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European Project for the development of HTR Technology - Materials for the HTR

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FIKI-CT-2000-00032

HTR-M
Material Database
scope and proposed stages of development

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Material Database
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By

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Summary

This document provides a brief outline of a strategy for developing a materials database for the High Temperature Reactor. The work is to be performed within the HTR-M Project. The paper is presented for discussion and comment from HTR-M members.

1 Introduction

The HTR-M project has as one of its main objectives the development of a database of materials information for the key components of the High Temperature Reactor.

The database is required to cover three main areas:

- The Reactor Pressure Vessel (and other pressure vessels used to contain primary circuit components).
- The high temperature components focusing in particular for the reactor internals on the control rod system and for the turbine on the blades and discs.
- The graphite core and its components. A summary of the work to be performed is given in section 2.

This document is a first step towards formalising the aims and outline of the materials database that will be developed as the project progresses through the mechanical testing phases of the HTR-M project.

2 HTR-M Project

The objectives of the project are to provide materials data for key components of the development of High Temperature Reactor (HTR) technology in Europe. The work programme is split into three Work Packages according to the type of materials and conditions experienced.

Work Package 1 consists of a review of vessel materials, focusing on existing thermal gas-cooled reactors and previous HTRs and includes the setting up of a materials property database on properties. This will lead to a recommendation for an appropriate vessel material, identification of data omissions and selection of a material for testing on welds for different vessel options. The project will look at materials for the cooled (current PBMR) and un-cooled vessel options. Tests on welded joints are planned covering tensile, creep and fracture toughness to determine properties under relevant conditions including the effects of irradiation. A further review and synthesis is planned on completion of the irradiation test work and examination.

In Work Package 2 consideration is given to the high temperature regions of the reactor covering the (WP2.1) internal structures (i.e. control rod) and (WP2.2) the turbine (discs and blades). The database of properties will be taking account of experience on existing high temperature and gas cooled reactors and include a reference to material composition, microstructure, manufacture (products and parts, etc.). The database will also cover materials required to withstand temperature levels experienced in emergency modes (e.g. Carbon based materials reinforced by Carbon fibers, Ni-based alloys, etc.). For turbine materials, the two most promising grades, will be studied looking at different options,

manufacturing aspects and characterisation of improved alloys made to the various manufacturing routes. Mechanical tests needed to quantify the materials in the HTR environment will be performed for both areas with tensile, fatigue, short term creep and creep / fatigue tests planned (in air, vacuum, helium) at temperatures up to 1300 ^{o}C. The results of the test programme will be transferred to the database as appropriate and recommendations made for long term verification of the chosen materials.

Work Package 3 involves setting up the database of properties on graphite with the emphasis on retention of existing experience from gas cooled and high temperature reactors. The project will also study the influence of oxidation arising from severe air ingress with core burning and investigation of protective coatings and innovative C-based materials. The outcome will be a platform of material data for future application and selection of graphites for the HTR.

The need for reliable materials data and properties is a key issue in the development of any innovative reactor technology and is especially important for those areas where safety considerations are uppermost. The aims of this project are:

- to provide a firm materials platform on which to develop the future HTR technological basis within Europe and,
- to provide a first step towards building an understanding of the behaviour and manufacturing requirements for some of the new materials that will be needed for such developments.

3 Scope and development of the Database

The way in which the database can be built up within HTR-M is illustrated in Figure 2. Existing Design Codes and current technological developments are used to identify suitable materials and properties for the database. A search of available information can then be made and property information assembled and collated. Any available raw test data is also assembled and together with HTR-M test data used to define / extrapolate / check the materials behaviour using an established property correlation or formulations (such as available in Alloys DB). A typical example of this would be the extension of property information to higher (or lower) temperatures. From this and the existing design code information a proposal for a design curve can be established which can be agreed and formalised for use. This approach can be used within each work package.

In terms of assembling and recording the data information the following steps have to be considered:

- Step 1: Identify materials / properties to be included.

  (material types, manufacturing processes / property requirements, design / analysis needs, safety / inspection considerations).

- Step 2: Identify material properties from available information sources.

  (review design codes, existing databases, published test data, ongoing research & development, service experience).

- Step 3: Decide on how the database is to be presented within the database.

  (review available formats, presentation media, security implications, central control requirements, existing tools, access, future use)

- Step 4: Develop formats and access tools required -(e.g integration with Alloys DB).

  (existing tools & databases to be used where possible, web access, language)

- Step 5: Collate / assemble information into common formats and make comparisons from different sources.

  (amount of data, type of data, graphical / tabular comparisons)

- Step 6: Produce draft version of database information.

  (carry out test evaluations / searches, example cases, prepare support documentation, set up access requirements)

- Step 7: Establish first production version with documentation.

4 Programme of Work

The program of work to be performed to provide information for the above steps has been defined in the HTR-M program in each work package. The tasks assigned to complete these steps are broken down in more detail in Appendix A. It is planned to complete a draft version of the database for each work package by the end of the first two years and establish a first production version (step 7) before the end of the project.

Some sources involved in steps 1 & 2 are given in Appendix B for information.

Steps 3 & 4 involve decisions on the presentation and formats to be used and may be identical in each Work Package. A proposal for the overall layout of the database is discussed in section 5. Possible tools and example presentation formats are discussed in section 6. Examples of presentation formats are given in Appendix D.

Proposals for the material property data to be included are given in Appendix C

The planned timetable for carrying the individual steps is given in Figure 1 and discussed further in section 7.

5 Proposed layout of Database

A possible layout for the database is presented schematically in figure 3.
This shows four parts covering the following aspects:

Part 1 Contents & Material designation.
Part 2 Manufacturing provisions, products & parts.
Part 3 Test Data information.
Part 4 Design property information.

The design property information is one of the main outputs from the database and also a means of deciding on future material information needs for the database. Design needs plus omissions and shortage of test data will be an important indicator for future R &D activities on developing HTR materials.

Parts 1,2 &3 represent the interactive / raw data sets to be accessed by materials experts and experimentalists. Each part can be assembled within each individual Work Package and assembled in subsets. Material identifiers can be used to cross reference all the information with additional designations for manufacturing provisions (heat treatments, etc.), products and parts introduced as appropriate. Specific test results and associated references to test condition, source, equipment etc. will be contained in part 3.

This information is not used for design. Part 4 contains the approved design information for feasibility and component investigations by design engineers and analysts

Users will be able to input information into parts 1, 2 & 3 as appropriate in a controlled manner, but part 4 will be a read only data set and contain only approved design information.

6 Possible tools and presentation formats

A list of possible media, tools and presentation formats that can be used to provide and store the database information are as follows:

Media	Tools	Formats
Paper CD-ROM Internet	Official Reports Micro films Intranet systems SINTER Web Pages Alloy-DB	Documents Tables Graphs Equations / Formulae

The application of these in the different sections of the proposed database in discussed below:

Part 1 Contents & material designations.

Some typical presentation formats for this information are shown in Appendix D taken from Design Codes and existing databases.

Updates will be entered in a controlled manner. A tabulated presentation could be used via an Excel spreadsheet such as that used to summarise the contents of the Alloy-DB database.

