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Structural Concept for Support of the RHIC Cold Mass Using Injection Molded Composite Posts

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RHIC PROJECT

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Conclusions

- The most severe loading condition anticipated for the cold mass support posts is the axial load due to a helium pressure imbalance over the length of the magnet. This is an upset condition rather than a normal operating state.

- The *worst <u>conceivable</u> case* is the pressure upset occurring during a cool-down or warm-up of the superconducting magnet. In this case the side posts are not in contact with their stops, and the center post alone must resist the end thrust.

- For this case the estimated stress and deflection are:
  Maximum stress intensity in post material = 8 200psi.
  Axial travel of cold mass = .193 inches.

- The center post cradle must be properly designed and tightly installed to transfer a bending moment of 75 600 pound inches between the post and the cold mass.

- The *worst <u>probable</u> case* is a pressure upset occurring while the magnet is either warm or cold. In either event, the side posts are in contact with the stops. At least one of them is in a position to assist the center post in transferring the upset load to the foundation.

- The estimates for the worst probable case are:
  Maximum stress intensity in post material = 4 300 psi.
  Axial travel of the cold mass = .094 inches.

Support Concept

The injection molded composite (IMC) posts will replace not only the shrink-fitted fiberglass reentrant posts, but also the diagonal straps. The IMC posts will have lower material and manufacturing costs, and will present a more simple cryostat assembly. The cryostat design using the IMC posts has fewer parts. The IMC posts are similar or better than the fiberglass posts from the standpoints of strength, stiffness, resistance to heat flow, and dimensional control.

The purpose of diagonal straps are to resist the end load due to pressure upset conditions. Since the IMC posts replace the diagonal fiberglass straps as well as the posts, the IMC posts are included in a structural system which must carry the end load. The structural concept upon which the design is based is one in which the lateral bending resistance of the post becomes paramount, and the cradle becomes a part of the bending moment transfer mechanism.

The end load due to a pressure upset has been estimated to be 12 500 pounds. In terms of the adverse effects upon the posts, the end load is a more severe condition than are the dead weight, seismic, or the dynamic transportation loads. Although, all the other loads will continue to be investigated, the 12 500 pound end load governs the conceptual design of the structural system for supporting the cold mass.

The structural system conceived for resisting the end load without the use of diagonal straps is shown schematically in Figure 1. The support cradles at the top of the two side posts allow the cold mass to expand and contract axially. However there are stops on these cradles which contact the side posts when the cold mass is fully cold and fully warm. The cradle atop the center post is fixed to both the cold mass and the post in all rotational and translational directions.

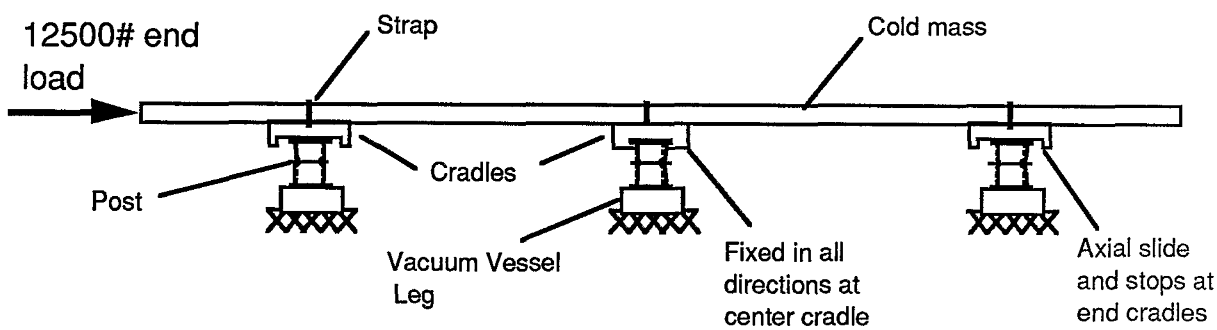


Figure 1. Schematic of the structural system supporting the cold mass.

The Worst Conceivable Case

The worst conceivable case occurs when the magnet is neither fully warm nor fully cold. If a pressure upset should occur during such a time, the full axial load must be carried through the center post without much help from the side posts. In order to better support the center post, the cradle of the center post fixes the top of that post to the cold mass, preventing it from freely rotating. This more favorably distributes the bending moment from the bottom to the top of the post. However, it also introduces a reacting bending moment into the cold mass. The bending moment diagram over the length of the cold mass is shown in Figure 2.

