End Clamp Deflections for DCA311 - DCA319

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S. Delchamps
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Purpose of this Report: This report is an attempt to re-assess the end clamp installation data for DCA311 - DCA319, in particular the change in diameter of the lead and return end clamp cylinders during clamp installation.

End Clamp Diameter Changes: The End Clamp Assembly Traveller ES-298290 specifies measurements of the end clamp cylinder before and after installation (i.e. in the "free" and "loaded" states.) These measurements are intended to help us assess how much radial clamping load is present in the end clamp region, which covers the last 3" of coil straight section as well as the turn-around section of the coils.

Figure 1 is a reproduction of a traveller page, showing the various measurement locations and the table in which the measurements are to be recorded. Micrometer measurements are made at eight positions along the length of the end clamp cylinder, corresponding to 0.5", 1.5", ..., 7.5" from the inside end of the cylinder. At each of the eight longitudinal positions, the diameter is measured along four axes, labeled horizontal, vertical, 45 degrees and 135 degrees. Pi-tape measurements of the diameter are made at the same eight longitudinal positions at which micrometer readings are taken. All of these measurements are made in the "free" and "loaded" states.

The diameter change data for lead and return end clamps on magnets DCA311 - DCA319 are summarized in Table 1. The first column gives the name of the clamp. ("L" means lead end and "R" means return end.) The second through fourth columns show the changes ("loaded" minus "free") in the end clamp cylinder diameter as measured by the micrometer on the four axes at the 1.5" longitudinal location[1]. These diameter changes will generally be referred to as "deflections" in what follows. The fifth column shows the average of the deflections along the four axes. The sixth column is the deflection measured with a pi-tape at the same longitudinal location.

Since the pi-tape measures an "overall" change in diameter, it might be expected that the pi-tape deflection would be well-correlated with the average of the horizontal, vertical, 45 degree, and 135 degree deflections. Figure 2 is a scatter-plot of these two quantities[2]. (Integer values by some of the points indicate the number of end clamps corresponding to the point in question.) It is seen that there is a good correlation between the micrometer and pi-tape measurements of end clamp deflection, with two clamps lying well outside the trend. These two outliers will be addressed later.

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[1] The 1.5" location is chosen because it corresponds to the straight section of the coils within the end clamp, and is probably far enough from the end of the clamp to avoid end effects.

[2] The DCA313 return end clamp is plotted with a best estimate value for the pi-tape deflection at the 1.5" location, due to the absurdity of the pi-tape readings recorded in the traveller.

Distribution: R. Bossert, J. Carson, W. Koska, G. Pewitt, D. Smith, J. Strait, D. Tinsley, M. Wake

The STOP Criterion: The traveller specifies that the change in the pi-tape diameter measurement (the "pi-tape deflection") at the 0.5" position should be no less than 5 mils. If the pi-tape deflection is smaller than 5 mils, a physicist or other authority is to be notified before proceeding with further assembly of the magnet.

The last column of Table 1 shows the pi-tape deflection at the 0.5" position for the final installation of each end clamp. It is seen that the change is sometimes less than 5 mils. Reasons for proceeding in these cases varied. Some were as follows:

-- It was not known how realistic the deflection criterion of 5 mils was, and it was hard to predict how large an increase in shimming material (layers of 5 mil kapton attached to the inner surfaces of the G10 insulators) was necessary to obtain a given increase in pi-tape deflection.

-- Initially, there was a strong prejudice against removing and reinstalling end clamps because of problems encountered on an early model magnet which were thought to be associated with end clamp installation.

-- In some cases, it was not clear whether the hydraulic installation fixture then available could supply adequate load to get the clamp in place if more shim were used.

-- In magnets DCA318 and DCA317, turn to turn shorts occurred which at first were thought to be associated with too much clamping load. These shorts caused schedule delays and caused further bias to moderate clamping loads in the later magnets in the series.

Some Suspect Values: Figure 2 shows that there is in general a good correlation between the average of the micrometer reading changes at the 1.5" position and the pi-tape deflection at the same position. The pi-tape deflection values for the DCA317 and DCA319 lead end clamps are suspect. Both of these clamps show up as obvious "outliers" in Figure 2. In the case of the DCA319 lead end clamp, the pi-tape measurement values have actually been altered in the traveller to indicate a 6 mil change in pi-tape reading. However, the average of the micrometer reading changes at the same position for this clamp is only 3 mils. The DCA317 lead end final state pi-tape readings are far from the corresponding micrometer averages.

