GENERAL INTRODUCTION: RPV

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- RPV DESIGN
- RPV MATERIALS
- RPV MANUFACTURING TECHNOLOGY
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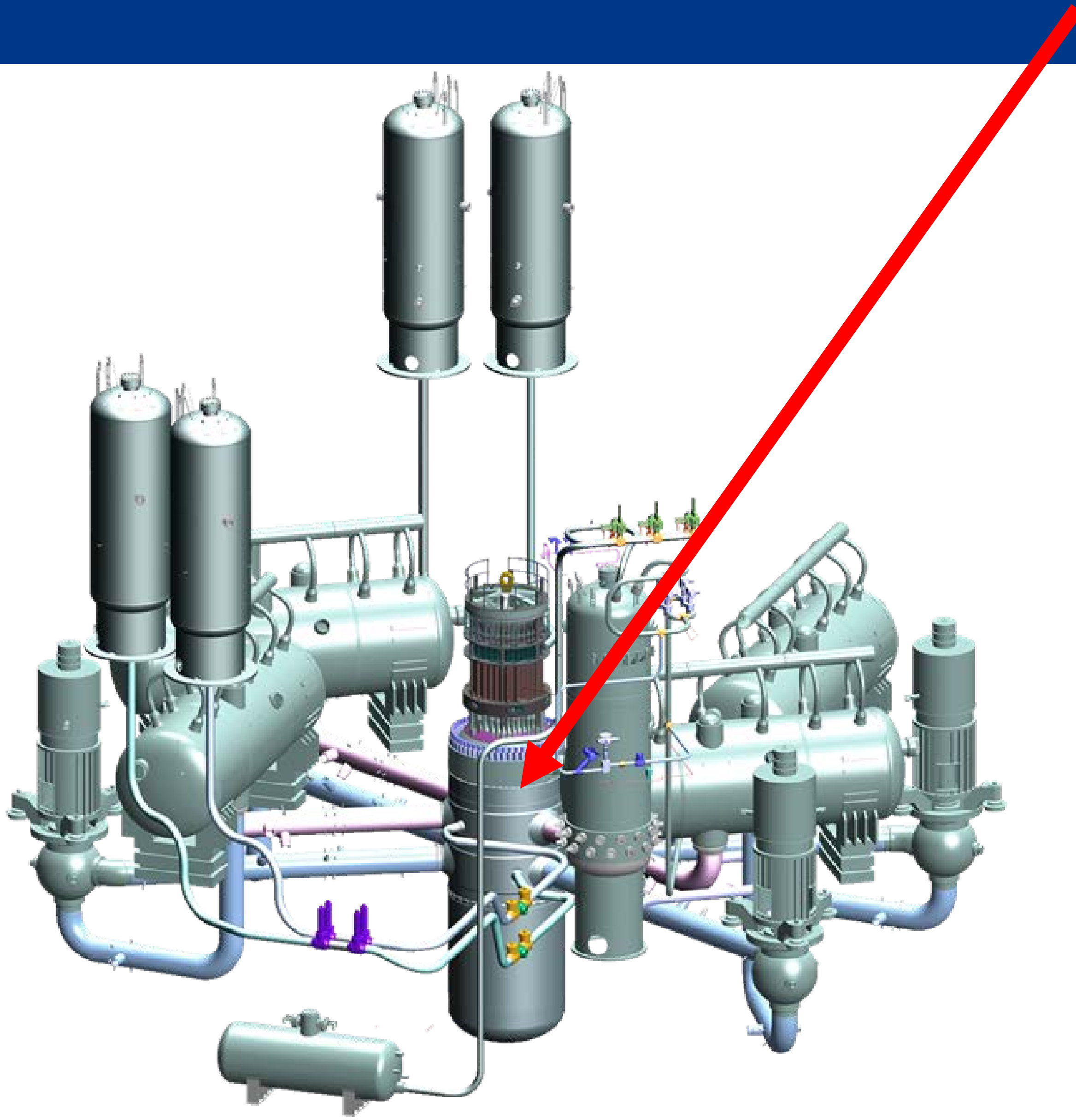
INTRODUCTION

REACTOR PRESSURE VESSEL



INTRODUCTION

❑ REACTOR PRESSURE VESSELS

- NUCLEAR REACTION IS REALIZED INSIDE RPV = HEART OF THE NPP
  - THUS, RPV IS THE MOST IMPORTANT COMPONENT OF THE WHOLE NPP
- RPV CONTAINS ALL NUCLEAR FISSION MATERIALS
  - THEIR PRACTICALLY 100 % INTEGRITY MUST BE ASSURED
- RPV PRACTICALLY CANNOT BE REPLACED
  - DETERMINES LIFETIME OF THE WHOLE NPP

INTRODUCTION

NEUTRONS	MODERATOR	COOLANT	RPV/TUBES	TYPE
THERMAL	H_2O	H_2O	RPV	**PWR** **VVER**
				BWR
	D_2O	D_2O	TUBES	CANDU
	D_2O	CO_2	RPV/TUBES	HWGCR = A1
	GRAFIT	H_2O	TUBES	RBMK
		He	TNR	HTR
FAST	-	Na/Pb+Bi	RV	FBR

VVER = WWER IS PWR DESIGNED IN ACCORDANCE WITH RUSSIAN CODES

WWER = WATER-WATER ENERGETICAL REACTOR

ВОДО-ВОДЯНЫЙ ЭНЕРГЕТИЧЕСКИЙ РЕАКТОР

INTRODUCTION

- RPV DESIGN MUST BE PERFORMED WITH RESPECT TO:
  - OPERATION CONDITIONS OF REACTOR AND NPP
    - REQUIREMENTS TO DESIGN OF ACTIVE CORE AND ALL NPP
    - OPERATION PRESSURE AND TEMPERATURE
    - REQUIRED LIFETIME
  - CURRENT CODES AND STANDARDS
    - IN PRINCIPLE: ASME (KTA, RCC-M, JSME) - PNAEG
  - TECHNOLOGICAL POSSIBILITIES
    - EXISTING/ALLOWED MATERIALS AND MANUFACTURING BASES
  - TRANSPORT REQUIREMENTS AND POSSIBILITIES
    - LOCATION/SITE OF NPP AND TRANSPORT POSSIBILITIES BETWEEN MANUFACTURER AND NPP

INTRODUCTION

- **RPV MUST ENSURE LONG TERM AND SAFE OPERATION UNDER CONDITIONS OF HIGH PRESSURE, TEMPERATURE AND RADIATION**

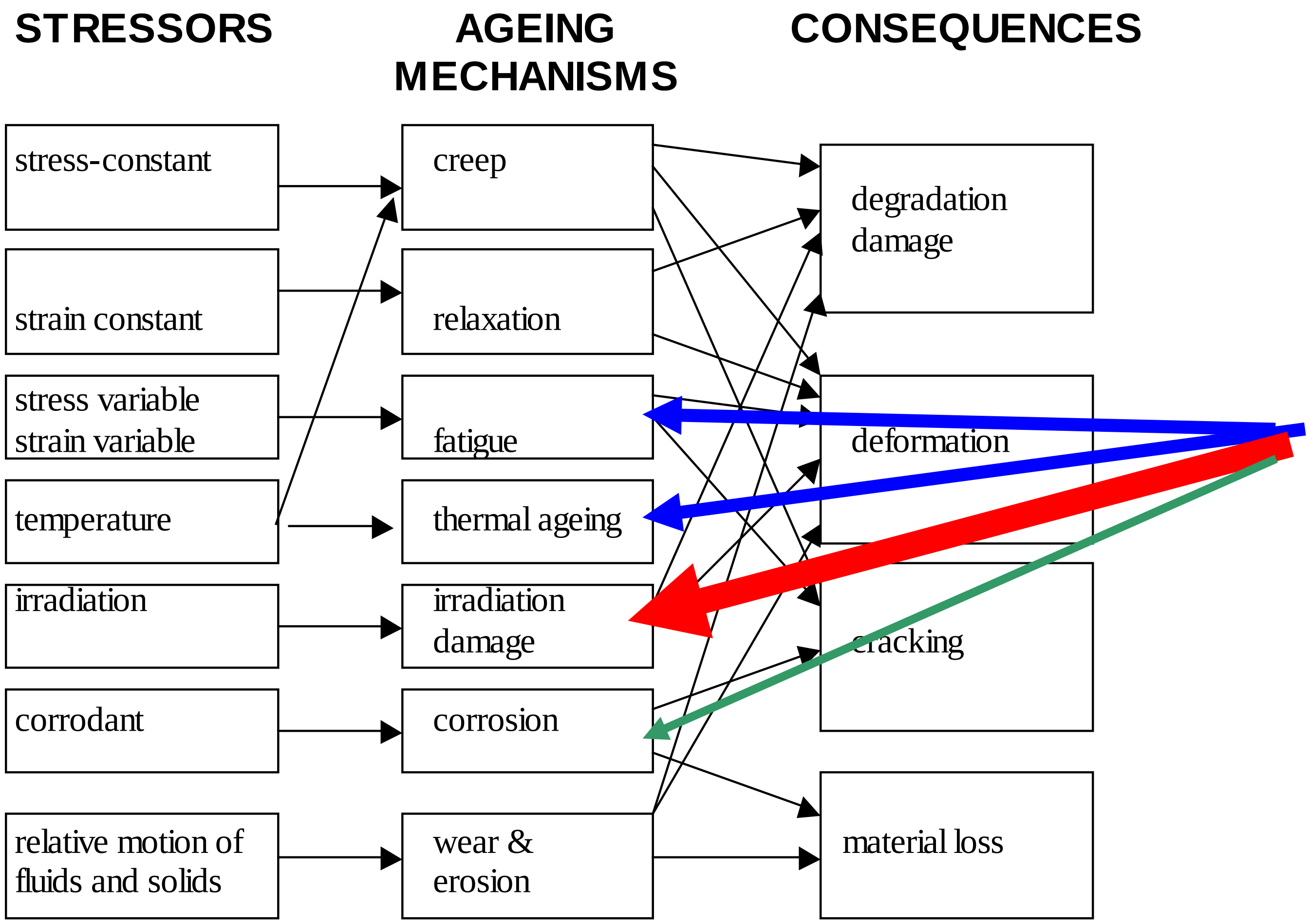
- **RPV MUST WITHSTAND EFFECTS OF SEVERAL STRESSORS RESULTING FROM OPERATING CONDITIONS**

PRESSURE: 12 – 18 MPa
TEMPERATURE: 270 – 325 °C

NEUTRON FLUENCE: 10^{18} – 2×10^{24} m^{-2}

(En > 1 MeV)

INTRODUCTION



Ageing factors, basic ageing mechanisms and possible consequences. A major stressor in an ageing structure is time itself. (For example, in the embrittlement of rubber and plastic materials in components)

INTRODUCTION

- HYDROGEN EFFECTS:

  - HYDROGEN EMBRITTLEMENT
    - USUALLY DUE TO DIFFUSION OF HYDROGEN DURING CORROSION – DECREASE IN FRACTURE TOUGHNESS
  - DELAYED FRACTURE
    - DUE TO ACCUMULATION OF HYDROGEN ON GB etc.
  - HYDROGEN FLAKES
    - HIGH CONTENT OF HYDROGEN THAT WAS NOT REMOVED BY VACUUM POURING AND/OR BY ANTIFLAKE ANNEALING

INTRODUCTION

- RPV LIFETIME DEPENDS PRACTICALLY ON RESISTANCE AGAINST BRITTLE/NON-DUCTILE FAILURE THAT IS GOVERNED BY RADIATION DAMAGE OF RPV BELTLINE MATERIALS
- THUS RADIATION EMBRITTLEMENT IS THE MOST IMPORTANT RPV DAMAGE MECHANISM
- RADIATION EMBRITTLEMENT TOGETHER WITH MATERIAL INITIAL PROPERTIES DETERMINES RPV LIFETIME

RPV DESIGN

RPV DESIGN

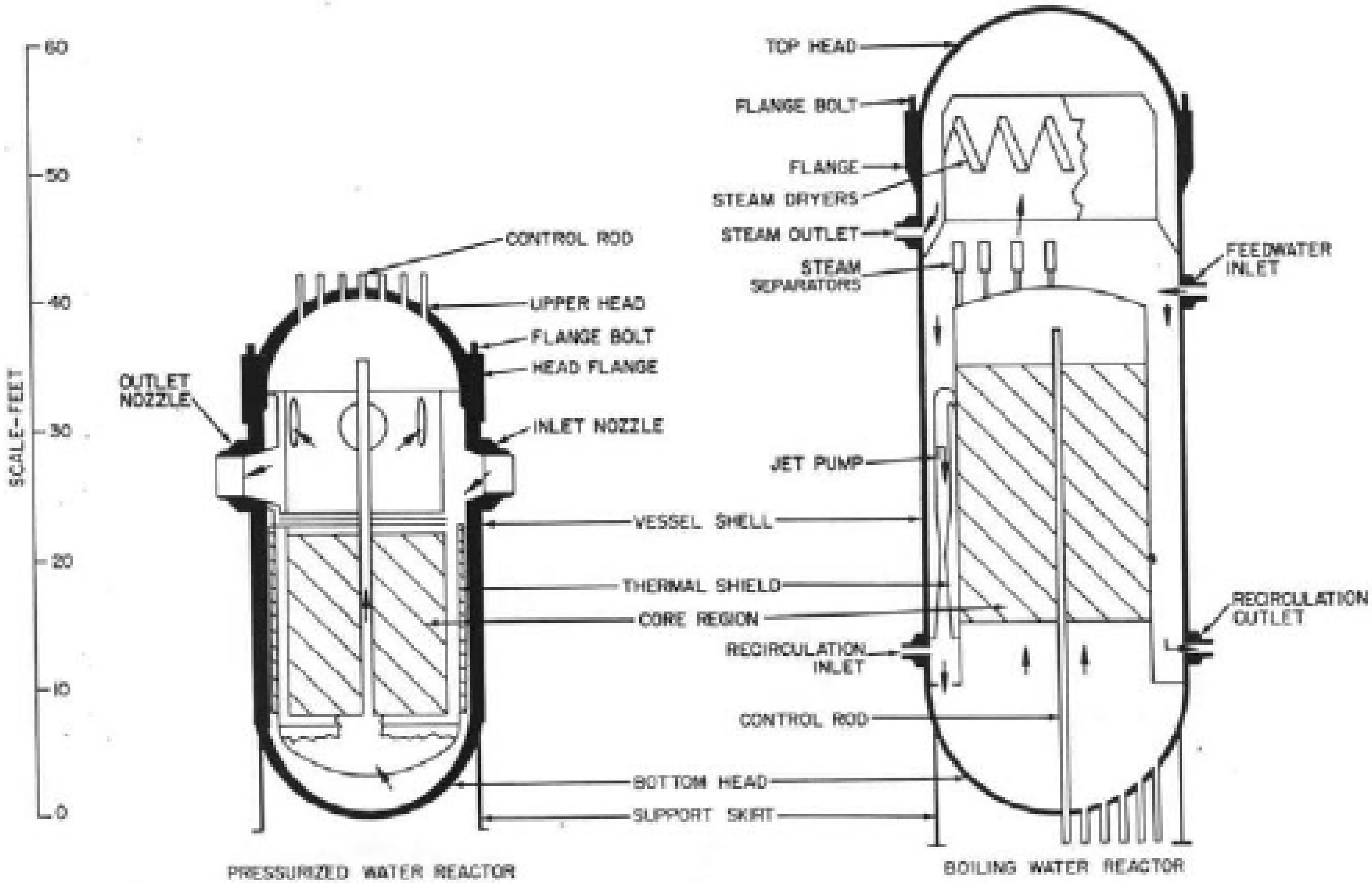


FIG. 6. Comparison of PWR and BWR RPVs with the same output.

