FETS Mechanical Engineering Update

by Peter Savage

17th November 2010

Copper specification

Key points taken from CERN document:

Materials for high vacuum technology: an overview

by S. Sgobba

Summary: Cu OFE, C10100, 99.99% min Cu. A high conductivity electrolytic copper (in the annealed state, conductivity > 101% IACS at 20^{0}C) with limits for oxygen and 17 other impurities [1].

1. OFE grade is preferred for applications involving vacuum brazing or electron beam welding.
2. Fine-grained products (CERN specifies a maximum grain size of 90 microns) are mandatory for vacuum applications, especially when thin-walled components are foreseen.
3. The supplied bars should be 100% ultrasonically inspected to detect possible continuity faults.
4. For ease of machining, half-hard tempers are preferred to fully soft conditions.

[1] ASTM B170-99(2004), Standard Specification for Oxygen-Free Electrolytic Copper - Refinery Shapes.
Now replaced by: ASTM B170-99(2010)
OFE – oxygen free electronic
IACS – International Annealed Copper Standard

Copper composition

ASTM specification

APPLICATION DATASHEET
Standard Designation For
WROUGHT ALLOYS
Last Update: July 14, 2010

Coppers
C10100 - C12099

Composition,percent maximum,unless shown as a range or a minimum

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Copper No.	Designation	Description	Cu(incl Ag)	Ag(%) Min	Ag(Troy oz) Min	As	Sb	P	Te	Other Named Elements
C10100 (1)	OFE	Oxygen-Free -Electronic	99.99min (3)	--	--	.0005	.0004	.0003	.0002	.0005 Oxygen (2)
C10200 (1)	OF	Oxygen-Free	99.95min	--	--	--	--	--	--	.0010 Oxygen
C10300	OFXLP	Oxygen-Free Copper	99.95min (4)	--	--	--	--	.001-.005	--	--
C10400 (1)	OFS	Oxygen-Free with Ag	99.95min	.027	8	--	--	--	--	.0010 Oxygen
C10500 (1)	OFS	Oxygen-Free with Ag	99.95min	.034	10	--	--	--	--	.0010 Oxygen
C10700 (1)	OFS	Oxygen-Free with Ag	99.95min	.085	25	--	--	--	--	.0010 Oxygen
C10800	OFLP	--	99.95min (4)	--	--	--	--	.005-.012	--	--
C10910 (1)	--	--	99.95min	--	--	--	--	--	--	.005 Oxygen
C10920	--	--	99.90min	--	--	--	--	--	--	.02 Oxygen
C10930	--	--	99.90min	.044	13	--	--	--	--	.02 Oxygen
C10940	--	--	99.90min	.085	25	--	--	--	--	.02 Oxygen
C11000 (1)	ETP	Electrolytic Tough Pitch	99.90min	--	--	--	--	--	--	(5)
C11010 (1)	RHC	Remelted High Conducivity	99.90min	--	--	--	--	--	--	(5)
C11020 (1)	FRHC	Fire-Refined High Conductivity	99.90min	--	--	--	--	--	--	(5)
C11030 (1)	CRTP	Chemically Refined Tough Pitch	99.90min	--	--	--	--	--	--	(5)
C11040 (1)	--	--	99.90min	--	--	.0005	.0004	--	.0002	(6)
C11045	ETP	ETP	99.90min	--	--	.0005	.0004	--	.0002	(7)
C11100 (1)	ETP	Electronic	99.90min	--	--	--	--	--	--	(8)

Temper designations

1. Annealed Tempers, O

Tempers produced by annealing to meet mechanical properties requirements.

