50mm SSC Collar Pack Assembly

Collar packs are assembled by stacking a number of laminations on a set of 6 inch long 1/4 inch diameter pins. The laminations are compressed longitudinally to a certain density. They are then held together by a pin assembly. They must be compressed tightly enough to make magnet assembly easy and to ensure that excessive flaring does not occur in the completed collared coil during assembly as shown in Figure 1. This flaring always exists but gaps between packs were as large as 1/16 inch on 40mm SSC magnets as shown. They also must not be stacked so tightly that they are flared in the free state as in Figure 2.

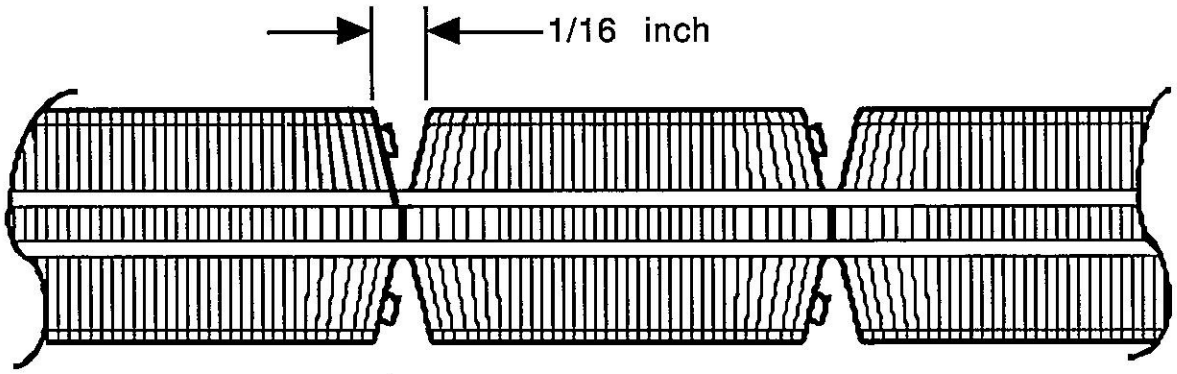

Figure 1.

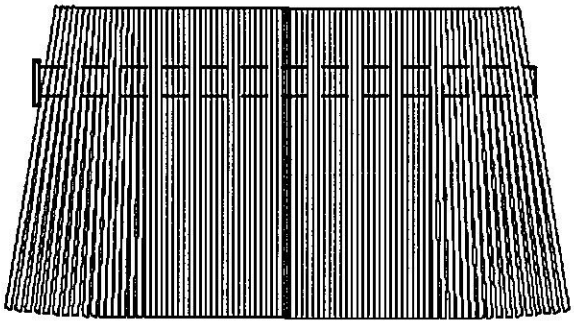

Figure 2.

Each pack is 6 inches long. A tolerance must be applied to this length. The tightness of this tolerance is affected by two things:

- The laminations may vary in thickness by +/-.003.
- The spot welds may vary in thickness by +/-.0015.

The sum of the manufacturing variations in the lamintions and spot welds over an entire pack length is (+/- .003 x 98) + (+/-.0015 x 47) = .364 inches. This means that if we stack packs to a pressure, use a specified number of laminations and let the length vary accordingly we will have packs which vary in length by +/-.364 inches.

Cross Flow Cooling

A cross flow cooling system has been proposed for use in SSC magnets.[1] This system requires the "gaps" between packs to be registered accurately and therefore imposes a specific tolerance upon the pack length. The cross flow cooling system is shown in Figure 3. Gaps between packs must be within about an inch of their specified positions along the entire length of the magnet if the cross flow system is used.

