DP700-Phase 1 Preparation for Commercial Demonstration of 700°C Power Plant

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Contents

- Introduction and Back Ground to DP700 Project
- Work Package 1: Design by Analysis
- Work Package 2: Material Properties
- Work Package 3: Material Modelling
- Work Package 4: State of the Art Component Manufacture
- Materials Property Database
- Next Steps

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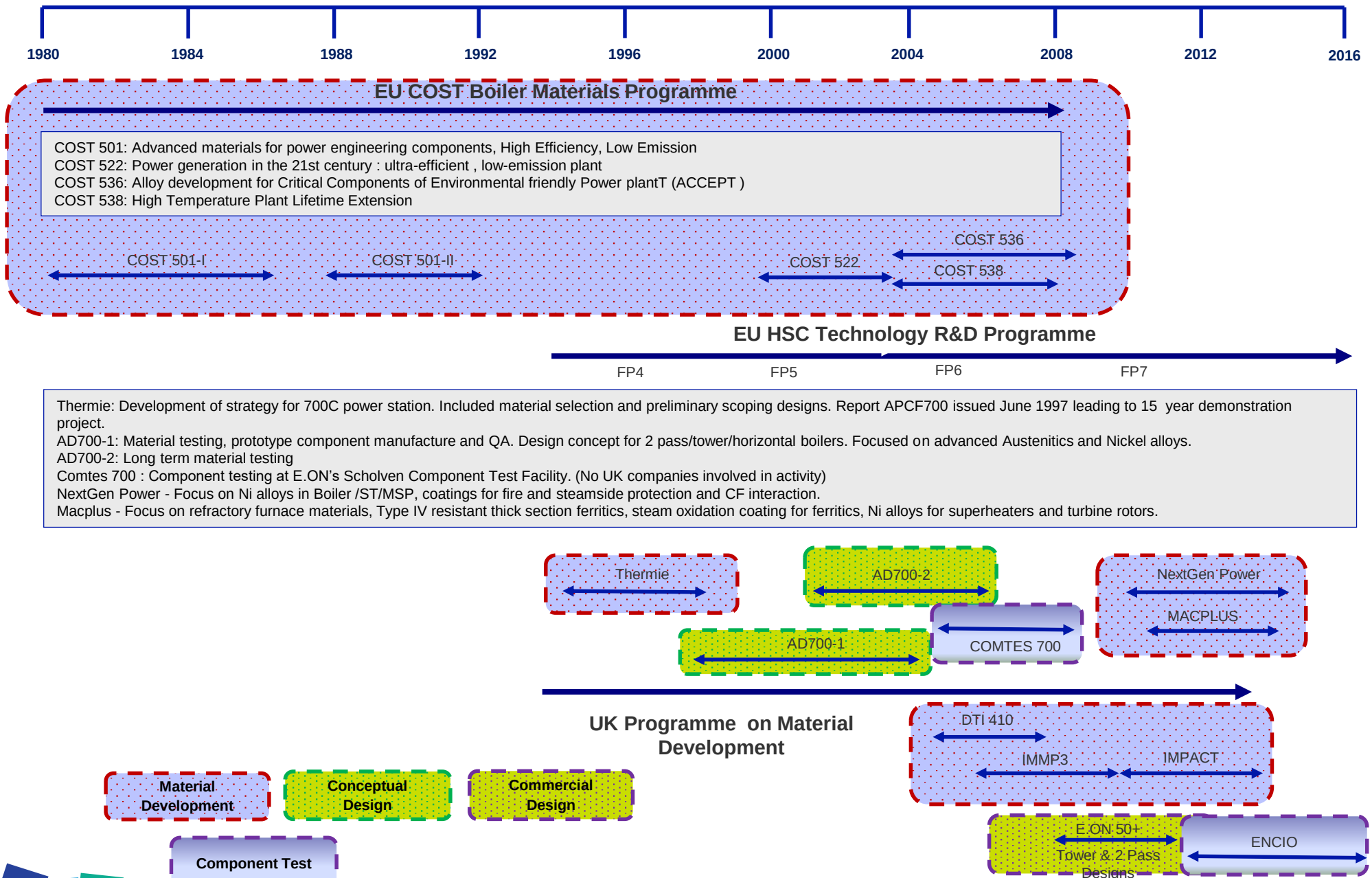
EU Historic Material Development Program



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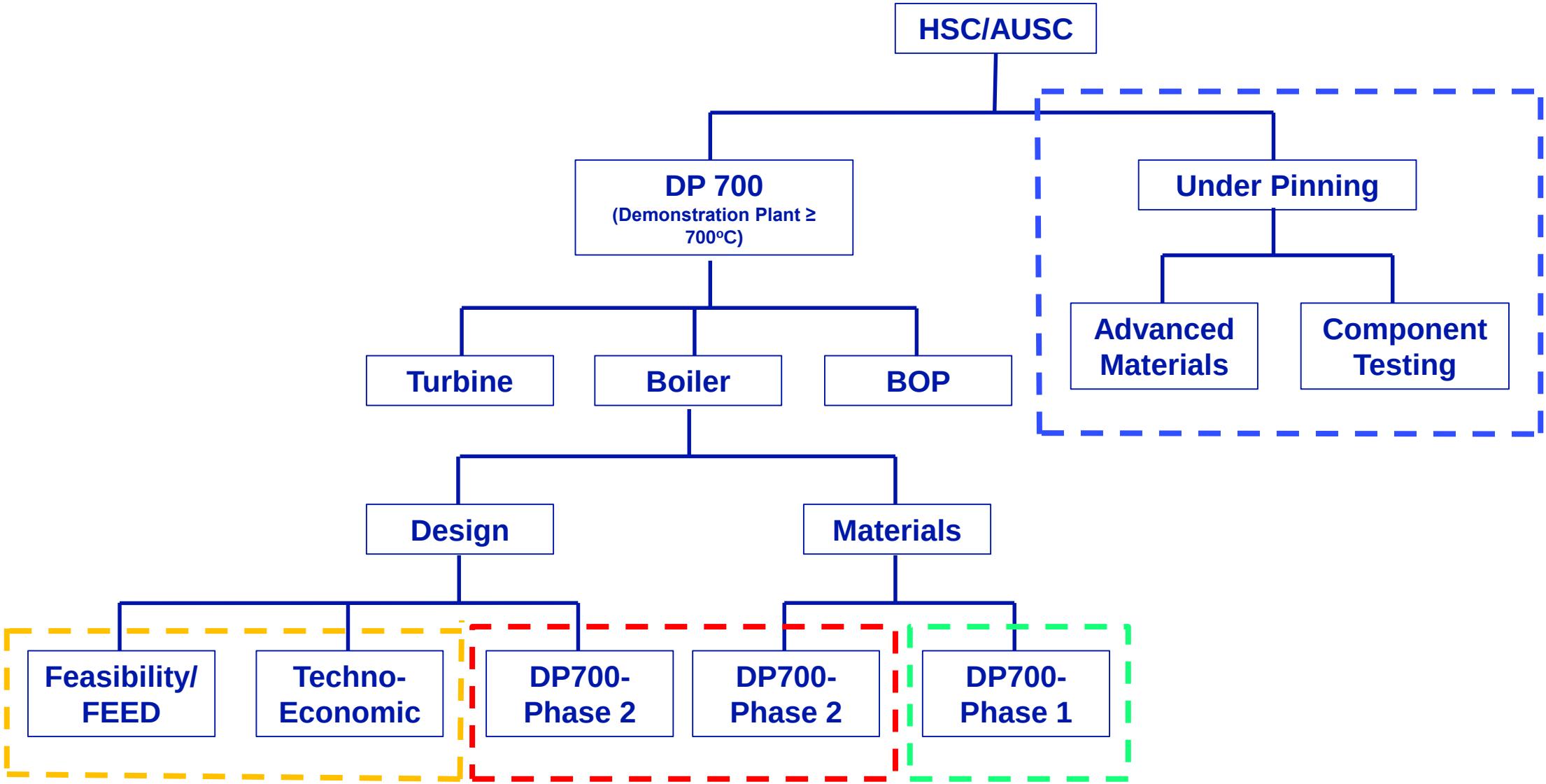
Big Picture



