HIGH TEMPERATURE STATIC STRAIN SENSOR DEVELOPMENT PROGRAM

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The purpose of this program is to develop electrical resistance strain gages useful for static strain measurements on nickel or cobalt superalloy parts inside a gas turbine engine on a test stand. Measurements of this type are of great importance in meeting the goals of the Host Program because, without reliable knowledge of the stresses and strains which exist in specific components, it will be difficult to fully appreciate where improvements in design and materials can be implemented. The first part of the effort has consisted of a strain gage alloy development program which is to be followed by an investigation of complete strain gage systems which will use the best of the alloys developed together with other system improvements.

The specific goal for the complete system is to make measurements to 2,000$\mu\varepsilon$ with error of only $\pm$ 10% over a 50 hour period. In addition to simple survival and stability, attaining a low thermal coefficient to resistivity, of order 100 ppm/K or less, is also a major goal. This need results from the presently unavoidable uncertainty in measurements of the exact temperatures in the turbine. The size and thickness requirements to avoid aerodynamic effects suggests the use of the sputtering technique as the best system fabrication approach. The results from the first year of this effort resulted in the identification of an FeCrAl alloy and the Pd-Cr alloy systems as the basis for further alloy modifications and development. Alloy candidates are evaluated and compared using a grading system consisting of the product of the following factors with their total weight potential given in parenthesis: Repeatability (20), Oxidation (18), Resistivity (16), Thermal Coefficient of Resistivity (14), Elastic Range (12), Differential Thermal Expansion (10) and Miscellaneous Judgements (10).

Although the final strain gage system fabrication procedure will probably use the sputtering technique, this is too expensive and too slow a process for alloy development work. A drop-casting technique using repeatedly arc-melted buttons was therefore developed. The cast rods produced are ground and polished using slotted plates to finally produce long, thin strips of material about 17cm long suitable for subsequent testing. Other techniques for producing the strain gage elements, such as wire drawing and melt spinning, are also to be examined in this program.

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The specially constructed thermal cycling apparatus developed earlier in this work to make resistivity measurements has been further developed to make more accurate measurements. This system employs a split tube metal heater which can be cycled or held at constant temperature under program control. The test sample is positioned axially in the center of this tube with Platinum leads for voltage measurements and thermocouple wires attached by spot welding. Special provisions have been added to better accomplish the faster (250K/min) heating and cooling rate testing. Additional computer program development has also been accomplished to improve both the data measurement and the data reduction process.

The FeCrAl alloy system studies have defined a ternary area whose edges define compositions whose average thermal coefficients of resistance are zero between room temperature and 1250K. Compositions along these edges provide significant improvements over the previously known best alloy (Kanthal A-1). Measurements of the resistances to oxidation of these alloys with different amounts of Hf, Y, Sc, Co and additional amounts of Al and Cr have shown that, although all show protective behavior, none are significantly better than the base FeCrAl alloy.

The Pd-Cr alloys develop a thin coherent, continuous coating of Cr_2O_3. A variety of other alloys containing oxide formers, especially the rare earth metals, are being examined to find compositions with even better resistance to oxidation and lower thermal coefficients of resistance.