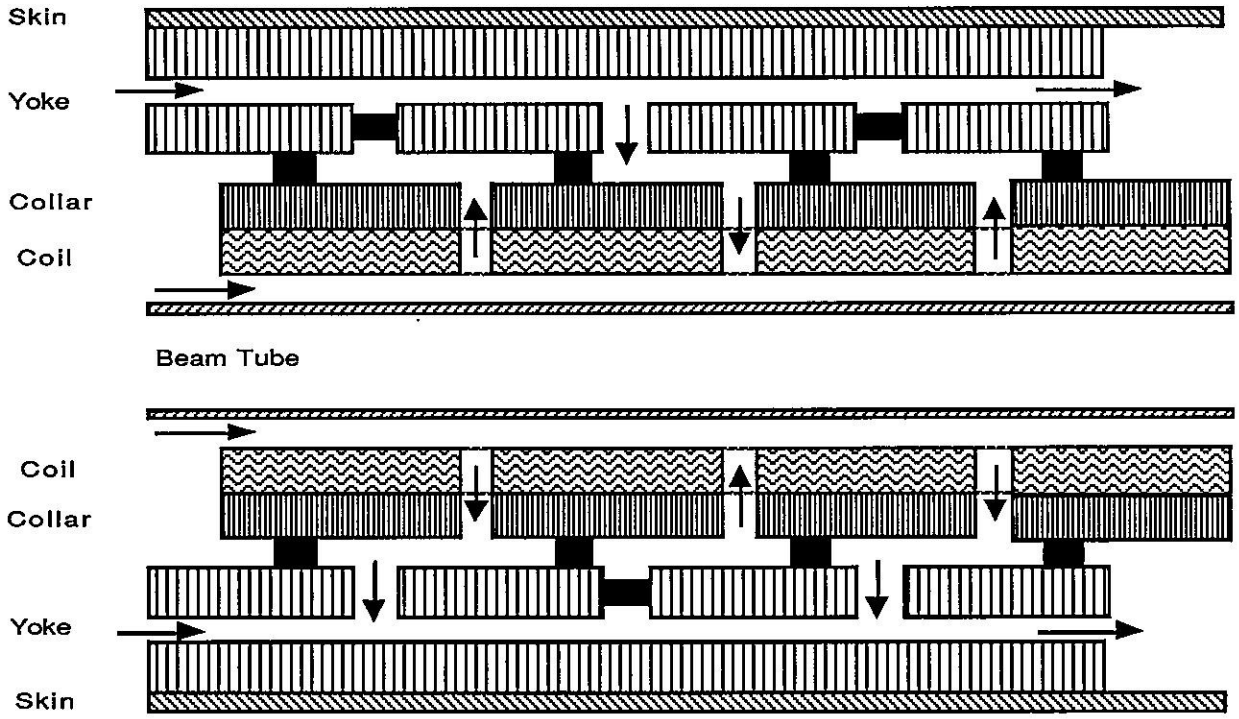

Figure 3.

If cross flow cooling is required, the total longitudinal tolerance for collar packs is therefore one inch for half the magnet (assuming we start placing the packs on the magnet in the center). There are 95 packs per magnet, or ≈ 48 per half magnet. This means that the pack tolerance needs to be 1 inch/48 or approximately .020 inches per pack full range. The tolerance on pack length would therefore need to be +/-.010 inches.

With 95 packs in a long magnet, the potential for misalignment of gaps is obviously far greater than the registration required for cross flow cooling. This leaves two design options.

1.) Each pack could be longitudinally shimmed during pack assembly to achieve the +/- .010 tolerance. The pack would first be compressed to a pressure, then measured. Pressure would then be released and a shim of the appropriate thickness would be added. The pack would then be compressed again and the pin would be terminated. BNL uses this method to make collar packs.

2.) Packs could be made to a pressure without using shims (thereby violating the +/-.010 tolerance). When they are assembled into the magnet, the position of the gaps would be monitored. When the gap becomes one inch away from it's design position, a special length pack could be made at assembly, bringing the gap back to it's design position. These "special" packs could be pre-made, in lengths equal to one inch longer and one inch shorter than the standard pack.

If cross flow cooling is not required, there are more desirable manufacturing options. We can simply stack packs to a pressure, use a specified number of laminations and let the length vary accordingly. This causes packs to vary in length by +/-.364 inches, as stated above, but this should not matter. Packs can be assembled on the magnet without regard for the position of the gaps. A special length pack is still needed at each end.

Several ways of terminating packs have been considered.

1.) Pins can be terminated by flaring the end as shown in Figure 4.

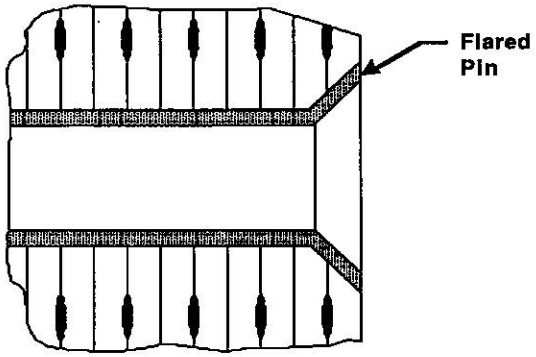

Figure 4.

