A High-Pressure Wire Gage Using Gold-Chrome Wire

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Precision experiments with manganin wire for the measurement of high pressures are made difficult by virtue of the temperature-resistance response of the manganin. The equilibrium time required for this material to steady out after rapid pressure changes makes manganin generally unsuited for uses in industrial-control applications. For this reason, a study was made of the pressure and temperature response characteristics of several new materials. An alloy of 2.1 per cent chromium in gold was found to have much less sensitivity to temperature, varying from +1 to −1 ppm per deg F over the range of 40 F to 200 F, while manganin varies from +5 to −40 ppm in this same interval. This alloy also has a strong pressure coefficient. Typical values are 0.67 to 0.72 × 10^{-7} ohm/ohm/psi for gold chrome as compared to 1.69 to 1.72 × 10^{-7} ohm/ohm/psi for the manganin tested. Although the pressure sensitivity is only 33 per cent that of manganin, the smaller temperature sensitivity of the gold chrome results in good discrimination between temperature and pressure changes. Gold chrome responds rapidly to pressure changes, quickly coming to equilibrium, and does not show the annoying drift so characteristic of manganin. It is generally pressure seasoned with a single application of pressure, as compared to several cycles usually required for manganin. Its long-term stability compares favorably with manganin.

Introduction

In the laboratory investigation of high-pressure phenomena, the use of a coil of manganin wire whose resistance changes linearly with exposure to fluid pressure, has been adopted, universally as a pressure-sensing device, as a result of the pioneering work of Dr. Bridgman.[3]

Manganin is especially suitable for the measurements of pressure from 50,000 psi up to values that are limited only by the structure used. Its resistance changes in the order of 1.7 ohms per 100 ohms of wire per 100,000 psi, a value which makes accurate resistance measurements quite simple.

It is well known that manganin changes its resistance slightly with temperature, and this resistance change is small only over a fairly narrow temperature range. If the temperature of the fluid departs very much from room temperature, an appreciable change in coil resistance results, and this cannot be distinguished from a pressure change. When precision measurements are attempted on fluids whose pressure has undergone a rapid change, a fairly long period of time is usually required for the manganin coil to come to equilibrium. This is due in part, at least, to the temperature change produced in the liquid by the pressure change. Although the equilibrium time is a nuisance in laboratory measurements, it can be tolerated, but this is not the case where high-pressure sensing devices are required for control of continuous industrial processes.

A great deal of work has been done in Germany on the development of alloys of gold, silver, and copper, for the purpose of developing resistance wire that has better temperature-resistance properties than manganin.[4] Of these, alloys containing 2 to 4 per cent chromium in gold have shown the most promise. The remarkable temperature properties of these alloys have been investigated at length by the Bureau of Standards with the objective of using gold chrome as a primary standard of resistance.[5] Material similar to that supplied to the Bureau of Standards was obtained from Sigmund Cohn and tested at Foxboro. An excellent agreement between our samples and those reported by the Bureau has been a gratifying check on the accuracy of our measurement technique. Their probable sensitivity to pressure also was predicted by the Germans. Experiment has shown that gold chrome is suitable for measurement of high pressure to values of the same order as manganin.

Gold-chromium wire has properties which make it particularly suitable for a pressure-sensing element for industrial purposes. It responds rapidly to pressure changes, it has a high degree of discrimination between temperature and pressure effects, it has adequate pressure-resistance sensitivity, and material with a high degree of uniformity is available.

Temperature Versus Resistance Properties—Experimental Procedure

Manganin. Samples to be tested were either loosely wound on a ceramic bobbin of small size to facilitate handling, or were self-supporting coils as in the case of pressure-sensing units. The coils thus wound contained locked-in mechanical strains which of necessity had to be removed before the coils became stable. For manganin coils, this stabilizing process was accomplished by the use of the Bridgman cycle. This consisted of exposing the completed coils to temperatures of −100 F for a period of at least 2 hr, and then placing them in an oven at a temperature of +250 F for a period of at least 8 hr. This cycle was recommended by Dr. Bridgman to produce the greatest stability in manganin wire, and frequently it was found that several such cycles were necessary before complete stability was attained. Coils were wound noninductively, since all measurements were made at 1000 cycles, in order to avoid contact-potential difficulties.

Measurements of the resistance of the coils were made by an automatic two-function recorder developed at Foxboro for this purpose. The recording chart was positioned according to the temperature of an oil bath in which the sample was placed, and the recording pen moved across the chart in response to resistance changes. The temperature sensitivity of this instrument had a

[1] The Foxboro Company, Foxboro, Mass.

[2] Harwood Engineering Company, Inc., Walpole, Mass.; formerly with The Foxboro Company. Jun. ASME.

[3] "The Physics of High Pressure," by P. W. Bridgman, The Macmillan Company, New York, N. Y., 1931.

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[4] "Werkstoffe für Widerstandsmanometer und Widerstandsthermometer," by Alfred Schulze, *Chemiker-Zeitung*, vol. 19, July, 1943, p. 228.

[5] "Gold Chromium Resistance Alloys," by J. L. Thomas, U. S. Bureau of Standards, *Journal of Research* (Research Paper No. 737), vol. 13, 1934, pp. 681–688.