HCCB
WBS Level 6 R&D Definition, Schedule and Initial Cost Estimate

1.8.2.1.2 R&D		
	1.8.2.1.2.1 Helium flow distribution and manifold testing	Calderoni
	1.8.2.1.2.2 Solid breeder thermomechanics and T recovery	Calderoni/Katoh
V	1.8.2.1.2.3 RAFS Fabrication development	Rowcliffe/Kurtz
	1.8.2.1.2.4 T control and predictive capability	Ying/Merrill
	1.8.2.1.2.5 Development of FS & SS transition element	Zinkle/Kurtz
V	1.8.2.1.2.6 Diagnostics and instrumentation	Calderoni
	1.8.2.1.2.7 1/2 Scale Mock-ups and Qualification tests	Tanaka
	1.8.2.1.2.8 In-pile pebble bed assembly test	Katoh/Calderoni

The R&D described in the WBS is required to gain critical data required to design, fabricate and operate test submodules that achieve their experimental goals related to understanding and quality of ITER test results, as well as to satisfy ITER safety and qualification criteria.

Compiled by A. Ying

US ITER TBM Conference Call

Oct. 6, 2005

R&D List for Helium-Cooled Ceramic Breeder Blanket Concepts

R&D Item	WBS	Comments
1. Ceramic breeder pebble fabrication, characterization, and recycling process technology development		To purchase
2. Beryllium pebble fabrication, characterization, and recycling		To purchase
3. Pebble bed thermo-physical and mechanical property characterization and thermomechanics performance evaluation	1.8.2.1.2.2	This R&D is “pebble” dependent.
4. Tritium release, permeation and inventory predictive capability	1.8.2.1.2.4	
5. Tritium recovery and processing technology development		Advanced R&D beyond 2015
6. Thermal hydraulic and flow distribution performance evaluation	1.8.2.1.2.1	
7. In-pile pebble bed assembly tests including irradiation test technology development	1.8.2.1.2.8	Irradiation test is “pebble” dependent. A collaborative effort.
8. Predictive capability development for performance as a function of fluences		Beyond 2015
9. RAFS material and joint technology development	1.8.2.1.2.3	
10. Blanket component fabrication technology development	1.8.2.1.4	
11. Blanket non-destructive testing and quality control development	1.8.2.1.2.7	
12. Diagnostics and instrumentation	1.8.2.1.2.6	

1.8.2.1.2.1 Helium flow distribution and manifold testing

Patrick Calderoni

WBS dictionary: Item # 1.8.2.1.2.1 - Helium flow distribution and manifold testing

Responsible ITER-TBM contact: P. Calderoni

The objective of this WBS item is to characterize the helium flow in the cooling channels and in the distributing manifolds of the test submodule as defined in WBS item # 1.8.2.1. [1]

The scope of the work includes the analysis of flow stability, the characterization of the uniformity of helium flow and the evaluation of pressure losses arising from flow distribution. In addition, the scope of the work includes the evaluation of the effect of the flow conditions on the other submodules that share the same cooling loop. The scope of the work does not include the effect of flow uniformity on heat transfer and the integrated thermal and mechanical response of the submodule to helium flow conditions, as they will be assessed by mock-up tests under item # 1.8.2.1.2.7.

The work is performed with numerical analysis using a computational fluid dynamic commercial code and with scaled experiments. The numerical analysis is used first to identify potential issues of flow stability in different cooling configurations. Then experiments are performed in two phases: at first the fundamental issues of flow distribution are investigated and the results are used to verify the model and to identify the optimal configuration for the submodule. Two test articles are designed using prototypical manifolds and cooling channels dimension, but with a limited number of channels arranged in parallel and series cooling schemes. In the second phase the cooling scheme of the layered configuration (EM and NT ITER phase) and the edge-on configuration (DD and DT phase) is tested with two full scaled test articles. The facility needed for the experiments include an helium loop operating at the submodule design pressure of 8 MPa, a maximum flow rate of 0.1 kg/s and at ambient temperature. Cost is minimized by designing a dual use cooling loop that can be shared with the facility dedicated to thermo-mechanics R&D (item 1.8.2.1.2.2). The cost associated with the design and construction of the loop however falls all under item 1.8.2.1.2.1.