O10	Cast and annealed (homogenized)
O11	As-cast and precipitation heat treated
O20	Hot forged and annealed
O25	Hot rolled and annealed
O30	Hot extruded and annealed
O31	Extruded and precipitation heat treated
O40	Hot pierced and annealed
O50	Light annealed
O60	Soft annealed
O61	Annealed
O65	Drawing annealed
O68	Deep-drawing annealed
O70	Dead-soft annealed
O80	Annealed to temper,1/8 hard
O81	Annealed to temper,1/4 hard
O82	Annealed to temper,1/2 hard

2. Annealed Tempers, OS

Tempers produced by annealing to meet standard

OS005	Average grain size, 0,005mm
OS010	Average grain size, 0,010mm
OS015	Average grain size, 0,015mm
OS025	Average grain size, 0,025mm
OS035	Average grain size, 0,035mm
OS050	Average grain size, 0,050mm
OS060	Average grain size, 0,060mm
OS070	Average grain size, 0,070mm
OS100	Average grain size, 0,100mm
OS120	Average grain size, 0,120mm
OS150	Average grain size, 0,150mm
OS200	Average grain size, 0,200mm

3. Manufactured Tempers, M

Tempers produced in the product by the primary manufacturing operations of casting and hot working and controlled by the methods employed in the operations.

M01	As-sand cast
M02	As-centrifugal cast
M03	As-plaster cast
M04	As-pressure die cast
M05	As-permanent mold cast
M06	As-investment cast
M07	As-continuous cast
M10	As-hot forged and air coole
M11	As-forged and quenched
M20	As-hot rolled
M30	As-hot extruded
M40	As-hot pierced
M45	As-hot pierced and rerolled

4. Cold-Worked Tempers, H

Tempers produced by controlled amounts of cold work, **Cold-Worked (Drawn)**, **Stress-Relieved Tempers**, HR-Tempers produced by controlled amounts of cold work followed by stress relief and **Order-Strengthening Tempers**, **HT-Tempers** produced by controlled amounts of cold work followed by a thermal treatment to produce order strengthening.

H00	1/8 hard
H01	1/4 hard
H02	1/2 hard
H03	3/4 hard
H04	Hard
H06	Extra hard
H08	Spring
H10	Extra spring
H12	Special spring
H13	Ultra spring
H14	Super spring
H50	Extruded and drawn
H52	Pierced and drawn
H55	Light drawn;light cold rolled
H58	Drawn general purpose
H60	Cold heading; forming
H63	Rivet
H64	Screw
H66	Bold
H70	Bending
H80	Hard drawn
H85	Medium-hard-drawn electrical wire
H86	Hard-drawn electrical wire
H90	As-finned
HR01	H01and stress relieved
HR02	H02 and stress relieved
HR04	H04and stress relieved
HR08	H08 and stress relieved
HR10	H10and stress relieved
HR20	As-finned
HR50	Drawn and stress relieved
HT04	H04 and order heat treated
HT08	H08 and order heat treated

OFC Worldwide Specifications

Material Spec.	Nation		Japan		USA		UK		Germany
	Standard No.		JISH2123		ASTMB170		BS6017		DINI787
	Item		Copper Billets and Cakes		Oxygen-Free Electrolytic Copper Refinery Shapes		Oxygen-Free Refined Coper		Oxygen-Free Coper without Deoxidizer
	Classification		Grade 1 C1011	Grade 2 C1020	Grade 1 C10100	Grade 2 C10200	Cu-OFE C103	Cu-OF C110	OF-Cu 2.0040
	Chemical Composition	*2 Cu (%min)	99.99	99.96	99.99	99.95	99.99	99.95	99.95
		O_2 P (ppm)	10 max 3 max	10 max NA	5 max 3 max	10 max NA	10 max 3 max	NA NA	NA NA
Related Standards of Formed Copper Products			JIS H3510 Oxygen free copper sheet, plate, strip, seamless pipe and tube, rod, bar and wire for electron devices	JIS H3100 3140 3250 3300 Copper bus bars, rods and bars, seamless pipes and tubes	ASTM F68 Oxygen free copper in wrought forms for electron devices Class 1 ~ Class 5	ASTUM B75 B152 B248 Tube, sheet, strip, plate and rolled bar	BS2870~2875 Tube, sheet, strip, plate and rolled bar		DIN40500-Part4 Copper material for electrical use

*2: Including silver

Hitachi OFC products meet all specifications above.

Material quote - C103 bulk copper

8 pieces: 130mm x 280mm x 1100mm 375kg each
8 pieces: 110mm x 130mm x 1100mm 146kg each

@ £9-70/kg for a total of 4168kg

Hot rolled to M temper to BS 2875

Delivery costs not included
Can supplier perform UT and annealing?

