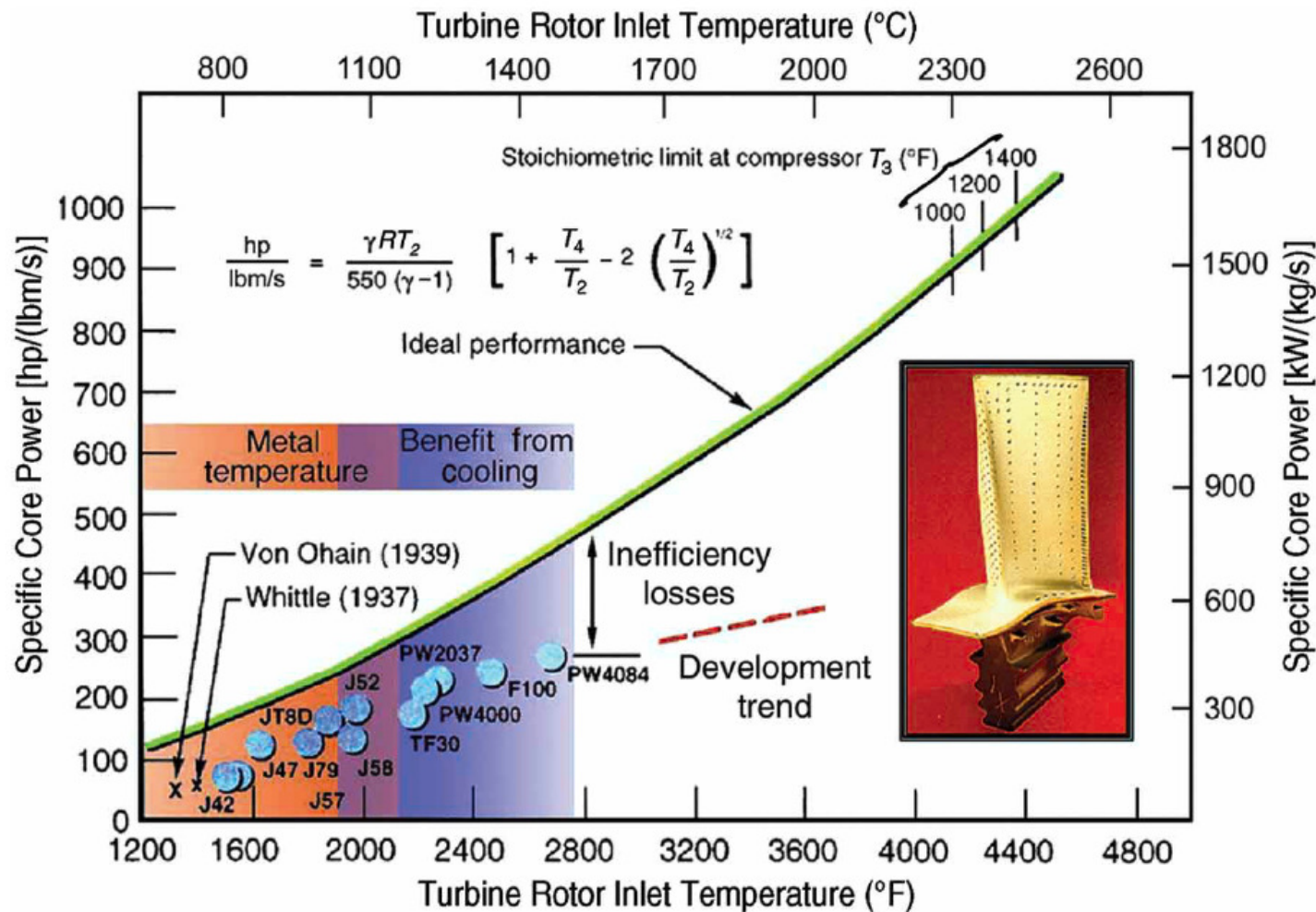
L. Rémy *et al.*, 9th Liège Conference – Materials for Advanced Power Engineering 2010, pp. 588-603, 2010