Item # 1.8.2.1.2.1 deliverables expected by the end of 2009 [2] are a comprehensive set of data and an experimentally verified modeling tool to be used for the design of ½ scale mock-up and qualification test (item # # 1.8.2.1.2.7), for submodule design optimization during the detailed design phase (# 1.8.2.1.3.3) and for submodule qualification and safety report (# 1.8.3.4). The results should identify the optimal configuration of the He cooling scheme, including the distributing manifold, which would ensure adequate flow stability for the HCCB TBM according to the developed modeling tool.

Notes:

[1] definition assumes that submodule is a generic definition which includes both the unit cell design and the 1/3 half port

[2] The work under item # 1.8.2.1.2.1 is schedule to start in 2007 under the preliminary HCCB schedule. However, I propose to start the numerical analysis as early as 2006.

WBS: 1.8.2.1.2.1 Helium flow distribution and manifold testing

Item #	Activity ID		Duration	2006	2007	2008	2009
1		Problem definition	3 months				
	1	Literature Review					
	2	Learn Ansys CFX capabilities					
2		Translate CAD design into FEM meshing	3 months				
	3	Unit cell					
	4	Sub-module					
3		Modeling analysis	1 year				
	5	Identify design issues					
	6	Preliminary design of scaled/section experiments					
4		He loop design and construction	18 months				
	7	Facility design					
	8	Material procurement					
	9	Fabrication/setup					
	10	Diagnostics and shake-down testing					
5		Test articles design and construction	15 months				
	11	Material procurement					
	12	Fabrication/setup					
	13	Diagnostics and shake-down testing					
6		Data collection	15 months				
	14	Data collection					
7		Data analysis	15 months				
	15	Data analysis					
	16	Documentation and Inputs to RPrS and TSD					
8		Detailed HCCB He flow modeling	15 months				
	17	Unit cell					
	18	Sub-module					

◊ Define cooling scheme and manifold configuration for HCCB TBM

WBS title: Helium flow distribution and manifold testing

WBS #: 1.8.2.1.2.1

Item #	Activity ID	Description	Material/Equipment				Sched.	Labor					Comments/Assumptions
			QTY	Units	k$/unit	Total k$	months	Researcher		Engineer			
								HRS	$/HR	HRS	$/HR	Total k$	
1	1,2	**Problem definition:** literature review and Ansys CFX learning				10	3	48	110			5.28	Ansys CFX licence: 2.5k$/yr
2	3,4	**Translate CAD design into FEM meshing:** consider unit cell and sub-module geometry					3					0	
3	5,6	**Modeling analysis:** identify design issues and preliminary design of scaled/section experiments					12	384	110			42.24	
4	7,8,9,10	**He loop design and construction:** facility design, material procurement, fabrication/set up, diagnostics	1	He loop	Apr-00	126	18	288	110	576	90	83.52	Pressurized vessel configuration with low Dp blower; max flow rate 0.1 kg/s; uncertainity due to heat exchanger capability and cost; the cooling loop is shared with the facility for HCCB thermo-mechanics R&D
5	11,12,13	**Test articles design and construction:** material procurement, fabrication/set up, diagnostics	4	test article	20 / 50	140	12	384	110	192	90	59.52	Use commercial square channel tubes (T-91 or other available high chrome SS) for first phase, consider hipping for second phase; diff pressure gauges, flow controllers and thermocouples as diagnostics
6	14	**Data collection**					15	240	110			26.4	
7	15,16	**Data analysis:** analysis, documentation and inputs to RPrS and TSD					15	480	110			52.8	
8	17,18	**Detailed HCCB He flow modeling:** unit cell and submodule					15	240	110			26.4	
		Additional										360	Graduate student: 90k/year
Subtotal						276						656.16	

1.8.2.1.2.1 Solid breeder thermomechanics and temperature window for tritium release

Patrick Calderoni

WBS dictionary Item # 1.8.2.1.2.2: Solid breeder thermo-mechanics and temperature window for tritium release [1]

Responsible ITER-TBM contact: P. Calderoni / Y. Katoh

The objective of this WBS item is to characterize the behavior of the ceramic breeder material under thermal and mechanical loads predicted to occur during the various phases of ITER operation in the test submodule as defined in WBS item # 1.8.2.1.[2] The results obtained will define operative temperature ranges for each candidate material and allow the definition of temperature windows for the assessment of tritium release, which is closely coupled with the operative temperature.