RPV DESIGN

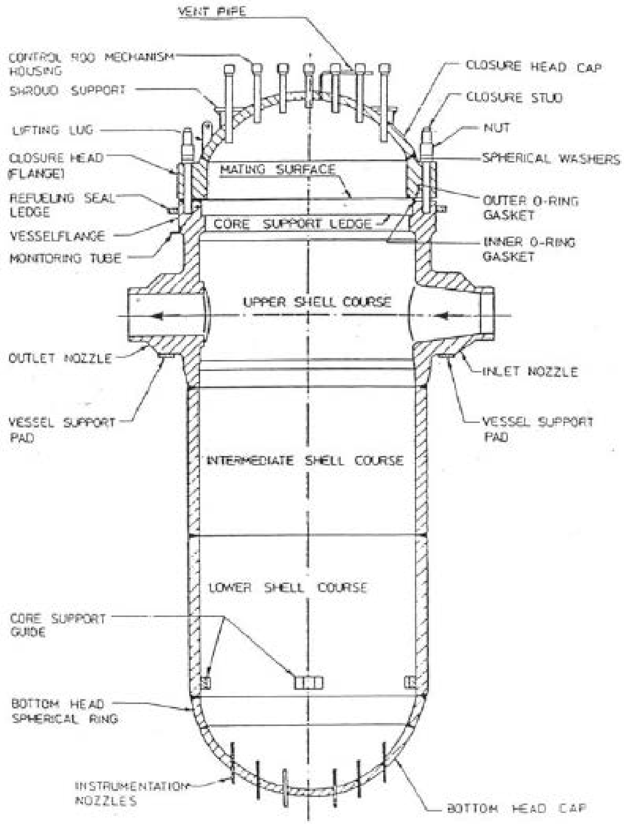


FIG. 2. Typical Westinghouse RPV.

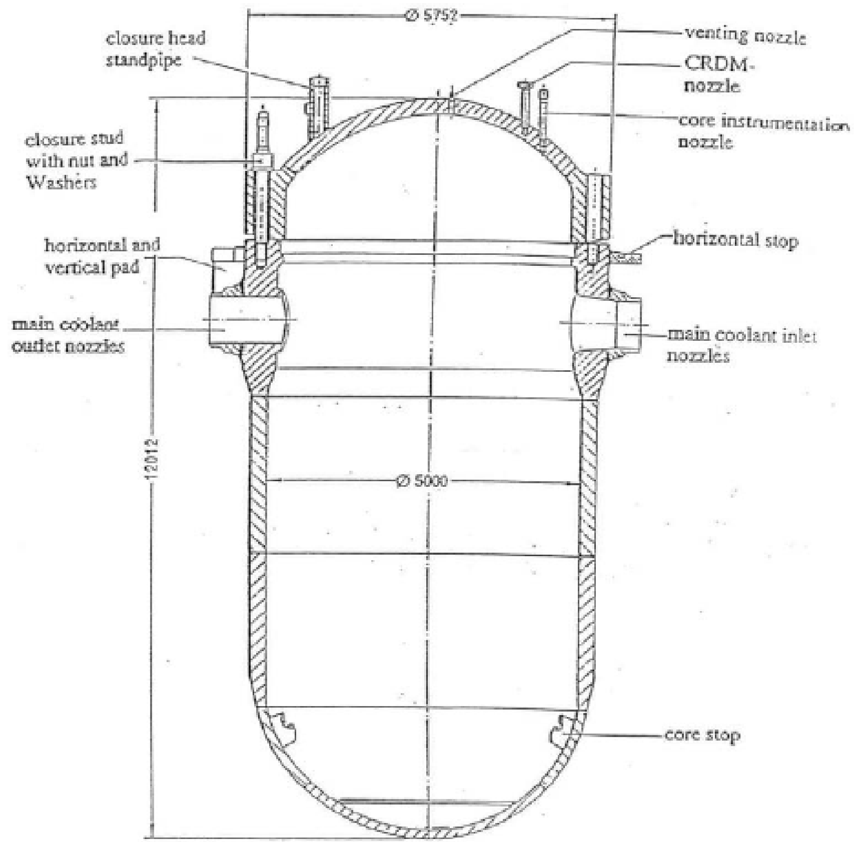
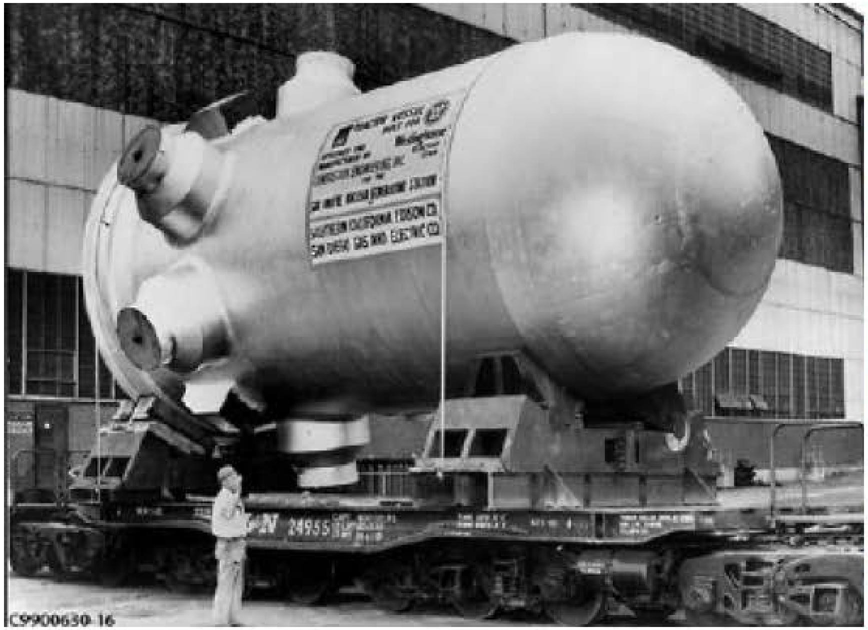


FIG. 4. A typical Siemens/KWU RPV for a 1300 MWe plant.

RPV DESIGN

TYPICAL PWR RPV



WWER-440 RPV

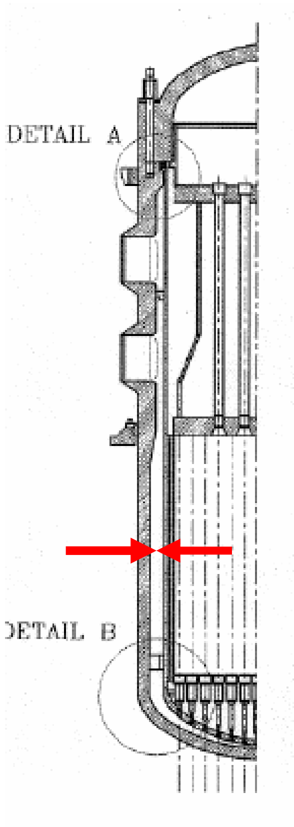
- Vessels may weigh up to 800t with wall thickness up to ~330mm.

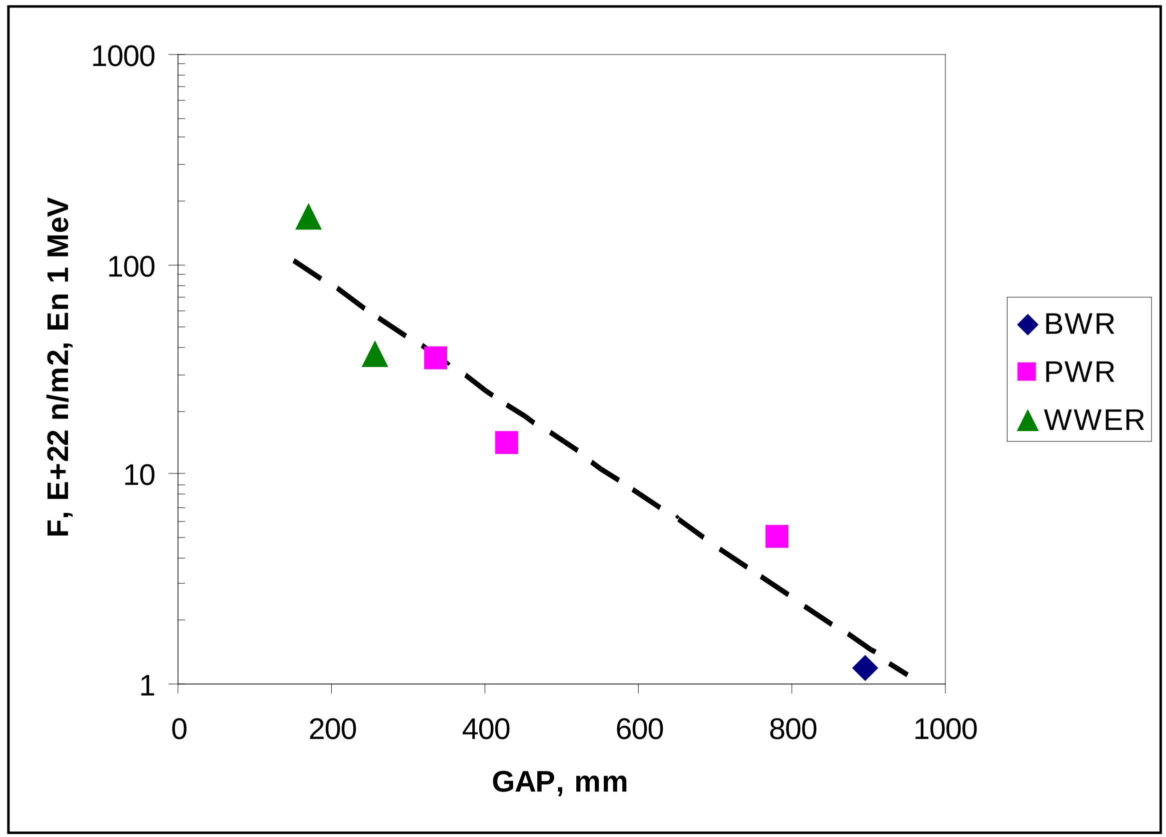
RPV DESIGN

. OPERATING LIFETIME FLUENCE FOR WWERs, PWRs AND THE BWR

REACTOR TYPE	**FLUX, $n.m^{-2}.sec^{-1}$ (E>1MeV)**	**LIFETIME* FLUENCE, $n.m^{-2}$ (E>1MeV)**
WWER-440 core weld	1.2×10^{15}	1.1×10^{24}
WWER-440 maximum	1.5×10^{15}	1.6×10^{24}
WWER-1000	$3\text{-}4 \times 10^{14}$	3.7×10^{23}
PWR (W)	4×10^{14}	4×10^{23}
PWR (B&W)	1.2×10^{14}	1.2×10^{23}
BWR	4×10^{13}	4×10^{22}

Design neutron fluence as a function of water gaps/ neutron reflector thickness





RPV MATERIALS

RPV MATERIALS

- ONLY MATERIALS THAT ARE DEFINED IN CODES CAN BE USED FOR MANUFACTURING OF RPVs
- USE OF A NEW MATERIAL AND/OR MODIFICATION MUST BE SUPPLIED BY A WIDE PROGRAMME OF TESTING (MATERIAL QUALIFICATION PROGRAMME) AND APPROVED BY APPROPRIATE INSTITUTION
- DIFFERENT TYPE OF MATERIALS ARE USED FOR WESTERN PWR/BWR AND WWER

RPV MATERIALS

Material specification	Used from	Steel type	Heat treatment	Rp 0,2/RT (minimum MPa)	Rm/RT (MPa)	A5/RT (minimum %)
PLATES						
A 212B	1955	C-Mn	HR or N	262	483-586	22
A 302B	1960	Mn-Mo	Q/T or N/T	345	552-689	20
A 302B (modified)	1965	Mn-Mo-Ni	Q/T	345	552-689	20
A 533 Gr.B Class 1	1967	Mn-Mo-Ni	Q/T	345	620-793	18
20MnMoNi55	1974	Mn-Mo-Ni	Q/T	440	590-740	18
15Kh2MFA	1960	Cr-Mo-V	Q/T	431	539-735	14
FORGINGS						
A 105	1955	C-Mn	A or N	248	483 min.	22
A 182	1956	Mn-Mo	A or N/T	276	483 min.	22
A 350-82	1956	Mn-Ni	A or N/T	207	414 min.	22
A 336 (modified)	1965	Mn-Mo-Ni	Q/T	345	550 min.	20

RPV MATERIALS

A 508 Class 2	1961	Mn-Mo-Ni	Q/T	345	550-725	18
A 508 Class 3	1965	Mn-Mo-Ni	Q/T	345	550-725	18
20MnMoNi55	1974	Mn-Mo-Ni	Q/T	440	590-740	18
22NiMoCr37	1980	Mn-Mo-Ni	Q/T	440	590-740	18
16 MN D5	1978	Mn-Mo-Ni	Q/T			
15Kh2MFA	1960	Cr-Mo-V	Q/T	431	539-735	14
15Lh2NMFA(A)	1975	Cr-Ni-Mo-V	Q/T	490	608	15
15Kh2NMFA Class 1	2000	Cr-Ni-Mo-V	Q/T	490	608	15
15Ch2V2FA	2005	Cr-V	Q/T	490	608	15
15Kh2MFA-A mod.A	2009	Cr-Mo-V	Q/T	490	608	15

HR = hot rolled, A = annealed, N = normalized,

N/T = normalized and tempered, Q/T = quenched and tempered

RPV MATERIALS

Designation	Elements (mass %)													
	C	Si	Mn	P	S	Cr	Mo	Ni	V	Cu	Al	Sn	N	As
ASTM A 302B	max 0.25	0.15 0.30	1.15 1.50	max 0.035	max 0.040		0.45 0.60							
ASTM A 336, Code Case 1236	0.19 0.25	0.15 0.35	1.10 1.30	max 0.035	max 0.035	max 0.35	0.50 0.60	0.40 0.50						
ASME A 508 Cl 2 (1971)	max 0.27	0.15 0.35	0.50 0.90	max 0.025	max 0.025	0.25 0.45	0.55 0.70	0.50 0.90	max 0.05					
ASME A 533 GR B (1971)	max 0.25	0.15 0.30	1.15 1.50	max 0.035	max 0.040		0.45 0.60	0.40 0.70						
ASME A 508 Cl 2 (1989)[a]	max 0.27	0.15 0.40	0.50 1.00	max 0..015	max 0.015	0.25 0.45	0.55 0.70	0.50 1.00	max 0.05	max 0.15				
ASME A 508 Cl 3 (1989)[a]	max 0.25	0.15 0.40	1.20 1.50	max 0.015	max 0.015	max 0.25	0.45 0.60	0.40 1.00	max 0.05					
ASME A 533Gr B (1989)	max 0.25	0.15 0.40	1.15 1.50	max 0.035	max 0.040		0.45 0.60	0.40 0.70						
16 MnD5 RCC-M 2111[b]	max 0.22	0.10 0.30	1.15 1.60	max 0.02	max 0.012	max 0.25	0.43 0.57	0.50 0.80	max 0.01	max 0.20	max 0.040			
18 MnD5 RCC-M 2112 (1988)	max 0.20	0.10 0.30	1.15 1.55	max 0.015	max 0.012	max 0.25	0.45 0.55	0.50 0.80	max 0.01	max 0.20	max 0.040			
20 Mn Mo Ni 5 5 (1983, 1990)[c,d]	0.17 0.23	0.15 0.30	1.20 1.50	max 0.012	max 0.008	max 0.20	0.40 0.55	0.50 0.80	max 0.02	max 0.12[e]	0.010 0.040	max 0.011	max 0.013	max 0.036
22 Ni Mo Cr 3 7 (1991)[f]	0.17 0.23	0.15 0.35	0.50 1.00	max 0.012	max 0.008	0.25 0.50	max 0.60	0.60 1.20[g]	max 0.02	max 0.12[e]	0.010 0.050	max 0.011	max 0.013	max 0.036

[a] Supplementary Requirement S 9.1(2) and S 9.2 for A 508 Cl 2 and A508 Cl 3.
[b] Forgings for reactor shells outside core region. Restrictions for core region (RCC-M 2111): $S \leq 0.008$, $P \leq 0.008$, $Cu \leq 0.08$.
[c] VdTÜV Material Specification 401, Issue 1983.
[d] KTA 3201.1 Appendix A, Issue 1990.
[e] Cu-Content for RPV (core region) shall be ≤0.10%.
[f] According to Siemens/KWU under consideration of SR 10 (MPA Stuttgart).
[g] For flanges and tube sheets the Ni content shall be ≤1.40%.