Superligas de níquel – Tendência



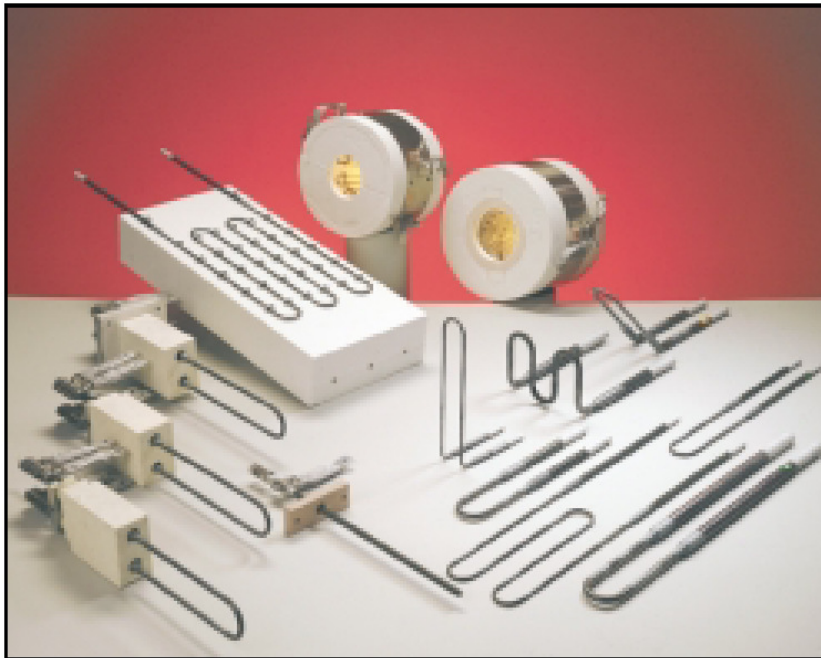
J.R. Nicholls, MRS Bulletin, pp. 659-670, 2003

Superligas de níquel – Tendência



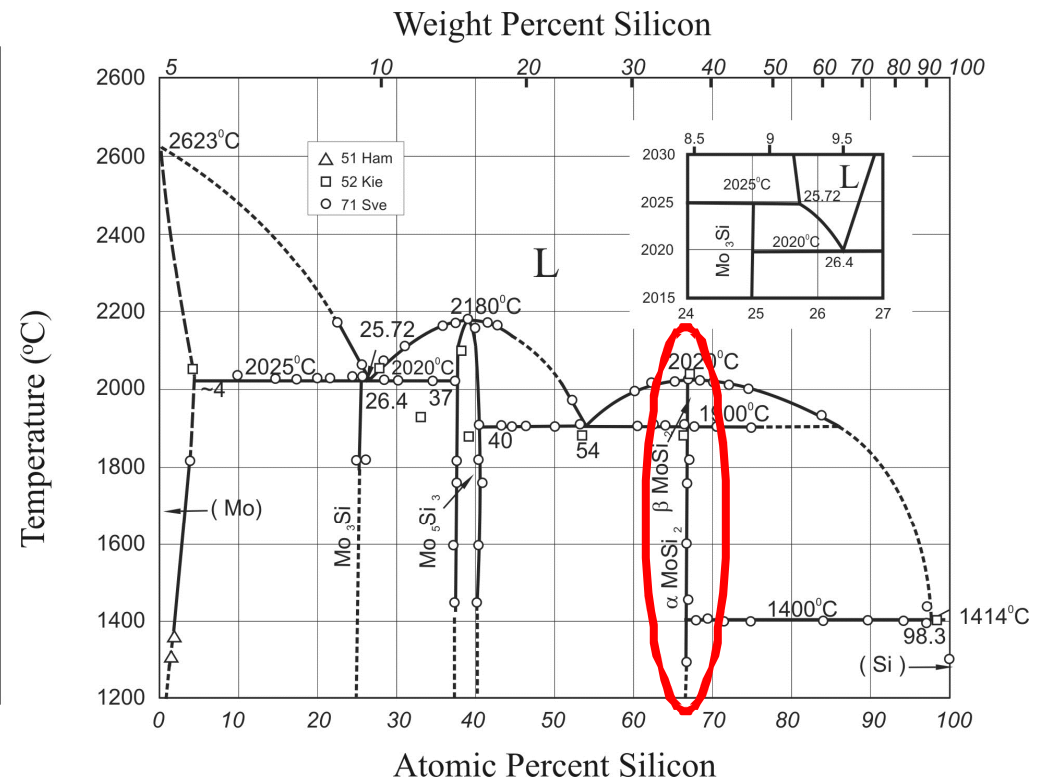
D.M. Dimiduk, J.H. Perepezko, MRS Bulletin, pp. 639-645, 2003