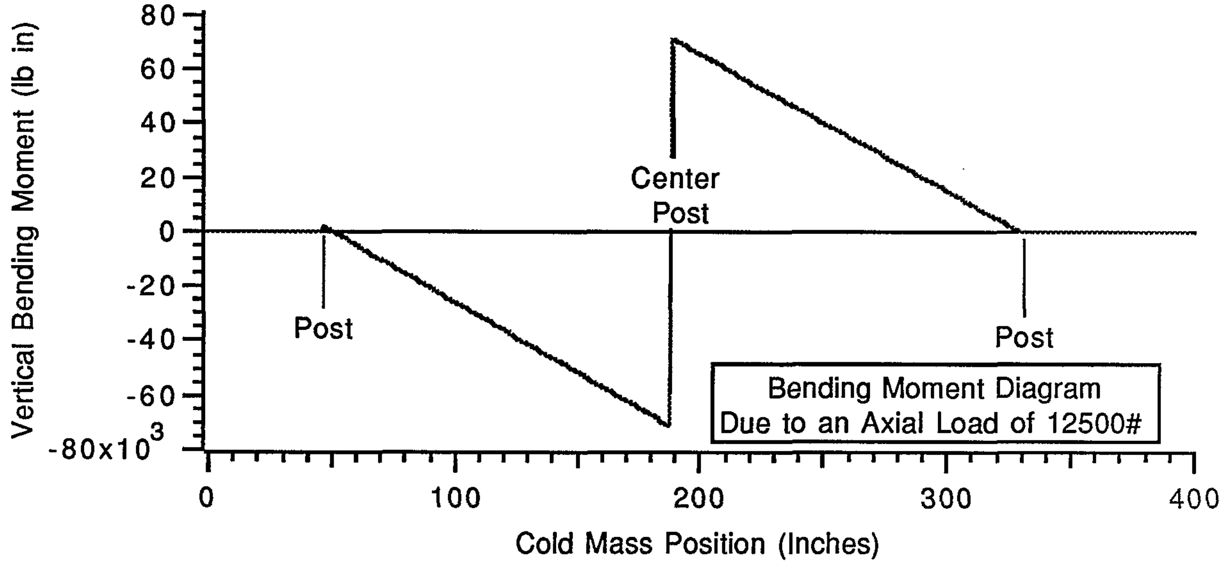


Figure 2. The bending moment distribution in the vertical direction over the length of the cold mass due to the worst conceivable loading case.

Because this cold mass support structure is highly statically indeterminate, a finite element analysis was done using MSC/PALS in order to estimate the moments, forces, stresses, and deflections. The loads upon the posts are dependant upon the relative stiffness of the structural members and upon the fixity between members. The static indeterminacy is aggravated by the sagitta which couples the elastic deformation in the vertical plane to that in the horizontal plane. Therefore, there is also a bending moment distribution in the horizontal direction. But, the absolute value of the horizontal moment is everywhere less than than 11×10^3 pound inches. The support reactions of interest are those shown in Figure 3.

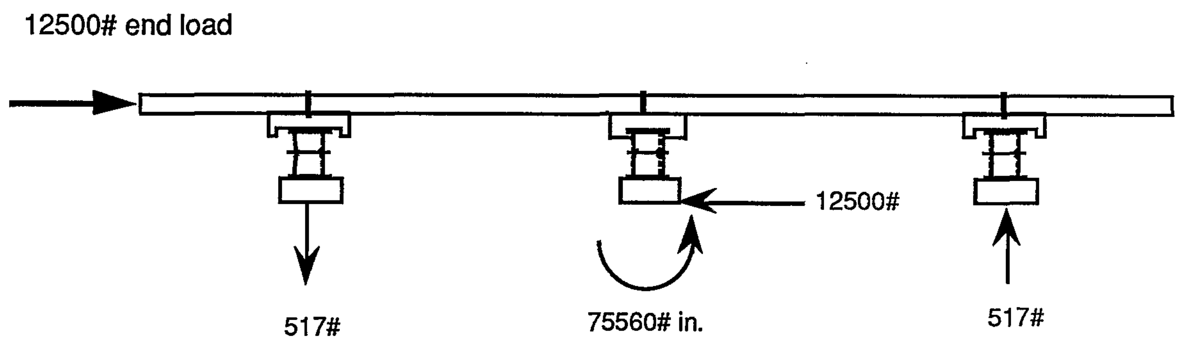


Figure 3, Support reactions on the cryostat structure due to the worst conceivable case.

