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ASSESSMENT OF EXISTING ALLOY 617 DATA FOR GEN IV MATERIALS HANDBOOK

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GEN IV Nuclear Energy Systems

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ABTRACT

Activities in preparing existing data on Alloy 617 for the *Gen IV Materials Handbook* through data mining and assessment are summarized. Status of existing data is reviewed and assessment approaches are discussed. Data classification is used to provide a reference for quality and reliability evaluation. A tracking system is developed so that all data elements can be traced back to their original source for background review whenever needed. To facilitate convenient data processing and future input into the *Gen IV Materials Handbook*, formats for data editing and compilation are established. Based on their priorities, existing data that are the most germane to the Gen IV nuclear reactor applications are evaluated for their data types, material status, testing conditions and other background information. Acquisition of European data on the alloy for nuclear applications is also reported.

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1. INTRODUCTION

1.1 Background and Motivation

In preparing structural materials information for design and analysis of the Generation IV (Gen IV) Nuclear Reactor Systems, a considerable effort has been initiated at the Oak Ridge National Laboratory (ORNL) to develop a *Gen IV Materials Handbook* [Rittenhouse, 2005]. Structural materials for all the Gen IV nuclear reactor concepts supported by the Department of Energy (DOE) will be included in this *Handbook*. The *Handbook* will provide an authoritative single source of highly qualified structural materials information and offer an extensive presentation of the mechanical and physical properties data including consideration of the effects of temperature, irradiation, and environment. Necessary descriptive information such as chemical compositions and technical specifications etc. will also be incorporated for each material.

To prepare data for the *Gen IV Materials Handbook*, various plans and tasks have been developed covering both metallic and non metallic structural materials. Alloy 617 has been identified by the *Handbook* task group as well as the Gen IV Materials Program management as the first material to be collected into the *Handbook* through existing data mining. In "High Temperature Metallic Materials Test Plan for Generation IV Nuclear Reactors" [Ren 2004], the alloy has also been listed as the first candidate material for the data collection through material testing.

Alloy 617, also designated as Inconel 617, UNS N06617, or W. Nr. 2.4663a, was developed in the early 1970's for high-temperature applications above 850ºC (1562ºF). It is a nickel-chromium-cobalt-molybdenum alloy with a good combination of high-temperature strength and oxidation resistance. The alloy also has excellent resistance to a wide range of corrosive environments, and it is readily formed and welded by conventional techniques. Since its development, its properties have made it an attractive material and often considered for use in aircraft and land-based gas turbines, chemical manufacturing components, metallurgical processing facilities, and fossil and nuclear power generation structures. Significant amount of data on the alloy has been generated domestically and internationally over the past more than 30 years for these applications. This existing data provides a wealth of information sources for the *Gen IV Materials Handbook*.

However, because the existing data were produced by different domestic and international sources, they may have been generated under different standards, using different testing techniques, through different data reduction procedures, and for different application purposes. Before these data can be accepted into the *Gen IV Materials Handbook*, their quality, suitability, testing conditions and other background information must be carefully collected, reviewed, classified, edited, compiled, and even verified by experiments when necessary. All this has necessitated the task of existing data assessment.

On the other hand, because the thermal, environmental, and service life conditions of the Gen IV nuclear reactors are unprecedented with respect to previous application experiences of the alloy, a large database is required to evaluate the alloy's viability and qualification for the intended service conditions. For example, in the leading Gen IV nuclear reactor candidate - the Very High Temperature Reactor (VHTR), helium coolant at an outlet temperature of 900 ~ 1000°C (1652 ~ 1932°F) and a design life of up to 60 years are required. Material properties data for some of such conditions may not exist, and must be generated through experiments under simulated reactor working conditions. Generating data under such severe testing conditions entails a considerable amount of cost, time and manpower. Needless to say, an assessment of the existing data can help efficiently identify the data gaps (data-unavailable) and pinpoint experimental and testing needs, and thus significantly reduce cost, save time, and minimize manpower in data generation. Therefore, in the "High Temperature Metallic Materials Test Plan for Generation IV Nuclear Reactors" [Ren 2004], assessment of existing data has been identified as one of the very important early steps in the Gen IV materials testing program.

1.2 Existing Data Status and Assessment Approaches

Information on Alloy 617 can be found in many sources including ASME and ASTM documents, recognized international codes and standards, various materials handbooks, manufacturer records as well as open literature. Early in this data assessment effort, sources containing information on Alloy 617 were searched through the CSA Materials Research Database with METADEX. A title search has yielded more than 100 documents; and a key word search has resulted in more than 700. Unpublished/internal documents have also been identified and located through conventional searching methods such as file digging and personal communications. As a matter of fact, much information germane to the Gen IV nuclear reactor applications on the alloy has been found in unpublished/internal documents, for example: the reports on investigation of Alloy 617 for DOE's High Temperature Gas-Cooled Reactors (HTGR) Program generated in the 1980's.

The data assessment process has included collecting, assembling, reviewing, analyzing, accepting or rejecting, compiling, and documenting the existing data. To manage and process such a large quantity of information, an early preliminary review was conducted to evaluate the status of the existing data and determine the assessment approaches. It was decided that to ensure efficiency of the entire assessment process, the identified documents must be evaluated on a priority basis. Therefore, documents that apparently contain data relevant and important to the Gen IV nuclear reactor service conditions have been evaluated first. Those with relatively lower relevancy to the Gen IV materials data needs have been left for future review due to the limited time frame given to deliver the present report. Some documents have been excluded from the assessment after the preliminary review indicated that the information was of little use or not germane to the Gen IV materials data needs. It has also been realized in the preliminary review that although a lot of documents exist, many of them contain data that are either duplicated or processed from data in other documents. For example, some ASME Code Cases and the draft Code Case for the design of Alloy 617 nuclear components contain data duplicated and/or processed from data in some other documents. There are also sources that have been identified to contain information of great interest to the Gen IV materials data needs, but have been unable to be evaluated for the present report due to availability limitations from factors such as proprietary rights and commercial interests. Communication and negotiations have been conducted and will be continued to gain access to those sources.

The early preliminary review has also revealed that most of the existing data are presented in various hard copy forms such as tables, figures and texts. To prepare these data for future input into the *Gen IV Materials Handbook* as well as the analyses during the assessment, appropriate formats for convenient data maneuvering should first be developed, and then the hard copy data must be digitized into electronic form and converted into the developed formats for future use. Moreover, to facilitate data analyses and future applications, a tracking system is also needed so that every data element, i. e., point, micrograph, quoted text statement etc., can be traced back to its original source when desired. To help evaluate the data quality and relevancy to the Gen IV nuclear reactor applications, classification criteria are also needed to categorize the existing data. To assist in conveniently identifying data gaps, the digitized and formatted data should be used to extract their testing conditions and matrices from which they have been generated.

The present report summarizes the efforts and progress in the collection and evaluation of the existing data on Alloy 617 over the period from October 2004 to June 2005. There is no doubt that new data are being generated somewhere around the world while the present assessment is in progress. Therefore, although the present report may have collected existing data on Alloy 617 most germane to the Gen IV nuclear reactors, it should not be considered a comprehensive and conclusive assessment. Efforts will be continued to collect and evaluate useful existing data on the alloy for the Gen IV materials program.

2. MANAGEMENT OF EXISTING DATA

2.1 Classification

Because the existing data are collected from various sources, decisions must be constantly made about their quality, reliability, relevancy, and acceptability. Without specific guidelines, these decisions will largely be left to personal judgment of the individuals who are processing the data. In this case, conflicts and inconsistencies would become inevitable. Therefore, it is necessary that some commonly agreed guidelines are provided for making such judgment. However, existing data from various sources may have been generated under different testing standards, processed with different procedures, and produced with different error allowances. It is very difficult to establish an absolute standard that can be used for judging their relative quality. Since the assessed data will eventually be input into the *Gen IV Materials Handbook*, the criteria for classification and identification proposed for the *Gen IV Materials Handbook* will be followed. Based mainly on the origin of the sources, the existing data will be categorized into five classes as follows [Rittenhouse 2005]:

Class 1 These materials data meet all DOE Gen IV Reactor Programs and NRC QA requirements (i.e., these are data generated in documented R&D programs that meet all of the requirements of 10CFR50 Appendix B and DOE/NRC agreed versions of NQA-1). It is expected that the new data generated in Gen IV materials programs will be of this category. Data with this pedigree, it is assumed, would be entirely acceptable to DOE, NRC, and reactor vendors for use in final design and design analyses, especially if they are submitted to and approved by appropriate codes and standards bodies.

Class 2 Materials data and data correlations provided in various sections of well-recognized U.S. codes and standards (e.g., ASME and ASTM) will be designated as Class 2. In many cases the raw data (i.e., individual data points) will not be available from these sources. Thus, the results of peer-approved analyses and resulting data correlations contained in these codes and standards may be the major Class 2 input to the *Handbook*. Further, although materials and materials data approved by codes and standards bodies are generally a necessary condition for acceptance of designs by State and Federal regulatory bodies, there may in some cases be additional requirements.

Class 3 Materials data provided in well-recognized international codes and standards will be categorized at present as Class 3. This may be revisited as the result of any international agreements reached relative to cooperation on the *Handbook*. For example, such agreements might result in Classes 2 and 3 being combined into a single class.

Class 4 Materials data obtained from materials handbooks such as the *Nuclear Systems Materials Handbook* and the *AFCI Materials Handbook* will be identified as Class 4. The data contained in these two examples have had careful and extensive analysis and peer review (equivalent to Class 2) but the data were generated under quality conditions ranging from "unknown" to equivalent to Class 1. In the latter case, the data from such handbooks would be listed as Class 1.

Class 5 Materials data obtained from sources such as manufacturers brochures and the open literature will be categorized as Class 5. Such data will, of course, be reviewed and approved before it is incorporated into the *Handbook*.

Although the classifications described above are not an absolute measure of the quality of existing data, they do provide a common basis for guidance on data acceptability and assurance. Further, questions relative to data uncertainties and ranges will be addressed in the *Gen IV Materials Handbook* by providing individual data points (whenever possible), including a characterization of each data point in terms of material and test parameters, source, and incorporating software packages for statistical analysis. An additional consideration for an attribute to determine data quality beyond test results and test condition is test technique. How the test was conducted can be a major indicator of the quality of the resulting data. If an existing data set appears obviously questionable, testing may also be conducted to verify the reliability before the data are rejected or accepted.

2.2 Tracking System

Because the existing data were generated by various sources, their detailed background information such as the testing conditions, standards, intended applications, data processing methods etcetera may vary from one another. In the present assessment and even when the data are used for the analysis and design of the Gen IV nuclear reactor components, such information may become very important for understanding the material behavior exhibited by the data, especially when questions arise about their background. Therefore, the origin of the data should not be lost or clouded when data points are assembled, edited, formatted, and compiled for the *Handbook* input or when they are used for design and analysis after they have been stored in the *Handbook*. It is apparent that a tracking system must be established and applied to all the data elements early in the assessment stage. When the data are installed into the *Handbook*, a user should be able to easily track down the origin of each data element. Because so many data elements need to be tracked, the system must be kept very simple but reasonably accurate. An efficient way to do this is to attach a short ID tag to each data element.

To clearly indicate the origin of a data element with a short ID tag, the tag must include the identification of the source, usually a document or an established electronic database that has originally contained the data element. The shortest identification for a source document in most cases is the last name of the author plus date of publication. For some corporate documents without an author identified, an acronym composed of the first letters of the company name, or its well known nickname may be used. The same method can be applied to tag data elements from established electronic databases. To keep the publication date short, only the month in numeric number and the last two digits of the year should be used. Furthermore, since in most cases the source document is large, the location of the data element in the source document should be identifiable from the tag. The location identification may not be that crucial for data elements from an established electronic database since electronic search functions are always available for such databases and electronic databases are usually dynamic and subject to changes. For hard copy source documents, the data element location can be indicated with Tx for Table x, Fy for Figure y, and Pz for page z. The tag for a data point of creep rupture stress from Table 4 of a document authored by John Doe published in July, 1978, for example, can be created as "Doe0778T4". Whenever the data point is listed in a compiled new table in the assessment, a Source Column is always dedicated for the tag. If the data element is a figure, the tag should be attached to the end of the caption; and for a text statement, the tag goes after the sentence. When the *Handbook* is developed, the tag may be used as a hypertext link to the source document if the document is installed in the electronic *Handbook* database. An easy click of finger on the tag should bring up the source document and display all the available background information for the user to review.

2.3 Formats for *Gen IV Materials Handbook* Input

Because the main purpose of the present assessment is to prepare qualified existing data for the *Gen IV Materials Handbook*, which will be constructed as a web-accessible electronic database with analytical and processing power, the assessed data should be edited and compiled into electronic files, and appropriate formats must be developed for data storage and presentation. The data that are originally presented in forms of numerical numbers or plots in hard copy source documents must first be converted into digitized electronic numbers that can be mathematically operated by computer.

The use of Microsoft Excel spread sheets has been selected for storing the evaluated data for future input into the *Gen IV Materials Handbook.* The spread sheet format provides a great advantage of being able to add multiple columns as needed without being limited by the width of document paper or computer screen. Its "Freeze Panes" function also allows the column and row titles to remain visible during scrolling along multiple columns and rows. Most importantly, because spread sheet is designed for data processing, many functions needed for data manipulation are available, and these functions may mostly be required by the *Gen IV Materials Handbook*.

For future convenient data input into the *Handbook*, the evaluated data should be categorized based on the types of property in the same manner as will be categorized in the *Handbook* [Rittenhouse 2005]. Therefore, appropriate data presentation formats have been developed for each type of property. Examples of the formats developed for tensile properties, creep properties, and toughness properties are shown as Table 1 for base metal tensile properties, Table 2 for weld tensile properties, Table 3 for base metal creep properties, Table 4 for weld creep properties, Table 5 for fatigue properties, and Table 6 for toughness properties, respectively. The specimen material conditions such as heat treatment and aging parameters are intentionally separated into columns of unaged treatment, aging time, aging temperature etc. so that the data can be conveniently sorted based on these parameters by using the "Sort" function of the spread sheet. Due to the limited page width of the present report, rows of the example tables are continuously presented on consecutive pages. Alphabet letters are used to indicate continuation of the rows on different pages. It should be stressed that the alphabet letters will neither be needed nor present in the full electronic version of the formatted data because the electronic tables can be continuously scrolled regardless of the width of computer screen. The explanations for acronyms and symbols in the examples will not present in the electronic *Handbook* in the fashion shown here but may be installed in a drop down dialogue window. User can click on the button to review them whenever he/she desires. The full version of the formatted data is not presented in this report partly due to its large size and electronic form. More importantly it is because converting hard copy numbers, plot points and curves into electronic data is a tedious, time consuming task that requires great care and accuracy, all the converted and formatted data must be double checked for error. Further, more existing data sources are still being obtained, and the spread sheets with formatted electronic data are subjected to continuous changes and expansions. Therefore, before the *Gen IV Materials Handbook* is ready to accept data input, release of the assessed, formatted existing data should be limited to avoid unnecessary multi-version confusion in the future.

To facilitate identifying the data gaps, the evaluated data tables have been further processed to extract the testing conditions under which the existing data were generated. The results of the extraction can be formatted into test matrices that were used to generate the existing data; and the conditions under which the material has not been tested can then be identified by comparing the test matrices with the data needs for analysis and design. Examples of the extracted test conditions and numbers of the existing data for each condition are given in Table 7 for tensile tests on base metal, Table 8 for tensile tests on weld metal, Table 9 for creep tests on base metal, Table 10 for creep tests on weld metal, and Table 11 for toughness tests on base metal. The extraction of testing conditions presented in the present report is only a preparation exercise for such practice. When the web-accessible *Gen IV Materials Handbook* is constructed, extraction of testing conditions for test matrices will be required as one of the important functionalities of the *Handbook*. With a click of finger, dedicated servers in the *Handbook* Application Tier will quickly browse through the entire database, extract the testing conditions of existing data, convert the conditions into test matrices that were used to generate the existing data, compare them with the data needs for analysis and design, and recommend new test matrices for generating new data to fill data gaps.

Table 1: Existing tensile property data under various testing conditions

Heat	**Form**	**Test ID**	**T-Test ºC**	**UnAged Treat**	**AgeEnv**	**T-Age ºC**	**a**
XX01A3US	13mm plate	16545	22	solution annealed	N/A	N/A	b
XX01A3US	13mm plate	16546	22	solution annealed	N/A	N/A	c
XX01A3US	13mm plate	16547	22	solution annealed	N/A	N/A	d
XX01A3US	13mm plate	17897	22	N/A	inert	538	e
XX01A3US	13mm plate	17898	22	N/A	inert	538	f
XX01A3US	13mm plate	17905	22	N/A	inert	871	g
XX01A3US	13mm plate	17906	22	N/A	inert	871	h
XX01A3US	13mm plate	IC43	22	N/A	inert	538	i
XX01A3US	13mm plate	16657	538	solution annealed	N/A	N/A	j
XX01A3US	13mm plate	17899	538	N/A	inert	538	k
XX01A3US	13mm plate	16664	704	solution annealed	N/A	N/A	l
XX01A3US	13mm plate	16665	704	solution annealed	N/A	N/A	m
XX01A3US	13mm plate	17903	704	N/A	inert	704	n
XX01A3US	13mm plate	179040	704	N/A	inert	704	o
XX01A3US	13mm plate	IC27	704	N/A	inert	704	p
XX01A3US	13mm plate	IC8	871	N/A	inert	871	q
XX01A3US	13mm plate	I-105	704	N/A	impure He	704	r
XX01A3US	13mm plate	I-120	871	N/A	impure He	871	s
XX09A4UK	9.5mm plate	203	704	unknown	N/A	N/A	t
XX09A4UK	9.5mm plate	204	760	unknown	N/A	N/A	u
XX01A3US	13mm plate	-	25	N/A	inert	482	v
↓	↓	↓	↓	↓	↓	↓	↓

Heat = heat identification
Form = product form
Test ID = identification of the test that generated the data
T-Test = test temperature
UnAged Treat = heat treatment for sample without aging
AgeEnv = aging environment for aged sample
T-Age = aging temperature

Table 1 (cont'd): Existing tensile property data under various testing conditions

a	t-Age h	0.2%YS MPa	UTS MPa	UnifStn %	TotalStn %	RA %	a
b	0	303	747	54.1	54.3	36.2	b
c	0	301	757	59.6	60.9	40.7	c
d	0	305	754	57.4	57.9	32.4	d
e	2,500	358	794	66.0	68.1	49.3	e
f	2,500	360	796	67.6	69.8	48.6	f
g	2,500	331	797	29.9	29.9	25.0	g
h	2,500	334	822	34.6	34.6	29.3	h
i	10,000	392	805	53.3	53.4	43.8	i
j	0	216	610	64.7	67.3	49.8	j
k	2,500	260	638	63.4	68.5	51.7	k
l	0	199	466	29.3	68.0	49.3	l
m	0	196	443	25.9	69.9	53.1	m
n	2,500	257	502	16.2	75.3	57.6	n
o	2,500	256	475	14.4	-	-	o
p	10,000	211	461	16.9	68.8	56.3	p
q	10,000	170	181	8.0	90.9	79.2	q
r	10,000	387	706	22.0	25.2	26.6	r
s	20,000	171	280	5.4	63.4	54.4	s
t	0	290	502	32.0	34.0	39.8	t
u	0	331	556	15.4	19.9	17.4	u
v	28300	401	859	52.2	52.8	48.9	v
↓	↓	↓	↓	↓	↓	↓	↓

t-Age = aging time
0.2%YS = 0.2% yield stress
UTS = ultimate tensile stress
UnifStn = uniform strain, the strain prior to necking
TotalStn = total strain, the strain at rupture
RA = area of reduction

Table 1 (cont'd): Existing tensile property data under various testing conditions

a	**Source**	**DC**	**Note**
b	McCoy0285T3	5	
c	McCoy0285T3	5	
d	McCoy0285T3	5	
e	McCoy0285T3	5	
f	McCoy0285T3	5	
g	McCoy0285T3	5	Broke at gage mark
h	McCoy0285T3	5	
i	McCoy0285T3	5	
j	McCoy0285T3	5	
k	McCoy0285T3	5	
l	McCoy0285T3	5	
m	McCoy0285T3	5	
n	McCoy0285T3	5	
o	McCoy0285T3	5	Pull rod broke before sample did
p	McCoy0285T3	5	
q	McCoy0285T3	5	
r	McCoy0285T4	5	
s	McCoy0285T4	5	
t	McCoy0285T5	5	
u	McCoy0285T5	5	
v	McCoy0285T7	5	sample made after block aged in steam
↓	↓	↓	↓

Source = the tag indicating data source as discussed in Section 2.2
DC = data classification as discussed in Section 2.1
Note = comments or explanations for the data point of the test

