

## NCSX Fabrication Project Cost and Schedule Estimating Form

### WBS 142 Modular Coil Windings and Coil Assembly

#### Labor

Activity Title	Manhours	FY2003 \$\$	Labor Type	Start Date Month/Yr	End Date Month/Yr	Comments
<b>Preliminary Design (Title I)</b>						
( 48% of design schedule)	203		<i>EAEM</i>	Apr-03	Oct-03	PPPL Engineer
	0		<i>EADM</i>	Apr-03	Oct-03	PPPL Designer
	3334		<i>ORNL Eng</i>	Apr-03	Oct-03	Composite of ORNL Engineer / Designer
	155		<i>ORNL Phys.</i>	Apr-03	Oct-03	Composite of ORNL Physics / scientific
	0		<i>PPPL Phys.</i>	Apr-03	Oct-03	PPPL Physics/scientific
<b>Final Design (Title II)</b>						
( 52% of design schedule)	217		<i>EAEM</i>	Oct-03	Apr-04	PPPL Engineer
	0		<i>EADM</i>	Oct-03	Apr-04	PPPL Designer
	3560		<i>ORNL Eng</i>	Oct-03	Apr-04	Composite of ORNL Engineer / Designer
	165		<i>ORNL Phys.</i>	Oct-03	Apr-04	Composite of ORNL Physicist
	0		<i>PPPL Phys.</i>	Oct-03	Apr-04	PPPL Physics/scientific
<b>Lab R&amp;D labor</b>						
	2589		<i>EAEM</i>	Apr-03	Oct-03	PPPL Engineer
	1726		<i>EADM</i>	Apr-03	Oct-03	PPPL Designer
	835		<i>ORNL Eng</i>	Apr-03	Oct-03	Composite of ORNL Engineer / Designer
	5683		<i>EASM</i>	Apr-03	Oct-03	PPPL monthly support
	8592		<i>EMTB</i>	Apr-03	Oct-03	PPPL Technician
<b>Lab Fab/Assembly/Installation (Title III)</b>						
	4260		<i>EAEM</i>	Jul-04	Oct-06	PPPL Engineer
	0		<i>EADM</i>	Jul-04	Oct-06	PPPL Designer
	2524		<i>ORNL Eng</i>	Jul-04	Oct-06	Composite of ORNL Engineer / Designer
	7852		<i>EASM</i>	Jul-04	Oct-06	PPPL monthly support
	37120		<i>EMTB</i>	Jul-04	Oct-06	PPPL Technician

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### WBS 142 Modular Coil Windings and Coil Assembly

#### Labor

*Manhours per fiscal year by labor category*

Level of Effort		FY2003	FY2004	FY2005	FY2006	FY2007	FY2008	TOTAL
PPPL Engineer	<i>EAEM</i>	2675	811	1891	1891	0	0	7269
PPPL Designer	<i>EADM</i>	1654	72	0	0	0	0	1726
Composite of ORNL Engineer / Designer	<i>ORNL Eng</i>	3994	4018	1121	1121	0	0	10253
PPPL monthly support	<i>EASM</i>	5445	1117	3487	3487	0	0	13535
PPPL Technician	<i>EMTB</i>	8232	4514	16483	16483	0	0	45712
Composite of ORNL Physics / scientific	<i>ORNL Phy</i>	148	172	0	0	0	0	320
PPPL Physics/scientific	<i>PPPL Phy</i>	0	0	0	0	0	0	0

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### WBS 142 Modular Coil Windings and Coil Assembly

#### M&S Costs

Activity Title	FY2003 \$\$	Comment
<b>Manufacturing Development (R&amp;D)</b>		
Purchased Design Services	\$0	
Procured Hardware/Material	\$392,670	
Profit	\$0	profit already included in these items
<i>total, manf/dev (R&amp;D)</i>	\$392,670	w/o G&A
<b>Procured Hardware/Material</b>		
0	\$0	
0	\$0	
0	\$0	
coil fab and VPI supplies	\$765,000	
0	\$0	
0	\$0	
subtotal, purchased parts	\$765,000	
Profit at 10%	\$0	included in costs
<i>total, procured hdwe/matl.</i>	\$765,000	w/o G&A
<b>Purchased Design Services</b>		
	\$0	no purchased services anticipated
<b>Procured Installation/Assembly Costs</b>		
	\$0	All installation and assembly costs are included in WBS 7

