

## NCSX Work Approval Form (WAF)

**WBS Number: 132**

**WBS Title: PF Coils**

**Job Numbers: 1302 and 1352**

**Job Title: PF Coil Design (1302) and PF Coil Procurements (1352)**

**Job Manager: Mike Kalish**

**Description:**

This WBS element consists of the manufacturing design and fabrication of the PF conductor assembly of the PF winding packs including interface elements for connections to power and cooling supply at the coils, and integration of the PF1a coils with the central solenoid structural elements.

**Schedule:**

See Attached

**Approvals:**

_____	_____
Job Manager	Date
_____	_____
Responsible Line Manager	Date
_____	_____
Project Manager	Date
_____	_____
Engineering Department Head	Date



**NCSX June 2007 ETC**  
**TABLE II - Materials and Subcontracts**

<b>Materials and Subcontracts (M&amp;S)</b>																									
<b>Description:</b>	<b>FY07\$K</b>										<b>HOURS</b>										<b>Basis of Estimate</b>				
	41MS	48MS	37STK	35TRV	L	31OT	ORNL EM	ORNL DSN	EMEM	EMSM	EMSB	EMTB	EAEM	EASB	EEEM	EESM	EESB	EETB	ECEM	ECSB		ECTB	RM2	RM3	
<b>Procurement &amp; Fabrication</b>																									
PF Coil RFQ and Procurement													120												Past Experience with procurement of TF Coils
Procurement Vendor Evaluation				5.00								40												Travel to Evaluate Vendors (2trips)	
Conductor Procurement PF4	29.80											16												Outokumpu (Luvata) estimate and internal calculation of weight of CU (adjusted for COMEX prices in mid-May 2007) - See Table V	
Conductor Procurement PF5	38.20											16												Outokumpu (Luvata) estimate and internal calculation of weight of CU (adjusted for COMEX prices in mid-May 2007) - See Table V	
Conductor Procurement PF6	27.30											16												Outokumpu (Luvata) estimate and internal calculation of weight of CU (adjusted for COMEX prices in mid-May 2007) - See Table V	
<b>Conductor Procurement Spare</b>	<b>19.10</b>																							<b>Enough copper to build one spare of any coil, Outokumpu (Luvata) estimate and internal calculation of weight of CU (adjusted for COMEX prices in mid-May 2007) - See Table V</b>	
PF 4 Materials	40.90																							Internal PF4 Estimate - See Table V	
PF 5 Materials	52.77											24												Internal PF5 Estimate - See Table V	
PF 6 Materials	42.00											24												Internal PF6 Estimate - See Table V	
PF 4 Tooling	72.00																							Everson e-mail (B. Umbenaur to M. Kalish) of 4/12/07 - see Table V	
Fabrication of PF4	40.20																							Everson e-mail (B. Umbenaur to M. Kalish) of 4/12/07 - see Table V	
Fabrication of PF 5, Including Tooling	415.00																							Everson e-mail (B. Umbenaur to M. Kalish) of 12/5/06 - see Table V	
Fabrication of PF 6, Including Tooling	485.00																							Everson e-mail (B. Umbenaur to M. Kalish) of 12/5/06 - see Table V	
Fabrication Oversight												784												During fabrication at vendor, 2days per week +80hrs drafting. Based on experience supporting TF Coil Procurement, Coverage is 2 days per week instead of 2.5 because coils are simpler than TF Coils	
Refurbish PF1a												80												Based on engineering evaluation of condition of PF1A	
PF Inspection and Testing												120	60											One week per fcoil set (upper & lower) for EMTB - basis of estimate	
PF1a Assembly												160	40											two technicians for two weeks with oversight - includes assembly of buswork but not fabrication of buswork, Based on engineering judgement and evaluation of the number of parts to assemble	

**NCSX June 2007 ETC**  
**TABLE III - Fabrication/Assembly Installation**

<b>In-house Fabrication and Assembly and Installation</b>																																	
<b>Description: Incl in Field Period Assembly and Machine Assembly Jobs</b>																																	