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DP700-Phase 1

Grant Agreement number: 709954 — DP700-Phase 1 — RFCS-2015/RFCS-2015

Associated with document Ref. Ares(2016)2832594 - 17/06/2016

EUROPEAN COMMISSION
DIRECTORATE-GENERAL FOR RESEARCH & INNOVATION
Industrial Technologies
Coal and steel

GRANT AGREEMENT

NUMBER — 709954 — DP700-Phase 1

This **Agreement** ('the Agreement') is **between** the following parties:

on the one part,

the **European Union (EU)** ('the Agency'), under the power delegated by the European Commission ('the Commission'),

represented for the purposes of signature of this Agreement by Head of Unit - Administration and Finance, DIRECTORATE-GENERAL FOR RESEARCH & INNOVATION, Industrial Technologies, Administration and finance, Patrik KOLAR,

and

on the other part,

1. 'the coordinator':

DOOSAN BABCOCK LIMITED (DOB) LTD, 00839354, established in MANOR ROYAL CRAWLEY BUSINESS QUARTER DOOSAN HOUSE, CRAWLEY RH10 9AD, United Kingdom, GB516304084 represented for the purposes of signing the Agreement by LSIGN,

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DP700-Phase 1 Partners

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DP700 - Phase 1 – Preparation for Commercial Demonstration Plant for 700°C Operation	
WP1 - Design By Analysis, DBA	
	Task 1.1 - ASME Committee Work
	Task 1.2 - FEA and Residual Stresses of Manufactured Components
	Task 1.3 - Cyclic and Monotonic Plasticity
	Task 1.4 - Creep & Creep Fatigue Interactions
	Task 1.5 - Corrosion Allowance
WP2 - Material Properties	
	Task 2.1 - Collation of Existing Knowledge
	Task 2.2 - Typical Design Data
	Task 2.3 - Review of Manufacturing and Composition Effects on Long Term Properties
	Task 2.4 - Long Term Evolution of Microstructure under Laboratory and Service Exposure
	Task 2.5 - Design Database Development
WP3 – Material Modelling	
	Task 3.1 – Derivation of Design Allowables from Known Data
	Task 3.2 – Extrapolation Techniques for Creep/Fatigue
	Task 3.3 – Remnant Life Predictions
WP4 – Component Manufacture	
	Task 4.1 – Trial Component Manufacture and Fabrication
	Task 4.2 – Development of Ni based Panel Manufacture
	Task 4.3 – Material and Component Specification/Quality Assurance
	Task 4.4 – Inspection
WP 5 - Project Management and Dissemination	
	Task 5.1 - Project Co-ordination
	Task 5.2 - Dissemination
	Task 5.3 - Open Access Material Database
	Task 5.4 - Organisation of Workshops and Seminars

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Design by Analysis

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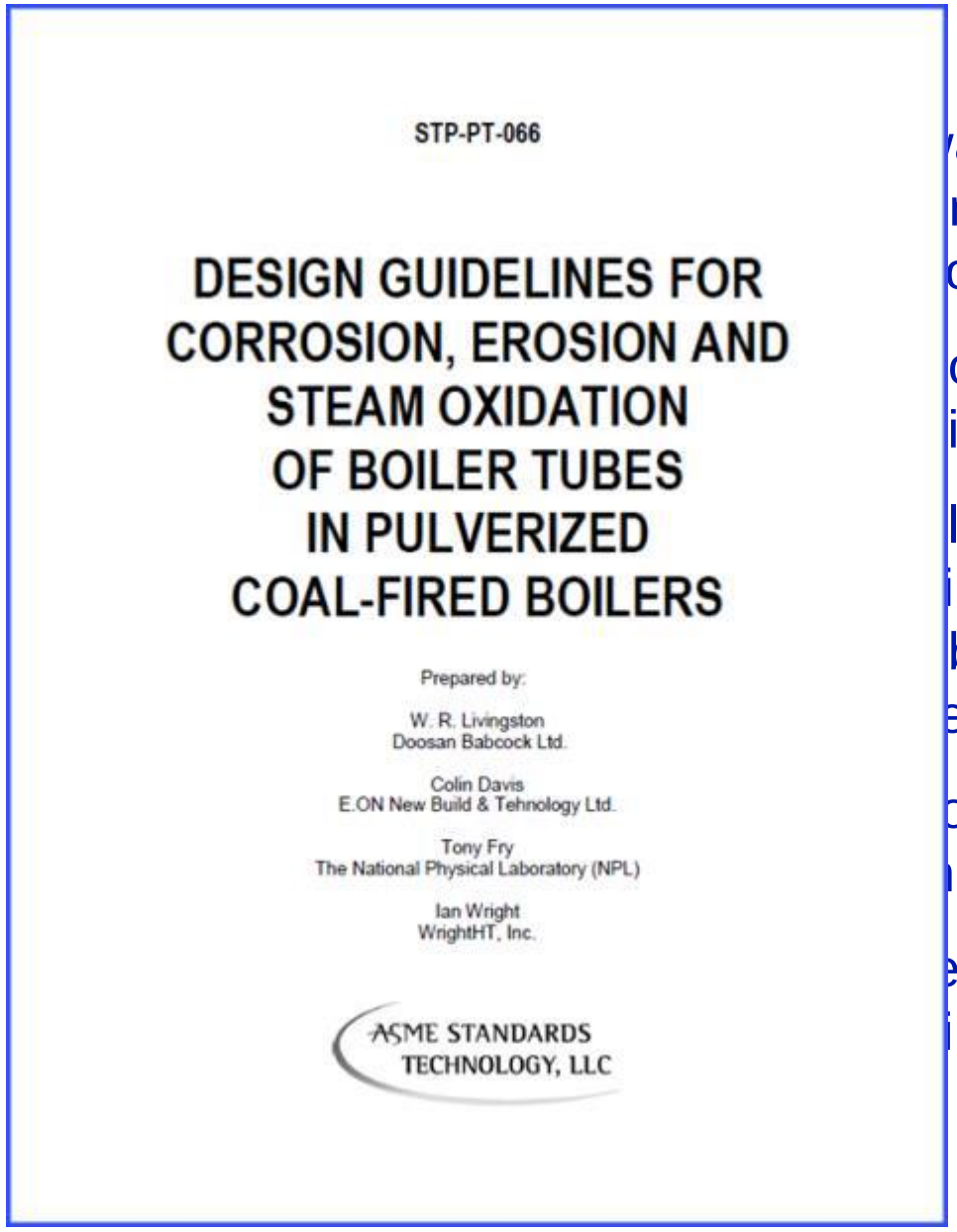
Design by Analysis


