MASTER

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5/29 19 80 By CHL

**Thermo
Electron**

CORPORATION

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TOPICAL REPORT
MANUFACTURING COST
OF FLAME HEATED
THERMIONIC CONVERTERS

April 1979

Prepared by:

George LaRue and Gabor Miskolczy
Thermo Electron Corporation
85 First Avenue
Waltham, Massachusetts 02154

Prepared for:

U.S. Department of Energy
Contract No. DE-AC02-76ET11292

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SUMMARY

The cost of thermionic converters has been estimated in support of the cost calculations for thermionic topping of central station powerplants. These calculations supersede the previous calculations made in 1975⁽¹⁾ and use a design concept similar to the current configuration of flame-heated converters. The cost of converters was estimated by obtaining quotations from manufactureres whenever possible. The selling cost was found to be \$110 per kilowatt.

DESCRIPTION OF CONVERTER

The emitter and collector of the thermionic converter are both dome-shaped as shown in Figure 1. The collector is hollow to accommodate jet impingement gas/steam cooling. An alumina insulator is used between the electrodes; this insulator is recessed in the collector cavity so that the converters can be closely packed. A cesium-graphite reservoir is used, which operates at collector temperature so that no independent temperature control is needed. The emitter flange and the collector cooling tube are used as eletrical output leads. The important parameters of the converter are shown in Table 1.

Figure 1. Assembly Chart for Low Cost Converter

TABLE 1

SUMMARY OF CONVERTER PARAMETERS

EMITTER

Domed

Diameter

120 mm

Inconel 671

COLLECTOR

Domed

CRES 304

INTERELECTRODE SPACE

1 mm

EFFECTIVE AREA

127 cm²

POWER OUTPUT DENSITY

3.35 W/cm²

POWER OUTPUT PER CONVERTER

425 watt

COST ESTIMATES

Numerous companies were contacted to obtain their estimates for the manufacturing cost of the converter components. A cost quotation for 200,000 parts per year was requested. It was assumed that a production line would be set up to assemble the components into a completed converter. A budgetary estimate of the required investment in capital equipment was also made. Costs were also allowed for material scrapping and labor inefficiencies. The costs are summarized in Table 2. The work sheets are shown in Appendix A and the quotations obtained from manufacturers, in Appendix B.

It is seen from Table 2 that each converter costs \$47; \$35 for purchased parts, \$3 for labor and \$8 for profit. With additional investment in machinery, the purchased parts could be manufactured in the same plant, reducing their cost and increasing the cost of labor.

TABLE 2
CONVERTER COST SUMMARY

PURCHASED PARTS	LABOR (Minutes)	COST (\$)
Emitter		21.05*
Collector		2.71
End Ring		2.30
Air Tube		1.26
Seal Ring		3.51
Air Deflector		0.17
Seal Flange		1.12
Shield		0.11
Total Purchased Parts		32.23
Labor for Purchased Parts	2.67	
Inspection	1.60	
Sub Assembly 1	0.57	1.00
Sub Assembly 2	3.07	
Final Assembly	1.07	0.25
Final Inspection	0.50	
Subtotals	9.48	\$33.48
Scrap		1.67
Rework	0.95	
Totals	10.43	\$35.15
Labor @ \$15 per hour		\$ 2.61
Subtotal		\$37.76
Profit		8.98
Total		\$46.74

Converter area 127 cm²
Power density 33.5 W/cm²
Power per converter 425 W
Cost per Kilowatt \$110

*Includes the Cost of INCONEL 671 Material at \$6.30 per lb.

COMPARISON WITH 1975 COST ESTIMATES

The costs of thermionic converters were estimated in 1975 in a topping study⁽¹⁾. The estimated cost of these converters was \$250 per kilowatt. The cost reduction for the present study was obtained by:

Redesign of the converter to simplify the component parts.

Elimination of the potassium heat pipe.

Replacement of the cesium reservoir with a cesium-graphite reservoir.

REFERENCES

1. Thermo Electron Corporation Phase One Report, Conversion Topping System Study," Report No. TE4207-29-76, December 15, 1975.

APPENDIX A

[illegible]

A-2

[illegible]

A-3

DRAWING/PART NO R355-3 PROJECT NAME & NO. LOW-COST CONVERTER

ESTIMATOR G. LaRue

DATE 3/11/79

NAME OF PART	END RING
1	1
2	2
3	3
4	4
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98	98
99	99
100	100

NO OF PART 200,000 Units Per Year

CHECKED BY _____ DEPARTMENT _____

THERMIONICS
 for Gabor Miskolczy

[illegible]

A-4

DRAWING/PART NO R355-4 PROJECT NAME & NO. LOW-COST CONVERTER

ESTIMATOR G. LaRue

DATE 3/11/79

NAME OF PART.	AIR TUBE
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NO OF PART 200,000 Units Per Year

— CHECKED BY.