RPV MATERIALS

Ocel	Země	C	Mn	Si	P	S	Cr	Ni	Mo	V
A-508 Gr.3Cl.1	USA	0,15-0,25	1,20-1,50	0,15-0,35	max. 0,025	max. 0,025	max. 0,25	0,40-1,00	0,45-0,60	max. 0,05
16 MND 5	Francie	0,16	1,38	0,24	0,005	0,008	0,17	0,70	0,50	0,005
22MnMoNi55	Německo	0,17-0,23	1,20-1,50	0,15-0,30	max. 0,015	max. 0,015	max. 0,02	0,45-0,80	0,45-0,60	max. 0,02
15Ch2MFA	Rusko	0,13-0,18	0,30-0,60	0,17-0,37	max. 0,025	max. 0,025	2,50-3,00	max. 0,40	0,60-0,80	0,25-0,35
15Ch2NMFA	Rusko	0,13-0,18	0,30-0,60	0,17-0,37	max. 0,020	max. 0,020	1,80-2,30	1,00-1,50	0,50-0,70	max. 0,10

REACTOR PRESSURE VESSELS-4

GUARANTEED MECHANICAL PROPERTIES OF LWR RPV MATERIALS*

MATERIAL	20 °C				350 °C				T_{k0} (1) RT_{NDT} (2
	$R_{p0.2}$	R_m	A_5	Z	$R_{p0.2}$	R_m	A_5	Z	
	[MPa]	[MPa]	[%]	[%]	[MPa]	[MPa]	[%]	[%]	[°C]
15Kh2MFA - base metal	431	519	14	50	392	490	14	50	0 (1)
- A/S weld metal	392	539	14	50	373	490	12	45	20 (1)
15Kh2NMFA - base metal	490	608	15	55	441	539	14	50	-10 (1)
15Kh2NMFAA – base metal	490	608	15	55	441	539	14	50	-25 (1)
- A/S weld metal	422	539	15	55	392	510	14	50	0 (1)
A 533-B, Cl.1	345	551	18	-	285	-	-	-	-12 (2)
A 508, Cl.3	345	551	18	38	285	-	-	-	-12 (2)

CURRENT RPV MATERIALS

REQUIREMENTS FOR BELTLINE RPV MATERIALS

MATERIAL	P	S	Cu	As	Sb	Sn	P+Sb+Sn	Co
GENERATION II								
15Kh2MFAA	0.012	0.015	0.08	0.010	0.005	0.005	0.015	0.020
15Kh2NMFAA	0.010	0.012	0.08	0.010	0.005	0.005	0.015	0.020
A 533-B, Class 1	0.012	0.015	0.10					
16 MnD 5	0.008	0.008	0.08					
20 MnMoNi 55	0.012	0.012	0.10	0.036		0.011		
GENERATION III								
SA-508 Grade 3 Class 1 SA 533-B	0.010	0.010	**0.03**					
16 MnD 5	0.008	0.008	0.08					
15Kh2NMFAA	0.010	0.012	0.08	0.010	0.005	0.005	0.015	

Element contents in mass %

RPV MATERIALS

- **RADIATION DAMAGE VALUE DEPENDS ON:**
  - **NEUTRON FLUENCE (DEPENDS ON REACTOR OUTPUT AND WATER MODERATOR THICKNESS)**
    - **THRESHOLD VALUES**
      - **0,5 MeV FOR VVER REACTORS**
      - **1 MeV FOR PWR REACTORS**
  - **IRRADIATION RATE, i.e. NEUTRON FLUX (FLUX RATE EFFECT)**
  - **IRRADIATION TEMPERATURE**
  - **STEEL TYPE - CARBON STEEL, LOW-ALLOY STEEL, MARAGING..**
  - **CONTENT OF IMPURITIES – P, Cu, …., As, Sb, Sn,…**
  - **CONTENT OF ALLOYING ELEMENTS – Ni, Mn, …**
- **More information -**
- Irradiation effects on RPV: microstructure & mechanical properties

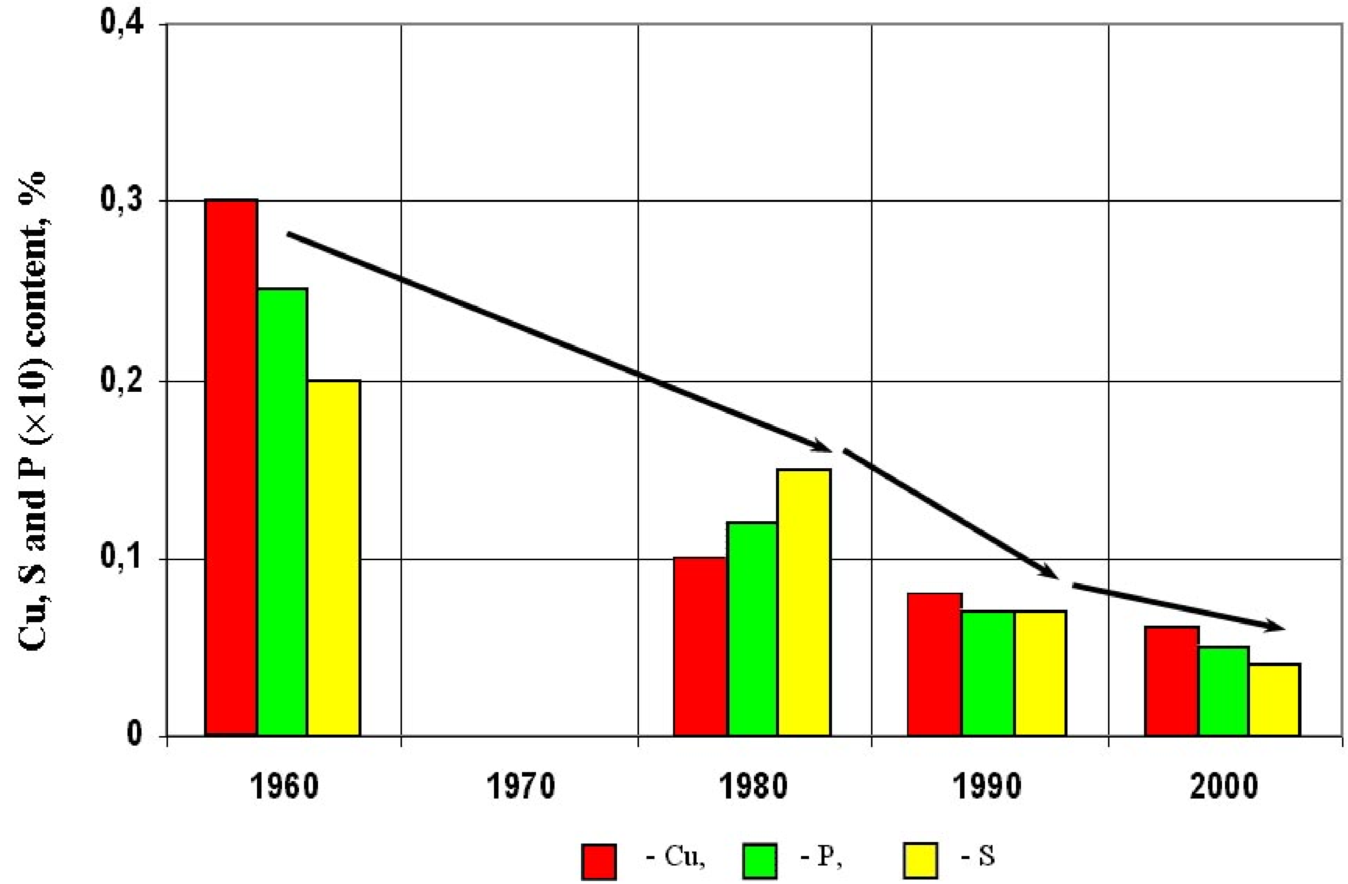
  L. Malerba

RPV MATERIALS

- RPV – 1st generation:
  - mostly welds with high content of Cu, P
  - Western PWR
    - High content of Cu from weld wire coatings (up to 0.40 mass %, nonhomogenous distribution)
    - Medium/low content of P
  - WWER
    - High content of P from welding flux (up to 0.045 %)
    - medium/low content of Cu)

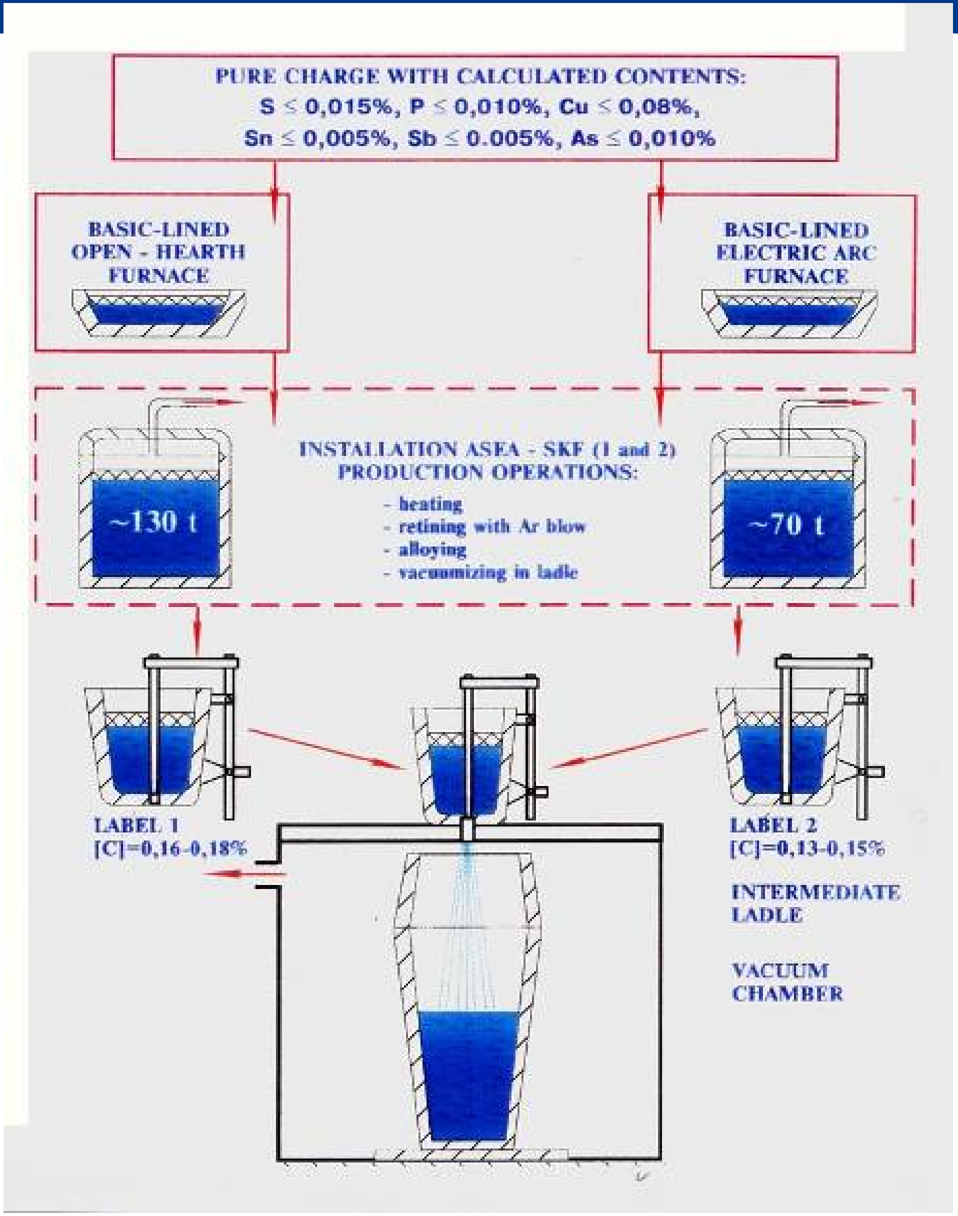
RPV MATERIALS

Trend of decrease of important impurities in RPV steels



RPV MANUFACTURING TECHNOLOGY

RPV MANUFACTURING TECHNOLOGY



RPV MANUFACTURING TECHNOLOGY

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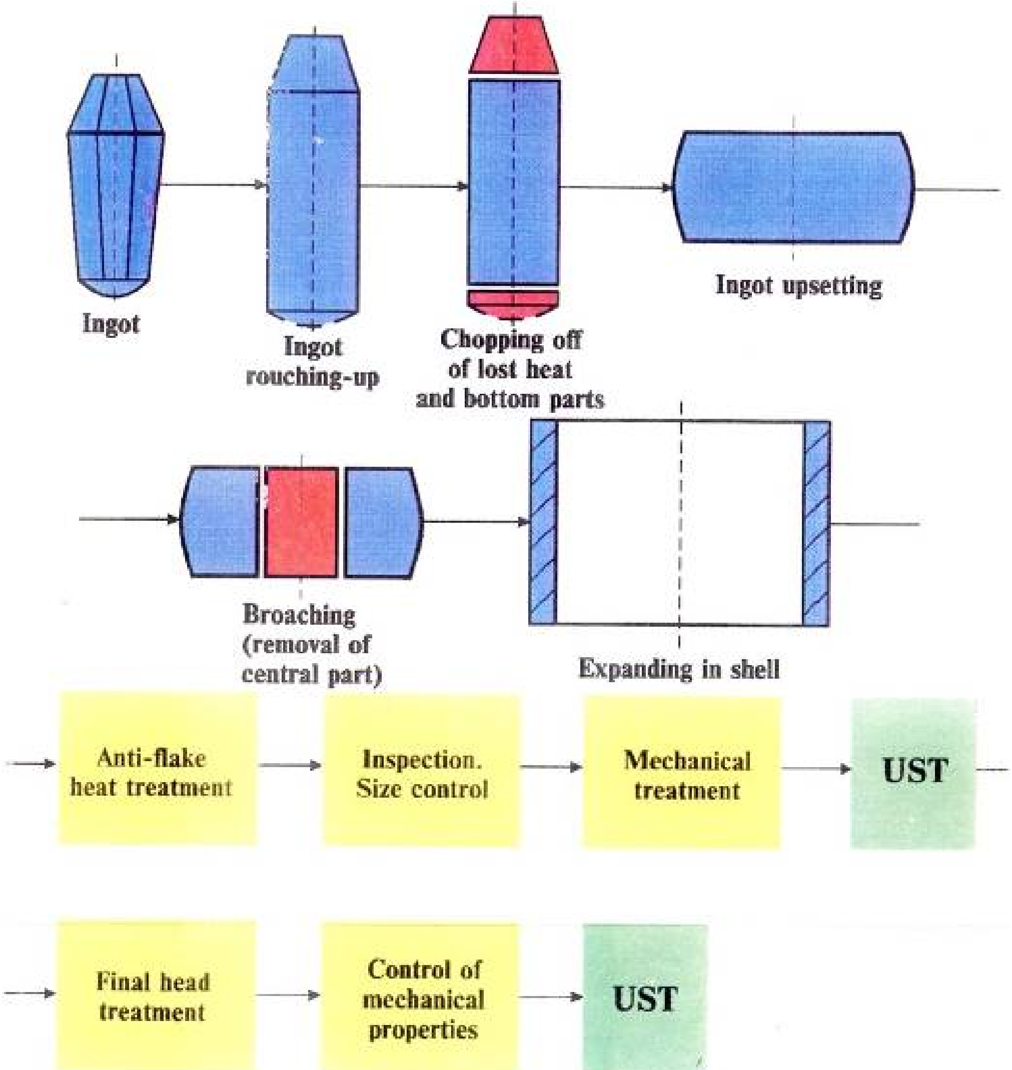