Table 2: Existing weld tensile property data under various testing conditions

BMID	BM Form	BM Treat	WMID	WM Form	a
XX14A6UK	13 mm plate	solution annealed	XX09A9UK	1.1 mm dia. wire	b
XX14A6UK	13 mm plate	solution annealed	XX09A9UK	1.1 mm dia. wire	c
XX14A6UK	13 mm plate	solution annealed	XX09A9UK	1.1 mm dia. wire	d
XX14A6UK	13 mm plate	solution annealed	XX09A9UK	1.1 mm dia. wire	e
XX14A6UK	13 mm plate	solution annealed	XX09A9UK	1.1 mm dia. wire	f
XX14A6UK	13 mm plate	solution annealed	XX09A9UK	1.1 mm dia. wire	g
XX14A6UK	13 mm plate	solution annealed	XX09A9UK	1.1 mm dia. wire	h
XX14A6UK	13 mm plate	solution annealed	XX09A9UK	1.1 mm dia. wire	i
XX14A6UK	13 mm plate	solution annealed	XX09A9UK	1.1 mm dia. wire	j
XX14A6UK	13 mm plate	solution annealed	XX09A9UK	1.1 mm dia. wire	k
XX14A6UK	13 mm plate	solution annealed	XX09A9UK	1.1 mm dia. wire	l
XX14A6UK	13 mm plate	solution annealed	XX09A9UK	1.1 mm dia. wire	m
XX14A6UK	13 mm plate	solution annealed	XX09A9UK	1.1 mm dia. wire	n
XX14A6UK	13 mm plate	solution annealed	XX09A9UK	1.1 mm dia. wire	o
↓	↓	↓	↓	↓	↓

BMID = heat identification of the base metal before welding
BM Form = product form of the base metal before welding
BM Treat = heat treatment of the base metal
WMID = heat identification of the weld metal
WM Form = product form of the weld metal

Table 2 (cont'd): Existing weld tensile property data under various testing conditions

a	**WM**	**Sample Content**	**SampleNoAge Treat**	**Sample AgeEnv**	**T-SampleAge ºC**	**t-SampleAge h**	**a**
b	GTA	W	as welded	N/A	N/A	0	b
c	GTA	W	as welded	N/A	N/A	0	c
d	GTA	W	as welded	N/A	N/A	0	d
e	GTA	W	as welded	N/A	N/A	0	e
f	GTA	W	as welded	N/A	N/A	0	f
g	GTA	BWB	N/A	impure He	593	20,000	g
h	GTA	BWB	N/A	impure He	704	20,000	h
i	GTA	BWB	N/A	impure He	871	10,000	i
j	GTA	BWB	N/A	impure He	871	20,000	j
k	GTA	BWB	N/A	impure He	593	10,000	k
l	GTA	BWB	N/A	impure He	593	20,000	l
m	GTA	BWB	N/A	impure He	704	10,000	m
n	GTA	BWB	N/A	impure He	704	20,000	n
o	GTA	BWB	N/A	impure He	871	10,000	o
↓	↓	↓	↓	↓	↓	↓	↓

WM = welding method to produce the sample weld: GTA = gas tungsten arc welding
Sample Content = composition of the sample: W = weld metal, B = base metal, BWB = weldment, the sample was machined across the weld to include the weld in the middle and base metal on both sides
SampleNoAge Treat = heat treatment of sample that has not been aged
Sample AgeEnv = aging environment of aged sample
T-SampleAge = sample aging temperature
t-SampleAge = sample aging time

Table 2 (cont'd): Existing weld tensile property data under various testing conditions

a	Test ID	T-Test ºC	0.2%YS MPa	UTS MPa	UnifStn %	TotalStn %	RA %	a
b	-	25	537	813	32.4	35.6	54.6	b
c	-	593	393	601	31.3	32.2	45.6	c
d	-	649	367	567	35.7	36.8	38.4	d
e	-	760	412	547	10.3	25.7	28.8	e
f	-	871	272	288	6.0	42.8	71.1	f
g	I-161	24	676	1020	19.5	19.9	10.6	g
h	I-165	24	626	867	5.0	5.2	8.3	h
i	I-156	24	394	450	0.7	0.7	3.2	i
j	I-169	24	356	476	0.8	0.8	3.3	j
k	I-168	593	259	514	29.0	29.4	33.3	k
l	I-160	593	623	800	15.2	16.2	26.6	l
m	I-153	704	460	756	15.7	19.9	35.0	m
n	I-164	704	445	740	12.2	15.6	8.5	n
o	I-157	871	223	270	6.0	26.8	56.0	o
↓	↓	↓	↓	↓	↓	↓	↓	↓

Test ID = identification of the test that generated the data
T-Test = test temperature
0.2%YS = 0.2% yield stress
UTS = ultimate tensile stress
UnifStn = uniform strain, the strain prior to necking
TotalStn = total strain, the strain at rupture
RA = area of reduction

Table 2 (cont'd). Existing weld tensile property data under various testing conditions

a	Source	FL	DC	Note
b	McCoy0285T8	N/A	5	
c	McCoy0285T8	N/A	5	
d	McCoy0285T8	N/A	5	
e	McCoy0285T8	N/A	5	
f	McCoy0285T8	N/A	5	
g	McCoy0285T9	B	5	
h	McCoy0285T9	B	5	
i	McCoy0285T9	B	5	
j	McCoy0285T9	B	5	
k	McCoy0285T9	W	5	
l	McCoy0285T9	B	5	
m	McCoy0285T9	W	5	
n	McCoy0285T9	B	5	
o	McCoy0285T9	W	5	
↓	↓	↓	↓	↓

Source = the tag indicating data source as discussed in Section 2.2
FL = failure location in the sample: W = weld, B = base metal
DC = data classification as discussed in Section 2.1
Note = comments or explanations for the data of the test

Table 3: Existing creep property data under various testing conditions

Heat	**Form**	**Test ID**	**T-Test ºC**	**TestSts MPa**	**Test Env**	**UnAged Treat**	**AgeEnv**	**a**
XX01A3US	13mm plate	22188	593	414	Air	solution annealed	N/A	b
XX01A3US	13mm plate	20531	593	414	He	solution annealed	N/A	c
XX01A3US	13mm plate	20521	593	414	He	N/A	impure He	d
XX01A3US	13mm plate	22645	593	414	He	N/A	impure He	e
XX01A3US	13mm plate	22200	593	345	He	N/A	impure He	f
XX09A4UK	9.5mm plate	23088	593	345	Air	solution annealed	N/A	g
XX01A3US	13mm plate	19106	649	414	He	solution annealed	N/A	h
XX01A3US	13mm plate	21589	649	345	Air	N/A	inert	i
XX01A3US	13mm plate	21610	649	345	Air	N/A	inert	j
XX01A3US	13mm plate	19182	649	276	He	solution annealed	N/A	k
XX01A3US	13mm plate	18483	649	276	He	solution annealed	N/A	l
XX01A3US	13mm plate	18440	649	276	Air	solution annealed	N/A	m
XX01A3US	13mm plate	19182	649	207	He	solution annealed	N/A	n
XX09A4UK	9.5mm plate	23085	649	276	Air	solution annealed	N/A	o
↓	↓	↓	↓	↓	↓	↓	↓	↓

Heat = heat identification
Form = product form
Test ID = identification of the test that generated the data
T-Test = test temperature
TestSts = test stress
TestEnv = test environment
UnAged Treat = heat treatment for sample without aging
AgeEnv = aging environment for aged sample

Table 3 (cont'd): Existing creep property data under various testing conditions

a	**T-Age ºC**	**t-Age h**	**t-1%Stn h**	**t-2%Stn h**	**t-5%Stn h**	**t-TerStn h**	**t-Rpt H**	**MCR 1/h**	**a**
b	N/A	N/A	20	-	3,350	3,445	3,570	4.8 E-6	b
c	N/A	N/A	380	1,700	-	4,534	4,534	4.9 E-6	c
d	593	10,000	500	-	-	-	548	1.0 E-5	d
e	593	20,000	2,000	-	-	2,600	2,676	2.4 E-6	e
f	593	10,000	-	-	-	-	5,629	5.5 E-7	f
g	N/A	N/A	-	-	-	-	2,107	1.4 E-6	g
h	N/A	N/A	0.5	5	145	168	186	1.6 E-4	h
i	482	28,300	280	1,100	-	1,700	1,813	1.3 E-5	i
j	538	28,300	189	837	-	-	1,063	2.4 E-5	j
k	N/A	N/A	5,000	8,600	15,100	8,000	16,718	2.0 E-6	k
l	N/A	N/A	7,600	-	-	-	15,850	1.1 E-6	l
m	N/A	N/A	8,850	16,480	25,510	16,000	25,566	9.3 E-7	m
n	N/A	N/A	-	-	-	-	26,515	9.9 E-8	n
o	N/A	N/A	-	-	-	-	1,121	1.9 E-6	o
↓	↓	↓	↓	↓	↓	↓	↓	↓	↓

T-Age = aging temperature
t-Age = aging time
t-1%Stn = time for reaching 1% creep strain
t-2%Stn = time for reaching 2% creep strain
t-5%Stn = time for reaching 5% creep strain
t-TerStn = time for reaching tertiary creep strain
t-Rpt = time for creep rupture
MCR = minimum creep rate

Table 3 (cont'd): Existing creep property data under various testing conditions

a	LdgStn %	CpStn %	RA %	Source	DC	Note
b	16	6.9	18.2	McCoy0285T14	5	
c	18	3.7	21.3	McCoy0285T14	5	
d		2.2	22.0	McCoy0285T14	5	
e	1.3	3.9	12.0	McCoy0285T14	5	
f	4.4	5.5	14.4	McCoy0285T14	5	
g	9.3	3.4	15.2	McCoy0285T14	5	
h	15.3	7.5	16.1	McCoy0285T14	5	
i	8.4	5.6	13.5	McCoy0285T14	5	
j	6.8	6.5	13.5	McCoy0285T14	5	
k	0.03	9.3	14.9	McCoy0285T14	5	
l	2.5	6.1	8.3	McCoy0285T14	5	
m	1.5	6.4	15.7	McCoy0285T14	5	
n	0.3	0.3	-	McCoy0285T14	5	test reloaded at a higher stress
o	1.5	1.4	4.5	McCoy0285T14	5	
↓	↓	↓	↓	↓	↓	↓

LdgStn = loading strain
CpStn = creep rupture strain
RA = area of reduction
Source = the tag indicating data source as discussed in Section 2.2
DC = data classification as discussed in Section 2.1
Note = comments or explanations for the data point of the test

Table 4: Existing weld creep property data under various testing conditions

BMID	**BM Form**	**BM Treat**	**WMID**	**WM Form**	**WM**	**a**
XX14A6UK	13 mm plate	solution annealed	XX09A9UK	1.1 mm dia. wire	GTA	b
XX14A6UK	13 mm plate	solution annealed	XX09A9UK	1.1 mm dia. wire	GTA	c
XX14A6UK	13 mm plate	solution annealed	XX09A9UK	1.1 mm dia. wire	GTA	d
XX14A6UK	13 mm plate	solution annealed	XX09A9UK	1.1 mm dia. wire	GTA	e
XX14A6UK	13 mm plate	solution annealed	XX09A9UK	1.1 mm dia. wire	GTA	f
XX14A6UK	13 mm plate	solution annealed	XX09A9UK	1.1 mm dia. wire	GTA	g
XX14A6UK	13 mm plate	solution annealed	XX09A9UK	1.1 mm dia. wire	GTA	h
XX14A6UK	13 mm plate	solution annealed	XX09A9UK	1.1 mm dia. wire	GTA	i
XX14A6UK	13 mm plate	solution annealed	XX09A9UK	1.1 mm dia. wire	GTA	j
XX14A6UK	13 mm plate	solution annealed	XX09A9UK	1.1 mm dia. wire	GTA	k
XX14A6UK	13 mm plate	solution annealed	XX09A9UK	1.1 mm dia. wire	GTA	l
XX14A6UK	13 mm plate	solution annealed	XX09A9UK	1.1 mm dia. wire	GTA	m
XX14A6UK	13 mm plate	solution annealed	XX09A9UK	1.1 mm dia. wire	GTA	n
↓	↓	↓	↓	↓	↓	↓

BMID = heat identification of the base metal before welding
BM Form = product form of the base metal before welding
BM Treat = heat treatment of the base metal
WMID = heat identification of the weld metal
WM Form = product form of the weld metal
WM = welding method to produce the sample weld: GTA = gas tungsten arc welding

Table 4 (cont'd): Existing weld creep property data under various testing conditions

a	Sample Content	SampleNoAge Treat	Sample AgeEnv	T-SampleAge ºC	t-SampleAge h	Test ID	a
b	W	as welded	N/A	N/A	0	20515	b
c	W	as welded	N/A	N/A	0	none	c
d	W	as welded	N/A	N/A	0	23071	d
e	W	as welded	N/A	N/A	0	21399	e
f	W	as welded	N/A	N/A	0	20513	f
g	W	as welded	N/A	N/A	0	20553	g
h	W	as welded	N/A	N/A	0	22741	h
i	W	as welded	N/A	N/A	0	22763	i
j	W	as welded	N/A	N/A	0	20735	j
k	W	as welded	N/A	N/A	0	20533	k
l	BWB	N/A	Impure He	593	10,000	20522	l
m	BWB	N/A	Impure He	704	10,000	20528	m
n	BWB	N/A	Impure He	704	20,000	21612	n
↓	↓	↓	↓	↓	↓	↓	↓

Sample Content = composition of the sample: W = weld metal, B = base metal, BWB = weldment, the sample was machined across the weld to include the weld in the middle and base metal on both sides
SampleNoAge Treat = heat treatment of sample that has not been aged
Sample AgeEnv = aging environment of aged sample
T-SampleAge = sample aging temperature
t-SampleAge = sample aging time
Test ID = identification of the test that generated the data

Table 4 (cont'd): Existing weld creep property data under various testing conditions

a	T-Test ºC	Sts-Test MPa	Test Env	t-1%Stn H	t-2%Stn h	t-5%Stn h	t-TerStn h	t-Rpt h	a
b	593	345	He	-	-	-	-	>13,726	b
c	593	414	He	-	-	-	-	1,296	c
d	593	414	He	-	-	-	-	2,034	d
e	649	345	He	525	-	-	-	526	e
f	649	276	He	-	-	-	-	3,467	f
g	649	242	He	15,400	-	-	-	18,182	g
h	704	276	He	775	-	-	785	790	h
i	704	207	He	4,250	10,500	14,900	6,000	14,978	i
j	760	138	He	2,900	3,750	4,750	2,600	5,190	j
k	871	69	He	1,467	1,570	-	-	1,623	k
l	593	414	He	-	-	-	-	645	l
m	704	207	He	4,830	6,380	-	5,100	6,932	m
n	704	207	He	1,100	3,250	5,470	3,025	5,496	n
↓	↓	↓	↓	↓	↓	↓	↓	↓	↓

T-Test = test temperature
Sts-Test = test stress
t-1%Stn = time for reaching 1% creep strain
t-2%Stn = time for reaching 2% creep strain
t-5%Stn = time for reaching 5% creep strain
t-TerStn = time for reaching tertiary creep strain
t-Rpt = creep rupture time

Table 4 (cont'd): Existing weld creep property data under various testing conditions

a	**MCR 1/h**	**LdgStn %**	**CpStn %**	**RA %**	**Source**	**FL**	**DC**	**Note**
b	1.2 E-7	0.6	0.4	-	McCoy0285T15	N/A	5	Discontinued before failure
c	-	0.09	0.1	-	McCoy0285T15	N/A	5	
d	1.3 E-6	0.72	2	5.1	McCoy0285T15	N/A	5	
e	8.1 E-6	0.1	2.6	3.3	McCoy0285T15	N/A	5	
f	5.4 E-7	0.1	2.3	1.4	McCoy0285T15	N/A	5	
g	4.7 E-7	0.2	1.8	2.9	McCoy0285T15	N/A	5	
h	8.0 E-6	0.5	4.4	5.9	McCoy0285T15	N/A	5	
i	5.5 E-7	0.04	7.7	14.1	McCoy0285T15	N/A	5	
j	1.8 E-6	-	17.1	43.5	McCoy0285T15	N/A	5	
k	-	0.07	10.7	21	McCoy0285T15	N/A	5	
l	-	-	1.7	5.2	McCoy0285T16	W	5	
m	2.6 E-6	0.3	3.7	17.1	McCoy0285T16	W	5	
n	3.7 E-6	0	6.5	17.6	McCoy0285T16	W	5	
↓	↓	↓	↓	↓	↓	↓	↓	↓

MCR = minimum creep rate
LdgStn = loading strain
CpStn = creep rupture strain
RA = area of reduction
Source = the tag indicating data source as discussed in Section 2.2
FL = failure location in the sample: W = weld, B = base metal
DC = data classification as discussed in Section 2.1
Note = comments or explanations for the data of the test

Table 5: Existing fatigue property data under various testing conditions

Heat	Form	Test ID	NoneAge Treat	AgeEnv	T-Age ºC	t-Age h	Test Env	a
XX14A6UK	16mm plate		Solution Annealed	N/A	N/A	N/A	Air	b
XX14A6UK	16mm plate		Solution Annealed	N/A	N/A	N/A	He	c
XX14A6UK	16mm plate		Solution Annealed	N/A	N/A	N/A	He	d
XX14A6UK	16mm plate		N/A	He	850	6000	He	e
XX14A6UK	16mm plate		N/A	He	950	6000	He	f
XX14A6UK	16mm plate		Solution Annealed	N/A	N/A	N/A	Air	g
XX14A6UK	16mm plate		Solution Annealed	N/A	N/A	N/A	He	h
XX14A6UK	16mm plate		Solution Annealed	N/A	N/A	N/A	He	i
XX14A6UK	16mm plate		N/A	He	850	6000	He	j
XX14A6UK	16mm plate		N/A	He	950	6000	He	k
XX63A8UK	44.5mm rd bar		Solution Annealed	N/A	N/A	N/A	Air	l
XX63A8UK	44.5mm rd bar		Solution Annealed	N/A	N/A	N/A	Air	m
XX63A8UK	44.5mm rd bar		N/A	He	950	6000	He	n
XX63A8UK	44.5mm rd bar		N/A	He	950	6000	He	o
XX63A8UK	44.5mm rd bar		Solution Annealed	N/A	N/A	N/A	Air	p
XX63A8UK	44.5mm rd bar		Solution Annealed	N/A	N/A	N/A	Air	q
XX63A8UK	44.5mm rd bar		Solution Annealed	N/A	N/A	N/A	Air	r
XX63A8UK	44.5mm rd bar		Solution Annealed	N/A	N/A	N/A	Air	s
↓	↓	↓	↓	↓	↓	↓	↓	↓

Heat = heat identification
Form = product form
Test ID = identification of the test that generated the data
UnAged Treat = heat treatment for sample without aging
AgeEnv = aging environment for aged sample
T-Age = aging temperature
t-Age = aging time
TestEnv = test environment

Table 5 (cont'd): Existing fatigue property data under various testing conditions

a	**T-Test ºC**	**Control**	**Wave**	**R**	**StnRng %**	**StsRng MPa**	**f Hz**	**StnRate 1/sec**	**a**
b	850	Stress	Sine	-1	0.27	413.7	0.5	N/A	b
c	950	Stress	Sine	-1	0.13	206.8	30	N/A	c
d	950	Stress	Sine	-1	0.17	248.2	30	N/A	d
e	850	Stress	Sine	-1	0.2	333.7	30	N/A	e
f	950	Stress	Sine	-1	0.24	317.2	30	N/A	f
g	850	Strain	Triangle	-1	0.4	572.3	N/A	0.4	g
h	950	Strain	Triangle	-1	0.4	391.6	N/A	0.4	h
i	950	Strain	Triangle	-1	1.0	375.1	N/A	0.4	i
j	850	Strain	Triangle	-1	0.3	435.8	N/A	0.4	j
k	950	Strain	Triangle	-1	1.0	404.0	N/A	0.4	k
l	950	Strain	Triangle	-1	1.0	441	N/A	0.4	l
m	950	Strain	Triangle	-1	0.25	368	N/A	0.05	m
n	950	Strain	Triangle	-1	1.0	510	N/A	0.4	n
o	950	Strain	Triangle	-1	0.25	354	N/A	0.05	o
p	950	Strain	Trapezoidal	-1	1.0	352	N/A	0.05	p
q	950	Strain	Trapezoidal	-1	0.6	372	N/A	0.1	q
r	950	Strain	Trapezoidal	-1	0.4	374	N/A	0.08	r
s	950	Strain	Trapezoidal	-1	0.6	363	N/A	0.1	s
↓	↓	↓	↓	↓	↓	↓	↓	↓	↓

T-Test = test temperature
Control = control signal of fatigue test
Wave = waveform of fatigue control signal
R = minimum stress or strain / maximum stress or strain
StnRng = strain range
StsRng = stress range
f = frequency
StnRate = strain rate