STP-PT-066

DESIGN GUIDELINES FOR CORROSION, EROSION AND STEAM OXIDATION OF BOILER TUBES IN PULVERIZED COAL-FIRED BOILERS

Prepared by:

W. R. Livingston
Doosan Babcock Ltd.

Colin Davis
E.ON New Build & Tehnology Ltd.

Tony Fry
The National Physical Laboratory (NPL)

Ian Wright
WrightHT, Inc.

ASME STANDARDS TECHNOLOGY, LLC

STP-PT-070

DESIGN GUIDELINES FOR THE EFFECTS OF CREEP, FATIGUE & CREEP-FATIGUE INTERACTION
WITH DESIGN-BY-ANALYSIS AND NONDESTRUCTIVE INSPECTION ACCEPTANCE CRITERIA

Prepared by:

Ian Perrin
Dan Peters
Nat Cofie
Structural Integrity Associates, Inc.

Jonathan Parker
John Shingledecker
Electric Power Research Institute

ASME STANDARDS TECHNOLOGY, LLC

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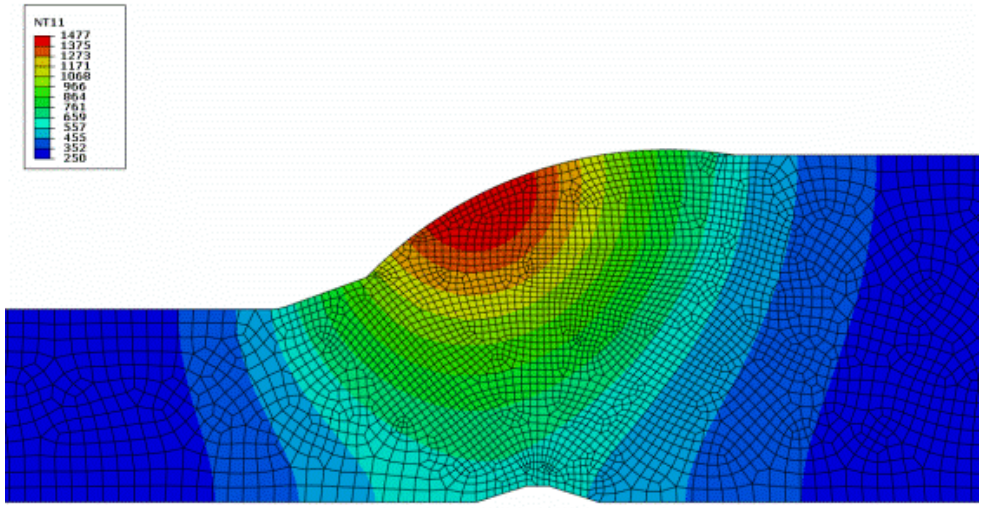
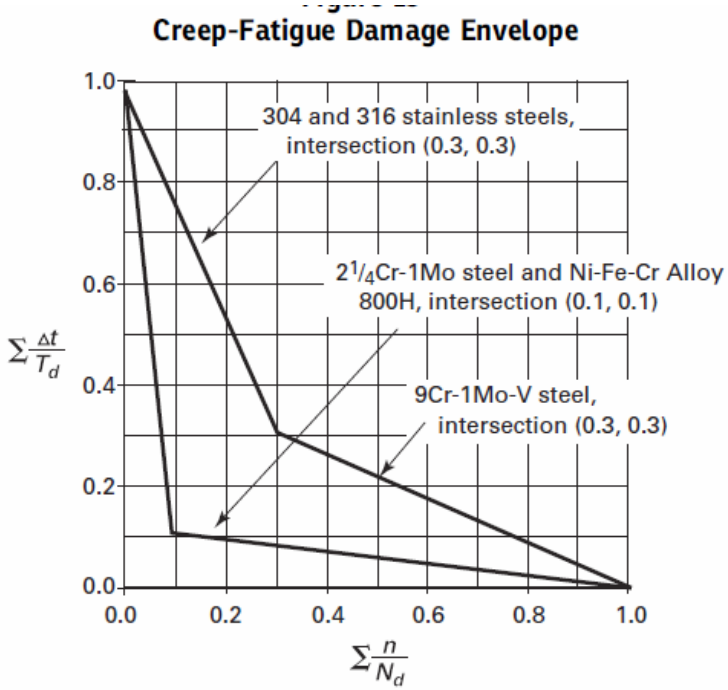
Design by Analysis





WP1 - Design By Analysis, DBA	
	Task 1.1 - ASME Committee Work
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	Task 1.4 - Creep & Creep Fatigue Interactions
	Task 1.5 - Corrosion Allowance

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Material Properties

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Materials List

Tube Definition: A component where heat transfer is it's primary function, i.e. independent of section thickness.		
Pipe Definition: A component where transport of the process medium is it's primary function, i.e. independent of section thickness.		
Tube	**Material**	**Pipe**
T1	16Mo3	P1
T36	WB36	
T12	13CrMo45	P12
T22	10CrMo9-10	P22
T23	7CrWVMoNb9-6	P23
T24	7CrMoVTiB10-10	P24
T9	X12 CrMo9-1	P9
T91	X10CrMoVNb9-1	P91
T92	X10CrWMoVNb9-2	P92
TP347HFG	(TUV547)	TP347HFG
Super 304H	X10CrNiCuNb18-9-3	Super 304H
HR3C/310NbN	(TUV550)	HR3C/310NbN
Sanicro 25	ASME CC 2753	Sanicro 25
HR6W	ASME CC 2684	HR6W
IN617B	ASME CC 2439	
	N07263	Nimonic 263
Alloy 740H	ASME CC 2702	Alloy 740H

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Material Properties

Thermo-Physical Data	
	Density
	Dynamic Modulus
	Young's Modulus
	Poisson's Ratio
	Coefficient of Expansion
	Specific Heat
	Thermal Conductivity
	Thermal Diffusivity
Quality Assurance Data	
	Hardness
	DBTT
	FATT
	Impact Strength
	Tensile Strength
	Proof Strength
	Rupture Elongation
	Reduction of Area