Part 2 Manufacturing provisions, products & parts.

Some typical presentation formats for this information are shown in Appendix D taken from Design Codes.

Since the information can be very detailed and in some case confidential to suppliers, qualification parameters could be used to catagorise the information, i.e. section thickness, format of product (bar, plate, etc.). These would also provide the user with a filter and could give access to summary information.

More detailed (or confidential information) could be stored in book form or on CD-Rom and held by individual organisations or alternatively stored on the SINTER network.

Part 3 Test data information.

Typical presentation formats for this information are as used in the Alloys DB

This would be accessed and up dated by material specialists. The Alloys-DB database could be adapted to provide this facility.

Part 4 Design property information.

Appendix C shows preliminary lists of properties required at the materials selection stage. Some expansion and additional detail would be required to describe the requirements for design information.

Some typical presentation formats for this information are shown in Appendix D and property values in Appendix C.

These are taken from existing Design Codes.

The requirement is to provide approved design information that can be used for HTR concept and design evaluation. The information could be presented in book form, on CD-ROM or in a secure area on a web site. The latter could be done through controlled access via the SINTER Network with approval of the information endorsed by HTR-TN.

7 Timetable

The work is to be completed within the time scale of the HTR-M project.

Specific milestones are identified in the project figure 1.

8 Conclusions

This document is currently in draft form.

Its purpose is to provide a brief outline of a strategy for developing a materials database for the High Temperature Reactor. The work is to be performed within the HTR-M Project.

The database will cover material designation, provisions, products & parts, test data information and design property information.

The design property information is one of the main outputs from the database.

Design and technological issues plus omissions and shortage of test data will be the basis on which the database will be built up and expanded.

The database will also provide a platform on which to judge future R & D needs.

The document is presented for discussion and comment from HTR-M members.

Figure 1 Database development program

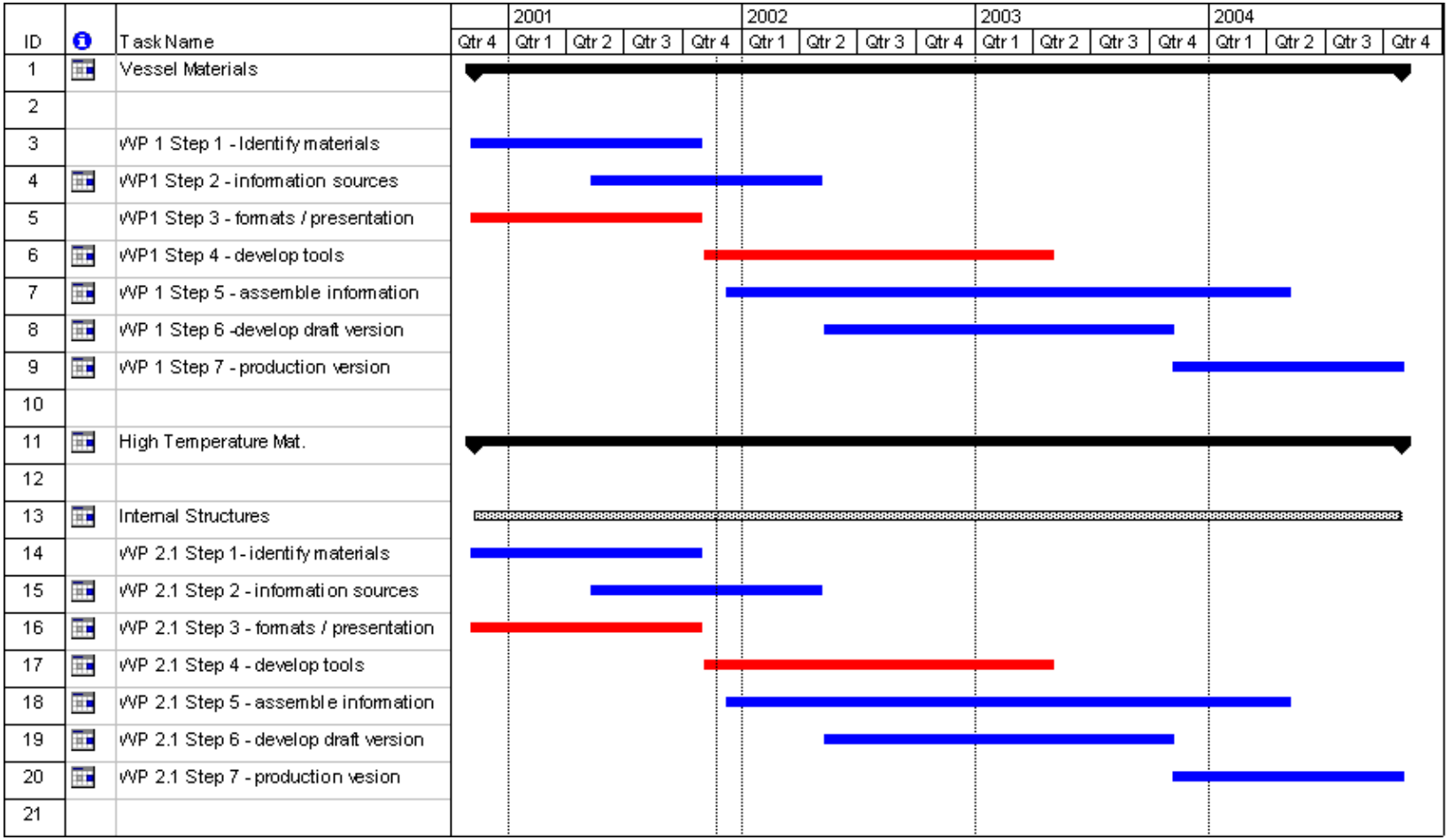


Figure 1 Database development program (Cont)