Novos Materiais – Aplicação em Ultra-Altas Temperaturas



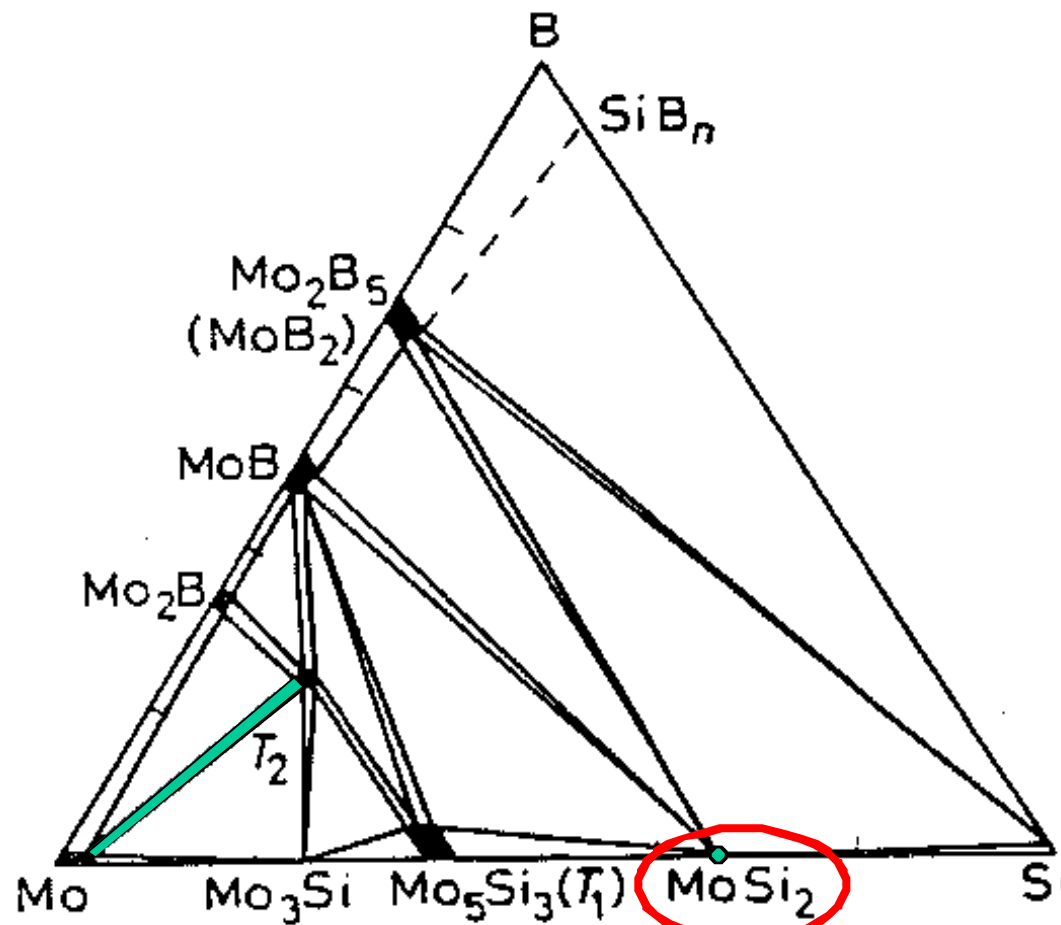
From the brochure “Kanthal Super”

