

## Work Authorization Document

### NSTX Upgrade Project

<b>Control Account #:</b>	1305	<b>Title:</b>	OHMIC Heating Coil (OH)
<b>WBS</b>	1.1.7	<b>Title:</b>	Magnet Systems

**Period of Performance:** 23 February 2009 through 10 October 2013

<b>Authorized Budget:</b>	\$4,556	<b>Control Account Manager:</b> Chrzanowski
<b>Revision #:</b>	0	<b>Revision Date:</b> July-11

**Authorized Work Description:**

The ohmic heating solenoid subsystem consists of the new coils that will make up the center solenoid. This WBS element includes the design, analysis, prototypes (as required), procurement activities and fabrication.

For the NSTX Upgrade a new OH Solenoid will be fabricated. This WBS element includes the design & fabrication of a new OH solenoid and associated components including a belleville washer spring assembly and support structures for the NSTX upgrades. It also includes all analytical & CAD design efforts. Includes advance procurement of the copper conductor and co-wound [glass/Kapton] insulation. Also includes the procurement of the Micro-therm insulation, conductive paint.

Includes the procurement and engineering oversight for the combined OH and TF bundle assembly. A single vendor will fabricate both components.

**Attachments:**

- 1- A detailed Control Account schedule showing all work packages and planning packages.
- 2- Budgeted Cost by month.
- 3- Original Work Authorization Form (WAF)
- 4- WBS Dictionary sheet that defines the scope of work for this WBS element.

#### Control Account History

ECP#	Implement Date	Prior Budget	New Budget	Signature

Approvals	Name	Signature	Date
NSTX-U Project Manager	R. Strykowski		
Control Account Manager	Chrzanowski		
Functional Manager	P. Heitzenroeder		

Activity ID	Activity Description	Work Days	BASELINE START	Forecast Start	BASELINE FINISH	Forecast Finish	Schedule Slip (Days)	Total Float	Budgeted Cost	PPCT	Earned value cost (BCWP)	Planned value cost (BCWS)	FY11	FY12	FY13	FY14	FY15	FY16
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# NSTX Upgrade Project

Subtotal		1,161	23FEB09A	23FEB09A	23SEP13	10OCT13	-13	-19	4,558,906.11		527,589.07	1,594,557.20						
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## Job: 1305 - OHMIC Heating Coil (OH)-CHRZANOWSKI

Subtotal		1,161	23FEB09A	23FEB09A	23SEP13	10OCT13	-13	-19	4,558,906.11		527,589.07	1,594,557.20						
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### Design

1305-0100	Finalize Calcs on OH Flow Optimization	25	24JUN10A	24JUN10A	29JUL10A	29JUL10A	0		0.00	100	0.00	0.00						
1305-0110	Check Flow Rates on Cavitation Issues	10	01SEP10A	01SEP10A	15SEP10A	15SEP10A	0		0.00	100	0.00	0.00						
1305-0120	Analyze Coax Lead Box	193*	30JUL10A	30JUL10A	15DEC10	09MAY11	-97	488	18,784.91	60	10,978.07	18,296.79	EA//EM =100 ;					
1305-0140	Fatigue Assessment	111*	02AUG10A	02AUG10A	14JAN11	14JAN11A	0		3,689.43	100	3,689.43	3,689.43	EA//EM =20 ;					
1305-0180	Calculation write/check & file	150*	17JAN11	04OCT10A	31MAR11	11MAY11	-29	488	19,268.00	75	14,451.00	19,268.00	EA//EM =60 ; EA//EM =40 ;					
1305-0510	Complete Detail & Assembly CAD Drawings	161*	01OCT10*	01OCT10A	26APR11	25MAY11	-21	139	87,437.00	99	86,562.63	87,437.00	EA//SB =700 ;					
1305-0515	OHMIC Heating Coil - Peer review	0				18MAY11*	0	126	0.00		0.00	0.00						
1305-0900	Prepare for FDR	21*	27APR11	19MAY11	10MAY11	17JUN11	-27	126	4,996.40		0.00	1,498.92	EA//SB =40 ;					
1305-0910	R&D for Tooling & For "Aquapour"	175*	01JUN10A	01JUN10A	22NOV10	14FEB11A	-52		53,214.58	100	52,187.32	52,187.32	EA//SB =40 ; EM//ST =244 ; EM//SM =80 ;					
1305-0915	N/R Additional R&D For "Aquapour"	20*	31AUG10A	31AUG10A	31AUG10A	31AUG10A	0		0.00	100	0.00	0.00						
1305-1410	Design TF Quadrant Mold (2)	97*	14FEB11*	14JAN11A	25MAR11	31MAY11	-46	135	14,989.20	85	12,740.82	14,989.20	EA//SB =120 ;					
1305-1430	Design TF Full Mold (3)	30	28MAR11*	01JUN11	06MAY11	13JUL11	-46	303	19,985.60		0.00	16,654.67	EA//SB =160 ;					
1305-1450	Design OH Mold (7)	30	06JUL11*	06JUL11	16AUG11	16AUG11	0	247	19,985.60		0.00	0.00	EA//SB =160 ;					
1305-1470	Design OH Winding Clamps (8)	25	20JUL11*	20JUL11	30AUG11	23AUG11	5	247	9,992.80		0.00	0.00	EA//SB =80 ;					
1305-1490	Design Lifting Beam -conductors & coils (4)	85*	18APR11	10JAN11A	06MAY11	06MAY11	0	135	9,992.80	80	7,994.24	6,661.87	EA//SB =80 ;					
1305-1510	Design Ground Wrap Station (6)	20	07JUN11	07JUN11	05JUL11	05JUL11	0	247	4,996.40		0.00	0.00	EA//SB =40 ;					
1305-1530	Design Tension Unit 99)	20	10AUG11	10AUG11	07SEP11	07SEP11	0	247	9,992.80		0.00	0.00	EA//SB =80 ;					
1305-1550	Design Mold for OH-TF Castable Material (10)	20	24AUG11	24AUG11	05OCT11	21SEP11	10	247	7,494.60		0.00	0.00	EA//SB =60 ;					
1305-1570	Design Braze Station (12)	20	06OCT11	08SEP11	02NOV11	05OCT11	20	247	10,137.64		0.00	0.00	EA//SB =80 ;					
1305-1580	Design Sandblast Station (5)	20	09MAY11	09MAY11	06JUN11	06JUN11	0	135	9,992.80		0.00	0.00	EA//SB =80 ;					
1305-1610	Dsgn OH/TF Facility Area Layout incl CleanRoom-1	193*	20DEC10*	03JAN11A	16FEB11	03OCT11	-160	135	29,993.41	40	11,991.36	29,978.40	EA//SB =240 ;					
1305-1620	Electrical Layout to Support Winding Area (11)	40	04APR11*	02MAY11*	27MAY11	27JUN11	-20	104	37,771.20		0.00	18,885.60	EM//SM =240 ;					

Data Date: 30APR11 1105  
 Run Date: 20MAY11 10:50

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**NSTX UPGRADES  
 RESOURCE LOADED SCHEDULE  
 CD-2 Schedule  
 April 2011**