Total cost = £40,429 material for full RFQ

OUTLOOK
Stockholders Limited

C10100 bulk copper

C10100 hot rolled copper plates temper M20 to ASTM B152 . Ultrasonically tested. Cannot confirm the grain size .

8 off pieces 130 x 280 x 1100 mm (375kg)
8 off pieces 110 x 130 x 1100 mm (146kg)

Price structure is unknown LME + £95.00 + 3.0% + conversion cost £3895 .

e.g. if daily LME (15th Nov) is £5412, selling price is (£5412 + £95.00) +3% = £5672 + (conversion £3895) = £9567 per 1000 kilos.

The LME fluctuates daily so until material is fixed with the mill selling price will fluctuate appropriately.

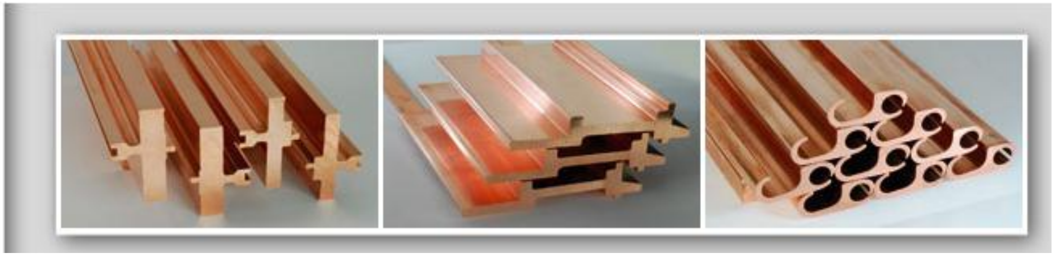
Test certificates £50.00 per occasion.

Lead time approx 5 working weeks.

Total weight = (375 x 8) + (146 x 8) = 4168 kg

Total cost = £39,875 material for full RFQ

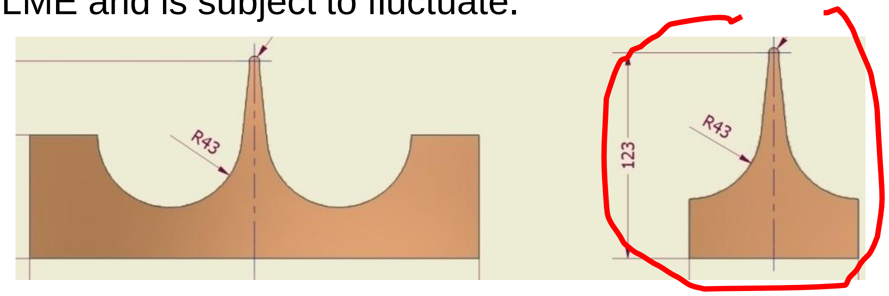
Copper profile quote



Metelec is a specialist stockholder and manufacturer of copper busbars, copper bar, copper profiles and copper components. Being the UK logistics arm of Gindre Duchavany, the largest manufacturer of copper extruded bars in Europe. Gindre extrude in excess of 55,000 tonnes of copper profile per annum and have a turnover in excess of €350,000,000.

Able to quote on the smaller of the two sections only
length of 1 metre -0+ 100mm
weight per metre 49.40 kg
tooling cost £3000
manufacturing price for 500 kilos = £10.706 per kilo based on LME £4882 (14th Sep 2010).

Please note that price varies in line with the daily LME and is subject to fluctuate.
Lead time tooling 6 weeks production 6 weeks .



