From: "Paul T. Williams" <williamspt@ornl.gov>
To: <RLT@nrc.gov>
Date: 10/18/02 9:01AM
Subject: DB Analysis Status report for October 18, 2002

Rob:

Attached is a brief status report for the week ending October 18, 2002, on the Task 9.1 stress analysis of the Davis-Besse problem.

I'm still working on Task 9.1D and have completed six of the nine models in the Case matrix. (see Table 1 in the status report) I hope to have all nine models finished by the end of next week.

I've developed these flaw models in such a way that they could also be applied to the Case matrices needed for other subtasks in Task 9.1.

Please let me know if you have any questions regarding this material.

Thanks

Paul

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CC: mark Kirk <MTK@nrc.gov>, <NCC1@nrc.gov>, <bassbr@ornl.gov>, <williamspt@ornl.gov>

H-17

From: Robert Tregoning RES
To: Jeannette Torres
Date: 11/27/02 8:28AM
Subject: Fwd: DB Analysis Status report for October 18, 2002

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M_E_M_O

DATE: 18 October 2002

TO: M. T. Kirk and Robert Tregoning

FROM: P. T. Williams and B. R. Bass

SUBJECT: Status Report on Davis-Besse Analyses

The attached Figs. 1-6 provide a summary of the Davis-Besse analyses performed to date under the new Task 9 of JCN Y6533. In Fig. 1, the cladding properties used in the current study are presented: (a) true stress versus true strain and (b) thermal expansion coefficient versus temperature. The remaining figures address a specific sub-task described in the workscope for Task 9.

Sub-task 9.1D requires an estimate for crack driving forces as a function of flaw size and applied membrane stress in cladding. Table 1 shows the Case Matrix developed for this subtask.

Figure 2 depicts the first step carried out in preparation for the *J*-integral analyses, i.e., calculation of an updated estimate of the exposed cladding "footprint" based on the recent "dental mold" cast from the D-B cavity. That footprint area was estimated to be 28.23 in^2. Comparisons of the latest "footprint" statistics with previous ORNL interpretations are given in the table of Fig. 2(b). The newly calculated "footprint" area was used to define a burst disk having the same cross-sectional area.

Table 2 presents ductile tearing data for three-wire series-arc stainless steel weld overlay cladding published in NUREG/CR-5511 [1]. The ductile-tearing data presented in Table 2 are plotted as a function of temperature in Fig. 3.

Figure 4 presents six finite-element models developed so far for this phase of the analysis. Surface-breaking flaws were centrally located in each burst disk with the three relative flaw depths: $a/t = 0.5$, 0.25, and 0.05. The models for two flaw lengths of 2.0 inches (50.8 mm) and 1.0 inch (25.4 mm) have been developed to date. The remaining three models in the case matrix of Table 1 will apply a flaw length of 3/8 in. (9.525 mm)

Each models were loaded with an increasing lateral pressure. The resulting *J*-integral loading paths for these six models are shown in Fig. 5. Figure 5 also presents a value of J_{Ic} for a temperature of 318.3 °C (605 °F) estimated by extrapolating from the data in Fig. 3a using a 4th order polynomial curve-fit.

Figure 6 compares the critical pressures (determined from the results shown in Fig. 5) for two potential failure modes of the burst-disk models. The ductile-tearing critical pressure is calculated from the point at which the load path for each flaw crosses the J_{Ic} line in Fig. 5 and represents the pressure at which stable ductile tearing initiates. The plastic-collapse critical pressure was estimated from the load at which each model began to approach a numerical instability in the analysis. From the curves in Fig. 6, the controlling failure mode for the two larger flaws in the current study was ductile tearing. The shallow flaw ($a/t = 0.05$) was close to the J_{Ic} line when it began to fail by plastic collapse. Decreasing the flaw length produces a slight increase in the ductile-tearing critical pressure.

Estimates of the applied tearing modulus shown in Fig. 3b were calculated using the data (see Fig. 5) from the three flaws with $2L = 2.0$ in. at a pressure of 6.4 MPa (0.928 ksi) and the three flaws with $2L = 1.0$ in. at a pressure of 8.2 MPa (1.19 ksi). As indicated by the comparison in Fig. 3b, this estimate of the applied tearing modulus indicates a *stable* ductile tearing for the larger flaws, thus implying *stable* tearing for the smaller flaws as well.