Sheet 1 of 8

- Early Bar
- Progress Bar
- Critical Activity

Activity ID	Activity Description	Work Days	BASELINE START	Forecast Start	BASELINE FINISH	Forecast Finish	Schedule Slip (Days)	Total Float	Budgeted Cost	PPCT	Earned value cost (BCWP)	Planned value cost (BCWS)	Fiscal Year								
													FY11	FY12	FY13	FY14	FY15	FY16			
1305-1630	Generate Manufacturing Procedures & Travelers	20	03OCT11*	26SEP11*	28OCT11	21OCT11	5	229	0.00		0.00	0.00									
<b>Tooling &amp; Equipment setup</b>																					
1305-4010	Remove NCSX Tooling & Spare Parts from NCSX TC	121*	01JUN11*	10JAN11A	28JUN11	28JUN11	0	103	19,842.00	10	1,984.20	0.00									
1305-4030	Setup Winding Area	40	29JUN11	29JUN11	24AUG11	24AUG11	0	103	59,526.00		0.00	0.00									
1305-4050	Setup Winding Equipment	40	03OCT11*	03OCT11*	29NOV11	29NOV11	0	77	52,219.20		0.00	0.00									
<b>TF/OH Material Procurements</b>																					
1304-3350	Spec-TF conductor stands- tube soldering	10	01SEP11*	01SEP11*	15SEP11	15SEP11	0	58	0.00		0.00	0.00									
1304-3352	Bid/Award TF Conductor Stands for Soldering	30	16SEP11	16SEP11	27OCT11	27OCT11	0	58	0.00		0.00	0.00									
1304-3354	Fab & Del TF Conductor Stands for Soldering	40	28OCT11	28OCT11	03JAN12	03JAN12	0	58	23,856.40		0.00	0.00									
1304-3450	Spec-TF conductor stands- for insulating	20	01SEP11*	01SEP11*	29SEP11	29SEP11	0	155	0.00		0.00	0.00									
1304-3452	Bid/Award TF Conductor Stand for Insulating	30	30SEP11	30SEP11	10NOV11	10NOV11	0	155	0.00		0.00	0.00									
1304-3454	Fab & Del TF Conductor Stands for Insulating	60	11NOV11	11NOV11	14FEB12	14FEB12	0	155	25,800.00		0.00	0.00									
1304-3550	Spec TF Quadrant mold	20	01SEP11*	01SEP11*	29SEP11	29SEP11	0	160	0.00		0.00	0.00									
1304-3552	Bid/Award-TF Quadrant Mold	30	30SEP11	30SEP11	10NOV11	10NOV11	0	160	0.00		0.00	0.00									
1304-3554	Fab & Deliver TF Quadrant Mold	60	11NOV11	11NOV11	14FEB12	14FEB12	0	160	107,706.40		0.00	0.00									
1304-3600	Spec - TF Full coil mold	20	01MAR12*	01MAR12*	28MAR12	28MAR12	0	147	0.00		0.00	0.00									
1304-3602	Bid/Award TF Full Coil Mold	30	29MAR12	29MAR12	09MAY12	09MAY12	0	147	0.00		0.00	0.00									
1304-3604	Fab & Deliver Full TF Coil Mold	60	10MAY12	10MAY12	03AUG12	03AUG12	0	147	127,056.40		0.00	0.00									
1304-3700	Spec - VPI delivery system	20	01SEP11*	01SEP11*	29SEP11	29SEP11	0	170	0.00		0.00	0.00									
1304-3702	Bid/Award VPI Delivery System	30	30SEP11	30SEP11	10NOV11	10NOV11	0	170	0.00		0.00	0.00									
1304-3704	Fab & Deliver VPI Delivery System	60	11NOV11	11NOV11	14FEB12	14FEB12	0	170	43,206.40		0.00	0.00									
1304-3800	Spec - Lift beam- conductor	20	01SEP11*	01SEP11*	29SEP11	29SEP11	0	203	0.00		0.00	0.00									
1304-3802	Bid/Award Lift Beam Conductor	30	30SEP11	30SEP11	10NOV11	10NOV11	0	203	0.00		0.00	0.00									
1304-3804	Fab & Deliver Lift Beam for Conductor	40	11NOV11	11NOV11	17JAN12	17JAN12	0	203	28,053.20		0.00	0.00									
1304-3900	Spec - Lift Beam for coil	20	26SEP11*	01SEP11*	21OCT11	29SEP11	16	175	0.00		0.00	0.00									
1304-3902	Bid/Award - Lift Beam for Coil	30	24OCT11	30SEP11	06DEC11	10NOV11	16	175	0.00		0.00	0.00									
1304-3904	Fab & deliver Lift Beam for Coil	40	07DEC11	11NOV11	08FEB12	17JAN12	16	175	40,953.20		0.00	0.00									
1305-1900	Spec- Taping machines [2]	20	02JUL12*	02JUL12*	30JUL12	30JUL12	0	84	0.00		0.00	0.00									
1305-1902	Bid/Award - Taping Machines	30	31JUL12	31JUL12	11SEP12	11SEP12	0	84	0.00		0.00	0.00									
1305-1904	Fab & Deliver Taping Machines	60	01OCT12*	01OCT12*	03JAN13	03JAN13	0	71	33,000.00		0.00	0.00									
1305-2000	Spec- Tension unit	20	02JUL12*	02JUL12*	30JUL12	30JUL12	0	84	0.00		0.00	0.00									

Activity ID	Activity Description	Work Days	BASELINE START	Forecast Start	BASELINE FINISH	Forecast Finish	Schedule Slip (Days)	Total Float	Budgeted Cost	PPCT	Earned value cost (BCWP)	Planned value cost (BCWS)							
													FY11	FY12	FY13	FY14	FY15	FY16	
1305-2002	Bid/Award Tension Unit	30	31JUL12	31JUL12	11SEP12	11SEP12	0	84	0.00		0.00	0.00							
1305-2004	Fab & Deliver Tension Unit	60	01OCT12*	01OCT12*	03JAN13	03JAN13	0	71	35,416.00		0.00	0.00							
1305-2100	Spec-Braze unit	20	01JUN12*	01JUN12*	28JUN12	28JUN12	0	85	0.00		0.00	0.00							
1305-2102	Bid/Award Braze Station	30	29JUN12	29JUN12	10AUG12	10AUG12	0	85	0.00		0.00	0.00							
1305-2104	Fab & Deliver Braze Station	80	13AUG12	13AUG12	05DEC12	05DEC12	0	85	130,725.00		0.00	0.00							
1305-2200	Spec-Braze fixture and work coil	20	02JUL12*	02JUL12*	30JUL12	30JUL12	0	84	0.00		0.00	0.00							
1305-2210	Bid/Award Braze Fixture for Work Coil	30	31JUL12	31JUL12	11SEP12	11SEP12	0	84	0.00		0.00	0.00							
1305-2220	Fab & Deliver Braze Fixture for Work Coil	60	01OCT12*	01OCT12*	03JAN13	03JAN13	0	71	26,529.60		0.00	0.00							
1305-2300	Spec Winding machine for OH	20	03JAN12*	03JAN12*	30JAN12	30JAN12	0	162	0.00		0.00	0.00							
1305-2310	Bid/Award Winding Machine for OH	60	31JAN12	31JAN12	23APR12	23APR12	0	162	0.00		0.00	0.00							
1305-2320	Fab & Deliver Winding Machine for OH	80	24APR12	24APR12	15AUG12	15AUG12	0	162	161,250.00		0.00	0.00							
1305-2400	Spec - Mold for OH-TF spacer [Aquapour]	20	26SEP11*	01SEP11*	21OCT11	29SEP11	16	291	0.00		0.00	0.00							
1305-2410	Bid/Award Mold for OH-TF Spacer	30	24OCT11	30SEP11	06DEC11	10NOV11	16	291	0.00		0.00	0.00							
1305-2420	Fab & Deliver Mold for OH-TF Spacer	60	07DEC11	11NOV11	07MAR12	14FEB12	16	291	12,900.00		0.00	0.00							
1305-2500	Spec - OH winding clamps- 4-sets	20	26SEP11*	01SEP11*	21OCT11	29SEP11	16	291	0.00		0.00	0.00							
1305-2510	Bid/Award OH Winding Clamps - 4 sets	30	24OCT11	30SEP11	06DEC11	10NOV11	16	291	0.00		0.00	0.00							
1305-2520	Fab & Deliver OH Winding Clamps 4 sets	60	07DEC11	11NOV11	07MAR12	14FEB12	16	291	25,800.00		0.00	0.00							
1305-2600	Spec - OH Mold	20	01MAY12*	01JUN12*	29MAY12	28JUN12	-22	85	0.00		0.00	0.00							
1305-2610	Bid/Award OH Mold	30	30MAY12	29JUN12	11JUL12	10AUG12	-22	85	0.00		0.00	0.00							
1305-2620	Fab & Deliver OH Mold	80	12JUL12	13AUG12*	01NOV12	05DEC12	-22	85	128,733.33		0.00	0.00							
1305-2650	Spec SandBlast Unit	20	26SEP11*	01SEP11*	21OCT11	29SEP11	16	100	0.00		0.00	0.00							
1305-2652	Bid/Award Sanblast Unit	30	24OCT11	30SEP11	06DEC11	10NOV11	16	100	0.00		0.00	0.00							
1305-2654	Fab & Deliver Sandblast Unit	80	07DEC11	11NOV11	04APR12	13MAR12	16	100	32,404.80		0.00	0.00							
1305-2700	Miscellaneous tools & fixtures	20	26SEP11*	01SEP11*	21OCT11	29SEP11	16	271	0.00		0.00	0.00							
1305-2702	Bid/Award Misc Tools & Fixtures	30	24OCT11	30SEP11	06DEC11	10NOV11	16	271	0.00		0.00	0.00							
1305-2704	Fab & deliver Misc Tools & Fixtures	80	07DEC11	11NOV11	04APR12	13MAR12	16	271	60,612.80		0.00	0.00							
1305-2800	Spec - "Aquapour"- castable material	20	26SEP11*	01SEP11*	21OCT11	29SEP11	16	291	0.00		0.00	0.00							
1305-2802	Bid/Award Aquapour	30	24OCT11	30SEP11	06DEC11	10NOV11	16	291	0.00		0.00	0.00							
1305-2820	Fab & Deliver Aquapour	60	07DEC11	11NOV11	07MAR12	14FEB12	16	291	12,900.00		0.00	0.00							
1305-2900	Spec-Insulation [fiberg tape, teflon and gnd p	20	26SEP11*	01SEP11*	21OCT11	29SEP11	16	155	0.00		0.00	0.00							