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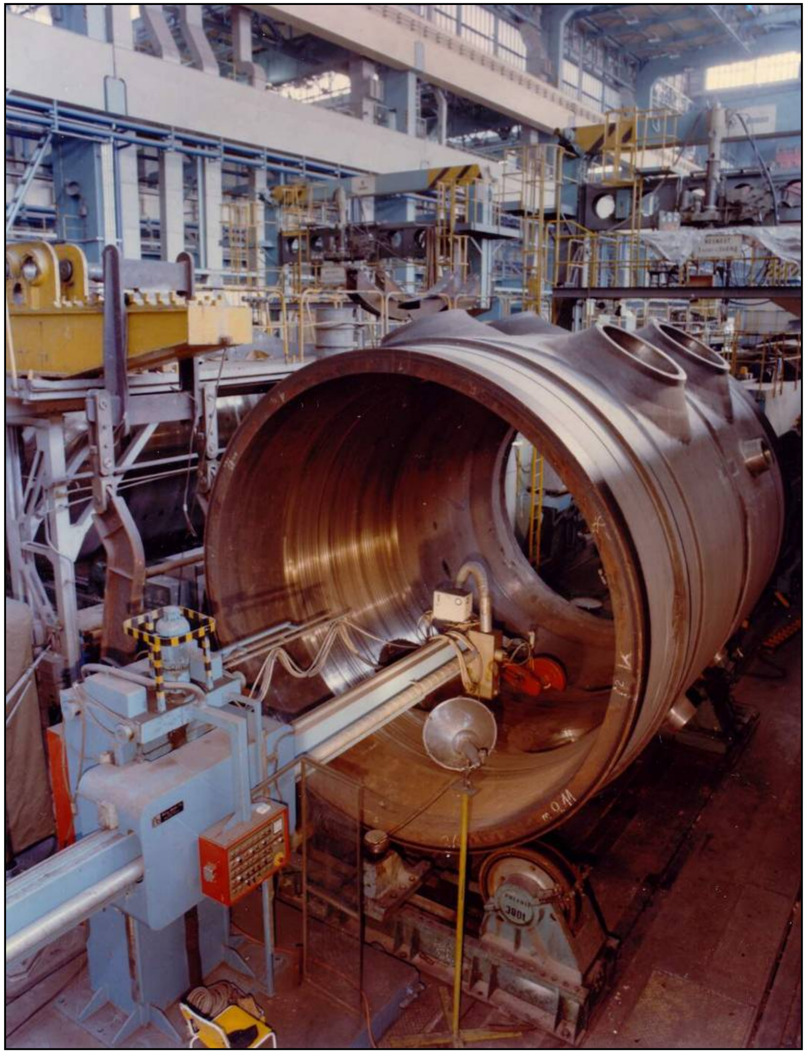

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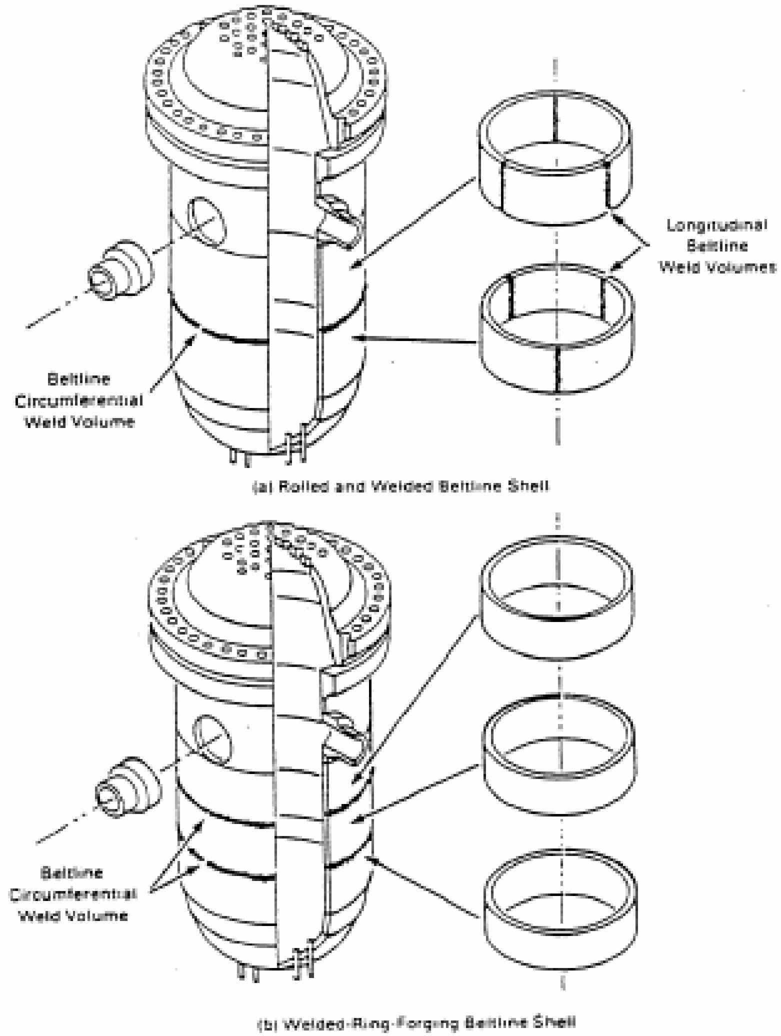
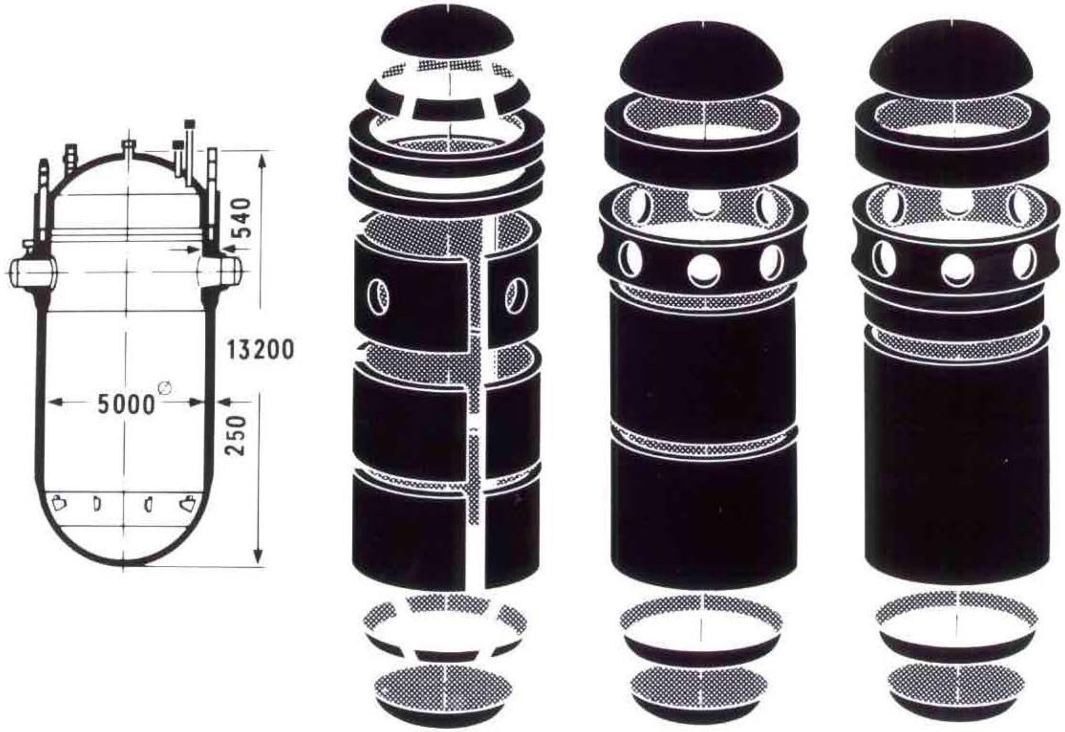


Fig. 9. Fabrication configuration of PWR beltline shells.

RPV MANUFACTURING TECHNOLOGY

RPV design developments



- ❑removal of axial welds
- ❑ decrease of number of circumferential welds (ISI, lowering of cost)
- ❑ removal od welds in beltline region

