Comparison of Strain Gage Resistance Measurement Techniques*

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During the final electrical checkout of DS0314, it was noted that two different techniques for measuring strain gage resistances are used in different phases of magnet construction and testing. In this memo, results of both measurement techniques on the DS0314 shell strain gages at room temperature are reported.

Lab 2 and the ICB Engineering Laboratory perform 4-wire measurements of strain gage resistances using a Hewlett-Packard 3457A meter[1]. Materials Development Laboratory and Magnet Construction personnel perform similar 4-wire measurements. However, they use a separate current source (Hewlett-Packard 6181C) run at 2.5 mA and measure the voltage across each strain gage with a Hewlett-Packard 3457A meter. The first technique gives a resistance reading automatically. The second technique gives a current reading and a voltage reading, which are divided by hand or in Excel files to get the resistance values.

A set of 12 shell strain gages was measured both ways. The results are shown below in Table 1.

Table 1. Shell Gage Resistance Measurements (All values in Ohms)

gage name	3457A / 6181C #1	3457A / 6181C #2	3457A 4-wire #1	3457A 4-wire #2	Diff
A9	349.766		349.764	349.765	-.002
L9	349.678		349.693	349.693	.015
C9	349.969	349.967	349.979	349.982	.010
A10	349.677	349.674	349.688	349.691	.011
L10	349.828	349.827	349.840	349.840	.012
C10	**349.772**	**349.896**	**349.644**	**349.644**	**-.128**
A1	349.774		349.788		.014
A2	**349.964**		**350.010**		**.046**
A5	349.486	349.484	349.498		.012
A6	349.817		349.830		.013
C1	350.364		350.378		.014
C2	**349.691**	**349.793**	**349.609**		**-.082**

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The first column in Table 1 gives the name of the shell gage. The letter A denotes an active gage measuring azimuthal strain. L means an active gage measuring longitudinal strain. C stands for a compensating gage.

The second and third columns contain resistance mesurements done with a separate current supply run at 2.5 mA. The second column values were recorded about one half hour before the third column values.

The third and fourth columns show the results for measurements made using the 4-wire technique. The fourth column values were taken shortly after the third column values. The repeatability is excellent.

The fifth column shows the difference between the fourth and second column values. The original goal of these measurements was to demostrate that these columns would be exactly the same. To our surprise, while in most cases a systematic shift of .010 - .015 ohms was observed, in some cases, shown in bold type, the differences were much larger.

For C2 and C10, it was found that the separate current supply readings (second and third columns) were not very repeatable. A repeat measurement on gage A2 was not made.[2] Other gages showed excellent repeatability with both measuring techniques, but the 4-wire technique was superior.

Why some gages should give repeatable measurements with a certain technique and not other gages is a mystery so far. However, all of this prompts the question: Why do we go on using the separate current supply technique at all? The IB3 apparatus could easily be adapted to the 4-wire technique, which saves one piece of equipment and many steps of hand calculation or typing into Excel. It is also self-correcting in the sense that the meter monitors its current automatically, while with the separate current supply technique the current must be recorded before and after a set of measurements and then averaged, or worse, recorded each time a measuiement is made.

I strongly recommend that the IB3 people try their own comparison of the 4-wire technique with their usual technique, since the former is superior in several ways, and does not seem to suffer from the "mysteries" referred to in this memo.

Notes

[1] I still haven't found a manual for the HP 3457A, so I don't know how much current it puts out, how it regulates the current, how it calculates the ratio of current and voltage, etc. The Engineering Lab has no manual. Nor does Marty Whitson that he can find. Nor does PREP, though manuals are "on order" there. (Tariq at Lab 2 believes the current is about a milliamp.) So far our complete or partial ignorance of how the thing works is the only "drawback" of this technique!

[2] At the time, the C2 and C10 differences were so striking that we only paid attention to these. I don't know whether it is relevant that both of the "flakey" gages are compensating gages. However, we later found that some of the compensating collar gages were giving values very far from their last-measured values, which, if taken seriously, would yield NEGATIVE stresses in several of the coils, and absurdly small values in others.

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