STP-PT-073

STRESS INTENSITY FACTOR AND K-FACTOR ALIGNMENT FOR METALLIC PIPES

ASME STANDARDS TECHNOLOGY, LLC

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FOREWORD

The purpose of this report is to align stress intensification and flexibility factors for metallic pipes used in ASME's Pressure Piping Codes (B31) and Boiler and Presure Vessel Code (B&PVC) Section III Class 2 and Class 3 Piping. The alignment recommendations are provided with examples along with major features of the aligned and updated equations. Validation is provided by comparison to existing Codes, alternate guidelines and test data in the supporting annexes.

Many people have graciously provided comments and recommendations during the course of this project, including: Ron Haupt, Bill Koves, John Cates WFI, Phil Ellenberger, John Minichiello, Don Edwards and Jim Montague (Conoco Phillips), Chris Hinnant, Peter Vu, Glynn Woods, Brian Holbrook, David Creates, Patrick Marcotte, and Ev Rodabaugh.

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ABSTRACT

This report's objective is to align stress intensification and flexibility factors for metallic pipe used in ASME's Pressure Piping Codes (B31) and Boiler and Presure Vessel Code (B&PVC) Section III Class 2 and Class 3 Piping, hereinafter the "Codes".

The alignment recommendations are given with examples in Annex A in this report. Validation is provided by comparison to existing Codes, alternate guidelines and test data in Annexes C through I in this report. References are included in Annex J in this report.

The steps that were taken to prepare the recommendations are:

- *(a)* Collect and compare test data and equations from different sources
- *(b)* Resolve differences
- *(c)* Develop consistent rules and translate to a single document
- *(d)* Perform verification
- *(e)* Produce examples

The major features of the aligned and updated equations are:

- *(a)* Flexibility factors were added for all branch connection types
  - *(1)* branch connection k-factors are adjusted when flanges are attached to one or both run ends
- *(b)* SIFs were updated to include:
  - *(1)* out-of-plane branch loading due to Schneider effect
  - *(2)* reduction of SIF for run loads where appropriate
  - *(3)* separation of branch and run SIF and flexibility factors
  - *(4)* weld-on fitting SIF correction
  - *(5)* individual development of in-plane, out-plane and torsional SIFs for both run and branch
  - *(6)* EPRI tests conducted after 1996
  - *(7)* clarification of locally thickened branch rules
  - *(8)* guidance for fabricated outer radius (r2) provided
  - *(9)* EPRI Rodabaugh/Wais results for concentric and eccentric reducers
  - *(10)* improved figures to identify branch connection types
  - *(11)* corrections when $t/T < 1$ for fabricated branch connections
  - *(12)* t/T effect for Sketch 2.2 and Sketch 2.3 iob when $t/T < 0.85$
- *(c)* Examples and Application notes were prepared.
- *(d)* Corrections and note changes recommended in WRC 329 were implemented.
- *(e)* Additional test requirements have been identified and a number are underway at PRG in Houston

ABBREVIATIONS AND ACRONYMS

D = mean diameter of matching pipe found from (D_o-T), in. (mm). For Sketches 2.1 through 2.6 in Table 1 of Annex A, the mean diameter of the matching run pipe

d = mean diameter of matching branch pipe found from (d_o-t), in. (mm)

E = modulus of elasticity, psi. (KPa)

I_b, I_r = matching branch and run pipe moment of inertia used in Table 2 of Annex A, in^4 (mm^4)

i = stress intensification factor (SIF)

k = flexibility factor with respect to the plane and component indicated

M = moment on branch or run legs shown in Fig. 2, in.-lb (N·mm)

P = gage pressure, psi (MPa)

r = mean radius of matching branch pipe found from (d_o-t)/2, in. (mm) for Sketches 2.1 through 2.6

r_2 = radii used with Fig. 5 and in Sketch 3.1, in.(mm). (See Annex A.)

R = mean radius of matching pipe found from (D_o-T)/2, in. (mm)

R_1 = bend radius of welding elbow or pipe bend, in. (mm)

r_p = radius to outside edge of fitting for Sketches 2.3 and 2.6 measured in longitudinal plane, in. (mm)

r_x = external crotch radius of welding tee per ASME B16.9, extruded outlet and welded-in contour insert [Sketches 2.1, 2.4 and 2.5], measured in the plane containing the centerline axes of the run and branch, in.(mm)

s = miter spacing at centerline, in. (mm)

SIF = stress intensification factor

t = nominal wall thickness of matching branch pipe, in. (mm)

t_n = local branch pipe thickness used with Fig. 5(a) and (b), in. (mm)

T = nominal wall thickness of the fitting for elbows and miter bends (Sketches 1.1 through 1.3), and the nominal wall thickness of the matching pipe for tees (Sketches 2.1 through 2.6) and other components, in. (mm)

T_c = crotch thickness in Sketches 2.1, 2.4 and 2.5 in Table 1 in Annex A measured at the center of the crotch and in the plane shown, in. (mm)

t_p = reinforcement pad or saddle thickness, in. (mm)

Z = section modulus of pipe, in^3, (mm^3) (See Note 10.)

Z_b = section modulus of matching branch pipe, in^3, (mm^3) (See Note 10 to Table 1 in Annex A.)

α = reducer cone angle, degree

1 INTRODUCTION

In the Welding Research Council's (WRC) WRC Bulletin 329 (1987) E.C. Rodabaugh [1] outlined a number of recommendations for AMSE B31.1 Power Piping (B31.1), ASME B31.3 Process Piping (B31.3), BPVC Section III - Div. 1 - Subsection NC - Rules for Construction of Nuclear Facility Components - Class 2 Components (BPVC Section III NC) and BPVC Section III - Div. 1 - Subsection ND - Rules for Construction of Nuclear Facility Components - Class 3 Components (BPVC Section III ND). Specific recommendations were provided in WRC 329 Appendix A for BPVC Section III NC-3600 which were subsequently incorporated into the BPVC Section III Code.

The WRC 329 Section 5.0 Recommendations for B31.1 and B31.3 have not been incorporated into the B31.1 and B31.3 Codes as of the 2010 versions. The resolution of issues raised in WRC 329 is one objective of this report.

Rodabaugh [1][2][3][4][5][6][7] and Schneider [8] have long recognized the significant influence branch connection flexibility factors can have on piping flexibility results. In WRC 329 Rodabaugh states, "…present Code guidance for flexibility of branch connections can be very inaccurate. If the Code guidance is followed, there can be inaccuracies in the calculated moments, and [the stresses], that may be greater than that due to any of the inaccuracies in i-factors." Widera [9] and Wais [10] presented flexibility factors for unreinforced branch connections, and Wais [6] provided flexibility factors for pad reinforced branch connections. In 1987 Moore and others [4][11][12] conducted instrumented tests of welding tees. For this report PRG ran in excess of 30,000 brick and shell finite element analyses on unreinforced, reinforced, and contoured branch connections. PRG also conducted several tests of 4x4 unreinforced branch connections for in-plane and out-of-plane branch moments. Regressions were run on the collected data, and manual adjustments made to envelope k-factors observed in the test data. Certain k-factors are affected by contour dimensions not controlled by MSS, ASTM or ASME standards. In these cases the user is cautioned and the range of expected variation noted.

Since 1987 Rodabaugh, Woods, Scavuzzo, Wais, Widera, Hinnant and others [2][6][9][13][14][15][16][17][18][19][20][21][22] have released additional SIF test results and addressed various aspects of piping component behavior. Effort was made to incorporate these results into the recommendations in Annex A in this report.

Rodabaugh in WRC 329 [1] demonstrated the conservatism in the BPVC Section III NC and ND stress calculation approach in part due to the use of a single maximum valued stress intensification factor. Comparisons between this report's i-factors and the NC Code i-factors show that the approach developed by Rodabaugh in WRC 329 is reasonably conservative except in some cases when t/T is less than 1 for branch connections when r_2 is not provided.

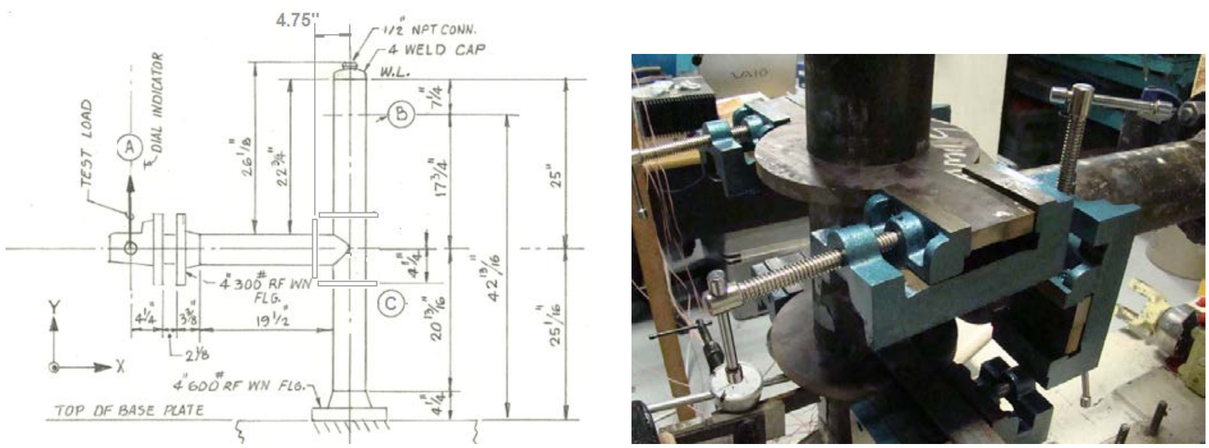
The major stress intensification and flexibility factor issues addressed in this report are summarized below.

(a) Provide flexibility factors for branch connections
(b) Modify R/T exponent in i-factor equations where needed (ref WRC 329 para 4.2.1)
(c) Thoroughly treat branch connections for d/D ratios less than 0.5.
(d) Provide torsional i-factors for branch connection run and branch sides
(e) Correct in-plane and out-of-plane relationship for run evaluation of branch connections
(f) Add notes to address geometrically ill-defined branch connections
(g) Address out-of-plane branch i-factor maximum that occurs between $0.5 < d/D < 1$.
(h) Address out-of-plane branch i-factor maximum that occurs for $t/T < 1$.
(i) Address fabricated branch connection where a radius is provided (r2)
(j) Update concentric and eccentric reducers to latest test and analysis recommendations
(k) Correct k-factor for 90 degree bends and elbows

- *(l)* Clarify locally thickened branch rules
- *(m)* Correct weld-on branch connection i-factor equations
- *(n)* Update reinforced fabricated tee branch connection rules per EPRI [6]
- *(o)* Remove incorrect guidance for corrugated straight pipe or creased bends

Flexibility factor tests for flanged ends on branch connections currently underway are shown in the sketches below. PRG is also attempting to reproduce lost Markl load-deflection data for several 4” branch connection configurations.

Figure 1-1: Radial Restraint k-Factor Branch Connection Test Setup



As part of the load-deflection development, torsional loads through both the run and the branch are applied and flexibility factors measured for these loads and components.

Figure 1-2: In-Plane Branch Load Deflection Test Configuration

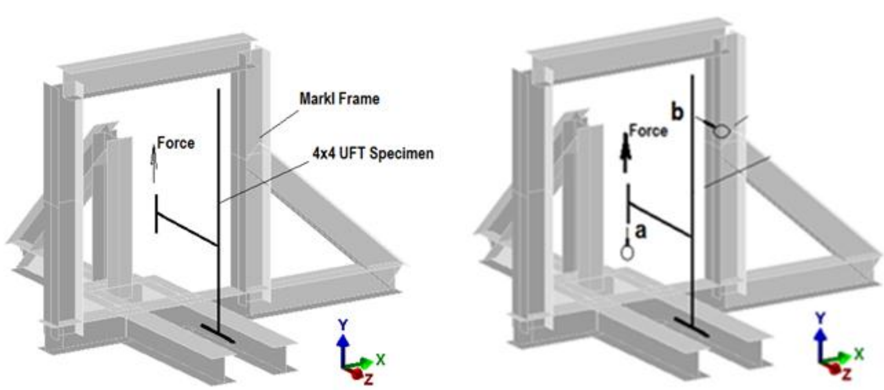


Figure 1-3: Torsional Run Load-Deflection Test

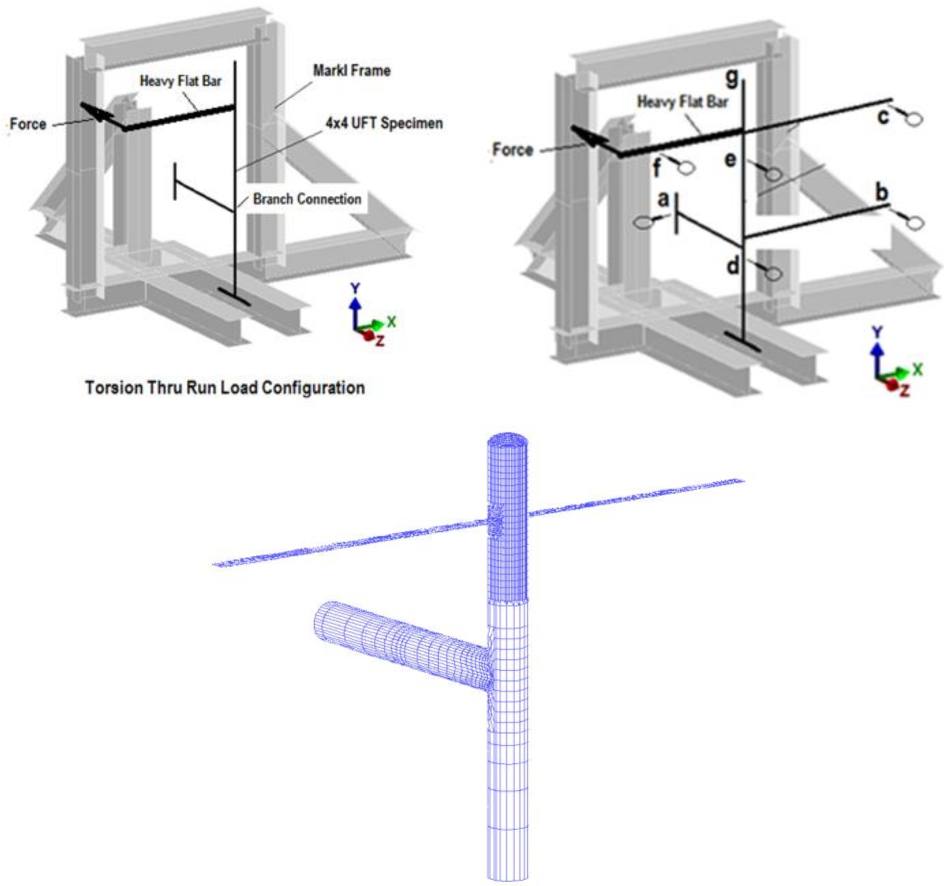
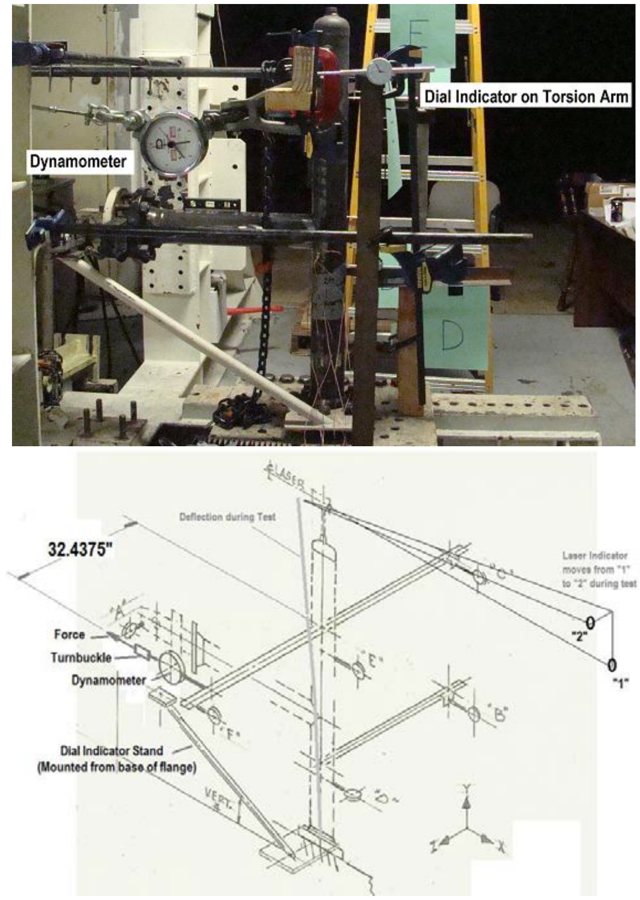


Figure 1-4: Torsional Run Load-Deflection Test Setup, Schematic and Preliminary Results



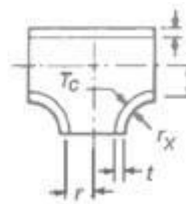
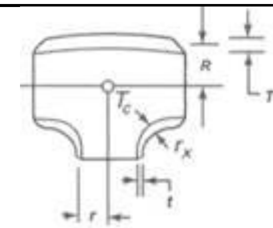
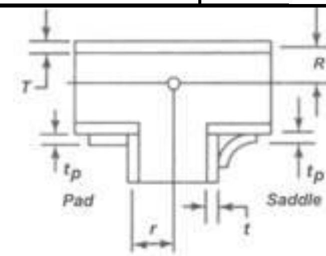
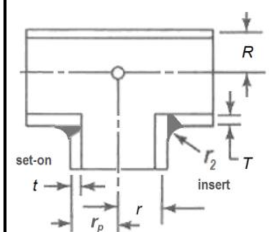
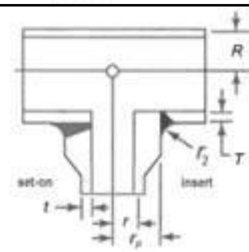
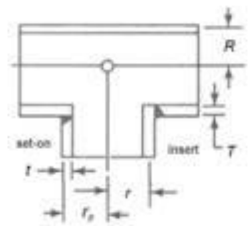
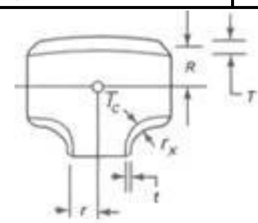
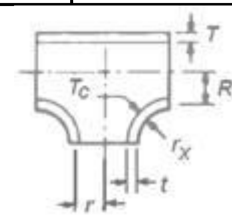
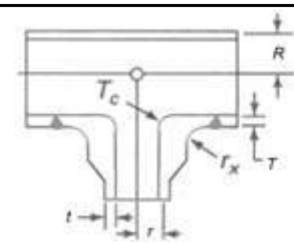
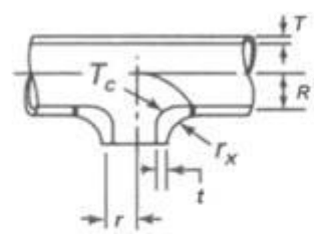
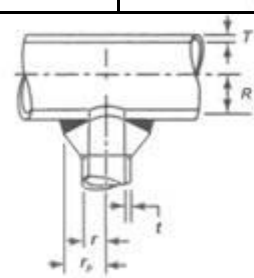
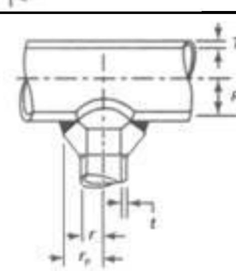
Funding for testing provided by PRG. Preliminary results are shown below:

Load Direction	Test	Beam No Flex	Beam ASME 07-02 Flex	Measurement Location:
Inplane Load thru Branch	0.093	0.0586 63%	0.0892 95.9%	Deflection at "a" (inch)
Torsional thru Run	0.129	0.0855 66.3%	0.1258 97.5%	Rotation at "g" (deg)

1.1 Updated Branch Connection Sketches

Table 1 Sketches 2.1 through 2.6 for branch connections are given in Figure 1-5 below. Additional figures were added to the sketches in the current B31.1 Table D-1 and the B31.3 Table D300 to help clarify the variation in the geometries covered by the equations in Table 1.

Figure 1-5: Branch Connection Sketch Numbers and Figures

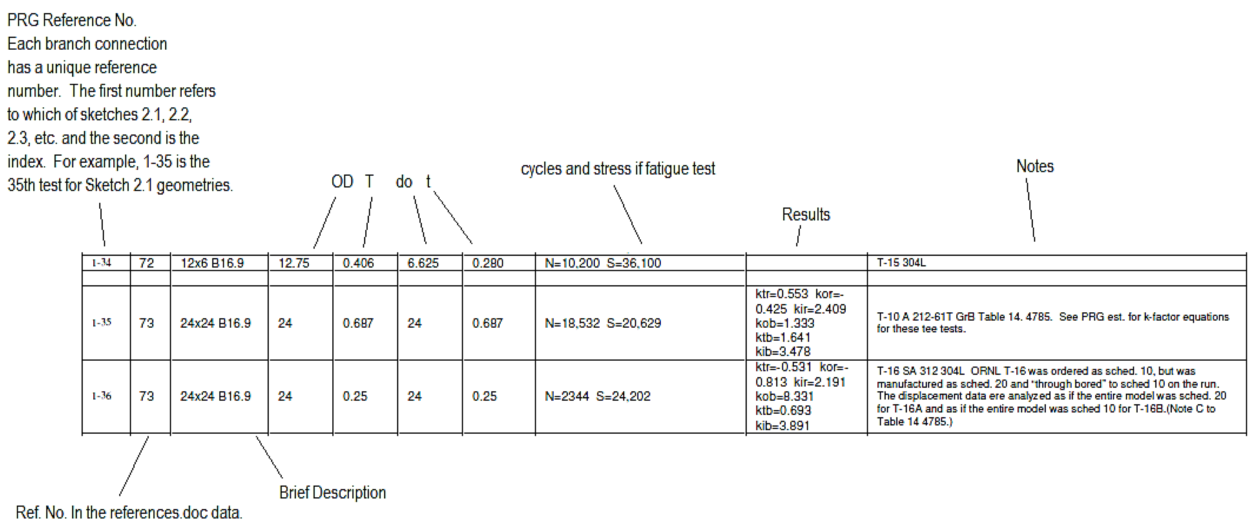
2.1 Welding tee per ASME B16.9			
2.2 Reinforced fabricated tee			
2.3 Fabricated tee			
2.4 Extruded outlet with			
2.5 Welded-in contour insert			
2.6 Integrally Reinforced Branch Welded-On Fittings [Notes (3),(10),(12)]			

2 USING THIS DOCUMENT

The majority of supporting information for this report is found in the Annexes. The alignment equations for SIFs and k-factors along with examples are given in Annex A in this report. Two sets of comparisons with existing Codes and guidelines are provided in Annex C in this report. The first set is in graphical form and is provided in the front of Annex C. The second set is in tabular form and is provided at the back of Annex C. Each set contains the same data. Instructions for reviewing the comparisons are given on the first page of Annex C. The equations used for all comparisons are given in Annex G in this report and are organized by source in VBA. A table of contents is available in the front of Annex G. Tabular and graphical comparisons with test data are provided in Annex E. Tables of compiled i-factor and k-factor data are in Annex F in this report. The source reference used for each entry are provided in the Annex F Table. In some cases a manipulation of the test data is required, for example, for the tests described in references [11] and [12]. A description of the manipulation is not included. Individual tests and k-factor development is found in other Appendices, but these are self-explanatory.

Two examples from the Annex F tables are shown below.

Figure 2-1: Test Data Matrix

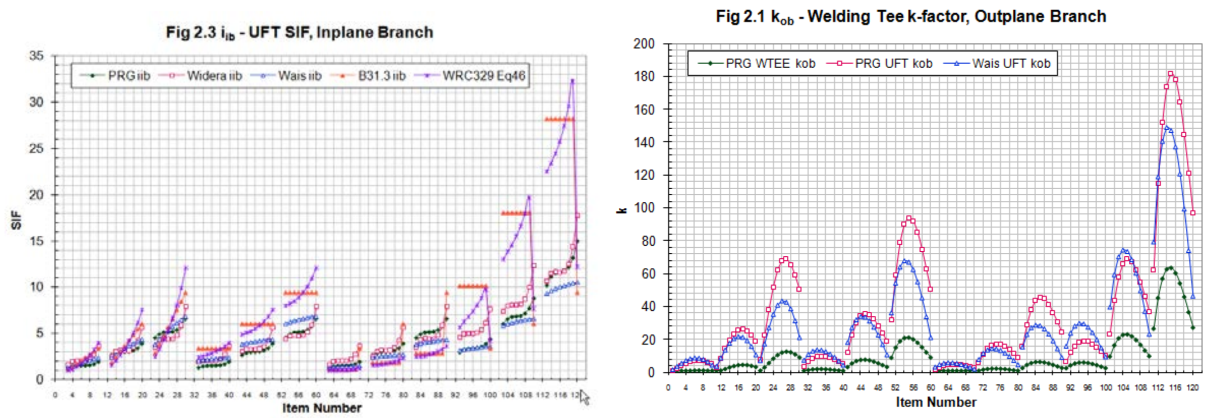


1-34	72	12x6 B16.9	12.75	0.406	6.625	0.280	N=10,200 S=36,100		T-15 304L
1-35	73	24x24 B16.9	24	0.687	24	0.687	N=18,532 S=20,629	ktr=0.553 kor=-0.425 kir=2.409 kob=1.333 ktb=1.641 kib=3.478	T-10 A 212-61T GrB Table 14. 4785. See PRG est. for k-factor equations for these tee tests.
1-36	73	24x24 B16.9	24	0.25	24	0.25	N=2344 S=24,202	ktr=-0.531 kor=-0.813 kir=2.191 kob=8.331 ktb=0.693 kib=3.891	T-16 SA 312 304L ORNL T-16 was ordered as sched. 10, but was manufactured as sched. 20 and "through bored" to sched 10 on the run. The displacement data ere analyzed as if the entire model was sched. 20 for T-16A and as if the entire model was sched 10 for T-16B.(Note C to Table 14 4785.)

Examples of the graphed comparisons against existing Codes and guidelines in Annex C are shown below in Figure 2-2. The item numbers for each graph are consistent and explained at the front of Annex C.

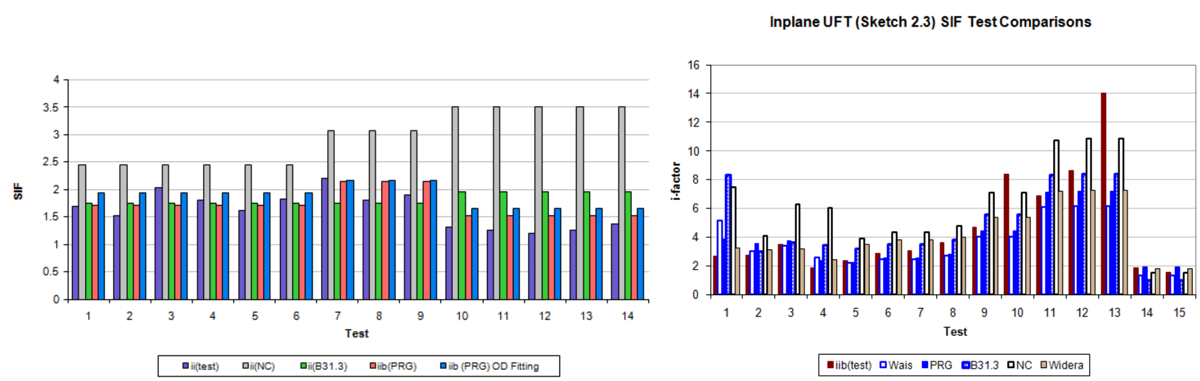
Annex D in this report contains plots that make relative comparisons of branch connection components. When higher order (cubic) equations are used to represent branch connection behavior incorrect relations between components may develop at the parameter range limits. The Annex D comparisons help to assure that appropriate relations between fittings are maintained through the entire parameter range, for example, that welding tees always show to have a lower i-factor than an unreinforced fabricated tee of the same branch and run dimensions. The Annex D results show only a subset of the relative comparison charts developed to assure a reasonable relation between all Sketch 2.1 through 2.6 branch connections is maintained through the entire parameter range.

Figure 2-2: Code Comparison Plots



Several example test comparison plots from Annex E in this report are shown below. A table follows all plots in Annex E that provides the reference for each test data point.

Figure 2-3: Test Data Comparison Plots



An interactive calculator for computing the branch connection SIFs and k-factors, and some B31, NC, NB, Wais and Widera SIFs and k-factors is available at PRG. The web version of this tool has been discontinued. The displayed tables permit comparison of the i- and k-factors with those from B31 and a variety of other sources. Versions are available from PRG for committee use.

In certain cases, data is generated outside of recommended parameter ranges since it is believed that this information is of interest. This report retains the limit on D/T of 100 since most tests have been conducted in this lower D/T range, and as d/D gets smaller, alternate lower bounds with t/T exist that are not practical when D/T is greater than than 100. The majority of Markl-Type fatigue tests have been conducted on size-on-size fittings where variations in t/T are not significant. For contoured fittings, t/T is not permitted to exceed 1.2 since test data is not available in these ranges and i- and k-factor equations have been adjusted to match what is considered the more applicable geometric condition where t/t is less than or equal to 1. Note 1 of Table 1 states,

> "Stress intensification factors in Table 1 have been developed from fatigue tests of representative commercially available matching product forms with assemblies manufactured from ductile ferrous materials and from numerical analysis using finite elements."

It is the Table 1 user's responsbility to make sure that the report's equations are not used with commercially obscure fittings, and this is thought to likely be the case, even though it is well-known that B31.3 Table D-

300 equations have been used by analysts for fittings well beyond what could be considered "commercially available matching product forms."

The reader is encouraged to evaluate comparison tables carefully to be sure that the parametric values being studied are within the applicable range of the equation.

Figure 2-4: Applicable i-factors and k-factors for Piping

Applicable i-factors and k-factors for Piping

Ver. 61 March. 14, 2011

Run Pipe Geometry [in. or mm.]

Run Outside diameter (Do) 4.5

Run Wall thickness (T) 0.237

Branch Pipe Geometry [in. or mm.]

Branch Outside diameter (do) 4.5

Branch Wall thickness (t) 0.237

Run Pipe Geometry

Outside Diameter (Do) 4.5

Wall Thickness (T) 0.237

Branch Geometry

Outside Diameter (do) 4.5

Wall Thickness (t) 0.237

Pad Thickness (tp) 0.237

Crotch Radius (rx) 0.125

Local Nozzle Thk (tn) 0.25

Extra Data

r/rp

Modulus of Elasticity 29E6

Compute/Update i, k and K

Calculate r/rp

Calculated Properties

Moment of Inertia (run)	7.2326
Moment of Inertia (branch)	7.2326
Mean Diameter (run)	4.2630
Mean Diameter (branch)	4.2630
Flexibility Characteristic, h	0.33357
One end flanged, c=h^1/6	0.833
Two ends flanged, c=h^1/3	0.694
Bend ki, ko = 1.3/h	3.8973
Bend ki, ko = 1.65/h	4.9465

PRG i-factors and k-factors for Branch Connections

		iib	iob	itb	iir	ior	itr	kib	kob	ktb	kir	kor	ktr
Sketch 2.1	WLT	1.4272	1.8164	1.8164	2.1140	1.1534	1.4704	1.5737	1.0000	1.0000	1.0433	1.0000	1.0000
Sketch 2.2	RFT	1.7162	2.0242	2.3543	2.2389	1.5161	1.9802	1.5441	1.4443	2.6935	1.1932	1.0000	1.4467
Sketch 2.3	UFT	2.3252	4.0566	2.6083	2.8891	2.3658	3.2960	4.6433	4.5471	5.8815	3.4535	1.0000	5.5472
Sketch 2.4	EXT	2.2651	3.4381	2.6083	2.8891	2.3460	2.2247	1.5737	1.0000	1.0000	1.0433	1.0000	1.0000
Sketch 2.5	SWP	1.5137	2.0759	1.9029	2.1571	1.3614	1.5569	1.9536	1.6304	1.0000	1.1391	1.0000	1.0000
Sketch 2.6	OLET	1.7375	2.8498	2.1229	2.5715	2.3658	3.2960	1.0000	1.5157	1.0000	1.4995	1.0000	1.0000
Sketch 2.3	Thk Noz	2.2903	3.9884	2.5113	2.8399	2.3053	3.2312	4.5316	4.3916	5.6341	3.4227	1.0000	5.4429

B31 i-factors and k-factors for Branch Connections

		iib	iob	itb	iir	ior	itr	kib	kob	ktb	kir	kor	ktr
Sketch 2.1	WLT	1.6231	1.8307		1.6231	1.8307							
Sketch 2.2	RFT	1.7352	1.9802		1.7352	1.9802							
Sketch 2.3	UFT	3.1692	3.8922		3.1692	3.8922							
Sketch 2.4	EXT	2.9803	3.6404		2.9803	3.6404							
Sketch 2.5	SWP	1.6231	1.8307		1.6231	1.8307							
Sketch 2.6	OLET	1.7560	1.7560		1.7560	1.7560							

NC/NB i-factors and k-factors for Unreinforced Fabricated Tees

		iib	iob	itb	iir	ior	itr	kib	kob	ktb	kir	kor	ktr
Sketch 2.1	WLT	1.4488	1.4488	1.4488	1.4488	1.4488	1.4488						
Sketch 2.3	UFT	3.6873	3.6873	3.6873	3.4598	3.4598	3.4598	3.7975	8.2736				

DNV i-factors for Unreinforced Fabricated Tees

		iib	iob	itb	iir	ior	itr	kib	kob	ktb	kir	kor	ktr
Sketch 2.3	UFT	1.4898	3.0854										

Wais i-factors and k-factors for Intersections (Applicable Ranges: 7.5<=D/T<=99, 7.5<=d/t<=198, 0.125<=d/D<=1)

		iib	iob	itb	iir	ior	itr	kib	kob	ktb	kir	kor	ktr
Sketch 2.2	RFT	1.4433	1.2914	1.6994	2.2216	1.2621	2.6164	2.0550	1.8699	3.1757	2.5842	2.2555	3.4007
Sketch 2.3	UFT	2.2094	2.2782	2.5491	2.1016	1.1464	2.5697	3.4517	3.7558	4.3062	3.2988	1.0000	3.8765

Widera i-factors and k-factors for Unreinforced Fabricated Tees (Applicable Ranges: 0.333<=d/D<1, 20<=D/T<250, d/D<t/T<3)

		iib	iob	itb	iir	ior	itr	kib	kob	ktb	kir	kor	ktr
Sketch 2.3	UFT	3.4871	2.9487					5.4459	3.8093				

3 DISCUSSION

Everett Rodabaugh in WRC 329 (1987)[1] made recommendations to resolve a number of issues with the then-current Codes. Following the publication of WRC 329, a number of additional tests and finite element studies were made to further support particular Code positions. Rodabaugh and Wais in WRC 463 (2001)[3] outlined methods for flexibility factor development from test data. Rodabaugh, Wais and Carter in work sponsored by Electric Power Research Institute ("EPRI") in 1999 [2][10] presented current and new branch connection test data and finite element correlations. As part of the Wais [2] work a set of i-factor and k-factor equations were developed for unreinforced branch connections. These equations deviated from earlier equations in that six i-factors were provided along with the corresponding k-factors for in-plane, out-of-plane and torsional moments acting through both the branch and run elements. Wais and Rodabaugh also presented similar sets of equations for pad-reinforced branch connections in EPRI TR-110755 [6], and for concentric and eccentric reducers in EPRI TR-106416 [18] in 1997. Widera and Wei in WRC 497 (2004) [14] released a set of equations for branch connection stresses in cylindrical shells that partially overlapped those released by Wais and Rodabaugh in 1999. Widera, Xue and Sang [9] also released two flexibility factor equations for intersecting cylinders in 2006 that also partially overlapped the Wais and Rodabaugh equations [2].

In 1998 Roarty, Rodabaugh, Wais, Ellenberger and Moore ran a series of fatigue tests for run moment loadings on small d/D branch connections [17], and in 2001 Wais and Rodabaugh released EPRI TR-1006227 [16] investigating the effect of directionality on the loading of branch connections and included additional fatigue test results.

In 2002, Wais and Rodabaugh [20] evaluated torsional stresses in girth butt welds using fatigue test results conducted at Ohio State University. In 1989 Woods and Rodabaugh [22] evaluated the effects of weld metal profile on the fatigue life of weld-on fittings [22], and in 1989 Woods and Rodabaugh ran fatigue tests on 4x3 ASME B16.9 Factory-Made Wrought Buttwelding Fittings (B16.9) tees providing both flexibility and i-factor data [21]. All EPRI tests conducted by Wais and Rodabaugh [6][10][16][18][20][22] included flexibility calculations as part of the load-deflection data developed during the SIF test. The twenty-two tests conducted by Khan [23][24] on unreinforced, pad reinforced, welded-in and welded-on branch connections also included flexibility calculations as part of the SIF test results.

In 2008 Hinnant presented additional fatigue tests and suggested that new fatigue life correlations could be used for more recent fatigue tests of welded pipe assemblies.

During the preparation of this report a resolution of the differences between the Wais [6] and Widera [14][9] equations was attempted, and additional pad-reinforced finite element analyses were run to complement the equations recommended by Wais [6]. Branch connections were identified along with other piping components by a Sketch number and additional figures were included to clarify the types of cross sections identified by the different Code i- and k-factor equations. The recommended Sketches are shown in Figure 1-5 above.

Among the branch connections evaluated are those considered well-defined, and those considered ill- or poorly-defined. Well-defined components are commercially available standard fittings whose geometries are well-known. Ill-defined components are commerically available standard fittings whose geometries are not well-known and whose dimensions are left to the manufacturer's discretion. In some cases i- and k-factors may be indicative only of the particular component tested and not of all components of a particular fitting type. Attempts were made to quantify the affect expected geometry variations have on the fatigue life and flexibility of commercially available fittings. In most cases this resulted in notes added to Table 1.

3.1 Unreinforced Branch Connections (Referenced in Figure 1-5, Sketch 2.3)

Are considered well-defined components because their geometry is reasonably well-known. The intersection weld introduces the typical unknowns associated with welds, but a wide variety of tests have been conducted on Sketch 2.3 geometries fabricated from ductile ferrous welded material used in piping systems. The "cat's-eye" geometry effect in size-on-size unreinforced fabricated branch connections has not been well studied but is not believed to cause a significant irregularity.

3.2 Pad Reinforced Branch Connections (Referenced in Figure 1-5, Sketch 2.2)

Are also considered reasonably well-defined components that are subject to an unknown pad-to-shell fit-up. For pad-reinforced branch connections where either $D/T < 100$, or $d/D < 0.5$, and the width of the pad is equal to or smaller than (0.5)(d) the affect of the pad-to-shell fit-up is not thought to have a significant affect on the pressure or fatigue strength of the fitting. In this case, the high stresses occur in either the branch-to-pad weld, or in the pad-to-shell weld and the fatigue life of each of these locations is believed to be well predicted by the bending stress in the thickness of the smallest adjacent component.

3.3 Integrally Reinforced Welded-On Fittings (Referenced in Figure 1-5, Sketch 2.6)

Are thought to be reasonably well-defined components because the shape of the fitting has been developed using a consistent, but essentially proprietary design methodology. Tested components are available with two different internal body contours. Fatigue tests for welded-on components exist for nominal branch-to-run ratios as low as 0.4[23]. Geometric requirements for welded-on components do not exist, and due to the body contours, sizes above nominal branch-to-run ratios of 0.5 may have a variety of shapes and weld completion requirements. Woods and Rodabaugh show in WRC 392[22] that weld metal profiles in the circumferential plane of these fittings can have a doubling effect on the stress intensification factor. Discussions with manufacturers indicate that experience has been developed from fatigue tests [22][23]regarding tolerances, installation instructions and weld cap requirements. These fittings are considered more sensitive to geometry and fabrication when the nominal branch to run ratio is greater than 0.7. This report's equations reflect the uncertainty in the geometry in the larger sizes, and essentially converge to the locally thickened fabricated tee in smaller sizes where the fitting geometry becomes similar to that of a locally thickened nozzle.

3.4 B16.9 Welding Tees (Referenced in Figure 1-5, Sketch 2.1)

Tested by Markl [25][26][27] and that serve as a basis for the code equations are shown in Figure 1.5. These tees have an average crotch and side-wall thickness equal to 1.6 times the matching nominal pipe wall thickness. B16.9 welding tees tested by ORNL in references [11][12] include stainless and carbon steel tees and have somewhat thinner sections but no thickness in the tee body removed from the branch or run side weld less than 1.2 times the matching nominal pipe wall thickness. B16.9 welding tees tested by Woods and Rodabaugh [21] showed that three of four tees tested did not have locally thickened crotch radii, but did have general body thicknesses removed from the weld ends at least 15% greater than the matching pipe thickness. In 2007 PRG measured the thicknesses of several stainless B16.9 welding tees. One of those tees (18x18x18) showed thicknesses throughout the tee body that were 4% lower than the matching nominal stainless pipe wall thickness. This result was discussed with a number of B16.9 welding tee suppliers and manufacturers. It appeared that some commodity B16.9 welding tee manufacturers were satisfying only the minimum wall thickness requirements found in B16.9. It is not known how many B16.9 tees are provided to users of B31.1, or B31.3 with wall thicknesses that are thinner than the matching pipe. It is similarly not known if these tees would satisfy the burst test requirements of B16.9 Section 9. Burst tests of contoured welding tees whose thicknesses are equal to or less than the wall thickness of the intended matching pipe, are currently underway at PRG in Houston.

Finite element studies suggest that welding tees become more flexible as the average body thickness approaches the thickness of the matching nominal wall pipe. This increase in flexibility generally accompanies an increase in the stress intensification factor.

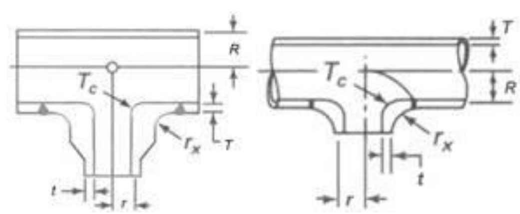
It is believed that the majority of B16.9 welding tees provided in 2010 in the United States have an average wall thickness of at least 1.15 times the smallest nominal matching wall and likely do not have an increased crotch thickness in the longitudinal plane. It is also thought that some stainless steel B16.9 tees may have wall thicknesses that approach, or are less than the nominal wall thickness of the matching pipe. No attempts were made to contact manufacturers or suppliers outside of the United States.

The welding tee i- and k-factor equations provided in Table 1 are intended to replicate the current B31 Code values when d/D = 1 for branch i-factors, and to replicate the NB3683 run i-factors for d/D = 1, and to demonstrate a conservative k-factor when compared to unreinforced fabricated tees. Typical welding tees, and in particular welding tees with bodies that are thicker than the matching run pipe have flexibility factors that are considerably lower than similar unreinforced fabricated tees. Assumptions for k-factors are made such that the k-factors will tend to be low, and will correspond with welding tees that have average body thicknesses that are greater than or equal to 1.2 times the nominal matching pipe wall thickness. Notes are provided that apply to thinner welding tees informing the reader that actual flexibility of the welding tee may increase by 3 to 4 times as the average welding tee thickness approaches that of the matching nominal wall pipe. The "average welding tee thickness" is not quantitatively defined. It is not clear if Markl's average of the crotch and side wall thickness as described in [25][27] is sufficient. Since the thickest portion of the welding tees tends to be in the crotch area, it was thought reasonable to use the cautionary wording "T_c approaching T_{nom} " as a lower bound limit for the point where the large increases in flexibility are observed. At the recommendation of Mr. David Creates additional lower bound limits were provided for B16.9 Welding tees and other contoured fittings. Those limits were added to Note 10 in the recommendations and state that the equations in Table 1 are only valid when t/T is less than or equal to 1.2 and the ratio Tc/T must be greater than 1.1.

3.5 Welded-in Contour Inserts (Referenced in Figure 1-5, Sketch 2.5)

Are fabricated using several different methods and as a result may have different body geometries. The two body geometries shown in the Sketch 2.5 are typical and fatigue tests on welded-in contour inserts were conducted on both. The left image in Figure 3-1 is more typical of current commerically available welded-in contour inserts and tend to be less expensive to form than the smooth body type shown in the right image in Figure 3-1 below.

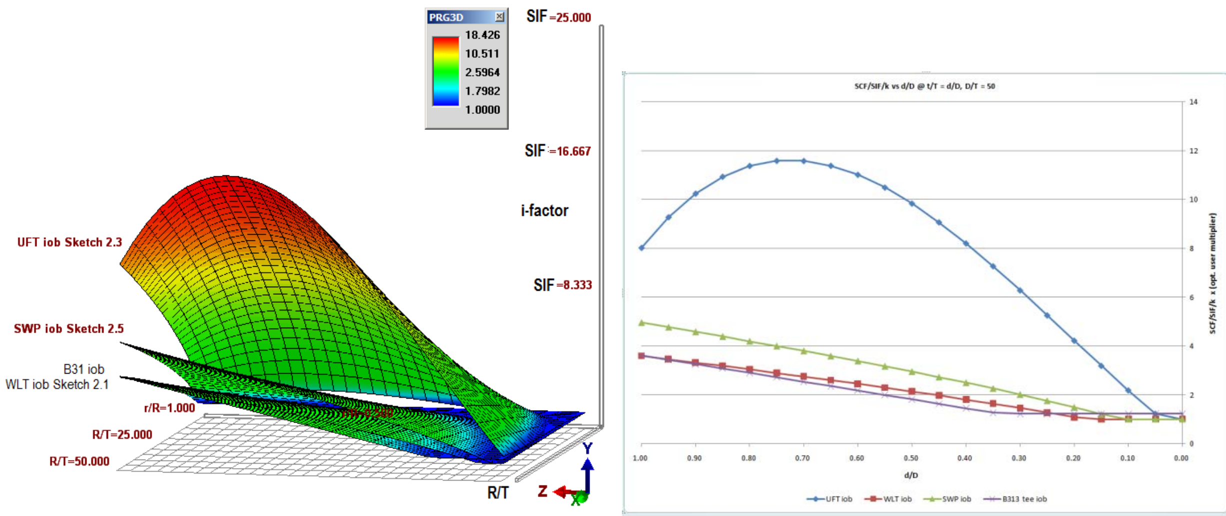
Figure 3-1: Welded-in Contour Inserts



Failures due to out-of-plane loading on the branch may often occur at or near the butt weld in the run pipe. It is expected that welding tees will be stronger than welded-in contour inserts since the typical welding tee is locally thicker all around the circumference of the run pipe in the intersection area, and does not have the girth weld in the vicinity of a geometric discontinuity. Welded-in contour inserts (SWP) should be stronger than unreinforced fabricated tees however since the junction weld is moved away from the intersection and a smooth contour is provided in the branch-to-run junction area.

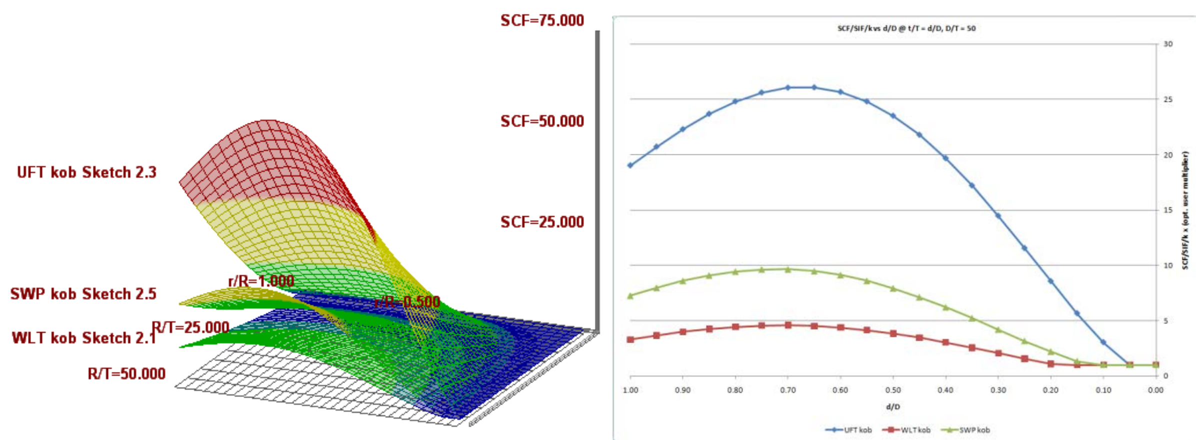
The relationships among the components of Sketches 2.1, 2.3, and 2.5 are shown below in Figure 3-2 for the branch loaded stress intensification factor i_{ob}. The welded-in contour insert Sketch 2.5 (SWP) is weaker than the Sketch 2.1 welding tee, but stronger than the Sketch 2.3 unreinforced fabricated tee. A 3-dimensional graph of the i_{ob} surface and a 2-dimensional planar section of the same surface is shown in Figure 3-2 below. The horizontal axes in the 3-dimensional graph are R/T and d/D. The vertical axis is the i-factor, shown in the plot as SCF. The 2-dimensional section is taken in the i-factor-d/D plane at R/T=25.

Figure 3-2: Welded-in Contour Insert i_{ob} Comparison with Unreinforced Fabricated Tee and B16.9 Welding Tee



The k_{ob} relationship should be similar (as shown in Figure 3-3), since the welded-in contoured component is not stiffened around the entire fitting by a thicker section.

Figure 3-3: Welded-in Contour Insert k_{ob} Comparison with Unreinforced Fabricated Tee and B16.9 Welding Tee



For all two-dimensional graphs generated, a table of comparison values is also produced for the range of dimensionless parameters requested. The table generated for the Figure 3-3 2-Dimensional graph is shown below.

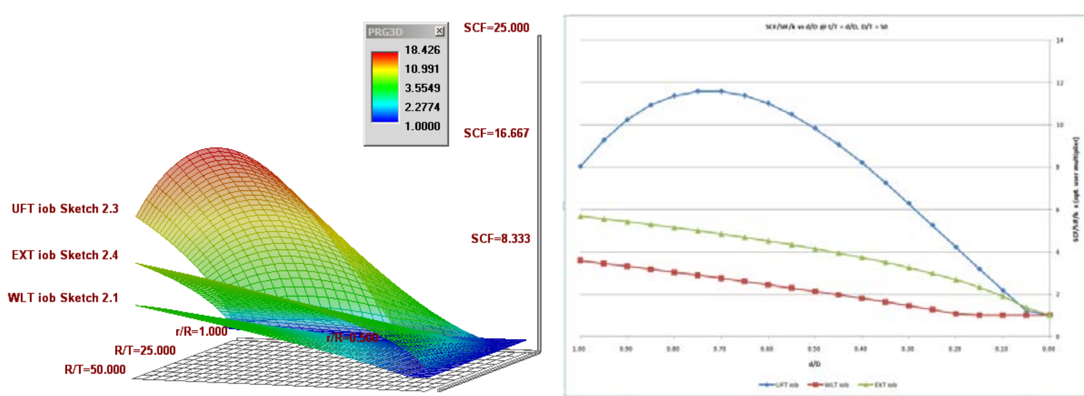
Figure 3-4: Two-Dimensional Graph Automated Table of Results

d/D	D/T	t/T	UFT kob	WLT kob	SWP kob
0.00	50.00	0.00	1.0000	1.0000	1.0000
0.05	50.00	0.05	1.0000	1.0000	1.0000
0.10	50.00	0.10	3.0504	1.0000	1.0000
0.15	50.00	0.15	5.6647	1.0000	1.3367
0.20	50.00	0.20	8.5647	1.0955	2.1989
0.25	50.00	0.25	11.5513	1.5712	3.1682
0.30	50.00	0.30	14.4724	2.0692	4.1912
0.35	50.00	0.35	17.2098	2.5653	5.2196
0.40	50.00	0.40	19.6720	3.0385	6.2103
0.45	50.00	0.45	21.7897	3.4706	7.1256
0.50	50.00	0.50	23.5131	3.8465	7.9333
0.55	50.00	0.55	24.8100	4.1539	8.6069
0.60	50.00	0.60	25.6638	4.3836	9.1256
0.65	50.00	0.65	26.0726	4.5295	9.4747
0.70	50.00	0.70	26.0483	4.5880	9.6456
0.75	50.00	0.75	25.6156	4.5591	9.6359
0.80	50.00	0.80	24.8117	4.4452	9.4497
0.85	50.00	0.85	23.6853	4.2520	9.0975
0.90	50.00	0.90	22.2964	3.9880	8.5968
0.95	50.00	0.95	20.7160	3.6648	7.9717
1.00	50.00	1.00	19.0255	3.2970	7.2533

3.6 Extruded Outlets (Sketch 2.4 Referenced in Figure 1-5)

May be fabricated in a manner similar to B16.9 tees and can experience the wide range of body thicknesses observed in B16.9 tees. Several extruded outlet tests are discussed in WRC 329 and are shown to have i-factors that are comparable to unreinforced fabricated tees if the body thickness of the extruded tee is used in the i-factor evaluation. (See WRC 329 Section 3.0.) It appears that generally manufacturers supply extruded tees that are thicker than matching wall pipe and so may have i-factors that are less than unreinforced fabricated tees. The tests in WRC 329 were not intended to apply to all, or even a given range of extruded tees and so the reduced i-factors found in the test are not considered to be standard. The i-factor equations for extruded outlets in this report give SIF values that are greater than those for B16.9 welding tees but less than those for unreinforced fabricated tees. In addition, the third order equation in d/D is not included for the out-of-plane branch loaded i-factor since Woods and Rodabaugh [6] showed that this affect is likely not present in contoured fittings, and PRG confirmed this conclusion with a variety of finite element studies on contoured branch connections [not published]. The WRC 329 Section 3.0 tests reinforce the belief that B16.9 tees should be provided with a minimum average tee wall thickness greater than the matching nominal pipe wall thickness by at least 1.15 times, and not just greater than 87.5% of the matching nominal pipe wall thickness. The relationship between the components in Sketches 2.1 (welding tees), 2.3 (unreinforced fabricated tees), and 2.4 (extruded tees) is shown in Figure 3-5 below.

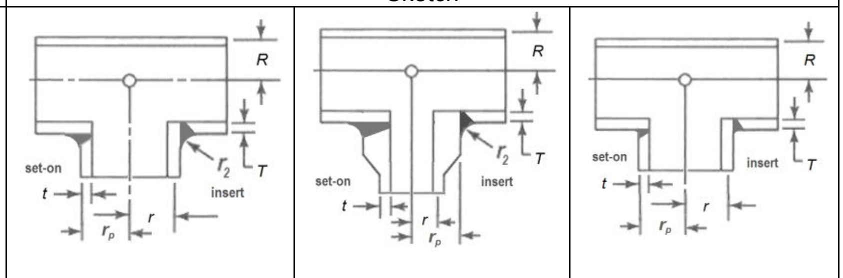
Figure 3-5: Extruded Outlet I_{ob} Comparison with Unreinforced Fabricated Tee and B16.9 Welding Tee



3.7 t/T Limitations

For certain parameter ranges for unreinforced (Sketch 2.3), and reinforced (Sketch 2.2) branch connections, when the d/D and t/T ratios are less than 1.0, the high stress location moves from the run pipe to the branch pipe. In this case the i-factor may increase as t/T is reduced. This is shown in the leftmost diagram in Figure 3-6 below. A similar inflection point is shown for the stress factor plot from Fig. 46 in WRC 297. Including this effect in the branch connection equations requires a t/T expression that possesses an maximum at around a value of t/T = 0.5. For many parameter ranges point "c" in the Figure 3-7 plot was not found to be significantly higher than point "b". In these cases the t/T affect could be adequately considered by limiting t/T to 1.0 for certain branch connection equations. This t/T effect for unreinforced branch connections, Sketch 2.3, is shown in the equations below:

Figure 3-6: t/T Effect for Unreinforced Branch Connections

2.3	Sketch
Fabricated tee [Notes (3),(10),(11)]	
Term	**Equation**
Branch SIF In-plane, i_{ib}	$(0.038 + 1.45(d/D) - 2.39(d/D)^2 + 1.34(d/D)^3)\,(R/T)^{0.76}\,(t/T)^{0.74}$ (when t/T < 1 use t/T=1)
Branch SIF Out-of-plane, i_{ob}	$(0.038 + 2(d/D) + 2(d/D)^2 - 3.1(d/D)^3)\,(R/T)^{2/3}\,(t/T)$ (when t/T < 1 use t/T=1)

Note 10 has been modified in Revision 3 to accommodate this inflection point since some geometries were found to have calculated i-factors that were 1.6 times too low using the Revision 2 equations. (These same geometries could have i-factors that were more than 3 times too low using existing B31 Appendix D equations.)

Figure 3-7: t/T Effects on i-factors and Stress-Factors (WRC 297)

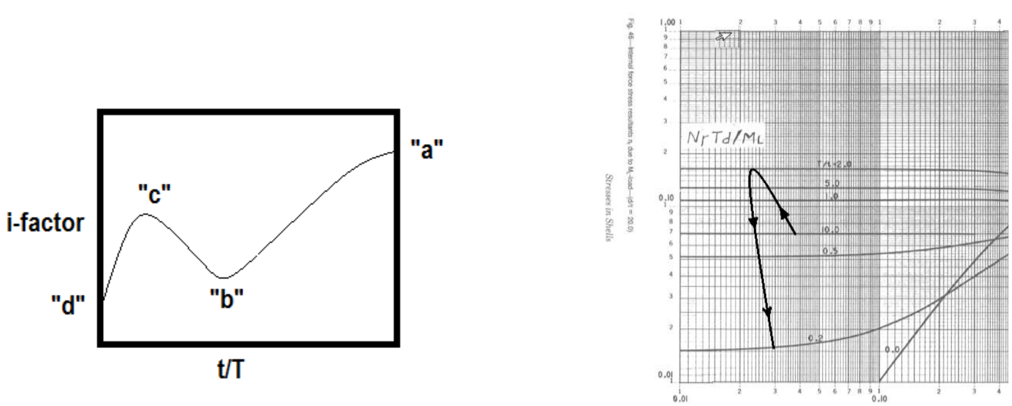
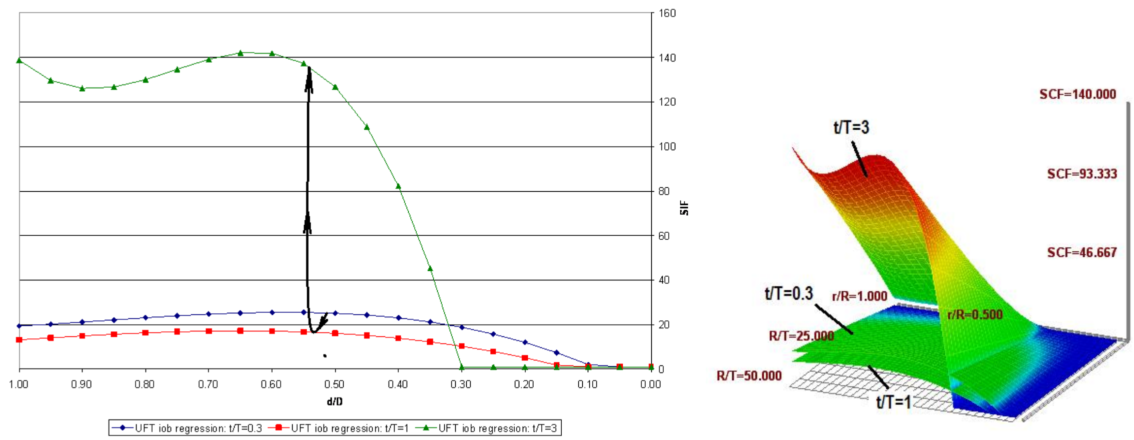


Figure 3-8: Two and Three-Dimensional i-factor Graphs Vs. d/D for R/T=50 For Different Values of t/T



3.8 Key Document Review

A large number of documents were reviewed for this report. A list of all documents referenced is included in Annex J in this report. The documents listed below are a subset of the Annex J documents and provide basic guidance and further references. The general method for developing i-factors from finite element and test data is outlined in the Wais and Rodabaugh EPRI TR-110996. BPVC Section VIII Division 2 Annex 5.A gives additional guidance for performing finite element studies using shell and brick model intersections.

SIFs:

(1) WRC 329 – Accuracy of Stress Intensification Factors for Branch Connections (1987) [1]
(2) WRC 497 – Part 3 Widera & Wei "Large Diameter Ratio Shell Intersections" (2004) [14]
(3) EPRI TR-110996 "Stress Intensification Factors and Flexibility Factors for Unreinforced Branch Connections", (1998) [10]
(4) "Experimental Stress Analysis and Fatigue Test of Five 12-in NPS ANSI Standard B16.9 Tees", ORNL/TM-8965, April 1984 [11]
(5) Moore, Hayes, Weed, "Experimental Stress Analysis and Fatigue Test of Five 24-in. NPS ANSI Standard Tees", ORNL/TM-9409[12]
(6) EPRI TR-110755, "Stress Intensification Factors and Flexibility Factors for Pad-Reinforced Branch Connections", (1998) [6]
(7) EPRI TR-1006227, "Investigation of Stress Intensification Factors and Directionality of Loading for Branch Connections", (2001) [16]
(8) WRC 436, "Evaluation of Small (r/R<0.5) Branch Connections with Through-Run Moments," (1998) [17] (Roarty, Ellenberger, Rodabaugh)
(9) EPRI TR-106416, "Stress Intensification Factors and Flexibility Modeling for Concentric and Eccentric Reducers", (1997)[18]
(10) "Experimental Evaluation of Markl Fatigue Methods…", (2008)[19] PVP 2008-61871
(11) "EPRI 1006905, "Investigation of Torsional Stress Intensification Factors and Stress Indices for Girth Butt Welds in Straight Pipe" (2002)[20]
(12) WRC 346 "WFI/PVRC Moment Fatigue Tests on 4x3 ANSI B16.9 Tees", (1989)[21]
(13) WRC 392 "Effects of Weld Metal Profile on Fatigue Life of Integrally Reinforced Weld-On Fittings", (1994)[22]

Flexibility Factors:

(1) NUREG/CR-4785 ORNL-6339, "Review and Evaluation of Design Analysis Methods for Calculating Flexibility of Nozzles and Branch Connections", (1987)[4] Rodabaugh, Mokhtarian, Gwaltney.
(2) WRC 463 "Standardized Method for Developing Flexibility Factors for Piping Components", (2001)[3]
(3) Phase Reports 1-6 TID-24342 Reactor Technology (1966)
(4) Refs. [11], [12] for B16.9 Tees. {10 Tees, All Flexibility Directions}
(5) "A Study of Fatigue Crack Initiation and Failure in Reinforced Shell to Shell Intersections", Khan for WFI.(1984) [23]{4 UFTs, 12 OLETs, 10 Contoured Inserts]
(6) EPRI TR-110996,"Stress Intensification Factors and Flexibility Factors for UFT's"
(7) EPRI-TR-110755,"Stress Intensification Factors and Flexibility Factors for Pads…"
(8) EPRI-1006227,"Stress Intensification Factors for Directionality of Loading".
(9) PVP2008-61871,PRG-UFT Tests.
(10) WRC 346, "WFI/PVRC Moment Fatigue Tests on 4x3 ANSI B16.9 Tees"
(11) WRC 392,"Effects of Weld Metal on the Fatigue Life of Integrally Reinforced Weld-On Fittings"
(12) Flexibility Factors for Branch Pipe Connections Subjected to In-Plane and Out-of-Plane Moments", Widera & Xue(2006) [9]

3.9 WRC 329 Items to Address:

Most of the recommendations made by E. Rodabaugh in WRC 329 have an influence on the use of SIFs and k-factors in the piping codes and were incorporated in the notes or guidance included in this report. Excerpts taken from WRC 329 are given below. The page number listed is from WRC 329. A full reading of WRC 329 may be required to supplement the excerpts. Comments by the author are provided in braces {}.

In the forward to WRC 329 written by Sam Moore, Mr. Moore writes: "[Mr. Rodabaugh] … identified a large number of problems with the different code's usage of branch connection SIFs in their design procedures."

In "Nomenclature", Mr. Rodabaugh writes, "We have elected to use the unsubscripted letters T,R, t and r to represent the basic dimensions of branch connections." A similar election is used for the nomenclature found in this report's alignment recommendations in Annex A.

p.9 "… using i = 1.0 for M_t on full size outlet branch connections can lead to inaccuracies far greater than the Mob inconsistency."

p.12 "We would rate the relative complexity of i-factors for pipe, elbows and branch connections by the ratios of 1:5:500. … [readers] will not find any simple answers in this report."

p.12 "…pad or saddle reinforced branch connections may share the M_{ob} inconsistency with other types of branch connections."

p.12 "The available data on pad-reinforced branch connections is too sparse for us to recommend any changes in present Code i-equations." {updated after EPRI-TR-110755}.

p.13 "Extruded outlets are somewhat related to ANSI B16.9 tees in that extruded outlets, like B16.9 tees, may vary significantly between manufacturers."

p.18 "If L_1 equals or exceeds 0.5 $(r_i T_b)^{0.5}$ then r'_m can be taken as the radius to the center of T_b. … if the lower bound of Eq. (9) controls, then the inconsistency would be 2^2=4, … leading to using i<1.0 which is not the intent of the Code." {The use of locally thickened nozzles are permitted but don't let i-factor with respect to the branch pipe become less than 1. This guidance is incorporated into Table 1 Note 11 rules for locally thickened branch connections.}

p.19 "… if a single, nonparametric exponent is to be used for (R/T) … this is a potent source of inaccuracy. … if a more accurate (R/T) exponent is 1.0 then the extrapolation would give i_f= 25, instead of 11.6."

p.19 " [C'_{2bo}] … suggests that the t/T variable for r/R between 0.5 and 0.95 is not very significant, and the Code assumption that σ/M is independent of t is not too bad."

p.20 "The Code i-factor equations, other than the lower bounds on i, appear to be more accurate for models where the critical location is in the run pipe." …{This is the reason for the t/T limit in equations for branch i-factors for unreinforced and reinforced branch connections.}

p.21 "[B31.3 i_{tb}=1] may be nonconservative by a factor of 2.7 … and may be nonconservative by a factor of 12 or more."

p.22 "For run moments on branch connections with small r/R, both intuition and Ref. 26 data indicate that the B31.3 relationship ii = 0.75io + 0.25 is at best, reversed in relative magnitude of iir and ior, … and in effect, [the] Code requirements are obviously silly."

p.24 "The available fatigue test data are inadequate to even guess at the general accuracy of Code i-factors for run moments or how they vary with R/T, r/R, t/T, r/rp or some other parameters."

p.24" values[for] M_{tr} indicate that the B31.3 SIF i=1.00 for M_{tr} is perhaps unconservative even for r/R < 0.5."

p.27 "[using $i_b=0.9/h^{2/3}$ instead of $1.5(R/T)^{2/3}(d/D)^{1/2}(t/T)(r/rp)$] could result in unnecessary changes."

p.28 "footnote 7 tied to weld-ons reads "The designer must be satisfied that this fabrication has a pressure rating equivalent to straight pipe. … insert the word "run" before "pipe" in the footnote."

p.28 "The M_{ob} tests indicate that there is a peak somewhere around 0.75."

p.29 ".. we do not necessarily achieve greater accuracy in Code evaluations by using more accurate i-factors *unless* more accurate k-factors are also used."

p.32-33 "… delete the use of $i_i = 0.75i_o + 0.25$ for branch connections tees, … [it] gives the wrong relative magnitude for M_{or} versus M_{ir}, [and] it underestimates the difference between M_{ob} and M_{ib} for r/R between about 0.3 and 0.95 and perhaps over-estimates the difference for r/R below 0.2 and for r/R = 1.0."

p.33 "For branch connections with r_2 provided, use $i_{ib}/2$." {This adjustment is provided in Note 11, although the reduction in the i-factor has been reduced from 2.0 to 1.4 and the dimensional requirements on r_2 have been reduced.}

p.33 "If B31.3 were to follow Recommendation (10), then Table 1 (c) and (f) should be removed, i.e., Eqs. (43)-(46) are intended to apply to both UFTs and Weld Ons."

p.37 "[limits on the inside radius of the branch connection are] dropped because moment fatigue tests and theory indicate that the inside corner radius is not a critical consideration."

p.37 "[The location of rp indicated in Fig. D-1(c) should be corrected.]" {Fig. 5(c) shows correction Rodabaugh gives on p.44 of WRC 329.}

p.37 "[Note 6 in B31.3 App D and Note 4 in B31.1 App D should be deleted. Problems with over-thickness elbows have arisen with wrought steel elbows, not cast elbows." {Note 6 adjusted to cover the specific situation where large thickness discontinuities in presumed matching components exist.}

p.38 "We have deleted corrugated straight pipe or creased bends, [the guideline] is almost meaningless."

p.38 Note for flange modifications: "But after such multiplication, values of k and i shall not be taken as less than 1.0." {This report has taken this as a directive to make clear that i-factors and k-factors shall be greater than 1 <u>after</u> all modifications are made.}

3.10 Regression, Visualization and Automation

After finite element data for this report was regressed, comparisons were made with available test data against other fitting types having the same branch and run diameters. Even though some regressions had high R^2 values, errors were not randomly distributed, and further adjustment was needed. To extend the application of the project equations, individual finite element runs were made in low parameter ranges using combinations of d/D, t/T and R/T. As part of this process the equations for branch connections were adjusted several times. After these adjustments, all comparisons against test data, current Codes, guidelines, and other fittings were regenerated. These comparisons are included in the current report Annexes C, D, and E. The table and graph production is automated using Microsoft Office tools.

An interactive graphical tool was also prepared to compare various branch connection types, and the finite element and test data. The finite element and test data is plotted as points on the three-dimensional images. The regressed equations, other Code equations and guidelines are plotted as surfaces. These images can be interactively queried so that errant points can be quickly identified. Differences between the current codes and new recommendations are easily discernable.

Options available for 2D and 3D comparative plotting are shown in Figure 3-9 below. Several Example 3D and 2D images are included in Figures 3-10 through 3-12.

Figure 3-9: Regression, 2D and 3D Plotting and Comparison Tool Input Form

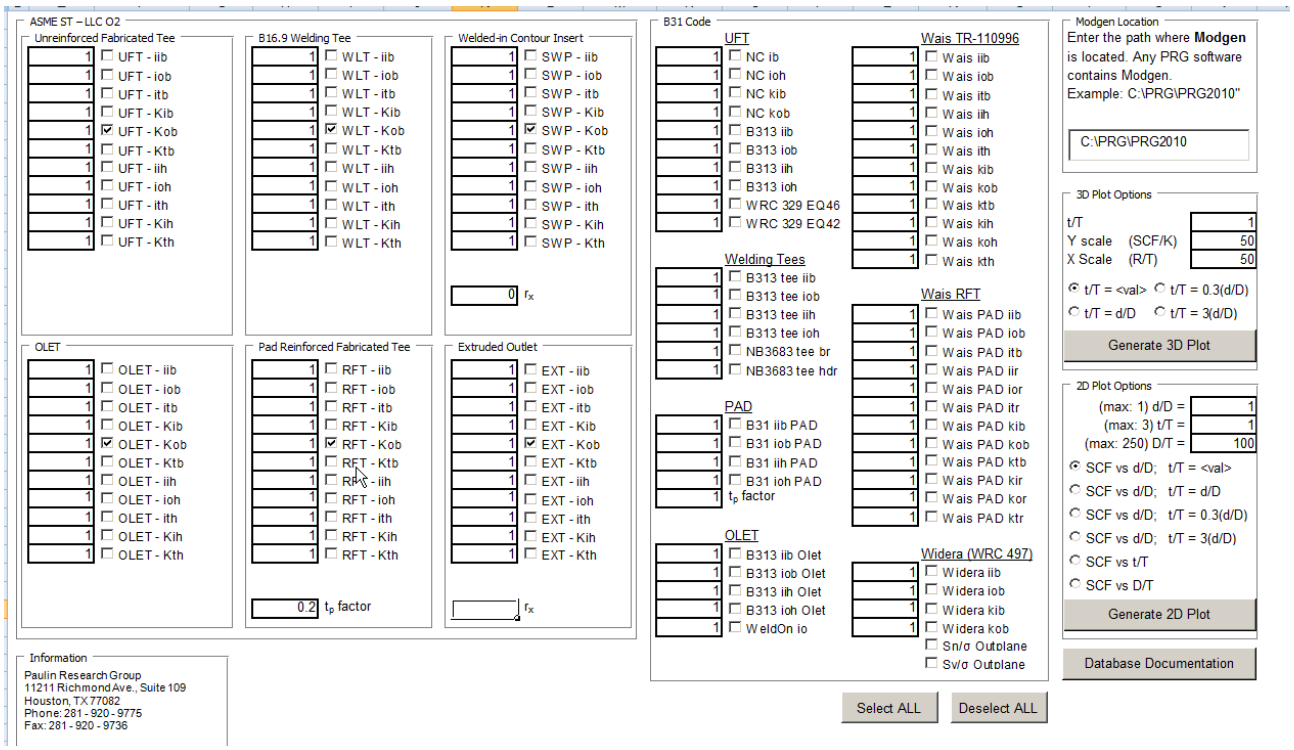


Figure 3-10: i_{ob} Comparison of DNV [32], Wais [10], Widera [14], and the Results for Unreinforced Fabricated Tees (Three Dimensional Image on Left, Two Dimensional Section Plot on Right)

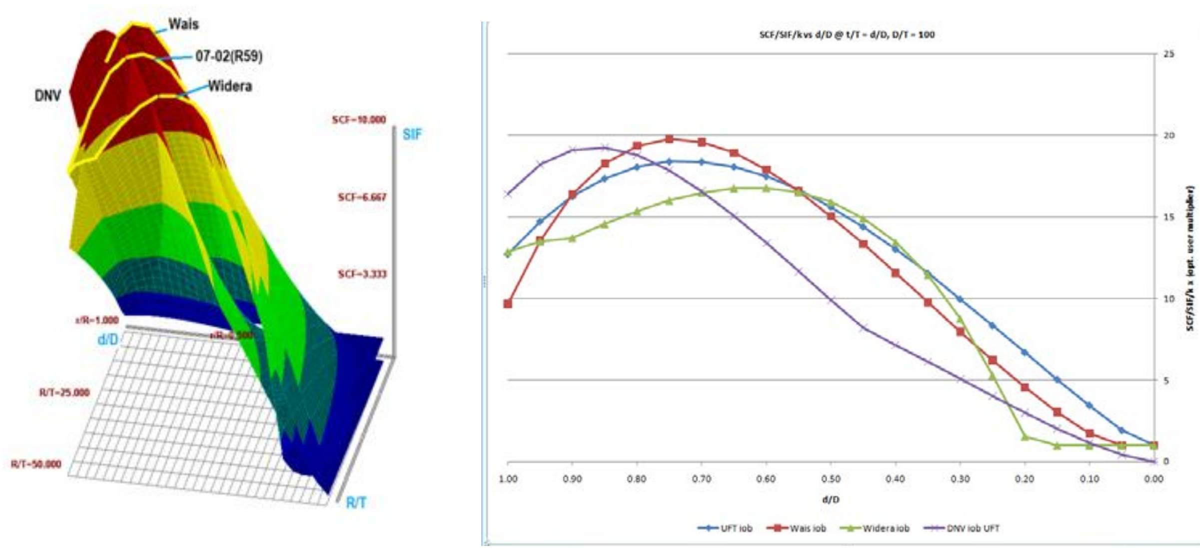


Figure 3-11: In-Plane i-factor Surfaces And Finite Element Data Points For Thru-Run (Left) and Thru-Branch (Right) Loads On Unreinforced Branch Connections. (SCF In These Plots Is The Stress Intensification Factor.)

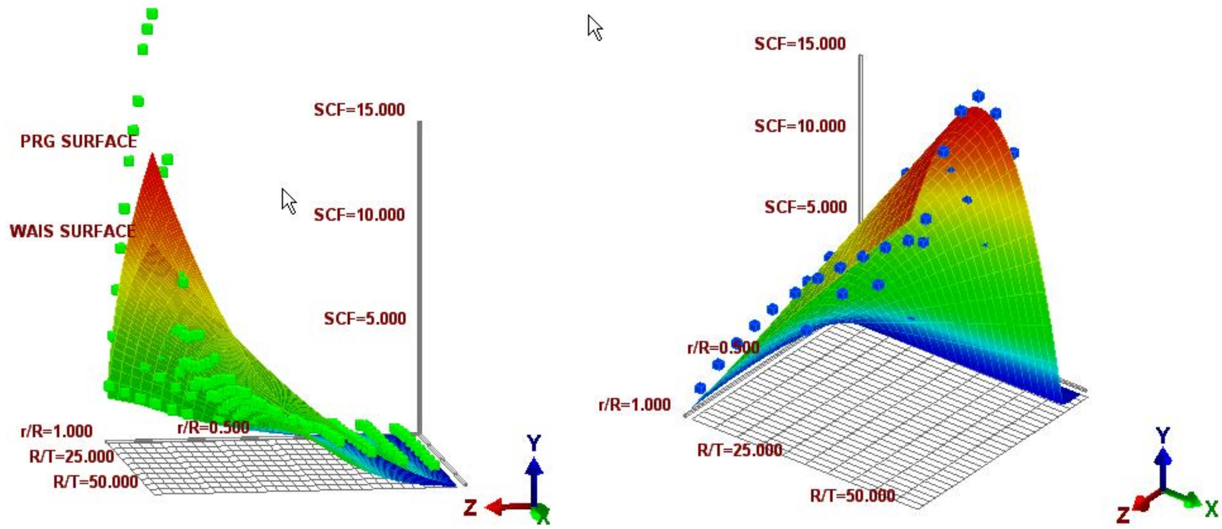
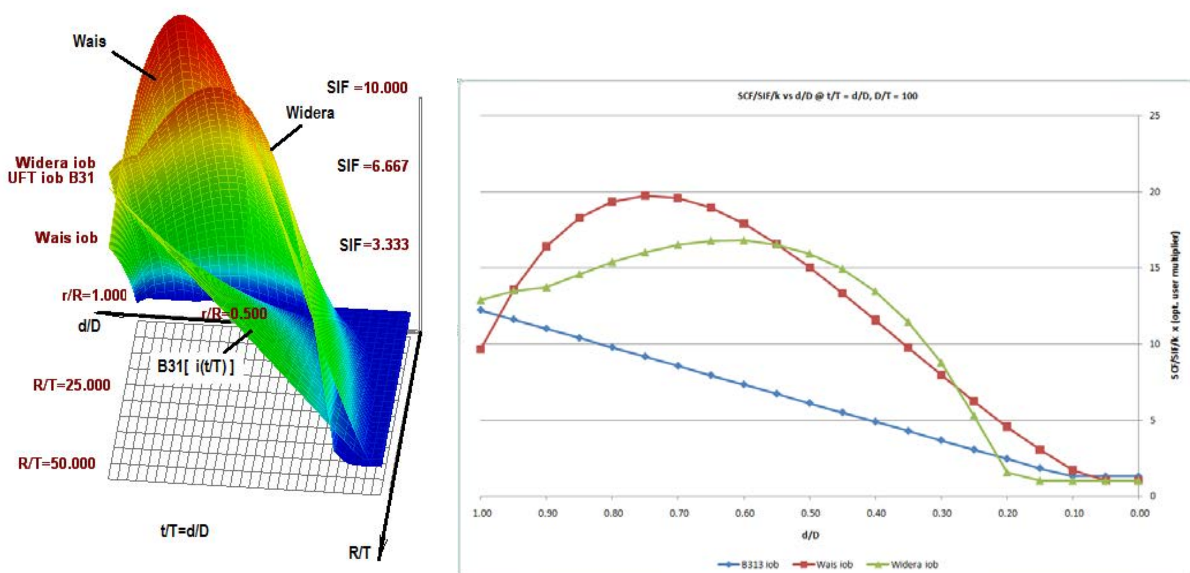


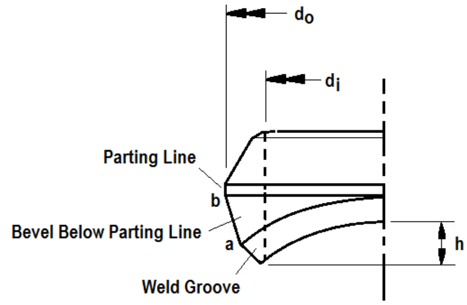
Figure 3-12: Out-of-Plane Branch i-factor for Unreinforced Fabricated Tee (Sketch 2.3), Wais [10], Widera [14], B31



3.11 Sketch 2.6 Geometry of Integrally Reinforced Branch Welded-On Fittings

Welded-On Fittings (Sketch 2.6) have the general geometry shown below when viewed in the circumferential plane.

Figure 3-13: Integrally Reinforced Branch Welded-On Fitting Profile in Circumferential Plane (Sketch 2.6)



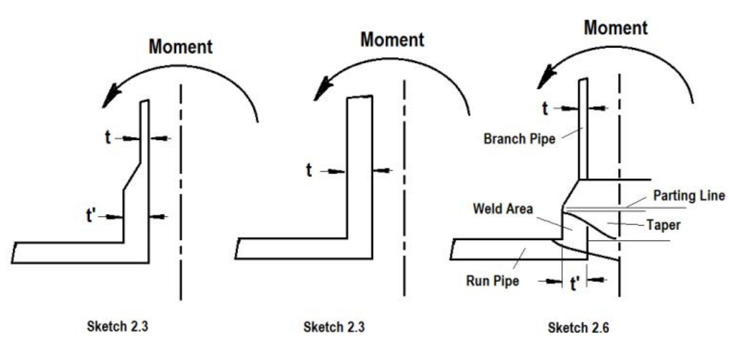
For Sketch 2.6 fittings with larger d/D ratios the bevel below the parting line in the circumferential plane may reduce the fitting thickness available for pressure containment in the circumferential plane in the vicinity of the weld to the run pipe such that it is smaller than the wall thickness of the attached matching branch pipe. Some discussion of the various weld profiles that can be accommodated by Sketch 2.6 fittings in the circumferential plane are discussed by Rodabaugh and Woods [22].

As the d/D ratio gets smaller the possible thickness reduction in the circumferential plane also gets smaller and the bevel below the parting line vanishes. Below the parting line for small d/D Sketch 2.6 branch connections the welded on fitting profile in the circumferential plane is similar to that of a typical thickened straight nozzle body. The dimension d_i shown in Figure 3-13 above is equal to the inside diameter of the matching pipe, and the outside diameter, (while not controlled by an MSS, ASTM or ASME standard), is often approximately the dimension X in Table 14 of ASEM B16.5 Pipe Flanges and Flanged Fittings.

For Sketch 2.6 welded outlet fittings it is expected that the i-factors and k-factors converge to those for Sketch 2.3 with a thickened, straight barrel length as described in Annex B Fig. 5 as the d/D ratio gets smaller. In this case, the stress is independent of the thickness of the attached branch pipe. Sketch 2.6 i-factor equations reflect this. In no case can the i-factor applied to the matching branch pipe be less than 1.0.

Some Sketch 2.6 welded outlet fittings do not follow the profile shown in the figure above. Generally in these cases, the outside diameter of the fitting is larger and the inner bore is tapered. Comparable, or improved behavior is expected in this case due in part to the larger footprint caused by the increased outside diameter. Available i-factor tests suggest that these larger fittings do have smaller i-factors. The larger fittings are not thought common for new construction however since the smaller Sketch 2.6 fittings are more economical and provide the same pressure capacity.

