Fermilab

Particle Physics Division

12-01-01

Mechanical Department Engineering Note

Number: MD-Eng/03-038

Date: February 25, 2004

Project: NuMi

Project Internal Reference:

Title: Power Supply Sliding Base Roller Footpad Assembly

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2-27-04

Key Words: NuMi , Power Supply Box Frame, Sliding Base Roller Footpad Assembly and Sliding Base support plate.

Abstract/Summary:

The NuMi Power Supply Sliding Base Roller Footpad Assembly was originally designed by David Tinsley. This engineering note is prepared in order to verify that this design is in compliance with the code.

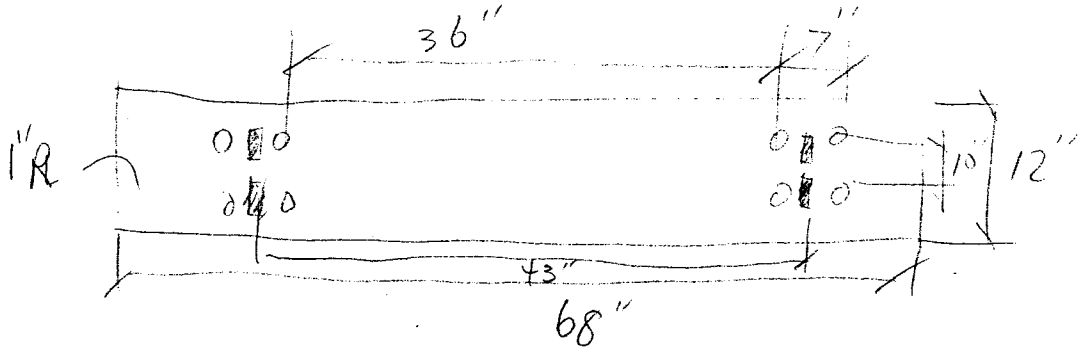
The Roller Footpad Assembly is used to support the Power Supply Box Frame at eight locations. The Power Supply Box Frame will also slide on top of this assembly through sixteen cam rollers. (see dwg. 8875.111-MD-431723 for details) The frame weights 21,500 pounds.

The design analysis was performed according to AISC "Allowable Stress Design" code. The results show that all parts including the modified Sliding Base Support Plate will safely support the Power Supply Box Frame within the allowable stress and deflection limits.

Applicable Codes:

1. AISC Manual of Steel Construction, Allowable Stress Design, Ninth Edition
2. Mark's Standard Handbook for Mechanical Engineers, Tenth Edition, Eugene A. Avallone,
3. Roark's Formulas for Stress & Strain, Sixth Edition, Warren C. Young

