FIRE Plasma Facing Component Cost Estimate

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Presented by

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WBS 1.1 Plasma Facing Components Cost

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WBS	Element	Non-Rec ($k)	Rec ($k)	Subtotal ($k)	Cont	Total ($k)
1.1.1	First Wall	5,168	9,900	15,068	21%	18,295
1.1.2	Outer Divertor Modules	8,264	18,400	26,664	21%	32,260
1.1.3	Baffle Structures	2,910	6,500	9,410	59%	15,006
1.1.4	Inner Divertor Plates	2,075	3,600	5,675	21%	6,889
1.1.5	Limiters & Armor	772	1,200	1,972	21%	2,395
1.1.6	Wall Conditioning Systems	1,113	3,300	4,413	21%	5,336
1.1.8	PFC R&D Needs	8,700	0	8,700	26%	11,000
	TOTAL	**34,102**	**37,800**	**71,902**	**27%**	**91,181**

Estimate updated October 2000

Costs given in constant-year FY'99 dollars

Baffle contingency may not cover added cost of active cooling

Contingency should be sufficient to cover other open issues

WBS 1.1.1 First Wall Tile Costing

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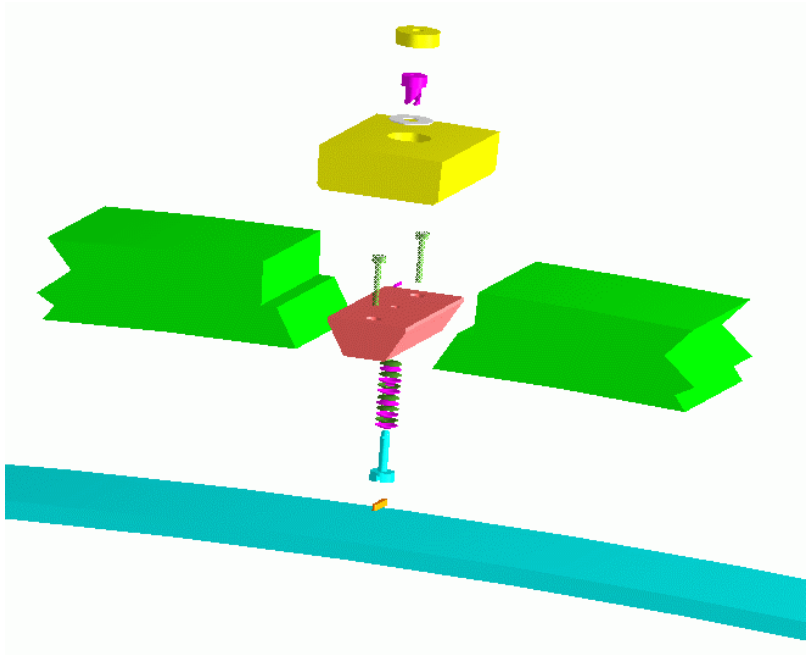
Configuration

- 40-mm thick CuCrZr plates with 5-mm thick plasma-sprayed beryllium armor
- Wedge-shaped SS316LN rails bolted to vessel, provide mechanical support
- Rails include captive fastener hardware for loading thermal interface contacts with cooled vessel



Costing Basis

- Quantity: 4 Proto, 8x16 IB, 8x16 OB
- Production Yield: 90%
- Size: IB 220 x 580 x 40 mm
  OB 190 x 420 x 40 mm
- Material costs: Escalated from CY'97 values obtained for ITER
- Fabrication costs: Derived from vendor quotes for ITER involving comparable complexity components and materials
- Be-armor costs: Derived from ITER estimate and updated guidance from Brush-Wellman for S65B powder and 5-mm thick coating
  - Plasma Spray cost: $2k /unit
  - S65B Powder cost: $2k /unit
  - Recurring unit cost $28k

WBS 1.1.2 Outer Divertor Costing

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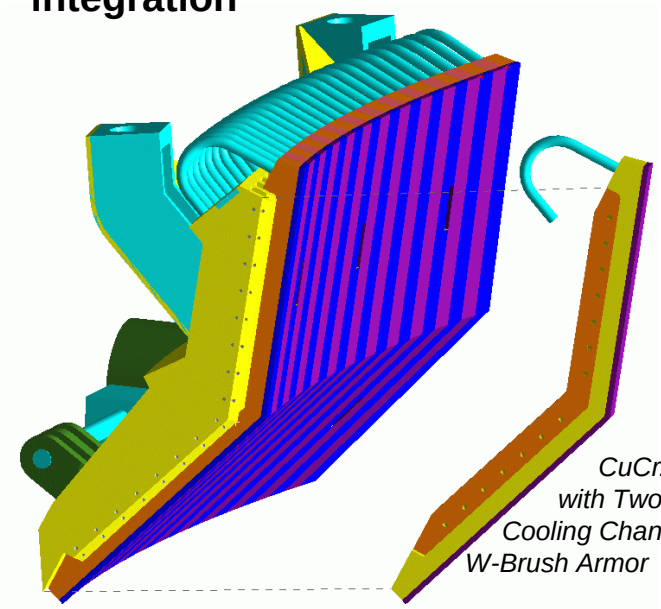
Configuration

