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# MEASUREMENT OF APPARENT STRAIN CURVES OF TWO MICROMEASUREMENTS STRAIN GAUGES MOUNTED ON G-10

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## Introduction

As part of the construction of the Chicago Cyclotron Magnet (CCM), strain gauges were mounted on structural members composed of G-10*. At temperatures other than room temperature, strain gauges experience a zero offset caused by the thermal coefficient of resistance of the coil and the difference between the thermal contractions of the gauge backing and the material to which it is bonded. This zero offset is called apparent strain. At cryogenic temperatures apparent strain can become very significant and it is necessary to obtain a plot of apparent strain v.s. temperature for the specific strain gauge and material used. The gauges selected were Micro-Measurements Wk-09-250BP-120 and Wk-06-125AD-350. These are both self temperature compensation gauges, which means that if they are mounted on the material for which they were designed the apparent strain will be very small (<100 $\mu\varepsilon$) between 300 K and 400 K. The Wk-09 gauge is designed for materials with a room temperature thermal expansion coefficient of 9 parts per million per degree Fahrenheit and Wk-06 is designed for 6 ppm/$^{o}$F. Since we are using our strain gauges at temperatures between 200 K to 300 K, it

*Fibre-glass epoxy laminates manufactured by Spaulding Fibre Co.

is necessary to correct for apparent strain. The manufacturer supplies apparent strain v.s. temperature curves for each gauge mounted on a representative material (for Wk-09, SS 304; for Wk-06, steel 1018). Since such curves are not available for gauges mounted on G-10 it is necessary to experimentally determine them.

## Experimental Set-Up

The two strain gauges were mounted on small pieces of G-10 and, for the Wk-06 gauge thermocouples were placed above and below the gauge, for the Wk-09 gauge four thermocouples were placed all around the gauge (see Fig. 1). With the use of a Strainsert Model TN8C strain gauge readout and an Omega Digital Type E Model 175 thermocouple readout, it was possible to read apparent strains and the corresponding temperatures. For the Wk-06 gauge, readings between 196 K and 300 K were taken by placing the sample in dry ice and recording temperature and apparent strain readings as the temperature dropped. Readings between 78 K and 196 K were taken by suspending the sample in a small dewar with liquid nitrogen in the bottom. By varying its height above the liquid nitrogen surface it is possible to vary the temperature of the sample. For temperatures below 78 K the same procedure was used with liquid helium in the dewar. It is found that the easiest way to vary temperature is with liquid nitrogen in a small dewar, so that method was used between 78 K and room temperature for the Wk-09 gauge. Since the temperature varied by several degrees for the thermocouples on each sample, the average of all the thermocouples on the sample was used for the data point.

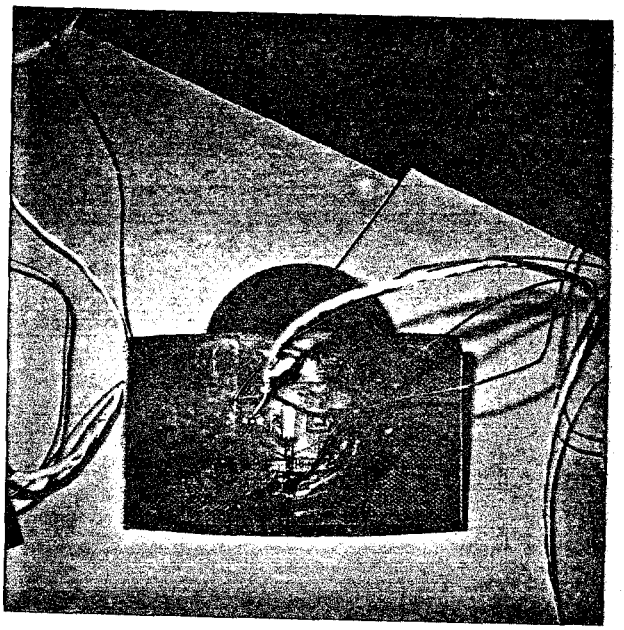
## Results

The curves shown in figures 2 and 3 are the apparent strain v.s. temperature curves for the respective gauges. The curve for the gauge used in the CCM (Wk-09) is plotted between room temperature and $LN_2$ temperature. The curve for the other gauge (Wk-06) is plotted between room temperature and LHe temperature. For the same strain gauges, H.S. Freynik etal, measured the apparent strain v.s. temperature for different substances: SS 316, 21-6-9 SS, OFHC Cu, a $Nb_3Sn$ multifilament conductor and a NbTi multifilament conductor. They noted that the curve turned sharply upwards near 20 K. We did not notice this phenomena for G-10 but it could exist because we had relatively few data points below $LN_z$ temperatures. However, the absolute value for the apparent strain at LHe temperature should be accurate.

Finally, it should be noted that a particular strain gauge, with a known apparent strain v.s. temperature curve can serve as a thermometer if it is mounted on an unloaded member. In the cool-down of the CCM, we used the strain gauges as additional temperature indicators apart from regular thermocouples so as to cut down the heat leak from instrumentation leads.