#### Other Costs

Activity Title	FY2003 \$\$	Comment
Travel	\$36,000	at least one trip per month is expected for three years

## NCSX Fabrication Project Cost and Schedule Estimating Form

### WBS 142 Modular Coil Windings and Coil Assembly Summary Costs

Activity Title	Manhours	FY2003 \$\$	Comment
<b>Labor</b>			
PPPL Effort	68,242	\$5,975,173	<i>Assumed rates:</i> <i>EAEM</i> 153 \$/hr <i>EADM</i> 100 \$/hr <i>ORNL Eng</i> 130 \$/hr <i>EASM</i> 100 \$/hr <i>EMTB</i> 73 \$/hr PPPL Phys 141 \$/hr ORNL Phys 160 \$/hr
ORNL effort	10,573	\$1,384,097	
subtotal, labor	78,815	\$7,359,270	
<b>M&amp;S, Other</b>			
Manufacturing Development (R&D)		\$392,670	
Procured Hardware/Material		\$765,000	
Purchased Design Services		\$0	
Procured Installation/Assembly Costs		\$0	
Travel		\$36,000	
subtotal, M&S		\$1,193,670	
<b>G&amp;A</b>		\$298,418	25% on all purchased materials, subcontracts, travel
<b>Subtotal without contingency</b>		\$8,851,358	
<b>Contingency</b>		\$3,540,543	40% Overall on this WBS
<b>Total cost</b>		\$12,391,901	

# NCSX Fabrication Project Cost and Schedule

## WBS 142 Modular Coil Windings and Coil Assembly

### In-house Fabrication and Assembly

**Description:**

This effort covers all Title I, II, and III engineering for the modular coil winding and individual coil assembly. The coil forms are designed as part of WBS 141. The coils will be wound in-house by PPPL. All installation oversight will be performed as part of WBS 7.

**Labor category**

	multiplier	unit	no.	hours	total fraction	EAEM fract.	hrs	EASM, EMSM fract.	hrs	EMTB fract.	hrs	EADM fract.	hrs
<b>Fab operations summary</b>													
		hrs/lot	1	0	2.00	0.00	0	0.20	0	0.80	0	1.00	0
		hrs/line	1	0	1.00	0.00	0	0.10	0	0.90	0	0.00	0
Fab fillers and lead hardware	247	hrs / coil	18	4440	1.00	0.00	0	1.00	4440	0.00	0	0.00	0
<i>subtotal</i>				4440			0		4440		0		0

	multiplier	unit	no.	hours	total fraction	EAEM fract.	hrs	EASM, EMSM fract.	hrs	EMTB fract.	hrs	EADM fract.	hrs
<b>Assembly operations summary</b>													
		hr/lot	1	0	1.00	0.10	0	0.10	0	0.80	0	0.00	0
electrical/cryo testing	48	hr/lot	18	864	1.00	0.05	43	0.20	173	0.75	648	0.00	0
Wind coils, VPI, Test	2026	hr/coil	18	36472	1.00	0.00	0	0.00	0	1.00	36472	0.00	0
Engr oversight for winding	7198	hours	1	7198	1.00	0.55	3959	0.45	3239	0.00	0	0.00	0
<i>subtotal</i>				44534			4002		3412		37120		0

<b>Schedule assumptions</b>	<b>start</b>	<b>duration (weeks)</b>	<b>end</b>
Title I Design, R&D	Nov-02	27	May-03
Title II Design	May-03	29	Dec-03
Procurement	Dec-03	22	May-04
In-house fab / sub-assy	May-04	72	Sep-05
Installation / final assembly	Sep-05	53	Oct-06