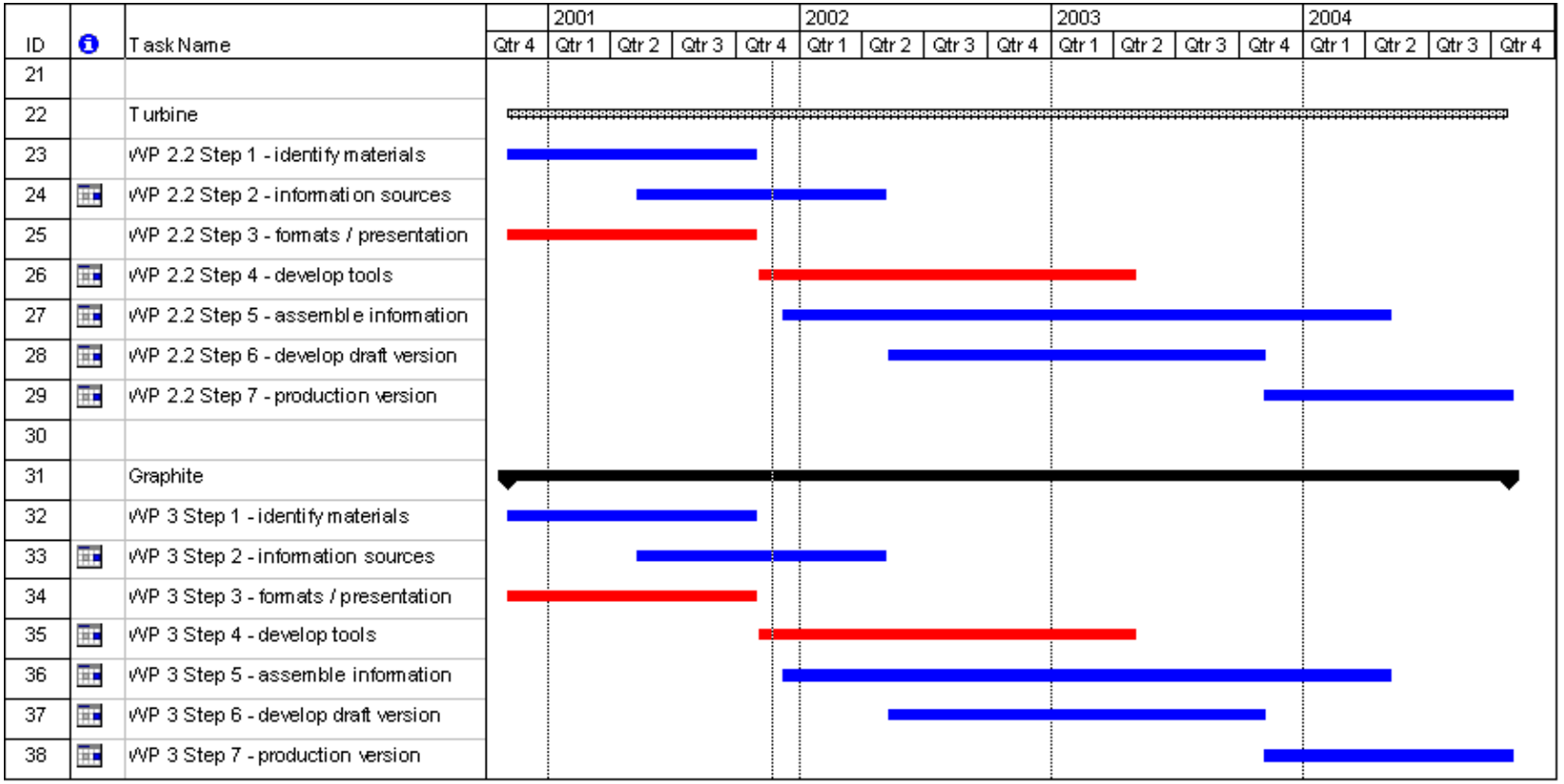


Figure 2 Integration of Design Considerations in HTR-M

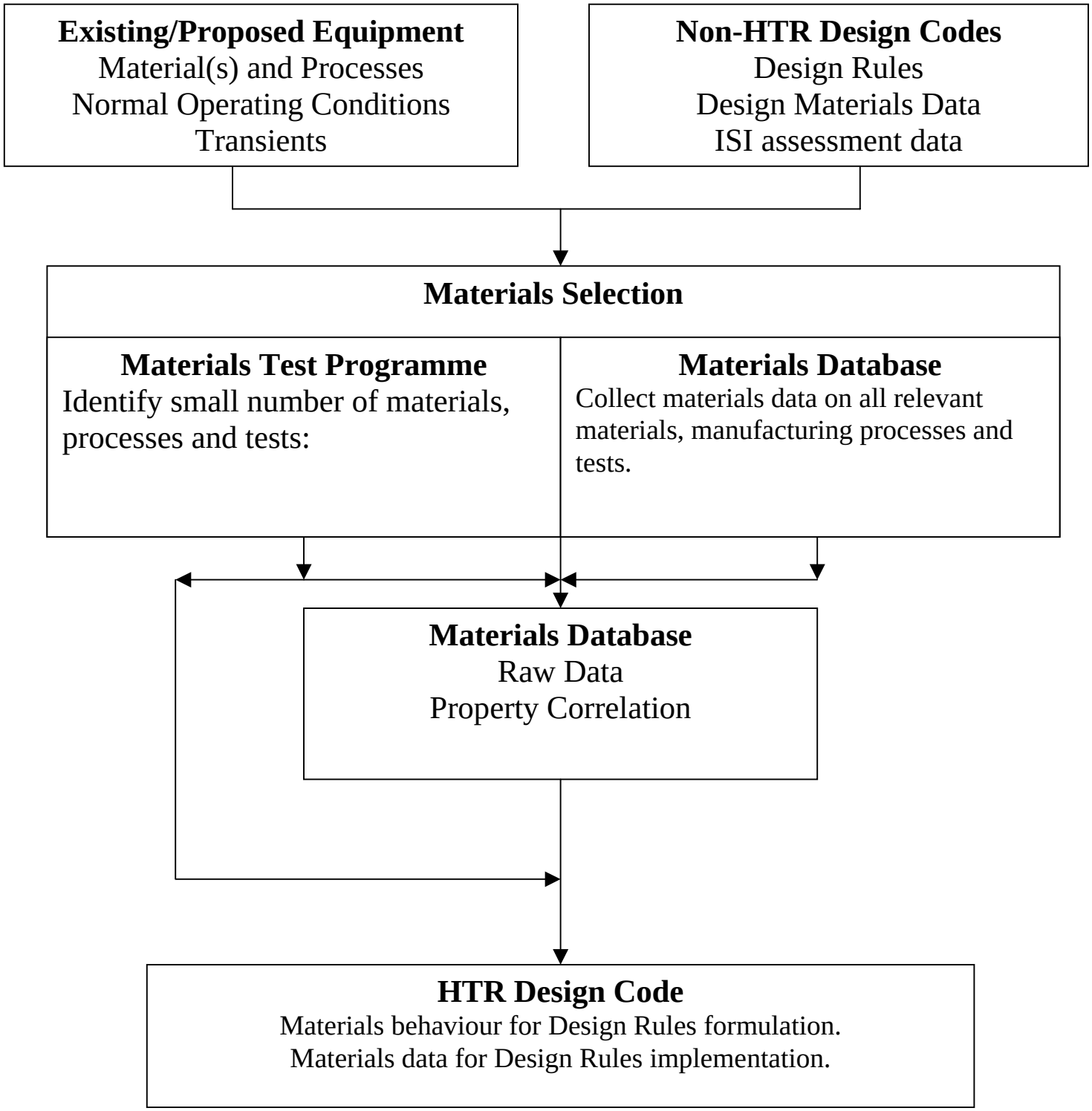
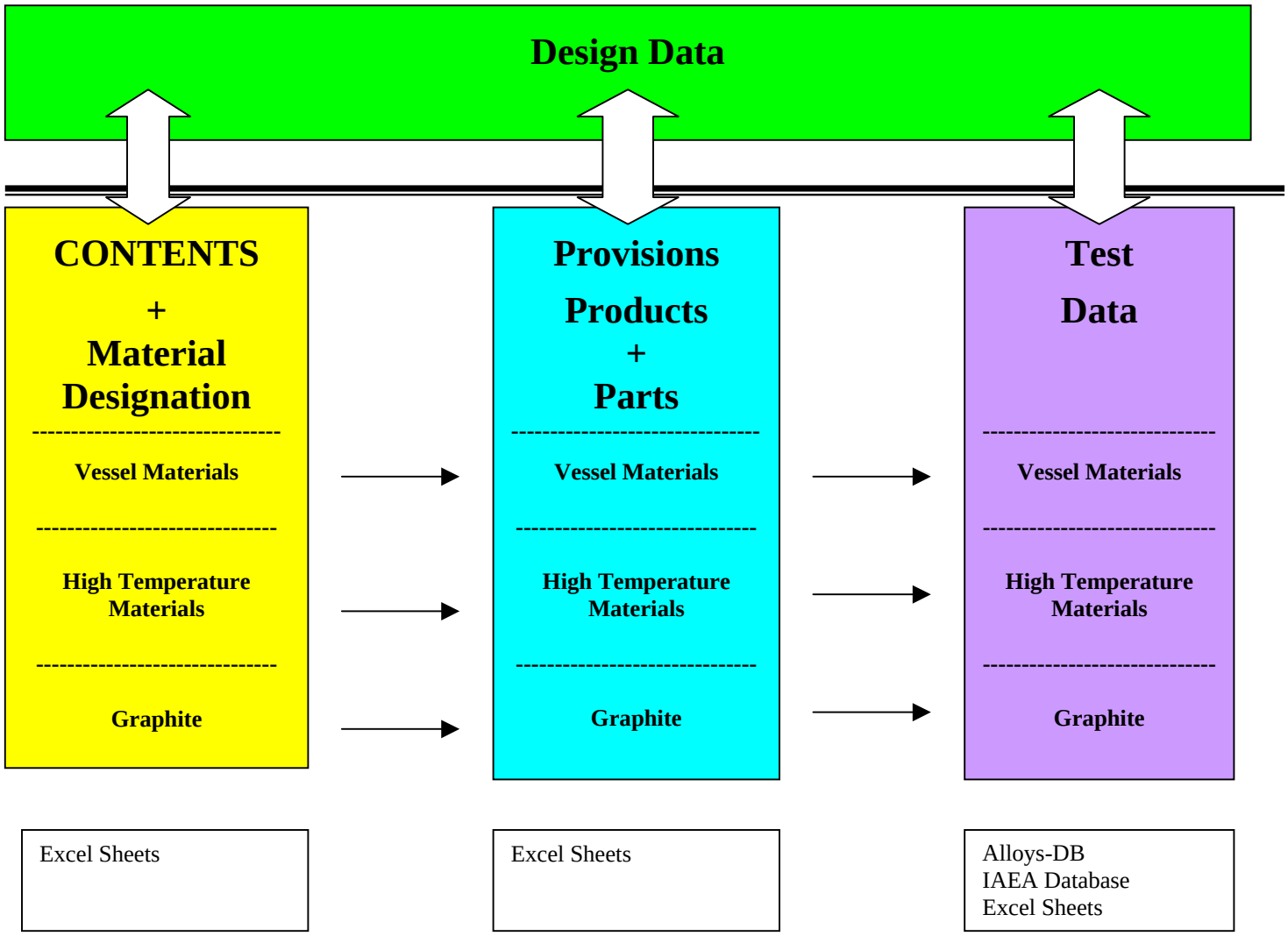