References

1. H.S. Freynik, Jr., D. R. Roach, D.W. Deis, D.G. Hirzel, "Evaluation of Metal Foil Strain Gauges for Cryogenic Application in High Magnetic Fields", Lawrence Livermore Laboratory, Livermore, California.



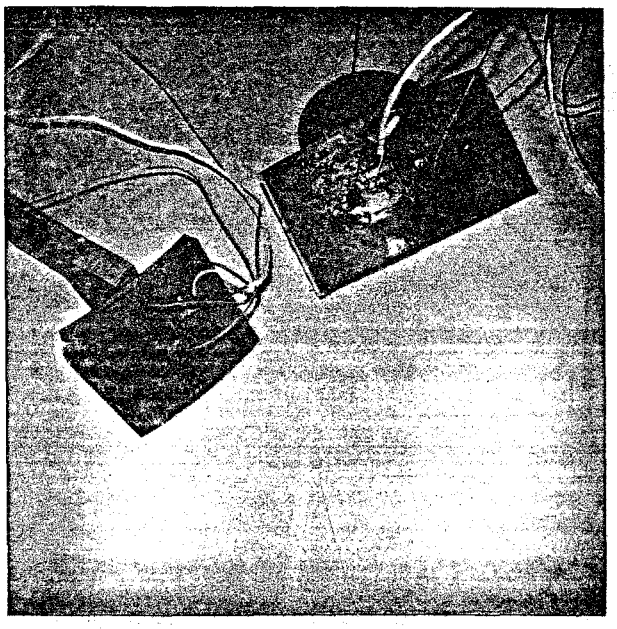


FIG. 1

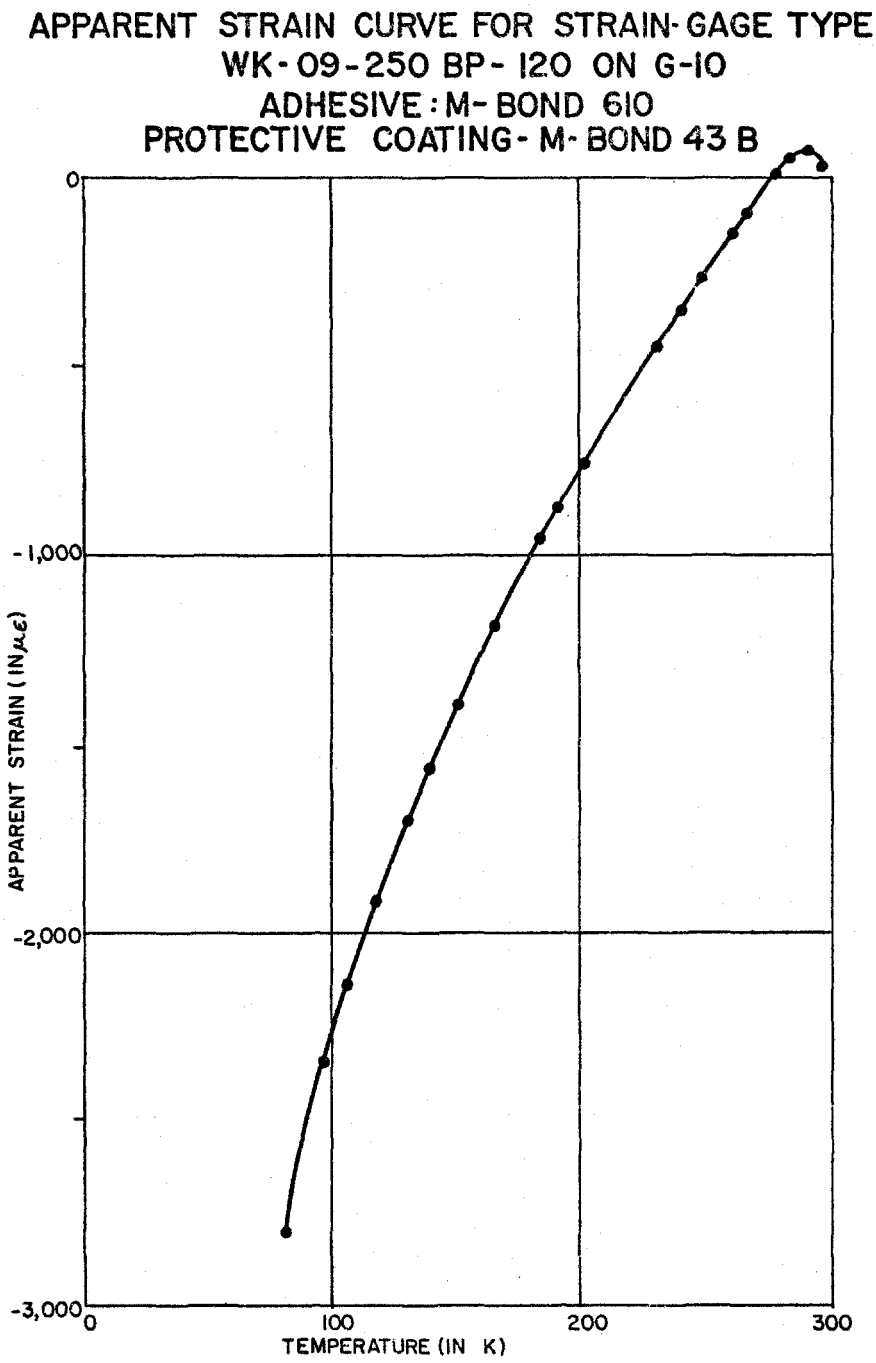

APPARENT STRAIN CURVE FOR STRAIN-GAGE TYPE
WK-09-250 BP-120 ON G-10
