Letters to the Editors

Hydrogen Movement in Zircaloy-2 Under Thermal Gradients

It is well known that under thermal gradients, hydrogen migrates in zirconium alloys toward the cool side; in fact, the movement can be predicted, using fairly well-developed thermodynamic equations (*1*, *2*, *3*). On the other hand, however, the mechanism by which the migration takes place is not known, except that it involves an interstitial or a vacancy type diffusion path.

The purpose of our experimental investigation was to study the fundamental characteristics of the hydrogen migration and its effects on the mechanical properties of the zircaloy-2 tubing. Known amounts of hydrogen were introduced into zircaloy-2 tubing (0.5 i.d., 28 in. long, 0.030-in. wall thickness open at both ends) by means of autoclaving at 850°F for 2, 5, and 6 days in 1000 psi steam.

It is possible to estimate the hydrogen content of a given specimen by metallographic examination; hydrogen analysis was performed using the hot extraction technique. Once a relationship was obtained, metallographic observations were used exclusively to study hydrogen migration in zircaloy-2.

To obtain a temperature gradient across the tubing wall, a special out-of-pile boiling water loop was used. The tubing was insulated from an electrically heated inner rod, transferring enough heat through the specimen to produce 5% quality steam at 546°F, 1000 psi. The heat flux was held at approximately 250,000 Btu/ft^2-hr with a calculated ΔT across the tubing sheath of 80°F. Time of loop exposures ranged from 154 to 1600 hr, and hydrogen migration was observed in all cases but to a lesser degree at the shorter times. This is consistent with theoretical prediction (*1*, *4*). The difference in degree of hydrogen redistribution in samples tested for 600 and 1600 hr is very small. The results of a 600-hr test are shown in Figs. 1, 2, and 3. Figure 4 shows a transverse cross section of tubing, tested for 1600 hr under thermal gradient. It appears that the hydride platelets tend to orient along specific paths in the tubing, the platelets being parallel to the extrusion direction and at angles to the walls of the tubing. The transverse ductility of hydride-redistributed samples is reduced appreciably, up to 250°F, and with as little hydrogen content as 60 ppm.

Fig. 1. Tubing cross section (reference sample) showing little hydrogen content, less than 20 ppm. Tubing in "as received" not intentionally hydrided, but containing some hydrogen initially (150 ×).