Stress-Strain Data	
	Monotonic
	Cyclic - Incremental Step
	Cyclic - LCF Loops
	Ramberg- Osgood Monotonic
	Ramberg- Osgood Cyclic
Time Dependent Data	
	Insignificant Creep
	Stress Rupture
	Creep Rupture
	Minimum Creep rate
	Rupture Elongation
	Reduction of Area
	Norton Cofficients
	Stress Relaxation - PWHT
	Stress Relaxation - Service

Cycle Dependent Data	
	LCF
	Smith Watson Topper
	Basquin-Coffin-Manson
Creep-Fatigue Data	
	Tensile Dwell LCF
	Cyclic Creep
	DB Psuedo Random
Fracture Mechanics	
	Fracture Toughness
	Fatigue Crack Growth
	Creep Crack growth
Environmental	
	Oxide Thermal Conductivity
	Parabolic Rate Constant
	Fireside Corrosion Rate

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Material Properties

Tube Definition: A component where heat transfer is it's primary function, i.e. independent of section thickness.		Stress-Strain Data					Time Dependent Data					
		Monotonic	Cyclic		Ramberg- Osgood		Insignificant	Stress	Creep	Minimum	Rupture	Reduction
			Incremental Step	LCF Loops	$\varepsilon = \frac{\sigma}{E} + 0.002\left[\frac{\sigma}{\sigma_{0.2}}\right]^{n-1}$		Creep	Rupture	Rupture	Creep Rate	Elongation	of Area
					Monotonic	Cyclic	Temp	$(10^2 \geq 3x10^4)$	$(10^2 \geq 3x10^4)$	$\dot{\varepsilon}_{min}$	El	RoA
Tube					(E; $\sigma_{0.2}$; n)	(E; $\sigma_{0.2}$; n)	(°C)	(hrs)	(hrs)	(hrs^{-1})	(%)	(%)
T1	16Mo3	RT, 325, 350, 375, 400°C						RT, 325, 350, 375, 400°C				
T36	WB36	RT, 375, 400, 425, 450°C						RT, 375, 400, 425, 450°C				
T12	13CrMo45	RT, 425, 450, 475, 500°C						RT, 425, 450, 475, 500°C				
T22	10CrMo9-10	RT, 450, 475, 500, 525°C						RT, 450, 475, 500, 525°C				
T23	7CrWVMoNb9-6	RT, 500, 525, 550, 575°C						RT, 500, 525, 550, 575°C				
T24	7CrMoVTiB10-10	RT, 500, 525, 550, 575°C						RT, 500, 525, 550, 575°C				
T9	X12 CrMo 9-1	RT, 500, 525, 550, 575°C						RT, 500, 525, 550, 575°C				

er 100khrs at stress of 1.25$\sigma_{0.2}$

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Material Properties

Alloy // Source	Sanic
Coating // Source	None
Original data format	

Material	Test Temperature [°C]	Applied Stress [MPa]	Test status (broken, continuing, discontinued)	Current test duration [h] (if continuing or discontinued)	Time to rupture [h]	Elongation [%]
Base metal	750	180	broken		264,6	
Base metal	750	200	broken		149,9	
Base metal	750	220	broken		73,9	
Base metal	750	240	broken		52,5	
Base metal	725	180	broken		1154,9	
Base metal	725	200	broken		609,6	
Base metal	725	220	broken		370,7	
Base metal	725	240	broken		201,2	
Base metal	700	180	broken		3553,2	
Base metal	700	200	broken		1831,1	
Base metal	700	220	broken		1142,7	
Base metal	700	240	broken		570,1	

name | Basic | Alloy comp. | Coati

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Material Properties

DP700 › Numbering.xlsx — Microsoft Excel Web App — Barnard, Pete (Extern)

FILE | EDIT WORKBOOK | SHARE | DATA | FIND

Number	Partner	Main Alloy	Other Alloys	First Author	Year of Pu	Title
0001	CSM	Inconel 740H		Chong	2015	Heat Treatment of a Candidate Material for 700C A-USC Power Plants
0002	TUG	Inconel 740H		deBarbadillo	2017	INCONEL alloy 740H
0003	TUG	Inconel 740H		Guo	2016	Microstructure and phase precipitate behavior of Inconel 740H during aging
0004	CSM	Inconel 740H		Patel	2013	Nickel Base Superalloys for Next Generation Coal Fired AUSC Power Plants
0005	TUG	Inconel 740H		Shingledecker	2013	Influences of composition and grain size on creep rupture behavior of-Inconel alloy 740
0006	TUG	Inconel 740H		Shingledecker	2017	The US DOE/OCDO A-USC materials technology R&D program
0007	TUG	Inconel 740H		Sorrentino	2017	Welding technologies for advanced ultra supercritical power plants materials
0008	TUG	Inconel 740H		Tan	2016	Microstructure and deformation behavior of nickel based superalloy Inconel 740 prepared by electron beam smelting
0009	TUG	Inconel 740H		Wang	2013	Hot workingcharacteristicsofnickel-basesuperalloy740H
0010	TUG	Inconel 740H		Yan	2014	Microstructure evolution and mechanical properties of Inconel 740H during aging at 750 C
0011	TUG	Inconel 740H		Yin	2016	Effects of long termthermal exposure on microstructure and mechanical property evolution of a new wrought Ni–Fe based superalloy
0012	DOB	T91		Ahmad	2010	Failure evaluation on a high-strength alloy SA213-T91 super heater tube of a power generation
0013	DOB	T91		Allen	2007	Fourcrack-An investigation of the creep performance of advanced high alloy steel welds
0014	DOB	P91		ASME	2013	Code Case 2770 Powder Metal P91

WP2 - Material Properties	
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Material Modelling

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Material Modelling

WP3 – Material Modelling	
	Task 3.1 – Derivation of Design Allowables from Known Data
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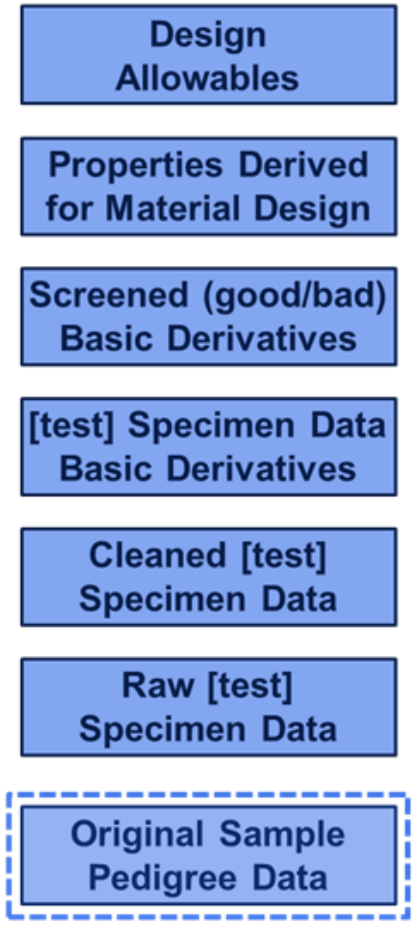
	Task 3.3 – Remnant Life Predictions