Figure 3 Overall database layout



Appendix A Descriptions of Work Programme

Work Package 1: Vessel Materials

Step 1 Identify materials / properties to be considered

- Review of existing and proposed RPV designs and materials.
- Provide a comparison of different grades of vessel materials (with service experience as available).
- Identify sensitive zones:
  - in relation to non-destructive examination possibilities, safety analysis methodology and the safety studies (defect location and defect size),
  - from a thermo-mechanical point of view (geometrical discontinuities, welds, zones submitted to thermal fluctuations or to thermal gradients).
- Identify damage mechanisms involved in relation with the considered operating conditions (excessive deformation, fatigue, creep, creep-fatigue, buckling, ratcheting) and verification of the suitability of the corresponding existing design rules for the concerned steel.

Step 2 : Identify material properties available

- Review status and information available in existing design codes; assessment procedures.
- Review information available in existing databases, from ongoing R&D.
- Temperature limits / influence of environment.

Step 3: Decide on how the database is to be presented

- Review available formats, presentation media, existing tools.
- Review security implications, central control requirements, access.
- Review requirements for future use.

Step 4: Develop formats and access tools required

- Review existing tools & databases, web access, language requirements.
- Validation tests.
- Prepare supporting documents.

Step 5: Collate / assemble information into common formats and make comparisons

- Build up information into required formats.
- Make test comparisons.

Work Package 2: High Temperature Materials

Step 1 Identify materials / properties to be considered

- Review of existing and proposed high temperature design needs & materials information.

  Includes geometry, service conditions, environment, manufacturing aspects.

- Provide a comparison of different grades of materials (with service experience as available).

- Identify sensitive issues;
  - in relation to examination, safety and operability,
  - from a thermo-mechanical point of view (welds, zones submitted to thermal fluctuations or to thermal gradients).

- Identify damage mechanisms / criteria involved in relation with the considered operating conditions (excessive deformation, fatigue, creep, creep-fatigue, ratcheting) and verification of the suitability of the corresponding existing design rules for the concerned materials.

Step 2 : Identify material properties available

- Review status and information available in existing design codes; assessment procedures.

- Review information available in existing databases and from ongoing R&D.

- Temperature limits / influence of environment.

Step 3: Decide on how the database is to be presented

- Review available formats, presentation media, existing tools.

- Review security implications, central control requirements, access.

- Review requirements for future use.

Step 4: Develop formats and access tools required

- Review existing tools & databases, web access, language requirements.

- Validation tests.

- Prepare supporting documents.

Step 5: Collate / assemble information into common formats and make comparisons

- Build up information into required formats.

- Make test comparisons.

Work Package 3: Graphite Materials

Step 1 Identify materials / properties to be considered

- Collect / review the relevant literature/ experience on nuclear graphite production, examination, testing, and application.
- Review of graphites used in HTRs & other gas reactors.
- Review of existing material bases / current graphites.
- Provide a comparison of different graphites (with service experience as available).
- Identify sensitive issues and design needs.

This involves assessment of the properties against design needs and limitations, (e.g. effects of shrinkage, expansion, creep strength, etc). For new designs the purpose would be to establish whether existing grades can be used or whether new versions are needed.

Step 2 : Identify material properties available

- Review status and information available in existing databases and design / assessment procedures.
- Review information available in existing databases & from ongoing R&D.

Step 3: Decide on how the database is to be presented

- Assess information suitability for nuclear purposes and for HTR design and decommissioning.
- Upgrade the data in a form suitable for designers.
- Review available formats, presentation media, existing tools.

The IAEA database could be a suitable vehicle for this. This would be for non-commercial purposes.

- Review security implications, central control requirements, access.
- Review requirements for future use.

Step 4: Develop formats and access tools required

- Review existing tools & databases, web access, language requirements.
- Prepare supporting documents.