DEPARTMENT

THERMIONICS
 for Gabor Miskolczy

[illegible]

A-5

ESTIMATOR G. LaRue

DATE 3/11/17

— CHECKED BY _____ DEPARTMENT THERMIONICS
for Gabor Miskolczy

[illegible]

DEPARTMENT. THERMIONICS

A-7

A-8

[illegible]

DRAWING/PART NO. R355-1000 PROJECT NAME & NO. LOW COST CONVERTER ESTIMATOR G. LaRue DATE 3/11/79
NAME OF PART SUB ASSY #1 NO. OF PART 200,000 UNITS PER YEAR CHECKED BY _____ DEPARTMENT THERMIONICS
PTS #4-6 for Gabor Miskolczy

[illegible]

A-10

[illegible]

A-11

[illegible]

DRAWING/PART NO. R355-1000 PROJECT NAME & NO. LOW COST CONVERTER ESTIMATOR G. LaRue DATE 3/11/79
NAME OF PART TOTAL COST SUMMARY NO. OF PART 200,000 Units Per Year CHECKED BY _____ DEPARTMENT THERMIONICS

[illegible]

A-13

APPENDIX B

COMMERCIAL SHEARING, INC.

36 SOUTH ST., • NEW PROVIDENCE, NJ. • 07974
201 - 464 - 7300

QUOTATION

TO THERMO ELECTRON CORPORATION
R & D CENTER
101 FIRST AVENUE
WALTHAM, MASS. 02154

6481 0001

RECEIVED

DATE MARCH 6, 1979

No.

PAGE 1 OF 1

REFERENCE: PRICE EFFECTIVE 1/15/79
YOUR LETTER 2/2/79

ATTENTION: GABOR MISKOLCZY
DIRECTOR ENERGY CONVERSION DEPT.

— All Quotations are Subject to the Terms and Conditions Herein and on Reverse Side Hereof. All Orders Resulting from this Quotation are Subject to Acceptance by the Home Office of Seller.

QUANTITY	DESCRIPTION	EST. SHIPPING WT.	UNIT PRICE
----------	-------------	-------------------	------------

ITEM #1.

CUSTOMER DRAWING NO. R355-1 EMITTER
4.7" O.D. X 3/16 X 3.9" R.D. X 3" O.A.H.
MATERIAL: 304 2B S.S.
NO MACHINING OF I.D. OR FLANGE BY C.S.I. PLAIN FORMED HEAD

500 pcs.	\$8.62 each
1000 pcs.	7.98 each
2000 pcs.	7.70 each
5000 pcs.	7.59 each
10,000 pcs.	7.49 each

TOOLS: \$3500.00

ITEM #2.

CUSTOMER DRAWING NO. R355-2 COLLECTOR
4.25" O.D. X 1/8 X 3.67" R.D. X 1-1/4" O.A.H.
MATERIAL: 304 2B S.S.
NO MACHINING OF I.D. AND FLANGE BY C.S.I. PLAIN FORMED HEAD

500 pcs.	\$4.68 each
1000 pcs.	3.21 each
2000 pcs.	2.95 each
5000 pcs.	2.80 each
10,000 pcs.	2.71 each

TOOLS: \$3000.00

ITEM #3.

CUSTOMER DRAWING NO. R355-7
NOT SUITED TO OUR FACILITIES. DECLINE QUOTING.

PRICES SUBJECT TO CHANGE AT TIME OF SHIPMENT DUE TO FLUCTUATION IN
COST OF STAINLESS STEEL. A CHARGE IN THE SUM LISTED FOR "TOOLS" WILL BE
YOUNGSTOWN, OHIO MADE COVERING COST OF ADAPTATION OF DIES AND/OR TOOLS PRESENTLY OWNED BY
F.O.B. US AND ANY ADDITIONAL SUCH EQUIPMENT NECESSARY IN FABRICATING THE PRODUCTS
TERMS COVERED BY THIS QUOTATION - ALL SUCH EQUIPMENT TO BE AND REMAIN OUR PROPERTY.
SUBJECT TO CREDIT APPROVAL

DV/sjw

John V. Edwards
JOHN V. EDWARDS, EASTERN REGIONAL SALES

QUOTATION

E-05-0301500

ORIGINAL

COORS PORCELAIN COMPANY

DATE 04/02/79

600 9TH STREET
GOLDEN, COLORADO, U.S.A. 80401
Telephone (303) 279-6565 Telex: 45593

NEW TELEPHONE NUMBER
(303) 278-4000

TO: THERMO ELECTRON ENGR CORP
85 FIRST AVENUE
WALTHAM 54 MASS

ATTN: G. Larve

YOUR INQUIRY:
YOUR DWG NO. R355-5 REF. REV.
YOUR PART NO.
PART DESCRIPTION Seal Rings
COORS DWG. NO.

QUANTITY

UNIT PRICE \$

200000

3.51

TOOLING SERVICE CHARGE: \$ 1135

1. Parts will be inspected per MIL-STD-105D at 4 AQL, visual and dimensional, non-accumulative.
2. The metallizing may overlap the edges .010" maximum.
3. Parts to be molybdenum metallized and nickel plated.
4. The .010" x 45 degree edge break to be .005" to .015" radius or chamfer break.
5. Chips to be .012" x .012" x unlimited length.