The scope of the work includes the establishment and experimental verification of a database of material properties necessary for thermal and mechanical analysis of the submodule for the two candidate materials, lithium orthosilicate and lithium metatitanate; the development and experimental verification of predictive capability for the thermomechanic analysis of ceramic pebble beds in configurations relevant to HCCB; the experimental investigation of the mechanical response of ceramic pebble beds under cyclic thermal loads, in particular the effect of thermally activated creep on bed deformation; the experimental investigation of the effect of contact stresses within the bed and at interfaces on the formation of surface cracks and the integrity of the ceramic materials. The scope of the work does not include experimental testing of fully integrated test articles, which is included in item # 1.8.2.1.2.7 (mock-up and qualification test) and the application of the predictive capability to the design and optimization of the submodule geometry, which is included in item # 1.8.2.1.3.1 and item # 1.8.2.1.3.2 (preliminary and detailed design).

Item # 1.8.2.1.2.1 deliverables are: the definition and experimental verification of temperature windows for the candidate ceramic materials within which the thermo-mechanical response of the pebble bed is acceptable, based on the predicted submodule operational requirements; the delivery of a database and predictive capability for the thermo-mechanical response of the pebbles beds that have been experimentally verified within the temperature window specified above. The analysis of the experimental results and the predictive capability is used as input for the design of mock-up and qualification test (item # 1.8.2.1.2.7), for submodule design optimization during the detailed design phase (# 1.8.2.1.3.3) and for submodule qualification and safety report (# 1.8.3.4). Delivery is expected by the end of 2009. [3]

Notes:

[1] Item title has changed from WBS 09/07/05 version.

[2] Assumes that submodule is a generic definition which includes both the unit cell design and the 1/3 half port.

[3] The tests should be phased out with the beginning of mock-up tests, and the development of the predicted capability should be completed by 2009 to allow enough time for detailed design of the submodule.

WBS: 1.8.2.1.2.2 Solid breeder thermo-mechanics and temperature window for tritium release

Item #	Activity ID		Duration	2006	2007	2008	2009
1		Finite Element Method modeling	18 months				
	1	Develop appropriate thermal creep model for pebble beds for Ansys					
	2	Submodule analysis to identify design issues					
	3	Design experiments focused on design issue optimization					
2		Experimental facility upgrade	2 years				
	4	Controlled mechanical load					
	5	Temperature gradient					
	6	Thermal cycling					
	7	High temperature diagnostics					
3		Test articles design and construction	18 months				
	8	Material procurement					
	9	Fabrication/setup					
4		Data collection	18 months				
	10	Data collection					
5		Data analysis	2 years				
	11	Data analysis					
	12	Documentation and Inputs to RPrS and TSD					

WBS title: Solid breeder thermo-mechanics and temperature window for tritium release

WBS #: 1.8.2.1.2.2

Item #	Activity ID	Description	Material/Equipment				Sched.	Labor					Comments/Assumptions
			QTY	Units	k$/unit	Total k$	months	Researcher		Engineer			
								HRS	$/HR	HRS	$/HR	Total k$	
1	1,2,3	**FEM modeling:** creep model development, submodule analysys, experiments design				24	18	288	110			31.68	Ansys licence: 6k$/yr
2	4,5,6,7	**Experimental facility upgrade:** controlled mechanical load, temp gradient, thermal cycling, high temp diagnostics				140	24	384	110	768	90	111.36	Controlled load based on uniaxial load cell (major cost uncertainity); temperature gradient and thermal cycling based on combination of radiative heating, contact heating and he cooling; dual use he cooling loop is shared with the facility for he flow distribution R&D; diagnostic system based on etxernally aligned LVDT sensors and embedded high temperature strain sensor
3	8,9	**Test articles design and construction:** material procurement, fabrication/set up				100	18	288	110	288	90	57.6	Addressed with multiple test articles; lithium ceramic material: 10k/kg
4	10	**Data collection**					18	288	110			31.68	
5	11,12	**Data analysis:** analysis, documentation and inputs to RPrS and TSD					24	768	110			84.48	
		Additional										360	Graduate student: 90k/year
Subtotal						264						676.8	