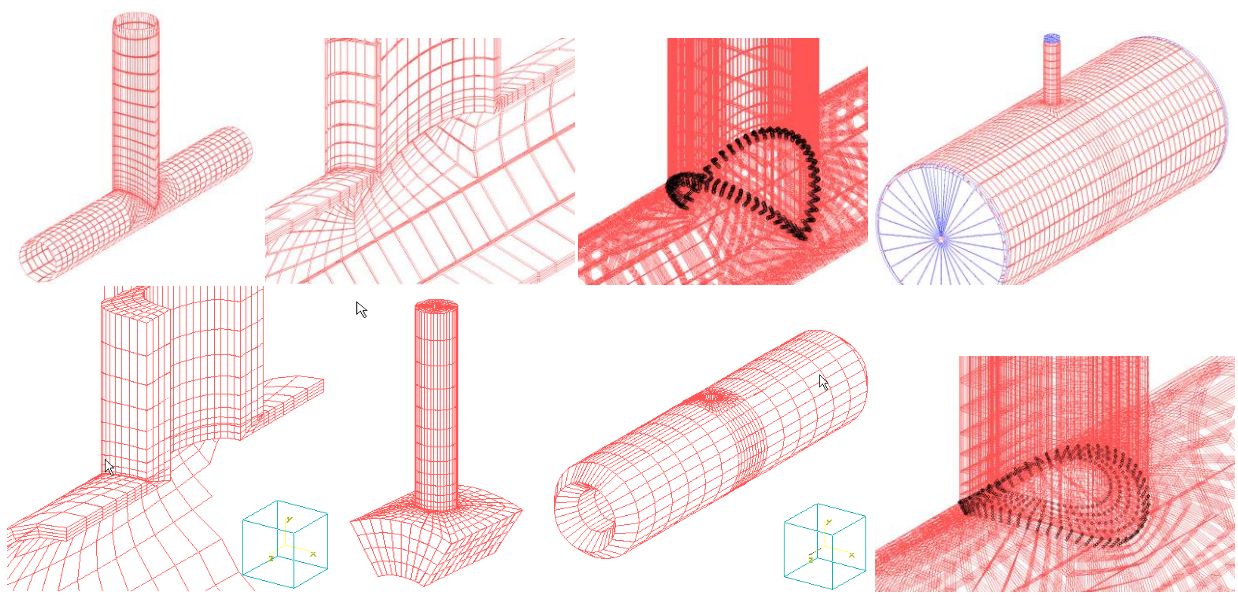
Figure 3-14: Geometric Similarities between Sketches 2.3 and 2.6 when d/D < 0.5



3.12 Finite Element Models

A variety of shell and brick finite element models were constructed for thi report to augment finite element results found in the literature,[14][30][31][32][33]. FE/Pipe Version 6.0 was used for the majority of the finite element modeling. Shell elements are of the eight-noded, doubly curved, reduced integration type, and brick elements are eight-noded with non-compatible displacement shapes. FE/Pipe is a convenient tool because the only basic input required is the geometry of the branch connection. FE/Pipe automatically extracts stress classification lines from branch connection intersection geometries, and develops contoured shell and brick intersection models with varying thicknesses that can be used to approximate B16.9 welding tee or other contoured geometries. Brick finite element SCL membrane and bending stress intensities were compared to shell membrane and bending stress intensities to verify the equation results when the equation dimensionless parameters become smaller and the i- and k-factors go to 1. Linear elastic analyses are used although some additional nonlinear elastic-plastic calculations are planned. Several example finite element models are shown below.

Figure 3-15: Example Brick Finite Element Geometries.



SCLs Are Shown In Two Models. One SCL Is Taken For Each Node Row Around Both The Nozzle And Through The Run, Normal To The Surface.

Figure 3-16: Example Contoured Shell Element Finite Element Models and Small d/D Intersections. Two Contour Shaded Intersections Show the Thickness Profiles Used In the B16.9 Welding Tee Models.

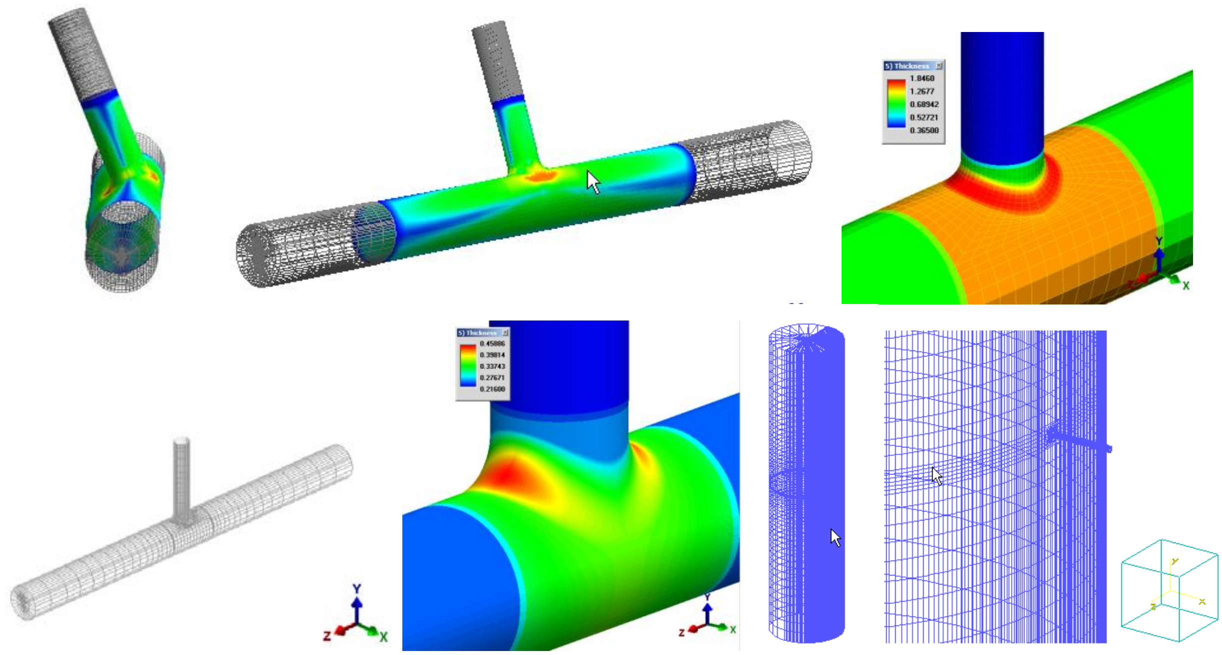
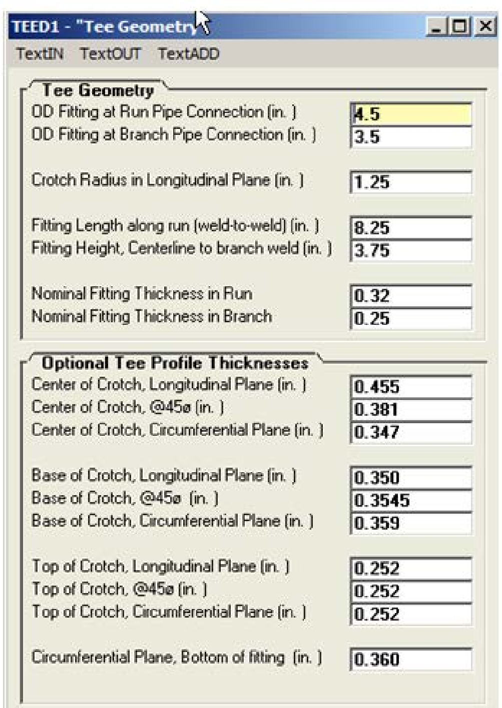


Figure 3-17: Finite Element Model Input for Contoured Branch Connections (Left), and Stress Classification Line Output for Volumetric Models



Maximum Values for This Load Case:

	Membrane	Bending	M+B(in)	M+B(out)	Region
Max Membrane	15104.21	2512.71	15103.43	15149.69	401
Max Bending	3936.43	17530.49	20492.68	15407.36	553
Max M+B(in)	4048.80	17240.90	20701.32	14100.67	555
Max M+B(out)	11428.70	11844.27	13668.84	18337.04	405

REGION = 555

Node	Sxx	Syy	Szz	Txy	Tyz	Txz (Global)
5286	-2344.8	-228.4	-8437.6	-422.1	-3037.6	-674.8
5340	1857.1	1316.7	-1293.5	-56.9	-1760.1	-671.3
5394	5648.6	3398.3	4740.9	416.7	-829.2	-21.9
5448	9294.5	4185.4	12046.1	1213.2	324.1	1215.4
5502	18687.9	14442.0	29428.8	3034.6	2088.8	8605.6

Node	Sxx	Syy	Szz	Txy	Tyz	Txz (Local)
5286	-149.4	-2440.8	-8420.6	-988.7	-1193.1	-2718.0
5340	1348.3	2051.7	-1519.7	-464.0	-364.0	-1569.5
5394	3324.4	5696.7	4766.8	-335.8	-219.8	-744.0
5448	3933.5	9029.0	12563.5	-278.9	-72.7	244.8
5502	13595.8	14859.7	34103.2	-1809.9	-3136.4	1450.5

	Membrane	Bending	M+B(in)	M+B(out)
SXX	3832.34	0.00	3832.34	3832.34
SYY	5746.67	7482.22	13228.89	-1735.54
SZZ	7162.94	17240.90	24403.84	-10077.97
Txy	-619.49	0.00	-619.49	-619.49
Tyz	-705.33	0.00	-705.33	-705.33
Txz	-675.64	0.00	-675.64	-675.64
SUM	4048.80	17240.90	20701.32	14100.67

Thru Thickness =	-0.1592	0.9873	0.0000
Normal Direction =	-0.9196	-0.1483	0.3639
Normal Direction =	0.3593	0.0579	0.9314

3.13 Markl Data

Chris Hinnant scanned and digitized the fatigue data in a number of the Markl [27] test figures to improve the accuracy of the extracted data points. For reference, that data is included in tables and plots in Figures 3-18 thru 2-22.

Figure 3-18: Markl [27] Fatigue Tests and Data of Piping Components & Data, 1952 ASME Transactions

Source:	Fatigue Tests of Piping Components					
Author:	A.R.C Markl					
Published:	1952 ASME Transactions					
Specimen	Figure	Bend Type	Loading Direction	Nf	Alternating M/Z	Range (M/Z)
				Cycles	psi	
4" STD WT 90 Deg Bend	6	Short Radius	In-Plane	293	50548	101095.0743
4" STD WT 90 Deg Bend	6	Short Radius	In-Plane	369	49091	98181.57523
4" STD WT 90 Deg Bend	6	Short Radius	In-Plane	1187	28807	57614.261
4" STD WT 90 Deg Bend	6	Short Radius	In-Plane	1453	27778	55555.87546
4" STD WT 90 Deg Bend	6	Short Radius	In-Plane	1605	28412	56823.7637
4" STD WT 90 Deg Bend	6	Short Radius	In-Plane	2834	27008	54016.94217
4" STD WT 90 Deg Bend	6	Short Radius	In-Plane	5476	17362	34724.01984
4" STD WT 90 Deg Bend	6	Short Radius	In-Plane	6937	20606	41212.59827
4" STD WT 90 Deg Bend	6	Short Radius	In-Plane	8316	17033	34066.69448
4" STD WT 90 Deg Bend	6	Short Radius	In-Plane	9515	17231	34461.16821
4" STD WT 90 Deg Bend	6	Short Radius	In-Plane	18841	15272	30544.28727
4" STD WT 90 Deg Bend	6	Short Radius	In-Plane	228981	8857	17714.54475
4" STD WT 90 Deg Bend	6	Short Radius	In-Plane	256389	9055	18110.48145
4" STD WT 90 Deg Bend	6	Short Radius	In-Plane	862780	5818	11636.70422
4" STD WT 90 Deg Bend	6	Short Radius	In-Plane	1124864	5444	10887.54582
4" STD WT 90 Deg Bend	6	Short Radius	In-Plane	1176522	5793	11585.90587
4" STD WT 90 Deg Bend	6	Short Radius	In-Plane	1637948	5706	11411.16528
4" STD WT 90 Deg Bend	8	Long Radius	In-Plane	6167	24367	48733.76847
4" STD WT 90 Deg Bend	8	Long Radius	In-Plane	7049	21928	43856.09871
4" STD WT 90 Deg Bend	8	Long Radius	In-Plane	8429	22105	44210.96513
4" STD WT 90 Deg Bend	8	Long Radius	In-Plane	10000	19783	39566.71508
4" STD WT 90 Deg Bend	8	Long Radius	In-Plane	17636	17334	34668.09641
4" STD WT 90 Deg Bend	8	Long Radius	In-Plane	21852	17567	35134.19405
4" STD WT 90 Deg Bend	8	Long Radius	In-Plane	36408	14652	29304.2085
4" STD WT 90 Deg Bend	8	Long Radius	In-Plane	50489	15527	31054.89003
4" STD WT 90 Deg Bend	8	Long Radius	In-Plane	89536	14771	29541.32671
4" STD WT 90 Deg Bend	8	Long Radius	In-Plane	614469	7716	15432.27649
4" STD WT 90 Deg Bend	8	Long Radius	In-Plane	921510	7364	14727.5327

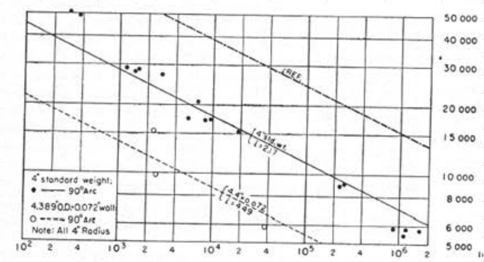


FIG. 6 SHORT-RADIUS ELBOWS, IN PLANE

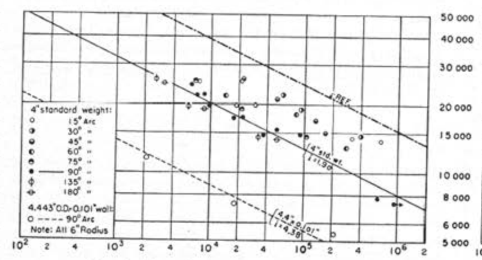


FIG. 8 LONG-RADIUS ELBOWS, IN PLANE

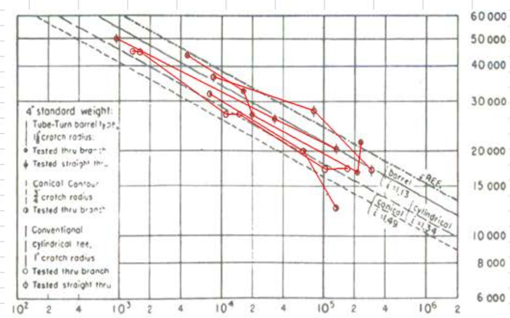
Source	Notes	Do in	T in	do in	t in	Direction	Loaded Thru	Failure Cycles N	M/Z Alt. psi	M/Z Range ksi	Markl SIF
Markl	4" Std Weight Through Branch	4.500	0.237	4.500	0.237	In Plane	Branch	7231	19724	39.448	2.101
Markl	4" Std Weight Through Branch	4.500	0.237	4.500	0.237	In Plane	Branch	8506	19720	39.439	2.034
Markl	4" Std Weight Through Branch	4.500	0.237	4.500	0.237	In Plane	Branch	25206	12948	25.896	2.493
Markl	4" Std Weight Through Branch	4.500	0.237	4.500	0.237	In Plane	Branch	28093	13125	26.250	2.406
Markl	4" Std Weight Through Branch	4.500	0.237	4.500	0.237	In Plane	Branch	28602	15798	31.596	1.992
Blair	6.5" OD x 0.26" Wall, Branch Set On	6.500	0.260	6.500	0.260	In Plane	Branch	31254	8676	17.351	3.564
Markl	4" Std Weight Through Branch	4.500	0.237	4.500	0.237	In Plane	Branch	32734	13146	26.292	2.330
Markl	4" Std Weight Through Branch	4.500	0.237	4.500	0.237	In Plane	Branch	34650	13152	26.304	2.303
Markl	4" Std Weight Through Branch	4.500	0.237	4.500	0.237	In Plane	Branch	87720	9917	19.835	2.536
Markl	4.489" OD x 0.203" Wall	4.489	0.203	4.489	0.203	In Plane	Branch	147299	7389	14.778	3.068
Markl	4" Std Weight Through Branch	4.500	0.237	4.500	0.237	In Plane	Branch	157761	8732	17.463	2.561
Markl	4" Std Weight Through Branch	4.500	0.237	4.500	0.237	In Plane	Branch	245584	8630	17.260	2.372
Markl	4" Std Weight Through Branch	4.500	0.237	4.500	0.237	In Plane	Branch	255682	8710	17.419	2.331
Blair	6.5" OD x 0.26" Wall, Branch Set On	6.500	0.260	6.500	0.260	In Plane	Branch	494083	4247	8.494	4.191
Blair	6.5" OD x 0.26" Wall, Branch Set On	6.500	0.260	6.500	0.260	In Plane	Branch	517607	4787	9.575	3.684
Blair	6.5" OD x 0.26" Wall, Branch Set In	6.500	0.260	6.500	0.260	In Plane	Branch	653732	4855	9.710	3.466
Blair	6.5" OD x 0.26" Wall, Branch Set In	6.500	0.260	6.500	0.260	In Plane	Branch	694225	4920	9.841	3.380

Markl Ref. [27] Figure 14.

Figure 3-19: Markl [27] Fatigue Tests of Piping Components & Data, ASME Paper No. 51-PET-21

Fatigue Test of Piping Components
ARC Markl
ASME Paper No. 51-PET-21

Paper Figure No.	log(N) (by AutoCAD)	log(S) (by AutoCAD)	Direction	Loaded Thru	Type	Crotch Radius	Thickness inches	Failure Cycles	(M/Z) Alternating ksi
10	3.6652	4.64	In Plane	Branch	Tube Turns Barrel	1.125	0.237	4626	43652
10	4.2133	4.5134	In Plane	Branch	Tube Turns Barrel	1.125	0.237	16342	32614
10	4.2996	4.4288	In Plane	Branch	Tube Turns Barrel	1.125	0.237	19934	26841
10	5.3302	4.2247	In Plane	Branch	Tube Turns Barrel	1.125	0.237	213895	16776
10	5.3639	4.3311	In Plane	Branch	Tube Turns Barrel	1.125	0.237	231153	21434
10	2.9699	4.7001	In Plane	Run	Tube Turns Barrel	1.125	0.237	933	50130
10	4.5216	4.4147	In Plane	Run	Tube Turns Barrel	1.125	0.237	33235	25984
10	5.1246	4.3072	In Plane	Run	Tube Turns Barrel	1.125	0.237	133229	20286
10	3.8825	4.5028	In Plane	Branch	Conical contour	0.75	0.237	7630	31827
10	4.7986	4.3006	In Plane	Branch	Conical contour	0.75	0.237	62893	19980
10	5.1206	4.0992	In Plane	Branch	Conical contour	0.75	0.237	132008	12566
10	3.1295	4.6535	In Plane	Branch	Conventional cylindrical tee	1	0.237	1347	45030
10	3.2015	4.6513	In Plane	Branch	Conventional cylindrical tee	1	0.237	1590	44802
10	4.0433	4.4304	In Plane	Branch	Conventional cylindrical tee	1	0.237	11048	26940
10	4.1741	4.431	In Plane	Branch	Conventional cylindrical tee	1	0.237	14931	26977
10	5.014	4.2354	In Plane	Branch	Conventional cylindrical tee	1	0.237	103276	17195
10	5.2346	4.2374	In Plane	Branch	Conventional cylindrical tee	1	0.237	171633	17274
10	3.9219	4.5623	In Plane	Run	Conventional cylindrical tee	1	0.237	8354	36501
10	4.9046	4.4425	In Plane	Run	Conventional cylindrical tee	1	0.237	80279	27701
10	5.472	4.2326	In Plane	Run	Conventional cylindrical tee	1	0.237	296483	17084
11	3.068	4.6501	Out of Plan	Branch	Tube Turns Barrel	1.125	0.237	1169	44679
11	3.6264	4.632	Out of Plan	Branch	Tube Turns Barrel	1.125	0.237	4231	42855
11	4.0989	4.4351	Out of Plan	Branch	Tube Turns Barrel	1.125	0.237	12557	27233
11	4.3981	4.4232	Out of Plan	Branch	Tube Turns Barrel	1.125	0.237	25009	26497
11	4.9892	4.239	Out of Plan	Branch	Tube Turns Barrel	1.125	0.237	97544	17338
11	5.225	4.2731	Out of Plan	Branch	Tube Turns Barrel	1.125	0.237	167880	18754
11	3.2086	4.7181	Out of Plan	Run	Tube Turns Barrel	1.125	0.237	1617	52252
11	4.4157	4.4096	Out of Plan	Run	Tube Turns Barrel	1.125	0.237	26044	25680
11	4.9592	4.2992	Out of Plan	Run	Tube Turns Barrel	1.125	0.237	91033	19916
11	3.3229	4.3986	Out of Plan	Branch	Conical contour	0.75	0.237	2103	25038
11	4.7638	4.1833	Out of Plan	Branch	Conical contour	0.75	0.237	58050	15251
11	5.7399	3.9855	Out of Plan	Branch	Conical contour	0.75	0.237	549414	9672
11	2.7731	4.6483	Out of Plan	Branch	Conventional cylindrical tee	1	0.237	593	44494
11	2.9596	4.6414	Out of Plan	Branch	Conventional cylindrical tee	1	0.237	911	43793
11	3.7461	4.3396	Out of Plan	Branch	Conventional cylindrical tee	1	0.237	5573	21857
11	4.2028	4.329	Out of Plan	Branch	Conventional cylindrical tee	1	0.237	15951	21330
11	5.5122	4.0684	Out of Plan	Branch	Conventional cylindrical tee	1	0.237	325237	11706
11	5.7815	4.0458	Out of Plan	Branch	Conventional cylindrical tee	1	0.237	604644	11112
11	3.9339	4.525	Out of Plan	Run	Conventional cylindrical tee	1	0.237	8588	33497
11	4.6421	4.4541	Out of Plan	Run	Conventional cylindrical tee	1	0.237	43863	28451
11	5.0156	4.1558	Out of Plan	Run	Conventional cylindrical tee	1	0.237	103657	14315



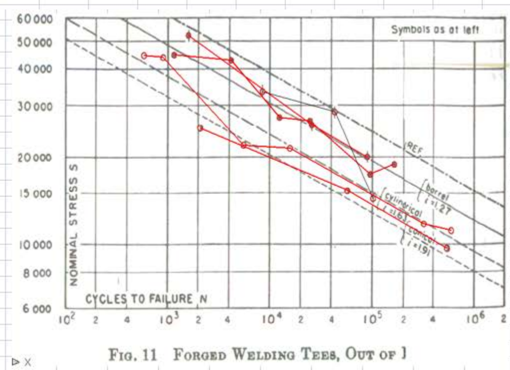


Figure 3-20: Markl [27] Fatigue Data of Piping Components, ASME Paper No. 51-PET-21, Chart 1

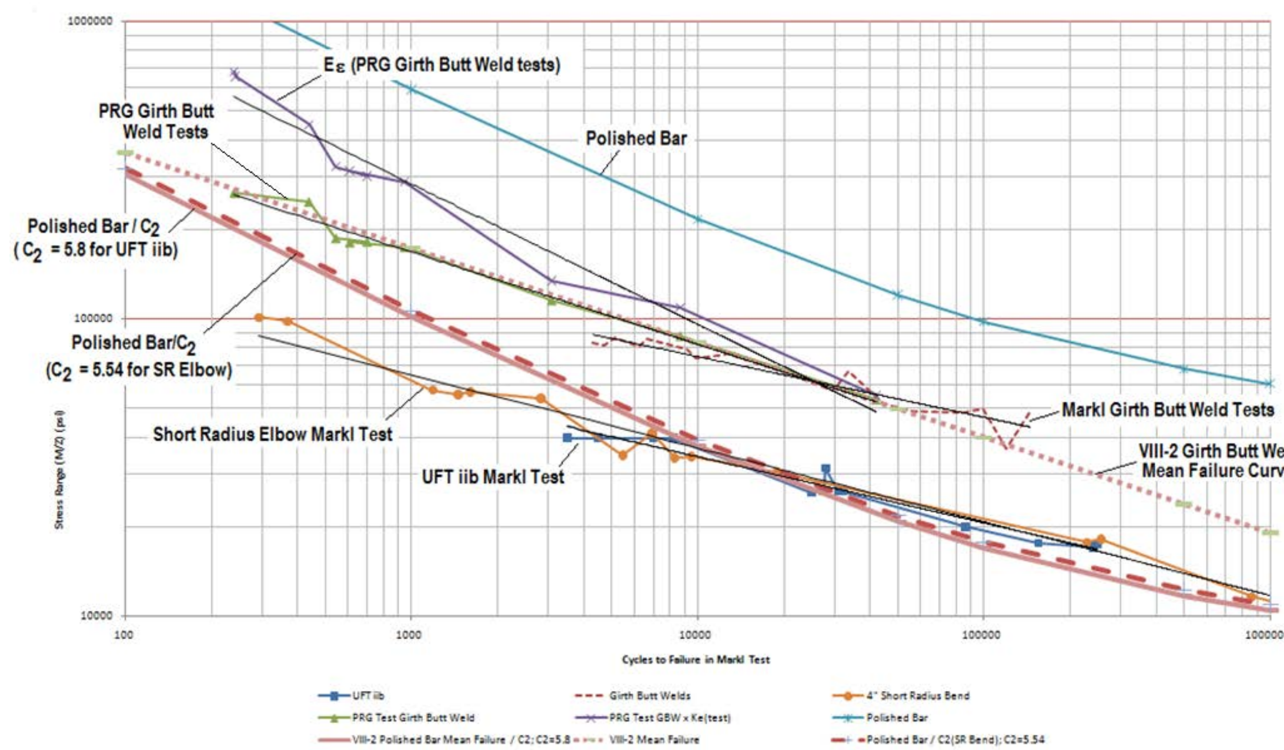


Figure 3-21: Markl [27] Fatigue Data of Piping Components, ASME Paper No. 51-PET-21, Chart 2

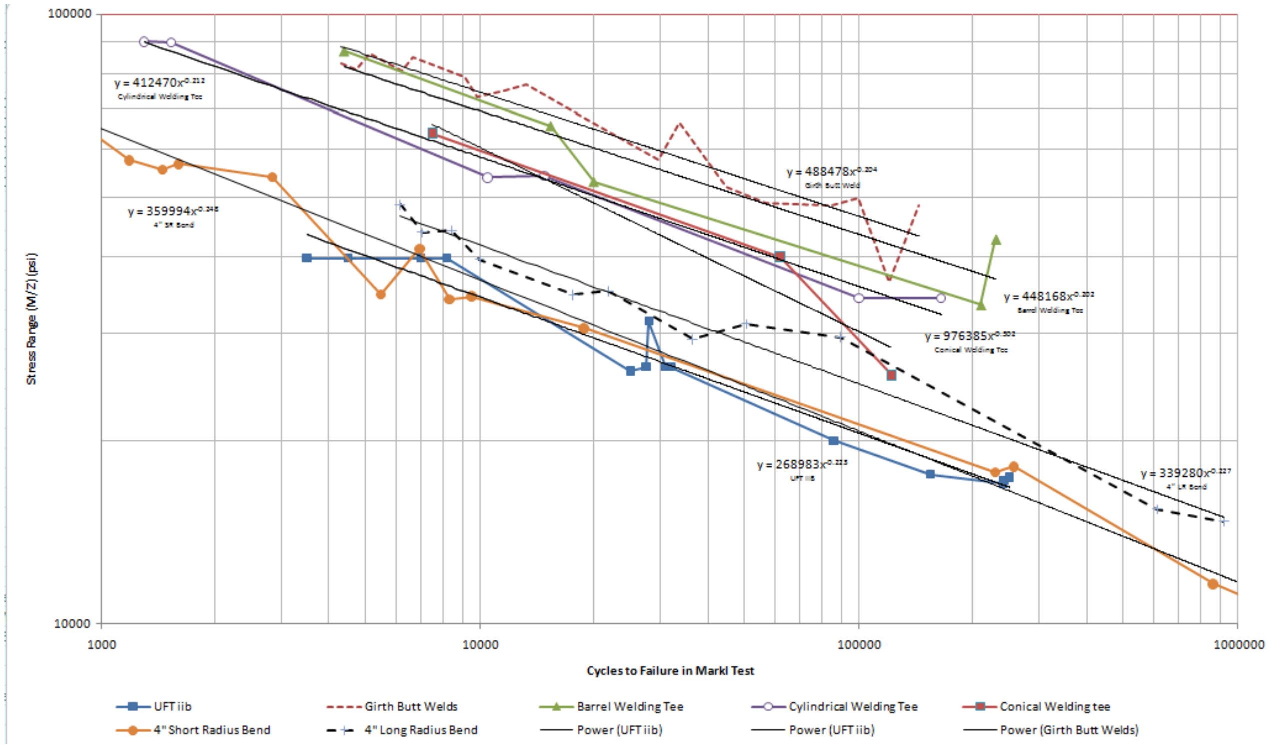
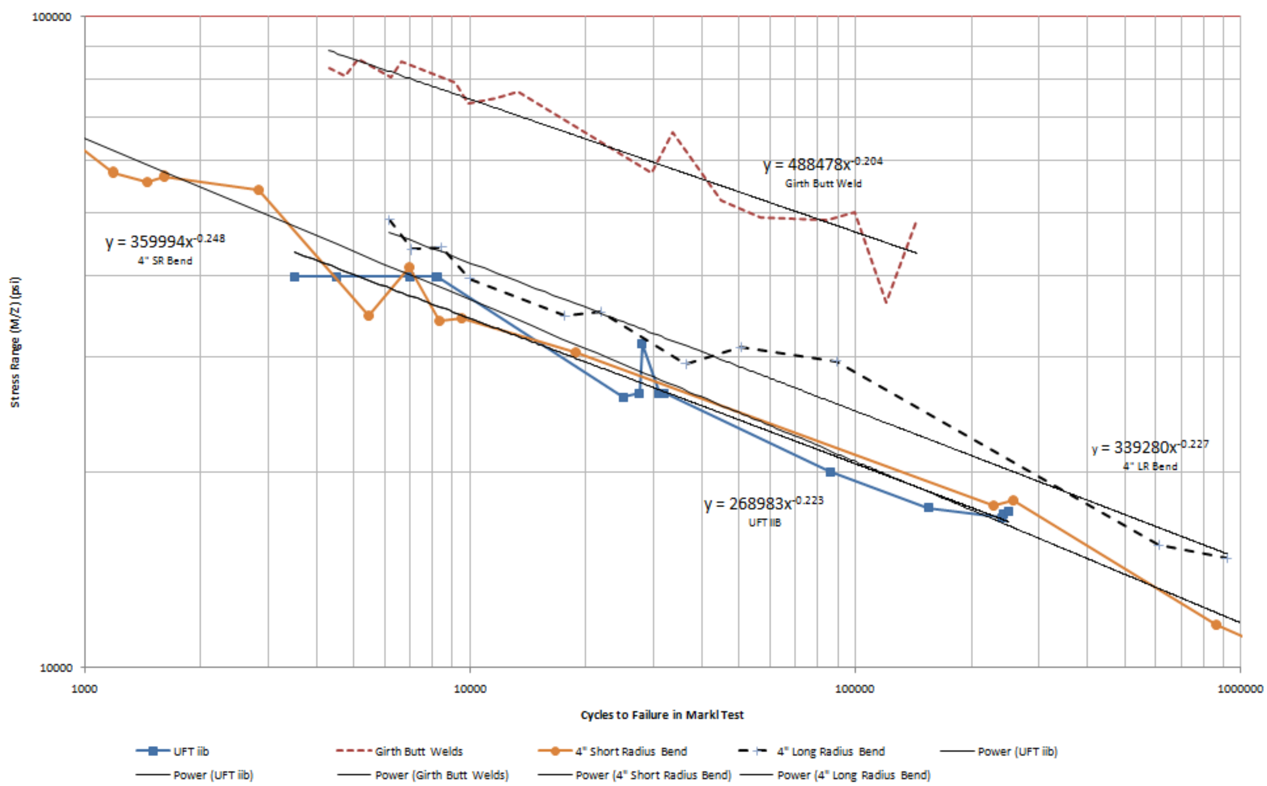


Figure 3-22: Markl [27] Fatigue Data of Piping Components, ASME Paper No. 51-PET-21, Chart 3



ANNEX A

Annex A – Recommendations (Formatted as Appendices to B31J)

- **Nonmandatory Appendix B** – Flexibility and Stress Intensification Factors *(Recommended for B31J)*
- **Nonmandatory Appendix C** – Example Use of Branch Connection Flexibility Factors *(Recommended for B31J)*
- **Nonmandatory Appendix D** – Calculating Flexibility Factors for Branch Connections *(Recommended for B31J)*

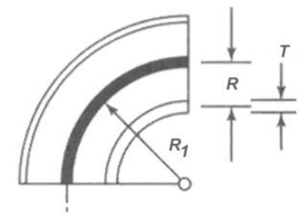
NONMANDATORY APPENDIX B

Flexibility and Stress Intensification Factors for Piping and Piping Components

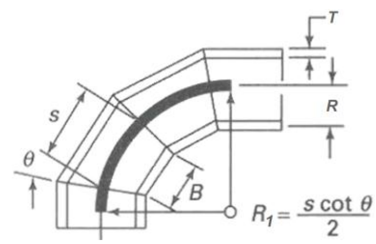
Contents

Table 1 – Flexibility and Stress Intensification Factors [Notes (1),(2),(4)]

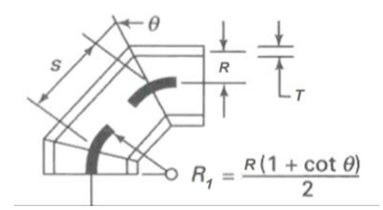
Sketch No. 1.1		
Welding elbow or pipe bend per ASME B16.9	[Notes (3),(5),(6),(7)]	Sketch
Flexibility Characteristic, h	TR_1/R^2	
Flexibility Factor In-plane, k_i	$1.65/h$	
Flexibility Factor Out-of-plane, k_o	$1.65/h$	
SIF In-plane, i_i	$0.9/h^{2/3}$	
SIF Out-of-plane, i_o	$0.75/h^{2/3}$	
SIF Torsional, i_t	1	

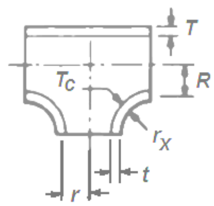
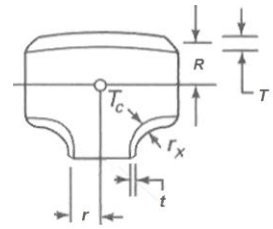


Sketch No. 1.2		
Closely spaced miter bend $s < R(1 + \tan\theta)$	[Notes (3),(5),(7)]	Sketch
Flexibility Characteristic, h	$sT \cot\theta/(2R^2)$	
Flexibility Factor In-plane, k_i	$1.52/h^{5/6}$	
Flexibility Factor Out-of-plane, k_o	$1.52h^{5/6}$	
SIF In-plane, i_i	$0.9/h^{2/3}$	
SIF Out-of-plane, i_o	$0.9/h^{2/3}$	
SIF Torsional, i_t	1	

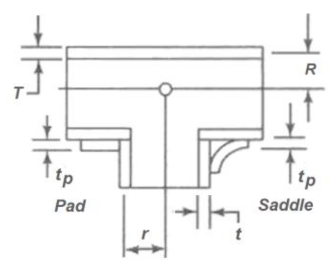


Sketch No. 1.3		
Widely spaced miter bend $s \geq R(1 + \tan\theta)$	[Notes (3),(7),(8)]	Sketch
Flexibility Characteristic, h	$T (1 + \cot\theta)/(2R)$	
Flexibility Factor In-plane, k_i	$1.52/h^{5/6}$	
Flexibility Factor Out-of-plane, k_o	$1.52/h^{5/6}$	
SIF In-plane, i_i	$0.9/h^{2/3}$	
SIF Out-of-plane, i_o	$0.9/h^{2/3}$	
SIF Torsional, i_t	1	

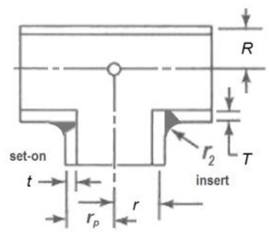
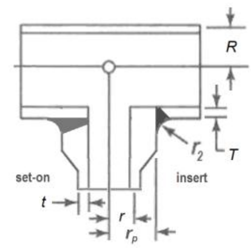
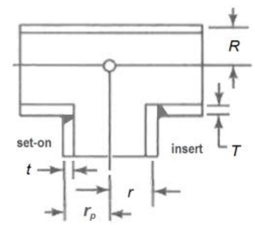


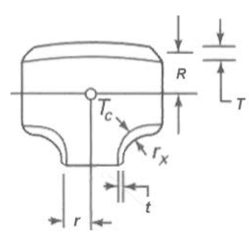
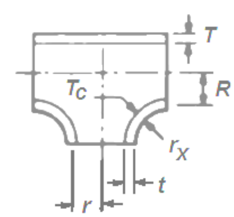
Sketch No. 2.1	Sketch	
Welding tee per ASME B16.9 [Notes (3),(9),(10)]		

Term	**Equation**
Run In-plane Flexibility Factor, k_{ir}	$0.18\ (R/T)^{0.8}\ (d/D)^{5}$
Run Out-of-plane Flexibility Factor, k_{or}	1
Run Torsional Flexibility Factor, k_{tr}	$0.08\ (R/T)^{0.91}\ (d/D)^{5.7}$
Branch In-plane Flexibility Factor, k_{ib}	$(1.91(d/D) - 4.32(d/D)^2 + 2.7(d/D)^3)\ (R/T)^{0.77}\ (d/D)^{0.47}\ (t/T)$
Branch Out-of-plane Flexibility Factor, k_{ob}	$(0.34\ (d/D) - 0.49(d/D)^2 + 0.18(d/D)^3)\ (R/T)^{1.46}\ (t/T)$
Branch Torsional Flexibility Factor, k_{tb}	$(1.08(d/D) - 2.44(d/D)^2 + 1.52(d/D)^3)\ (R/T)^{0.77}\ (d/D)^{1.61}\ (t/T)$
Run SIF In-plane, i_{ir}	$0.98\ (R/T)^{0.35}\ (d/D)^{0.72}\ (t/T)^{-0.52}$
Run SIF Out-of-plane, i_{or}	$0.61\ (R/T)^{0.29}\ (d/D)^{1.95}\ (t/T)^{-0.53}$
Run SIF Torsional, i_{tr}	$0.34\ (R/T)^{2/3}\ (d/D)\ (t/T)^{-0.5}$
Branch SIF In-plane, i_{ib}	$0.33\ (R/T)^{2/3}\ (d/D)^{0.18}\ (t/T)^{0.7}$
Branch SIF Out-of-plane, i_{ob}	$0.42\ (R/T)^{2/3}\ (d/D)^{0.37}\ (t/T)^{0.37}$
Branch SIF Torsional, i_{tb}	$0.42\ (R/T)^{2/3}\ (d/D)^{1.1}\ (t/T)^{1.1}$

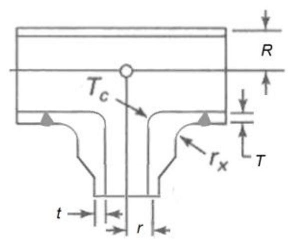
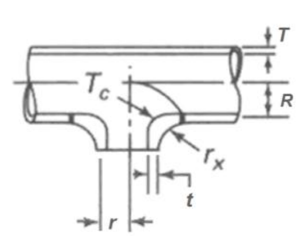
Sketch No. 2.2	Sketch
Reinforced fabricated tee [Notes (3),(10)] (when t_p>1.5T use t_p=1.5T)	

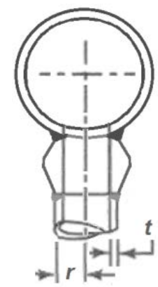
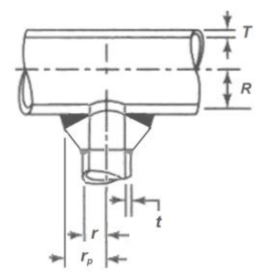
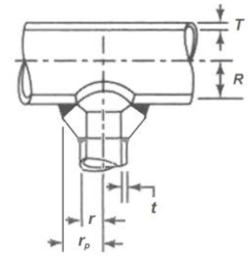
Term	**Equation**
Run In-plane Flexibility Factor, k_{ir}	$0.21\ (R / [T+0.5t_p])^{0.97}\ (t/T)^{-0.65}\ (d/D)^{6.2}$
Run Out-of-plane Flexibility Factor, k_{or}	1
Run Torsional Flexibility Factor, k_{tr}	$0.12\ (R / [T+0.5t_p])^{1.39}\ (t/T)^{-0.74}\ (d/D)^{8.5}$
Branch In-plane Flexibility Factor, k_{ib}	$(1.29(d/D) - 2.73(d/D)^2 + 1.62(d/D)^3)\ (R / [T+0.5t_p])^{1.2}\ (t/T)^{0.56}\ (d/D)^{0.33}$
Branch Out-of-plane Flexibility Factor, k_{ob}	$(0.84(d/D) - 1.27(d/D)^2 + 0.5(d/D)^3)\ (R / [T+0.5t_p])^{1.69}\ (t/T)^{0.68}\ (d/D)^{0.21}$
Branch Torsional Flexibility Factor, k_{tb}	$1.1\ (R / [T+0.5t_p])^{0.5}\ (d/D)^{5.42}$
Run SIF In-plane, i_{ir}	$(R / [T+0.5t_p])^{0.45}\ (d/D)^{0.54}\ (t/T)^{-0.34} \geq 1.5$
Run SIF Out-of-plane, i_{or}	$(1.29(d/D) - 2.87(d/D)^2 + 2.39(d/D)^3)\ (t/T)^{-0.25}\ (R / [T+0.5t_p])^{0.35}$
Run SIF Torsional, i_{tr}	$0.36\ (R / [T+0.5t_p])^{2/3}\ (t/T)^{-0.6}\ (d/D)^{1.4}$
Branch SIF In-plane, i_{ib}	$(3.33(d/D) - 5.49(d/D)^2 + 2.94(d/D)^3)\ (TR^{2/3})\ (T+0.5t_p)^{-5/3}\ (t/T)^{0.3}$
Branch SIF Out-of-plane, i_{ob}	$(2.86(d/D) + 2.4(d/D)^2 - 4.34(d/D)^3)\ (TR^{2/3})\ (T+0.5t_p)^{-5/3}\ (t/T)^{0.3}$ (when t/T < 0.85 use t/T= 0.85)
Branch SIF Torsional, i_{tb}	$0.642\ (d/D)^2\ (TR^{2/3})\ (T+0.5t_p)^{-5/3}\ (t/T)^{0.3}$

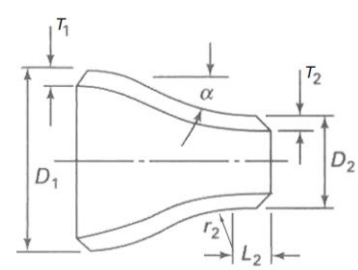
Sketch No. 2.3	Sketch
Fabricated tee [Notes (3),(10),(11)]	  
Term	**Equation**
Run In-plane Flexibility Factor, k_{ir}	$1.23\ (R/T)^{0.47}\ (t/T)^{-0.47}\ (d/D)^{5.3}$
Run Out-of-plane Flexibility Factor, k_{or}	1
Run Torsional Flexibility Factor, k_{tr}	$(R/T)^{0.78}\ (t/T)^{-0.8}(d/D)^{7.8}$
Branch In-plane Flexibility Factor, k_{ib}	$(3.15(d/D) - 6.4(d/D)^2 + 4(d/D)^3)\ (R/T)^{0.83}\ (t/T)^{0.49}\ (d/D)^{-0.2}$
Branch Out-of-plane Flexibility Factor, k_{ob}	$(2.05(d/D) - 2.94(d/D)^2 + 1.1(d/D)^3)\ (R/T)^{1.4}\ (t/T)^{0.6}(d/D)^{0.12}$
Branch Torsional Flexibility Factor, k_{tb}	$0.95\ (R/T)^{0.83}\ (d/D)^{5.42}$
Run SIF In-plane, i_{ir}	$1.2(d/D)^{0.5}\ (R/T)^{0.4}\ (t/T)^{-0.35} \geq 1.5$
Run SIF Out-of-plane, i_{or}	$(\ d/D - 2.7(d/D)^2 + 2.62(d/D)^3)\ (R/T)^{0.43}\ (t/T)^{-0.7}$ (when $d/D < 0.5$ use $d/D = 0.5$; when $t/T < 0.5$ use $t/T = 0.5$)
Run SIF Torsional, i_{tr}	$1.2\ (R/T)^{0.46}\ (t/T)^{-0.45}(d/D)^{1.37}$ (when $t/T < 0.15$ use $t/T= 0.15$)
Branch SIF In-plane, i_{ib}	$(0.038 + 1.45(d/D) - 2.39(d/D)^2 + 1.34(d/D)^3)\ (R/T)^{0.76}\ (t/T)^{0.74}$
Branch SIF Out-of-plane, i_{ob}	$(0.038 + 2(d/D) + 2(d/D)^2 - 3.1(d/D)^3)\ (R/T)^{2/3}\ (t/T)$ (when $t/T < 0.85$ use $t/T=0.85$)
Branch SIF Torsional, i_{tb}	$0.45\ (R/T)^{0.8}\ (t/T)^{0.29}\ (d/D)^2$

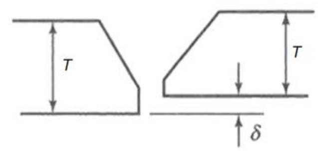
Sketch No. 2.4	Sketch
Extruded outlet with $r_x \geq 0.05d_o$ $T < T_c < 1.5T$ [Notes (3),(10),(16)]	 
Term	**Equation**
Run In-plane Flexibility Factor, k_{ir}	$0.18\ (R/T)^{0.8}\ (d/D)^5$
Run Out-of-plane Flexibility Factor, k_{or}	1
Run Torsional Flexibility Factor, k_{tr}	$0.08\ (R/T)^{0.91}\ (d/D)^{5.7}$
Branch In-plane Flexibility Factor, k_{ib}	$(1.91(d/D) - 4.32(d/D)^2 + 2.7(d/D)^3)\ (R/T)^{0.77}\ (d/D)^{0.47}\ (t/T)$
Branch Out-of-plane Flexibility Factor, k_{ob}	$(0.34\ (d/D) - 0.49(d/D)^2 + 0.18(d/D)^3)\ (R/T)^{1.46}\ (t/T)$
Branch Torsional Flexibility Factor, k_{tb}	$(1.08(d/D) - 2.44(d/D)^2 + 1.52(d/D)^3)\ (R/T)^{0.77}\ (d/D)^{1.79}\ (t/T)$

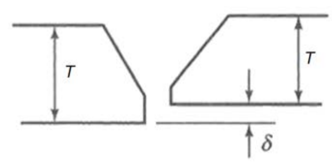
Run SIF In-plane, i_{ir}	$1.45\ (1+r_x/R)^{-2/3}\ (R/T)^{0.35}\ (d/D)^{0.72}\ (t/T)^{-0.52}$
Run SIF Out-of-plane, i_{or}	$0.58\ (1+r_x/R)^{-2/3}\ (R/T)^{2/3}\ (d/D)^{2.69}$
Run SIF Torsional, i_{tr}	$0.55\ (1+r_x/R)^{-2/3}\ (R/T)^{2/3}\ (d/D)\ (t/T)^{-0.5}$
Branch SIF In-plane, i_{ib}	$0.56\ (1+r_x/R)^{-2/3}\ (R/T)^{2/3}\ (d/D)^{0.68}$
Branch SIF Out-of-plane, i_{ob}	$0.85\ (1+r_x/R)^{-2/3}\ (R/T)^{2/3}\ (d/D)^{0.5}$
Branch SIF Torsional, i_{tb}	$0.71\ (1+r_x/R)^{-2/3}\ (R/T)^{2/3}\ (d/D)^{2}$

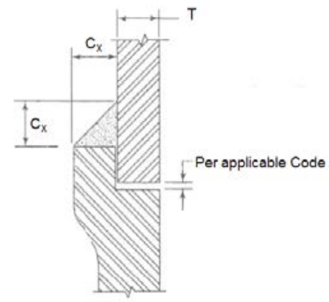
Sketch No. 2.5	Sketch	
Welded-in contour insert [Notes (3),(9),(10)] (when r_x is not provided, use $r_x = 0$)		
Term	**Equation**	
Run In-plane Flexibility Factor, k_{ir}	$0.18\ (R/T)^{0.84}\ (d/D)^{5}$	
Run Out-of-plane Flexibility Factor, k_{or}	1	
Run Torsional Flexibility Factor, k_{tr}	$0.1\ (R/T)^{0.91}\ (d/D)^{5.7}$	
Branch In-plane Flexibility Factor, k_{ib}	$(2.36(d/D) - 5.33(d/D)^2 + 3.33(d/D)^3)\ (R/T)^{0.77}\ (d/D)^{0.47}\ (t/T)$	
Branch Out-of-plane Flexibility Factor, k_{ob}	$(1+r_x/R)\ (0.67(d/D) - 0.97(d/D)^2 + 0.36(d/D)^3)\ (R/T)^{1.46}\ (t/T)$	
Branch Torsional Flexibility Factor, k_{tb}	$(1.05(d/D) - 2.36(d/D)^2 + 1.49(d/D)^3)\ (R/T)^{0.77}\ (d/D)^{1.61}\ (t/T)$	
Run SIF In-plane, i_{ir}	$(R/T)^{0.35}\ (d/D)^{0.72}\ (t/T)^{-0.52}$	
Run SIF Out-of-plane, i_{or}	$0.72\ (R/T)^{0.29}\ (d/D)^{1.95}\ (t/T)^{-0.53}$	
Run SIF Torsional, i_{tr}	$0.36\ (R/T)^{2/3}\ (d/D)\ (t/T)^{-0.5}$	
Branch SIF In-plane, i_{ib}	$0.35\ (R/T)^{2/3}\ (d/D)^{0.18}\ (t/T)^{0.7}$	
Branch SIF Out-of-plane, i_{ob}	$0.48\ (R/T)^{2/3}\ (d/D)^{0.37}\ (t/T)^{0.37}$	
Branch SIF Torsional, i_{tb}	$0.44\ (R/T)^{2/3}\ (d/D)^{1.1}\ (t/T)^{1.1}$	

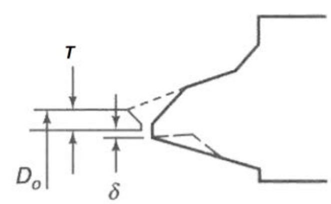
Sketch No. 2.6	Sketch
Integrally reinforced branch welded-on fittings [Notes (3),(10),(12)]	  
Term	**Equation**
Run In-plane Flexibility Factor, k_{ir}	$0.5\ (R/T)^{0.5}\ (d/D)^{5}$
Run Out-plane Flexibility Factor, k_{or}	1
Run Torsional Flexibility Factor, k_{tr}	$0.1\ (R/T)\ (d/D)^{5.7}$
Branch In-plane Flexibility Factor, k_{ib}	$(\ 0.55(d/D) - 1.13(d/D)^2 + 0.69(d/D)^3\ )\ (R/T)\ \ (t/T)$
Branch Out-of-plane Flexibility Factor, k_{ob}	$(\ 1.03(d/D) - 1.55(d/D)^2 + 0.59(d/D)^3\ )\ (R/T)^{1.4}\ \ (t/T)\ (d/D)^{0.33}$
Branch Torsional Flexibility Factor, k_{tb}	$(\ 0.37(d/D) - 0.75(d/D)^2 + 0.46(d/D)^3\ )\ (R/T)\ \ (t/T)\ (d/D)^{1.2}$
Run SIF In-plane, i_{ir}	$(R/T)^{0.43}\ (d/D)^{0.2} \geq 1.5$
Run SIF Out-of-plane, i_{or}	$(\ 0.02 + 0.88(d/D) - 2.56(d/D)^2 + 2.58(d/D)^3\ )\ (R/T)^{0.43}$
Run SIF Torsional, i_{tr}	$1.3\ (R/T)^{0.45}\ (d/D)^{1.37}$
Branch SIF In-plane, i_{ib}	$(\ 0.08 + 1.28(d/D) - 2.35(d/D)^2 + 1.45(d/D)^3\ )\ (R/T)^{0.81}\ (t/T)\ (r/rp)$
Branch SIF Out-of-plane, i_{ob}	$(\ 1.83(d/D) - 1.07(d/D)^3\ )\ (R/T)^{0.82}\ (t/T)\ (r/rp)^{1.18}$
Branch SIF Torsional, i_{tb}	$0.77\ (R/T)^{2/3}\ (t/T)\ (d/D)^2\ (r/rp)$

Sketch No. 3.1		
Concentric or Eccentric reducer per ASME B16.9	[Note (15)]	Sketch
SIF In-plane, i_i	$0.6 + 0.003(\alpha T_2/T_1)^{0.8}(D_2/T_2)^{0.25}\ (D_2/r_2)$	
SIF Out-of-plane, i_o	$0.6 + 0.003(\alpha T_2/T_1)^{0.8}(D_2/T_2)^{0.25}\ (D_2/r_2)$	
SIF Torsional, i_t	$0.3 + 0.0015(\alpha T_2/T_1)^{0.8}(D_2/T_2)^{0.25}(D_2/r_2)$	

Sketch No. 4.1		
Butt weld $T \geq 6$ mm (0.237 in.), $\delta_{max} \leq 1.5$ mm (1/16in.), and $\delta_{avg}/T \leq 0.13$	[Note (14)]	Sketch
SIF In-plane, i_i	1.0	
SIF Out-of-plane, i_o	1.0	
SIF Torsional, i_t	1.0	

Sketch No. 4.2		
Butt weld $T \geq 6$ mm (0.237 in.), $\delta_{max} \leq 3$ mm (1/8in.), and δ_{avg}/T = any value or $T < 6$ mm (0.237 in.), $\delta_{max} \leq$ 1.5 mm (1/16 in.), and $\delta_{avg}/T \leq 0.33$	[Note (14)]	Sketch
SIF In-plane, i_i	1.9 max. or $0.9 + 2.7(\delta_{avg}/T)$ but not less than 1.0	
SIF Out-of-plane, i_o	1.9 max. or $0.9 + 2.7(\delta_{avg}/T)$ but not less than 1.0	
SIF Torsional, i_t	$0.45 + 1.35(\delta_{avg}/T)$ but not less than 1.0	

Sketch No. 4.3		
Fillet welded joint, socket welded flange or fitting per Sketch $C_x \geq 0.75T$.	[Note (13)]	Sketch
SIF In-plane, i_i	1.3	
SIF Out-of-plane, i_o	1.3	
SIF Torsional, i_t	1.3	

Sketch No. 4.4		
Tapered transition per applicable Code sections and ASME B16.25		Sketch
SIF In-plane, i_i	1.9 max. or $1.3 + 0.0036(D_o/T) + 3.6(\delta/T)$	
SIF Out-of-plane, i_o	1.9 max. or $1.3 + 0.0036(D_o/T) + 3.6(\delta/T)$	
SIF Torsional, i_t	1.3	

Notes:

(1) Nomenclature:

A_p = metal area of pipe cross section, in.^{2} (mm^2)

b = branch subscript corresponding to Leg 3 in Fig. 2

B = length of miter segment at crotch, in. (mm)

c = factor for rigid ends adjacent to bends, miters and branch connections in Sketches 1.1, 1.2 and Sketches 2.1 through 2.6 in Table 1

C_x = minimum socket weld leg length, in. (mm)

D = mean diameter of matching pipe found from (D_o-T), in.(mm). For Sketches 2.1 through 2.6 in Table 1, the mean diameter of the matching run pipe

d = mean diameter of matching branch pipe found from (d_o-t), in.(mm)

d' = effective branch diameter used with Fig. 5(a), (b) and (c), in.(mm)

d_i = inside diameter of matching branch pipe found from (d_o-2t), in.(mm)

d_o = outside diameter of the matching branch pipe, in.(mm)

D_o = outside diameter of matching pipe, in. (mm). For Sketches 2.1 through 2.6 in Table 1, the outside diameter of the matching run pipe

D_i = inside diameter of matching run pipe found from (D_o-2T), in. (mm)

D_1, D_2 = large and small end of reducer, respectively, in.(mm)

E = modulus of elasticity, psi. (KPa)

I_b, I_r = matching branch and run pipe moment of inertia used in Table 2, in^4 (mm^4)

i = stress intensification factor (SIF)
k = flexibility factor with respect to the plane and component indicated
L_1 = length of taper or thicker branch section in Fig. 5, in. (mm).
L_2 = length of the cylindrical portion at small end of reducer in Sketch 3.1, in. (mm).
M = moment on branch or run legs shown in Fig. 2, in.-lb (N·mm)
N_c = number of flanges or other rigid components adjacent to the run pipe end of a branch connection (1 or 2)
P = gage pressure, psi (MPa)
r = mean radius of matching branch pipe found from (d_o-t)/2, in.(mm) for Sketches 2.1 through 2.6 in Table 1
r_2 = radii used with Fig. 5 and in Sketch 3.1, in.(mm)
R = mean radius of matching pipe found from (D_o-T)/2, in.(mm)
R_1 = bend radius of welding elbow or pipe bend, in.(mm)
r_i = inside radius used with Fig. 5, in.(mm)
r_p = radius to outside edge of fitting for Sketches 2.3 and 2.6 measured in longitudinal plane, in.(mm)
r_x = external crotch radius of welding tee per ASME B16.9, extruded outlet and welded-in contour insert [Sketches 2.1, 2.4 and 2.5], measured in the plane containing the centerline axes of the run and branch, in.(mm)
s = miter spacing at centerline, in.(mm)
SIF = stress intensification factor
t = nominal wall thickness of matching branch pipe, in.(mm)
t' = effective branch thickness used with Fig. 5(a), (b) and (c), in.(mm)
t_n = local branch pipe thickness used with Fig. 5(a) and (b), in. (mm)
T = nominal wall thickness of the fitting for elbows and miter bends (Sketches 1.1 through 1.3), and the nominal wall thickness of the matching pipe for tees (Sketches 2.1 through 2.6) and other components, in.(mm)
T_c = crotch thickness in Sketches 2.1, 2.4 and 2.5 in Table 1 measured at the center of the crotch and in the plane shown, in.(mm)
t_p = reinforcement pad or saddle thickness, in.(mm)
T_1, T_2 = nominal wall thickness of large end and small end of reducer, respectively, in. (mm)
y = large end of tapered hub used with Fig. 5(c), and found from ($L_1 \tan \theta_n$), in. (mm)
Z = section modulus of pipe, in^3, (mm^3) (See Note 10.)
Z_b = section modulus of matching branch pipe, in^3, (mm^3) (See Note 10.)
α = reducer cone angle, deg
δ = mismatch, in.(mm)
θ = one-half angle between adjacent miter axes, deg
θ_n = hub angle used with Fig. 5(c), deg
θ_{ib}, θ_{ob}, θ_{tb}, θ_{ir}, θ_{or}, θ_{tr} = rotations at branch or run legs shown in Fig. 2, rad

(2) Stress intensification and flexibility factor data in Table 1 shall be used in the absence of more directly applicable data. Their validity has been demonstrated for D/T ≤ 100. Other limits may also apply and are given below.

Flexibility and stress intensification factors shall not be less than 1.0.

Stress intensification factors in Table 1 have been developed from fatigue tests of representative commercially available matching product forms with assemblies manufactured from ductile ferrous materials and from numerical analysis using finite elements. The allowable stress-range is based on tests of carbon and stainless steels. Caution should be exercised when applying these rules for certain nonferrous materials (e.g., copper and aluminum alloys) for other than low cycle applications.

Corrugated straight pipe or corrugated or creased bends should be designed using the principles found in B31.3 Appendix X, EJMA or similar standards.

(3) Stress intensification and flexibility factors apply over the effective arc length (shown by heavy centerlines in the sketches) for curved and miter bends.

Stress intensification factors for Sketches 2.1 through 2.6 apply to the intersection point for Legs 1 and 2 as shown in Figs. 1 and 2.

Stress intensification factors apply to the intersection point for branch Leg 3 in Figs. 1 and 2 when do/Do > 0.5, and to the branch centerline at the surface of the run pipe when do/Do ≤ 0.5.

Flexibility factors for Sketches 2.1 through 2.6 shall be applied as shown in Figs 1 and 2 for all do/Do.

(4) The highest in-plane or out-of-plane stress intensification factor shall be used when only a single stress intensification factor is needed. Flexibility factors should always be used with the orientation specified. For Sketches 3.1 through 5.1, the in-plane and out-of-plane orientations must be orthogonal to each other and to the pipe axis but may otherwise be arbitrarily oriented.

(5) Where flanges or other rigid components are attached to one or both ends, the in-plane and out-of-plane values of k and i in Table 1 shall be multiplied by the factor c from Chart B, entering with the computed h.

(6) When the bend angle is 90 deg., and the thickness of the bend is equal to the thickness of the matching pipe the flexibility factors k_i and k_o may be found from 1.3/h and adjusted where applicable by the factor c from Chart B.

(7) In large diameter thin-wall elbows and bends, pressure can affect the magnitudes of k and i. To correct values from Table 1, divide k by

$$\left[1+6\left(\frac{P}{E}\right)\left(\frac{R}{T}\right)^{7/3}\left(\frac{R_1}{R}\right)^{1/3}\right]$$

and divide i by

$$\left[1+3.25\left(\frac{P}{E}\right)\left(\frac{R}{T}\right)^{5/2}\left(\frac{R_1}{R}\right)^{2/3}\right]$$

For consistency, use kPa and mm for SI metric, and psi and in. for U.S. customary notation.

Stress intensification factors shall be used with the section modulus of the matching pipe or the section modulus of the bend, whichever is smaller.

(8) Sketch 1.3 includes single miter joints.

(9) If $r_x \geq (1/8)(d_o)$ and $T_c \geq 1.5T$ the factors k and i may be divided by 1.26.

(10) The flexibility and stress intensification factors apply only if the following conditions are satisfied:

a) The branch pipe axis is normal to within 5 deg. of the surface of the run pipe unless otherwise noted.
b) R/T ≤ 50
c) d/D ≤ 1
d) r/t ≤ 50
e) The matching run pipe thickness (T) and diameter (D) is maintained for at least two run pipe diameters on each side of the branch centerline.
f) For Sketches 2.1, 2.4, and 2.5 the ratio (t/T) must be less than or equal to 1.2 and the ratio (T_c/T) must be greater than 1.1.

When a Table 2 flexibility factor is less than or equal to 1.0 the stiffness associated with that flexibility factor shall be rigid.

Sketch 2.1 through 2.6 flexibility factors k_{ib}, k_{ob} and k_{tb} shall be multiplied by the factor c from Table 3 when flanges or other rigid components are adjacent to one or more of the run pipe ends. A flange or other rigid component is adjacent to the run pipe end when the length of any straight run pipe between the branch and the flange or rigid component is less than $0.1D^{1.4}/T^{0.4}$.

Stress intensification factors may be used without flexibility factors.

Sketch 2.1, 2.2, 2.4, 2.5 and 2.6 stress intensification factors i_{ib}, i_{ob}, i_{tb}, i_{ir}, i_{or}, and i_{tr}, and the flexibility factors k_{ib}, k_{ob}, k_{tb}, k_{ir}, k_{or}, and k_{tr} shall not be greater than the corresponding stress intensification and flexibility factors for Sketch 2.3 Fig.5(d) calculated using matching branch and run pipe dimensions and r_2=0. Sketch 2.4 and Sketch 2.5 stress intensification and flexibility factors shall not be less than the corresponding stress intensification and flexibility factors for Sketch 2.1 calculated using T_c = 1.1T. If i_{ob} is less than i_{ib} for any of Sketches 2.1 through 2.6 then use $i_{ob}=i_{ib}$. If i_{ir} is less than i_{or} for any of Sketches 2.1 through 2.6 then use $i_{ir} = i_{or}$.

Table 1 stress intensification factors i_{ib}, i_{ob}, i_{ir}, i_{or}, and i_{tr},can be used for Sketches 2.2, 2.3, 2.5 and 2.6 when the branch pipe axis is in the same plane as the run pipe axis and is normal to within 45 deg. of the surface of the run pipe providing D/T < 50 and d/D ≤ 0.6, and in the absence of more applicable data i_{tb} can be taken equal to i_{ob}.

Sketch 2.3 stress intensification factor i_{ob} shall be multiplied by the larger of $(0.75(t/T) – 0.89(t/T)^2 + 0.18)(D/T)^{0.34}$, or 1.0 when t/T is less than or equal to 0.85, d/D is less than 1, and D/T is greater than or equal to 25.

Sketch 2.2 stress intensification factor i_{ob} shall be multiplied by the larger of $(1.07(t/T) – 1.08(t/T)^2 + 0.026)(D/T)^{0.34}$, or 1.0 when t/T is less than or equal to 0.85, d/D is less than 1, and D/T is greater than or equal to 25.

The designer must be satisfied that the branch connection pressure rating is greater than or equal to that of the matching run pipe.

Branch connection stress intensification factors shall be used with the section modulus of the matching pipe. The section modulus can be calculated by either of the two equations below for the run

$$Z = \left[\frac{\pi}{32}\right]\left[\frac{D_o^4 - D_i^4}{D_o}\right]$$

$$Z = \left[\frac{\pi}{4}\right]D^2 T$$

and by either of the two equations below for the branch

$$Z_b = \left[\frac{\pi}{32}\right]\left[\frac{d_o^4 - d_i^4}{d_o}\right]$$

$$Z_b = \left[\frac{\pi}{4}\right]d^2 t$$

(11) The in-plane, out-of-plane, and torsional stress intensification factors for both the branch and the run may be multiplied by the factor 0.7 for the geometries shown in Fig. 5 when the outer radius r_2 (Fig. 5) is provided and is not less than the smaller of T/2, t/2, $(r_p-r_i)/2$, or (t + y)/2.

For Fig. 5(a),(b) and (c):

(a) Flexibility and stress intensification factors shall be calculated by replacing the parameters t/T with t’/T, and d/D with d’/D.

(b) Stress intensification factors i_{ib}, i_{ob}, and i_{tb}, and the flexibility factors k_{ib}, k_{ob}, and k_{tb} shall also be multiplied by $(t/t')(d/d')^2$.

(c) t' is found by:

For Fig. 5(a) and (b):

$t' = t_n$ if $L_1 \geq 0.5(2r\, t_n)^{1/2}$

$= t$ if $L_1 < 0.5(2r\, t_n)^{1/2}$

For Fig. 5(c):

$t' = t + (2/3)y$ if $\theta_n \leq 30$ deg.

$t' = t + 0.385L_1$ if $\theta_n > 30$ deg.

(d) d' is found by:

$d' = d - t + t'$

(e) Stress intensification factors i_{ib}, i_{ob}, i_{ir}, and i_{tr} shall not be less than 1.5.

(12) When r/r_p is not available a value of 0.85 may be used. If $r/r_p < 0.6$ then use $r/r_p = 0.6$. For size-on-size fittings multiply i_{ib}, i_{ob} and i_{tb} by 0.75.

(13) For welds to socket welded fittings, the stress intensification factor is based on the assumption that the pipe and fitting are matched in accordance with ASME B16.11 and that the weld is made as shown in Sketch 4.3.

For welds to socket welding flanges, the stress intensification factor is based on the weld geometry shown in Sketch 4.3. Blending the toe of the fillet weld with no undercut smoothly into the pipe wall, as shown in Fig. 4 sketches (b) and (d) has been shown to improve the fatigue performance of the weld. The designer is cautioned that large diameter socket welded flanges may induce stresses in the socket welds that are not considered in the stress intensification factor.

(14) The stress intensification factors apply to girth butt welds between two items for which the wall thicknesses are between 0.875T and 1.10T for an axial distance of $(D_oT)^{1/2}$. D_o and T are the outside diameter and nominal wall thickness, respectively. δ_{avg} is the average mismatch or offset.

(15) The flexibility and stress intensification factors apply only if the following conditions are satisfied:

(a) $5 < \alpha < 60$ deg.

(b) $5 < D_2/T_2 < 80$

(c) The wall thickness is not less than T_1 throughout the body of the reducer, except in and immediately adjacent to the cylindrical portion on the small end, where the thickness shall not be less than T_2

(d) $0.08 < r_2/D_2 < 0.7$

(e) $1 < T_1/T_2 < 2.12$

(f) If $L_2 < (D_2T_2)^{0.5}$ the stress intensification factors should be multiplied by $(2 - L_2/(D_2T_2)^{0.5})$

The maximum stress intensification factor need not be greater than 2.0 but shall in no case be less than 1.0. Reducers with a D_2/T_2 ratio less than or equal to 55 can be modeled with a step change in diameter and thickness from D_2,T_2 to D_1,T_1 at the middle of the reducer. When the D_2/T_2 ratio is greater than 55 consideration should be given to adding flexibility to the beam model to accurately represent the flexibility of the reducer. For eccentric reducers the dimensions shown in Sketch 3.1 are to be taken at the location on the circumference where α is the maximum. When r_2 is not given, use $r_2 = 0.1D_1$. When L_2 is not given, use $L_2 = 0.1D_2$. When α is not given, use α equal to the smaller of $60(D_1/D_2-1)$, or 60.

(16) When r_x is not provided, use $r_x = 0.05d_o$. If $r_x/r > 1$ use $r_x/r = 1$.

Table 2 – Moment Rotation Relationships for Sketches 2.1 through 2.6 of Table 1

Moment (Fig 2)	Flexibility Factor k (unitless)	Stiffness in.lb/rad (Nmm/rad)	Stiffness in.lb/rad (Nmm/rad)
M_{i3} (Leg 3)	k_{ib}	M_{ib}/θ_{ib}	$(E)(I_b)/(k_{ib}\, d)$
M_{o3} (Leg 3)	k_{ob}	M_{ob}/θ_{ob}	$(E)(I_b)/(k_{ob}\, d)$
M_{t3} (Leg 3)	k_{tb}	M_{tb}/θ_{tb}	$(E)(I_b)/(k_{tb}\, d)$
$M_{i1,2}$ (Legs 1,2)	k_{ir}	M_{ir}/θ_{ir}	$(E)(I_r)/(k_{ir}\, D)$
$M_{o1,2}$ (Legs 1,2)	k_{or}	M_{or}/θ_{or}	$(E)(I_r)/(k_{or}\, D)$
$M_{t1,2}$ (Legs 1,2)	k_{tr}	M_{tr}/θ_{tr}	$(E)(I_r)/(k_{tr}\, D)$

The moment rotation relationships in Table 2 are developed by independantly applying moments to the respective run or branch leg. Simultaneous run and branch moment-rotation interaction must be accomodated by the model.

Fig. 1 Flexibility Element Locations

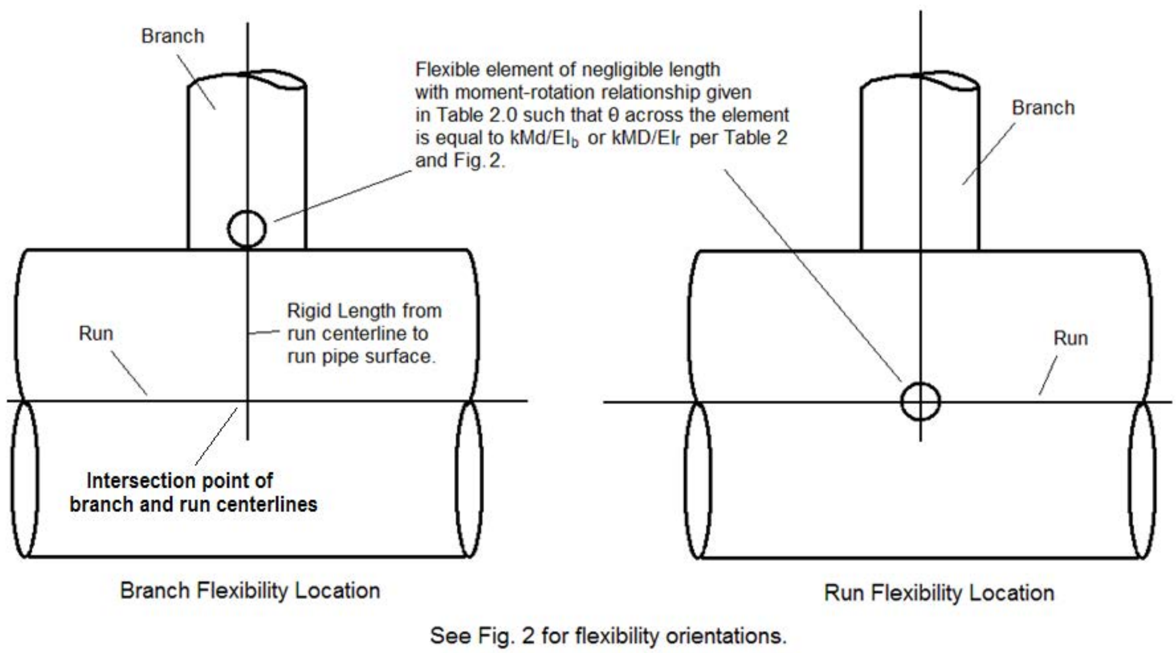


Fig. 2 Orientations for Sketches 2.1 through 2.6 of Table 1

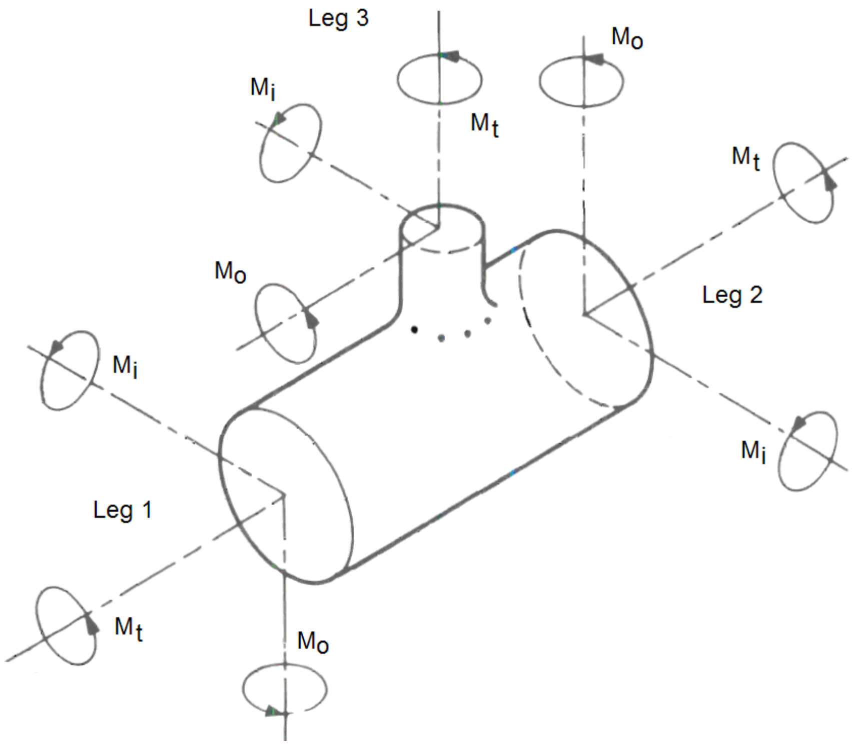


Fig. 3 Orientations for Bends

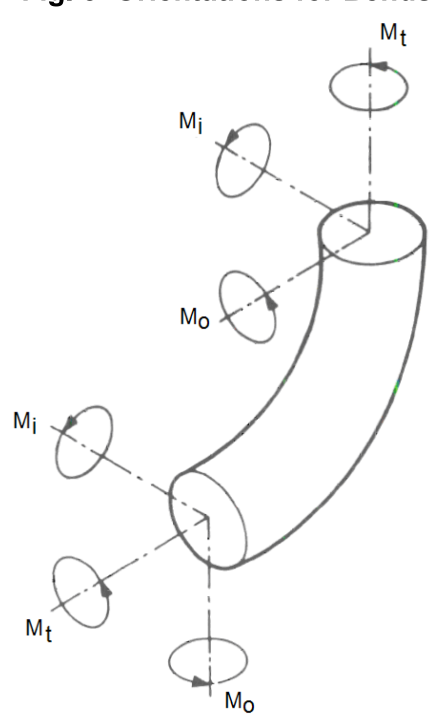


Fig. 4 Fillet Weld Contours

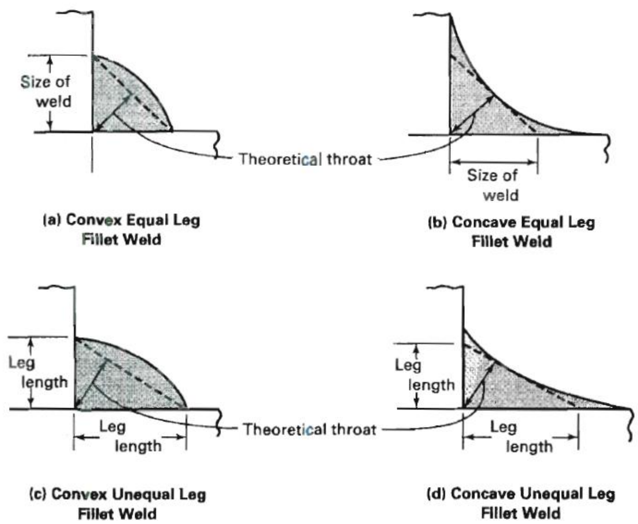


Fig. 5 Branch Dimensions

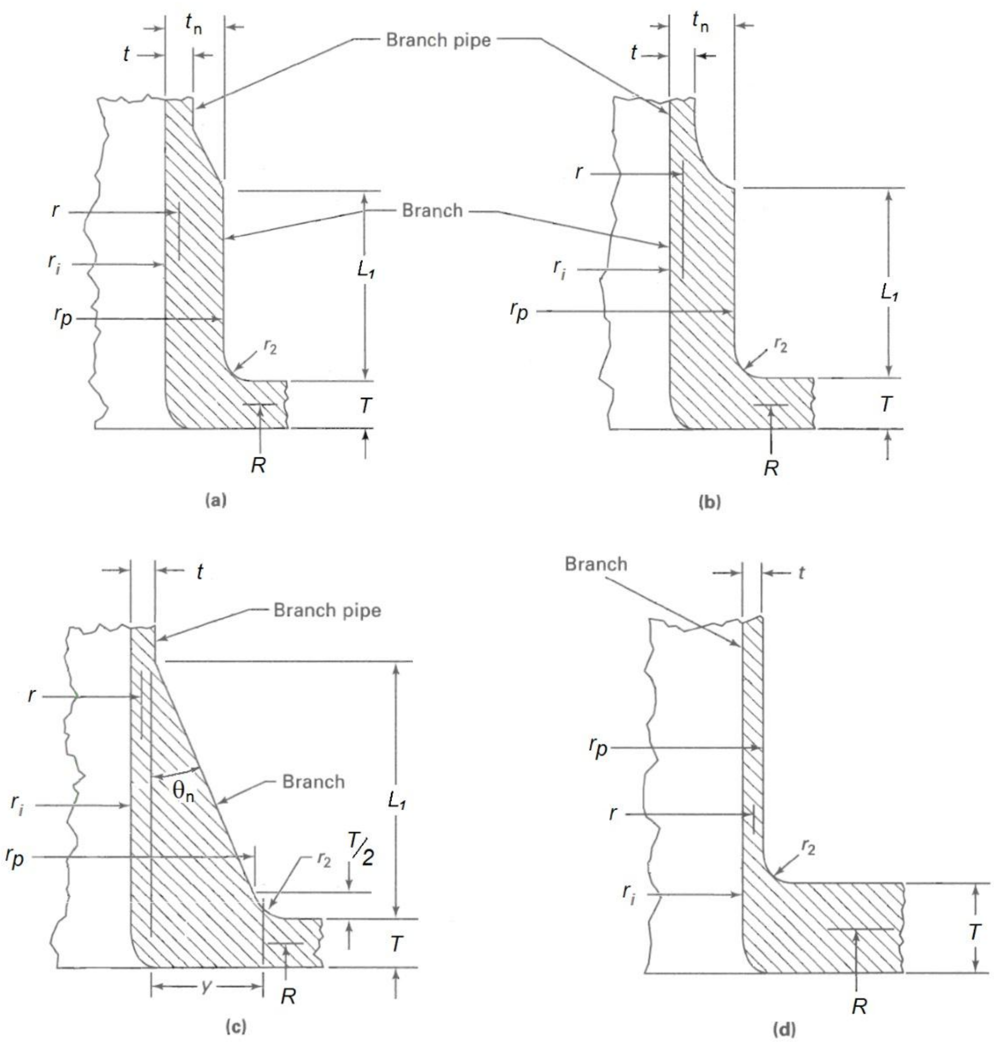


Chart A Flexibility and Stress Intensification Factors for Bends and Miters

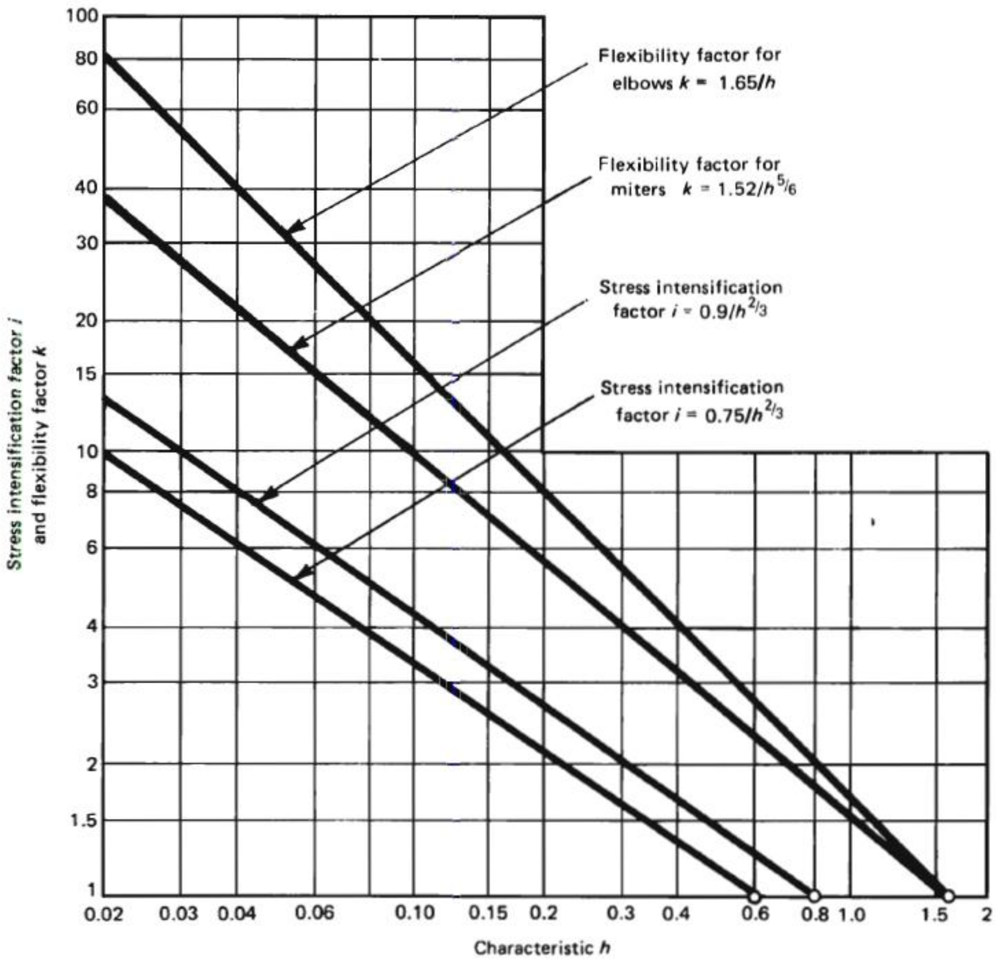


Chart B Flanged End Corrections for Bends and Miters

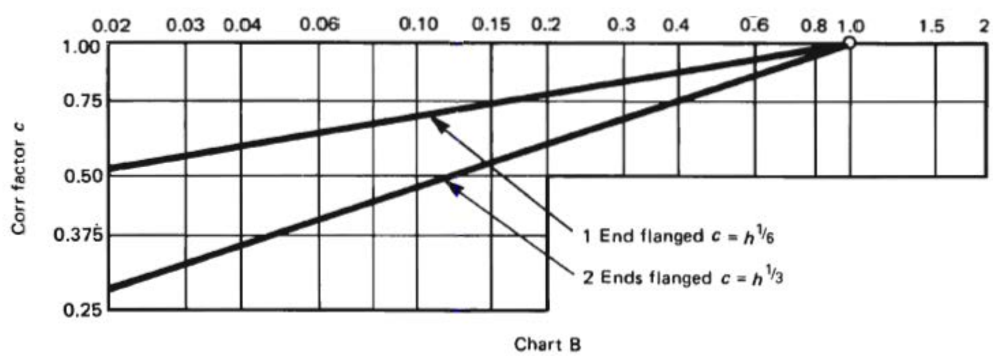


Table 3 – Flanged End Correction Coefficients for Sketches 2.1 through 2.6 of Table 1

Flexibility Factor	Flexibility Factor Multiplier c
k_{ib}	$1 - 0.032\, N_c^{1.345}\, D/T^{\,0.431}\, d/D^{\,0.903}$
k_{ob}	$1 - 0.07\, N_c^{\,0.61}\, D/T^{\,0.44}\, d/D^{\,0.339}$
k_{tb}	$1 - 0.003\, N_c^{\,3.962}\, D/T^{\,0.548}\, d/D^{\,0.693}$

NONMANDATORY APPENDIX C

Example Use of Branch Connection Flexibility Factors (R6)

C-1 Summary:

Five example piping models demonstrate the use of branch connection flexibilities given in Appendix B Table 1. The results from the example models are summarized in Table C1. The use of branch connection flexibilities is shown to either increase or decrease calculated forces and moments due to load redistribution within the beam model of the piping system. The use of branch connection flexibilities is not considered to be either more or less conservative, but is considered to provide a more accurate analysis of the piping system.

