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Axial Compliance and Packing Fraction of the Yoke for the 50 mm SSC Collider Dipole Magnet

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Required Yoke Compliance

It is desirable that the yoke be compliant enough that the axial thermal contraction of the yoke-shell system is dominated by the shell. Due to the greater thermal contraction of the shell than the yoke material, the shell will be in relative tension and the yoke in relative compression following cooldown. We can estimate the amount of shell tension by measuring the force required to compress the yoke by the full 1 part in 1000 difference between the integrated thermal contractions of the yoke and shell. This force has been measured (see below) to be 400 lbs. for a 139.5 inch pack with the design packing factor of 98%. For the shell to apply this force it must have an axial stress of 400 lbs./$2\pi rt$ = 50 psi, where r = 6.595" is the radius and t = 0.195" is the thickness of the shell. This stress corresponds to a strain of 1 part in 10^6 which is trivial. Thus the yoke packs are sufficiently compliant that the thermal contraction will be dominated by the shell.

This condition would be satisfied as long as the axial strain in the shell induced by the differential thermal contraction is less than about 1 part in 10^4. In this case ≥90% of the difference would be taken by compression of the yoke and <10% would be taken by the shell. A strain in the shell of 10^{-4} corresponds to a stress of 3000 psi and an axial force of 24×10^3 lbs. Thus as long as the force required to compress the yoke by 1 part in 1000 is $<< 24 \times 10^3$ lbs. the axial thermal contraction of the yoke-shell system will be dominated by the shell and there should be little or no effect on the axial mechanics of the magnet from the yoke compliance.

Yoke Stacking Method

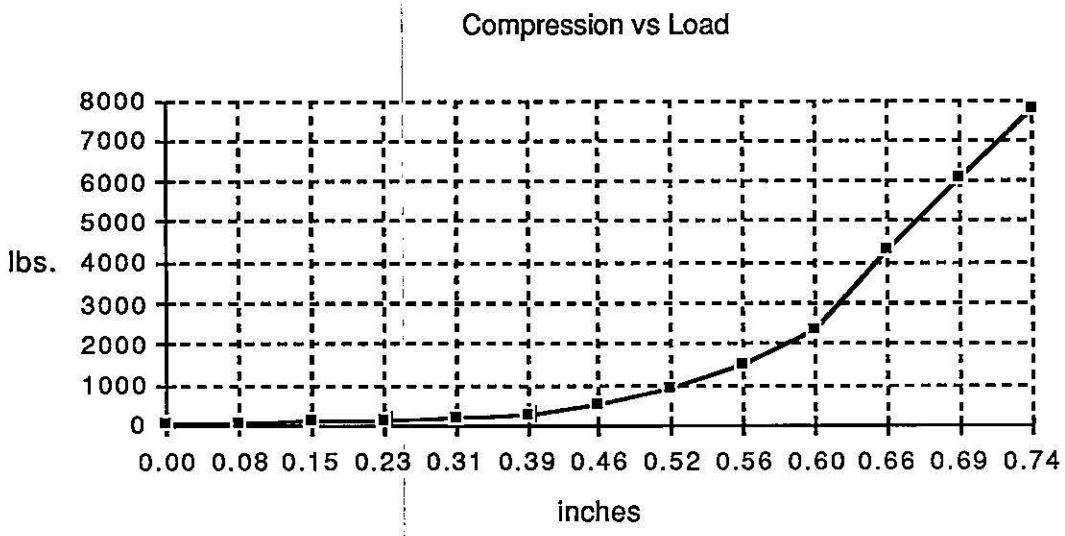
The yoke assembly consists of six packs per magnet per half magnet. Four will be 139.5 inches and two ten inch monolithic packs on either end. It is estimated that the long packs will stretch 1/8

inch after stacking, the actual amount of stretch will be determined in practice. Until the actual length tolerance can be determined differences in lengths of the long packs will be accounted for in the monolithic packs.

The greatest design concern is maintaining the 98% packing factor. The packing factor has been defined as the actual amount of steel divided by the maximum possible amount of steel by weight in the yoke pack. The correct packing factor will be maintained by weighing laminations prior to stacking. The packs must be packed to 98% to assure proper yoke compliance. The yoke pack compliance takes place in closing the "gaps" between laminations which occur as a result of the 98% packing factor. Gaps do not actually occur because the laminations are not flat. The laminations are actually belvilled, which causes the yoke pack to act as a spring.

Measured Yoke Compliance

To measure the yoke compliance a 24 inch section of yokes was stacked on the stacking press. A Lebow electronic load cell was placed between the yokes and the press ram. The yokes were compressed, from the loose condition to fully compressed. Readings were taken from the load cell in ≈0.05 inch intervals. Results are displayed below. The last data point on the right represents a closed pack, an increase in load would give little increase in compression. To achieve the 98% packing, this size pack would be backed off one half inch from fully compressed. Backing down the loading graph one half inch corresponds to .23 inches. At this point the pack has a spring force of about 150 pounds. This was verified by reversing the press and observing the load cell. A 139.5 inch pack will have the same spring force at 98% packing, this has been verified with a load cell in a similar arrangement. If the 24 inch pack is compressed 1 part in 1000 by the skin, the spring load will increase slightly. The lower graph shows the effect of an increase in compression in greater detail. In a magnet two yoke packs are used in a given length, one on top and one on bottom, so the yoke compliance is doubled. Thus, 400 pounds is a conservative value for the compliance of a yoke assembly, stacked to 98%.


Compression vs Load
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7000
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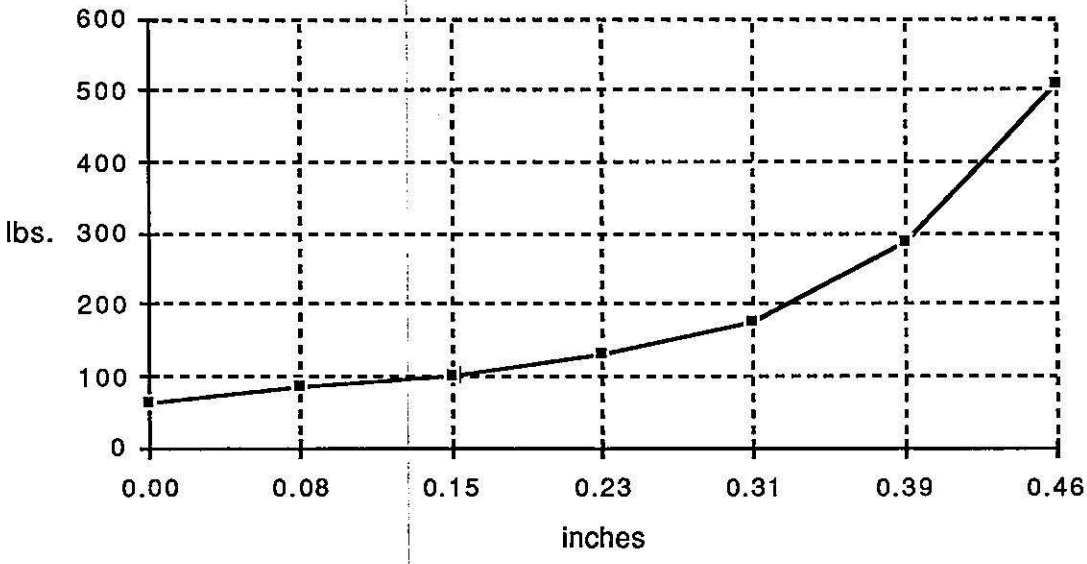
inches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