1.8.2.1.2.4 Tritium control and predictive capability

Alice Ying

WBS dictionary: Item # 1.8.2.1.2.4
Tritium Control and Predictive Capability
Responsible ITER-TBM contact: A. Ying/B. Merrill

The objective of this WBS item is to resolve tritium control issues in a typical helium-cooled ceramic breeder pebble bed blanket. Analysis has been performed in the past; however, there remain uncertainties in the database as well as in predictive capability. The main path by which tritium may get to the ambient atmosphere is given by: 1) implementation of tritium from the plasma into the first wall which then permeates to the helium coolant system; 2) permeation of tritium from the tritium purging system to the helium coolant system; and 3) tritium permeation from the helium coolant system to the steam generator and turbine cycle. Because the permeation of tritium from the purging system to the helium coolant is the most critical in the tritium control, it is the primary focus of this WBS. A recent analysis, taking into account convective and isotope swamping effects, shows that a relatively narrow operating window exists where the permeation can be low and acceptable (< 0.5%) without using a permeation reduction barrier for tritium permeation control in helium-cooled ceramic breeder blanket designs.

The scope of the work includes the development and experimental verification of predictive capability for the tritium permeation in configurations relevant to HCCB designs including flow in the complex geometry, temperature distribution, and tritium production profiles; the establishment of a database of material properties such as tritium (deuterium) solubility, permeability at lower pressure regimes (<10 Pa) under flow conditions, and the experimental investigation of the effect of isotope swamping and velocity profile on the permeation rate.

The deliverables include the definition and experimental verification of purge gas composition and flow conditions for the candidate ceramic materials within which the permeation rate from the pebble bed to the helium coolant is acceptable; the delivery of a database and predictive capability for the tritium control that have been experimentally verified within typical HCCB blanket configurations and operating conditions. The analysis of the experimental results and the predictive capability is used as input for the design of in-pile pebble bed assembly tests (item # # 1.8.2.1.2.8), and for submodule qualification and safety report (# 1.8.3.4). Delivery is expected in 2011.

Deliverable: Data on purge gas flow conditions, in which tritium permeation from purge gas into the helium coolant is acceptable plus a computational code that is capable for analyzing tritium permeation in a complex geometrical configuration under reactor relevant operating conditions (temperature and tritium production profiles)

WBS: 1.8.2.1.2.4 Tritium Control and Predictive Capability

Item #	Activity ID		Durations	2005	2006	2007	2008	2009	2010	2011
1	1	Problem definition	6 months							
		Literature Review								
		Scope & Objective								
		Methodology Definition								
2	2	Model development	24 months							
3	3	Single-effect experimental study	27 months							
	3.1	Measurements and Operating regimes	6 months							
	3.2	Design	6 months							
	3.3	Material procurement	6 months							
	3.4	Fabrication/setup	6 months							
	3.5	Experiments	9 months							
4	4	Single-effect Benchmark Simulations	3 months							
5	5	Documentation	3 months							
6	6	Multiple-effect Experimental Study	27 months							
	6.1	Measurements and Operating regimes	5 months							
	6.2	Design Upgrade	4 months							
	6.3	Material procurement	4 months							
	6.4	Setup	4 months							
	6.5	Experiments	6 months							
7	7	Multiple-effect Benchmark Simulations	3 months							
8	8	Documentation	3 months							
9	9	Documentation and Inputs to RPrS and TSD	6 months							

