

4.2.4 Focusing horns

Figure 4.2-14 and **Figure 4.2-15** show the horns, which are pulsed to produce toroidal magnetic fields. Slightly idealized parameterizations of the conductor shapes are listed in **Table 4.2-7**. The field strength falls off linearly with radius. The highest field is at the neck of horn 1 (3 Tesla at 200 kA).

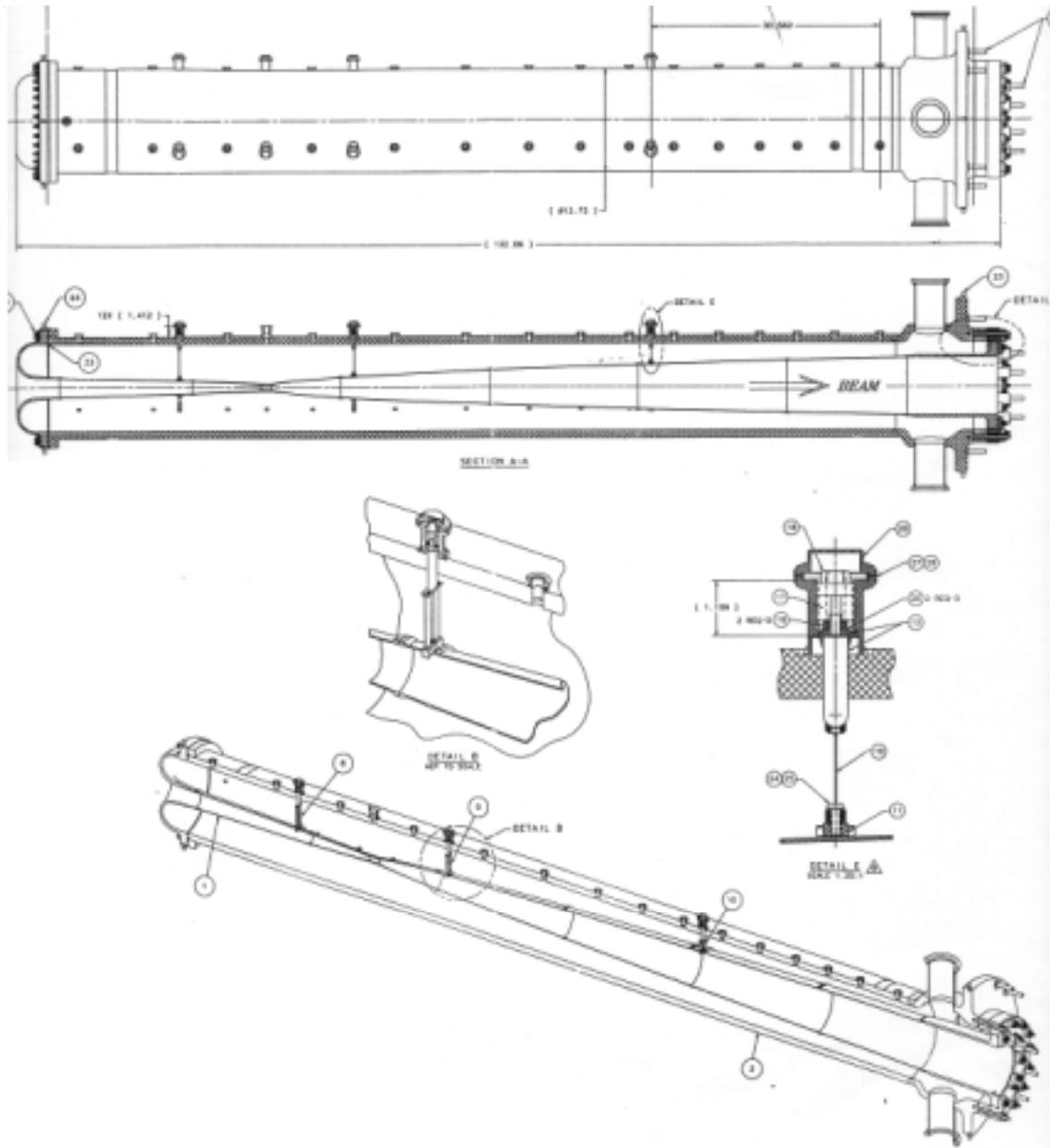


Figure 4.2-14 Horn 1 assembly drawing, with detail of inner conductor support spider. (From drawing 8875.112-ME-363092)