1. CHECK PWR SUPPLY SLIDING BASE SUPPORT PLAT
8875.111-MD-431691



Knowing: $W_{powersupply} = 22{,}000$ lbs

use $W_{powersupply} = 25{,}000$ lbs
to include the dead load

Thus, $W_{each\ corner} = \frac{1}{2} W_{powersupply}$

$= \frac{1}{2} \times 25000$

$= 12500$ lbs

$W_{each\ Roller\ assy} = \frac{1}{3} W_{each\ corner}$

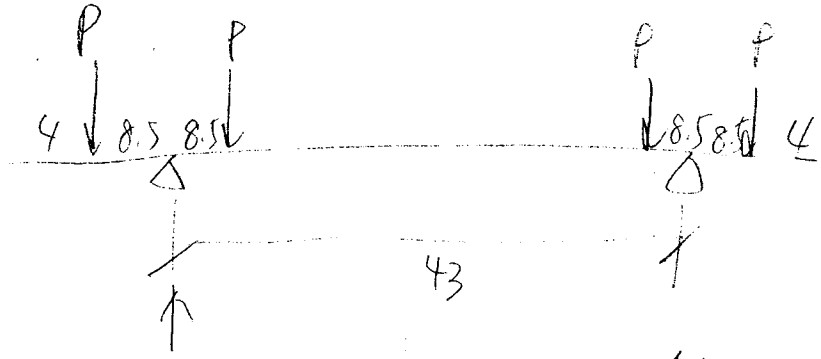
$= \frac{1}{3} \times 12500$ lbs

$= 4166.7$ lbs

$W_{each\ foot\ pad} = \frac{1}{3} W_{each\ Roller\ assy}$

$= \frac{1}{3} \times 4166.7$ lbs

≈ 1400 lbs



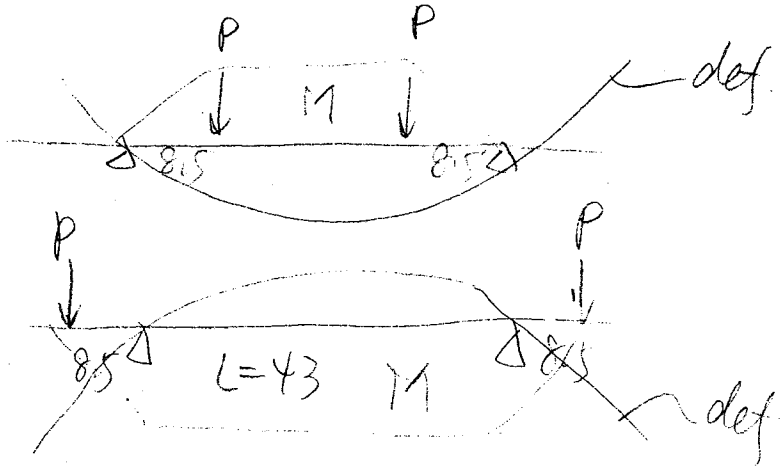
4 W each foot pad
$= 4 \times 1400$
$= 5600$ lbs.

4 W each foot pad
$= 4 \times 1400$
$= 5600$ lbs.

$4P = 5600 + 5600$

$P = 2800$ lbs

Case 1
+
Case 2



For Case 1: $M_{1max} = Pa = 2800 \times 8.5 = 23800$ lb-in

$$I = \frac{ab^3}{12} = \frac{12 \times 1}{12} = 1 \text{ in}^4$$

$$\text{def at center} = \frac{Pa}{24EI}(3L^2 - 4a^2)$$

$$= \frac{2800 \times 8.5}{24 \times 29 \times 10^6 \times 1}(3 \times 43^2 - 4 \times 8.5^2) = 0.179 \text{ in}$$

$$\text{def at load point} = \frac{Pa}{6EI}(3La - 3a^2 - x^2)$$

$$= \frac{2800 \times 8.5}{6 \times 29 \times 10^6 \times 1}(3 \times 43 \times 8.5 - 3 \times 8.5^2 - 8.5^2) = 0.1302 \text{ in}$$

For case 2 $M_{2\,max} = -Pa$

$= -2800 \times 8.5 = -23800$ lb·in

$$\text{def at center} = \frac{-PL^2 a}{8EI}$$

$$= \frac{-2800 \times 43^2 \times 8.5}{8 \times 29 \times 10^6 \times 1} = -0.189 \text{ in}$$

Combined cases.

$$M_{total} = |M_{1\,max}| + |M_{2\,max}|$$

$$= 238000 + 238000 = 476000 \text{ lb·in}$$

$$S = \frac{ab^2}{6} = \frac{12 \times 1^2}{6} = 2 \text{ in}^3$$

$$f_b = \frac{M_{total}}{S} = \frac{476000}{2} = 23.8 \text{ ksi} < F_b = 40.5 \text{ ksi}$$

OK

Allowable F_b:

check for width-thickness ratio $\frac{b}{t}$

$$\frac{b}{t} = \frac{12}{1} = 12$$

$$190/\sqrt{F_y} = 190/\sqrt{54} = 25.85 \quad \text{for } 440 \; F_y = 54$$

$$\frac{b}{t} < 190/\sqrt{F_y} \quad \text{— compact}$$

Thus, $F_b = 0.75 F_y$

$= 0.75 \times 54 = 40.5$ ksi

∴ Total deflection on the plate

$def_{t\text{-}center} = 0.179 + (-0.189)$

$= -0.010$ in (upward) < 0.125 in

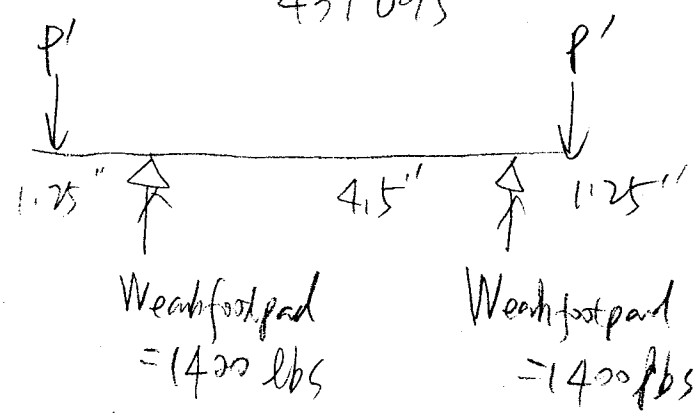
$def_{t\text{-}load} = 0.130 + (-0.189)$

$= -0.059$ in (up-ward) < 0.125 in

Since the Gap between the support plate and Guide plate is 0.125 in, the cam rollers will roll freely under the plate deflection.