ADHESIVE: M-BOND 610
PROTECTIVE COATING- M-BOND 43 B
0
-1,000
-2,000
-3,000
APPARENT STRAIN (IN με)
0
100
200
300
TEMPERATURE (IN K)

Fig. 2

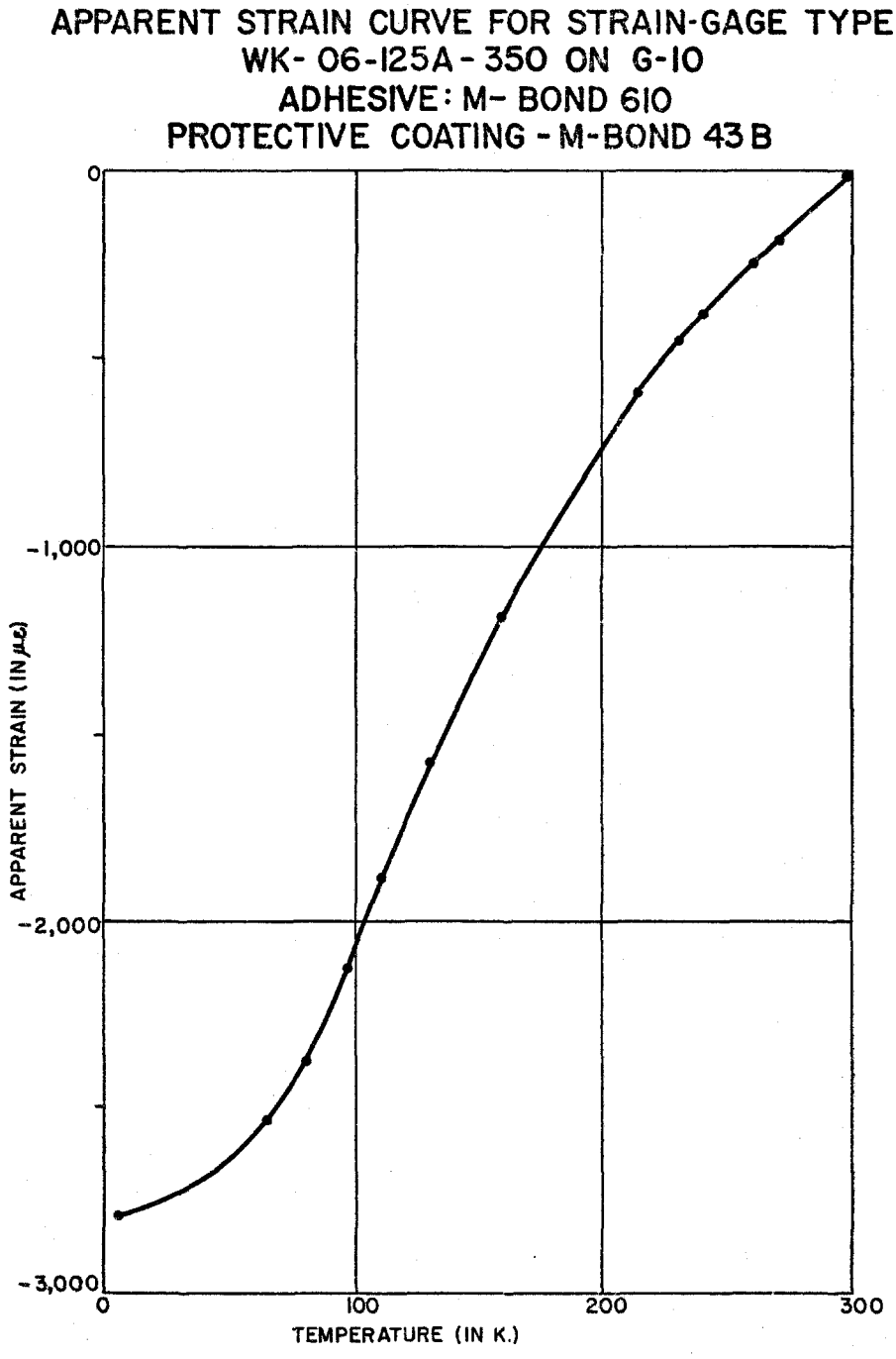

APPARENT STRAIN CURVE FOR STRAIN-GAGE TYPE
WK- 06-125A-350 ON G-10
ADHESIVE: M- BOND 610
PROTECTIVE COATING - M-BOND 43 B
0
-1,000
-2,000
-3,000
APPARENT STRAIN (IN με)
0
100
200
300
TEMPERATURE (IN K.)

Fig. 3