- **when viewed from the top down, most of the process of *materials information management* is 'invisible'**
  - CAD/CAE designers may see only allowables; they sometimes see properties, but rarely anything further down the process 'tree'
  - supplier datasheets may show only properties; anything further down the process 'tree' tends to be haphazard and/or untraceable
- **the process involves various levels of seniority**
  - principal/chief engineers need to sign off on ***design allowables*** derived from design properties
  - senior/principal/chief engineers need to sign off on ***advanced design properties*** derived from screened basic derivatives
  - junior/senior/principal engineers need to review and screen ***basic mathematical derivatives*** calculated from cleaned data
  - junior/senior technicians need to deliver ***cleaned data***, traceable to ***original raw data*** generated by test instruments
  - Prior to generating original data, junior/senior engineers need to capture ***pedigree data*** for samples of received test material

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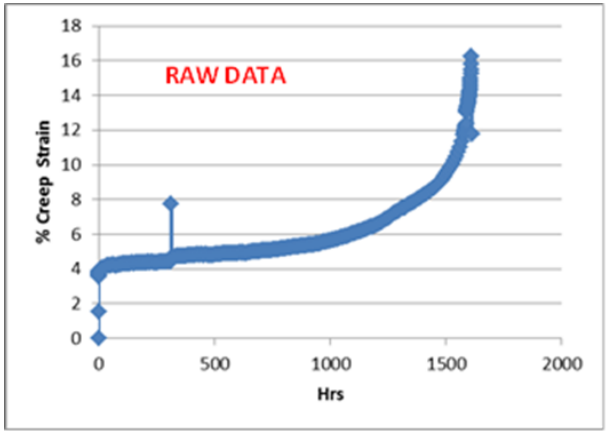
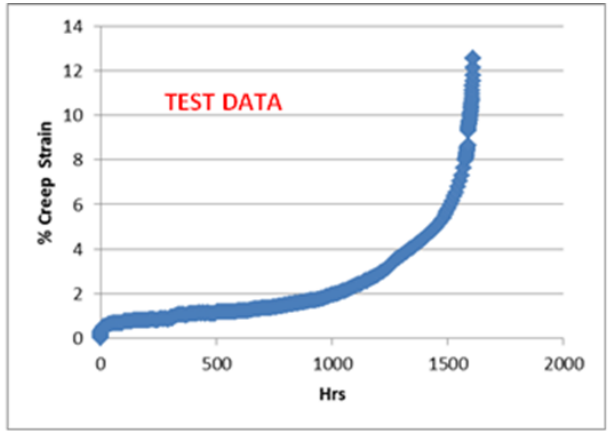
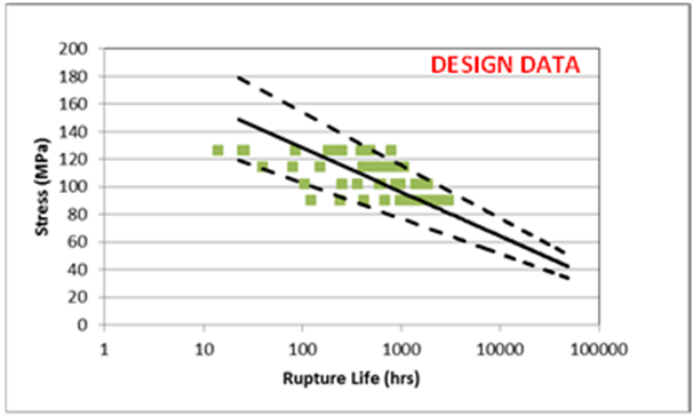
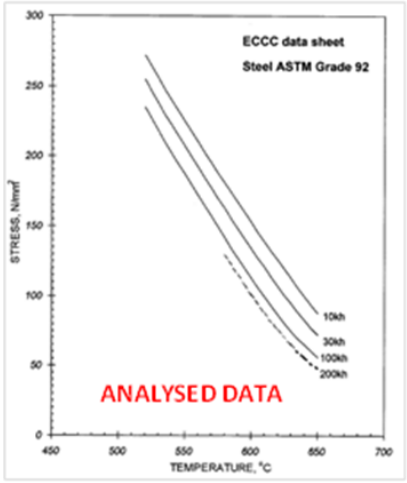
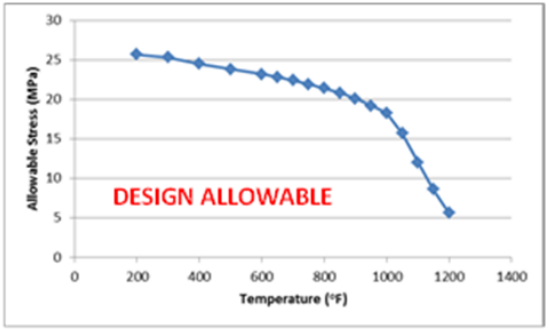
Material Modelling











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State of the Art Component Manufacture

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State of the Art Component Manufacture

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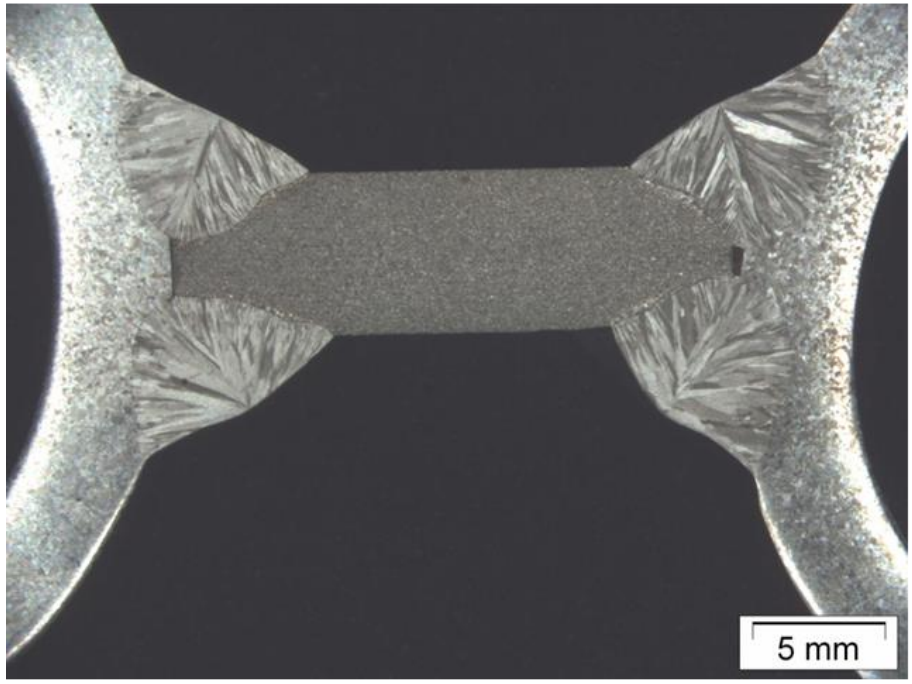