• Advantages - few parts required because no screw or rivet is used. No extra operation (internal threads) needed to manufacture pin.
• Disadvantages - The flaring operation is rather time consuming if done by hand, although this problem could be corrected by automating the operation. Use of a flared pin would certainly require longitudinal shimming of packs because the pins come in only one length and are not adjustable.

Flared pins have been used in NC9 40mm SSC magnets and in the BNL design of C358 40mm SSC magnets. The above problems were encountered. Packs at BNL are shimmed.

2.) Pins can be terminated by using a standard screw as shown in Figure 5.

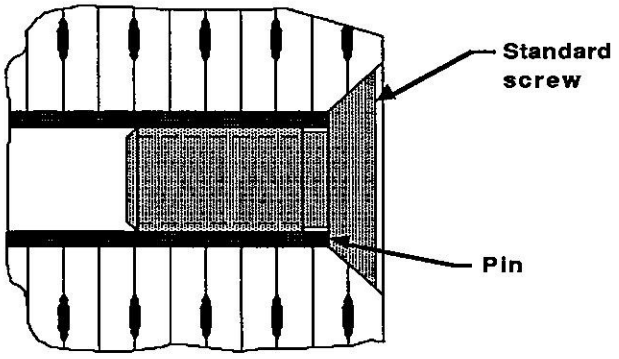

Figure 5.

• Advantages - the screws are readily available. Packs can be easily disassembled. Threaded area can be made very long, allowing packs to vary in length by turning in the screw by different amounts. It may not be possible to achieve the entire +/- .364 range by varying the amount of screw insertion, but +/-1/16 inch is easily achievable, allowing the lamination pairs to be used as the "shim", or mechanism for length adjustment. This eliminates the necessity to manufacure the extra shim.

• Disadvantages - More parts required. Extra manufacturing operation (threading) required on inside diameter of pin. Screw has no self locking feature so could presumably loosen during handling, although this has not been a problem in practice.

This method has been used for strain gage packs both at FNAL and BNL in 40mm and 50mm SSC magnets.

3.) Pins can be terminated by using a knurled rivet as shown in Figure 6.

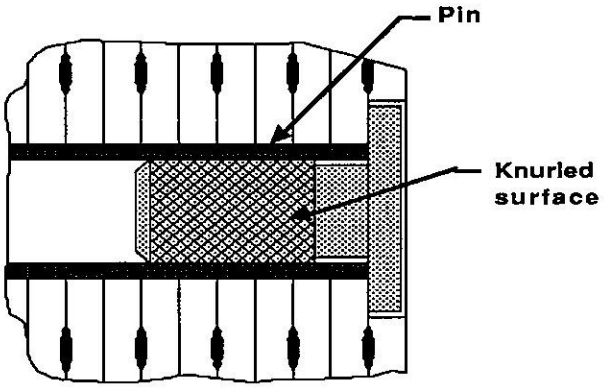

Figure 6.

• Advantages - No internal threading operation required on pin. Knurled area can be made very long, allowing packs to vary in length by driving in the knurled nut by different amounts. It may not be possible to achieve the entire +/- .364 range by varying the amount of nut insertion, but +/-1/16 inch is possible, allowing the lamination pairs to be used as the mechanism for adjustment. This eliminates the necessity to manufacure the extra shim.
• Disadvantages - The knurled nut is an extra part to be manufactured. It is also necessary to hold the tolerance on the inside diameter of the pin closely so it will accept the knurled nut with the proper amount of compression. This system was tried on the 40mm FNAL SSC collar packs. Due to size variations in both the nut outside diameter and the pin inside diameter, it became necessary to make several size knurled nuts, sort the nuts and the pins according to size and match them. If a knurled nut is to be used, therefore, an extra operation would be required to ream the inside of the pin to the proper diameter.

4.) Pins can be terminated by using a special self-locking screw assembly as shown in Figure 7.