The material of the helium containment vessel, which encases the cold mass, is more than 30 times stiffer than the IMC material. Therefore, the cold mass deflections are small in comparison to those of the posts. The stresses introduced into the helium containment vessel are everywhere less than 19% of the yield stress for its material. The deflections of the magnet structure from the finite element analysis are shown in a side view, an isometric view and an end view on the attached pages. It is clear from these exaggerated views that the largest part of the elastic action and stresses will be absorbed by the IMC posts.

In this worst conceivable case, the center post does all the work of resisting the end load. The center post carries a large shear force and bending moment as shown in Figure 4. The highest Von Mises stress intensity is 8 200 psi, which occurs at the bottom of the center post where the bending moment is the greatest. The bending moment at the top of the center post is opposite in direction but a little less than that at the bottom, producing a stress intensity of 7 400 psi. If the saddle were not able to transfer the bending moment to the cold mass, the bending moment would be redistributed unfavorably to the bottom of the post, almost doubling it to 143 800 pound inches. The stress intensity at the bottom would then be increased to an unacceptable level of 15 600 psi., and the axial movement of the cold mass would be increased to .337 inches. Therefore, the cradle connection is very important.

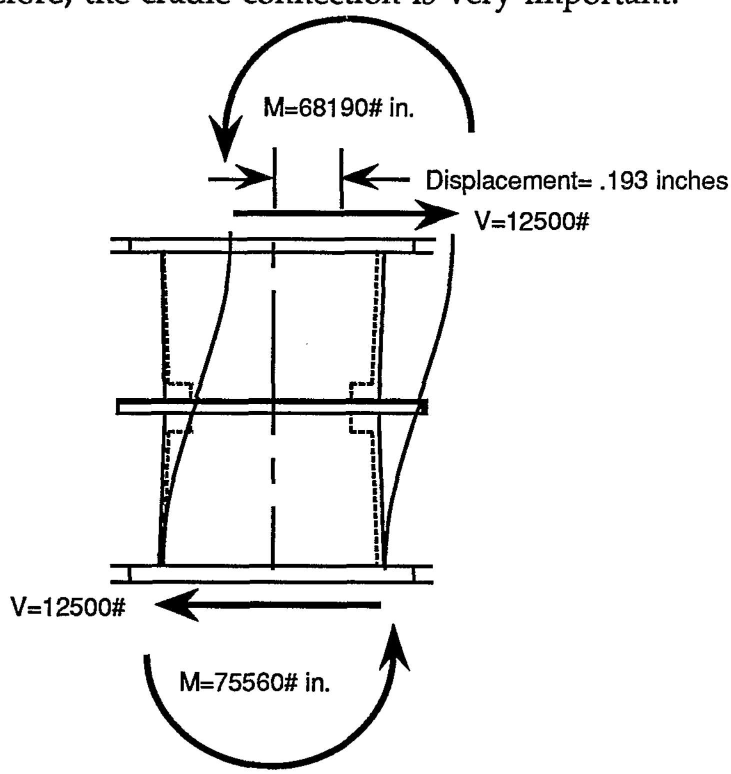


Figure 4. Forces, moments and deflection of the center post under the worst conceivable case.

Post Development Program

This *worst conceivable case* guides the development of the IMC posts. Warm and cold coupon tests have been conducted on Noryl and Ultem materials. Preliminary post tests have been done on special pressure molded Ultem spools which were machined to final shape. Finite element modeling using the IDEAS system has been conducted for a post conforming to what is likely to be the final geometry. Injection molded posts of Ultem and Noryl have been ordered for testing.

A test fixture shown in Figure 5 is being built to test the posts under the shearing force and bending moments likely to be encountered. That fixture will test two identical posts together in order to get the opposing bending moments at the opposite ends of the posts as depicted in the previous figure. It will also simultaneously apply a force simulating the 3 000 pound dead weight of the cold mass. The test fixture has been carefully constructed to have about the same bending stiffness as the cold mass itself so as to give a truly representational test. Since there are two posts sharing the load in the test fixture, the testing force needs to be twice the 12 500 shear force for which the posts are designed.

