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50mm SSC Yoke Pack Design

This note summarizes the issues surrounding the yoke pack design and describes the initial 50mm SSC design. There are many interrelated design alternatives available. They involve:

1.) Packing Factor
2.) Pack Length
3.) Method of preventing column instability.
4.) Method of holding packs together

1.) Packing Factor - defined as the actual amount of steel divided by the maximum possible amount of steel by weight in the yoke. The 40mm specification is 97.4% +/-.1%. The 40mm packs are stacked to this specification. 40mm packs, however, used 1/8 inch of non-magnetic steel between every 6 inch pack. This effectively cut the packing factor by 2%.

50mm packs have been stacked at 98%.

2.) Pack Length - At the 98% packing factor, 50mm packs have been stacked to a length of 24 inches for short magnets. One preliminary 12 foot long pack has been made. It is believed that with the proper fixturing much longer packs could be stacked, although the existing Fermilab stacking tables are limited to 20 feet.

The length of the final stacked assembly must be 578 inches. This length must be held as closely as possible to maintain the correct iron density. Making yoke packs very long has several advantages. They are:

- No need to compress yoke packs at assembly.
- Many less constituent parts would be necessary.
- Fewer yoke packs, simplifying assembly.
- Steel density resolution is increased. A discussion of the density resolution follows:

40mm packs are 5.576 inches long. Since the packing factor tolerance is +/-.1%, the adjustment for these packs must be .010 inches of length or 1/6 of a lamination thickness. The packing factor must therefore be achieved by using special 17 and 18 gage

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laminations or sorting the standard laminations by weight and placing them in packs in the proper quantities. 50mm packs, being very long, (approximately 12 feet), would need an adjustment mechanism equal to +/- 3 laminations to meet the same +/-.1% density requirement. This would eliminate special thinner laminations and the weighing of laminations before pack assembly. Of course, this is all based on the assumption that long packs can be stacked uniformly along their entire length.

3.) Method of preventing Column Instability. - Due to the vertical load placed on the yokes during the final assembly, pressing and welding, the individual yoke laminations may buckle while under load in the press as shown in Figure 1. This effect has been observed in the 40mm magnets. The problem was solved by incorporating monolithic (epoxied) end packs. It is anticipated that column instability will be a problem in the 50mm program, although at this time the magnitude is not known.

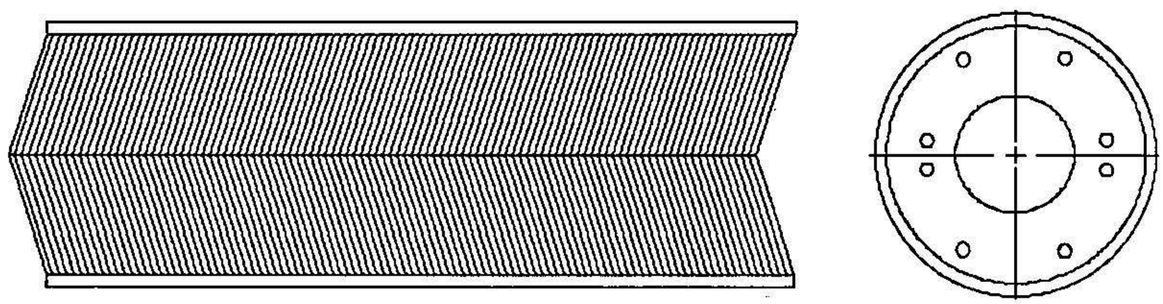

Figure 1.

The 50mm solution will also be to add monotithic packs at the appropriate places. These may be separate packs or monolithic "ends" of some length (possibly 4 inches) to the regular packs. The present design calls for one ten inch thick monolithic pack at each end of the magnet. Regular packs currently have no monolithic ends. This design will be verified both by calculation and by the yoking of a practice magnet.

4.) Method of holding packs together. There are two methods. Packs can be held together by pins or longitudinal welds. If pins are used, they may be terminated by screws, flared pin ends or welds.

Advantages of longitudinal welds -
• Less parts are required.

Disadvantages of welding -
• Fusion welds (i. e., welds with no filler added) are not strong enough to hold the packs together. Short packs must be made and welded together in a second operation with an additional weld if long welded packs are to be used.

Welds can be used with filler material, but cutouts in the laminations are necessary. The cutout could either be filled with weld filler or a solid bar which would be longitudinally welded to the laminations (using more filler material). The cutouts have the disadvantage of reducing the magnetic field. The uncertainty in the shape of the weld may also change the field in an uncontrolled way.
• Welds tend to lock in any misregistration. The welds may or may not be strong enough to maintain this misregistration after the skin is pressed onto the magnet.
• Welds impede the lamination's ability to move longitudinally with respect to each other during cooldown. This may be necessary because of differential shrinkage.
• If pack flaring or 'bellevilling" as shown in Figure 2 is to be avoided, the pack must be welded on the bottom surface as well as the top (see Figure 3.). This causes a more elaborate stacking procedure and fixture to be necessary, since the pack needs to be rolled over during assembly.

