Some Comments on Manganin Wire Pressure Gauges *

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A standard manganin wire pressure gauge is examined by comparing it with a recently developed 0.01% CaF_2 capacitive pressure gauge. The effects of the Bridgman "water kick" and intrinsic time constant are clearly shown and the results punctuate the usual assertion that manganin wire gauges are extremely difficult to use approaching the 0.1% level.

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It is well known that if attempts are made to use a manganin wire pressure gauge at the 0.1% level, a great deal of difficulty is encountered. This note presents a close look at some of the associated problems by comparing a standard manganin wire gauge with a 0.01% CaF_2 capacitive gauge.¹

Several 300 ohm lengths of No. 40 B. & S. gauge double silk covered wire obtained from the Driver and Harris Co. (Dated 1955) were wound into 3mm - 7mm diameter, strain-free coils. All of the coils were "Bridgman cycled" over varying periods of time. In addition, some of the coils were pressure cycled over ranges of 0-3 to 0-6 kilobars. Each of the coils was placed in a pressure system, which is described elsewhere², along with a 6pF CaF_2 pressure sensor and the changes in the capacitance, ΔC , and the resistance, ΔR , with pressure monitored. All of the work was done at 308°K. The resultant curves were fitted to an equation of the form:

$$\Delta C/C_0 = a(\Delta R/R_0) + b(\Delta R/R_0)^2 \quad (1)$$

where a and b are the fitting parameters and C_0 and R_0 are the zero pressure capacitance and resistance, respectively. A typical curve of the difference between the experimental data and the fitted equation is plotted in Figure 1. The first effect to be noted is the anomalous behavior at low

pressures. This is attributed to the Bridgman "water kick,"³ which is due to the leakage resistance of the manganin wire to ground through the pressure medium. The loss mechanism is water contamination in the pressure fluid. The effect is seen to disappear at around 700 bars. An independent investigation was made in which the resistance of the fluid as a function of pressure was observed. The resistance showed an increase from a finite value at small pressures to essentially infinity at nominally the same pressure at which the resistive aberration disappeared. Of course, this effect can be greatly reduced by using high quality oils such as the Spinesstic 38 series, but even the finest oils contain some water.

Also evident from Figure 1 is a hysteresis loop. The following experiment showed this to be due to a time constant intrinsic to the manganin wire. The CaF_2 sensor and a coil of manganin wire were pumped up to three kilobars and the capacitance and resistance monitored for several hours. Figure 2a defines the quantity δ , which is essentially a measure of the deviation of the system from ideal behavior. This is plotted against time in Figure 2b. The slow asymptotic approach to equilibrium is shown. As a check on the CaF_2 gauge, the CaF_2 pressure sensor was left at that pressure while the manganin wire was reduced to atmospheric pressure. After several days, the manganin

wire was pumped up to three kilobars and reconnected to the CaF_2 gauge. Figure 2c shows the results. The same sort of relaxation occurred showing that the manganin wire was responsible.

Thus, a closer examination of the variation of the resistance of manganin wire with pressure leads to results which punctuate the assertion that manganin wire gauges are extremely difficult to use approaching the 0.1% level.

Figure 1. Comparison between manganin wire and CaF_2 .

The C' scale is the residual capacitance after the linear and quadratic contributions have been removed. Two units are approximately equivalent to 10^{-5} picofarads on that scale. ΔR is the change in resistance of a length of manganin wire in ohms. One ohm is equivalent to 1.4 kilobars.

Figure 2. (a) Definition of the quantity δ where C is the capacitance of a CaF_2 sample, and ΔR is the change in resistance of a coil of manganin wire. (b) δ is plotted against time for a system of manganin wire. Eight divisions of δ are approximately equal to one milliohm, and the time is in hours. (c) δ plotted against time, in this case, after the manganin wire had been allowed to relax to room pressure for several days. The units are the same as for Figure 2b.

REFERENCES

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