2. check Beam Block:

8875.111-MB-431696
431695



$P' = 1400$ lbs

$M_{max} = Pa = 1400 \times 1.25 = 1750$ lb·in

$S = \frac{ab^2}{6} = \frac{2 \times 2.375^2}{6} = 1.88$ in^2

$f_b = \frac{M_{max}}{S} = \frac{1750}{1.88} = 0.930$ ksi $< F_b = 21.6$ ksi

$\therefore F_b = 0.60 F_y$ where $F_y = 36$ ksi for A36

$= 0.60 \times 36$

$= 21.6$ ksi

3. check the connection to the Bearing Blocks

For $\phi 3/4''$ Bolt. allowable shear $= 2.8$ kips

actual load $= 2 \times 1400$ lbs

$= 2800$ lbs

$= 2.8$ kips < 8.8 kips <u>ok</u>

$SF = \frac{8.8}{2.8} = 3.14$

4. check the leveling foot pad

8875.111-178-431722

Weak foot pad $= 1400$ lbs

Compression: $f_a = \frac{P}{A}$ where $P = 1400$ lbs

$A = \frac{1}{4}\pi d^2 = \frac{1}{4}\pi \times 0.75^2 = 0.44$ in^2

$= \frac{1400}{0.44}$

$= 3.181$ ksi < 20.95 ksi <u>ok</u>

Find F_a

$\frac{kl}{r} = \frac{1 \times 2.62}{0.187} = 13.97$

$r = \sqrt{\frac{I}{A}} = \sqrt{\frac{\frac{\pi d^4}{64}}{\frac{1}{4}\pi d^2}} = 0.187$ in

$C_c = 126.1$ for A36

$\frac{kl}{r} < C_c \therefore F_a = C_a F_y$

$$\frac{\frac{Kl}{r}}{C_c} = \frac{13.97}{126.1} = 0.11 \longrightarrow C_a = 0.582$$

$F_a = C_a F_y$ $\rightarrow$ $F_y = 36$ ksi for A36

$= 0.582 \times 36$

$= 20.95$ ksi

bearing: $f_p = \frac{F}{A}$ where $F = 1400$ lbs

$A = \frac{1}{4}\pi d^2 = \frac{1}{4}\pi \times 1.5^2 = 1.767 \text{ in}^2$

$= \frac{1400}{1.767}$

$= 0.792$ ksi

for steel $F_p = 0.90 F_y$ $\quad F_y = 36$ ksi for A36

$= 0.90 \times 36$

$= 32.4$ ksi $\gg 0.565$ ksi OK

for concrete 3500 psi $\quad F_p = 0.35 \times 3500$ psi

$= 1.225$ ksi > 0.565 ksi OK

5. CHECK the cam follower CCF-165

For REID TOOL SUPPLY CCF-165,

Rhoning: $\phi 2\frac{1}{2}''$ capacity $= 11{,}720$ lbs

Actual load $= \frac{1}{2}$(Weach foot pad $\times 4$)

$= \frac{1}{2}(1400 \times 4)$

$= 2800$ lbs

6. check the end retainer

2875.441-168-431692

a. Horizontal load:

assume $F_H = 10\% V$

$= 10\% \times 5600 = 560$ lbs (governs)

b. Rolling friction force:

According to Mark's Handbook, page 3-25,

know: $P = \left(\frac{K}{r}\right) L$

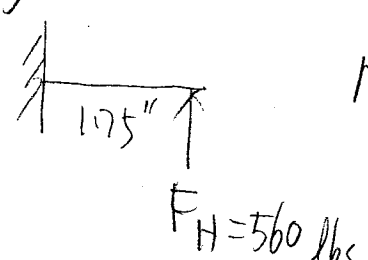
where $K = 0.01$ for steel to steel

$r = \frac{2.5}{2}$ in

$L = 5600$ lbs

$$P = \left(\frac{0.01}{2.5/2}\right) \times 5600 = 44.8 \text{ lbs}$$

Bending.