www.kanthal.com



A.B. Gockhale, G.J. Abbaschian, *J. Phase Equilib.* 12(4)
(1991) 493-498

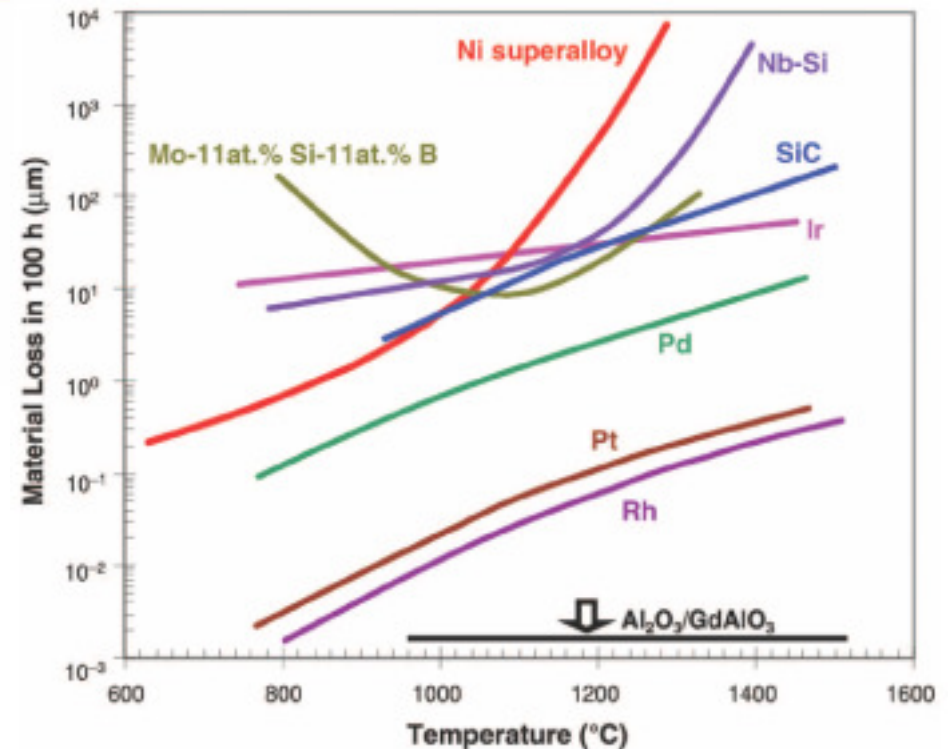
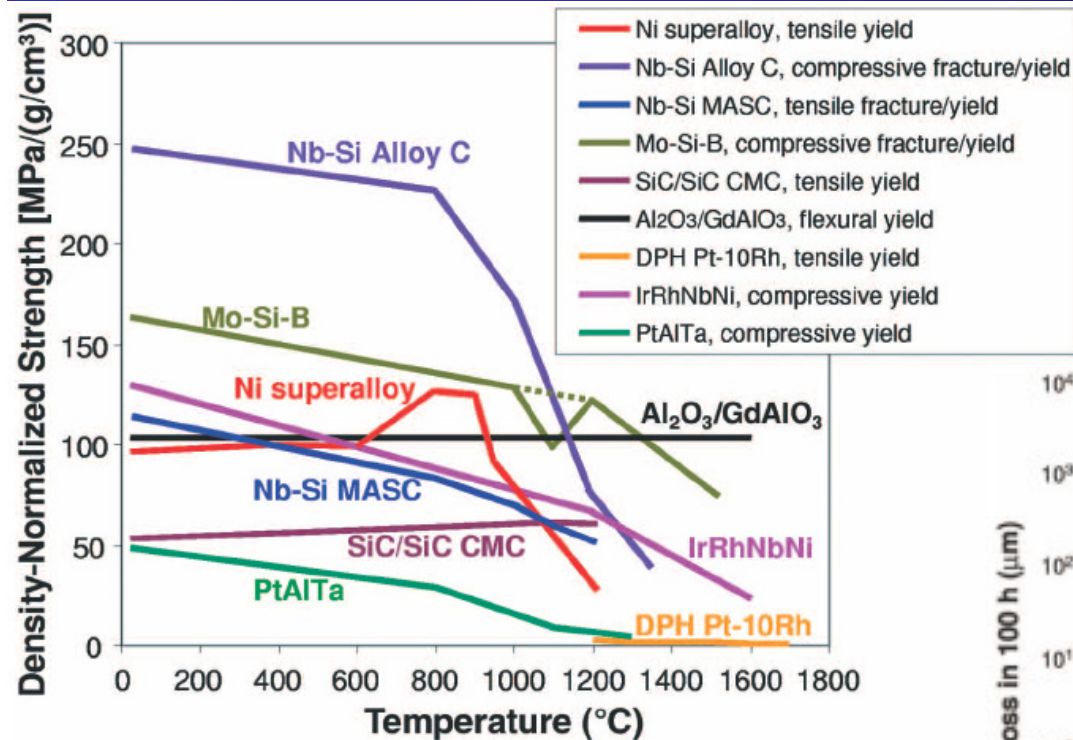
Novos Materiais – Aplicação em Ultra-Altas Temperaturas



