BNL-105142-2014-TECH

Booster Technical Note No. 95;BNL-105142-2014-IR

Development of a three point roll bend for Booster dipole vacuum chamber

B. McDowell

October 1987

Collider Accelerator Department

Brookhaven National Laboratory

U.S. Department of Energy

USDOE Office of Science (SC)

DISCLAIMER

DEVELOPMENT OF A THREE POINT ROLL BEND FOR BOOSTER DIPOLE VACUUM CHAMBER

AD

Booster Technical Note

No. 95

B. McDOWELL

OCTOBER 30, 1987

ACCELERATOR DEVELOPMENT DEPARTMENT

Brookhaven National Laboratory

Upton, N.Y. 11973

DEVELOPMENT OF A THREE POINT ROLL BEND OF BOOSTER DIPOLE VACUUM CHAMBER

B. McDowell

Summary

Three point roll bending with sand packing produces a bend that is well within the tolerances specified for the Booster dipole vacuum chamber. However, before this method can be adopted, each of the issues mentioned under recommendations must be addressed and proven.

Background

Three point roll bending (roll bending) is a classical method of bending a wide variety of products. As applied to this application, roll bending employs four rollers cut to the cross-section of the tube to be bent. (Figure 1.)

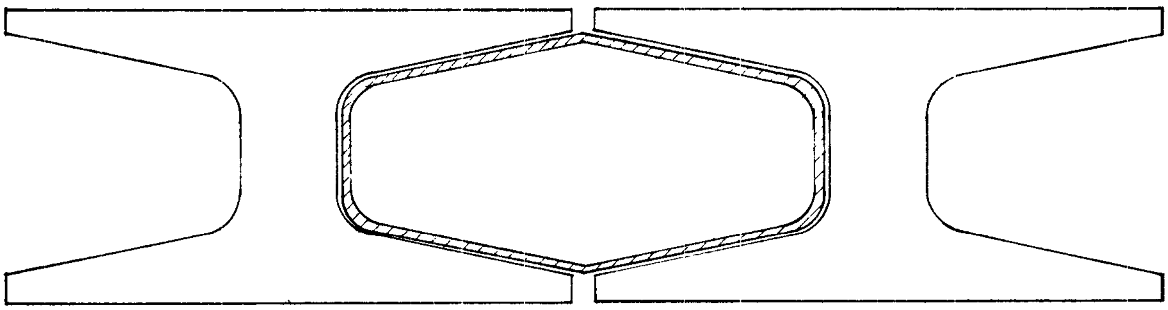


FIG. 1 BENDING ROLLERS

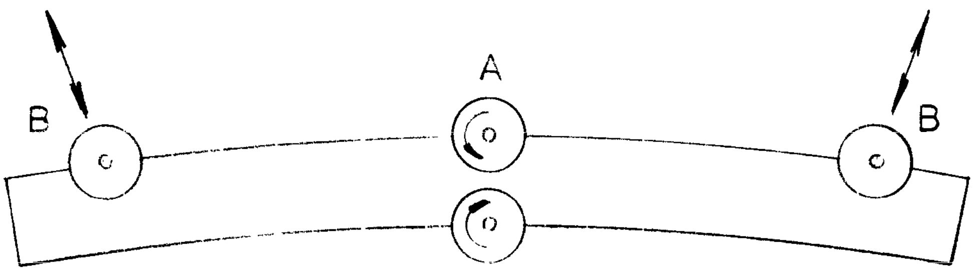


FIG. 2 ROLLER CONFIGURATION

Two driver rollers (A) power the specimen through the machine while wing rollers (B) mounted on power screws are moved along the line of action shown to produce the bend. This method of producing the dipole chamber bend is attractive because of low tooling costs (~ 5-8K) and low processing costs (200-300 ea).

Tube Manufacture and Processing

Youngstown Welding was contracted to manufacture two 144" straight chambers as per drawing D36-M-0573-3C. The finished length of the chamber is 107" with the extra 37" serving as a "leader" for the bending operation.

The first complication was encountered during inspection of the Youngstown chambers. Measurement of major and minor axis of cross-section revealed a maximum duration from nominal dimensions of +.134" and +.262" respectively.