- SS316LN backplate structure/manifold
- 24 CuCrZr finger plates with W-brush armor, attached to backplate using roll pins
- Actively cooled using concentric pipe feed through divertor ports
- HIP-bond armor using separate canister welds around each finger plate
- HHF cycle plates to verify joint prior to integration



CuCrZr Finger Plate with Two 8-mm dia Cooling Channels and W-Brush Armor

Costing Basis

- Quantity: 2 Proto, 32 Production
- Production Yield: 80%
- Size: 720 x 1500 x 60 mm CuCrZr plate
  680 x 740 x 150 mm SS316 plate
  508 mm long In 625 HW inserts
  3 mm dia pointed W-rods
  125 dia x 3000 mm coaxial water feed
- Material costs: Escalated from CY'97 values obtained for ITER
- Fabrication costs: Derived from vendor quotes for ITER vertical target involving comparable components and materials
- W-armor costs: Based on large area direct-HIP bonding development started for ITER
  – HIP-bonding cost: $90k /unit
  – W-rod cost: $17k /unit
  – Recurring unit cost $388k

Open Issues

- Electrical connector costs not included, likely within contingency
- Baffle cooling implications not considered

WBS 1.1.3 Baffle Plate Costing

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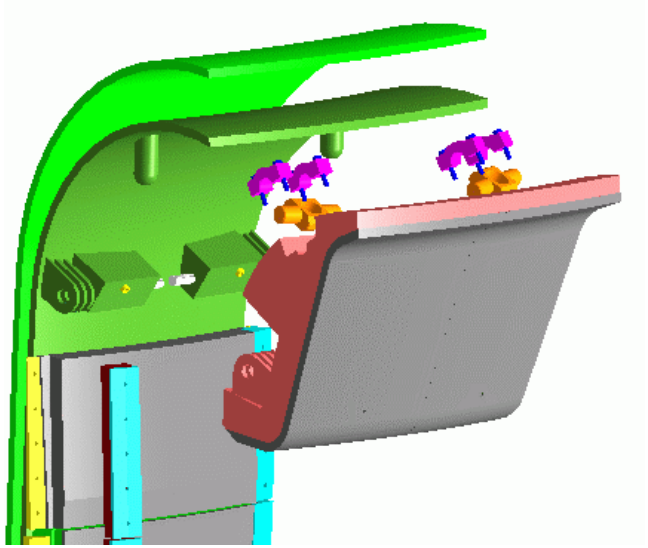
Configuration

- Passively cooled CuCrZr forging with W-brush armor for erosion control
- Attached to vessel using upper pins/rotating sockets and lower shear plates/pins
- HIP-bond armor over entire surface using single perimeter e-beam weld



Costing Basis

- Quantity: 2 Proto, 32 Production
- Production Yield: 86%
- Size: 600 x 750 x 200 mm CuCrZr forging
  3-mm dia pointed W-rods
- Material costs: Escalated from CY'97 values obtained for ITER
- Fabrication costs: Derived from vendor quotes for ITER dome-PFC involving comparable components and materials
- W-armor costs: Based on large area direct-HIP bonding development started for ITER
  - HIP-bonding cost: $43k /unit
  - W-rod cost: $17k /unit
  - Recurring unit cost $145k

Open Issues

- Need to update for actively-cooled configuration, contingency may not be sufficient

WBS 1.1.4 Inner Divertor Costing

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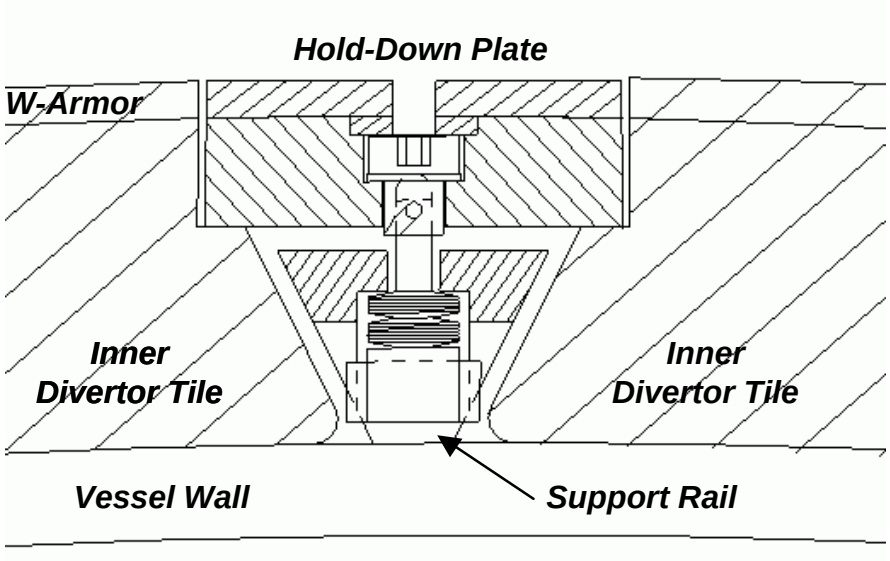
Configuration