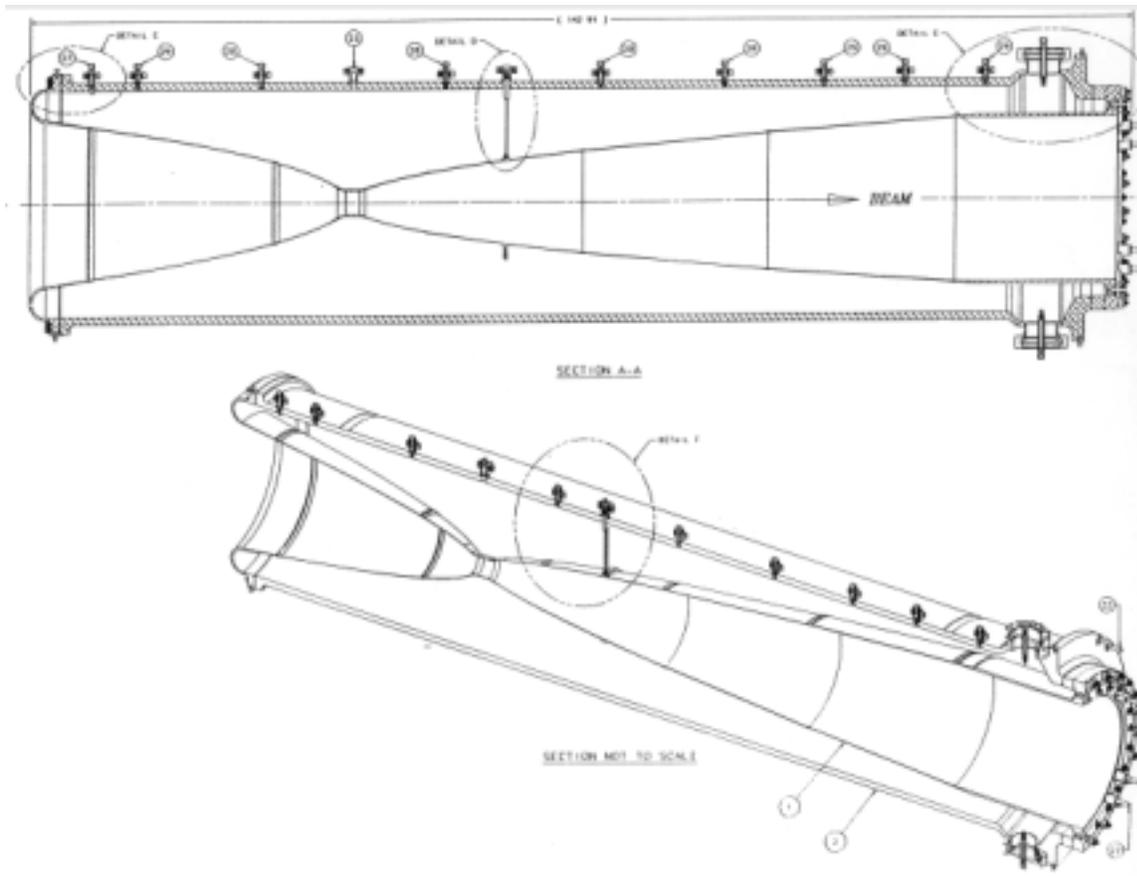


Figure 4.2-15 Horn 2 assembly drawing. (From drawing 8875.112-ME-363382).

PH2M Horn Parameters

Horn#1	Upstream		Neck	Downstream	
Z, cm	0.-44.047	44.047-80.	80.-83.982	83.982-95.128	95.128-300.
R_{in}^{IC} , cm	$\sqrt{\frac{92.8454-Z}{7.0483}} - 0.2$	$\sqrt{\frac{85.7091-Z}{7.0483}}$	0.90	$\sqrt{\frac{Z-82.2123}{2.1850}}$	$\sqrt{\frac{Z-80.}{2.1850}} - 0.2$
R_{out}^{IC} , cm	$\sqrt{\frac{92.8454-Z}{7.0483}}$		1.35	$\sqrt{\frac{Z-80.}{2.1850}}$	
R_{in}^{OC} , cm			15.83 14.92		
R_{out}^{OC} , cm			16.20 17.46		

