

### **50mm SSC Long Coil Springback Estimate**

Coils are wound around the curing tooling with a specified amount of tension. When they are removed from the curing tooling, they shrink in size longitudinally as the tension is relieved. This "springback" is proportional to both the length of the coil and the winding tension. As a result of springback, the coils after curing are significantly shorter than their design size.

This problem will be corrected on the 50mm program. First the amount of springback will be determined. The curing tooling will then be corrected by making it longer than the design by the amount of springback. Determination of the actual springback cannot be done until some 50mm coils have been wound and cured. We can, however, make an estimate based on measurements of 40 and 50mm short and 40mm long coils.

There are three different coil length measurements which can be taken. They are shown in Figure 1. Only a measurement of dim. "A" is useful to predict coil springback. This measurement must be taken with the keys tightly seated against the first turn. Dimension "B" does not yield consistent results because the first turn generally curls away from the pole key by an inconsistent amount as shown in Figure 2. Dimension "C" cannot be used reliably because end current block lengths vary from coil to coil making it impossible to predict dim. "A" from dim. "C". Saddles were sometimes cut to different lengths before these measurements were taken, making them even more uncertain, particularly for short coils.

#### **Coil Dimensions**

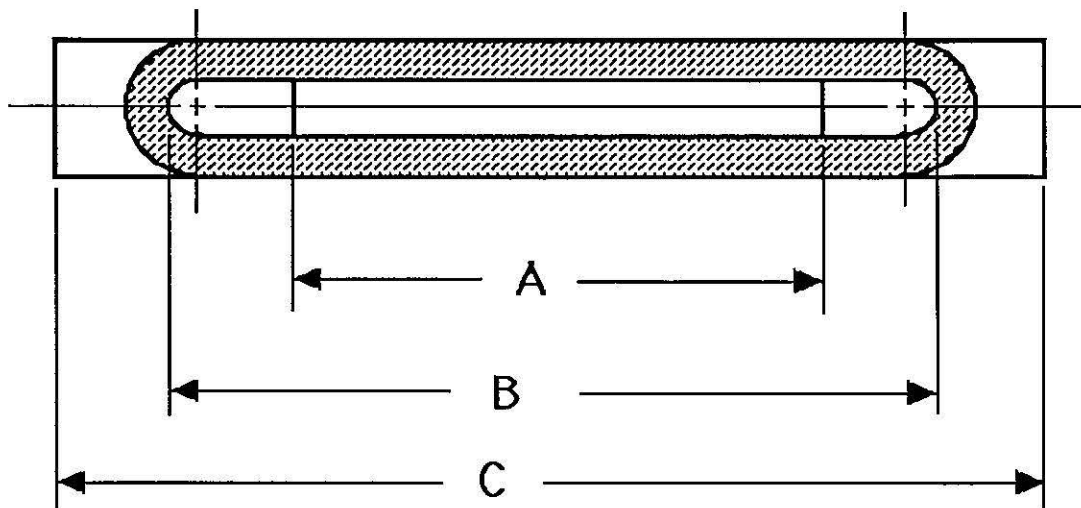


Figure 1.

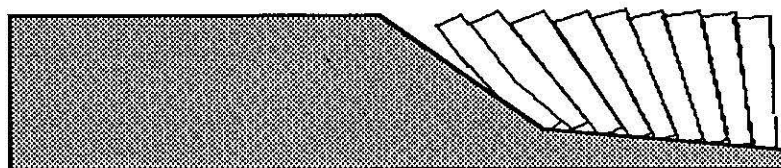


Figure 2.

### Coil Measurements

#### 40mm short:

These measurements were taken only sporadically on 40mm short coils as they were produced. The measurements that were taken were dimension "C" only. This data is not of much use.

There are, however, two 40mm outer coils still on the production floor. They have been measured. No 40mm short inner coils still exist.

Design Inner Coil Dim "A"	46.75 inches
Design Outer Coil Dim. "A"	40 inches
Coil #312 Dim. "A"	40 inches
Coil #324 Dim. "A"	40 inches

So within measuring errors these 40mm short outer coils did not shrink longitudinally.