Table 5 (cont'd): Existing fatigue property data under various testing conditions

a	t-Hold sec	N-Sep Cycle	N-5%StsR Decrease	N-50%StsR Decrease	Source	a
b	0	2.80E+07	N/A	N/A	Baldwin0486T8	b
c	0	1.90E+06	N/A	N/A	Baldwin0486T8	c
d	0	961000	N/A	N/A	Baldwin0486T8	d
e	0	1.2E+06	N/A	N/A	Baldwin0486T8	e
f	0	42800	N/A	N/A	Baldwin0486T8	f
g	0	-	3100	3685	Baldwin0486T9	g
h	0	-	5900	7153	Baldwin0486T9	h
i	0	-	1000	1423	Baldwin0486T9	i
j	0	-	16300	18997	Baldwin0486T9	j
k	0	-	940	985	Baldwin0486T9	k
l	0	-	590	-	Baldwin0486T10	l
m	0	-	19000	-	Baldwin0486T10	m
n	0	-	1615	-	Baldwin0486T10	n
o	0	-	47000	-	Baldwin0486T10	o
p	120	-	420	-	Baldwin0486T11	p
q	120	-	850	-	Baldwin0486T11	q
r	120	-	2000	-	Baldwin0486T11	r
s	1200	-	610	-	Baldwin0486T11	s
↓	↓	↓	↓	↓	↓	↓

t-Hold = hold time
N-Sep = number of cycles to total separation
N-5%StsR = number of cycles to a 5% decrease in the stress range below the saturation value
N-50%StsR = number of cycles to a 50% decrease in the stress range below the saturation value
Source = the tag indicating data source as discussed in Section 2.2

Table 5 (cont'd): Existing fatigue property data under various testing conditions

a	DC	Note
b	4	Extensometer for 300 cycles
c	4	
d	4	
e	4	
f	4	
g	4	StsRng value at 50%StsR/2
h	4	StsRng value at 50%StsR/2
i	4	StsRng value at 50%StsR/2
j	4	StsRng value at 50%StsR/2
k	4	StsRng value at 5%StsR/2
l	4	StsRng value at 5%StsR/2
m	4	StsRng value at 5%StsR/2
n	4	StsRng value at 5%StsR/2
o	4	StsRng value at 5%StsR/2
p	4	StsRng value at 5%StsR/2
q	4	StsRng value at 5%StsR/2
r	4	StsRng value at 5%StsR/2
s	4	StsRng value at 5%StsR/2
↓	↓	↓

DC = data classification as discussed in Section 2.1
Note = comments or explanations for the data point of the test

Table 6: Existing toughness property data under various testing conditions

Heat	Form	UnAged Treat	AgeEnv	T-Age ºC	t-Age h	E-CharpyV J	a
XX01A3US	13mm plate	solution annealed	N/A	N/A	0	175	b
XX01A3US	13mm plate	solution annealed	N/A	N/A	0	175	c
XX01A3US	13mm plate	solution annealed	N/A	N/A	0	175	d
XX01A3US	13mm plate	solution annealed	N/A	N/A	0	175	e
XX09A4UK	9.5mm plate	solution annealed	N/A	N/A	0	298	f
XX01A3US	13mm plate	N/A	impure He	871	100	91	g
XX01A3US	13mm plate	N/A	inert	871	100	98	h
XX09A4UK	9.5mm plate	N/A	impure He	871	100	61	i
XX01A3US	13mm plate	N/A	inert	871	1000	53	j
XX09A4UK	9.5mm plate	N/A	inert	871	1000	26	k
XX01A3US	13mm plate	N/A	inert	538	10000	81	l
XX01A3US	13mm plate	N/A	inert	704	10000	31	m
XX01A3US	13mm plate	N/A	inert	871	10000	26	n
XX01A3US	13mm plate	N/A	inert	538	20000	103	o
XX01A3US	13mm plate	N/A	inert	704	20000	20	p
XX01A3US	13mm plate	N/A	inert	871	20000	20	q
XX01A3US	13mm plate	N/A	inert	492	28300	190	r
↓	↓	↓	↓	↓	↓	↓	↓

Heat = heat identification
Form = product form
UnAged Treat = heat treatment for sample without aging
AgeEnv = aging environment for aged sample
T-Age = aging temperature
t-Age = aging time
E-CharpyV = Charpy V impact energy

Table 6 (cont'd): Existing toughness property data under various testing conditions

a	Source	DC	Note
b	McCoy0285T13	5	
c	McCoy0285T13	5	
d	McCoy0285T13	5	
e	McCoy0285T13	5	
f	McCoy0285T13	5	
g	McCoy0285T13	5	
h	McCoy0285T13	5	sample machined after block aged in air
i	McCoy0285T13	5	
j	McCoy0285T13	5	sample machined after block aged in air
k	McCoy0285T13	5	sample machined after block aged in air
l	McCoy0285T13	5	sample machined after block aged in air
m	McCoy0285T13	5	sample machined after block aged in air
n	McCoy0285T13	5	sample machined after block aged in air
o	McCoy0285T13	5	sample machined after block aged in air
p	McCoy0285T13	5	sample machined after block aged in air
q	McCoy0285T13	5	sample machined after block aged in air
r	McCoy0285T13	5	sample machined after block aged in steam
↓	↓	↓	↓

Source = the tag indicating data source as discussed in Section 2.2
DC = data classification as discussed in Section 2.1
Note = comments or explanations for the data point of the test

Table 7: Number of existing tensile property data and testing conditions

T-Test ºC	**UnAged Treat**	**AgeEnv**	**T-Age ºC**	**t-Age h**	**E Data**	**YS Data**	**a**
22	N/A	inert gas	538	2,500	0	2	b
22	N/A	inert gas	538	20000	0	1	c
22	N/A	inert gas	704	2,500	0	2	d
22	N/A	inert gas	704	20000	0	1	e
22	N/A	inert gas	871	2,500	0	2	f
22	N/A	inert gas	871	20000	0	1	g
22	solution annealed	N/A	N/A	N/A	0	3	h
24	N/A	impure He	593	20000	0	1	i
24	N/A	impure He	704	20000	0	1	j
24	N/A	impure He	871	20000	0	1	k
25	N/A	impure He	871	26117	0	1	l
25	N/A	inert	482	28300	0	1	m
25	N/A	inert	538	28300	0	1	n
25	unknown	N/A	N/A	0	0	2	o
538	N/A	inert gas	538	2500	0	2	p
538	N/A	inert gas	538	10000	0	2	q
538	N/A	inert gas	538	20000	0	2	r
538	N/A	inert gas	704	10000	0	2	s
538	solution annealed	N/A	N/A	0	0	2	t
593	N/A	impure He	593	20000	0	1	u
593	unknown	N/A	N/A	0	0	1	v
649	unknown	N/A	N/A	0	0	1	w
704	N/A	impure He	704	20000	0	1	x
704	N/A	inert gas	704	2500	0	2	y
704	N/A	inert gas	704	20000	0	1	z
704	solution annealed	N/A	N/A	0	0	3	a1
760	unknown	N/A	N/A	0	0	1	b2
871	N/A	impure He	871	20000	0	1	c3
↓	↓	↓	↓	↓	↓	↓	↓

T-Test = test temperature
UnAged Treat = heat treatment for sample without aging
AgeEnv = aging environment for aged sample
T-Age = aging temperature
t-Age = aging time
E = Young's modulurs
YS = yield stress

Table 7 (cont'd): Number of existing tensile property data and testing conditions

a	**UTS Data**	**UnifStn Data**	**TotalStn Data**	**RA Data**	**DC**
b	2	2	2	2	5
c	1	1	1	1	5
d	2	2	2	2	5
e	1	1	1	1	5
f	2	2	2	2	5
g	1	1	1	1	5
h	3	3	3	3	5
i	1	1	1	1	5
j	1	1	1	1	5
k	1	1	1	1	5
l	1	1	1	1	5
m	1	1	1	1	5
n	1	1	1	1	5
o	2	2	2	2	5
p	2	2	2	2	5
q	2	2	2	2	5
r	2	2	2	2	5
s	2	2	2	2	5
t	2	2	2	2	5
u	1	1	1	1	5
v	1	1	1	1	5
w	1	1	1	1	5
x	1	1	1	1	5
y	2	2	1	1	5
z	1	1	1	1	5
a1	3	3	3	3	5
b2	1	1	1	1	5
c3	1	1	1	1	5
↓	↓	↓	↓	↓	↓

UTS = ultimate tensile stress
UnifStn = uniform strain, the strain prior to necking
TotalStn = total strain, the strain at rupture
RA = area of reduction
DC = data classification as discussed in Section 2.1

Table 8: Number of existing weld tensile property data and testing conditions

BM Treat	WM	Sample Content	SampleNoAge Treat	Sample AgeEnv	T-SampleAge ºC	a
solution annealed	GTA	W	as welded	N/A	N/A	b
solution annealed	GTA	W	as welded	N/A	N/A	c
solution annealed	GTA	W	as welded	N/A	N/A	d
solution annealed	GTA	W	as welded	N/A	N/A	e
solution annealed	GTA	W	as welded	N/A	N/A	f
solution annealed	GTA	BWB	N/A	impure He	593	g
solution annealed	GTA	BWB	N/A	impure He	593	h
solution annealed	GTA	BWB	N/A	impure He	704	i
solution annealed	GTA	BWB	N/A	impure He	704	j
solution annealed	GTA	BWB	N/A	impure He	871	k
solution annealed	GTA	BWB	N/A	impure He	593	l
solution annealed	GTA	BWB	N/A	impure He	704	m
solution annealed	GTA	BWB	N/A	impure He	871	n
↓	↓	↓	↓	↓	↓	↓

BM Treat = heat treatment of the base metal
WM = welding method to produce the sample weld: GTA = gas tungsten arc welding
Sample Content = composition of the sample: W = weld metal, B = base metal, BWB = weldment, the sample was machined across the weld to include the weld in the middle and base metal on both sides
SampleNoAge Treat = heat treatment of sample that has not been aged
Sample AgeEnv = aging environment of aged sample
T-SampleAge = sample aging temperature

Table 8 (cont'd): Number of weld existing tensile property data and testing conditions

a	t-SampleAge H	T-Test ºC	0.2%YS Data	UTS Data	UnifStn Data	TotalStn Data	RA Data
b	0	25	1	1	1	1	1
c	0	593	1	1	1	1	1
d	0	649	1	1	1	1	1
e	0	760	1	1	1	1	1
f	0	871	1	1	1	1	1
g	10,000	24	1	1	1	1	1
h	20,000	24	1	1	1	1	1
i	10,000	24	1	1	1	1	1
j	20,000	24	1	1	1	1	1
k	20,000	24	1	1	1	1	1
l	20,000	593	1	1	1	1	1
m	20,000	704	1	1	1	1	1
n	20,000	871	1	1	1	1	1
	↓	↓	↓	↓	↓	↓	↓

t-SampleAge = sample aging time
T-Test = test temperature
0.2%YS = 0.2% yield stress
UTS = ultimate tensile stress
UnifStn = uniform strain, the strain prior to necking
TotalStn = total strain, the strain at rupture
RA = area of reduction

Table 9: Number of existing creep property data and testing conditions

TestT ºC	**TestSts MPa**	**TestEnv**	**UnAged Treat**	**AgeEnv**	**T-Age ºC**	**t-Age h**	**t-1%Stn Data**	**a**
593	345	Air	solution annealed	N/A	N/A	N/A	0	b
593	345	He	N/A	impure He	593	10,000	0	c
593	414	Air	solution annealed	N/A	N/A	N/A	1	d
593	414	He	solution annealed	N/A	N/A	N/A	1	e
593	414	He	N/A	impure He	593	10,000	1	f
593	414	He	N/A	impure He	593	20,000	1	g
649	207	He	solution annealed	N/A	N/A	N/A	0	h
649	276	Air	solution annealed	N/A	N/A	N/A	1	i
649	276	He	solution annealed	N/A	N/A	N/A	2	j
649	276	He	solution annealed	N/A	N/A	N/A	0	k
649	345	Air	N/A	inert	482	28,300	1	l
649	345	Air	N/A	inert	538	28,300	1	m
649	414	He	solution annealed	N/A	N/A	N/A	1	n
704	172	He	solution annealed	N/A	N/A	N/A	1	o
704	207	Air	solution annealed	N/A	N/A	N/A	0	p
704	207	He	N/A	impure He	704	10,000	1	q
↓	↓	↓	↓	↓	↓	↓	↓	↓

T-Test = test temperature
TestSts = test stress
TestEnv = test environment
UnAged Treat = heat treatment for sample without aging
AgeEnv = aging environment for aged sample
T-Age = aging temperature
t-Age = aging time
t-1%Stn = time for reaching 1% creep strain

Table 9 (cont'd): Number of existing creep property data and testing conditions

a	t-2%Stn Data	t-5%Stn Data	t-TerStn Data	t-Rpt Data	MCR Data	LdgStn Data	CpStn Data	RA Data	DC
b	0	0	0	1	1	1	1	1	5
c	0	0	0	1	1	1	1	1	5
d	0	1	1	1	1	1	1	1	5
e	1	0	1	1	1	1	1	1	5
f	0	0	0	1	1	0	1	1	5
g	0	0	1	1	1	1	1	1	5
h	0	0	0	1	1	1	1	0	5
i	1	1	1	3	3	3	3	3	5
j	1	1	1	2	2	2	2	2	5
k	0	0	0	1	1	1	1	1	5
l	1	0	1	1	1	1	1	1	5
m	1	0	0	1	1	1	1	1	5
n	1	1	1	1	1	1	1	1	5
o	1	0	0	1	1	1	1	0	5
p	0	0	0	1	1	1	1	1	5
q	1	0	1	1	1	0	1	1	5
↓	↓	↓	↓	↓	↓	↓	↓	↓	↓

t-2%Stn = time for reaching 2% creep strain
t-5%Stn = time for reaching 5% creep strain
t-TerStn = time for reaching tertiary creep strain
t-Rpt = creep rupture time
MCR = minimum creep rate
LdgStn = loading strain
CpStn = creep rupture strain
RA = area of reduction
DC = data classification as discussed in Section 2.1

Table 10: Number of existing weld creep property data and testing conditions

BM Treat	WM	Sample Content	SampleNoAge Treat	Sample AgeEnv	T-SampleAge ºC	a
solution annealed	GTA	W	as welded	N/A	N/A	b
solution annealed	GTA	W	as welded	N/A	N/A	c
solution annealed	GTA	W	as welded	N/A	N/A	d
solution annealed	GTA	W	as welded	N/A	N/A	e
solution annealed	GTA	W	as welded	N/A	N/A	f
solution annealed	GTA	W	as welded	N/A	N/A	g
solution annealed	GTA	W	as welded	N/A	N/A	h
solution annealed	GTA	W	as welded	N/A	N/A	i
solution annealed	GTA	W	as welded	N/A	N/A	j
solution annealed	GTA	BWB	N/A	impure He	593	k
solution annealed	GTA	BWB	N/A	impure He	704	l
solution annealed	GTA	BWB	N/A	impure He	704	m
↓	↓	↓	↓	↓	↓	↓

BM Treat = heat treatment of the base metal
WM = welding method to produce the sample weld: GTA = gas tungsten arc welding
Sample Content = composition of the sample: W = weld metal, B = base metal, BWB = weldment, the sample was machined across the weld to include the weld in the middle and base metal on both sides
SampleNoAge Treat = heat treatment of sample that has not been aged
Sample AgeEnv = aging environment of aged sample
T-SampleAge = sample aging temperature

Table 10 (cont'd): Number of weld existing creep property data and testing conditions

a	t-SampleAge H	T-Test ºC	TestSts MPa	Test Env	t-1%Stn Data	t-2%Stn Data	t-5%Stn Data	a
b	0	593	345	He	0	0	0	b
c	0	593	414	He	0	0	0	c
d	0	649	345	He	1	0	0	d
e	0	649	276	He	0	0	0	e
f	0	649	242	He	1	0	0	f
g	0	704	276	He	1	0	0	g
h	0	704	207	He	1	1	1	h
i	0	760	138	He	1	1	1	i
j	0	871	69	He	1	1	0	j
k	10,000	593	414	He	0	0	0	k
l	10,000	704	207	He	1	1	0	l
m	20,000	704	207	He	1	1	1	m
↓	↓	↓	↓	↓	↓	↓	↓	↓

t-SampleAge = sample aging time
T-Test = test temperature
TestSts = test stress
t-1%Stn = time for reaching 1% creep strain
t-2%Stn = time for reaching 2% creep strain
t-5%Stn = time for reaching 5% creep strain

Table 10 (cont'd): Number of weld existing creep property data and testing conditions

a	**t-TerStn Data**	**t-Rpt Data**	**MCR Data**	**LdgStn Data**	**CpStn Data**	**RA Data**
b	0	1	1	1	1	0
c	0	2	1	2	2	1
d	0	1	1	1	1	1
e	0	1	1	1	1	1
f	0	1	1	1	1	1
g	1	1	1	1	1	1
h	1	1	1	1	1	1
i	1	1	1	0	1	1
j	0	1	0	1	1	1
k	0	1	0	0	1	1
l	1	1	1	1	1	1
m	1	1	1	0	1	1
	↓	↓	↓	↓	↓	↓

t-TerStn = time for reaching tertiary creep strain
t-Rpt = creep rupture time
MCR = minimum creep rate
LdgStn = loading strain
CpStn = creep rupture strain
RA = area of reduction

Table 11: Number of existing toughness property data and testing conditions

UnAged Treat	**AgeEvn**	**T-Age ºC**	**t-Age h**	**E-CharpyV Data**	**DC**
solution annealed	N/A	N/A	0	5	5
N/A	impure He	871	100	2	5
N/A	inert	871	100	1	5
N/A	inert	871	1000	2	5
N/A	inert	538	10000	1	5
N/A	inert	704	10000	1	5
N/A	inert	871	10000	1	5
N/A	inert	538	20000	1	5
N/A	inert	704	20000	1	5
N/A	inert	871	20000	1	5
N/A	inert	492	28300	1	5
N/A	inert	538	28300	1	5
↓	↓	↓	↓	↓	↓

UnAged Treat = heat treatment for sample without aging
AgeEnv = aging environment for aged sample
T-Age = aging temperature
t-Age = aging time
E-CharpyV = Charpy V impact energy
DC = data classification as discussed in Section 2.1

3. MAJOR DATA SOURCES

Alloy 617 has been selected for many high-temperature and corrosion-resistant applications around the world since its introduction into the marketplace in the early 1970's, and a large amount of data has been generated on the alloy. In this section, the major data sources that have been considered most important to the Gen IV nuclear reactors and processed in the assessment are discussed. Those that have been identified to be of great interest to the *Gen IV Materials Handbook* but are still under negotiation for access are also introduced. For each data source, basic information germane to the data generation, if available, is provided for a good understanding of the data background.

3.1 Assessment of Major Data Sources

<u>ORNL-HTGR Data</u>

The ORNL-HTGR data source contains the data on Alloy 617 generated at the Oak Ridge National Laboratory (ORNL) for the High-Temperature Gas-Cooled Reactor (HTGR) Project in the 1980's under DOE Contract No. DE-AC05-84OR21400. The source document [McCoy 1985] is a summary report about materials testing results on Alloy 617 and Alloy 618. The report includes tensile properties data generated from 73 tensile tests at temperatures of 24, 538, 593, 649, 704, 760, and 871°C (75, 1000, 1100, 1200, 1300, 1400, and 1600°F), creep properties data generated from 51 creep tests at temperatures of 593, 649, 704, 760, and 871°C (1100, 1200, 1300, 1400 and 1600°F), and toughness property data generated from 20 Charpy V impact tests at room temperature. It also includes the result of 1 tensile test on a specimen after long-term creep testing at 871°C (1600°F). A summary of the tests that generated the ORNL-HTGR data is given in Table 12. The tensile properties include 0.2% yield strength, ultimate tensile strength, uniform strain, total strain, and reduction in area. The creep properties include times to 1%, 2%, and 5% total strains (Among the three, the time to 1% total strain is the most important to design.), time to tertiary creep, creep rupture time, creep rupture stress, minimum creep rate, loading strain, creep rupture strain, and reduction in area. The toughness data include Charpy V impact energy. Based on the *Gen IV Materials Handbook* Data Classification Criteria, these data are classified as Class 5.

Four heats produced by Huntington Alloy Product Division, predecessor of Special Metals, were used to generate the ORNL-HTGR data. The heat chemical compositions and product forms are presented in Table 13 and Table 14, respectively. Three heats in plate form were used as the base metal; and one heat in wire form was used as the weld filler metal. The welds were produced using the gas tungsten arc (GTA) welding process.

All three base metal heats exhibited fairly coarse grains. The microstructure of Heat XX0lA3US exhibited a characteristic of inhomogeneous stringers in the primary working direction of the plate. Heat XX09A4UK exhibited a slightly coarser grain size than that in Heat XX0lA3US, and its stringers were not nearly as pronounced as those in Heat XX0lA3US. The microstructure of the as-received Heat XX14A6UK was not available but that after aging at 593°C x 10,000 hours showed no indication of apparent grain size alteration compared to the former two heats. Heat XX14A6UK had the largest grain size of the three but presented no evidence of longitudinal stringers.

