PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

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Phil. Trans. R. Soc. Lond. A 1980 **295**, 209
doi: 10.1098/rsta.1980.0101

Phil. Trans. R. Soc. Lond. A **295**, 209 (1980) [209]
Printed in Great Britain

Temper embrittlement at high alloy contents: a 12% Cr martensitic steel*

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It is shown that the minimum in impact toughness of martensitic 12% Cr steels, classically associated with the maximum hardening between 475 and 500 °C, is shifted towards 550 °C in a commercial heat containing phosphorus, while the brittle mode of failure becomes predominantly intergranular. This phenomenon is shown to be typical temper embrittlement induced by the segregation of phosphorus and chromium to the former austenitic grain boundaries, the fragility being amplified by the steel's relatively high strength. The kinetics of phosphorus segregation are studied by Auger electron spectroscopy. The temperature dependence of equilibrium segregation is shown to be consistent with the theory of synergistic ternary segregation, which is discussed with particular emphasis on the effect of high alloying element concentrations. In particular the high Cr content is responsible for the segregation (thus the embrittlement) to remain significant at much higher temperatures (e.g. 700 °C) than in low alloy steels. Therefore, embrittlement cannot be thoroughly alleviated by a reversion treatment without crossing Ac_1, unless the phosphorus concentration is kept to a minimum, or molybdenum additions are made which counteract the effect of phosphorus.

* Abstract only; the full paper is published in *Metal Sci.* **13**, 496 (1979).