**NCSX June 2007 ETC**  
**TABLE IV - Uncertainty of Estimate and Residual Risk Assessment**

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<b>Uncertainty of the Estimate</b>					
	<u>High</u>	<u>Medium</u>	<u>Low</u>	<u>Uncertainty Range (%)</u>	<u>Comments/Other Considerations</u>
<b>Job 1302</b>				-15%/+25%	
Design Maturity			X		Still in initial design phases - although much design work accomplished, still haven't held PDR. Interfaces with coil structures still not finalized.
Design Complexity			X		PPPL has significant experience designing conventional solid copper round coils (e.g., TFTR, PLT, PBX-M, etc.)
<b>Job 1352</b>				-15%/+25%	
Design Maturity			X		Still in initial design phases - although much design work accomplished, still haven't held PDR. Interfaces with coil structures still not determined.
Design Complexity			X		Both PPPL and outside vendors have significant experience manufacturing conventional solid copper round coils (e.g., TFTR, PLT, PBX-M, etc.)

Other Comments: Have budget estimates from a single vendor, risk that final estimate could increase. See COMEX quote on 5/10/2007. Original pricing based on April COMEX quote @ \$3.14/lb => as of May 10, 2007, now at ~\$3.60/lb => used this COMEX quote as of mid-May.

Note: High/Medium/Low uncertainty assessment from Job Manager. Uncertainty range based on AACEI recommended practice 18R-97 as amended for NCSX.

<b>Residual Impacts</b>								
<u>Job</u>	<u>Risk Description</u>	<u>Likelihood of Occurring</u>	<u>Mitigation Plan</u>	<u>Basis of estimate</u>	<u>Cost Impact</u>		<u>Schedule Impact</u>	
					<u>Low</u>	<u>High</u>	<u>Low</u>	<u>High</u>
1302 - NONE								
1352 PF vendor produces a non-compliant coil requiring fabrication of an additional coil		VU	Conductor for extra coil will be procured in advance and available to wind a new coil if required. Float in schedule appears adequate to avoid critical path impact.	Increase PPPL Title III by ~1 man-month	+\$15	+\$35	+ 0.00	+ 0.00
No suitable PF coil vendor submits bid. PC coils need to be built in-house.		U	PF is last major, special procurement. Sources sought received two qualified respondents. Capability to build at PPPL exists if needed.	Cost impact estimated to be up to \$300k (1/3 of fabrication costs) for potentially higher labor rates at PPPL. No impact on critical path expected.	+\$0	+\$300	+ 0.00	+ 0.00

- Notes:
- Low cost and schedule impacts are considered the minimum (0-percentile) impacts should the event occur. High cost and schedule impacts are considered the maximum (100-percentile) impacts should the event occur
  - Cost impacts should be entered as man-hours (by demographic) and M&S direct cost under basis of estimate. Cost impacts should NOT include standing army costs which are separately calculated from the schedule impact. Project control is responsible for quantifying the low and high cost impacts based on the labor hours and M&S identified
  - The schedule impacts should be entered as the min and max impacts on the critical path. 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=Unlikley (40%>P>10%), VU=Very Unlikely (P<10%), NC=Non-credible (P<1%)

**NCSX June 2007 ETC  
TABLE V - Basis of Estimate**

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**M&S Estimate Backup**

Internal Estimate of Materials - based on quotes (Outokumpo), past procurements, & engineering