Table 12: Summary of ORNL-HTGR data on Alloy 617

Test Type	**Specimen Treatment**	**Test Env**	**Test Temperature ºC**						
			25[d]	**538**	**593**	**649**	**704**	**760**	**871**
Tensile Base Metal	He aging[a]	Air	7		2		2		2
	Inert aging[b]	Air	11	4			3		3
	solution annealing	Air	2[c]	1	1	1	2	1	2
Tensile Weld[e]	As-welded	Air	1		1	1		1	1
	He aging[a]	Air	6		2		2		2
Creep Base Metal	He aging[a]	He			3		2		1
	inert aging[b]	Air				2			
		He					1	1	1
	solution annealing	Air			2	1	1	2	4
		He			1	4	3	3	3
Creep Weld[e]	As-welded	He			3	3	2	1	1
	He aging[a]	He			1		2		
Charpy Base Metal	He aging[a]	Air	2						1
	inert aging[b]	Air	13						
	solution annealing	Air	5						

a. Specimens were aged in simulated HTGR helium mostly for 10000 or 20000 hours at the same temperature as the test temperature, except room temperature.
b. Block material was aged in steam; then the specimens were machined.
c. One of the two was reported with unknown sample treatment, solution annealing assumed.
d. Test temperatures of 22, 24 and 25ºC were reported, all are summarized as room temperature = 25ºC.
e. Weld represents weld metal or weldment.

The data for welds were generated from three types of specimens: base metal, weld metal, and weldment. The base metal specimens were machined with their axis parallel to the primary working direction of the original plate. The weld metal specimens were cut parallel to the weld direction with the gage section composed totally of the weld metal. And the weldment specimens were produced with the gage section spanning perpendicular to the weld and containing the base metal, the weld metal, and the heat affected zone.

Table 13: Compositions (wt. %) of the Alloy 617 heats used for the ORNL-HTGR data generation [McCoy285T1]

Heat	Ni	Cr	Co	Mn	Mo	Fe	Al	Si	C	S
XX0lA3US	57.35	20.30	11.72	0.05	8.58	1.01	0.76	0.16	0.07	0.004
XX09A4UK	55.11	21.83	12.55	0.02	8.79	0.38	1.15	0.10	0,07	0.001
XX14A6UK	55.13	21.74	12.32	0.02	8.91	0.53	1.11	0.18	0.06	0.002
XX09A9UK	54.38	22.14	12.66	0.02	8.79	0.39	1.37	0.17	0.08	0.001

Table 14: Product characterization of the Alloy 617 heats used for the ORNL-HTGR data generation [McCoy85T2]

Heat	Product Form	Grain Size (μm)	Heat Treatment
XX0lA3US	Plate, 13 mm (0.5 in.) thick	130	Solution annealed by vendor
XX09A4UK	Plate, 9.5 mm (0.38 in.) thick	210	Unknown
XX14A6UK	Plate, 13 mm (0.5 in.) thick	270	Solution annealed by vendor
XX09A9UK	Wire, 1.1 mm (0.045 in.) diameter		Unknown

The tensile properties data were generated from the material aged at temperatures of 482, 538, 593, 704, and 871°C (900, 1000, 1100, 1300, and 1600°F) for 2500, 10000, 20000, 26117 and 28300 hours. The creep properties data were generated from materials aged at 482, 538, 593, 704, and 871°C (900, 1000, 1100, 1300, and 1600°F) for 10000, 20000 and 28300 hours. And the toughness data were generated from material aged at 492, 538, 704, 871, (918, 1000, 1300, 1600°F) for 100, 1000, 10000, 20000 and 28300 hours. [Note: Although the original report had 492°C (918°F) as the toughness material aging temperature, from the context the 492°C (918°F) might be a typo for 482°C (900°F). Verification is underway.] The material was aged in two environments, i. e., inert and simulated HTGR helium environments. The inert environment included two situations: In the first situation, the specimens were stacked in metal containers, which were then evacuated, filled with an inert gas, and welded shut for aging. In the second situation, the material was exposed to a steam loop in the form of blocks, and specimens were machined out of the blocks after the exposure, so the only important effect from the exposure was the thermal aging because any effects from chemical interaction with the steam environment were machined away. The HTGR helium-aged specimens were aged continuously in specially designed stainless steel retorts, except that the retort operating at 871°C (1600°F) was replaced with an aluminum oxide retort in the middle of the aging process and the specimens were simply stacked in place.

The simulated HTGR helium for generating the ORNL-HTGR creep data was premixed and flowed into the testing environmental chamber at rates of 15 to 100 cm^3/min. The helium composition in the test chamber was 34.0 (337) H_2, 3.2 (32) CH_4, 1.9 (19) CO, 0.2 (2) H_2O, and <0.05 (<0.5) N_2 in pascals (micro atmospheres). Oxygen was removed by reaction with the H_2 as the gas passed through a furnace at 500°C (932°F).

The standard test startup for generating the ORNL-HTGR creep data consisted of assembling the new test specimen in the chamber, evacuating air from the chamber, pressurizing the chamber with test gas and establishing flow at 83 kPa gage (12 psig), leak-checking with a helium sniffer, heating to 400°C (752°F) and holding for at least 24 hours until moisture was less than 10 ppm, heating to test temperature, and applying load to start the test. All impurities were initially high, but the outgassing period at 400°C (752°F) allowed the gas composition to reach the desired operating level. Some elevation in impurity levels (less than a factor of 2) occurred during heating to the test temperature, but the gas reached the desired operating levels within 24 hours.

ORIGINAL ORNL - HTGR DATA

Data ID:	McCoy285T3	**Data Class:**	5
Project:	ORNL US DOE HTGR Project	**Reference:**	McCoy 1985
Comment: Material was aged in static air in the form of blocks before specimens were machined. The aging environment is therefore considered inert.			

Table 3. Tensile properties of Inconel 617 (heat XX01A3US) as received and after aging in static air

[Specimens machined after aging. Gage sections were 31.8 mm (1.25 in.) long by 6.4 mm (0.25 in.) in diameter.]

Test	Aging condition			0.2% Yield strength		Ultimate tensile strength		Elongation[a] (%)		Reduction of area (%)
	Temperature		Time (h)							
	(°C)	(°F)		(MPa)	(ksi)	(MPa)	(ksi)	Uniform	Total	
Tested at 22°C (72°F)										
16545			0	303	43.9	747	108.3	54.1	54.3	36.2
16546			0	301	43.7	757	109.8	59.6	60.9	40.7
16547			0	305	44.3	754	109.3	57.4	57.9	32.4
17897	538	1000	2,500	358	51.9	794	115.2	66.0	68.1	49.3
17898	583	1000	2,500	360	52.2	796	115.5	67.6	69.8	48.6
17901	704	1300	2,500	371	53.8	847	122.9	39.2	39.2	32.0
17902	704	1300	2,500	372	54.7	848	123.1	44.1	44.1	35.0
17905[b]	871	1600	2,500	331	48.0	797	115.6	29.9	29.9	25.0
17906	871	1600	2,500	334	48.5	822	119.2	34.6	34.6	29.3
IC43	538	1000	10,000	392	56.9	805	116.8	53.3	53.4	43.8
IC25	704	1300	10,000	369	53.5	798	115.7	29.6	29.6	23.3
IC7	871	1600	10,000	290	42.0	695	100.8	28.3	28.3	21.0
IC38	538	1000	20,000	379	55.0	822	119.2	62.4	62.7	43.7
IC20	704	1300	20,000	395	57.3	813	117.9	21.1	21.1	17.3
IC02	871	1600	20,000	300	43.5	658	95.4	20.2	20.2	15.9
Tested at 538°C (1000°F)										
16657			0	216	31.3	610	88.5	64.7	67.3	49.8
16658			0	207	30.0	606	87.9	61.1	64.4	46.1
17899	538	1000	2,500	260	37.7	638	92.5	63.4	68.5	51.7
17900	538	1000	2,500	259	37.6	638	92.5	66.3	69.2	48.9
IC44	538	1000	10,000	222	32.2	669	97.0	36.4	36.5	30.5
IC26	704	1300	10,000	274	39.8	629	91.3	58.9	58.9	46.3
IC39	538	1000	20,000	281	40.8	621	90.0	64.6	66.2	51.4
Tested at 704°C (1300°F)										
16664			0	199	28.8	466	67.6	29.3	68.0	49.3
16665			0	196	28.4	443	64.2	25.9	69.9	53.1
16666			0	196	28.4	454	65.9	29.9	74.7	52.5
17903	704	1300	2,500	257	37.3	502	72.8	16.2	75.3	57.6
17904[c]	704	1300	2,500	256	37.1	475	69.0	14.4		
IC27	704	1300	10,000	211	30.6	461	66.9	16.9	68.8	56.3
IC21	704	1300	20,000	285	41.3	525	76.2	13.6	53.1	48.5
Tested at 871°C (1600°F)										
16672			0	181	26.3	194	28.1	3.2	88.0	87.8
16673			0	189	27.4	194	28.1	3.2	91.6	86.0
17907	871	1600	2,500	154	22.3	168	24.3	5.1		
17908	871	1600	2,500	170	24.6	179	25.9	4.3	98.2	91.0
IC8	871	1600	10,000	170	24.7	181	26.2	8.0	90.9	79.2
IC3	871	1600	20,000	180	26.1	255	37.0	8.8	89.9	72.8

[a]Elongation in 31.8 mm (1.25 in.).

[b]Broke at gage mark.

[c]Pull rod broke before specimen broke.

Data ID:	McCoy285T4	**Data Class:**	5
Project:	ORNL US DOE HTGR Project	**Reference:**	McCoy 1985
Comment:			

Table 4. Tensile properties of Inconel 617 (heat XX01A3US) after aging in HTGR-He

[Specimens machined before aging. Gage sections were 25.4 mm (1.00 in.) long by 3.18 mm (0.125 in.) in diameter.]

Specimen	Aging condition			0.2% Yield strength		Ultimate tensile strength		Elongation (%)		Reduction of area (%)
	Temperature		Time (h)					Uniform	Total	
	(°C)	(°F)		(MPa)	(ksi)	(MPa)	(ksi)			
				Tested at 24°C (75°F)						
I-100	593	1100	10,000	316	45.9	737	106.9	53.5	59.6	57.1
I-113	593	1100	20,000	510	74.0	919	133.3	24.4	24.8	29.1
I-104	704	1300	10,000	531	77.0	818	118.6	14.1	14.3	14.6
I-117	704	1300	20,000	523	75.8	794	115.3	9.6	10.0	15.5
I-108	871	1600	10,000	392	56.8	623	90.3	11.4	11.4	14.2
I-121	871	1600	20,000	303	44.0	509	73.8	6.0	6.2	6.8
				Tested at 593°C (1100°F)						
I-101	593	1100	10,000	238	34.5	572	82.9	44.6	48.2	44.4
I-112	593	1100	20,000	378	54.8	687	99.6	24.7	25.6	30.6
				Tested at 704°C (1300°F)						
I-105	704	1300	10,000	387	56.1	706	102.4	22.0	25.2	26.6
I-116	704	1300	20,000	378	54.8	698	101.2	17.5	19.3	22.0
				Tested at 871°C (1600°F)						
I-109	871	1600	10,000	219	31.7	283	41.0	8.0	59.4	61.2
I-120	871	1600	20,000	171	24.8	280	40.6	5.4	63.4	54.4

Data ID:	McCoy285T5	**Data Class:**	5
Project:	ORNL US DOE HTGR Project	**Reference:**	McCoy 1985
Comment:			

Table 5. Tensile properties of as-received Inconel 617 (heat XX09A4UK)

Specimen	Test temperature		0.2% Yield strength		Ultimate tensile strength		Elongation (%)		Reduction of area (%)
	(°C)	(°F)	(MPa)	(ksi)	(MPa)	(ksi)	Uniform	Total	
24	25	77	394	57.1	766	111	53.7	56.5	62.9
200	25	77	363	52.7	765	111	48.7	50.2	53.5
201	593	1100	216	31.4	556	80.7	49.5	52.2	48.6
202	649	1200	235	34.2	549	79.7	46.0	48.3	45.4
203	704	1300	290	42.1	502	72.8	32.0	34.0	39.8
204	760	1400	331	48.1	556	80.7	15.4	19.9	17.4
205	871	1600	268	38.8	284	41.2	13.0	20.4	26.1

Data ID:	McCoy285T7	**Data Class:**	5
Project:	ORNL US DOE HTGR Project	**Reference:**	McCoy 1985
Comment:			

Table 7. Tensile properties of Inconel 617 (heat XX01A3US) base metal at 25°C after aging 28,300 h in steam

(Sample machined from block after exposure, so aging environment was inert)

Aging temperature		0.2% Yield strength		Ultimate tensile strength		Elongation (%)		Reduction of area (%)
(°C)	(°F)	(MPa)	(ksi)	(MPa)	(ksi)	Uniform	Total	
482	900	401	58.2	859	124.6	52.2	52.8	48.9
538	1000	387	56.1	838	121.5	51.8	52.5	46.6

Data ID:	McCoy285T8	**Data Class:**	5
Project:	ORNL US DOE HTGR Project	**Reference:**	McCoy 1985
Comment:			

Table 8. Properties of Inconel 617 weld metal as welded

[Base material heat XX14A6UK, filler wire XX09A9UK, specimen gage section 25 mm (1.0 in.) long by 3.2 mm (0.13 in.) in diameter, tested at strain rate of 0.05/min]

Test temperature		0.2% Yield strength		Ultimate tensile strength		Elongation (%)		Reduction of area (%)
(°C)	(°F)	(MPa)	(ksi)	(MPa)	(ksi)	Uniform	Total	
25	77	537	77.9	813	117.9	32.4	35.6	54.6
593	1100	393	57.0	601	87.1	31.3	32.2	45.6
649	1200	367	53.2	567	82.3	35.7	36.8	38.4
760	1400	412	59.8	547	79.4	10.3	25.7	28.8
871	1600	272	39.4	288	41.8	6.0	42.8	71.1

Data ID:	McCoy285T9	**Data Class:**	5
Project:	ORNL US DOE HTGR Project	**Reference:**	McCoy 1985
Comment:			

Table 9. Tensile properties of Inconel 617 transverse weld specimens after aging in HTGR-He

(Welds made by the gas tungsten arc process from heat XX14A6UK base metal and XX09A9UK filler wire)

Specimen	Aging condition			0.2% Yield strength		Ultimate tensile strength		Elongation (%)		Reduction of area (%)	Failure location
	Temperature (°C)	Temperature (°F)	Time (h)	(MPa)	(ksi)	(MPa)	(ksi)	Uniform	Total		
				Tested at 24°C (75°F)							
I-148	593	1100	10,000	330	47.8	1004	145.6	26.0	26.3	28.3	Base
I-161	593	1100	20,000	676	98.0	1020	148.0	19.5	19.9	10.6	Base
I-152	704	1300	10,000	331	48.0	927	134.4	14.2	14.4	21.0	Base
I-165	704	1300	20,000	626	90.3	867	125.8	5.0	5.2	8.3	Base
I-156	871	1600	10,000	394	57.1	450	65.2	0.7	0.7	3.2	Base
I-169	871	1600	20,000	356	51.6	476	69.0	0.8	0.8	3.3	Base
				Tested at 593°C (1100°F)							
I-168	593	1100	10,000	259	37.6	514	74.6	29.0	29.4	33.3	Weld
I-160	593	1100	20,000	623	90.4	800	116.0	15.2	16.2	26.6	Base
				Tested at 704°C (1300°F)							
I-153	704	1300	10,000	460	66.7	756	109.7	15.7	19.9	35.0	Weld
I-164	704	1300	20,000	445	64.5	740	107.4	12.2	15.6	8.5	Base
				Tested at 871°C (1600°F)							
I-157	871	1600	10,000	223	32.4	270	39.1	6.0	26.8	56.0	Weld
I-168	871	1600	20,000	218	31.6	277	40.2	2.3	23.9	71.8	Weld

Data ID:	McCoy285T18	**Data Class:**	5
Project:	ORNL US DOE HTGR Project	**Reference:**	McCoy 1985
Comment:			

Table 18. Tensile properties at 25°C of Inconel 617 and 618 after exposures in creep tests

Material	Pretest condition	0.2% Yield stress		Ultimate tensile stress		Elongation (%)		Reduction of area (%)
		(MPa)	(ksi)	(MPa)	(ksi)	Uniform	Total	
Inconel 617, XX09A4UK	Test 21602, 871°C, 21 MPa, 26,117 h, 0.233% C	326	47.3	446	64.7	4.0	4.0	0.3
Inconel 618, transverse weld, Y09B9	Test 23083, 760°C, 69 MPa, 11,158 h, 0.062% C	565	53.0	582	84.4	19.7	19.7	22.3

Data ID:	McCoy285T13	**Data Class:**	5
Project:	ORNL US DOE HTGR Project	**Reference:**	McCoy 1985
Comment:			

Table 13. Charpy-V impact properties at 25°C for Inconel 617 and 618 after various treatments

Heat	Aging temper-ature (°C)	Impact energy [J (ft-lb)] after each aging time						
		0	100 h	1000 h	10,000 h	11,786 h	20,000 h	28,300 h
				Inconel 617				
XX01A3US	492	175 (129)						190 (140)[a]
XX01A3US	538	175 (129)			81 (60)		103 (76)	138 (102)[a]
XX01A3US	704	175 (129)			31 (23)		20 (15)	
XX01A3US	871	175 (129)	91 (67)[b] 98 (72)	53 (39)	26 (19)		20 (15)	
XX09A4UK	871	298 (220)	61 (45)[b]	26 (19)				
				Inconel 618				
Y09B9								
Base metal	871	94 (69)	88 (65)	94 (69)		100 (74)	104 (77)	
Weld metal	871	151 (111)	134 (99)	115 (85)		109 (80)	91 (67)	

[a]Exposed to steam environment before specimens were machined.

[b]Aged in HTGR-He; all other samples machined after aging in inert gas or air.

Data ID:	McCoy285T14	**Data Class:**	5
Project:	ORNL US DOE HTGR Project	**Reference:**	McCoy 1985
Comment: Material was aged in steam in the form of blocks before specimens were machined. Therefore the aging environment is considered inert.			

Table 14. Results of creep tests on Inconel 617 base metal

Test	Heat[a]	Stress (MPa)	Stress (ksi)	Environment	Condition[b]	Time to indicated creep strain (h) 1%	2%	5%	Time to tertiary creep (h)	Rupture or test (h)	Steady-state creep rate (h^{-1})	Elongation (%) Loading	Creep	Reduction of area (%)
					Tested at 593°C (1100°F)									
22188	A	414	60	Air	As received	20		3,350	3,445	3,570	4.8 E-6	16.0	6.9	18.2
20531	A	414	60	He	As received	380	1,700		4,534	4,534	4.9 E-6	18.0	3.7	21.3
20521	A	414	60	He	593/10,000/He	500				548	1.0 E-5		2.2	22.0
22645	A	414	60	He	593/20,000/He	2,000			2,600	2,676	2.4 E-6	1.3	3.9	12.0
22200	A	345	50	He	593/10,000/He					5,629	5.5 E-7	4.4	5.5	14.4
23088	B	345	50	Air	As received					2,107	1.4 E-6	9.3	3.4	15.2
					Tested at 649°C (1200°F)									
19106	A	414	60	He	As received	0.5	5	145	168	186	1.6 E-4	15.3	7.5	16.1
21589	A	345	50	Air	482/28,300/Steam	280	1,100		1,700	1,813	1.3 E-5	8.4	5.6	13.5
21610	A	345	50	Air	538/28,300/Steam	189	837			1,063	2.4 E-5	6.8	6.5	13.5
19182	A	276	40	He	As received	5,000	8,600	15,100	8,000	16,718	2.0 E-6	0.03	9.3	14.9
18483	A	276	40	He	As received	7,600				15,850	1.1 E-6	2.5	6.1	8.3
18440	A	276	40	Air	As received	8,850	16,480	25,510	16,000	25,566	9.3 E-7	1.5	6.4	15.7
19182	A	207	30	He	As received					26,515[c]	9.9 E-8	0.3	0.3	
23085	B	276	40	Air	As received					1,121	1.9 E-6	1.5	1.4	4.5
23339	B	276	40	Air	As received					667	3.1 E-6	4.6	1.9	10.0
22751	B	276	40	He	As received					1,208	3.0 E-6	2.3	0.8	10.6
					Tested at 704°C (1300°F)									
22742	A	276	40	He	As received	7	13	47	212	329	5.1 E-4	3.5	33.0	45.2
21579	A	276	40	He	704/10,000/He					584			9.1	17.8
20526	A	207	30	He	704/10,000/He	3,450	5,050		3,800	5,424	2.0 E-6		3.7	2.4
22180	A	207	30	He	704/20,000/Inert	925	2,285	4,529	2,500	5,585	7.1 E-7	0.2	10.9	14.3
23342	B	207	30	Air	As received					2,621	1.2 E-6	0.4	1.2	1.6
22753	B	207	30	He	As received	6,200			6,700	7,034	1.2 E-6	0.4	2.5	3.6
22760	B	172	25	He	As received	9,600	16,400			18,526[d]	6.5 E-6	0.5	2.9	
					Tested at 760°C (1400°F)									
17563	A	172	25	He	As received	9	20	57	105	280	8.9 E-4	0.2	53.6	74.1
23091	A	138	20	Air	As received	10	28	123	780	1,305	2.2 E-4		48.5	56.9
21578	A	138	20	He	538/28,300/Steam	209	440	870	550	1,762	3.9 E-5	0.06	24.5	46.2
20032	A	103	15	Air	As received	125	750	3,500	17,000	20,702	1.0 E-5		28.0	31.9
22754	B	172	25	He	As received	513	740	935	517	948	1.3 E-3		5.4	9.4
22755	B	138	20	He	As received					4,585		0.3	9.4	21.8
					Tested at 871°C (1600°F)									
21611	A	69	10	Air	As received	5	20			576			45.1	44.7
20492	A	48	7	Air	As received	240	500	1,200	2,400	4,800	4.1 E-5	0.09	26.2	28.3
20545	A	48	7	He	As received	2,500	3,500		3,000	3,562	1.1 E-4		11.8	18.4
20544	A	48	7	He	871/20,000/Inert	40	92	345	2,200	2,282	5.7 E-5		21.3	28.7
22185	A	48	7	He	871/20,000/He	40	100	320	1,880	1,933	5.7 E-5		18.8	24.0
19393	A	35	5	He	As received	3,200	5,848	13,875	26,800	29,544	3.7 E-6	0.002	16.5	22.3
19761	A	35	5	Air	As received	3,100	4,780	8,670	23,200	34,231	7.9 E-6	0.07	30.3	23.3
23827	B	48	7	He	As received	2,900	3,700	5,670	2,300	7,543	1.6 E-4	0.02	11.4	11.6
21603	B	21	3	Air	As received					26,117[e]	1.9 E-7	0.01	1.3	
21602	B	21	3	He	As received					25,699[e]	2.6 E-7		0.27	

[a] A = heat XX01A3US; B = heat XX09A4UK.