$M = PL$

$= 560 \times 1.75 = 980$ lb-in

$$S = \frac{ab^2}{6} = \frac{(4.56 - 2 \times 0.406) \times 0.25^2}{6} = 0.039 \text{ in}^2$$

$$f_b = \frac{M}{S} = \frac{980}{0.039} = 25.101 \text{ ksi} < F_b = 27 \text{ ksi} \quad \underline{\text{OK}}$$

$$\frac{b}{t} = \frac{4.56 - 2 \times 0.406}{0.25} = 14.992 \qquad \frac{190}{\sqrt{F_y}} = \frac{190}{\sqrt{36}} = 31.66 \qquad F_y = 36 \text{ ksi for A36}$$

$\because \frac{b}{t} < \frac{190}{\sqrt{F_y}}$ — compact

$\therefore F_b = 0.75 F_y = 0.75 \times 36 = 27$ ksi

For A36

Shear:

$f_v = \frac{F}{A}$ where $F = F_H = 560$ lbs

$A = 1.062 \times 0.25 = 0.2655 \text{ in}^2$

$= \frac{560}{0.2655}$

$= 2.109$ ksi $\ll 14.4$ ksi ok

$F_v = 0.40 F_y$

$= 0.40 \times 36$

$= 14.4$ ksi

$F_y = 36$ ksi for A36

7. Check the Bolt connection in the retainer.

Tension: $\phi 3/8$ allowable $= F_t A$

where $F_t = 20 \times 10^3$ psi for A307 Bolt

$A = \frac{1}{4}\pi d^2 = \frac{1}{4}\pi \times 0.375^2$

$= 0.11 \text{ in}^2$

allowable Tension $= 20 \times 10^3 \times 0.11$

$= 2200$ lbs

Actual load $= F_H = 560$ lbs

$SF = \frac{2200}{560} = 3.92$ ok

8. check the bolt connection between Guide plate and support plate:

for Bolt $\Phi 3/8$. shear allowable $= 10$ ksi

actual stress: $f_v = \frac{F/3}{A}$ where $F = F_H = 560$ lbs

$= \frac{560/3}{0.11}$ $\quad A = \frac{1}{4}\pi d^2$

$= \frac{1}{4}\pi \times 0.375^2$

$= 1.7$ ksi $\quad = 0.11 \text{ in}^2$

< 10 ksi

OK

9. check Hertz's contact stress between the cam roller and support plate.

According to Roark's Formulas for Stress & Stress. Table 33, 2a, knowing:

$$b = 1.60\sqrt{p\, k_D\, C_Z}$$

where $p = \frac{P}{L} = \frac{2800}{2.50} = 1120$ lb/in

$k_D = D_r = 2.5$ in

$$C_Z = \frac{1-\nu_1^2}{E_1} + \frac{1-\nu_2^2}{E_2}$$

$E_1 = E_2 =$ steel

$\nu_1 = \nu_2 = 0.3$

$$= \frac{2-2\nu^2}{E} = \frac{2-2\times 0.3^2}{29\times 10^6}$$

$$= 0.063\times 10^{-6}$$

Thus, $b = 1.60\sqrt{1120 \times 2.5 \times 0.063 \times 10^{-6}}$

$= 0.02125$ in

$\text{Max } \sigma_c = 0.591\sqrt{\frac{PE}{K_D}}$

$= 0.591\sqrt{\frac{1120 \times 29 \times 10^6}{2.5}}$

$= 67.4$ ksi $> F_p = 48.6$ ksi N.G.

allowable $F_p = 0.90\,F_y$ $\quad F_y = 54$ ksi for 4140

$= 0.90 \times 54$

$= 48.6$ ksi

propose to change material from 4140 to T1 Type A Alloy steel ASTM A514 Grade B with $F_y = 100$ ksi min.