RPV MATERIAL PROPERTIES

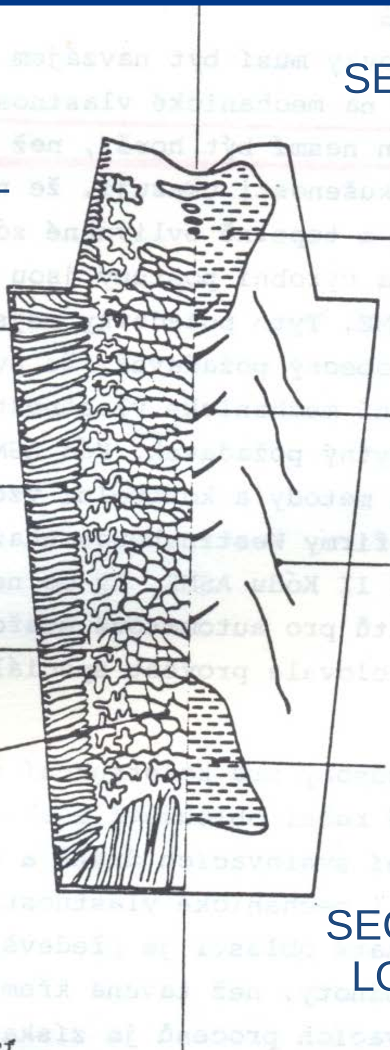
RPV MATERIAL PROPERTIES

FINE EQUIAXIAL CRYSTALS

COLUMN DEDRITIC

BRANCH DENDRITIC

EQUIAXIAL GROWTH OF CRASTALS



POSITIVE SEGREGATION RICH WITH ALLOYING ELEMENTS

V-TYPE SEGREGATION

A-TYPE SEGREGATION

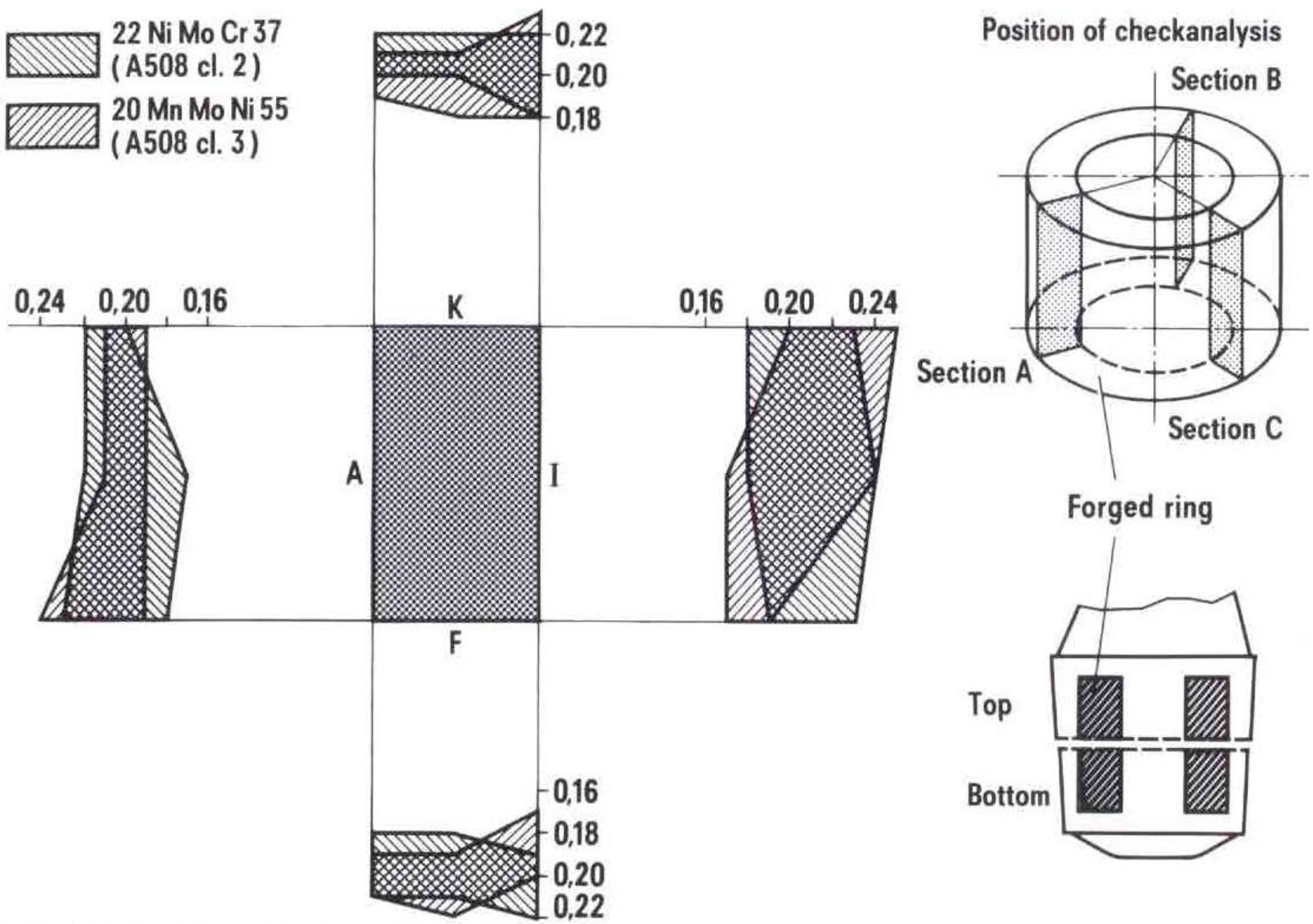
NEGATIVE SEGREGATION WITH LOWER ALLOYING CONTENTS

SOLIFICATION

SEGREGATIONS

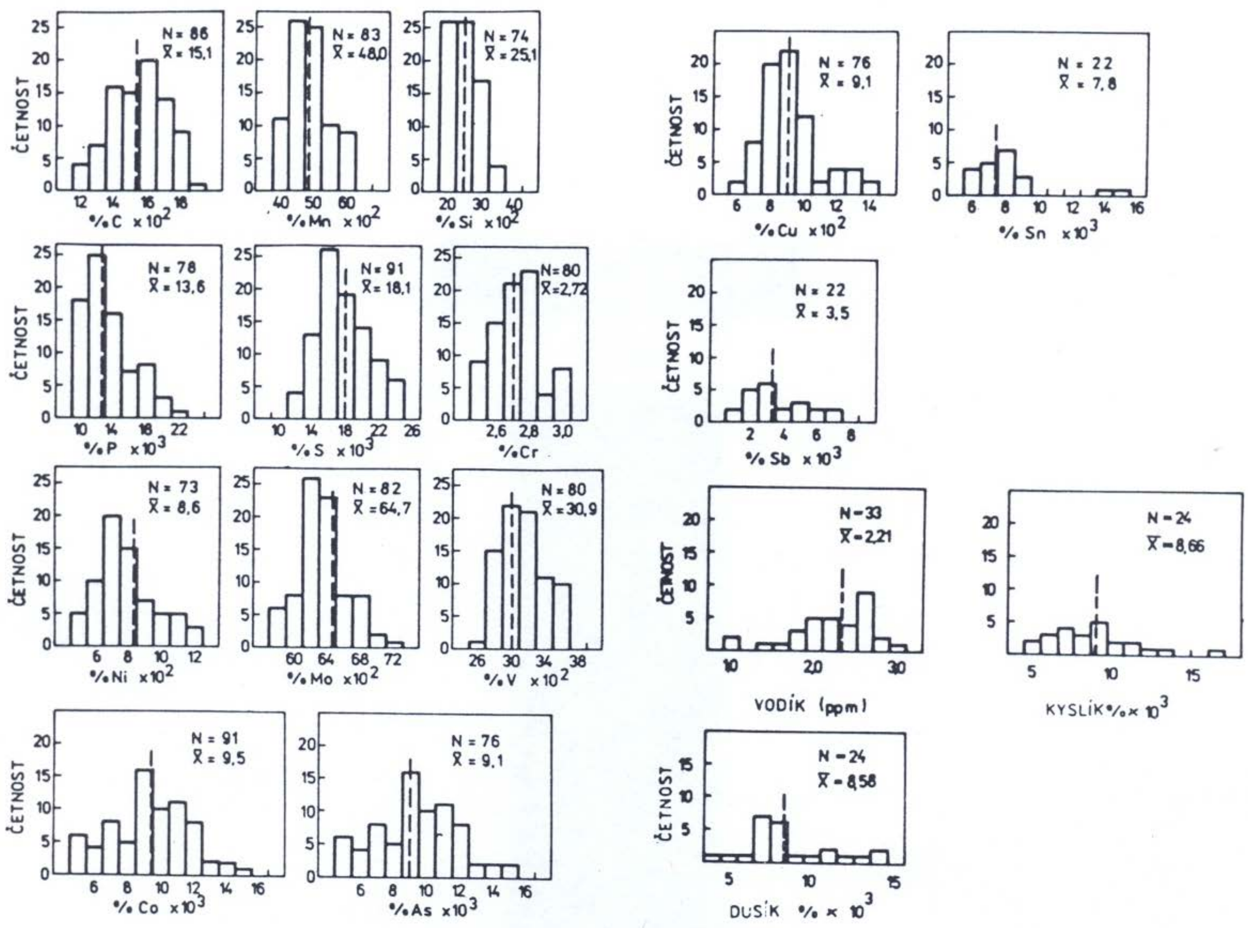
RPV MATERIAL PROPERTIES

RESULTING CARBON SEGREGATION IN 400 T FORGING



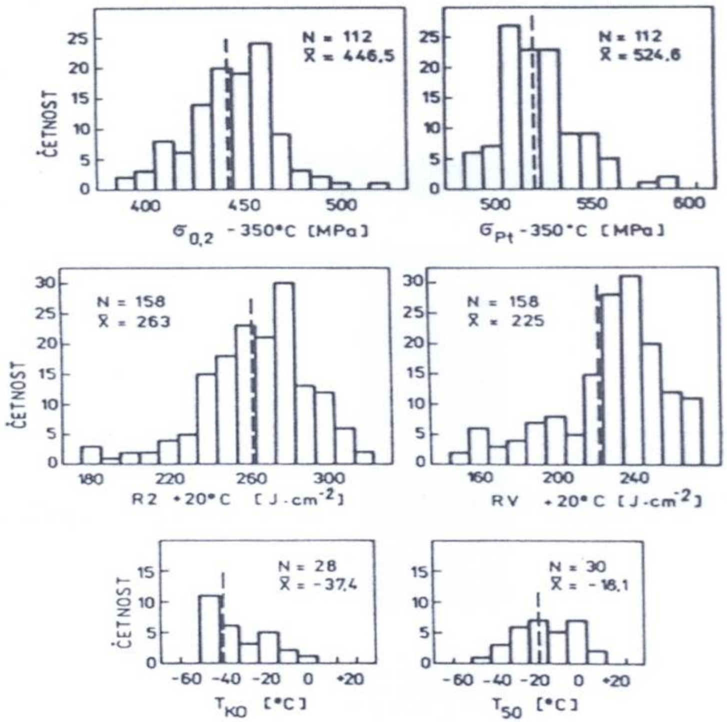
RPV MATERIAL PROPERTIES

TYPICAL DISTRIBUTION OF ELEMENTS IN FAMILY OF FORGINGS



RPV MATERIAL PROPERTIES

TYPICAL DISTRIBUTION OF MECHANICAL PROPERTIES IN FAMILY OF FORGINGS



RPV MATERIAL PROPERTIES

SOTERIA

- MECHANICAL PROPERTIES OF RPV ELEMENTS ARE DETERMINED FOR SPECIMENS CUT FROM ¼ OF RPV WALL THICKNESS
- DUE TO A LARGE MASS AND VOLUME OF INGOTS THERE IS A LARGE SCATER/DISTRIBUTION OF CHEMICAL COMPOSITION/MECHANICAL PROPERTIES WITHIN THE COMPONENT BUT ONLY DATA FROM ¼ OF THICKNESS ARE PART OF ACCEPTANCE TESTS
- MECHANICAL PROPERTIES PRIMARILY DEPEND ON CHEMICAL COMPOSITION AND ON MICROSTRUCTURE IN GIVEN LOCATION
- MICROSTRUCTURE PRIMARILY DEPENDS ON CHEMICAL COMPOSITION AND COOLING RATE IN GIVEN LOCATION

RPV MATERIAL PROPERTIES

MICROSTRUCTURE OF 15Kh2MFA STEEL AS A RESULT OF DIFFERENT COOLING RATE DURING QUENCHING

0,04 °C/s (2,4 °C/min)

0,15 °C/s (8,0 °C/min)

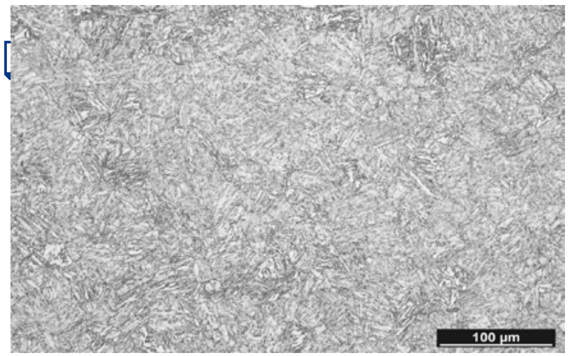
0,30 °C/s (18 °C/min)

1,0 °C/s (60 °C/min)

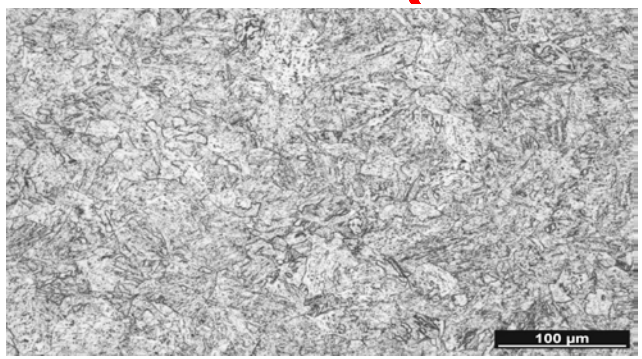
3,0 °C/s (180 °C/min)

RPV MATERIAL PROPERTIES

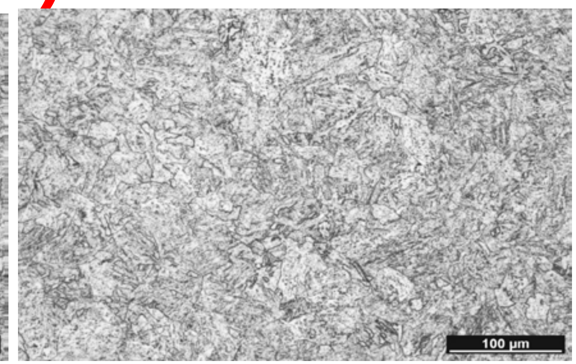
- **MICROSTRUCTURE OF ASTM A533B/JRQ STEEL THROUGH PLATE THIKCKNESS (220 mm)**



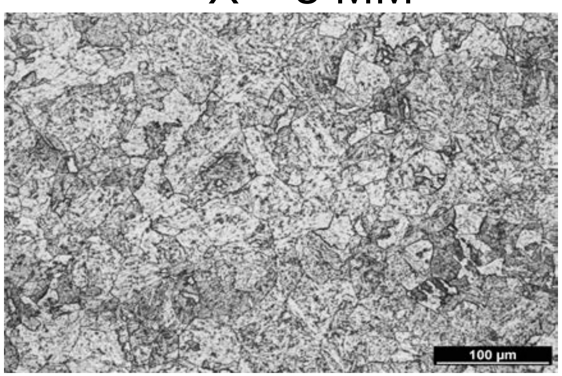
X = 5 MM



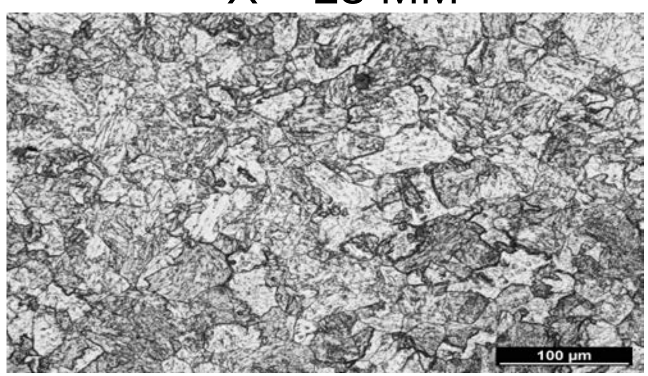
X = 23 MM



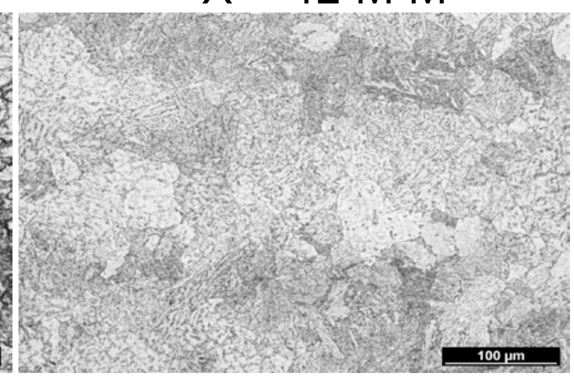
X = 41 M M



X = 59 MM



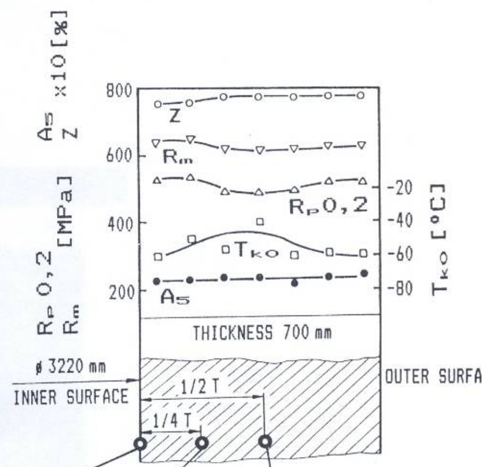
X = 77 MM

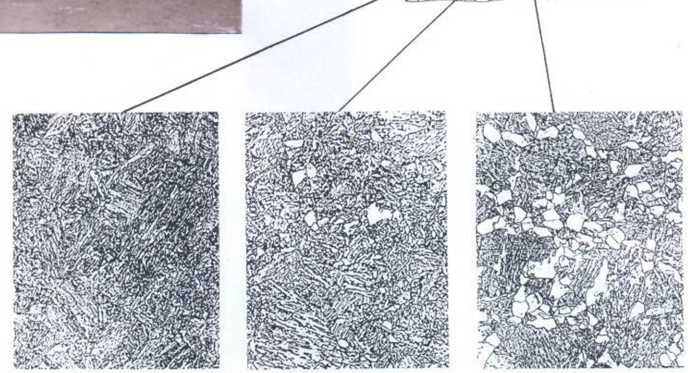


X = 113 MM

RPV MATERIAL PROPERTIES

METALLURGICAL CHARACTERISTIC OF FLANGE RING





Product chemical analysis [weight %]

	C	Mn	Si	P	S	Cr	Ni	Mo	V	Co	As	Cu	Sn	Sb
TOP	0,12	0,38	0,27	0,011	0,007	2,22	1,17	0,57	0,09	0,008	0,0045	0,06	0,0045	0,001
BOTTOM	0,12	0,40	0,27	0,009	0,005	2,24	1,18	0,58	0,09	0,009	0,0040	0,06	0,0060	0,001

RPV MATERIAL PROPERTIES

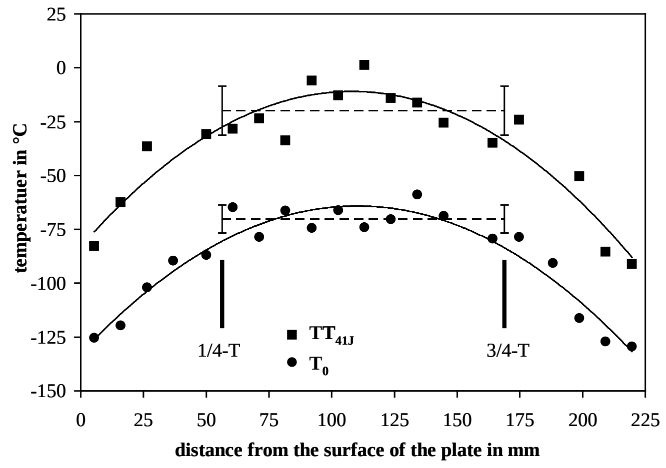
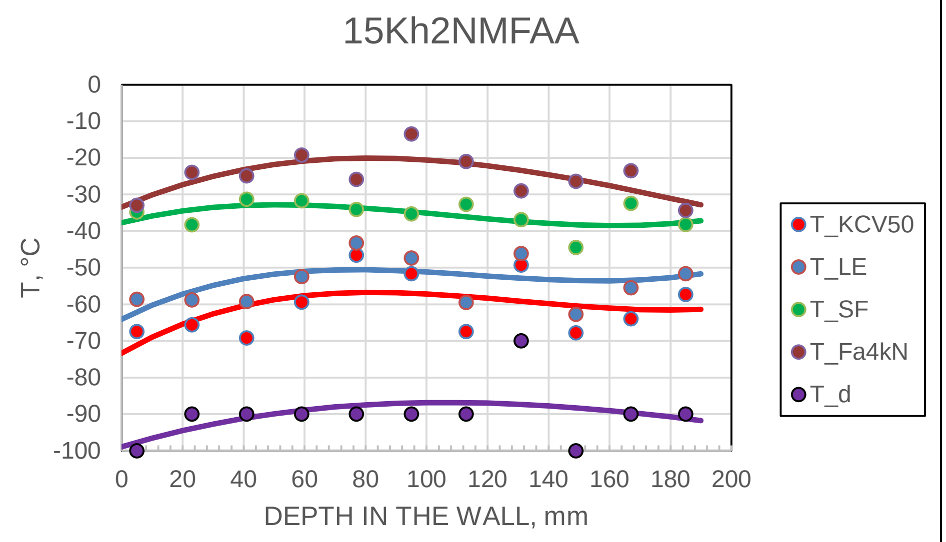


Figure 2. Charpy T_{41J} and T_0 versus distance from the surface in Block 5JRQ22.