- Passively cooled CuCrZr plate with W-brush armor for erosion control
- Attached to vessel using rail and fastener approach like first wall
- HIP-bond armor over entire surface using single perimeter e-beam weld



Costing Basis

- Quantity: 2 Proto, 32 Production
- Production Yield: 86%
- Size: 280 x 620 x 60 mm CuCrZr plate
  220 x 50 x 30 mm SS316 rails
  3-mm dia pointed W-rods
  Cu-foam layer for thermal contact
- Material costs: Escalated from CY'97 values obtained for ITER
- Fabrication costs: Derived from vendor quotes for ITER dome-PFC for comparable materials with reduction factors for passive cooling
- W-armor costs: Based on large area direct-HIP bonding development started for ITER
  - HIP-bonding cost: $33k /unit
  - W-rod cost: $ 5k /unit
  - Recurring unit cost $70k

Open Issues

- Need to reassess following disruption effect mitigation resizing

WBS 1.1.5 Limiters and Armor and WBS 1.1.6 Wall Conditioning Cost

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Configuration

- Startup Limiters and armor not specifically designed and priced for this estimate
- Expected configuration is toroidal belt limiters at two OB locations or OB poloidal rails at two toroidal locations
- Wall conditioning based on glow discharge cleaning system (CIT) and wall boronization system (TFTR)

Costing Basis Limiters/Armor

- Quantitiy: 10% of First wall cost
- Production Yield: TBD
- Size: Rail belt limiters at 2 locations
  PS-Be armor

Costing Basis Wall Conditioning

- Cleaning costs: Escalated CY'91 values for CIT glow discharge pumping system
  - Glow discharge cost $1.2M
- Conditioning costs: Escalated CY'89 cost estimate for installing a diborane injection system in TFTR. Included complexity factor for implications associated with FIRE tritium levels and remote handling.
  - Wall conditioning cost $1.3M

Open Issues

- Need to update once better definition is available

Required R&D Tasks to Confirm Design

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	Cost
❑ Complete W-brush fabrication process development and HHF testing begun under ITER to validate performance	$1.5M
❑ Scale-up finger fabrication process (combine W-brush, SWT/HWI, and SS transition) to demonstrate, reliability, manufacturability, and NDE procedures for initial quality screening of critical bonds, welds, etc.	$3.0M
❑ Demonstrate Cu-finger integration with SS back structure (pins, welds, alignment, etc.) through prototype fabrication and testing	$1.0M
❑ Continue baffle fabrication process development and scale-up to demonstrate large-area HIP-diffusion bonding, W-brush integration, and end manifold closeout welds / SS transition joints	$0.8M
❑ Develop effective passive heat transfer layer for first wall and inner divertor tiles (copper foam metals, etc.)	$0.3M
❑ Fabricate and test electrical connectors to validate performance and in-service design guidelines	$0.9M
❑ Fabricate end effectors/dummy elements to use for validating remote handling interfaces and procedures	$0.2M
❑ Industrialize Be plasma spray process developed under ITER for the first wall armor application	$0.9M
❑ Fabrication/testing to verify sliding pin mounting scheme and in-service performance	$0.1M
Total	**$8.7M**

Open PFC Costing Issues

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- **Active cooling will increase baffle unit cost (compare passive baffle to outer divertor) need to update estimate once conceptual design completed**
- **Need to assess toroidal electrical connector costs if they are adopted to help reduce disruption loading conditions**
- **Need to reassess inner divertor plate costs once changes due to disruption loads have been incorporated in the design**