**NCSX PF Fabrication Material Cost Estimate**

<b>PF Coil Manufacturing Cost Details</b>				
<b>II. Materials M&amp;S</b>		<b>PF4</b>	<b>PF5</b>	<b>PF6</b>
Copper extrusion cost		\$/kg	\$/kg	\$/kg
Copper order factor		factor	factor	factor
copper cost / coils	\$	<b>\$29,812</b>	<b>\$38,174</b>	<b>\$27,267</b>
misc matl - \$ per lb of Cu in coils	2.0	\$/kg	\$/kg	\$/kg
glass insul width	mm	25.4	25.4	25.4
turn insul - length/meter of cond./layer	m/m	3.15	3.15	3.15
turn ins. Tape Thickness	mm	0.19	0.19	0.19
No. half lapped layers	#	2	2	2
meters of ins. /roll	m	10.00	10.00	10.00
no. rolls/coil	#	330.4	422.1	301.3
insulation waste factor	multiplier	1.3	1.3	1.3
total rolls of turn ins. reqd. 2 coils	#	858.9	1097.6	783.5
turn insulation cost per roll	\$/roll	4	4	4
Kapton insul width	mm	25.4	25.4	25.4
turn insul - length/meter of cond./layer	m/m	3.15	3.15	3.15
turn ins. Tape Thickness	mm	0.19	0.19	0.19
No. half lapped layers	#	1	1	1
meters of ins. /roll	m	10.00	10.00	10.00
no. rolls/coil	#	155.2	211.1	150.7
insulation waste factor	multiplier	1.3	1.3	1.3
total rolls of turn ins. reqd. 2 coils	#	429.5	548.8	391.7
turn insulation cost per roll	\$/roll	40	40	40
turn insulation total cost. 2 coils	\$	<b>\$29,376</b>	<b>\$37,537</b>	<b>\$26,784</b>
ground wall tape thickness	mm	0.38	0.38	0.38
No. half lapped layers	#	2.00	2.00	2.00
total ground wall thick	mm	1.52	1.52	1.52
ground wall tape width	cm	6	6	6
gw tape length reqd	m	96	240	267
meters of ins. /roll	m	10	10	10
no. rolls/coil	#	10	24	27
insulation waste factor	multiplier	1.30	1.30	1.30
no. rolls of GW insulation, pair of coils	#	25	62	69
GW tape cost per roll	\$	50	50	50
GW insulation cost. 2 coils	\$	<b>\$1,880</b>	<b>\$4,716</b>	<b>\$5,241</b>
Epoxy volume reqd. (15% void fraction)	l	23	33	24
Epoxy cost/liter	\$/l	30	30	30
Epoxy cost for pair of coils	\$	<b>\$2,066</b>	<b>\$2,963</b>	<b>\$2,175</b>
Leads and coolant connections/tool	\$	2500	2500	2500
Leads & coolant coils, pair of coils	\$	<b>\$7,550</b>	<b>\$7,550</b>	<b>\$7,550</b>
<b>Material Costs Insulation and Leads Only, Coil Pair</b>		<b>\$40,902</b>	<b>\$52,786</b>	<b>\$41,781</b>
<b>Total Material Cost Including Copper Conductor</b>		<b>\$70,714</b>	<b>\$90,940</b>	<b>\$69,028</b>

From: B. Umbenhaur [bumbenhaur@eversontesla.com]  
 Sent: Tuesday, December 05, 2006 10:52 AM  
 To: Michael R. Kalish; Rodney D. Templon  
 Cc: jstafiniak@eversontesla.com  
 Subject: PF Coils

Hi Mike,  
 For the PF Coil Budgetary, please use the following numbers based on some assumptions. The costs shown are for the coils only and no shipping or facilities related costs are included. The shipping costs will have an impact at the coils are so large. The coils are a little too large for the current configuration of the clean space we are using to wind the TF coils.

The coils are also too large for our ovens so we would plan to use steam to cure the coils during the VPI process. We have done this successfully in the past.

We have a material supply configuration as on the TF coils where the conductor and insulation is supplied by PPPL.

The current winding specification calls for a difficult winding scheme.

PF5 Coils (Quantity 2)

\$415,000 for two coils including tooling

PF6 Coils (Quantity 2)

\$485,000 for two coils including tooling

Please let me know if you have any questions or concerns. Thanks.  
 Bill

**Everson Quote on PF5 and PF6 Fabrication and Tooling**

**NCSX June 2007 ETC**  
**TABLE V - Basis of Estimate**

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**Job Manager: Mike Kalish**

CU Cost Estimate - Internal

Copper Cost Estimate for PF4, PF5 and PF6  
 Note : Includes 25% spare in final cost calculation

CopperPrice := 3.60 dollars

**PF 4** The Weight of the conductor is: PF4Length := 262.4m

$$.323 \frac{\text{lb}}{\text{in}^3} \left[ (.787\text{in})^2 - \pi \left( \frac{.354\text{-in}}{2} \right)^2 \right] \cdot \text{PF4Length} = 1.738 \times 10^3 \text{ lb}$$

$$\text{PF4Weight} := .323 \frac{\text{lb}}{\text{in}^3} \left[ (.787\text{in})^2 - \pi \left( \frac{.354\text{-in}}{2} \right)^2 \right] \cdot \text{PF4Length}$$