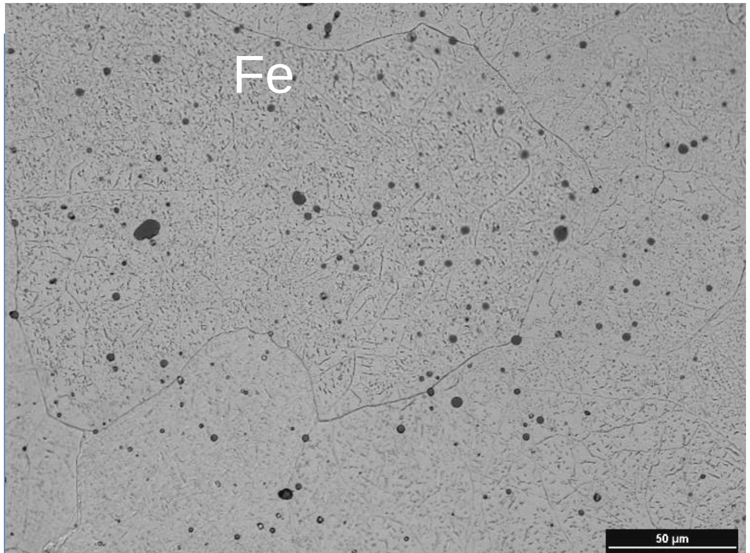
Charpy transition temperatures in 15Kh2NFAA forging

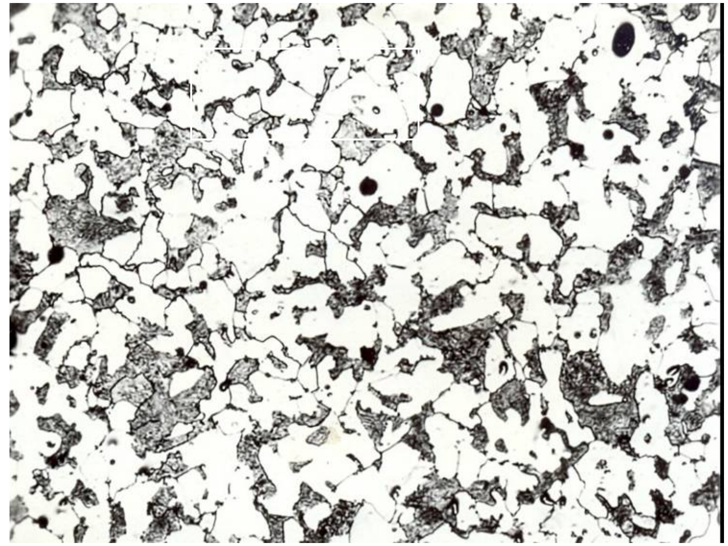
OPEN ISSUES

OPEN QUESTIONS

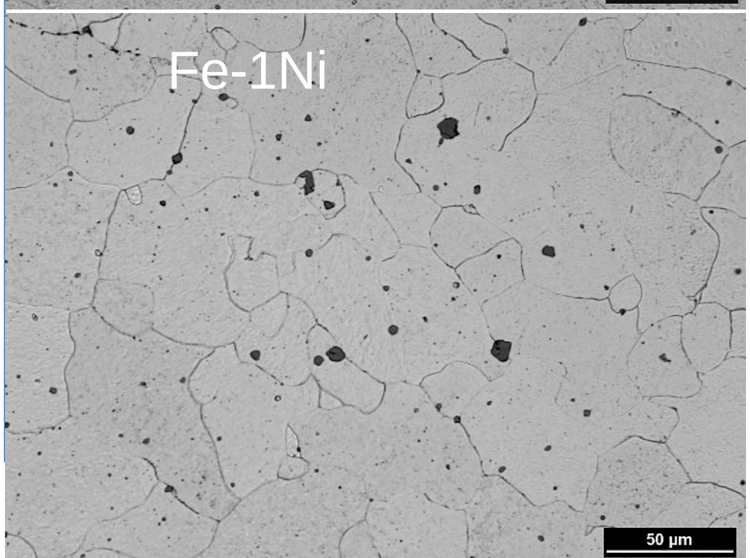
- **QUESTION?**
- **CAN MODEL ALLOYS WELL REPRESENT RADIATION DAMAGE IN STEELS?**
- **MODEL ALLOYS ARE USUALLY ONLY FERRITIC ALLOYS WITHOUT CARBON CONTENT**
- **STEELS ARE COMPOUND OF DIFFERENT PHASES, FERRITIC PART IS MOSTLY VERY SMALL, IF ANY**
- **THE RESPONSE OF MODEL ALLOYS TO RADIATION IS MOSTLY LARGER THAN IN RPV COMMERCIAL STEELS, BUT MOSTLY SHOWED SOME SIMILITUDE TO THE RESPONSE OF COMMERCIAL STEELS ALLOWING SOME CONFIDENCE IN EXTRAPOLATION**

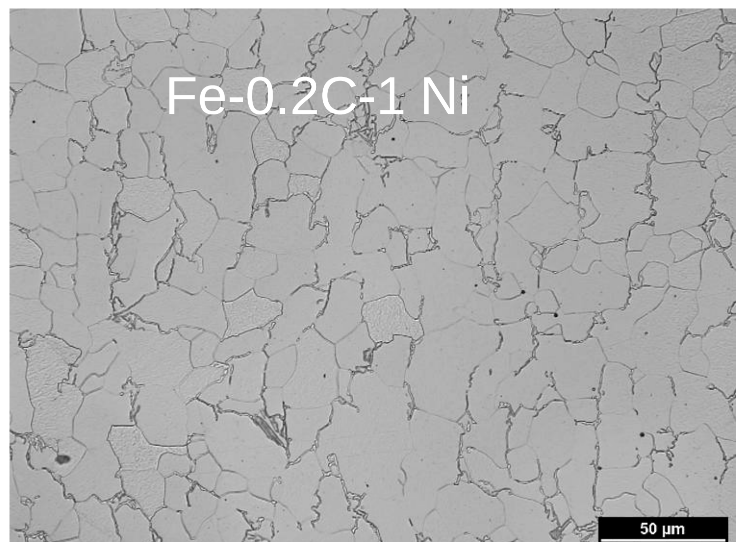
OPEN QUESTIONS





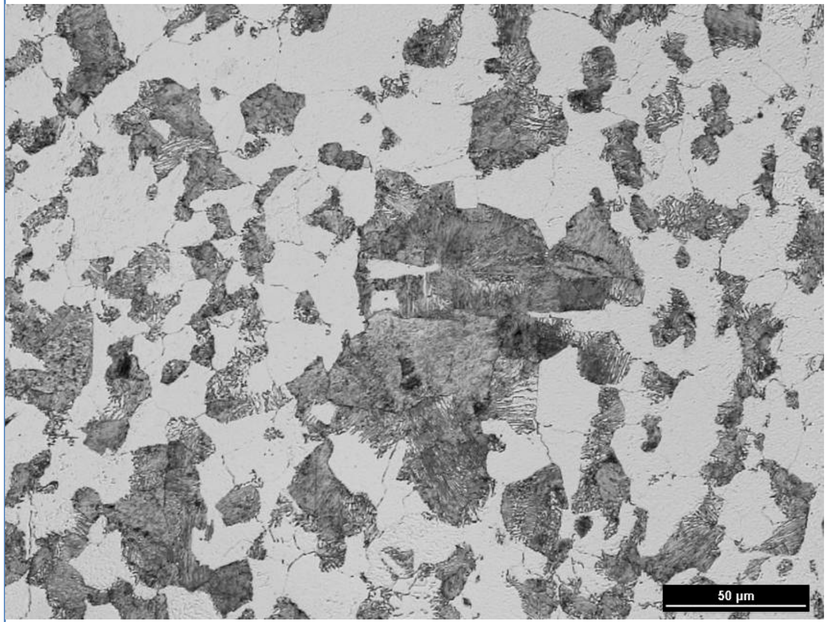
Fe-0.2C



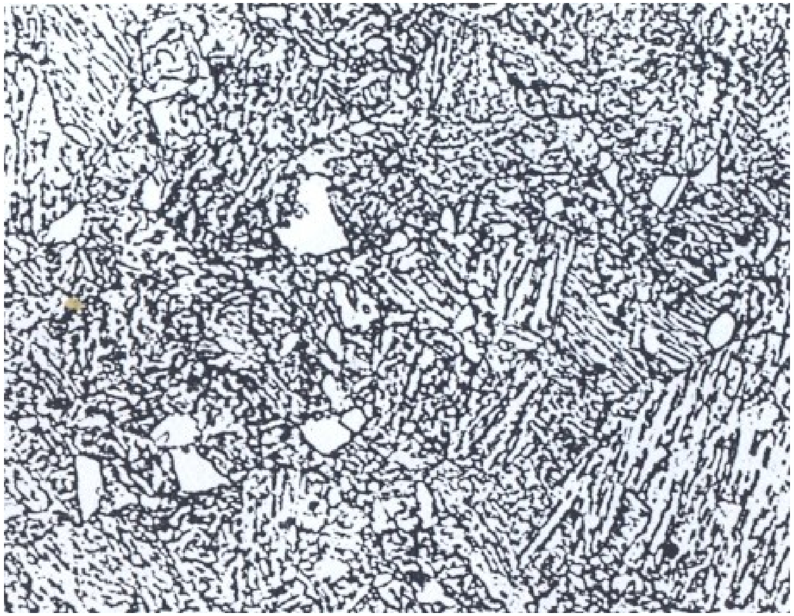


OPEN QUESTIONS

Fe-C-1Cr-1Ni



RPV steel



OPEN QUESTIONS

SOTERIA

- **QUESTION?**
- **DOES RADIATION DAMAGE/EMBRITTLEMENT DEPEND ON STEEL MICROSTRUCTURE?**
- **DIFFERENT MICROSTRUCTURE EXIST IN DIFFERENT LOCATION OF RPV THICKNESS AND LOCATION**
- **CHEMICAL COMPOSITION OF PLATES, FORGINGS AND WELDS IS DIFFERENT EVEN FOR ONE TYPE OF RPV MATERIAL, e.g. CONTENT OF CARBON IS SUBSTANTIALLY DIFFERENT IN PLATES/FORGINGS (0.15-0.23 mass %) WHILE ONLY 0.03-0.12 mass % IN WELD METALS**
- **FORMULAE FOR PREDICTION OF RADIATION EMBRITTLEMENT (SHIFT IN TRANSITION TEMPERATURE) ARE DIFFERENT FOR PLATES/FORGINGS/WELDS WITH THE SAME COMPOSITION OF Cu, P, Ni (Mn, Si)**
- **THESE FORMULAE ARE ALSO DIFFERENT FOR MATERIALS MANUFACTURED ACCORDING THE SAME STANDARD BUT IN DIFFERENT PLACES**
- **ONLY RARE TEST RESULTS ARE AVAILABLE**

OPEN QUESTIONS

SOTERIA

Miroslav Vacek[1]

Effect of Various Metallurgical Microstructures on the Response of the Nickel-Molybdenum-Chromium BH 70 Steel to Neutron Irradiation at 285°C

TABLE 1—*Chemical composition of the BH 70 steel in percent by weight.*

C	Si	Mn	Cr	Mo	Ni	P	S	Ti	V	Cu	Al
0.18	0.25	0.39	0.35	0.39	3.28	0.013	0.014	0.01	0.04	0.15	0.015

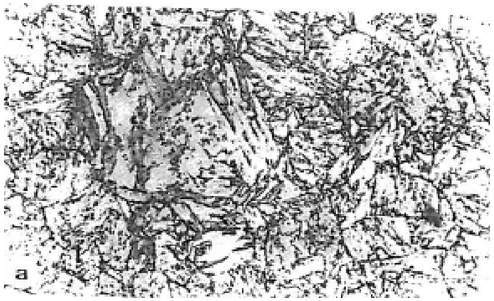
TABLE 2—*Heat treatment of the BH 70 steel and corresponding Vickers hardness number of bars.*

Condition	Heat Treatment	Vickers[a] Hardness, VHN 30
A	920°C, 1 h, water	446
B	920°C, 1 h, water + 650°C, 10 h, water	276
C	920°C, 1 h, salt bath 450°C, 0.5 h, water	294
D	920°C, 1 h, salt bath 450°C, 0.5 h, water + 650°C, 10 h, water	254
E	920°C, 1 h, control cooling in the closed furnace to 630°C[b] + 650°C, 10 h, water	253
F	commercial heat treatment: (870 to 930) °C, water + (600 to 700) °C, 7 h, air	246

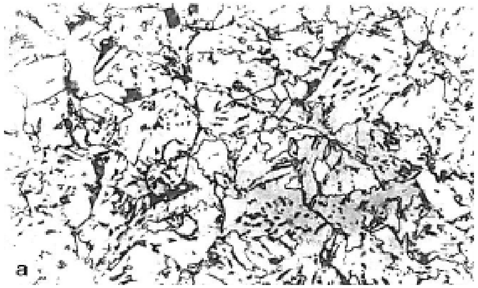
[a] Mean value minimally of 15 tests.
[b] From 920°C to 740°C in 1.5 h (120°C/h), to 710°C in 3 h (10°C/h), to 630°C in 1.5 h (53°C/h).