**Notes and worksheets**

**Modular coil fabrication**

*ref J. Chrzanowski, April, 2003*

## NCSX Fabrication Project Cost and Schedule

### WBS 142 Modular Coil Windings and Coil Assembly

#### In-house Fabrication and Assembly

TASK DESCRIPTION	Duration	Start	End	EAEM	EEEM	EADM	EMSM	EMSM	EMTB	M&S	
				Engr	Engr	Design	Meighan	machinist	Tech		
				hours	hours	hours	hours	hours	hours	w/o G&A	w/G&A
<b>ENGINEERING and OVERSIGHT</b>											
LOE FY04		1-Oct-03	30-Sep-04	1726			864				
LOE FY05		1-Oct-04	30-Sep-05	1728			1728				
LOE FY06		1-Oct-05	30-Sep-06	576			576				
Sub total				4030			3168				
<b>MATERIAL &amp; SUPPLIES</b>											
<b>Coil Supplies</b>											
1) Insulation [estimate \$5000.00 per coil]											\$90,000
2) Epoxy- CTD-101K [15 gallons per coil @ \$300.00 per gallon- assume 20 injections]											\$90,000
3) Chill Plates and coil clamps [estimate \$12.0k per coil]											\$216,000
5) Copper conductor [approx. 1000 ft per coil x 20 coils @ \$13.00/foot]											\$260,000
6) G-11 fillers Fillers for transitions and lead areas (assume 10 per coil)								3000			\$15,000
7) Lead hardware								1440			\$18,000
8) Safety and PPE equipment and supplies Includes gloves, masks, safety equipment & supplies											\$15,000
9) Miscellaneous supplies Includes rags, hardware, etc.											\$10,000
<b>VPI Supplies</b>											
1) Epoxy for mold shell [CTD-522]											\$15,000

## NCSX Fabrication Project Cost and Schedule

### WBS 142 Modular Coil Windings and Coil Assembly

#### In-house Fabrication and Assembly

2) Vulcanizing tape, felt and silicone caulking											\$21,000		
3) Disposable VPI hardware											1000		
valves											\$10,000		
High & low temperature vac. Tubing											\$25,000		
Copper tubing											\$5,000		
													<b>Total</b>
											4440	1000	\$1,480,560.00
											#####	#####	
											\$790,000	#####	

**MODULAR COILS...**

M1, Type A, Banana Shaped coil

M2, Type B, Mid Shaped coil

M3, Type C, Bullet Shaped coil



M1, Type A,  
se141-011



M2, Type B,  
se141-012



M3, Type C,  
se141-013

Rate	per Hr
EM	\$155.00
SM	\$101.50
TB	\$74.00
DM	\$101.38

## NCSX Fabrication Project Cost and Schedule

### WBS 142 Modular Coil Windings and Coil Assembly

#### In-house Fabrication and Assembly

TASK DESCRIPTION	Working Days	Shifts per day	No. of Tech.	No. of an-days	No. of Items	Total Manhrs							
<b>EMTB</b>													
<b>Station No. 1- Casting Preparation</b>	<b>12</b>	<b>Total working days</b>											
<b>Inspect casting</b>	2	1	3	48		18	864						
Dimensional measure winding face				0									
Inspect surfaces for flaws, etc.				0									
Electrically check poloidal break				0									
<b>Mount casting in ring</b>	1	1	3	24		18	432						
Position and mount casting to support ring				0									
<b>Install studs for winding clamps</b>	3	1	3	72		18	1296						
Position and weld studs for winding and coil clamps				0									
Install anchor mounts for bag mold				0									
<b>Clean casting</b>	1	1	2	16		18	288						
Clean casting using acceptable solvents				0									
Inspect and clean all threaded holes				0									
<b>Install inner chill plates</b>	3	1	4	96		18	1728						
Position and secure copper chill plates				0									
<b>Install inner diagnostic loops</b>	2	1	2	32		18	576						
							<b>Total</b>	<b>5184</b>			<b>\$383,616</b>		
<b>Station No. 2- Conductor Insulating</b>	<b>4</b>	<b>Total working days</b>				<b>1</b>							
<b>Receive and inspect copper conductor</b>	4	1	2	64		1	64						
Unload and sample measure each spool				0									
<b>1st. Coil</b>							<b>Coils 2 thru 18</b>						
TASK DESCRIPTION	Working Days	Shifts per day	No. of Tech.	No. of an-hours	Working Days	Shifts per day	No. of Tech.	No. of an-hour	No. of Items	Man-hrs 2 thru 18	Total Man-hrs		
<b>Station No. 3- Coil Winding</b>	<b>38</b>	<b>Total working days 1st. coil</b>			<b>16.5 Total working days 2nd. Thru 18th. coil</b>								
<b>Prepare winding station for winding pancake #1</b>	<b>5</b>			<b>128</b>	<b>2</b>			<b>104</b>	<b>17</b>	<b>1768</b>	<b>1896</b>		
Install coil in turning fixture	1	1	4	32	0.5	2	4	32					
Install winding clamps	2	1	3	48	0.5	2	3	24					
Position inner groundwrap insulation onto winding form	2	1	3	48	1	2	3	48					
Note: The first coil will be wound on 1 shift. Coils 2 thru 18 will be wound on (2) shifts													