Activity ID	Activity Description	Work Days	BASELINE START	Forecast Start	BASELINE FINISH	Forecast Finish	Schedule Slip (Days)	Total Float	Budgeted Cost	PPCT	Earned value cost (BCWP)	Planned value cost (BCWS)									
													FY11	FY12	FY13	FY14	FY15	FY16			
1305-2902	Bid/Award - Insulation	30	24OCT11	30SEP11	06DEC11	10NOV11	16	155	0.00		0.00	0.00									
1305-2904	Fab & Deliver Insulation	60	07DEC11	11NOV11	07MAR12	14FEB12	16	155	25,800.00		0.00	0.00									
1305-3000	Epoxy- CTD-101	20	26SEP11*	01SEP11*	21OCT11	29SEP11	16	155	0.00		0.00	0.00									
1305-3002	Bid/Award Epoxy-CTD-101	30	24OCT11	30SEP11	06DEC11	10NOV11	16	155	0.00		0.00	0.00									
1305-3004	Fab & Deliver Epoxy-CTD-101	60	07DEC11	11NOV11	07MAR12	14FEB12	16	155	19,350.00		0.00	0.00									
1305-3100	Spec-Copper pre-tinned tubing [TF conductor]	20	26SEP11*	01SEP11*	21OCT11	29SEP11	16	58	0.00		0.00	0.00									
1305-3102	Bid/Award Copper pre-tinned tubing	30	24OCT11	30SEP11	06DEC11	10NOV11	16	58	0.00		0.00	0.00									
1305-3104	Fab & Deliver pre-tinned tubing	30	07DEC11	11NOV11	25JAN12	03JAN12	16	58	6,450.00		0.00	0.00									
1305-3200	G-10 Filler modifications	40	03OCT11*	03OCT11*	29NOV11	29NOV11	0	204	17,608.50		0.00	0.00									
1305-3300	Req/Order - Conductor primer	20	26SEP11*	08SEP11*	21OCT11	05OCT11	12	206	0.00		0.00	0.00									
1305-3310	Fab & Deliver Conductor Primer	40	24OCT11	06OCT11	20DEC11	02DEC11	12	206	2,580.00		0.00	0.00									
1305-3400	Req/Order-Safety and PPE equipment and supplies	20	26SEP11*	01SEP11*	21OCT11	29SEP11	16	58	0.00		0.00	0.00									
1305-3410	Fab & Deliver Safety & PPE	40	24OCT11	30SEP11	20DEC11	28NOV11	16	58	6,446.25		0.00	0.00									
1305-3500	Req/Order Miscellaneous supplies	30	26SEP11*	01SEP11*	04NOV11	13OCT11	16	175	0.00		0.00	0.00									
1305-3510	Fab & Deliver Misc Supplies	60	07NOV11	14OCT11	08FEB12	17JAN12	16	175	25,800.00		0.00	0.00									
1305-3600	Req/OrderRTV and silicone caulk for mold sealing	20	26SEP11*	01SEP11*	21OCT11	29SEP11	16	225	0.00		0.00	0.00									
1305-3610	Fab & Deliver RTV & Silcone for Mold Sealing	20	24OCT11	30SEP11	18NOV11	27OCT11	16	225	6,442.50		0.00	0.00									
1305-3700	Specify-valves & fittinngs (VPI Disposables)	20	26SEP11*	01SEP11*	21OCT11	29SEP11	16	175	0.00		0.00	0.00									
1305-3710	Bid/Awad-Valves & Fittings (VPI)	30	24OCT11	30SEP11	06DEC11	10NOV11	16	175	0.00		0.00	0.00									
1305-3720	Fab & Deliver Valves-Fittings (VPI)	40	07DEC11	11NOV11	08FEB12	17JAN12	16	175	12,900.00		0.00	0.00									
1305-3800	spec-High &Low Temp Vac Tubing (VPI)	20	03OCT11*	03OCT11*	28OCT11	28OCT11	0	154	0.00		0.00	0.00									
1305-3810	Bid/Award High & Low Temp Vac Tubing (VPI)	30	31OCT11	31OCT11	13DEC11	13DEC11	0	154	0.00		0.00	0.00									
1305-3820	Fab & deliver High & Low Temp Vac Tube (VPI)	40	14DEC11	14DEC11	15FEB12	15FEB12	0	154	12,900.00		0.00	0.00									
1305-3900	Fabricate - VPI manifolds	40	03OCT11*	03OCT11*	29NOV11	29NOV11	0	204	28,208.00		0.00	0.00									
<b>OH Conductor &amp; Other Hardware</b>																					
1305-0920	Generate SOW for OH Conductor	20	16JUL12*	16JUL12*	10AUG12	10AUG12	0	60	0.00		0.00	0.00									
1305-0930	Prep Requisition & Submit to Procurement	5	13AUG12	13AUG12	17AUG12	17AUG12	0	60	0.00		0.00	0.00									
1305-0940	Bid & Award OH Conductor Fabrication	30	20AUG12	20AUG12	01OCT12	01OCT12	0	60	0.00		0.00	0.00									
1305-0950	Manufacture OH Copper Conductor	70	02OCT12	02OCT12	18JAN13	18JAN13	0	60	139,392.00		0.00	0.00									
1305-0960	Generate Requisition for Kapton/Glass Insulation	5	13AUG12*	13AUG12*	17AUG12	17AUG12	0	80	1,380.64		0.00	0.00									
1305-0980	Bid & Award Kapton/Glass Insulation	30	20AUG12	20AUG12	01OCT12	01OCT12	0	80	0.00		0.00	0.00									

Activity ID	Activity Description	Work Days	BASELINE START	Forecast Start	BASELINE FINISH	Forecast Finish	Schedule Slip (Days)	Total Float	Budgeted Cost	PPCT	Earned value cost (BCWP)	Planned value cost (BCWS)	FY11	FY12	FY13	FY14	FY15	FY16		
1305-1000	Fab & Deliver Kapton/Glass Insulation	50	02OCT12	02OCT12	12DEC12	12DEC12	0	80	34,412.64		0.00	0.00			EM//SM =08 ; 41=25,000 ;					
1305-1010	Prep Requisition for Belleville Washer Assembly	10	13AUG12*	13AUG12*	24AUG12	24AUG12	0	75	0.00		0.00	0.00								
1305-1030	Bid & Award Belleville Washer Assembly	30	27AUG12	27AUG12	08OCT12	08OCT12	0	75	0.00		0.00	0.00								
1305-1050	Fab & Deliver Belleville Washer Assembly	50	09OCT12	09OCT12	19DEC12	19DEC12	0	75	46,200.00		0.00	0.00			EM//SM =41=35,000 ;					
1305-1060	Prepare Requisition for G-10 Fillers	10	13AUG12*	13AUG12*	24AUG12	24AUG12	0	65	0.00		0.00	0.00								
1305-1080	Bid & Award G-10 Fillers	30	27AUG12	27AUG12	08OCT12	08OCT12	0	65	0.00		0.00	0.00								
1305-1100	Fab & Deliver G-10 Filers	60	09OCT12	09OCT12	11JAN13	11JAN13	0	65	46,200.00		0.00	0.00			EM//SM =41=35,000 ;					
1305-1110	Prep Requisition for Lead Blocks & Cooling Fitti	10	13AUG12*	13AUG12*	24AUG12	24AUG12	0	45	0.00		0.00	0.00								
1305-1130	Bid & Award Lead Blocks & Cooling Fittings	30	27AUG12	27AUG12	08OCT12	08OCT12	0	45	0.00		0.00	0.00								
1305-1150	Fab & Deliver Lead Blocks & Cooling Fittings	80	09OCT12	09OCT12	08FEB13	08FEB13	0	45	39,600.00		0.00	0.00			EM//SM =41=30,000 ;					
1305-1160	Prep Requisition for Misc Parts	10	20AUG12*	20AUG12*	31AUG12	31AUG12	0	60	0.00		0.00	0.00								
1305-1180	Bid & Award Misc Parts	30	04SEP12	04SEP12	15OCT12	15OCT12	0	60	0.00		0.00	0.00								
1305-1200	Fab & Deliver Misc Parts	60	16OCT12	16OCT12	18JAN13	18JAN13	0	60	19,800.00		0.00	0.00			EM//SM =41=15,000 ;					
1305-1210	Prep Requisition for OH Lwr Lead & Suppt Struct	10	20AUG12*	20AUG12*	31AUG12	31AUG12	0	60	0.00		0.00	0.00								
1305-1230	Bid & Award OH Lwr Lead & Supt Struct	30	04SEP12	04SEP12	15OCT12	15OCT12	0	60	0.00		0.00	0.00								
1305-1250	Fab & deliver OH Lwr Lead & Suppt Struct	60	16OCT12	16OCT12	18JAN13	18JAN13	0	60	33,000.00		0.00	0.00			EM//SM =41=25,000 ;					
<b>Inner TF Conductor Receipt/Inspection/Prep</b>																				
1304-1310	Inspect Machined TF Conductors	20	06MAR12	23MAR12	02APR12	19APR12	-13	-19	34,812.80		0.00	0.00			EM//ST =320 ;					
1304-1330	Solder TF cooling tubes [40 conductors]	72	03APR12	20APR12	13JUL12	01AUG12	-13	-19	125,326.08		0.00	0.00			EM//ST =1,152 ;					
1304-1340	Cleanup TF conductors- post solder	60	17MAY12	06JUN12	10AUG12	29AUG12	-13	-19	69,625.60		0.00	0.00			EM//ST =640 ;					
1304-1350	Sandblast TF conductor length for primer	40	13AUG12	30AUG12	08OCT12	25OCT12	-13	-19	70,321.76		0.00	0.00			EM//ST =640 ;					
1304-1360	Apply primer [40 TF conductors]	5	09OCT12	26OCT12	15OCT12	01NOV12	-13	-19	8,886.40		0.00	0.00			EM//ST =80 ;					
<b>Inner TF Quadrant 1</b>																				
1304-1510	Supervise TF/OH Coil Manufacturing	240	02OCT12	19OCT12	19SEP13	08OCT13	-13	-18	212,064.00		0.00	0.00			EM//SM =1,200 ;					
1304-1520	Apply turn insulation Quadrant #1	5	02OCT12	19OCT12	08OCT12	25OCT12	-13	-19	17,772.80		0.00	0.00			EM//ST =160 ;					
1304-1530	Assemble Quadrant #1	10	09OCT12	26OCT12	22OCT12	08NOV12	-13	-19	44,432.00		0.00	0.00			EM//ST =400 ;					
1304-1540	Prepare VPI operation	3	23OCT12	09NOV12	25OCT12	13NOV12	-13	-19	10,663.68		0.00	0.00			EM//ST =96 ;					
1304-1550	VPI- fill quadrant	2	26OCT12	14NOV12	29OCT12	15NOV12	-13	-19	7,109.12		0.00	0.00			EM//ST =64 ;					
1304-1560	Cure VPI'd coil	8	30OCT12	16NOV12	08NOV12	29NOV12	-13	-19	7,109.12		0.00	0.00			EM//ST =64 ;					
1304-1570	Remove Quadrant #1 from mold	1	09NOV12	30NOV12	09NOV12	30NOV12	-13	-19	3,554.56		0.00	0.00			EM//ST =32 ;					
1304-1580	Cleanup quadrant	2	12NOV12	03DEC12	13NOV12	04DEC12	-13	-19	3,554.56		0.00	0.00			EM//ST =32 ;					