Table C1 – Example Model Descriptions

Example No.	Description	Result
1	Rodabaugh Flexibility Example from WRC 329 Fig. 15	Branch connection flexibilities reduce moment by 12 times
2	4x4 Markl Unreinforced Fabricated Tee Piping Assembly	Without branch connection flexibilities displacement underestimated by 22%
3	Piping Attached to Pump Discharge	Including branch connection flexibilities reduces pump flange moment by 43.7%
4	Spare Pump Branch Configuration	Branch and run flexibilities reduce moment by 3.2 times
5	Heater Piping	Branch and run flexibilities increase moment by 2.4 times

Each example demonstrates the change in piping system forces and moments due to the inclusion of branch connection flexibilities in the piping system analysis.

More detailed illustration of branch connection flexibility use is provided in Appendix D.

The effect of branch connection flexibilities on dynamic solutions is discussed in Section C-8.

The properties of a generic carbon steel material are used in these examples. The modulus of elasticity is 29e6 psi. Poisson’s ratio is 0.3. The weight density of the steel is 0.283 lbm/cu.in.

C-2 - Nomenclature:

Anchor – nodal component in a piping system model that provides restraint against all degrees of freedom at the point where the anchor is applied.

Branch connection equivalent length – length of straight pipe that has the same moment-rotation relationship as the branch connection in a beam model of the piping system. The equivalent length is found by multiplying the branch connection flexibility factors in Appendix B by the mean diameter of the respective branch or run pipe.

For all other terms see Appendix B or Appendix D.

C-3 Example No. 1 Rodabaugh Example in WRC 329 Fig. 15 Reference [1]

Rodabaugh provides the following example in Section 4.9 of WRC 329:

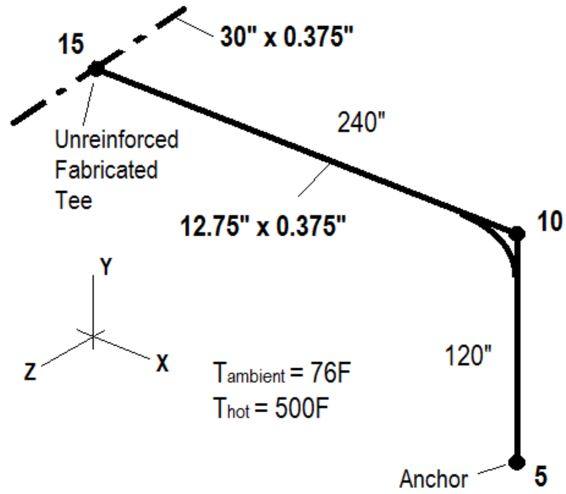


Figure C1 – WRC 329 Fig. 15 Example Piping Model

Without considering the branch connection flexibility of the 12x30" fabricated tee at point 15, the out-of-plane (Z) bending moment at point 15 is 29e3 ft.lb.

Including the branch connection flexibility reduces the bending moment to 2.4e3 ft-lb a reduction of 12.

The 30" run pipe side of the branch connection at point 15 is not included in the beam model of the piping system. The only significant moment load on the intersection at 15 is due to the out-of-plane bending moment caused by the thermal expansion of the branch and so only the k_{ob} branch connection flexibility needs to be considered. Other local stiffnesses at the branch connection are assumed to be rigid. Many piping systems will not be planar or this geometrically simple and it is not expected that the designer will intuitively know which local stiffnesses will be important.

The Appendix B Table 1 Sketch 2.3 k_{ob} flexibility factor for the 30x12 fabricated tee is 65. The mean branch pipe diameter is 12.375." The equivalent length associated with the out-of-plane branch flexibility factor is $(k_{ob})(12.375) = (65)(12.375) = 804$ in. The cumulative length of 12" pipe in the model is approximately 240 + 120=360". The single elbow in the model has a k=1.3/h = 7.37, and an equivalent length equal to $(k)(\pi/2)(R_1) = 208$". The sum of the piping system equivalent lengths without the branch connection is 360 + 208=568". The equivalent branch connection length of pipe is greater than the total equivalent length of pipe in the model and so there is reason to believe that incorporation of the branch connection flexibilities in the piping system analysis will have an effect on the moment at the intersection.

The updated model for the piping system in Fig. C1 includes a rotational stiffness in the out-of-plane direction (Z) whose magnitude is $EI_b/k_o d$. (See Appendix B Table 2).

Rodabaugh writes in WRC 329, "The significance of [the branch connection flexibility factor] k depends upon the specifics of the piping system. Qualitatively, if k is small compared to the length (in d-units) of the piping system, including the effect of elbows and their k-factors, then the inclusion of k for branch connections will have only minor effects on the calculated moments. Conversely, if k is large compared to the piping system length, then inclusion of k for branch connections will have major effects."

Comparing the equivalent length of branch connections and pipe does not always provide an accurate assessment of the effect the branch connection flexibility has on a piping system. A more detailed evaluation includes the distribution of the moments in the piping system and this determination is usually done by a piping flexibility analysis computer program. Inspection of the pipe routing and comparison of equivalent lengths should help designers be aware of situations where branch flexibilities may have an impact. When the equivalent pipe length between two intersections is short with respect to the equivalent length of pipe provided by the branch connection, the branch connection flexibilities may control the moments and stresses at the branch connection.

The out-of-plane flexibility factor used in WRC 329 Fig. 15 for this example from BPVC Section III NB 3686.5 is 45. The k_{ob} value is 65 for this example. The k_{ob} for this example computed by Wais [10] is 53.5 and by Widera [9] is 81.

C-4 Example No. 2 - Markl Style Fabricated Tee Fatigue Assembly [25]

A 4x4 standard wall fabricated tee fatigue assembly of the type used by Markl [25]**Error! Reference ource not found.** is shown in Figure C2. The run end is loaded and deflects in the out-of-plane direction an average of 1.0 inch when the applied load is 1670 lb.

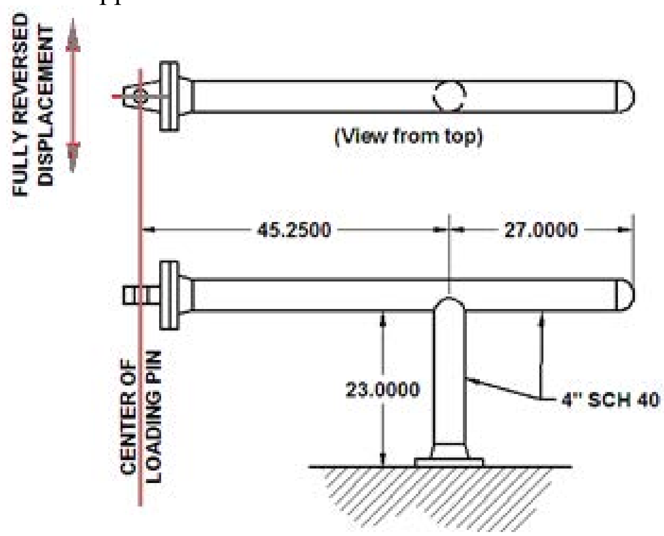


Figure C2 – 4x4 Markl Test Pipe Assembly for Out-of-plane Loading

Appendix B Table 1 Sketch 2.3 provides k-factors for fabricated tee intersections of this type. The k-factors are given for both the branch and the run. Appendix B Figure 2 shows the location of the branch and run rotational stiffnesses. Run piping k-factors should be included in a static beam piping model when each of the following conditions exist.

1) There are significant moment loads on both run pipe legs framing into the branch connection intersection point.
2) The run k-factor is greater than 1 and the equivalent length of run pipe found from kD, where k is the run branch connection flexibility factor, is of the same order as the length of attached run piping.

The Markl test assembly in Figure C2 is loaded on one end of the run pipe only. The opposite run pipe end is free. Since there are loads on only a single end of the run pipe, the rotational stiffnesses due to run side k-factors are not needed.

The beam model of the piping assembly in Figure C2 without branch connection flexibilities included is shown in Figure C3.

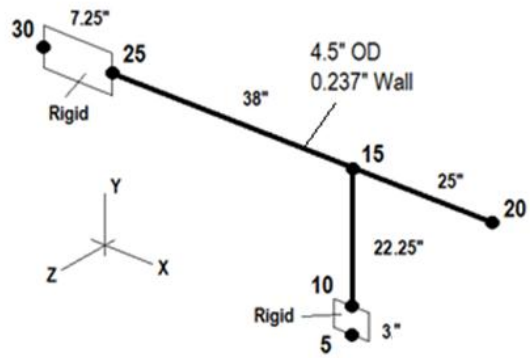


Figure C3 – Beam Model of Test Assembly without Branch Connection Flexibilities

When a 1670 lb force is applied at point 30 in the Z direction, the beam model without flexibilities deflects in the Z direction at point 30 an amount equal to 0.74 inch. When a 1670 lb force is applied at point 30 in the Z direction in a beam model that includes branch connection flexibilities the point 30 deflects 1.09 inches. The beam model without branch connection flexibilities is stiffer than the actual assembly and computed displacements are smaller than measured values.
The 1670 lb load on point 30 induces an out-of-plane and torsional branch moment on the fabricated intersection at point 15. Run flexibility factors are not included in the model since there are significant loads on only a single end of the run pipe framing into the intersection point 15. The in-plane branch flexibility is not considered since in-plane loads on the test assembly piping do not exist.

The flexibility factor equations in Appendix B Table 1 define an equivalent length of matching branch pipe concentrated at the surface of the run pipe that contributes to the overall beam deflection of the piping model.

For the 4" fabricated tee Markl test assembly, the applicable flexibility factors and resulting lengths are given in Table C-3:

Table C3 Markl 4x4 UFT Flexibility Factors and Equivalent Lengths

Sketch	Flexibility Factor	Value	Mean Diameter (d) (in.)	Equivalent Length (in.)
2.3	k_{ob}	4.485	4.263	19.1
2.3	k_{tb}	5.88	4.263	25.1

The equivalent lengths for the out-of-plane and torsional flexibility factors in Table C3 are about the of the same and so torsional moments about the branch will produce as much local rotation as out-of-plane moments about the branch.

The beam model adjusted to include the k_{ob} and k_{tb} branch flexibilities is shown in Fig. C4 below:

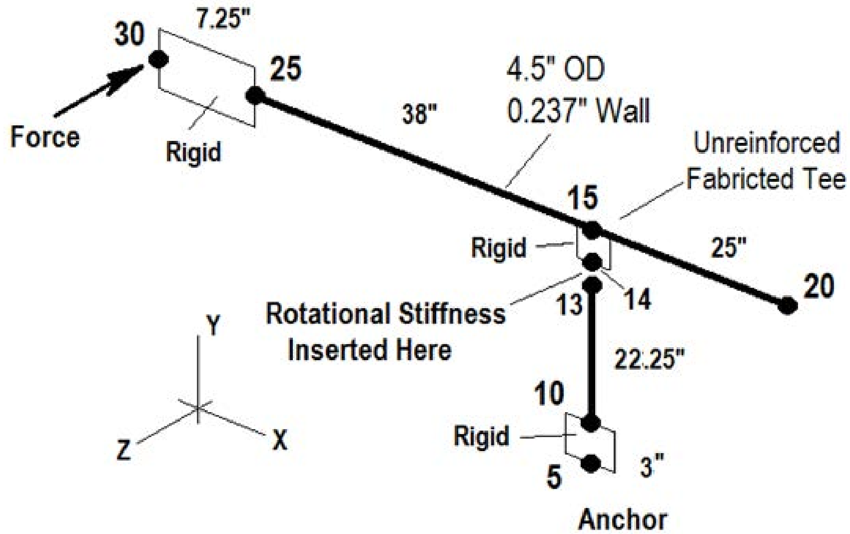


Figure C4 – Beam Model Adjusted to Accommodate Branch Connection Flexibilities

A rigid element is inserted in the model from the centerline to the surface of the run pipe from points 14 to 15 whose length is equal to half the outside diameter of the run pipe. The flexibility factors are added in between points 13 and 14 which are at essentially the same point in space. The flexibility factor alignment with the global coordinate system is shown in Table C4 below. Rigid stiffnesses are inserted in flexibility factor directions not given or considered insignificant. The bending stiffness associated with the flexibility factor direction is found from the equations given in Appendix B Table 2. When the flexibility factor (k) is one or less than one, the rotational stiffness associated with the flexibility factor direction is rigid.

Table C4 – Markl 4x4 UFT Flexibility Factors, Associated Direction and Stiffnesses

Global Direction	Flexibility Factor Direction	Flexibility Factor Used	Stiffness Used
θx	kob	4.547	192,108 in.lb/deg
θy	ktb	5.88	274,015 in.lb/deg
θz	kib	0	Rigid – Infinite – Large

d_o = outside diameter = 4.5 inches
d_i = inside diameter = 4.026 inches
d = mean diameter = 4.263 inches

E = elastic modulus = 29.5E6 psi

$I = \pi/64\ (d_o^4 - d_i^4)$
$= \pi/64\ ((4.5)^4 - (4.026)^4)$
$= 7.2326\ in^4$

Branch Out-of-plane Stiffness $= EI / (k_{ob} d)$
$= (29.5E6)(7.2326) / (4.547)(4.263) * (\pi/180)$
$= 188{,}852$ in-lb/deg

Flexibility factors for the run are given in Table C5 below.

Table C5 – Markl 4x4 UFT Run-Side Flexibility Factors and Equivalent Lengths

Global Direction	Flexibility Factor Direction	Flexibility Factor Used	Equivalent Length
θy	k_{or}	1	Not Applicable
θx	k_{tr}	5.547	23.64"
θz	k_{ir}	3.45	14.7"

The torsional run flexibilities and equivalent lengths are significant compared to the branch lengths but there are no torsional loads through the run pipe and so the run pipe flexibility factors are not used.

The calculated displacement using the branch connection flexibility factors is 1.09 inches.

The 4x4 Fabricated Tee Markl Test results are summarized below:

Table C6 – Markl 4x4 UFT Displacement Error

Beam Model	Displacement	Error
No Flexibility	0.74 in.	26%
Flexibilities Added	1.09 in.	9%
Test Accuracy[1]		1.8%

[1]The test accuracy is found as the ratio of the average test error divided by the average test displacement.

Since stresses in piping systems are often caused by thermal displacements the 26% error in the model displacement could equate to a 26% overestimate of the load. A 26% error in the calculated load is of the same magnitude as the error in the stress intensification factor and so is probably not too significant in a typical piping system analysis unless load-sensitive rotating equipment is involved.

C-5 Example No. 3 Pump Discharge

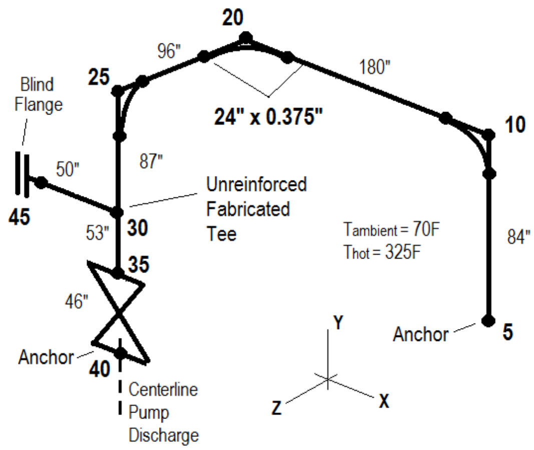
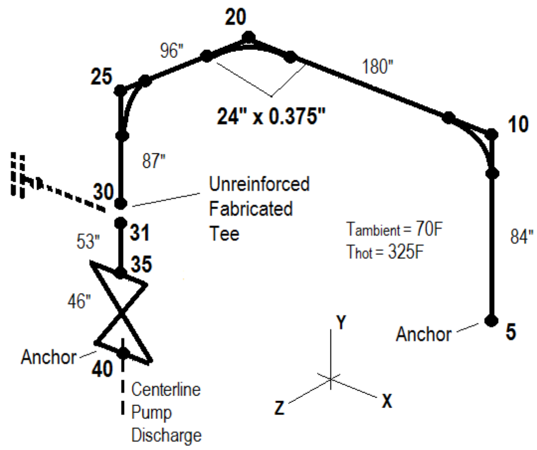


Figure C5 – Isometric of Pump Discharge



Isometric with Nodes for Run-Side Stiffnesses due to Branch Connection Flexibility

Fig. C5 above shows an unreinforced fabricated tee attached above a valve at the discharge of a pump. The intersection branch pipe is terminated with a blind flange for future use. If the weight of the blind flange and pipe stub are negligible, the flexibility factors associated with the branch pipe can be ignored. The loads through the run pipe may be significant since the piping system operates at 325F. A beam model to evaluate the effect of the run flexibilities is shown in the right sketch in Fig. C5. The thermal loads acting through the run pipe cause forces and moments on the pump discharge nozzle at node 40. The presence of the unreinforced intersection at node 30 will cause the run pipe to be more flexible and reduce thermal loads on the pump anchor. The objective of the analysis is to quantify this reduction of the loading. The run pipe k-factors found using the equations in Appendix B Table 1 Sketch 2.3 are given in Table C7 below:

Table C7 – Run-Side Flexibility and Equivalent Length for Fabricated Tee at Node 30

k-factor direction	Global Direction	Flexibility Factor	Equivalent Length (kD)
k_{ir}	θz	6.224	149”
k_{or}	θx	1	0”
k_{tr}	θy	14.746	353”

The piping system length from node 35 to node 25 experiences torsion and bending due to the thermal expansion of the piping from the anchor at node 5. The length of piping from node 35 to node 25 is 87+53 = 140”. This does not include the equivalent length of the three 90 deg bends. The flexibility factor for a 90 degree bend is given in Appendix B Table 1 Sketch 1.1 and in Table 1 Note 6. The flexibility factor k = 1.3/h and $h = TR_1/R^2$ where R_1 is the bend radius. The equivalent length contributed by the three 90 degree bends is:

$$\text{Equivalent Bend Length} = (3)k(\pi/2)R_1 = (3)(13.4)(\pi/2)(36) = 2{,}200”$$

If the bends were flanged, or ovalization of the bend was otherwise restricted, the bend equivalent length would drop by more than one-half.

The equivalent length associated with the run torsional flexibility factor at the unreinforced fabricated tee is 353”. (See k_{tr} in Table C6.) The equivalent length associated with the in-plane flexibility factor at the unreinforced fabricated tee is 149”. The equivalent length due to the local flexibility of the branch connection is less than the equivalent length of the piping system. It is difficult to determine without a detailed calculation if the flexibility of the intersection in close proximity to the pump flange will have a significant effect on the resulting moments. The comparative moments at the pump flange are given in Table C8 below.

The importance of branch connection flexibility in a portion of a piping system exposed to a constant moment can be estimated from:

$$J = \Sigma(k_i d_i) / [\, \Sigma(1.3L_j) + \Sigma(L_k) + \Sigma(k_m R_m \phi_m) + \Sigma(k_i d_i)\,] \qquad \text{Eq. C1}$$

where:

J = importance factor, a value of unity reflecting the highest possible importance

k_i =flexibility factor from branch connection "i"

d_i = diameter from branch connection "i" used with k_i

L_j = length of pipe subject to torsional

L_k = length of pipe subject to bending

k_m = flexibility factor for bend "m"

R_m = radius of bend "m"

ϕ_m = angle of bend "m"

Table C8 – Pump Flange Overturning Moments (ft.-lb)

Condition	Mx	My	Mz
Rigid Intersection at Node 30 ($k \le 1$)	19020	31720	95673
Intersection at Node 30 modeled using branch connection flexibilities from Appendix B Table 1 Sketch 2.3	15403 (19% reduction)	17656 (44% reduction)	64784 (32.7% reduction)

If a 0.5" thick pad is added to the unreinforced branch connection at node 30 to provide additional strength to the intersection the loads on the pump will increase since the stiffness of the branch connection changes. The results due to the addition of a reinforcing pad to the intersection at node 30 are shown in Table C9.

Table C9 – Pump Flange Overturning Moments (ft.-lb) – Unreinforced vs. Pad Reinforced

Condition	Mx	My	Mz
Unreinforced Intersection Modeled with local flexibilities	15403	17656	64784
Pad Reinforced Intersection modeled with local flexibilities	16459 (7% increase)	22733 (28% increase)	75412 (16% increase)

Adding a reinforcing pad to the intersection increases the torsional load on the pump discharge flange by 28% and the bending load on the pump flange by about 16%.

C-6 Example No. 4 Discharge Branches

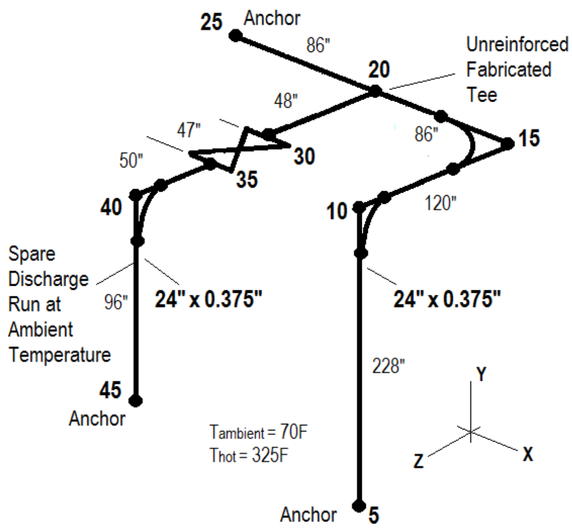
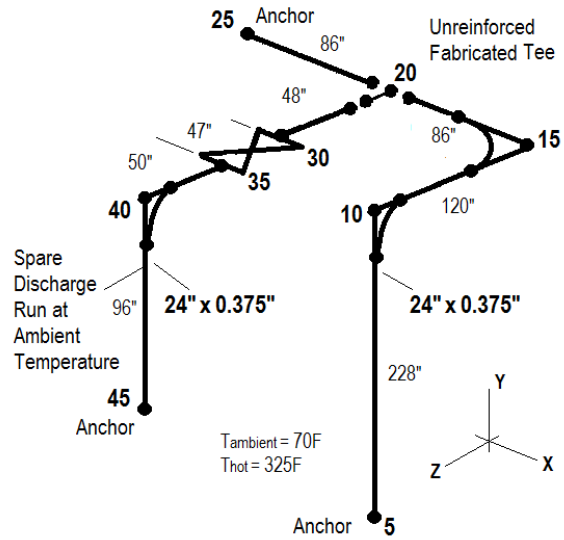


Figure C6 – Isometric of Pump Discharge



Isometric with Nodes to Incorporate Branch Connection Flexibilities at Node 20

In the standard operating condition for the system shown above the spare pump discharge line is at ambient temperature while the main discharge line is at 325 ºF. The thermal expansion of the main discharge line induces in-plane, out-of-plane and torsional loads through both the run and branch legs of the unreinforced fabricated tee at node 20.

The branch and run local stiffnesses act in series and so the independently determined branch and run rotational stiffnesses must be modified before being used in the piping system analysis. The general form of the rotational stiffness equation when the run and branch intersection flexibilities are used together (in series) is provided in Equations C1 and C2 below.

$$K_{run} = 2K_r \qquad \text{Eq. C1}$$

$$K_{branch} = [1/K_b - 1/(2K_r)]^{-1}. \qquad \text{Eq. C2}$$

where:

K_{run} = Stiffness used in between run node points shown in Fig. C7.

K_r = Independent run side stiffness found from Appendix B Table 2 for the appropriate run orientation.

K_{branch} = Stiffness used in between branch node points shown in Fig. C7.

K_b = Independent branch side stiffness found from Appendix B Table 2 for the appropriate branch orientation.

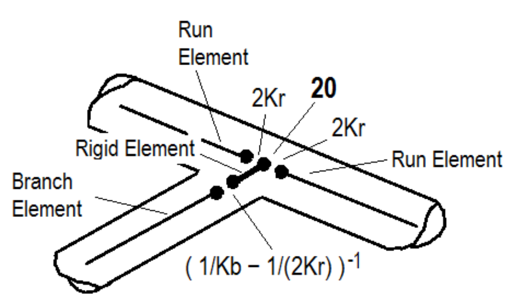


Figure C7 – Location for Local Branch Connection Stiffnesses

The appropriate directional stiffnesses must be combined when the branch and run flexibility factors and load-deflection relationships from Appendix B Table 2 are used together in series as shown in Eq. C2. Table C10 gives the appropriate directional branch and run stiffnesses to combine using Eq. C2.

Table C10 – Branch and Run Flexibility Factors in Series

Direction	Branch	Run
Branch In-plane	k_{ib}	k_{ir}
Branch Out-of-plane	k_{ob}	k_{tr}
Branch Torsional	k_{tr}	k_{or}

When the load-deflection relationships (rotational stiffnesses) due to branch and run flexibilities are combined in the model of the beam analysis of the pipe system in Fig. C6 the branch and run moments change as shown in Table C11 below.

Table C11 – Effect of Branch and Run Flexibilities on Intersection Moments (ft.-lb)

Location	Direction	Moment when Branch Connection Flexibilities Included In Piping Model	Moment when Branch Connection Flexibilities NOT Included in Piping Model	Amount Moment Overestimated When Branch Connection Flexibilities are NOT Included
Branch	In-plane	21,778	71,178	326%
	Out-of-plane	5985	15,010	251%
	Torsion	5027	18,411	366%
Run	In-plane	13,558	55,381	408%
	Out-of-plane	1936	7397	382%
	Torsion	11,756	15,367	130%

Including branch and run branch connection flexibilities are shown to have significant effects on the load distribution in the piping system.

C-7 Example No. 5 Heater Piping

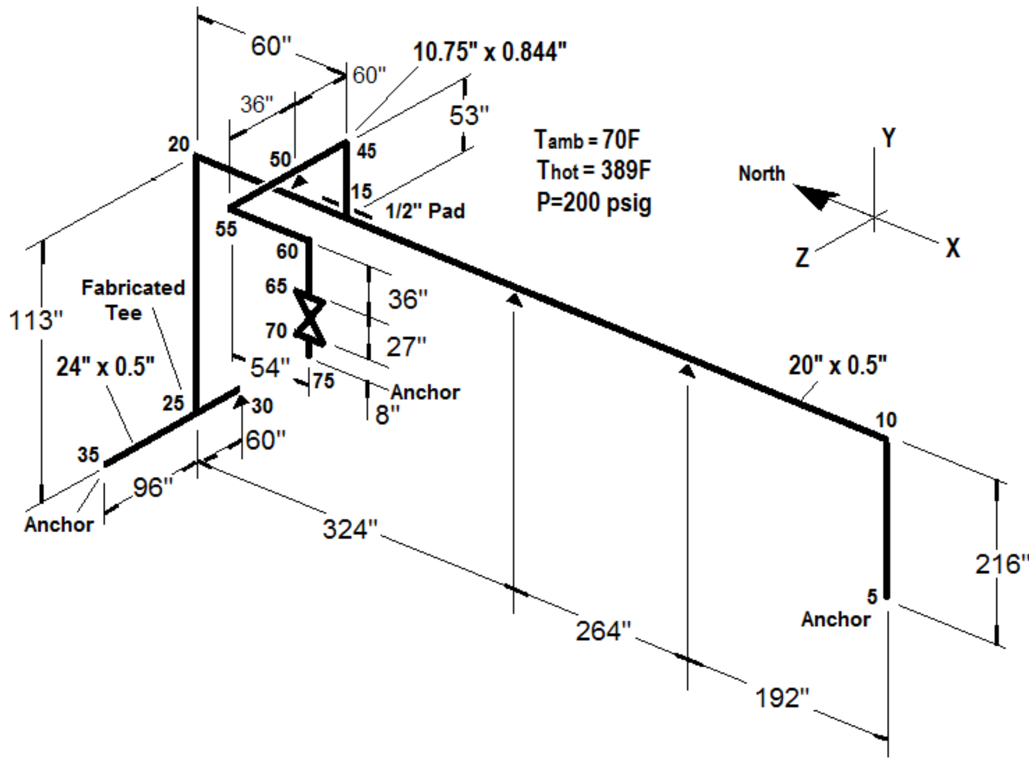


Figure C8 – Heater Piping Isometric

The piping system shown in Fig. C8 is anchored at both the north and south ends. At the north end the piping is anchored 96 inches west of the 24-inch header tie-in. A 10-inch branch line coming from the north end of the 20-inch header is also anchored in the vicinity of the north end of the piping system. Flexibility is provided at the north end of the piping system by the cantilevered 113-inch and 96-inch pipe legs. Flexibility is provided at the south end of the piping system by the cantilevered 216-inch pipe leg.

Flexibility is also provided by the two branch connections in the north end of the pipe system. When branch connection rotational stiffnesses are included in the beam model the displacement at node 20 in the north (-X) direction increases due to the added out-of-plane branch and torsional run flexibility. The additional displacement at node 20 pulls the smaller 10-inch branch line in a northerly direction <u>increasing</u> the moment at the 10” branch tie-in. This can also occur in the vicinity of rotating equipment nozzles, where additional flexibility provides for increased displacement, and greater loads on the rotating equipment rigid boundary conditions.

The branch and run models used together are shown schematically in Figure C9 below.

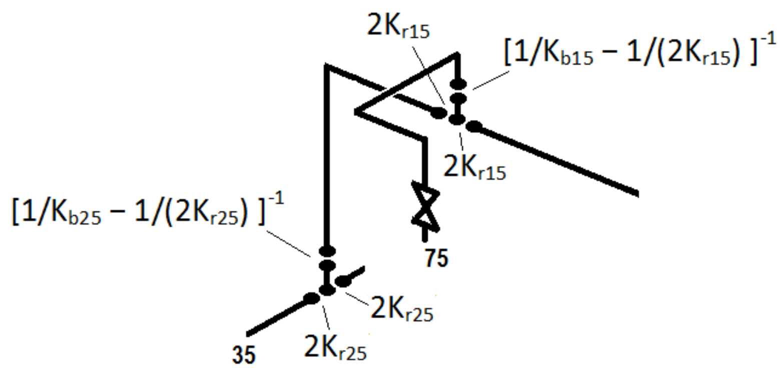


Figure C9 – Heater Piping North End Branch Connection Flexibility Models

Table C12 – Results When Flexibilities are added to Heater Piping (Moments in ft.lb.)

Load Location	Direction	Flexibilities Included	No Flexibilities	Effect of Adding Local Branch Connection Flexibility
75 Anchor	Bending (Z)	19,637	5629	348% Load Increase
	Torsion (Y)	12,385	5357	231% Load Increase
	Bending (X)	2562	4213	40% Load Reduction
35 Anchor	Bending (Y)	97,914	140,709	30% Load Reduction
	Torsion (Z)	48,009	115,298	58% Load Reduction
	Bending (X)	33,088	26,787	23% Load Increase
Displacement At Node 20	North (X)	0.59"	0.39"	51% Displacement Increase

Results in Table C12 show that moment redistribution due to the inclusion of branch connection flexibilities can cause an increase in forces and moments in parts of the system where displacements have increased.

C-8 Effect of Branch Connection Flexibility Factors on Dynamic Analyses

Natural frequencies and mode shapes can be affected by the inclusion of branch connection flexibilities in the piping system model. Affected natural frequencies are lowered. For dynamic problems involving seismic excitation this may cause additional mode shapes to fall within the higher energy portion of the earthquake spectrum resulting in greater displacements and stresses. For narrow or broad band dynamic events, the calculated frequencies, shapes and response properties should be more accurate.
The natural frequencies for the five systems analyzed above are given in the following table for the case where branch connection flexibilities were used and are compared against the case where branch connection flexibilities are not used. Table values are in Hz.

Table C-13 Effect of Branch Connection Flexibilities on Natural Frequency Calculation

Model	Natural Frequencies Model WITH Branch Connection Flexibilities	Natural Frequencies NO Branch Connection Flexibilities
Example No. 1	12.77 20.57 27.01	14.55 28.62 32.29
Example No. 2	2.98 3.31 21.56	3.63 3.98 23.04
Example No. 3	9.03 17.28 21.04 26.47 34.50	9.05 17.31 22.48 27.58 35.13
Example No. 4	9.47 13.01 17.65 35.99 38.35 49.85	10.17 14.89 18.6 43.3 46.47 49.9
Example No. 5	3.37 5.55 7.12 13.2 15.42 22.19 25.93	3.43 6.56 7.18 14.19 17.81 23.47 27.82

NONMANDATORY APPENDIX D

Calculating Flexibility Factors for Branch Connection Models in Piping Systems (R5)

D-1 Nomenclature
b = subscript indicating branch
d = mean branch pipe diameter
d_o =outside diameter of matching branch pipe
D = mean run pipe diameter
D_o = outside diameter of matching run pipe
E = elastic modulus
I = pipe moment of inertia
I_b = branch pipe moment of inertia
I_r = run pipe moment of inertia
K = rotational stiffness
K_b = branch leg rotational stiffness (See Leg 3 Appendix B Fig. 2)
K_r = run leg rotational stiffness (See Legs 1 and 2 Appendix B Fig. 2)
K_i = in-plane rotational stiffness
K_o = out-of-plane rotational stiffness
K_t = torsional rotational stiffness
k_i = in-plane flexibility factor
k_o = out-of-plane flexibility factor
k_t = torsional flexibility factor
k = flexibility factor
r = subscript indicating run

D-2 General

Equations and guidance for the use of flexibility factors for branch connections in piping systems are given in Appendix B, are used in the examples in Appendix C and are discussed in Reference [1]. These flexibility factors are intended to be used with beam models of piping systems where each point, or node, in the piping system model has at least six degrees of freedom defined about a local or global orthogonal axis. Three of these degrees of freedom are translational and three are rotational.

The flexibility factors for branch connections in Appendix B Sketches 2.1 through 2.6 are used with Appendix B Table 2 moment-rotation relationships, or "rotational stiffnesses." These rotational stiffnesses are a function of the flexibility factor, modulus of elasticity, moment of inertia and branch or run diameter given Equation D-1 below and in Appendix B Table 2.

$$K = (EI)/(kd) \qquad \text{Eq. D-1}$$

The calculated rotational stiffnesses define the rotation of one point on a branch or run pipe element in the piping system with respect to another. The ends of these elements are located at the same point in space or at very nearly the same point in space so that there is a negligible distance between the two points. This is shown in Figure D1 below:

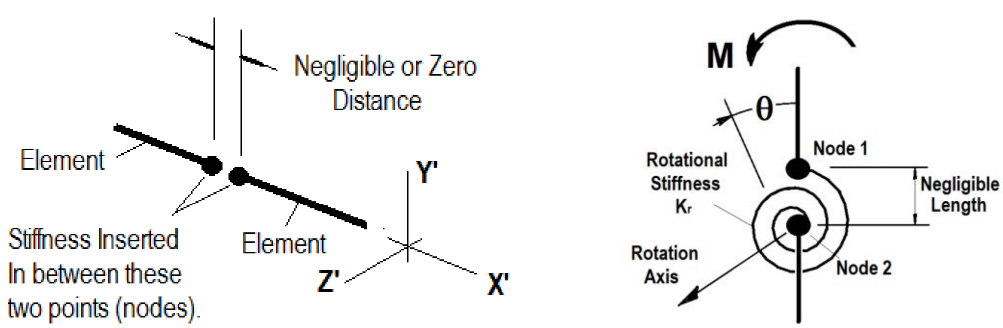


Figure D1 – Rotational Stiffness Location in Between Two Nodes

The coordinate system in Figure D1 is a local X', Y' and Z' coordinate system where X' is along the element centerline axis, Y' is normal to the element axis, and Z' is orthogonal to X' and Y'. The Y' and Z' coordinate axes are generally aligned along a defined in-plane or out-of-plane orientation for the branch connection. For elements that make-up branch connection models in a piping system the in-plane orientation is shown in Figure D2. The out-of-plane orientation is different for branch and run elements and is found by crossing the branch element axial direction vector into the in-plane orientation vector shown in Figure D2 below to find the branch out-of-plane orientation. The out-of-plane orientation is found by crossing the run element axial direction vector into the in-plane orientation vector to find the run out-of-plane orientation.

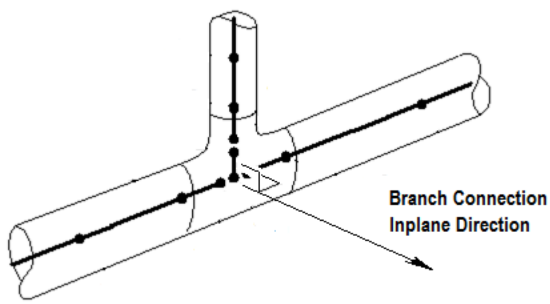


Figure D2 – Branch Connection In-plane Direction

There may be up to three moment-rotation node-pair relationships for each location on the branch connection in a beam model of a piping system depending on whether the branch, run, or both the branch and run flexibilities should be considered. See Figures D5 through D7. There are three branch moment-rotation relationships (rotational stiffnesses), and three run moment-rotation relationships (rotational stiffnesses) for each intersection in Appendix B Sketches 2.1 through 2.6. The run rotational stiffnesses may be used as shown in Figures D6 and D7. The branch rotational stiffnesses may be used as shown in figures D5 and D7.

The piping designer must determine which of the models is most appropriate. In all cases the run and branch rotational stiffnesses may be used together in series to provide an accurate simulation. Including the branch stiffness relationships only is reasonable when the run stiffness relationships are rigid or approximately rigid. When the d/D ratio for a branch connection is less than one the run flexibility factors will often be less than one and need not be used. When a flexibility factor is not used the corresponding rotational stiffness should be rigid. (See Appendix B Note 3.) The three combinations available for each branch connection are:

1) Branch flexibilities included only
2) Run flexibilities included only
3) Branch and Run flexibilities included together (in series)

Historically, branch and run flexibilities are developed independently and can be used without modification in the beam model of the piping system when either the branch or the run flexibilities are needed. Several examples in Appendix C illustrate when branch and run flexibilities can be used independently in a piping system analysis.

When both the branch and run flexibilities are used together for the same intersection model the interaction of loads through the branch and run stiffnesses should be considered and the branch connection symmetry maintained. These requirements are satisfied in the model shown in Figure D7.

The three most often used branch connection models are shown in Figures D5 through D7 below:

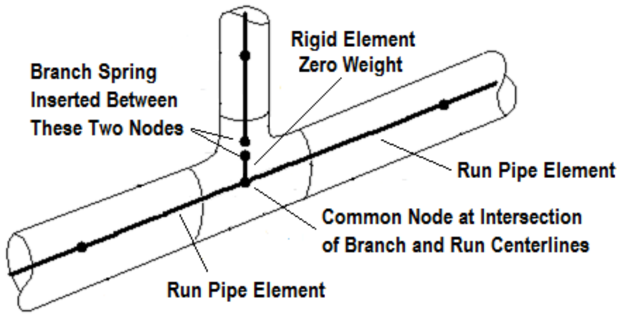


Figure D5 – Branch Connection Flexibilities used on Branch Side Only

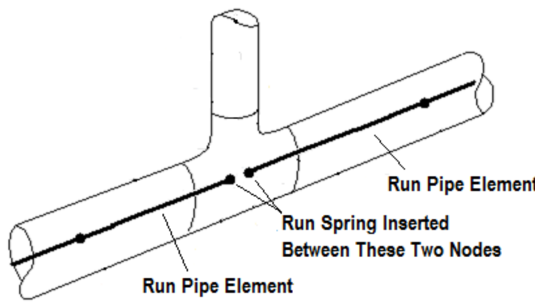


Figure D6 – Branch Connection Flexibilities used on Run side Only

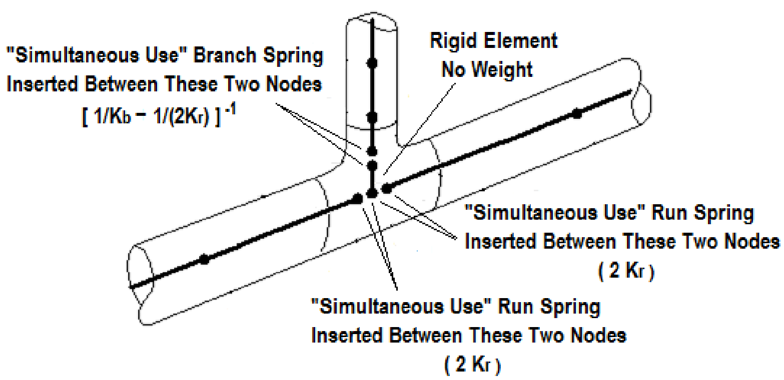


Figure D7 – Branch and Run Flexibilities Used Together (In Series)

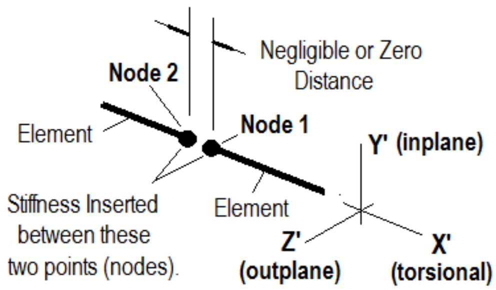
A model including <u>only</u> the branch flexibilities (Figure D5) is often used because:

1) It is easy to add to an existing beam model of a piping system
2) Run flexibility factors are often less than or close to 1.
3) Significant loads do not act through both run side pipe elements
4) Branch flexibility factors are >> 1

A model including <u>only</u> the run flexibilities (Figure D6) might be used because:

1) There are no significant loads acting on the branch pipe, or
2) The branch pipe is not included in the piping system model
3) Run flexibility factors are >>1

The branch and run flexibility factors are used to calculate rotational stiffnesses that define the moment-rotation relationship between two nodes in the branch connection model that are at approximately the same point in space, or are a negligible distance apart. The translations are equal for each node and the translational stiffnesses between the nodes should be rigid. Rotational stiffnesses should be inserted between the two nodes so that the rotation of one node relative to the other is given by the branch connection moment-rotation relationship in the appropriate direction. This is illustrated in Figure D8 where the rotational stiffnesses are given with respect to the nodes numbered 1 and 2.



Stiffness	Axis	Stiffness Equation
Rotational Inplane	Y′	$EI/(k_i d)$
Rotational Outplane	Z′	$EI/(k_o d)$
Rotational Torsion	X′	$EI/(k_t d)$

Figure D8 – Rotational Flexibility Definitions

For the branch moment-rotation relationship, the moment of inertia, k-factor and mean diameter (d) of the branch pipe should be used. For the run moment-rotation relationship, the moment of inertia, k-factor and mean diameter (D) for the run pipe should be used. Branch and run node locations are shown in Figure D9:

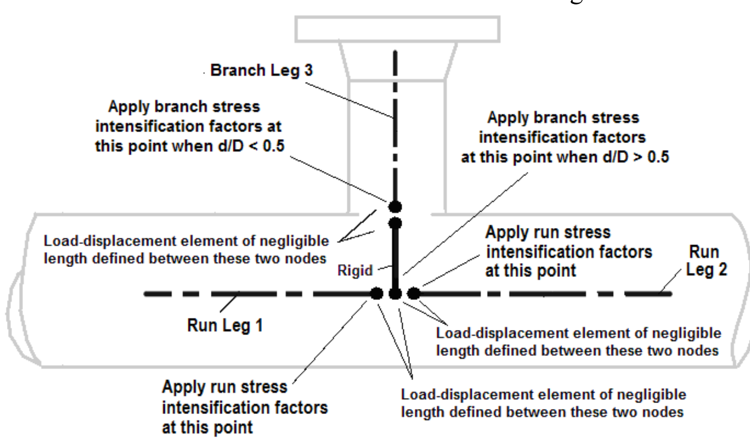


Figure D9 – Branch and Run SIF and k-Factor Intersection Orientations

D-3 Unreinforced Fabricated Tee 16x20 Standard Wall Example

An example illustrating each step of the rotational stiffness calculation is shown below for a beam model of a 16x20 unreinforced fabricated tee intersection that includes the branch and run stiffnesses together in series.

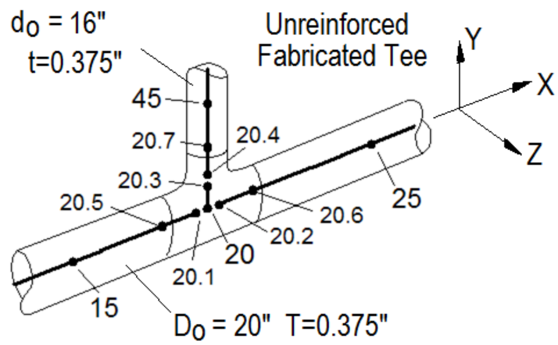


Figure D10 – Example Flexibility Model

Appendix B Sketch 2.3 gives the equations to calculation branch and run flexibility factors for a fabricated tee. These flexibility factors are used with the branch and run rotational stiffness equations given in Appendix B Table 2 to find the negligible length element stiffnesses that should be inserted into the piping system model with the appropriate orientation. Figure D10 shows a global X,Y and Z coordinate system for the intersection. The local –to-global stiffness orientations for the branch connection shown in Fig D10 are provided in Table D2 below. The modulus of elasticity used for the example calculation is 29 x 10^6 psi. The simultaneous, in-series stiffnesses to be used in the Fig. D10 model are included in Table D3.

Table D1 – Branch Connection Geometry Properties

	Outside Diameter (in.)		Thickness (in.)		Mean Diameter (in.)		Moment of Inertia (in^4)	
Branch	d_o	16	t	0.375	d	15.625	I_b	562
Run	D_o	20	T	0.375	D	19.625	I_r	1113

Table D2 – Fig. D10 Computed Branch Connection Stiffnesses from Appendix B Table 2

Moment-Rotation Direction	Stiffness Term Appendix B Table 2	Degree of Freedom	Model Restrained Direction	k-factor	Stiffness	
Branch In-plane		Translation	Z	0		Rigid
Branch Out-of-plane		Translation	X	0		Rigid
Branch Torsion		Translation	Y	0		Rigid
Branch In-plane	K_{ib}	Rotation	Z	7.4	$EI_b/(k_{ib}d)$	2,467 kip in./deg
Branch Out-of-plane	K_{ob}	Rotation	X	30.2	$EI_b/(k_{ob}d)$	598 kip in./deg
Branch Torsion	K_{tb}	Rotation	Y	4.15	$EI_b/(k_{tb}d)$	4,388 kip in./deg
Run In-plane		Translation	Z	0		Rigid
Run Out-of-plane		Translation	Y	0		Rigid
Run Torsion		Translation	X	0		Rigid
Run In-plane	K_{ir}	Rotation	Z	1.7	$EI_r/(k_{ir}D)$	16,836 kip in./deg
Run Out-of-plane	K_{or}	Rotation	Y	1	$EI_r/(k_{or}D)$	Rigid
Run Torsion	K_{tr}	Rotation	X	2.16	$EI_r/(k_{tr}D)$	13,314 kip in./deg

Table D3 – Fig. D10 Branch Connection Stiffnesses for Input to Beam Model

Moment-Rotation Direction	Element Nodes	Degree of Freedom	Model Restrained Direction	Stiffness	
Branch In-plane	20.3 to 20.4	Translation	Z		Rigid
Branch Out-of-plane	20.3 to 20.4	Translation	X		Rigid
Branch Torsion	20.3 to 20.4	Translation	Y		Rigid
Branch In-plane	20.3 to 20.4	Rotation	Z	$[1/K_{ib}+1/(2K_{ir})]^{-1}$	2,298 kip in./deg
Branch Out-of-plane	20.3 to 20.4	Rotation	X	$[1/K_{ob}+1/(2K_{tr})]^{-1}$	585 kip in./deg
Branch Torsion	20.3 to 20.4	Rotation	Y	$[1/K_{tb}+1/(2K_{or})]^{-1}$	4,388 kip in./deg
Run In-plane	20 to 20.1	Translation	Z		Rigid
Run Out-of-plane	20 to 20.1	Translation	Y		Rigid
Run Torsion	20 to 20.1	Translation	X		Rigid
Run In-plane	20 to 20.1	Rotation	Z	$2K_{ir}$	33,672 kip in./deg
Run Out-of-plane	20 to 20.1	Rotation	Y	$2K_{or}$	Rigid
Run Torsion	20 to 20.1	Rotation	X	$2K_{tr}$	26,628 kip in./deg
Run In-plane	20 to 20.2	Translation	Z		Rigid
Run Out-of-plane	20 to 20.2	Translation	Y		Rigid
Run Torsion	20 to 20.2	Translation	X		Rigid
Run In-plane	20 to 20.2	Rotation	Z	$2K_{ir}$	33,672 kip in./deg
Run Out-of-plane	20 to 20.2	Rotation	Y	$2K_{or}$	Rigid
Run Torsion	20 to 20.2	Rotation	X	$2K_{tr}$	26,628 kip in.lb/deg

ANNEX B – KHAN FLEXIBILITY CALCULATION EQUATIONS REFS. [23], [24]

Contents:

1.0 Discussion and Derivation

The equations used to compute flexibility factors from Markl style fatigue test results can be found in Khan, *"A Study of Flexibility Factors of Integrally Reinforced Shell to Shell Intersections",* Int. J. Pres. Ves. & Piping 29 (1987) 23-31. The assumptions and derivations used in Khan's paper are discussed here so that they can be extended and used with other fatigue test results. This exercise produces a result similar to the one outlined by E. Rodabaugh and G. Woods in WRC 346. A numerical iterative approach to find flexibility factors from test data is also described in Section 4.0. The numerical method requires the availability of a beam analysis tool that can be used to model the various test configurations.

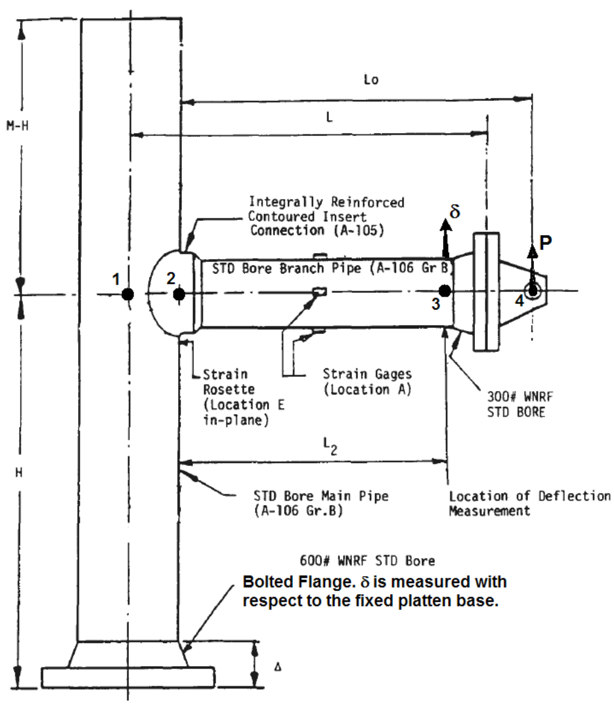


Figure 1 Fatigue Test Configuration for Branch Connections from Kahn (with added notes)

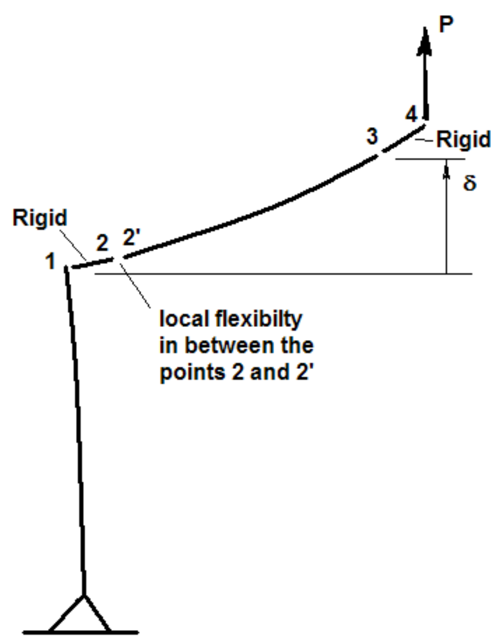


Figure 2 – Exaggerated Fatigue Test Displaced Shape

Khan's nomenclature has been modified and reproduced below.

$$\theta_a = \frac{\delta}{L_2} \qquad (3)$$

$$\theta_b = \frac{P}{6EI_b}(L_2^2 - 3L_oL_2) \qquad (4)$$

$$\theta_c = \frac{P(L_o + R)(H - \Delta)}{EI_m} \qquad (5)$$

$$\theta = |\theta_a| - |\theta_b| - |\theta_c| \qquad (6)$$

δ_3 = Measured deflection at L_2 relative to bolted flange
L_o = Point of application of load P
R = Outside radius of main pipe
I_b = Moment of inertia of branch pipe
I_m = Moment of inertia of main pipe

H = Height of intersection from fixed end of main pipe
θ = Rotation due to flexibility of intersection
d_o = Outside diameter of branch pipe
Δ = Height of main pipe flange
P = Applied force on end of branch pipe

$$\bar{k} = \theta/\theta_{nom} = \theta EI_b/M_bd_o \qquad (7)$$

The "rotations" used by Khan in his equations (3) through (6) above have been changed to alphanumeric subscripts to keep them separate from from the "rotation" defintions used in the derivation below. This separation is maintained principally because θ_a is not the rotation at the point where the deflection is measured. In the Khan document θ_a above is labeled θ_1. The rotation at the point where the deflection is measured is not used in the derivation below.

In the derivation below it is convenient to divide the displacement at the point of load application by the length L_2 to clear L_2 from the numerator in a number of the terms on both the right and left side of the equals sign. This produces the term δ/L_2 which Khan labels θ_1. δ/L_2 is not the pipe rotation at the measurement point.

The absolute value signs are removed from Khan's equation (6) since they are not needed if it is recognized that θ_b as given in Khan Eq. (4) above is always negative when the force "P" is positive.

The force P acting at point 4 shown in Fig. 1 above produces internal forces and moments at points 1, 2 and 3. In the experiment, the displacement (δ) at point 3 is measured along with the force (P) at point 4. From these measured values, rotations and displacements at any point can be calculated using beam theory.

For the inplane load shown in Figures 1 and 2 above, the vertical displacement (δ) at point 3 where the displacements in the Khan test are measured can be found by summing:

$$\delta_3 = \delta_1 + \delta_{1,2} + \delta_{2,3} \qquad \text{[Eq. 1]}$$

δ_1 is the displacement at point 1 in the vertical direction in Figure 2. δ_1 is assumed to be negligible and is taken as 0. δ_1 is not zero for the out-plane load test. $\delta_{x,y}$ is the relative displacement of point y with respect to point x. The local flexibility (k,k_m) between points 2 and 2' is defined such that $\theta_{2'} > \theta_2$, but $\delta_{2'} = \delta_2$.

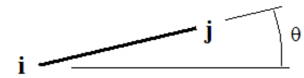
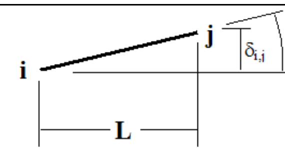
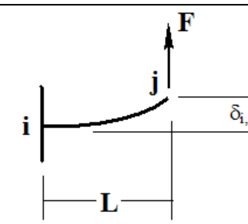
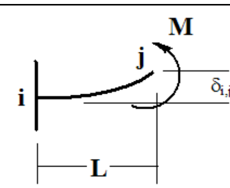
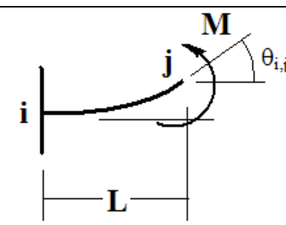
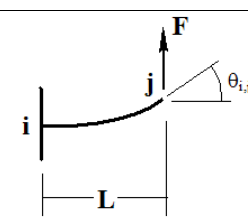
$\delta_{1,2}$ is the displacement of point 2 with respect to point 1 due to the rigid body rotation of the element in between points 1 and 2, and is equal to $R\theta_1$. $\delta_{2,3}$ is the displacement of point 3 with respect to point 2 due to the rigid body rotation of the element from 2' to 3, and the deflection of the pipe element from point 2' to point 3 due to force and moment acting at point 3. Small rotation theory is assumed.

The local stiffness (k_m) exists in between points 2 and 2'.

Displacements due to the shear force (P) acting at node 3 will have an (F) subscript, and displacements due to the moment (M) acting at section 3 will have an (M) subscript.

$\delta_{2,3} = \delta_{2',3F} + \delta_{2',3M} + \delta_{2',3\theta}$ where $\delta_{2',3F}$ is the relative displacement of point 3 with respect to point 2' due to the vertical shear force acting on point 3, and $\delta_{2',3M}$ is the relative displacement of point 3 with respect to point 2' due to the moment acting on point 3. This moment is equal to $(P)(L_o\text{-}L_2)$. $\delta_{2',3\theta}$ is the rigid body displacement of node 3 with respect to the rotation of node 2'.
The beam equations (shear deflections omitted) used in the derivation are given in Table 1 below:

Table 1 – Beam Load Displacement Relationships

#	Degree of Freedom	Conditions	Parameter of Interest	
1	θ_j due to θ_i	End (i) pinned , Rigid body rotation	rotation at j	 $\theta_j = \theta_i$
2	$\delta_{i,j}$ due to θ_i	End (i) pinned, Rigid body rotation	displacement at j	 $\delta_{i,j} = (L)(\theta_i) = (L)(\theta_j)$
3	$\delta_{i,j}$ due to F_j	End (i) fixed, Force at (j)	displacement at j	 $\delta_{i,j} = FL^3/(3EI)$
4	$\delta_{i,j}$ due to M_j	End (i) fixed, Moment at (j)	displacmeent at j	 $\delta_{i,j} = ML^2/(2EI)$
5	$\theta_{i,j}$ due to M_j	End (i) fixed, Moment at (j)	rotation at j [when the moment and rotation at end j is torsional, the equation becomes: $\theta_{i,j} = 1.3ML/(EI)$]	 $\theta_{i,j} = ML/(EI)$
6	$\theta_{i,j}$ due to F_j	End (i) fixed, Force at j	rotation at j	 $\theta_{i,j} = FL^2/(2EI)$

1.1 Inplane Loading

Solving for each vertical displacement component:

$$\delta_{1,2} = R\theta_1 \quad \textbf{[Eq. 2]}$$

$$\theta_1 = (M\ell)/(EI) = M(H\text{-}\Delta) /(E\ I_r) = (P)(L_o{+}R)(H\text{-}\Delta) /(E\ I_r) \quad \textbf{[Eq. 3]}$$

$$I_r = (\pi)(R^3)(T) \quad \textbf{[Eq. 4]}$$

R = mean radius of run pipe

T = thickness of run pipe

r = mean radius of branch pipe attached to fitting

t = thickness of branch pipe attached to fitting

ℓ = pipe length

$$\delta_{1,2} = \ = (R)(P)(L_o{+}R)(H\text{-}\Delta) /(E\ I_r) \quad \textbf{[Eq. 2a]}$$

$$\delta_{2',3\theta} = (\theta_{2'})(L_2) \quad \textbf{[Eq. 5]}$$

$$\theta_{2'} = \theta_1 + M/K_{2,2'\theta} = \theta_1 + (P)(L_o)/K_{2,2'\theta} \quad \textbf{[Eq. 6]}$$

$$K_{2,2'\theta} = EI_b / k_m d \quad \textbf{[Eq. 7]}$$

k_m = flexibility factor for fitting.

$$\theta_{2'} = \theta_1 + M/K_{2,2'\theta} = \theta_1 + (P)(L_o)/K_{2,2'\theta} = (P)(L_o{+}R)(H\text{-}\Delta) /(E\ I_r) + (P)(L_o)/K_{2,2'\theta} \quad \textbf{[Eq. 6a]}$$

$$\delta_{2',3\theta} = (\theta_{2'})(L_2) = [\ (P)(L_o{+}R)(H\text{-}\Delta) /(E\ I_r) + (P)(L_o)/K_{2,2'\theta}\ ]\ (L_2) \quad \textbf{[Eq. 5a]}$$

Replacing $K_{2,2'\theta}$ with the expression for k_m:

$$\delta_{2',3\theta} = (\theta_{2'})(L_2) = [\ (P)(L_o{+}R)(H\text{-}\Delta) /(E\ I_r) + (P)(L_o)\ (k_m d)/(EI_b)\ ]\ (L_2) \quad \textbf{[Eq. 5b]}$$

In the expression $K_{2,2'\theta}$ above [Eq.7], (d) can be taken as (2r) or the outside diameter of the branch pipe (d_o). Either one is considered sufficiently accurate. The value chosen: (d) or (d_o), should be used consistently for the definition and use of (k_m).

$$\delta_{2',3F} = (F\ell^3)/(3EI) = (P)(L_2^3) / (3E\ I_b) \quad \textbf{[Eq. 8]}$$

$$I_b = (\pi)(r^3)(t) \quad \textbf{[Eq. 9]}$$

$$\delta_{2',3M} = (M\ell^2)/(2EI) = (P)(L_o\text{-}L_2)(L_2^2) / (2E\ I_b) \quad \textbf{[Eq. 10]}$$

Expanding the equations for δ_3:

$$\delta_3 = \delta_1 + \delta_{1,2} + \delta_{2,3} = 0.0 + R\theta_1 + \delta_{2',3F} + \delta_{2',3M} + \delta_{2,3\theta} \quad \textbf{[Eq. 1a]}$$

$$\delta_3 = 0. + (R)(P)(L_o{+}R)(H\text{-}\Delta)/(EI_r) + PL_2^3/(3EI_b) + P(L_o\text{-}L_2)(L_2^2)/(2EI_b) +$$
$$L_2[P(L_o{+}R)(H\text{-}\Delta)/(EI_r)] + L_2P(L_o)k_m d/(EI_b) \quad \textbf{[Eq. 1b]}$$

The terms on the right hand side in the equation above that include the bending of the run pipe can be combined:

$$\delta_3 = (R{+}L_2)(P)(L_o{+}R)(H\text{-}\Delta)/(EI_r) + PL_2^3/(3EI_b) + P(L_o\text{-}L_2)(L_2^2)/(2EI_b) + (L_2)(P)(L_o)k_m d/(EI_b) \quad \textbf{[Eq. 1c]}$$

Rearrange the above equation [1c] to compare more directly to Khan's equation and to solve for k_m.

$$L_2\ [(P)(L_o)k_m d/(EI_b)] = \delta_3 - (R{+}L_2)(P)(L_o{+}R)(H\text{-}\Delta)/(EI_r) - PL_2^3/(3EI_b) - P(L_o\text{-}L_2)(L_2^2)/(2EI_b) \quad \textbf{[Eq. 11]}$$

Divide the above equation (11) by L_2 to compare with Khan's Equation (6). The equation (12) below includes a term for the δ_3 contribution due to the rigid body rotation of the element from 1-to-2, and rearranges θ_b from Khan's Eq. (4) since Khan's Eq. (4) will always be negative since $L_o > L_2$.

$(P)(L_o)k_m d/(EI_b) = \delta_3/L_2 -$ … (θ_a) Equal to Khan (Eq. 3) **[Eq. 12]**

$(R/L_2)(P)(L_o{+}R)(H\text{-}\Delta)/(EI_r) -$ … (θ_R) Rotation from point 1-to-2 not in Khan

$(P)(L_o{+}R)(H\text{-}\Delta)/(EI_r) -$ … (θ_c) Equal to Khan Eq. (5)

$PL_2^2/(3EI_b) - P(L_o\text{-}L_2)(L_2)/(2EI_b)$ … (θ_b) Equal to Khan Eq. (4) with sign change

$$= \theta_a - \theta_R - \theta_c - \theta_b \quad \text{[Eq. 13]}$$

Rearranging Eqs. (12) and (13) to find k_m:

$$k_m = (\theta_a - \theta_R - \theta_c - \theta_b)(EI_b) / [(P)(L_o)(d)] \quad \text{[Eq. 14]}$$

The above approach is for inplane i-factor tests. For outplane tests θ_1 is replaced by:

$$\theta_1 = (M\ell)/(GJ) \quad \text{[Eq. 15]}$$

where for isotropic material $G = E / [(2)(1+v)]$ and for pipe sections $J = 2I$.

$$\theta_1 = (M\ell)/(GJ) = (1.3)(M\ell)/(E\ I) \quad \text{[Eq. 15a]}$$

Additionally, δ_1 is not zero for outplane loads.

1.2 Outplane Loading

For out-of-plane loading δ_1 is not 0.0, and the equation for δ_1 should be included in the overall displacement equation when the run pipe and branch pipe are close in diameter and/or when the run pipe lengths are long. To find the outplane displacement equation, replace θ_1 in the inplane PRG displacement equation (10) with the outplane θ_1 in Eq.15a above and include the expression for δ_1:

$(P)(L_o)k_{mo}d/(EIb) = \delta_3/L_2 -$ … Equal to Khan θ_a (Eq. 3) **[Eq. 16]**

$\delta_1/L_2 -$ … Displacement at top of run pipe due to load.

$(R/L_2)(P)(L_o+R)(H-\Delta)/(2GI_r) -$ … Rotation from point 1-to-2 not in Khan

$(P)(L_o+R)(H-\Delta)/(2GI_r) -$ … Equal to Khan Eq. (5)

$PL_2^2/(3EI_b) - P(L_o-L_2)(L_2)/(2EI_b)$ … Equal to Khan Eq. (4) with sign change

The displacement in the direction of the load at the centerline of the run pipe at the elevation where the centerline of the branch intersects the header is given by:

$$\delta_1 = FL^3/(3EI) = (P)(H-\Delta)^3 / (3EI_r) \quad \text{[Eq. 17]}$$

Inserting this expression for δ_1/L_2 in equation (16) to describe outplane loading:

$(P)(L_o)k_{mo}d/(EIb) = \delta_3/L_2 -$ … equal to Khan θ_a (Eq. 3) **[Eq. 16a]**

$(P)(H-\Delta)^3 / (3L_2EI_r) -$ … displacement at top of run pipe due to load.

$(R/L_2)(P)(L_o+R)(H-\Delta)/(2GI_r) -$ … rotation from point 1-to-2 not in Khan

$(P)(L_o+R)(H-\Delta)/(2GI_r) -$ …. Equal to Khan Eq. (8)

$PL_2^2/(3EI_b) - P(L_o-L_2)(L_2)/(2EI_b)$ … Equal to Khan Eq. (4) with sign change

2.0 Comparison with Khan Equations

2.1 Inplane Loading

Khan's Eq. 6 is given as:

$$\theta = |\theta_1| - |\theta_2| - |\theta_3| \quad \text{[Eq. 18]}$$

Using (d) instead of (d_o) to maintain consistency with the approach above:

$$\theta = k_m Md/(EI_b) \text{… Khan Eq. 7} \quad \text{[Eq. 19]}$$

Since Khan's θ_1 and θ_3 will always be positive as long as (P) is positive, the absolute values can be excluded from Khan's Eq. 6. Since Khan's θ_2 will always be negative, the length term inside of Khan Eq.(4) can have its sign changed and Khan's Eq. 6 rewritten using Khan's Eqs. (3-5):

$$\theta = k_m Md/(EI_b) = \delta/L_2 - P/(6EI_b)[3L_oL_2 - L_2^2] - P(L_o+R)(H-\Delta)/(EI_r) \quad \text{[Eq. 19a]}$$

(M) in Khan's rearranged Eq. 6 above [19a] is equal to $(P)(L_o)$. Compare the above equation [19a] to the PRG equation (12) describing the inplane displacements derived above:

$$(M)k_md/(EI_b) = \delta_3/L_2 - PL_2^2/(3EI_b) - P(L_o\text{-}L_2)(L_2)/(2EI_b) - (R/L_2)(P)(L_o+R)(H\text{-}\Delta)/(EI_r) - (P)(L_o+R)(H\text{-}\Delta)/(EI_r) \quad \textbf{[Eq. 12a]}$$

Rearrange the PRG equation [12a] above to segregate the EI_b and EI_r terms so the equation can be more easily compared with Khan's equation.

$$(M)k_md/(EI_b) = \delta_3/L_2 - P/(6EI_b)(\ 2L_2^2+ 3(L_o\text{-}L_2)(L_2)\ ) - (P)/(EI_r)\ [(R/L_2)\ (L_o+R)(H\text{-}\Delta) + (L_o+R)(H\text{-}\Delta)\ ] \quad \textbf{[Eq. 12b]}$$

The EI_b term can be expanded:

$$(M)k_md/(EI_b) = \delta_3/L_2 - P/(6EI_b)(\ 2L_2^2+ 3(L_2L_o) - 3L_2^2)\ ) - (P)/(EI_r)\ [(R/L_2)\ (L_o+R)(H\text{-}\Delta) + (L_o+R)(H\text{-}\Delta)\ ] \quad \textbf{[Eq. 12c]}$$

The EI_b term simplified:

$$(M)k_md/(EI_b) = \delta_3/L_2 - P/(6EI_b)(\ 3(L_2L_o) - L_2^2)\ ) - (P)/(EI_r)\ [(R/L_2)\ (L_o+R)(H\text{-}\Delta) + (L_o+R)(H\text{-}\Delta)\ ] \quad \textbf{[Eq. 12d]}$$

It is now easier to compare the Khan version of Eq.6 (slightly modified as described above), and the PRG expression [12d] for the inplane test:

Khan: **[Eq. 19a]**

$$k_mMd/(EI_b) = \delta/L_2 - P/(6EI_b)[3L_oL_2 - L_2^2] - P/(EI_r)\ (L_o+R)(H\text{-}\Delta)/(EI_r)$$

PRG: **[Eq. 12d]**

$$k_mMd/(EI_b) = \delta_3/L_2 - P/(6EI_b)(\ 3L_2L_o - L_2^2)\ ) - (P)/(EI_r)\ [(R/L_2)\ (L_o+R)(H\text{-}\Delta) + (L_o+R)(H\text{-}\Delta)\ ]$$

The PRG definition for δ_3 is almost equal to the Khan definition for δ. The additional PRG term in Eq. 12d is the contribution from P/EI_r: $(R/L_2)\ (L_o+R)(H\text{-}\Delta)$ which is the vertical displacement at point 3 due to the rotation of the rigid element from the run centerline to its surface, and is considered small relative to the rotation of the run pipe. This displacement component is ignored in the Khan formulation. The PRG approach compares to the Khan approach for the inplane displacement expressions.

2.2 Outplane Loadings (Comparison to Khan)

The Khan outplane equation is found by replacing Khan's Eq. (5) with (8). This results in the following expression:

$$\theta = k_{mo}Md/(EI_b) = \delta/L_2 - P/(6EI_b)[3L_oL_2 - L_2^2] - 1.3P(L_o+R)(H\text{-}\Delta)/(EI_r) \quad \textbf{[Eq. 20]}$$

The only difference between this Khan equation (20) and the Khan inplane equation (19a) is the 1.3 multiplier on the run pipe (P) term. (See Khan equations 5 and 8.)

The branch terms using I_b have already been manipulated to compare with Khan, so using the updated PRG branch term and the derived PRG equation for outplane displacements [16a], the result for comparison with Khan is:

$$k_{mo}Md/(EI_b) = \delta_3/L_2 - P/(6EI_b)[3L_oL_2 - L_2^2] - (P)(H\text{-}\Delta)^3 / (3L_2EI_r) - (R/L_2)(P)(L_o+R)(H\text{-}\ \Delta)/(2GI_r) - (P)(L_o+R)(H\text{-}\Delta)/(2GI_r) \quad \textbf{[Eq. 21]}$$

Assume that Poisson's ratio is 0.3, then replace $G = E/[(2)(1.3)]$:

$$k_{mo}Md/(EI_b) = \delta_3/L_2 - P/(6EI_b)[3L_oL_2 - L_2^2] - (P)(H\text{-}\Delta)^3 / (3L_2EI_r) - (R/L_2)(1.3)(P)(L_o+R)(H\text{-}\Delta)/(EI_r) - (1.3)(P)(L_o+R)(H\text{-}\Delta)/(EI_r) \quad \textbf{[Eq. 21a]}$$

Simplifying:

$$k_{mo}Md/(EI_b) = \delta_3/L_2 - P/(6EI_b)[3L_oL_2 - L_2^2] - (P)/(L_2EI_r)\,[(H\text{-}\Delta)^3/3 + (R)(1.3)(L_o+R)(H\text{-}\Delta) + (L_2)(1.3)(L_o+R)(H\text{-}\Delta)] \quad \text{[Eq. 21b]}$$

Khan:

$$k_{mo}Md/(EI_b) = \delta/L_2 - P/(6EI_b)[3L_oL_2 - L_2^2] - 1.3P(L_o+R)(H\text{-}\Delta)/(EI_r) \quad \text{[Eq. 20]}$$

PRG:

$$k_{mo}Md/(EI_b) = \delta_3/L_2 - P/(6EI_b)[3L_oL_2 - L_2^2] - (P)/(EI_r)\,[(H\text{-}\Delta)^3/(3L_2) + (R/L_2)(1.3)(L_o+R)(H\text{-}\Delta) + (1.3)(L_o+R)(H\text{-}\Delta)] \quad \text{[Eq. 21b]}$$

As before, $\delta_{3PRG} = \delta_{Kahn}$. The PRG expression includes the effect of the displacement due to the rotation of the rigid element from the centerline to the surface, which Khan omits, and the lateral displacement of the run pipe which Khan also omits, (although these are expected to be relatively small quantities.)

The EI_r term comparions for the outplane equations 20 and 21b are:

Khan:

$$[P/(EI_r)](1.3)(L_o+R)(H\text{-}\Delta) \quad \text{[Eq. 22]}$$

PRG:

$$[P/(EI_r)](1.3)\,[(0.2564)(H\text{-}\Delta)^3/(L_2) + (R/L_2)(L_o+R)(H\text{-}\Delta) + (L_o+R)(H\text{-}\Delta)] \quad \text{[Eq. 23]}$$

3.0 Comparison with WRC 346

3.1 Outplane Loading

In WRC 346 Section 6. (p.7) E. Rodabaugh computed the flexibility factor for outplane 4x3 fatigue tests of reduced welding tees. The equation he used is identical to the PRG out-plane equation derived here [16a]. The WRC 346 equations represent a procedure that can be described as:

1) Analytically find the displacement of the pipe structural components without including the local stiffness. (This displacement is due only to flexure of the pipe in the test.)
2) Compute the additional displacement of the pipe at the point of measurement due to the local stiffness.
3) Use the actual displacement at the point of measurement to find the local stiffness.

The equations for each of these steps are taken from WRC 346 Figure 10 and are discussed below:

The WRC 346 analytical displacement of the pipe structural components omitting the local flexibility of the intersection is given by equation [24] below: (F=P, and length nomenclature given in WRC 346 Fig. 10 are converted to nomenclature used here.)

$$\delta n = F/E\ [\ 1.3(L_o+R)(H-\Delta)(L_2+R)/I_r + (H-\Delta)^3/(3I_r) + (L_o-L_2)L_2^2\ /\ (2I_b) + L_2^3/(3I_b)\ ] \quad \text{[Eq. 24]}$$

To find the PRG expression for the analytical flexure of the pipe components, the expression for δ_3/L_2 from Eq. 16a can be used and k_m set to zero. P/E can be extracted from the equation with the following result for comparison with Eq. 24.

$$\delta_3/L_2 = F/E[\ (R/L_2)\ (L_o+R)(H-\Delta)(1.3)/I_r + (L_o+R)(H-\Delta)1.3/I_r + L_2^2/(3I_b) + (L_o-L_2)(L_2)^2/(2I_b) + (H-\Delta)^3/(3I_r)\ ] \quad \text{[Eq. 25]}$$

L_2 can be cleared from the expression to find δ_3 for a direct comparison with δn.

$$\delta n = \delta_3 = F/E[\ (R)\ (L_o+R)(H-\Delta)(1.3)/I_r + (L_o+R)(L_2)(H-\Delta)1.3/I_r + L_2^3/(3I_b) + (L_o-L_2)(L_2)^3/(2I_b) + (H-\Delta)^3/(3I_r)\ ] \quad \text{[Eq. 26]}$$

As can be seen by separating the terms, δ_3 is identical to δn.

Evaluating the displacement at the measured point due to the local flexibility:

$\delta = \theta L_2$, where θ is the rotation of the point spring at the surface of the run pipe and connecting to the branch.

The displacement relationship for the local flexibility is: $\theta = Mk_m d/(EI_b)$.

The difference between the computed analytical model displacement (δn) at the measured point, and the measured displacement (δm) should be due to the local flexibility. This can be expressed as:

$$\delta m - \delta n = \theta L_2 = [Mk_m d/(EI_b)](L_2) = (FL_o)(L_2)k_m d\ /\ (EI_b) \quad \text{[Eq. 27]}$$

k_m can be calculated directly from the above equation (27) and can be seen to be equivalent to the expression given in Fig. 10 of WRC 346 for k_o.

Looking more closely at the PRG outplane equation:

$$k_{mo}Md/(EIb) = \delta_3/L_2 - P/(6EI_b)[3L_oL_2 - L_2^2] - (P)/(EI_r)\ [\ (H-\Delta)^3\ /\ (3L_2) + (R/L_2)(1.3)(L_o+R)(H-\Delta) + (1.3)(L_o+R)(H-\Delta)] \quad \text{[Eq. 21b]}$$

Replace the following:

$$\delta_3 = \delta_m \quad \text{[Eq. 28]}$$

Noting above that the PRG analytical displacement for the pipe without the local stiffness is equal to δn. Divide δn by L_2:

$$\delta n/L_2 = P/(6EI_b)[3L_oL_2 - L_2^2] + (P)/(EI_r)\ [\ (H\text{-}\Delta)^3 / (3L_2) + (R/L_2)(1.3)(L_o+R)(H\text{-}\Delta) + (1.3)(L_o+R)(H\text{-}\Delta)] \quad \textbf{[Eq. 29]}$$

$$k_{mo} = k_o = (EI_b/Md)(\delta_3/L_2 - \delta n/L_2) = (EI_b)/(FL_2L_od)\ [\ \delta_3 - \delta n\ ] \quad \textbf{[Eq. 30]}$$

This last equation is identical to the expression used in WRC 346.

4.0 Numerical Comparisons

Iterating with a pipe stress or structural program can also be used to find the value of k_m desired without recourse to solving the above equations. This might actually be more straightforward given the point of measured displacement often varies from test-to-test, and deriving the equations for each unique point is prone to errors. The procedure for performing the numerical iteration is:

1) Build a model of the test geometry. Include a point spring at the surface of the run pipe as recommend in Annex A.

2) Guess at the rotational stiffness of the point spring: $EI_b/(k_m d)$ and insert this value into the model at the appropriate location.

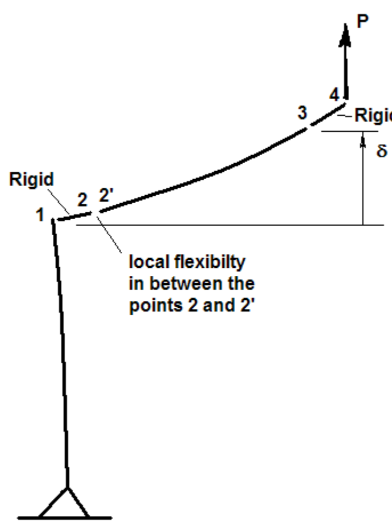
3) Perform the analysis with the test model and local stiffness.

4) If the displacements from the analytical model are too high, then increase the estimated point spring rotational stiffness. If the displacement from the analytical model is too low, then reduce the estimated point spring rotational stiffness.

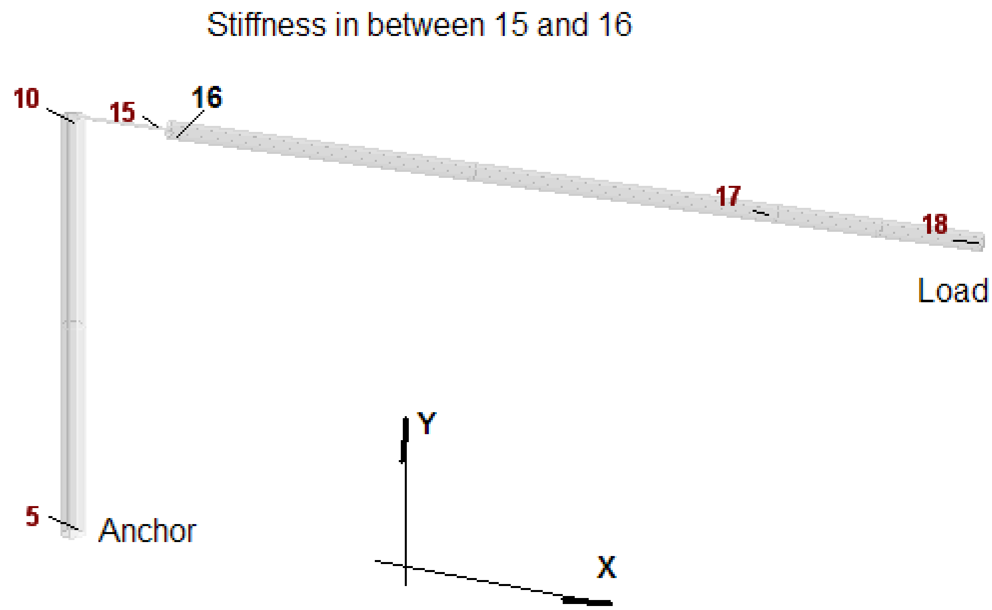
5) Repeat steps 3 and 4 until the result is close enough to the measured test displacement.

6) Evaluate the error in k_m due to the assumed modulus and the approximation in the iteration.

An example demonstrating the use of numerical results is shown below:



A model plot showing the "Khan" stiffness model is shown below. The ER stiffness model is contructed in the same way (starting from node 5), but the nodes are incremented by 100, i.e. the Khan model is 5-10-15-16-17-18, and the ER model is 5-110-115-116-117-118.