## NCSX Fabrication Project Cost and Schedule

### WBS 142 Modular Coil Windings and Coil Assembly

#### In-house Fabrication and Assembly

<b>Wind pancake #1</b>	<b>14</b>			<b>336</b>		<b>6</b>	<b>2</b>		<b>288</b>	<b>17</b>	<b>4896</b>	<b>5232</b>
Position & secure 1st. coil lead	2	1	3	48		1	2	3	48			
Wind layer #1 - [9] turns of conductors onto casting	10	1	3	240		4	2	3	192			
Reconfigure station for 2nd.layer				0								
Wind layer #2 - [9] turns of conductors onto casting												
Position & secure 2nd. coil lead	2	1	3	48		1	2	3	48			
<b>Prepare station for pancake #2</b>	<b>3</b>			<b>72</b>		<b>1.5</b>			<b>72</b>	<b>17</b>	<b>1224</b>	<b>1296</b>
Reposition winding equipment	1	1	3	24		0.5	2	3	24			
Position groundwrap insulation onto winding form	2	1	3	48		1	2	3	48			
<b>Wind pancake #2</b>	<b>14</b>			<b>336</b>		<b>6</b>			<b>288</b>	<b>17</b>	<b>4896</b>	<b>5232</b>
Position & secure 1st. coil lead	2	1	3	48		1	2	3	48			
Wind layer #1 - [9] turns of conductors onto casting	10	1	3	240		4	2	3	192			
Reposition station for 2nd.layer												
Wind layer #2 - [9] turns of conductors onto casting												
Position & secure 2nd. coil lead	2	1	3	48		1	2	3	48			
<b>Final coil winding activities</b>	<b>2</b>			<b>48</b>		<b>1</b>			<b>48</b>	<b>17</b>	<b>816</b>	<b>864</b>
Complete groundwrap installation	2	1	3	48		1	2	3	48			
											<b>Total</b>	<b>14520</b> <b>\$1,074,480</b>

TASK DESCRIPTION	Working Days	Shifts per day	No. of Tech.	No. of man-hours	No. of Items	Total Manhrs
<b>Station No. 4- Final coil prep &amp; Mold Application</b>	<b>15</b>	<b>Total working days per coil</b>				
Transfer modular coil to mold station	1	1	4	32	18	576
<b>Install final coil clamps &amp; chill plates</b>	<b>4</b>	<b>1</b>	<b>4</b>	<b>128</b>	<b>18</b>	<b>2304</b>
Remove winding clamps		1	4			0
Install external chill plates		1	4			0
Install final coil clamps and plumbing		1	4			0
<b>Install outer Diagnostic loops</b>	<b>2</b>	<b>1</b>	<b>4</b>	<b>64</b>	<b>18</b>	<b>1152</b>
Perform pre-VPI elect. & pressure tests		1	4	32	18	576

## NCSX Fabrication Project Cost and Schedule

### WBS 142 Modular Coil Windings and Coil Assembly

#### In-house Fabrication and Assembly

Pressure test cryo lines						0	
Perform preliminary electrical tests						0	
<b>Install bag mold around modular coil</b>	<b>7</b>	<b>1</b>	<b>4</b>	<b>224</b>	<b>18</b>	<b>4032</b>	
Install silicone bag & sprues	3	1	4				
Vacuum pumpdown & leak repair	2	1	4				
Install epoxy shell	2	1	4				
<b>Total</b>						<b>8640</b>	<b>\$639,360</b>