For 2 coils using Outo Kumpu Quote

$$\text{PF4Weight} \cdot 2 \cdot 1.25 \left( \frac{3.10 + 1.57}{\text{lb}} \right) = 2.029 \times 10^4 \text{ dollars} \quad \text{at time of quote}$$

$$\text{PF4Weight} \cdot 2 \cdot 1.25 \left( \frac{3.10 + \text{CopperPrice} + .16}{\text{lb}} \right) = 25812 \text{ dollars}$$

inflated to 5/07  
 3.10=engineering  
 3.60=copper  
 .16= silver bearing

**PF 5** The Weight of the conductor is: PFSLength := 336m

$$.323 \frac{\text{lb}}{\text{in}^3} \left[ (.787\text{in})^2 - \pi \left( \frac{.354\text{-in}}{2} \right)^2 \right] \cdot \text{PFSLength} = 2.226 \times 10^3 \text{ lb}$$

$$\text{PF5Weight} := .323 \frac{\text{lb}}{\text{in}^3} \left[ (.787\text{in})^2 - \pi \left( \frac{.354\text{-in}}{2} \right)^2 \right] \cdot \text{PFSLength}$$

For 2 coils using Outo Kumpu Quote

$$\text{PF5Weight} \cdot 2 \cdot 1.25 \left( \frac{3.10 + 1.57}{\text{lb}} \right) = 2.599 \times 10^4 \text{ dollars} \quad \text{at time of quote}$$

$$\text{PF5Weight} \cdot 2 \cdot 1.25 \left( \frac{3.10 + \text{CopperPrice} + .16}{\text{lb}} \right) = 38174 \text{ dollars}$$

inflated to 5/07  
 3.10=engineering  
 3.60=copper  
 .16= silver bearing

CopperPrice = 3.6 dollars

**PF 6** The Weight of the conductor is: PF6Length := 240m

$$.323 \frac{\text{lb}}{\text{in}^3} \left[ (.787\text{in})^2 - \pi \left( \frac{.354\text{-in}}{2} \right)^2 \right] \cdot \text{PF6Length} = 1.59 \times 10^3 \text{ lb}$$

$$\text{PF6Weight} := .323 \frac{\text{lb}}{\text{in}^3} \left[ (.787\text{in})^2 - \pi \left( \frac{.354\text{-in}}{2} \right)^2 \right] \cdot \text{PF6Length}$$

For 2 coils using Outo Kumpu Quote

$$\text{PF6Weight} \cdot 2 \cdot 1.25 \left( \frac{3.10 + 1.57}{\text{lb}} \right) = 1.856 \times 10^4 \text{ dollars} \quad \text{at time of quote}$$

$$\text{PF6Weight} \cdot 2 \cdot 1.25 \left( \frac{3.10 + \text{CopperPrice} + .16}{\text{lb}} \right) = 27267 \text{ dollars}$$

inflated to 5/07  
 3.10=engineering  
 3.60=copper  
 .16= silver bearing

$$(\text{PF6Weight} + \text{PF5Weight}) \cdot 2 \cdot 1.25 \left( \frac{3.10 + 3.14 + .16}{\text{lb}} \right) + 4000 = 6.505 \times 10^4$$

NCSX June 2007 ETC  
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PRINCETON PLASMA PHYSICS

FAX 609-243-3248  
Tel 609-243-2277

**OUTOKUMPU**

RFQ on copper conductor

1 (1)  
May 9, 2007

Dear Mike,

Outokumpu Quote

Please find our offer as follows:

**Product specification and quantity:**

- \* CDA102 Copper, soft temper
- \* Size 20mm Square with round 9mm ID, Outokumpu tool # 8456
- \* In pancake coils of approximately 100 ft
- \* Qty to be determined later.