GENERAL RULES CONCERNING ρ AND α

Matthieson: $\rho = \rho_O + \rho_T$

Dellinger: $\rho\alpha = \text{Constant} \quad \alpha = \frac{d\rho}{dT}$

Linde: $\Delta\rho \propto V_X^2$

V = valence
X = alloying element

Norbury: $\rho\alpha(N - N_X)^2$

N = atomic number
X = alloying element

Figure 1

HIGH-SPEED THERMAL CYCLE/ RESISTIVITY MEASUREMENT APPARATUS

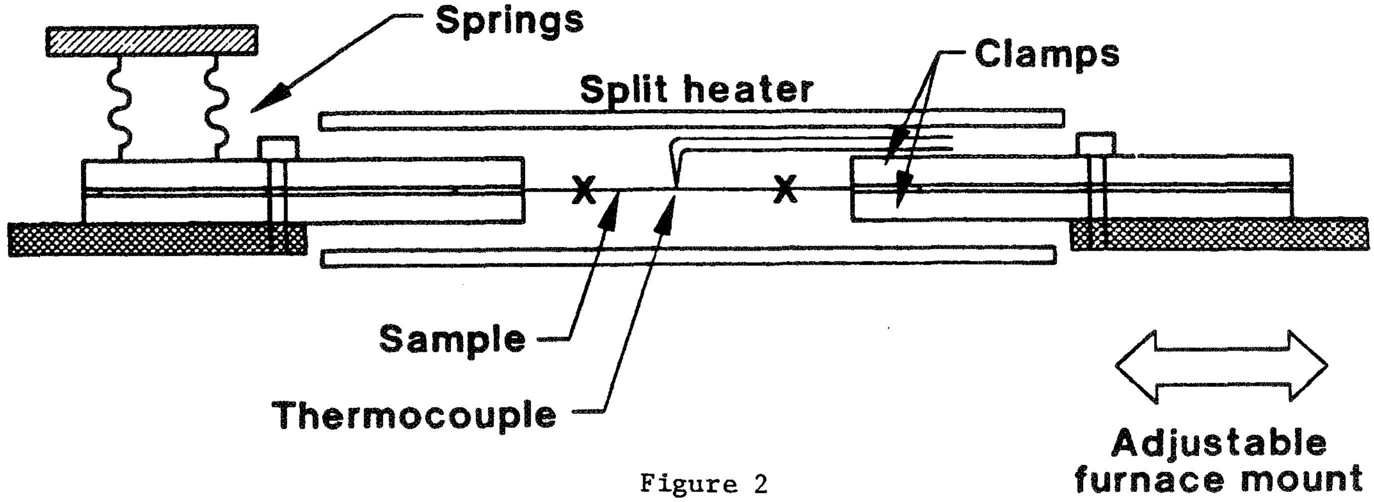

Figure 2

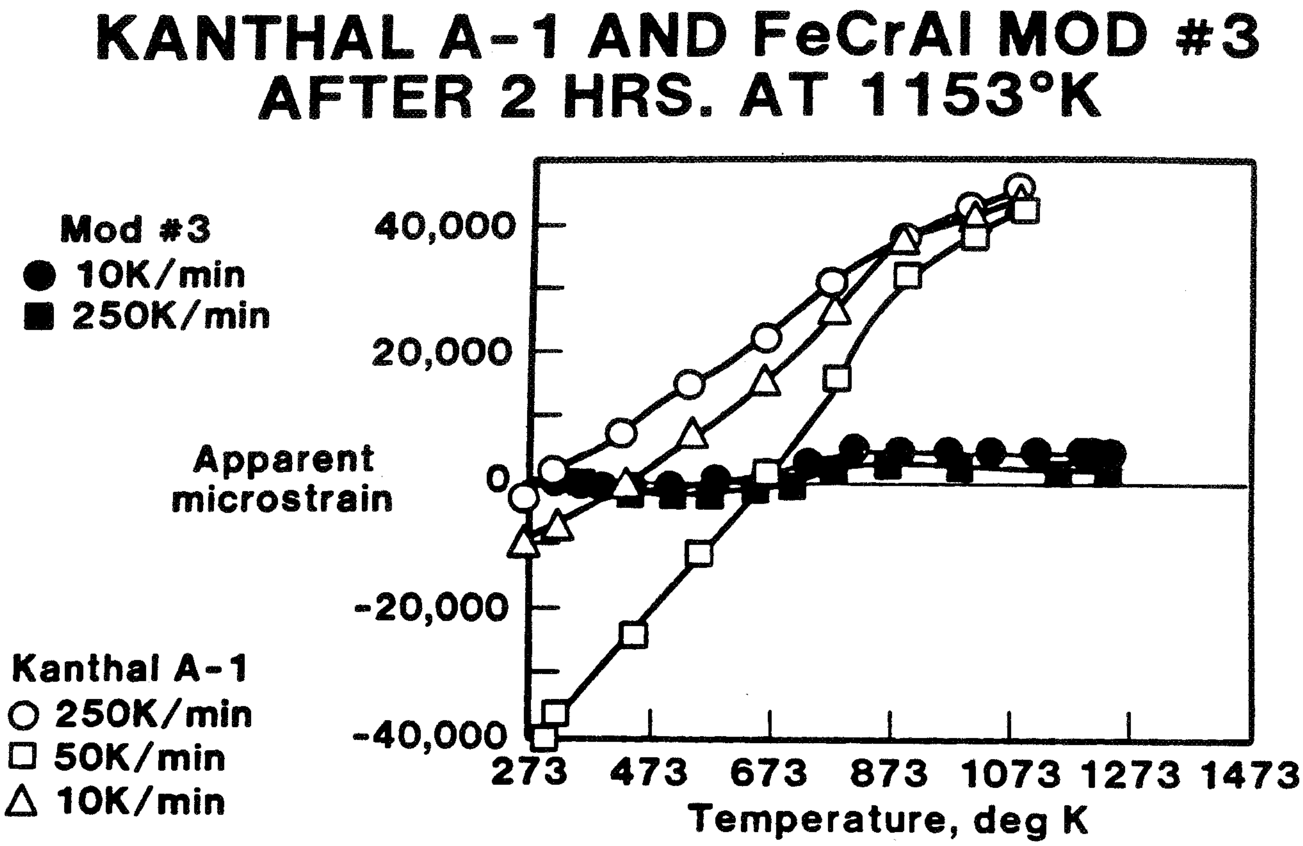

Figure 3

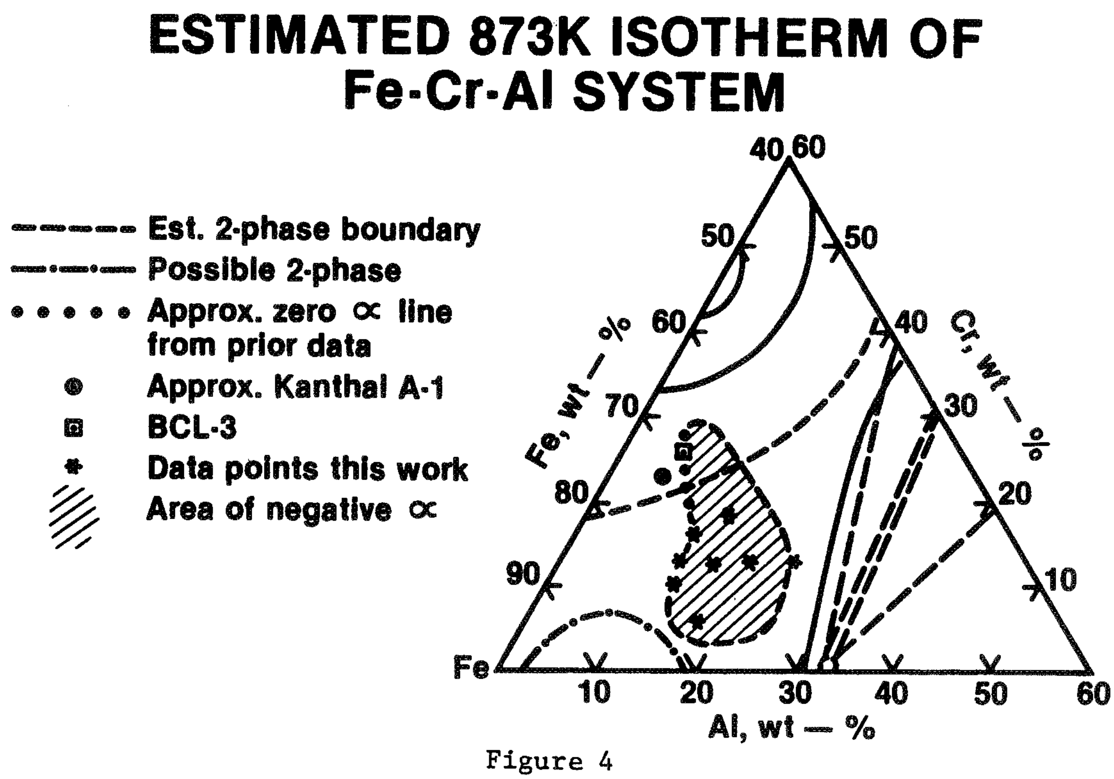

Figure 4

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