Cost comparison – extruded versus bulk

(for MINOR vane only)

Extruded:

Tooling cost	= £3,000	
Weight per m	= 50 kg	
Cost per kg	= £10	
Cost per m	= £500	
Cost per 8m	= £7,000 *	one 4m RFQ's minor vane material

But, assuming both 352 MHz and 324 MHz RFQs could share the same (over-sized) extruded profile then the tooling costs are shared, giving:

Cost per 16m = £3000 + (16 x £500) = £11,000 **

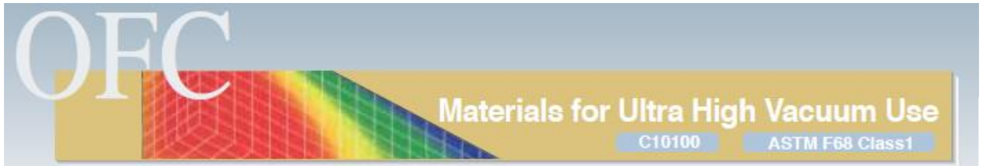
Bulk:

Size	= 130mm x 110mm x 1100mm	
Weight per m	= £146 kg	
Cost per kg	= £10	
Cost per m	= £1,460	
Cost per 8m	= £11,680 *	one 4m RFQ's minor vane material
Cost per 16m	= £23,360 **	

* *Total material cost for minor vanes for a 4m long RFQ*

** *Total material cost for minor vanes for two 4m long RFQs*

Another potential supplier...



Accelerator Cavities
(courtesy of Fermi National Accelerator Lab.)

Magnetrons

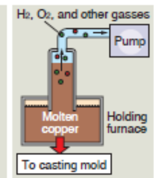
Electron Tubes

HitachiCable
Empowering Energy & Communication

Features

- Oxygen Free Copper (OFC) is the best material for electron tubes, wave guides and other vacuum equipments because of its superb electrical and thermal conductivity.
- A Minimum-Risk of contaminations in microstructure ensures a leak tight operation.
- The vacuum degassed OFC that meets ASTM F68 Class1 is strongly recommended for its lowest gas desorption and highest discharge breakdown field.

Microstructure improvement by vacuum degassing



Schematic view of degassing plant

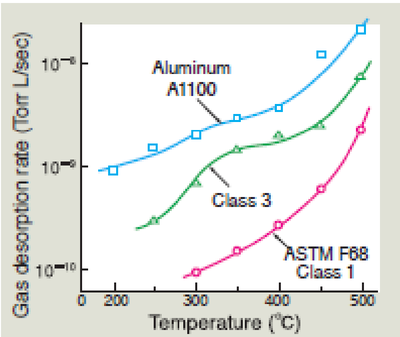
Applications

Electronics Components	Magnetrons, back plates of sputtering apparatus and hearths for CVD systems. Target material
Telecommunication Infrastructures	Microwave transmission tubes and vacuum circuit breakers
High Energy Physics	Accelerator cavities, wave guides, klystrons, and gaskets
Medical Instruments	CT scanner and laser components
Others	Magnet wires and audio/video cables

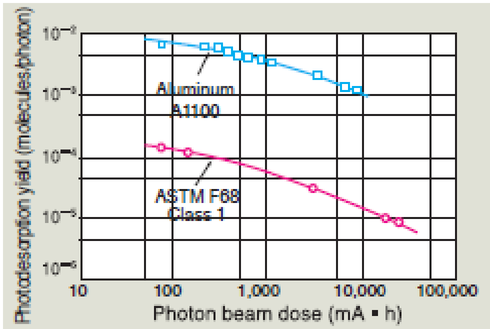
Available Shapes

Bars, Plates, Tubes and other custom shapes upon customers' request.