OPEN QUESTIONS

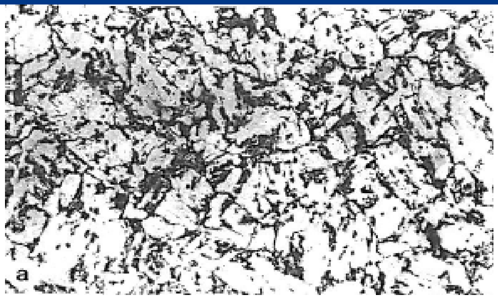
A-Untempered martensite



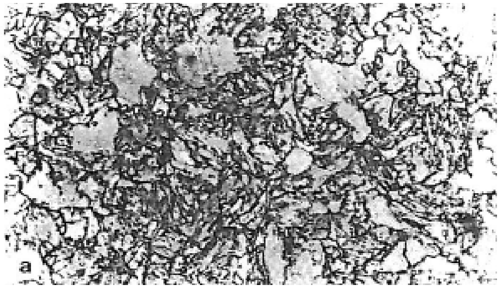
B-Tempered martensite



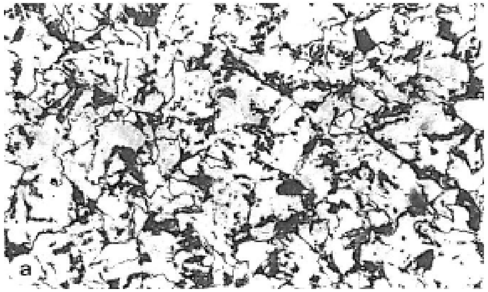
C-Tempered bainite



D-Tempered bainite



E-ferrite,perlite,bainite, martensite



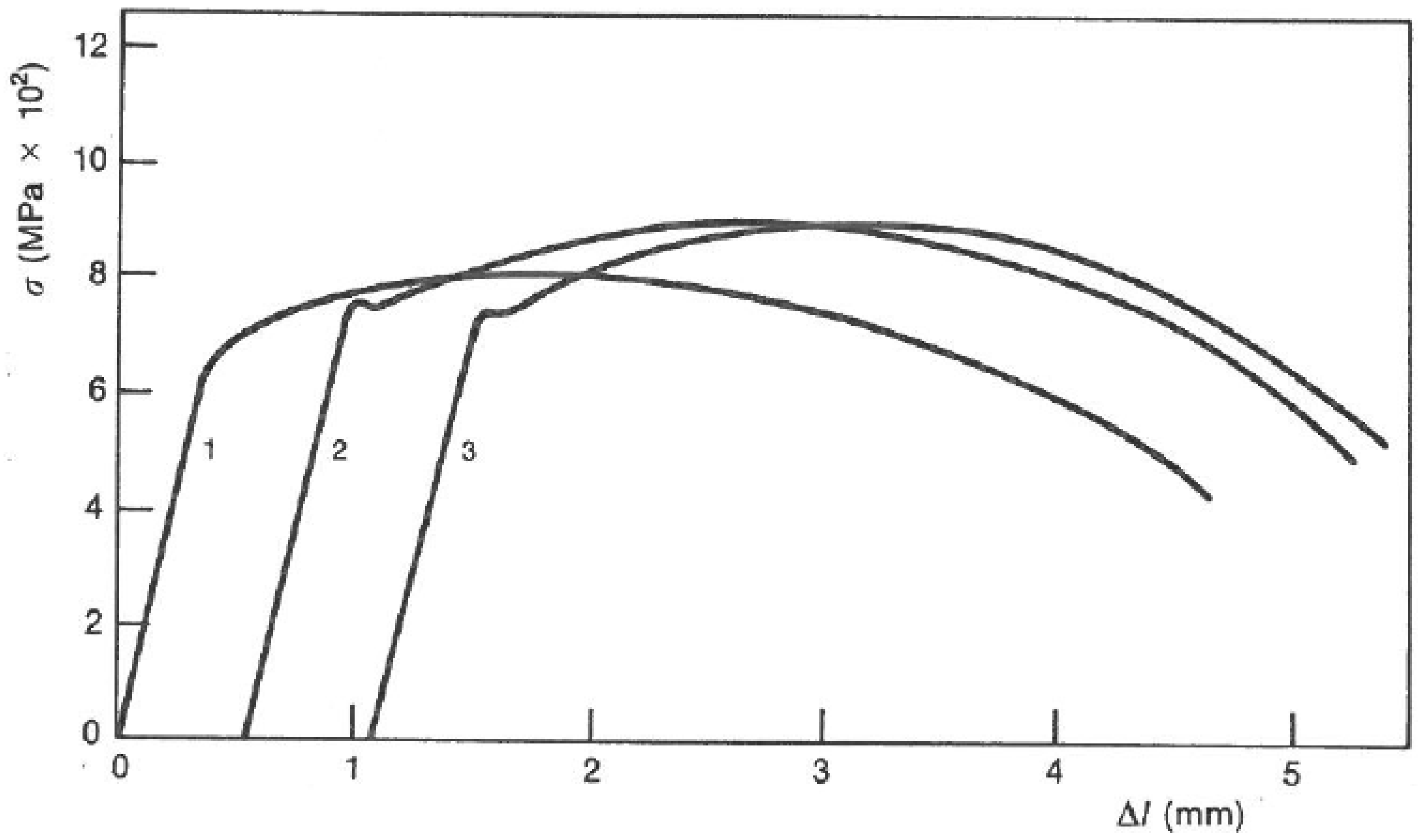
F-tempered martensite, perlite, bainite

OPEN QUESTIONS

- **QUESTION?**
- **WHAT IS AN EFFECT OF CARBON IN STEELS DURING IRRADIATION?**
- **EFFECT OF CARBON IS STILL UNDERESTIMATED/NEGLECTED IN PREDICTING FORMULAE AND MODELS**
- **EFFECT OF CARBON CAN BE SEEN IN TENSILE STRESS-STRAIN DIAGRAMS – EFFECT OF COTTRELL ATMOSPHERES ON EXISTENCE OF YIELD POINT AND LÜDERS STRAIN**
  - **THIS EFFECT IS DIFFERENT FOR DIFFERENT STEELS AND ALSO MANUFACTURING TECHNOLOGIES**
  - **THIS EFFECT IS ALSO CHANGING DURING IRRADIATION – IN SOME STEELS IS DIMISHING, IN SOME STEELS IS ARRISING**

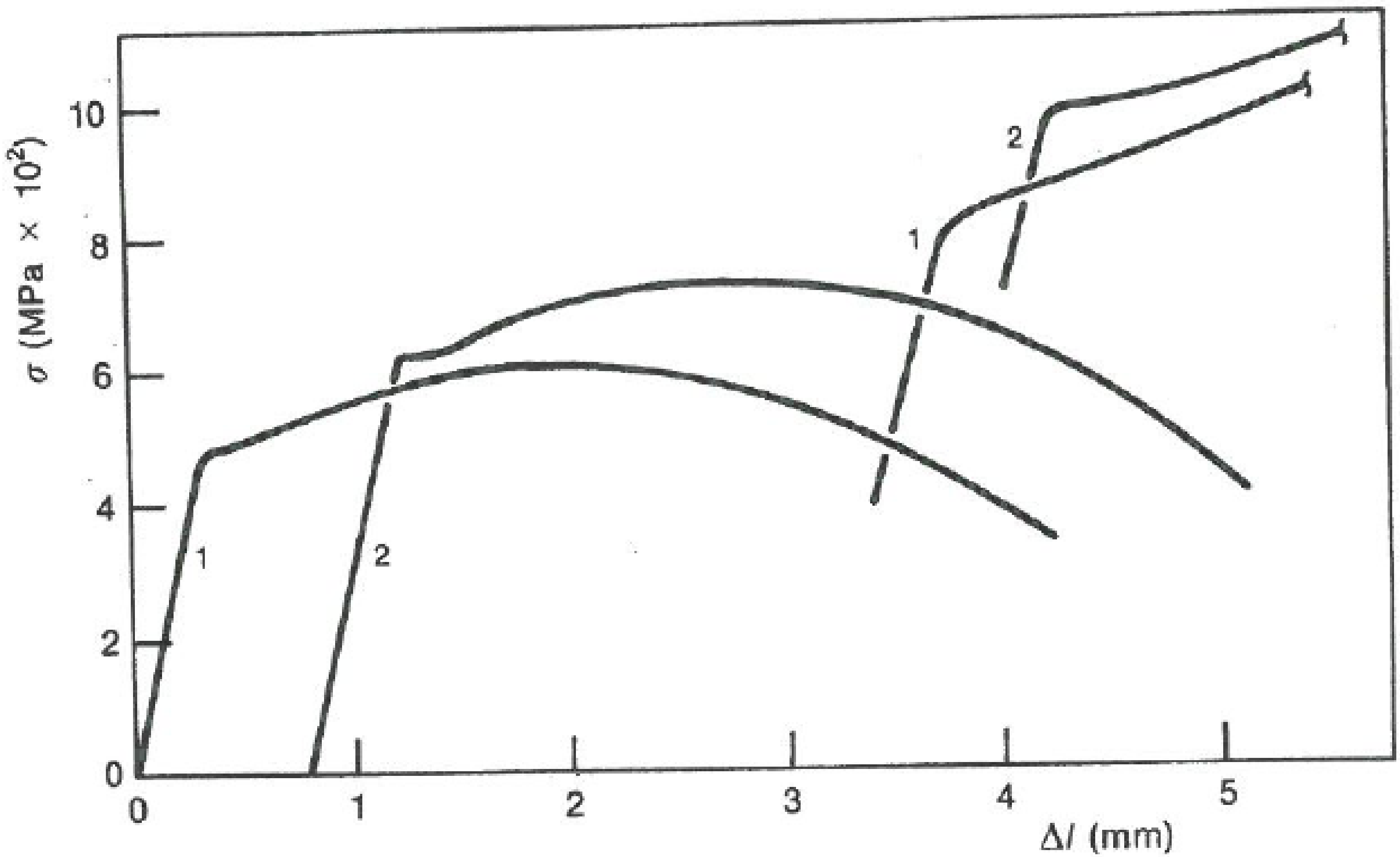
OPEN QUESTIONS

STRESS-ELONGATION CURVES FOR 15Kh2MFA TYPE STEEL



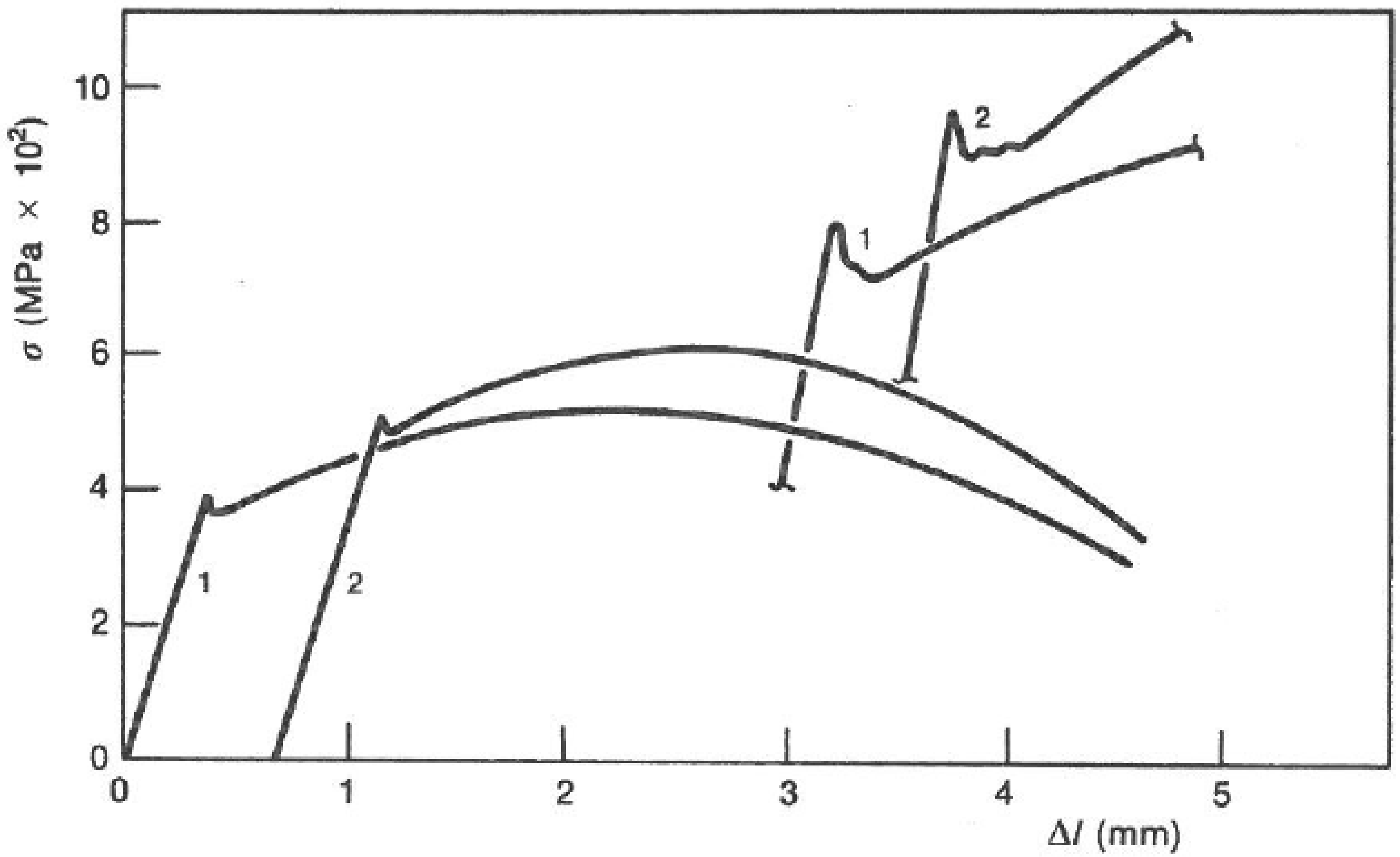
OPEN QUESTIONS

STRESS-ELONGATION CURVES FOR ASTM A 533-B STEEL



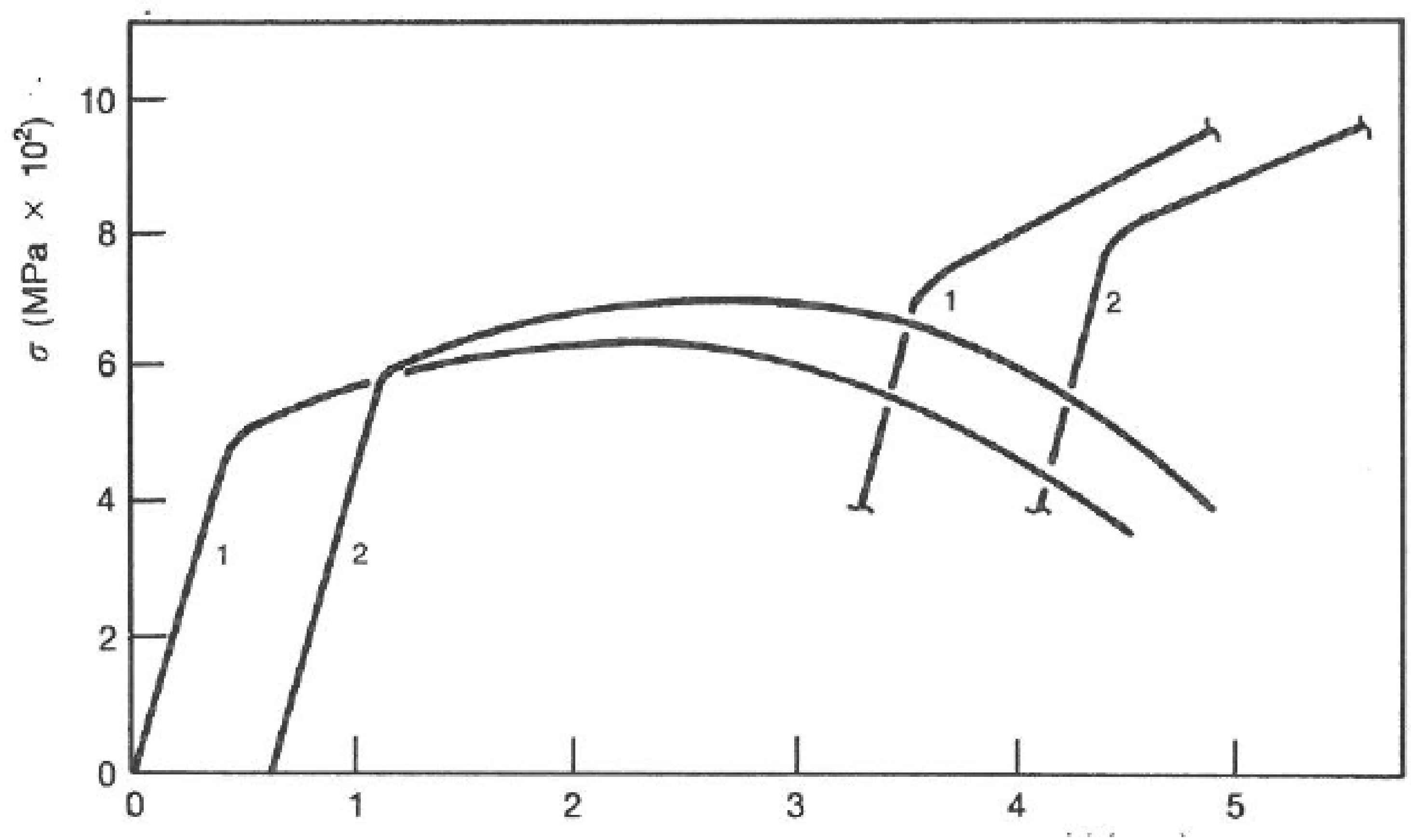
OPEN QUESTIONS

STRESS-ELONGATION CURVES FOR JAPANESE A 508 Cl.3 FORGING



OPEN QUESTIONS

STRESS-ELONGATION CURVES FOR FRENCH A 508 Cl.3 FORGING



CONCLUSIONS

CONCLUSIONS

- FAMILY OF STEELS USED FOR RPV MANUFACTURING IS LIMITED BY CODES AND STANDARDS
- DUE TO LARGE MASS AND VOLUME OF RPV COMPONENTS THERE IS A SCATTER OF CHEMICAL COMPOSITION, MICROSTRUCTURE AND MECHANICAL PROPERTIES WITHIN THESE COMPONENTS
- EFFECT OF MICROSTRUCTURE AND SOME OTHER ELEMENTS (e.g. CARBON) ON RADIATION DAMAGE IS STILL NOT FULLY UNDERSTAND AND INCLUDED IN PREDICTING FORMULAE