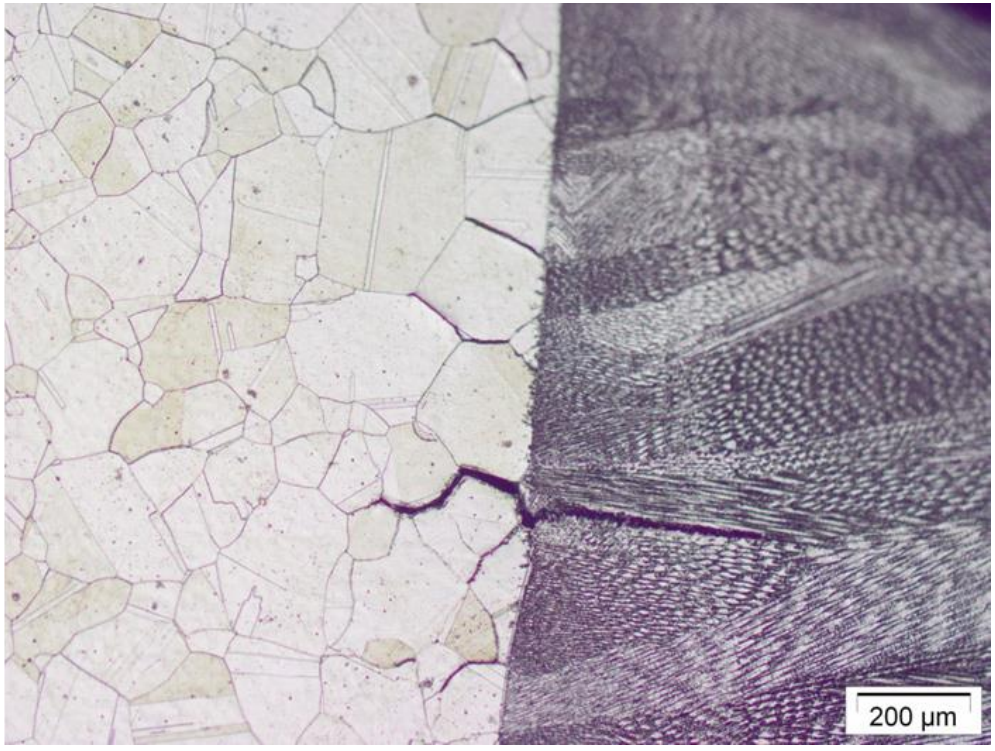

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Materials Property Database

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Materials Property Database

Material property data gathered during this project is collected via the pre-defined MS-Excel importer files and the database populated with that information. These data originate from open source literature, permissive data and other collated data sets. At this stage no proprietary data is stored on the open access database.

The collated materials data has been stored in an open access database hosted within the Granta MI system. For the DP700 project the database is hosted by Cranfield University (CRU) on behalf of the project team. It should be noted that currently this database is only accessible by consortium members, with the intention of going live at the end of the project in April 2018, with a sub set of the uploaded database which will exclude confidential data.

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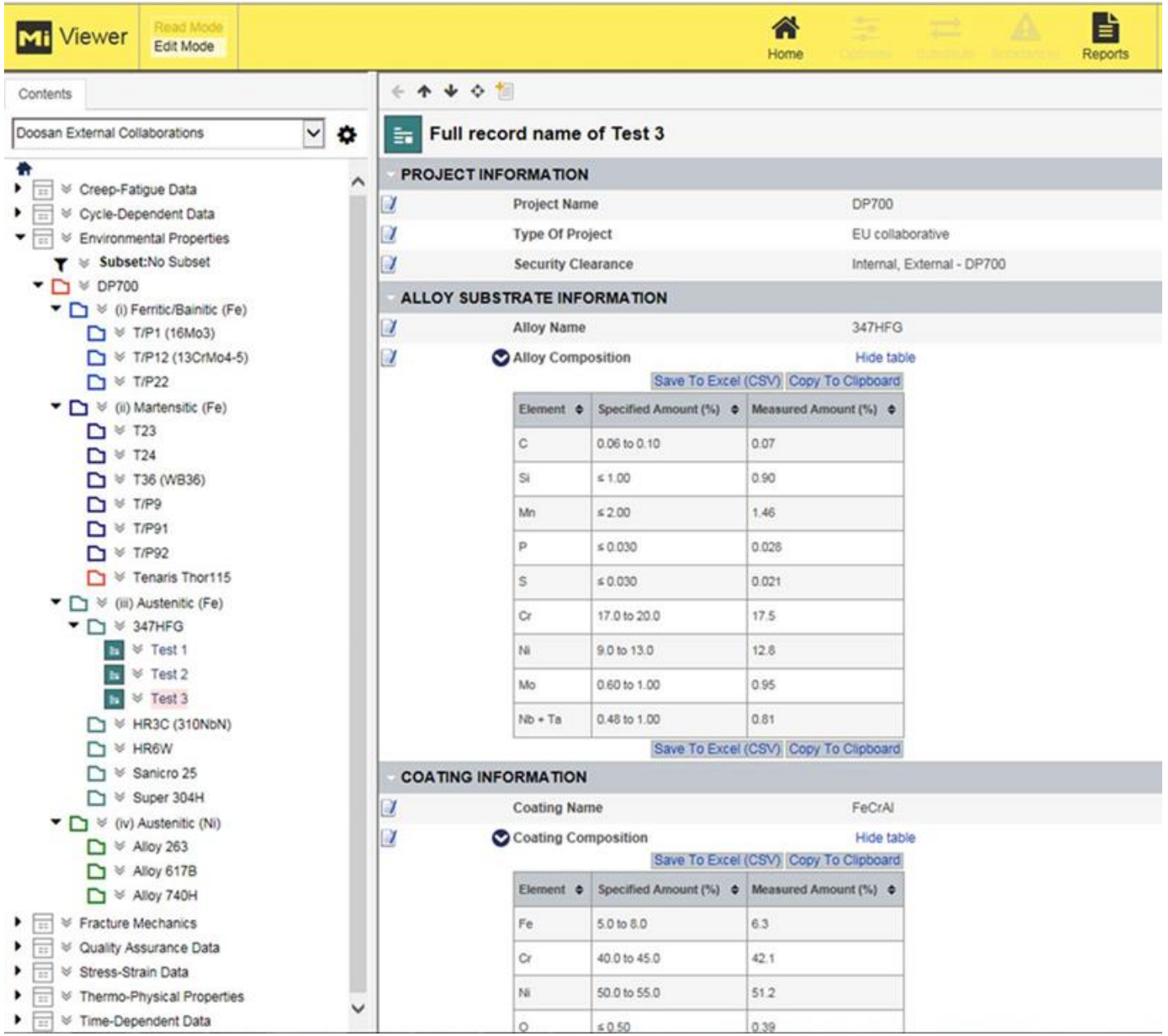
Materials Property Database