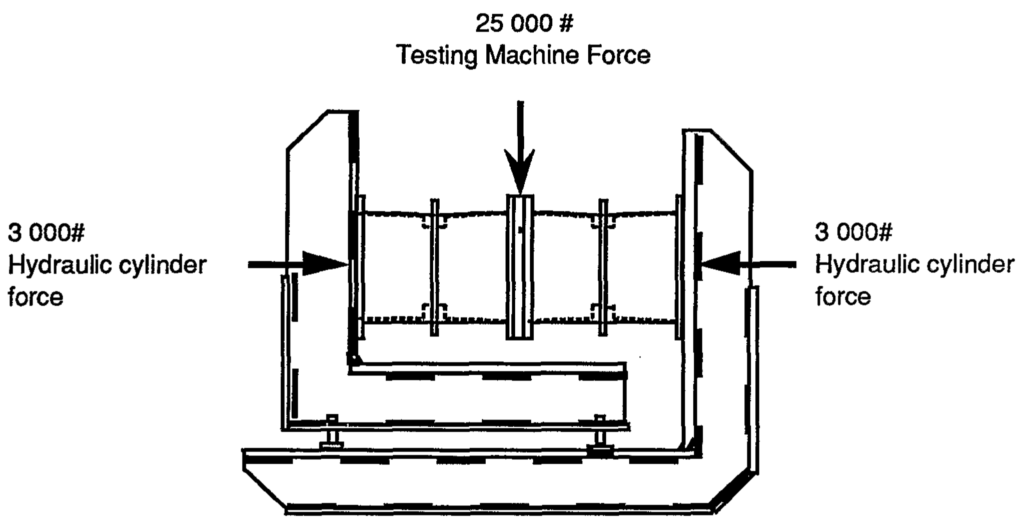


Figure 5. Test fixture simulating the worst conceivable loading upon the IMC posts.

Worst Probable Case

Although the worst case is the pressure upset occurring when the cold mass is neither warm nor cold, that is not a probable case. There is a greater probability of an upset occurring while the cold mass is either at room temperature or below 80°K. In either of these cases the cold mass will be further restrained by the stops on the end posts. And, one of the side posts will then be available to assist the center post in carrying the 12 500# axial pressure thrust.

If the cold mass is at room temperature, the post on the far end will share the load with the center post. If the cold mass is below 80°K, the stop on the end post nearest the pressure end will contact the post, and that post plus the center post will transfer the 12 500 pound load to the foundation. As an illustration, consider the latter condition with the near post positioned to carry load. That condition is appears in Figure 6. For this *worst probable case* the Von Mises stress intensities are estimated to be 4 320 and 4 190 psi. respectively for the left end post and the center post. The axial travel of the center cradle due to the pressure upset is .094 inches.

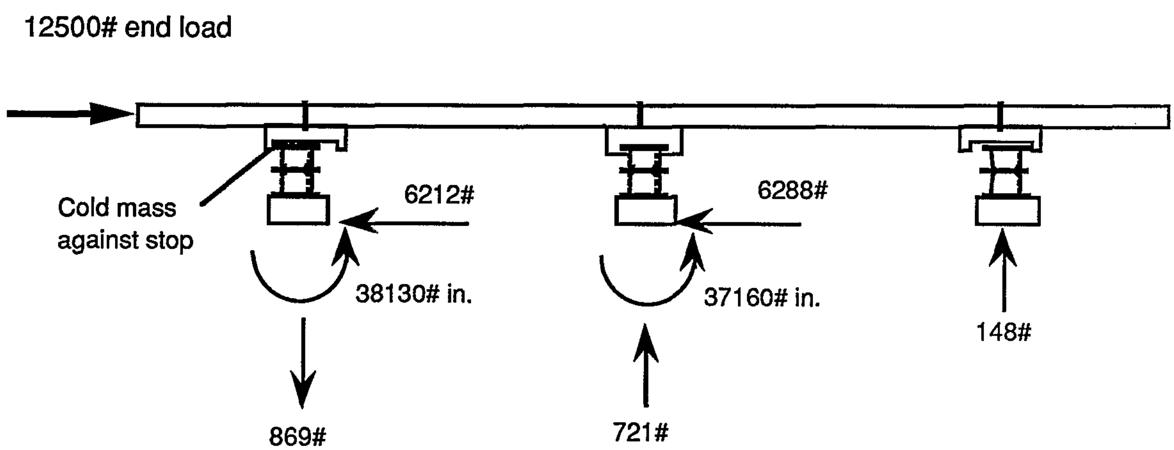


Figure 6. Support reactions for the worst probable case.

