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SECTOR THIN WEB SPECIMEN THERMAL SHOCK TESTS
(EML-15)
(Title Unclassified)

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Astronuclear Laboratory
Westinghouse Electric Corporation

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BACKGROUND

High thermal stresses were predicted for the outer reflector sector during startup. The thin webs at the control drum cavity are cooled on both their inner and outer surfaces by the cryogenic gas flow entering the reactor. The heavy section of the sector remains close to room temperature for a number of seconds and restrains the thin webs from thermally shortening in the direction of the sector. The result of this condition is an axial tensile strain in the thin webs. Under certain reactor startup conditions, such as a liquid hydrogen ramp, it is estimated that a ΔT greater than 210°F between the bulk of the sector and the thin webs can be attained. This ΔT would produce a strain higher than 0.062%, which is the approximate elastic strain for the sector material. Since beryllium is commonly reported to have no ductility at low temperatures, a number of tests were run on a small specimen of beryllium, shown in Figure 1, to bracket the ductility of the sector material at operating temperatures.

PROCEDURE

The specimen was subjected to three thermal shock tests with cold helium gas in the test rig shown in Figure 2. Thermocouples were attached to the specimen, as shown in Figures 3 and 4, and connected to a continuous recorder using light beam galvanometers. The time constant for these temperature measurements was estimated to be about 0.27 sec. To run the test, the system was pressurized with the specimen door latch closed (see Figure 2). The heat exchanger was filled with liquid nitrogen and some cold test gas was bled off at the bleed valve just upstream of the specimen to chill all of the delivery piping. The trapped gas in the specimen remained at room temperature due to the specific heat of the specimen and the holding blocks. The specimen door latch was then tripped and the pressure control valve acted to maintain the preset delivery pressure regardless of flow rate (see Figure 5). The pressure at the specimen was recorded and found

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to be approximately constant at 840 psi. The flow temperature reached 225°R in 0.025 sec and 140°R in 1.0 sec. The flow shutoff valve was closed after about 15 sec.

RESULTS

In the first test, the specimen tested had a 0.040 in. thick web. Fracture did not occur. The maximum indicated ΔT for this test was 220°R, occurring one second after the start of flow. The direct thermocouple measurements showed the outside of the thin web to be at 305°R and the body of the specimen to be at about 525°R. This gave an approximate web strain of 0.113%. When the thermocouples were corrected for their time lag, thick section and web temperatures of 532 and 300°R, respectively, were obtained, and an approximate thermal strain of 0.119% was calculated. The strain at the yield point of this piece of material is about 0.089% at 300°R, and therefore the condition that existed in the specimen (assuming no work hardening) was an elastic strain of 0.089% and a plastic strain of about 0.030%. It is seen that far less than 0.20% ductility was needed to resist fracture.

In the second test, the first test specimen was used with webs remachined to a 0.030 in. thickness; again no fracture occurred. In this case, the corrected thick section and web temperatures were 533 and 265°R, respectively, and the calculated approximate total strain was 0.129%. The plastic strain was about 0.040%.

The third test was conducted with the same test specimen used in the second test. In this case, the specimen was preheated to about 710°R before the specimen door latch was tripped. Post-test inspection revealed four transverse cracks in each web, spaced 1.3 in. apart (see Figure 6). Metallographic sections showed the cracks to go through the material grains (see Figure 7) and pass completely through both webs and end about 1/8 in. deep into the thick sides of the specimen. The corrected thick section and web temperatures were 700 and 310°R, respectively, and the calculated approximate total strain was 0.250%. The plastic strain was about 0.161%.

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The approximate strains in the above results agree closely with the more precise values obtained from computer calculations in which temperature variations throughout the specimens were considered, reported in TME-817 and TME-858.

CONCLUSIONS

These tests have shown that at about 300°R the specimen tested had a ductility greater than 0.040% and an unknown amount less than 0.161%; and therefore, was able to accommodate a thermal strain equivalent to an elastic thermal stress higher than about 58,800 psi, 19,600 psi in excess of the yield strength of the material. It should be noted that the preheated case test was much more severe than the tests starting at room temperature, requiring about four times as much ductility to resist fracture. This is due in part to a rapid increase in the coefficient of expansion of beryllium above room temperature.

RECOMMENDATIONS

Although plastic strains have been demonstrated for beryllium at cryogenic temperatures, it is felt that the data that has been obtained is very limited and should be augmented in order to better understand the capability of the sector to resist thermal strains. Another consideration in recommending additional testing is that higher thermal stresses than those experienced in the cold flow tests could occur in future reactor tests either at the beginning of prechill or during restart.

The additional testing required should be performed with a full sector, rather than small specimens, because this would permit the effects of the actual reflector sector geometry to be investigated under closely simulated reactor operating conditions.

THIN WEB THERMAL SHOCK SPECIMEN BEFORE TESTING

FIGURE 1

THERMAL SHOCK TEST SYSTEM

FIGURE 2

THIN WEB THERMAL SHOCK SPECIMEN
AFTER TESTING SHOWING THERMOCOUPLES INSTALLED

FIGURE 3

Thermocouple Locations - •

SECTION A-A
(Full Size)

FIGURE 4 REFLECTOR SECTOR THIN WEB THERMAL SHOCK SPECIMEN

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THERMAL SHOCK TEST IN PROGRESS

FIGURE 5

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THIN WEB THERMAL SHOCK SPECIMEN
SHOWING DYE PENETRANT CRACK INDICATIONS

FIGURE 6

SECTION TAKEN NORMAL TO PLANE OF CRACK
(200X)

FIGURE 7