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Next Steps

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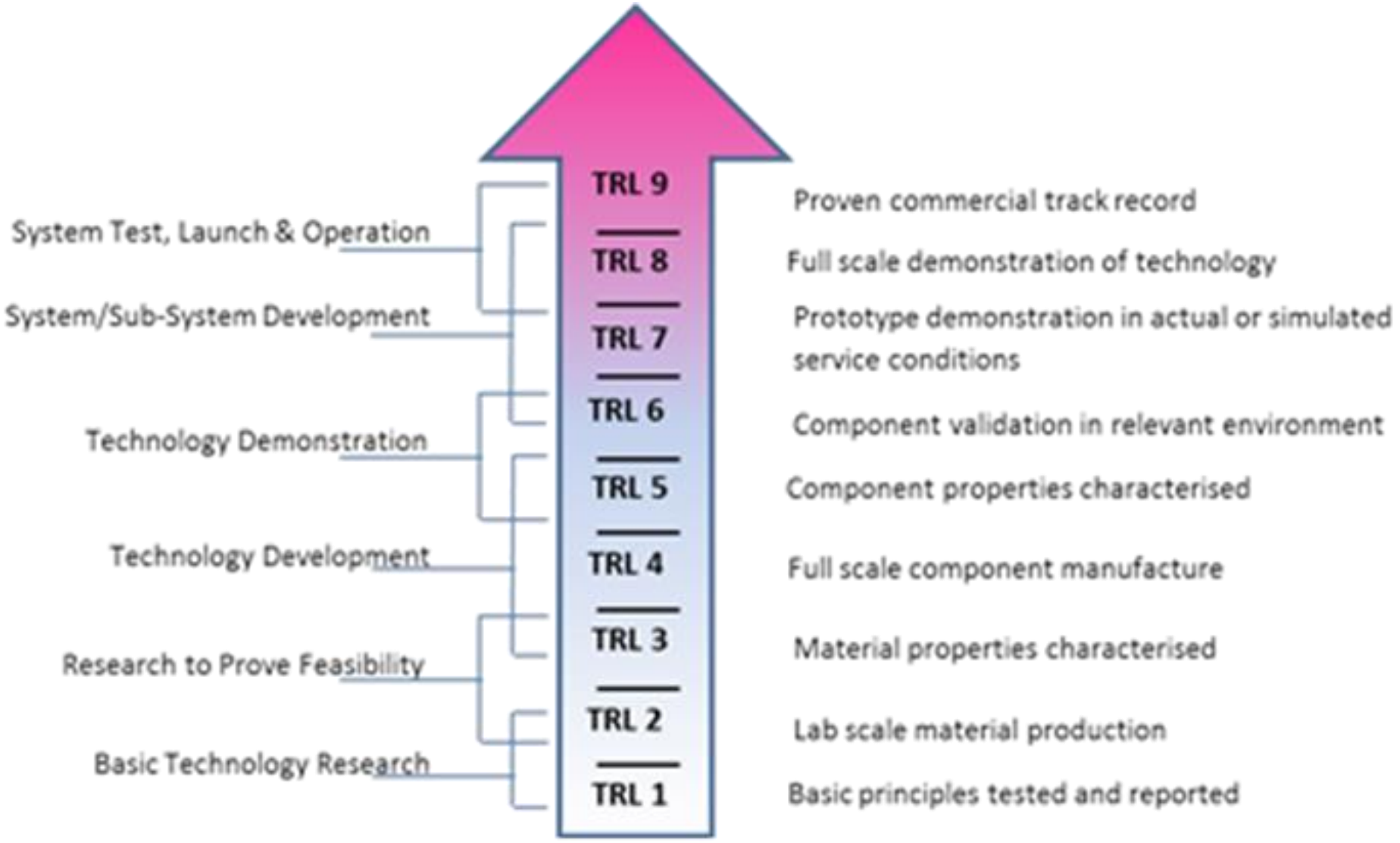
Technology Readiness Levels



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Technology Readiness Levels

	T23	T/P92	MarBN	347HFG	S304H	Sanicro25	310HNbN	HR6W	Nim 263	IN617B	Ha282	IN740H
Microstructural Understanding	8,8,8 [(1)]	7,8,7	6,-,7	8,8,8	8,8,8	7,7,-	8,8,8	5,6,7	6,7,-	8,8,6	6,8,-	6,8,-
Thermophysical Properties	8,8,8	7,7,7	5,-,6	8,8,8	8,8,8	6,6,-	8,8,8	6,7,7	6,7,-	8,8,7	6,8,-	6,8,-
Mechanical Properties	8,8,8	7,8,7	4,-,6	8,8,8	8,8,8	7,7,-	8,8,8	6,7,7	5,6,-	7,7,6	6,7,-	5,7,-
Corrosion/Oxidation	8,8,8	7,8,7	4,-,5	7,7,7	7,7,7	7,7,-	7,7,8	6,6,6	4,4,-	6,6,5	6,6,-	5,6,-
Welding Similar	8,8,8	8,8,8	5,-,6	8,8,7	8,8,8	7,7,-	8,8,8	6,6,6	4,6,-	7,7,5	6,7,-	6,7,-
Welding Dis-Similar	8,8,8	7,7,7	3,-,-	6,7,-	6,7,6	-,-,-	-,-,-	5,5,6	4,5,-	6,6,5	5,6,-	6,6,-
Inspection/NDT	8,8,8	8,8,8	4,-,6	8,8,8	8,8,8	6,-,-	8,8,8	5,6,6	4,6,-	6,6,-	5,6,-	6,6,-
Cold Work	8,8,8	7,7,7	-,-,-	7,6,6	7,8,-	6,5,-	7,6,-	5,5,6	n/a	6,6,6	5,7,-	4,5,-
Induction Bending	n/a	7,7,7	0,0,0	n/a	n/a	n/a	n/a	0,0,5	0,-,-	-,-,-	n/a	0,4,-
Repair	8,8,8	7,7,7	-,-,-	7,-,-	7,-,-	6,-,-	7,-,-	5,5,5	3,5,-	6,6,-	5,6,-	5,5,-
SCC in SCW	8,8,8	7,7,7	-,-,-	7,7,-	7,7,7	5,-,-	7,7,7	5,5,5	3,-,-	5,5,-	5,6,-	5,5,-

Legend: EU, US, Asia (Asia includes CH, IN,JP)

