EUROPEAN COMMISSION
5th EURATOM FRAMEWORK PROGRAMME 1998-2002
KEY ACTION : NUCLEAR FISSION

HTR-M

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

CONTRACT N°
FIKI-CT-2000-00032

Database on Pressure Vessel steel plate and weld material for Reactor Pressure Vessel (RPV)

A. A. Braithwaite

NNC Ltd., UK

Dissemination level: CO
Document Number: HTR-M 02/11-D-0.0.50
Deliverable No. 1.1

Database on Pressure Vessel steel plate and weld material for Reactor Pressure Vessel (RPV)

by

A. A. Braithwaite

C6463/TR/018
Issue 02
June 2004

DOCUMENT ISSUE RECORD
(engineering documents)

Adding value through knowledge

Document Title :	Database on Pressure Vessel steel plate and weld material for Reactor Pressure Vessel (RPV)
Project Reference:	64631

Purpose of Issue : Final Issue

Security Class : Commercial-in-Confidence

Issue	Description of Amendment	Originator/ Author	Checker	Approver	Date
01	Initial Issue	A.A. Braithwaite	D.E. Buckthorpe	T. Lennox	November 2002
02	Final Issue Including Comments from HTR-M Partners	A.A. Braithwaite	D.E. Buckthorpe	T. Lennox	June 2004

Total number of pages:	Intro: iii	Text 3	Tables 6	Figures 1	Appendices A3

Previous issues of this document shall be destroyed or marked **SUPERSEDED**

Distribution: S. Casalta (EU), M. Hugon (CEC), SINTER,
A.A. Braithwaite, D.E. Buckthorpe, R.D.W .Bestwick (NNC), EDMS

Table of Contents

List of Figures

1 Introduction

An aim of the HTR-M project is to provide design data for potential HTR pressure vessel materials. Where such data are not available in existing codes, it is necessary to collect materials property information so that it can be reviewed and evaluated to provide design data. It is intended to assemble a materials property database for the selected materials, to include code data where available, and raw data for analysis. This report sets out the scope and structure of the database, and describes how it will be maintained.

2 Scope

2.1 Materials

It is intended that data for five steels will be included in the database. Four of the materials (C-Mn steel, 2¼Cr 1Mo steel, SA 508 and modified 9Cr 1Mo steel) have been specified for existing or future HTRs (Ref. 1), and the fifth, 12CrMoVNb steel, has the capability for use at temperatures appropriate to a 'warm' HTR vessel. The material designations are intended to be generic descriptions, thus for example SA 508 type material is understood to include the ASME specifications SA 508 Grade 3 Class 1 and SA 533 Type B Class 1, and the equivalent European designations 20 MnMoNi 5 5 (Germany) and 15MND 5 or 18MND 5 (France).

2.2 Properties

A provisional list of properties for the database is given in Appendix 1. It is expected that the list will develop as further design requirements are established. The requirements for 'cold' and 'warm' vessel materials will of course be different in some respects.

Data from standards or design codes will be included, where such information is available no further data are required. However an important function of the database is to record information regarding the effect of operational factors (e.g. welding, thermal ageing, irradiation) on standard properties.

3 Structure of the database

The structure of the database is described in detail in Appendix 1 (derived from Ref. 2). The system is based on that used in a number of collaborative CEC projects (e.g. Refs. 3 and 4), and consists essentially of a set of Microsoft Excel files. There will be one file for each material.

Within each file is a series of worksheets containing material details and test data (or standard data), as illustrated in Fig. 1.

It should be noted that the database structure can be extended to meet the needs of the data. Thus:

- worksheets can be added to cover additional properties;

- columns can be added within worksheets to record additional data, for example details of material irradiation.

To record a series of test results on a particular material, information on the test material is first entered into material detail sheets and the material identified by a unique number. Results from tests on the material are then entered into associated worksheets. Each set of test data is then accompanied by the material unique number, so that the essential link between material information and test data is maintained.