Data Used For Estimates:

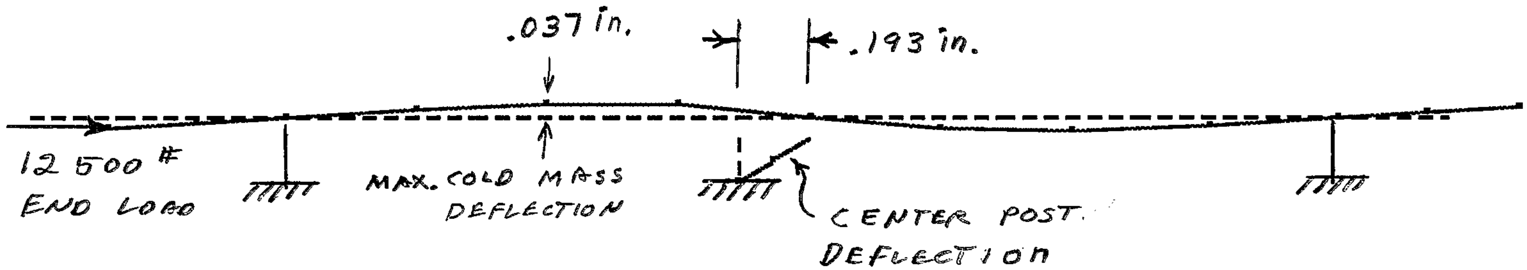
	Posts	Cold Mass Vessel
Elastic Modulus (Psi.)	.7E6	30E6
Poisson's Ratio	.3	.3
Outside Diameter (In.)	8.1875	10.50
Wall Thickness (In.)	3/16	3/16
Length (In.)	5 [1]	379
Sagitta (In.)	1.195 [2]	1.877 [3]

[1] The post consists of two hat-shaped sections, each with an elastic length of five inches, separated by 1.5 inches of rigid flanges and heat shield support. The cold mass centerline is 6 inches above the elastic length of the posts.

[2] The three posts are on a chord line 1.195 inches inboard of the sagitta arc.

[3] Radius of curvature = 9 566 inches over 2.298° of arc.

Side View of Deformation



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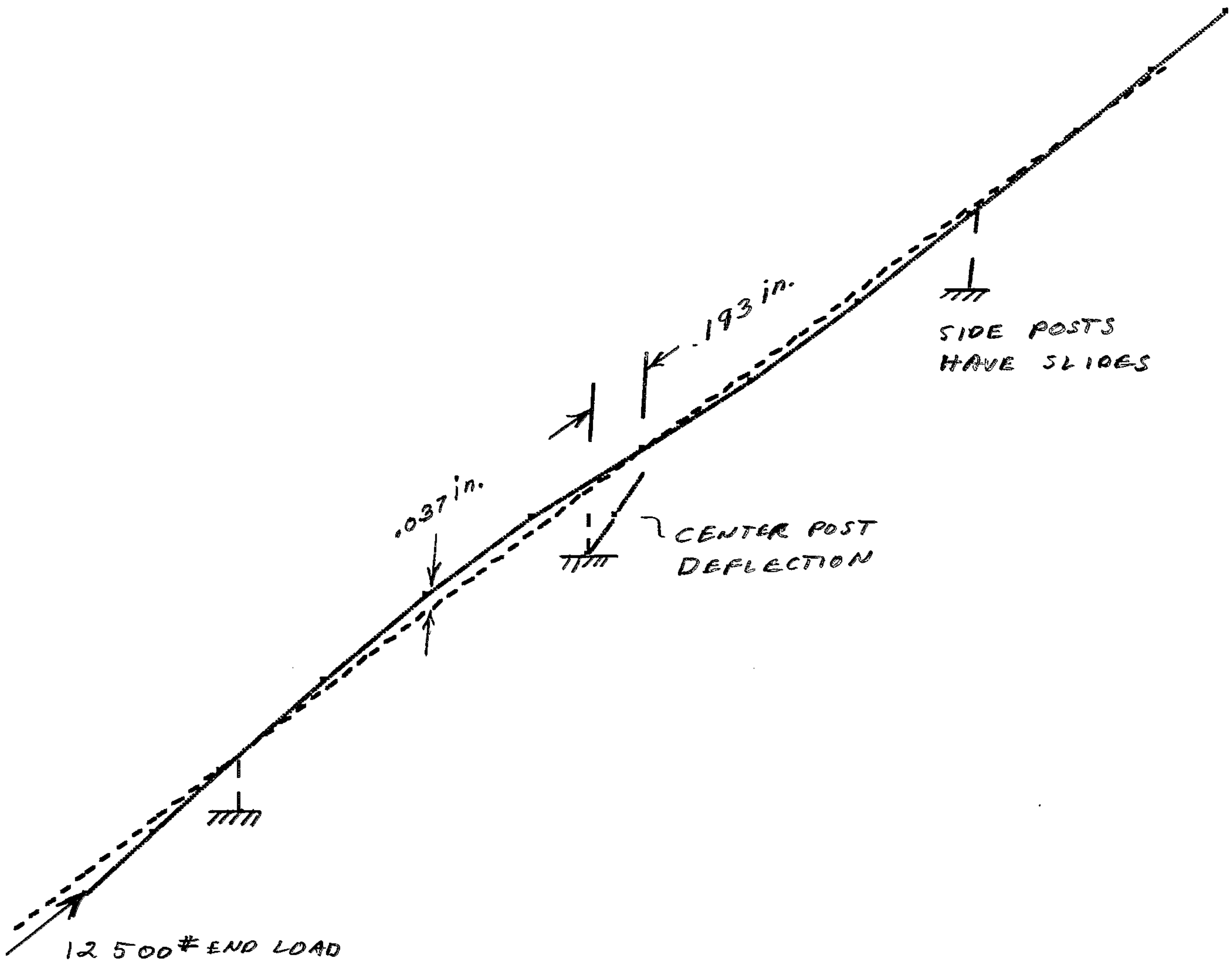
Oblique View of Deformation