References

Table 1. Case Matrix for Task 9.1D

Case Number	*a* (inches)	2*L* (inches)	*a/t* (-)	2*L/a* (-)
9.1D1	0.1250	2	0.50	16
9.1D2	0.0625	2	0.25	32
9.1D3	0.0125	2	0.05	160
9.1D4	0.1250	1	0.50	8
9.1D5	0 0625	1	0.25	16
9.1D6	0.0125	1	0.05	80
9.1D7	0.1250	0.375	0.50	3
9.1D8	0.0625	0.375	0.25	6
9.1D9	0.0125	0.375	0 05	30

Table 2. Ductile Tearing Data Extracted from Table 13 of NUREG/CR-5511.

Specimen	Test Temperature (°C)	J_{Ic} (kJ/m^2)	Tearing Modulus
Unirradiated Specimens			
A13G	-75	117	64
H2	-75	137	49
A15B[a]	20	165	270
A13D	20	134	209
A10G	20	171	176
A10E	120	128	246
H5	120	119	229
H3	120	120	232
A13F[a]	120	159	359
H6	200	90	240
H4	200	111	231
A15D	288	77	267
A13C	288	66	170
H1	288	82	192
Irradiated Specimens			
A15F	-75	78	40
A15G	-75	56	36
A13A	30	144	177
A15C	50	124	146
A10F	120	94	175
A15A	288	25	191

[a] Specimen was not side-grooved, while all other specimens in table were side-grooved 20%.