Isothermal Section at 1600°C.

H. Nowotny et al., *Monatsh. Chem.* 88 (1957) 180-192.

Novos Materiais – Aplicação em Ultra-Altas Temperaturas



J.C. Zhao, J.H. Westbrook, MRS Bulletin, pp. 622-630, 2003

Conclusão: IPCC (Intergovernmental Panel on Climate Change)

<http://www.ipcc.ch/>



The screenshot shows the IPCC website homepage. At the top, there is a navigation bar with the IPCC logo, the text "INTERGOVERNMENTAL PANEL ON climate change", and links for "Languages", "IPCC web pages", and a "Search" box. Below the navigation bar is a large banner image of sand dunes with camels, titled "Moving towards the Fifth Assessment Report (AR5)". To the left of the banner is a sidebar menu with links: Home, Organization, Working Groups / Task Force, Activities, Calendar of Meetings, Meeting Documentation, News and Events, Publications and Data, Presentations and Speeches, Press Information, IPCC Scholarship Programme, Links, and Contact. To the right of the banner is a red box announcing the "IPCC 32nd Plenary Session Busan, Republic of Korea" from 11-14 October 2010. Below this, there is a section for "Plenary Session NEW" with links for "Inf. 9 - Draft Guidance Notes for Lead Authors of the IPCC Fifth Assessment Report on Consistent Treatment of Uncertainties" and "Inf. 10 - Draft Memorandum of Understanding between IAMC And IPCC Working Groups". At the bottom, there is a blue box for "IPCC Fifth Assessment Report (AR5)" with links for "AR5 Outline and Reference Material" and "AR5 Authors".

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Moving towards the Fifth Assessment Report (AR5)

IPCC Fifth Assessment Report (AR5)

IPCC 32nd Plenary Session
Busan, Republic of Korea
11-14 October 2010

Dr. Pachauri's opening statement
Inv. letter for FPs/MFAs
Inv. letter for Organizations

Plenary Session NEW
Inf. 9 - Draft Guidance Notes for Lead Authors of the IPCC Fifth Assessment Report on Consistent Treatment of Uncertainties
Inf. 10 - Draft Memorandum of Understanding between IAMC And IPCC Working Groups

AR5 Outline and Reference Material
Key documents approved at the 31st Session

AR5 Authors
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Conclusão: Publicações Diversas



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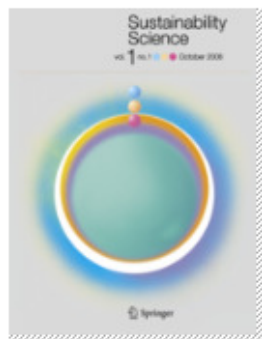
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SPECIAL FEATURE: ORIGINAL ARTICLE