TBM Costing Input Table

WBS Title: 1.8.2.1.2.4 Tritium Control and Predictive Capability

	Schedule		Material/Equipment					Labor			Travel	
Item #	**Activity ID**	**Description**	**QTY**	**Units**	**$/unit**	**Shipping/Tax**	**Total $**	**HRS**	**$/HR**	**Total $**		**Comments/Assumptions**
1	1	Problem definition: Critical survey of state-of-art knowledge; identify scope and						720	42	30240		graduate student hourly rate: $42
2	2	Model development: develop a mathematical and numerical model that accurately represents environmental conditions where the tritium permeation process takes place						1920	42	80640	2000	
3	3	Sinle effect experimnetal study										
	3.1	Measuring techniques and operating regimes: Identify proper diagnostics as well as to define primary variable operating conditions						480	42	20160		
	3.2	Design: Develop experimental setup schematics including test section fabrication drawing						240 /320	42/ 93.75	10080+ 30000		Technical engineer hourly rate: $93.75
	3.3	Material procurement:						240	42	10800		
	3.3-1	Residual Gas Analyzer and associated vacuum pumping stetem	1	1	20,000		20,000					Catalog Price/PPR100
	3.3-2	Baratron capacitance manometer/pressure gauge controller	2	2	3,545		7,090					Catalog Price/MKS
	3.4	Fabrication/set up: Fabricate test article and conduct shake-down tests	1		5000		5,000	240/ 160	42/ 65	10080 + 10400		Data acquisition, Ferrtic steel and ceramic pipes, Swagelock fittings.
	3.5	Experiments						1200	42	50400		
4	4	Conduct numerical simulations under experimental conditions to validate the code						240	42	10080		
5	5	Documentation: Ph. D. Thesis						480	42	20160	5000	2 domestic trips
6	6	Multi-effect experimental study										
	6.1	Measuring techniques and operating regimes: Define operating conditions for secondary parameters and upgrade diagnostics						800	42	33600		
	6.2	Design upgrade: upgrade the exisitng set-up to include seondary parameter						480/ 160	42/ 93.75	20160 + 15000		
	6.3	Material procurement: heaters and power controllers	1	1	3000		3000	480	42	20160		heater, power controller, thermocouples
	6.4	Fabrication/set up: Fabricate test article and conduct shake-down tests						640	42	26880		
	6.5	Experiments						960	42	40320		
7	7	Multiple-effect Benchmark Simulations: Conduct numerical simulations under experimental conditions to validate the code						480	42	20160		
8	8	Documentation: Master Thesis						480	42	20160	5000	2 domestic trips
9	9	Documentation and Inputs to RPrS and TSD						120	180	21600	2500	1 domestic trip
Subtotal							35,090			508680	12500	

1.8.2.1.2.5 Development of FS & SS transition element

Steve Zinkle

WBS Item # 1.8.2.1.2.5
Development of FS and SS Transition Element
Responsible Task Performers: S. Zinkle/R. Kurtz

- This WBS includes research and development tasks required to determine the most appropriate ferritic steel pipe/austenitic steel joining techniques. This transition element is needed in order to use the available ITER standard remote handling tools for remote welding during the TBM replacement. This is a common task for all ITER TBWG Parties.