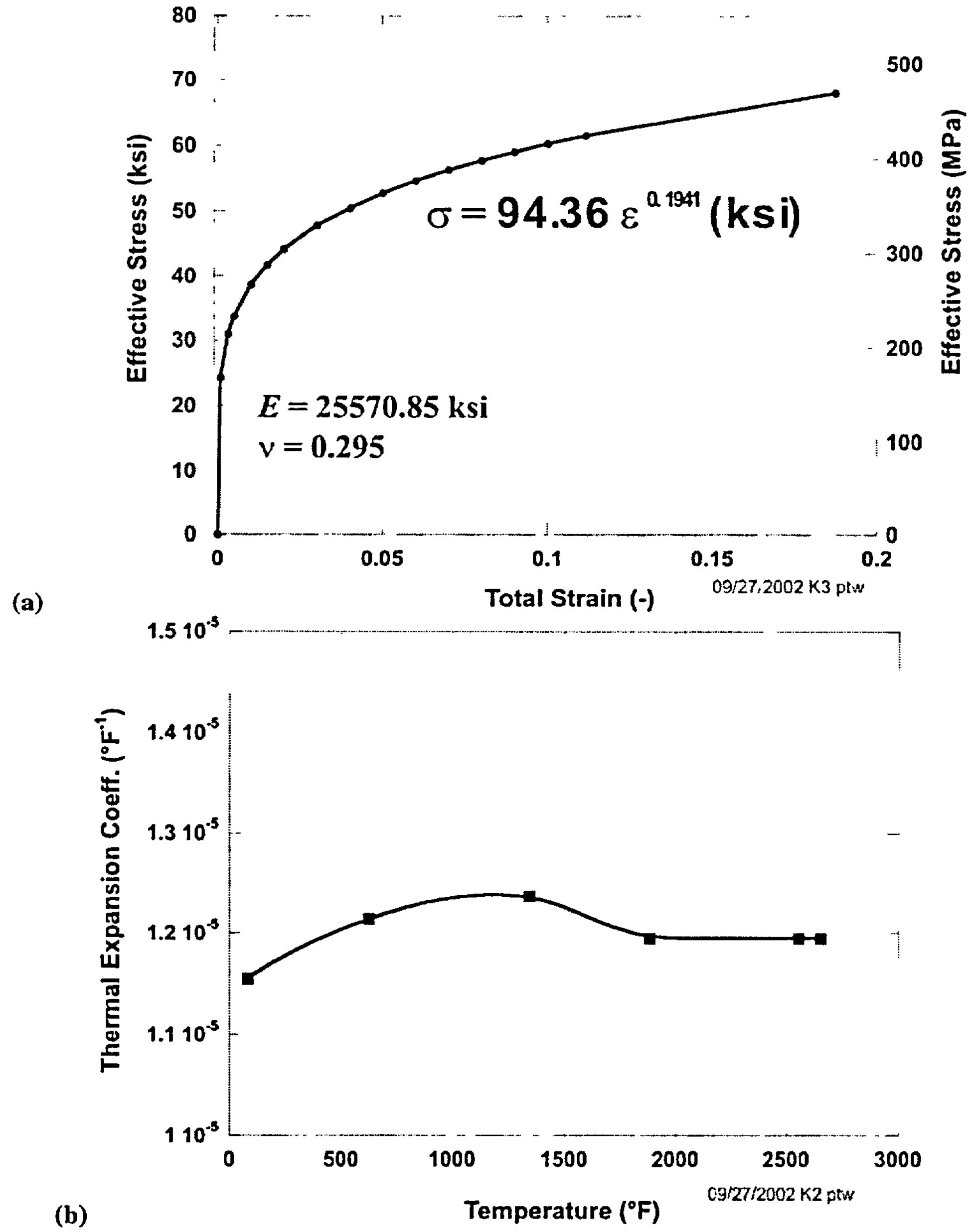
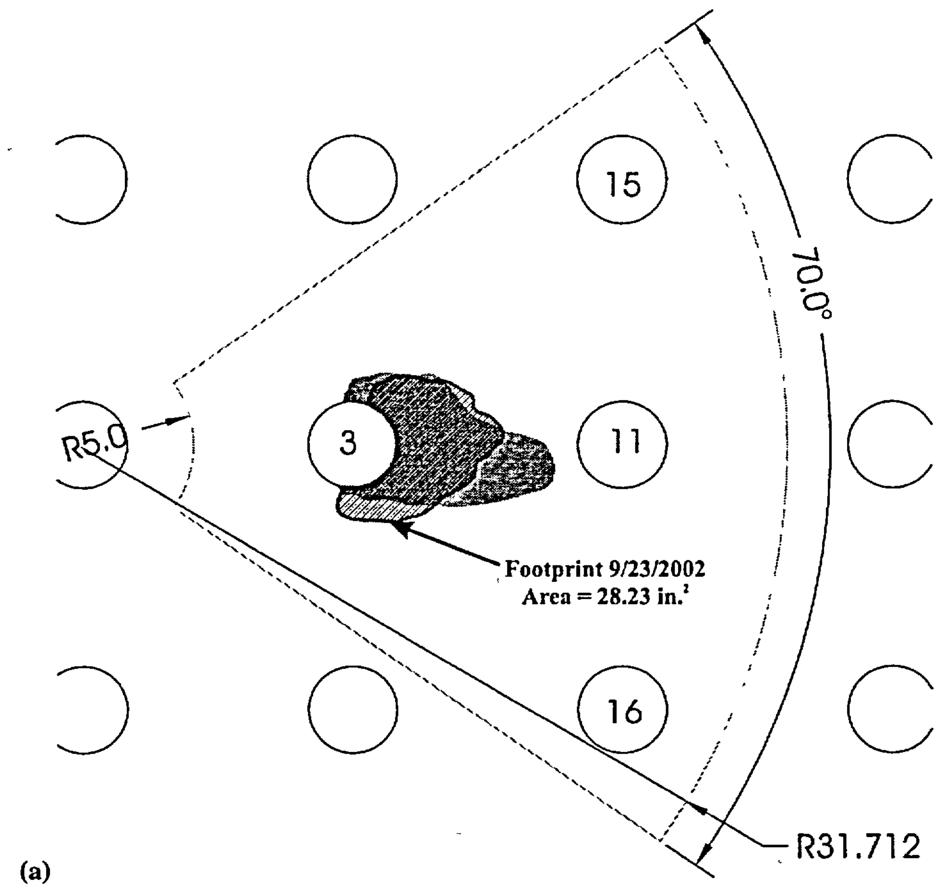


Fig. 1. Cladding properties used in the current study: (a) true stress vs true strain and (b) thermal expansion coefficient.