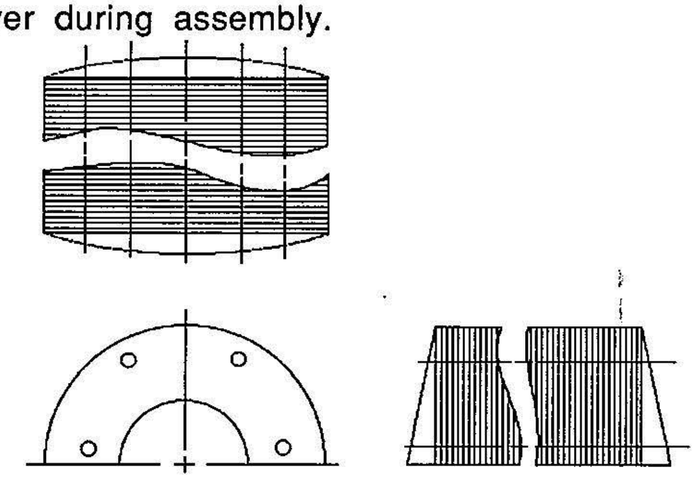

Figure 2.

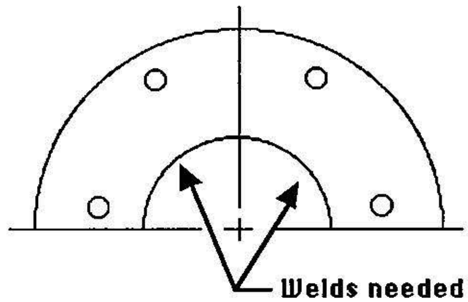

Figure 3.

Advantages to pins -
- Only one operation is necessary to stack packs.
- No locked in misregistration. The pins allow movement between laminations. Final registraion is determined by the skin.
- No modifications to the yoke laminations are necessary.
- Flaring on the ends of packs held with pins does not appear to be a problem.
- A relatively simple stacking fixture is required.

Disadvantages to pins - .
- More parts are required, particularly if screws are used to terminate them.

50mm SSC long magnet yoke pack design:

1.) The packing factor will be 97.4% +/- .1%. This is the same as the 40mm design if the gaps between 40mm packs are disregarded.

2.) Six packs per magnet will be used as shown in Figure 4. Four will be 139.5 inches long. The two end packs will be monolithic and will be ten inches long. 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, monotithic pack lengths will be adjusted to compensate for any "out of tolerance" condition in the long packs.

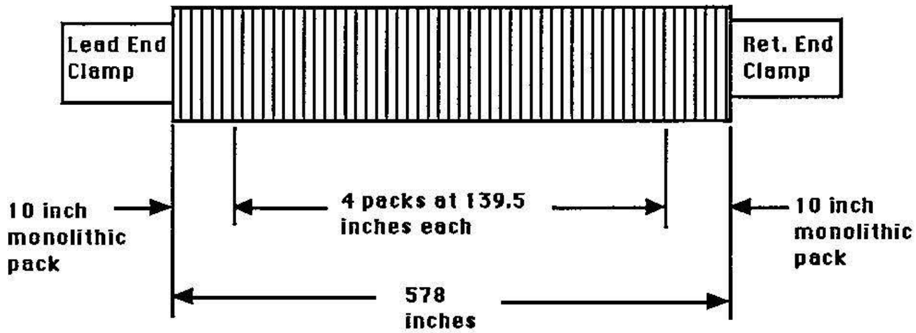

Figure 4.

3.) Monolithic epoxied end packs will be used to provide column stability. A practice magnet will be built to determine if the present design will effectively prevent buckling.

4.) Packs will be held together with four 1/2 inch diameter x 1/16 inch wall full length pins. The pins on regular packs will be welded to the laminations on both ends to secure the packs. Monolithic packs will have pins which are welded on one end and flared on the other.

5.) A special slotted yoke lamination will be placed approximately every six inches within each pack. The slots will create helium flow paths between the groove in the collar lamination used for lifting the collared coil assembly and the 1.15 inch holes in the yoke laminations. These slots will provide escape paths for helium during a quench. These laminations will be made of regular yoke iron. Non-magnetic high manganese stainless steel is a future option. The final material choice will be determined by consideration of the effect of the slot on the magnetic field.

6.) Thin "filler" yoke laminations will be used on each end to support the skin in the end clamp area. They will be made of high manganese stainless steel. The coefficient of thermal expansion of the high manganese stainless steel is similar to that of regular yoke iron. This will allow the filler laminations to provide support after cooldown. They are non-magnetic to prevent contributing to the field over the ends of the magnet. They will be held together by 1/4 inch diameter pins. The pins will be welded to the lamination on one end and flared on the other.