TABLE 1

MEASUREMENTS OF 144" STRAIGHT CHAMBERS

Specified Height 2.900 ± 1/64, Width 6.5 ± 1/64

Sample 1

	1ft	2ft	3ft	4ft	5ft	6ft	7ft	8ft	9ft	10ft	11ft
Height	2.985	3.079	3.128	3.162	3.120	3.069	3.059	3.086	3.142	3.151	3.061
Width	6.610	6.604	6.588	6.579	6.587	6.626	6.630	6.625	6.584	6.565	6.585

Sample 2

	1ft	2ft	3ft	4ft	5ft	6ft	7ft	8ft	9ft	10ft	11ft
Height	3.051	3.088	3.121	3.130	3.021	3.030	3.072	3.115	3.155	3.117	3.062
Width	6.575	6.584	6.595	6.625	6.634	6.620	6.601	6.600	6.589	6.567	6.563

The top and bottom seams were visibly rippled from the heat of welding with several severe (1/32") dimples caused by poor alignment of matching halves prior to welding. By carefully cutting a template out of cardboard the edges of the chamber containing the .45" radii were checked and found to be under by approximately 3/16". Twist was crudely measured by approximately ½".

After conferring with management, it was decided to utilize these chambers to learn as much as possible about the feasibility and mechanics of the bending process.

The chambers were shipped to DFK Fabrications, Inc. which had been contracted to do the bending. The first chamber was repeatedly run through the drive rollers of the bending machine (see Figure 2) in an attempt to size the chamber. This measure was reasonably successful at the cost of additional cold working of the chamber. Before and after measurements are presented in Table 2 below.

TABLE 2

BEFORE AND AFTER MEASUREMENTS OF SIZED CHAMBER

Width	Before	6.610	6.604	6.588	6.579	6.587	6.626	6.630	6.625	6.584	6.565	6.585
	After	6.500	6.528	6.493	6.510	6.496	6.511	6.509	6.505	6.508	6.504	6.534
Height	Before	2.985	3.079	3.128	3.162	3.120	3.069	3.059	3.086	3.142	3.151	3.061
	After	2.940	2.989	2.995	3.027	2.990	2.970	2.956	2.990	2.954	2.920	2.920

Upon completion of the sizing operation an attempt was made to bend this chamber without sand packing. This attempt was unsuccessful and caused the chamber to buckle first on the longer spans of the bottom and top and finally on the sides (figure 3).

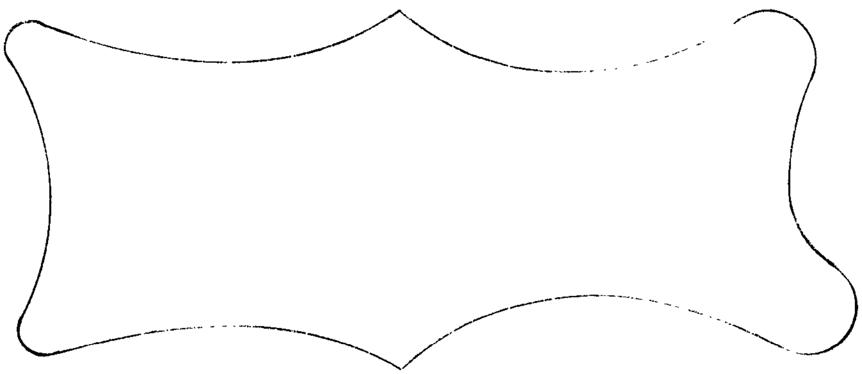


Figure 3
Buckling Pattern of Unpacked Chamber

The second chamber was reworked at Youngstown Welding to remove some of the more severe concavities.

Upon its return to DFK it was decided to sand pack and flame anneal the chamber prior to sizing and bending. After allowing the packed chamber to cool overnight it was transported to the bending machine for sizing. Sizing was not as successful with the sand filled chamber, and a large crown (Figure 4) developed on the top and bottom.