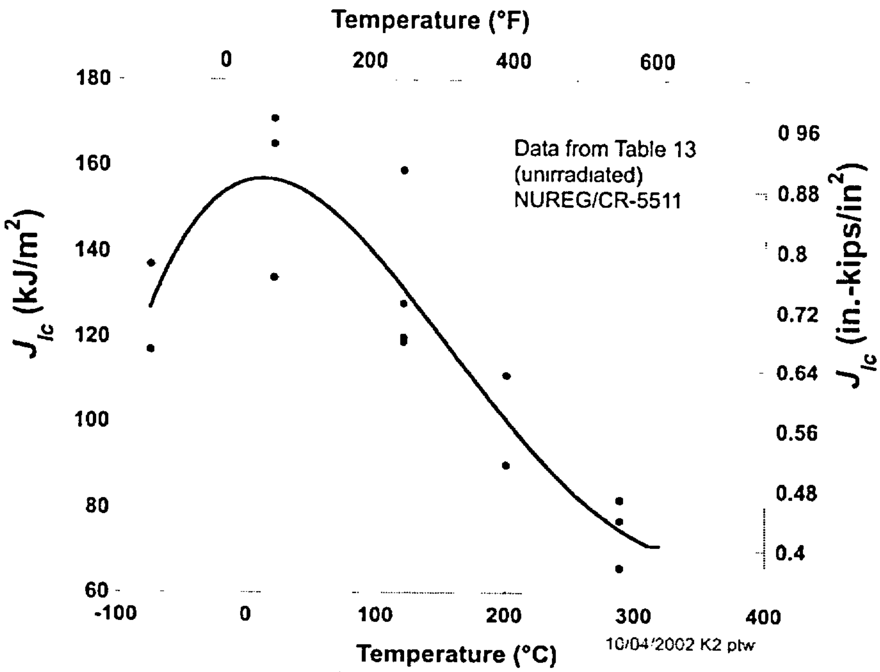
(a)

Description	Scaling Factor	Area (in²)	Perimeter (in.)	Centroid of Wastage Area Footprint x_c (in.)	y_c (in.)	Moments of Interia About the Centroid I_{xx} (in⁴)	I_{yy} (in⁴)	I_{xy} (in⁴)	Eigenvalue Extraction for Prinicipal Moments and Directions: Principal Moments I_1 (in⁴)	I_2 (in⁴)	Principal Directions I_1 <n_x, n_y>	I_2 <n_x, n_y>
As Found Footprint	1	35 36	30.36	16.4122	-0 1194	98.89	9699.33	-117 16	75 26	197 41	<0 9004 -0 4351>	<0 4351, 0 9004>
Adjusted Footprint for Bounding Calculation	0.25 in	40 06	31 78	16 4301	-0 1255	129 02	11031 81	-141 35	99 00	245 71	<0.8943, -0 4476>	<0 4476, 0 8943>
As Found Footprint 9/23/2002	1	28.23	24.55	15.332	-0 18	95 56	6708 63	-50.52	54 01	113 07	[0.558 0.830]	[-0.830 0.558]

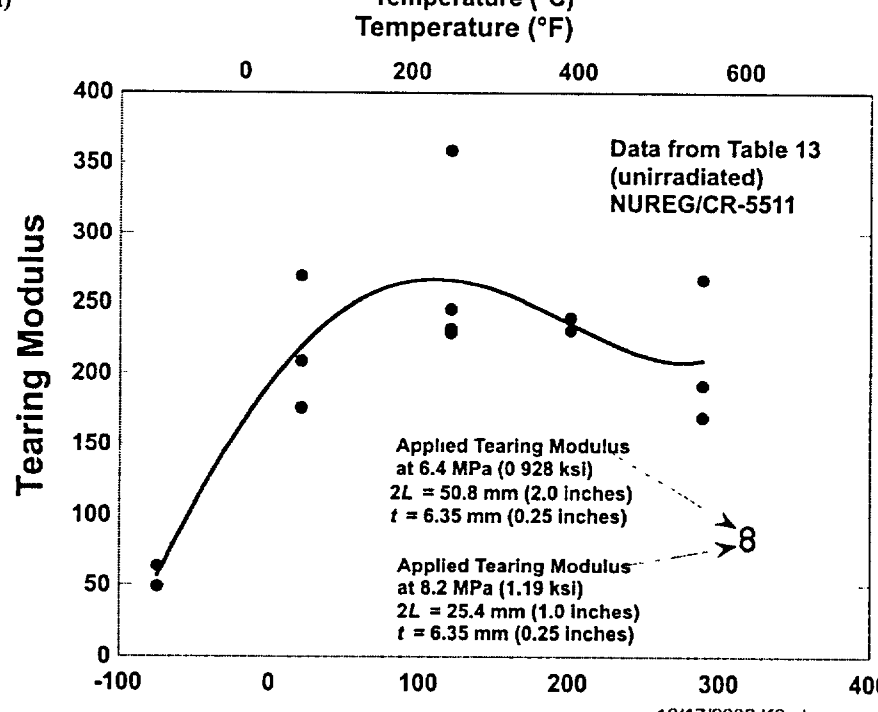
Footprint centroid is in global coordinates
Global coordinate system has its z-axis aligned with the vertical centerline of the vessel.
The x-y plane of the global coordinate system is a horizontal plane
with the x-axis along the line between the centerlines of Nozzles 3 and 11

(b)

Fig. 2. Latest footprint estimated from "dental mold".