[b] Aging temperature (°C)/aging time (h)/aging environment.

[c] Test reloaded at a higher stress.

[d] Test in progress.

[e] Discontinued before failure.

Data ID:	McCoy285T15	**Data Class:**	5
Project:	ORNL US DOE HTGR Project	**Reference:**	McCoy 1985
Comment:			

Table 15. Results of creep tests on Inconel 617 weld metal in helium environment

(Weld metal heat XX09A9UK)

Test	Stress (MPa)	Stress (ksi)	Time to indicated creep strain (h) 1%	2%	5%	Time to tertiary creep (h)	Rupture or test (h)	Steady-state creep rate (h^{-1})	Elongation (%) Loading	Elongation (%) Creep	Reduction of area (%)
						Tested at 593°C (1100°F)					
20515	345	50					13,726[a]	1.2 E-7	0.6	0.4	
	414	60					1,296		0.09	0.1	
23071	414	60					2,034	1.3 E-6	0.72	2.0	5.1
						Tested at 649°C (1200°F)					
21399	345	50	525				526	8.1 E-6	0.1	2.6	3.3
20513	276	40					3,467	5.4 E-7	0.1	2.3	1.4
20553	242	35	15,400				18,182	4.7 E-7	0.2	1.8	2.9
						Tested at 704°C (1300°F)					
22741	276	40	775			785	790	8.0 E-6	0.5	4.4	5.9
22763	207	30	4,250	10,500	14,900	6,000	14,978	5.5 E-7	0.04	7.7	14.1
						Tested at 760°C (1400°F)					
20735	138	20	2,900	3,750	4,750	2,600	5,190	1.8 E-6		17.1	43.5
						Tested at 871°C (1600°F)					
20533	69	10	1,467	1,570			1,623		0.07	10.7	21.0

[a]Discontinued before failure.

Data ID:	McCoy285T16	**Data Class:**	5
Project:	ORNL US DOE HTGR Project	**Reference:**	McCoy 1985
Comment:			

Table 16. Results of creep tests on Inconel 617 transverse welds in helium environment

(Base plate heat XX14A6UK, weld metal XX09A9UK)

Test	Condition[a]	Time to indicated creep strain (h) 1%	2%	5%	Time to tertiary creep (h)	Rupture or test (h)	Steady-state creep rate (h^{-1})	Elongation (%) Loading	Elongation (%) Creep	Reduction of area (%)
					Tested at 593°C (1100°F) and 414 MPa (60 ksi)					
20522	593/10,000/He					645			1.7	5.2
					Tested at 704°C (1300°F) and 207 MPa (30 ksi)					
20528	704/10,000/He	4,830	6,380		5,100	6,932	2.6 E-6	0.3	3.7	17.1
21612	704/20,000/He	1,100	3,250	5,470	3,025	5,496	3.7 E-6	0.0	6.5	17.6

[a]Aging temperature (°C)/aging time (h)/aging environment.

GE-HTGR Data

The GE-HTGR data source contains the data generated over a period of eight years from 1978 to 1986 for the HTGR project by General Electric Company (GE) under DOE contract No. DE-AC03-80ET34034. The source document [Baldwin 1986] is a summary report on fatigue and creep test results on Alloy 617 and Alloy 800H. The report includes creep properties data from 36 creep tests at temperatures of 750, 850, 950, 1050 and 1100ºC (1382, 1552, 1742, 1922 and 2012ºF); creep-fatigue properties data from 7 creep-fatigue test at 950ºC (1742ºF); fatigue properties data from 40 fatigue tests at temperatures of 850 and 950ºC (1562 and 1742ºF), which consist of 27 low cycle fatigue tests conducted under strain control and 13 high cycle fatigue tests conducted under load control. A summary of the tests that generated the GE-HTGR data is given in Table 15. The creep properties include the elastic and plastic components of the loading strains, times to 0.1%, 0.2%, 0.5%, 1%, 2%, and 5% total strain, time to onset of tertiary creep, time to 0.2% offset tertiary creep, minimum creep rate, total creep strain, reduction in area, creep rupture time, and creep rupture stress. The fatigue and creep-fatigue properties include fatigue life data and strain-life curves. Based on the *Gen IV Materials Handbook* Data Classification Criteria, the data are classified as Class 5.

Table 15: Summary of GE-HTGR data on Alloy 617 (no weld data)

Test Type	**Sample Treatment**	**Test Evironment**	**Test Temperature ºC**				
			750	**850**	**950**	**1050**	**1100**
Creep	Solution Annealed	Air	1	10	10	3	1
		He	1	3	3	4	
Low Cycle Fatigue	He Aging*	He		3	3		
	Solution Annealing	Air		3	7		
		He		1	10		
High Cycle Fatigue	He Aging*	He		3	3		
	Solution Annealing	Air		1			
		He		3	3		
Creep-Fatigue	Solution Annealing	Air			7		

* Aged in simulated HTGR helium for 6000 hours at the same temperature as the test temperature

Table 16: Compositions (wt. %) of the Alloy 617 heats produced for the GE-HTGR data [Baldwin486T3]

Heat		**Ni**	**Cr**	**Co**	**Mn**	**Mo**	**Fe**	**A1**	**Si**	**C**	**S**	**Ti**	**Cu**	**B**
XX14A6UK	Max	bal	21.74	12.32	0.02	8.91	0.53	1.11	0.18	0.060[a]	0.002	0.30	0.11	0.003
	Min	bal	23.12	12.14	0.034	9.09	0.53	1.31	0.257	0.054[c]	-	0.363	-	-
XX63A8UK	Max	bal	22.30	12.10	0.06	9.27	1.02	1.07	0.19	0.07[a]	0.001	0.37	0.09	0.003
	Min	bal	21.8	11.8	0.049	9.3	0.93	0.92	0.19	0.075[c]	-	0.39	0.092	0.005

a. From vendor certificated values, c. Values determined at GE

All the GE-HTGR data were generated at GE's High Temperature Reactor Materials Testing Laboratory from two commercial heats produced by Huntington Alloy Product Division. The compositions of the heats are given in Table 16, and their product characterization is listed in Table 17. It is noted that Heat XX14A6UK was also tested to generate the previously discussed ORNL-HTGR data.

Table 17: Product characterization of the Alloy 617 heats produced by Huntington Alloy Product Division for the GE-HTGR data [Baldwin486T2]

Heat No.	Product Form	Heat Treatment	Grain Size[a]	Grain Size[b]
XX14A6UK	16 mm (5/8") plate	Solution Annealing 1204°C	00	0.5
XX63A8UK	44.5 mm (1.75") round bar	Solution Annealing 1177°C	4.5	-

a. measured by vendor, b. measured by GE

The simulated HTGR helium for generating the GE-HTGR data was premixed and flowed to the testing environmental chamber at a nominal flow rate of 2 std L/min. The helium composition supplied to the test chamber was controlled within the limits as shown in Table 18. During normal operation, the total gas pressure in the test chamber was 202,650 Pa (2 atm) absolute. The estimated gas chemistries at the test specimen position are given in Table 19. The estimation was based on an assumption that 50% of the total change in gas composition between the chamber inlet and outlet had occurred before the test gas reached the specimen located at the radial and longitudinal center of the chamber uniform hot zone.

Table 18: Helium composition in the environmental test chamber for the GE-HTGR data [Baldwin486P5]

H_2		H_2O		CO		CO_2		CH_4		N_2	
Pa	μatm	Pa	μatm	Pa	μatm	Pa	μatm	Pa	μatm	Pa	μatm
40.53 ±7.5994	400 ±75	0.20 ±0.0760	2 ±0.75	4.05 ±0.7599	40 ±7.5	0.02 ±0.0051	0.2 ±0.05	2.0 ±0.7599	20 ±7.5	0.61 ±0.3040	6 ±3

Table 19: Estimated local gas compositions at the position of the test specimens for the GE-HTGR creep tests in simulated HTGR helium [Baldwin486]

Temp. °C	Impurity Partial Pressure (Pa)					
	H_2	H_2O	CO	CO_2	CH_4	N_2
750	40.1	0.18	4.01	0.0195	2.00	0.6
850	40.2	0.07	4.07	0.019	1.96	0.6
950	40.3	<0.01	4.19	0.13	1.85	0.6
1050	40.5	<0.001	4.26	<0.010	1.62	0.6

It is worth mentioning that after the GE-HTGR testing program was terminated, a few of the environmental chambers and some testing accessories were shipped to ORNL. Some of these parts can still be used for the Gen IV materials testing.

ORIGINAL GE - HTGR DATA

Due to large size of the original document, only summary data are presented. For detailed data, the original source document must be used.

Data ID:	Baldwin486T4	**Data Class:**	4
Data Source:	GE HTGR Project	**Reference:**	Baldwin 1986
Comment:			

TABLE 4

CREEP AND RUPTURE TEST RESULTS FOR INCONEL 617

Specimen No.	Temperature °C	(°F)	Stress MPa	ksi	Environment	Time to 1% Total Strain h	Time to Initiate Stage II h	Minimum Creep Rate %/h	Time to Onset of Tertiary Creep h	Time to 0.2% Offset Tertiary Creep h	Rupture Life h	Elongation %	Reduction in Area %
Heat No. 1													
1A00CR01	750	(1382)	200	29.0	Air	97	-	-	-	-	625	19.6	24.8
1A00CR27	750	(1382)	159	23.0	Helium	24	120	0.0136	490	533	750	17.5	23.2
1A00CR02	850	(1552)	72.4	10.5	Air	20.5	-	-	-	-	1126	58.3	60.9
1A00CR08	850	(1562)	56.6	8.20	Air	1100	70	0.00042	142	785	12207	43.1	75.2
1A00CR11	850	(1562)	52.4	7.60	Helium	990	60	0.000605	530	882	17146	41.2	44.0
1A00CR14	850	(1562)	79.3	11.5	Air	16.5	-	0.0535	215	260	596	56.7	64.1
1A00CR17	850	(1562)	79.3	11.5	Helium	21	3.5	0.0410	20	43	383	36.7	42.7
1A00CR25	850	(1562)	62.1	9.00	Helium	-	-	-	-	-	4143	46.7	56.0
1A00CR206	850	(1562)	64.8	9.40	Air	13.8	-	-	-	-	1046	68.7	59.1
1A00CR04	950	(1742)	48.3	7.00	Air	6.7	-	-	-	-	334	46.9	46.9
1A00CR09	950	(1742)	25.5	3.70	Air	2750	-	0.000119	-	-	22188	-	-
1A00CR12	950	(1742)	24.1	3.50	Helium	4400	1900	0.0000446	4300	5060	28920	25.8	20.4
1A00CR15	950	(1742)	37.9	5.50	Air	70	-	-	-	-	723	34.9	33.9
1A00CR18	950	(1742)	37.9	5.50	Helium	440	10	0.000285	26	315	2025	28.1	46.1
1A00CR21	950	(1742)	29.0	4.20	Helium	1630	-	0.000175	185	1240	3173	8.5	9.4
1A00CR04	1050	(1922)	20.7	3.00	Air	125	-	-	-	-	1146	23.2	35.4
1A00CR10	1050	(1922)	10.7	1.55	Air	3100	370	0.000078	370	2140	8514	14.5	13.7
1A00CR16	1050	(1922)	14.5	2.10	Air	950	-	0.00026	305	639	9285	33.0	26.6
1A00CR19	1050	(1922)	14.5	2.10	Helium	380	110	0.00104	325	550	3752	28.3	43.8
1A00CR22	1050	(1922)	9.66	1.40	Helium	1280	110	0.000460	430	1060	18580	35.2	48.7
1A00CR23	1050	(1922)	9.66	1.40	Helium	1620	480	0.000420	1060	1640	Disc.	-	-
1A00CR26	1050	(1922)	14.5	2.10	Helium	580	65	0.000680	135	382	5123	22.9	40.2
1A00CR05	1100	(2012)	15.2	2.20	Air	70	-	-	-	-	723	34.9	33.9
Heat No. 4													
1A30CR03	850	(1562)	96.6	14.0	Air	2.4	3	0.325	>24	-	86	81.2	80.1
1A30CR05	850	(1562)	66.2	9.60	Air	26	8	0.0304	330	358	791	42.1	77.6
1A30CR06	850	(1562)	75.9	11.0	Air	8.5	4	0.0960	80	110	326	78.1	81.0
1A30CR07	850	(1562)	56.6	8.20	Air	55	280	0.0116	850	1150	2296	66.8	57.0
1A30CR09	850	(1562)	44.8	6.50	Air	218	500	0.00332	3400	4400	7723	41.7	90.8
1A30CR14	850	(1562)	48.3	7.00	Air	160	850	0.00495	1800	2540	4818	40.3	65.1
1A30CR04	950	(1742)	55.2	8.00	Air	1.3	4.5	0.612	>25	-	51	56.0	66.0
1A30CR08	950	(1742)	24.1	3.50	Air	255	15	0.00165	90	195	2390	40.5	30.0
1A30CR10	950	(1742)	37.9	5.50	Air	16	-	0.0490	10	19	282	38.8	47.2
1A30CR11	950	(1742)	44.8	6.50	Air	-	-	-	-	-	140	55.4	50.4
1A30CR12	950	(1742)	20.7	3.00	Air	475	60	0.00101	190	372	5017	36.4	28.2
1A30CR207	950	(1742)	31.0	4.50	Air	14	235	0.0180	>858	-	1284	41.4	42.6
1A30CR211	950	(1742)	31.0	4.50	Air	45	250	0.0190	680	788	1114	31.5	37.9

Data ID:	Baldwin486T8	**Data Class:**	4
Data Source:	GE HTGR Project	**Reference:**	Baldwin 1986
Comment:			

TABLE 8

INCONEL 617 FATIGUE TEST DATA (HCF), Heat No. XX14A6UK

Temperature °C(°F)	Strain Range %[a]	Frequency Hz	Life[b] N_f	Stress Range MPa	ksi
Air Tests: As-received Condition					
850 (1562)	0.27[c]	0.5	2.8×10^7	413.7	60.0
Simulated HTGR Helium Tests: As-received Condition					
850 (1562)	0.18	30	849000	310.3	45.0
	0.20	30	1.5×10^6	344.7	50.0
	0.26	30	178800	413.7	60.0
950 (1742)	0.11	30	4.0×10^6	179.3	26.0
	0.13	30	1.9×10^6	206.8	30.0
	0.17	30	961000	248.2	36.0
Simulated HTGR Helium Tests: Test Specimens Exposed 6000 Hours in Simulated HTGR Helium at Same Temperature as Test Temperature					
850 (1562)	0.2	30	1.2×10^6	333.7	48.4
	0.24	30	359900	390.2	56.6
	0.18	30	2.42×10^6	317.2	46.0
950 (1742)	0.13	30	1.13×10^6	206.8	30.0
	0.19	30	126000	275.8	40.0
	0.24	30	42800	317.2	46.0

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a = Reported values determined from stress strain curves.
b = N_f is the number of cycles to total separation.
c = Extensometer in place for 300 cycles.

Data ID:	Baldwin486T9	**Data Class:**	4
Data Source:	GE HTGR Project	**Reference:**	Baldwin 1986
Comment:			

TABLE 9

INCONEL 617 FATIGUE TEST DATA (LCF), Heat No. XX14A6UK

Temperature °C(°F)	Strain Range %	Strain Rate Hz	Life N_5[a]	Life N_f[b]	Stress Range[c] MPa	Stress Range[c] ksi
Air Tests: As-received Condition						
850 (1562)	0.3	0.4	734000	734000	413.7	60.0
	0.4	0.4	3100	3685	572.3	83.0
	0.7	0.4	850	1250	488.2	70.8
Simulated HTGR Helium Tests: As-received Condition						
850 (1562)	0.4	0.4	7800	11137	463.3	67.2
950 (1742)	0.4	0.4	5900	7153	391.6	56.8
	1.0	0.4	1000	1423	375.1	54.4
Simulated HTGR Helium Tests: Test Specimens Exposed 6000 Hours in Simulated HTGR Helium at Same Temperature as Test Temperature						
850 (1562)	0.3	0.4	16300	18997	435.8	63.2
	0.4	0.4	5800	6363	463.3	67.2
	0.6	0.4	1800	2246	554.3	80.4
950 (1742)	0.4	0.4	7500	8156	386.1	56.0
	0.7	0.4	1400	1771	380.6	55.2
	1.0	0.4	940	985	404.0	58.6

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a = N_5 is the number of cycles to a 5% decrease in the stress range below the saturation value.
b = N_f is the number of cycles to a 50% decrease in stress range.
c = Reported values are at $N_f/2$.

Data ID:	Baldwin486T10	**Data Class:**	4
Data Source:	GE HTGR Project	**Reference:**	Baldwin 1986
Comment:			

TABLE 10

INCONEL 617 FATIGUE TEST DATA (LCF), Heat No. XX63A8UK

Temperature °C(°F)	Strain Range %	Strain Rate 1/Sec	Life N_5[a]	Stress Range[b] MPa	Stress Range[b] ksi
Air Tests: As-received Condition					
950 (1742)	1.0	0.4	590	441	63.9
	0.6	0.2	1300	424	61.5
	0.4	0.1	2820	412	59.7
	0.3	0.04	22190	377	54.7
	0.3	0.05	9990	365	52.9
	0.3	0.05	6690	372	53.9
	0.25	0.05	19000	368	53.3
Simulated HTGR Helium Tests: Test Specimens Exposed 6000 Hours in Simulated HTGR Helium at 950°C					
950 (1742)	1.0	0.4	1615	510	73.9
	1.0	0.05	900	339	49.1
	0.6	0.05	3200	359	52.1
	0.6	0.15	2500	343	49.7
	0.4	0.1	3500	336	48.7
	0.3	0.05	11900	311	45.1
	0.25	0.05	36000	359	52.1
	0.25	0.05	47000	354	51.3

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a = N_5 is the number of cycles to a 5% decrease in the stress range below the saturation value.
b = Reported values are at approximately $N_5/2$.

Data ID:	Baldwin486T11	**Data Class:**	4
Data Source:	GE HTGR Project	**Reference:**	Baldwin 1986
Comment:			

TABLE 11

INCONEL 617 CREEP FATIGUE TEST DATA, Heat No. XX63A8UK

Temperature °C(°F)	Strain Range %	Strain Rate 1/Sec	Life N_5[a]	Stress Range[b] MPa	Stress Range[b] ksi
Air Tests: As-received Condition					
950 (1742)					
2 Minute Tensile Hold:					
	1.0	0.05	420	352	51.1
	0.6	0.1	850	372	53.9
	0.4	0.08	2000	374	54.2
	0.3	0.05	3100	352	51.1
20 Minute Tensile Hold:					
	1.0	0.05	360	316	45.9
	0.6	0.1	610	363	52.7
	0.4	0.05	1750	314	45.5

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a = N_5 is the number of cycles to a 5% decrease in the stress range below the saturation value.

b = Reported values are at approximately $N_5/2$.