Thus, allowable $F_p = 0.90\,F_y$ $\quad F_y = 100$ ksi for T-1

$= 0.90 \times 100$

$= 90$ ksi

$SF = \frac{90}{67.4} = 1.3$ OK

Shear stress:

$$\max \tau = \frac{1}{3}(\max \sigma_c)$$
$$= \frac{1}{3}(67.4)$$
$$= 22.47 \text{ ksi}$$

Allowable $F_v = 0.40 F_y$

$F_y = 100$ ksi for T-1

$$= 0.40 \times 100$$
$$= 40 \text{ ksi}$$

$$SF = \frac{40}{22.47} = 1.780 \text{ OK}$$

max τ at a depth of $0.4b$ below the surface of the support plate

$$0.4b = 0.4 \times 0.02125$$
$$= 0.009''$$

CAM FOLLOWERS

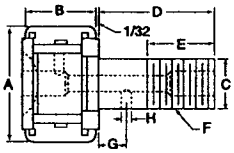
Steel and Stainless Steel
Needle Bearing

Regular Duty Steel - The inner and outer race are made of high carbon chrome bearing steel through hardened and ground. The studs are low carbon steel. The steel type are slotted. Hex socket types are available as special order. Please call for price and delivery.

Regular Duty Stainless Steel - Made of 440C stainless steel. Extends your bearing life and reduces maintenance cost. They use food grade lubricant. The stainless type have a hex socket.

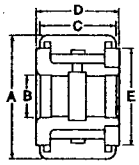
Heavy Duty Steel - Similar to the regular duty but the studs are thicker. The heavy duty steel type have a hex socket. Other sizes available as special order. Please call for price and delivery.

Stud Type Followers



Steel Cat. No.	Stainless Cat. No.	Size	+.000 -.001 A	+.000 -.005 B	+.010 -.000 C	+.010 -.010 D	E	F	G	H	Dynamic Rating Lbs. Steel	Dynamic Rating Lbs. Stainless	Static Rating Lbs. Steel	Static Rating Lbs. Stainless	Price Each 1-24 Steel	Price Each 1-24 Stainless
Regular Duty																
CCF-5	CCF-350	1/2	.500	.375	.190	.625	.250	10-32	—	—	680	544	790	632	6.57	38.25
CCF-10	CCF-355	5/8	.625	.438	.250	.750	.312	1/4-28	—	—	995	796	1,215	796	6.53	38.00
CCF-15	CCF-360	3/4	.750	.500	.375	.875	.375	3/8-24	1/4	3/32	1,660	1,328	2,065	1,652	5.96	38.48
CCF-20	—	7/8	.875	.500	.375	.875	.375	3/8-24	1/4	3/32	1,660	—	2,065	—	6.10	—
CCF-25	CCF-370	1	1.000	.625	.438	1.000	.500	7/16-20	1/4	3/32	2,225	1,780	2,065	2,448	7.47	46.69
CCF-30	—	1 1/8	1.125	.625	.438	1.000	.500	7/16-20	1/4	3/32	2,225	—	3,060	—	7.81	—
CCF-35	CCF-380	1 1/4	1.250	.750	.500	1.250	.625	1/2-20	5/16	3/32	3,930	3,144	4,250	3,400	9.31	56.00
CCF-40	—	1 3/8	1.375	.750	.500	1.250	.625	1/2-20	5/16	3/32	3,930	—	4,250	—	9.80	—
CCF-45	CCF-390	1 1/2	1.500	.875	.625	1.500	.750	5/8-18	3/8	3/32	4,840	3,872	5,640	4,572	11.10	68.58
CCF-50	—	1 5/8	1.625	.875	.625	1.500	.750	5/8-18	3/8	3/32	4,840	—	5,640	—	11.31	—
CCF-55	CCF-400	1 3/4	1.750	1.000	.750	1.750	.875	3/4-16	7/16	3/32	6,385	5,108	7,920	6,336	14.17	85.32
CCF-60	—	1 7/8	1.875	1.000	.750	1.750	.875	3/4-16	7/16	3/32	6,385	—	7,920	—	14.63	—
CCF-65	CCF-410	2	2.000	1.250	.875	2.000	1.000	7/8-14	1/2	1/8	8,090	6,472	10,570	8,456	20.24	118.25
CCF-70	—	2 1/4	2.250	1.250	.875	2.000	1.000	7/8-14	1/2	1/8	8,090	—	10,570	—	21.44	—
CCF-75	—	2 1/2	2.500	1.500	1.000	2.250	1.125	1-14	9/16	1/8	11,720	—	16,450	—	26.96	—
CCF-80	—	3	3.000	1.750	1.250	2.500	1.250	1 1/4-12	5/8	1/8	15,720	—	24,910	—	54.64	—
Heavy Duty																
CCF-500	—	1/2	.500	.375	.250	.625	.250	1/4-28	—	—	680	—	1,580	—	7.94	—
CCF-505	—	5/8	.625	.438	.313	.750	.312	5/16-24	—	—	955	—	2,480	—	7.87	—
CCF-510	—	3/4	.750	.500	.438	.875	.375	7/16-20	1/4	3/32	1,660	—	4,130	—	7.96	—
CCF-515	—	7/8	.875	.500	.438	.875	.375	7/16-20	1/4	3/32	1,660	—	4,130	—	8.14	—
CCF-520	—	1	1.000	.625	.625	1.000	.500	5/8-18	1/4	3/32	2,225	—	6,120	—	9.73	—
CCF-525	—	1 1/4	1.250	.750	.750	1.250	.625	3/4-16	5/16	3/32	3,930	—	8,500	—	11.71	—
CCF-530	—	1 3/8	1.375	.750	.750	1.250	.625	3/4-16	5/16	3/32	3,930	—	8,500	—	12.36	—
CCF-535	—	1 1/2	1.500	.875	.875	1.500	.750	7/8-14	3/8	3/32	4,840	—	11,280	—	14.46	—
CCF-540	—	1 3/4	1.750	1.000	1.000	1.750	.875	1-14	7/16	3/32	6,385	—	15,840	—	17.96	—
CCF-545	—	2	2.000	1.250	1.125	2.000	1.000	1 1/8-12	1/2	1/8	8,090	—	21,140	—	24.86	—
CCF-550	—	2 1/4	2.250	1.250	1.125	2.000	1.000	1 1/8-12	1/2	1/8	8,090	—	21,140	—	26.26	—
CCF-555	—	2 1/2	2.500	1.500	1.250	2.250	1.125	1 1/4-12	9/16	1/8	11,720	—	32,900	—	32.21	—