(a)



(b)

Fig. 3. Ductile tearing data for three-wire series stainless steel weld overlay cladding from Table 13 of NUREG/CR-5511: (a) J_{Ic} data from unirradiated specimens and (b) tearing modulus data from unirradiated specimens

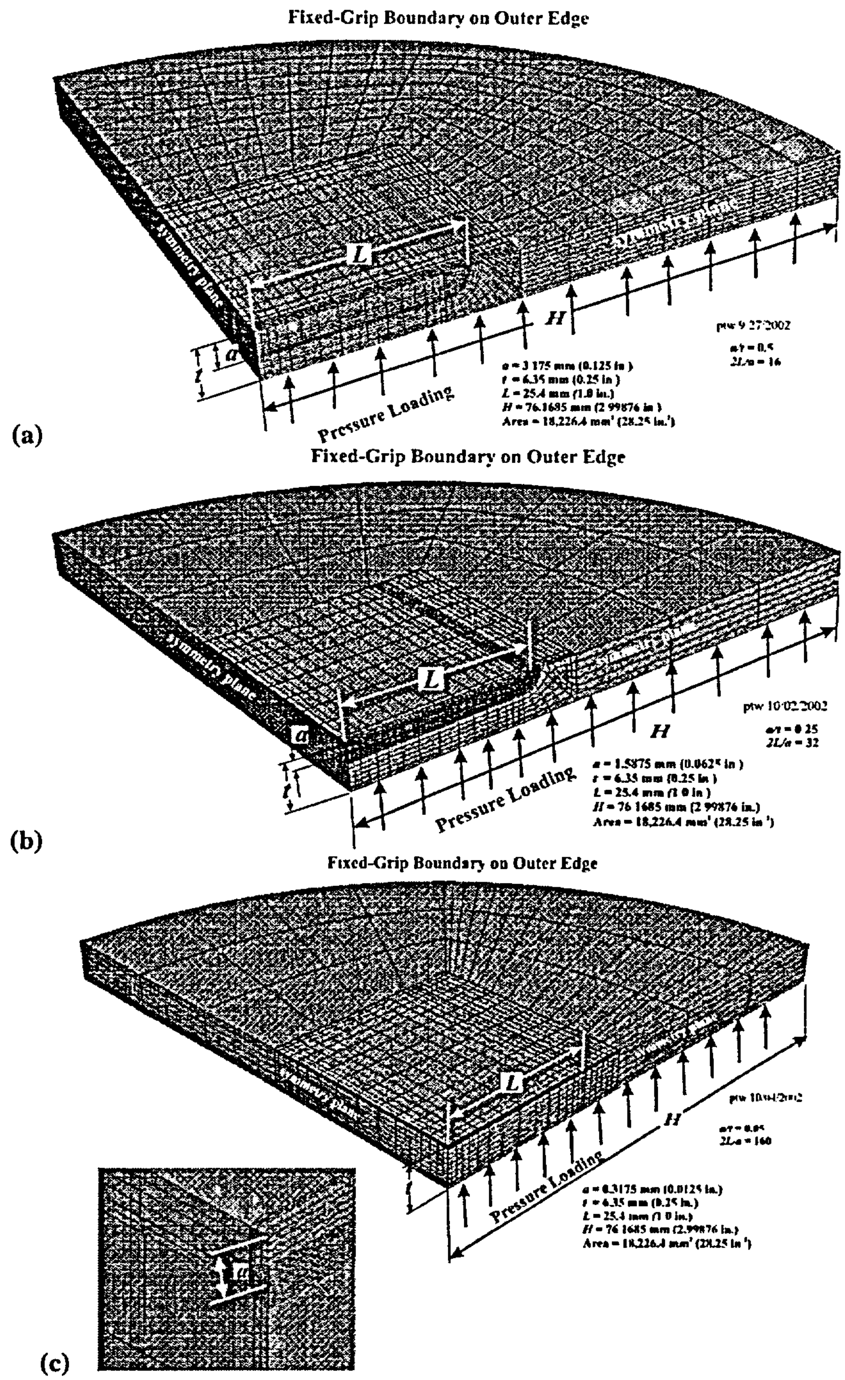
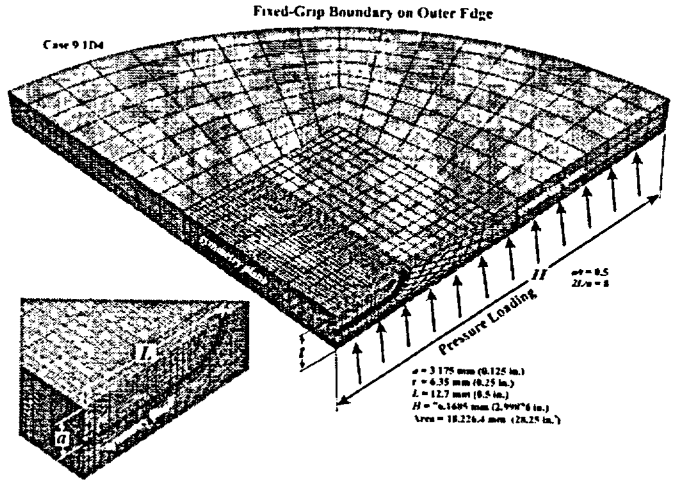
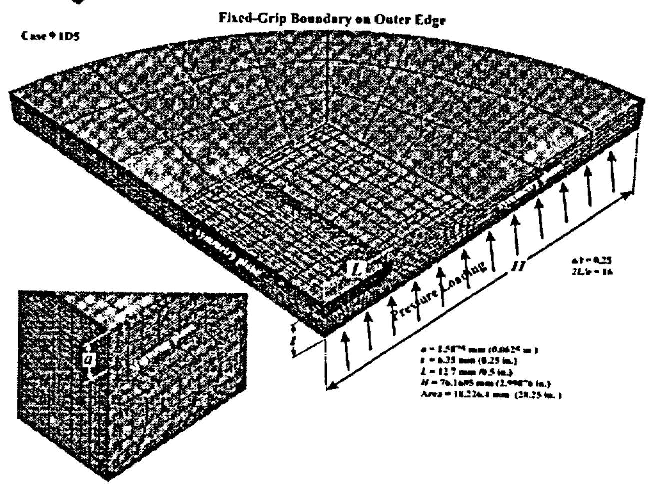