The displacement solution from the beam analysis is given below:

Displacement Solution

Load Case: 1 Type: SUSTAINED (Rotations in Degrees)

	X	Y	Z	RX	RY	RZ
5.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10.0	-0.0111	0.0002	0.0000	0.0000	0.0000	0.0669
10.0	-0.0111	0.0002	0.0000	0.0000	0.0000	0.0669
15.0	-0.0111	0.0053	0.0000	0.0000	0.0000	0.0672
16.0	-0.0111	0.0053	0.0000	0.0000	0.0000	0.5303
17.0	-0.0111	0.2998	0.0000	0.0000	0.0000	0.6689
17.0	-0.0111	0.2998	0.0000	0.0000	0.0000	0.6689
18.0	-0.0111	0.4097	0.0000	0.0000	0.0000	0.6784
5.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
110.0	-0.0111	0.0002	0.0000	0.0000	0.0000	0.0669
110.0	-0.0111	0.0002	0.0000	0.0000	0.0000	0.0669
115.0	-0.0111	0.0053	0.0000	0.0000	0.0000	0.0672
116.0	-0.0111	0.0053	0.0000	0.0000	0.0000	0.5965
117.0	-0.0111	0.3313	0.0000	0.0000	0.0000	0.7350
117.0	-0.0111	0.3313	0.0000	0.0000	0.0000	0.7350
118.0	-0.0111	0.4519	0.0000	0.0000	0.0000	0.7445

The input listing is given below:

```
ELEMENT DATA

Khan Model:

5 -to- 10 -to- 15                        PIPE Page: 1
Dx1 = 0. in.     Dy1 = 19. in.    Dz1 = 0. in.
Dx2 = 4.3125 in.     Dy2 = 0. in.    Dz2 = 0. in.
Outside Diameter = 8.625 in.
Pipe Wall Thickness = 0.322 in.
2nd Element is a Rigid element with Zero Weight.
Elastic Modulus = 0.3000E+08 psi
Poissons Ratio = 0.3
--------------------------------------------------------------------
16 -to- 17 -to- 18                        PIPE Page: 2
Dx1 = 27.25 in.     Dy1 = 0. in.    Dz1 = 0. in.
Dx2 = 9.25 in.     Dy2 = 0. in.    Dz2 = 0. in.
Outside Diameter = 6.625 in.
Pipe Wall Thickness = 0.28 in.
--------------------------------------------------------------------
ER Model:

5 -to- 110 -to- 115                        PIPE Page: 3
Dx1 = 0. in.     Dy1 = 19. in.    Dz1 = 0. in.
Dx2 = 4.3125 in.     Dy2 = 0. in.    Dz2 = 0. in.
Outside Diameter = 8.625 in.
Pipe Wall Thickness = 0.322 in.
2nd Element is a Rigid element with Zero Weight.
--------------------------------------------------------------------
116 -to- 117 -to- 118                        PIPE Page: 4
Dx1 = 27.25 in.     Dy1 = 0. in.    Dz1 = 0. in.
Dx2 = 9.25 in.     Dy2 = 0. in.    Dz2 = 0. in.
Outside Diameter = 6.625 in.
Pipe Wall Thickness = 0.28 in.
--------------------------------------------------------------------

RESTRAINT DATA

    5
Directions =  ALL
--------------------------------------------------------------------
    15
Restraint Nodes Connected to = 16
Directions =  ALL
Restraint Stiffness (1:1) with Directions (lb.perin.orin.lb.perdeg)
RIGID RIGID RIGID RIGID RIGID RIGID 0.25811E+06
Info: Khan Th2
--------------------------------------------------------------------
    115
Restraint Nodes Connected to = 116
Directions =  ALL
Restraint Stiffness (1:1) with Directions (lb.perin.orin.lb.perdeg)
RIGID RIGID RIGID RIGID RIGID RIGID 0.22585E+06
Info: ER Th2
--------------------------------------------------------------------
Forces Moment Definition
Applies to Nodes:
    18
Directions =  Y
   Weight (Sustained) Case Forces/Moments (lb. or lb.in.)
    0.32750E+04
--------------------------------------------------------------------
Applies to Nodes:
    118
```

```
 Directions =  Y
    Weight (Sustained) Case Forces/Moments (lb. or lb.in.)
     0.32750E+04
--------------------------------------------------------------------

    Model is defined in English units.

            1 FROM      5        0.0000      0.0000      0.0000
            2 FROM     10        0.0000     19.0000      0.0000
              TO       15        4.3125     19.0000      0.0000
            3 FROM     16        4.3125     19.0000      0.0000
            4 FROM     17       31.5625     19.0000      0.0000
              TO       18       40.8125     19.0000      0.0000
            5 FROM      5        0.0000      0.0000      0.0000
            6 FROM    110        0.0000     19.0000      0.0000
              TO      115        4.3125     19.0000      0.0000
            7 FROM    116        4.3125     19.0000      0.0000
            8 FROM    117       31.5625     19.0000      0.0000
              TO      118       40.8125     19.0000      0.0000

 ELEMENT SPECIFIC DATA

 From/To =       5        10

    Outside Diameter (in.) =  8.625  Thickness (in.) =  0.322
    Element Length (in.)  =  19.

 From/To =      10        15

    RIGID OD (in.) =  17.009  Thickness (in.) =  3.22
    Element Length (in.)  =  4.312
    Cold/Hot Allowable (psi) =  0. 0.

 From/To =      16        17

    Outside Diameter (in.) =  6.625  Thickness (in.) =  0.28
    Element Length (in.)  =  27.25

 From/To =      17        18

    Outside Diameter (in.) =  6.625  Thickness (in.) =  0.28
    Element Length (in.)  =  9.25

 From/To =       5       110

    Outside Diameter (in.) =  8.625  Thickness (in.) =  0.322
    Element Length (in.)  =  19.

 From/To =     110       115

    RIGID OD (in.) =  17.009  Thickness (in.) =  3.22
    Element Length (in.)  =  4.312

 From/To =     116       117

    Outside Diameter (in.) =  6.625  Thickness (in.) =  0.28
    Element Length (in.)  =  27.25

 From/To =     117       118

    Outside Diameter (in.) =  6.625  Thickness (in.) =  0.28
    Element Length (in.)  =  9.25
```

ANNEX C – COMPARISONS WITH EXISTING CODES

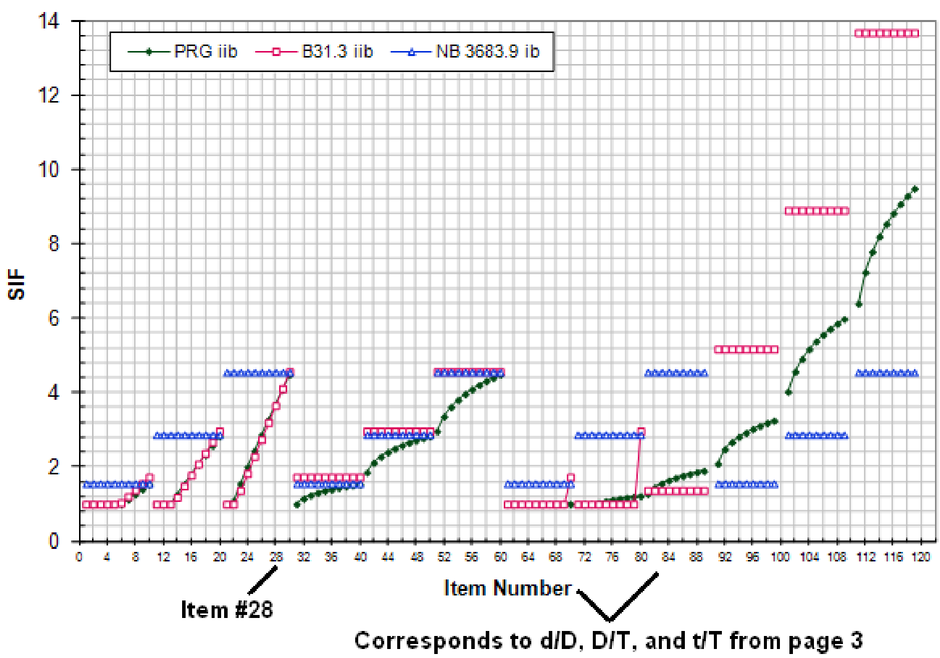
This annex contains comparisons of the branch connection i-factor and k-factor equation results for Sketches 2.1 through 2.6 with those for similar components in B31 and BPVC Section III.

The comparisons are made for each component for the range of parameters given on the following page. Where no comparable k-factor is available, a comparison with the k-factor for unreinforced fabricated tees (Sketch 2.3) is provided.

The equations used to produce the results for each component are given in Annex G along with applicable nomenclature. These charts are generated automatically using the R70 version of ST-LLC 07-02, Microsoft Word and Microsoft Excel. “R70 version of ST-LLC 07-02” is the name given to the automatic feature embedded in this document to generate these charts.

An example comparison plot is shown below for the in-plane stress intensification factor for welding tees. The B31.3 equation used to produce the B31 points on this plot can be found in Annex G Section 1.1.

Fig 2.1 i_{ib} - Welding Tee SIF, Inplane Branch



The ***Item Number*** 28 on the plot above corresponds to the geometry table from page 3, a part of which is shown below for Item # 28.

Item #	D/T	d/D	t/T	r/rp
27	100	0.7	0.7	0.99
28	100	0.8	0.8	0.99
29	100	0.9	0.9	0.99
30	100	1	1	0.99

Over the three years of product development a number of terms have been used as abbreviations for branch connection names and features. Nomenclature used in this and other annexes are given in the table below.

Item	Sketch	Abbrev
Unreinforced Fabricated Tee	Sketch 2.3	UFT
Pad or Saddle Reinforced Fabricated Tee	Sketch 2.2	RFT
B16.9 Welding Tee	Sketch 2.1	WLT
Extruded Outlet	Sketch 2.4	EXT
Welded-in Contour Insert	Sketch 2.5	SWP
Integrally Reinforced Branch Welded-on Fittings	Sketch 2.6	OLET

Items # 91 through 120 are for t/T = 3 and so are outside the permissible range for the Project'ST-LLC 07-02 equations for contoured branch connections. (All commercially available contoured fittings tested, and/or inspected by PRG for the 07-02 project have had t/T ratios less than 1.2.) THE ST-LLC-07-02 EQUATIONS ARE USED TO COMPUTED VALUES FOR CONTOURED FITTINGS IN THIS RANGE FOR INFORMATION ONLY. Other combinations in the comparison tables also represent fittings that may, but are not commonly fabricated. For example, any combination where d/D=1 and t/T<1. These combinations are produced so that i- and k-factors found using the ST-LLC 07-02 equations may be compared to current Code equations.

Notes:

1) When NC is referenced along with Sketch 2.6, where not explicitly given in the test data, a value of 0.85 is used for r/rp.

2) t/T>1 for d/D=1 results in an component where do>Do, and in some cases these components are omitted from comparison. These are not considered "matching" components as described in Table 1 Note 2, "Stress intensification factors in Table 1 have been developed for fatigue tests of representative commercially available matching product forms. Caution should be exercised when applying these rules for … irregular or non-matching product forms."

Tables of the plotted results follow all plotted results in this annex. The plots and the tables provide the same data, organized in a different way. The tables provide a more direct comparison individual points on the plot and provide immediate feedback regarding the dimensionless parameter affect on the evaluated i- or k-factor.

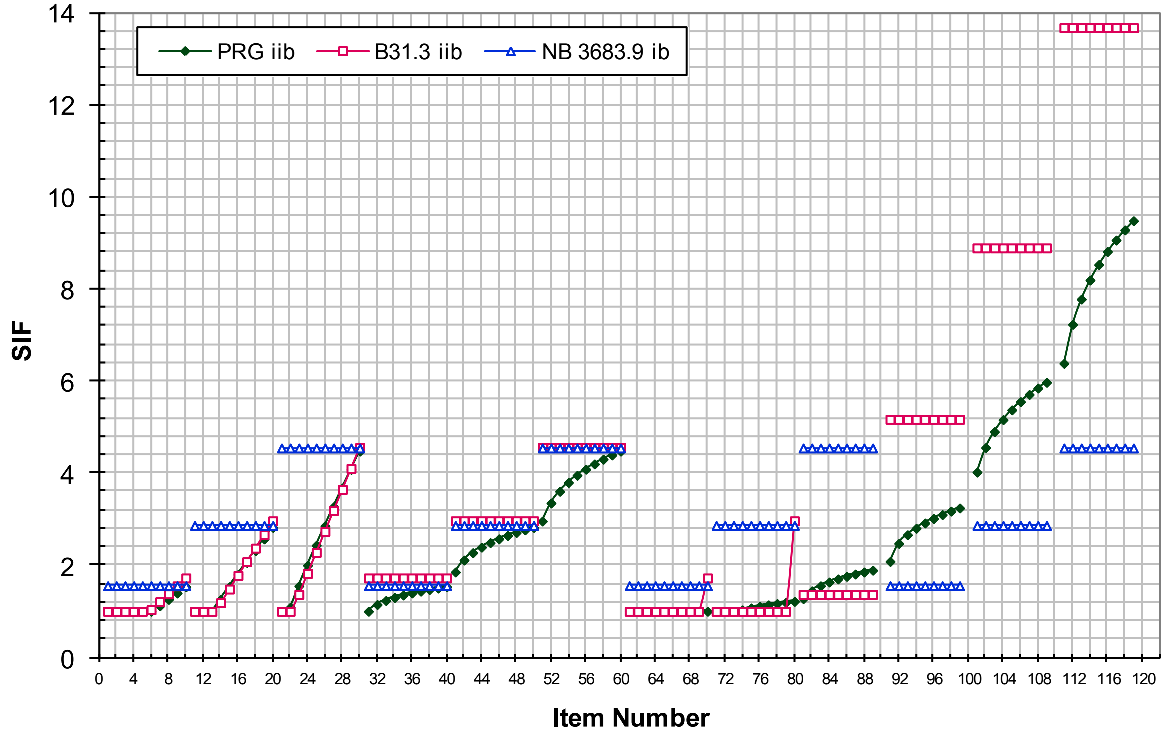
When NC is referenced for a contoured fitting type, (Sketch 2.1, 2.4, 2.5), the reference is to NB3683.9 unless otherwise noted.

3) When geometries are considered unknown, results from finite element models or similar geometries are used to establish low k-factor values for the branch connection. For example, extruded tees can be of any manufactured selected thickness to satisfy pressure design requirements. Tested extruded tees were twice as thick as the matching pipe. (See WRC 329.) In this case k-factors are expected to be low, and where precise values are needed for a particular project or study, the user should develop k-factors based on the exact geometry of the branch connection.

1) Parameter Ranges for Figs. 2.1 through 2.6 Comparison Plots

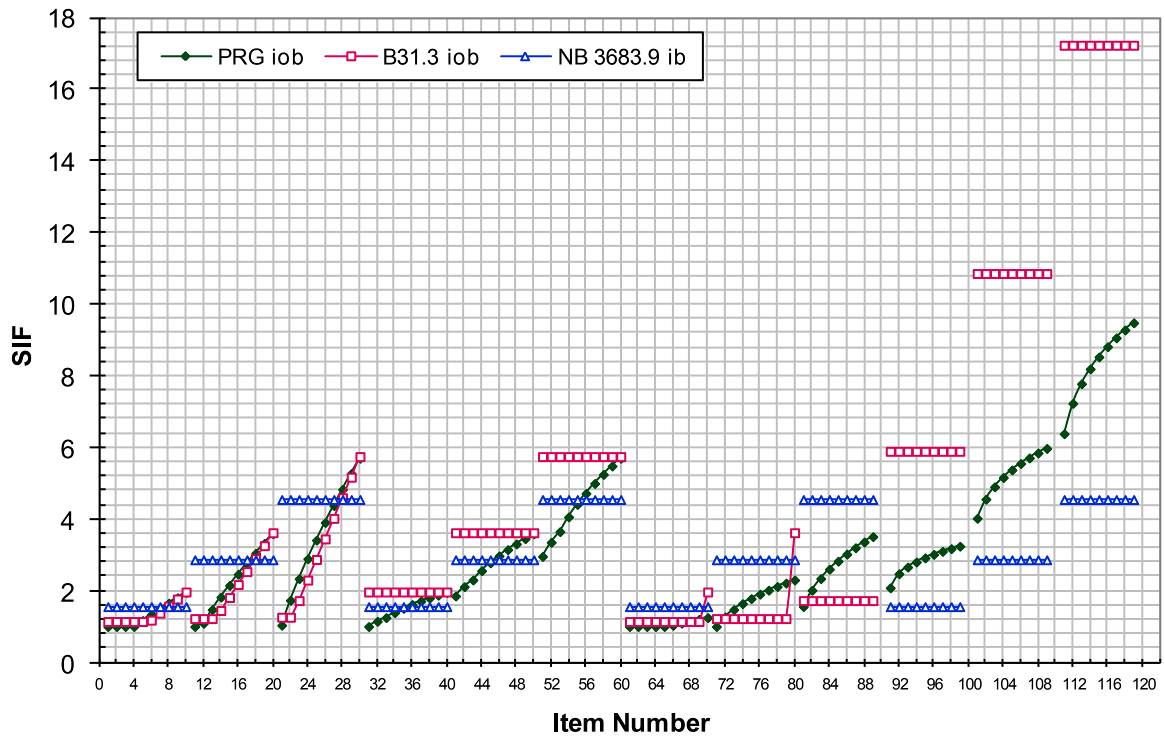
Item #	D/T	d/D	t/T	r/rp
1	20	0.1	0.1	0.95
2	20	0.2	0.2	0.95
3	20	0.3	0.3	0.95
4	20	0.4	0.4	0.95
5	20	0.5	0.5	0.95
6	20	0.6	0.6	0.95
7	20	0.7	0.7	0.95
8	20	0.8	0.8	0.95
9	20	0.9	0.9	0.95
10	20	1	1	0.95
11	50	0.1	0.1	0.98
12	50	0.2	0.2	0.98
13	50	0.3	0.3	0.98
14	50	0.4	0.4	0.98
15	50	0.5	0.5	0.98
16	50	0.6	0.6	0.98
17	50	0.7	0.7	0.98
18	50	0.8	0.8	0.98
19	50	0.9	0.9	0.98
20	50	1	1	0.98
21	100	0.1	0.1	0.99
22	100	0.2	0.2	0.99
23	100	0.3	0.3	0.99
24	100	0.4	0.4	0.99
25	100	0.5	0.5	0.99
26	100	0.6	0.6	0.99
27	100	0.7	0.7	0.99
28	100	0.8	0.8	0.99
29	100	0.9	0.9	0.99
30	100	1	1	0.99
31	20	0.1	1	0.67
32	20	0.2	1	0.80
33	20	0.3	1	0.86
34	20	0.4	1	0.89
35	20	0.5	1	0.91
36	20	0.6	1	0.92
37	20	0.7	1	0.93
38	20	0.8	1	0.94
39	20	0.9	1	0.95
40	20	1	1	0.95
41	50	0.1	1	0.83
42	50	0.2	1	0.91
43	50	0.3	1	0.94
44	50	0.4	1	0.95
45	50	0.5	1	0.96
46	50	0.6	1	0.97
47	50	0.7	1	0.97
48	50	0.8	1	0.98
49	50	0.9	1	0.98
50	50	1	1	0.98
51	100	0.1	1	0.91
52	100	0.2	1	0.95
53	100	0.3	1	0.97
54	100	0.4	1	0.98
55	100	0.5	1	0.98
56	100	0.6	1	0.98
57	100	0.7	1	0.99
58	100	0.8	1	0.99
59	100	0.9	1	0.99
60	100	1	1	0.99
61	20	0.1	0.3	0.87
62	20	0.2	0.3	0.93
63	20	0.3	0.3	0.95
64	20	0.4	0.3	0.96
65	20	0.5	0.3	0.97
66	20	0.6	0.3	0.98
67	20	0.7	0.3	0.98
68	20	0.8	0.3	0.98
69	20	0.9	0.3	0.98
70	20	1	0.3	0.99
71	50	0.1	0.3	0.94
72	50	0.2	0.3	0.97
73	50	0.3	0.3	0.98
74	50	0.4	0.3	0.99
75	50	0.5	0.3	0.99
76	50	0.6	0.3	0.99
77	50	0.7	0.3	0.99
78	50	0.8	0.3	0.99
79	50	0.9	0.3	0.99
80	50	1	0.3	0.99
81	100	0.1	0.3	0.97
82	100	0.2	0.3	0.99
83	100	0.3	0.3	0.99
84	100	0.4	0.3	0.99
85	100	0.5	0.3	0.99
86	100	0.6	0.3	1.00
87	100	0.7	0.3	1.00
88	100	0.8	0.3	1.00
89	100	0.9	0.3	1.00
90	100	1	0.3	1.00
91	20	0.1	3	0.40
92	20	0.2	3	0.57
93	20	0.3	3	0.67
94	20	0.4	3	0.73
95	20	0.5	3	0.77
96	20	0.6	3	0.80
97	20	0.7	3	0.82
98	20	0.8	3	0.84
99	20	0.9	3	0.86
100	20	1	3	0.87
101	50	0.1	3	0.63
102	50	0.2	3	0.77
103	50	0.3	3	0.83
104	50	0.4	3	0.87
105	50	0.5	3	0.89
106	50	0.6	3	0.91
107	50	0.7	3	0.92
108	50	0.8	3	0.93
109	50	0.9	3	0.94
110	50	1	3	0.94
111	100	0.1	3	0.77
112	100	0.2	3	0.87
113	100	0.3	3	0.91
114	100	0.4	3	0.93
115	100	0.5	3	0.94
116	100	0.6	3	0.95
117	100	0.7	3	0.96
118	100	0.8	3	0.96
119	100	0.9	3	0.97
120	100	1	3	0.97

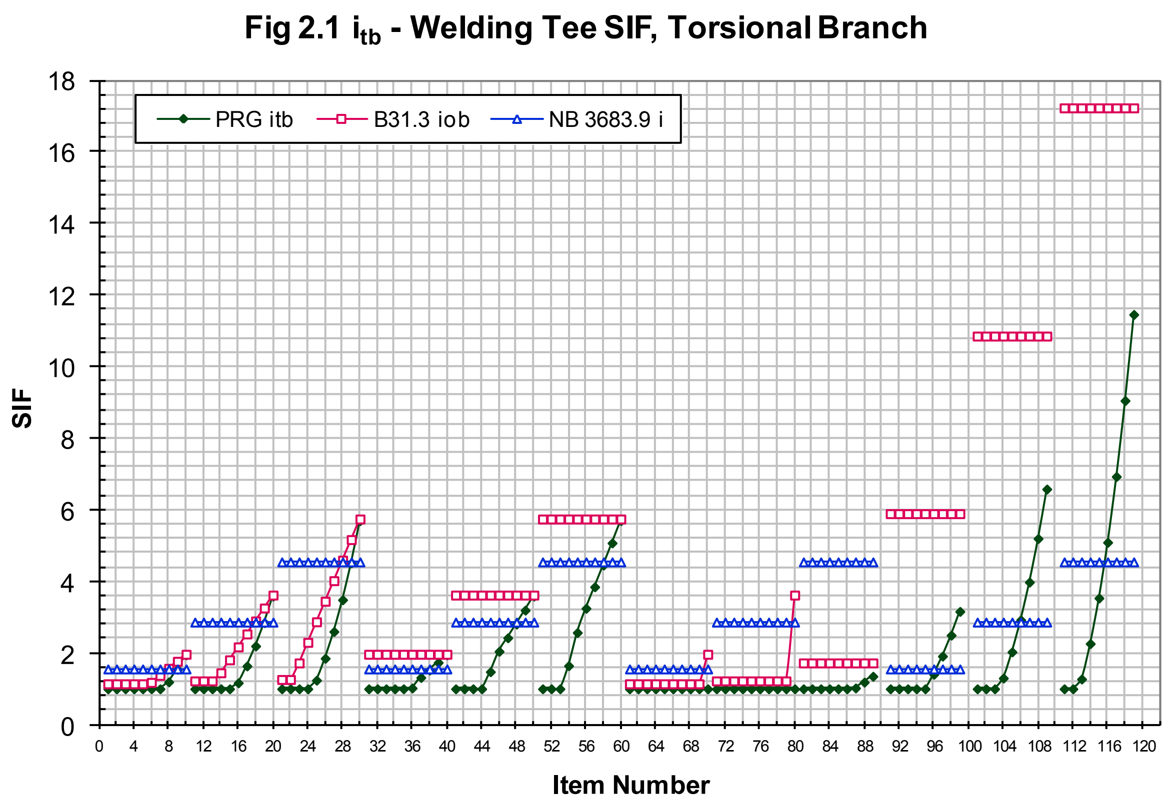
Fig 2.1 i_{ib} - Welding Tee SIF, Inplane Branch



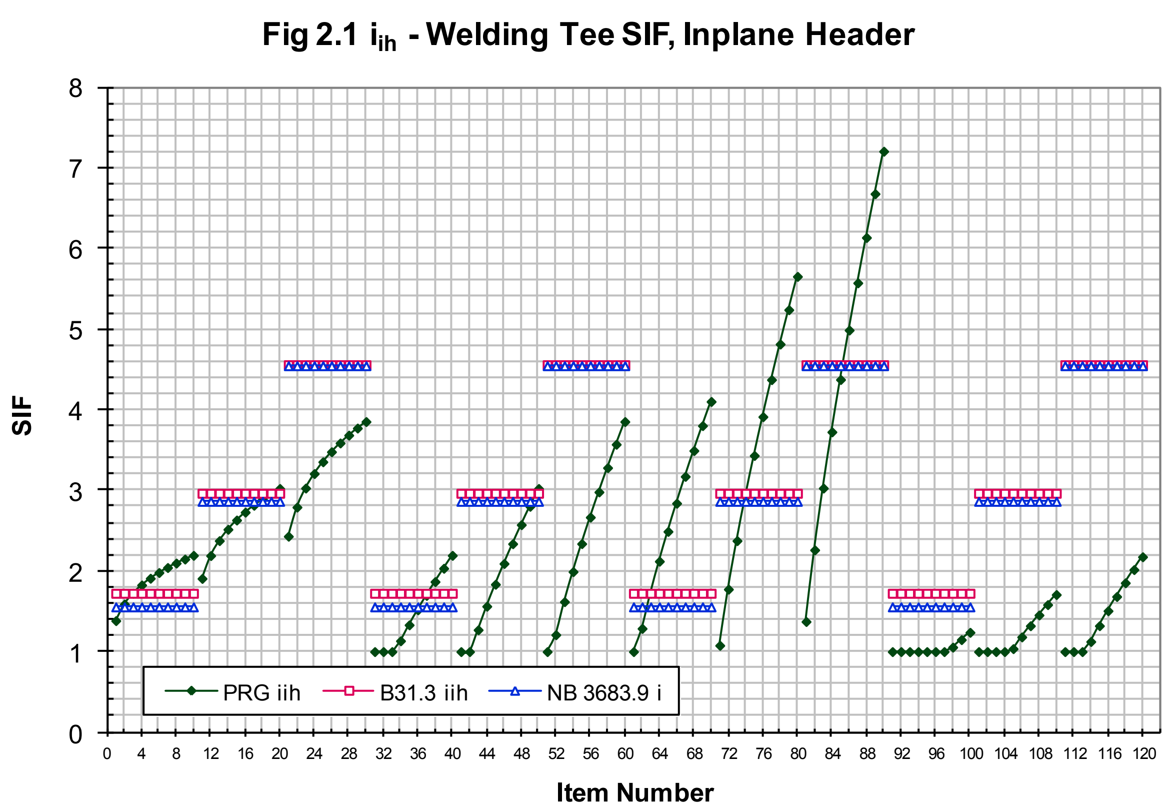
Note that Items 91 through 120 are for t/T = 3 and are outside the 07-02 parameter range for contoured fittings.

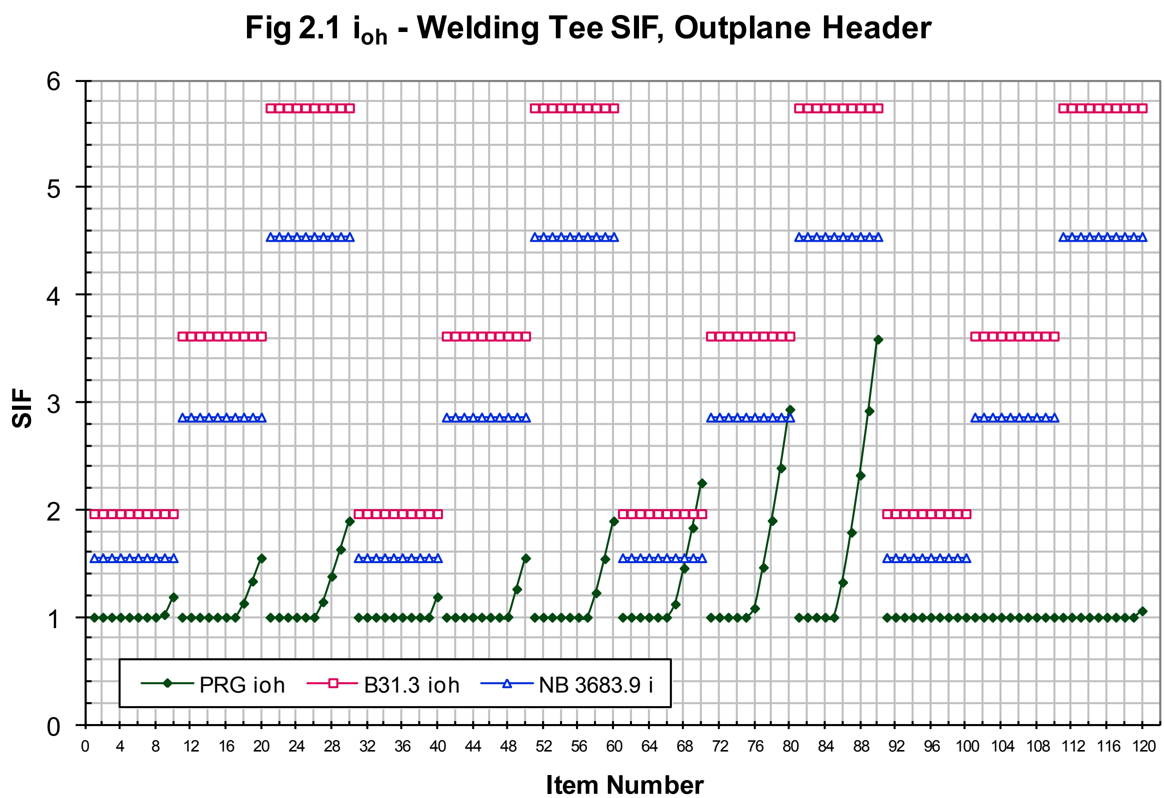
Fig 2.1 i_{ob} - Welding Tee SIF, Outplane Branch



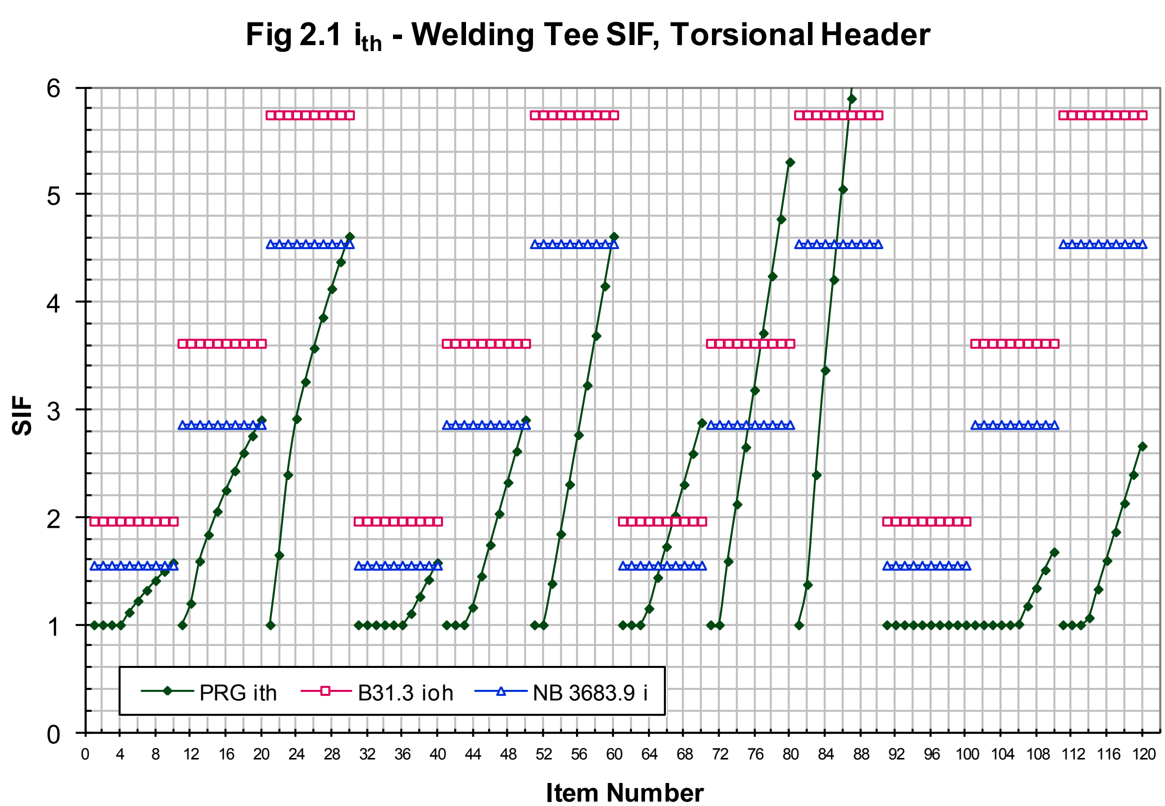


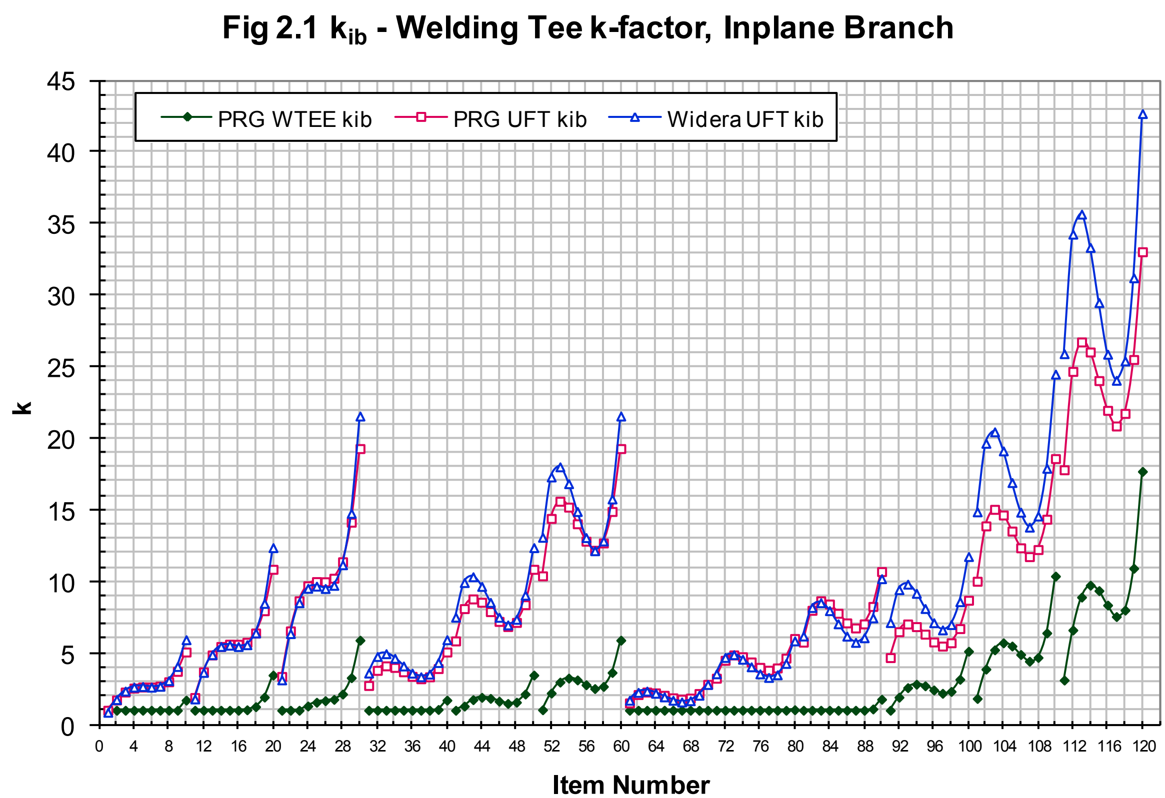
Note that Items 91 through 120 are for t/T = 3 and are outside the 07-02 parameter range for contoured fittings.





Note that Items 91 through 120 are for t/T = 3 and are outside the 07-02 parameter range for contoured fittings.





Note that Items 91 through 120 are for t/T = 3 and are outside the 07-02 parameter range for contoured fittings.

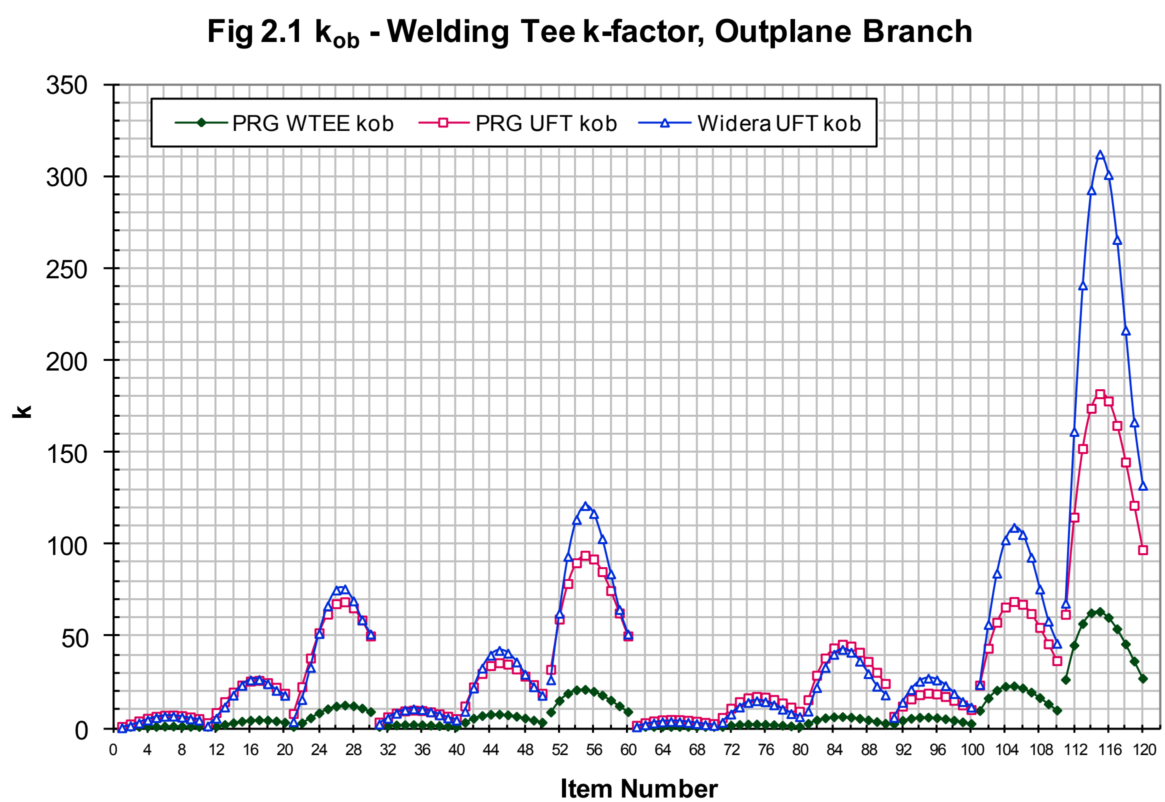
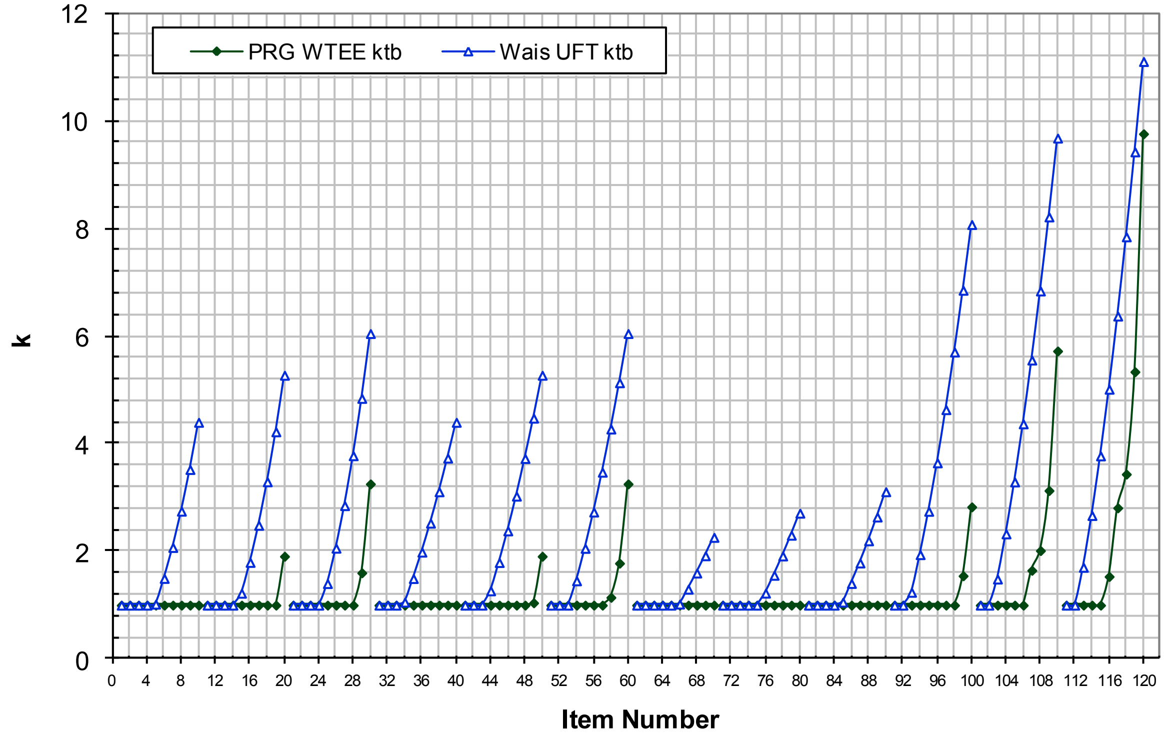
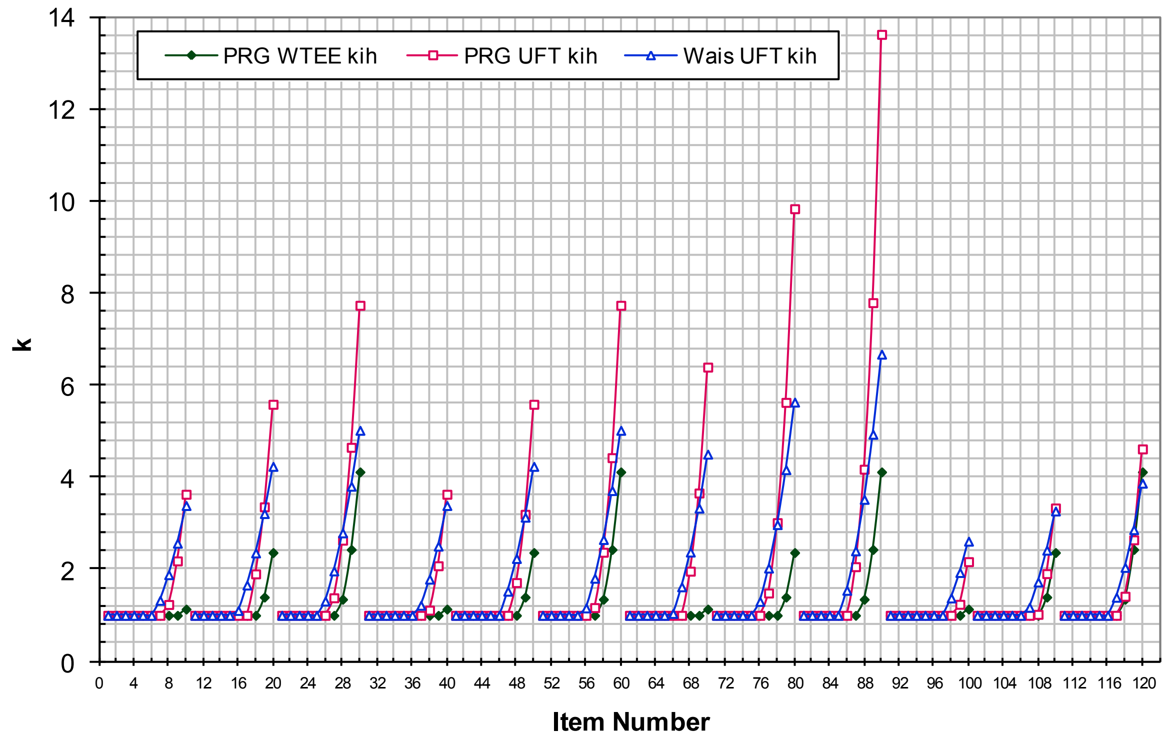


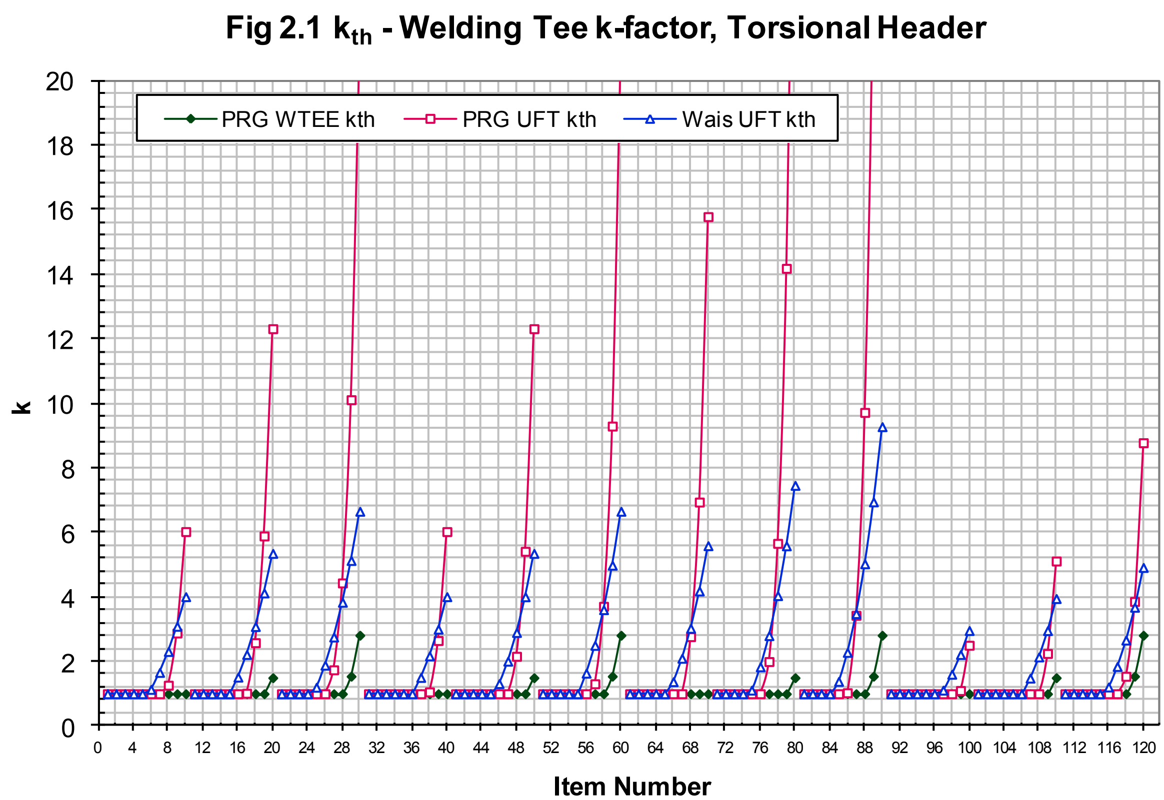
Fig 2.1 k_{tb} - Welding Tee k-factor, Torsional Branch



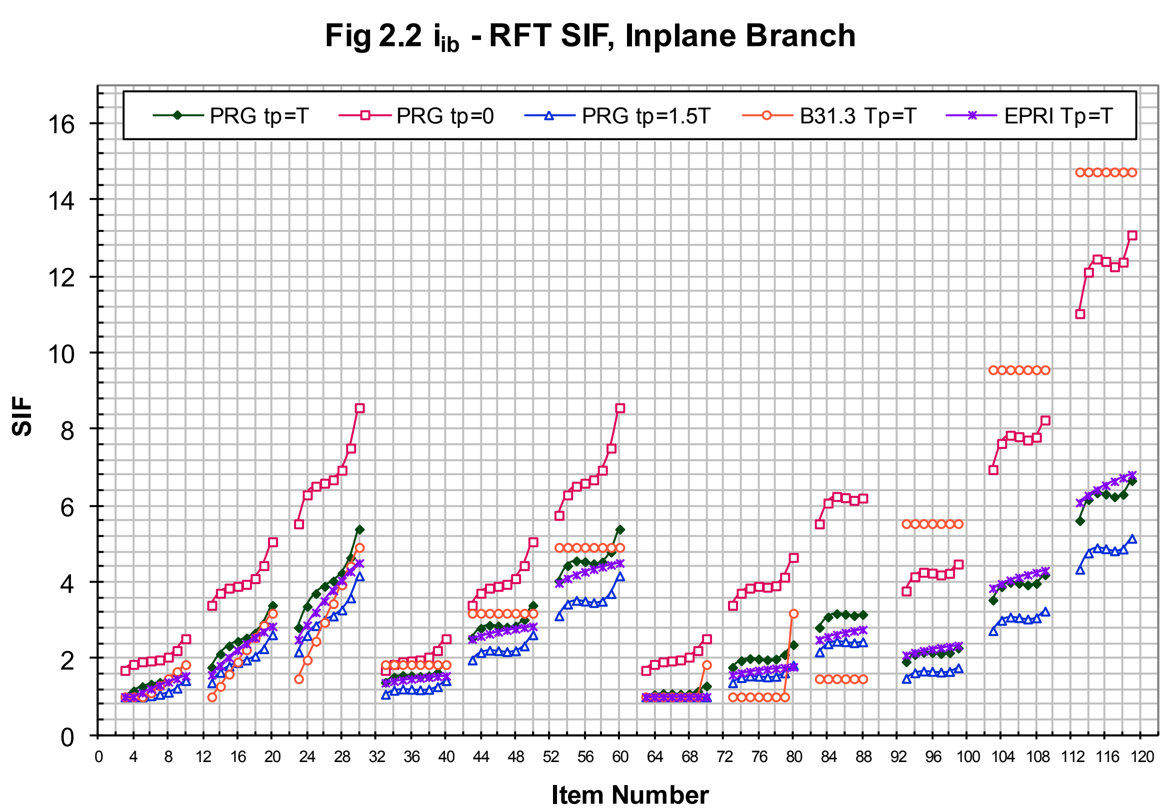
Note that Items 91 through 120 are for t/T = 3 and are outside the 07-02 parameter range for contoured fittings.

Fig 2.1 k_{ih} - Welding Tee k-factor, Inplane Header





Note that Items 91 through 120 are for t/T = 3 and are outside the 07-02 parameter range for contoured fittings.



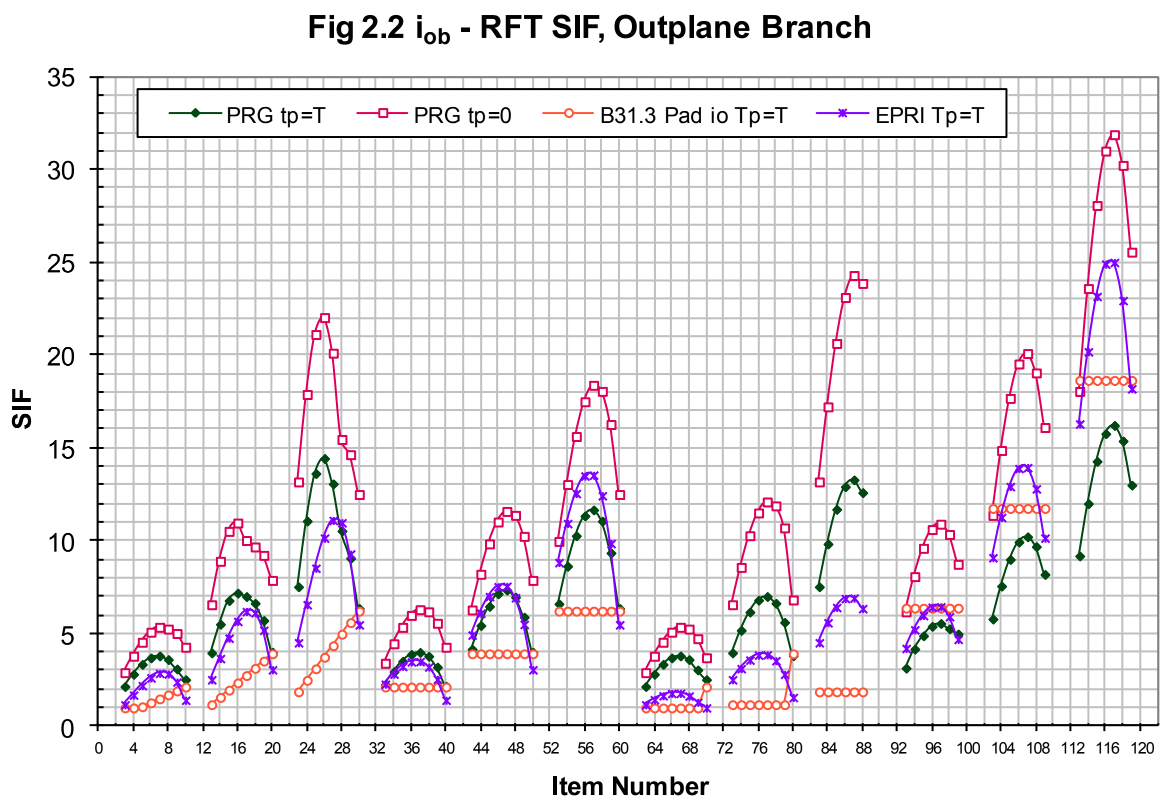


Fig 2.2 i_{ob} - RFT SIF, Outplane Branch
PRG tp=T
PRG tp=0
B31.3 Pad io Tp=T
EPRI Tp=T
SIF
Item Number
0
5
10
15
20
25
30
35
0 4 8 12 16 20 24 28 32 36 40 44 48 52 56 60 64 68 72 76 80 84 88 92 96 100 104 108 112 116 120

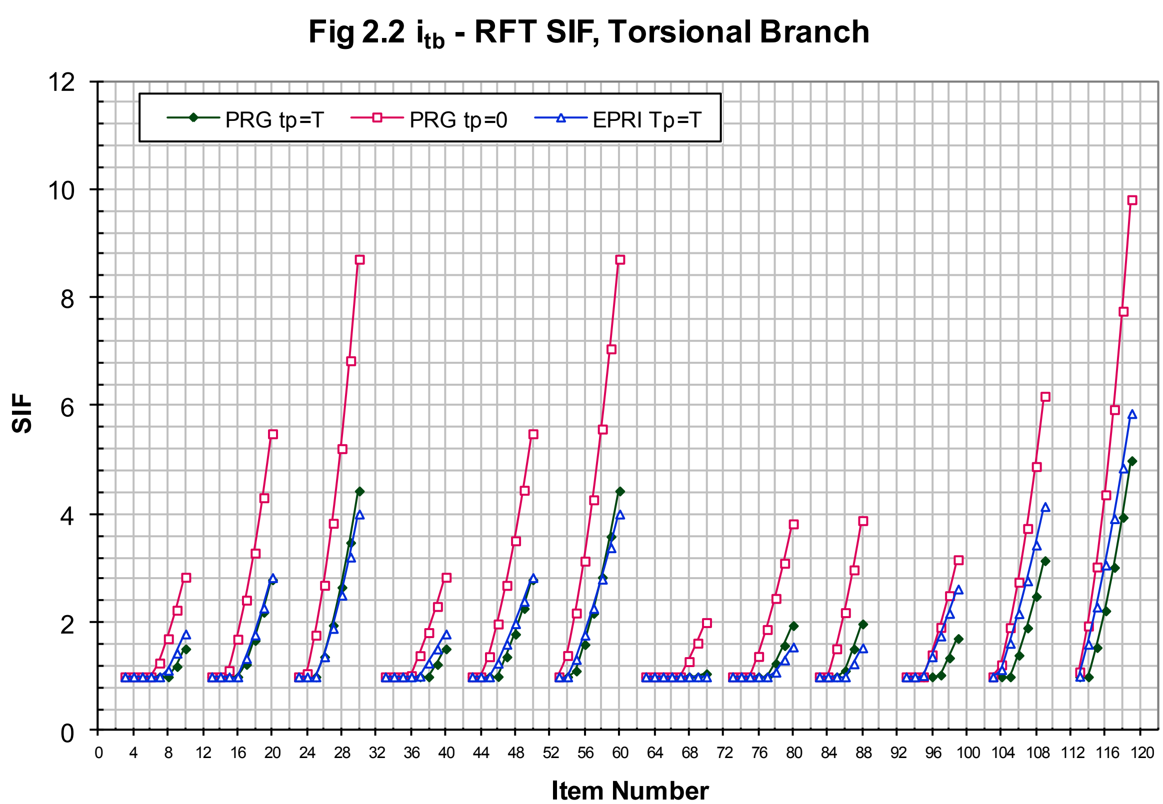


Fig 2.2 i_{tb} - RFT SIF, Torsional Branch
PRG tp=T
PRG tp=0
EPRI Tp=T
SIF
Item Number
0
2
4
6
8
10
12
0 4 8 12 16 20 24 28 32 36 40 44 48 52 56 60 64 68 72 76 80 84 88 92 96 100 104 108 112 116 120

Fig 2.2 i_{ih} - RFT SIF, Inplane Header

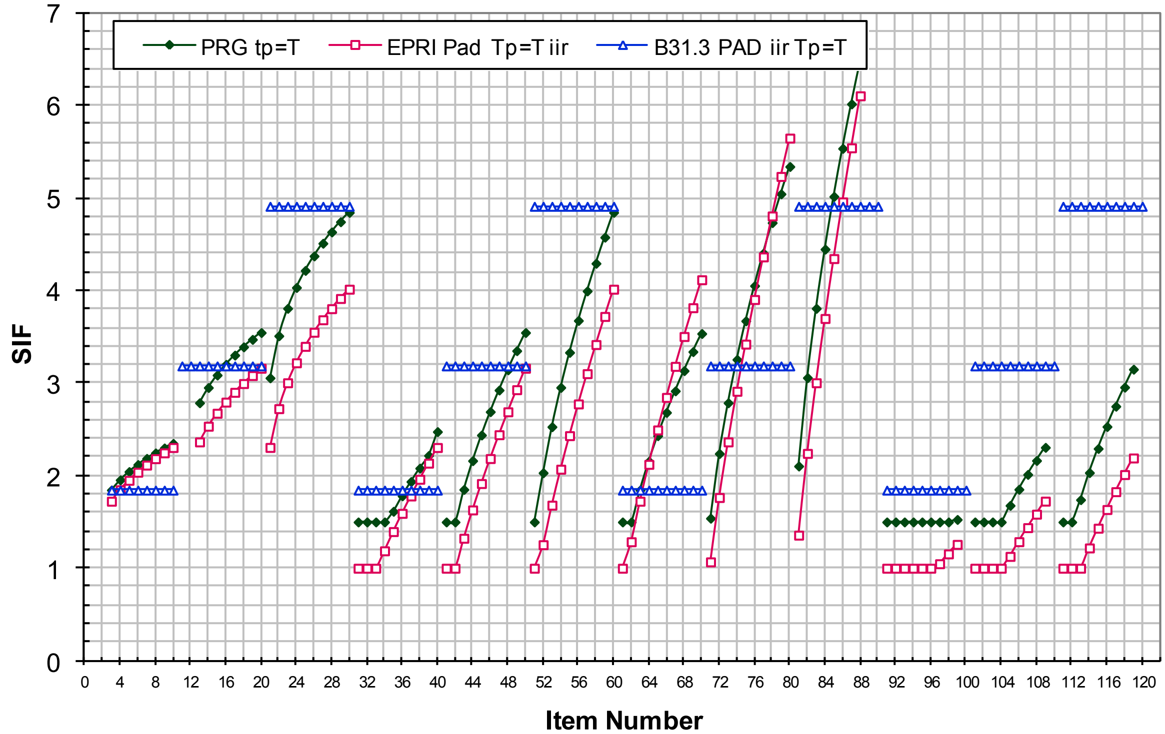


Fig 2.2 i_{oh} - RFT SIF, Outplane Header

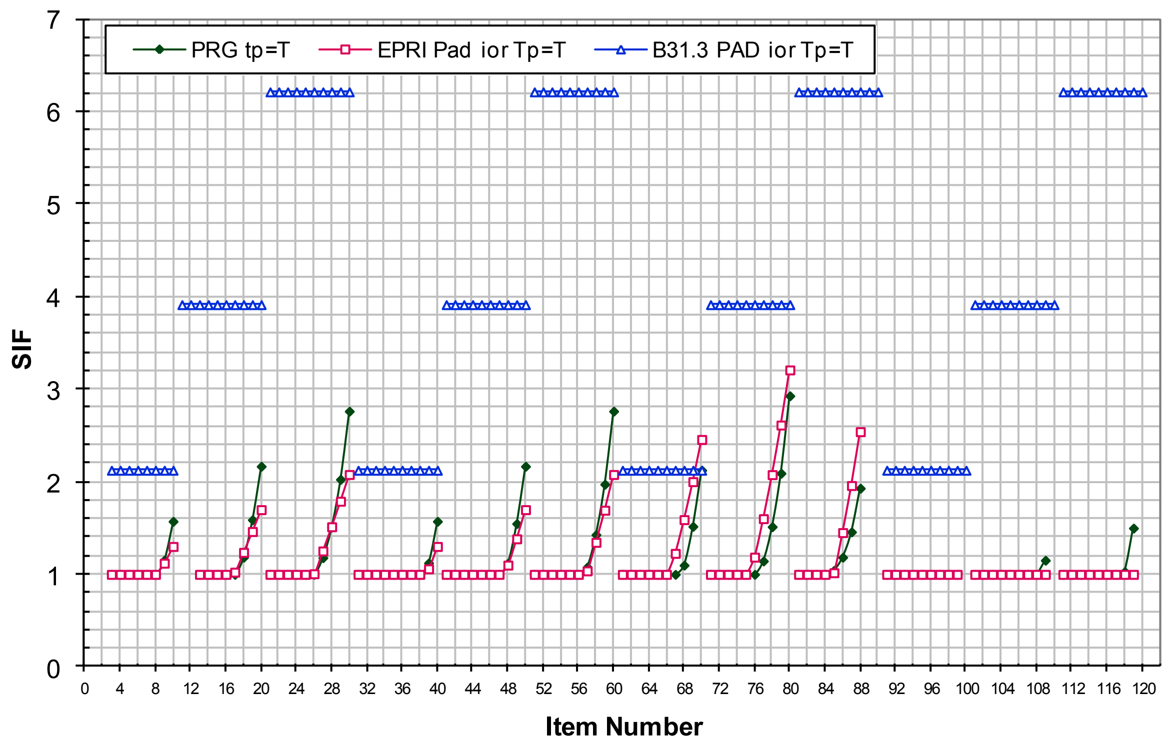


Fig 2.2 i_{th} - RFT SIF, Torsional Header

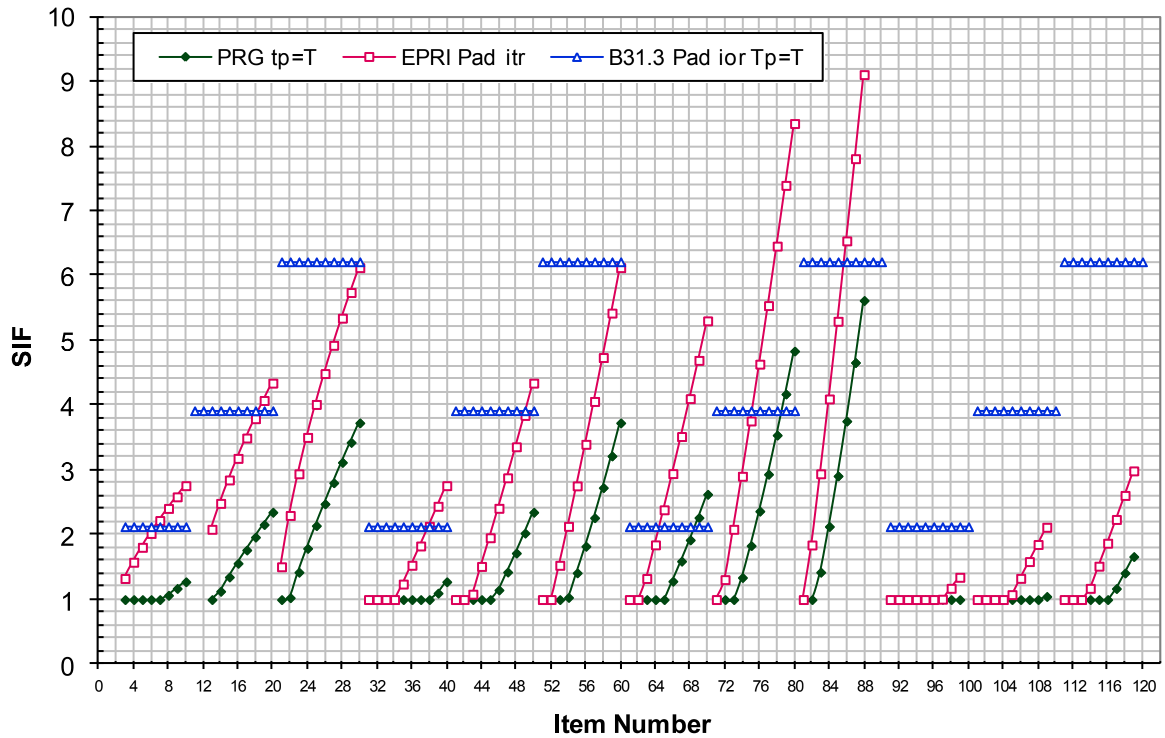


Fig 2.2 k_{ib} - RFT k-factor, Inplane Branch

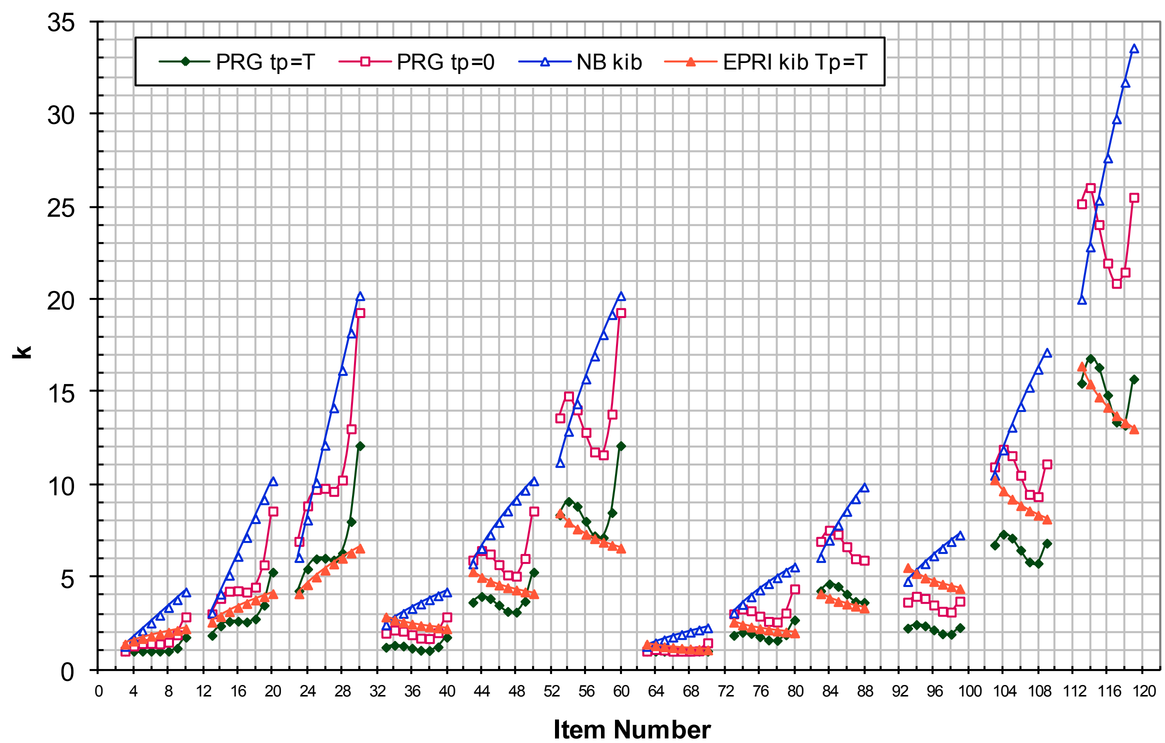


Fig 2.2 k_{ob} - RFT k-factor, Outplane Branch

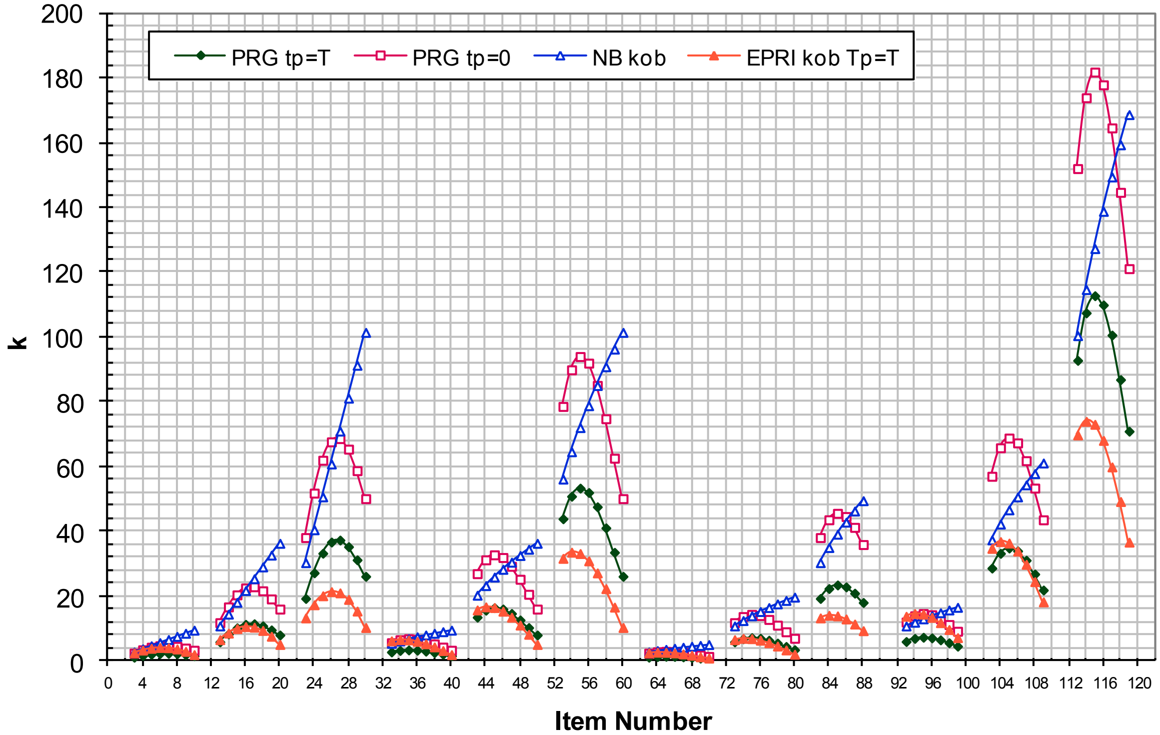
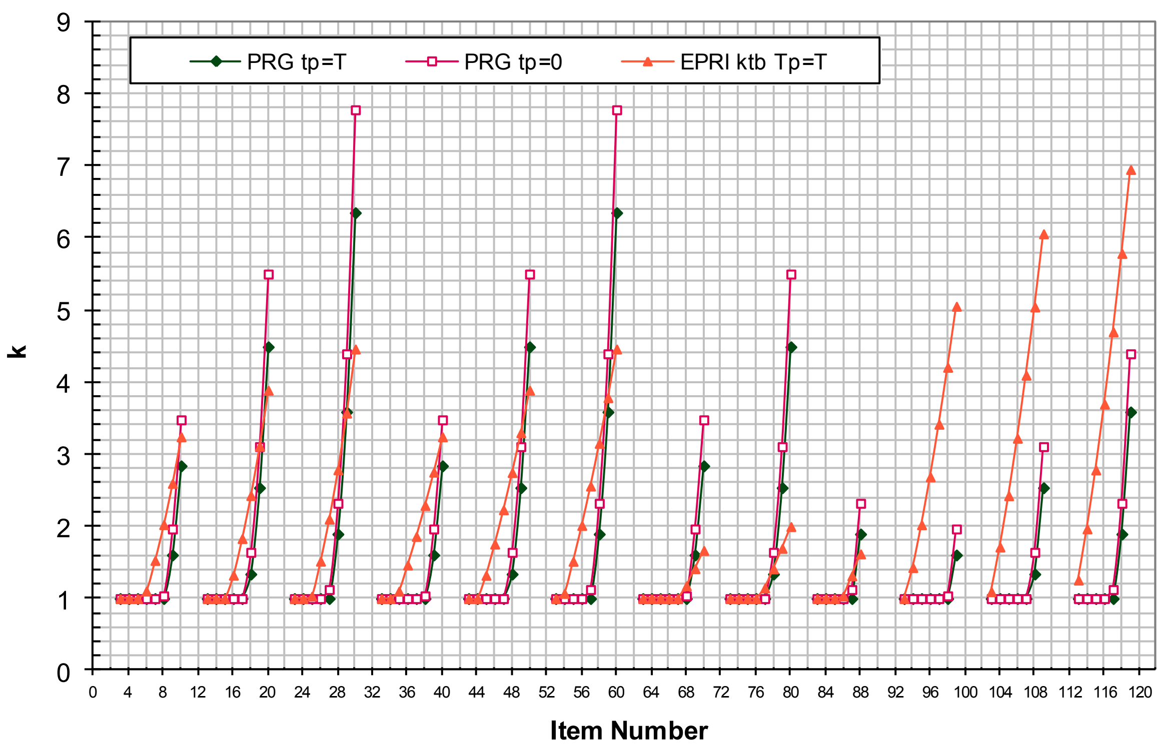


Fig 2.2 k_{tb} - RFT k-factor, Torsional Branch



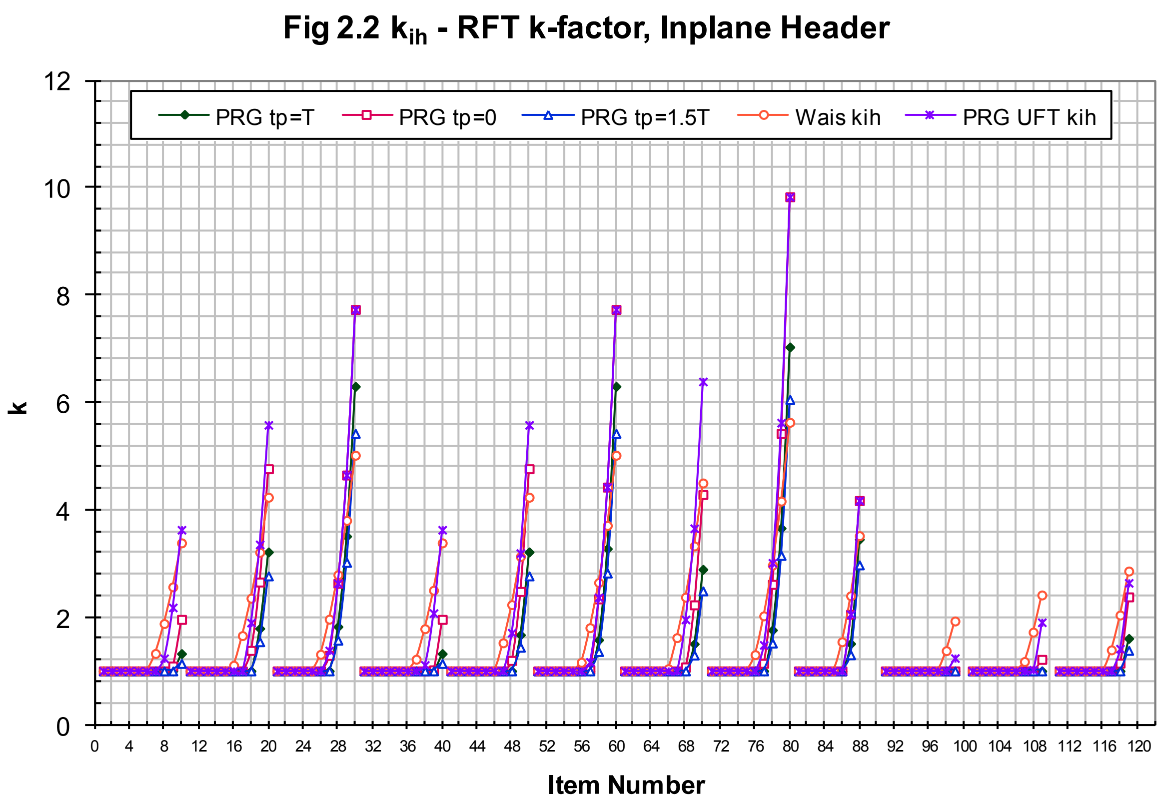


Fig 2.2 k_{ih} - RFT k-factor, Inplane Header
PRG tp=T
PRG tp=0
PRG tp=1.5T
Wais kih
PRG UFT kih
k
Item Number

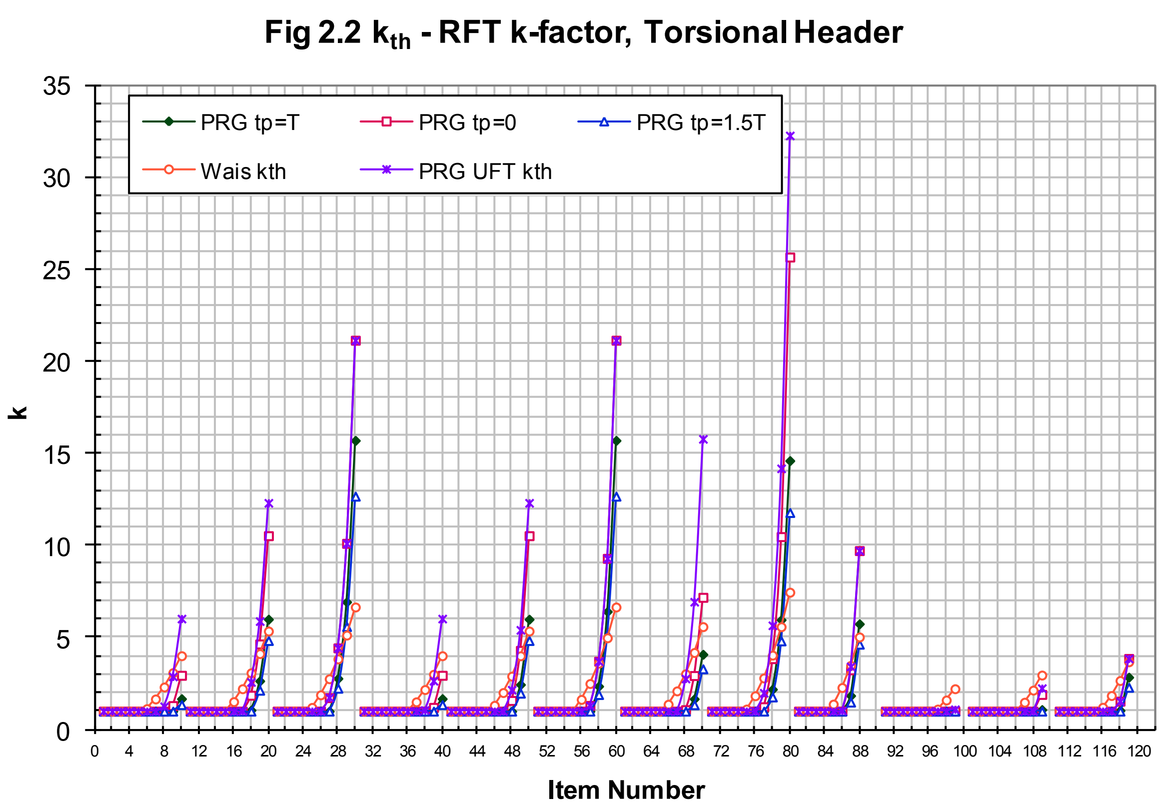


Fig 2.2 k_{th} - RFT k-factor, Torsional Header
PRG tp=T
PRG tp=0
PRG tp=1.5T
Wais kth
PRG UFT kth
k
Item Number