NOTE: For your convenience, your local representative is

Mr. Bob Traves, phone number 617-887-8144.

We offer to manufacture products for you according to the specifications and terms on the front and back of the Quotation, WHICH INCLUDE LIMITATIONS OF WARRANTIES AND REMEDIES. We invite your acceptance at this time by the placement of your order for the quantity desired.

Type of Coors
Ceramic to be
used:

AD94

F.O.B POINT OF MANUFACTURE

Estimated Shipment after receipt of your order

First Order	14	weeks
Subsequent Orders	13	weeks

Payment is **NET 30 DAYS**
upon approval of our Credit
Department.

Shipments will be within
10% of quantities ordered.

Coors / CERAMICS

ES/4010/04476

Jan Wisor

By

B-3

Quotation from

PHONE (201) 471-777

MANUFACTURING CORPORATION

35 INDUSTRIAL ROAD/P.O. BOX 275/LODI, NEW JERSEY 07644

February 14, 1979
WQ79-390

Thermo Electron Corporation-R&D Center
101 First Avenue
Waltham, MA 02154

Attn: Gabor Miskolczy

Inquiry of 2-2-79

PLEASE READ standard manufacturing terms and conditions on reverse side hereof under which orders resulting from this quotation will be executed. Prices quoted herein are based on these terms.

Terms: To Approved Accounts
Net 30 days
Labor only-Net 10 days
Tools-Net 10 days

F.O.B. OUR FACTORY
local representative

O'Donnell Associate
20 Walnut Street
Wellesley Hills, MA

ITEM	PART	SIZE OR DESCRIPTION				QUANTITY	PRICE
1	Flat	2.80 ±.01	x	1.003 +.003 -.000	x .06	200,000	\$172.20

304 Stainless Steel

One Time Engineering Charge

\$5,040.00

Estimated Delivery: 16/18 Weeks
GC:lh

Present delivery time is predicated on current lead time for raw material delivery and available tool time per date of this quotation. If your requirements do not co-incide, feel free to discuss this with us as economic conditions vary daily in regard to these two factors.

Very truly yours,

Gary Caravito
H. K. METALCRAFT MFG. CORP.

Gary Caravito

Quotation from

PHONE (201) 471-7770

MANUFACTURING CORPORATION

35 INDUSTRIAL ROAD/P.O. BOX 275/LODI, NEW JERSEY 07644

March 21, 1979
WQ79-784

Thermo Electron Corporation
R & D Center
101 First Avenue
Waltham, MA 02154

Attn: G. Miskolczy

Inquiry of 3-1-79

PLEASE READ standard manufacturing terms and conditions on reverse side hereof under which orders resulting from this quotation will be executed. Prices quoted herein are based on these terms.

Terms: To Approved Accounts

Net 30 days

Labor only—Net 10 days

Tools—Net 10 days

F.O.B. OUR FACTORY

local representative

O'Donnell Associates

20 Walnut Street

Wellesley Hills, MA

ITEM	PART	SIZE OR DESCRIPTION	QUANTITY	PRICE
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1	R 355-7	4.059 x 2.749 x .010 +.000 +.000 -.003 -.003	200,000	\$561.00/M
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Nickel, Deep drawing quality.

Less finish 63AA

Overall Height .800

Shape & form per b/p.

One Time Engineering Charge

\$5,945.00

Note: We would require clarification of finish 63 AA prior to quoting this requirement.

2	P/N R355-2	This item that you require is not suitable for our manufacturing equipment.
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Note: Raw material, labor, and outside processing costs are subject to change. Therefore, this quotation is for immediate acceptance, and is subject to change without prior notification by us to you.

Estimated Delivery: 100 M pcs. 18 Weeks
WJB:lh Balance 22 Weeks

Present delivery time is predicated on current lead time for raw material delivery and available tool time per date of this quotation. If your requirements do not co-incide, feel free to discuss this with us as economic conditions vary daily in regard to these two factors.

Very truly yours,

Walter J. Bailey
H. K. METALCRAFT MFG. CORP.
Walter J. Bailey

QUOTATION

1357 EAST RODNEY FRENCH BLVD.
P. O. BOX E-915
NEW BEDFORD, MASSACHUSETTS 027
(617) 996-5691 TWX (710) 344-13
CABLE: RODMETALS

Date March 21, 1979

Name Thermo Electron

Address 85 First Avenue

City & State Waltham, Mass. 02154

Attention Mr. George LaRue

Reference _____

Our Inquiry No. 22498

WE ARE PLEASED TO QUOTE ON YOUR REQUIREMENTS AS FOLLOWS:

ITEM	QUANTITY	DESCRIPTION	PRICE
1	500#	Nickel 200, Full Hard, .010 x 6.00"	\$6.2461/#
		Packing Charge	\$15.00/skid

F.O.B. New Bedford, MA
Point: _____

Terms: 1/2 10, net 30

Shipping August 1979 *
Date: _____

Prices reflect those in effect at time of shipment.

*Based on availability
of material.

TELEDYNE RODNEY METALS

Thomas Davis
Thomas Davis, Sales Correspondent