TASK DESCRIPTION	Working Days	Shifts per day	No. of Tech.	No. of man-hours	No. of Items	Total Manhrs	
<b>Station No. 5- VPI Coil</b>	<b>12</b>	<b>Total working days per coil</b>					
Transfer modular coil to Autoclave	1	1	4	32	18	576	
Prepare modular coil for VPI	3					0	
Connect fill lines, manifolds, hookup thermocouples & leak check	3	1	4	96	18	1728	
VPI modular coil	8					0	
Vacuum pumpdown mold and autoclave	1	1	3	24	18	432	
Epoxy fill coil	1	3	4	96	18	1728	
Temperature rampup and Cure	1	3	3	72	18	1296	
[parallel activity] Station cleanup during cure	1	1	3	24	18	432	
Temperature rampup and Post cure	1	2	2	32	18	576	
Temperature rampdown	1	1	1	8	18	144	
Cleanup & ready autoclave	2	1	4	64	18	1152	
<b>Total</b>							<b>8064</b> <b>\$596,736.00</b>

TASK DESCRIPTION	Working Days	Shifts per day	EMTB man-hours	EETB man-hours	EESM	EEEM man-hours	EMEM man-hours	
<b>Station No. 6- Final Cryo &amp; Electrical Tests</b>	<b>7</b>							
Transfer modular coil to Test Stand	1	1	32	0	0	0	0	
Connect cryo and electrical systems	1	1	16	16	4	0	4	
Chill down modular coil	2	3	64	0	0	0	8	
Perform electrical cryo/tests	2	1	32	48	16	16	16	

## NCSX Fabrication Project Cost and Schedule

### WBS 142 Modular Coil Windings and Coil Assembly

#### In-house Fabrication and Assembly

Disassemble and remove modular coil	1	1	32	8	0	0	0		
Warm tests only	2	1	32	0	0	0	16		

**Note: Electrical tests can only be performed during NSTX maintenance weeks**

	x 18	176	72	20	16	28		
cryo/electrical tests		3168	1296	360	288	504		
		\$234,432	#####	\$36,540	\$44,640	\$78,120		
warm tests only	x18	576	0	0	0	288		4464
		\$42,624	\$0	\$0	\$0	\$44,640		1152
							Total \$489,636.00	<i>not used</i>
							Total \$87,264.00	

**NCSX Fabrication Project Cost and Schedule**

**WBS 142 Modular Coil Windings and Coil Assembly**

**Materials and Subcontracts (M&S)**

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**Description:**

This effort covers all Title I, II, and III engineering for the modular coil winding and individual coil assemblies. The coil forms are designed as part of WBS 141. The coils will be wound in-house by PPPL. All installation oversight will be performed as part of WBS 7.

**Assumptions:**

outside engr rate = 120 \$ per hour  
 outside fab rate = 60 \$ per hour  
 outside inspection/technician rate = 80 \$ per hour

**Purchased parts:**

subtotal, purchased parts \$0

**Purchased materials for in-house fabrication and sub-assembly**

coil fab and VPI supplies \$765,000

subtotal purchased materials \$765,000

**Worksheet:**

**Copper cable conductor**

Coil dimensions:		spool size for single winding (one side of coil):
M1 length / turn	7.4 m	1015.6 ft, with 50 feet extra for leads, crossovers, etc.
M2 length / turn	7.2 m	991.3 ft, with 50 feet extra for leads, crossovers, etc.
M3 length / turn	6.7 m	924.1 ft, with 50 feet extra for leads, crossovers, etc.
avg / turn	7.1 m	

avg length/turn	23.2 ft	Assumed spool size for procurement
no of turns/ winding pack	40	1000 ft

no of prod coils 18

spools	36
25% over	9
total	45
total length	45000 ft

conductor price 5 \$/ft based on budgetary quote from New England Wire  
 cost \$225,000 for production conductor, without G&A, profit





## NCSX Fabrication Project Cost and Schedule

### WBS 142 Modular Coil Windings and Coil Assembly

#### Engineering, Title I, II and III

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**Description:**

This effort covers all Title I, II, and III engineering for the modular coil winding and individual coil assembly. The coil forms are designed as part of WBS 141. The coils will be wound in-house by PPPL.