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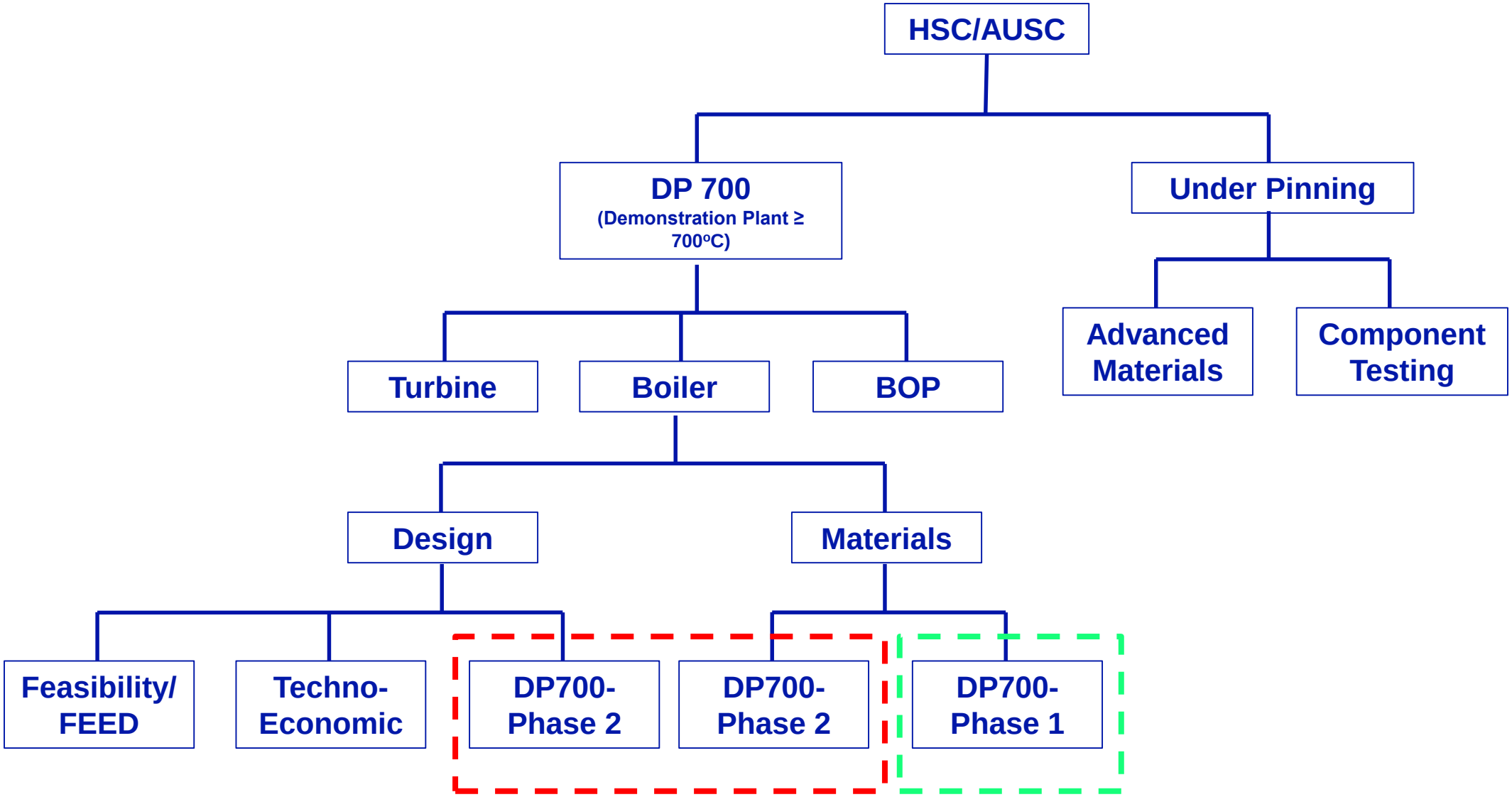
Big Picture



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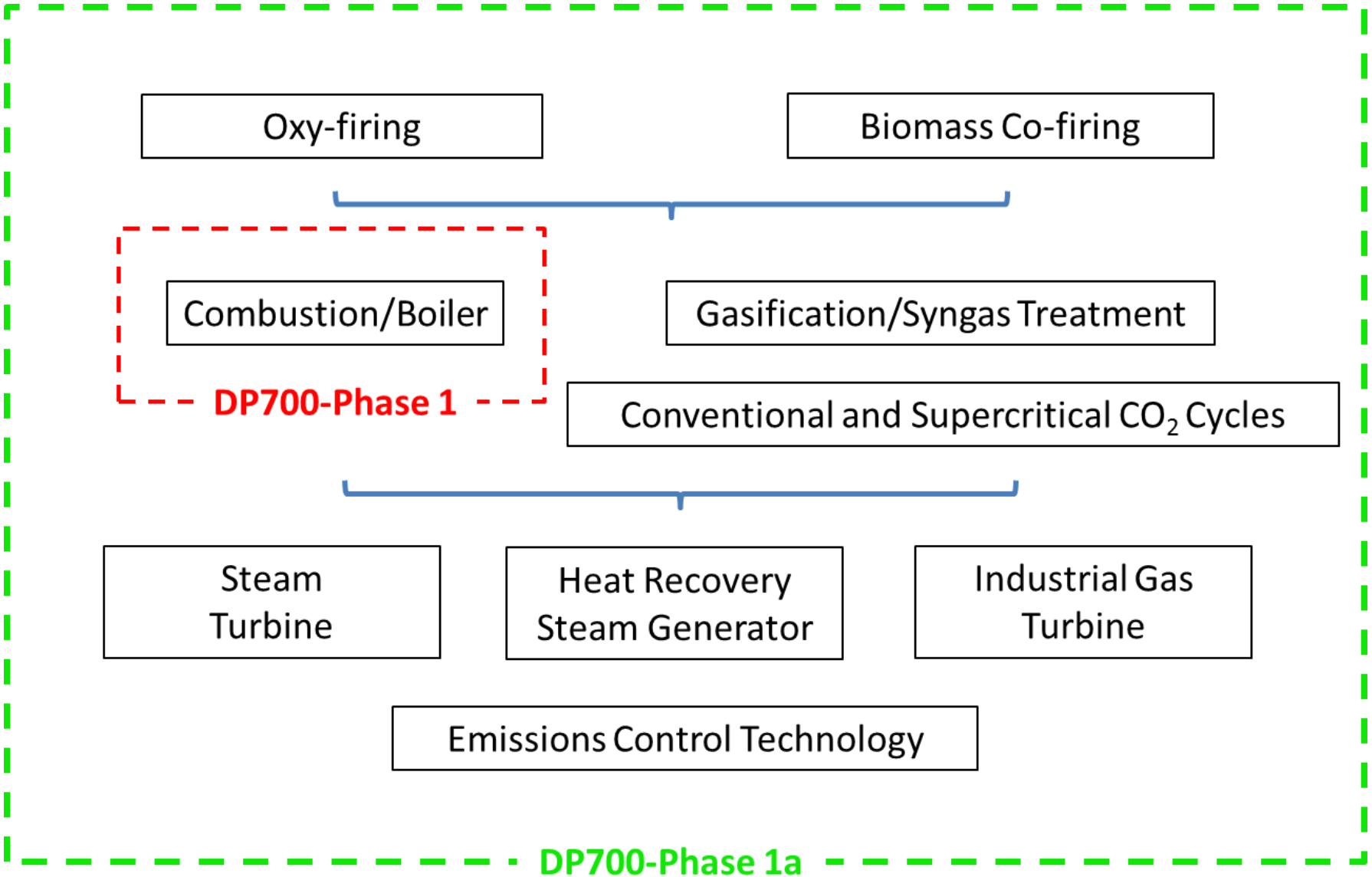
Next Phase ?



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Input to the DP700 Database is not restricted to the DP700 partners.

If you have data you wish to share or publicise you are more than welcome to upload your data.

If your interested send me an email

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Thank You For Your Attention

Any Questions ?

peter.barnard@doosan.com

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