Fig 2.3 i_{ib} - UFT SIF, Inplane Branch

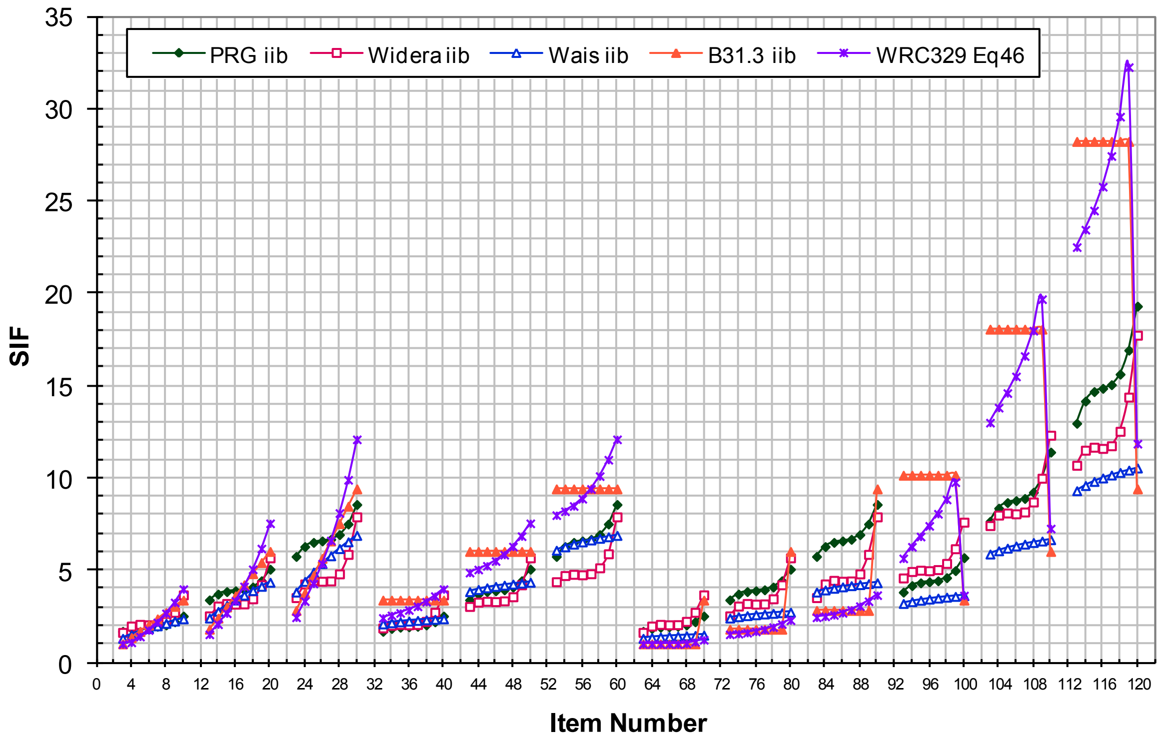
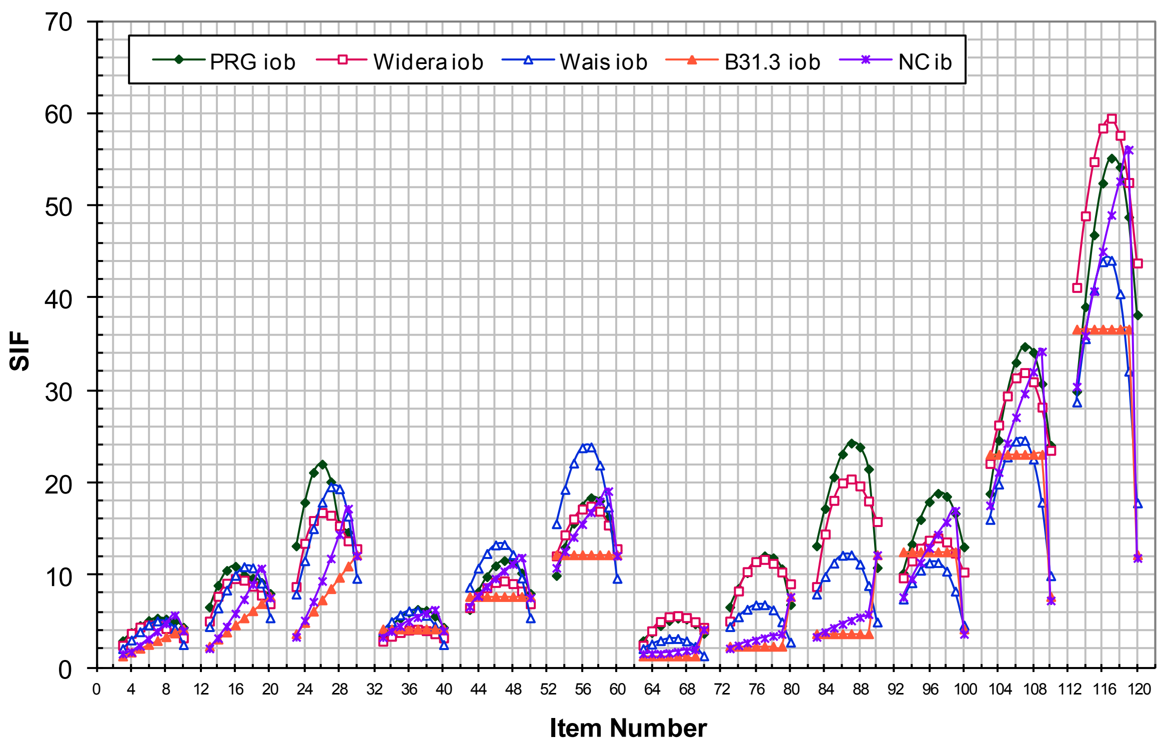


Fig 2.3 i_{ob} - UFT SIF, Outplane Branch



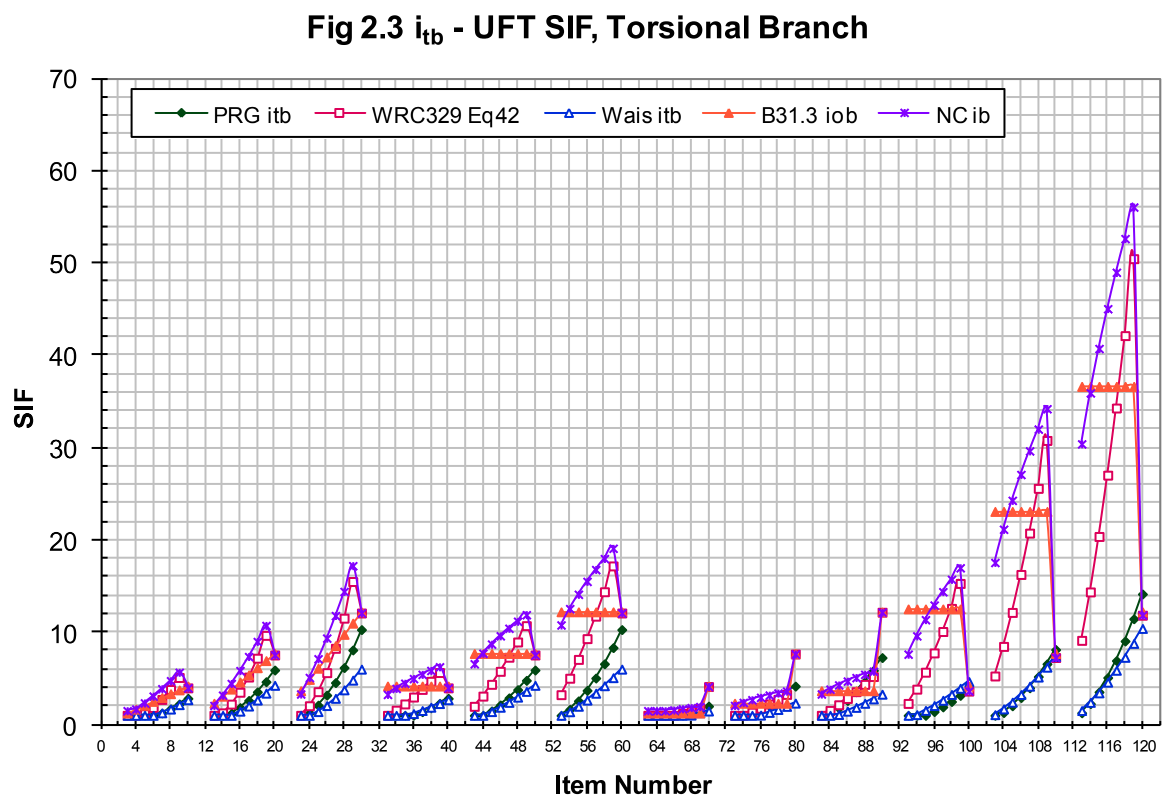


Fig 2.3 i_{tb} - UFT SIF, Torsional Branch
PRG itb
WRC329 Eq42
Wais itb
B31.3 iob
NC ib
SIF
Item Number

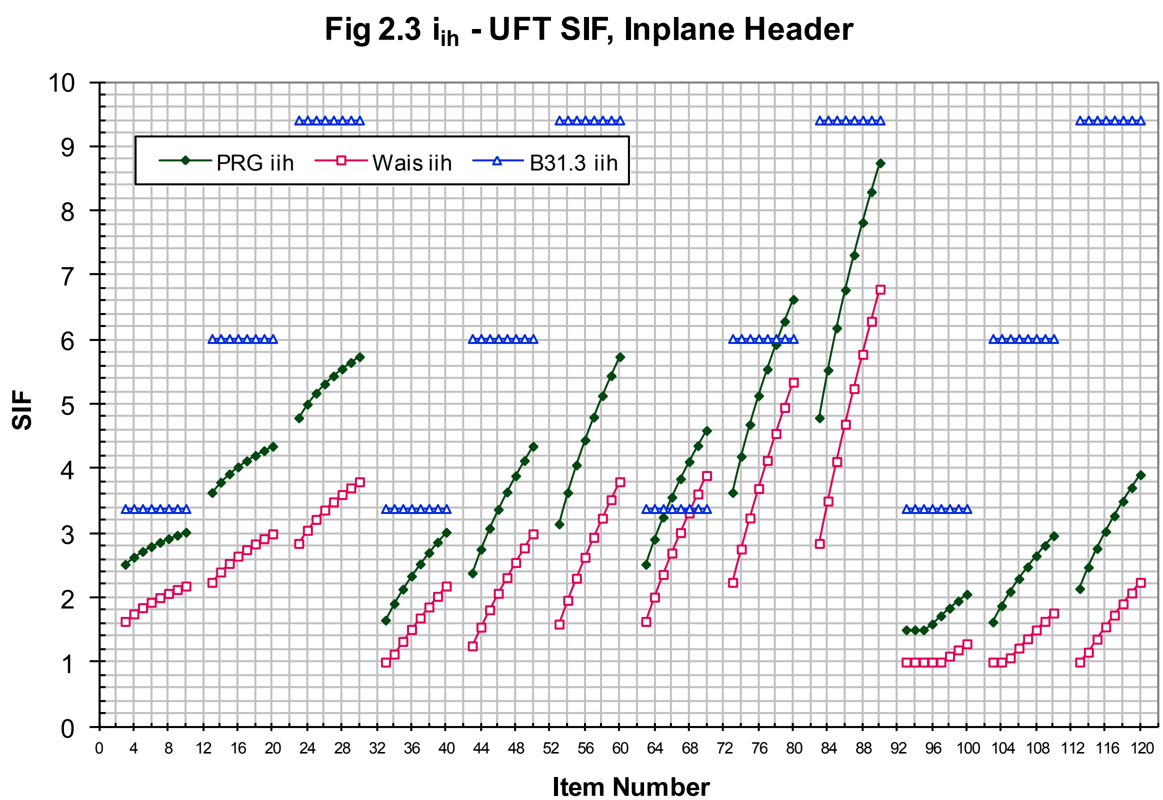


Fig 2.3 i_{ih} - UFT SIF, Inplane Header
PRG iih
Wais iih
B31.3 iih
SIF
Item Number

Fig 2.3 i_{oh} - UFT SIF, Outplane Header

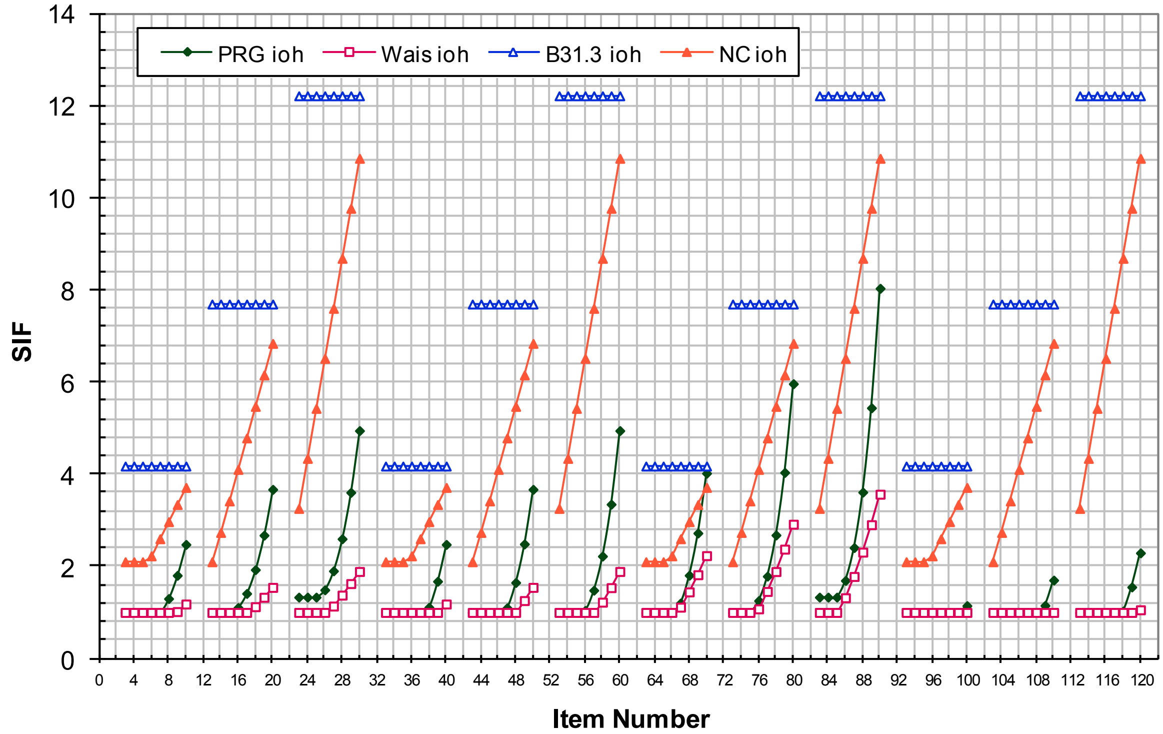


Fig 2.3 i_{th} - UFT SIF, Torsional Header

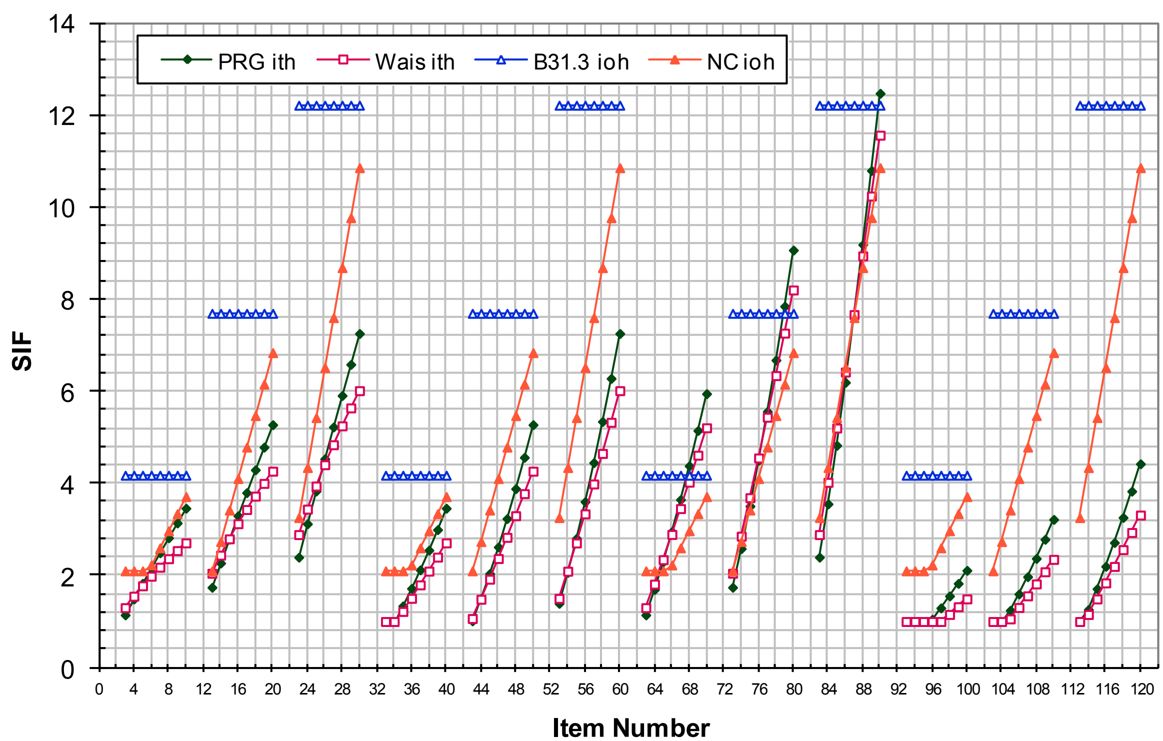


Fig 2.3 k_{ib} - UFT k-factor, Inplane Branch

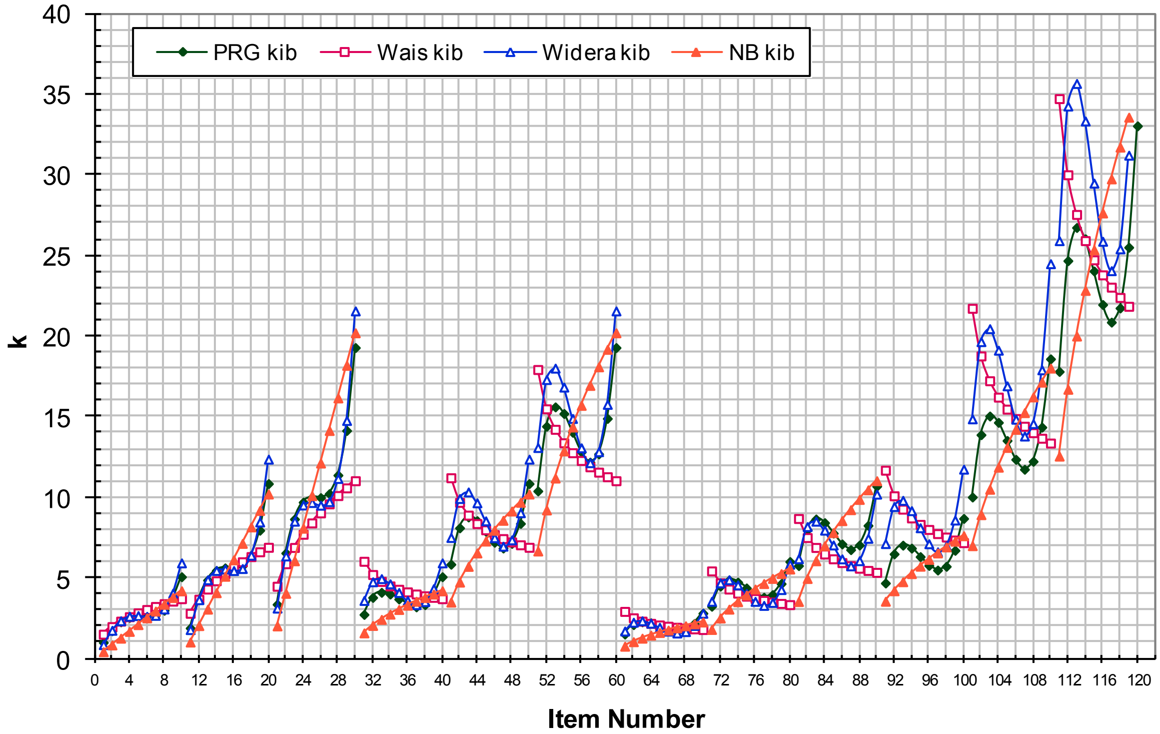
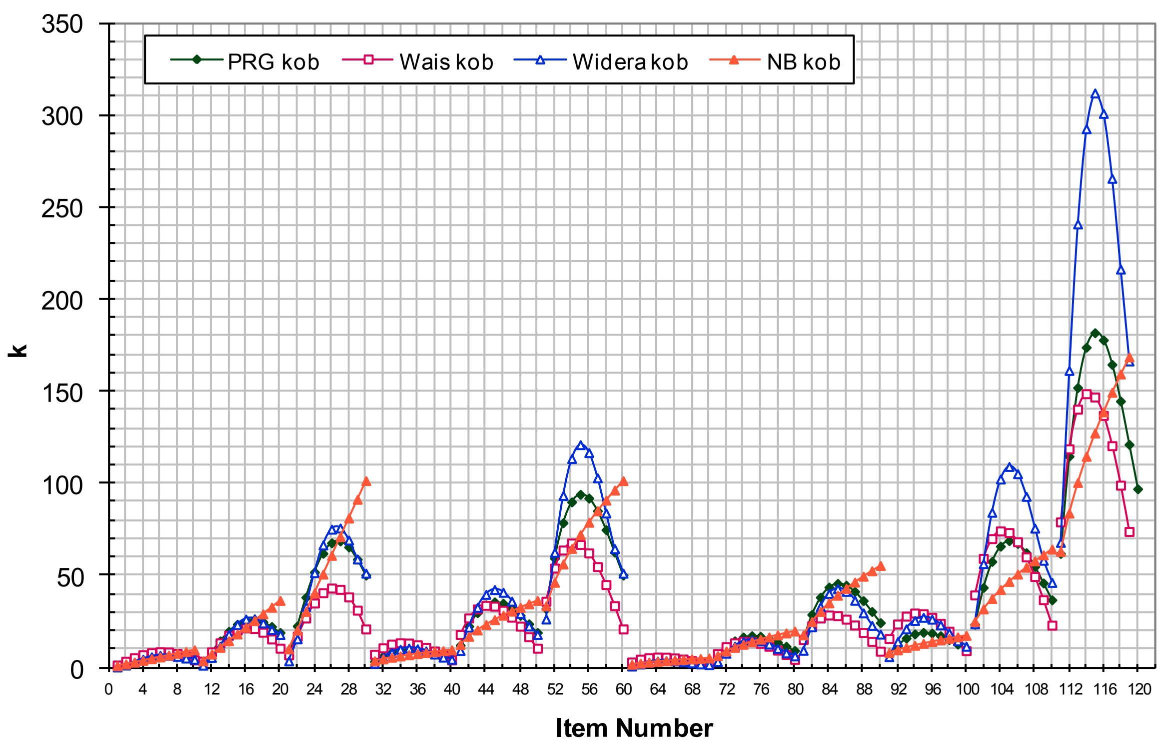


Fig 2.3 k_{ob} - UFT k-factor, Outplane Branch



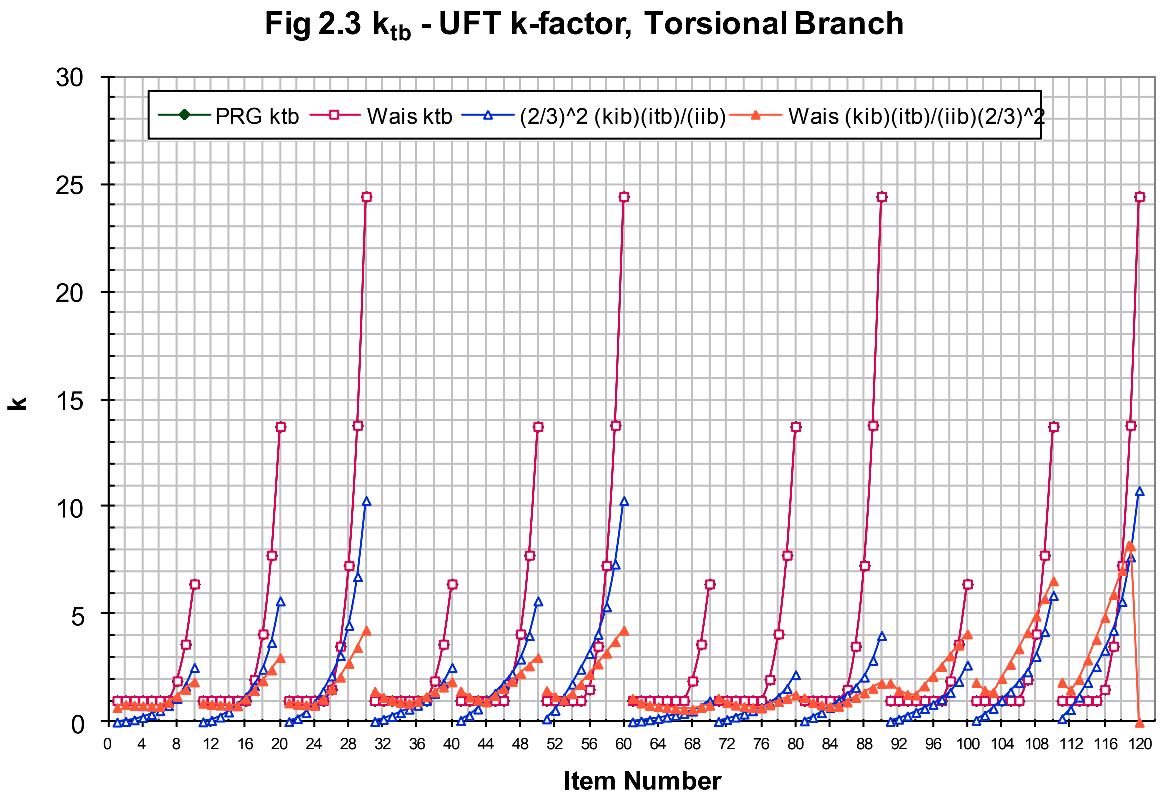


Fig 2.3 k_{tb} - UFT k-factor, Torsional Branch
PRG ktb
Wais ktb
(2/3)^2 (kib)(itb)/(iib)
Wais (kib)(itb)/(iib)(2/3)^2
k
Item Number

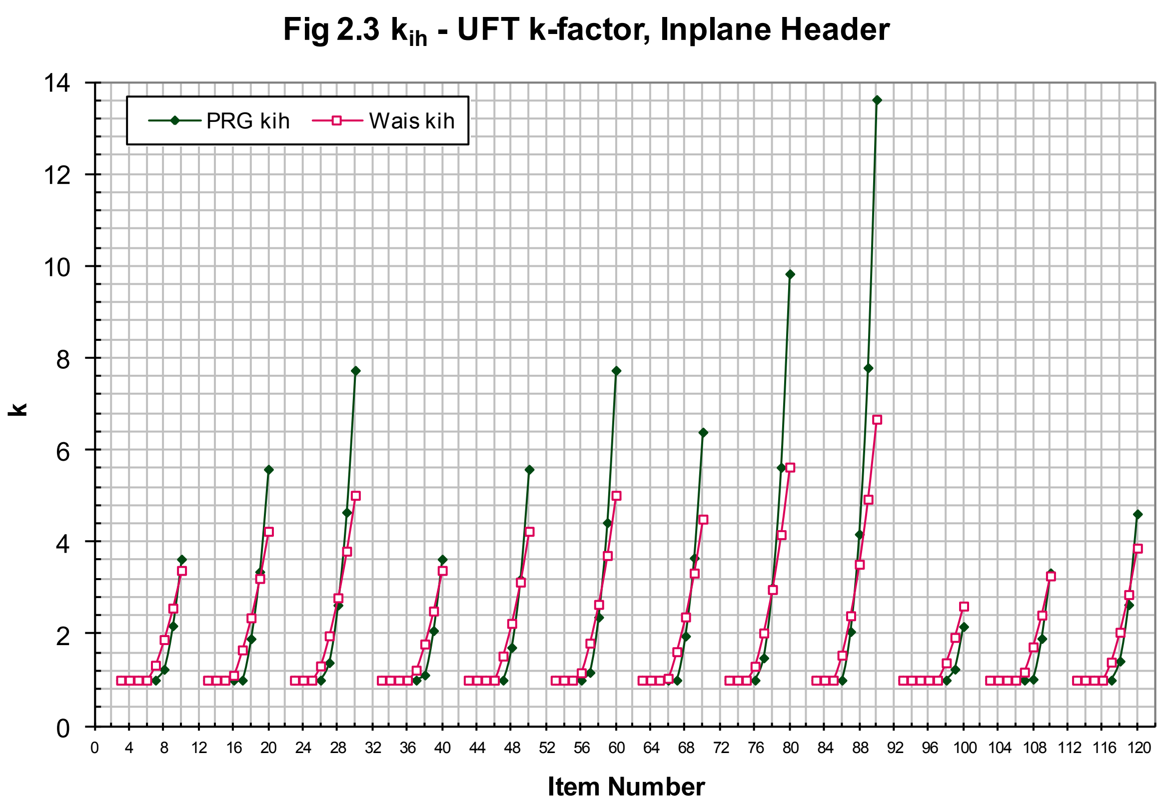


Fig 2.3 k_{ih} - UFT k-factor, Inplane Header
PRG kih
Wais kih
k
Item Number

Fig 2.3 k_{th} - UFT k-factor, Torsional Header

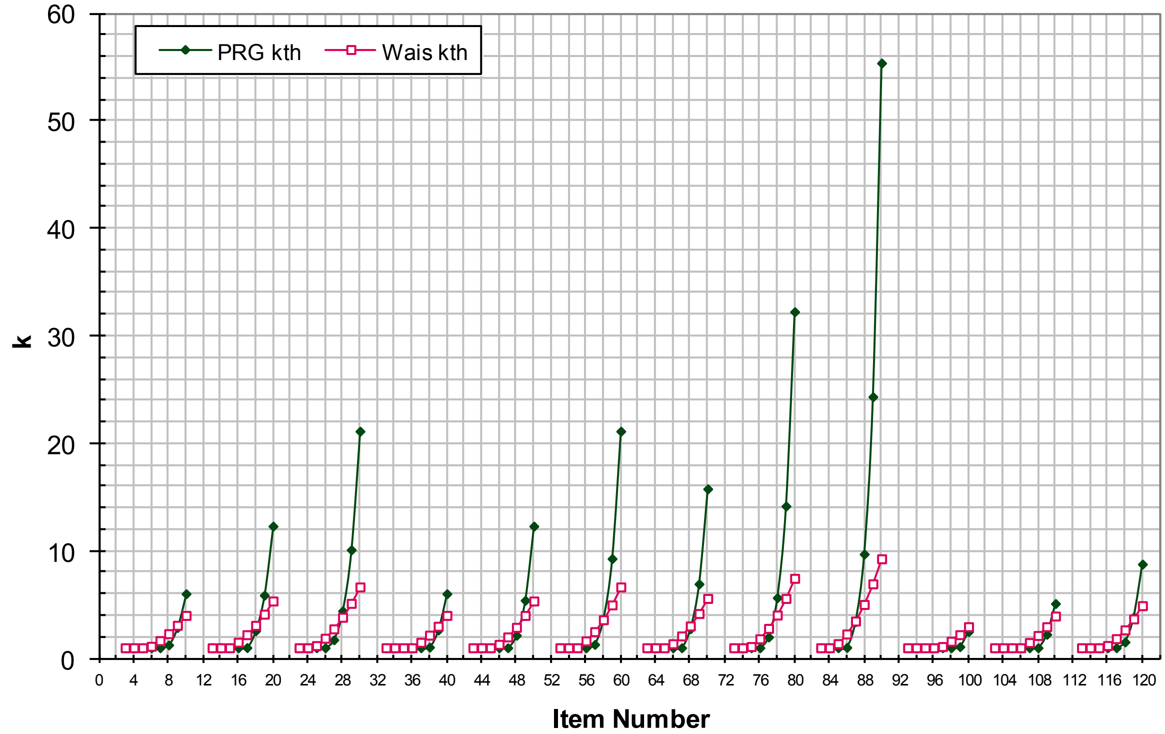
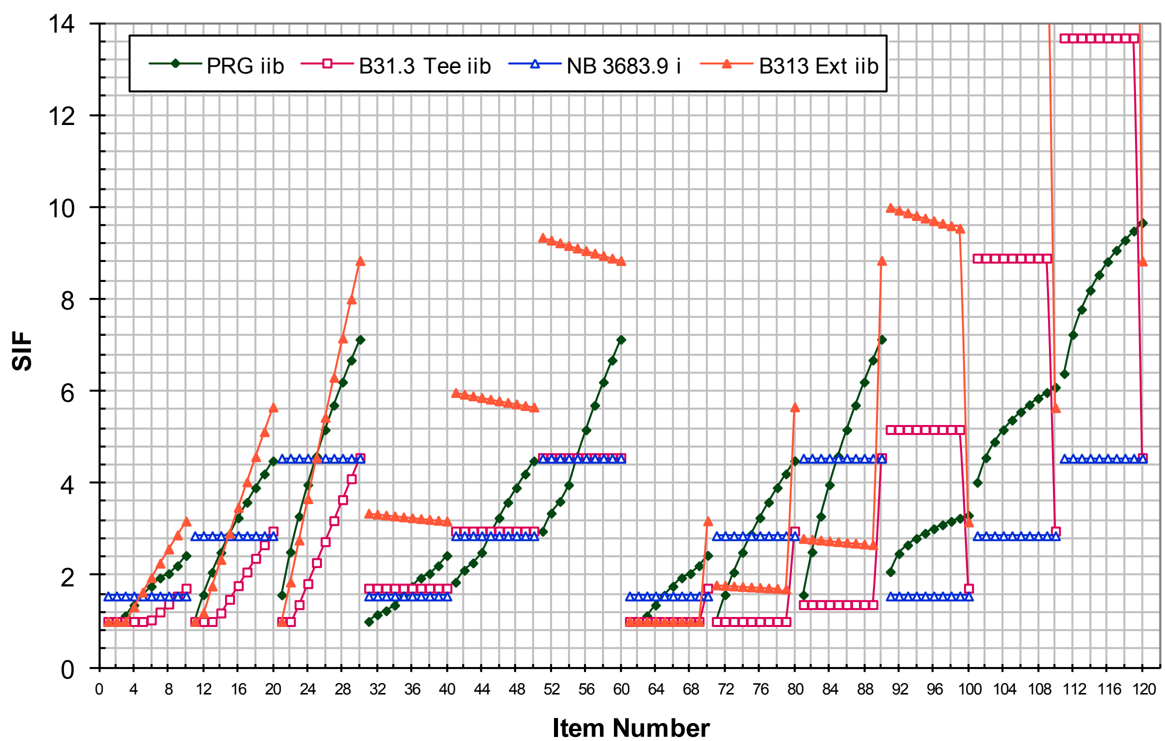


Fig 2.4 i_{ib} - Extruded Tee SIF, Inplane Branch



Note that Items 91 through 120 are for t/T = 3 and are outside the 07-02 parameter range for contoured fittings.

Fig 2.4 i_{ob} - Extruded Tee SIF, Outplane Branch

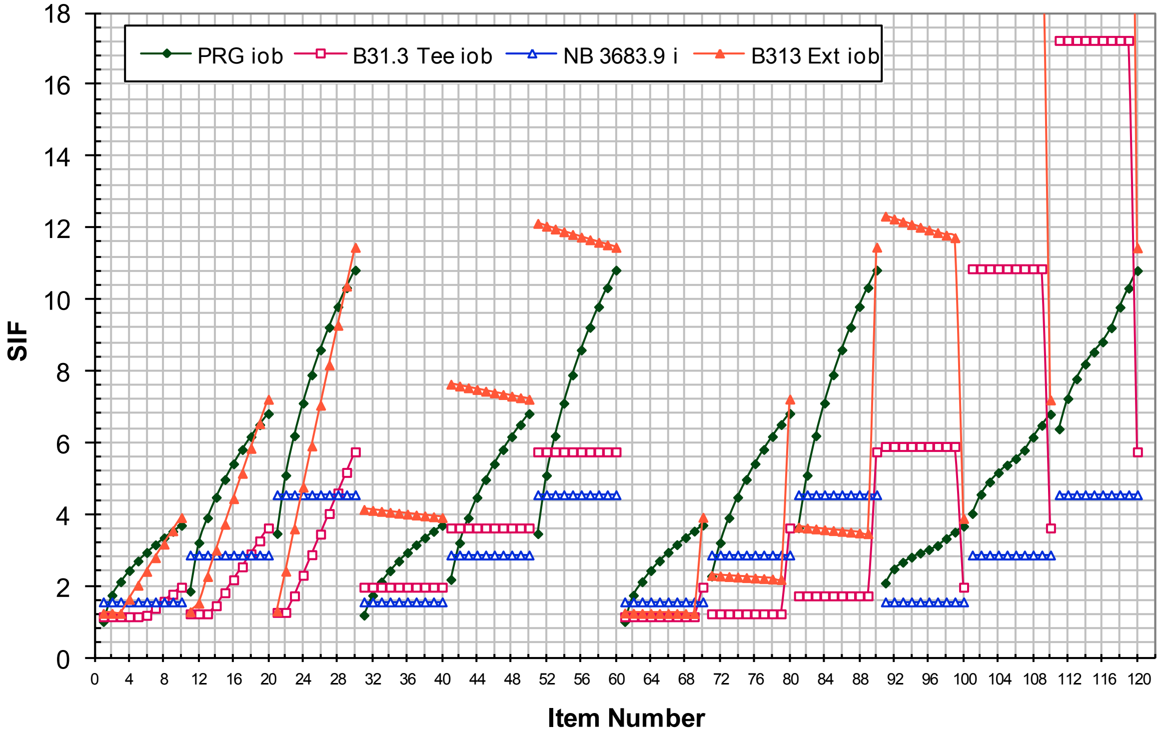
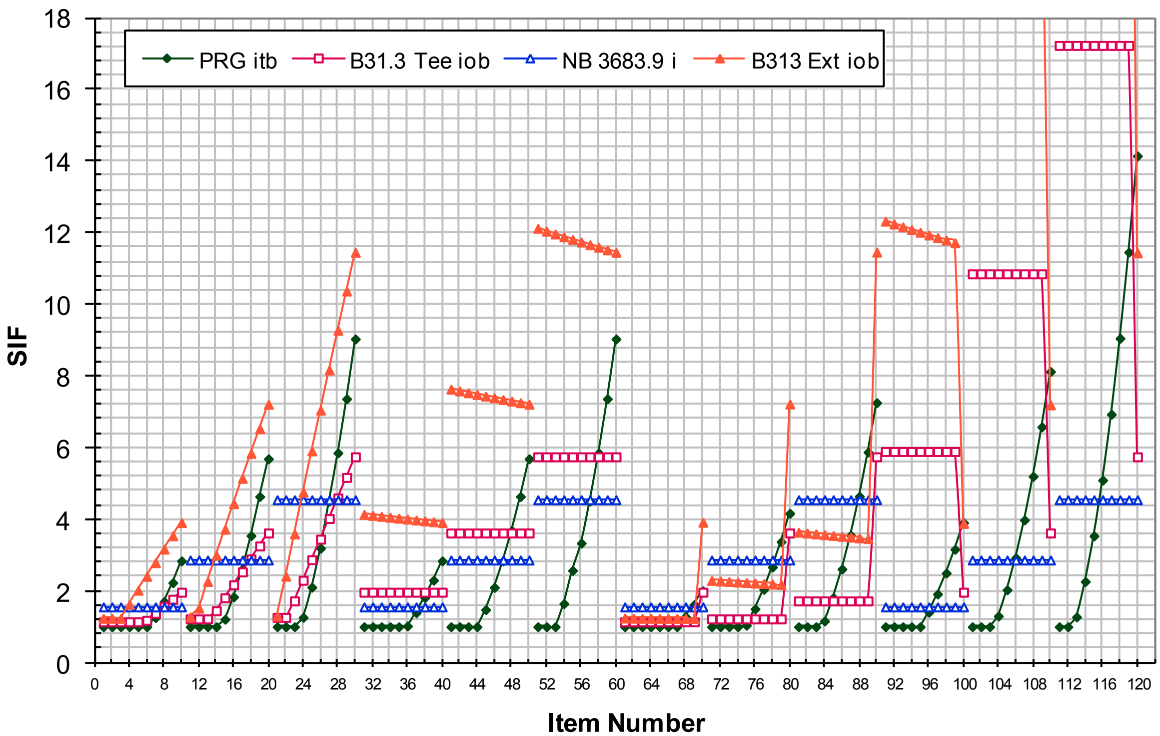
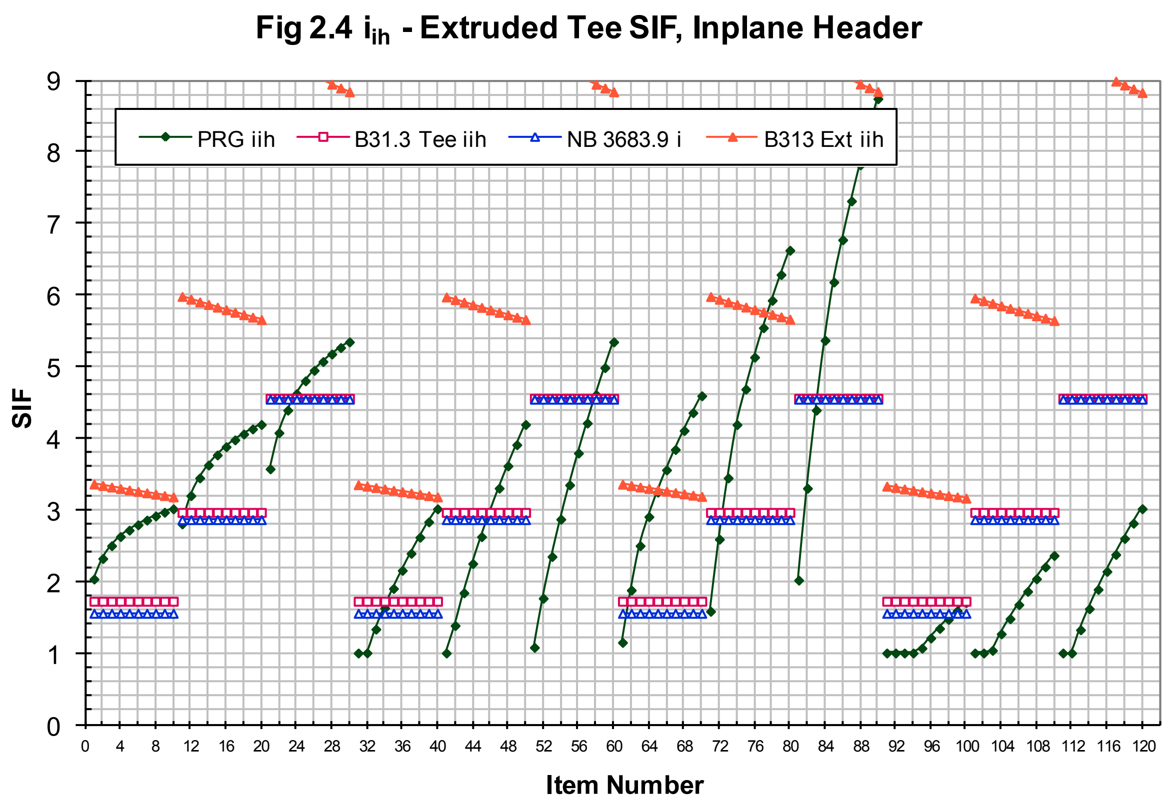
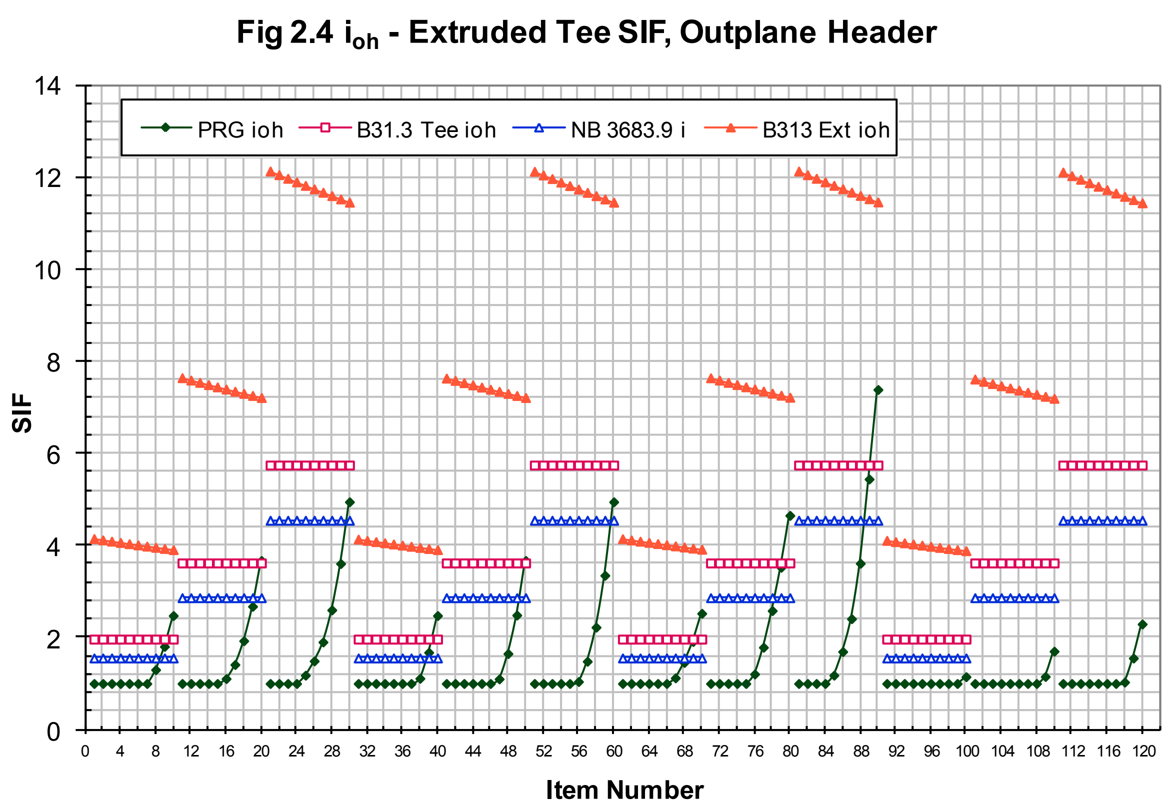


Fig 2.4 i_{tb} - Extruded Tee SIF, Torsional Branch

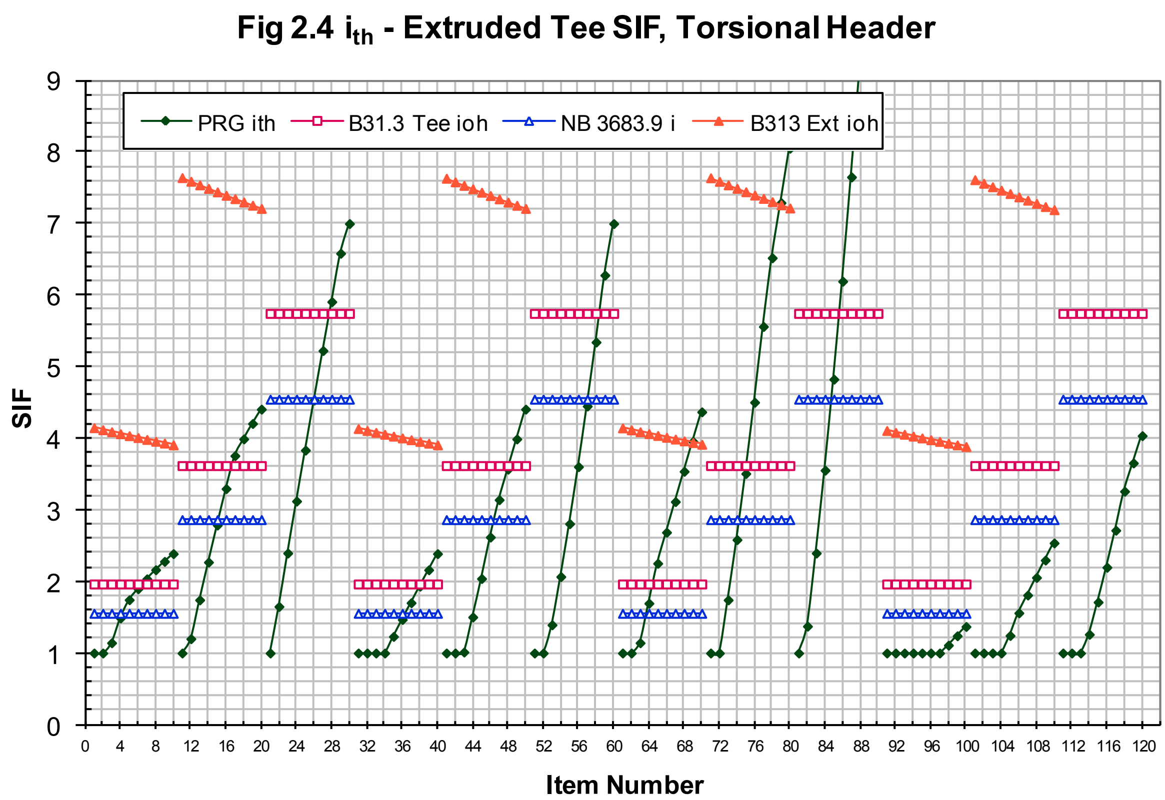


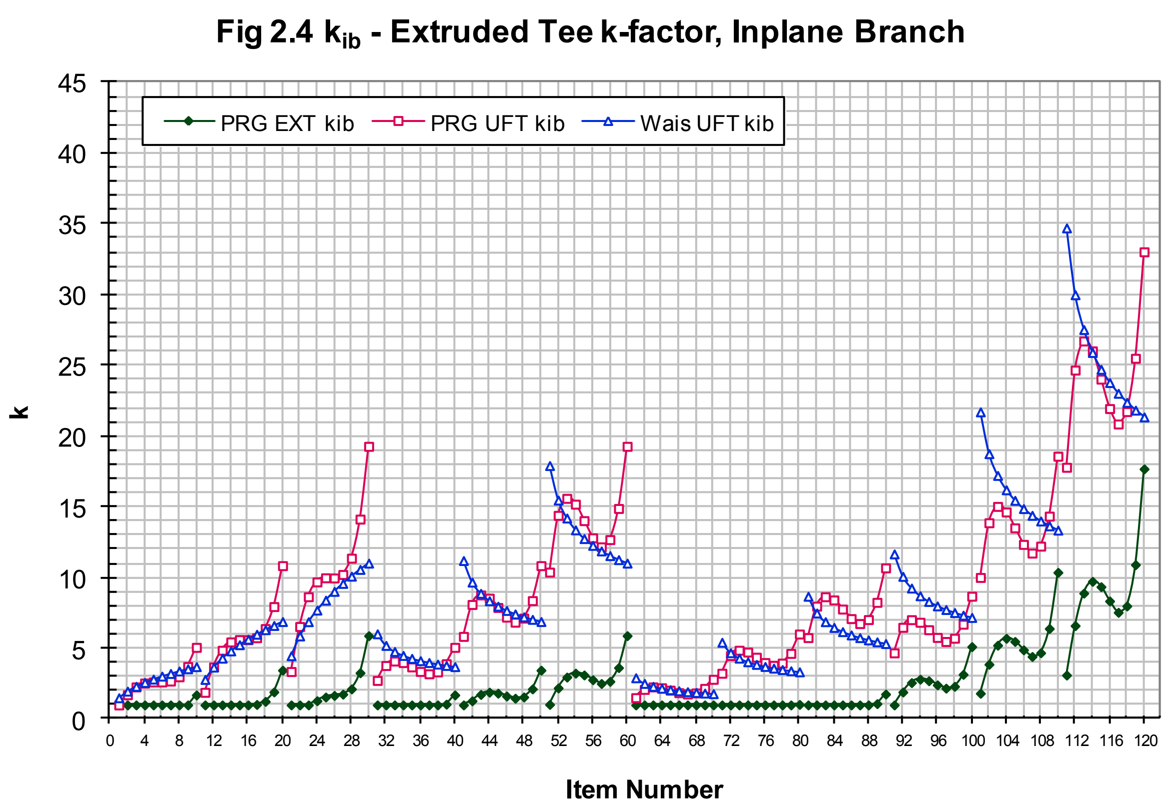
Note that Items 91 through 120 are for t/T = 3 and are outside the 07-02 parameter range for contoured fittings.





Note that Items 91 through 120 are for t/T = 3 and are outside the 07-02 parameter range for contoured fittings.





Note that Items 91 through 120 are for t/T = 3 and are outside the 07-02 parameter range for contoured fittings.

Fig 2.4 k_{ob} - Extruded Tee k-factor, Outplane Branch

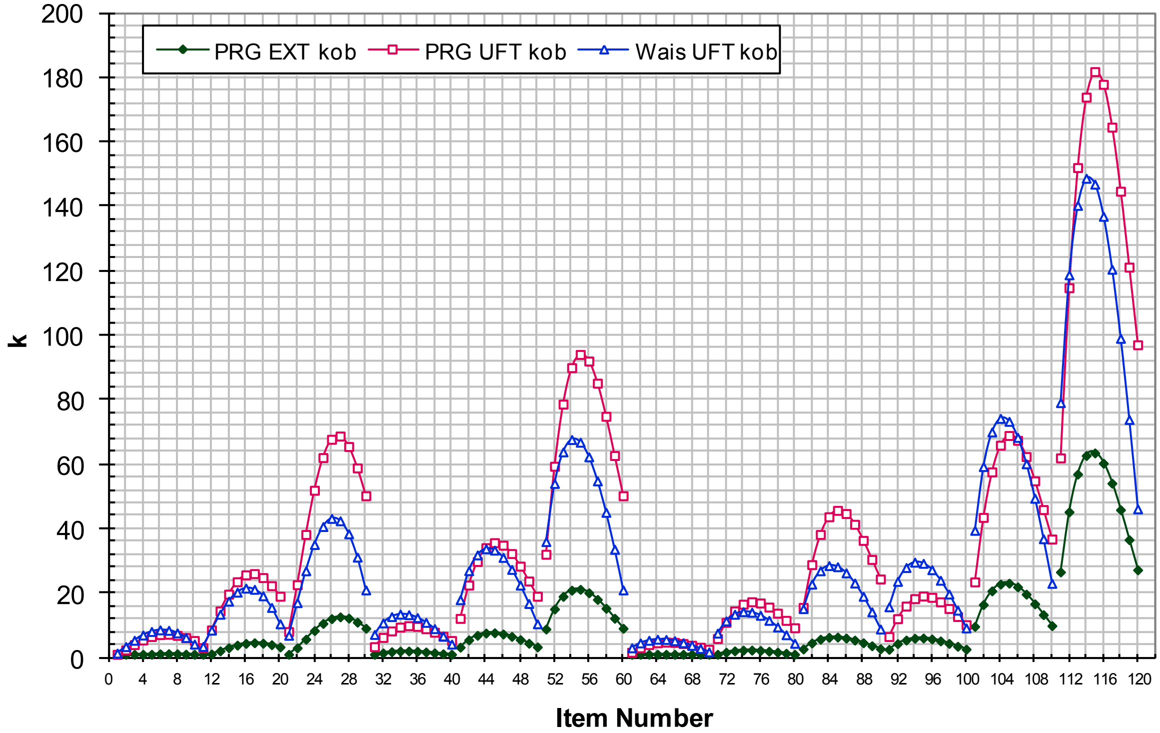
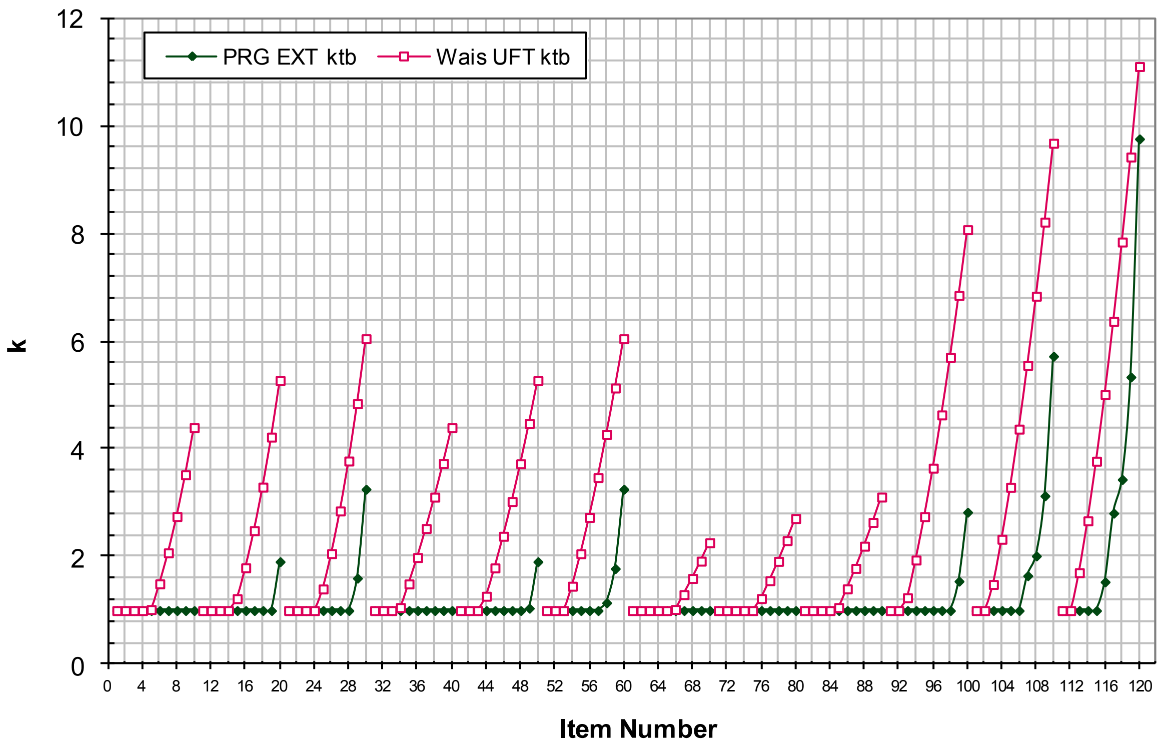


Fig 2.4 k_{tb} - Extruded Tee k-factor, Torsional Branch



Note that Items 91 through 120 are for t/T = 3 and are outside the 07-02 parameter range for contoured fittings.

Fig 2.4 k_{ih} - Extruded Tee k-factor, Inplane Header

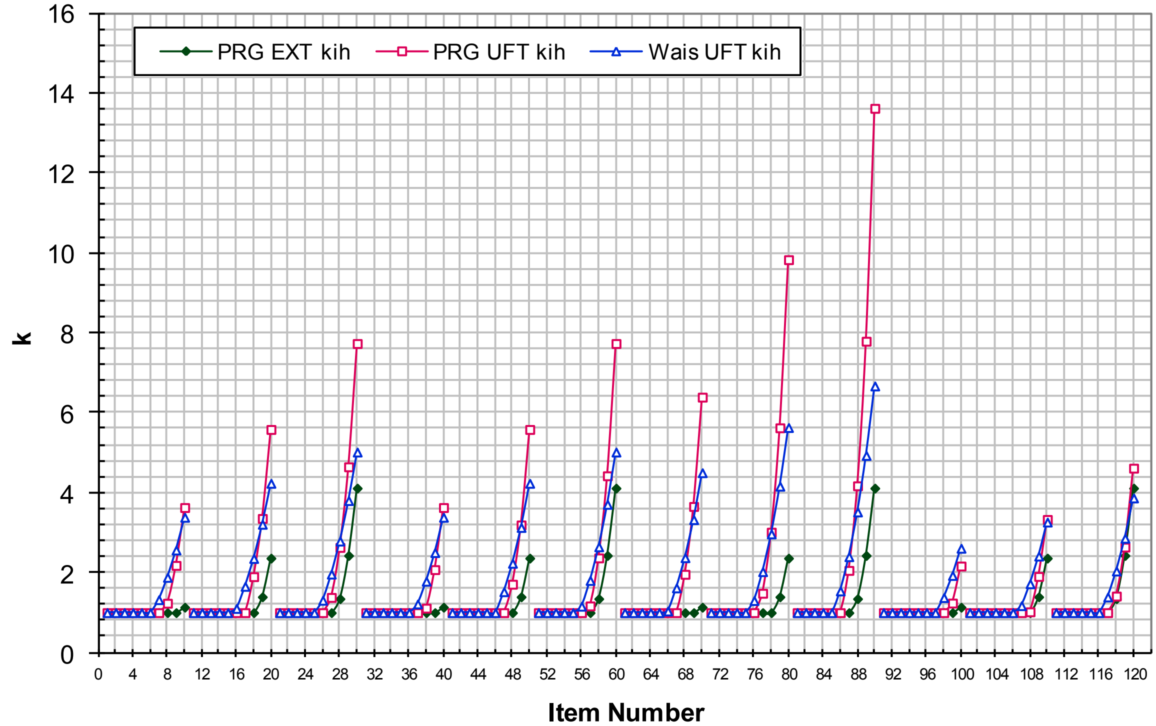
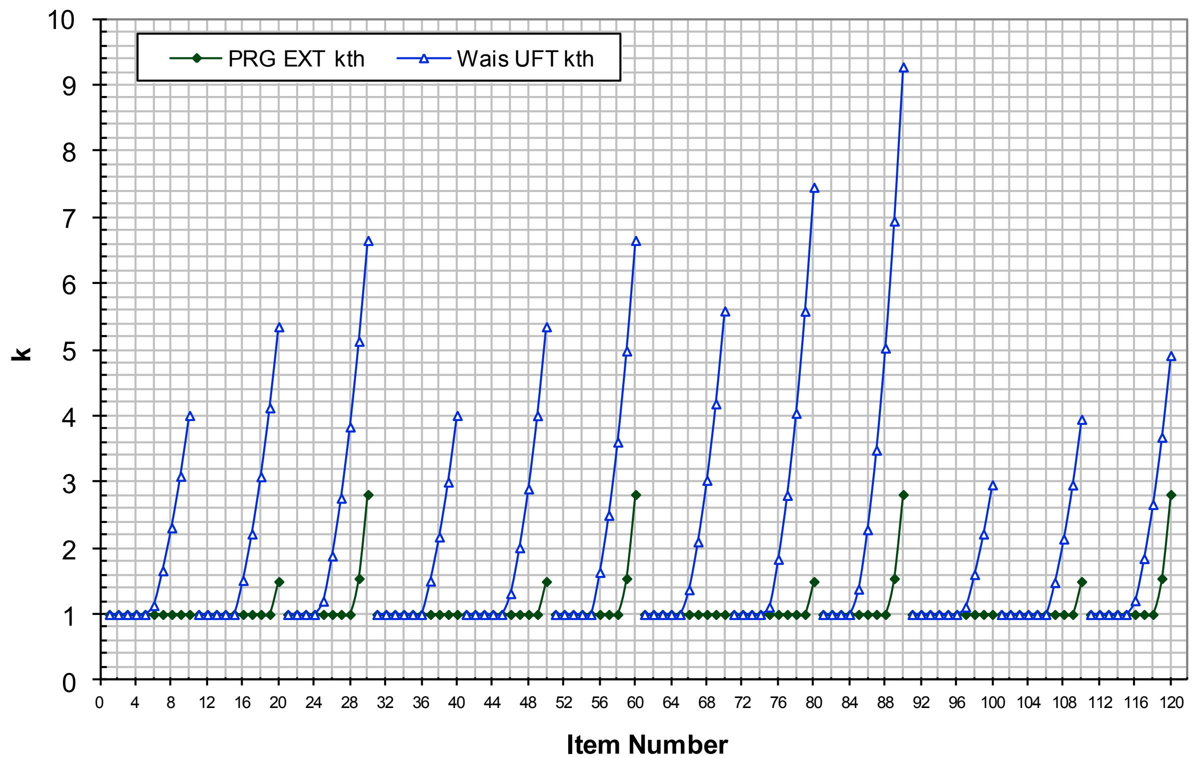
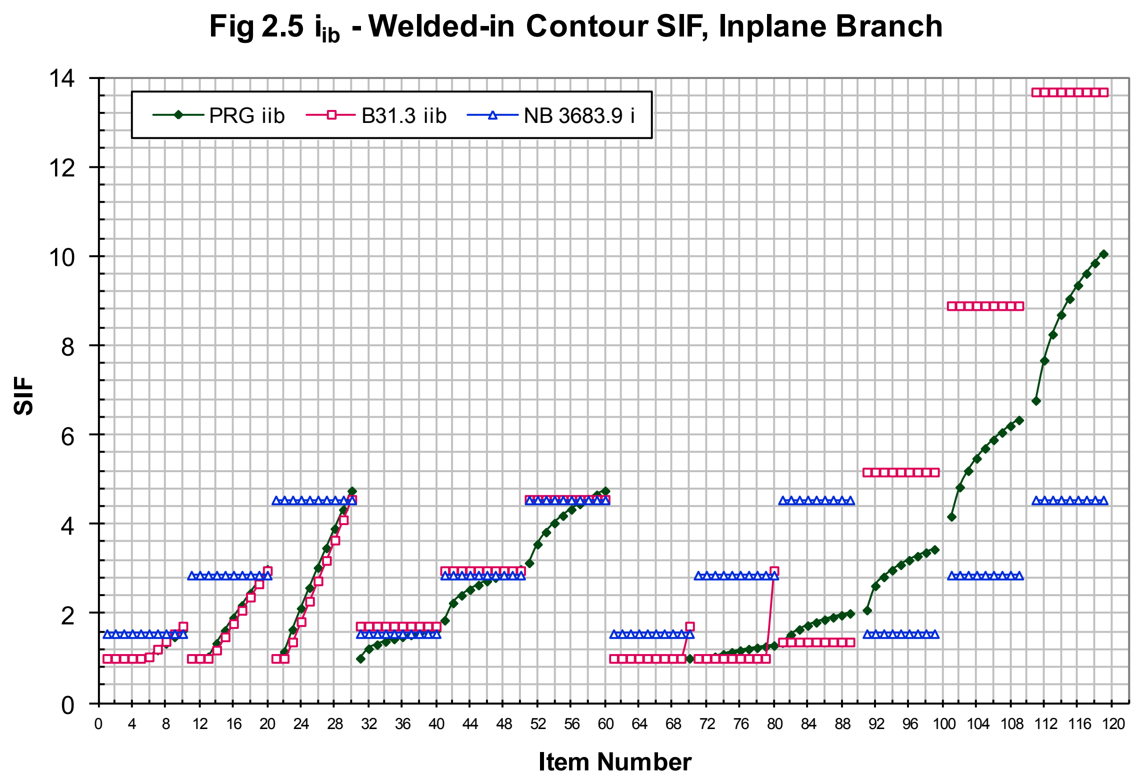


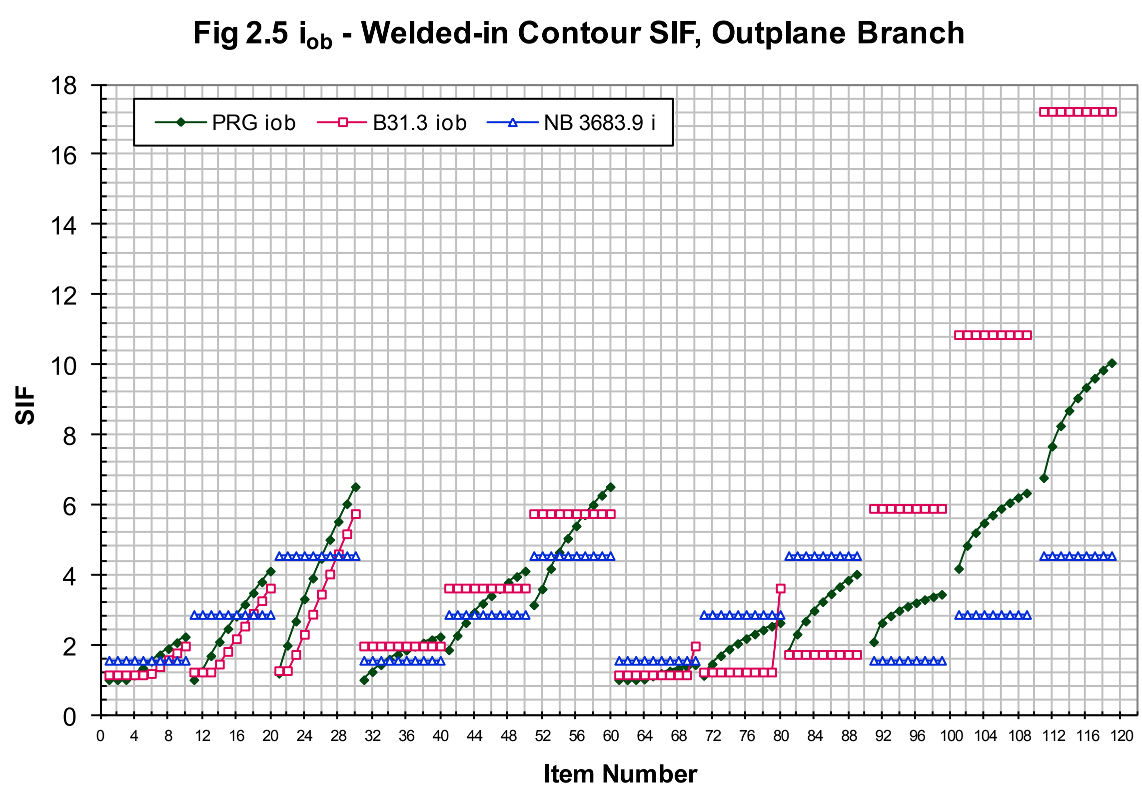
Fig 2.4 k_{th} - Extruded Tee k-factor, Torsional Header

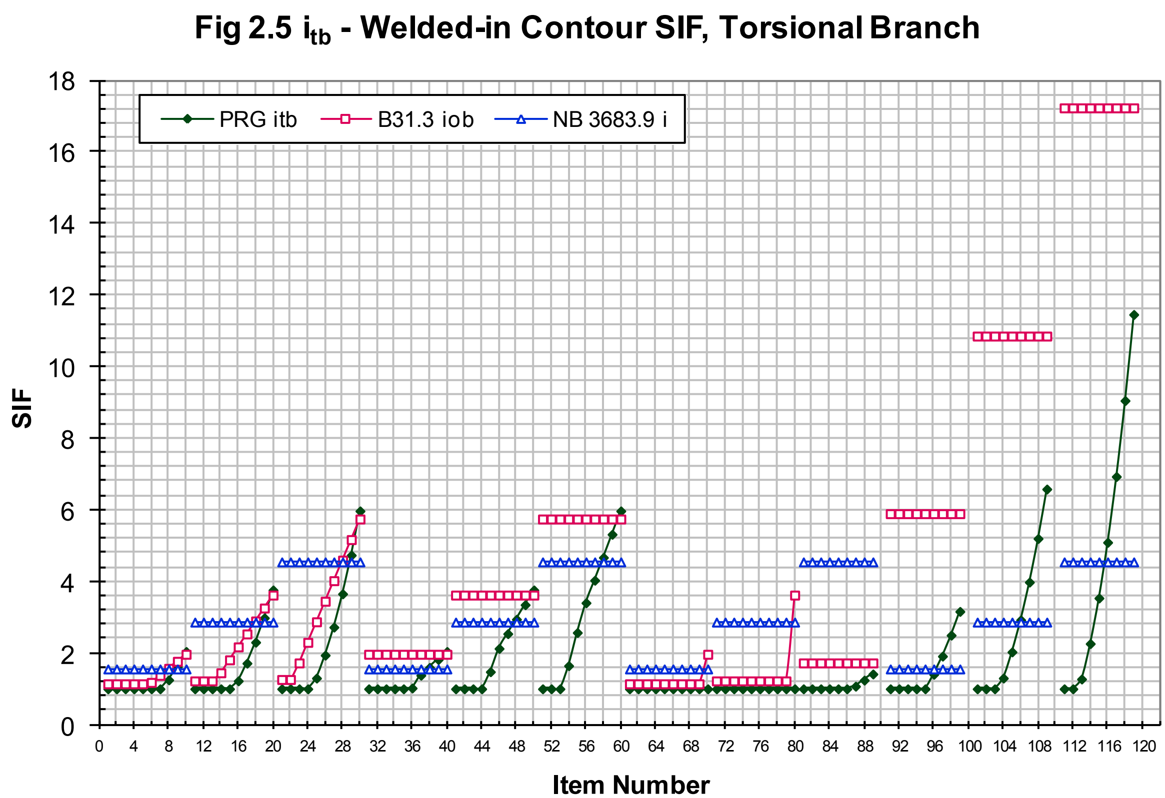


Note that Items 91 through 120 are for t/T = 3 and are outside the 07-02 parameter range for contoured fittings.



Note that Items 91 through 120 are for t/T = 3 and are outside the 07-02 parameter range for contoured fittings.





Note that Items 91 through 120 are for t/T = 3 and are outside the 07-02 parameter range for contoured fittings.

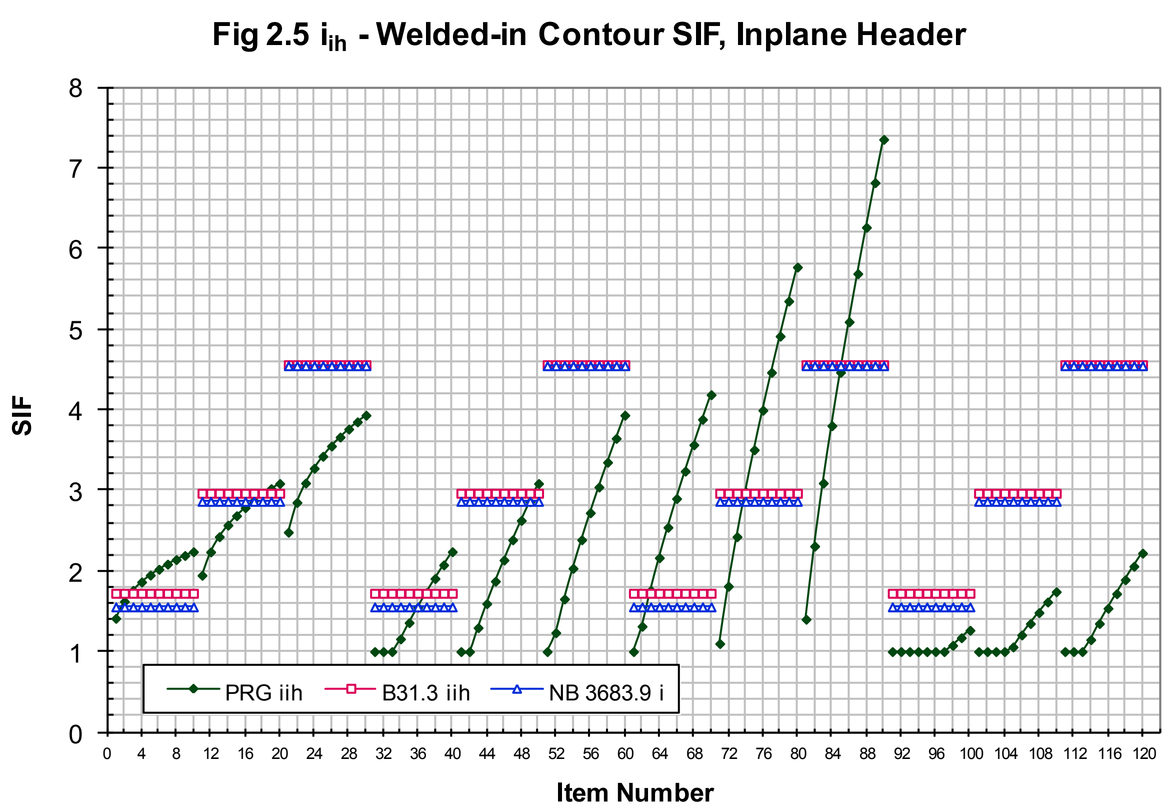
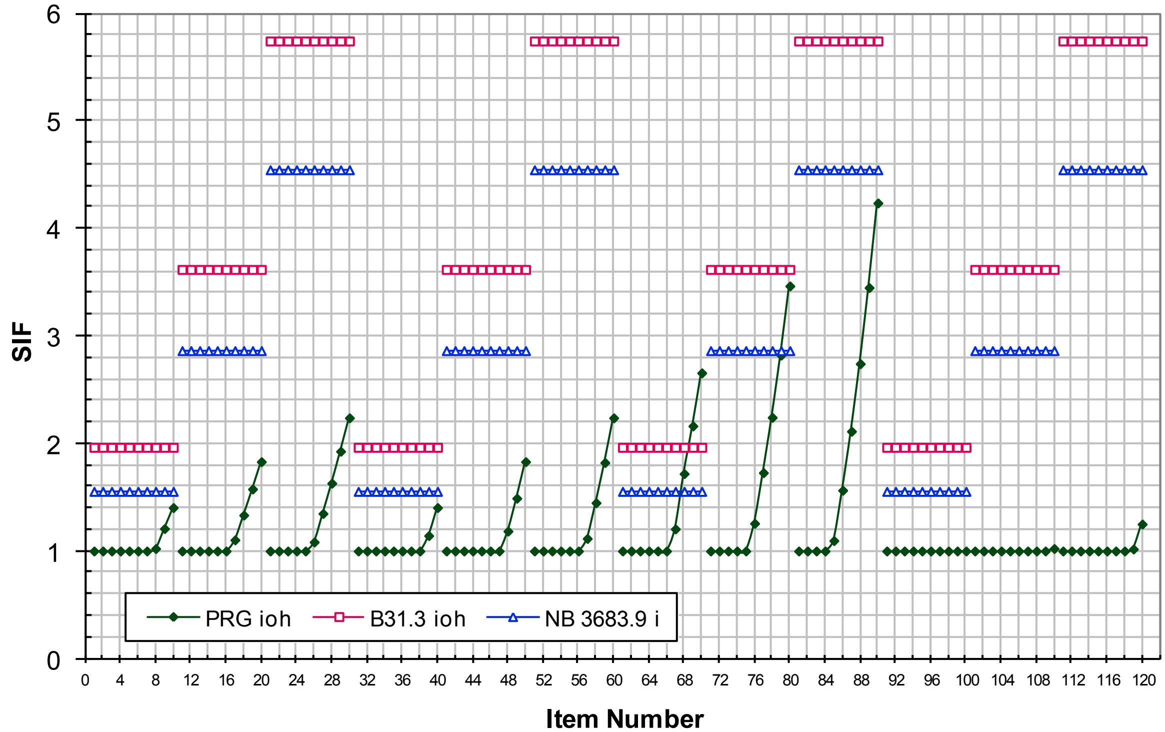


Fig 2.5 i_{oh} - Welded-in Contour SIF, Outplane Header



Note that Items 91 through 120 are for t/T = 3 and are outside the 07-02 parameter range for contoured fittings.

Fig 2.5 i_{th} - Welded-in Contour SIF, Torsional Header

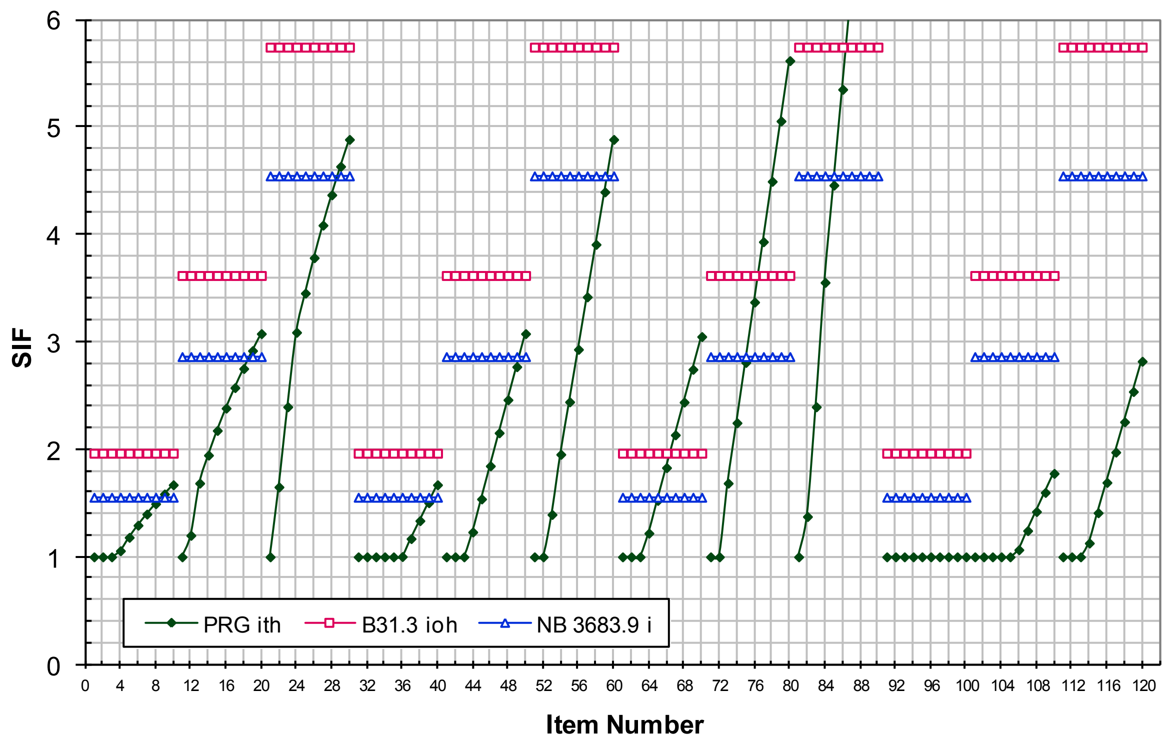
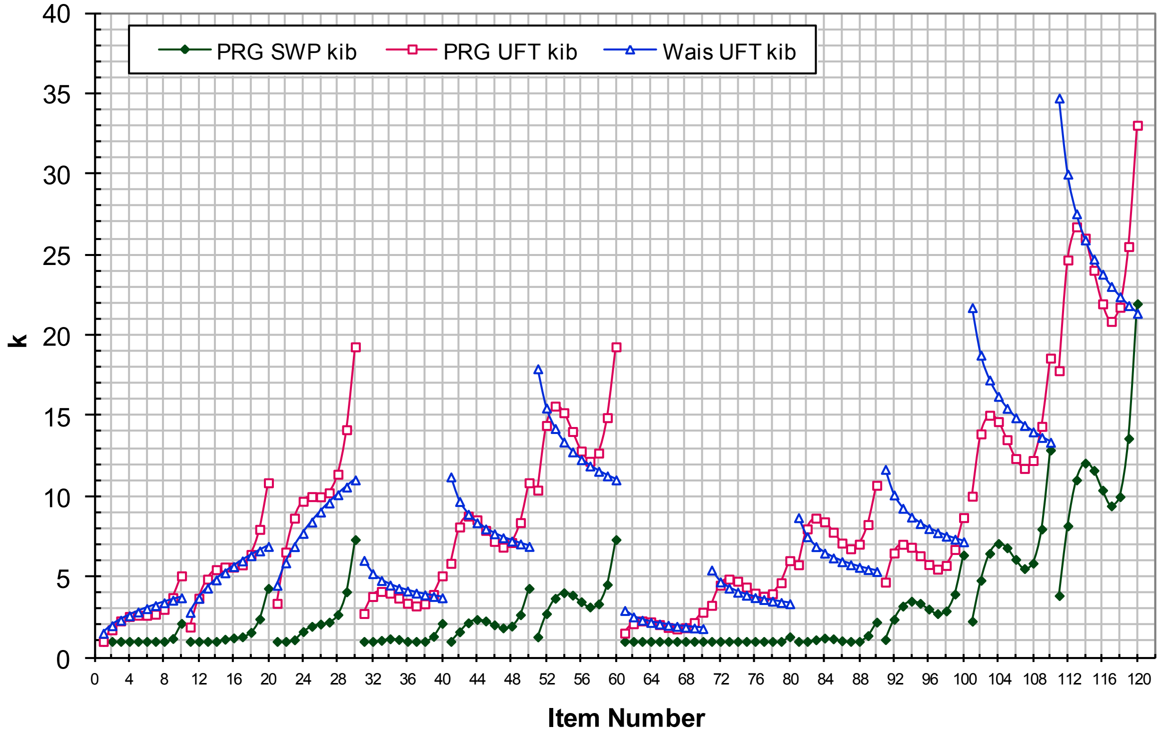
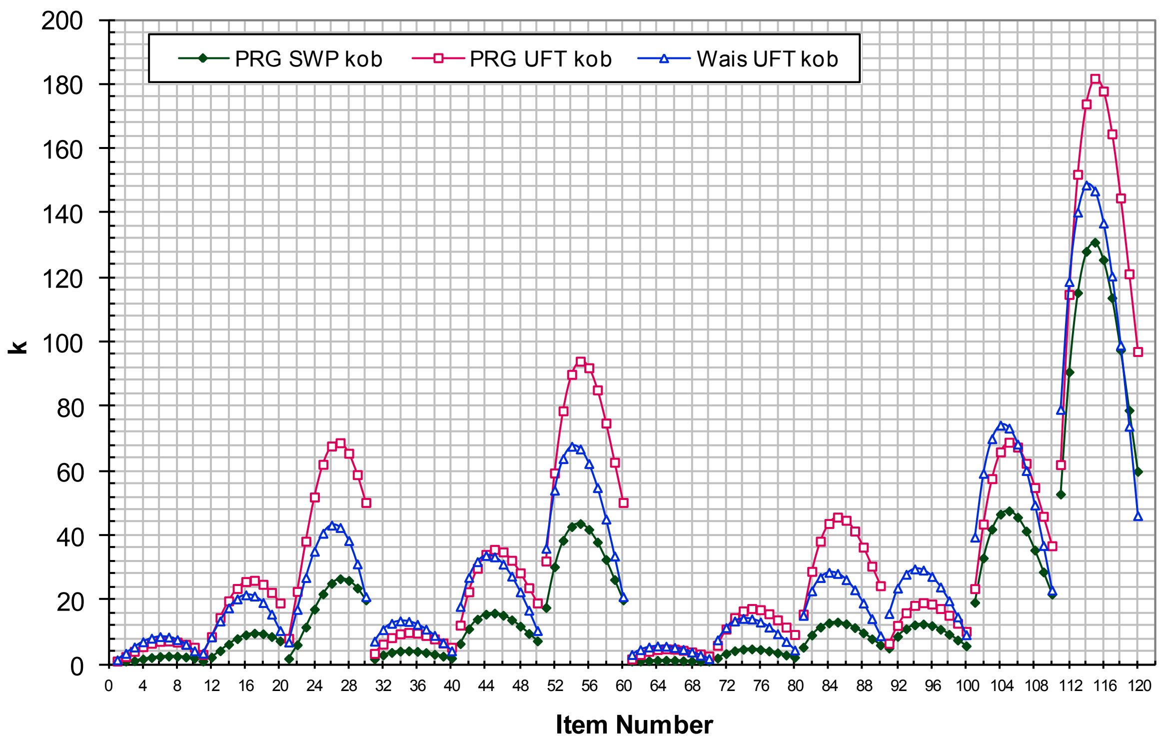


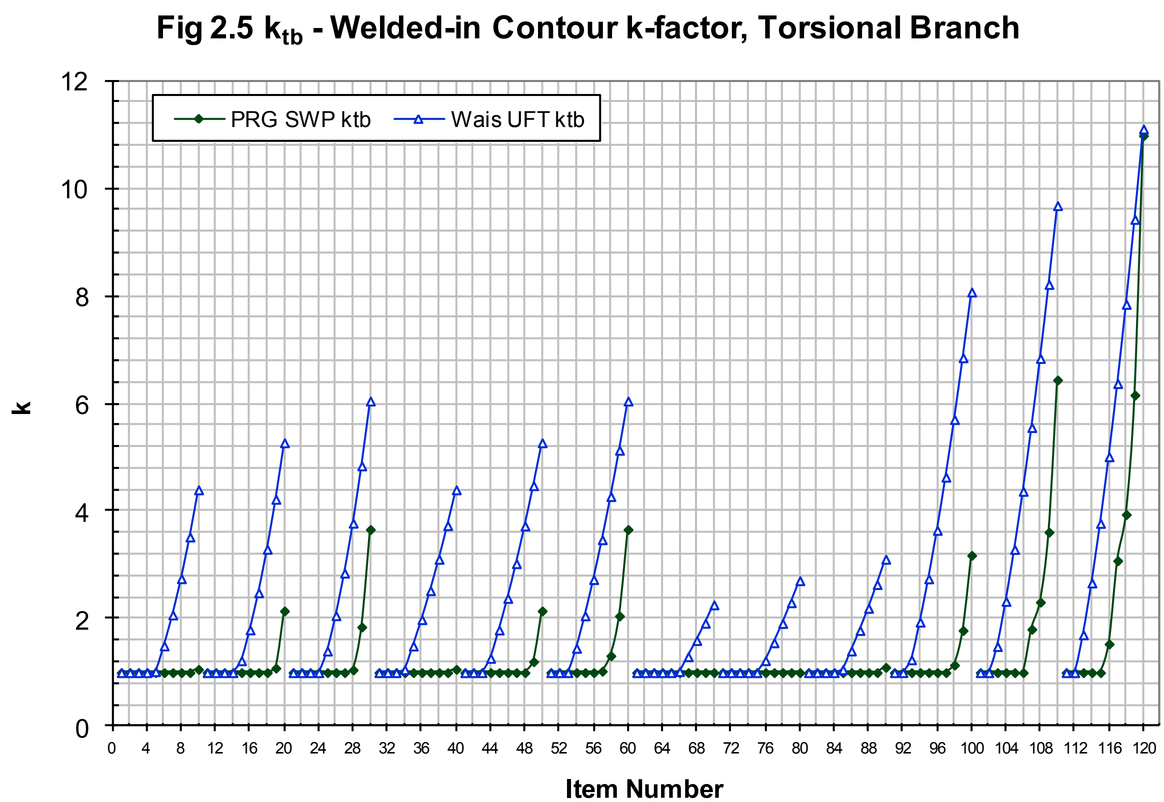
Fig 2.5 k_{ib} - Welded-in Contour k-factor, Inplane Branch



Note that Items 91 through 120 are for t/T = 3 and are outside the 07-02 parameter range for contoured fittings.