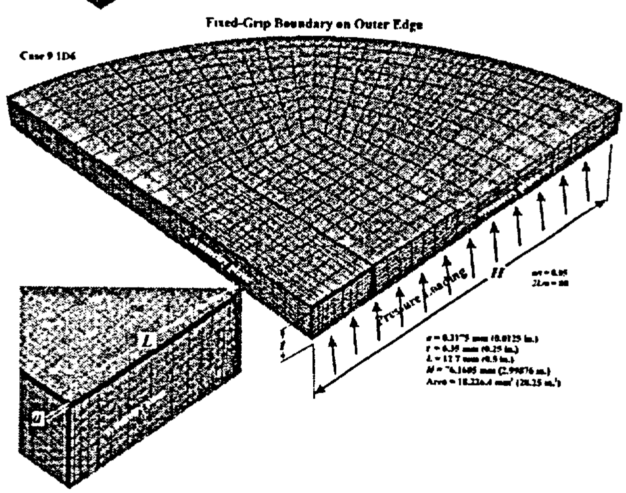
Fig. 4. Finite-element models used in calculating applied *J*-integrals produced by pressure loading of burst disk: (a) Model 9.1D1 ($a/t = 0.5$, $2L/a = 16$) (b) Model 9.1D2 ($a/t = 0.25$, $2L/a = 32$), and (c) Model 9.1D3 ($a/t = 0.05$, $2L/a = 160$) (Task 9.1D)



(d)



(e)



(f)

Fig. 4. (continued) Finite-element models used in calculating applied *J*-integrals produced by pressure loading of burst disk: (d) Model 9.1D4 ($a/t = 0.5$, $2L/a = 8$) (e) Model 9.1D5 ($a/t = 0.25$, $2L/a = 16$), and (f) Model 9.1D6 ($a/t = 0.05$, $2L/a = 80$) (Task 9.1D)

