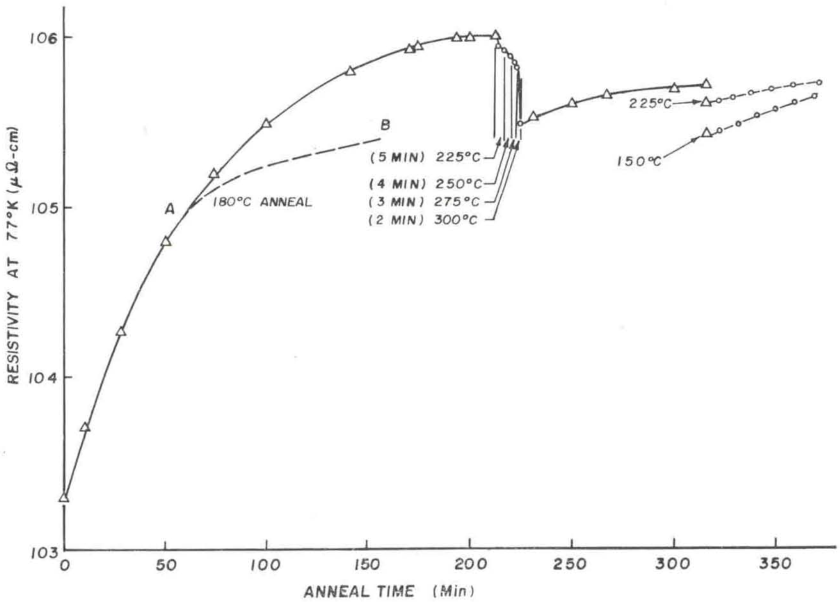
increase when the specimens were quenched from above 560°c, and (2) decrease with increasing chromium concentration. It is noted that both Ni–22 Cr and Ni–30 Cr approach a zero ordering rate at 704°c that is lower than for 648°c. The decrease in saturation resistivity between 648° and 704°c is, at present, inexplicable. A possible explanation may be attributed to anti-phase domain boundaries. In quenching from relatively high temperatures (704°c) anti-phase domain boundaries serve as sinks for defect motion during annealing.

Additional experiments were performed on the Ni–22 Cr alloy in order to determine the role of vacancy diffusion in the ordering process, and in order to determine the number of processes activated during annealing. Ni–22 Cr specimens were quenched from 760°c and annealed at 180°c for 200 min so that the ordering rate was essentially zero. The annealing temperature was then changed to higher temperatures of 225°, 250°, 275°, and 300°c for 5, 4, 3, and 2 min, and then lowered to 180°c again. The decrease in resistivity which occurred at the higher annealing temperature indicates that partial disordering (non-equilibrium vacancies) exists within antiphase domains. The first flattening of the curve indicates the formation of antiphase domains. The results of these experiments are summarized in fig. 4.

After holding two specimens at 180°c for 100 min, the temperature was changed from 180° to 225°c and from 180° to 150°c. As shown in fig. 4, the

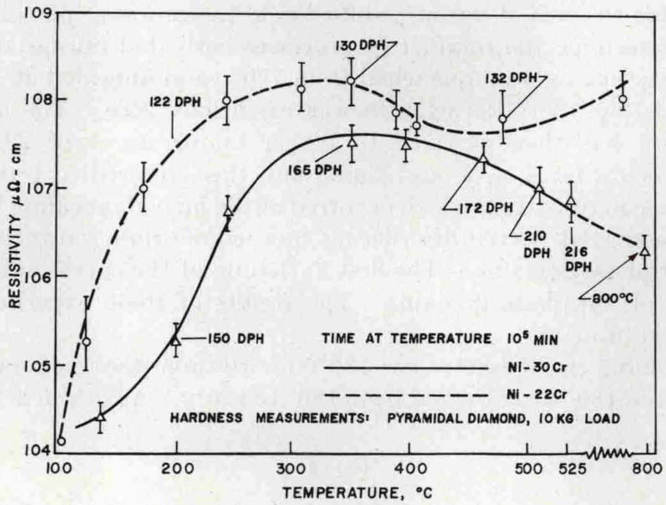
Fig. 4




Isothermal annealing at 180°c with subsequent breaks at 225°, 250°, 275° and 300°c (Ni–22 Cr).

resistivity initially decreased in both cases. Holding the two specimens at 225° and 150°C resulted in a higher resistivity at 225° than at 150°C. These results indicate that two parallel processes with different temperature response are contributing to the resistivity change. The first process is the increase in resistivity with temperature and the second is the partial disordering attributed to a non-equlibrium concentration of point defects.

Fig. 5




Effect of long time anneals on the final resistivity and hardness of Ni-22 Cr and Ni–30 Cr.

The final resistivity of the initially disordered specimens (quenched specimens) was determined by long time annealing ($10^5$ min) and by measuring the resistivity at temperature. Figure 5 shows a maximum around 350°C for Ni–22 Cr and a decrease between 350° and 400°C. Figure 5 also shows a decrease in resistivity for Ni–30 Cr at 400°–450°C. Annealing at 800°C shows an additional decrease in resistivity for Ni–30 Cr. Hence, there is an inherent difference between the resistivity curves of Ni–22 Cr and Ni–30 Cr. This effect for the Ni–30 Cr alloy was not caused by any permanent change such as the loss of chromium reported by Manene (1959) for Nichrome. Chemical analysis for Ni–30 Cr did not show a decrease in chromium after the long-time anneals. It is of interest to note that the hardness for the Ni–30 Cr alloy increased in two steps which corresponded to the increase and subsequent decrease in electrical resistivity. Only the first increase in hardness was recognized for the Ni–22 Cr alloy (fig. 5). The hardness measurements were taken on the same specimens used for the long-time anneal experiments. The specimens were furnace cooled to room temperature before hardness measurements were taken.