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Quarterly Technical Progress Report
INVESTIGATION OF
THERMAL-STRESS-FATIGUE BEHAVIOR
OF STAINLESS STEELS

ATL Job 4287

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STATEMENT OF PROBLEM

The thermal-stress-fatigue behavior of reactor materials, in particular stainless steels, cannot be predicted by extrapolation of known data such as conventional fatigue data. Because thermal fatigue may be a major consideration in reactor core and vessel design, suitable engineering data are needed. The objective of this program is to obtain thermal-stress-fatigue data on various types of stainless steels for the conditions that may be encountered in reactor operation and if possible to separate the effects of the various environmental and metallurgical variables. The isolation of variables should allow a theoretical treatment of data that would eventually lead to the formalization of generalized equations for predicting thermal-stress-fatigue life for any reactor conditions.

SUMMARY OF PROGRESS TO DATE

1. The three ATL thermal-stress-cycling machines are being reconditioned and slightly reworked to improve their performance characteristics. Similar work is also being done on the two ATL strain-cycling machines.

2. The control and recording capabilities of the equipment are being upgraded by both the addition of new electronic equipment and the modification of the existing experimental setup. This work not only will allow more economical operation during the testing program, but also should reduce the scatter in data, thus increasing the data accuracy.

3. Equipment is being ordered to build a new thermal-stress-fatigue tester. This new machine will be a refined version of the existing testers with greater versatility in allowable experimental procedures.

4. At a meeting with the San Francisco Operations Office of the AEC, the decision was made to test austenitic, Type 304-L stainless steel first, followed by ferritic and martensitic stainless steels later in the program. A brief outline of the variables to be investigated and the proposed testing program was submitted by ATL and tentatively approved (see Appendix). The primary reason for this detailed outline is the desire to separate the effects of individual variables.

5. A preliminary testing program is underway to compare the behavior of test specimens fabricated from tube and bar stock. The results obtained for specimens machined from bar stock may not be comparable to those for tube-stock specimens. Austenitic, Type

304-L stainless steel has been obtained in both cold-drawn tube form and in cold-forged bar form. Hardness and tensile testing, as well as metallographic examination, is in progress.

This preliminary program is based on the following considerations:

- a) The starting material will be all of one form and from one heat; hence, it will be ordered in one lump amount.
- b) Bar stock material will enable a greater variety in test variables, such as specimen size.
- c) Fabrication cost of test specimens is essentially the same with either tube or bar stock.
- d) The primary interest of the AEC appears to be in tube material.

PROGRESS JANUARY-MARCH 1962

Work was initiated on this program on 1 March 1962; therefore progress during this quarter is reported under "Summary of Progress to Date. "

CONCLUSIONS

The preparatory work in progress will result in a highly specialized experimental laboratory for studying thermal-stress fatigue. The preliminary experimentation underway will ensure that the data obtained are as meaningful as possible in terms of the objectives of this program.

PLANS FOR FUTURE WORK

The order for the required amount of Type 304-L stainless steel will be placed in the near future. Actual experimentation should start during the next quarter if steel in the form ordered is available.

PRINCIPAL INVESTIGATORS

Investigators on the project include: R. S. Stewart, Section Supervisor; K. E. Horton, Metallurgist and Project Leader.

APPENDIX

VARIABLES TO BE INVESTIGATED

The investigation of the thermal-stress-fatigue variables listed below is believed necessary because: 1) data obtained should provide a thorough explanation of thermal-stress-fatigue theory, and 2) such data should be applicable to actual design conditions and, hence, be useful as "handbook" data.

Structure-Sensitive Variables

1. Sensitization.
2. Grain size.
3. Degree of cold work.

Structure-Insensitive Variables

1. Strain rate.
2. Hold time.
3. Atmosphere.
4. Specimen size
5. Temperature
6. Loading factors (e.g.,
prestraining, reverse
loading).
7. Stress-corrosion cracking.

The "Proposed Testing Program" outlined on the following page is designed to allow investigation of all of the listed variables and to establish their interdependence. An accurate prediction of the time necessary to perform this experimental program is not possible; however, the detail of the investigation will be a function of available time and all data points indicated may not be involved. A reduction in the number of data points is possible without a reduction in the number of variables to be investigated.

PROPOSED TESTING PROGRAM

DESCRIPTION OF TESTS
(Experimental Temperatures, Temperature Changes, and Strains)

Thermal-Stress Fatigue

	$T_e^* = 400$		$T_e = 500$		$T_e = 600$
ΔT	$T_2 - T_1$	ΔT	$T_2 - T_1$	ΔT	$T_2 - T_1$
200	500-300	200	600-400	200	700-500
300	550-250	400	700-300	400	800-400
400	600-200	600	800-200	500	850-350
600	700-100	800	900-100	600	900-300

$$* T_e = \frac{T_2 + T_1}{2}$$

Strain-Cycle Fatigue
at Constant Temperature

Temperature of Tests	Strain ($=\alpha\Delta T$)		
	$\Delta T = 400$	$\Delta T = 600$	$\Delta T = 800$
400	X	X	
500		X	X
600	X	X	

Note: All temperatures in $^{\circ}\text{C}$.

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