Step 5: Collate / assemble information into common formats and make comparisons

- Build up information into required formats.
- Make test comparisons.
- Decide on R&D work necessary for developing and irradiation testing candidate graphite grades.

This would involve two steps;

a) to specify testing requirements for validation of HTRs,
b) to specify a minimum test programme to satisfy data ommisions.

Appendix B Sources of material information

1. General

RCC-MR /RCC-M / ASME Design Code Information

EUR Reports

IAEA Reports

IWGGCR Documents

HTR Sources

Fast Reactor Sources

2. Vessel Steels

Worldwide LWR materials database on neutron embrittlement.

CO_2 cooled reactor sources.

3. High Temperature Materials

High Temperature metallic materials for Gas Cooled Reactors - IWGGCR/18
Cracow, June 1988.

High Temperature metallic materials for application in gas-cooled reactors - IWGGCR/4
Vienna, May 1981.

4. Graphite

IAEA Graphite Database.

The status of Graphite development for Gas Cooled Reactors - IAEA-TECHDOC-690
Japan, 1991.

Graphite moderator lifecycle behaviour - IAEA-TECHDOC-901, UK, 1995.

Irradiation damage in Graphite due to Fast Neutrons in Fission and Fusion systems -
IAEA-TECHDOC-1154, April 2000.

Appendix C Examples of Material property requirements

Proposal from Siemens

	Project: HTR-M, M1, Work Package W1					SNP GmbH Dep. NT1/Friedrich			12/8/00		
	1st attempt data collection for pressure vessel materials										
	Material Type										
	9Cr 1 Mo				Temperature in °C						
	Property / Attribute	**Dimension**	**RT**	**250**	**300**	**350**	**400**	**450**	**500**	**Data Source / Reference**	
	Base Material (Sheets, Forgings, ..)										
	Yield Strength 0.2% Offset	MPa	Data	Data	Data	Data	Data	**No Data**		/1, 2, 3...../	
	Tensile Strength	MPa	Data	Data	Data	Data	Data	**No Data**			
	Elongation after fracture (A5)	%	Data	Data	Data	Data	Data	**No Data**			
	Reduction of Area after Fracture	%	Data	Data	Data	Data	Data	**No Data**			
	....										
	Design Stress Limit Sy										
	Design Stress Limit Su										
	....										
	....										
	Creep Strength 10 000 h	MPa									
	Creep Strength 100 000 h	MPa									
	....										
	Low cycle Fatigue (10^4 cyc)	MPa									
	High cycle Fatigue (10^6 cyc)	MPa									
	....										
	Impact Toughness (Charpy-V-Specimen)	J									
	....										
	....										
	Fracture Mechanic Properties										
	KIc (specimen, conditions etc....)	N*m ^ -3/2								/32, 35, .../	
	....										
	Properties in irradiated condition										
	Elongation after fracture (A5) 10^21	%									
	Elongation after fracture (A5) 10^22	%									
	....										
	Impact Toughness (Charpy-V-Specimen)	J									
	....										
	....										
	Fracture Mechanic Properties										
	KIc (specimen, conditions etc....)	N*m ^ -3/2									
	Weld Metal (weld metal supply forms...)										
	....										
	Similar property items as for "base materials"										
	....										
	Weldability	***Reference to detailed and extensive reports***									
	Post Weld Heat Treatment	***Reference to detailed and extensive reports***									
	Non-destructive Examination										
	Base Material (Sheets, Forgings, ..)										
	Technique										
	Assessment Criteria/Evaluation Criteria	***Condensed tables and reference to detailed and extensive reports***									
	Weld Seams										
	Technique										
	Assessment Criteria/Evaluation Criteria	***Condensed tables and reference to detailed and extensive reports***									
	Operation Experiences	***Reference to detailed and extensive reports***									

Graphite Property List

- Stress - Strain relationships: Young's Modulus
- Strength
- Dimensional change and Dimensional change rate
- Coefficient of Thermal Expansion
- Thermal conductivity
- Irradiation induced creep
- Specific Heat and stored Energy
- Gas transport properties
- Bulk Density / Open Pore Volume

List of typical RCC-MR data information

APPENDIX A3 - 1S

PROPERTIES GROUP 1S

Appendix D Examples of presentation formats

ASME Format for contents / specification

TABLE 1A (CONT'D)
SECTION I; SECTION III, CLASS 2 AND 3;* AND SECTION VIII, DIVISION 1
MAXIMUM ALLOWABLE STRESS VALUES S FOR FERROUS MATERIALS
(*See Maximum Temperature Limits for Restrictions on Class)

Nominal Composition	Product Form	Spec. No.	Type/Grade	Alloy Desig./ UNS No.	Class/ Cond./ Temper	Size/Thickness	P-No.	Group No.
5Cr–½Mo	Forgings	SA-336	...	...	F5	...	5	2
5Cr–½Mo	Forgings	SA-336	...	...	F5	...	5	2
5Cr–½Mo	Forgings	SA-182	F5	...	...	...	5	2
5Cr–½Mo	Forgings	SA-182	F5	...	...	...	5	2
5Cr–½Mo	Plate	SA-387	5	...	2	...	5	2
5Cr–½Mo	Forgings	SA-336	...	...	F5A	...	5	2
5Cr–½Mo	Forgings	SA-336	...	...	F5A	...	5	2
5Cr–½Mo	Castings	SA-217	C5	...	...	...	5	2
5Cr–½Mo	Cast pipe	SA-426	CP5	...	...	...	5	2
5Cr–½Mo	Forgings	SA-182	F5a	...	...	...	5	2
5Cr–½Mo	Forgings	SA-182	F5a	...	...	...	5	2
5Cr–½Mo–Si	Smls. tube	SA-213	T5b	...	...	...	5	2
5Cr–½Mo–Si	Smls. pipe	SA-335	P5b	...	...	...	5	2
5Cr–½Mo–Ti	Smls. tube	SA-213	T5c	...	...	...	5	2
5Cr–½Mo–Ti	Smls. pipe	SA-335	P5c	...	...	...	5	2
7Cr–½Mo	Tube	SA-199	T7	...	...	...	5	2
7Cr–½Mo	Tube	SA-213	T7	...	...	...	5	2
7Cr–½Mo	Fittings	SA-234	WP7	...	...	...	5	2
7Cr–½Mo	Pipe	SA-335	P7	...	...	...	5	2
7Cr–½Mo	Forged pipe	SA-369	FP7	...	...	...	5	2
7Cr–½Mo	Cast pipe	SA-426	CP7	...	...	...	5	2
7Cr–½Mo	Forgings	SA-182	F7	...	...	...	5	2
9Cr–1Mo	Tube	SA-199	T9	...	...	...	5	2
9Cr–1Mo	Smls. tube	SA-213	T9	...	...	...	5	2
9Cr–1Mo	Fittings	SA-234	WP9	...	...	...	5	2
9Cr–1Mo	Fittings	SA-234	WP9	...	...	...	5	2
9Cr–1Mo	Smls. pipe	SA-335	P9	...	...	...	5	2
9Cr–1Mo	Forged pipe	SA-369	FP9	...	...	...	5	2
9Cr–1Mo	Forgings	SA-182	F9	...	...	...	5	2
9Cr–1Mo	Forgings	SA-182	F9	...	...	...	5	2
9Cr–1Mo	Forgings	SA-336	...	...	F9	...	5	2
9Cr–1Mo	Castings	SA-217	C12	...	...	...	5	2
9Cr–1Mo	Castings	SA-217	C12	...	...	...	5	2
9Cr–1Mo	Castings	SA-217	C12	...	...	...	5	2
9Cr–1Mo	Cast pipe	SA-426	CP9	...	...	...	5	2
9Cr–1Mo–V	Forgings	SA-182	F91	...	...	...	5	4
9Cr–1Mo–V	Forgings	SA-182	F91	...	...	...	5	4
9Cr–1Mo–V	Smls. tube	SA-213	T91	...	...	...	5	4
9Cr–1Mo–V	Tube	SA-213	T91	...	...	...	5	4
9Cr–1Mo–V	Fittings	SA-234	WP91	...	...	...	5	4
9Cr–1Mo–V	Smls. pipe	SA-335	P91	...	...	...	5	4
9Cr–1Mo–V	Pipe	SA-335	P91	...	...	...	5	4
9Cr–1Mo–V	Forgings	SA-336	...	...	F91	...	5	4
9Cr–1Mo–V	Forgings	SA-336	...	...	F91	...	5	4
9Cr–1Mo–V	Forged pipe	SA-369	FP91	...	...	...	5	4
9Cr–1Mo–V	Plate	SA-387	91	...	...	...	5	4
9Cr–1Mo–V	Plate	SA-387	91	...	2	...	5	4

