MASTER

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THERMAL STABILITY OF FERRITIC ALLOYS
FOR FOSSIL-FUEL PROCESSING SYSTEMS

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The experimental work within the latest reporting period has concentrated on electrical resistance measurements designed to monitor the thermal instability of four ternary Fe-Cr-Al alloys over the range 400°C to 600°C. Special emphasis is being placed on the phenomenon of 475°C embrittlement which is of practical and technical importance in the application of commercial ferritic stainless steels containing above 12 percent chromium. The program is concentrating on the kinetics and severity of the 475°C embrittling reaction in Fe-Cr alloys containing varying amounts of ternary elements; the present studies are concerned with the effects of small amounts of aluminum.

Electrical resistance measurements at appropriate intervals during isothermal aging treatments have proven to be sufficiently sensitive for monitoring the progress of metallurgical instability in both binary Fe-Cr and ternary Fe-Cr-Al alloys. For example, at an aging temperature of 450°C an alloy of Fe-18Cr-5Al exhibits a decrease in electrical resistivity of 1.1 percent over a period of 100 hours at temperature, while at 500°C for the same time period a 2.9 percent decrease is observed. For an Fe-18Cr-3Al alloy the corresponding decreases in resistance are 1.4 percent and 2.8 percent. These resistance

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decreases are considerably less than the values measured under similar aging conditions for a binary Fe-Cr alloy, thereby suggesting that ternary additions of aluminum have a beneficial effect on the microstructural stability at 450°C-500°C. The results are also consistent with those reported in a previous progress report for a series of Fe-Cr-Al-Hf alloys supplied by Lockheed Research Laboratories.

Additional experiments have shown that raising the aluminum content increases the initial resistivity of solution treated Fe-Cr-Al alloys at -196°C in comparison to that observed in binary Fe-Cr alloys of comparable chromium content. A linear relationship has been determined between the resistivity and a composition parameter corresponding to the atomic percentage ratio $\frac{\%Fe + \%Cr}{\%Al}$. The measurement of resistance at different temperatures has confirmed an anomalous dependence of $\frac{d\rho}{dt}$ on the aluminum content, with increasing aluminum greatly reducing the thermal contribution to resistivity over the range -196°C to +100°C. For aluminum contents in excess of about 8.5 atomic percent, a decrease in resistivity with increasing temperature is observed. The data indicate that Fe-Cr-Al alloys having a value of the ratio $\frac{\%Fe + \%Cr}{\%Al}$ of about 11 should exhibit a constant electrical resistance over the temperature range -196°C to 0°C, i.e. a value of $\frac{d\rho}{dt} = 0$. This anomalous effect of aluminum on the resistivity is receiving additional attention as a possible basis for developing an analytical model for characterizing the influence of ternary aluminum additions on the thermal stability of Fe-Cr alloys. Such a method would be useful in identifying the extent of aluminum redistribution by diffusion during prolonged holding at elevated temperatures and might provide a useful quantitative approach for characterizing the kinetics of microstructural instability in these alloys.

A meaningful interpretation of the electrical resistance data also requires the use of other analytical methods for the direct determination of the structural and compositional changes that occur due to microstructural instability. Consequently, X-ray diffraction analysis, scanning electron microscopy, and transmission electron microscopy techniques will be employed during the next several months in an effort to correlate the structural changes during decomposition with the results of the electrical resistance studies. Such correlations are essential in formulating meaningful quantitative models of the kinetics of the instability reaction and the influence of ternary additions in these alloys.