Horn#2	Upstream	Neck	Downstream
Z, cm	0.-97.617	97.617-104.803	104.803-300.
R_{in}^{IC} , cm	$\sqrt{\frac{100.-Z}{0.1351}} - 0.2$ 0.3	4.00 3.90	$\sqrt{\frac{Z-100.}{0.2723}} - 0.2$ 0.3
R_{out}^{IC} , cm	$\sqrt{\frac{100.-Z}{0.1351}}$	4.20 4.40	$\sqrt{\frac{Z-100.}{0.2723}}$
R_{in}^{OC} , cm			37.00 ✓
R_{out}^{OC} , cm			37.87 39.54

Table 4.2-7 Idealized equations describing shape of horn conductors. Z is distance along beamline, and R gives inner and outer edges of inner and outer conductors. See construction drawings for details of rounded corners, endcaps, cooling ports, etc.

The horns are designed for 205 kA maximum current pulse of 5.2 ms half-sine wave width, with a repetition rate of 1.87 sec. The pulse width planned for use with the low energy beam is between 1.7 ms and 2.3 ms, which will reduce the joule heating. However, the horn is still baselined to be able to run at 5.2 ms pulse width, and the following section is entirely based on that more stringent case as indicated in **Table 4.2-8**.

Parameter	Horn 1	Horn 2
Inductance (nH)	690	~457
Resistance ($\mu\Omega$)	208 (meas.)	<112
Average Power from Current Pulse (kW)	17.0	<7.5
Power Flux at Neck (W/cm ²)	14.5	<4.7
Temperature Rise at Neck (°C)	22.8	<7.1
Outer conductor beam energy deposition (kW)	14.5	5.4

Table 4.2-8 Electrical parameters for 5.2 ms pulse width.

Summary of stresses:

- US end cap: minimum stress before pulse is -1030 psi; maximum stress at mid-pulse is -9020 psi; mean stress is -5025 psi with an alternating stress of 3995 psi; Stress ratio $R=0.11$
- Under the above calculated stress levels, allowable maximum stress for 10^7 cycles at the endcap is 26.5 ksi resulting in fatigue safety factor of 2.9
- Neck of horn: stress at mid-pulse is +4351 psi; stress at end of pulse is -3742 psi; mean stress is 304 psi with alternating stress 4047 psi; Stress ratio $R = -0.86$ (*Note: Negative value of R results in lower value of fatigue stress limit*)
- Under the above calculated stress levels, allowable maximum stress for 10^7 cycles at neck is 15.3 ksi resulting in fatigue safety factor of 3.5
- Stress in conductor weldment regions is very low ($\ll 4$ kpsi)

** Fatigue data from Aerospace Structural Metals Handbook*

Fabrication

- Inner conductor fabricated from 6061-T6 billet per QQA 200/8
- Relatively good strength (UTS ~ 45 ksi, YS ~ 40 ksi, R=-1 FS ~ 16 ksi)

Welding:

- Single pass, full penetration CNC TIG weld is required to minimizing conductor distortion, assure repeatability, and control internal weld porosity
- Proper cleaning, handling, fixtures, and weld parameters are crucial to minimize conductor distortion and internal weld porosity.

Coating:

- Inner Conductor and conductor supports are coated high phosphorus electroless nickel (0.0005” - 0.0007” thick).
- Outer conductor is anodized: Type III (hard coat sulfuric acid, 0.0023”), R_C 60-65, dielectric strength of ~800 V/mil
- Stripline contact surfaces use 0.0005” silver brush plating

Mechanical:

- Water Seals- Total of 64 water seals in horn
 - Utilize EVAC aluminum delta seals on KF style flange
- Bolted Connections
 - Utilize TimeSert threaded inserts, pullout exceeds 9600 lb. on 3/8” insert
 - As a reference, maximum end wall reaction is approximately 4270 lb.
- Current Contact Surfaces
 - Current surfaces have 32 μin finish, 0.0003”-0.0005” silver plate finish
 - Interface clamping pressure exceeds 1400 psi
 - Prototype horn 1 contact area is 9.2 in² for 7250 Arms.