Complete results on mechanical properties of hydrided

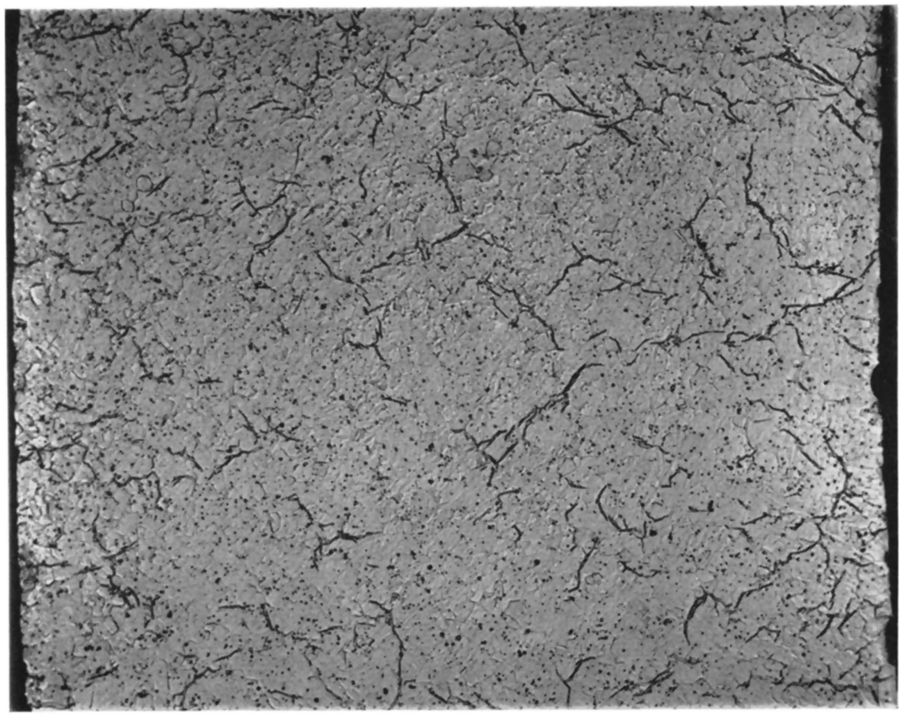

FIG. 2. Tubing cross section showing uniformly distributed hydrides in an intentionally hydrided reference sample. Hydrogen, 140 ppm, was introduced in an autoclave at 850°F steam, 1000 psi, 2 days. Sample sectioned after hydriding with no further testing (150 ×).

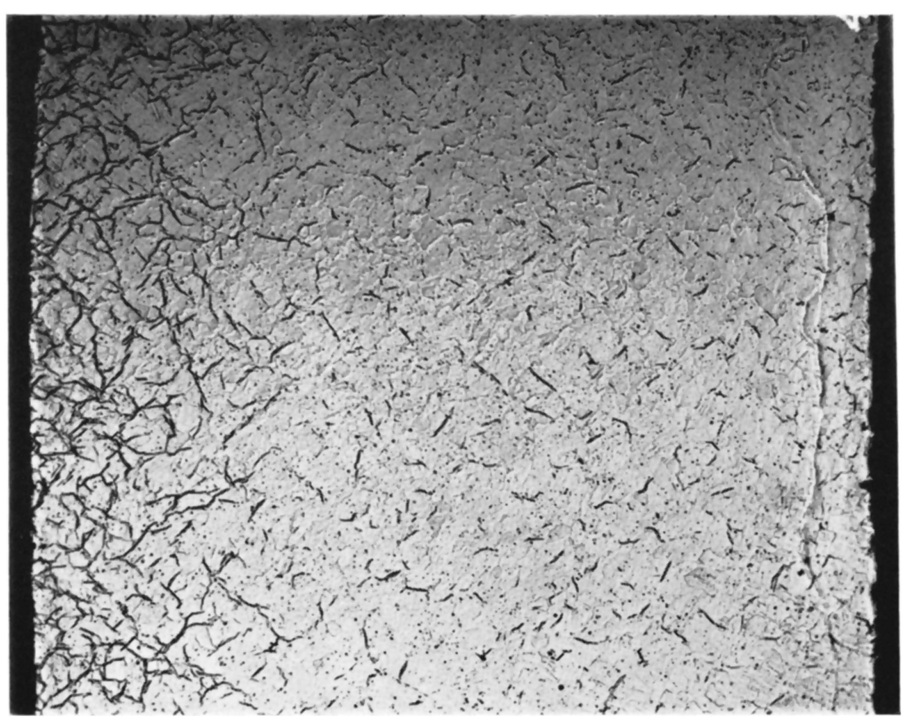

FIG. 3. Tubing cross section of intentionally hydrided reference sample with redistributed hydride after 600 testing (thermal gradient 80°F) (150 ×).

FIG. 4. Tubing cross section of intentionally hydrided reference sample, showing hydride redistribution which occurred under thermal gradient, after 1600 hr of testing. The uniform hydrogen content before redistribution was 140 ppm (150 ×).

ziracaloy-2 tubing and that containing hydrogen concentration gradients (such as that in Fig. 3) will be reported at a later date.

REFERENCES

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Breeding Potential of Thermal Reactors

The breeding potential of thermal reactors was recently reviewed by Chernick and Moore (*1*). A number of the statements made in this review concerning the depletion of uranium reserves, the need for breeder reactors, and the breeding potentialities of certain reactor systems are open to question and should not be left unchallenged.

One of the principal arguments usually advanced in discussions concerning the necessity for developing breeder reactor systems may be referred to as the conservation argument. Essentially, this argument states that unless breeders are developed, economically recoverable reserves of uranium ore are insufficient to significantly extend U. S. energy resources. The key to the validity of such an argument lies in part in the definition of the term "eco-