Data from design codes or material standards are entered in the same way, except that the material specification details (e.g. composition range) are entered in the material detail sheets.

Note that all data will be entered numerically, as x-y pairs. If data are only available graphically or expressed as an equation, then a series of x-y pairs must be generated (by digitising a graph, or by calculation from an equation) for insertion into the database.

4 Management of the database

The master version of the database will be available on SINTER as a read-only copy. The master version will be maintained by NNC (coordinator D. Buckthorpe).

Worksheet templates for the addition of data are contained in Excel file "HTR M vessel database Nov 02" which will be sent to all participants. To add data, contributors are requested to enter the data on the template worksheets, and post these on SINTER. The coordinator will then arrange for the data to be added to the master database, and for the master version on SINTER to be updated.

If a need for additional worksheets is recognised, the format should be agreed with the coordinator. The new data can then be added in the normal way.

5 References

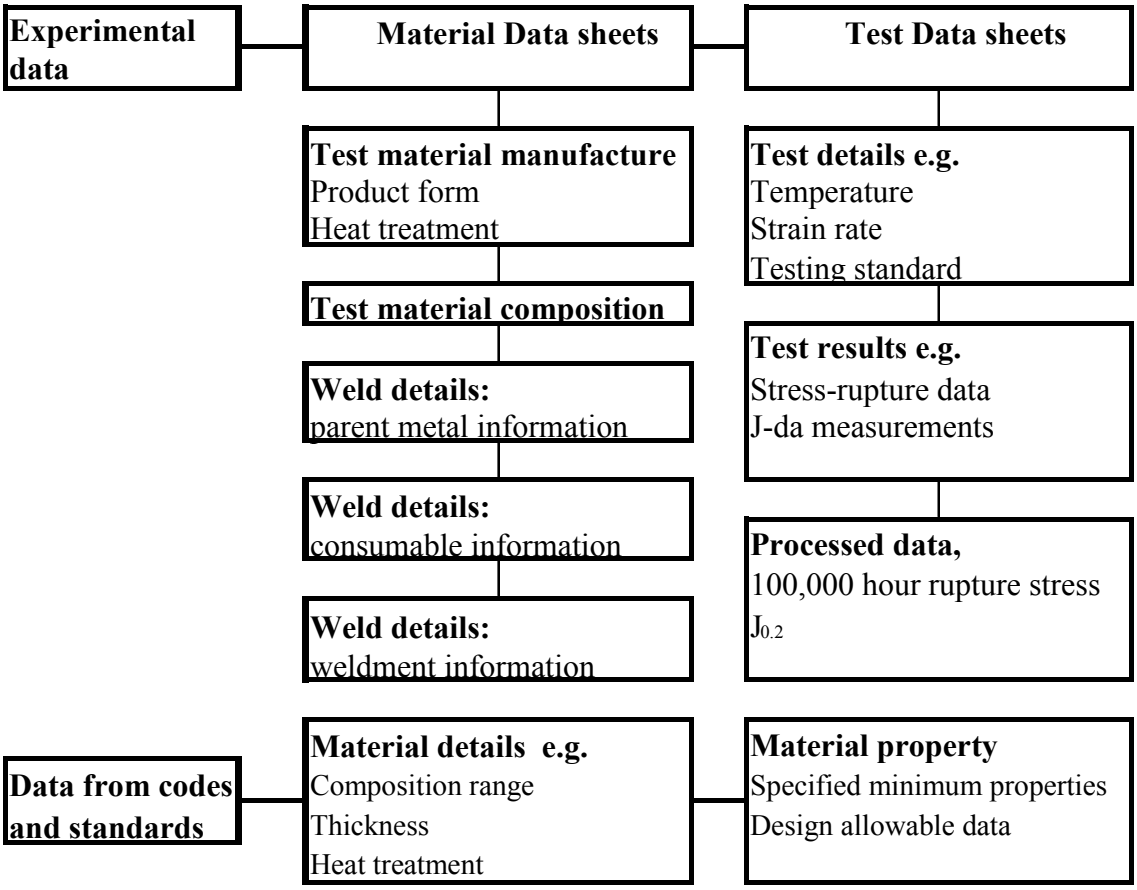
1. HTR-M Project – Preliminary review of RPV materials used on HTR and other gas-cooled reactors. RDW Bestwick. HTR-M-01/9-D-1.1.9