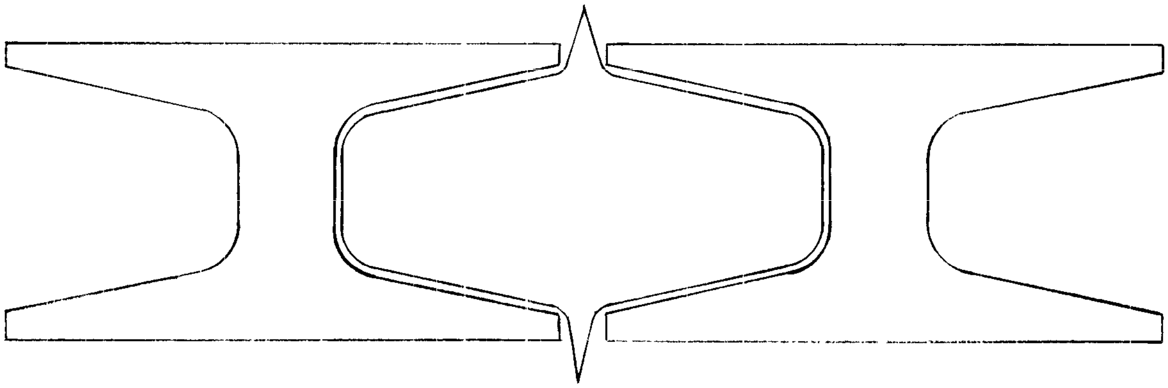


Figure 4
Crown Produced During Sizing of Sand Filled Chamber

Eventually the danger of piercing the chamber wall forced the sizing operation to be stopped.

The work piece was transported to a hydraulic ram where the crown was flattened enough to get it through the rollers of the bending machine. (Figure 5.)

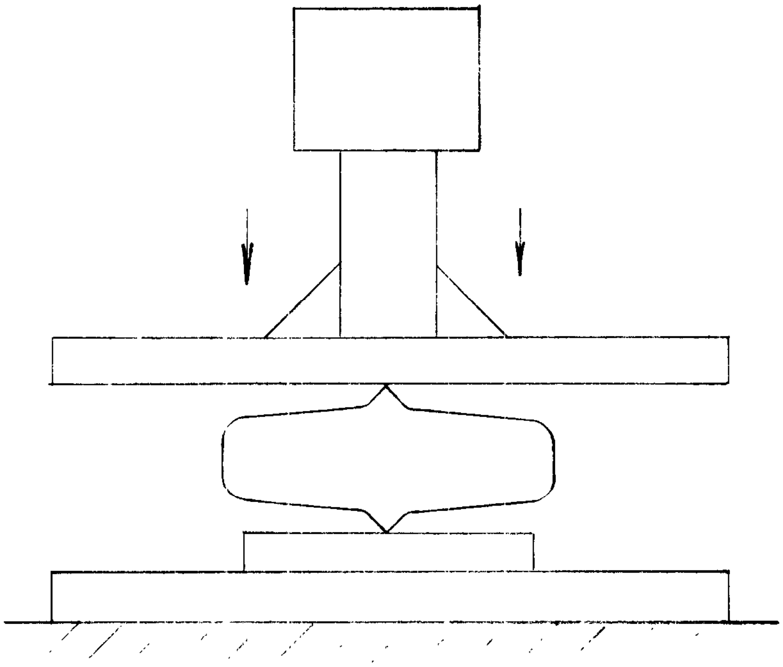


Figure 5
Hydraulic Ram

Upon completion of the last sizing pass the major and minor axis of x secton were measured. (See Table 3.)