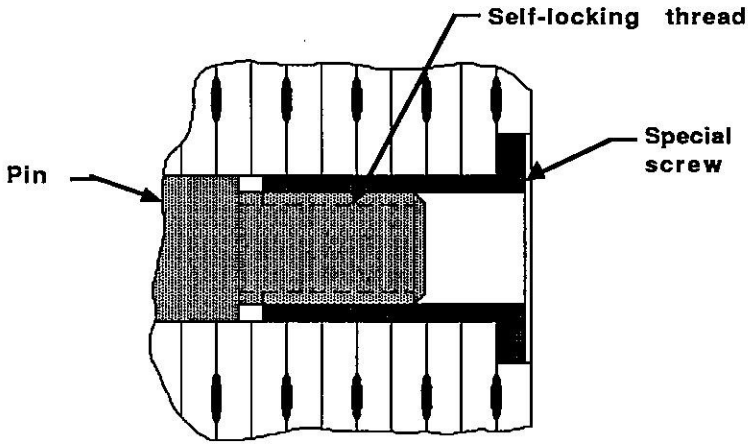

Figure 7.

• Advantages - Screw assembly can be made very long, making it possible to avoid using shims by driving screws in by varying amounts. Again, it may not be possible to achieve the entire +/- .364 range by varying the amount of screw insertion, but at least +/- 1/16 is easily achievable, allowing the lamination pairs to be the mechanism for adjustment. This method is also very easy to automate.
• Disadvantages - Probably the most expensive option for parts manufacturing, although the cost differences between all options using pins is small. Reliance on few vendors for the special screws is also necessary. FNAL has to date found only one vendor (AVK Industries) who is willing to produce these parts.

5.) The packs can be assembled by using longitudinal welds, eliminating pins entirely. This is the method that was used on the Tevatron magnets.

• Advantages - No pins, screws, or rivets of any kind are necessary. Use of shims during assembly is completely eliminated. Welds help to eliminate the pack flaring problems shown in Figures 1 and 2. Welding is fairly easy to automate. Welded packs have been tested extensively in the Tevatron magnets.
• Disadvantages - Welding will be difficult to automate in the short run. If it is not automated, it is the most time consuming procedure. Welds could possibly magnetize parts of the collars, affecting the magnet's harmonics. Welds, if they are too strong, might lock in a misregistration between laminations. Welds impede the lamination's ability to move longitudinally with respect to each other during cooldown. This may be necessary because of differential shrinkage.

50mm SSC Default Design

FNAL will make packs for the 50mm SSC long magnets with the standard screw (option #3). Welded packs or self locking screws may be tried in some short models.

So the assembly procedure for the default 50mm SSC design is:

Pins are made to a length which causes the pack to be 6 inches long when the screw is fully inserted (bottomed out). When we make a pack, we first stack (49) lamination pairs on the pins (both top and bottom halves). A hydraulic force is longitudinally applied to the pack. The pack height is then measured. If it is less than 6 inches, a lamination pair is added. If it is more than 6 1/8 inches, a lamination pair is removed.* The threaded screw is then driven into the pin. Very little force is used to drive in the screw, so that it will not compress the pack further.

Packs are stacked in pairs. That is, packs for both upper and lower halves of the magnet are stacked together in the same fixture and kept together during storage and assembly. This is necessary because the large difference in length between the longest and shortest packs prevents them from being interchangable.

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*Although the total of all tolerances on pack components allows maximum possible differences between pack lengths to be +/- .364 inches, within a production run of laminations these differences will be much smaller. As a result, the process of deciding the correct number of laminations (checking the pack height and adding or removing lamination pairs) will probably take place only at the beginning of a new run of lamination steel, when the steel thickness is likely to have changed. During the majority of the pack assemblies, this time consuming process will not be necessary.

Packs are therefore all made with the same density and with a length tolerance of +/- 1/16 inch. There are 95 six inch packs in a long magnet plus two 4 inch packs on each end. If the packs are placed on the coil beginning at the centerline of magnet, there will be 47 packs to stack on each side. The maximum amount of misregistration of the gaps is therefore 47 x 1/16 inch = 2 15/16 inches. A special pack (different in length for each magnet) will be made to take up the space left over at assembly. This is the same assembly procedure used on the Tevatron.

If problems develop with screws loosening due to the lack of a self-locking feature, we will use "lock tight" to keep the screws in place. This will be time consuming, but possible for a prototype program. It is recommended that, in production, a system with a self locking feature should be used.

1.) Shutt, R. P., "SSC Magnet Cooling Methods", Brookhaven National Laboratory, 2-15-89.

2.) Pewitt, G., ed., "50mm Collider Dipole Magnet Requirements and Specifications", Fermi National Accelerator Laboratory.