Activity ID	Activity Description	Work Days	BASELINE START	Forecast Start	BASELINE FINISH	Forecast Finish	Schedule Slip (Days)	Total Float	Budgeted Cost	PPCT	Earned value cost (BCWP)	Planned value cost (BCWS)	FY11	FY12	FY13	FY14	FY15	FY16			
1304-1590	Perform T/T electrical tests	1	14NOV12	05DEC12	14NOV12	05DEC12	-13	-19	1,777.28		0.00	0.00				EM//ST =16 ;					
<b>Inner TF Quadrant 2</b>																					
1304-1620	Apply turn insulation Quadrant #2	5	15NOV12	06DEC12	21NOV12	12DEC12	-13	-19	17,772.80		0.00	0.00				EM//ST =160 ;					
1304-1630	Assemble Quadrant #2	5	26NOV12	13DEC12	30NOV12	19DEC12	-13	-19	22,216.00		0.00	0.00				EM//ST =200 ;					
1304-1640	Prepare VPI operation	3	03DEC12	20DEC12	05DEC12	02JAN13	-13	-19	10,663.68		0.00	0.00				EM//ST =96 ;					
1304-1650	VPI- fill quadrant	2	06DEC12	03JAN13	07DEC12	04JAN13	-13	-19	7,109.12		0.00	0.00				EM//ST =64 ;					
1304-1660	Cure VPI'd coil	8	10DEC12	07JAN13	19DEC12	16JAN13	-13	-19	7,109.12		0.00	0.00				EM//ST =64 ;					
1304-1670	Remove Quadrant #2 from mold	1	20DEC12	17JAN13	20DEC12	17JAN13	-13	-19	3,554.56		0.00	0.00				EM//ST =32 ;					
1304-1680	Cleanup quadrant	2	21DEC12	18JAN13	02JAN13	21JAN13	-13	-19	3,554.56		0.00	0.00				EM//ST =32 ;					
1304-1690	Perform T/T electrical tests	1	03JAN13	22JAN13	03JAN13	22JAN13	-13	-19	1,777.28		0.00	0.00				EM//ST =16 ;					
<b>Inner TF Quadrant 3</b>																					
1304-1720	Apply turn insulation Quadrant #3	5	04JAN13	23JAN13	10JAN13	29JAN13	-13	-19	17,772.80		0.00	0.00				EM//ST =160 ;					
1304-1730	Assemble Quadrant #3	5	11JAN13	30JAN13	17JAN13	05FEB13	-13	-19	22,216.00		0.00	0.00				EM//ST =200 ;					
1304-1740	Prepare VPI operation	3	18JAN13	06FEB13	22JAN13	08FEB13	-13	-19	10,663.68		0.00	0.00				EM//ST =96 ;					
1304-1750	VPI- fill quadrant	2	23JAN13	11FEB13	24JAN13	12FEB13	-13	-19	7,109.12		0.00	0.00				EM//ST =64 ;					
1304-1760	Cure VPI'd coil	8	25JAN13	13FEB13	05FEB13	22FEB13	-13	-19	7,109.12		0.00	0.00				EM//ST =64 ;					
1304-1770	Remove Quadrant #3 from mold	1	06FEB13	25FEB13	06FEB13	25FEB13	-13	-19	3,554.56		0.00	0.00				EM//ST =32 ;					
1304-1780	Cleanup quadrant	2	07FEB13	26FEB13	08FEB13	27FEB13	-13	-19	3,554.56		0.00	0.00				EM//ST =32 ;					
1304-1790	Perform T/T electrical tests #4	1	11FEB13	28FEB13	11FEB13	28FEB13	-13	-19	1,777.28		0.00	0.00				EM//ST =16 ;					
<b>Inner TF Quadrant 4</b>																					
1304-1820	Apply turn insulation Quadrant #4	5	12FEB13	01MAR13	18FEB13	07MAR13	-13	-19	17,772.80		0.00	0.00				EM//ST =160 ;					
1304-1830	Assemble Quadrant #4	5	19FEB13	08MAR13	25FEB13	14MAR13	-13	-19	22,216.00		0.00	0.00				EM//ST =200 ;					
1304-1840	Prepare VPI operation	3	26FEB13	15MAR13	28FEB13	19MAR13	-13	-19	10,663.68		0.00	0.00				EM//ST =96 ;					
1304-1850	VPI- fill quadrant	2	01MAR13	20MAR13	04MAR13	21MAR13	-13	-19	7,109.12		0.00	0.00				EM//ST =64 ;					
1304-1860	Cure VPI'd coil	8	05MAR13	22MAR13	14MAR13	02APR13	-13	-19	7,109.12		0.00	0.00				EM//ST =64 ;					
1304-1870	Remove Quadrant #4 from mold	1	15MAR13	03APR13	15MAR13	03APR13	-13	-19	3,554.56		0.00	0.00				EM//ST =32 ;					
1304-1880	Cleanup quadrant	2	18MAR13	04APR13	19MAR13	05APR13	-13	-19	3,554.56		0.00	0.00				EM//ST =32 ;					
1304-1890	Perform T/T electrical tests	1	20MAR13	08APR13	20MAR13	08APR13	-13	-19	1,777.28		0.00	0.00				EM//ST =16 ;					
<b>Inner TF Coil Assemble Quadrants</b>																					
1304-4800	Assemble quadrants together	5	21MAR13	09APR13	27MAR13	15APR13	-13	-19	22,216.00		0.00	0.00				EM//ST =200 ;					
1304-4900	Apply groundwrap insulation	2	28MAR13	16APR13	29MAR13	17APR13	-13	-19	3,554.56		0.00	0.00				EM//ST =32 ;					

Activity ID	Activity Description	Work Days	BASELINE START	Forecast Start	BASELINE FINISH	Forecast Finish	Schedule Slip (Days)	Total Float	Budgeted Cost	PPCT	Earned value cost (BCWP)	Planned value cost (BCWS)	FY11	FY12	FY13	FY14	FY15	FY16	
1304-5000	Prepare VPI operation	3	01APR13	18APR13	03APR13	22APR13	-13	-19	10,663.68		0.00	0.00							EM//ST =96 ;
1304-5100	VPI full TF coil	2	04APR13	23APR13	05APR13	24APR13	-13	-19	7,109.12		0.00	0.00							EM//ST =64 ;
1304-5200	Cure VPI'd coil	8	08APR13	25APR13	17APR13	06MAY13	-13	-19	7,109.12		0.00	0.00							EM//ST =64 ;
1304-5300	Remove full TF from mold and cleanup	1	18APR13	07MAY13	18APR13	07MAY13	-13	-19	1,777.28		0.00	0.00							EM//ST =16 ;
1304-5400	Perform Final electrical tests	1	19APR13	08MAY13	19APR13	08MAY13	-13	-19	1,777.28		0.00	0.00							EM//ST =16 ;
1304-5500	Transfer TF to OH station	1	22APR13	09MAY13	22APR13	09MAY13	-13	-19	4,443.20		0.00	0.00							EM//ST =40 ;
<b>TF/OH Fabrication</b>																			
1305-5600	Prepare TF for OH winding	5	23APR13	10MAY13	29APR13	16MAY13	-13	-19	13,329.60		0.00	0.00							EM//ST =120 ;
1305-5700	Install intermediate spacer between OH/TF bundle	8	30APR13	17MAY13	09MAY13	29MAY13	-13	-19	21,327.36		0.00	0.00							EM//ST =192 ;
1305-5800	Apply slip plane, and inner groundwall insulatio	2	10MAY13	30MAY13	13MAY13	31MAY13	-13	-19	3,554.56		0.00	0.00							EM//ST =32 ;
1305-5900	Braze first lead and prepare for winding	5	14MAY13	03JUN13	20MAY13	07JUN13	-13	-19	8,886.40		0.00	0.00							EM//ST =80 ;
1305-6000	Wind 1st half of layer #1	5	21MAY13	10JUN13	28MAY13	14JUN13	-13	-19	13,329.60		0.00	0.00							EM//ST =120 ;
1305-6100	Make [2] in-line brazes	1	29MAY13	17JUN13	29MAY13	17JUN13	-13	-19	1,777.28		0.00	0.00							EM//ST =16 ;
1305-6200	Wind second half of layer #1	5	30MAY13	18JUN13	05JUN13	24JUN13	-13	-19	13,329.60		0.00	0.00							EM//ST =120 ;
1305-6300	Perform prelim electrical tests	1	06JUN13	25JUN13	06JUN13	25JUN13	-13	-19	1,777.28		0.00	0.00							EM//ST =16 ;
1305-6400	Braze layer to layer joint	1	07JUN13	26JUN13	07JUN13	26JUN13	-13	-19	1,777.28		0.00	0.00							EM//ST =16 ;
1305-6500	Wind 1st half of layer #2	5	10JUN13	27JUN13	14JUN13	03JUL13	-13	-19	13,329.60		0.00	0.00							EM//ST =120 ;
1305-6600	Make [2] in-line brazes	1	17JUN13	08JUL13	17JUN13	08JUL13	-13	-19	1,777.28		0.00	0.00							EM//ST =16 ;
1305-6700	Wind second half of layer #2	5	18JUN13	09JUL13	24JUN13	15JUL13	-13	-19	13,329.60		0.00	0.00							EM//ST =120 ;
1305-6800	Perform prelim electrical tests	1	25JUN13	16JUL13	25JUN13	16JUL13	-13	-19	1,777.28		0.00	0.00							EM//ST =16 ;
1305-6900	Braze layer to layer joint	1	26JUN13	17JUL13	26JUN13	17JUL13	-13	-19	1,777.28		0.00	0.00							EM//ST =16 ;
1305-7000	Wind 1st half of layer #3	5	27JUN13	18JUL13	03JUL13	24JUL13	-13	-19	13,329.60		0.00	0.00							EM//ST =120 ;
1305-7100	Make [2] in-line brazes	1	08JUL13	25JUL13	08JUL13	25JUL13	-13	-19	1,777.28		0.00	0.00							EM//ST =16 ;
1305-7200	Wind second half of layer #3	5	09JUL13	26JUL13	15JUL13	01AUG13	-13	-19	13,329.60		0.00	0.00							EM//ST =120 ;
1305-7300	Perform prelim electrical tests	1	16JUL13	02AUG13	16JUL13	02AUG13	-13	-19	1,777.28		0.00	0.00							EM//ST =16 ;
1305-7400	Braze layer to layer joint	2	17JUL13	05AUG13	18JUL13	06AUG13	-13	-19	1,777.28		0.00	0.00							EM//ST =16 ;
1305-7500	Wind 1st half of layer #4	5	19JUL13	07AUG13	25JUL13	13AUG13	-13	-19	13,329.60		0.00	0.00							EM//ST =120 ;
1305-7600	Make [2] in-line brazes	1	26JUL13	14AUG13	26JUL13	14AUG13	-13	-19	1,777.28		0.00	0.00							EM//ST =16 ;
1305-7700	Wind second half of layer #4	5	29JUL13	15AUG13	02AUG13	21AUG13	-13	-19	13,329.60		0.00	0.00							EM//ST =120 ;
1305-7800	Apply groundwrap insulation	1	05AUG13	22AUG13	05AUG13	22AUG13	-13	-19	1,777.28		0.00	0.00							EM//ST =16 ;
1305-7900	Mount OH mold around coil	5	06AUG13	23AUG13	12AUG13	29AUG13	-13	-19	17,772.80		0.00	0.00							EM//ST =160 ;