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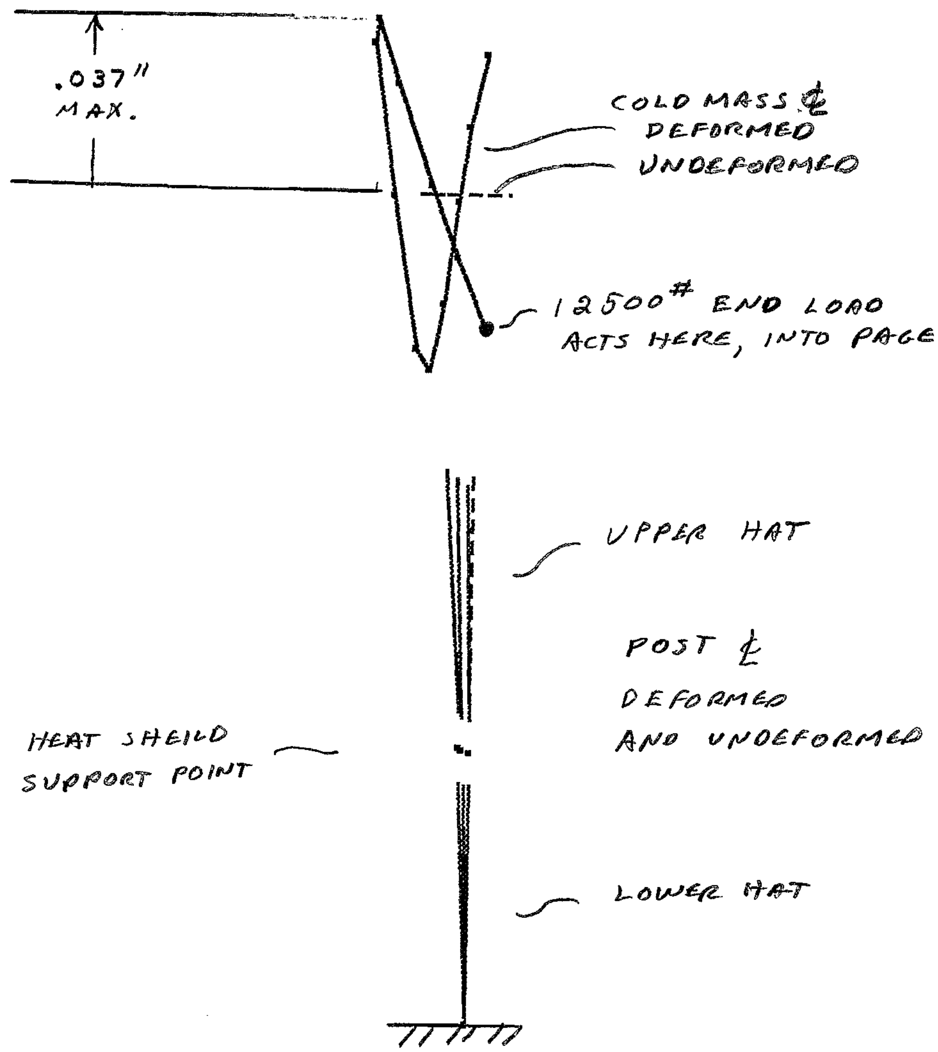
End View of Deformation



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