ASME Format for contents / specification (cont)

TABLE 1A (CONT'D)
SECTION I; SECTION III, CLASS 2 AND 3;* AND SECTION VIII, DIVISION 1
MAXIMUM ALLOWABLE STRESS VALUES S FOR FERROUS MATERIALS
(*See Maximum Temperature Limits for Restrictions on Class)

Min. Tensile Strength, ksi	Min. Yield Strength, ksi	Applicability and Max. Temp. Limits (NP = Not Permitted) I	III	VIII-1	External Pressure Chart No.	Notes Reference I	III	VIII-1
60	36	NP	NP	1200	CS-2	---	---	C1
60	36	1200	NP	NP	---	A1: (27)	---	---
70	40	1200	NP	NP	---	A1: (27)	---	---
70	40	NP	700	1200	CS-2	---	B1	C1
75	45	NP	700	1200	CS-3	---	B1	C1
80	50	1200	NP	NP	---	A1: (27)	---	---
80	50	NP	NP	1200	CS-3	---	---	C1
90	60	1200	700	1200	CS-3	A1: (4)(5)(27)	B1: (4)	C1: (5)(6)
90	60	NP	700	NP	---	---	B1: (4)	---
90	65	1200	NP	NP	---	A1: (27)	---	---
90	65	NP	NP	1200	CS-3	---	---	C1
60	30	1200	NP	1200	CS-2	A1	---	C1
60	30	1200	NP	1200	CS-2	A1	---	C1
60	30	1200	NP	1200	CS-2	A1	---	C1
60	30	1200	NP	1200	CS-2	A1	---	C1
60	25	NP	NP	1200	CS-1	---	---	C1
60	30	NP	700	1200	CS-2	---	B1: (1)	C1
60	30	NP	NP	1200	CS-2	---	---	C1: (37)
60	30	NP	700	1200	CS-2	---	B1: (1)	C1
60	30	NP	700	1200	CS-2	---	B1	C1
60	30	NP	700	NP	---	---	B1: (4)	---
70	40	NP	NP	1200	CS-3	---	---	C1
60	25	NP	NP	1200	CS-1	---	---	C1
60	30	1200	700	1200	CS-2	A1	B1: (1)	C1
60	30	1200	NP	NP	---	A1: (20)(27)	---	---
60	30	NP	NP	1200	CS-2	---	---	C1: (37)
60	30	1200	700	1200	CS-2	A1	B1: (1)	C1
60	30	1200	700	1200	CS-2	A1	B1	C1
85	55	1200	NP	NP	---	A1: (27)	---	---
85	55	NP	NP	1200	CS-3	---	---	C1
85	55	NP	NP	1200	CS-2	---	---	C1
90	60	1200	NP	NP	---	A1: (4)(5)(27)	---	---
90	60	NP	NP	1200	CS-3	---	---	C1: (5)(6)
90	60	NP	700	NP	---	---	---	---
90	60	NP	700	NP	---	---	B1: (4)	---
85	60	1200	NP	NP	---	A1: (27)	---	---
85	60	NP	NP	1200	CS-3	---	---	C1: (38)
85	60	1200	NP	NP	---	A1: (27)	---	---
85	60	NP	NP	1200	CS-3	---	---	C1
85	60	1200	NP	NP	---	A1: (27)	---	---
85	60	1200	NP	NP	---	A1: (27)	---	---
85	60	NP	NP	1200	CS-3	---	---	C1
85	60	NP	NP	1200	CS-3	---	---	C1: (38)
85	60	1200	NP	NP	---	A1: (27)	---	---
85	60	1200	NP	NP	---	A1: (27)	---	---
85	60	1200	NP	NP	---	A1: (27)	---	---
85	60	NP	NP	1200	CS-3	---	---	C1

RCC-MR Format for contents / specification

Ref. Proc. Spec.	Type of product	Grade	Maximum diameter or thickness (mm)	Required acceptance values at room temperature R_m (MPa)	Min. $R_{0,002}$ (MPa)	Properties group
RM 3325	Bars	Z6CND17-12	≤ 150	≥ 520	210	1 S
		Z5CND17-12	≤ 150	≥ 520	210	1 S
		Controlled nitrogen Z2CND18-12	≤ 150	≥ 520	220	1 S
		Z6 CN18-10	≤ 150	≥ 520	210	2 S
		Z6 CN19-10	≤ 150	≥ 520	210	2 S
		Controlled nitrogen Z2 CN19-10	≤ 150	≥ 520	210	2 S (3)
		Z2CND17-12	≤ 150	≥ 490	175	3 S
		Z2 CN18-10	≤ 150	≥ 490	175	4 S
RM 3326	Forgings	Z15CNW22-12		600 (2)	240 (2)	6 S (to be issued)
RM 3331	Plates	Controlled nitrogen Z2CND17-12	5-300	≥ 525	220	1 S
RM 3332	Plates	Z6CND17-12	3-100	≥ 520	210	1 S
		Z5CND17-12	3-100	≥ 520	210	1 S
		Z6 CN18-10	3-100	≥ 520	210	2 S
		Z5 CN18-10	3-100	≥ 520	210	2 S
		Controlled nitrogen Z2 CN19-10	3-100	≥ 520	210	2 S (3)
		Z2CND17-12	3-100	≥ 490	175	3 S
		Z2 CN18-10	3-100	≥ 490	175	4 S
		Controlled nitrogen Z2CND18-12	3-100	≥ 520	220	1 S

AUSTENITIC STAINLESS STEELS (Cont.)