Yoke Type Rollers



Similar in construction to the followers above. Can support heavier loads because stud deflection is not a factor. Bearings are sealed.

Steel Cat. No.	Stainless Cat. No.	Size	+.000 -.001 A	+.0002 -.0004 B	+.000 -.005 C	+.005 -.010 D	E	Oil Hole Dia.	Dynamic Rating Lbs. Steel	Dynamic Rating Lbs. Stainless	Static Rating Lbs. Steel	Static Rating Lbs. Stainless	Price Each 1-24 Steel	Price Each 1-24 Stainless
CCF-105	CCF-430	3/4	.750	.2500	.500	.5625	5/8	3/32	1,660	1,328	4,130	3,304	6.97	33.23
CCF-110	—	7/8	.875	.2500	.500	.5625	5/8	3/32	1,660	—	4,130	—	7.08	—
CCF-115	CCF-440	1	1.000	.3125	.625	.6875	23/32	3/32	2,225	1,780	6,120	4,896	8.42	40.43
CCF-120	—	1 1/8	1.125	.3125	.625	.6875	23/32	3/32	2,225	—	6,120	—	8.45	—
CCF-125	CCF-450	1 1/4	1.250	.3750	.750	.8125	1	3/32	3,930	3,144	8,500	6,800	9.29	44.56
CCF-130	—	1 3/8	1.375	.3750	.750	.8125	1	3/32	3,930	—	8,500	—	9.74	—
CCF-135	CCF-460	1 1/2	1.500	.4375	.875	.9375	1 1/8	3/32	4,840	3,872	11,280	9,024	11.26	54.12
CCF-145	CCF-470	1 3/4	1.750	.5000	1.000	1.0625	1 1/4	3/32	6,385	5,180	15,840	12,672	14.25	68.43
CCF-150	—	1 7/8	1.875	.5000	1.000	1.0625	1 1/4	3/32	6,385	—	15,840	—	14.46	—
CCF-155	—	2	2.000	.6250	1.250	1.3125	1 1/2	3/32	8,090	—	21,140	—	19.09	—
CCF-160	—	2 1/4	2.250	.6250	1.250	1.3125	1 1/2	3/32	8,090	—	21,140	—	20.43	—
CCF-165	—	2 1/2	2.500	.7500	1.500	1.5625	1 3/4	1/8	11,720	—	32,900	—	26.83	—
CCF-170	—	3	3.000	1.0000	1.750	1.8125	2 1/4	1/8	15,720	—	49,820	—	48.88	—