Activity ID	Activity Description	Work Days	BASELINE START	Forecast Start	BASELINE FINISH	Forecast Finish	Schedule Slip (Days)	Total Float	Budgeted Cost	PPCT	Earned value cost (BCWP)	Planned value cost (BCWS)	FY11 FY12 FY13 FY14 FY15 FY16					
													FY11	FY12	FY13	FY14	FY15	FY16
1305-8000	Prepare VPI operation	3	13AUG13	30AUG13	15AUG13	04SEP13	-13	-19	10,663.68		0.00	0.00					EM//ST =96 ;	
1305-8100	VPI- mold	2	16AUG13	05SEP13	19AUG13	06SEP13	-13	-19	7,109.12		0.00	0.00					EM//ST =64 ;	
1305-8200	Cure VPI'd coil	8	20AUG13	09SEP13	29AUG13	18SEP13	-13	-19	7,109.12		0.00	0.00					EM//ST =64 ;	
1305-8300	Remove mold from OH coil	1	30AUG13	19SEP13	30AUG13	19SEP13	-13	-19	3,554.56		0.00	0.00					EM//ST =32 ;	
1305-8400	Cleanup OH coil	2	03SEP13	20SEP13	04SEP13	23SEP13	-13	-19	3,554.56		0.00	0.00					EM//ST =32 ;	
1305-8500	Silverplate all electrical surfaces [OH/TF]	3	05SEP13	24SEP13	09SEP13	26SEP13	-13	-19	2,665.92		0.00	0.00					EM//ST =24 ;	
1305-8600	Perform Final OH electrical tests	1	10SEP13	27SEP13	10SEP13	27SEP13	-13	-19	1,777.28		0.00	0.00					EM//ST =16 ;	
1305-8700	Remove intermediate spacer between OH and TF bun	5	11SEP13	30SEP13	17SEP13	04OCT13	-13	-19	13,690.56		0.00	0.00					EM//ST =120 ;	
1305-8800	Perform hydrostat and flow tests- OH/TF coils	3	18SEP13	07OCT13	20SEP13	09OCT13	-13	-19	5,512.32		0.00	0.00					EM//ST =48 ;	
1305-8900	Transport to CS assembly station	1	23SEP13	10OCT13	23SEP13	10OCT13	-13	-19	4,593.60		0.00	0.00					EM//ST =40 ;	
<b>OH TIG Braze Test CSU R&amp;D Plan</b>																		
1303-000G	7.1 Layer t/ LayerBraze Tst after Conductor Proc	1	01OCT10*	19OCT12*	01OCT10	19OCT12	-513	116	0.00		0.00	0.00						
<b>OH Conductor Brazes CSU R&amp;D Plan</b>																		
1303-000H	8.1 Inline Braze Test after Conductor Procurement	1	01OCT10*	19OCT12*	01OCT10	19OCT12	-513	116	0.00		0.00	0.00						
<b>OH-TF Spacer Test CSU R&amp;D Test</b>																		
1303-000I	9.1 Test MTRL/Process f/Manufactg to 0.1" Gap	1	01OCT10*	19OCT12*	01OCT10	19OCT12	-513	116	0.00		0.00	0.00						
FY091310	FY09 Actual Cost	22*	23FEB09A	23FEB09A	30SEP09A	30SEP09A	0		1,051,480.00	100	051,480.00	1,051,480.00						
FY091315	FY09 Actual Cost	22*	23FEB09A	23FEB09A	30SEP09A	30SEP09A	0		4,085.00	100	4,085.00	4,085.00						
FY101305	FY10 Actual Cost	85	01JAN10A	01JAN10A	30APR10A	30APR10A	0		168,034.00	100	168,034.00	168,034.00						
FY101305A	FY10 Actual Cost	110	03MAY10A	03MAY10A	30SEP10A	30SEP10A	0		101,411.00	100	101,411.00	101,411.00	81=103106					





1305 Ohmic Heating Coil (Chrzanowski)	31JAN2011	28FEB2011	31MAR2011	30APR2011	31MAY2011	30JUN2011	31JUL2011	31AUG2011	30SEP2011	31OCT2011	30NOV2011	31DEC2011
BCWS	34	35	35	52	37	29	46	51	8	64	122	166
CUM BCWS	1,473	1,508	1,542	1,595	1,632	1,661	1,706	1,757	1,765	1,829	1,950	2,116
BCWP	41	13	7	12	0	0	0	0	0	0	0	0
CUM BCWP	1,496	1,509	1,516	1,527	1,527	1,527	1,527	1,527	1,527	1,527	1,527	1,527
ACWP	42	54	43	26	0	0	0	0	0	0	0	0
CUM ACWP	1,504	1,558	1,601	1,626	1,626	1,626	1,626	1,626	1,626	1,626	1,626	1,626
CV	-8	-49	-85	-99	-99	-99	-99	-99	-99	-99	-99	-99
SV	23.	1.	-27.	-67.	-104.	-133.	-179.	-230.	-237.	-301.	-423.	-589.
CPI	.99	.97	.95	.94	.94	.94	.94	.94	.94	.94	.94	.94
SPI	1.02	1	0.98	0.96	0.94	0.92	0.89	0.87	0.87	0.84	0.78	0.72

1305 Ohmic Heating Coil (Chrzanowski)	31JAN2012	29FEB2012	31MAR2012	30APR2012	31MAY2012	30JUN2012	31JUL2012	31AUG2012	30SEP2012	31OCT2012	30NOV2012	31DEC2012
BCWS	165	92	64	49	129	143	152	123	96	321	254	176
CUM BCWS	2,281	2,373	2,437	2,486	2,615	2,759	2,911	3,034	3,130	3,451	3,705	3,881
BCWP	0	0	0	0	0	0	0	0	0	0	0	0
CUM BCWP	1,527	1,527	1,527	1,527	1,527	1,527	1,527	1,527	1,527	1,527	1,527	1,527
ACWP	0	0	0	0	0	0	0	0	0	0	0	0
CUM ACWP	1,626	1,626	1,626	1,626	1,626	1,626	1,626	1,626	1,626	1,626	1,626	1,626
CV	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99
SV	-754.	-846.	-910.	-959.	-1088.	-1231.	-1383.	-1506.	-1603.	-1924.	-2178.	-2354.
CPI	.94	.94	.94	.94	.94	.94	.94	.94	.94	.94	.94	.94
SPI	0.67	0.64	0.63	0.61	0.58	0.55	0.52	0.5	0.49	0.44	0.41	0.39



## Annex I – WBS Dictionary

This Work Breakdown Structure (WBS) organizes and defines the scope of the NSTX Upgrade using the WBS as established by the original NSTX project and modified to accommodate the NSTX Upgrade.