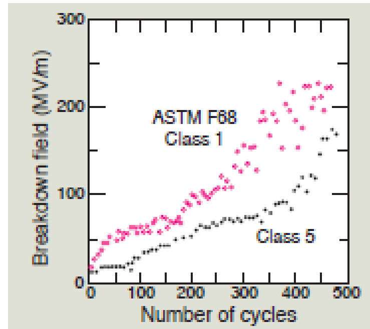
Properties



Thermal Gas Desorption

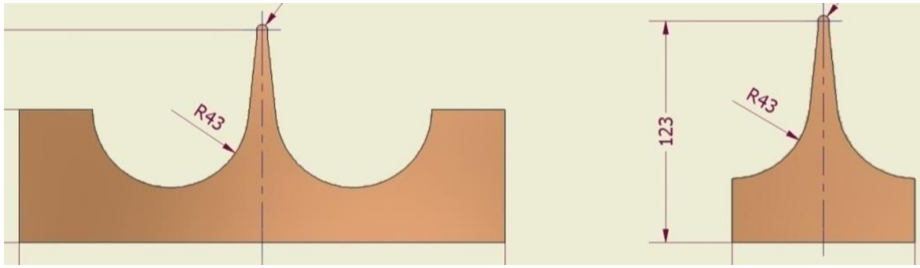


Photon Stimulated Gas Desorption

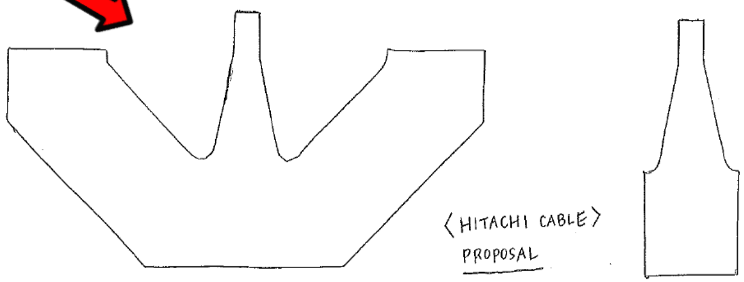


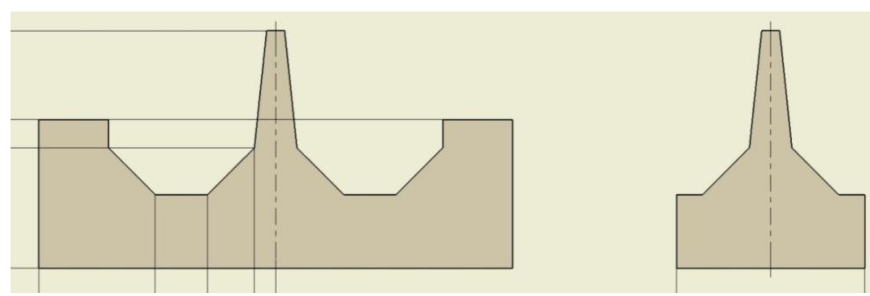
Discharge Breakdown in Vacuum

RFQ extruded profile – quote requested



Factory cannot guarantee half-hard temper or grain size.





Hitachi Cable
Empowering Energy & Communication

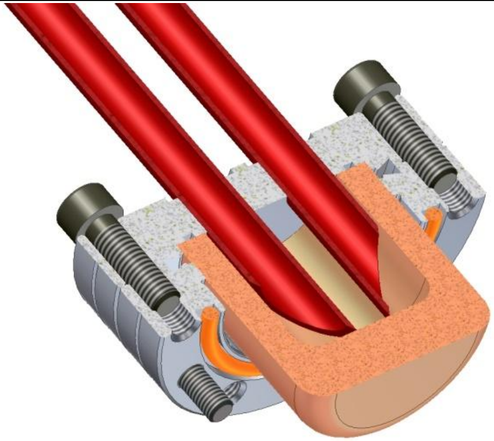
RFQ manufacturing cost

Produced a spreadsheet detailing the cost of manufacturing a one metre length of RFQ including material, manufacturing tuners, assembly rigs, transportation etc. Based upon machining time estimated at £50 per hour. All in-house items include only material cost.

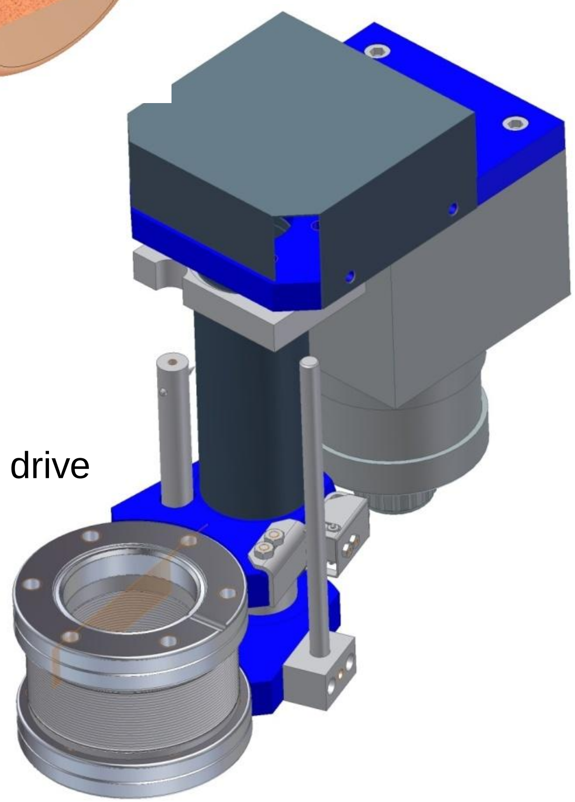
Costs do not include vacuum system and RF system. Joining costs are included but for the Indium method (which is by far the least expensive). End flanges including valves, toroids and bellows are not included.