2. Scheme for HTR-M Data collection. AA Braithwaite. HTR-M-01/11-D-0.0.22

3. Final report on CEC study contract RAI-0227-UK, A A Braithwaite (NNC), C Escaravage (Novatome), H Huthmann (Siemens), D Lehmann, A A Tavassoli (CEA). NNC Report C9261/TR/001 1996.

4. Final report on CEC study contract, RAI-0214-UK, A A Braithwaite (NNC), H Breitling (Siemens), I Curbishley (AEA-T), C Escaravage (Novatome), D Lehmann, A A Tavassoli (CEA). NNC Report C8642/TR/001 1996.

Figure 1 Database contents



Appendix A - *Details of the database structure*

A.1 The Excel worksheets

The database consists of a set of Excel files, one for each material being considered. The template for each material file is contained in Excel file "HTR M vessel material database Nov 02" which is being sent to participants.

The worksheet headings for each material file are listed in Table A-1. It will be seen that the file contains four worksheets for recording material and weld details, and a number of other worksheets for recording material property details.

It should be noted that the database structure can be extended to meet the needs of the data. Thus:

- worksheets can be added to cover additional properties;
- columns can be added within worksheets to record additional data, for example details of material irradiation.

A.1.1 Material worksheets

The detailed contents of the material worksheets are shown in Table A-1. Sheet 1.1 contains information relating to parent material production, while Sheet 1.2 contains compositional information. Each material is given a unique number (see A.2 below) to allow a link to be maintained between the material and its test results.

If the test material involves a weldment, then two additional sheets (1.3 and 1.4) are used: these allow details of the weld consumable and of the weldment itself to be entered. Compositional details of the weld or the consumable are entered on Sheet 1.2. Again, weld and consumable are identified by unique reference numbers.

Examples of material details recorded using the system are shown in Table A-3. These illustrate the link between the weld, parent metal and consumable.

A.1.2 Mechanical property details

The extent and the precise format of the test worksheets are governed by the requirements of the data. Examples of sheets used for some of the properties which will be required are given in Table A-4.

For tensile test results (see 2.1 on Table A-4) all the information is collected on a single worksheet, with a second worksheet for recording code data.

However, for more complex tests more than one sheet is needed. Generally three linked sheets are used: one for materials test details, one for the basic property measurements (i.e. recording the data for re-analysis if desired), and one for the derived properties which are normally used in design or assessment. The link between information on the three sheets is maintained by means of a unique number allocated to each test. Separate sheets are designated for the recording of design (or assessment) data, from codes or standards.

Sheets 3.1 to 3.3 in Table A-4 show column headings used in linked worksheets for fracture toughness. For fracture toughness properties, the test information (specimen details, testing standard etc) is recorded in Sheet 3.1, original J and δa values are recorded in 3.2, and 3.3 contains values of $J_{initiation}$, J_{IC} etc. obtained in the original work.

Sheets 4.1 to 4.4 in Table A-4 include information arranged similarly for creep properties, except that in this case an additional sheet is included to record creep rupture data.

Similar worksheets may be used for the collection of fatigue, fatigue crack growth and impact properties, and it is envisaged that the same general structure would be used for the recording of other property information.

Examples of data entries for tensile and fracture toughness properties are shown in Table A-5. These examples illustrate the way in which the material and test unique numbers maintain the link between information on different worksheets.

A.1.3 Design data

For each particular property, a separate sheet is designated for the recording of design (or assessment) data, from codes or standards. This allows comparisons to be made between experimental data recorded on the database and the equivalent design data.