Backup Charts

Starting Material Costs

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PART NAME	MATERIAL	PRODUCT FORM	UNIT WGT/LEN	# TO MAKE	SCRAP RATE	MATERIAL NEED	MATERIAL UNIT COST	MATERIAL COST
			(kg or m)		(%)	(kg or m)	($/kg)	($ CY99)
FIRST WALL ELEMENTS 1.1.1								
Outer FW Plates	CuCrZr	plate	28	142	5	4,240	14.33	60,760
Inner FW Plates	CuCrZr	plate	45	142	5	6,770	14.33	97,015
Outer Attachment Rails	316L	plate	2	142	5	340	3.50	1,190
Inner Attachment Rails	316L	plate	3	142	5	390	3.50	1,365
Rail Cover Plates	CuCrZr	plate	3	426	5	1,400	14.33	20,062
Outer PS Beryllium Armor	Be	powder	1	142	10	150	1,100	165,000
Inner PS Beryllium Armor	Be	powder	2	142	10	240	1,100	264,000
Misc First Wall Items	all	all					5% extra	9,020
TOTAL 1.1.1							**TOTAL**	**618,411**
OUTER DIVERTOR MODULES 1.1.2								
Gundrilled Front Plates	CuCrZr	plate	577	34	5	20,590	14.33	295,057
HIP-Can Close-out Covers	OFHC Cu	plate	16.3	34	5	580	5.20	3,016
Cooling Channel Close-out	CuCrZr	plate	1.2	34	5	40	14.33	573
Helical Wire Inserts	In 625	spring	30.5	34	10	1,140	15.47	17,638
Backing Plate / Manifold	316L	plate	672	36	5	25,390	3.50	88,865
Finger Tube Stubs	316L	Seamless Tube	0.12	2040	5	250	68.80	17,200
Water Feed Lines	316L	Concentric Pipe	93.1	36	5	3,520	16.80	59,136
Attachment Structure	316L	plate	1.2	432	5	570	3.50	1,995
Tungsten Brush Armor	W-Rods	3-mm-dia	5.3	34	5	2,572,209	0.26	676,748
Misc Outer Divertor Items	all	all					5% extra	24,174
TOTAL 1.1.2							**TOTAL**	**1,184,402**

Starting Material Costs, Con't

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PART NAME	MATERIAL	PRODUCT FORM	UNIT WGT/LEN	# TO MAKE	SCRAP RATE	MATERIAL NEED	MATERIAL UNIT COST	MATERIAL COST
			(kg or m)		(%)	(kg or m)	($/kg)	($ CY99)
BAFFLE STRUCTURES 1.1.3								
Starting Material	CuCrZr	hand forging	801	40	5	33,640	16.69	561,487
HIP-Can Close-out Covers	OFHC Cu	plate	13	40	5	540	5.20	2,808
Attachment Structure	316L	plate	1	432	5	570	3.50	1,995
Tungsten Brush Armor	W-Rods	3-mm-dia	4	40	5	2,387,279	0.26	628,093
Misc Inner Divertor Items	all	all					5% extra	28,315
TOTAL 1.1.3							**TOTAL**	**1,222,698**
INNER DIVERTOR PLATES 1.1.4								
Starting Material	CuCrZr	plate	93	40	5	3,890	14.33	55,744
HIP-Can Close-out Covers	OFHC Cu	plate	4	40	5	160	5.20	832
Attachment Rails	316L	plate	3	40	5	120	3.50	420
Rail Cover Plates	CuCrZr	plate	3	60	5	200	14.33	2,866
Tungsten Brush Armor	W-Rods	3-mm-dia	1	40	5	688,296	0.26	181,091
Misc Inner Divertor Items	all	all					5% extra	2,850
TOTAL 1.1.4							**TOTAL**	**243,803**
OUTER PASSIVE PLATES 1.2.4								
Starting Material	CuCrZr	plate	231	37	5	8,970	14.33	128,541
Attachment Rails	316L	plate	6	40	5	260	3.50	910
Rail Cover Plates	CuCrZr	plate	7	60	5	410	14.33	5,875
Outer PS Beryllium Armor	Be	powder	8	37	10	320	1,100	352,000
Misc Passive Plate Items	all	all					5% extra	6,473
TOTAL 1.2.4							**TOTAL**	**493,799**

Unit Cost Comparison for PFC Elements

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	First Wall	Outer Div	Baffle	Inner Div
Armor Form	*PS-Be*	*W-Brush*	*W-Brush*	*W-Brush*
Number Modules	284	40	37	37
Module Area (m2)	0.10	0.49	0.48	0.14
Yield	90%	80%	86%	86%
Starting Material Cost ($K)	943	1,452	943	253
Recurring Fab Cost ($K)	5,500	9,564	2,550	1,018
Armor Joining Cost ($K)	948	3,311	1,457	1,127
Unit Fab Cost ($K)	22.7	259.8	78.7	29.8
Unit Armor Join ($K)	2.0	82.8	39.4	30.5
Unit Armor Mtl ($K)	1.4	15.6	15.7	4.5
Total Unit Cost ($K)	26.0	358.2	133.8	64.8