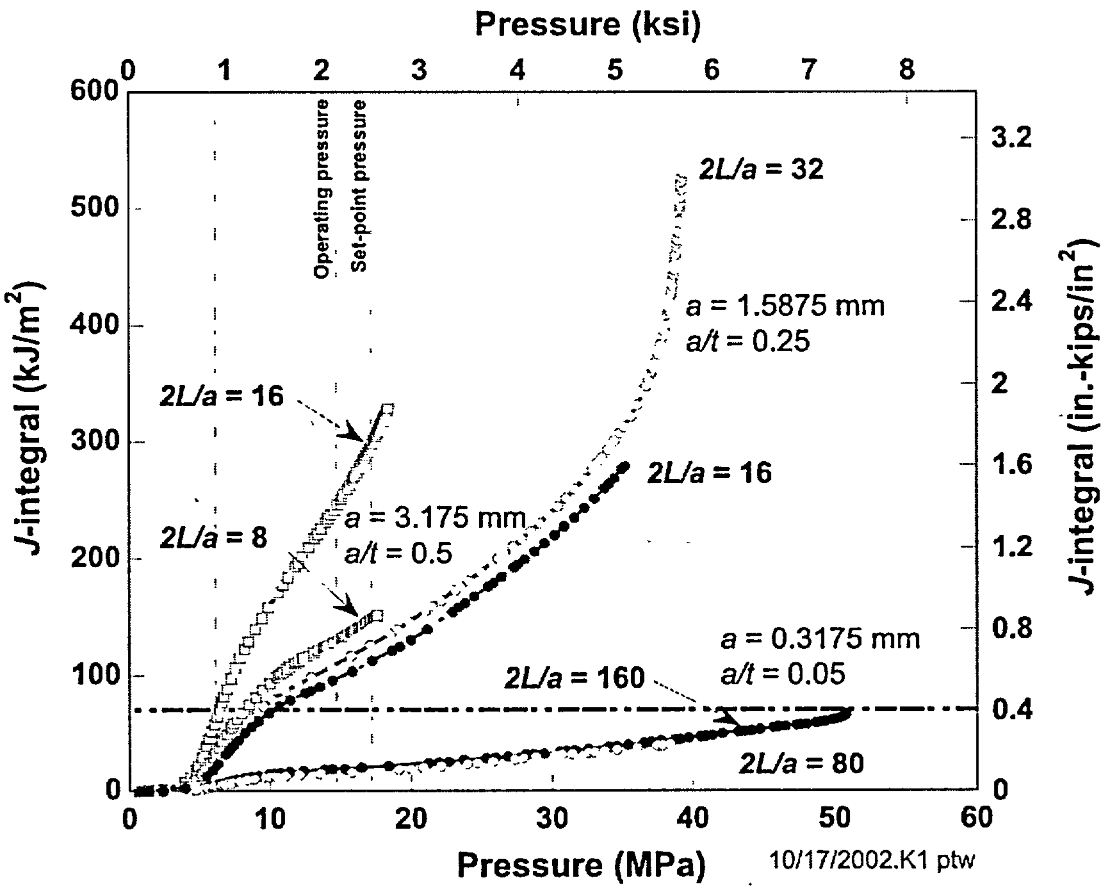


Fig. 5. ***J*-integral driving forces from three finite-element models as a function of applied pressure.**