Fig 2.5 k_{ob} - Welded-in Contour k-factor, Outplane Branch





Note that Items 91 through 120 are for t/T = 3 and are outside the 07-02 parameter range for contoured fittings.

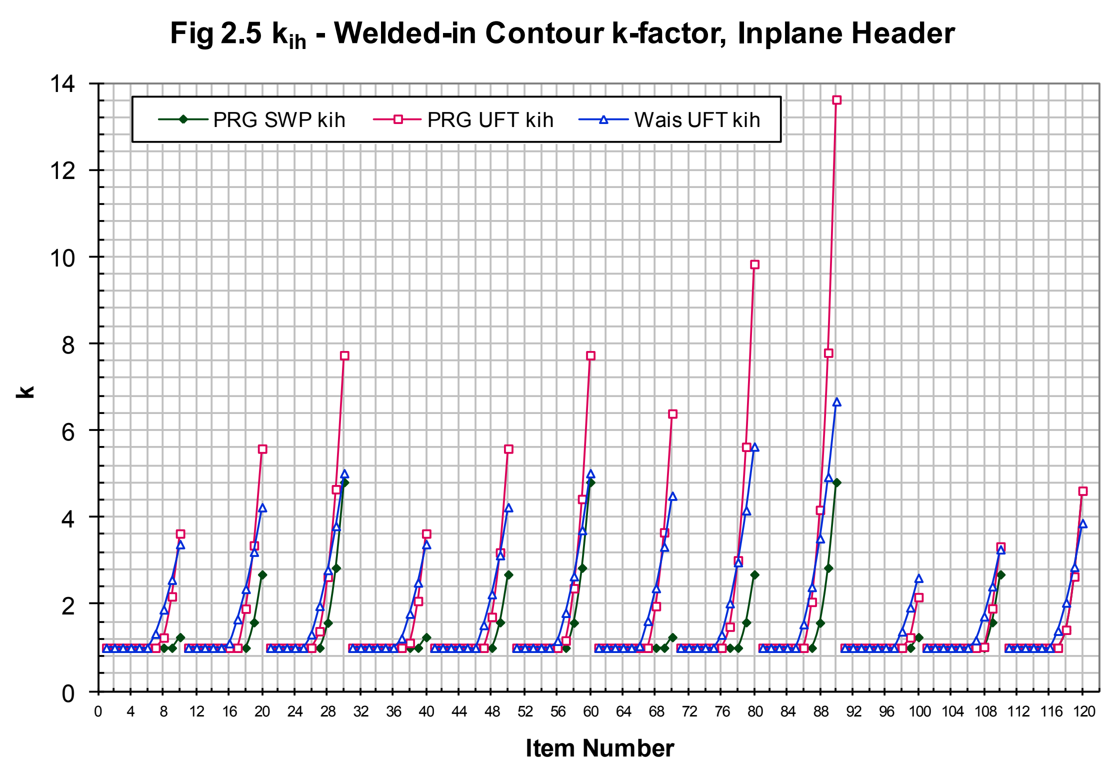
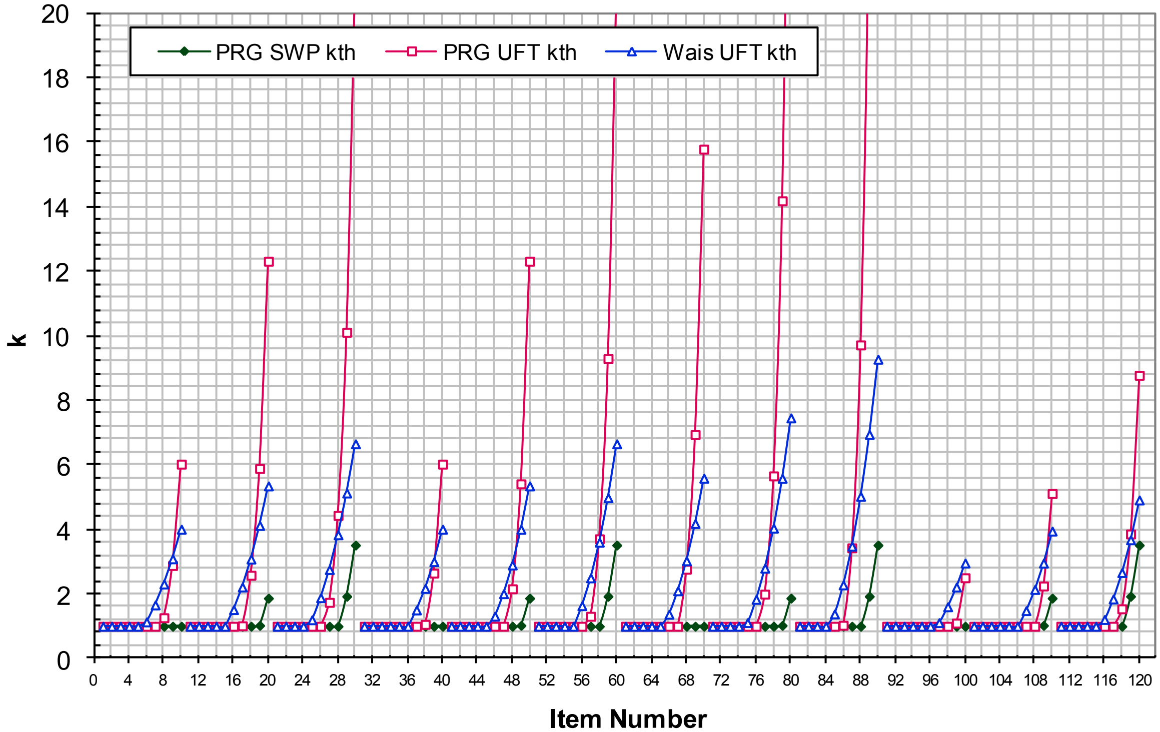


Fig 2.5 k_{th} - Welded-in Contour k-factor, Torsional Header



Note that Items 91 through 120 are for t/T = 3 and are outside the 07-02 parameter range for contoured fittings.

Fig 2.6 i_{ib} - Outlet SIF, Inplane Branch

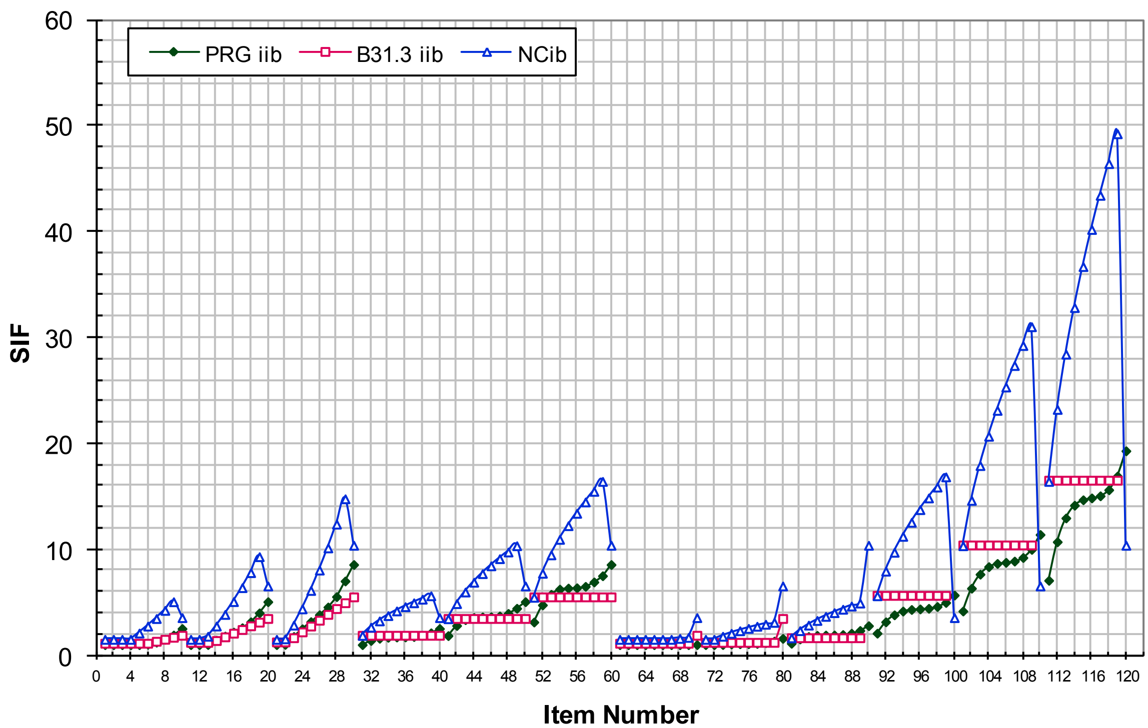


Fig 2.6 i_{ob} - Outlet SIF, Outplane Branch

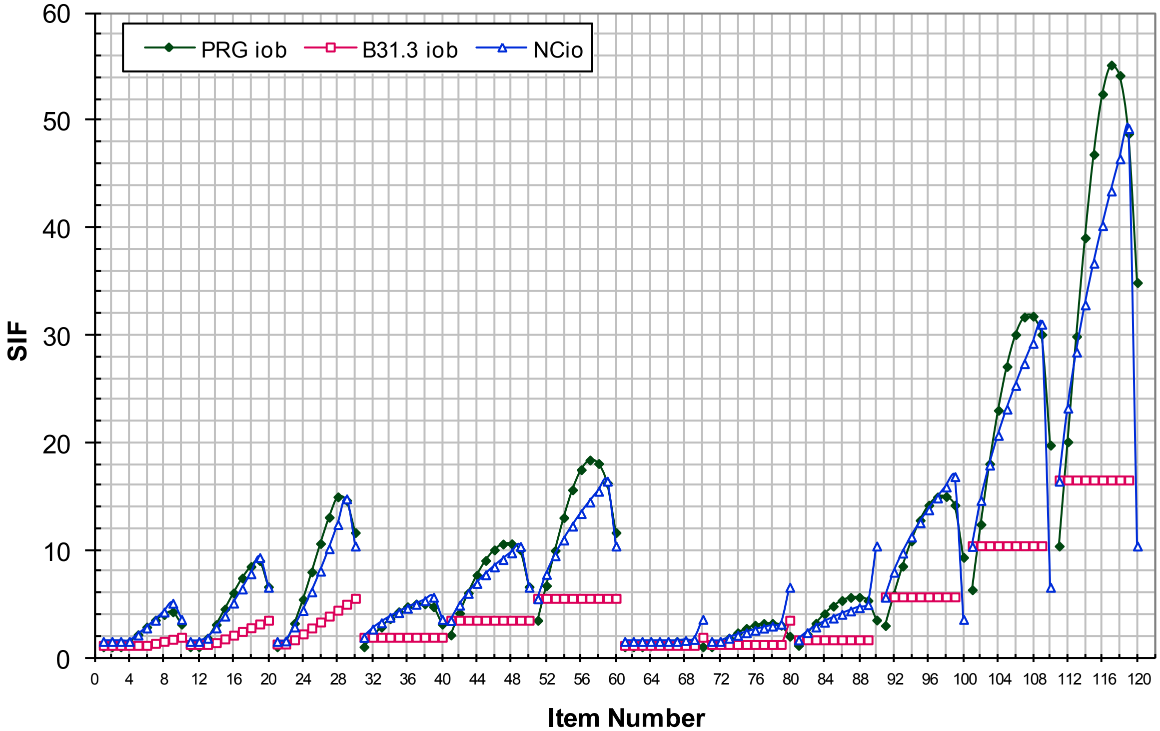
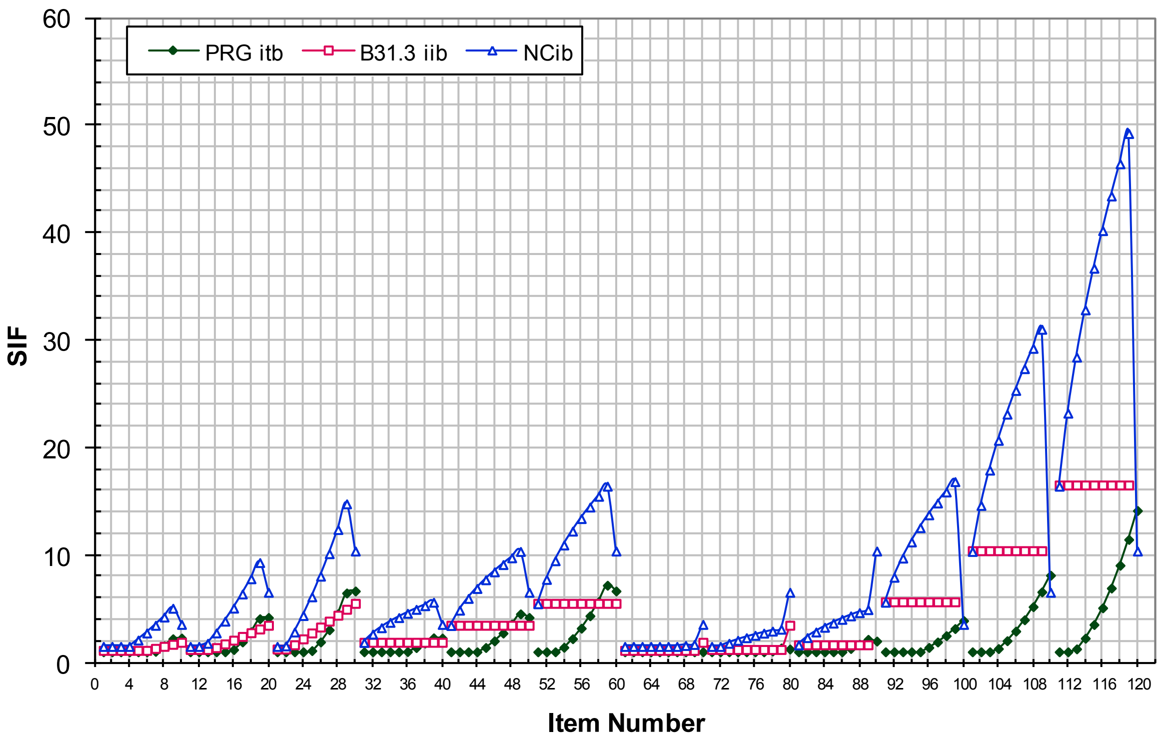


Fig 2.6 i_{tb} - Outlet SIF, Torsional Branch



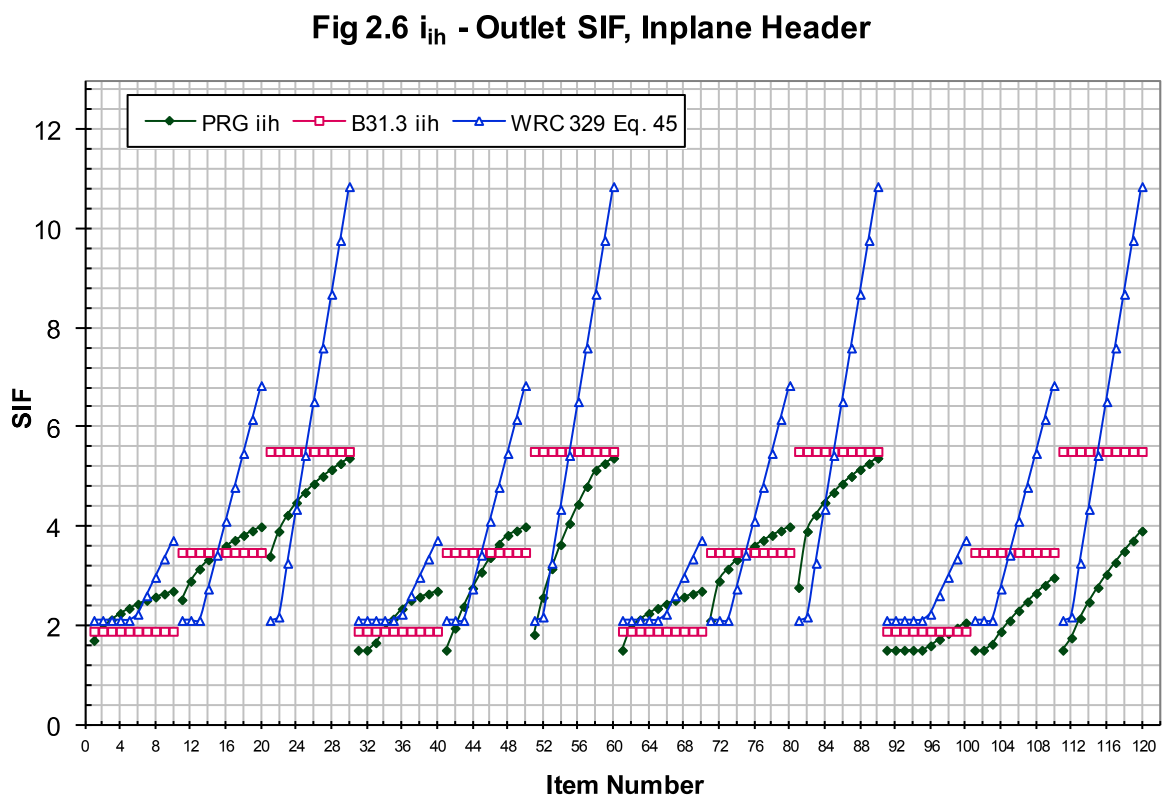


Fig 2.6 i_{ih} - Outlet SIF, Inplane Header
PRG iih
B31.3 iih
WRC 329 Eq. 45
SIF
Item Number

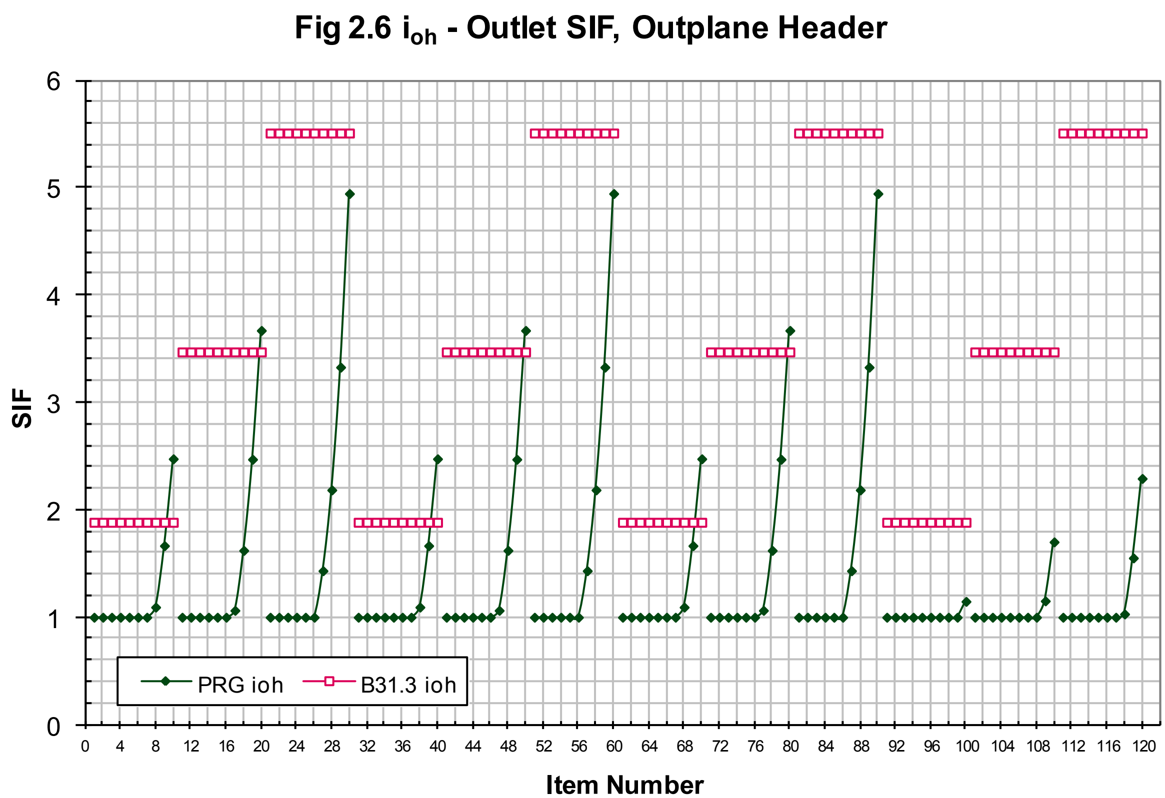


Fig 2.6 i_{oh} - Outlet SIF, Outplane Header
PRG ioh
B31.3 ioh
SIF
Item Number

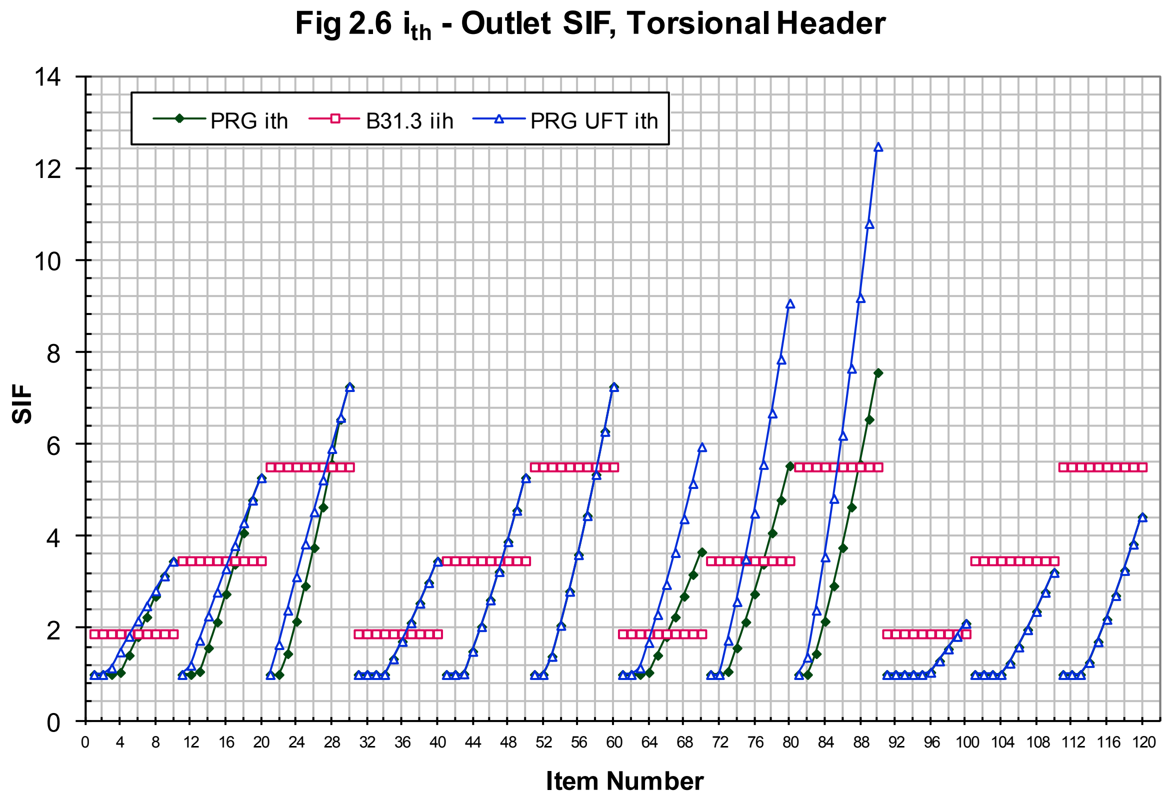


Fig 2.6 i_{th} - Outlet SIF, Torsional Header
PRG ith
B31.3 iih
PRG UFT ith
SIF
Item Number

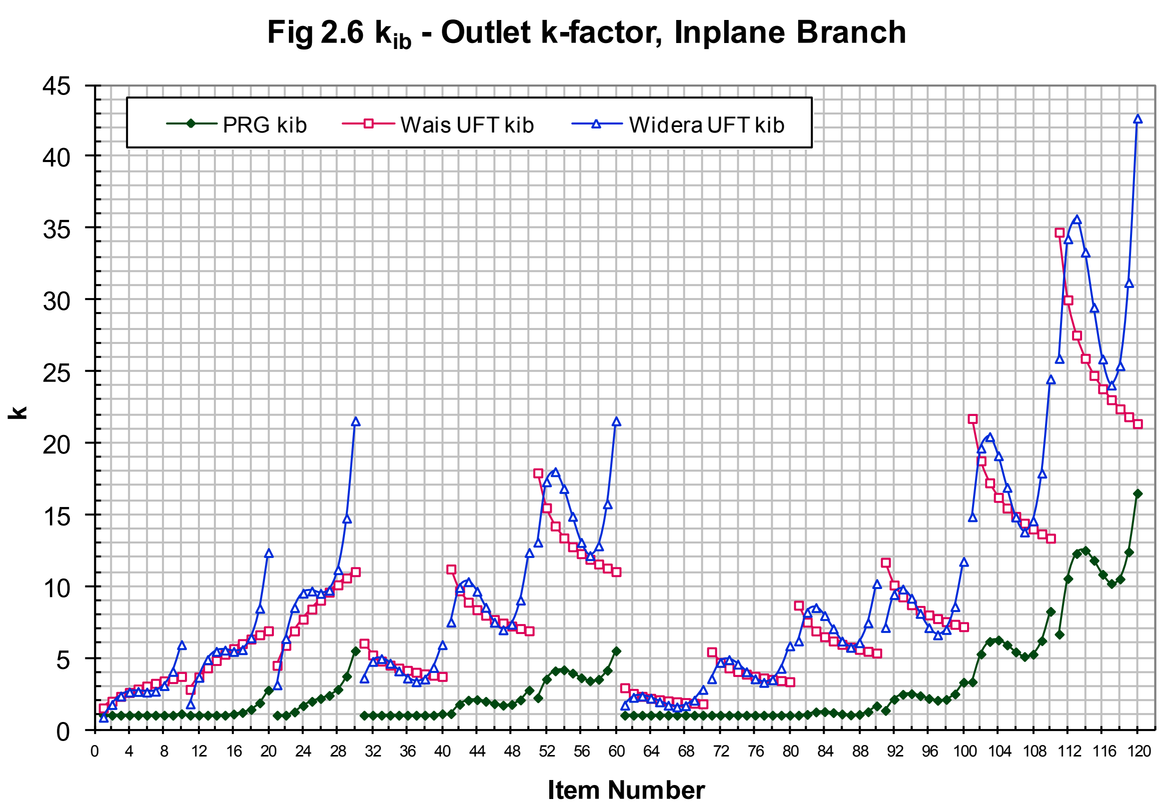


Fig 2.6 k_{ib} - Outlet k-factor, Inplane Branch
PRG kib
Wais UFT kib
Widera UFT kib
k
Item Number

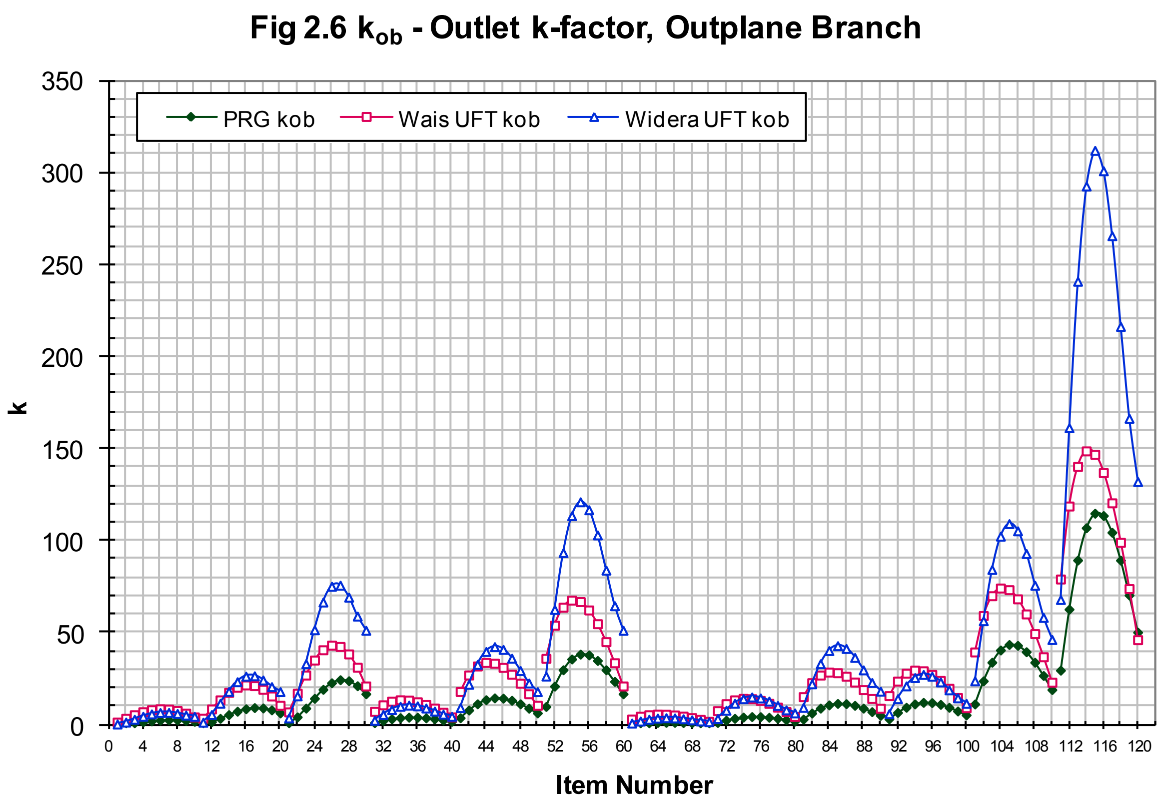


Fig 2.6 k_{ob} - Outlet k-factor, Outplane Branch
PRG kob
Wais UFT kob
Widera UFT kob
k
Item Number

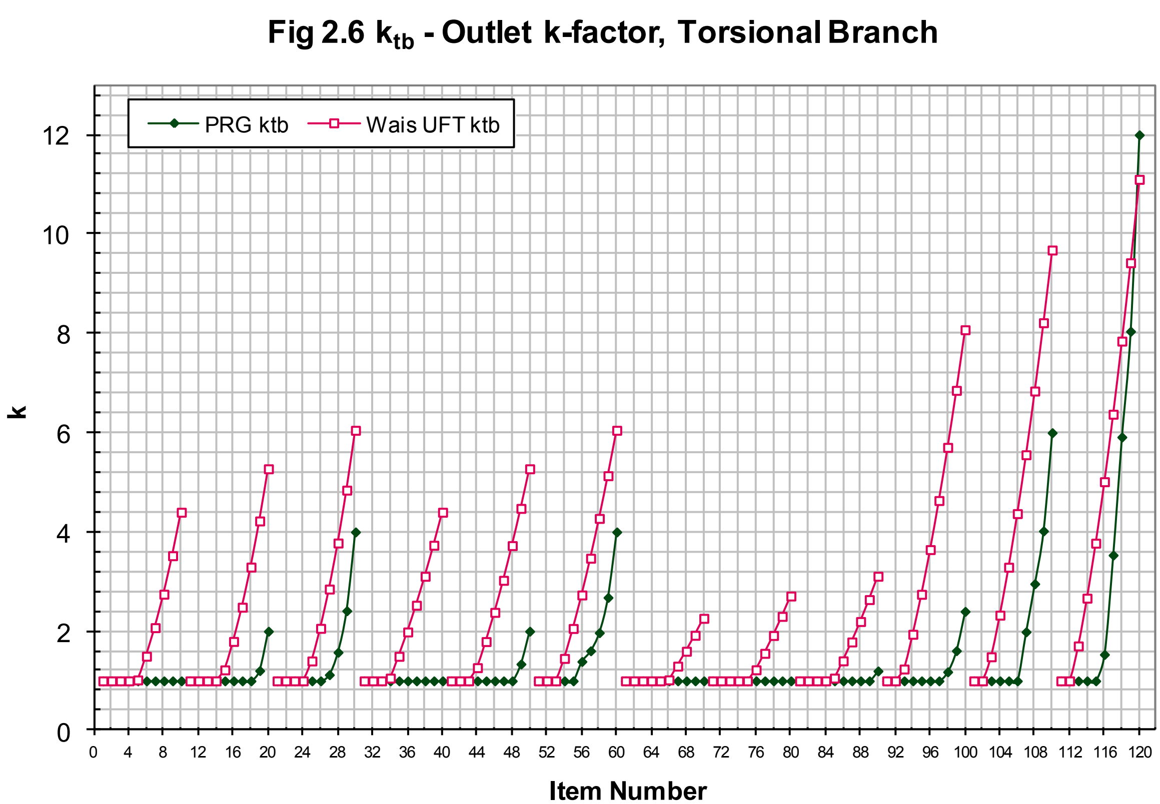


Fig 2.6 k_{tb} - Outlet k-factor, Torsional Branch
PRG ktb
Wais UFT ktb
k
Item Number

Fig 2.6 k_{ih} - Outlet k-factor, Inplane Header

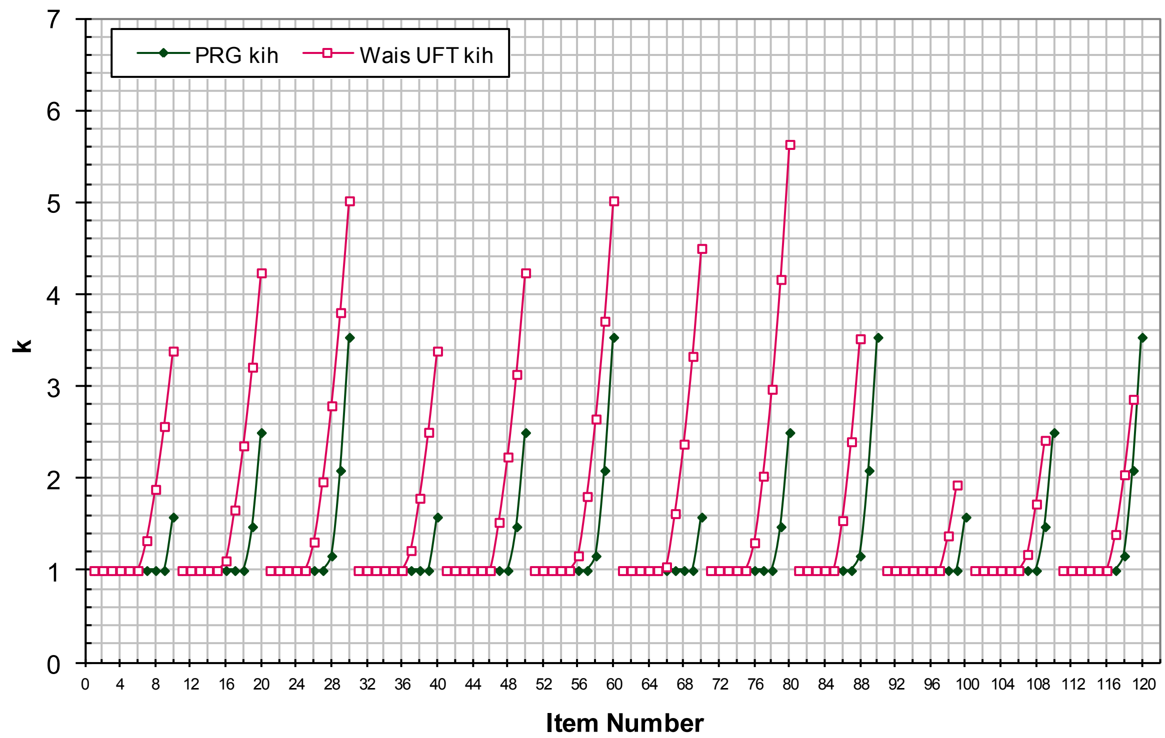
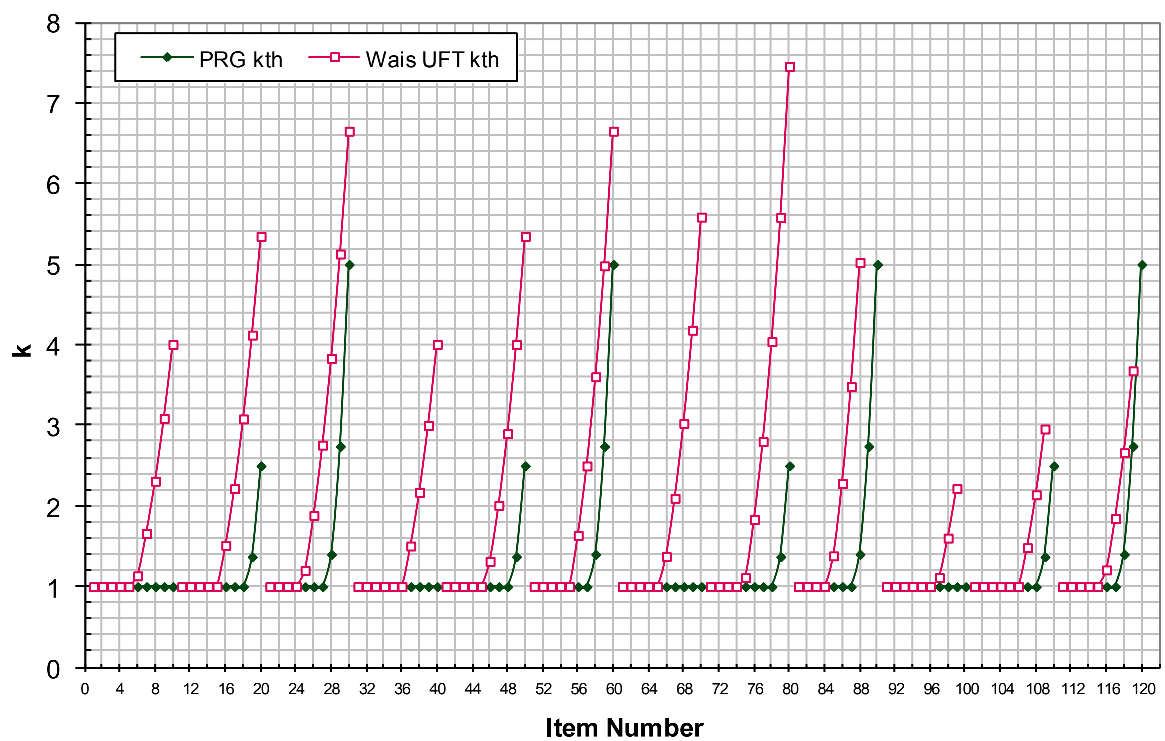


Fig 2.6 k_{th} - Outlet k-factor, Torsional Header



Item #	D/T	d/D	t/T	PRG iib	B31.3 iib	NB-3683.9 ib
1	20	0.1	0.1	1.000	1.000	1.555
2	20	0.2	0.2	1.000	1.000	1.555
3	20	0.3	0.3	1.000	1.000	1.555
4	20	0.4	0.4	1.000	1.000	1.555
5	20	0.5	0.5	1.000	1.000	1.555
6	20	0.6	0.6	1.000	1.034	1.555
7	20	0.7	0.7	1.119	1.207	1.555
8	20	0.8	0.8	1.259	1.379	1.555
9	20	0.9	0.9	1.396	1.551	1.555
10	20	1	1	1.532	1.724	1.555
11	50	0.1	0.1	1.000	1.000	2.864
12	50	0.2	0.2	1.000	1.000	2.864
13	50	0.3	0.3	1.000	1.000	2.864
14	50	0.4	0.4	1.260	1.186	2.864
15	50	0.5	0.5	1.533	1.482	2.864
16	50	0.6	0.6	1.800	1.779	2.864
17	50	0.7	0.7	2.061	2.075	2.864
18	50	0.8	0.8	2.318	2.372	2.864
19	50	0.9	0.9	2.572	2.668	2.864
20	50	1	1	2.821	2.964	2.864
21	100	0.1	0.1	1.000	1.000	4.547
22	100	0.2	0.2	1.087	1.000	4.547
23	100	0.3	0.3	1.552	1.368	4.547
24	100	0.4	0.4	2.000	1.824	4.547
25	100	0.5	0.5	2.434	2.279	4.547
26	100	0.6	0.6	2.857	2.735	4.547
27	100	0.7	0.7	3.272	3.191	4.547
28	100	0.8	0.8	3.680	3.647	4.547
29	100	0.9	0.9	4.082	4.103	4.547
30	100	1	1	4.479	4.559	4.547
31	20	0.1	1	1.000	1.724	1.555
32	20	0.2	1	1.146	1.724	1.555
33	20	0.3	1	1.233	1.724	1.555
34	20	0.4	1	1.299	1.724	1.555
35	20	0.5	1	1.352	1.724	1.555
36	20	0.6	1	1.397	1.724	1.555
37	20	0.7	1	1.436	1.724	1.555
38	20	0.8	1	1.471	1.724	1.555
39	20	0.9	1	1.503	1.724	1.555
40	20	1	1	1.532	1.724	1.555
41	50	0.1	1	1.852	2.964	2.864
42	50	0.2	1	2.112	2.964	2.864
43	50	0.3	1	2.272	2.964	2.864
44	50	0.4	1	2.392	2.964	2.864
45	50	0.5	1	2.491	2.964	2.864
46	50	0.6	1	2.574	2.964	2.864
47	50	0.7	1	2.646	2.964	2.864
48	50	0.8	1	2.710	2.964	2.864
49	50	0.9	1	2.768	2.964	2.864
50	50	1	1	2.821	2.964	2.864
51	100	0.1	1	2.959	4.559	4.547
52	100	0.2	1	3.352	4.559	4.547
53	100	0.3	1	3.606	4.559	4.547
54	100	0.4	1	3.798	4.559	4.547
55	100	0.5	1	3.953	4.559	4.547
56	100	0.6	1	4.085	4.559	4.547
57	100	0.7	1	4.200	4.559	4.547
58	100	0.8	1	4.302	4.559	4.547
59	100	0.9	1	4.395	4.559	4.547
60	100	1	1	4.479	4.559	4.547
61	20	0.1	0.3	1.000	1.000	1.555
62	20	0.2	0.3	1.000	1.000	1.555
63	20	0.3	0.3	1.000	1.000	1.555
64	20	0.4	0.3	1.000	1.000	1.555
65	20	0.5	0.3	1.000	1.000	1.555
66	20	0.6	0.3	1.000	1.000	1.555
67	20	0.7	0.3	1.000	1.000	1.555
68	20	0.8	0.3	1.000	1.000	1.555
69	20	0.9	0.3	1.000	1.000	1.555
70	20	1	0.3	1.000	1.724	1.555
71	50	0.1	0.3	1.000	1.000	2.864
72	50	0.2	0.3	1.000	1.000	2.864
73	50	0.3	0.3	1.000	1.000	2.864
74	50	0.4	0.3	1.030	1.000	2.864
75	50	0.5	0.3	1.072	1.000	2.864
76	50	0.6	0.3	1.108	1.000	2.864
77	50	0.7	0.3	1.139	1.000	2.864
78	50	0.8	0.3	1.167	1.000	2.864
79	50	0.9	0.3	1.192	1.000	2.864
80	50	1	0.3	1.215	2.964	2.864
81	100	0.1	0.3	1.274	1.368	4.547
82	100	0.2	0.3	1.443	1.368	4.547
83	100	0.3	0.3	1.552	1.368	4.547
84	100	0.4	0.3	1.635	1.368	4.547
85	100	0.5	0.3	1.702	1.368	4.547
86	100	0.6	0.3	1.759	1.368	4.547
87	100	0.7	0.3	1.808	1.368	4.547
88	100	0.8	0.3	1.852	1.368	4.547
89	100	0.9	0.3	1.892	1.368	4.547
90	100	1	0.3			
91	20	0.1	3	2.082	5.171	1.555
92	20	0.2	3	2.474	5.171	1.555
93	20	0.3	3	2.661	5.171	1.555
94	20	0.4	3	2.802	5.171	1.555
95	20	0.5	3	2.917	5.171	1.555
96	20	0.6	3	3.015	5.171	1.555
97	20	0.7	3	3.099	5.171	1.555
98	20	0.8	3	3.175	5.171	1.555
99	20	0.9	3	3.243	5.171	1.555
100	20	1	3			
101	50	0.1	3	4.022	8.893	2.864
102	50	0.2	3	4.557	8.893	2.864
103	50	0.3	3	4.902	8.893	2.864
104	50	0.4	3	5.162	8.893	2.864
105	50	0.5	3	5.374	8.893	2.864
106	50	0.6	3	5.553	8.893	2.864
107	50	0.7	3	5.709	8.893	2.864
108	50	0.8	3	5.848	8.893	2.864
109	50	0.9	3	5.973	8.893	2.864
110	50	1	3			
111	100	0.1	3	6.385	13.677	4.547
112	100	0.2	3	7.233	13.677	4.547
113	100	0.3	3	7.781	13.677	4.547
114	100	0.4	3	8.194	13.677	4.547
115	100	0.5	3	8.530	13.677	4.547
116	100	0.6	3	8.815	13.677	4.547
117	100	0.7	3	9.063	13.677	4.547
118	100	0.8	3	9.283	13.677	4.547
119	100	0.9	3	9.482	13.677	4.547
120	100	1	3			

B16.9 Welding Tee (WLT) - Sketch 2.1 - Branch Outplane SIF

Item #	D/T	d/D	t/T	PRG iob	B31.3 iob	NB-3683.9 ib
1	20	0.1	0.1	1.000	1.140	1.555
2	20	0.2	0.2	1.000	1.140	1.555
3	20	0.3	0.3	1.000	1.140	1.555
4	20	0.4	0.4	1.000	1.140	1.555
5	20	0.5	0.5	1.167	1.140	1.555
6	20	0.6	0.6	1.336	1.179	1.555
7	20	0.7	0.7	1.497	1.375	1.555
8	20	0.8	0.8	1.653	1.572	1.555
9	20	0.9	0.9	1.803	1.768	1.555
10	20	1	1	1.949	1.965	1.555
11	50	0.1	0.1	1.000	1.221	2.864
12	50	0.2	0.2	1.091	1.221	2.864
13	50	0.3	0.3	1.473	1.221	2.864
14	50	0.4	0.4	1.823	1.448	2.864
15	50	0.5	0.5	2.150	1.810	2.864
16	50	0.6	0.6	2.461	2.172	2.864
17	50	0.7	0.7	2.758	2.534	2.864
18	50	0.8	0.8	3.044	2.895	2.864
19	50	0.9	0.9	3.322	3.257	2.864
20	50	1	1	3.591	3.619	2.864
21	100	0.1	0.1	1.037	1.260	4.547
22	100	0.2	0.2	1.732	1.260	4.547
23	100	0.3	0.3	2.339	1.724	4.547
24	100	0.4	0.4	2.893	2.298	4.547
25	100	0.5	0.5	3.413	2.873	4.547
26	100	0.6	0.6	3.906	3.447	4.547
27	100	0.7	0.7	4.378	4.022	4.547
28	100	0.8	0.8	4.833	4.596	4.547
29	100	0.9	0.9	5.273	5.171	4.547
30	100	1	1	5.700	5.745	4.547
31	20	0.1	1	1.000	1.965	1.555
32	20	0.2	1	1.146	1.965	1.555
33	20	0.3	1	1.249	1.965	1.555
34	20	0.4	1	1.389	1.965	1.555
35	20	0.5	1	1.508	1.965	1.555
36	20	0.6	1	1.614	1.965	1.555
37	20	0.7	1	1.708	1.965	1.555
38	20	0.8	1	1.795	1.965	1.555
39	20	0.9	1	1.875	1.965	1.555
40	20	1	1	1.949	1.965	1.555
41	50	0.1	1	1.852	3.619	2.864
42	50	0.2	1	2.112	3.619	2.864
43	50	0.3	1	2.300	3.619	2.864
44	50	0.4	1	2.558	3.619	2.864
45	50	0.5	1	2.779	3.619	2.864
46	50	0.6	1	2.973	3.619	2.864
47	50	0.7	1	3.147	3.619	2.864
48	50	0.8	1	3.306	3.619	2.864
49	50	0.9	1	3.454	3.619	2.864
50	50	1	1	3.591	3.619	2.864
51	100	0.1	1	2.959	5.745	4.547
52	100	0.2	1	3.352	5.745	4.547
53	100	0.3	1	3.651	5.745	4.547
54	100	0.4	1	4.061	5.745	4.547
55	100	0.5	1	4.411	5.745	4.547
56	100	0.6	1	4.719	5.745	4.547
57	100	0.7	1	4.996	5.745	4.547
58	100	0.8	1	5.249	5.745	4.547
59	100	0.9	1	5.482	5.745	4.547
60	100	1	1	5.700	5.745	4.547
61	20	0.1	0.3	1.000	1.140	1.555
62	20	0.2	0.3	1.000	1.140	1.555
63	20	0.3	0.3	1.000	1.140	1.555
64	20	0.4	0.3	1.000	1.140	1.555
65	20	0.5	0.3	1.000	1.140	1.555
66	20	0.6	0.3	1.034	1.140	1.555
67	20	0.7	0.3	1.094	1.140	1.555
68	20	0.8	0.3	1.150	1.140	1.555
69	20	0.9	0.3	1.201	1.140	1.555
70	20	1	0.3	1.249	1.965	1.555
71	50	0.1	0.3	1.000	1.221	2.864
72	50	0.2	0.3	1.268	1.221	2.864
73	50	0.3	0.3	1.473	1.221	2.864
74	50	0.4	0.3	1.639	1.221	2.864
75	50	0.5	0.3	1.780	1.221	2.864
76	50	0.6	0.3	1.904	1.221	2.864
77	50	0.7	0.3	2.016	1.221	2.864
78	50	0.8	0.3	2.118	1.221	2.864
79	50	0.9	0.3	2.212	1.221	2.864
80	50	1	0.3	2.300	3.619	2.864
81	100	0.1	0.3	1.558	1.724	4.547
82	100	0.2	0.3	2.013	1.724	4.547
83	100	0.3	0.3	2.339	1.724	4.547
84	100	0.4	0.3	2.601	1.724	4.547
85	100	0.5	0.3	2.825	1.724	4.547
86	100	0.6	0.3	3.022	1.724	4.547
87	100	0.7	0.3	3.200	1.724	4.547
88	100	0.8	0.3	3.362	1.724	4.547
89	100	0.9	0.3	3.512	1.724	4.547
90	100	1	0.3			
91	20	0.1	3	2.082	5.895	1.555
92	20	0.2	3	2.474	5.895	1.555
93	20	0.3	3	2.661	5.895	1.555
94	20	0.4	3	2.802	5.895	1.555
95	20	0.5	3	2.917	5.895	1.555
96	20	0.6	3	3.015	5.895	1.555
97	20	0.7	3	3.099	5.895	1.555
98	20	0.8	3	3.175	5.895	1.555
99	20	0.9	3	3.243	5.895	1.555
100	20	1	3			
101	50	0.1	3	4.022	10.858	2.864
102	50	0.2	3	4.557	10.858	2.864
103	50	0.3	3	4.902	10.858	2.864
104	50	0.4	3	5.162	10.858	2.864
105	50	0.5	3	5.374	10.858	2.864
106	50	0.6	3	5.553	10.858	2.864
107	50	0.7	3	5.709	10.858	2.864
108	50	0.8	3	5.848	10.858	2.864
109	50	0.9	3	5.973	10.858	2.864
110	50	1	3			
111	100	0.1	3	6.385	17.236	4.547
112	100	0.2	3	7.233	17.236	4.547
113	100	0.3	3	7.781	17.236	4.547
114	100	0.4	3	8.194	17.236	4.547
115	100	0.5	3	8.530	17.236	4.547
116	100	0.6	3	8.815	17.236	4.547
117	100	0.7	3	9.063	17.236	4.547
118	100	0.8	3	9.283	17.236	4.547
119	100	0.9	3	9.482	17.236	4.547
120	100	1	3			

B16.9 Welding Tee (WLT) - Sketch 2.1 - Branch Torsional SIF

Item #	D/T	d/D	t/T	PRG itb	B31.3 iob	NB-3683.9 ib
1	20	0.1	0.1	1.000	1.140	1.555
2	20	0.2	0.2	1.000	1.140	1.555
3	20	0.3	0.3	1.000	1.140	1.555
4	20	0.4	0.4	1.000	1.140	1.555
5	20	0.5	0.5	1.000	1.140	1.555
6	20	0.6	0.6	1.000	1.179	1.555
7	20	0.7	0.7	1.000	1.375	1.555
8	20	0.8	0.8	1.193	1.572	1.555
9	20	0.9	0.9	1.546	1.768	1.555
10	20	1	1	1.949	1.965	1.555
11	50	0.1	0.1	1.000	1.221	2.864
12	50	0.2	0.2	1.000	1.221	2.864
13	50	0.3	0.3	1.000	1.221	2.864
14	50	0.4	0.4	1.000	1.448	2.864
15	50	0.5	0.5	1.000	1.810	2.864
16	50	0.6	0.6	1.167	2.172	2.864
17	50	0.7	0.7	1.638	2.534	2.864
18	50	0.8	0.8	2.198	2.895	2.864
19	50	0.9	0.9	2.848	3.257	2.864
20	50	1	1	3.591	3.619	2.864
21	100	0.1	0.1	1.000	1.260	4.547
22	100	0.2	0.2	1.000	1.260	4.547
23	100	0.3	0.3	1.000	1.724	4.547
24	100	0.4	0.4	1.000	2.298	4.547
25	100	0.5	0.5	1.241	2.873	4.547
26	100	0.6	0.6	1.853	3.447	4.547
27	100	0.7	0.7	2.601	4.022	4.547
28	100	0.8	0.8	3.489	4.596	4.547
29	100	0.9	0.9	4.521	5.171	4.547
30	100	1	1	5.700	5.745	4.547
31	20	0.1	1	1.000	1.965	1.555
32	20	0.2	1	1.000	1.965	1.555
33	20	0.3	1	1.000	1.965	1.555
34	20	0.4	1	1.000	1.965	1.555
35	20	0.5	1	1.000	1.965	1.555
36	20	0.6	1	1.022	1.965	1.555
37	20	0.7	1	1.317	1.965	1.555
38	20	0.8	1	1.525	1.965	1.555
39	20	0.9	1	1.736	1.965	1.555
40	20	1	1	1.949	1.965	1.555
41	50	0.1	1	1.000	3.619	2.864
42	50	0.2	1	1.000	3.619	2.864
43	50	0.3	1	1.000	3.619	2.864
44	50	0.4	1	1.000	3.619	2.864
45	50	0.5	1	1.477	3.619	2.864
46	50	0.6	1	2.047	3.619	2.864
47	50	0.7	1	2.426	3.619	2.864
48	50	0.8	1	2.809	3.619	2.864
49	50	0.9	1	3.198	3.619	2.864
50	50	1	1	3.591	3.619	2.864
51	100	0.1	1	1.000	5.745	4.547
52	100	0.2	1	1.000	5.745	4.547
53	100	0.3	1	1.000	5.745	4.547
54	100	0.4	1	1.646	5.745	4.547
55	100	0.5	1	2.572	5.745	4.547
56	100	0.6	1	3.250	5.745	4.547
57	100	0.7	1	3.850	5.745	4.547
58	100	0.8	1	4.460	5.745	4.547
59	100	0.9	1	5.076	5.745	4.547
60	100	1	1	5.700	5.745	4.547
61	20	0.1	0.3	1.000	1.140	1.555
62	20	0.2	0.3	1.000	1.140	1.555
63	20	0.3	0.3	1.000	1.140	1.555
64	20	0.4	0.3	1.000	1.140	1.555
65	20	0.5	0.3	1.000	1.140	1.555
66	20	0.6	0.3	1.000	1.140	1.555
67	20	0.7	0.3	1.000	1.140	1.555
68	20	0.8	0.3	1.000	1.140	1.555
69	20	0.9	0.3	1.000	1.140	1.555
70	20	1	0.3	1.000	1.965	1.555
71	50	0.1	0.3	1.000	1.221	2.864
72	50	0.2	0.3	1.000	1.221	2.864
73	50	0.3	0.3	1.000	1.221	2.864
74	50	0.4	0.3	1.000	1.221	2.864
75	50	0.5	0.3	1.000	1.221	2.864
76	50	0.6	0.3	1.000	1.221	2.864
77	50	0.7	0.3	1.000	1.221	2.864
78	50	0.8	0.3	1.000	1.221	2.864
79	50	0.9	0.3	1.000	1.221	2.864
80	50	1	0.3	1.000	3.619	2.864
81	100	0.1	0.3	1.000	1.724	4.547
82	100	0.2	0.3	1.000	1.724	4.547
83	100	0.3	0.3	1.000	1.724	4.547
84	100	0.4	0.3	1.000	1.724	4.547
85	100	0.5	0.3	1.000	1.724	4.547
86	100	0.6	0.3	1.000	1.724	4.547
87	100	0.7	0.3	1.024	1.724	4.547
88	100	0.8	0.3	1.186	1.724	4.547
89	100	0.9	0.3	1.350	1.724	4.547
90	100	1	0.3			
91	20	0.1	3	1.000	5.895	1.555
92	20	0.2	3	1.000	5.895	1.555
93	20	0.3	3	1.000	5.895	1.555
94	20	0.4	3	1.000	5.895	1.555
95	20	0.5	3	1.000	5.895	1.555
96	20	0.6	3	1.406	5.895	1.555
97	20	0.7	3	1.913	5.895	1.555
98	20	0.8	3	2.499	5.895	1.555
99	20	0.9	3	3.163	5.895	1.555
100	20	1	3			
101	50	0.1	3	1.000	10.858	2.864
102	50	0.2	3	1.000	10.858	2.864
103	50	0.3	3	1.000	10.858	2.864
104	50	0.4	3	1.300	10.858	2.864
105	50	0.5	3	2.032	10.858	2.864
106	50	0.6	3	2.926	10.858	2.864
107	50	0.7	3	3.982	10.858	2.864
108	50	0.8	3	5.201	10.858	2.864
109	50	0.9	3	6.583	10.858	2.864
110	50	1	3			
111	100	0.1	3	1.000	17.236	4.547
112	100	0.2	3	1.000	17.236	4.547
113	100	0.3	3	1.273	17.236	4.547
114	100	0.4	3	2.264	17.236	4.547
115	100	0.5	3	3.537	17.236	4.547
116	100	0.6	3	5.094	17.236	4.547
117	100	0.7	3	6.933	17.236	4.547
118	100	0.8	3	9.056	17.236	4.547
119	100	0.9	3	11.461	17.236	4.547
120	100	1	3			

B16.9 Welding Tee (WLT) - Sketch 2.1 - Header Inplane SIF

Item #	D/T	d/D	t/T	PRG iih	B31.3 iih	NB-3683.9 i
1	20	0.1	0.1	1.384	1.724	1.555
2	20	0.2	0.2	1.590	1.724	1.555
3	20	0.3	0.3	1.724	1.724	1.555
4	20	0.4	0.4	1.827	1.724	1.555
5	20	0.5	0.5	1.910	1.724	1.555
6	20	0.6	0.6	1.981	1.724	1.555
7	20	0.7	0.7	2.043	1.724	1.555
8	20	0.8	0.8	2.098	1.724	1.555
9	20	0.9	0.9	2.148	1.724	1.555
10	20	1	1	2.194	1.724	1.555
11	50	0.1	0.1	1.908	2.964	2.864
12	50	0.2	0.2	2.191	2.964	2.864
13	50	0.3	0.3	2.376	2.964	2.864
14	50	0.4	0.4	2.517	2.964	2.864
15	50	0.5	0.5	2.632	2.964	2.864
16	50	0.6	0.6	2.730	2.964	2.864
17	50	0.7	0.7	2.815	2.964	2.864
18	50	0.8	0.8	2.891	2.964	2.864
19	50	0.9	0.9	2.960	2.964	2.864
20	50	1	1	3.023	2.964	2.864
21	100	0.1	0.1	2.431	4.559	4.547
22	100	0.2	0.2	2.793	4.559	4.547
23	100	0.3	0.3	3.029	4.559	4.547
24	100	0.4	0.4	3.208	4.559	4.547
25	100	0.5	0.5	3.355	4.559	4.547
26	100	0.6	0.6	3.479	4.559	4.547
27	100	0.7	0.7	3.588	4.559	4.547
28	100	0.8	0.8	3.685	4.559	4.547
29	100	0.9	0.9	3.773	4.559	4.547
30	100	1	1	3.854	4.559	4.547
31	20	0.1	1	1.000	1.724	1.555
32	20	0.2	1	1.000	1.724	1.555
33	20	0.3	1	1.000	1.724	1.555
34	20	0.4	1	1.134	1.724	1.555
35	20	0.5	1	1.332	1.724	1.555
36	20	0.6	1	1.519	1.724	1.555
37	20	0.7	1	1.697	1.724	1.555
38	20	0.8	1	1.868	1.724	1.555
39	20	0.9	1	2.034	1.724	1.555
40	20	1	1	2.194	1.724	1.555
41	50	0.1	1	1.000	2.964	2.864
42	50	0.2	1	1.000	2.964	2.864
43	50	0.3	1	1.271	2.964	2.864
44	50	0.4	1	1.563	2.964	2.864
45	50	0.5	1	1.836	2.964	2.864
46	50	0.6	1	2.093	2.964	2.864
47	50	0.7	1	2.339	2.964	2.864
48	50	0.8	1	2.575	2.964	2.864
49	50	0.9	1	2.803	2.964	2.864
50	50	1	1	3.023	2.964	2.864
51	100	0.1	1	1.000	4.559	4.547
52	100	0.2	1	1.210	4.559	4.547
53	100	0.3	1	1.620	4.559	4.547
54	100	0.4	1	1.992	4.559	4.547
55	100	0.5	1	2.340	4.559	4.547
56	100	0.6	1	2.668	4.559	4.547
57	100	0.7	1	2.981	4.559	4.547
58	100	0.8	1	3.282	4.559	4.547
59	100	0.9	1	3.572	4.559	4.547
60	100	1	1	3.854	4.559	4.547
61	20	0.1	0.3	1.000	1.724	1.555
62	20	0.2	0.3	1.288	1.724	1.555
63	20	0.3	0.3	1.724	1.724	1.555
64	20	0.4	0.3	2.121	1.724	1.555
65	20	0.5	0.3	2.491	1.724	1.555
66	20	0.6	0.3	2.840	1.724	1.555
67	20	0.7	0.3	3.174	1.724	1.555

Item #	D/T	d/D	t/T	PRG iih	B31.3 iih	NB-3683.9 i
68	20	0.8	0.3	3.494	1.724	1.555
69	20	0.9	0.3	3.803	1.724	1.555
70	20	1	0.3	4.103	1.724	1.555
71	50	0.1	0.3	1.077	2.964	2.864
72	50	0.2	0.3	1.775	2.964	2.864
73	50	0.3	0.3	2.376	2.964	2.864
74	50	0.4	0.3	2.923	2.964	2.864
75	50	0.5	0.3	3.433	2.964	2.864
76	50	0.6	0.3	3.914	2.964	2.864
77	50	0.7	0.3	4.374	2.964	2.864
78	50	0.8	0.3	4.815	2.964	2.864
79	50	0.9	0.3	5.242	2.964	2.864
80	50	1	0.3	5.655	2.964	2.864
81	100	0.1	0.3	1.373	4.559	4.547
82	100	0.2	0.3	2.262	4.559	4.547
83	100	0.3	0.3	3.029	4.559	4.547
84	100	0.4	0.3	3.726	4.559	4.547
85	100	0.5	0.3	4.375	4.559	4.547
86	100	0.6	0.3	4.989	4.559	4.547
87	100	0.7	0.3	5.575	4.559	4.547
88	100	0.8	0.3	6.137	4.559	4.547
89	100	0.9	0.3	6.681	4.559	4.547
90	100	1	0.3	7.207	4.559	4.547
91	20	0.1	3	1.000	1.724	1.555
92	20	0.2	3	1.000	1.724	1.555
93	20	0.3	3	1.000	1.724	1.555
94	20	0.4	3	1.000	1.724	1.555
95	20	0.5	3	1.000	1.724	1.555
96	20	0.6	3	1.000	1.724	1.555
97	20	0.7	3	1.000	1.724	1.555
98	20	0.8	3	1.055	1.724	1.555
99	20	0.9	3	1.149	1.724	1.555
100	20	1	3	1.239	1.724	1.555
101	50	0.1	3	1.000	2.964	2.864
102	50	0.2	3	1.000	2.964	2.864
103	50	0.3	3	1.000	2.964	2.864
104	50	0.4	3	1.000	2.964	2.864
105	50	0.5	3	1.037	2.964	2.864
106	50	0.6	3	1.182	2.964	2.864
107	50	0.7	3	1.321	2.964	2.864
108	50	0.8	3	1.454	2.964	2.864
109	50	0.9	3	1.583	2.964	2.864
110	50	1	3	1.708	2.964	2.864
111	100	0.1	3	1.000	4.559	4.547
112	100	0.2	3	1.000	4.559	4.547
113	100	0.3	3	1.000	4.559	4.547
114	100	0.4	3	1.125	4.559	4.547
115	100	0.5	3	1.321	4.559	4.547
116	100	0.6	3	1.507	4.559	4.547
117	100	0.7	3	1.684	4.559	4.547
118	100	0.8	3	1.853	4.559	4.547
119	100	0.9	3	2.018	4.559	4.547
120	100	1	3	2.177	4.559	4.547

B16.9 Welding Tee (WLT) - Sketch 2.1 - Header Outplane SIF

Item #	D/T	d/D	t/T	PRG ioh	B31.3 ioh	NB-3683.9 i
1	20	0.1	0.1	1.000	1.965	1.555
2	20	0.2	0.2	1.000	1.965	1.555
3	20	0.3	0.3	1.000	1.965	1.555
4	20	0.4	0.4	1.000	1.965	1.555
5	20	0.5	0.5	1.000	1.965	1.555
6	20	0.6	0.6	1.000	1.965	1.555
7	20	0.7	0.7	1.000	1.965	1.555
8	20	0.8	0.8	1.000	1.965	1.555
9	20	0.9	0.9	1.024	1.965	1.555
10	20	1	1	1.189	1.965	1.555
11	50	0.1	0.1	1.000	3.619	2.864
12	50	0.2	0.2	1.000	3.619	2.864
13	50	0.3	0.3	1.000	3.619	2.864
14	50	0.4	0.4	1.000	3.619	2.864
15	50	0.5	0.5	1.000	3.619	2.864
16	50	0.6	0.6	1.000	3.619	2.864
17	50	0.7	0.7	1.000	3.619	2.864
18	50	0.8	0.8	1.130	3.619	2.864
19	50	0.9	0.9	1.336	3.619	2.864
20	50	1	1	1.551	3.619	2.864
21	100	0.1	0.1	1.000	5.745	4.547
22	100	0.2	0.2	1.000	5.745	4.547
23	100	0.3	0.3	1.000	5.745	4.547
24	100	0.4	0.4	1.000	5.745	4.547
25	100	0.5	0.5	1.000	5.745	4.547
26	100	0.6	0.6	1.000	5.745	4.547
27	100	0.7	0.7	1.143	5.745	4.547
28	100	0.8	0.8	1.382	5.745	4.547
29	100	0.9	0.9	1.633	5.745	4.547
30	100	1	1	1.897	5.745	4.547
31	20	0.1	1	1.000	1.965	1.555
32	20	0.2	1	1.000	1.965	1.555
33	20	0.3	1	1.000	1.965	1.555
34	20	0.4	1	1.000	1.965	1.555
35	20	0.5	1	1.000	1.965	1.555
36	20	0.6	1	1.000	1.965	1.555
37	20	0.7	1	1.000	1.965	1.555
38	20	0.8	1	1.000	1.965	1.555
39	20	0.9	1	1.000	1.965	1.555
40	20	1	1	1.189	1.965	1.555
41	50	0.1	1	1.000	3.619	2.864
42	50	0.2	1	1.000	3.619	2.864
43	50	0.3	1	1.000	3.619	2.864
44	50	0.4	1	1.000	3.619	2.864
45	50	0.5	1	1.000	3.619	2.864
46	50	0.6	1	1.000	3.619	2.864
47	50	0.7	1	1.000	3.619	2.864
48	50	0.8	1	1.004	3.619	2.864
49	50	0.9	1	1.263	3.619	2.864
50	50	1	1	1.551	3.619	2.864
51	100	0.1	1	1.000	5.745	4.547
52	100	0.2	1	1.000	5.745	4.547
53	100	0.3	1	1.000	5.745	4.547
54	100	0.4	1	1.000	5.745	4.547
55	100	0.5	1	1.000	5.745	4.547
56	100	0.6	1	1.000	5.745	4.547
57	100	0.7	1	1.000	5.745	4.547
58	100	0.8	1	1.228	5.745	4.547
59	100	0.9	1	1.545	5.745	4.547
60	100	1	1	1.897	5.745	4.547
61	20	0.1	0.3	1.000	1.965	1.555
62	20	0.2	0.3	1.000	1.965	1.555
63	20	0.3	0.3	1.000	1.965	1.555
64	20	0.4	0.3	1.000	1.965	1.555
65	20	0.5	0.3	1.000	1.965	1.555
66	20	0.6	0.3	1.000	1.965	1.555
67	20	0.7	0.3	1.123	1.965	1.555

Item #	D/T	d/D	t/T	PRG ioh	B31.3 ioh	NB-3683.9 i
68	20	0.8	0.3	1.457	1.965	1.555
69	20	0.9	0.3	1.833	1.965	1.555
70	20	1	0.3	2.251	1.965	1.555
71	50	0.1	0.3	1.000	3.619	2.864
72	50	0.2	0.3	1.000	3.619	2.864
73	50	0.3	0.3	1.000	3.619	2.864
74	50	0.4	0.3	1.000	3.619	2.864
75	50	0.5	0.3	1.000	3.619	2.864
76	50	0.6	0.3	1.085	3.619	2.864
77	50	0.7	0.3	1.465	3.619	2.864
78	50	0.8	0.3	1.901	3.619	2.864
79	50	0.9	0.3	2.391	3.619	2.864
80	50	1	0.3	2.937	3.619	2.864
81	100	0.1	0.3	1.000	5.745	4.547
82	100	0.2	0.3	1.000	5.745	4.547
83	100	0.3	0.3	1.000	5.745	4.547
84	100	0.4	0.3	1.000	5.745	4.547
85	100	0.5	0.3	1.000	5.745	4.547
86	100	0.6	0.3	1.326	5.745	4.547
87	100	0.7	0.3	1.791	5.745	4.547
88	100	0.8	0.3	2.324	5.745	4.547
89	100	0.9	0.3	2.924	5.745	4.547
90	100	1	0.3	3.591	5.745	4.547
91	20	0.1	3	1.000	1.965	1.555
92	20	0.2	3	1.000	1.965	1.555
93	20	0.3	3	1.000	1.965	1.555
94	20	0.4	3	1.000	1.965	1.555
95	20	0.5	3	1.000	1.965	1.555
96	20	0.6	3	1.000	1.965	1.555
97	20	0.7	3	1.000	1.965	1.555
98	20	0.8	3	1.000	1.965	1.555
99	20	0.9	3	1.000	1.965	1.555
100	20	1	3	1.000	1.965	1.555
101	50	0.1	3	1.000	3.619	2.864
102	50	0.2	3	1.000	3.619	2.864
103	50	0.3	3	1.000	3.619	2.864
104	50	0.4	3	1.000	3.619	2.864
105	50	0.5	3	1.000	3.619	2.864
106	50	0.6	3	1.000	3.619	2.864
107	50	0.7	3	1.000	3.619	2.864
108	50	0.8	3	1.000	3.619	2.864
109	50	0.9	3	1.000	3.619	2.864
110	50	1	3	1.000	3.619	2.864
111	100	0.1	3	1.000	5.745	4.547
112	100	0.2	3	1.000	5.745	4.547
113	100	0.3	3	1.000	5.745	4.547
114	100	0.4	3	1.000	5.745	4.547
115	100	0.5	3	1.000	5.745	4.547
116	100	0.6	3	1.000	5.745	4.547
117	100	0.7	3	1.000	5.745	4.547
118	100	0.8	3	1.000	5.745	4.547
119	100	0.9	3	1.000	5.745	4.547
120	100	1	3	1.060	5.745	4.547

B16.9 Welding Tee (WLT) - Sketch 2.1 - Header Torsional SIF

Item #	D/T	d/D	t/T	PRG ith	B31.3 ioh	NB-3683.9 i
1	20	0.1	0.1	1.000	1.965	1.555
2	20	0.2	0.2	1.000	1.965	1.555
3	20	0.3	0.3	1.000	1.965	1.555
4	20	0.4	0.4	1.000	1.965	1.555
5	20	0.5	0.5	1.116	1.965	1.555
6	20	0.6	0.6	1.222	1.965	1.555
7	20	0.7	0.7	1.320	1.965	1.555
8	20	0.8	0.8	1.412	1.965	1.555
9	20	0.9	0.9	1.497	1.965	1.555
10	20	1	1	1.578	1.965	1.555
11	50	0.1	0.1	1.000	3.619	2.864
12	50	0.2	0.2	1.200	3.619	2.864
13	50	0.3	0.3	1.592	3.619	2.864
14	50	0.4	0.4	1.839	3.619	2.864
15	50	0.5	0.5	2.056	3.619	2.864
16	50	0.6	0.6	2.252	3.619	2.864
17	50	0.7	0.7	2.432	3.619	2.864
18	50	0.8	0.8	2.600	3.619	2.864
19	50	0.9	0.9	2.758	3.619	2.864
20	50	1	1	2.907	3.619	2.864
21	100	0.1	0.1	1.000	5.745	4.547
22	100	0.2	0.2	1.651	5.745	4.547
23	100	0.3	0.3	2.397	5.745	4.547
24	100	0.4	0.4	2.918	5.745	4.547
25	100	0.5	0.5	3.263	5.745	4.547
26	100	0.6	0.6	3.574	5.745	4.547
27	100	0.7	0.7	3.861	5.745	4.547
28	100	0.8	0.8	4.127	5.745	4.547
29	100	0.9	0.9	4.378	5.745	4.547
30	100	1	1	4.615	5.745	4.547
31	20	0.1	1	1.000	1.965	1.555
32	20	0.2	1	1.000	1.965	1.555
33	20	0.3	1	1.000	1.965	1.555
34	20	0.4	1	1.000	1.965	1.555
35	20	0.5	1	1.000	1.965	1.555
36	20	0.6	1	1.000	1.965	1.555
37	20	0.7	1	1.105	1.965	1.555
38	20	0.8	1	1.263	1.965	1.555
39	20	0.9	1	1.420	1.965	1.555
40	20	1	1	1.578	1.965	1.555
41	50	0.1	1	1.000	3.619	2.864
42	50	0.2	1	1.000	3.619	2.864
43	50	0.3	1	1.000	3.619	2.864
44	50	0.4	1	1.163	3.619	2.864
45	50	0.5	1	1.453	3.619	2.864
46	50	0.6	1	1.744	3.619	2.864
47	50	0.7	1	2.035	3.619	2.864
48	50	0.8	1	2.326	3.619	2.864
49	50	0.9	1	2.616	3.619	2.864
50	50	1	1	2.907	3.619	2.864
51	100	0.1	1	1.000	5.745	4.547
52	100	0.2	1	1.000	5.745	4.547
53	100	0.3	1	1.384	5.745	4.547
54	100	0.4	1	1.846	5.745	4.547
55	100	0.5	1	2.307	5.745	4.547
56	100	0.6	1	2.769	5.745	4.547
57	100	0.7	1	3.230	5.745	4.547
58	100	0.8	1	3.692	5.745	4.547
59	100	0.9	1	4.153	5.745	4.547
60	100	1	1	4.615	5.745	4.547
61	20	0.1	0.3	1.000	1.965	1.555
62	20	0.2	0.3	1.000	1.965	1.555
63	20	0.3	0.3	1.000	1.965	1.555
64	20	0.4	0.3	1.153	1.965	1.555
65	20	0.5	0.3	1.441	1.965	1.555
66	20	0.6	0.3	1.729	1.965	1.555
67	20	0.7	0.3	2.017	1.965	1.555

Item #	D/T	d/D	t/T	PRG ith	B31.3 ioh	NB-3683.9 i
68	20	0.8	0.3	2.305	1.965	1.555
69	20	0.9	0.3	2.593	1.965	1.555
70	20	1	0.3	2.881	1.965	1.555
71	50	0.1	0.3	1.000	3.619	2.864
72	50	0.2	0.3	1.000	3.619	2.864
73	50	0.3	0.3	1.592	3.619	2.864
74	50	0.4	0.3	2.123	3.619	2.864
75	50	0.5	0.3	2.654	3.619	2.864
76	50	0.6	0.3	3.184	3.619	2.864
77	50	0.7	0.3	3.715	3.619	2.864
78	50	0.8	0.3	4.246	3.619	2.864
79	50	0.9	0.3	4.777	3.619	2.864
80	50	1	0.3	5.307	3.619	2.864
81	100	0.1	0.3	1.000	5.745	4.547
82	100	0.2	0.3	1.375	5.745	4.547
83	100	0.3	0.3	2.397	5.745	4.547
84	100	0.4	0.3	3.370	5.745	4.547
85	100	0.5	0.3	4.212	5.745	4.547
86	100	0.6	0.3	5.055	5.745	4.547
87	100	0.7	0.3	5.897	5.745	4.547
88	100	0.8	0.3	6.740	5.745	4.547
89	100	0.9	0.3	7.582	5.745	4.547
90	100	1	0.3	8.425	5.745	4.547
91	20	0.1	3	1.000	1.965	1.555
92	20	0.2	3	1.000	1.965	1.555
93	20	0.3	3	1.000	1.965	1.555
94	20	0.4	3	1.000	1.965	1.555
95	20	0.5	3	1.000	1.965	1.555
96	20	0.6	3	1.000	1.965	1.555
97	20	0.7	3	1.000	1.965	1.555
98	20	0.8	3	1.000	1.965	1.555
99	20	0.9	3	1.000	1.965	1.555
100	20	1	3	1.000	1.965	1.555
101	50	0.1	3	1.000	3.619	2.864
102	50	0.2	3	1.000	3.619	2.864
103	50	0.3	3	1.000	3.619	2.864
104	50	0.4	3	1.000	3.619	2.864
105	50	0.5	3	1.000	3.619	2.864
106	50	0.6	3	1.007	3.619	2.864
107	50	0.7	3	1.175	3.619	2.864
108	50	0.8	3	1.343	3.619	2.864
109	50	0.9	3	1.511	3.619	2.864
110	50	1	3	1.678	3.619	2.864
111	100	0.1	3	1.000	5.745	4.547
112	100	0.2	3	1.000	5.745	4.547
113	100	0.3	3	1.000	5.745	4.547
114	100	0.4	3	1.066	5.745	4.547
115	100	0.5	3	1.332	5.745	4.547
116	100	0.6	3	1.599	5.745	4.547
117	100	0.7	3	1.865	5.745	4.547
118	100	0.8	3	2.131	5.745	4.547
119	100	0.9	3	2.398	5.745	4.547
120	100	1	3	2.664	5.745	4.547