Importance of these Measurements: Why is all of this interesting? One magnet with small pi-tape deflection, DCA313, had a single training quench in the region of the lead end clamp. It should be emphasized that this training is not necessarily associated with too-small clamping load. However, magnets DCA311 and DCA312, which showed no training, had at least 4 mil pi-tape deflection in both lead and return end clamps. On the other hand, DCA314 had 4 mil pi-tape deflections in both end clamps, and it had a single training quench similar to the DCA313 quench.

All of this is consistent with at least two scenarios: In the first scenario, the training quenches have nothing to do with the end clamps, and we must find another feature which distinguishes DCA311 and DCA312 from DCA313 and DCA314. No obvious changes in end clamp installation procedure occurred between DCA312 and DCA313[3]. In the second scenario, a marginal situation exists with respect to end clamp load. In this latter scenario, all of the magnets are susceptible to initial training, and only two of the four tested so far have shown the behavior.

Conclusions:

-- The DCA317 lead end, DCA318 return end, and DCA319 lead end clamps are probably no more tightly clamped than the DCA313 lead end clamp. Therefore, if the training quench seen in DCA313 is related to the somewhat looser than average lead end clamp, we may see such quenches in the last three ASST magnets. DCA318 has not yet been yoked, so that an end clamp could in principle be removed and reinstalled from this magnet with fairly minor delays in the schedule. The removal and reinstallation of the "looser" end clamps of DCA317 and DCA319 would have more severe impact on the schedule.

-- Having consulted with John Carson and Don Tinsley, I am recommending several revisions to the End Clamp Installation Traveller which should clarify the "free" and "loaded" state diameter measurements and bring about greater consistency between readings by different technicians, and greater precision in evaluation of diameter changes during installation. Jo Ann Larson has begun to implement these changes in the Traveller in draft form.

-- It is certainly important that the data in the Traveller not be tampered with for any reason. Necessary changes may be made in an appropriate manner, but all technicians should be aware that changes in raw data can cause confusion if the reason and intent of such changes is unclear. The changes made in the DCA319 data are particularly suggestive of an atmosphere in which the desire to get the "right answer" is stronger than the desire to record the true measured value.

-- Finally, it should be restated that all "STOP" criteria in the Traveller should be respected.

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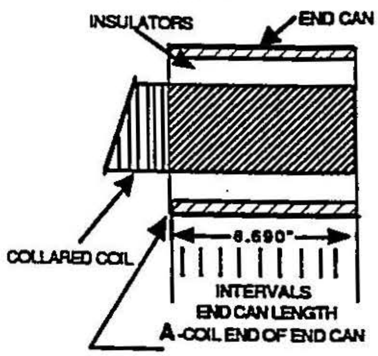
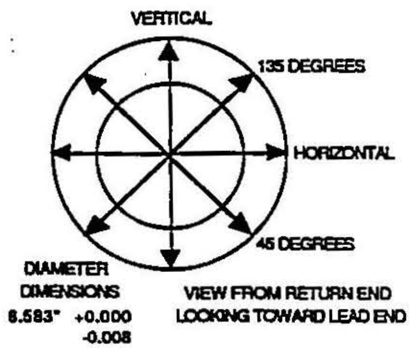
[3]However, DCA313 was the first magnet to employ end clamp insulators manufactured with a different technique which brought certain key dimensions closer to the design values.

1.5 Measure diameter of the Return Aluminum End Can (MB-292205) in the free state in the horizontal, vertical, 45 degree, and 135 degree directions at 1" intervals using PI Tape and an Starrett 8"-9" Micrometer. Use a permanent, fine line marker (not black) to mark .5 inches from the coil end of End Can (point A), and then at 1 inch intervals throughout the total length of the End Can. Also draw a line connecting the interval markings throughout the length of the End Can occuring around it's circumference at horizontal, vertical, 45 degree, and 135 degree positions. Mark the "TOP" direction of the End Can.