Huntington Alloys Data

The Huntington Alloys data source is a collection of mechanical properties data on Alloy 617 provided by its manufacturer Huntington Alloys, Inc. Unlike the ORNL-HTGR data and the GE-HTGR data that were generated for the purpose of design and construction of nuclear reactors, the Huntington Alloys data were produced for general applications of the alloy, which included manufacturing such components as ducting, combustion cans, transition liners in both aircraft and land-based gas turbines, catalyst-grid supports for the production of nitric acid, heat-treating baskets in metallurgical processing, reduction boats in the refining of molybdenum and many others. The Huntington Alloys data collected for the present report include tensile properties data generated from 179 tensile tests at temperatures of 25, 38, 93, 149, 204, 260, 316, 371, 427, 482, 538, 593, 649, 704, 760, 816, 871, 927, 982, 1038, and 1093ºC (75, 100, 200, 300, 400, 500, 600, 700, 800, 900, 1000, 1100, 1200, 1300, 1400, 1500, 1600, 1700, 1800, 1900, and 2000ºF), and creep properties data generated from 249 creep tests at temperatures of 593, 649, 704, 760, 816, 871, 927, 982, 1000, 1038, 1093ºC (1100, 1200, 1300, 1400, 1500, 1600, 1700, 1800, 1832, 1900, 2000ºF). The tensile properties include yield strength, ultimate tensile strength, total strain, and reduction in area. The creep

Table 20: Summary of the Huntington Alloys data of Alloy 617

Temperature ºC	Tensile Tests on Base Metal	Tensile Tests on Weld	Creep Tests on Base Metal	Creep Tests on Weld
24	26	9		
38	3			
93	6	2		
149	3			
204	6	2		
260	3			
316	6	2		
371	3			
427	6	2		
482	3			
538	8	4		
593	5	2	7	
649	9	4	22	
704	4	2	8	
760	9	4	24	
816	3	3	28	3
871	8	4	65	3
927	3	2	6	
982	6	4	29	2
1000			16	
1038	3		5	
1093	6	4	31	
Total	129	50	241	8

properties include creep rupture time, creep rupture stress, creep rupture strain, minimum creep rate, time to 1% total strain, and time to 0.2% offset tertiary creep. A summary of the tests that generated the Huntington Alloys data is given in Table 20. It should be pointed out that due to poor copy quality of the source documents obtained, some data are not included in this table. Efforts will continue to collect these missing data. Since the Huntington Alloys data came from the manufacturer, they should be classified as Class 5. However, because these data have also been accepted for the development of several ASME B&PV Code cases, such as the draft Code Case for the design of Alloy 617 nuclear components at the request of the DOE for the HTGR Program in the 1980's [Corum 1991], and applications in designing a natural gas reformer based on the requirements of ASME B&PV Code Section VIII, Division 1 for producing synthesis gas, these data may be qualified as Class 2 after being reviewed and approved by the *Gen IV Materials Handbook* management.

Table 21: Compositions (wt. %) of the Alloy 617 heats for the Huntington Alloys data

Heat	Ni	Cr	Co	Mo	Fe	Mn	Al	C
XX00A1US	53.91	22.51	12.67	8.91	0.13	0.04	1.05	0.07
XX00A2US	54.6	22.77	12.72	8.59	0.18	0.02	0.98	0.07
XX00A3US	54.76	22.64	12.5	8.82	0.09	0.03	1.01	0.06
XX00A4US	54.73	22.31	12.46	9.09	0.15	0.02	1.06	0.07
XX00A5US	55.91	21.77	12.24	8.71	0.19	0.03	0.99	0.07
XX05A4UK	54.97	22.04	12.46	9	0.24	0.02	1.08	0.07
XX05A7UK	55.02	21.77	12.57	9.15	0.21	0.01	1.07	0.06
XX07A7UK	55.12	21.99	12.3	8.52	0.52	0.02	1.31	0.08
XX10A3UK	54.16	22.17	12.7	9.29	0.33	0.04	1.04	0.09
XX18A4UK	54.22	21.86	12.35	8.95	0.72	0.01	1.03	0.051
XX20A5UK	55.61	21.32	12.67	8.85	0.28	0.01	1.05	0.06
XX26A8UG	54.54	21.89	12.48	9	0.48	0.03	1.17	0.06
XX41A7UK	54.01	21.42	12.9	8.83	1.35	0.02	0.92	0.06
Heat	**Cu**	**Si**	**S**	**Ti**	**P**	**B**	**N**	**Mg**
XX00A1US	0.23	0.04	0.007	0.41	0.003	0.0051		0.029
XX00A2US	0.01	0.04	0.008	0.25	0.002	0.005	0.019	0.022
XX00A3US	0.01	0.06	0.007	0.39	0.004	0.004	0.023	0.007
XX00A4US	0.01	0.08	0.007	0.35	0.003	0.0043	0.012	0.029
XX00A5US	0.02	0.06	0.007	0.46	0.003	0.0059	0.011	0.024
XX05A4UK	0.07	0.12	0.002	0.43	0.006	0.002		0.043
XX05A7UK	0.07	0.14	0.004	0.51	0.004	0.002		0.051
XX07A7UK	0.09	0.14	0.003	0.43	0.004	0.001		0.07
XX10A3UK	0.19	0.18	0.003	0.32	0.003	0.001		0.04
XX18A4UK	0.09	0.17	0.006	0.28	0.001	0.003		0.03
XX20A5UK	0.1	0.15	0.001	0.27	0.002	0.002		0.021
XX26A8UG		0.09	0.001	0.26	0.001	0.002		0.039
XX41A7UK	0.04	0.19	0.001	0.3	0.002	0.001		0.051

The Huntington Alloys data that are reviewed in the present assessment were generated from thirteen heats plus one heat for welding filler metal. Chemical compositions and product forms of the thirteen heats are presented in Tables 21 and 22, respectively. All the heats were solution annealed. The welds were produced using Alloy 617 welding electrodes of four different diameters. The chemical compositions of the electrodes are given in Table 23. The welds were produced using tungsten inert gas (TIG) welding and pulsed gas metal arc welding processes.

Table 22: Product forms of the Alloy 617 for the Huntington Alloys data

Heat	Product Form	Heat	Product Form
XX00A1USL	0.062” Cold Rolled Sheet	XX00A4USL	1" Hot Rolled Round
	3/4" Hot Rolled Round		Hot Rolled Round
	Cold Rolled Sheet	XX05A4UK	1/2" Hot Rolled Round
	Hot Rolled Round		Hot Rolled Round
XX00A2USL	3/4" Hot Rolled Round	XX05A7UK	1" CD Tube
	9/16" Hot Rolled Round		CD Tube
	Hot Rolled Round	XX07A7UK	5/8" Hot Rolled Round
XX00A3USL	1" Flat		Hot Rolled Round
	1/2" Flat	XX10A3UK	Extruded Tube
	12" Square	XX18A4UK	0.188" Cold Rolled Sheet
	Forged Square		Cold Rolled Sheet
	Hot Rolled Flat	XX20A5UK	0.187" Cold Rolled Sheet
XX00A5USL	0.032" Cold Rolled Sheet		Cold Rolled Sheet
	5/8" Hot Rolled Round	XX26A8UK	0.040" Cold Rolled Sheet
	Cold Rolled Sheet	XX41A7UK	Cold Rolled Sheet
	Hot Rolled Round		

Note: For heats that have same product form with and without a dimension prefix, the product form descriptions are original from the source. They may have the same dimension.

Table 23: Chemical compositions of Alloy 617 welding electrodes used for generating the Huntington Alloys data

Diameter		Element											
mm	inch	Ni	Cr	Co	Mo	Fe	Mn	Al	C	Si	S	Ti	Nb+Ta
2.38	3/32	Bal	23.07	11.48	9.24	1.15	1.45	0.22	0.10	0.50	0.005	0.09	0.56
3.18	1/8	Bal	23.14	11.47	9.23	1.18	1.39	0.21	0.11	0.49	0.004	0.08	0.47
3.97	5/32	Bal	23.33	11.71	9.32	0.89	0.66	0.26	0.10	0.48	0.004	0.10	0.02
4.76	3/16	Bal	23.16	11.75	9.33	0.85	0.63	0.22	0.10	0.46	0.003	0.16	N/A

ORIGINAL HUNTINGTON ALLOYS DATA

Data ID: HA83T1 **Data Class:** 5
Data Source: Huntington Alloys **Reference:** Huntington 1983
Comment:

TABLE I 5/17/79

TENSILE TEST DATA

MELT	FORM	YS KSI	TS KSI	ELONG %	RA %
ROOM TEMPERATURE					
XX00A1USL	0.062" CR SHEET	47.0	111.0	54.0	-
XX00A1USL	0.062" CR SHEET	51.3	116.7	55.5	-
XX00A1USL	3/4" HR ROUND	42.9	106.6	70.0	57.2
XX00A2USL	9/16" HR ROUND	45.9	111.4	68.0	58.2
XX00A2USL	3/4" HR ROUND	44.3	107.1	72.0	56.6
XX00A3USL	1/2" FLAT	44.4	107.8	70.0	62.1
XX00A3USL	1/2" FLAT	44.6	107.5	68.0	61.3
XX00A3USL	1" FLAT	44.8	107.5	66.0	58.3
XX00A3USL	1" FLAT	44.8	106.7	66.0	58.8
XX00A3USL	12" SQUARE	50.5	116.5	60.0	57.6
XX00A3USL	12" SQUARE	44.5	105.1	68.0	57.6
XX00A3USL	12" SQUARE	46.5	111.3	66.0	58.1
XX00A3USL	12" SQUARE	44.9	102.7	62.0	46.1
XX00A4USL	1" HR ROUND	51.6	111.6	61.0	53.9
XX00A4USL	1" HR ROUND	56.1	113.9	58.0	49.0
XX00A5USL	5/8" HR ROUND	46.6	111.3	64.0	54.5
XX00A5USL	0.032" CR SHEET	50.2	119.0	50.0	-
XX05A4UK	1/2" HR ROUND	50.6	105.9	64.0	53.2
XX05A4UK	1/2" HR ROUND	47.8	107.1	61.0	53.1
XX05A7UK	1" CD TUBE	52.5	107.5	74.0	-
XX07A7UK	5/8" HR ROUND	53.8	110.8	59.0	49.8
XX07A7UK	5/8" HR ROUND	53.2	112.5	56.0	49.1
XX18A4UK	0.188" CR SHEET	51.5	108.0	61.0	-
XX20A5UK	0.187" CR SHEET	49.0	106.0	62.0	-
XX20A5UK	0.187" CR SHEET	49.4	104.7	63.5	-
XX26A8UK	0.040" CR SHEET	52.0	117.6	53.0	-

2 TABLE I (CONT'D) 5/17/79

MELT	FORM	YS KSI	TS KSI	ELONG %	RA %
100F					
XX05A4UK	1/2" HR ROUND	46.4	112.9	46.4	51.8
XX07A7UK	5/8" HR ROUND	49.6	112.0	53.6	47.3
XX26A0UK	0.040" CR SHEET	50.9	111.2	33.5	-
200F					
XX00A4USL	1" HR ROUND	65.7	110.7	55.0	49.0
XX00A5USL	5/8" HR ROUND	45.6	105.2	60.0	49.0
XX05A4UK	1/2" HR ROUND	38.6	106.4	59.1	54.2
XX07A7UK	5/8" HR ROUND	47.8	108.3	56.4	52.1
XX20A5UK	0.187" CR SHEET	44.9	100.1	65.4	-
XX26A0UK	0.040 CR SHEET	49.0	116.7	-	-
300F					
XX05A4UK	1/2" HR ROUND	35.4	102.4	60.4	54.0
XX07A7UK	5/8" HR ROUND	42.4	105.3	56.7	51.2
XX26A0UK	0.040 CR SHEET	47.1	108.8	21.3	-
400F					
XX00A4USL	1"0 HR ROUND	57.0	103.2	57.0	52.9
XX00A5USL	5/8" HR ROUND	38.5	97.7	64.0	50.7
XX05A4UK	1/2" HR ROUND	37.2	97.8	63.3	57.8
XX07A7UK	5/8" HR ROUND	42.6	103.5	55.9	55.0
XX20A5UK	0.187" CR SHEET	39.6	95.1	64.3	-
XX26A8UK	0.040 CR SHEET	43.7	111.6	58.0	-

3 TABLE I(CONT'D) 5/17/79

MELT	FORM	YS KSI	TS KSI	ELONG. %	RA %
*********	*****************	*****	*****	*****	****
500F					
XX05A4UK	1/2" HR ROUND	33.5	99.2	60.4	54.2
XX07A7UK	5/8" HR ROUND	39.1	101.5	57.4	54.3
XX26A8UK	0.040 CR SHEET	41.4	109.9	53.2	-
600F					
XX00A4USL	1" HR ROUND	51.9	100.1	60.0	53.4
XX00A5USL	5/8" HR ROUND	34.1	96.7	64.0	56.1
XX05A4UK	1/2" HR ROUND	33.8	94.0	64.7	60.7
XX07A7UK	5/8" HR ROUND	37.8	100.3	59.0	54.5
XX20A5UK	0.187" CR SHEET	35.7	91.9	70.5	-
XX26A8UK	0.040 CR SHEET	40.2	107.4	58.0	-
700F					
XX05A4UK	1/2" HR ROUND	31.7	91.6	65.6	58.1
XX07A7UK	5/8" HR ROUND	36.0	98.2	60.4	54.0
XX26A8UK	0.040 CR SHEET	38.6	105.9	62.0	-
800F					
XX00A4USL	1" HR ROUND	50.4	96.5	61.0	53.9
XX00A5USL	5/8" HR ROUND	31.8	91.7	68.0	52.9
XX05A4UK	1/2" HR ROUND	33.3	91.2	67.9	58.7
XX07A7UK	5/8" HR ROUND	37.6	98.0	61.6	56.3
XX20A5UK	0.187" CR SHEET	36.2	88.5	70.4	-
XX26A8UK	0.040 CR SHEET	39.6	105.7	59.5	-

4 TABLE I(CONT'D) 5/17/79

MELT	FORM	YS KSI	TS KSI	ELONG. %	RA %
*********	*****************	*****	*****	*****	****
900F					
XX05A4UK	1/2" HR ROUND	38.1	91.9	63.2	56.1
XX07A7UK	5/8" HR ROUND	36.6	93.1	56.4	44.8
XX26A8UK	0.040 CR SHEET	38.8	102.3	55.3	-
1000F					
XX00A1USL	.062" CR SHEET	31.5	85.5	56.0	-
XX00A1USL	3/4" HR ROUND	28.3	84.1	69.0	57.6
XX00A4USL	1" HR ROUND	50.3	91.4	63.0	51.8
XX00A5USL	5/8" HR ROUND	31.6	85.1	66.0	52.9
XX05A4UK	1/2" HR ROUND	33.3	84.9	64.1	64.3
XX07A7UK	5/8" HR ROUND	35.4	90.5	58.4	50.4
XX20A5UK	0.187" CR SHEET	33.1	82.0	71.6	-
XX26A8UK	0.040 CR SHEET	37.6	102.5	59.0	-
1100F					
XX00A4USL	1" HR ROUND	47.9	87.4	62.0	53.9
XX00A5USL	5/8" HR ROUND	29.6	85.4	65.0	56.1
XX05A4UK	1/2" HR ROUND	28.1	89.3	62.2	46.2
XX07A7UK	5/8" HR ROUND	37.1	89.9	57.4	43.0
XX26A8UK	0.040 CR SHEET	36.0	98.5	57.0	-

5 TABLE I(CONT'D) 5/17/79

MELT	FORM	YS KSI	TS KSI	ELONG %	RA %
1200F					
XX00A1USL	0.062" CR SHEET	28.5	84.0	62.0	-
XX00A1USL	3/4" HR ROUND	24.8	82.4	75.0	54.5
XX00A4USL	1" HR ROUND	44.0	89.5	61.0	46.7
XX00A5USL	5/8" HR ROUND	26.3	83.8	64.0	52.9
XX00A5USL	0.032" CR SHEET	28.0	90.5	65.0	-
XX05A4UK	1/2" HR ROUND	30.8	82.4	65.6	56.3
XX07A7UK	5/8" HR ROUND	39.5	88.0	54.6	48.3
XX20A5UK	0.187" CR SHEET	32.6	89.4	51.5	-
XX26A8UK	0.040 CR SHEET	37.1	99.6	61.5	-
1300F					
XX00A4USL	1" HR ROUND	35.3	81.4	64.0	48.4
XX05A4UK	1/2" HR ROUND	38.8	80.9	53.0	42.3
XX07A7UK	5/8" HR ROUND	43.0	85.3	48.4	43.3
XX26A8UK	0.040 CR SHEET	37.3	86.3	46.7	-
1400F					
XX00A1USL	0.062" CR SHEET	30.0	67.5	76.0	-
XX00A1USL	3/4" HR ROUND	25.6	64.8	84.0	64.6
XX00A4USL	1" HR ROUND	47.5	80.6	58.0	51.2
XX00A5USL	5/8" HR ROUND	30.8	72.5	72.0	53.9
XX00A5USL	0.032" CR SHEET	31.0	63.5	84.0	-
XX05A4UK	1/2" HR ROUND	33.7	73.9	52.4	47.8
XX07A7UK	5/8" HR ROUND	47.0	84.8	36.7	34.2
XX20A5UK	0.187" CR SHEET	37.0	66.9	59.1	-
XX26A8UK	0.040 CR SHEET	39.4	72.8	42.1	-

6 TABLE I(CONT'D) 5/17/79

MELT	FORM	YS KSI	TS KSI	ELONG. %	RA %
1500F					
XX05A4UK	1/2" HR ROUND	34.1	58.3	46.5	53.3
XX07A7UK	5/8" HR ROUND	44.5	64.2	34.2	38.2
XX26A8UK	0.040 CR SHEET	37.8	56.5	61.3	-
1600F					
XX00A1USL	0.062" CR SHEET	30.5	36.0	92.0	-
XX00A1USL	3/4" HR ROUND	28.4	40.7	120.0	92.5
XX00A4USL	1" HR ROUND	39.5	48.2	74.0	68.7
XX00A5USL	5/8" HR ROUND	31.5	40.4	99.0	86.4
XX05A4UK	1/2" HR ROUND	39.4	51.8	42.9	52.3
XX07A7UK	5/8" HR ROUND	36.9	47.0	41.7	47.8
XX20A5UK	0.187" CR SHEET	28.1	39.9	73.0	-
XX26A8UK	0.040 CR SHEET	33.3	62.6	67.5	-
1700F					
XX05A4UK	1/2" HR ROUND	25.4	33.1	62.9	79.8
XX07A7UK	5/8" HR ROUND	25.6	31.3	61.0	59.9
XX26A8UK	0.040 CR SHEET	21.9	29.7	52.0	-
1800F					
XX00A1USL	0.062" CR SHEET	14.5	19.5	58.0	-
XX00A1USL	3/4" HR ROUND	21.0	21.4	124.0	94.1
XX05A4UK	1/2" HR ROUND	20.1	24.4	72.1	72.6
XX07A7UK	5/8" HR ROUND	20.4	24.8	68.7	65.3
XX20A5UK	0.187" CR SHEET	13.3	21.5	92.9	-
XX26A8UK	0.040 CR SHEET	15.0	22.1	60.5	-

TABLE I (CONT'D)

MELT	FORM	YS KSI	TS KSI	ELONG. %	RA %
1900F					
XX05A4UK	1/2" HR ROUND	15.2	18.2	79.1	73.9
XX07A7UK	5/8" HR ROUND	15.2	20.4	61.4	55.3
XX26A8UK	0.040 CR SHEET	13.4	15.2	38.5	-
2000F					
XX00A1USL	0.062" CR SHEET	7.5	10.5	58.0	-
XX00A1USL	3/4" HR ROUND	7.4	11.5	90.0	77.5
XX05A4UK	1/2" HR ROUND	10.7	12.6	71.4	60.8
XX07A7UK	5/8" HR ROUND	11.9	15.7	60.0	62.3
XX20A5UK	0.187" CR-SHEET	7.4	11.6	76.2	-
XX26A8UK	0.040"CRRS\(EVT	9.5	11.9	59.0	-

Data ID: HA83T2 **Data Class:** 5
Data Source: Huntington Alloys **Reference:** Huntington 1983
Comment:

1 TABLE II 11/15/82

CREEP AND RUPTURE STRENGTH DATA

INCONEL ALLOY 617

MELT	FORM	STRESS KSI	LIFE HRS.	ELONG. %	MCR %/HR.	HR. TO 1% T.S.	HR. TO .2% 3RD STAGE
1100 F							
XX00A4USL	HR ROUND	78.0	98.4	45.5	.0159	<.1	63
XX00A4USL	HR ROUND	60.0	2666.7	13.2	.0003	<.1	2610
XX00A4USL	HR ROUND	50.0	28735.4	5.5	.000011	<.1	26800
XX00A5USL	HR ROUND	75.0	147.9	42.0	.016	<.1	140
XX00A5USL	HR ROUND	65.0	639.4	29.2	.0029	<.1	615
XX00A5USL	HR ROUND	56.0	3809.1	20.0	.000045	<.1	3800
XX00A5USL	HR ROUND	47.0	21447.1	8.9	.000023	3160	21000
1200 F							
XX00A1USL	HR ROUND	75.0	5.7	66.0	-	<.1	-
XX00A1USL	HR ROUND	60.0	149.3	31.0	-	-	-
XX00A1USL	HR ROUND	45.0	1091.0	11.5	.00069	<.1	1075
XX00A1USL	HR ROUND	35.0	956.2D	2.9	.00009	<.1	>956
XX00A4USL	HR ROUND	45.0	6153.1	1.9	.00026	2860	5500
XX00A4USL	HR ROUND	40.0	11296.3D	1.4	.000054	7200	>11296
XX00A4USL	HR ROUND	35.0	7243.8D	0.3	.00001	>7243	>7243
XX00A4USL	HR ROUND	35.0	16562.0D	>0.6	.000015	>16562	>16562
XX00A5USL	HR ROUND	55.0	265.2	18.7	.0075	<.1	240
XX00A5USL	HR ROUND	45.0	2784.1	10.0	.00049	<.1	2680
XX00A5USL	HR ROUND	40.0	9699.0	6.7	.00012	<.1	9600
XX00A5USL	HR ROUND	35.0	8757.0D	-	.000026	<.1	-
XX05A4UK	HR ROUND	45.0	1027.1	8.3	.00045	<.1	995
XX05A4UK	HR ROUND	40.0	2301.4	6.9	.00012	<.1	2300
XX07A7UK	HR ROUND	45.0	4197.3	2.7	.00015	1450	4190
XX07A7UK	HR ROUND	40.0	8559.7	0.6	.000077	>8559	8559
XX07A7UK	HR ROUND	35.0	24481.5	1.0	.000021	24482	24200

"D" IN LIFE HRS. COLUMN INDICATES DISCONTINUED TEST.