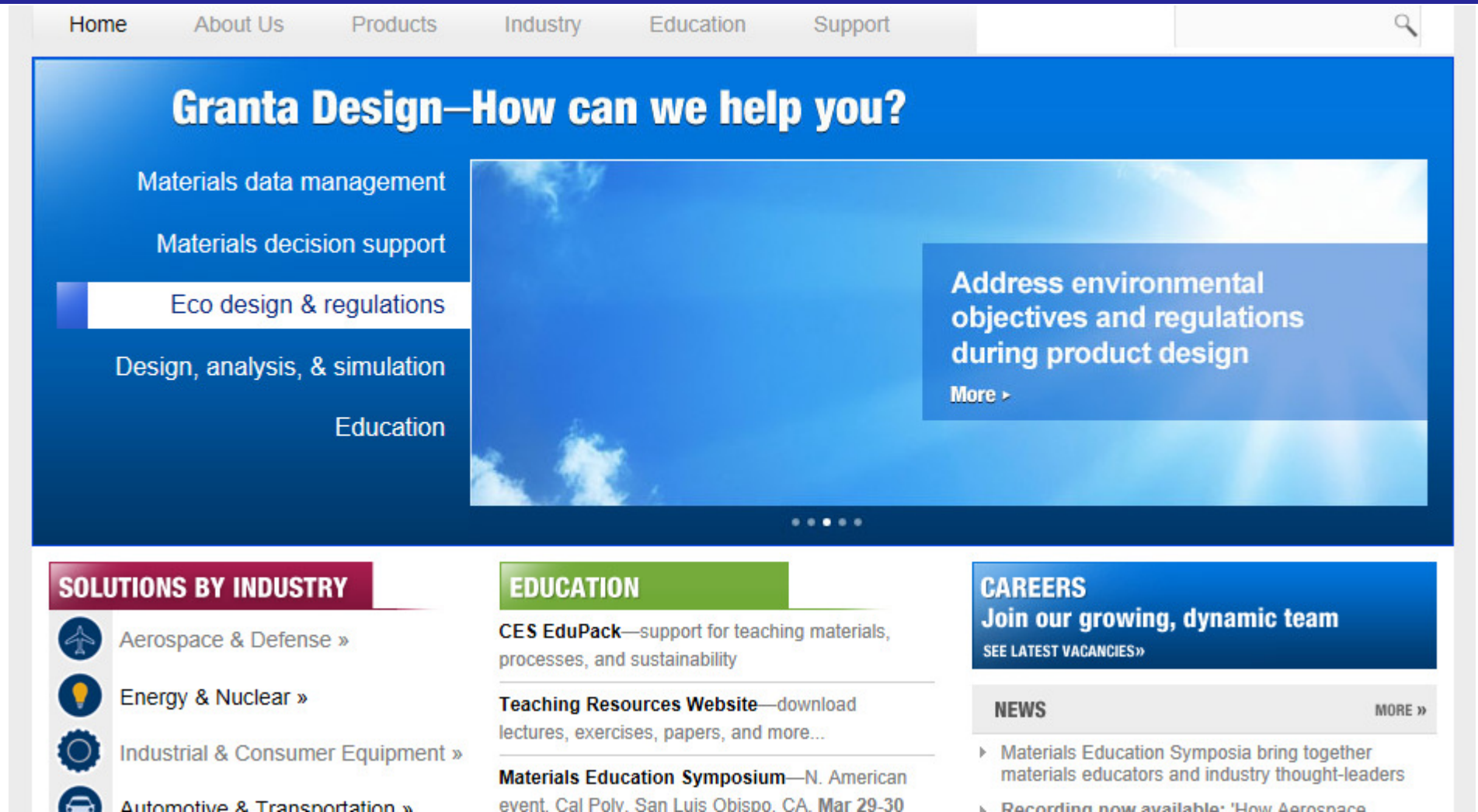
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Daniel J. Lang, Arnim Wiek, Matthias Bergmann, Michael Stauffacher, Pim Martens, Peter Moll, Mark Swilling and Christopher J. Thomas

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Conclusão: Publicações Diversas

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Conclusão

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