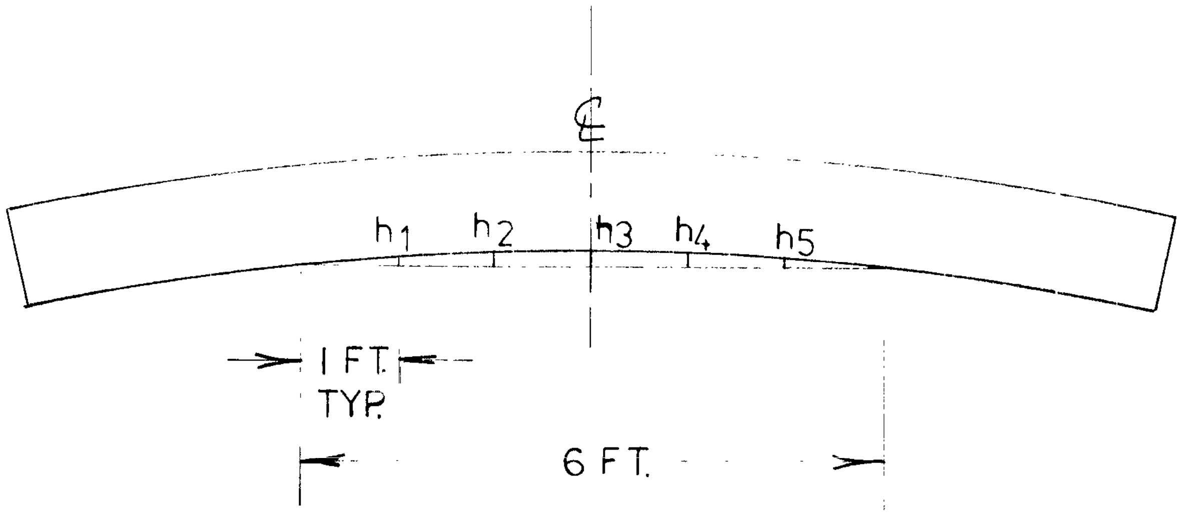
The bend was produced using 21 passes moving the wing rollers approx. .060" per pass. A two foot long gauge was used to check the radius of curvature as the bend progressed. Upon completion of the bend the arc height was measured over a six foot span on center.

Results

As stated earlier, bending without sand packing was unsuccessful. DFK feels that if a tube could be obtained to the proper tolerance, full annealed and without stress rises that an unfilled chamber could be bent. This remains to be seen.

The surface finish of the sand packed chamber was very poor after bending. This is due to scoring of the drive rollers during the sizing operations. The rollers, hardness R_c~23, were not designed for this purpose.

The bend obtained over the six foot span measured, was well within the ±1/16" tolerance specified on Drawing 36-M-0574-3A. Figure 6 below gives the arc coordinates measured at 1 ft intervals.



	h_1	h_2	h_3	h_4	h_5
Actual	43/64	1 5/64	1 11/64	1 6/64	43/64
Nominal	.669	1.071	1.205	1.071	.669

Figure 6
Arc Coordinates

An average width reduction of .038" was observed after bending. Table 3 below gives width and height measurements at 1ft intervals before and after bending.

Table 3
Cross-Section Measurements Before and After Bending

Prior to Bending

	1ft	2ft	3ft	4ft	5ft	6ft	7ft	8ft	9ft	10ft	11ft
Height	2.946	2.933	2.899	2.934	2.939	2.911	2.874	2.877	2.875	2.906	2.965
Width	6.515	6.518	6.524	6.517	6.521	6.505	6.513	6.508	6.505	6.516	6.553

After Bending

Height	2.898	2.908	2.874	2.903	2.915	2.885	2.900	2.899	2.866	2.910	2.934
Width	6.521	6.529	6.446	6.448	6.457	6.458	6.445	6.439	6.456	6.515	6.556

Recommendations

When the bend specimen is received it should be cut at regular intervals and the cross-section accurately measured point by point. Particular attention should be given to any changes in wall thickness and the impact upon the application of same.

Rollers will have to be remade due to a height change made to the cross-section. A surface finish of at least 16 and a hardness R_c~63 should be specified. The edge of the roller should be broken with a radius. The above measures should preserve the finish of the chambers.

The cross-section of the chambers will have to be held to at least ±.030" at all locations. Our own Central Shops have demonstrated the ability to hold this tolerance which is not unreasonable.

Electron beam welding is recommended for the seam weld. This method imparts the least heat to the work piece thereby minimizing distortion. Excellent results have been obtained on small samples manufactured on site.

The chambers should be delivered to the bending contractor fully annealed. The "leader" should be increased to 2ft 3in and can be a disposable or reusable weld on.

The chamber design of Drawing D36-M-0574 should be revised to eliminate the straight sections at the ends. These straight sections are impractical to produce by this method.

The effects of the packing sand on vacuum and corrosion will have to be investigated. Special cleaning procedures or an alternate packing material may be required.

The need for a leader and possible cold forming effects impacts upon the plan to shuffle chamber halves by resistance. The feasibility and merits of this technique will need to be accessed.