2 TABLE II(CONT'D) 11/15/82

MELT	FORM	STRESS KSI	LIFE HRS.	ELONG. %	MCR %/HR.	HR. TO 1% T.S.	HR. TO .2% 3RD STAGE
1200 F(CONT'D)							
XX10A3UK	EXT TUBE	50.0	887.1	2.6	.0013	480	855
XX20A5UK	CR SHEET	50.0	158.7	13.8	.0053	<.1	143
XX20A5UK	CR SHEET	42.0	520.1	6.3	.00081	<.1	500
XX20A5UK	CR SHEET	35.0	8414.2	1.5	.000048	8400	8400
XX41A7UK	CR SHEET	40<0	1772.3	5.0	.00057	<.1	1070
1300 F							
XX05A4UK	HR ROUND	45.0	218.0	7.3		-	-
XX05A4UK	HR ROUND	35.0	2113.8	4.6	.000564	1080	1160
XX05A4UK	HR ROUND	30.0	4991.4	6.9	.000365	2070	2200
XX05A4UK	HR ROUND	20.0	23342.8D	0.8	.000032	28200E	>23342
XX07A7UK	HR ROUND	35.0	1609.2	4.6	.00816	990	1345
XX07A7UK	HR ROUND	30.0	5184.3	5.3	.00031	2180	2950
XX07A7UK	HR ROUND	25.0	20022.5	9.7	.0002	4400	12800
XX20A5UK	CR SHEET	26.0	2283.7	8.9	.0021	185	1320
1400 F							
XX00A1USL	HR ROUND	37.0	40.2	54.0	-	-	-
XX00A1USL	HR ROUND	30.0	124.3	98.5	.325	2.4	10.5
XX00A1USL	HR ROUND	25.0	320.8	84.0	-	-	-
XX00A1USL	HR ROUND	20.0	424.6	38.2	.056	7	340
XX00A1USL	HR ROUND	15.0	10330.5D	9.5	.00026	75	>10330
XX00A4USL	HR ROUND	20.0	2581.6	46.2	.0031	162	365
XX00A4USL	HR ROUND	20.0	2019.0	20.0	.0075	30	1920
XX00A4USL	HR ROUND	17.0	18232.4	38.5	.000087	4100	3100

"D" IN LIFE HRS. COLUMN INDICATES DISCONTINUED TEST.

3 TABLE II(CONTD) 11/15/82

MELT	FORM	STRESS KSI	LIFE HRS.	ELONG. %	MCR %/HR.	HR. TO 1% T.S.	HR. TO .2% 3RD. STAGE
1400 F(CONT'D)							
XX00A4USL	HR ROUND	16.0	6789.20	5.7	.00021	2800	2450
XX00A4USL	HR ROUND	12.0	713.2D	0.3	.000095	>713	>713
XX00A4USL	HR ROUND	10.0	13504.7D	0.2	.000007	>13504	>13504
XX00A5USL	HR ROUND	19.0	3753.5	27.3	.0043	36	3000
XX00A5USL	HR ROUND	14.0	40126.7	23.5	.00011	350	13000
XX00A5USL	HR ROUND	14.0	1932.2D	2.7	.00135	110	-
XX00A5USL	HR ROUND	11.0	9907.7D	1.6	.00016	3953	>9907
XX00A5USL	HR ROUND	9.0	35646.7D	0.6	.000015	35646	>35646
XX05A4UK	HR ROUND	20.0	1098.4	23.3	.0134	40	595
XX05A4UK	HR ROUND	15.0	9861.6	38.3	.0015	446	2130
XX05A7UK	CD TUBING	20.0	650.9	22.7	.0156	30	475
XX07A7UK	HR ROUND	20.0	2471.5	27.1	.00052	928	825
XX07A7UK	HR ROUND	15.0	10242.2	28.1	.00014	3420	3100
XX10A3UK	EXT. TUBE	20.0	1434.7	15.8	.00093	630	590
XX20A5UK	CR SHEET	20.0	450.2	43.9	.0215	45	54
XX20A5UK	CR SHEET	16.0	2106.7	43.4	.0059	160	520
1500 F							
XX00A1USL	CR SHEET	24.0	30.7	102.0	-	-	-
XX00A1USL	CR SHEET	24.0	45.0	107.0	-	-	-
XX00A1USL	HR ROUND	24.0	92.5	91.0	.394	1.8	25
XX00A1USL	HR ROUND	17.0	216.9	101.0	.175	4.5	120
XX00A1USL	HR ROUND	13.0	2145.6	52.5	.0123	26	1250
XX00A1USL	HR ROUND	10.0	3023.0D	8.4	.0023	105	>3023
XX00A2USL	HR ROUND	24.0	65.4	86.0	-	-	-
XX00A2USL	HR ROUND	24.0	65.4	110.0	-	-	-
XX00A3USL	HR FLAT	24.0	73.1	101.0	-	-	-

"D" IN LIFE HRS. COLUMN INDICATES DISCONTINUED TEST.

4 TABLE II(CONTD) 11/15/82

MELT	FORM	STRESS KSI	LIFE HRS.	ELONG. %	MCR %/HR.	HR. TO 1% T.S.	HR. TO .2% 3RD. STAGE
1500 F(CONT'D)							
XX00A3USL	HR FLAT	24.0	32.7	83.0	-	-	-
XX00A3USL	HR FLAT	24.0	88.5	98.0	-	-	-
XX00A3USL	HR FLAT	24.0	72.0	97.0	-	-	-
XX00A3USL	FORGED SQ.	24.0	46.4	92.0	-	-	-
XX00A3USL	FORGED SQ.	24.0	67.3	94.0	-	-	-
XX00A3USL	FORGED SQ.	24.0	40.8	100.0	-	-	-
XX00A3USL	FORGED SQ.	24.0	41.2	106.0	-	-	-
XX00A3USL	FORGED SQ.	24.0	72.3	89.0	-	-	-
XX00A3USL	FORGED SQ.	24.0	30.8	87.0	-	-	-
XX05A4UK	HR ROUND	12.0	1153.1	54.6	.0309	20	425
XX05A4UK	HR ROUND	10.0	2504.0	37.9	.0074	65	1065
XX05A4UK	HR ROUND	8.0	19088.2	33.8	.0011	310	10800
XX07A7UK	HR ROUND	18.0	45.5	51.2	.059	2.5	33.5
XX07A7UK	HR ROUND	14.0	293.1	47.4	.0798	8	190
XX07A7UK	HR ROUND	12.0	777.1	43.2	.0295	30	330
1600 F							
XX00A1USL	CR SHEET	14.0	66.3	68.0	-	-	-
XX00A1USL	CR SHEET	14.0	61.4	72.0	-	-	-
XX00A1USL	CR SHEET	10.0	64.1D	-	.0525	11	>64
XX00A1USL	CR SHEET	7.0	280.4D	-	.0064	99	>280
XX00A1USL	CR SHEET	7.0	161.6D	-	.0055	144	>161
XX00A1USL	CR SHEET	5.0	713.2D	-	.0005	>713	>713
XX00A1USL	CR SHEET	4.0	844.7D	-	.00016	>844	>844
XX00A1USL	CR SHEET	4.0	413.0D	-	.00027	>413	>413
XX00A1USL	HR ROUND	17.0	66.5	85.0	-	-	-
XX00A1USL	HR ROUND	14.0	101.1	120.0	.414	1	48
XX00A1USL	HR ROUND	12.0	234.4	69.5	-	-	-
XX00A1USL	HR ROUND	9.0	1929.6	45.5	.013	10	1440

"D" IN LIFE HRS. COLUMN INDICATES DISCONTINUED TEST.

5 TABLE II(CONT'D) 11/15/82

MELT	FORM	STRESS KSI	LIFE HRS.	ELONG. %	MCR %/HR.	HR. TO 1% T.S.	HR. TO .2% 3RD STAGE
1600 F(CONT'D)							
XX00A1USL	HR ROUND	7.0	142.3D	-	.005	102	>142
XX00A1USL	HR ROUND	7.0	2896.4D	11.5	.0048	38	>2896
XX00A1USL	HR ROUND	5.0	594.7D	1.0	.0013	503	>595
XX00A1USL	HR ROUND	4.0	1726.5D	1.4	.00053	780	>1727
XX00A1USL	HR ROUND	4.0	666.3D	0.4	.00025	>666	>666
XX00A2USL	HR ROUND	14.0	111.0	70.0	-	-	-
XX00A2USL	HR ROUND	14.0	73.6	83.1	-	-	-
XX00A2USL	HR ROUND	7.0	119.1D	1.2	.00675	100	>119
XX00A2USL	HR ROUND	5.0	545.5D	0.5	.00057	>545	>545
XX00A3USL	HR FLAT	14.0	69.6	84.0	-	-	-
XX00A3USL	HR FLAT	14.0	26.0	86.0	-	-	-
XX00A3USL	HR FLAT	14.0	78.4	99.0	-	-	-
XX00A3USL	HR FLAT	14.0	75.3	102.0	-	-	-
XX00A3USL	FORGED SQ.	14.0	95.2	78.0	-	-	-
XX00A3USL	FORGED SQ.	14.0	53.6	128.0	-	-	-
XX00A3USL	FORGED SQ.	14.0	67.7	115.0	-	-	-
XX00A3USL	FORGED SQ.	14.0	48.4	100.0	-	-	-
XX00A3USL	FORGED SQ.	14.0	90.6	98.0	-	-	-
XX00A3USL	FORGED SQ.	14.0	51.6	104.0	-	-	-
XX00A4USL	HR ROUND	12.0	212.2	60.8	-	-	-
XX00A4USL	HR ROUND	10.0	1041.8	30.3	.009	100	320
XX00A4USL	HR ROUND	10.0	993.2	29.9	.021	30	785
XX00A4USL	HR ROUND	7.5	2464.5	15.5	.00167	477	535
XX00A4USL	HR ROUND	6.5	9667.0	15.7	.00016	3250	2950
XX00A4USL	HR ROUND	6.5	16462.1	17.4	.00067	1100	1900
XX00A4USL	HR ROUND	4.0	828.4D	0.6	.00035	>828	>828
XX00A4USL	HR ROUND	3.6	26680.2D	1.0	.0000055	26600	22500
XX00A4USL	HR ROUND	3.1	2927.5D	0.1	.000015	>2927	>2927
XX00A5USL	CR SHEET	14.0	76.7	35.0	-	-	-

"D" IN LIFE HRS. COLUMN INDICATES DISCONTINUED TEST.

6 TABLE II(CONT'D) 11/15/82

MELT	FORM	STRESS KSI	LIFE HRS.	ELONG. %	MCR %/HR.	HR. TO 1% T.S.	HR. TO .2% 3RD STAGE
1600 F(CONT'D)							
XX00A5USL	HR ROUND	10.0	545.0	26.2	.031	14	375
XX00A5USL	HR ROUND	7.0	3562.7	25.4	.004	137	1290
XX00A5USL	HR ROUND	5.5	15169.2	37.5	.001	471	10100
XX00A5USL	HR ROUND	4.0	7044.0D	1.1	.0002	3700	>7044
XX00A5USL	HR ROUND	3.5	1149.4D	0.2	.000059	>1149	>1149
XX05A4UK	HR ROUND	14.0	38.9	82.7	-	-	-
XX05A4UK	HR ROUND	10.0	279.9	57.8	.07	13.2	30
XX05A4UK	HR ROUND	6.0	7010.4	43.1	.0035	369	6480
XX05A4UK	HR ROUND	4.0	2150.8D	-	.000084	-	-
XX05A7UK	CD TUBE	14.0	42.5	62.5	-	-	-
XX05A7UK	CD TUBE	7.5	656.9	31.5	.0174	30	575
XX05A7UK	CD TUBE	5.5	5751.9	25.9	.0023	242	4240
XX05A7UK	CD TUBE	4.0	5036.3D	5.0	.00035	1700	>5036
XX07A7UK	HR ROUND	14.0	29.3	42.7	-	-	-
XX07A7UK	HR ROUND	10.0	167.1	46.5	.09	6.5	39
XX07A7UK	HR ROUND	6.0	5386.5	45.0	.0004	1300	1140
XX07A7UK	HR ROUND	4.0	10985.2	25.0	.00016	3275	2875
XX10A3UK	EXT. TUBE	14.0	237.3	40.6	-	-	-
XX10A3UK	EXT. TUBE	13.0	292.7	42.9	-	-	-
XX18A4UK	CR SHEET	14.0	36.1	82.0	-	-	-
XX20A5UK	CR SHEET	14.0	54.1	44.0	-	-	-
XX20A5UK	CR SHEET	13.0	111.3	51.6	-	-	-
XX20A5UK	CR SHEET	7.0	6803.1	69.2	.00021	1820	1425
XX41A7UK	CR SHEET	5.0	>3000.				
1700 F							
XX00A1USL	HR ROUND	13.0	13.2	80.5	-	-	-
XX00A1USL	HR ROUND	11.0	34.6	67.0	-	-	-
XX00A1USL	HR ROUND	6.0	1589.8	40.0	.0147	4.5	1220

"D" IN LIFE HRS. COLUMN INDICATES DISCONTINUED TEST.

7 TABLE II(CONTD) 11/15/82

MELT	FORM	STRESS KSI	LIFE HRS.	ELONG. %	MCR %/HR.	HR. TO 1% T.S.	HR. TO .2% 3RD STAGE
1700 F(CONT'D)							
XX10A3UK	EXT. TUBE	5.0	100.00	0.1	.000015	-	-
XX20A5UK	CR SHEET	5.0	2036.00	4.8	.00009	1240	1040
XX41A7UK	CR SHEET	4.0	>3000.				
1800 F							
XX00A1USL	CR SHEET	4.0	120.20	-	.0242	38	118
XX00A1USL	CR SHEET	3.0	522.40	-	.00193	290	260
XX00A1USL	CR SHEET	2.0	1364.00	-	.00091	1080	>1364
XX00A1USL	HR ROUND	7.0	47.9	74.0	-	-	-
XX00A1USL	HR ROUND	5.0	224.9	47.5	-	-	-
XX00A1USL	HR ROUND	4.0	1225.6	50.0	.03	9	1040
XX00A1USL	HR ROUND	3.5	118.00	2.3	.017	42	>118
XX00A1USL	HR ROUND	3.0	3331.9	41.5	.0035	335	1760
XX00A1USL	HR ROUND	3.0	379.40	1.3	.0029	285	379
XX00A1USL	HR ROUND	2.8	356.50	2.7	.0055	56	>356
XX00A1USL	HR ROUND	2.0	729.00	-	.0002	>729	>729
XX00A2USL	HR ROUND	3.5	119.40	1.3	.009	97	120
XX00A2USL	HR ROUND	3.0	284.20	3.7	.0031	218	246
XX00A4USL	HR ROUND	2.5	4788.0	17.3	.00058	1300	1450
XX00A4USL	HR ROUND	2.1	1224.30	0.2	.00015	>1224	>1224
XX00A4USL	HR ROUND	1.8	3087.80	1.0	.00021	3050	2562
XX00A5USL	HR ROUND	4.0	867.8	33.3	.0212	49	600
XX00A5USL	HR ROUND	2.5	4560.0	22.5	.00076	540	400
XX05A4UK	HR ROUND	4.0	1091.2	32.5	.011	105	265
XX05A4UK	HR ROUND	3.0	4047.8	27.4	.00011	1060	640
XX05A7UK	CD TUBING	3.5	713.6	23.8	.019	63	560
XX05A7UK	CD TUBING	2.5	3159.2	34.3	.0013	309	220
XX07A7UK	HR ROUND	4.0	545.3	15.8	.0038	175	160
XX10A3UK	EXT. TUBE	3.0	2522.6	8.8	.0005	1170	1100
XX41A7UK	CR SHEET	4.0	492.6	25.1	.0063	75	48

"D" IN LIFE HRS. COLUMN INDICATES DISCONTINUED TEST.

8 TABLE II(CONTD) 11/15/82

MELT	FORM	STRESS KSI	LIFE HRS.	ELONG. %	MCR %/HR.	HR. TO 1% T.S.	HR. TO .2% 3RD STAGE
1832 F							
XX00A2USL	HR ROUND	5.0	104.0	58.4	-	-	-
XX00A2USL	HR ROUND	5.0	137.3	53.2	-	-	-
XX00A2USL	HR ROUND	4.5	353.0	42.2	-	-	-
XX00A4USL	HR ROUND	4.0	749.8	31.1	.0022	263	240
XX00A4USL	HR ROUND	2.9	1263.8D	-	.00215	331 (711)	640
XX00A4USL	HR ROUND	1.5	1340.5D	-	.000173	>1340	>1340
XX00A5USL	HR ROUND	4.0	444.5	38.0	-	-	-
XX00A5USL	HR ROUND	4.0	60.1	31.4	-	-	-
XX00A5USL	HR ROUND	1.5	1816.4D	-	.00011	>1816	>1816
XX05A4UK	HR ROUND	5.0	156.9	37.6	-	-	-
XX05A4UK	HR ROUND	3.0	1975.4	23.6	.00064	543	400
XX05A4UK	HR ROUND	1.5	934.3D	-	.00003	-	-
XX05A7UK	CD TUBE	5.0	157.4	37.4	-	-	-
XX05A7UK	CD TUBE	2.5	1337.9	18.8	.00375	182	217
XX07A7UK	HR ROUND	5.0	94.8	19.3	-	-	-
XX07A7UK	HR ROUND	1.5	1368.4D	-	.0002	-	-
1900 F							
XX00A1USL	HR ROUND	6.0	20.3	66.0	-	-	-
XX00A1USL	HR ROUND	4.0	157.1	54.2	.156	4.5	115
XX00A1USL	HR ROUND	3.6	242.1	44.3	-	-	-
XX00A1USL	HR ROUND	2.4	1165.1	26.5	.013	43	735
XX00A1USL	HR ROUND	2.0	2621.4	41.0	.00021	320	160
2000 F							
XX00A1USL	CR SHEET	3.0	41.1	40.0	-	-	-
XX00A1USL	CR SHEET	3.0	49.3	42.0	-	-	-
XX00A1USL	CR SHEET	1.5	137.5D	-	.0045	80	35

"D" IN LIFE HRS. COLUMN INDICATES DISCONTINUED TEST.

9 TABLE II(CONT'D) 11/15/82

MELT	FORM	STRESS KSI	LIFE HRS.	ELONG. %	MCR %/HR.	HR. TO 1% T.S.	HR. TO .2% 3RD STAGE
*********	*********	*****	********	*****	********	******	*******
2000 F(CONT'D)							
XX00A1USL	CR SHEET	1.2	382.8D	-	.00057	272	200
XX00A1USL	CR SHEET	0.9	911.6D	-	.00063	545	410
XX00A1USL	HR ROUND	3.0	31.2	87.5	-	-	-
XX00A1USL	HR ROUND	2.5	101.1	102.0	-	-	-
XX00A1USL	HR ROUND	1.8	834.8	41.5	.0228	-	525
XX00A1USL	HR ROUND	1.5	262.2D	2.5	.0045	154	137
XX00A1USL	HR ROUND	1.2	474.5D	1.3	.001	395	305
XX00A1USL	HR ROUND	1.2	1612.4D	9.6	.0055	175	1460
XX00A1USL	HR ROUND	0.9	666.7D	1.1	.0008	625	450
XX00A2USL	HR ROUND	3.0	83.0	84.0	-	-	-
XX00A2USL	HR ROUND	3.0	74.8	70.0	-	-	-
XX00A2USL	HR ROUND	1.5	865.0	44.8	.0035	154	124
XX00A2USL	HR ROUND	0.9	5323.0	57.0	.00005	-	-
XX00A3USL	HR FLAT	3.0	98.7	43.0	-	-	-
XX00A3USL	HR FLAT	3.0	105.6	50.0	-	-	-
XX00A3USL	HR FLAT	3.0	83.5	72.0	-	-	-
XX00A3USL	HR FLAT	3.0	78.4	42.0	-	-	-
XX00A3USL	FORGED SQ.	3.0	80.1	32.0	-	-	-
XX00A3USL	FORGED SQ.	3.0	71.4	113.0	-	-	-
XX00A3USL	FORGED SQ.	3.0	66.8	114.0	-	-	-
XX00A3USL	FORGED SQ.	3.0	98.2	-	-	-	-
XX00A3USL	FORGED SQ.	3.0	26.8	74.0	-	-	-
XX00A3USL	FORGED SQ.	3.0	46.4	56.0	-	-	-
XX00A5USL	CR SHEET	3.0	48.1	18.5	-	-	-
XX05A4UK	HR ROUND	1.0	5099.7	39.5	.00013	817	415
XX07A7UK	HR ROUND	1.5	530.0	20.4	.0035	183	140
XX07A7UK	HR ROUND	1.0	2774.2	40.2	.00025	425	210
XX10A3UK	EXT. TUBE	1.5	1118.0	40.0	.0123	125	500

"D" IN LIFE HRS. COLUMN INDICATES DISCONTINUED TEST.