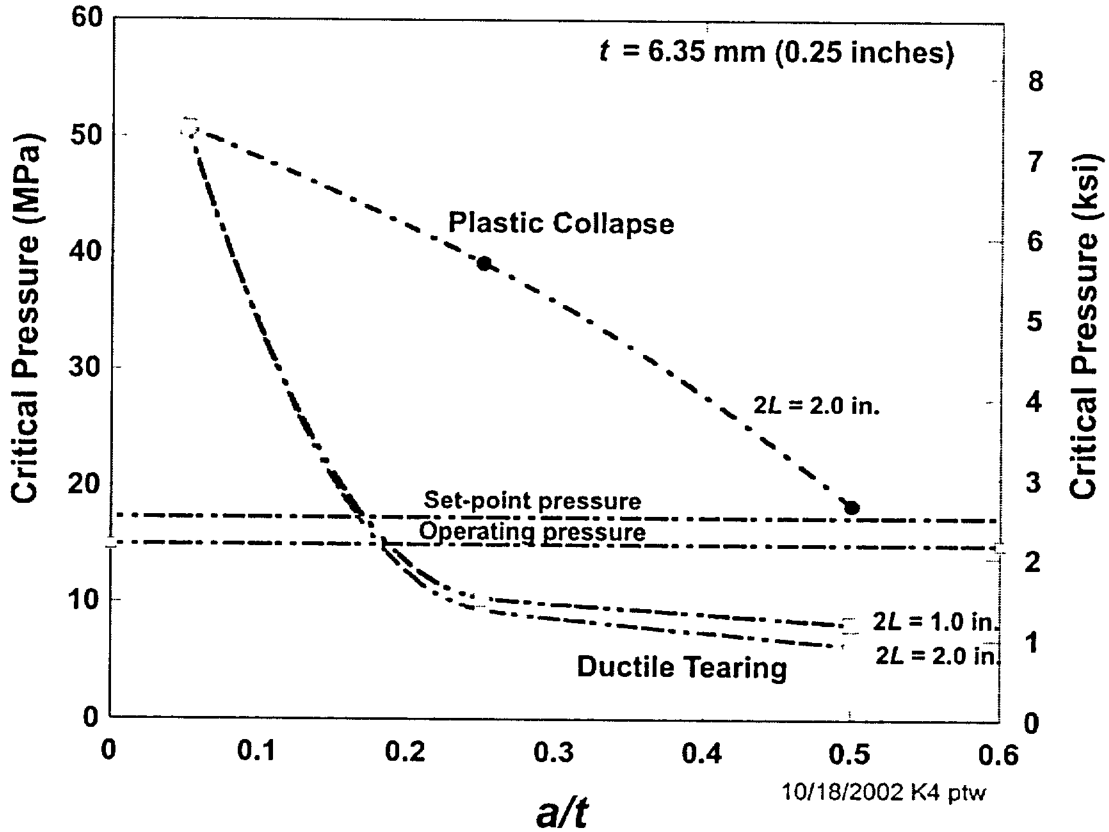


Fig. 6. Comparison of critical pressures for two failure modes as a function of relative flaw depth. Two flaw lengths (2 in. (50.8 mm) and 1 in. (25.4 mm)) were used in the current analysis.

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[1] F. M. Haggag, W. R. Corwin, and R. K. Nanstad, *Irradiation Effects on Strength and Toughness of Three-Wire Series-Arc Stainless Steel Weld Overlay Cladding*, NUREG/CR-5511 (ORNL/TM-11439), Oak Ridge National Laboratory, February 1990.

FORM NIS-2 OWNER'S REPORT FOR REPAIR/REPLACEMENT ACTIVITY

As Required by the Provisions of the ASME Code Section XI

1. Owner (1) Name — Address Date (2) Sheet (3) of

2 Plant (4) Name — Address Unit (5)

(6) Repair/Replacement Organization P.O. No., Job No., etc

3 Work Performed by (7) Name — Address

Type Code Symbol Stamp (8)
Authorization No (9)
Expiration Date (10)

4. Identification of System (11)

5 (a) Applicable Construction Code (12) Edition, Addenda, Code Case
(b) Applicable Edition of Section XI Used for Repair/Replacement Activity 19
(c) Applicable Section XI Code Case(s)

6 Identification of Components

Name of Component	Name of Manufacturer	Manufacturer Serial No	National Board No.	Other Identification	Year Built	Corrected, Removed, or Installed	ASME Code Stamped (Yes or No)
(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)

SAMPLE

7. Description of Work (21)

8. Tests Conducted (22) Hydrostatic ☐ Pneumatic ☐ Nominal Operating Pressure ☐ Exempt ☐
Other ☐ Pressure ____ psi Test Temp ____ °F

NOTE Supplemental sheets in form of lists, sketches, or drawings may be used, provided (1) size is 8½ in. x 11 in., (2) information in Items 1 through 6 on this report is included on each sheet, and (3) each sheet is numbered and the number of sheets is recorded at the top of this form

This Form (E00030) may be obtained from the ASME Order Dept., 22 Law Drive, Box 2300, Fairfield, NJ 07007-2300

FORM NIS-2 (Back)

9. Remarks ______ (23) ______
Applicable Manufacturer's Data Reports to be attached

______

______

______

CERTIFICATE OF COMPLIANCE

I certify that the statements made in the report are correct and that this conforms to the requirements of the ASME Code, Section XI.

Type Code Symbol Stamp ______ (25) ______

Certificate of Authorization No. ______ (26) ______ Expiration Date ______

Signed ______ (27) ______ Date ______, 19 ______
Owner or Owner's Designee, Title

CERTIFICATE OF INSERVICE INSPECTION

I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and the State or Province of ______ (28) ______ and employed by ______ (29) ______ of ______ (30) ______ have inspected the components described in this Owner's Report during the period ______ (31) ______ to ______ (32) ______, and state that to the best of my knowledge and belief, the Owner has performed examinations and taken corrective measures described in this Owner's Report in accordance with the requirements of the ASME Code, Section XI.

By signing this certificate neither the Inspector nor his employer makes any warranty, expressed or implied, concerning the examinations and corrective measures described in this Owner's Report. Furthermore, neither the Inspector nor his employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection.

______ (33) ______ Commissions ______ (34) ______
Inspector's Signature — National Board, State, Province, and Endorsements

Date ______ (35) ______ 19 ______