1.8.2.1.2.7 1/2 Scale Mock-ups and Qualification tests

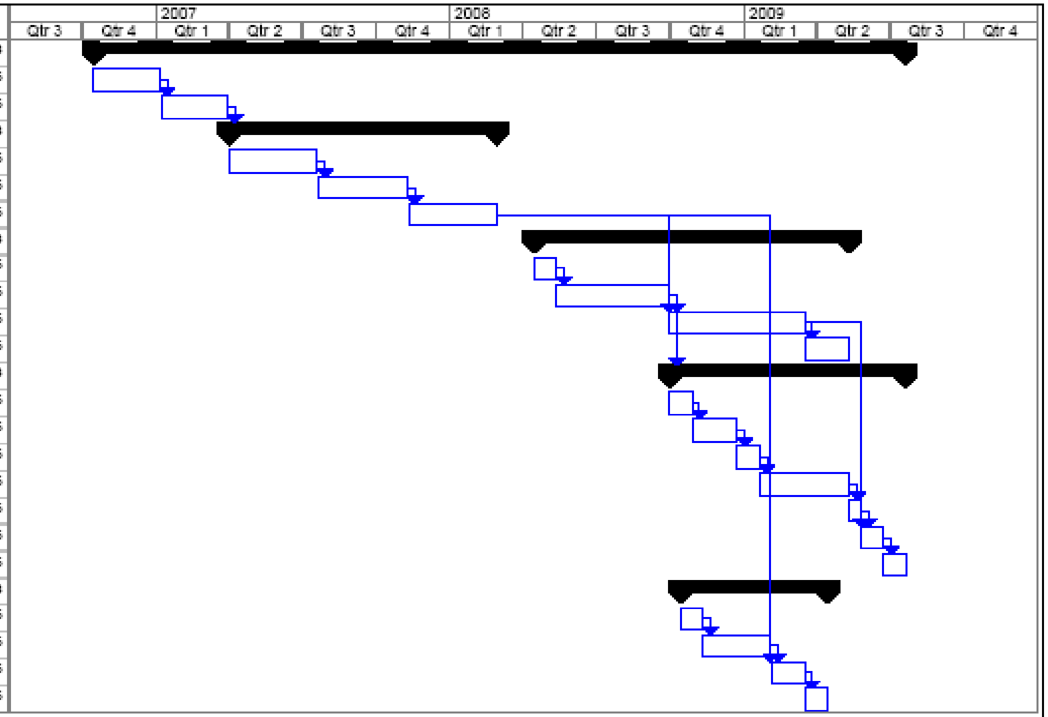
Tina Tanaka

WBS Item # 1.8.2.1.2.7
½ Scale Mock-ups and Qualification Tests
Responsible Task Performers: T. Tanaka

- The objective of this WBS item is to perform research and development tasks including the associated administration to enable integrated testing on ~½ scale HCCB TBM mockup under appropriate environmental conditions to simulate behavior in ITER. The purpose of such tests are to validate fabrication processes, demonstrate capability of non-destructive testing, and address critical performance and safety issues and procedures needed for ITER qualification. The environmental test will consist of flowing preheated He at appropriate flow rates and pressures through the HCCB test module. The scope of the work includes: building a mockup, testing the mockups using NDE techniques, and modification/fabrication of testing facilities. Diagnostics to be used on the TBM (i.e., 1.8.2.1.2.6) will be included as is practical. Opportunities for combined testing at international facilities will be investigated. Steps here do not include those listed above under 1.8.1.1.2.11 for He loop upgrade and locating an overpressure test facility.

Task schedule

ID	Task Name	Duration
1	**Integrated Testing**	**722 days**
2	Design He loop	60 days
3	Procurement Activities	60 days
4	**Fabrication & Install He L**	**240 days**
5	Fabrication	80 days
6	Installation	80 days
7	System Testing	60 days
8	**DCLL Mockup**	**280 days**
9	Design DCLL mockup	20 days
10	Fabricate 1/2 Mockup	100 days
11	Test Mockup	120 days
12	Post Test Examinatior	40 days
13	**Over Pressure Test**	**210 days**
14	Test Facility Specifica	20 days
15	Test Facility Modificat	40 days
16	Mockup Design	20 days
17	Mockup Fabrication	80 days
18	NDE on Mockup	10 days
19	Mockup Testing	20 days
20	Post Test Analysis	20 days
21	**HCCB Mockup**	**130 days**
22	Design HCCB Mockup	20 days
23	Fabricate HCCB Mock	60 days
24	Test HCCB Mockup	30 days
25	Post Test Analysis	20 days



Project: TBM Integ Test
Date: Tue 10/4/05

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Rough Cost Breakdown

Task	Cost
He loop	$2,660K
DCLL test	$1,680K
HCCB test (1.8.2.1.2.7)	$200K*

less $40K if DCLL is also done.