German HTGR Data

When the U. S. was generating data on Alloy 617 for the HTGR project during the 1970's and 1980's, the Germans also selected Alloy 617 as one of the candidate materials for their nuclear reactor program and produced a large amount of data. The source document for the present assessment is a published summary paper [Schubert 1984] containing experimental results of several candidate materials including Alloy 617 generated in the 1980's in the German HTGR Materials Test Program. These experiments included tests up to approximately 20000 hours. The goal of the test program was to generate long term creep rupture data in the temperature range of 800 to 1000ºC (1472 to 1932ºF) to enable extrapolation to 100000 hours of creep rupture life. The effects of the HTGR service environments on the mechanical behavior of the material were also investigated. Because it is a published journal paper, no tabulated materials mechanical data are provided. All the mechanical properties data are presented in plots. If acquisition of the original numerical data, which is currently in negotiation, can not be successfully achieved, digitization of the plots will be needed to prepare data for the input into the *Gen IV Materials Handbook*; and certain tolerance must be allowed for digitization error. Also, because no tabulated mechanical properties data are presented in the paper, the total number of tests conducted to generate the data can only be estimated by counting data points in the figures exhibited. When different numbers of data points are presented for different creep properties at a same given temperature, the greater number is considered to be closer to the actual number of the tests. For example, at 800ºC, 24 data points were presented for creep rupture stress while 45 data points for time to 1% creep strain. The larger number 45 is considered to be the test number based on the assumption that the difference in 24 and 45 may have resulted from termination of some tests before rupture occurred, therefore, more 1% creep strain data points were obtained than creep rupture data points. In some figures where data points severely overlap, the number of tests can only be approximately estimated. Counting data points in the figures in such a manner indicates that the paper includes creep properties data generated from approximately 294 creep tests at temperatures of 800, 850, 900, 950, and 1000ºC (1472, 1562, 1652, 1742, and 1832ºF). The resulting summary of the tests that generated the German HTGR data is given in Table 24. The creep properties include time to 1% total strain, creep rupture time, creep rupture stress, creep strain, and minimum creep rate. Based on the *Gen IV Materials Handbook* Data Classification criteria, the data are classified as Class 5.

Table 24: Summary of the assessed German HTGR data of Alloy 617

Specimen Type	**Test Environment**	**Test Temperature ºC 800**	**850**	**900**	**950**	**1000**
Base Metal	Air	45	78	55	62	29
Weld with Matching Filler Metal	Air		2			
	He		2			
	Processing Gas*		9			
Weld with Filler Metal 112	Air		4			
	He		4		9	

* methane reforming gas

The German HTGR data were generated from several heats of Alloy 617 provided by Huntington Alloys and VDM. All these heats were from commercial or semi-commercial production. No chemical compositions of the heats were presented in the paper. It was stated in the paper that no attempt was made to obtain special heats that would allow systematic investigations of compositional variations within the specification or of grain size effects. The material was solution treated at temperatures 1150 to 1205ºC for 0.1 to 0.5 hour depending on grain sizes and then cooled in air.

The weld specimens for the German HTGR data exhibited in Table 24 were all transverse weldment specimens consisting of weld metal in the center gage section and base metal on both sides. The "Filler Metal 112" specimens were machined from weldment produced using the Inconel welding electrode 112 (Ni-22Cr-9Mo-3.5Nb). No post welding treatment was reported.

Creep strain of the German HTGR data were measured in two fashions. To maximize the number of specimens simultaneously being tested for long-term creep properties, multi-specimen creep rigs were used. The creep strains of specimens tested in the multi-specimen creep rigs were measured at intervals by interruption of the test. Only those tested in single specimen creep rigs were measured for strain by continuous monitoring.

ORIGINAL GERMAN HTGR DATA

Data ID:	Schubert84F1	**Data Class:**	5
Data Source:	German HTGR Project	**Reference:**	Schubert 1984
Comment: Creep in air			

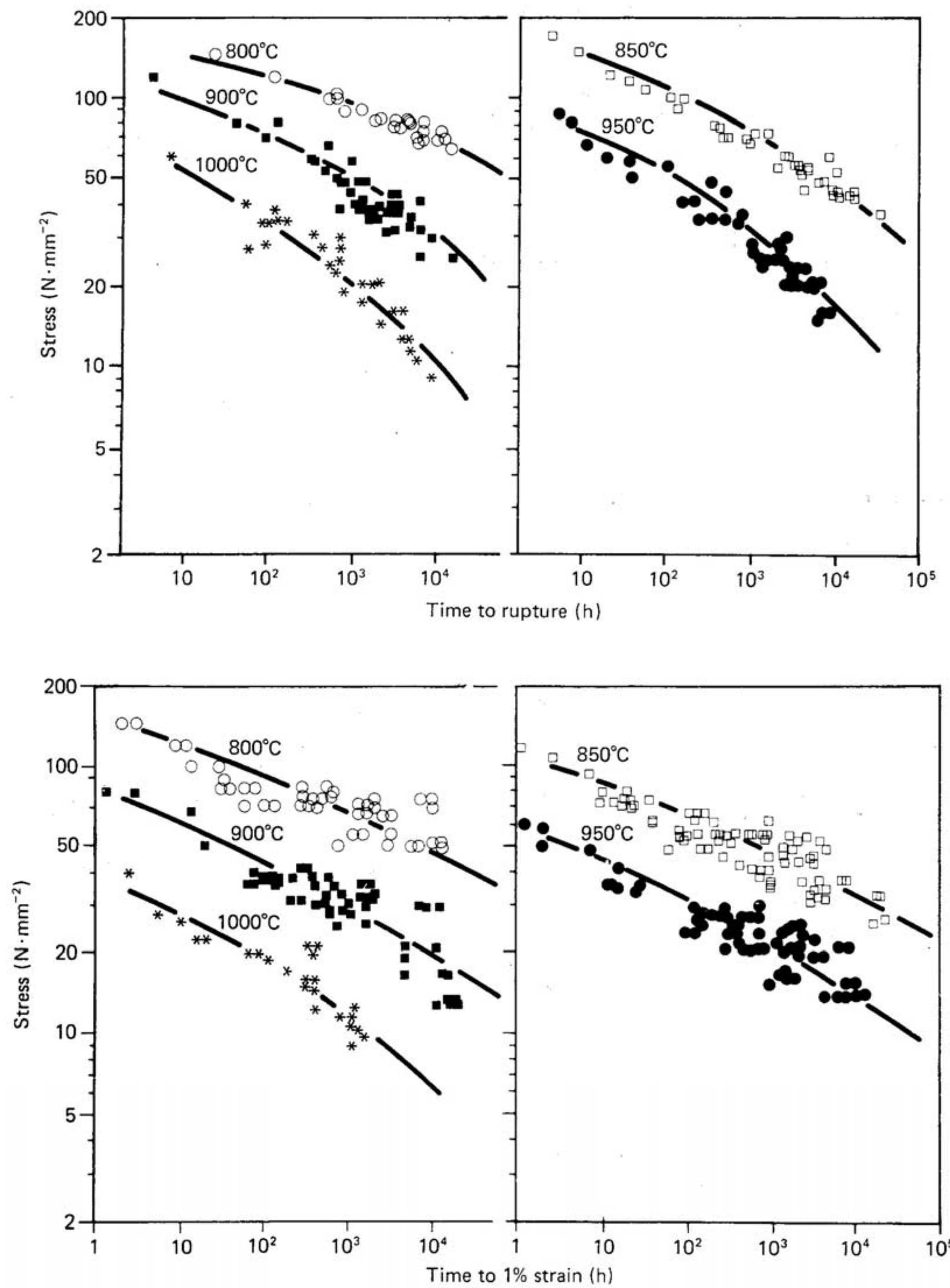
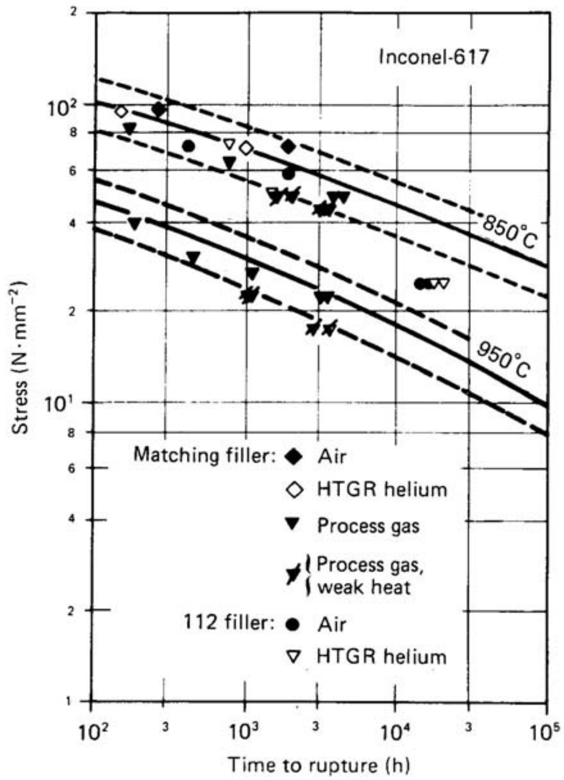
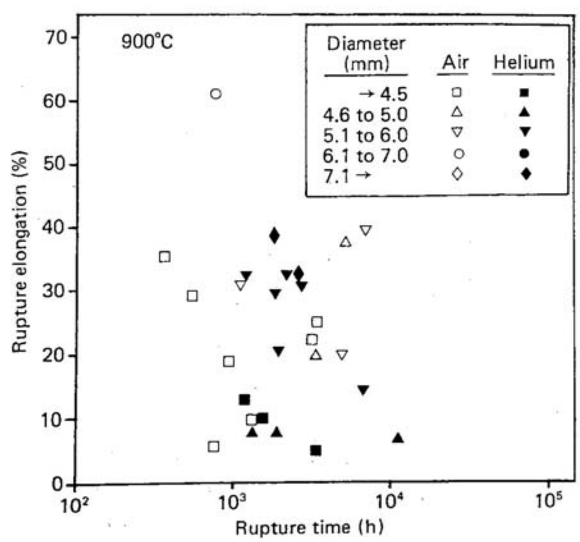


Fig. 1. Creep rupture properties of Inconel-617.

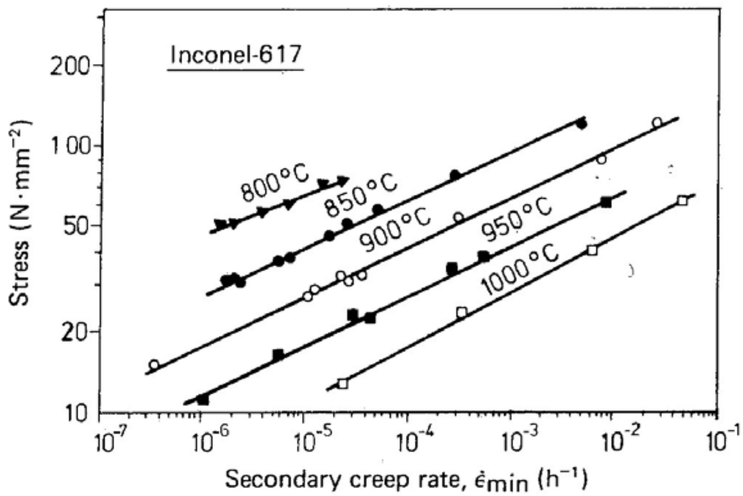
Data ID:	Schubert84F6	**Data Class:**	5
Data Source:	German HTGR Project	**Reference:**	Schubert 1984
Comment: Creep in various environments			



Data ID:	Schubert84F8	**Data Class:**	5
Data Source:	German HTGR Project	**Reference:**	Schubert 1984
Comment: Creep in air and helium			



Data ID:	Schubert84F10	**Data Class:**	5
Data Source:	German HTGR Project	**Reference:**	Schubert 1984
Comment:			



3.2 Major Data Sources in Acquisition

GE-HTGR Reports

The source document on the GE-HTGR data assessed in Section 3.1 is only one volume of a series of reports developed by General Electric for the Advanced Gas Cooled Nuclear Reactor Materials Evaluation and Development Program [GCRME&DP] under contract with the Department of Energy during the 1970's to 1980's. A copy of the report series has been located at Technical Insights (TI), a company in San Diego, California. Negotiations were conducted and have reached an agreement that the company will duplicate the series for ORNL at a reasonable service cost. The acquisition is currently in progress. This series consists of 55 progress reports, topical reports, and final reports published from June 30, 1976 to July 1, 1989 on materials of interest to the *Gen IV Materials Handbook* including Alloy 617. Because the GE-HTGR data document assessed in Section 3.1 is a summary of GE's efforts on creep and fatigue of Alloy 617 over the eight years from 1978 to 1986, a significant amount of additional processed data may not be expected from the TI duplicates. However, if progress reports on Alloy 617 are included in the duplicates, detailed and less processed data such as creep curves, fatigue loops etc., which are of great interest to the High Temperature Design Methodology (HTDM) development, may be included. Data of other material properties may also be discovered in the duplicates. Furthermore, because some of the GE facility components used in the HTGR materials testing were shipped to ORNL after the program was terminated, detailed testing procedures and facilities design descriptions may still provide valuable information for refurbishing the ORNL testing facilities for the Gen IV Materials Program.

Petten Data

The German HTGR data reviewed in Section 3.1 were generated during the same period of time when the ORNL-HTGR and GE-HTGR data were generated. After the termination of the U. S. HTGR program around the end of the 1980's much more applicable data on Alloy 617 continued to be generated in Germany [Schubert 1993].

Under the leadership of European Commission Joint Research Centre (JRC), a data network called "Online Data & Information Network" (ODIN) has been developed for the European energy research community. The ODIN contains engineering databases, document management sites and other information related to European research in the area of nuclear and conventional energy. The scientific and technical responsibilities for the engineering, nuclear and document databases and its administration reside at the Institute for Energy (IE-Petten, located in Petten, Netherlands) in the Data Management & Dissemination sector. Initially the material properties data were collected into two databases, Alloys-DB and Corrosion-DB respectively. The Alloys-DB covered mechanical and thermo-physical properties for engineering alloys at low and elevated temperatures for base materials and joints. It also included irradiation materials testing in the field of fusion and fission, tests on thermal barrier coating for gas turbines and mechanical properties testing on a corroded specimen. The Corrosion-DB contained weight gain/loss data of high temperature exposed engineering alloys, ceramics and hot isostatic pressed (HIP) powder materials and covered corrosion tests such as oxidation, sulfidation and nitridation. The two databases were later merged into a single database named AllCor-DB to include both Alloys (All-) and Corrosion (Cor-) data, and recently the AllCor-DB was renamed as Mat-DB.

The Mat-DB is designed to contain experimental data delivered by laboratories in defined formats and quality. In total, the database for base materials contains more than 130 tables and 1850 fields, which are grouped into several logical entities: data source, material, specimen, and test condition, as summarized in Table 25. The test results data are divided into three parts: mechanical, thermo-physical, and corrosion, each with tables containing test type specific data. The mechanical part covers 23 types of mechanical properties data such as uniaxial tensile, multiaxila tensile, unicaxial creep etc.; the thermo-physical part holds 10 types of thermo-physical properties data such as density, specific heat, etc.; and the corrosion part contains high temperature corrosion data. The extension to other types of corrosion is also under consideration by the management. A summary of the Mat-DB test result data is given in Table 26.

Table 25: A summary of Mat-DB entities

Entity	Content
Data Source	Organization, laboratory, scientist, R&D project
Material	Material characterization, chemical composition, heat treatment, process data, microstructure
Specimen	Sampling, orientation, geometry, coating layers
Test condition	Test environment, mechanical or thermal pre-exposure, irradiation
Joining	Process method, joining parameters, joining geometry, filler metal
Test result	See Table 26

The data of Mat-DB are commercialized information. Properties of Alloy 617 are included in the Mat-DB together with those of Hastelloy X, Nimonic 86 and Alloy 800H etc. as a package designated as JZ Jülich HTR Data Sets at a sales price of €7000. (€1.00 = $1.22159 on 10 June, 2005 when this is being written. Introduction for the Mat-DB indicates that the data on Alloy 617 were generated from the German HTGR project. A summary of the Mat-DB data on Alloy 617 is given in Table 27. Communication is underway with the ODIN administration to gain more detailed information about the database and to negotiate the purchase of desired data. The negotiation will include issues such as price and user license agreement, i. e., permission for the purchased data to be collected into the *Gen IV Materials Handbook* and used by future reactor designers. The purchase will not be realized until it is economically and technically justified. Approximately $8550 is needed for the FZ Jülich HTR Data Sets. Preliminary responses from the ODIN administration indicate that the “Test Results” entry in Table 27 means the actual number of tests. This means there are many more data points than those test numbers in the Mat-DB. For example, one tensile test can generate several tensile property data points including yield stress, ultimate tensile stress, yield strain, etc. Compared to the cost to experimentally generate the same amount of data, it appears cost effective to purchase the Petten data, especially since the package also includes a similar amount of data for Alloy 800H, another candidate material for Gen IV nuclear reactors. Another advantage of purchasing the data is that the original data that were used to produce the plots in the German HTGR data source document [Schubert 1984] can be obtained.

Table 26: Mat-DB test result entity

MECHANICAL PROPERTIES	***Irradiation***
Crack Growth & Fracture	Irradiation creep
Creep crack growth	Swelling
Cyclic creep crack growth	***Tensile***
Fatigue crack growth	Compression
Fracture toughness	Multiaxial tensile
Impact	Uniaxial tensile
Creep	Small punch tensile
Cyclic creep	**THERMO-PHYSICAL PROPERTIES**
Multiaxial creep	Density
Torsional creep	Electrical resistivity
Uniaxial creep	Emissivity
Small punch creep	Linear thermal expansion
Relaxation	Poisson’s ratio
Multiaxial relaxation	Specific heat
Uniaxial relaxation	Shear modulus
Fatigue	Thermal conductivity
High cycle fatigue	Thermal diffusivity
Low cycle fatigue (load control)	Young's modulus
Low cycle fatigue (strain control)	**CORROSION**
Thermal fatigue	High temperature corrosion
Thermo-mechanical fatigue	

Table 27: European mechanical properties data on Alloy 617 in Mat-DB

Test Type	Combined Material	Test Results	Temperature ºC
Creep crack growth		26	800 - 1000
Low cycle fatigue (strain control)		261	20 - 950
Uniaxial creep		1134	550 - 1000
	similar joint	152	600 - 1000
	irradiated	175	550 - 1000
Uniaxial tensile		141	20 - 1000
	irradiated	109	20 - 1000
	irradiated, similar joint	26	20 - 1000
	service exposed	2	20 - 20

4. OTHER DATA SOURCES AND FUTURE WORK

As previously mentioned in Section 1.2, a title search on Alloy 617 through the CSA Materials Research Database with METADEX has yielded more than 100 documents and a key word search has resulted in more than 700. To efficiently conduct the existing data assessment within the given timeframe and manpower, the principle of 80/20 must be applied in combination with the priority assessment basis. Once the most important existing data sources are identified, 20 percent of the time spent may complete the assessment of 80 percent of the existing data that are really germane to the Gen IV nuclear reactor materials needs. The remaining data will be assessed on an "as necessary" basis as long as time allows. To date, the priorities have been identified mainly based on the relevancy of the data sources to the intended nuclear application as well as the amount of data contained. The identified high priority data sources have been evaluated or are in the acquisition process as described in the previous two sections. These data sources are believed to cover a fairly large portion of the existing data relevant to Gen IV materials needs for Alloy 617. For future assessment activities, the priority will be identified mainly based on design and qualification requirements for specific property types such as low cycle fatigue, creep crack growth, biaxial fatigue etc. To facilitate this effort and for the purpose of complete documentation, documents that may contain applicable data on Alloy 617 are also listed in the References Section.

It should be pointed out that because most of the existing data were generated from heats that complied with the ASTM standard specifications, which offer considerable allowances for parameters such as chemical composition range, grain size etc., significant data scatter in mechanical properties have been observed. A task has been underway to refine the standard specifications of the alloy in an effort to develop a nuclear application specification with reduced mechanical properties data scatter and improved high temperature properties [Ren 2005]. If that effort is successful, the applicability of the existing data for design and analysis must then be re-evaluated.

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