#### 40mm long:

8 of the 40mm long inner coils and 9 of the long 40mm outer coils were measured by the production crew. Unfortunately only dimensions "B" and "C" were taken. Results are shown below:

	Dim. "B"	Dim. "C"	End Length (C-B)
Inner Coil Design Length	649.5 in.	658 in.	8.5 in.
1007R	649.125	657.75	8.625
1009	649.125	657.562	8.437
1011R	649	657.5	8.5
1012	649	657.5	8.5
1013	649.25	657.5	8.25
1014R	649	657.5	8.5
1015	649.375	658	8.625
1016	649.25	657.75	8.5
MEAN	649.14	657.63	8.49

These number are suspect for the reasons stated above, but I will try to interpret them. On the inner coils, both B and C average about  $\frac{3}{8}$  inch smaller than the design. The total length of the ends (C-B) averages about the same as the design. We know that the ends on inner coils are actually about  $\frac{3}{16}$  longer than the design on each end due to our inability to properly seat the parts. This information implies that the measurements of the B dimension are incorrect by  $\frac{3}{8}$  total because of the curling effect shown in Figure 2. The interpretation would then be that the springback is  $\frac{3}{4}$  inch but the coil ends are too long by a total of  $\frac{3}{8}$  inch, making the total coil length short by  $\frac{3}{8}$  inch.

There is a problem with this interpretation. It relies on the assumption that the curling effect shown in Figure 2 causes the B dimension to be incorrect by  $\frac{3}{16}$  inch on each end or a total of  $\frac{3}{8}$  inch. This seems unlikely from observation of coils. The curling effect looks smaller than  $\frac{1}{16}$  inch on all inner coils observed. More measurements of long coils are needed to resolve this issue.

#### 40mm long Outer Coils:

			C-B
Outer Coil Design Length	649.5 in.	658 in.	8.5 in.
2005R	649.75	657.5	7.75
2006R	649.3125	657.625	8.312
2008	649.25	657.5	8.25
2008R	649.25	657.625	8.375
2009	649.125	657.25	8.125
2011	649.25	657.5	8.25
2012	649.25	657.5	8.25
2014R	649.25	657.75	8.5
2015	648.75	657	8.25
MEAN	649.24	657.47	8.23

Coil 2005R is drastically different from all the rest. This may be due to a saddle which was cut back in length before curing. It may be a measuring or transposition error. I will disregard this coil.

The rest of the outer coils average  $\frac{1}{2}$  inch too short overall but only  $\frac{1}{4}$  inch too short from pole turn to pole turn, making the total end length (C-B) average  $\frac{1}{4}$  inch too short. We know the average end length on outer coils should be about  $\frac{1}{4}$  inch too long total ( $\frac{1}{8}$  inch per end). This again implies that the curling effect causes the B dimension to be incorrect by  $\frac{1}{4}$  inch on each end. This doesn't seem likely, but we will continue with the analysis anyway. The interpretation of the data would then be that the coil springback is  $\frac{3}{4}$  inch but the coil ends are too long by a total of  $\frac{1}{4}$  inch, making the total coil length too short by  $\frac{1}{2}$  inch.

This interpretation is also in disagreement with observation of outer coils. The curling effect appears to be less than 1/8 inch, not the 1/4 inch implied by the data. Once again, only more measurements will resolve the issue.

Coils with higher winding tension are supposed to have higher springback. The reworked coils, those marked with "R", were wound with higher tension. The measurements do not seem to support this contention.

#### 50mm short:

50mm short coil length measurements are taken routinely and recorded in the traveler. Until recently, due to a misunderstanding, the short coils have been measured while still on the curing mandrel. This still gives us information about length of end current blocks.

Measurements of coil lengths are useless, however, because the coil shrinkback does not take place until the coil is removed from the mandrel. Several coils are in storage on the IB#3 floor. Measurements of dimension "A" on these coils follows:

<u>Inner Coils:</u>	Dim. "A"	Dim. "B"
Design Value	44 inches	51.2 inches
Coil #109	43 15/16	51 3/16
Coil #110	43 15/16	51 7/32
Coil #113	43 15/16	51 7/32

#### Outer coils:

Design Value	44 inches
Coil #203	43 15/16

These measurements seem to indicate that the short inner and outer coils are springing back by 1/16 inch. Note that on inner coils, where dim. "B" was taken, there does not appear to be any significant effect from the pole turn curving, as in Figure 2. This may be due to a superior end part design on 50mm coils.

Conclusion: None of the data is consistent or believable enough to draw any reasonable conclusions. It seems that the long coils are springing back by at least 1/4 inch but any other conclusions are highly speculative. If we have the time we could measure any long 40mm coils that still exist in a more reliable manner (if it is possible). If not, a conservative (and probably low) estimate is 1/4 inch.