**Pricing:**

Fabrication cost:	Up to 500lbs	One lump sum \$3,980 plus copper value
	1,000lbs	FAB \$ 4.90/lb plus copper value
	2,000lbs	FAB \$ 3.10/lb plus copper value

For Silver-bearing copper (CDA 107) add \$0.16/lb

The copper value based on the Comex market for November 2004 shipments is currently \$ 1.57/ lb.

The copper value may be firmed for the month of shipment the day an order is placed, up to two weeks prior to the confirmed ex mill date, or will be automatically firmed at Outokumpu published price the Friday preceding the confirmed ex mill date.

**Payment terms:**

60 days from the date of invoice. Subject to credit approval.

**Lead time and delivery terms:**

Ex mill Pon, Finland, November 4, 2004 plus 4 weeks (estimated) ocean transit. Delivered Duty Paid (DDP Incoterms 2000) to Princeton, NJ.

**Other Terms:**

According to the Outokumpu Poricopper Oy's General Terms for Sales (has been supplied earlier). The interest rate in the USA for overdue payment is 12%.

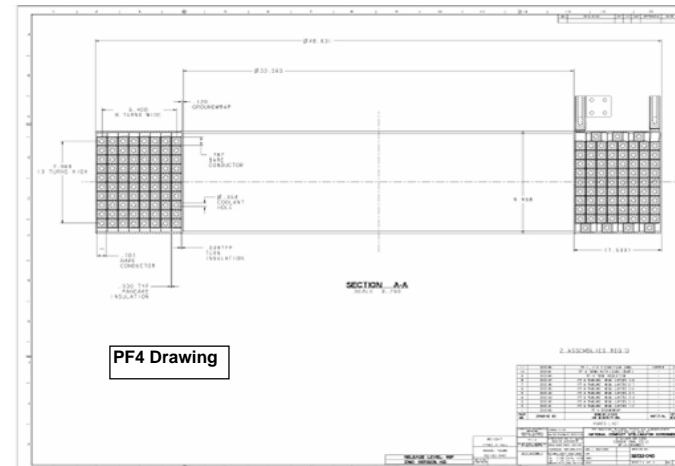
Sincerely,

Outokumpu Copper – Electrical Power & Components

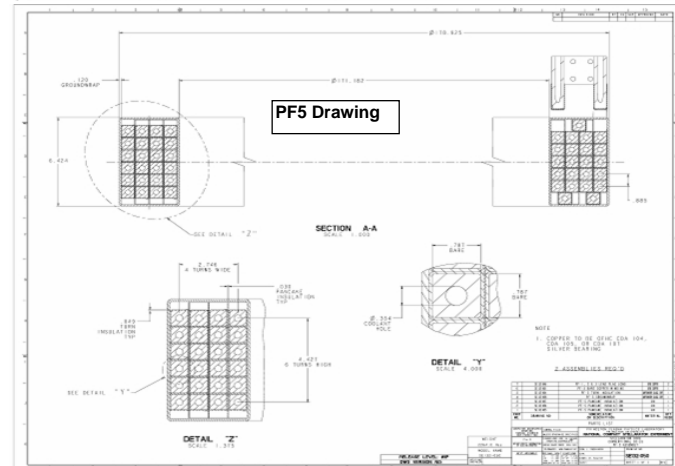
Petri Nordling  
Sales Manager

Cc: Asko Hakkinen, Paivi Nieminen, Denise Nolan

OUTOKUMPU COPPER – EPC Europe Division  
801 Pittsburgh Drive, Delaware OH 43015 / Tel. 740-368-7946 / Fax 740-363-3847



PF4 Drawing



PF5 Drawing





NCSX June 2007 ETC  
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Everson Quote on PF Fabrication  
and Tooling

**From:** B. Umbenhour [bumbenhour@eversontesla.com]  
**Sent:** Thursday, April 12, 2007 12:30 PM  
**To:** Michael R. Kalish  
**Subject:** PF4 Coil  
Hi Mike,  
Budgetary pricing for the PF4 Coil

Tooling: - \$72,000  
PF4 Coil - \$20,100/coil (\$40,200 for two coils)

Thanks.  
Bill

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Visit Everson Tesla Inc. on the web at <http://www.eversontesla.com>