The additional sheets are indicated on Table A-4 as 2.2 for tensile data, 3.4 for fracture toughness, 4.5 for creep rupture and 4.6 for creep strain. The precise form of the toughness and creep data sheets will depend upon the data available, so no column headings are shown for these sheets on Table A-4.

An example of code data entry for creep rupture properties is shown in Table A-6.

A.2 Unique numbering

The link between material and test results in the database is maintained by the assignment of unique reference numbers as described below.

A.2.1 Material numbers.

Each different material (or, for example, different heat treated batches of the same original material) should be given a unique number. It is proposed that the numbers take the form XYZ/Q/nnnn, where:

- XYZ identifies the source (eg NRG, NNC, CEA, FRF for Framatome France and FRD for Framatome Germany);
- Q identifies the type of material (M for parent material, C for consumable and W for weld deposit);
- nnnn is a number allocated by the originator (suggested 4-digit sequential number).

Thus for example CEA/C/1234 would indicate a weld consumable material, details supplied by CEA.

A.2.2 Test numbers

It will be seen from Table A-4 that in those cases where test details and test results are recorded on different worksheets, it is necessary to assign a unique number to a specific test. It is proposed that these numbers take a similar form to the material numbers, but contain the letter T instead of the material letter M, C or W. Thus for example NRG/T/1234 would indicate a test, details supplied by NRG.

Table A-1 Worksheets for a material file in the database

Sheet No	Title
Materials	
1.1	Parent metal details
1.2	Chemical analysis
1.3	Weld consumable details
1.4	Weldment details
Tensile properties	
2.1	Test data
2.2	Code data
Fracture toughness properties	
3.1	Test details
3.2	J-δa values
3.3	Test results
3.4	Code data
Creep properties	
4.1	Test details
4.2	Rupture test results
4.3	Creep strain test data
4.4	Creep strain test results
4.5	Rupture code data
4.6	Creep strain code data
Fatigue properties	
5.1 etc	
Fatigue crack growth properties	
6.1 etc	
Impact properties	
7.1 etc	

Other worksheets can be added as required

Table A-2 Worksheet headings for materials information

1.1 Parent metal details											
Material Unique No	Specification	Producer	Product form	Cast No	Heat No	Section Size, mm	Heat Treatment		Cold work	Reference	Other Information
							As rec	Additional			

1.2 Chemical analysis					
Material Unique No	Element wt%	C	Mn	etc	Other information

1.3 Weld Consumable details							
Consumable unique no	Steel making practice	Manufacturer	Product Name	Batch No	Wire/rod diameter	Reference	Other Information

1.4 Weldment details										
Weldment Unique No	Consumable unique no	Welding process	Weld geometry	Heat input	Preheat Temperature	Interpass Temperature	PWHT Temp	PWHT Time	Reference	Other information

1.1 Parent metal details

Material Unique No	Specification	Producer	Product form	Cast No	Heat No	Section Size, mm	Heat Treatment		Cold work	Reference	Other Information
							As rec	Additional			
M5000	(grade 91)	Creusot Loire	Plate	85 829		40	N&T			2	

1.2 Chemical analysis

Material unique no	C wt %	Mn	Si	S	P	Ni	Cr	Mo	(etc)	Reference	Other Information
M5000	0.105	0.38	0.43	0.003	0.009	0.13	8.26	0.85		2	Ladle analysis
M5000	0.105	0.38	0.40	0.002	0.009	0.13	8.30	0.97		2	Product analysis
C5000	0.107	0.75	0.32	0.007	0.010	0.07	8.25	0.92		2	Product analysis

1.3 Weld Consumable details

Consumable unique no	Manufacturer	Product Name	Batch no	Wire/rod diameter	Reference	Other information
C5000	Oerlikon	Cromocord 9M	029.578	5 mm	2	

1.4 Weldment details

Weldment unique no	Material unique no	Consumable unique no	Welding process	Weld Geometry	Heat input	Preheat temp	Interpass temp	PWHT temp	PWHT time	Reference	Other Information
W5003	M5000	C5000	MMA	double V, 12/45°				760°C	16 h	2	