WBS/Title: 1.8.2.1.7 1/2 scale integrated testing

One Sheet for Each WBS Level 5 or below

COSTING BY / DATE

Tina Tanaka 10/4/05

FY 2006 year's dollars*

				MATERIAL/EQUIPMENT					LABOR			TRAVEL	COST CODES		
WBS #	Item #	Schedule Activity ID	DESCRIPTION	QTY	UNITS	$ / UNIT (burdened)	PACKAGING & SHIPPING $	TOTAL-$	HRS	$/HR (Burdened)	TOTAL-$	$$	PARTICIPANT CODE	BURDENED COST	COMMENTS/ASSUMPTIONS
1.8.2.1.7			1/2 scale HCCB integrated testing												This assumes that the He flow loop is procured, fabricated, installed and checked out and we find an overpressure test faciity as in 1.8.1.1.2.11.1. Otherwise those costs must transfer here from items 1.8.1.1.2.11.1, items 1 to 4, and items 1.8.1.1.2.11.2. The helium loop will not be quite as costly because of the lower flow rate.
	1	YYYY					$ -	$ -			$ -	$ -			
	1		HCCB Mockup Design				$ -	$ -			$ -			$ 20,000	Engineering Estimate
	2		Fabricate HCCB Mockup				$ -	$ -			$ -			$ 50,000	
	3		Test HCCB Mockup				$ -	$ -			$ -	$ -		$ 60,000	
	4		Post test analysis											$ 30,000	
							$ -	$ -		$ -	$ -	$ -		$ -	
							$ -	$ -		$ -	$ -	$ -		$ -	
							$ -	$ -		$ -	$ -	$ -		$ -	
							$ -	$ -		$ -	$ -	$ -		$ -	
							$ -	$ -		$ -	$ -	$ -		$ -	
							$ -	$ -		$ -	$ -	$ -		$ -	
	subtotal						$ -	$ -			$ -	$ -		$ 160,000	
					Sales Tax			Tot FTEs	0.00						
			Indirects: *Industry markups*		Indirects			$			$				
			Overhead: *DOE Laboratory markups*		Overhead			$			$	$			

1.8.2.1.2.8 In-pile pebble bed assembly test

Yutai Katoh

WBS Item # 1.8.2.1.2.8
In-Pile Pebble Bed Assembly Test
Responsible Task Performers: Y. Katoh/P. Calderoni

- The objective of this WBS item is to confirm integrity and performance of HCCB pebble bed subassembly during neutron irradiation in conditions relevant to the HCCB blanket operation. The work scope includes reference strategy development of the in-pile testing, designing and construction of pebble bed subassembly and irradiation facilities, in-pile experiment, and post-irradiation examination. The program will be developed to best utilize potential opportunity of international collaboration, including sharing of an irradiation vehicle.

WBS #												
1.8.2.1.2.8		**In-pile Pebble Bed Assembly Test**	**Year**									
			1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	1	**Reference Strategy Development**										
	2	**Conceptual Experimental Design**										
	3	**Experimental Matrix Development**										
	4	**Capsule and Facility Design, Construction, QA**										
	5	**In-Pile Test**										
	6	**Post-Irradiation Examination**										

		Schedule		Material/Equipment					Labor			Travel	
WBS#	Item #	Activity ID	Description	QTY	Units	$/unit	O/H	Total $	HRS	$/HR	Total $		Comments/Assumptions
1.8.2.1.2.8	1	1	**Reference Strategy Development**						40	180	7200	7500	
	2	2	**Conceptual Experimental Design**						160	180	28800	15000	
	3	3	**Experimental Matrix Development**						160	180	28800	15000	
	4	4	**Capsule and Facility Design, Construction, QA**	1	unit	3000000	1393200	4393200	10000	180	1800000	22500	
	5	5	**In-Pile Test**	1	unit	1000000		1000000	4000	200	800000	7500	
	6	6	**Post-Irradiation Examination**						3000	200	600000	7500	
	1.8.2.1.2.8 Total							5393200			$3,264,800	75000	

Note: 'Shipping/Tax' includes ORNL overhead.