		In-house manufacture
Per RFQ one metre "MAJOR" vane	£21,792	£10,405
Per RFQ one metre "MINOR" vane	£8,636	£3,502
Total	£30,428	£13,907
Grand total (2 of each type)	£60,856	£27,814

RFQ automatic tuners



Tuner plug assembly



VG Scienta
ZLTM50W linear drive

Can we buy and manufacture 4 automatic tuner assemblies?

We need:

3 x Linear drives: £1810 each + VAT
(Price in April 2009)

4 x tuner plug assemblies:

Flanges:	£50 per assembly
Material:	£50 per assembly
Brazing:	£25 per assembly
Pipes, bolts, O rings:	£10 per assembly
Total:	£7000

QN: We currently use a 50mm travel drive. A 25mm travel drive is available and may be less expensive. Investigate or prefer 4 identical units?

RFQ cold model plans

1. It has been agreed that we should use the RFQ cold model to perform thermal and RF tests.
2. The first step is to perform a vacuum test on the cold model.
3. Flanges have been made to blank off the ports. Need to make time for the test.
4. Cold model transported to RH for early Jan, return to IC end Feb.
5. Start machining (4x) cooling pockets in Mar / Apr / May
6. Goal to perform RF tests summer 2011.
7. Waveguide required (~17m) @ 35kg per metre – needs support framework.

Conclusions

1. I have found a supplier for bulk C10100 copper but the grain size cannot be confirmed. Do we care about grain size? If yes, could request samples at M20 temper and measure with microscope.

2. The total bulk material cost for a 4m RFQ is around £40K.

3. Extruded profile is approximately half the cost of bulk (and *presumably* reduces machining time). Not yet clear if it is available to us. Metelec could only produce extruded profile for the minor vane. Awaiting response from Hitachi Cable.

4. Total build cost for 1m of RFQ is around £60K (material included).

5. We can afford (just) to build 1m of RFQ with our present (Imperial) budget and RFQ design. Not clear if we can purchase linear drives for automatic tuners.

6. Daresbury have the capability to manufacture our RFQ and have shown *some* interest. More detailed discussion is required.

Thank you.

My notes

Tuning System:

•Plan to build 4 moveable tuners.

•Estimate cost for build (~10K - check). Spend this before financial year end?

•Make list of parts required with costs for next FETS meeting.

•Output coupler: needs modification so that it can be made shorter i.e. not so visible inside the cavity. Make this a priority.

Bead pull / Royal Holloway (RH)/ Cooling:

•It has been agreed that we should make RFQ cold model thermal and RF test.

•First need to perform vacuum test – can it be done before Xmas?

•Will need a circulator – has been ordered by Spanish, delivery due in June.

•Cold model to RH for Jan and Feb. Return to IC end of Feb.

•Start manufacturing (4) cooling pockets March / April / May.

•RF test will need waveguide system.

•Saad will estimate how much waveguide we need and deduce ballpark cost.

•Waveguide planning to include two flexible sections – for either side of wall.

•What will the waveguide weigh?

•Support framework for waveguide (use wall brackets + MiniTec)

•Waveguide to coax converter will be required (but later on).

•Aim to make thermal and RF test summer 2011.

RFQ build slide for next FETS meeting:

•Material cost per metre of RFQ + material spec?

•Build cost per metre of RFQ with breakdown?

•Produce timetable.


CNC