<u>WBS</u>			
<u>L1</u>	<u>L2</u>	<u>L3</u>	<u>Description</u>
1			<b>NSTX UPGRADE PROJECT</b>
	<b>1.1</b>		<b>Torus Systems</b>
		1.1.0	Project Integrated Model
		1.1.1	Plasma Facing Components
		1.1.2	Vacuum Vessel and Support Structure
		1.1.3	Magnet Systems
	<b>1.2</b>		<b>Plasma Heating and Current Drive Systems</b>
		1.2.1	High Harmonic Fast Wave (HHFW)
		1.2.2	Coaxial Helicity Injection (CHI) Current Drive
		1.2.3	Electron Cyclotron Heating (ECH)
		1.2.4	Neutral Beam Injection (NBI)
	<b>1.3</b>		<b>Auxiliary Systems</b>
		1.3.1	Vacuum Pumping System
		1.3.2	Coolant Systems
		1.3.3	Bakeout Heating System
		1.3.4	Gas Delivery System
		1.3.5	Glow Discharge Cleaning System
	<b>1.4</b>		<b>Plasma Diagnostics</b>
		1.4.1	Plasma Diagnostics
	<b>1.5</b>		<b>Power Systems</b>
		1.5.1	AC Power Systems
		1.5.2	AC/DC Converters
		1.5.3	DC Systems
		1.5.4	Control and Protection System
		1.5.5	General Power Systems and Integration
	<b>1.6</b>		<b>Central Instrumentation and Controls (I&amp;C)</b>
		1.6.1	Control System
		1.6.2	Data Acquisition System
	<b>1.7</b>		<b>Project Support &amp; Integration</b>
		1.7.1	Project Management and Integration
		1.7.2	Project Physics
		1.7.3	Integrated Systems Tests
	<b>1.8</b>		<b>Site Preparation and Assembly</b>
		1.8.1	Site Preparation
		1.8.2	Torus Assembly and Construction

## Annex I – WBS Dictionary

**WBS Element: 1.1.3.3**

**WBS Level: 4**

**WBS Title: Center Stack Assembly (CSA)**

Definition: The CSA consists of the inner TF coil legs, the OH solenoid, the shaping coils, and the center stack casing. Also included in this WBS element are the TF coil joint (flex bus assembly) and the ceramic break assembly. The scope of this WBS element includes the design, analysis, prototypes (as required), procurement activities, fabrication and assembly of the Center Stack.

**WBS Element: 1.1.3.3.1**

**WBS Level: 5**

**WBS Title: Center Stack - TF Inner Legs/Bundle**

Definition: The TF inner leg subsystem consists of the new coil sections that will make up the TF inner bore and bundle. Also included in the scope of this WBS element is the TF coil joint (flex bus assembly) and testing of the new TF coil joint design.

For the NSTX Upgrade Project a new TF Inner Leg will be fabricated. This WBS element includes the design of the TF Bundle, the TF flex bus and flex bus supports and includes all analytical and CAD design efforts for these components. It also includes the early procurement of the TF conductor [80 lengths] and procurement of the TF flex bus and supports. It does not include the procurement/fabrication of the Inner TF bundle, which is included as part of the OH procurement in WBS 1.1.3.3.2.

**{Inner Toroidal Field Bundle (Job 1304)}**

For the NSTX Upgrade Project a test stand to measure the required performance parameters on the new NSTX TF joint design will be designed and fabricated. Test parameter measurements and cyclic lifetime tests of the new TF joint will be performed and testing data will be compiled. The test stand will be modified for revised design configurations as needed and tests repeated with a final comprehensive test report generated that includes all test data.

**{TF Joint Stand & Performance Test (Job 1303)}**

**WBS Element: 1.1.3.3.2**

**WBS Level: 5**

**WBS Title: Ohmic Heating Solenoid**

Definition: The ohmic heating solenoid subsystem consists of the new coils that will make up the center solenoid. This WBS element includes the design, analysis, prototypes (as required), procurement activities and fabrication.

For the NSTX Upgrade a new OH Solenoid will be fabricated. This WBS element includes the design & fabrication of a new OH solenoid and associated components including a Belleville washer spring assembly and support structures for the NSTX upgrades. It also includes all analytical & CAD design efforts. Includes advance procurement of the copper conductor and co-wound [glass/Kapton] insulation. Also includes the procurement of the Micro-therm insulation, conductive paint.

Includes the procurement and engineering oversight for the combined OH



## Annex I – WBS Dictionary

and TF bundle assembly. A single vendor will fabricate both components.  
{Ohmic Heating Solenoid (Job 1305)}

**WBS Element:** 1.1.3.3.3

**WBS Level:** 5

**WBS Title:** Inner Poloidal Field Coils

**Definition:** The inner poloidal/shaping coils subsystem consists of the new coils that will make up the poloidal field coils 1A, 1B and 1C. This WBS element includes the design, analysis, prototypes (as required), procurement activities and fabrication.

For the NSTX Upgrade three new sets of inner poloidal field coils will be installed. This WBS element include the design and procurement of the Inner poloidal field coils and supports which includes all analytical and CAD design efforts for these components. It includes the early procurement of the PF conductor and co-wound [Glass/Kapton] insulation.  
{Inner Poloidal Field Coils (Job 1306)}

**WBS Element:** 1.1.3.3.4

**WBS Level:** 5

**WBS Title:** Center Stack Casing and Assembly

**Definition:** This WBS element includes the design and fabrication of the Center Stack casing and ceramic break assembly for the upgraded Center Stack as well as the assembly of the new Center Stack.

The Center Stack Casing effort includes analysis and CAD design for the casing components; the procurement of the Inconel tubing, forgings, bellows and organ pipes; the fabrication of Center Stack support legs; the procurement/fabrication of a new ceramic break assembly; the in-house assembly of the casing components; and mounting of the PF1A and PF1B structure/coils to the casing.  
{CS Casing (Job 1307)}

The Center Stack Assembly effort involves all activities associated with the assembly of the Center Stack and includes design modifications and upgrade of the coil assembly stand; procedures for assembling the Center Stack and for installation; assembly of the Center Stack components including the OH/TF coil supports, mounting of the surface diagnostics and thermal blanket, inconel casing and inner PF coils and setup and tear down of the Center Stack assembly area.  
{Center Stack Assembly (Job 1302)}

**WBS Element:** 1.1.3.4

**WBS Level:** 4

**WBS Title:** Coil Bus Runs

**Definition:** This WBS element includes the design and fabrication of the coil bus runs/supports between the NSTX coils and the FCPC cable terminations located in the NSTX test cell.

{Coil Bus Runs (Job 5501)}

## Work Approval Form (WAF)

**Cost Center:** 9417  
**Job Number:** 1305  
**Job Title:** Ohmic Heating Solenoid  
**Job Manager:** James H. Chrzanowski  
**Rev 1 7/6/2010**

**Description:**

Design & fabricate a new OH solenoid and associated components including a belleville washer spring assembly and support structures for the NSTX upgrades. Estimate includes all analytical & Cad design efforts. Includes advance procurement of the copper conductor and co-wound [glass/Kapton] insulation. Also includes the procurement of the Micro-therm insulation, conductive paint.

**Includes the in-house fabrication of the combined OH and TF bundle assembly.**

Does not include any installation or assembly tasks.

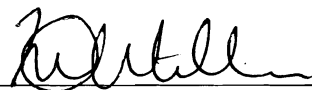
**Schedule:**

Refer to Primavera Data-Base

**Approvals:**

 7/20/10  
Job Manager

 8/3/10  
Project Manager

 8/3/10  
Engineering Department Head



Cost Center	Work Package	Job #	Activity Name	Duration (Weeks)	Start Date	EAEM1 (Chizary)	EAEM2 (Collaghan)	EAEM3 (Mason)	EAEM4 (Tha)	EAEM5 (Mech)	EABD2 (Electrical)	EABD3 (Upcoming)	EWTS (Tech)	EMSM (Milestone)	M&S (\$)	OS (\$)	Travel (\$)	Sitkm (\$)	Subtotal M&S (\$)	Base of Estimate	Category	Contingency %		
9417	1305		Final Design Activities																					
			Finalize calculations on OH flow optim. & thermal stresses																					
			Check flow rates cavitation issues					100																10%
			Analyze Coax lead box						40															10%
			Fatigue assessment							20														10%
			OH bus bar analysis							40														10%
			Calculation with/leak and fill							60														10%
			Analysis of manufacturing tooling and CS support future																					10%
			Complete detail and assembly Cad drawings										700											10%
			Program for FDR																					20%
			Complete R&D for tooling							40														20%
			Additional R&D for Aquepour																					10%
			Purchase & Fabrication																					
			Conductor																					
			Generate SCW for conductor					x																10%
			Prep requisition & submit to procurement					x																10%
			Bid & award conductor order (250k)																					10%
			Manufacture Copper conductor (extrusion)																					25%
			Miscellaneous parts														\$105.6							25%
	Prep requisition & submit to procurement (insulation)																					10%		
	Procure Kapton/glass co-wound insulation																					6		
	Prep requisition & submit to procurement (bellville)																					2		
	Bid & Award bellville washer assembly																					2		
	Procure G-10 fillers (OH coil)																					2		
	Procure lead blocks and cooling fittings																					2		
	Procure miscellaneous parts																					2		
	Procure OH lower lead and support structure														\$15.0							2		
	High Coax Tooling & Equipment for manufacturing																					2		
	These items are coated in Tab E- Coil Fab																					6		
	Procure TF Chisler mold																					20%		
	Procure Full TF mold																							
	Procure OH Mold																					2		
	Procure new coil winding machine																					2		
	Procure custom brace station																					2		
	<b>TECH PREFERENCE</b>																							
	Note: The OH/F coils will be fabricated in house together as one unit																							
	Design tooling for manufacturing OH/F coil																							
	TF Chisler mold							120														2		
	TF full mold							160														2		
	OH mold							80														2		
	OH winding clamps							80														2		
	Lifting beam- conductors & coil							80														2		
	Ground wrap station							40														2		
	Tension unit							80														2		
	Mold for OH/F castable material							60														2		
	Brace station							80														2		
	Stringer station							80														2		
	Facility Layout							240														2		
	Area layout including classroom							300														2		
	Electrical layout to support winding area																					2		
	Area Preparation																					2		
	Remove NCSX tooling and spare parts from TC							200														2		
	Setup Winding area							600														2		
	Setup winding equipment							480														2		
	Manufacture OH/F coil																					2		
	Generate Manufacturing Procedures & Travelers																					10%		
	Manufacture OH/F coil (see Tab E for details)																					40%		
	Deliver OH/F to CS Assembly area																							
								0	300	40	40	1200	300	700	1644	\$21,128.6	\$0.0	\$0.0	\$2,169.6	\$2,169.6	1776	10%		
							\$30,984.0	\$4,980.0	\$7,410.8	\$152,459.0	\$37,485.0	\$87,485.0	\$146,351.8	\$196,740.2	\$41.0	\$21,128.6	\$0.0	\$0.0	\$2,169.6	\$2,169.6	\$2,847,643.7	10%		
<b>CATEGORIZATION CODES:</b> 1 - National Standards 2 - Engineering Judgement/Experience 3 - Estimate/Data from External Sources (e.g., WTX, ATF, etc.) 4 - Previous PPI/OJRNL Experience (e.g., TFR, NSTX, PLT, etc.) 5 - Prototype Data/Test Results 6 - Catalogue Price/Vendor Quote 7 - Placed Contracts 8 - Actual experience for NCSX Work 9 - Other																								