Ref. Proc. Spec.	Type of product	Grade	Maximum diameter or thickness (mm)	Required acceptance values at room temperature R_m (MPa)	Min. $R_{0,002}$ (MPa)	Properties group
RM 3333 (to be issued)	Formed plates	Controlled nitrogen Z2CND17-12	3-100	≥ 525	220	1 S
		Z6CND17-12	3-100	≥ 520	210	1 S
		Z5CND17-12	3-100	≥ 520	210	1 S
		Controlled nitrogen Z2CND18-12	3-100	≥ 520	220	1 S
		Z6 CN18-10	3-100	≥ 520	210	2 S
		Z6 CN18-10	3-100	≥ 520	210	2 S
		Controlled nitrogen Z2 CN19-10	3-100	≥ 520	210	2 S (3)
		Z2CND17-12	5-300	≥ 490	175	3 S
		Z2 CN18-10	3-100	≥ 490	175	4 S
RM 3335	Plate, sheet and strip (for supports)	Z6CND17-11	≤ 5	560-760	225	1 S
		Z6CND17-11	5-50	560-760	215	1 S
		Z6 CN18-09	≤ 5	540-740	215	2 S
		Z6 CN18-09	5-20	540-740	205	2 S
		Z6 CN18-09	20-50	520-720	205	2 S
		Z2CND17-12	≤ 5	510-710	215	3 S
		Z2CND17-12	5-50	510-710	205	3 S
		Z2CND17-13	≤ 5	510-710	215	3 S
		Z2CND17-13	5-50	510-710	205	3 S
		Z2 CN18-10	≤ 5	490-690	205	4 S
		Z2 CN18-10	5-50	490-690	195	4 S
RM 3341	Seamless tubes for exchangers	Z2 CN18-10	0,8-4	≥ 490	175	4 S
		Controlled nitrogen Z2 CN19-10	0,8-4	≥ 520	210	2 S (3)
		Z2CND17-12	0,8-4	≥ 490	175	3 S
		Controlled nitrogen Z2CND17-12	0,8-4	≥ 525	220	1 S

AUSTENITIC STAINLESS STEELS (Cont.)

ASME data Format

TABLE 1A (CONT'D)
SECTION I; SECTION III, CLASS 2 AND 3;* AND SECTION VIII, DIVISION 1
MAXIMUM ALLOWABLE STRESS VALUES S FOR FERROUS MATERIALS
(*See Maximum Temperature Limits for Restrictions on Class)

Maximum Allowable Stress, ksi (Multiply by 1000 to Obtain psi), for Metal Temperature, °F, Not Exceeding

−20 to 100	150	200	250	300	400	500	600	650	700	750	800	850	900	950
15.0	...	15.0	...	14.5	14.4	14.4	14.2	13.9	13.7	13.2	12.8	12.1	10.9	8.0
15.0	...	15.0	...	14.5	14.4	14.4	14.2	13.9	13.7	13.2	12.8	12.1	10.9	8.0
17.5	...	17.5	...	17.0	16.8	16.8	16.5	16.3	16.0	15.4	14.9	14.1	10.8	8.0
17.5	...	17.5	...	17.0	16.8	16.8	16.5	16.3	16.0	15.4	14.8	14.1	10.8	8.0
18.8	...	18.7	...	18.2	18.0	18.0	17.7	17.4	17.1	16.5	16.0	15.1	10.9	8.0
20.0	...	20.0	...	19.4	19.2	19.2	18.7	18.6	18.2	17.6	17.0	14.3	10.8	8.0
20.0	...	20.0	...	19.4	19.2	19.2	18.9	18.6	18.2	17.6	17.0	14.3	10.9	8.0
22.5	...	22.4	...	21.8	21.6	21.6	21.3	20.9	20.5	19.8	19.1	14.8	10.8	8.0
22.5	...	22.4	...	21.8	21.6	21.6	21.3	20.9	20.5	...	...	...	...	...
22.5	...	22.4	...	21.8	21.6	21.6	21.3	20.9	20.5	19.8	19.1	14.8	10.8	8.0
22.5	...	22.4	...	21.8	21.6	21.6	21.3	20.9	20.5	19.8	19.1	14.3	10.9	8.0
15.0	...	15.0	...	14.5	14.4	14.4	14.2	13.9	13.7	13.2	12.8	12.1	10.9	8.0
15.0	...	15.0	...	14.5	14.4	14.4	14.2	13.9	13.7	13.2	12.8	12.1	10.9	8.0
15.0	...	15.0	...	14.5	14.4	14.4	14.2	13.9	13.7	13.2	12.8	12.1	10.9	8.0
15.0	...	15.0	...	14.5	14.4	14.4	14.2	13.9	13.7	13.2	12.8	12.1	10.9	8.0
15.0	...	14.1	...	13.6	13.4	13.3	13.1	12.9	12.8	12.4	12.1	11.6	10.9	8.0
15.0	...	15.0	...	14.5	14.4	14.4	14.2	13.9	13.7	13.2	12.8	12.1	10.9	8.0
15.0	...	15.0	...	14.5	14.4	14.4	14.2	13.9	13.7	13.2	12.8	12.1	10.9	8.0
15.0	...	15.0	...	14.5	14.4	14.4	14.2	13.9	13.7	13.2	12.8	12.1	10.9	8.0
15.0	...	15.0	...	14.5	14.4	14.4	14.2	13.9	13.7	13.2	12.8	12.1	10.9	8.0
15.0	...	15.0	...	14.5	14.4	14.4	14.2	13.9	13.7	...	...	...	...	...
17.5	...	17.5	...	17.0	16.8	16.8	16.5	16.3	16.0	15.4	14.9	14.1	10.9	8.0
15.0	...	14.1	...	13.6	13.4	13.3	13.1	12.9	12.8	12.4	12.1	11.6	11.0	10.3
15.0	...	15.0	...	14.5	14.4	14.4	14.2	13.9	13.7	13.2	12.8	12.1	11.4	10.6
15.0	...	15.0	...	14.5	14.4	14.4	14.2	13.9	13.7	13.2	12.8	12.1	11.4	10.6
15.0	...	15.0	...	14.5	14.4	14.4	14.2	13.9	13.7	13.2	12.8	12.1	11.4	10.6
15.0	...	15.0	...	14.5	14.4	14.4	14.2	13.9	13.7	13.2	12.8	12.1	11.4	10.6
15.0	...	15.0	...	14.5	14.4	14.4	14.2	13.9	13.7	13.2	12.8	12.1	11.4	10.6
21.3	...	21.2	...	20.6	20.4	20.4	20.1	19.9	19.4	18.7	18.1	17.1	16.2	11.0
21.3	...	21.2	...	20.6	20.4	20.4	20.1	19.7	19.4	18.7	18.1	17.1	16.2	11.0
21.3	...	21.2	...	20.6	20.4	20.4	20.1	19.7	19.4	18.7	18.1	17.1	15.2	11.0
22.5	...	22.4	...	21.8	21.6	21.6	21.3	20.9	20.5	19.8	19.1	18.2	16.5	11.0
22.5	...	22.4	...	21.8	21.6	21.6	21.3	20.9	20.5	19.8	19.1	18.2	16.5	11.0
22.5	...	22.4	...	21.2	21.2	21.2	21.2	21.0	20.6	...	...	...	...	...
22.5	...	22.4	...	21.0	21.6	21.6	21.6	20.9	20.5	...	...	...	...	...
21.3	...	21.3	...	21.2	21.2	21.1	20.8	20.5	20.0	19.4	18.7	17.8	16.7	15.5
21.3	...	21.3	...	21.2	21.2	21.1	20.8	20.5	20.0	19.4	18.7	17.8	16.7	15.5
21.3	...	21.3	...	21.2	21.2	21.1	20.8	20.5	20.0	19.4	18.7	17.8	16.7	15.5
21.3	...	21.3	...	21.2	21.2	21.1	20.8	20.5	20.0	19.4	18.7	17.8	16.7	15.5
21.3	...	21.3	...	21.2	21.2	21.1	20.8	20.5	20.0	19.4	18.7	17.8	16.7	15.5
21.3	...	21.3	...	21.2	21.2	21.1	20.8	20.5	20.0	19.4	18.7	17.8	16.7	15.5
21.3	...	21.3	...	21.2	21.2	21.1	20.8	20.5	20.0	19.4	18.7	17.8	16.7	15.5
21.3	...	21.3	...	21.2	21.2	21.1	20.8	20.5	20.0	19.4	18.7	17.8	16.7	15.5
21.3	...	21.3	...	21.2	21.2	21.1	20.8	20.5	20.0	19.4	18.7	17.8	16.7	15.5
21.3	...	21.3	...	21.2	21.2	21.1	20.8	20.5	20.0	19.4	18.7	17.8	16.7	15.5
21.3	...	21.3	...	21.2	21.2	21.1	20.8	20.5	20.0	19.4	18.7	17.8	16.7	15.5
21.3	...	21.3	...	21.2	21.2	21.1	20.8	20.5	20.0	19.4	18.7	17.8	16.7	15.5