Table A-4 Worksheet headings for data collection

2 Tensile Properties												
2.1 Tensile test results												
Material Unique No	Specimen orientation	Specimen location	Test temp °C	YS MPa	UTS MPa	Elongation %	R of A %	Reference	Other information			
2.2 Tensile design data												
Temp °C	YS MPa	UTS MPa	Elongation %	R of A %	Reference	Other Information						
3 Fracture toughness properties												
3.1 Fracture toughness test details												
Material unique no	Test unique no	Test temp, °C	Specimen type	Specimen size, mm	Specimen orientation	Specimen location	Side grooves	Testing standard	Crack monitoring	Blunting Line	Reference	Other information
3.2 Fracture toughness J-δa values												
Test unique no	J, $kJ.m^2$	δa, mm	Other information									
3.3 Fracture toughness test results												
Test unique no	J initiation definition	J initiation kJ/m^2	J_{lmm} kJ/m^2	J_{IC} kJ/m^2	dJ/da kN/m^2	Equation J=f(δa)	Other information					
3.4 Fracture toughness design data												
4 Creep properties												
4.1 Creep test details												
Material unique no	Test Unique No	Specimen orientation	Specimen location	Test Temp, °C	Stress MPa	Reference	Other Information					
4.2 Creep rupture test results												
Test unique no	Time to fail, h	Elongation %	R of A %	Other Information								
4.3 Creep strain test data												
Test Unique No	Time, h	Strain %	Other information									
4.4 Creep Strain Results												
Test Unique No	Primary creep rate	Secondary creep rate	Other information									
4.5 Creep rupture design data												
4.6 Creep strain design data												

2.1 Tensile Properties

Material unique no	Specimen orientation	Specimen location	Test temp, °C	YS MPa	UTS MPa	Elongation &	R of A %	Reference	Other information
M2001	S		100	320	490	20	68	1	

3 Fracture Toughness Properties

3.1 Fracture Toughness Test Details

Material unique no	Test Unique no	Test temp, °C.	Specimen type	Specimen size, mm	Specimen orientation	Specimen location	Side grooves	Testing standard	Crack Monitoring	Blunting line	Reference	Other information
M2001	T201	100	CTJ	25	ST		yes	NF A 03-183	compliance	4	1	

3.2 Fracture toughness J – a values

Test unique no	J, kJ/m^2	a, mm	Other information
T2101	7.5 19.9 56.1 77 98.2 119.5 (etc)	0 0.25 0.16 0.2 0.23 0.32	

3.3 Fracture Toughness Test Results

Test unique no	$J_{initiation}$ definition	$J_{initiation}$ kJ/m^2	$J_{1\,mm}$ kJ/m^2	J_{IC} kJ/m^2	J_{max} kJ/m^2	dJ/ kN/m^2	Equation J = f(a)	A	C	Other information
T2101	0.2BL	349	549	299	597	215	J = A +C (a)	259	216	

4 Creep properties											
4.5 Creep rupture design data											
Temp, °C	**Minimum creep rupture stress S_r in N/mm^2, for time t hours**										
	1	**10**	**30**	**100**	**300**	**1000**	**3000**	**10000**	**30000**	**100000**	**300000**
350	365	365	365	365	365	365	365	365	365	365	365
375	365	365	365	365	365	365	365	365	365	355	318
400	365	365	365	365	365	365	350	330	298	260	239
425	365	365	365	365	340	308	280	248	216	193	171
450	365	362	353	330	290	250	224	198	170	150	132
475	365	327	298	264	235	202	180	158	138	120	103
500	362	288	255	222	194	166	146	129	110	98	82
525	312	241	211	184	159	136	118	103	87	76	63
550	260	198	175	150	131	109	94	80	68	57	47
Source: RCC-MR June 1985 Section 1- Subsection Z, Appendix A3-16S, Table A3.16S.5.3.2 (Grade 7CD9-10)											