Category	Hourly Rates
ELEM	\$185.27
ELEM	\$165.16
ELEM	\$176.71
ELEM	\$174.65
ELEM	\$145.16
ELEM	\$119.25
ELEM	\$80.36
ELEM	\$128



Cost Center:		9417												
Job Number:		1305												
Job Title:		Ohmic Heating Solenoid												
Job Manager:		James H. Chrzanowski												
Uncertainty of the Estimate		High		Medium		Low		Uncertainty Range (%)						
Design Maturity				x										
Design Complexity				X										
Residual Impacts														
Risk Description								Likelihood of Occurring		Mitigation Plan		Basis of estimate		
												Cost Impact		
												Low (\$K)		
												High (\$K)		
												Schedule Impact		
												Low (weeks)		
												High (Weeks)		
1	TF Quadrant- Poor VPI impregnation							U	Evaluate condition of coil- Local dry areas could be repaired, but larger failure would require rebuilding TF Quadrant			200		12
2	TF Quadrant- Fails electrical tests							U	If unable to repair short, rebuild quadrant			200		12
3	TF Full Bundle- Poor VPI impregnation							U	Evaluate condition of coil- Local dry areas could be repaired, but larger failure would require separating quadrants and re-assy and VPI of bundle			250		16
4	TF Full Bundle- Fails electrical tests							U	Repair electrical short			75		
5	OH Bundle- Poor VPI impregnation							U	Evaluate condition of coil- Local dry areas could be repaired, but larger failure would require cutting OH coil from TF and rebuilding OH			500		30
6	OH coil fails during final testing							U	If fault cannot be repaired- Coil must be cut off and rebuilt			500		30
7	Unable to completely remove temporary spacer between OH and TF after completion of Fabrication							U	Administrative controls during operation requiring OH and TF to be powered together			N/A		N/A
Notes:														
(1) Cost impacts should NOT include standing army costs which are separately calculated from the schedule impact														
(2) The schedule impacts should be entered as the min and max impacts on the critical path.														
(3) If there is no critical path impact then the schedule entries should be zero.														
Likelihood of occurrence should be entered consistent with our risk classification methodology, i.e.														
VL= Very Likely (P>80%), L=Likely (80%>P>40%), U=Unlikely (40%>P>10%), VU=Very Unlikely (P<10%), NC=Non-credible (P<1%)														

Comments/Other Considerations

Design Complexity		Design Maturity Definition				
Low	High	High	Low			
Low	-15%	+25%	-20%	+40%	+60%	Final design available. All design features/requirements well known. No further design development or evolution expected that will impact estimate.
Medium	-10%	+15%	-15%	+25%	+40%	Preliminary design available. Some additional design evolution likely. Further developments can be somewhat expected or anticipated and reflected in estimate.
High	-5%	+10%	-10%	+15%	+25%	No better than conceptual design basis currently available. Design details, procedures, etc. still need much development and evolution of requirements beyond estimate basis is likely and expected.
Design Complexity Definition		Design Maturity Definition				
Low	Medium	High	Low			
Low	Medium	High	Low	Work is fairly well understood -- either standard construction or repetition of activities performed in past. Little likelihood of estimate not being well understood and requirements not being well defined.		
Medium	High	Low	Medium	More complex work requirements that have potential to impact cost and schedule estimates. Limited experience performing similar tasks, so ability to estimate accurately is somewhat suspect		
High	Low	Medium	High	Extremely challenging tasks and/or requirements. Unique or first-of-a-kind assembly or work tasks. No good basis for estimating work exists so there is a high degree of estimate uncertainty. Based on standard industry and DOE estimate classifications (Per AACEI Recommended		

Cost Center: 9417		k\$		Basis of Estimate	
Job Number: 1305					
Job Title: Ohmic Heating Solenoid					
Job Manager: James H. Chrzanowski					
Materials and Subcontracts (M&S)					
Description:		k\$			
OH Copper conductor		\$105.6		4	
Co-wound insulation [Kapton/glass]		\$25.0		3	
OH/TF bundle fabrication		\$1,899.0		4	
Belleville washer assembly		\$35.0		2	
Miscellaneous		\$15.0		9	
TF conductor stands- tube soldering		\$5.0		2	
TF conductor stands- insulating		\$15.0		2	
Quadrant mold		\$70.0		2	
Full coil mold		\$65.0		2	
VPI delivery system		\$20.0		2	
Lift beam- conductor		\$15.0		2	
Lift beam for coil		\$25.0		2	
Taping machines [2]		\$25.0		2	
Tension unit		\$10.0		2	
Braze fixture and work coil		\$10.0		2	
Winding machine for OH		\$125.0		2	
Mold for OH-TF spacer [Aquepour]		\$10.0		2	
OH winding clamps- 4-sets		\$20.0		2	
OH Mold		\$65.0		2	
Miscellaneous tools & fixtures		\$20.0		2	
"Aquepour"- castable material		\$10.0		2	
Insulation [fiberglass tape, teflon and ground plane		\$20.0		6	
Epoxy- CTD-101		\$15.0		6	
Copper pre-linned tubing [TF conductor]		\$1.0		6	
Filler modifications		\$1.0		6	
Conductor primer		\$2.0		6	
Safety and PPE equipment and supplies		\$5.0		6	
Miscellaneous supplies		\$20.0		6	
RTV and silicone caulking for mold sealing		\$5.0		6	
Disposable VPI hardware					
valves & fittings		\$10.0		6	
High & low temperature vac. Tubing		\$10.0		6	
VPI manifolds		\$5.0		6	
<b>CATEGORIZATION CODES:</b> 1 - National Standards 2 - Engineering Judgment/Experience 3 - Estimates/Data from External Sources (e.g., WTX, ATF, etc.) 4 - Previous PP/LORNL Experience (e.g., TFTR, NSTX, PLT, etc.) 5 - Prototype Data/Test Results 6 - Catalogs Price/Vendor Quote 7 - Placed Contracts 8 - Actual experience for NCSX Work 9 - Other					
				<b>TOTALS</b>	