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ASME data Format (cont)

TABLE 1A (CONT'D)
SECTION I; SECTION III, CLASS 2 AND 3;* AND SECTION VIII, DIVISION 1
MAXIMUM ALLOWABLE STRESS VALUES *S* FOR FERROUS MATERIALS
(*See Maximum Temperature Limits for Restrictions on Class)

Maximum Allowable Stress, ksi (Multiply by 1000 to Obtain psi), for Metal Temperature, °F, Not Exceeding											Type/ Grade	Spec. No.
1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500		
5.8	4.2	2.9	1.8	1.0	...	...	...	...	...	...	...	SA-336
5.8	4.2	2.9	1.8	1.0	...	...	...	...	...	...	...	SA-336
5.8	4.2	2.9	1.8	1.0	...	...	...	...	...	...	F5	SA-182
5.8	4.2	2.9	1.8	1.0	...	...	...	...	...	...	F5	SA-182
5.8	4.2	2.9	1.8	1.0	...	...	...	...	...	...	5	SA-387
5.8	4.2	2.9	1.8	1.0	...	...	...	...	...	...	...	SA-336
5.8	4.2	2.9	1.8	1.0	...	...	...	...	...	...	...	SA-336
5.8	4.2	2.9	1.8	1.0	...	...	...	...	...	...	C5	SA-217
...	...	...	...	...	...	...	...	...	...	...	CP5	SA-426
5.8	4.2	2.9	1.8	1.0	...	...	...	...	...	...	F5a	SA-182
5.8	4.2	2.9	1.8	1.0	...	...	...	...	...	...	F5a	SA-182
5.8	4.2	2.9	1.8	1.0	...	...	...	...	...	...	T5b	SA-213
5.8	4.2	2.9	1.8	1.0	...	...	...	...	...	...	P5b	SA-335
5.8	4.2	2.9	1.8	1.0	...	...	...	...	...	...	T5c	SA-213
5.8	4.2	2.9	1.8	1.0	...	...	...	...	...	...	P5c	SA-335
5.8	4.2	2.9	2.0	1.3	...	...	...	...	...	...	T7	SA-199
5.8	4.2	2.9	2.0	1.3	...	...	...	...	...	...	T7	SA-213
5.8	4.2	2.9	2.0	1.3	...	...	...	...	...	...	WP7	SA-234
5.8	4.2	2.9	2.0	1.3	...	...	...	...	...	...	P7	SA-335
5.8	4.2	2.9	2.0	1.3	...	...	...	...	...	...	FP7	SA-369
...	...	...	...	...	...	...	...	...	...	...	CP7	SA-426
5.8	4.2	2.9	2.0	1.3	...	...	...	...	...	...	F7	SA-182
7.4	5.0	3.3	2.2	1.5	...	...	...	...	...	...	T9	SA-199
7.4	5.0	3.3	2.2	1.5	...	...	...	...	...	...	T9	SA-213
7.4	5.0	3.3	2.2	1.5	...	...	...	...	...	...	WP9	SA-234
7.4	5.0	3.3	2.2	1.5	...	...	...	...	...	...	WP9	SA-234
7.4	5.0	3.3	2.2	1.5	...	...	...	...	...	...	P9	SA-335
7.4	5.0	3.3	2.2	1.5	...	...	...	...	...	...	FP9	SA-369
7.4	5.0	3.3	2.2	1.5	...	...	...	...	...	...	F9	SA-182
7.4	5.0	3.3	2.2	1.5	...	...	...	...	...	...	F9	SA-182
7.4	5.0	3.3	2.2	1.5	...	...	...	...	...	...	...	SA-336
7.4	5.0	3.3	2.2	1.5	...	...	...	...	...	...	C12	SA-217
7.4	5.0	3.3	2.2	1.5	...	...	...	...	...	...	C12	SA-217
...	...	...	...	...	...	...	...	...	...	...	C12	SA-217
...	...	...	...	...	...	...	...	...	...	...	CP9	SA-426
14.3	12.9	10.3	7.0	4.3	...	...	...	...	...	...	F91	SA-182
14.3	12.9	10.3	7.0	4.3	...	...	...	...	...	...	F91	SA-182
14.3	12.9	10.3	7.0	4.3	...	...	...	...	...	...	T91	SA-213
14.3	12.9	10.3	7.0	4.3	...	...	...	...	...	...	T91	SA-213
14.3	12.9	10.3	7.0	4.3	...	...	...	...	...	...	WP91	SA-234
14.3	12.9	10.3	7.0	4.3	...	...	...	...	...	...	P91	SA-335
14.3	12.9	10.3	7.0	4.3	...	...	...	...	...	...	P91	SA-335
14.3	12.9	10.3	7.0	4.3	...	...	...	...	...	...	...	SA-336
14.3	12.9	10.3	7.0	4.3	...	...	...	...	...	...	...	SA-336
14.3	12.9	10.3	7.0	4.3	...	...	...	...	...	...	FP91	SA-369
14.3	12.9	10.3	7.0	4.3	...	...	...	...	...	...	91	SA-387
14.3	12.9	10.3	7.0	4.3	...	...	...	...	...	...	91	SA-387

Plan for RCC-MR data information

APPENDIX A3 - 1S

PROPERTIES GROUP 1S