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# NASA TECH BRIEF



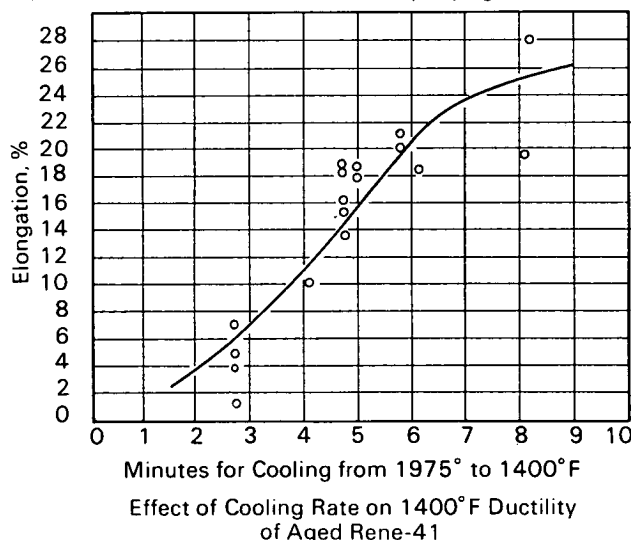
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## Mechanical Properties of Rene-41 Affected by Rate of Cooling after Solution Annealing

### The problem:

Prevention of failure of F-1 turbine manifolds of Rene-41 (percentages:  $\leq 0.12$  C,  $\leq 0.1$  Mn,  $\leq 0.5$  Si,  $\leq 0.015$  S, 18-20 Cr, 10-12 Co, 9-10.5 Mo,  $\leq 5$  Fe, 3-3.3 Ti, 1.4-1.8 Al, 0.003-0.01 B; balance Ni) caused by variations in mechanical properties. Samples placed at various locations on a manifold during the final, in-process, solution heat treatment (1975°F) and aging (16 hours at 1400°F) show extreme variations in elongation during tensile tests at 1400°F (see fig.).

Data Taken from Tensile Bars Accompanying Actual Parts



### The solution:

An investigation of the effect of the rate of cooling of 0.09-in. sheet, from 1975°F to 1200°F after solution annealing, has led to the following conclusions which provide partial solution of the problem:

1. The rate of such cooling profoundly affects most properties; within the useful range of rates ( $< 150^\circ\text{F}$ ), yield and ultimate strength vary by 20%.
2. The ductility at 1400°F varies almost linearly with the time for such cooling.
3. Neither the Charpy impact strength nor the ambient elongation is significantly changed by slowing of the cooling rate from the normal 75° to 20°F/min; elongation at 1400°F was doubled to 36% for the test heat.
4. Minimum ductility does not necessarily occur at 1400°F, but is a function of cooling rate; for 20°F/min it is at  $\leq 1100^\circ\text{F}$ , while for 75°F/min it is at 1200°F; it is probably at 1400°F for only rapidly quenched material.
5. There are indications that the quantities of carbide at grain boundaries affect high-temperature ductility.

It is not known why high-temperature ductility is enhanced by slow cooling, although other alloys are affected similarly. The effect may be due to more globular carbide formation, grain-boundary gamma prime precipitation, or formation of a soft zone adjacent to the grain boundary (due to depletion of chromium and the resultant gamma prime "solutioning"). Yet the light microscope revealed only heavier precipitation of carbide at the grain boundaries of the more slowly cooled specimens. On the other hand, the overall structure was typically banded, and the amount of carbide varied from location to location even on a single tensile specimen. Slow cooling not only improves high-temperature ductility; it also provides more uniform properties throughout a man-

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ifold and thus permits more-realistic receiving-inspection procedures.

It seems possible to trade strength for high temperature ductility and to "shift" the ductility minimum to a harmless location. Only one heat was studied in great detail; thus it may have been fortuitous that ambient elongation and impact resistance were not reduced by the lowest cooling rates. If this heat is an exception rather than the rule, the trade-off becomes more complex and slow cooling becomes less attractive.

The variation in properties, obtainable through heat treatment, precludes establishment of guaranteed minimum data before the maximum and minimum possible cooling rates can be firmly stated. Then each property should be checked after the most adverse heat treatment; for example, high-temperature ductility would be based on the most rapid cooling, while strength would be associated with the lowest cooling rate.

**Note:**

Requests for further information may be directed to:

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No patent action is contemplated by NASA.

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