TASK DESCRIPTION	Total Shifts	No. of Tech	Hours per Shift	Total Manhrs EM/TB	Start Date
<b>Conductor Receipt and Inspection</b>					
Inspect machined conductors 100% [40 conductors]	20	2	8.0	320.0	15-Jul-11
Solder cooling tubes [40 conductors]	72	2	8.0	1152.0	
Cleanup conductors- post solder	40	2	8.0	640.0	
Sandblast conductor length for primer	40	2	8.0	640.0	
Apply primer [40 conductors]	5	2	8.0	80.0	
<b>Quadrant #1</b>					
Apply turn insulation Quadrant #1	5	4	8.0	160.0	
Assemble Quadrant #1	10	5	8.0	400.0	
Prepare VPI operation	3	4	8.0	96.0	
VPI- fill quadrant	2	4	8.0	64.0	
Cure VPI'd coil	8	1	8.0	64.0	
Remove Quadrant #1 from mold	1	4	8.0	32.0	
Cleanup quadrant	2	2	8.0	32.0	
Perform T/T electrical tests	1	2	8.0	16.0	
<b>Quadrant #2</b>					
Apply turn insulation Quadrant #2	5	4	8.0	160.0	
Assemble Quadrant #2	5	5	8.0	200.0	
Prepare VPI operation	3	4	8.0	96.0	
VPI- fill quadrant	2	4	8.0	64.0	
Cure VPI'd coil	8	1	8.0	64.0	
Remove Quadrant #2 from mold	1	4	8.0	32.0	
Cleanup quadrant	2	2	8.0	32.0	
Perform T/T electrical tests	1	2	8.0	16.0	
<b>Quadrant #3</b>					
Apply turn insulation Quadrant #3	5	4	8.0	160.0	
Assemble Quadrant #3	5	5	8.0	200.0	
Prepare VPI operation	3	4	8.0	96.0	
VPI- fill quadrant	2	4	8.0	64.0	
Cure VPI'd coil	8	1	8.0	64.0	
Remove Quadrant #3 from mold	1	4	8.0	32.0	
Cleanup quadrant	2	2	8.0	32.0	
Perform T/T electrical tests	1	2	8.0	16.0	
<b>Quadrant #4</b>					
Apply turn insulation Quadrant #4	5	4	8.0	160.0	
Assemble Quadrant #4	5	5	8.0	200.0	
Prepare VPI operation	3	4	8.0	96.0	
VPI- fill quadrant	2	4	8.0	64.0	
Cure VPI'd coil	8	1	8.0	64.0	
Remove Quadrant #4 from mold	1	2	8.0	16.0	
Cleanup quadrant	2	2	8.0	32.0	
Perform T/T electrical tests	1	2	8.0	16.0	
<b>Full mold</b>					
Assemble quadrants together	5	5	8.0	200.0	
Apply groundwrap insulation	2	2	8.0	32.0	
Prepare VPI operation	3	4	8.0	96.0	
VPI full TF coil	2	4	8.0	64.0	
Cure VPI'd coil	8	1	8.0	64.0	
Remove full TF from mold and cleanup	1	2	8.0	16.0	
Perform Final electrical tests	1	2	8.0	16.0	
<b>OH Coil winding operations</b>					
Transfer TF to OH station	1	5	8.0	40.0	
Prepare TF for OH winding	5	3	8.0	120.0	
Install intermediate spacer between OH/TF bundles [requires mold installation and oven cure]	8	3	8.0	192.0	
Apply slip plane, and inner groundwall insulation	2	2	8.0	32.0	
Braze first lead and prepare for winding	5	2	8.0	80.0	
Wind 1st half of layer #1	5	3	8.0	120.0	
Make [2] in-line brazes	1	2	8.0	16.0	
Wind second half of layer #1	5	3	8.0	120.0	
Perform prelim electrical tests	1	2	8.0	16.0	
Braze layer to layer joint	1	2	8.0	16.0	
Wind 1st half of layer #2	5	3	8.0	120.0	
Make [2] in-line brazes	1	2	8.0	16.0	
Wind second half of layer #2	5	3	8.0	120.0	
Perform prelim electrical tests	1	2	8.0	16.0	
Braze layer to layer joint	1	2	8.0	16.0	
Wind 1st half of layer #3	5	3	8.0	120.0	
Make [2] in-line brazes	1	2	8.0	16.0	
Wind second half of layer #3	5	3	8.0	120.0	

Tab E OHTF Coil Fabrication

Perform prelim electrical tests	1	2	8.0	16.0	
Braze layer to layer joint	1	2	8.0	16.0	
Wind 1st half of layer #4	5	3	8.0	120.0	
Make [2] in-line brazes	1	2	8.0	16.0	
Wind second half of layer #4	5	3	8.0	120.0	
Apply groundwrap insulation	1	2	8.0	16.0	
<b>VPI</b>	<b>SHIFTS</b>	<b># Tech</b>	<b>Hr/Shift</b>	<b>Total Hrs</b>	
Mount OH mold around coil	5	4	8.0	160.0	
Prepare VPI operation	3	4	8.0	96.0	
VPI- mold	2	4	8.0	64.0	
Cure VPI'd coil	8	1	8.0	64.0	
Remove mold from OH coil	1	4	8.0	32.0	
Cleanup OH coil	2	2	8.0	32.0	
Silverplate all electrical surfaces [OH/TF]	3	1	8.0	24.0	
Perform Final OH electrical tests	1	2	8.0	16.0	
Remove intermediate spacer between OH and TF bundles	5	3	8.0	120.0	
Perform hydrostat and flow tests- OH/TF coils	3	2	8.0	48.0	
Transport to CS assembly station	1	5	8.0	40.0	
	106			2296.0	
				<b>10752.0</b>	
				<b>\$971,550.72</b>	<b>\$971.55</b>

<b>TOOLING &amp; EQUIPMENT</b>	<b>Machinist Man-hours</b>	<b>Technician Man-hours</b>	<b>M&amp;S Revised k\$</b>	<b>Start Date</b>
TF conductor stands- tube soldering		160	\$5.0	
TF conductor stands- insulating			\$20.0	
Quadrant mold	160		\$70.0	
Full coil mold	160		\$85.0	
VPI delivery system		160	\$20.0	
Lift beam- conductor		80	\$15.0	
Lift leam for coil		80	\$25.0	
Taping machines [2]			\$25.0	
Tension unit	120	80	\$10.0	
Braze unit			\$100.0	
Braze fixture and work coil	80	40	\$10.0	
Winding machine for OH			\$125.0	
Mold for OH-TF spacer [Aquapour]			\$10.0	
OH winding clamps- 4-sets			\$20.0	
OH Mold	160		\$85.0	
Sandblast unit		120	\$15.0	
Miscellaneous tools & fixtures	160	160	\$20.0	
"Aquapour"- castable material			\$10.0	
	840	880	\$670.0	
	<b>\$75,902.40</b>	<b>\$79,516.80</b>		<b>\$825.4</b>

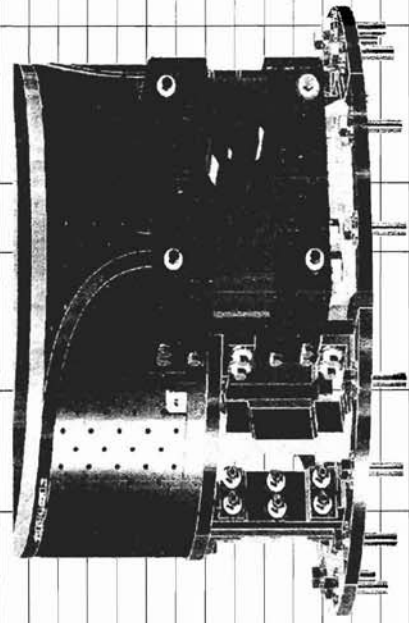
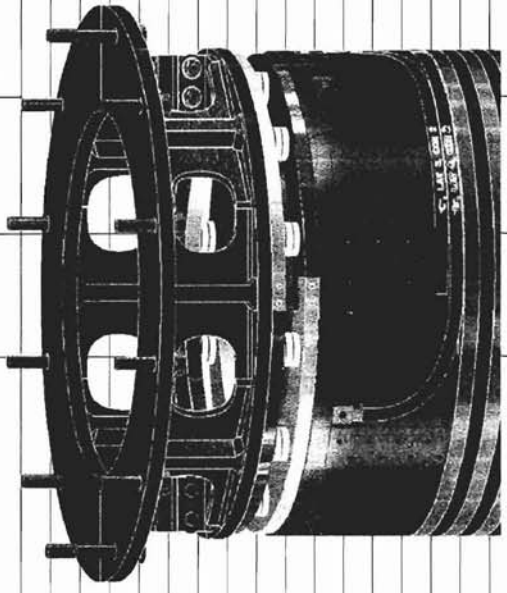
<b>MATERIAL &amp; SUPPLIES</b>	<b>Machinist Man-hours</b>	<b>Technician Man-hours</b>	<b>M&amp;S k\$</b>		
Insulation [fiberglass tape, teflon and ground plane]			\$20.0	<b>FY2009 Hourly Rates</b>	
Epoxy- CTD-101			\$15.0	EA/EM	\$185.27
Copper pre-tinned tubing [TF conductor]			\$5.0	EM/EM	\$165.16
G-10 Filler modifications	150		\$1.0	EE/EM	\$175.71
Conductor primer			\$5.0	EAD/SB	\$124.95
Safety and PPE equipment and supplies Includes gloves, masks, safety equipment & supplies			\$5.0	EM/SM	\$145.16
Miscellaneous supplies Includes cotton clothes, hardware, etc.			\$20.0	EM/SB	\$119.23
<b>VPI Supplies</b>				EM/TB	\$90.36
RTV and silicone caulking for mold sealing			\$5.0	M&S	\$1.28
Disposable VPI hardware valves & fittings			\$10.0		
High & low temperature vac. Tubing			\$10.0		
VPI manifolds		200	\$5.0		
	150	200	\$101.0		
	hours	hours		<b>M&amp;S Total</b>	<b>\$101.0</b>

<b>TOTAL</b>	<b>\$1,898.0</b>
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Table used for reference only to get a rough estimate for new OH/TF coils

Conductor assume \$7.5/lb	\$7.50	\$48,000.00	2.2	\$105,600.0					
OH conductor		\$40.0	1.2992	\$52.0	6400	2.2	5		
		FY97 cost	Escal		12800	\$92.2			
OH solenoid		1997 \$	Inflator %	2009 \$	# Orig	# Upgrade			
TF bundle		\$136.3	1.2992	\$177.1	2340	6400	3.0		
		\$83.0	1.2992	\$107.8					
		Orig Costs	Inflation	New Cost					
				TF+OH	\$1,139.66				
					\$1,481.56	30%	difficulty		

TASK DESCRIPTION	Total Shifts	No. of Tech./Shift	Hours per Shift
Setup Winding area	25	3	8.0
Setup winding equipment	20	3	8.0





•OH Cooling fittings