	multiplier	unit	no.	hours	Labor category											
					total		EAEM		EADM		ORNL Eng		ORNL Physics		PPPL Physics	
					fraction	hrs	fraction	hrs	fraction	hrs	fraction	hrs	fraction	hrs	fraction	hrs
<b>Title I, II design</b>																
Pro-E models (avg)	8	hrs/model	150	1200	1.00	0.00	0	0.00	0	1.00	1200	0.00	0	0.00	0	
assy dwgs	40	hrs/dwg	21	840	1.00	0.00	0	0.00	0	1.00	840	0.00	0	0.00	0	
Detail drawings	20	hrs/dwg	168	3360	1.00	0.00	0	0.00	0	1.00	3360	0.00	0	0.00	0	
installation dwg	40	hrs/dwg	3	120	1.00	0.00	0	0.00	0	1.00	120	0.00	0	0.00	0	
cooling schematic	20	hrs/dwg	3	60	1.00	0.00	0	0.00	0	1.00	60	0.00	0	0.00	0	
electrical schematic	20	hrs/dwg	3	60	1.00	0.00	0	0.00	0	1.00	60	0.00	0	0.00	0	
I&C schematic	20	hrs/dwg	3	60	1.00	0.00	0	0.00	0	1.00	60	0.00	0	0.00	0	
stress analysis	40	hrs/calc	9	360	1.00	0.50	180	0.00	0	0.50	180	0.00	0	0.00	0	
thermal analysis	40	hrs/calc	6	240	1.00	0.50	120	0.00	0	0.50	120	0.00	0	0.00	0	
special analysis (electromagnetics)	160	hrs/calc	2	320	1.00	0.00	0	0.00	0	0.00	0	1.00	320	0.00	0	
procurement/fab specifications	160	hrs/spec	1	160	1.00	0.75	120	0.00	0	0.25	40	0.00	0	0.00	0	
preliminary and final design reviews	80	hrs/rev	2	160	1.00	0.00	0	0.00	0	1.00	160	0.00	0	0.00	0	
meetings/reporting/presentations	10%	% of tot	6940	694	1.00	0.00	0	0.00	0	1.00	694	0.00	0	0.00	0	
<i>subtotal</i>				7634			420		0		6894		320		0	
<b>Title III</b>																
vendor oversight, inspection	2	hrs/wk	22	44	1.00	0.50	22	0.00	0	0.00	0	0.50	22			
Disposition of deviation requests and non-conformances	8	hrs/wk	147	1177	1.00	0.20	235	0.00	0	0.00	0	0.80	942			
As-built drawings	8	hrs/dwg	195	1560	1.00	0.00	0	0.00	0	0.00	0	1.00	1560			
Installation oversight and inspection	0	hrs/wk	53	0	1.00	0.25	0	0.75	0	0.00	0	0.00	0			
<i>subtotal</i>				2781			258		0		0		2524			
<b>Schedule assumptions</b>																
	<b>start</b>	<b>duration (weeks)</b>	<b>end</b>													
Title I Design	Apr-03	27	Oct-03													
Title II Design	Oct-03	29	Apr-04													

## NCSX Fabrication Project Cost and Schedule

### WBS 142 Modular Coil Windings and Coil Assembly

#### Engineering, Title I, II and III

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Procurement	Jul-04	22	Dec-04
In-house fab / sub-assy	Jan-05	72	May-06
Installation / final assembly	Sep-05	53	Oct-06

#### Notes and worksheets

#### Coil Winding / Assembly Design and analysis

	total	per coil	windings and insulation	leads and crossovers	G-10 fillers	clamps	chill plates
Pro-E models	150	50	2	2	12	2	32
assy dwgs	21	7	2	2		1	2
Detail drawings	168	56	4	6	12	2	32
installation dwg	3	1	1				
cooling schematic	3	1	1				
electrical schematic	3	1	1				
I&C schematic	3	1	1				
stress analysis	9	3	1	1		1	
thermal analysis	6	2	1				1
special analysis	2 one em force analysis and one magnetic geometry confirmation analysis for all coils						
procurement specifications	1 global specification for coil, similar to procurement spec. Other specs included in R&D estimate						
preliminary and final design reviews	2 reviews						
meetings/reporting/presentations	15% this will get a lot of attention						