B16.9 Welding Tee (WLT) - Sketch 2.1 - Branch Inplane K

Item #	D/T	d/D	t/T	PRG WTEE kib	PRG UFT kib	Widera UFT kib
1	20	0.1	0.1	1.000	1.000	0.859
2	20	0.2	0.2	1.000	1.721	1.749
3	20	0.3	0.3	1.000	2.274	2.342
4	20	0.4	0.4	1.000	2.550	2.619
5	20	0.5	0.5	1.000	2.627	2.661
6	20	0.6	0.6	1.000	2.623	2.616
7	20	0.7	0.7	1.000	2.689	2.676
8	20	0.8	0.8	1.000	2.991	3.071
9	20	0.9	0.9	1.000	3.718	4.060
10	20	1	1	1.708	5.071	5.929
11	50	0.1	0.1	1.000	1.892	1.792
12	50	0.2	0.2	1.000	3.682	3.647
13	50	0.3	0.3	1.000	4.866	4.884
14	50	0.4	0.4	1.000	5.456	5.460
15	50	0.5	0.5	1.000	5.619	5.548
16	50	0.6	0.6	1.000	5.613	5.454
17	50	0.7	0.7	1.033	5.752	5.580
18	50	0.8	0.8	1.251	6.399	6.404
19	50	0.9	0.9	1.921	7.954	8.467
20	50	1	1	3.458	10.848	12.364
21	100	0.1	0.1	1.000	3.363	3.124
22	100	0.2	0.2	1.000	6.546	6.358
23	100	0.3	0.3	1.000	8.650	8.516
24	100	0.4	0.4	1.299	9.699	9.520
25	100	0.5	0.5	1.560	9.989	9.673
26	100	0.6	0.6	1.670	9.977	9.509
27	100	0.7	0.7	1.761	10.225	9.729
28	100	0.8	0.8	2.133	11.376	11.166
29	100	0.9	0.9	3.276	14.140	14.762
30	100	1	1	5.897	19.284	21.557
31	20	0.1	1	1.000	2.732	3.599
32	20	0.2	1	1.000	3.787	4.759
33	20	0.3	1	1.000	4.103	4.953
34	20	0.4	1	1.000	3.995	4.630
35	20	0.5	1	1.000	3.689	4.095
36	20	0.6	1	1.000	3.370	3.594
37	20	0.7	1	1.000	3.202	3.341
38	20	0.8	1	1.000	3.337	3.528
39	20	0.9	1	1.054	3.915	4.335
40	20	1	1	1.708	5.071	5.929
41	50	0.1	1	1.000	5.846	7.505
42	50	0.2	1	1.292	8.102	9.923
43	50	0.3	1	1.741	8.778	10.329
44	50	0.4	1	1.904	8.548	9.655
45	50	0.5	1	1.829	7.892	8.539
46	50	0.6	1	1.632	7.209	7.494
47	50	0.7	1	1.475	6.850	6.966
48	50	0.8	1	1.563	7.139	7.358
49	50	0.9	1	2.135	8.376	9.040
50	50	1	1	3.458	10.848	12.364
51	100	0.1	1	1.037	10.392	13.085
52	100	0.2	1	2.203	14.403	17.302
53	100	0.3	1	2.969	15.604	18.008
54	100	0.4	1	3.246	15.195	16.833
55	100	0.5	1	3.119	14.030	14.888
56	100	0.6	1	2.783	12.815	13.066
57	100	0.7	1	2.516	12.178	12.146
58	100	0.8	1	2.666	12.690	12.828
59	100	0.9	1	3.640	14.889	15.762
60	100	1	1	5.897	19.284	21.557
61	20	0.1	0.3	1.000	1.515	1.702
62	20	0.2	0.3	1.000	2.099	2.251
63	20	0.3	0.3	1.000	2.274	2.342
64	20	0.4	0.3	1.000	2.215	2.190
65	20	0.5	0.3	1.000	2.045	1.937
66	20	0.6	0.3	1.000	1.868	1.700
67	20	0.7	0.3	1.000	1.775	1.580

Item #	D/T	d/D	t/T	PRG WTEE kib	PRG UFT kib	Widera UFT kib
68	20	0.8	0.3	1.000	1.850	1.669
69	20	0.9	0.3	1.000	2.170	2.050
70	20	1	0.3	1.000	2.811	2.804
71	50	0.1	0.3	1.000	3.241	3.549
72	50	0.2	0.3	1.000	4.492	4.693
73	50	0.3	0.3	1.000	4.866	4.884
74	50	0.4	0.3	1.000	4.738	4.566
75	50	0.5	0.3	1.000	4.375	4.038
76	50	0.6	0.3	1.000	3.996	3.544
77	50	0.7	0.3	1.000	3.798	3.294
78	50	0.8	0.3	1.000	3.957	3.479
79	50	0.9	0.3	1.000	4.643	4.275
80	50	1	0.3	1.037	6.014	5.847
81	100	0.1	0.3	1.000	5.761	6.188
82	100	0.2	0.3	1.000	7.985	8.182
83	100	0.3	0.3	1.000	8.650	8.516
84	100	0.4	0.3	1.000	8.423	7.961
85	100	0.5	0.3	1.000	7.777	7.040
86	100	0.6	0.3	1.000	7.104	6.179
87	100	0.7	0.3	1.000	6.751	5.744
88	100	0.8	0.3	1.000	7.035	6.066
89	100	0.9	0.3	1.092	8.254	7.454
90	100	1	0.3	1.769	10.690	10.194
91	20	0.1	3	1.000	4.681	7.128
92	20	0.2	3	1.914	6.488	9.425
93	20	0.3	3	2.579	7.029	9.810
94	20	0.4	3	2.820	6.845	9.170
95	20	0.5	3	2.710	6.320	8.110
96	20	0.6	3	2.418	5.773	7.118
97	20	0.7	3	2.186	5.485	6.616
98	20	0.8	3	2.316	5.716	6.988
99	20	0.9	3	3.162	6.707	8.586
100	20	1	3	5.123	8.687	11.743
101	50	0.1	3	1.824	10.014	14.863
102	50	0.2	3	3.875	13.880	19.653
103	50	0.3	3	5.223	15.037	20.456
104	50	0.4	3	5.711	14.643	19.121
105	50	0.5	3	5.488	13.520	16.911
106	50	0.6	3	4.896	12.350	14.842
107	50	0.7	3	4.426	11.735	13.796
108	50	0.8	3	4.690	12.229	14.571
109	50	0.9	3	6.404	14.349	17.904
110	50	1	3	10.374	18.584	24.487
111	100	0.1	3	3.111	17.802	25.915
112	100	0.2	3	6.608	24.675	34.265
113	100	0.3	3	8.906	26.732	35.665
114	100	0.4	3	9.739	26.031	33.338
115	100	0.5	3	9.358	24.034	29.484
116	100	0.6	3	8.349	21.954	25.877
117	100	0.7	3	7.547	20.862	24.054
118	100	0.8	3	7.997	21.740	25.405
119	100	0.9	3	10.920	25.508	31.216
120	100	1	3	17.690	33.037	42.693

B16.9 Welding Tee (WLT) - Sketch 2.1 - Branch Outplane K

Item #	D/T	d/D	t/T	PRG WTEE kob	PRG UFT kob	Widera UFT kob
1	20	0.1	0.1	1.000	1.000	0.316
2	20	0.2	0.2	1.000	2.375	1.365
3	20	0.3	0.3	1.000	4.013	2.890
4	20	0.4	0.4	1.000	5.454	4.499
5	20	0.5	0.5	1.009	6.519	5.815
6	20	0.6	0.6	1.150	7.115	6.562
7	20	0.7	0.7	1.204	7.222	6.616
8	20	0.8	0.8	1.167	6.879	6.046
9	20	0.9	0.9	1.047	6.182	5.148
10	20	1	1	1.000	5.275	4.473
11	50	0.1	0.1	1.000	3.050	1.268
12	50	0.2	0.2	1.095	8.565	5.469
13	50	0.3	0.3	2.069	14.472	11.583
14	50	0.4	0.4	3.038	19.672	18.029
15	50	0.5	0.5	3.846	23.513	23.303
16	50	0.6	0.6	4.384	25.664	26.296
17	50	0.7	0.7	4.588	26.048	26.513
18	50	0.8	0.8	4.445	24.812	24.229
19	50	0.9	0.9	3.988	22.296	20.631
20	50	1	1	3.297	19.025	17.927
21	100	0.1	0.1	1.000	8.050	3.623
22	100	0.2	0.2	3.014	22.602	15.630
23	100	0.3	0.3	5.692	38.193	33.105
24	100	0.4	0.4	8.359	51.915	51.527
25	100	0.5	0.5	10.582	62.052	66.598
26	100	0.6	0.6	12.060	67.727	75.155
27	100	0.7	0.7	12.622	68.742	75.774
28	100	0.8	0.8	12.229	65.479	69.247
29	100	0.9	0.9	10.971	58.841	58.963
30	100	1	1	9.070	50.209	51.236
31	20	0.1	1	1.000	3.367	2.302
32	20	0.2	1	1.437	6.237	5.464
33	20	0.3	1	1.810	8.263	8.160
34	20	0.4	1	1.993	9.451	9.911
35	20	0.5	1	2.019	9.881	10.568
36	20	0.6	1	1.917	9.667	10.192
37	20	0.7	1	1.720	8.945	8.997
38	20	0.8	1	1.458	7.865	7.328
39	20	0.9	1	1.163	6.585	5.637
40	20	1	1	1.000	5.275	4.473
41	50	0.1	1	3.218	12.144	9.225
42	50	0.2	1	5.477	22.495	21.898
43	50	0.3	1	6.897	29.804	32.700
44	50	0.4	1	7.596	34.089	39.719
45	50	0.5	1	7.693	35.639	42.354
46	50	0.6	1	7.306	34.868	40.844
47	50	0.7	1	6.554	32.264	36.056
48	50	0.8	1	5.556	28.366	29.368
49	50	0.9	1	4.431	23.751	22.592
50	50	1	1	3.297	19.025	17.927
51	100	0.1	1	8.853	32.048	26.366
52	100	0.2	1	15.069	59.366	62.585
53	100	0.3	1	18.975	78.652	93.458
54	100	0.4	1	20.898	89.961	113.516
55	100	0.5	1	21.164	94.053	121.046
56	100	0.6	1	20.100	92.018	116.732
57	100	0.7	1	18.032	85.146	103.049
58	100	0.8	1	15.286	74.859	83.933
59	100	0.9	1	12.190	62.680	64.568
60	100	1	1	9.070	50.209	51.236
61	20	0.1	0.3	1.000	1.635	0.815
62	20	0.2	0.3	1.000	3.029	1.936
63	20	0.3	0.3	1.000	4.013	2.890
64	20	0.4	0.3	1.000	4.590	3.511
65	20	0.5	0.3	1.000	4.798	3.744
66	20	0.6	0.3	1.000	4.694	3.610
67	20	0.7	0.3	1.000	4.344	3.187
68	20	0.8	0.3	1.000	3.819	2.596
69	20	0.9	0.3	1.000	3.198	1.997
70	20	1	0.3	1.000	2.561	1.585
71	50	0.1	0.3	1.000	5.897	3.268
72	50	0.2	0.3	1.643	10.924	7.757
73	50	0.3	0.3	2.069	14.472	11.583
74	50	0.4	0.3	2.279	16.553	14.069
75	50	0.5	0.3	2.308	17.306	15.003
76	50	0.6	0.3	2.192	16.932	14.468
77	50	0.7	0.3	1.966	15.667	12.772
78	50	0.8	0.3	1.667	13.774	10.403
79	50	0.9	0.3	1.329	11.534	8.003
80	50	1	0.3	1.000	9.239	6.350
81	100	0.1	0.3	2.656	15.562	9.339
82	100	0.2	0.3	4.521	28.828	22.169
83	100	0.3	0.3	5.692	38.193	33.105
84	100	0.4	0.3	6.269	43.684	40.210
85	100	0.5	0.3	6.349	45.671	42.878
86	100	0.6	0.3	6.030	44.683	41.349
87	100	0.7	0.3	5.409	41.346	36.502
88	100	0.8	0.3	4.586	36.351	29.731
89	100	0.9	0.3	3.657	30.437	22.872
90	100	1	0.3	2.721	24.381	18.149
91	20	0.1	3	2.533	6.509	5.934
92	20	0.2	3	4.312	12.057	14.087
93	20	0.3	3	5.430	15.974	21.036
94	20	0.4	3	5.980	18.271	25.550
95	20	0.5	3	6.056	19.102	27.245
96	20	0.6	3	5.752	18.689	26.274
97	20	0.7	3	5.160	17.293	23.194
98	20	0.8	3	4.374	15.204	18.892
99	20	0.9	3	3.489	12.731	14.533
100	20	1	3	2.596	10.197	11.532
101	50	0.1	3	9.653	23.476	23.783
102	50	0.2	3	16.432	43.488	56.453
103	50	0.3	3	20.692	57.616	84.301
104	50	0.4	3	22.789	65.900	102.394
105	50	0.5	3	23.079	68.897	109.187
106	50	0.6	3	21.918	67.407	105.295
107	50	0.7	3	19.663	62.372	92.953
108	50	0.8	3	16.669	54.837	75.710
109	50	0.9	3	13.293	45.916	58.242
110	50	1	3	9.891	36.780	46.216
111	100	0.1	3	26.558	61.954	67.970
112	100	0.2	3	45.206	114.765	161.343
113	100	0.3	3	56.925	152.049	240.931
114	100	0.4	3	62.693	173.911	292.640
115	100	0.5	3	63.491	181.821	312.055
116	100	0.6	3	60.299	177.887	300.932
117	100	0.7	3	54.095	164.602	265.657
118	100	0.8	3	45.859	144.716	216.378
119	100	0.9	3	36.571	121.173	166.455
120	100	1	3	27.211	97.062	132.084

B16.9 Welding Tee (WLT) - Sketch 2.1 - Branch Torsional K

Item #	D/T	d/D	t/T	PRG WTEE ktb	Wais UFT ktb
1	20	0.1	0.1	1.000	1.000
2	20	0.2	0.2	1.000	1.000
3	20	0.3	0.3	1.000	1.000
4	20	0.4	0.4	1.000	1.000
5	20	0.5	0.5	1.000	1.019
6	20	0.6	0.6	1.000	1.497
7	20	0.7	0.7	1.000	2.072
8	20	0.8	0.8	1.000	2.746
9	20	0.9	0.9	1.000	3.521
10	20	1	1	1.000	4.398
11	50	0.1	0.1	1.000	1.000
12	50	0.2	0.2	1.000	1.000
13	50	0.3	0.3	1.000	1.000
14	50	0.4	0.4	1.000	1.000
15	50	0.5	0.5	1.000	1.221
16	50	0.6	0.6	1.000	1.794
17	50	0.7	0.7	1.000	2.484
18	50	0.8	0.8	1.000	3.292
19	50	0.9	0.9	1.000	4.221
20	50	1	1	1.908	5.272
21	100	0.1	0.1	1.000	1.000
22	100	0.2	0.2	1.000	1.000
23	100	0.3	0.3	1.000	1.000
24	100	0.4	0.4	1.000	1.000
25	100	0.5	0.5	1.000	1.401
26	100	0.6	0.6	1.000	2.058
27	100	0.7	0.7	1.000	2.849
28	100	0.8	0.8	1.000	3.777
29	100	0.9	0.9	1.601	4.842
30	100	1	1	3.253	6.048
31	20	0.1	1	1.000	1.000
32	20	0.2	1	1.000	1.000
33	20	0.3	1	1.000	1.000
34	20	0.4	1	1.000	1.056
35	20	0.5	1	1.000	1.495
36	20	0.6	1	1.000	1.985
37	20	0.7	1	1.000	2.524
38	20	0.8	1	1.000	3.107
39	20	0.9	1	1.000	3.732
40	20	1	1	1.000	4.398
41	50	0.1	1	1.000	1.000
42	50	0.2	1	1.000	1.000
43	50	0.3	1	1.000	1.000
44	50	0.4	1	1.000	1.266
45	50	0.5	1	1.000	1.792
46	50	0.6	1	1.000	2.380
47	50	0.7	1	1.000	3.026
48	50	0.8	1	1.000	3.725
49	50	0.9	1	1.043	4.475
50	50	1	1	1.908	5.272
51	100	0.1	1	1.000	1.000
52	100	0.2	1	1.000	1.000
53	100	0.3	1	1.000	1.000
54	100	0.4	1	1.000	1.452
55	100	0.5	1	1.000	2.055
56	100	0.6	1	1.000	2.730
57	100	0.7	1	1.000	3.471
58	100	0.8	1	1.145	4.273
59	100	0.9	1	1.779	5.133
60	100	1	1	3.253	6.048
61	20	0.1	0.3	1.000	1.000
62	20	0.2	0.3	1.000	1.000
63	20	0.3	0.3	1.000	1.000
64	20	0.4	0.3	1.000	1.000
65	20	0.5	0.3	1.000	1.000
66	20	0.6	0.3	1.000	1.020
67	20	0.7	0.3	1.000	1.297

Item #	D/T	d/D	t/T	PRG WTEE ktb	Wais UFT ktb
68	20	0.8	0.3	1.000	1.597
69	20	0.9	0.3	1.000	1.918
70	20	1	0.3	1.000	2.260
71	50	0.1	0.3	1.000	1.000
72	50	0.2	0.3	1.000	1.000
73	50	0.3	0.3	1.000	1.000
74	50	0.4	0.3	1.000	1.000
75	50	0.5	0.3	1.000	1.000
76	50	0.6	0.3	1.000	1.223
77	50	0.7	0.3	1.000	1.555
78	50	0.8	0.3	1.000	1.914
79	50	0.9	0.3	1.000	2.299
80	50	1	0.3	1.000	2.709
81	100	0.1	0.3	1.000	1.000
82	100	0.2	0.3	1.000	1.000
83	100	0.3	0.3	1.000	1.000
84	100	0.4	0.3	1.000	1.000
85	100	0.5	0.3	1.000	1.056
86	100	0.6	0.3	1.000	1.403
87	100	0.7	0.3	1.000	1.783
88	100	0.8	0.3	1.000	2.196
89	100	0.9	0.3	1.000	2.638
90	100	1	0.3	1.000	3.108
91	20	0.1	3	1.000	1.000
92	20	0.2	3	1.000	1.000
93	20	0.3	3	1.000	1.239
94	20	0.4	3	1.000	1.938
95	20	0.5	3	1.000	2.744
96	20	0.6	3	1.000	3.645
97	20	0.7	3	1.000	4.633
98	20	0.8	3	1.000	5.704
99	20	0.9	3	1.546	6.852
100	20	1	3	2.826	8.073
101	50	0.1	3	1.000	1.000
102	50	0.2	3	1.000	1.000
103	50	0.3	3	1.000	1.485
104	50	0.4	3	1.000	2.324
105	50	0.5	3	1.000	3.290
106	50	0.6	3	1.000	4.370
107	50	0.7	3	1.647	5.555
108	50	0.8	3	2.014	6.839
109	50	0.9	3	3.130	8.215
110	50	1	3	5.723	9.679
111	100	0.1	3	1.000	1.000
112	100	0.2	3	1.000	1.000
113	100	0.3	3	1.000	1.703
114	100	0.4	3	1.000	2.666
115	100	0.5	3	1.000	3.774
116	100	0.6	3	1.533	5.012
117	100	0.7	3	2.809	6.372
118	100	0.8	3	3.434	7.845
119	100	0.9	3	5.338	9.423
120	100	1	3	9.760	11.103

B16.9 Welding Tee (WLT) - Sketch 2.1 - Header Inplane K

Item #	D/T	d/D	t/T	PRG WTEE kih	PRG UFT kih	Wais UFT kih
1	20	0.1	0.1	1.000	1.000	1.000
2	20	0.2	0.2	1.000	1.000	1.000
3	20	0.3	0.3	1.000	1.000	1.000
4	20	0.4	0.4	1.000	1.000	1.000
5	20	0.5	0.5	1.000	1.000	1.000
6	20	0.6	0.6	1.000	1.000	1.000
7	20	0.7	0.7	1.000	1.000	1.325
8	20	0.8	0.8	1.000	1.235	1.883
9	20	0.9	0.9	1.000	2.182	2.566
10	20	1	1	1.136	3.630	3.385
11	50	0.1	0.1	1.000	1.000	1.000
12	50	0.2	0.2	1.000	1.000	1.000
13	50	0.3	0.3	1.000	1.000	1.000
14	50	0.4	0.4	1.000	1.000	1.000
15	50	0.5	0.5	1.000	1.000	1.000
16	50	0.6	0.6	1.000	1.000	1.105
17	50	0.7	0.7	1.000	1.000	1.658
18	50	0.8	0.8	1.000	1.900	2.355
19	50	0.9	0.9	1.396	3.357	3.211
20	50	1	1	2.364	5.584	4.236
21	100	0.1	0.1	1.000	1.000	1.000
22	100	0.2	0.2	1.000	1.000	1.000
23	100	0.3	0.3	1.000	1.000	1.000
24	100	0.4	0.4	1.000	1.000	1.000
25	100	0.5	0.5	1.000	1.000	1.000
26	100	0.6	0.6	1.000	1.000	1.310
27	100	0.7	0.7	1.000	1.381	1.964
28	100	0.8	0.8	1.349	2.632	2.791
29	100	0.9	0.9	2.430	4.650	3.804
30	100	1	1	4.116	7.734	5.019
31	20	0.1	1	1.000	1.000	1.000
32	20	0.2	1	1.000	1.000	1.000
33	20	0.3	1	1.000	1.000	1.000
34	20	0.4	1	1.000	1.000	1.000
35	20	0.5	1	1.000	1.000	1.000
36	20	0.6	1	1.000	1.000	1.000
37	20	0.7	1	1.000	1.000	1.218
38	20	0.8	1	1.000	1.112	1.786
39	20	0.9	1	1.000	2.077	2.503
40	20	1	1	1.136	3.630	3.385
41	50	0.1	1	1.000	1.000	1.000
42	50	0.2	1	1.000	1.000	1.000
43	50	0.3	1	1.000	1.000	1.000
44	50	0.4	1	1.000	1.000	1.000
45	50	0.5	1	1.000	1.000	1.000
46	50	0.6	1	1.000	1.000	1.000
47	50	0.7	1	1.000	1.000	1.524
48	50	0.8	1	1.000	1.711	2.234
49	50	0.9	1	1.396	3.195	3.132
50	50	1	1	2.364	5.584	4.236
51	100	0.1	1	1.000	1.000	1.000
52	100	0.2	1	1.000	1.000	1.000
53	100	0.3	1	1.000	1.000	1.000
54	100	0.4	1	1.000	1.000	1.000
55	100	0.5	1	1.000	1.000	1.000
56	100	0.6	1	1.000	1.000	1.160
57	100	0.7	1	1.000	1.168	1.805
58	100	0.8	1	1.349	2.370	2.647
59	100	0.9	1	2.430	4.425	3.710
60	100	1	1	4.116	7.734	5.019
61	20	0.1	0.3	1.000	1.000	1.000
62	20	0.2	0.3	1.000	1.000	1.000
63	20	0.3	0.3	1.000	1.000	1.000
64	20	0.4	0.3	1.000	1.000	1.000
65	20	0.5	0.3	1.000	1.000	1.000
66	20	0.6	0.3	1.000	1.000	1.041
67	20	0.7	0.3	1.000	1.000	1.619
68	20	0.8	0.3	1.000	1.959	2.374
69	20	0.9	0.3	1.000	3.657	3.328
70	20	1	0.3	1.136	6.392	4.501
71	50	0.1	0.3	1.000	1.000	1.000
72	50	0.2	0.3	1.000	1.000	1.000
73	50	0.3	0.3	1.000	1.000	1.000
74	50	0.4	0.3	1.000	1.000	1.000
75	50	0.5	0.3	1.000	1.000	1.000
76	50	0.6	0.3	1.000	1.000	1.302
77	50	0.7	0.3	1.000	1.485	2.026
78	50	0.8	0.3	1.000	3.013	2.971
79	50	0.9	0.3	1.396	5.626	4.164
80	50	1	0.3	2.364	9.833	5.632
81	100	0.1	0.3	1.000	1.000	1.000
82	100	0.2	0.3	1.000	1.000	1.000
83	100	0.3	0.3	1.000	1.000	1.000
84	100	0.4	0.3	1.000	1.000	1.000
85	100	0.5	0.3	1.000	1.000	1.000
86	100	0.6	0.3	1.000	1.000	1.543
87	100	0.7	0.3	1.000	2.057	2.400
88	100	0.8	0.3	1.349	4.174	3.520
89	100	0.9	0.3	2.430	7.792	4.933
90	100	1	0.3	4.116	13.620	6.673
91	20	0.1	3	1.000	1.000	1.000
92	20	0.2	3	1.000	1.000	1.000
93	20	0.3	3	1.000	1.000	1.000
94	20	0.4	3	1.000	1.000	1.000
95	20	0.5	3	1.000	1.000	1.000
96	20	0.6	3	1.000	1.000	1.000
97	20	0.7	3	1.000	1.000	1.000
98	20	0.8	3	1.000	1.000	1.377
99	20	0.9	3	1.000	1.239	1.930
100	20	1	3	1.136	2.166	2.611
101	50	0.1	3	1.000	1.000	1.000
102	50	0.2	3	1.000	1.000	1.000
103	50	0.3	3	1.000	1.000	1.000
104	50	0.4	3	1.000	1.000	1.000
105	50	0.5	3	1.000	1.000	1.000
106	50	0.6	3	1.000	1.000	1.000
107	50	0.7	3	1.000	1.000	1.175
108	50	0.8	3	1.000	1.021	1.723
109	50	0.9	3	1.396	1.906	2.415
110	50	1	3	2.364	3.332	3.266
111	100	0.1	3	1.000	1.000	1.000
112	100	0.2	3	1.000	1.000	1.000
113	100	0.3	3	1.000	1.000	1.000
114	100	0.4	3	1.000	1.000	1.000
115	100	0.5	3	1.000	1.000	1.000
116	100	0.6	3	1.000	1.000	1.000
117	100	0.7	3	1.000	1.000	1.392
118	100	0.8	3	1.349	1.414	2.041
119	100	0.9	3	2.430	2.640	2.861
120	100	1	3	4.116	4.615	3.870

B16.9 Welding Tee (WLT) - Sketch 2.1 - Header Torsional K

Item #	D/T	d/D	t/T	PRG WTEE kth	PRG UFT kth	Wais UFT kth
1	20	0.1	0.1	1.000	1.000	1.000
2	20	0.2	0.2	1.000	1.000	1.000
3	20	0.3	0.3	1.000	1.000	1.000
4	20	0.4	0.4	1.000	1.000	1.000
5	20	0.5	0.5	1.000	1.000	1.000
6	20	0.6	0.6	1.000	1.000	1.135
7	20	0.7	0.7	1.000	1.000	1.661
8	20	0.8	0.8	1.000	1.264	2.310
9	20	0.9	0.9	1.000	2.882	3.090
10	20	1	1	1.000	6.026	4.008
11	50	0.1	0.1	1.000	1.000	1.000
12	50	0.2	0.2	1.000	1.000	1.000
13	50	0.3	0.3	1.000	1.000	1.000
14	50	0.4	0.4	1.000	1.000	1.000
15	50	0.5	0.5	1.000	1.000	1.000
16	50	0.6	0.6	1.000	1.000	1.515
17	50	0.7	0.7	1.000	1.014	2.217
18	50	0.8	0.8	1.000	2.582	3.083
19	50	0.9	0.9	1.000	5.890	4.124
20	50	1	1	1.497	12.314	5.349
21	100	0.1	0.1	1.000	1.000	1.000
22	100	0.2	0.2	1.000	1.000	1.000
23	100	0.3	0.3	1.000	1.000	1.000
24	100	0.4	0.4	1.000	1.000	1.000
25	100	0.5	0.5	1.000	1.000	1.201
26	100	0.6	0.6	1.000	1.000	1.884
27	100	0.7	0.7	1.000	1.741	2.758
28	100	0.8	0.8	1.000	4.434	3.835
29	100	0.9	0.9	1.543	10.113	5.130
30	100	1	1	2.813	21.144	6.655
31	20	0.1	1	1.000	1.000	1.000
32	20	0.2	1	1.000	1.000	1.000
33	20	0.3	1	1.000	1.000	1.000
34	20	0.4	1	1.000	1.000	1.000
35	20	0.5	1	1.000	1.000	1.000
36	20	0.6	1	1.000	1.000	1.000
37	20	0.7	1	1.000	1.000	1.505
38	20	0.8	1	1.000	1.057	2.172
39	20	0.9	1	1.000	2.649	3.001
40	20	1	1	1.000	6.026	4.008
41	50	0.1	1	1.000	1.000	1.000
42	50	0.2	1	1.000	1.000	1.000
43	50	0.3	1	1.000	1.000	1.000
44	50	0.4	1	1.000	1.000	1.000
45	50	0.5	1	1.000	1.000	1.000
46	50	0.6	1	1.000	1.000	1.316
47	50	0.7	1	1.000	1.000	2.009
48	50	0.8	1	1.000	2.160	2.899
49	50	0.9	1	1.000	5.414	4.005
50	50	1	1	1.497	12.314	5.349
51	100	0.1	1	1.000	1.000	1.000
52	100	0.2	1	1.000	1.000	1.000
53	100	0.3	1	1.000	1.000	1.000
54	100	0.4	1	1.000	1.000	1.000
55	100	0.5	1	1.000	1.000	1.000
56	100	0.6	1	1.000	1.000	1.637
57	100	0.7	1	1.000	1.309	2.499
58	100	0.8	1	1.000	3.709	3.606
59	100	0.9	1	1.543	9.296	4.983
60	100	1	1	2.813	21.144	6.655
61	20	0.1	0.3	1.000	1.000	1.000
62	20	0.2	0.3	1.000	1.000	1.000
63	20	0.3	0.3	1.000	1.000	1.000
64	20	0.4	0.3	1.000	1.000	1.000
65	20	0.5	0.3	1.000	1.000	1.000
66	20	0.6	0.3	1.000	1.000	1.374
67	20	0.7	0.3	1.000	1.000	2.098

Item #	D/T	d/D	t/T	PRG WTEE kth	PRG UFT kth	Wais UFT kth
68	20	0.8	0.3	1.000	2.770	3.028
69	20	0.9	0.3	1.000	6.941	4.184
70	20	1	0.3	1.000	15.787	5.588
71	50	0.1	0.3	1.000	1.000	1.000
72	50	0.2	0.3	1.000	1.000	1.000
73	50	0.3	0.3	1.000	1.000	1.000
74	50	0.4	0.3	1.000	1.000	1.000
75	50	0.5	0.3	1.000	1.000	1.112
76	50	0.6	0.3	1.000	1.000	1.834
77	50	0.7	0.3	1.000	1.997	2.801
78	50	0.8	0.3	1.000	5.660	4.041
79	50	0.9	0.3	1.000	14.184	5.584
80	50	1	0.3	1.497	32.262	7.458
81	100	0.1	0.3	1.000	1.000	1.000
82	100	0.2	0.3	1.000	1.000	1.000
83	100	0.3	0.3	1.000	1.000	1.000
84	100	0.4	0.3	1.000	1.000	1.000
85	100	0.5	0.3	1.000	1.000	1.383
86	100	0.6	0.3	1.000	1.031	2.282
87	100	0.7	0.3	1.000	3.430	3.484
88	100	0.8	0.3	1.000	9.719	5.027
89	100	0.9	0.3	1.543	24.355	6.947
90	100	1	0.3	2.813	55.399	9.278
91	20	0.1	3	1.000	1.000	1.000
92	20	0.2	3	1.000	1.000	1.000
93	20	0.3	3	1.000	1.000	1.000
94	20	0.4	3	1.000	1.000	1.000
95	20	0.5	3	1.000	1.000	1.000
96	20	0.6	3	1.000	1.000	1.000
97	20	0.7	3	1.000	1.000	1.111
98	20	0.8	3	1.000	1.000	1.604
99	20	0.9	3	1.000	1.100	2.216
100	20	1	3	1.000	2.502	2.960
101	50	0.1	3	1.000	1.000	1.000
102	50	0.2	3	1.000	1.000	1.000
103	50	0.3	3	1.000	1.000	1.000
104	50	0.4	3	1.000	1.000	1.000
105	50	0.5	3	1.000	1.000	1.000
106	50	0.6	3	1.000	1.000	1.000
107	50	0.7	3	1.000	1.000	1.483
108	50	0.8	3	1.000	1.000	2.140
109	50	0.9	3	1.000	2.248	2.958
110	50	1	3	1.497	5.113	3.950
111	100	0.1	3	1.000	1.000	1.000
112	100	0.2	3	1.000	1.000	1.000
113	100	0.3	3	1.000	1.000	1.000
114	100	0.4	3	1.000	1.000	1.000
115	100	0.5	3	1.000	1.000	1.000
116	100	0.6	3	1.000	1.000	1.208
117	100	0.7	3	1.000	1.000	1.845
118	100	0.8	3	1.000	1.540	2.663
119	100	0.9	3	1.543	3.860	3.680
120	100	1	3	2.813	8.780	4.914

Pad or Saddle Reinforced Branch Connection (RFT) - Sketch 2.2 - Branch Inplane SIF

Item #	D/T	d/D	t/T	PRG ii tp=T	PRG ii tp=0	PRG ii tp=1.5T	B31.3 ii tp=T	EPRI iib
1	20	0.1	0.1					
2	20	0.2	0.2					
3	20	0.3	0.3	1.000	1.692	1.000	1.000	1.000
4	20	0.4	0.4	1.151	1.849	1.000	1.000	1.000
5	20	0.5	0.5	1.266	1.916	1.000	1.000	1.103
6	20	0.6	0.6	1.330	1.939	1.029	1.106	1.206
7	20	0.7	0.7	1.378	1.965	1.066	1.291	1.300
8	20	0.8	0.8	1.448	2.040	1.120	1.475	1.388
9	20	0.9	0.9	1.586	2.209	1.227	1.660	1.471
10	20	1	1	1.842	2.520	1.425	1.844	1.549
11	50	0.1	0.1					
12	50	0.2	0.2					
13	50	0.3	0.3	1.771	3.395	1.370	1.000	1.576
14	50	0.4	0.4	2.121	3.710	1.640	1.274	1.814
15	50	0.5	0.5	2.332	3.845	1.804	1.593	2.024
16	50	0.6	0.6	2.450	3.891	1.895	1.912	2.213
17	50	0.7	0.7	2.538	3.943	1.963	2.230	2.387
18	50	0.8	0.8	2.667	4.093	2.063	2.549	2.548
19	50	0.9	0.9	2.922	4.433	2.260	2.868	2.700
20	50	1	1	3.393	5.057	2.624	3.186	2.843
21	100	0.1	0.1					
22	100	0.2	0.2					
23	100	0.3	0.3	2.811	5.526	2.174	1.473	2.495
24	100	0.4	0.4	3.366	6.284	2.604	1.964	2.873
25	100	0.5	0.5	3.702	6.511	2.863	2.455	3.205
26	100	0.6	0.6	3.890	6.590	3.009	2.947	3.504
27	100	0.7	0.7	4.029	6.678	3.116	3.438	3.779
28	100	0.8	0.8	4.234	6.931	3.275	3.929	4.035
29	100	0.9	0.9	4.639	7.508	3.588	4.420	4.275
30	100	1	1	5.386	8.564	4.166	4.911	4.501
31	20	0.1	1					
32	20	0.2	1					
33	20	0.3	1	1.380	1.692	1.067	1.844	1.368
34	20	0.4	1	1.515	1.849	1.172	1.844	1.409
35	20	0.5	1	1.559	1.916	1.205	1.844	1.442
36	20	0.6	1	1.551	1.939	1.199	1.844	1.469
37	20	0.7	1	1.533	1.965	1.186	1.844	1.493
38	20	0.8	1	1.548	2.040	1.198	1.844	1.513
39	20	0.9	1	1.637	2.209	1.266	1.844	1.532
40	20	1	1	1.842	2.520	1.425	1.844	1.549
41	50	0.1	1					
42	50	0.2	1					
43	50	0.3	1	2.542	3.395	1.966	3.186	2.511
44	50	0.4	1	2.792	3.710	2.159	3.186	2.587
45	50	0.5	1	2.871	3.845	2.220	3.186	2.647
46	50	0.6	1	2.856	3.891	2.209	3.186	2.697
47	50	0.7	1	2.824	3.943	2.185	3.186	2.740
48	50	0.8	1	2.852	4.093	2.206	3.186	2.778
49	50	0.9	1	3.016	4.433	2.333	3.186	2.812
50	50	1	1	3.393	5.057	2.624	3.186	2.843
51	100	0.1	1					
52	100	0.2	1					
53	100	0.3	1	4.034	5.750	3.120	4.911	3.976
54	100	0.4	1	4.431	6.284	3.427	4.911	4.096
55	100	0.5	1	4.557	6.511	3.525	4.911	4.191
56	100	0.6	1	4.534	6.590	3.507	4.911	4.270
57	100	0.7	1	4.484	6.678	3.468	4.911	4.339
58	100	0.8	1	4.527	6.931	3.502	4.911	4.399
59	100	0.9	1	4.788	7.508	3.703	4.911	4.453
60	100	1	1	5.386	8.564	4.166	4.911	4.501
61	20	0.1	0.3					
62	20	0.2	0.3					
63	20	0.3	0.3	1.000	1.692	1.000	1.000	1.000
64	20	0.4	0.3	1.056	1.849	1.000	1.000	1.000
65	20	0.5	0.3	1.086	1.916	1.000	1.000	1.000
66	20	0.6	0.3	1.081	1.939	1.000	1.000	1.000
67	20	0.7	0.3	1.069	1.965	1.000	1.000	1.000
68	20	0.8	0.3	1.079	2.040	1.000	1.000	1.000
69	20	0.9	0.3	1.141	2.209	1.000	1.000	1.000
70	20	1	0.3	1.284	2.520	1.000	1.844	1.000
71	50	0.1	0.3					
72	50	0.2	0.3					
73	50	0.3	0.3	1.771	3.395	1.370	1.000	1.576
74	50	0.4	0.3	1.945	3.710	1.505	1.000	1.623
75	50	0.5	0.3	2.001	3.845	1.547	1.000	1.661
76	50	0.6	0.3	1.990	3.891	1.539	1.000	1.693
77	50	0.7	0.3	1.968	3.869	1.522	1.000	1.720
78	50	0.8	0.3	1.987	3.907	1.537	1.000	1.743
79	50	0.9	0.3	2.102	4.131	1.626	1.000	1.765
80	50	1	0.3	2.364	4.647	1.829	3.186	1.784
81	100	0.1	0.3					
82	100	0.2	0.3					
83	100	0.3	0.3	2.811	5.526	2.174	1.473	2.495
84	100	0.4	0.3	3.088	6.070	2.388	1.473	2.570
85	100	0.5	0.3	3.176	6.242	2.456	1.473	2.630
86	100	0.6	0.3	3.160	6.210	2.444	1.473	2.680
87	100	0.7	0.3	3.124	6.141	2.416	1.473	2.723
88	100	0.8	0.3	3.155	6.201	2.440	1.473	2.761
89	100	0.9	0.3					
90	100	1	0.3					
91	20	0.1	3					
92	20	0.2	3					
93	20	0.3	3	1.918	3.771	1.484	5.532	2.093
94	20	0.4	3	2.107	4.142	1.630	5.532	2.156
95	20	0.5	3	2.167	4.259	1.676	5.532	2.206
96	20	0.6	3	2.156	4.238	1.668	5.532	2.248
97	20	0.7	3	2.132	4.190	1.649	5.532	2.284
98	20	0.8	3	2.153	4.232	1.665	5.532	2.315
99	20	0.9	3	2.277	4.475	1.761	5.532	2.343
100	20	1	3					
101	50	0.1	3					
102	50	0.2	3					
103	50	0.3	3	3.534	6.946	2.733	9.558	3.842
104	50	0.4	3	3.881	7.629	3.002	9.558	3.957
105	50	0.5	3	3.992	7.846	3.087	9.558	4.049
106	50	0.6	3	3.971	7.806	3.072	9.558	4.126
107	50	0.7	3	3.927	7.719	3.037	9.558	4.192
108	50	0.8	3	3.966	7.795	3.067	9.558	4.250
109	50	0.9	3	4.193	8.242	3.243	9.558	4.302
110	50	1	3					
111	100	0.1	3					
112	100	0.2	3					
113	100	0.3	3	5.609	11.026	4.339	14.733	6.083
114	100	0.4	3	6.161	12.110	4.765	14.733	6.266
115	100	0.5	3	6.336	12.455	4.901	14.733	6.412
116	100	0.6	3	6.304	12.391	4.876	14.733	6.533
117	100	0.7	3	6.234	12.253	4.821	14.733	6.638
118	100	0.8	3	6.295	12.373	4.869	14.733	6.730
119	100	0.9	3	6.657	13.084	5.148	14.733	6.812
120	100	1	3					

Pad or Saddle Reinforced Branch Connection (RFT) - Sketch 2.2 - Branch Outplane SIF

Item #	D/T	d/D	t/T	PRG io tp=T	PRG io tp=0	B31.3 io tp=T	EPRI iob
1	20	0.1	0.1				
2	20	0.2	0.2				
3	20	0.3	0.3	2.152	2.897	1.000	1.163
4	20	0.4	0.4	2.812	3.786	1.000	1.691
5	20	0.5	0.5	3.346	4.539	1.063	2.198
6	20	0.6	0.6	3.694	5.083	1.275	2.616
7	20	0.7	0.7	3.800	5.345	1.488	2.862
8	20	0.8	0.8	3.603	5.250	1.700	2.830
9	20	0.9	0.9	3.098	5.005	1.913	2.396
10	20	1	1	2.520	4.270	2.125	1.412
11	50	0.1	0.1				
12	50	0.2	0.2				
13	50	0.3	0.3	3.964	6.556	1.174	2.515
14	50	0.4	0.4	5.508	8.903	1.566	3.657
15	50	0.5	0.5	6.781	10.513	1.957	4.754
16	50	0.6	0.6	7.184	10.962	2.349	5.659
17	50	0.7	0.7	6.999	10.011	2.740	6.190
18	50	0.8	0.8	6.637	9.671	3.132	6.121
19	50	0.9	0.9	5.707	9.219	3.523	5.183
20	50	1	1	5.057	7.866	3.915	3.054
21	100	0.1	0.1				
22	100	0.2	0.2				
23	100	0.3	0.3	7.523	13.173	1.864	4.508
24	100	0.4	0.4	11.066	17.888	2.486	6.556
25	100	0.5	0.5	13.625	21.122	3.107	8.522
26	100	0.6	0.6	14.435	22.025	3.729	10.145
27	100	0.7	0.7	13.071	20.114	4.350	11.096
28	100	0.8	0.8	10.535	15.461	4.972	10.973
29	100	0.9	0.9	9.059	14.635	5.593	9.290
30	100	1	1	6.353	12.486	6.214	5.475
31	20	0.1	1				
32	20	0.2	1				
33	20	0.3	1	2.259	3.408	2.125	2.276
34	20	0.4	1	2.952	4.454	2.125	2.819
35	20	0.5	1	3.513	5.340	2.125	3.236
36	20	0.6	1	3.879	5.980	2.125	3.479
37	20	0.7	1	3.989	6.288	2.125	3.492
38	20	0.8	1	3.783	6.177	2.125	3.205
39	20	0.9	1	3.198	5.561	2.125	2.541
40	20	1	1	2.520	4.270	2.125	1.412
41	50	0.1	1				
42	50	0.2	1				
43	50	0.3	1	4.162	6.278	3.915	4.924
44	50	0.4	1	5.438	8.204	3.915	6.099
45	50	0.5	1	6.470	9.837	3.915	6.999
46	50	0.6	1	7.145	11.016	3.915	7.526
47	50	0.7	1	7.349	11.583	3.915	7.553
48	50	0.8	1	6.968	11.378	3.915	6.933
49	50	0.9	1	5.890	10.244	3.915	5.497
50	50	1	1	5.057	7.866	3.915	3.054
51	100	0.1	1				
52	100	0.2	1				
53	100	0.3	1	6.607	9.966	6.214	8.826
54	100	0.4	1	8.633	13.024	6.214	10.932
55	100	0.5	1	10.271	15.615	6.214	12.547
56	100	0.6	1	11.342	17.486	6.214	13.491
57	100	0.7	1	11.665	18.386	6.214	13.539
58	100	0.8	1	11.061	18.062	6.214	12.428
59	100	0.9	1	9.350	16.261	6.214	9.853
60	100	1	1	6.669	12.486	6.214	5.475
61	20	0.1	0.3				
62	20	0.2	0.3				
63	20	0.3	0.3	2.152	2.897	1.000	1.163
64	20	0.4	0.3	2.812	3.786	1.000	1.440
65	20	0.5	0.3	3.346	4.539	1.000	1.653
66	20	0.6	0.3	3.694	5.083	1.000	1.777
67	20	0.7	0.3	3.800	5.345	1.000	1.784

Item #	D/T	d/D	t/T	PRG io tp=T	PRG io tp=0	B31.3 io tp=T	EPRI iob
68	20	0.8	0.3	3.603	5.250	1.000	1.637
69	20	0.9	0.3	3.046	4.727	1.000	1.298
70	20	1	0.3	2.069	3.701	2.125	1.000
71	50	0.1	0.3				
72	50	0.2	0.3				
73	50	0.3	0.3	3.964	6.556	1.174	2.515
74	50	0.4	0.3	5.180	8.568	1.174	3.115
75	50	0.5	0.3	6.163	10.272	1.174	3.575
76	50	0.6	0.3	6.805	11.503	1.174	3.844
77	50	0.7	0.3	6.999	12.095	1.174	3.858
78	50	0.8	0.3	6.637	11.882	1.174	3.541
79	50	0.9	0.3	5.610	10.697	1.174	2.808
80	50	1	0.3	5.057	6.817	3.915	1.560
81	100	0.1	0.3				
82	100	0.2	0.3				
83	100	0.3	0.3	7.523	13.173	1.864	4.508
84	100	0.4	0.3	9.830	17.215	1.864	5.584
85	100	0.5	0.3	11.696	20.640	1.864	6.409
86	100	0.6	0.3	12.915	23.114	1.864	6.891
87	100	0.7	0.3	13.283	24.303	1.864	6.916
88	100	0.8	0.3	12.596	23.874	1.864	6.348
89	100	0.9	0.3				
90	100	1	0.3				
91	20	0.1	3				
92	20	0.2	3				
93	20	0.3	3	3.771	6.175	6.376	4.202
94	20	0.4	3	4.105	8.069	6.376	5.205
95	20	0.5	3	4.884	9.600	6.376	5.973
96	20	0.6	3	5.393	10.600	6.376	6.423
97	20	0.7	3	5.547	10.903	6.376	6.446
98	20	0.8	3	5.260	10.338	6.376	5.917
99	20	0.9	3	4.475	8.739	6.376	4.691
100	20	1	3				
101	50	0.1	3				
102	50	0.2	3				
103	50	0.3	3	5.787	11.374	11.745	9.089
104	50	0.4	3	7.561	14.862	11.745	11.258
105	50	0.5	3	8.996	17.683	11.745	12.921
106	50	0.6	3	9.934	19.526	11.745	13.893
107	50	0.7	3	10.217	20.083	11.745	13.943
108	50	0.8	3	9.688	19.043	11.745	12.799
109	50	0.9	3	8.190	16.098	11.745	10.147
110	50	1	3				
111	100	0.1	3				
112	100	0.2	3				
113	100	0.3	3	9.186	18.056	18.643	16.293
114	100	0.4	3	12.003	23.593	18.643	20.180
115	100	0.5	3	14.281	28.070	18.643	23.161
116	100	0.6	3	15.770	30.996	18.643	24.904
117	100	0.7	3	16.219	31.879	18.643	24.994
118	100	0.8	3	15.379	30.229	18.643	22.942
119	100	0.9	3	13.001	25.553	18.643	18.189
120	100	1	3				

Pad or Saddle Reinforced Branch Connection (RFT) - Sketch 2.2 - Branch Torsional SIF

Item #	D/T	d/D	t/T	PRG it tp=T	PRG it tp=0	EPRI itb
1	20	0.1	0.1			
2	20	0.2	0.2			
3	20	0.3	0.3	1.000	1.000	1.000
4	20	0.4	0.4	1.000	1.000	1.000
5	20	0.5	0.5	1.000	1.000	1.000
6	20	0.6	0.6	1.000	1.000	1.000
7	20	0.7	0.7	1.000	1.255	1.000
8	20	0.8	0.8	1.000	1.703	1.122
9	20	0.9	0.9	1.190	2.231	1.436
10	20	1	1	1.516	2.839	1.792
11	50	0.1	0.1			
12	50	0.2	0.2			
13	50	0.3	0.3	1.000	1.000	1.000
14	50	0.4	0.4	1.000	1.000	1.000
15	50	0.5	0.5	1.000	1.115	1.000
16	50	0.6	0.6	1.000	1.695	1.000
17	50	0.7	0.7	1.230	2.417	1.340
18	50	0.8	0.8	1.672	3.286	1.773
19	50	0.9	0.9	2.192	4.308	2.271
20	50	1	1	2.793	5.489	2.833
21	100	0.1	0.1			
22	100	0.2	0.2			
23	100	0.3	0.3	1.000	1.000	1.000
24	100	0.4	0.4	1.000	1.059	1.000
25	100	0.5	0.5	1.000	1.769	1.000
26	100	0.6	0.6	1.369	2.691	1.371
27	100	0.7	0.7	1.952	3.836	1.895
28	100	0.8	0.8	2.653	5.215	2.508
29	100	0.9	0.9	3.479	6.838	3.212
30	100	1	1	4.433	8.713	4.007
31	20	0.1	1			
32	20	0.2	1			
33	20	0.3	1	1.000	1.000	1.000
34	20	0.4	1	1.000	1.000	1.000
35	20	0.5	1	1.000	1.000	1.000
36	20	0.6	1	1.000	1.022	1.000
37	20	0.7	1	1.000	1.391	1.013
38	20	0.8	1	1.000	1.817	1.254
39	20	0.9	1	1.228	2.300	1.514
40	20	1	1	1.516	2.839	1.792
41	50	0.1	1			
42	50	0.2	1			
43	50	0.3	1	1.000	1.000	1.000
44	50	0.4	1	1.000	1.000	1.000
45	50	0.5	1	1.000	1.372	1.000
46	50	0.6	1	1.005	1.976	1.251
47	50	0.7	1	1.368	2.690	1.601
48	50	0.8	1	1.787	3.513	1.983
49	50	0.9	1	2.262	4.446	2.394
50	50	1	1	2.793	5.489	2.833
51	100	0.1	1			
52	100	0.2	1			
53	100	0.3	1	1.000	1.000	1.000
54	100	0.4	1	1.000	1.394	1.000
55	100	0.5	1	1.108	2.178	1.322
56	100	0.6	1	1.596	3.137	1.770
57	100	0.7	1	2.172	4.270	2.264
58	100	0.8	1	2.837	5.576	2.804
59	100	0.9	1	3.591	7.058	3.385
60	100	1	1	4.433	8.713	4.007
61	20	0.1	0.3			
62	20	0.2	0.3			
63	20	0.3	0.3	1.000	1.000	1.000
64	20	0.4	0.3	1.000	1.000	1.000
65	20	0.5	0.3	1.000	1.000	1.000
66	20	0.6	0.3	1.000	1.000	1.000
67	20	0.7	0.3	1.000	1.000	1.000

Item #	D/T	d/D	t/T	PRG it tp=T	PRG it tp=0	EPRI itb
68	20	0.8	0.3	1.000	1.282	1.000
69	20	0.9	0.3	1.000	1.622	1.000
70	20	1	0.3	1.056	2.003	1.000
71	50	0.1	0.3			
72	50	0.2	0.3			
73	50	0.3	0.3	1.000	1.000	1.000
74	50	0.4	0.3	1.000	1.000	1.000
75	50	0.5	0.3	1.000	1.000	1.000
76	50	0.6	0.3	1.000	1.377	1.000
77	50	0.7	0.3	1.000	1.874	1.000
78	50	0.8	0.3	1.245	2.448	1.086
79	50	0.9	0.3	1.576	3.098	1.311
80	50	1	0.3	1.946	3.825	1.552
81	100	0.1	0.3			
82	100	0.2	0.3			
83	100	0.3	0.3	1.000	1.000	1.000
84	100	0.4	0.3	1.000	1.000	1.000
85	100	0.5	0.3	1.000	1.518	1.000
86	100	0.6	0.3	1.112	2.186	1.000
87	100	0.7	0.3	1.514	2.975	1.240
88	100	0.8	0.3	1.977	3.886	1.536
89	100	0.9	0.3			
90	100	1	0.3			
91	20	0.1	3			
92	20	0.2	3			
93	20	0.3	3	1.000	1.000	1.000
94	20	0.4	3	1.000	1.000	1.000
95	20	0.5	3	1.000	1.000	1.024
96	20	0.6	3	1.000	1.406	1.371
97	20	0.7	3	1.033	1.913	1.754
98	20	0.8	3	1.349	2.499	2.172
99	20	0.9	3	1.707	3.163	2.622
100	20	1	3			
101	50	0.1	3			
102	50	0.2	3			
103	50	0.3	3	1.000	1.000	1.000
104	50	0.4	3	1.000	1.221	1.133
105	50	0.5	3	1.000	1.908	1.619
106	50	0.6	3	1.398	2.747	2.167
107	50	0.7	3	1.903	3.740	2.773
108	50	0.8	3	2.485	4.884	3.434
109	50	0.9	3	3.145	6.182	4.146
110	50	1	3			
111	100	0.1	3			
112	100	0.2	3			
113	100	0.3	3	1.000	1.090	1.011
114	100	0.4	3	1.000	1.938	1.602
115	100	0.5	3	1.541	3.029	2.289
116	100	0.6	3	2.219	4.361	3.065
117	100	0.7	3	3.020	5.936	3.922
118	100	0.8	3	3.945	7.754	4.856
119	100	0.9	3	4.992	9.813	5.864
120	100	1	3			

Pad or Saddle Reinforced Branch Connection (RFT) - Sketch 2.2 - Header Inplane SIF

Item #	D/T	d/D	t/T	PRG ii tp=T	EPRI iir	B31.3 ii tp=T
1	20	0.1	0.1			
2	20	0.2	0.2			
3	20	0.3	0.3	1.846	1.724	1.844
4	20	0.4	0.4	1.955	1.848	1.844
5	20	0.5	0.5	2.044	1.950	1.844
6	20	0.6	0.6	2.120	2.037	1.844
7	20	0.7	0.7	2.187	2.115	1.844
8	20	0.8	0.8	2.246	2.184	1.844
9	20	0.9	0.9	2.299	2.247	1.844
10	20	1	1	2.348	2.304	1.844
11	50	0.1	0.1			
12	50	0.2	0.2			
13	50	0.3	0.3	2.788	2.365	3.186
14	50	0.4	0.4	2.953	2.535	3.186
15	50	0.5	0.5	3.088	2.675	3.186
16	50	0.6	0.6	3.202	2.795	3.186
17	50	0.7	0.7	3.303	2.901	3.186
18	50	0.8	0.8	3.392	2.996	3.186
19	50	0.9	0.9	3.473	3.082	3.186
20	50	1	1	3.547	3.161	3.186
21	100	0.1	0.1	3.057	2.305	4.911
22	100	0.2	0.2	3.512	2.724	4.911
23	100	0.3	0.3	3.808	3.004	4.911
24	100	0.4	0.4	4.034	3.220	4.911
25	100	0.5	0.5	4.218	3.397	4.911
26	100	0.6	0.6	4.374	3.550	4.911
27	100	0.7	0.7	4.511	3.684	4.911
28	100	0.8	0.8	4.634	3.805	4.911
29	100	0.9	0.9	4.744	3.915	4.911
30	100	1	1	4.845	4.015	4.911
31	20	0.1	1	1.500	1.000	1.844
32	20	0.2	1	1.500	1.000	1.844
33	20	0.3	1	1.500	1.000	1.844
34	20	0.4	1	1.500	1.188	1.844
35	20	0.5	1	1.615	1.396	1.844
36	20	0.6	1	1.782	1.593	1.844
37	20	0.7	1	1.937	1.781	1.844
38	20	0.8	1	2.082	1.961	1.844
39	20	0.9	1	2.218	2.135	1.844
40	20	1	1	2.348	2.304	1.844
41	50	0.1	1	1.500	1.000	3.186
42	50	0.2	1	1.500	1.000	3.186
43	50	0.3	1	1.851	1.324	3.186
44	50	0.4	1	2.162	1.630	3.186
45	50	0.5	1	2.439	1.915	3.186
46	50	0.6	1	2.692	2.185	3.186
47	50	0.7	1	2.925	2.443	3.186
48	50	0.8	1	3.144	2.690	3.186
49	50	0.9	1	3.351	2.929	3.186
50	50	1	1	3.547	3.161	3.186
51	100	0.1	1	1.500	1.000	4.911
52	100	0.2	1	2.032	1.254	4.911
53	100	0.3	1	2.529	1.681	4.911
54	100	0.4	1	2.954	2.070	4.911
55	100	0.5	1	3.332	2.433	4.911
56	100	0.6	1	3.677	2.775	4.911
57	100	0.7	1	3.996	3.102	4.911
58	100	0.8	1	4.295	3.417	4.911
59	100	0.9	1	4.577	3.721	4.911
60	100	1	1	4.845	4.015	4.911
61	20	0.1	0.3	1.500	1.000	1.844
62	20	0.2	0.3	1.500	1.286	1.844
63	20	0.3	0.3	1.846	1.724	1.844
64	20	0.4	0.3	2.156	2.123	1.844
65	20	0.5	0.3	2.432	2.494	1.844
66	20	0.6	0.3	2.684	2.846	1.844
67	20	0.7	0.3	2.917	3.181	1.844

Item #	D/T	d/D	t/T	PRG ii tp=T	EPRI iir	B31.3 ii tp=T
68	20	0.8	0.3	3.135	3.504	1.844
69	20	0.9	0.3	3.341	3.815	1.844
70	20	1	0.3	3.536	4.117	1.844
71	50	0.1	0.3	1.540	1.069	3.186
72	50	0.2	0.3	2.240	1.764	3.186
73	50	0.3	0.3	2.788	2.365	3.186
74	50	0.4	0.3	3.256	2.912	3.186
75	50	0.5	0.3	3.673	3.422	3.186
76	50	0.6	0.3	4.053	3.904	3.186
77	50	0.7	0.3	4.405	4.364	3.186
78	50	0.8	0.3	4.735	4.806	3.186
79	50	0.9	0.3	5.045	5.234	3.186
80	50	1	0.3	5.341	5.648	3.186
81	100	0.1	0.3	2.104	1.357	4.911
82	100	0.2	0.3	3.059	2.241	4.911
83	100	0.3	0.3	3.808	3.004	4.911
84	100	0.4	0.3	4.448	3.698	4.911
85	100	0.5	0.3	5.018	4.346	4.911
86	100	0.6	0.3	5.537	4.958	4.911
87	100	0.7	0.3	6.018	5.543	4.911
88	100	0.8	0.3	6.468	6.105	4.911
89	100	0.9	0.3			
90	100	1	0.3			
91	20	0.1	3	1.500	1.000	1.844
92	20	0.2	3	1.500	1.000	1.844
93	20	0.3	3	1.500	1.000	1.844
94	20	0.4	3	1.500	1.000	1.844
95	20	0.5	3	1.500	1.000	1.844
96	20	0.6	3	1.500	1.000	1.844
97	20	0.7	3	1.500	1.049	1.844
98	20	0.8	3	1.500	1.155	1.844
99	20	0.9	3	1.527	1.257	1.844
100	20	1	3			
101	50	0.1	3	1.500	1.000	3.186
102	50	0.2	3	1.500	1.000	3.186
103	50	0.3	3	1.500	1.000	3.186
104	50	0.4	3	1.500	1.000	3.186
105	50	0.5	3	1.679	1.128	3.186
106	50	0.6	3	1.853	1.287	3.186
107	50	0.7	3	2.014	1.438	3.186
108	50	0.8	3	2.164	1.584	3.186
109	50	0.9	3	2.306	1.725	3.186
110	50	1	3			
111	100	0.1	3	1.500	1.000	4.911
112	100	0.2	3	1.500	1.000	4.911
113	100	0.3	3	1.741	1.000	4.911
114	100	0.4	3	2.033	1.219	4.911
115	100	0.5	3	2.294	1.432	4.911
116	100	0.6	3	2.531	1.634	4.911
117	100	0.7	3	2.751	1.827	4.911
118	100	0.8	3	2.956	2.012	4.911
119	100	0.9	3	3.150	2.191	4.911
120	100	1	3			

Pad or Saddle Reinforced Branch Connection (RFT) - Sketch 2.2 - Header Outplane SIF

Item #	D/T	d/D	t/T	PRG io tp=T	EPRI ior	B31.3 io tp=T
1	20	0.1	0.1			
2	20	0.2	0.2			
3	20	0.3	0.3	1.000	1.000	2.125
4	20	0.4	0.4	1.000	1.000	2.125
5	20	0.5	0.5	1.000	1.000	2.125
6	20	0.6	0.6	1.000	1.000	2.125
7	20	0.7	0.7	1.000	1.000	2.125
8	20	0.8	0.8	1.000	1.000	2.125
9	20	0.9	0.9	1.154	1.121	2.125
10	20	1	1	1.573	1.302	2.125
11	50	0.1	0.1			
12	50	0.2	0.2			
13	50	0.3	0.3	1.000	1.000	3.915
14	50	0.4	0.4	1.000	1.000	3.915
15	50	0.5	0.5	1.000	1.000	3.915
16	50	0.6	0.6	1.000	1.000	3.915
17	50	0.7	0.7	1.000	1.024	3.915
18	50	0.8	0.8	1.186	1.238	3.915
19	50	0.9	0.9	1.590	1.463	3.915
20	50	1	1	2.168	1.699	3.915
21	100	0.1	0.1	1.000	1.000	6.214
22	100	0.2	0.2	1.000	1.000	6.214
23	100	0.3	0.3	1.000	1.000	6.214
24	100	0.4	0.4	1.000	1.000	6.214
25	100	0.5	0.5	1.000	1.000	6.214
26	100	0.6	0.6	1.000	1.007	6.214
27	100	0.7	0.7	1.180	1.253	6.214
28	100	0.8	0.8	1.511	1.515	6.214
29	100	0.9	0.9	2.027	1.790	6.214
30	100	1	1	2.764	2.079	6.214
31	20	0.1	1	1.000	1.000	2.125
32	20	0.2	1	1.000	1.000	2.125
33	20	0.3	1	1.000	1.000	2.125
34	20	0.4	1	1.000	1.000	2.125
35	20	0.5	1	1.000	1.000	2.125
36	20	0.6	1	1.000	1.000	2.125
37	20	0.7	1	1.000	1.000	2.125
38	20	0.8	1	1.000	1.000	2.125
39	20	0.9	1	1.124	1.060	2.125
40	20	1	1	1.573	1.302	2.125
41	50	0.1	1	1.000	1.000	3.915
42	50	0.2	1	1.000	1.000	3.915
43	50	0.3	1	1.000	1.000	3.915
44	50	0.4	1	1.000	1.000	3.915
45	50	0.5	1	1.000	1.000	3.915
46	50	0.6	1	1.000	1.000	3.915
47	50	0.7	1	1.000	1.000	3.915
48	50	0.8	1	1.121	1.100	3.915
49	50	0.9	1	1.549	1.384	3.915
50	50	1	1	2.168	1.699	3.915
51	100	0.1	1	1.000	1.000	6.214
52	100	0.2	1	1.000	1.000	6.214
53	100	0.3	1	1.000	1.000	6.214
54	100	0.4	1	1.000	1.000	6.214
55	100	0.5	1	1.000	1.000	6.214
56	100	0.6	1	1.000	1.000	6.214
57	100	0.7	1	1.080	1.038	6.214
58	100	0.8	1	1.429	1.346	6.214
59	100	0.9	1	1.974	1.693	6.214
60	100	1	1	2.764	2.079	6.214
61	20	0.1	0.3	1.000	1.000	2.125
62	20	0.2	0.3	1.000	1.000	2.125
63	20	0.3	0.3	1.000	1.000	2.125
64	20	0.4	0.3	1.000	1.000	2.125
65	20	0.5	0.3	1.000	1.000	2.125
66	20	0.6	0.3	1.000	1.000	2.125
67	20	0.7	0.3	1.000	1.227	2.125

Item #	D/T	d/D	t/T	PRG io tp=T	EPRI ior	B31.3 io tp=T
68	20	0.8	0.3	1.099	1.591	2.125
69	20	0.9	0.3	1.519	2.002	2.125
70	20	1	0.3	2.126	2.458	2.125
71	50	0.1	0.3	1.000	1.000	3.915
72	50	0.2	0.3	1.000	1.000	3.915
73	50	0.3	0.3	1.000	1.000	3.915
74	50	0.4	0.3	1.000	1.000	3.915
75	50	0.5	0.3	1.000	1.000	3.915
76	50	0.6	0.3	1.000	1.186	3.915
77	50	0.7	0.3	1.145	1.602	3.915
78	50	0.8	0.3	1.515	2.078	3.915
79	50	0.9	0.3	2.093	2.614	3.915
80	50	1	0.3	2.930	3.209	3.915
81	100	0.1	0.3	1.000	1.000	6.214
82	100	0.2	0.3	1.000	1.000	6.214
83	100	0.3	0.3	1.000	1.000	6.214
84	100	0.4	0.3	1.000	1.000	6.214
85	100	0.5	0.3	1.043	1.018	6.214
86	100	0.6	0.3	1.185	1.451	6.214
87	100	0.7	0.3	1.459	1.960	6.214
88	100	0.8	0.3	1.931	2.542	6.214
89	100	0.9	0.3			
90	100	1	0.3			
91	20	0.1	3	1.000	1.000	2.125
92	20	0.2	3	1.000	1.000	2.125
93	20	0.3	3	1.000	1.000	2.125
94	20	0.4	3	1.000	1.000	2.125
95	20	0.5	3	1.000	1.000	2.125
96	20	0.6	3	1.000	1.000	2.125
97	20	0.7	3	1.000	1.000	2.125
98	20	0.8	3	1.000	1.000	2.125
99	20	0.9	3	1.000	1.000	2.125
100	20	1	3			
101	50	0.1	3	1.000	1.000	3.915
102	50	0.2	3	1.000	1.000	3.915
103	50	0.3	3	1.000	1.000	3.915
104	50	0.4	3	1.000	1.000	3.915
105	50	0.5	3	1.000	1.000	3.915
106	50	0.6	3	1.000	1.000	3.915
107	50	0.7	3	1.000	1.000	3.915
108	50	0.8	3	1.000	1.000	3.915
109	50	0.9	3	1.152	1.000	3.915
110	50	1	3			
111	100	0.1	3	1.000	1.000	6.214
112	100	0.2	3	1.000	1.000	6.214
113	100	0.3	3	1.000	1.000	6.214
114	100	0.4	3	1.000	1.000	6.214
115	100	0.5	3	1.000	1.000	6.214
116	100	0.6	3	1.000	1.000	6.214
117	100	0.7	3	1.000	1.000	6.214
118	100	0.8	3	1.030	1.000	6.214
119	100	0.9	3	1.500	1.000	6.214
120	100	1	3			

Pad or Saddle Reinforced Branch Connection (RFT) - Sketch 2.2 - Header Torsional SIF

Item #	D/T	d/D	t/T	PRG it tp=T	EPRI itr	B31.3 io tp=T
1	20	0.1	0.1			
2	20	0.2	0.2			
3	20	0.3	0.3	1.000	1.325	2.125
4	20	0.4	0.4	1.000	1.578	2.125
5	20	0.5	0.5	1.000	1.808	2.125
6	20	0.6	0.6	1.000	2.020	2.125
7	20	0.7	0.7	1.000	2.219	2.125
8	20	0.8	0.8	1.067	2.407	2.125
9	20	0.9	0.9	1.172	2.586	2.125
10	20	1	1	1.275	2.758	2.125
11	50	0.1	0.1			
12	50	0.2	0.2			
13	50	0.3	0.3	1.000	2.086	3.915
14	50	0.4	0.4	1.129	2.486	3.915
15	50	0.5	0.5	1.349	2.848	3.915
16	50	0.6	0.6	1.561	3.182	3.915
17	50	0.7	0.7	1.766	3.495	3.915
18	50	0.8	0.8	1.965	3.791	3.915
19	50	0.9	0.9	2.159	4.073	3.915
20	50	1	1	2.349	4.343	3.915
21	100	0.1	0.1	1.000	1.507	6.214
22	100	0.2	0.2	1.029	2.298	6.214
23	100	0.3	0.3	1.423	2.942	6.214
24	100	0.4	0.4	1.791	3.505	6.214
25	100	0.5	0.5	2.142	4.015	6.214
26	100	0.6	0.6	2.478	4.487	6.214
27	100	0.7	0.7	2.803	4.928	6.214
28	100	0.8	0.8	3.119	5.346	6.214
29	100	0.9	0.9	3.427	5.743	6.214
30	100	1	1	3.729	6.124	6.214
31	20	0.1	1	1.000	1.000	2.125
32	20	0.2	1	1.000	1.000	2.125
33	20	0.3	1	1.000	1.000	2.125
34	20	0.4	1	1.000	1.000	2.125
35	20	0.5	1	1.000	1.241	2.125
36	20	0.6	1	1.000	1.531	2.125
37	20	0.7	1	1.000	1.829	2.125
38	20	0.8	1	1.000	2.133	2.125
39	20	0.9	1	1.100	2.442	2.125
40	20	1	1	1.275	2.758	2.125
41	50	0.1	1	1.000	1.000	3.915
42	50	0.2	1	1.000	1.000	3.915
43	50	0.3	1	1.000	1.085	3.915
44	50	0.4	1	1.000	1.511	3.915
45	50	0.5	1	1.000	1.954	3.915
46	50	0.6	1	1.149	2.411	3.915
47	50	0.7	1	1.426	2.880	3.915
48	50	0.8	1	1.719	3.359	3.915
49	50	0.9	1	2.027	3.847	3.915
50	50	1	1	2.349	4.343	3.915
51	100	0.1	1	1.000	1.000	6.214
52	100	0.2	1	1.000	1.000	6.214
53	100	0.3	1	1.000	1.530	6.214
54	100	0.4	1	1.034	2.131	6.214
55	100	0.5	1	1.413	2.756	6.214
56	100	0.6	1	1.824	3.400	6.214
57	100	0.7	1	2.263	4.060	6.214
58	100	0.8	1	2.728	4.736	6.214
59	100	0.9	1	3.217	5.424	6.214
60	100	1	1	3.729	6.124	6.214
61	20	0.1	0.3	1.000	1.000	2.125
62	20	0.2	0.3	1.000	1.000	2.125
63	20	0.3	0.3	1.000	1.325	2.125
64	20	0.4	0.3	1.000	1.845	2.125
65	20	0.5	0.3	1.000	2.386	2.125
66	20	0.6	0.3	1.284	2.944	2.125
67	20	0.7	0.3	1.594	3.516	2.125

Item #	D/T	d/D	t/T	PRG it tp=T	EPRI itr	B31.3 io tp=T
68	20	0.8	0.3	1.921	4.100	2.125
69	20	0.9	0.3	2.266	4.696	2.125
70	20	1	0.3	2.626	5.302	2.125
71	50	0.1	0.3	1.000	1.000	3.915
72	50	0.2	0.3	1.000	1.308	3.915
73	50	0.3	0.3	1.000	2.086	3.915
74	50	0.4	0.3	1.341	2.906	3.915
75	50	0.5	0.3	1.833	3.758	3.915
76	50	0.6	0.3	2.366	4.636	3.915
77	50	0.7	0.3	2.936	5.537	3.915
78	50	0.8	0.3	3.539	6.458	3.915
79	50	0.9	0.3	4.174	7.396	3.915
80	50	1	0.3	4.837	8.351	3.915
81	100	0.1	0.3	1.000	1.000	6.214
82	100	0.2	0.3	1.000	1.844	6.214
83	100	0.3	0.3	1.423	2.942	6.214
84	100	0.4	0.3	2.129	4.097	6.214
85	100	0.5	0.3	2.910	5.299	6.214
86	100	0.6	0.3	3.756	6.537	6.214
87	100	0.7	0.3	4.660	7.807	6.214
88	100	0.8	0.3	5.618	9.106	6.214
89	100	0.9	0.3			
90	100	1	0.3			
91	20	0.1	3	1.000	1.000	2.125
92	20	0.2	3	1.000	1.000	2.125
93	20	0.3	3	1.000	1.000	2.125
94	20	0.4	3	1.000	1.000	2.125
95	20	0.5	3	1.000	1.000	2.125
96	20	0.6	3	1.000	1.000	2.125
97	20	0.7	3	1.000	1.007	2.125
98	20	0.8	3	1.000	1.174	2.125
99	20	0.9	3	1.000	1.345	2.125
100	20	1	3			
101	50	0.1	3	1.000	1.000	3.915
102	50	0.2	3	1.000	1.000	3.915
103	50	0.3	3	1.000	1.000	3.915
104	50	0.4	3	1.000	1.000	3.915
105	50	0.5	3	1.000	1.076	3.915
106	50	0.6	3	1.000	1.328	3.915
107	50	0.7	3	1.000	1.586	3.915
108	50	0.8	3	1.000	1.850	3.915
109	50	0.9	3	1.048	2.118	3.915
110	50	1	3			
111	100	0.1	3	1.000	1.000	6.214
112	100	0.2	3	1.000	1.000	6.214
113	100	0.3	3	1.000	1.000	6.214
114	100	0.4	3	1.000	1.174	6.214
115	100	0.5	3	1.000	1.518	6.214
116	100	0.6	3	1.000	1.872	6.214
117	100	0.7	3	1.171	2.236	6.214
118	100	0.8	3	1.411	2.608	6.214
119	100	0.9	3	1.664	2.987	6.214
120	100	1	3			

Pad or Saddle Reinforced Branch Connection (RFT) - Sketch 2.2 - Branch Inplane K

Item #	D/T	d/D	t/T	PRG kib tp=T	PRG kib tp=0	NB kib	EPRI ki
1	20	0.1	0.1				
2	20	0.2	0.2				
3	20	0.3	0.3	1.000	1.004	1.260	1.379
4	20	0.4	0.4	1.000	1.282	1.680	1.543
5	20	0.5	0.5	1.000	1.411	2.100	1.684
6	20	0.6	0.6	1.000	1.420	2.520	1.808
7	20	0.7	0.7	1.000	1.396	2.940	1.921
8	20	0.8	0.8	1.000	1.484	3.360	2.024
9	20	0.9	0.9	1.159	1.886	3.780	2.119
10	20	1	1	1.754	2.853	4.200	2.208
11	50	0.1	0.1				
12	50	0.2	0.2				
13	50	0.3	0.3	1.854	3.016	3.060	2.564
14	50	0.4	0.4	2.367	3.851	4.080	2.870
15	50	0.5	0.5	2.605	4.237	5.100	3.131
16	50	0.6	0.6	2.620	4.263	6.120	3.362
17	50	0.7	0.7	2.576	4.191	7.140	3.571
18	50	0.8	0.8	2.740	4.458	8.160	3.763
19	50	0.9	0.9	3.481	5.663	9.180	3.940
20	50	1	1	5.266	8.566	10.200	4.106
21	100	0.1	0.1				
22	100	0.2	0.2				
23	100	0.3	0.3	4.259	6.929	6.060	4.100
24	100	0.4	0.4	5.438	8.846	8.080	4.588
25	100	0.5	0.5	5.984	9.735	10.100	5.006
26	100	0.6	0.6	6.020	9.793	12.120	5.376
27	100	0.7	0.7	5.919	9.628	14.140	5.710
28	100	0.8	0.8	6.295	10.241	16.160	6.016
29	100	0.9	0.9	7.997	13.009	18.180	6.300
30	100	1	1	12.098	19.284	20.200	6.564
31	20	0.1	1				
32	20	0.2	1				
33	20	0.3	1	1.212	1.971	2.425	2.847
34	20	0.4	1	1.317	2.142	2.750	2.679
35	20	0.5	1	1.279	2.080	3.040	2.556
36	20	0.6	1	1.162	1.890	3.305	2.459
37	20	0.7	1	1.048	1.704	3.550	2.381
38	20	0.8	1	1.034	1.682	3.779	2.314
39	20	0.9	1	1.230	2.000	3.995	2.258
40	20	1	1	1.754	2.853	4.200	2.208
41	50	0.1	1				
42	50	0.2	1				
43	50	0.3	1	3.639	5.919	5.713	5.293
44	50	0.4	1	3.954	6.432	6.545	4.982
45	50	0.5	1	3.840	6.247	7.283	4.752
46	50	0.6	1	3.488	5.674	7.952	4.573
47	50	0.7	1	3.146	5.117	8.570	4.427
48	50	0.8	1	3.105	5.051	9.145	4.304
49	50	0.9	1	3.693	6.007	9.687	4.198
50	50	1	1	5.266	8.566	10.200	4.106
51	100	0.1	1				
52	100	0.2	1				
53	100	0.3	1	8.359	13.598	11.191	8.463
54	100	0.4	1	9.084	14.778	12.870	7.965
55	100	0.5	1	8.823	14.030	14.354	7.598
56	100	0.6	1	8.014	12.815	15.698	7.312
57	100	0.7	1	7.227	11.757	16.936	7.078
58	100	0.8	1	7.133	11.604	18.090	6.881
59	100	0.9	1	8.483	13.800	19.174	6.712
60	100	1	1	12.098	19.284	20.200	6.564
61	20	0.1	0.3				
62	20	0.2	0.3				
63	20	0.3	0.3	1.000	1.004	1.260	1.379
64	20	0.4	0.3	1.000	1.092	1.446	1.298
65	20	0.5	0.3	1.000	1.060	1.611	1.238
66	20	0.6	0.3	1.000	1.000	1.761	1.191
67	20	0.7	0.3	1.000	1.000	1.898	1.153

Item #	D/T	d/D	t/T	PRG kib tp=T	PRG kib tp=0	NB kib	EPRI ki
68	20	0.8	0.3	1.000	1.000	2.027	1.121
69	20	0.9	0.3	1.000	1.019	2.147	1.094
70	20	1	0.3	1.000	1.454	2.262	1.070
71	50	0.1	0.3				
72	50	0.2	0.3				
73	50	0.3	0.3	1.854	3.016	3.060	2.564
74	50	0.4	0.3	2.015	3.278	3.525	2.413
75	50	0.5	0.3	1.957	3.183	3.935	2.302
76	50	0.6	0.3	1.777	2.891	4.306	2.215
77	50	0.7	0.3	1.603	2.608	4.648	2.144
78	50	0.8	0.3	1.582	2.574	4.966	2.085
79	50	0.9	0.3	1.882	3.061	5.265	2.034
80	50	1	0.3	2.683	4.365	5.548	1.989
81	100	0.1	0.3				
82	100	0.2	0.3				
83	100	0.3	0.3	4.259	6.929	6.060	4.100
84	100	0.4	0.3	4.629	7.530	6.989	3.858
85	100	0.5	0.3	4.496	7.313	7.808	3.681
86	100	0.6	0.3	4.083	6.642	8.549	3.542
87	100	0.7	0.3	3.683	5.991	9.231	3.429
88	100	0.8	0.3	3.635	5.913	9.865	3.333
89	100	0.9	0.3				
90	100	1	0.3				
91	20	0.1	3				
92	20	0.2	3				
93	20	0.3	3	2.242	3.647	4.762	5.515
94	20	0.4	3	2.436	3.963	5.265	5.190
95	20	0.5	3	2.366	3.849	5.724	4.952
96	20	0.6	3	2.149	3.496	6.148	4.765
97	20	0.7	3	1.938	3.153	6.545	4.612
98	20	0.8	3	1.913	3.112	6.920	4.484
99	20	0.9	3	2.275	3.701	7.275	4.374
100	20	1	3				
101	50	0.1	3				
102	50	0.2	3				
103	50	0.3	3	6.732	10.950	10.496	10.255
104	50	0.4	3	7.316	11.900	11.864	9.651
105	50	0.5	3	7.105	11.557	13.090	9.208
106	50	0.6	3	6.453	10.498	14.211	8.860
107	50	0.7	3	5.820	9.468	15.250	8.577
108	50	0.8	3	5.744	9.344	16.222	8.338
109	50	0.9	3	6.831	11.113	17.139	8.134
110	50	1	3				
111	100	0.1	3				
112	100	0.2	3				
113	100	0.3	3	15.465	25.158	19.999	16.397
114	100	0.4	3	16.807	26.031	22.829	15.431
115	100	0.5	3	16.322	24.034	25.345	14.721
116	100	0.6	3	14.826	21.954	27.633	14.166
117	100	0.7	3	13.371	20.862	29.745	13.712
118	100	0.8	3	13.197	21.468	31.717	13.331
119	100	0.9	3	15.695	25.508	33.573	13.004
120	100	1	3				

STP-PT-073: Stress Intensity Factor and K-Factor Alignment for Metallic Pipes

Pad or Saddle Reinforced Branch Connection (RFT) - Sketch 2.2 - Branch Outplane K