RETURN END CLAMP ASSEMBLY





Distance from Coil End of End Can (A)	Horizontal	Vertical	45 Degree	135 Degree	Pi Tape
0.5 inches					
1.5 inches					
2.5 inches					
3.5 inches					
4.5 inches					
5.5 inches					
6.5 inches					
7.5 inches					

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Technician(s)

____
Date

FIGURE 1

End Clamp	ΔH (mils) (1.5")	ΔV (mils) (1.5")	Δ45 (mils) (1.5")	Δ135 (mils) (1.5")	<Δ> (mils) (1.5")	Δπ-tape (mils) (1.5")	Δπ-tape (mils) (0.5")
311 L	2	9	6	8	6	5	3
311 R	-3	6	6	7	4	5	4
312 L	1	3	0	5	2	4	2
312 R	-1	6	5	4	4	5	3
313 L	0	5	3	5	3	2	3
313 R	1	6	2	4	3	0*	-1*
314 L	2	5	3	4	4	4	5
314 R	4	7	3	4	5	4	4
315 L	1	5	2	4	3	4	4
315 R	0	5	4	3	4	4	4
316 L	3	5	3	7	5	5	4
316 R	1	9	6	6	6	5	5
317 L	2	3	1	3	2	6**	6
317 R	2	6	5	5	5	5	5
318 L	5	4	5	6	5	4	4
318 R	2	4	2	4	3	3	3
319 L	1	4	3	3	3	6***	6
319 R	1	6	7	5	5	5	4

Table 1. Diameter Changes of End Clamp Cylinder
1.5" from Collared Portion of Coil, Measured with
Micrometer and Pi-tape

* Pi-tape measurements are inconsistent with micrometer measurements. Best estimate of 1.5" position pi-tape deflection is 3 mils

** Pi-tape measurements in clamped state are inconsistent with micrometer measurements

*** Pi-tape measurements in clamped state have been altered in traveller, and are inconsistent with micrometer measurements

End Clamp Deflection Measured with Pi-Tape and Micrometer 1.5" from Collars

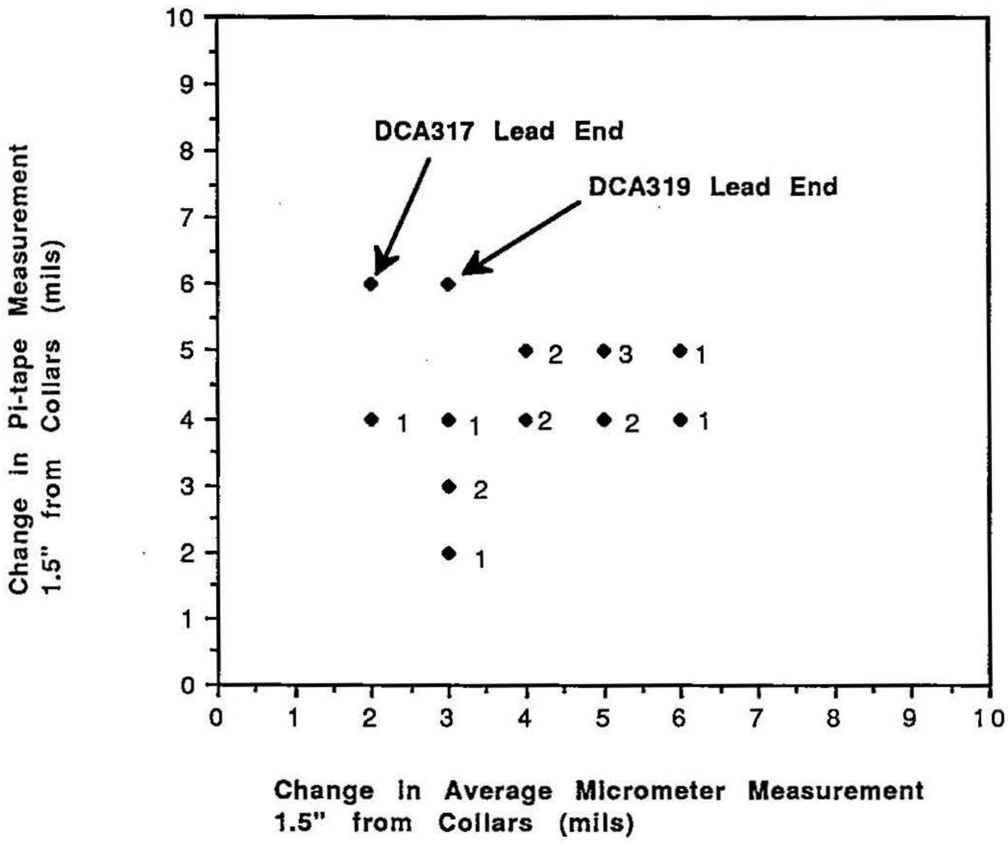

FIGURE 2