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Outline

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COMPARISONS OF HIGH-TEMPERATURE STRUCTURAL TEST RESULTS WITH INELASTIC ANALYSIS PREDICTIONS BASED ON INTERIM CONSTITUTIVE EQUATIONS FOR LIQUID-METAL FAST BREEDER REACTOR SYSTEM COMPONENTS*

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I. INTRODUCTION - ROLE OF STRUCTURAL TESTS IN HIGH-TEMPERATURE STRUCTURAL DESIGN METHODS DEVELOPMENT

- A. Schematic Representation of Coordinated Effort to Develop and Evaluate Inelastic Analysis Methods SLIDE 1
- B. Ten Types of Structures Planned for Testing in the LMFBF Base Technology Programs SLIDE 2

II. BRIEF OVERVIEW OF SIX TYPES OF STRUCTURAL TESTING CURRENTLY BEING UNDERTAKEN IN ORNL PROGRAM

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- B. Simply-Supported Circular Plates
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- D. Finite-Width Plate with Circular Hole - Moire Strain Analysis, Catholic University
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*Research sponsored by the U.S. Atomic Energy Commission under contract with the Union Carbide Corporation.

F. Pipe Thermal Ratchetting Tests

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III. PRESENTATION OF TYPICAL EARLY TEST RESULTS AND COMPARISONS WITH INELASTIC ANALYSIS PREDICTIONS

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5. Comparison of measured and predicted creep deflections
vs time for circular plate

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IV. CONCLUSIONS

The limited results presented indicate that currently recommended constitutive equations can be used to predict, reasonably well, the basic features of simple high-temperature inelastic behavior.

Coordinated Effort to Develop and Evaluate Analytical Methods.

(1) SIMPLY-SUPPORTED BEAMS

(2) SIMPLY-SUPPORTED FLAT CIRCULAR PLATES

(3) CAPPED CIRCULAR-CYLINDRICAL SHELLS

(4) FINITE-WIDTH FLAT PLATE WITH CIRCULAR HOLE

(5) STIFFENED SHEAR LAG PANEL

(6) PIPE THERMAL RATCHETTING

(7) PIPING ELBOWS (WITH INTERNAL PRESSURE)

(8) NOZZLE ATTACHMENT THERMAL RATCHETTING (WITH INTERNAL PRESSURE)

(9) NOZZLE-TO-SPHERE ATTACHMENTS

(10) INTERSECTING CYLINDRICAL SHELLS (WITH INTERNAL PRESSURE)

DOUBLE ACTING SERVO-CONTROLLED
5000-lb HYDRAULIC RAM FOR CYCLIC LOADINGS

ORNL-DWG 72-2584AR

Photo 79316

SLIDE 4

Photo 4601-72

SLIDE 6

Photo 46 02-72

SLIDE 7

Photo 79322

SLIDE 8

$\sigma_{aN} = 12,500$ psi
 $\sigma_{aG} = 9821$ psi
 NET FORCE = 34,375 lb
 $\sigma_{max} = 2.43 \sigma_{aN} = 30,375$ psi*

*BASED ON ELASTIC BEHAVIOR
 (SEE FIG 9.15 OF DURELLI,
 PHILLIPS, AND TSAO)

(a) TEST SPECIMEN

ORNL-DWG 72-12417
 TEST TEMPERATURE 1100 °F

(b) LOADING HISTORY

Elevated-Temperature Moire Strain Analysis of Plate
 (In-Plane Loaded Finite-Width Plate with Circular Hole)

DIMENSIONS IN INCHES

(a) TEST SPECIMEN

(b) LOADING HISTORY

Elevated-Temperature Shear-Lag Specimen Test
(Thin Square Plate with In-Plane Loading Through Tapered Stiffeners)

Photo 4537-72

SLIDE 11

8.44 in. OD x 0.375 in. WALL

NORMAL SODIUM
CONDITIONS: 1100 °F, 700 psi

(a) TEST SPECIMEN

(b) TEMPERATURE-PRESSURE HISTOGRAMS

(c) PREDICTED RATCHETTING BEHAVIOR

Pipe Thermal Ratchetting Tests

ORNL-DWG 72-8481

SLIDE 13

Photo 4.536-72

SLIDE 14

(d) TEST SPECIMEN

BEAM TEST B3

BEAM TEST B4

(b) LOADING HISTORIES

Elevated-Temperature Beam Tests.

FINITE ELEMENT IDEALIZATION
832 ELEMENTS
477 NODES

Elastic-Plastic-Creep
Beam Test Specimen

TYPE 304 STAINLESS STEEL, ANNEALED (HEAT 8043813)

ROOM TEMPERATURE

STRAIN RATE 0.005/min

STRAIN RANGE $\approx 0.9\%$

ORNL-DWG 72-12208

TYPE 304 STAINLESS STEEL, ANNEALED (HEAT 8043813)

ROOM TEMPERATURE

STRAIN RATE 0.005/min

STRAIN RANGE $\approx 0.9\%$

2

SLIDE 17

BEAM B2, FIRST CYCLE
ANALYSIS BASED ON ACP 0.9%
ROOM TEMPERATURE

TYPE 304 STAINLESS STEEL, ANNEALED (8043813)
 TEMPERATURE: 1200°F
 STRAIN RATE: 0.005/min

TYPE 304 STAINLESS STEEL, ANNEALED (HEAT 8043813)
TEMPERATURE 1200°F

BEAM B3
1200°F

BEAM EA, 1200" FIRST CYCLE

LOAD, P (k)

CENTER DEFLECTION (in)

2

FINITE ELEMENT IDEALIZATION
784 ELEMENTS
464 NODES

Elastic-Plastic-Creep

FINITE ELEMENT IDEALIZATION
784 ELEMENTS
464 NODES

Elastic-Plastic-Creep
Circular Plate Test Specimen

2

SLIDE 25

TYPE 304 STAINLESS STEEL, ANNEALED (HEAT 9T2796)

TEMPERATURE 1100°F

STRAIN RATE 0.005/min

STRAIN RATE 0.4%

TYPE 304 STAINLESS STEEL, ANNEALED (HEAT 972796)
TEMPERATURE 1100°F

EXPERIMENTAL DATA

CREEP LAW
 $\epsilon = r(t) e^{K_1 t} + K_2 t$

$C = 1.0$
 $A(t) = 6.59 \times 10^{-4} e^{0.044 t}$
 $r(t) = 7.03 \times 10^{-4}$ exp (0.11070)
 $K(t) = 6.73 \times 10^{-7}$ [sinh (0.1486)]^{3.0}

$C = 17.5 \text{ ksi}$

$C = 15 \text{ ksi}$

$C = 12.5 \text{ ksi}$

$C = 10 \text{ ksi}$

$C = 7.5 \text{ ksi}$

SLIDE 27

PLATE QP1, 1100°F
INITIAL LOADING

K&E 10 X 10 TO THE INCH 46 0782
 7 X 10 INCHES
 MADE IN U.S.A.
 KRUPP & ESSER CO.

DEFLECTION (.001 IN)

ORNL DWG 72-12839

TE CPl, 1100°F
SECTION 3.33 IN. FROM CENTER

P-302516

2

Time (sec)

SLIDE 29