LITERATURE

LITERATURE

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Assessment and Management of Ageing of Major Nuclear Power Plant Components Important to Safety:

PWR Pressure Vessels

2007 Update

IAEA
International Atomic Energy Agency

June 2007

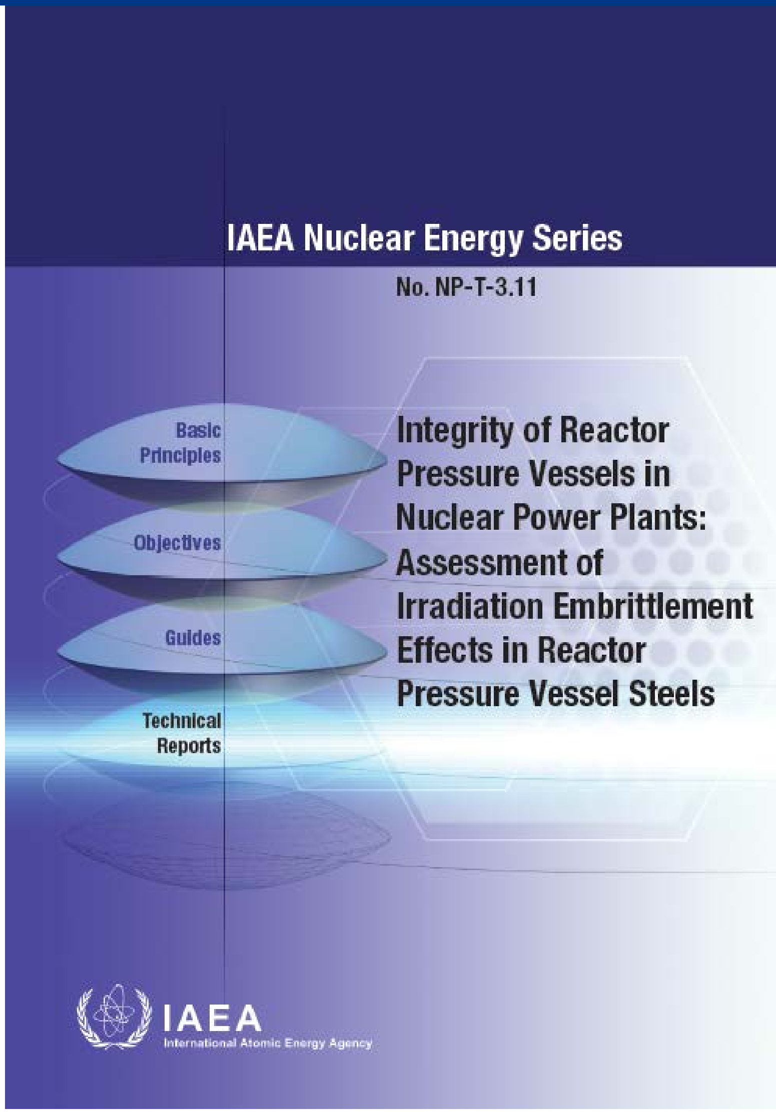
IAEA-TECDOC-1470

Assessment and management of ageing of major nuclear power plant components important to safety:

BWR pressure vessels

IAEA
International Atomic Energy Agency

October 2005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Objectives
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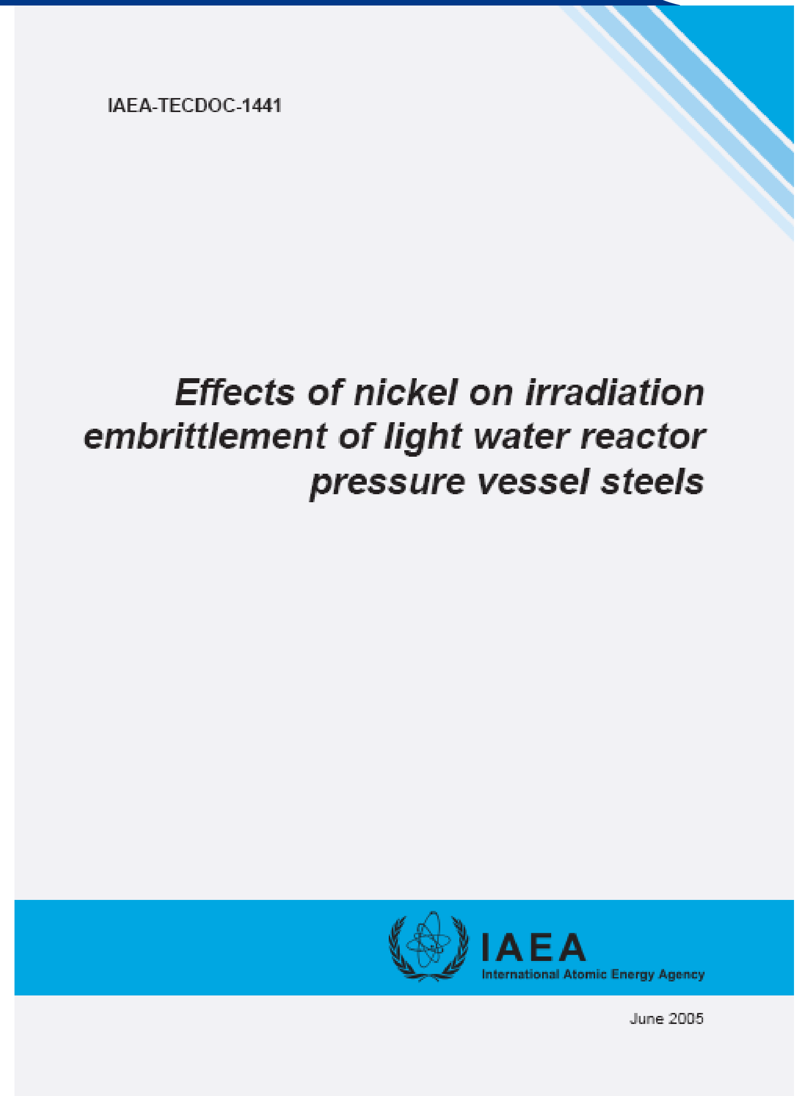
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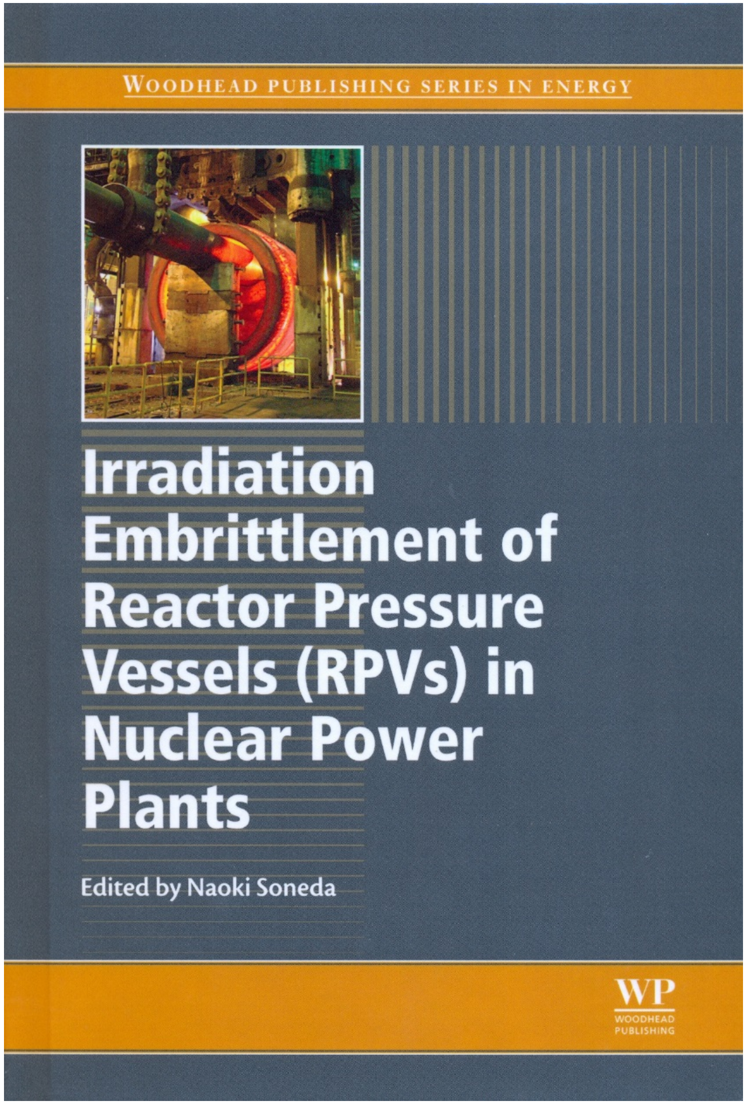
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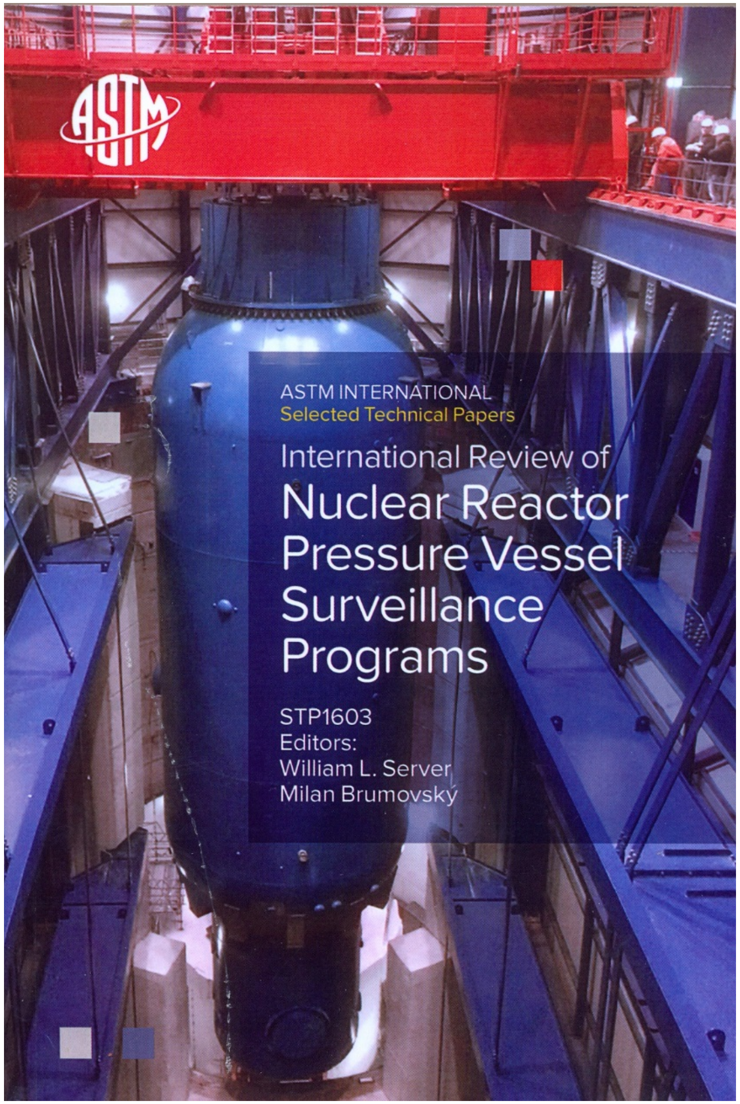
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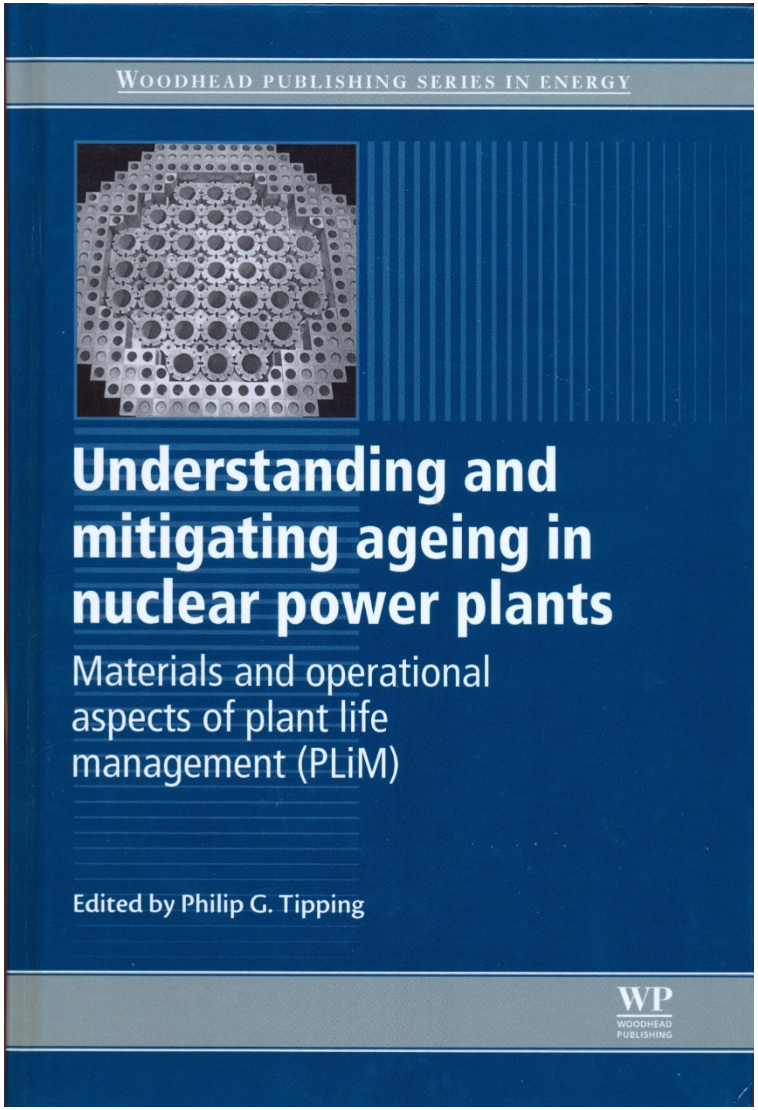
STP1603
Editors:
William L. Server
Milan Brumovsky



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Understanding and mitigating ageing in nuclear power plants
Materials and operational aspects of plant life management (PLiM)
Edited by Philip G. Tipping
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THANK YOU
ANY
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PLEASE?

The SOTERIA Consortium

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