Item #	D/T	d/D	t/T	PRG kob tp=T	PRG kob tp=0	NB kob	EPRI ko
1	20	0.1	0.1				
2	20	0.2	0.2				
3	20	0.3	0.3	1.278	2.536	2.887	2.668
4	20	0.4	0.4	1.800	3.571	3.849	3.475
5	20	0.5	0.5	2.198	4.361	4.812	4.028
6	20	0.6	0.6	2.425	4.812	5.774	4.279
7	20	0.7	0.7	2.465	4.892	6.736	4.206
8	20	0.8	0.8	2.331	4.626	7.699	3.805
9	20	0.9	0.9	2.063	4.094	8.661	3.088
10	20	1	1	1.728	3.428	9.623	2.080
11	50	0.1	0.1				
12	50	0.2	0.2				
13	50	0.3	0.3	6.013	11.932	10.926	6.688
14	50	0.4	0.4	8.467	16.800	14.569	8.713
15	50	0.5	0.5	10.339	20.516	18.211	10.099
16	50	0.6	0.6	11.409	22.638	21.853	10.728
17	50	0.7	0.7	11.599	23.015	25.495	10.544
18	50	0.8	0.8	10.968	21.763	29.137	9.539
19	50	0.9	0.9	9.706	19.259	32.779	7.741
20	50	1	1	8.129	16.129	36.421	5.214
21	100	0.1	0.1				
22	100	0.2	0.2				
23	100	0.3	0.3	19.402	38.193	30.451	13.403
24	100	0.4	0.4	27.318	51.915	40.601	17.462
25	100	0.5	0.5	33.360	62.052	50.752	20.239
26	100	0.6	0.6	36.812	67.727	60.902	21.500
27	100	0.7	0.7	37.425	68.742	71.053	21.132
28	100	0.8	0.8	35.389	65.479	81.203	19.117
29	100	0.9	0.9	31.317	58.841	91.353	15.515
30	100	1	1	26.228	50.209	101.504	10.449
31	20	0.1	1				
32	20	0.2	1				
33	20	0.3	1	2.898	5.751	5.556	6.325
34	20	0.4	1	3.356	6.659	6.300	6.704
35	20	0.5	1	3.521	6.987	6.965	6.622
36	20	0.6	1	3.432	6.811	7.572	6.172
37	20	0.7	1	3.142	6.235	8.133	5.432
38	20	0.8	1	2.713	5.384	8.659	4.465
39	20	0.9	1	2.216	4.398	9.154	3.330
40	20	1	1	1.728	3.428	9.623	2.080
41	50	0.1	1				
42	50	0.2	1				
43	50	0.3	1	13.636	27.056	20.400	15.856
44	50	0.4	1	15.788	31.326	23.371	16.806
45	50	0.5	1	16.565	32.869	26.005	16.600
46	50	0.6	1	16.148	32.041	28.396	15.473
47	50	0.7	1	14.783	29.332	30.600	13.616
48	50	0.8	1	12.765	25.329	32.656	11.194
49	50	0.9	1	10.427	20.690	34.590	8.349
50	50	1	1	8.129	16.129	36.421	5.214
51	100	0.1	1				
52	100	0.2	1				
53	100	0.3	1	43.996	78.652	56.234	31.778
54	100	0.4	1	50.940	89.961	64.672	33.683
55	100	0.5	1	53.448	94.053	72.128	33.269
56	100	0.6	1	52.101	92.018	78.884	31.010
57	100	0.7	1	47.697	85.146	85.104	27.290
58	100	0.8	1	41.188	74.859	90.900	22.434
59	100	0.9	1	33.643	62.680	96.348	16.732
60	100	1	1	26.228	50.209	101.504	10.449
61	20	0.1	0.3				
62	20	0.2	0.3				
63	20	0.3	0.3	1.278	2.536	2.887	2.668
64	20	0.4	0.3	1.480	2.937	3.314	2.828
65	20	0.5	0.3	1.553	3.081	3.691	2.793
66	20	0.6	0.3	1.514	3.003	4.034	2.603
67	20	0.7	0.3	1.386	2.750	4.350	2.291
68	20	0.8	0.3	1.197	2.374	4.644	1.883
69	20	0.9	0.3	1.000	1.939	4.920	1.405
70	20	1	0.3	1.000	1.512	5.182	1.000
71	50	0.1	0.3				
72	50	0.2	0.3				
73	50	0.3	0.3	6.013	11.932	10.926	6.688
74	50	0.4	0.3	6.962	13.815	12.586	7.089
75	50	0.5	0.3	7.305	14.495	14.050	7.002
76	50	0.6	0.3	7.121	14.130	15.376	6.526
77	50	0.7	0.3	6.519	12.936	16.597	5.743
78	50	0.8	0.3	5.629	11.170	17.733	4.721
79	50	0.9	0.3	4.598	9.124	18.801	3.521
80	50	1	0.3	3.585	7.113	19.811	2.199
81	100	0.1	0.3				
82	100	0.2	0.3				
83	100	0.3	0.3	19.402	38.193	30.451	13.403
84	100	0.4	0.3	22.465	43.684	35.118	14.207
85	100	0.5	0.3	23.571	45.671	39.234	14.032
86	100	0.6	0.3	22.977	44.683	42.958	13.080
87	100	0.7	0.3	21.035	41.346	46.383	11.511
88	100	0.8	0.3	18.164	36.042	49.572	9.462
89	100	0.9	0.3				
90	100	1	0.3				
91	20	0.1	3				
92	20	0.2	3				
93	20	0.3	3	6.118	12.139	10.912	13.904
94	20	0.4	3	7.083	14.055	12.064	14.738
95	20	0.5	3	7.432	14.747	13.114	14.557
96	20	0.6	3	7.245	14.376	14.087	13.569
97	20	0.7	3	6.632	13.160	14.997	11.941
98	20	0.8	3	5.727	11.364	15.855	9.816
99	20	0.9	3	4.678	9.283	16.668	7.321
100	20	1	3				
101	50	0.1	3				
102	50	0.2	3				
103	50	0.3	3	28.782	57.109	37.477	34.857
104	50	0.4	3	33.324	65.900	42.364	36.946
105	50	0.5	3	34.965	68.897	46.742	36.492
106	50	0.6	3	34.084	67.407	50.744	34.015
107	50	0.7	3	31.203	61.914	54.453	29.934
108	50	0.8	3	26.944	53.464	57.925	24.607
109	50	0.9	3	22.009	43.671	61.200	18.353
110	50	1	3				
111	100	0.1	3				
112	100	0.2	3				
113	100	0.3	3	92.866	152.049	100.494	69.858
114	100	0.4	3	107.522	173.911	114.714	74.046
115	100	0.5	3	112.817	181.821	127.356	73.136
116	100	0.6	3	109.974	177.887	138.852	68.171
117	100	0.7	3	100.677	164.602	149.466	59.992
118	100	0.8	3	86.938	144.716	159.375	49.317
119	100	0.9	3	71.014	121.173	168.703	36.783
120	100	1	3				

Pad or Saddle Reinforced Branch Connection (RFT) - Sketch 2.2 - Branch Torsional K

Item #	D/T	d/D	t/T	PRG ktb tp=T	PRG ktb tp=0	EPRI kt
1	20	0.1	0.1			
2	20	0.2	0.2			
3	20	0.3	0.3	1.000	1.000	1.000
4	20	0.4	0.4	1.000	1.000	1.000
5	20	0.5	0.5	1.000	1.000	1.000
6	20	0.6	0.6	1.000	1.000	1.104
7	20	0.7	0.7	1.000	1.000	1.528
8	20	0.8	0.8	1.000	1.038	2.025
9	20	0.9	0.9	1.605	1.965	2.597
10	20	1	1	2.840	3.479	3.243
11	50	0.1	0.1			
12	50	0.2	0.2			
13	50	0.3	0.3	1.000	1.000	1.000
14	50	0.4	0.4	1.000	1.000	1.000
15	50	0.5	0.5	1.000	1.000	1.000
16	50	0.6	0.6	1.000	1.000	1.323
17	50	0.7	0.7	1.000	1.000	1.832
18	50	0.8	0.8	1.340	1.641	2.428
19	50	0.9	0.9	2.537	3.107	3.113
20	50	1	1	4.491	5.500	3.888
21	100	0.1	0.1			
22	100	0.2	0.2			
23	100	0.3	0.3	1.000	1.000	1.000
24	100	0.4	0.4	1.000	1.000	1.000
25	100	0.5	0.5	1.000	1.000	1.033
26	100	0.6	0.6	1.000	1.000	1.518
27	100	0.7	0.7	1.000	1.125	2.101
28	100	0.8	0.8	1.895	2.321	2.785
29	100	0.9	0.9	3.588	4.394	3.571
30	100	1	1	6.351	7.778	4.460
31	20	0.1	1			
32	20	0.2	1			
33	20	0.3	1	1.000	1.000	1.000
34	20	0.4	1	1.000	1.000	1.000
35	20	0.5	1	1.000	1.000	1.102
36	20	0.6	1	1.000	1.000	1.464
37	20	0.7	1	1.000	1.000	1.861
38	20	0.8	1	1.000	1.038	2.291
39	20	0.9	1	1.605	1.965	2.752
40	20	1	1	2.840	3.479	3.243
41	50	0.1	1			
42	50	0.2	1			
43	50	0.3	1	1.000	1.000	1.000
44	50	0.4	1	1.000	1.000	1.000
45	50	0.5	1	1.000	1.000	1.321
46	50	0.6	1	1.000	1.000	1.755
47	50	0.7	1	1.000	1.000	2.231
48	50	0.8	1	1.340	1.641	2.747
49	50	0.9	1	2.537	3.107	3.300
50	50	1	1	4.491	5.500	3.888
51	100	0.1	1			
52	100	0.2	1			
53	100	0.3	1	1.000	1.000	1.000
54	100	0.4	1	1.000	1.000	1.071
55	100	0.5	1	1.000	1.000	1.516
56	100	0.6	1	1.000	1.000	2.013
57	100	0.7	1	1.000	1.125	2.560
58	100	0.8	1	1.895	2.321	3.151
59	100	0.9	1	3.588	4.394	3.785
60	100	1	1	6.351	7.778	4.460
61	20	0.1	0.3			
62	20	0.2	0.3			
63	20	0.3	0.3	1.000	1.000	1.000
64	20	0.4	0.3	1.000	1.000	1.000
65	20	0.5	0.3	1.000	1.000	1.000
66	20	0.6	0.3	1.000	1.000	1.000
67	20	0.7	0.3	1.000	1.000	1.000

Item #	D/T	d/D	t/T	PRG ktb tp=T	PRG ktb tp=0	EPRI kt
68	20	0.8	0.3	1.000	1.038	1.177
69	20	0.9	0.3	1.605	1.965	1.414
70	20	1	0.3	2.840	3.479	1.667
71	50	0.1	0.3			
72	50	0.2	0.3			
73	50	0.3	0.3	1.000	1.000	1.000
74	50	0.4	0.3	1.000	1.000	1.000
75	50	0.5	0.3	1.000	1.000	1.000
76	50	0.6	0.3	1.000	1.000	1.000
77	50	0.7	0.3	1.000	1.000	1.147
78	50	0.8	0.3	1.340	1.641	1.412
79	50	0.9	0.3	2.537	3.107	1.696
80	50	1	0.3	4.491	5.500	1.998
81	100	0.1	0.3			
82	100	0.2	0.3			
83	100	0.3	0.3	1.000	1.000	1.000
84	100	0.4	0.3	1.000	1.000	1.000
85	100	0.5	0.3	1.000	1.000	1.000
86	100	0.6	0.3	1.000	1.000	1.035
87	100	0.7	0.3	1.000	1.125	1.315
88	100	0.8	0.3	1.895	2.321	1.619
89	100	0.9	0.3			
90	100	1	0.3			
91	20	0.1	3			
92	20	0.2	3			
93	20	0.3	3	1.000	1.000	1.000
94	20	0.4	3	1.000	1.000	1.430
95	20	0.5	3	1.000	1.000	2.024
96	20	0.6	3	1.000	1.000	2.688
97	20	0.7	3	1.000	1.000	3.417
98	20	0.8	3	1.000	1.038	4.207
99	20	0.9	3	1.605	1.965	5.053
100	20	1	3			
101	50	0.1	3			
102	50	0.2	3			
103	50	0.3	3	1.000	1.000	1.095
104	50	0.4	3	1.000	1.000	1.714
105	50	0.5	3	1.000	1.000	2.426
106	50	0.6	3	1.000	1.000	3.222
107	50	0.7	3	1.000	1.000	4.097
108	50	0.8	3	1.340	1.641	5.043
109	50	0.9	3	2.537	3.107	6.058
110	50	1	3			
111	100	0.1	3			
112	100	0.2	3			
113	100	0.3	3	1.000	1.000	1.256
114	100	0.4	3	1.000	1.000	1.966
115	100	0.5	3	1.000	1.000	2.783
116	100	0.6	3	1.000	1.000	3.697
117	100	0.7	3	1.000	1.125	4.699
118	100	0.8	3	1.895	2.321	5.785
119	100	0.9	3	3.588	4.394	6.950
120	100	1	3			

Pad or Saddle Reinforced Branch Connection (RFT) - Sketch 2.2 - Header Inplane K

Item #	D/T	d/D	t/T	PRG kih tp=T	PRG kih tp=0	PRG kih tp=1.5T	Wais kih	PRG UFT kih
1	20	0.1	0.1	1.000	1.000	1.000	1.000	1.000
2	20	0.2	0.2	1.000	1.000	1.000	1.000	1.000
3	20	0.3	0.3	1.000	1.000	1.000	1.000	1.000
4	20	0.4	0.4	1.000	1.000	1.000	1.000	1.000
5	20	0.5	0.5	1.000	1.000	1.000	1.000	1.000
6	20	0.6	0.6	1.000	1.000	1.000	1.000	1.000
7	20	0.7	0.7	1.000	1.000	1.000	1.325	1.000
8	20	0.8	0.8	1.000	1.000	1.000	1.883	1.235
9	20	0.9	0.9	1.000	1.092	1.000	2.566	2.182
10	20	1	1	1.323	1.960	1.139	3.385	3.630
11	50	0.1	0.1	1.000	1.000	1.000	1.000	1.000
12	50	0.2	0.2	1.000	1.000	1.000	1.000	1.000
13	50	0.3	0.3	1.000	1.000	1.000	1.000	1.000
14	50	0.4	0.4	1.000	1.000	1.000	1.000	1.000
15	50	0.5	0.5	1.000	1.000	1.000	1.000	1.000
16	50	0.6	0.6	1.000	1.000	1.000	1.105	1.000
17	50	0.7	0.7	1.000	1.000	1.000	1.658	1.000
18	50	0.8	0.8	1.000	1.382	1.000	2.355	1.900
19	50	0.9	0.9	1.792	2.656	1.544	3.211	3.357
20	50	1	1	3.217	4.767	2.770	4.236	5.584
21	100	0.1	0.1	1.000	1.000	1.000	1.000	1.000
22	100	0.2	0.2	1.000	1.000	1.000	1.000	1.000
23	100	0.3	0.3	1.000	1.000	1.000	1.000	1.000
24	100	0.4	0.4	1.000	1.000	1.000	1.000	1.000
25	100	0.5	0.5	1.000	1.000	1.000	1.000	1.000
26	100	0.6	0.6	1.000	1.000	1.000	1.310	1.000
27	100	0.7	0.7	1.000	1.290	1.000	1.964	1.381
28	100	0.8	0.8	1.826	2.632	1.573	2.791	2.632
29	100	0.9	0.9	3.511	4.650	3.024	3.804	4.650
30	100	1	1	6.301	7.734	5.426	5.019	7.734
31	20	0.1	1	1.000	1.000	1.000	1.000	1.000
32	20	0.2	1	1.000	1.000	1.000	1.000	1.000
33	20	0.3	1	1.000	1.000	1.000	1.000	1.000
34	20	0.4	1	1.000	1.000	1.000	1.000	1.000
35	20	0.5	1	1.000	1.000	1.000	1.000	1.000
36	20	0.6	1	1.000	1.000	1.000	1.000	1.000
37	20	0.7	1	1.000	1.000	1.000	1.218	1.000
38	20	0.8	1	1.000	1.000	1.000	1.786	1.112
39	20	0.9	1	1.000	1.020	1.000	2.503	2.077
40	20	1	1	1.323	1.960	1.139	3.385	3.630
41	50	0.1	1	1.000	1.000	1.000	1.000	1.000
42	50	0.2	1	1.000	1.000	1.000	1.000	1.000
43	50	0.3	1	1.000	1.000	1.000	1.000	1.000
44	50	0.4	1	1.000	1.000	1.000	1.000	1.000
45	50	0.5	1	1.000	1.000	1.000	1.000	1.000
46	50	0.6	1	1.000	1.000	1.000	1.000	1.000
47	50	0.7	1	1.000	1.000	1.000	1.524	1.000
48	50	0.8	1	1.000	1.195	1.000	2.234	1.711
49	50	0.9	1	1.674	2.480	1.441	3.132	3.195
50	50	1	1	3.217	4.767	2.770	4.236	5.584
51	100	0.1	1	1.000	1.000	1.000	1.000	1.000
52	100	0.2	1	1.000	1.000	1.000	1.000	1.000
53	100	0.3	1	1.000	1.000	1.000	1.000	1.000
54	100	0.4	1	1.000	1.000	1.000	1.000	1.000
55	100	0.5	1	1.000	1.000	1.000	1.000	1.000
56	100	0.6	1	1.000	1.000	1.000	1.160	1.000
57	100	0.7	1	1.000	1.023	1.000	1.805	1.168
58	100	0.8	1	1.580	2.341	1.360	2.647	2.370
59	100	0.9	1	3.279	4.425	2.823	3.710	4.425
60	100	1	1	6.301	7.734	5.426	5.019	7.734
61	20	0.1	0.3	1.000	1.000	1.000	1.000	1.000
62	20	0.2	0.3	1.000	1.000	1.000	1.000	1.000
63	20	0.3	0.3	1.000	1.000	1.000	1.000	1.000
64	20	0.4	0.3	1.000	1.000	1.000	1.000	1.000
65	20	0.5	0.3	1.000	1.000	1.000	1.000	1.000
66	20	0.6	0.3	1.000	1.000	1.000	1.041	1.000
67	20	0.7	0.3	1.000	1.000	1.000	1.619	1.000
68	20	0.8	0.3	1.000	1.075	1.000	2.374	1.959
69	20	0.9	0.3	1.505	2.230	1.296	3.328	3.657
70	20	1	0.3	2.893	4.286	2.491	4.501	6.392
71	50	0.1	0.3	1.000	1.000	1.000	1.000	1.000
72	50	0.2	0.3	1.000	1.000	1.000	1.000	1.000
73	50	0.3	0.3	1.000	1.000	1.000	1.000	1.000
74	50	0.4	0.3	1.000	1.000	1.000	1.000	1.000
75	50	0.5	0.3	1.000	1.000	1.000	1.000	1.000
76	50	0.6	0.3	1.000	1.000	1.000	1.302	1.000
77	50	0.7	0.3	1.000	1.142	1.000	2.026	1.485
78	50	0.8	0.3	1.764	2.614	1.519	2.971	3.013
79	50	0.9	0.3	3.661	5.425	3.152	4.164	5.626
80	50	1	0.3	7.035	9.833	6.058	5.632	9.833
81	100	0.1	0.3	1.000	1.000	1.000	1.000	1.000
82	100	0.2	0.3	1.000	1.000	1.000	1.000	1.000
83	100	0.3	0.3	1.000	1.000	1.000	1.000	1.000
84	100	0.4	0.3	1.000	1.000	1.000	1.000	1.000
85	100	0.5	0.3	1.000	1.000	1.000	1.000	1.000
86	100	0.6	0.3	1.000	1.000	1.000	1.543	1.000
87	100	0.7	0.3	1.510	2.057	1.300	2.400	2.057
88	100	0.8	0.3	3.455	4.174	2.975	3.520	4.174
89	100	0.9	0.3					
90	100	1	0.3					
91	20	0.1	3	1.000	1.000	1.000	1.000	1.000
92	20	0.2	3	1.000	1.000	1.000	1.000	1.000
93	20	0.3	3	1.000	1.000	1.000	1.000	1.000
94	20	0.4	3	1.000	1.000	1.000	1.000	1.000
95	20	0.5	3	1.000	1.000	1.000	1.000	1.000
96	20	0.6	3	1.000	1.000	1.000	1.000	1.000
97	20	0.7	3	1.000	1.000	1.000	1.000	1.000
98	20	0.8	3	1.000	1.000	1.000	1.377	1.000
99	20	0.9	3	1.000	1.000	1.000	1.930	1.239
100	20	1	3					
101	50	0.1	3	1.000	1.000	1.000	1.000	1.000
102	50	0.2	3	1.000	1.000	1.000	1.000	1.000
103	50	0.3	3	1.000	1.000	1.000	1.000	1.000
104	50	0.4	3	1.000	1.000	1.000	1.000	1.000
105	50	0.5	3	1.000	1.000	1.000	1.000	1.000
106	50	0.6	3	1.000	1.000	1.000	1.000	1.000
107	50	0.7	3	1.000	1.000	1.000	1.175	1.000
108	50	0.8	3	1.000	1.000	1.000	1.723	1.021
109	50	0.9	3	1.000	1.214	1.000	2.415	1.906
110	50	1	3					
111	100	0.1	3	1.000	1.000	1.000	1.000	1.000
112	100	0.2	3	1.000	1.000	1.000	1.000	1.000
113	100	0.3	3	1.000	1.000	1.000	1.000	1.000
114	100	0.4	3	1.000	1.000	1.000	1.000	1.000
115	100	0.5	3	1.000	1.000	1.000	1.000	1.000
116	100	0.6	3	1.000	1.000	1.000	1.000	1.000
117	100	0.7	3	1.000	1.000	1.000	1.392	1.000
118	100	0.8	3	1.000	1.146	1.000	2.041	1.414
119	100	0.9	3	1.605	2.379	1.382	2.861	2.640
120	100	1	3					

Pad or Saddle Reinforced Branch Connection (RFT) - Sketch 2.2 - Header Torsional K

Item #	D/T	d/D	t/T	PRG kth tp=T	PRG kth tp=0	PRG kth tp=1.5T	Wais kth	PRG UFT kth
1	20	0.1	0.1	1.000	1.000	1.000	1.000	1.000
2	20	0.2	0.2	1.000	1.000	1.000	1.000	1.000
3	20	0.3	0.3	1.000	1.000	1.000	1.000	1.000
4	20	0.4	0.4	1.000	1.000	1.000	1.000	1.000
5	20	0.5	0.5	1.000	1.000	1.000	1.000	1.000
6	20	0.6	0.6	1.000	1.000	1.000	1.135	1.000
7	20	0.7	0.7	1.000	1.000	1.000	1.661	1.000
8	20	0.8	0.8	1.000	1.000	1.000	2.310	1.264
9	20	0.9	0.9	1.000	1.300	1.000	3.090	2.882
10	20	1	1	1.677	2.946	1.353	4.008	6.026
11	50	0.1	0.1	1.000	1.000	1.000	1.000	1.000
12	50	0.2	0.2	1.000	1.000	1.000	1.000	1.000
13	50	0.3	0.3	1.000	1.000	1.000	1.000	1.000
14	50	0.4	0.4	1.000	1.000	1.000	1.000	1.000
15	50	0.5	0.5	1.000	1.000	1.000	1.000	1.000
16	50	0.6	0.6	1.000	1.000	1.000	1.515	1.000
17	50	0.7	0.7	1.000	1.000	1.000	2.217	1.014
18	50	0.8	0.8	1.061	1.863	1.000	3.083	2.582
19	50	0.9	0.9	2.645	4.648	2.135	4.124	5.890
20	50	1	1	5.992	10.527	4.836	5.349	12.314
21	100	0.1	0.1	1.000	1.000	1.000	1.000	1.000
22	100	0.2	0.2	1.000	1.000	1.000	1.000	1.000
23	100	0.3	0.3	1.000	1.000	1.000	1.000	1.000
24	100	0.4	0.4	1.000	1.000	1.000	1.000	1.000
25	100	0.5	0.5	1.000	1.000	1.000	1.201	1.000
26	100	0.6	0.6	1.000	1.000	1.000	1.884	1.000
27	100	0.7	0.7	1.000	1.733	1.000	2.758	1.741
28	100	0.8	0.8	2.779	4.434	2.243	3.835	4.434
29	100	0.9	0.9	6.933	10.113	5.596	5.130	10.113
30	100	1	1	15.703	21.144	12.674	6.655	21.144
31	20	0.1	1	1.000	1.000	1.000	1.000	1.000
32	20	0.2	1	1.000	1.000	1.000	1.000	1.000
33	20	0.3	1	1.000	1.000	1.000	1.000	1.000
34	20	0.4	1	1.000	1.000	1.000	1.000	1.000
35	20	0.5	1	1.000	1.000	1.000	1.000	1.000
36	20	0.6	1	1.000	1.000	1.000	1.000	1.000
37	20	0.7	1	1.000	1.000	1.000	1.505	1.000
38	20	0.8	1	1.000	1.000	1.000	2.172	1.057
39	20	0.9	1	1.000	1.203	1.000	3.001	2.649
40	20	1	1	1.677	2.946	1.353	4.008	6.026
41	50	0.1	1	1.000	1.000	1.000	1.000	1.000
42	50	0.2	1	1.000	1.000	1.000	1.000	1.000
43	50	0.3	1	1.000	1.000	1.000	1.000	1.000
44	50	0.4	1	1.000	1.000	1.000	1.000	1.000
45	50	0.5	1	1.000	1.000	1.000	1.000	1.000
46	50	0.6	1	1.000	1.000	1.000	1.316	1.000
47	50	0.7	1	1.000	1.000	1.000	2.009	1.000
48	50	0.8	1	1.000	1.580	1.000	2.899	2.160
49	50	0.9	1	2.447	4.299	1.975	4.005	5.414
50	50	1	1	5.992	10.527	4.836	5.349	12.314
51	100	0.1	1	1.000	1.000	1.000	1.000	1.000
52	100	0.2	1	1.000	1.000	1.000	1.000	1.000
53	100	0.3	1	1.000	1.000	1.000	1.000	1.000
54	100	0.4	1	1.000	1.000	1.000	1.000	1.000
55	100	0.5	1	1.000	1.000	1.000	1.000	1.000
56	100	0.6	1	1.000	1.000	1.000	1.637	1.000
57	100	0.7	1	1.000	1.309	1.000	2.499	1.309
58	100	0.8	1	2.356	3.709	1.902	3.606	3.709
59	100	0.9	1	6.413	9.296	5.176	4.983	9.296
60	100	1	1	15.703	21.144	12.674	6.655	21.144
61	20	0.1	0.3	1.000	1.000	1.000	1.000	1.000
62	20	0.2	0.3	1.000	1.000	1.000	1.000	1.000
63	20	0.3	0.3	1.000	1.000	1.000	1.000	1.000
64	20	0.4	0.3	1.000	1.000	1.000	1.000	1.000
65	20	0.5	0.3	1.000	1.000	1.000	1.000	1.000
66	20	0.6	0.3	1.000	1.000	1.000	1.374	1.000
67	20	0.7	0.3	1.000	1.000	1.000	2.098	1.000

Item #	D/T	d/D	t/T	PRG kth tp=T	PRG kth tp=0	PRG kth tp=1.5T	Wais kth	PRG UFT kth
68	20	0.8	0.3	1.000	1.077	1.000	3.028	2.770
69	20	0.9	0.3	1.669	2.932	1.347	4.184	6.941
70	20	1	0.3	4.086	7.180	3.298	5.588	15.787
71	50	0.1	0.3	1.000	1.000	1.000	1.000	1.000
72	50	0.2	0.3	1.000	1.000	1.000	1.000	1.000
73	50	0.3	0.3	1.000	1.000	1.000	1.000	1.000
74	50	0.4	0.3	1.000	1.000	1.000	1.000	1.000
75	50	0.5	0.3	1.000	1.000	1.000	1.112	1.000
76	50	0.6	0.3	1.000	1.000	1.000	1.834	1.000
77	50	0.7	0.3	1.000	1.238	1.000	2.801	1.997
78	50	0.8	0.3	2.192	3.850	1.769	4.041	5.660
79	50	0.9	0.3	5.964	10.479	4.814	5.584	14.184
80	50	1	0.3	14.604	25.659	11.788	7.458	32.262
81	100	0.1	0.3	1.000	1.000	1.000	1.000	1.000
82	100	0.2	0.3	1.000	1.000	1.000	1.000	1.000
83	100	0.3	0.3	1.000	1.000	1.000	1.000	1.000
84	100	0.4	0.3	1.000	1.000	1.000	1.000	1.000
85	100	0.5	0.3	1.000	1.000	1.000	1.383	1.000
86	100	0.6	0.3	1.000	1.000	1.000	2.282	1.031
87	100	0.7	0.3	1.846	3.243	1.490	3.484	3.430
88	100	0.8	0.3	5.744	9.719	4.636	5.027	9.719
89	100	0.9	0.3					
90	100	1	0.3					
91	20	0.1	3	1.000	1.000	1.000	1.000	1.000
92	20	0.2	3	1.000	1.000	1.000	1.000	1.000
93	20	0.3	3	1.000	1.000	1.000	1.000	1.000
94	20	0.4	3	1.000	1.000	1.000	1.000	1.000
95	20	0.5	3	1.000	1.000	1.000	1.000	1.000
96	20	0.6	3	1.000	1.000	1.000	1.000	1.000
97	20	0.7	3	1.000	1.000	1.000	1.111	1.000
98	20	0.8	3	1.000	1.000	1.000	1.604	1.000
99	20	0.9	3	1.000	1.000	1.000	2.216	1.100
100	20	1	3					
101	50	0.1	3	1.000	1.000	1.000	1.000	1.000
102	50	0.2	3	1.000	1.000	1.000	1.000	1.000
103	50	0.3	3	1.000	1.000	1.000	1.000	1.000
104	50	0.4	3	1.000	1.000	1.000	1.000	1.000
105	50	0.5	3	1.000	1.000	1.000	1.000	1.000
106	50	0.6	3	1.000	1.000	1.000	1.000	1.000
107	50	0.7	3	1.000	1.000	1.000	1.483	1.000
108	50	0.8	3	1.000	1.000	1.000	2.140	1.000
109	50	0.9	3	1.085	1.907	1.000	2.958	2.248
110	50	1	3					
111	100	0.1	3	1.000	1.000	1.000	1.000	1.000
112	100	0.2	3	1.000	1.000	1.000	1.000	1.000
113	100	0.3	3	1.000	1.000	1.000	1.000	1.000
114	100	0.4	3	1.000	1.000	1.000	1.000	1.000
115	100	0.5	3	1.000	1.000	1.000	1.000	1.000
116	100	0.6	3	1.000	1.000	1.000	1.208	1.000
117	100	0.7	3	1.000	1.000	1.000	1.845	1.000
118	100	0.8	3	1.045	1.540	1.000	2.663	1.540
119	100	0.9	3	2.844	3.860	2.296	3.680	3.860
120	100	1	3					

Unreinforced Fabricated Tee (UFT) - Sketch 2.3 - Branch Inplane SIF

Item #	D/T	d/D	t/T	PRG ii	Widera ii	Wais ii	B31.3 ii	WRC329 Eq. 46 ii
1	20	0.1	0.1					
2	20	0.2	0.2					
3	20	0.3	0.3	1.692	1.636	1.314	1.015	1.000
4	20	0.4	0.4	1.849	1.979	1.513	1.353	1.095
5	20	0.5	0.5	1.916	2.069	1.688	1.692	1.409
6	20	0.6	0.6	1.939	2.047	1.845	2.030	1.763
7	20	0.7	0.7	1.965	2.055	1.990	2.368	2.175
8	20	0.8	0.8	2.040	2.233	2.125	2.706	2.665
9	20	0.9	0.9	2.209	2.723	2.251	3.045	3.257
10	20	1	1	2.520	3.668	2.370	3.383	3.979
11	50	0.1	0.1					
12	50	0.2	0.2					
13	50	0.3	0.3	3.395	2.531	2.412	1.806	1.529
14	50	0.4	0.4	3.710	3.062	2.777	2.408	2.076
15	50	0.5	0.5	3.845	3.202	3.098	3.011	2.672
16	50	0.6	0.6	3.891	3.167	3.388	3.613	3.344
17	50	0.7	0.7	3.943	3.179	3.654	4.215	4.124
18	50	0.8	0.8	4.093	3.455	3.901	4.817	5.053
19	50	0.9	0.9	4.433	4.214	4.133	5.419	6.176
20	50	1	1	5.057	5.675	4.352	6.021	7.544
21	100	0.1	0.1					
22	100	0.2	0.2					
23	100	0.3	0.3	5.750	3.521	3.820	2.823	2.451
24	100	0.4	0.4	6.284	4.260	4.398	3.764	3.328
25	100	0.5	0.5	6.511	4.454	4.906	4.706	4.283
26	100	0.6	0.6	6.590	4.406	5.364	5.647	5.360
27	100	0.7	0.7	6.678	4.422	5.785	6.588	6.612
28	100	0.8	0.8	6.931	4.806	6.176	7.529	8.101
29	100	0.9	0.9	7.508	5.862	6.543	8.470	9.901
30	100	1	1	8.564	7.895	6.890	9.411	12.094
31	20	0.1	1					
32	20	0.2	1					
33	20	0.3	1	1.692	1.879	2.094	3.383	2.419
34	20	0.4	1	1.849	2.023	2.157	3.383	2.555
35	20	0.5	1	1.916	2.069	2.207	3.383	2.690
36	20	0.6	1	1.939	2.047	2.249	3.383	2.848
37	20	0.7	1	1.965	2.065	2.285	3.383	3.045
38	20	0.8	1	2.040	2.233	2.316	3.383	3.292
39	20	0.9	1	2.209	2.723	2.345	3.383	3.600
40	20	1	1	2.520	3.668	2.370	3.383	3.979
41	50	0.1	1					
42	50	0.2	1					
43	50	0.3	1	3.395	3.042	3.844	6.021	4.874
44	50	0.4	1	3.710	3.275	3.960	6.021	5.042
45	50	0.5	1	3.845	3.321	4.052	6.021	5.241
46	50	0.6	1	3.891	3.303	4.128	6.021	5.501
47	50	0.7	1	3.943	3.343	4.195	6.021	5.843
48	50	0.8	1	4.093	3.566	4.253	6.021	6.286
49	50	0.9	1	4.433	4.214	4.305	6.021	6.848
50	50	1	1	5.057	5.675	4.352	6.021	7.544
51	100	0.1	1					
52	100	0.2	1					
53	100	0.3	1	5.750	4.381	6.087	9.411	7.987
54	100	0.4	1	6.284	4.716	6.270	9.411	8.199
55	100	0.5	1	6.511	4.782	6.415	9.411	8.483
56	100	0.6	1	6.590	4.755	6.537	9.411	8.875
57	100	0.7	1	6.678	4.814	6.642	9.411	9.405
58	100	0.8	1	6.931	5.134	6.734	9.411	10.102
59	100	0.9	1	7.508	5.894	6.816	9.411	10.989
60	100	1	1	8.564	7.895	6.890	9.411	12.094
61	20	0.1	0.3					
62	20	0.2	0.3					
63	20	0.3	0.3	1.692	1.636	1.314	1.015	1.000
64	20	0.4	0.3	1.849	1.979	1.354	1.015	1.000
65	20	0.5	0.3	1.916	2.069	1.385	1.015	1.000
66	20	0.6	0.3	1.939	2.047	1.411	1.015	1.000
67	20	0.7	0.3	1.965	2.055	1.434	1.015	1.000
68	20	0.8	0.3	2.040	2.233	1.454	1.015	1.030
69	20	0.9	0.3	2.209	2.723	1.471	1.015	1.121
70	20	1	0.3	2.520	3.668	1.487	3.383	1.235
71	50	0.1	0.3					
72	50	0.2	0.3					
73	50	0.3	0.3	3.395	2.531	2.412	1.806	1.529
74	50	0.4	0.3	3.710	3.062	2.485	1.806	1.565
75	50	0.5	0.3	3.845	3.202	2.543	1.806	1.616
76	50	0.6	0.3	3.891	3.167	2.591	1.806	1.688
77	50	0.7	0.3	3.943	3.179	2.632	1.806	1.788
78	50	0.8	0.3	4.093	3.455	2.669	1.806	1.919
79	50	0.9	0.3	4.433	4.214	2.701	1.806	2.086
80	50	1	0.3	5.057	5.675	2.731	6.021	2.295
81	100	0.1	0.3					
82	100	0.2	0.3					
83	100	0.3	0.3	5.750	3.521	3.820	2.823	2.451
84	100	0.4	0.3	6.284	4.260	3.934	2.823	2.502
85	100	0.5	0.3	6.511	4.454	4.026	2.823	2.580
86	100	0.6	0.3	6.590	4.406	4.102	2.823	2.693
87	100	0.7	0.3	6.678	4.422	4.168	2.823	2.850
88	100	0.8	0.3	6.931	4.806	4.226	2.823	3.057
89	100	0.9	0.3	7.508	5.862	4.277	2.823	3.322
90	100	1	0.3	8.564	7.895	4.324	9.411	3.654
91	20	0.1	3					
92	20	0.2	3					
93	20	0.3	3	3.815	4.584	3.203	10.149	5.645
94	20	0.4	3	4.169	4.935	3.300	10.149	6.271
95	20	0.5	3	4.320	5.004	3.376	10.149	6.828
96	20	0.6	3	4.373	4.977	3.440	10.149	7.406
97	20	0.7	3	4.431	5.038	3.495	10.149	8.060
98	20	0.8	3	4.599	5.373	3.544	10.149	8.837
99	20	0.9	3	4.981	6.168	3.587	10.149	9.772
100	20	1	3	5.683	7.608	3.626	3.383	3.633
101	50	0.1	3					
102	50	0.2	3					
103	50	0.3	3	7.655	7.423	5.881	18.064	12.998
104	50	0.4	3	8.366	7.992	6.058	18.064	13.811
105	50	0.5	3	8.669	8.103	6.198	18.064	14.600
106	50	0.6	3	8.774	8.059	6.316	18.064	15.502
107	50	0.7	3	8.890	8.158	6.417	18.064	16.606
108	50	0.8	3	9.228	8.701	6.506	18.064	17.981
109	50	0.9	3	9.995	9.988	6.585	18.064	19.687
110	50	1	3	11.402	12.319	6.657	6.021	7.259
111	100	0.1	3					
112	100	0.2	3					
113	100	0.3	3	12.964	10.689	9.311	28.233	22.509
114	100	0.4	3	14.167	11.507	9.591	28.233	23.453
115	100	0.5	3	14.680	11.668	9.814	28.233	24.487
116	100	0.6	3	14.858	11.604	10.000	28.233	25.779
117	100	0.7	3	15.056	11.747	10.161	28.233	27.443
118	100	0.8	3	15.627	12.529	10.301	28.233	29.575
119	100	0.9	3	16.927	14.382	10.427	28.233	32.259
120	100	1	3	19.309	17.738	10.541	9.411	11.859

Unreinforced Fabricated Tee (UFT) - Sketch 2.3 - Branch Outplane SIF

Item #	D/T	d/D	t/T	PRG io	Widera io	Wais io	B31.3 io	NC
1	20	0.1	0.1					
2	20	0.2	0.2					
3	20	0.3	0.3	2.897	2.412	2.052	1.253	1.500
4	20	0.4	0.4	3.786	3.699	2.984	1.671	1.677
5	20	0.5	0.5	4.539	4.378	3.878	2.089	2.344
6	20	0.6	0.6	5.083	4.617	4.616	2.506	3.082
7	20	0.7	0.7	5.345	4.536	5.049	2.924	3.883
8	20	0.8	0.8	5.250	4.225	4.993	3.342	4.745
9	20	0.9	0.9	5.005	3.761	4.227	3.760	5.662
10	20	1	1	4.354	3.210	2.491	4.177	3.979
11	50	0.1	0.1					
12	50	0.2	0.2					
13	50	0.3	0.3	6.556	5.029	4.438	2.308	2.066
14	50	0.4	0.4	8.903	7.712	6.454	3.078	3.181
15	50	0.5	0.5	10.513	9.128	8.389	3.847	4.445
16	50	0.6	0.6	10.962	9.628	9.985	4.617	5.844
17	50	0.7	0.7	10.011	9.458	10.921	5.386	7.364
18	50	0.8	0.8	9.671	8.810	10.800	6.156	8.997
19	50	0.9	0.9	9.219	7.842	9.143	6.925	10.735
20	50	1	1	8.020	6.909	5.388	7.695	7.544
21	100	0.1	0.1					
22	100	0.2	0.2					
23	100	0.3	0.3	13.173	8.767	7.956	3.664	3.312
24	100	0.4	0.4	17.888	13.446	11.569	4.886	5.099
25	100	0.5	0.5	21.122	15.915	15.037	6.107	7.126
26	100	0.6	0.6	22.025	16.787	17.899	7.329	9.368
27	100	0.7	0.7	20.114	16.491	19.577	8.550	11.805
28	100	0.8	0.8	15.461	15.360	19.359	9.772	14.423
29	100	0.9	0.9	14.635	13.719	16.390	10.993	17.210
30	100	1	1	12.731	12.869	9.658	12.215	12.094
31	20	0.1	1					
32	20	0.2	1					
33	20	0.3	1	3.408	2.853	4.017	4.177	3.269
34	20	0.4	1	4.454	3.391	4.975	4.177	3.914
35	20	0.5	1	5.340	3.797	5.710	4.177	4.476
36	20	0.6	1	5.980	4.060	6.139	4.177	4.978
37	20	0.7	1	6.288	4.146	6.161	4.177	5.437
38	20	0.8	1	6.177	3.995	5.655	4.177	5.861
39	20	0.9	1	5.561	3.662	4.483	4.177	6.257
40	20	1	1	4.354	3.210	2.491	4.177	3.979
41	50	0.1	1					
42	50	0.2	1					
43	50	0.3	1	6.278	6.492	8.689	7.695	6.585
44	50	0.4	1	8.204	7.715	10.762	7.695	7.725
45	50	0.5	1	9.837	8.640	12.350	7.695	8.720
46	50	0.6	1	11.016	9.214	13.279	7.695	9.614
47	50	0.7	1	11.583	9.382	13.326	7.695	10.432
48	50	0.8	1	11.378	9.090	12.232	7.695	11.191
49	50	0.9	1	10.244	8.284	9.697	7.695	11.902
50	50	1	1	8.020	6.909	5.388	7.695	7.544
51	100	0.1	1					
52	100	0.2	1					
53	100	0.3	1	9.966	12.091	15.576	12.215	10.791
54	100	0.4	1	13.024	14.368	19.290	12.215	12.562
55	100	0.5	1	15.615	16.092	22.138	12.215	14.113
56	100	0.6	1	17.486	17.161	23.803	12.215	15.511
57	100	0.7	1	18.386	17.474	23.888	12.215	16.793
58	100	0.8	1	18.062	16.931	21.926	12.215	17.984
59	100	0.9	1	16.261	15.429	17.382	12.215	19.101
60	100	1	1	12.731	12.869	9.658	12.215	12.094
61	20	0.1	0.3					
62	20	0.2	0.3					
63	20	0.3	0.3	2.897	2.412	2.052	1.253	1.500
64	20	0.4	0.3	3.786	3.977	2.541	1.253	1.500
65	20	0.5	0.3	4.539	4.979	2.916	1.253	1.500
66	20	0.6	0.3	5.083	5.499	3.136	1.253	1.578
67	20	0.7	0.3	5.345	5.616	3.147	1.253	1.711
68	20	0.8	0.3	5.250	5.409	2.888	1.253	1.834
69	20	0.9	0.3	4.727	4.960	2.290	1.253	1.949
70	20	1	0.3	3.701	4.348	1.272	4.177	4.116
71	50	0.1	0.3					
72	50	0.2	0.3					
73	50	0.3	0.3	6.556	5.029	4.438	2.308	2.066
74	50	0.4	0.3	8.568	8.292	5.497	2.308	2.397
75	50	0.5	0.3	10.272	10.382	6.308	2.308	2.688
76	50	0.6	0.3	11.503	11.466	6.782	2.308	2.951
77	50	0.7	0.3	12.095	11.710	6.807	2.308	3.192
78	50	0.8	0.3	11.882	11.280	6.248	2.308	3.416
79	50	0.9	0.3	10.697	10.344	4.953	2.308	3.626
80	50	1	0.3	6.817	9.067	2.752	7.695	7.649
81	100	0.1	0.3					
82	100	0.2	0.3					
83	100	0.3	0.3	13.173	8.767	7.956	3.664	3.312
84	100	0.4	0.3	17.215	14.457	9.853	3.664	3.834
85	100	0.5	0.3	20.640	18.102	11.308	3.664	4.293
86	100	0.6	0.3	23.114	19.991	12.158	3.664	4.707
87	100	0.7	0.3	24.303	20.416	12.201	3.664	5.088
88	100	0.8	0.3	23.874	19.667	11.199	3.664	5.442
89	100	0.9	0.3	21.494	18.034	8.878	3.664	5.775
90	100	1	0.3	10.821	15.809	4.933	12.215	12.178
91	20	0.1	3					
92	20	0.2	3					
93	20	0.3	3	10.225	9.713	7.416	12.532	7.627
94	20	0.4	3	13.362	11.542	9.184	12.532	9.607
95	20	0.5	3	16.020	12.927	10.540	12.532	11.361
96	20	0.6	3	17.941	13.785	11.332	12.532	12.943
97	20	0.7	3	18.864	14.037	11.373	12.532	14.392
98	20	0.8	3	18.531	13.600	10.439	12.532	15.732
99	20	0.9	3	16.683	12.394	8.276	12.532	16.985
100	20	1	3	13.061	10.337	4.598	4.177	3.633
101	50	0.1	3					
102	50	0.2	3					
103	50	0.3	3	18.835	22.099	16.040	23.085	17.561
104	50	0.4	3	24.613	26.261	19.866	23.085	21.159
105	50	0.5	3	29.510	29.411	22.799	23.085	24.291
106	50	0.6	3	33.047	31.365	24.513	23.085	27.093
107	50	0.7	3	34.748	31.938	24.600	23.085	29.649
108	50	0.8	3	34.135	30.944	22.580	23.085	32.012
109	50	0.9	3	30.731	28.200	17.901	23.085	34.219
110	50	1	3	24.059	23.520	9.946	7.695	7.259
111	100	0.1	3					
112	100	0.2	3					
113	100	0.3	3	29.898	41.158	28.753	36.645	30.411
114	100	0.4	3	39.071	48.910	35.610	36.645	35.932
115	100	0.5	3	46.844	54.777	40.867	36.645	40.742
116	100	0.6	3	52.459	58.416	43.940	36.645	45.055
117	100	0.7	3	55.158	59.482	44.097	36.645	48.999
118	100	0.8	3	54.185	57.632	40.475	36.645	52.652
119	100	0.9	3	48.782	52.521	32.088	36.645	56.071
120	100	1	3	38.192	43.805	17.829	12.215	11.859

Unreinforced Fabricated Tee (UFT) - Sketch 2.3 - Branch Torsional SIF

Item #	D/T	d/D	t/T	PRG it	WRC329 Eq. 42 it	Wais it	B31.3 io	NC
1	20	0.1	0.1					
2	20	0.2	0.2					
3	20	0.3	0.3	1.000	1.000	1.000	1.253	1.500
4	20	0.4	0.4	1.000	1.000	1.000	1.671	1.677
5	20	0.5	0.5	1.000	1.172	1.000	2.089	2.344
6	20	0.6	0.6	1.000	1.849	1.000	2.506	3.082
7	20	0.7	0.7	1.255	2.718	1.271	2.924	3.883
8	20	0.8	0.8	1.703	3.796	1.682	3.342	4.745
9	20	0.9	0.9	2.231	5.095	2.154	3.760	5.662
10	20	1	1	2.839	3.979	2.688	4.177	3.979
11	50	0.1	0.1					
12	50	0.2	0.2					
13	50	0.3	0.3	1.000	1.000	1.000	2.308	2.066
14	50	0.4	0.4	1.000	1.272	1.000	3.078	3.181
15	50	0.5	0.5	1.208	2.223	1.000	3.847	4.445
16	50	0.6	0.6	1.835	3.506	1.454	4.617	5.844
17	50	0.7	0.7	2.611	5.155	2.010	5.386	7.364
18	50	0.8	0.8	3.545	7.197	2.660	6.156	8.997
19	50	0.9	0.9	4.643	9.662	3.406	6.925	10.735
20	50	1	1	5.910	7.544	4.250	7.695	7.544
21	100	0.1	0.1					
22	100	0.2	0.2					
23	100	0.3	0.3	1.000	1.000	1.000	3.664	3.312
24	100	0.4	0.4	1.262	2.040	1.000	4.886	5.099
25	100	0.5	0.5	2.104	3.563	1.402	6.107	7.126
26	100	0.6	0.6	3.194	5.621	2.056	7.329	9.368
27	100	0.7	0.7	4.546	8.263	2.842	8.550	11.805
28	100	0.8	0.8	6.173	11.538	3.762	9.772	14.423
29	100	0.9	0.9	8.084	15.489	4.817	10.993	17.210
30	100	1	1	10.289	12.094	6.010	12.215	12.094
31	20	0.1	1					
32	20	0.2	1					
33	20	0.3	1	1.000	1.000	1.000	4.177	3.269
34	20	0.4	1	1.000	1.566	1.000	4.177	3.914
35	20	0.5	1	1.000	2.238	1.000	4.177	4.476
36	20	0.6	1	1.022	2.987	1.187	4.177	4.978
37	20	0.7	1	1.391	3.806	1.519	4.177	5.437
38	20	0.8	1	1.817	4.689	1.881	4.177	5.861
39	20	0.9	1	2.300	5.632	2.271	4.177	6.257
40	20	1	1	2.839	3.979	2.688	4.177	3.979
41	50	0.1	1					
42	50	0.2	1					
43	50	0.3	1	1.000	1.976	1.000	7.695	6.585
44	50	0.4	1	1.000	3.090	1.000	7.695	7.725
45	50	0.5	1	1.477	4.360	1.402	7.695	8.720
46	50	0.6	1	2.127	5.768	1.877	7.695	9.614
47	50	0.7	1	2.896	7.302	2.402	7.695	10.432
48	50	0.8	1	3.782	8.953	2.974	7.695	11.191
49	50	0.9	1	4.787	10.712	3.591	7.695	11.902
50	50	1	1	5.910	7.544	4.250	7.695	7.544
51	100	0.1	1					
52	100	0.2	1					
53	100	0.3	1	1.000	3.237	1.000	12.215	10.791
54	100	0.4	1	1.646	5.025	1.387	12.215	12.562
55	100	0.5	1	2.572	7.057	1.983	12.215	14.113
56	100	0.6	1	3.704	9.306	2.654	12.215	15.511
57	100	0.7	1	5.042	11.755	3.397	12.215	16.793
58	100	0.8	1	6.585	14.387	4.206	12.215	17.984
59	100	0.9	1	8.334	17.191	5.078	12.215	19.101
60	100	1	1	10.289	12.094	6.010	12.215	12.094
61	20	0.1	0.3					
62	20	0.2	0.3					
63	20	0.3	0.3	1.000	1.000	1.000	1.253	1.500
64	20	0.4	0.3	1.000	1.000	1.000	1.253	1.500
65	20	0.5	0.3	1.000	1.000	1.000	1.253	1.500
66	20	0.6	0.3	1.000	1.000	1.000	1.253	1.578
67	20	0.7	0.3	1.000	1.198	1.000	1.253	1.711
68	20	0.8	0.3	1.282	1.467	1.030	1.253	1.834
69	20	0.9	0.3	1.622	1.754	1.244	1.253	1.949
70	20	1	0.3	2.003	4.116	1.472	4.177	4.116
71	50	0.1	0.3					
72	50	0.2	0.3					
73	50	0.3	0.3	1.000	1.000	1.000	2.308	2.066
74	50	0.4	0.3	1.000	1.000	1.000	2.308	2.397
75	50	0.5	0.3	1.042	1.344	1.000	2.308	2.688
76	50	0.6	0.3	1.500	1.770	1.028	2.308	2.951
77	50	0.7	0.3	2.042	2.234	1.316	2.308	3.192
78	50	0.8	0.3	2.668	2.733	1.629	2.308	3.416
79	50	0.9	0.3	3.376	3.263	1.967	2.308	3.626
80	50	1	0.3	4.168	7.649	2.328	7.695	7.649
81	100	0.1	0.3					
82	100	0.2	0.3					
83	100	0.3	0.3	1.000	1.000	1.000	3.664	3.312
84	100	0.4	0.3	1.161	1.534	1.000	3.664	3.834
85	100	0.5	0.3	1.814	2.146	1.086	3.664	4.293
86	100	0.6	0.3	2.612	2.824	1.454	3.664	4.707
87	100	0.7	0.3	3.556	3.562	1.860	3.664	5.088
88	100	0.8	0.3	4.644	4.354	2.304	3.664	5.442
89	100	0.9	0.3	5.878	5.197	2.781	3.664	5.775
90	100	1	0.3	7.257	12.178	3.292	12.215	12.178
91	20	0.1	3					
92	20	0.2	3					
93	20	0.3	3	1.000	2.288	1.000	12.532	7.627
94	20	0.4	3	1.000	3.843	1.075	12.532	9.607
95	20	0.5	3	1.000	5.681	1.536	12.532	11.361
96	20	0.6	3	1.406	7.766	2.056	12.532	12.943
97	20	0.7	3	1.913	10.074	2.631	12.532	14.392
98	20	0.8	3	2.499	12.586	3.258	12.532	15.732
99	20	0.9	3	3.163	15.286	3.933	12.532	16.985
100	20	1	3	3.905	3.633	4.656	4.177	3.633
101	50	0.1	3					
102	50	0.2	3					
103	50	0.3	3	1.000	5.268	1.072	23.085	17.561
104	50	0.4	3	1.300	8.464	1.699	23.085	21.159
105	50	0.5	3	2.032	12.145	2.428	23.085	24.291
106	50	0.6	3	2.926	16.256	3.251	23.085	27.093
107	50	0.7	3	3.982	20.754	4.160	23.085	29.649
108	50	0.8	3	5.201	25.609	5.151	23.085	32.012
109	50	0.9	3	6.583	30.797	6.219	23.085	34.219
110	50	1	3	8.127	7.259	7.361	7.695	7.259
111	100	0.1	3					
112	100	0.2	3					
113	100	0.3	3	1.273	9.123	1.517	36.645	30.411
114	100	0.4	3	2.264	14.373	2.403	36.645	35.932
115	100	0.5	3	3.537	20.371	3.434	36.645	40.742
116	100	0.6	3	5.094	27.033	4.597	36.645	45.055
117	100	0.7	3	6.933	34.299	5.883	36.645	48.999
118	100	0.8	3	9.056	42.122	7.285	36.645	52.652
119	100	0.9	3	11.461	50.464	8.795	36.645	56.071
120	100	1	3	14.150	11.859	10.410	12.215	11.859

Unreinforced Fabricated Tee (UFT) - Sketch 2.3 - Header Inplane SIF

Item #	D/T	d/D	t/T	PRG ii	Wais ii	B31.3 ii
1	20	0.1	0.1			
2	20	0.2	0.2			
3	20	0.3	0.3	2.516	1.631	3.383
4	20	0.4	0.4	2.627	1.748	3.383
5	20	0.5	0.5	2.717	1.845	3.383
6	20	0.6	0.6	2.792	1.927	3.383
7	20	0.7	0.7	2.857	2.000	3.383
8	20	0.8	0.8	2.915	2.066	3.383
9	20	0.9	0.9	2.967	2.125	3.383
10	20	1	1	3.014	2.180	3.383
11	50	0.1	0.1			
12	50	0.2	0.2			
13	50	0.3	0.3	3.630	2.237	6.021
14	50	0.4	0.4	3.790	2.398	6.021
15	50	0.5	0.5	3.919	2.530	6.021
16	50	0.6	0.6	4.028	2.644	6.021
17	50	0.7	0.7	4.122	2.744	6.021
18	50	0.8	0.8	4.206	2.834	6.021
19	50	0.9	0.9	4.280	2.915	6.021
20	50	1	1	4.349	2.990	6.021
21	100	0.1	0.1			
22	100	0.2	0.2			
23	100	0.3	0.3	4.790	2.842	9.411
24	100	0.4	0.4	5.001	3.046	9.411
25	100	0.5	0.5	5.171	3.214	9.411
26	100	0.6	0.6	5.315	3.358	9.411
27	100	0.7	0.7	5.439	3.485	9.411
28	100	0.8	0.8	5.549	3.599	9.411
29	100	0.9	0.9	5.648	3.703	9.411
30	100	1	1	5.738	3.798	9.411
31	20	0.1	1			
32	20	0.2	1			
33	20	0.3	1	1.651	1.000	3.383
34	20	0.4	1	1.906	1.124	3.383
35	20	0.5	1	2.131	1.321	3.383
36	20	0.6	1	2.335	1.507	3.383
37	20	0.7	1	2.522	1.684	3.383
38	20	0.8	1	2.696	1.855	3.383
39	20	0.9	1	2.860	2.020	3.383
40	20	1	1	3.014	2.180	3.383
41	50	0.1	1			
42	50	0.2	1			
43	50	0.3	1	2.382	1.252	6.021
44	50	0.4	1	2.750	1.542	6.021
45	50	0.5	1	3.075	1.812	6.021
46	50	0.6	1	3.368	2.067	6.021
47	50	0.7	1	3.638	2.311	6.021
48	50	0.8	1	3.890	2.545	6.021
49	50	0.9	1	4.126	2.771	6.021
50	50	1	1	4.349	2.990	6.021
51	100	0.1	1			
52	100	0.2	1			
53	100	0.3	1	3.143	1.591	9.411
54	100	0.4	1	3.629	1.958	9.411
55	100	0.5	1	4.057	2.301	9.411
56	100	0.6	1	4.445	2.625	9.411
57	100	0.7	1	4.801	2.935	9.411
58	100	0.8	1	5.132	3.232	9.411
59	100	0.9	1	5.444	3.520	9.411
60	100	1	1	5.738	3.798	9.411
61	20	0.1	0.3			
62	20	0.2	0.3			
63	20	0.3	0.3	2.516	1.631	3.383
64	20	0.4	0.3	2.905	2.008	3.383
65	20	0.5	0.3	3.248	2.359	3.383
66	20	0.6	0.3	3.558	2.692	3.383
67	20	0.7	0.3	3.844	3.009	3.383

Item #	D/T	d/D	t/T	PRG ii	Wais ii	B31.3 ii
68	20	0.8	0.3	4.109	3.314	3.383
69	20	0.9	0.3	4.358	3.609	3.383
70	20	1	0.3	4.594	3.895	3.383
71	50	0.1	0.3			
72	50	0.2	0.3			
73	50	0.3	0.3	3.630	2.237	6.021
74	50	0.4	0.3	4.192	2.754	6.021
75	50	0.5	0.3	4.687	3.237	6.021
76	50	0.6	0.3	5.134	3.693	6.021
77	50	0.7	0.3	5.545	4.128	6.021
78	50	0.8	0.3	5.928	4.547	6.021
79	50	0.9	0.3	6.288	4.951	6.021
80	50	1	0.3	6.628	5.343	6.021
81	100	0.1	0.3			
82	100	0.2	0.3			
83	100	0.3	0.3	4.790	2.842	9.411
84	100	0.4	0.3	5.531	3.499	9.411
85	100	0.5	0.3	6.184	4.111	9.411
86	100	0.6	0.3	6.774	4.690	9.411
87	100	0.7	0.3	7.317	5.243	9.411
88	100	0.8	0.3	7.822	5.775	9.411
89	100	0.9	0.3	8.297	6.288	9.411
90	100	1	0.3	8.745	6.786	9.411
91	20	0.1	3			
92	20	0.2	3			
93	20	0.3	3	1.500	1.000	3.383
94	20	0.4	3	1.500	1.000	3.383
95	20	0.5	3	1.500	1.000	3.383
96	20	0.6	3	1.590	1.000	3.383
97	20	0.7	3	1.717	1.000	3.383
98	20	0.8	3	1.835	1.092	3.383
99	20	0.9	3	1.947	1.190	3.383
100	20	1	3	2.052	1.284	3.383
101	50	0.1	3			
102	50	0.2	3			
103	50	0.3	3	1.622	1.000	6.021
104	50	0.4	3	1.872	1.000	6.021
105	50	0.5	3	2.093	1.067	6.021
106	50	0.6	3	2.293	1.217	6.021
107	50	0.7	3	2.477	1.361	6.021
108	50	0.8	3	2.648	1.499	6.021
109	50	0.9	3	2.809	1.632	6.021
110	50	1	3	2.960	1.761	6.021
111	100	0.1	3			
112	100	0.2	3			
113	100	0.3	3	2.140	1.000	9.411
114	100	0.4	3	2.471	1.153	9.411
115	100	0.5	3	2.762	1.355	9.411
116	100	0.6	3	3.026	1.546	9.411
117	100	0.7	3	3.268	1.728	9.411
118	100	0.8	3	3.494	1.903	9.411
119	100	0.9	3	3.706	2.073	9.411
120	100	1	3	3.906	2.237	9.411

Unreinforced Fabricated Tee (UFT) - Sketch 2.3 - Header Outplane SIF

Item #	D/T	d/D	t/T	PRG io	Wais io	B31.3 io	NC
1	20	0.1	0.1				
2	20	0.2	0.2				
3	20	0.3	0.3	1.000	1.000	4.177	2.100
4	20	0.4	0.4	1.000	1.000	4.177	2.100
5	20	0.5	0.5	1.000	1.000	4.177	2.100
6	20	0.6	0.6	1.000	1.000	4.177	2.228
7	20	0.7	0.7	1.000	1.000	4.177	2.599
8	20	0.8	0.8	1.301	1.000	4.177	2.971
9	20	0.9	0.9	1.805	1.018	4.177	3.342
10	20	1	1	2.476	1.182	4.177	3.713
11	50	0.1	0.1				
12	50	0.2	0.2				
13	50	0.3	0.3	1.000	1.000	7.695	2.100
14	50	0.4	0.4	1.000	1.000	7.695	2.736
15	50	0.5	0.5	1.000	1.000	7.695	3.420
16	50	0.6	0.6	1.107	1.000	7.695	4.104
17	50	0.7	0.7	1.412	1.000	7.695	4.788
18	50	0.8	0.8	1.929	1.124	7.695	5.472
19	50	0.9	0.9	2.677	1.329	7.695	6.156
20	50	1	1	3.672	1.544	7.695	6.840
21	100	0.1	0.1				
22	100	0.2	0.2				
23	100	0.3	0.3	1.332	1.000	12.215	3.257
24	100	0.4	0.4	1.332	1.000	12.215	4.343
25	100	0.5	0.5	1.332	1.000	12.215	5.429
26	100	0.6	0.6	1.491	1.000	12.215	6.515
27	100	0.7	0.7	1.903	1.138	12.215	7.600
28	100	0.8	0.8	2.599	1.376	12.215	8.686
29	100	0.9	0.9	3.606	1.626	12.215	9.772
30	100	1	1	4.947	1.889	12.215	10.858
31	20	0.1	1				
32	20	0.2	1				
33	20	0.3	1	1.000	1.000	4.177	2.100
34	20	0.4	1	1.000	1.000	4.177	2.100
35	20	0.5	1	1.000	1.000	4.177	2.100
36	20	0.6	1	1.000	1.000	4.177	2.228
37	20	0.7	1	1.000	1.000	4.177	2.599
38	20	0.8	1	1.113	1.000	4.177	2.971
39	20	0.9	1	1.677	1.000	4.177	3.342
40	20	1	1	2.476	1.182	4.177	3.713
41	50	0.1	1				
42	50	0.2	1				
43	50	0.3	1	1.000	1.000	7.695	2.100
44	50	0.4	1	1.000	1.000	7.695	2.736
45	50	0.5	1	1.000	1.000	7.695	3.420
46	50	0.6	1	1.000	1.000	7.695	4.104
47	50	0.7	1	1.100	1.000	7.695	4.788
48	50	0.8	1	1.650	1.000	7.695	5.472
49	50	0.9	1	2.486	1.257	7.695	6.156
50	50	1	1	3.672	1.544	7.695	6.840
51	100	0.1	1				
52	100	0.2	1				
53	100	0.3	1	1.000	1.000	12.215	3.257
54	100	0.4	1	1.000	1.000	12.215	4.343
55	100	0.5	1	1.000	1.000	12.215	5.429
56	100	0.6	1	1.043	1.000	12.215	6.515
57	100	0.7	1	1.482	1.000	12.215	7.600
58	100	0.8	1	2.223	1.223	12.215	8.686
59	100	0.9	1	3.350	1.538	12.215	9.772
60	100	1	1	4.947	1.889	12.215	10.858
61	20	0.1	0.3				
62	20	0.2	0.3				
63	20	0.3	0.3	1.000	1.000	4.177	2.100
64	20	0.4	0.3	1.000	1.000	4.177	2.100
65	20	0.5	0.3	1.000	1.000	4.177	2.100
66	20	0.6	0.3	1.000	1.000	4.177	2.228
67	20	0.7	0.3	1.205	1.115	4.177	2.599
Item #	D/T	d/D	t/T	PRG io	Wais io	B31.3 io	NC
68	20	0.8	0.3	1.808	1.446	4.177	2.971
69	20	0.9	0.3	2.724	1.818	4.177	3.342
70	20	1	0.3	4.023	2.233	4.177	3.713
71	50	0.1	0.3				
72	50	0.2	0.3				
73	50	0.3	0.3	1.000	1.000	7.695	2.100
74	50	0.4	0.3	1.000	1.000	7.695	2.736
75	50	0.5	0.3	1.000	1.000	7.695	3.420
76	50	0.6	0.3	1.257	1.078	7.695	4.104
77	50	0.7	0.3	1.787	1.455	7.695	4.788
78	50	0.8	0.3	2.681	1.887	7.695	5.472
79	50	0.9	0.3	4.039	2.374	7.695	6.156
80	50	1	0.3	5.965	2.915	7.695	6.840
81	100	0.1	0.3				
82	100	0.2	0.3				
83	100	0.3	0.3	1.332	1.000	12.215	3.257
84	100	0.4	0.3	1.332	1.000	12.215	4.343
85	100	0.5	0.3	1.332	1.000	12.215	5.429
86	100	0.6	0.3	1.694	1.318	12.215	6.515
87	100	0.7	0.3	2.408	1.780	12.215	7.600
88	100	0.8	0.3	3.612	2.309	12.215	8.686
89	100	0.9	0.3	5.442	2.905	12.215	9.772
90	100	1	0.3	8.036	3.566	12.215	10.858
91	20	0.1	3				
92	20	0.2	3				
93	20	0.3	3	1.000	1.000	4.177	2.100
94	20	0.4	3	1.000	1.000	4.177	2.100
95	20	0.5	3	1.000	1.000	4.177	2.100
96	20	0.6	3	1.000	1.000	4.177	2.228
97	20	0.7	3	1.000	1.000	4.177	2.599
98	20	0.8	3	1.000	1.000	4.177	2.971
99	20	0.9	3	1.000	1.000	4.177	3.342
100	20	1	3	1.148	1.000	4.177	3.713
101	50	0.1	3				
102	50	0.2	3				
103	50	0.3	3	1.000	1.000	7.695	2.100
104	50	0.4	3	1.000	1.000	7.695	2.736
105	50	0.5	3	1.000	1.000	7.695	3.420
106	50	0.6	3	1.000	1.000	7.695	4.104
107	50	0.7	3	1.000	1.000	7.695	4.788
108	50	0.8	3	1.000	1.000	7.695	5.472
109	50	0.9	3	1.152	1.000	7.695	6.156
110	50	1	3	1.702	1.000	7.695	6.840
111	100	0.1	3				
112	100	0.2	3				
113	100	0.3	3	1.000	1.000	12.215	3.257
114	100	0.4	3	1.000	1.000	12.215	4.343
115	100	0.5	3	1.000	1.000	12.215	5.429
116	100	0.6	3	1.000	1.000	12.215	6.515
117	100	0.7	3	1.000	1.000	12.215	7.600
118	100	0.8	3	1.030	1.000	12.215	8.686
119	100	0.9	3	1.553	1.000	12.215	9.772
120	100	1	3	2.293	1.057	12.215	10.858

Unreinforced Fabricated Tee (UFT) - Sketch 2.3 - Header Torsional SIF

Item #	D/T	d/D	t/T	PRG it (Widera Ls)	Wais it	B31.3 io	NC
1	20	0.1	0.1				
2	20	0.2	0.2				
3	20	0.3	0.3	1.143	1.301	4.177	2.100
4	20	0.4	0.4	1.490	1.550	4.177	2.100
5	20	0.5	0.5	1.829	1.775	4.177	2.100
6	20	0.6	0.6	2.163	1.984	4.177	2.228
7	20	0.7	0.7	2.493	2.179	4.177	2.599
8	20	0.8	0.8	2.819	2.364	4.177	2.971
9	20	0.9	0.9	3.141	2.540	4.177	3.342
10	20	1	1	3.461	2.708	4.177	3.713
11	50	0.1	0.1				
12	50	0.2	0.2				
13	50	0.3	0.3	1.743	2.048	7.695	2.100
14	50	0.4	0.4	2.271	2.441	7.695	2.736
15	50	0.5	0.5	2.788	2.796	7.695	3.420
16	50	0.6	0.6	3.297	3.125	7.695	4.104
17	50	0.7	0.7	3.799	3.432	7.695	4.788
18	50	0.8	0.8	4.296	3.723	7.695	5.472
19	50	0.9	0.9	4.788	4.000	7.695	6.156
20	50	1	1	5.275	4.266	7.695	6.840
21	100	0.1	0.1				
22	100	0.2	0.2				
23	100	0.3	0.3	2.397	2.888	12.215	3.257
24	100	0.4	0.4	3.123	3.441	12.215	4.343
25	100	0.5	0.5	3.835	3.943	12.215	5.429
26	100	0.6	0.6	4.535	4.406	12.215	6.515
27	100	0.7	0.7	5.226	4.840	12.215	7.600
28	100	0.8	0.8	5.909	5.250	12.215	8.686
29	100	0.9	0.9	6.586	5.640	12.215	9.772
30	100	1	1	7.256	6.014	12.215	10.858
31	20	0.1	1				
32	20	0.2	1				
33	20	0.3	1	1.000	1.000	4.177	2.100
34	20	0.4	1	1.000	1.000	4.177	2.100
35	20	0.5	1	1.339	1.219	4.177	2.100
36	20	0.6	1	1.719	1.503	4.177	2.228
37	20	0.7	1	2.123	1.796	4.177	2.599
38	20	0.8	1	2.549	2.094	4.177	2.971
39	20	0.9	1	2.996	2.399	4.177	3.342
40	20	1	1	3.461	2.708	4.177	3.713
41	50	0.1	1				
42	50	0.2	1				
43	50	0.3	1	1.014	1.065	7.695	2.100
44	50	0.4	1	1.503	1.484	7.695	2.736
45	50	0.5	1	2.041	1.919	7.695	3.420
46	50	0.6	1	2.620	2.368	7.695	4.104
47	50	0.7	1	3.236	2.828	7.695	4.788
48	50	0.8	1	3.886	3.298	7.695	5.472
49	50	0.9	1	4.566	3.778	7.695	6.156
50	50	1	1	5.275	4.266	7.695	6.840
51	100	0.1	1				
52	100	0.2	1				
53	100	0.3	1	1.394	1.502	12.215	3.257
54	100	0.4	1	2.068	2.092	12.215	4.343
55	100	0.5	1	2.807	2.706	12.215	5.429
56	100	0.6	1	3.604	3.339	12.215	6.515
57	100	0.7	1	4.451	3.988	12.215	7.600
58	100	0.8	1	5.345	4.651	12.215	8.686
59	100	0.9	1	6.281	5.327	12.215	9.772
60	100	1	1	7.256	6.014	12.215	10.858
61	20	0.1	0.3				
62	20	0.2	0.3				
63	20	0.3	0.3	1.143	1.301	4.177	2.100
64	20	0.4	0.3	1.696	1.812	4.177	2.100
65	20	0.5	0.3	2.302	2.343	4.177	2.100
66	20	0.6	0.3	2.955	2.891	4.177	2.228
67	20	0.7	0.3	3.650	3.453	4.177	2.599

Item #	D/T	d/D	t/T	PRG it (Widera Ls)	Wais it	B31.3 io	NC
68	20	0.8	0.3	4.382	4.027	4.177	2.971
69	20	0.9	0.3	5.150	4.612	4.177	3.342
70	20	1	0.3	5.949	5.208	4.177	3.713
71	50	0.1	0.3				
72	50	0.2	0.3				
73	50	0.3	0.3	1.743	2.048	7.695	2.100
74	50	0.4	0.3	2.584	2.853	7.695	2.736
75	50	0.5	0.3	3.508	3.690	7.695	3.420
76	50	0.6	0.3	4.504	4.553	7.695	4.104
77	50	0.7	0.3	5.563	5.438	7.695	4.788
78	50	0.8	0.3	6.680	6.342	7.695	5.472
79	50	0.9	0.3	7.849	7.264	7.695	6.156
80	50	1	0.3	9.068	8.202	7.695	6.840
81	100	0.1	0.3				
82	100	0.2	0.3				
83	100	0.3	0.3	2.397	2.888	12.215	3.257
84	100	0.4	0.3	3.555	4.023	12.215	4.343
85	100	0.5	0.3	4.826	5.203	12.215	5.429
86	100	0.6	0.3	6.195	6.419	12.215	6.515
87	100	0.7	0.3	7.652	7.667	12.215	7.600
88	100	0.8	0.3	9.188	8.942	12.215	8.686
89	100	0.9	0.3	10.797	10.242	12.215	9.772
90	100	1	0.3	12.474	11.564	12.215	10.858
91	20	0.1	3				
92	20	0.2	3				
93	20	0.3	3	1.000	1.000	4.177	2.100
94	20	0.4	3	1.000	1.000	4.177	2.100
95	20	0.5	3	1.000	1.000	4.177	2.100
96	20	0.6	3	1.048	1.000	4.177	2.228
97	20	0.7	3	1.295	1.000	4.177	2.599
98	20	0.8	3	1.555	1.153	4.177	2.971
99	20	0.9	3	1.827	1.321	4.177	3.342
100	20	1	3	2.111	1.492	4.177	3.713
101	50	0.1	3				
102	50	0.2	3				
103	50	0.3	3	1.000	1.000	7.695	2.100
104	50	0.4	3	1.000	1.000	7.695	2.736
105	50	0.5	3	1.245	1.057	7.695	3.420
106	50	0.6	3	1.598	1.304	7.695	4.104
107	50	0.7	3	1.974	1.557	7.695	4.788
108	50	0.8	3	2.370	1.816	7.695	5.472
109	50	0.9	3	2.785	2.081	7.695	6.156
110	50	1	3	3.218	2.349	7.695	6.840
111	100	0.1	3				
112	100	0.2	3				
113	100	0.3	3	1.000	1.000	12.215	3.257
114	100	0.4	3	1.261	1.152	12.215	4.343
115	100	0.5	3	1.712	1.490	12.215	5.429
116	100	0.6	3	2.198	1.839	12.215	6.515
117	100	0.7	3	2.715	2.196	12.215	7.600
118	100	0.8	3	3.260	2.561	12.215	8.686
119	100	0.9	3	3.831	2.934	12.215	9.772
120	100	1	3	4.426	3.312	12.215	10.858

Unreinforced Fabricated Tee (UFT) - Sketch 2.3 - Branch Inplane K

Item #	D/T	d/D	t/T	PRG ki	Wais ki	Widera ki	NB kib
1	20	0.1	0.1	1.000	1.507	0.859	0.420
2	20	0.2	0.2	1.721	1.977	1.749	0.840
3	20	0.3	0.3	2.274	2.316	2.342	1.260
4	20	0.4	0.4	2.550	2.592	2.619	1.680
5	20	0.5	0.5	2.627	2.828	2.661	2.100
6	20	0.6	0.6	2.623	3.037	2.616	2.520
7	20	0.7	0.7	2.689	3.226	2.676	2.940
8	20	0.8	0.8	2.991	3.399	3.071	3.360
9	20	0.9	0.9	3.718	3.559	4.060	3.780
10	20	1	1	5.071	3.709	5.929	4.200
11	50	0.1	0.1	1.892	2.803	1.792	1.020
12	50	0.2	0.2	3.682	3.676	3.647	2.040
13	50	0.3	0.3	4.866	4.307	4.884	3.060
14	50	0.4	0.4	5.456	4.820	5.460	4.080
15	50	0.5	0.5	5.619	5.259	5.548	5.100
16	50	0.6	0.6	5.613	5.648	5.454	6.120
17	50	0.7	0.7	5.752	5.999	5.580	7.140
18	50	0.8	0.8	6.399	6.320	6.404	8.160
19	50	0.9	0.9	7.954	6.618	8.467	9.180
20	50	1	1	10.848	6.896	12.364	10.200
21	100	0.1	0.1	3.363	4.481	3.124	2.020
22	100	0.2	0.2	6.546	5.877	6.358	4.040
23	100	0.3	0.3	8.650	6.886	8.516	6.060
24	100	0.4	0.4	9.699	7.706	9.520	8.080
25	100	0.5	0.5	9.989	8.408	9.673	10.100
26	100	0.6	0.6	9.977	9.030	9.509	12.120
27	100	0.7	0.7	10.225	9.591	9.729	14.140
28	100	0.8	0.8	11.376	10.105	11.166	16.160
29	100	0.9	0.9	14.140	10.581	14.762	18.180
30	100	1	1	19.284	11.026	21.557	20.200
31	20	0.1	1	2.732	6.029	3.599	1.587
32	20	0.2	1	3.787	5.208	4.759	2.049
33	20	0.3	1	4.103	4.781	4.953	2.425
34	20	0.4	1	3.995	4.500	4.630	2.750
35	20	0.5	1	3.689	4.293	4.095	3.040
36	20	0.6	1	3.370	4.131	3.594	3.305
37	20	0.7	1	3.202	3.999	3.341	3.550
38	20	0.8	1	3.337	3.887	3.528	3.779
39	20	0.9	1	3.915	3.792	4.335	3.995
40	20	1	1	5.071	3.709	5.929	4.200
41	50	0.1	1	5.846	11.210	7.505	3.499
42	50	0.2	1	8.102	9.685	9.923	4.737
43	50	0.3	1	8.778	8.891	10.329	5.713
44	50	0.4	1	8.548	8.367	9.655	6.545
45	50	0.5	1	7.892	7.983	8.539	7.283
46	50	0.6	1	7.209	7.681	7.494	7.952
47	50	0.7	1	6.850	7.435	6.966	8.570
48	50	0.8	1	7.139	7.229	7.358	9.145
49	50	0.9	1	8.376	7.051	9.040	9.687
50	50	1	1	10.848	6.896	12.364	10.200
51	100	0.1	1	10.392	17.923	13.085	6.666
52	100	0.2	1	14.403	15.485	17.302	9.211
53	100	0.3	1	15.604	14.215	18.008	11.191
54	100	0.4	1	15.195	13.378	16.833	12.870
55	100	0.5	1	14.030	12.763	14.888	14.354
56	100	0.6	1	12.815	12.281	13.066	15.698
57	100	0.7	1	12.178	11.888	12.146	16.936
58	100	0.8	1	12.690	11.558	12.828	18.090
59	100	0.9	1	14.889	11.274	15.762	19.174
60	100	1	1	19.284	11.026	21.557	20.200
61	20	0.1	0.3	1.515	2.920	1.702	0.761
62	20	0.2	0.3	2.099	2.523	2.251	1.041
63	20	0.3	0.3	2.274	2.316	2.342	1.260
64	20	0.4	0.3	2.215	2.180	2.190	1.446
65	20	0.5	0.3	2.045	2.080	1.937	1.611
66	20	0.6	0.3	1.868	2.001	1.700	1.761
67	20	0.7	0.3	1.775	1.937	1.580	1.898
68	20	0.8	0.3	1.850	1.883	1.669	2.027
69	20	0.9	0.3	2.170	1.837	2.050	2.147
70	20	1	0.3	2.811	1.797	2.804	2.262
71	50	0.1	0.3	3.241	5.431	3.549	1.801
72	50	0.2	0.3	4.492	4.692	4.693	2.511
73	50	0.3	0.3	4.866	4.307	4.884	3.060
74	50	0.4	0.3	4.738	4.053	4.566	3.525
75	50	0.5	0.3	4.375	3.867	4.038	3.935
76	50	0.6	0.3	3.996	3.721	3.544	4.306
77	50	0.7	0.3	3.798	3.602	3.294	4.648
78	50	0.8	0.3	3.957	3.502	3.479	4.966
79	50	0.9	0.3	4.643	3.416	4.275	5.265
80	50	1	0.3	6.014	3.341	5.847	5.548
81	100	0.1	0.3	5.761	8.683	6.188	3.533
82	100	0.2	0.3	7.985	7.501	8.182	4.960
83	100	0.3	0.3	8.650	6.886	8.516	6.060
84	100	0.4	0.3	8.423	6.481	7.961	6.989
85	100	0.5	0.3	7.777	6.183	7.040	7.808
86	100	0.6	0.3	7.104	5.949	6.179	8.549
87	100	0.7	0.3	6.751	5.759	5.744	9.231
88	100	0.8	0.3	7.035	5.599	6.066	9.865
89	100	0.9	0.3	8.254	5.461	7.454	10.462
90	100	1	0.3	10.690	5.341	10.194	11.026
91	20	0.1	3	4.681	11.680	7.128	3.550
92	20	0.2	3	6.488	10.091	9.425	4.200
93	20	0.3	3	7.029	9.263	9.810	4.762
94	20	0.4	3	6.845	8.718	9.170	5.265
95	20	0.5	3	6.320	8.317	8.110	5.724
96	20	0.6	3	5.773	8.003	7.118	6.148
97	20	0.7	3	5.485	7.747	6.616	6.545
98	20	0.8	3	5.716	7.532	6.988	6.920
99	20	0.9	3	6.707	7.347	8.586	7.275
100	20	1	3	8.687	7.185	11.743	7.613
101	50	0.1	3	10.014	21.719	14.863	6.997
102	50	0.2	3	13.880	18.764	19.653	8.920
103	50	0.3	3	15.037	17.226	20.456	10.496
104	50	0.4	3	14.643	16.211	19.121	11.864
105	50	0.5	3	13.520	15.466	16.911	13.090
106	50	0.6	3	12.350	14.882	14.842	14.211
107	50	0.7	3	11.735	14.406	13.796	15.250
108	50	0.8	3	12.229	14.005	14.571	16.222
109	50	0.9	3	14.349	13.662	17.904	17.139
110	50	1	3	18.584	13.361	24.487	18.010
111	100	0.1	3	17.802	34.725	25.915	12.552
112	100	0.2	3	24.675	30.001	34.265	16.696
113	100	0.3	3	26.732	27.541	35.665	19.999
114	100	0.4	3	26.031	25.919	33.338	22.829
115	100	0.5	3	24.034	24.727	29.484	25.345
116	100	0.6	3	21.954	23.793	25.877	27.633
117	100	0.7	3	20.862	23.032	24.054	29.745
118	100	0.8	3	21.740	22.392	25.405	31.717
119	100	0.9	3	25.508	21.842	31.216	33.573
120	100	1	3	33.037	21.362	42.693	35.332

Unreinforced Fabricated Tee (UFT) - Sketch 2.3 - Branch Outplane K

Item #	D/T	d/D	t/T	PRG ko	Wais ko	Widera ko	NB kob
1	20	0.1	0.1	1.000	1.374	0.316	0.962
2	20	0.2	0.2	2.375	3.391	1.365	1.925
3	20	0.3	0.3	4.013	5.358	2.890	2.887
4	20	0.4	0.4	5.454	6.981	4.499	3.849
5	20	0.5	0.5	6.519	8.091	5.815	4.812
6	20	0.6	0.6	7.115	8.595	6.562	5.774
7	20	0.7	0.7	7.222	8.448	6.616	6.736
8	20	0.8	0.8	6.879	7.642	6.046	7.699
9	20	0.9	0.9	6.182	6.202	5.148	8.661
10	20	1	1	5.275	4.177	4.473	9.623
11	50	0.1	0.1	3.050	3.445	1.268	3.642
12	50	0.2	0.2	8.565	8.501	5.469	7.284
13	50	0.3	0.3	14.472	13.433	11.583	10.926
14	50	0.4	0.4	19.672	17.500	18.029	14.569
15	50	0.5	0.5	23.513	20.283	23.303	18.211
16	50	0.6	0.6	25.664	21.547	26.296	21.853
17	50	0.7	0.7	26.048	21.178	26.513	25.495
18	50	0.8	0.8	24.812	19.158	24.229	29.137
19	50	0.9	0.9	22.296	15.549	20.631	32.779
20	50	1	1	19.025	10.472	17.927	36.421
21	100	0.1	0.1	8.050	6.904	3.623	10.150
22	100	0.2	0.2	22.602	17.038	15.630	20.301
23	100	0.3	0.3	38.193	26.921	33.105	30.451
24	100	0.4	0.4	51.915	35.072	51.527	40.601
25	100	0.5	0.5	62.052	40.651	66.598	50.752
26	100	0.6	0.6	67.727	43.183	75.155	60.902
27	100	0.7	0.7	68.742	42.443	75.774	71.053
28	100	0.8	0.8	65.479	38.397	69.247	81.203
29	100	0.9	0.9	58.841	31.162	58.963	91.353
30	100	1	1	50.209	20.988	51.236	101.504
31	20	0.1	1	3.367	7.162	2.302	3.637
32	20	0.2	1	6.237	10.753	5.464	4.696
33	20	0.3	1	8.263	12.704	8.160	5.556
34	20	0.4	1	9.451	13.465	9.911	6.300
35	20	0.5	1	9.881	13.300	10.568	6.965
36	20	0.6	1	9.667	12.397	10.192	7.572
37	20	0.7	1	8.945	10.910	8.997	8.133
38	20	0.8	1	7.865	8.968	7.328	8.659
39	20	0.9	1	6.585	6.689	5.637	9.154
40	20	1	1	5.275	4.177	4.473	9.623
41	50	0.1	1	12.144	17.955	9.225	12.492
42	50	0.2	1	22.495	26.956	21.898	16.915
43	50	0.3	1	29.804	31.847	32.700	20.400
44	50	0.4	1	34.089	33.756	39.719	23.371
45	50	0.5	1	35.639	33.341	42.354	26.005
46	50	0.6	1	34.868	31.078	40.844	28.396
47	50	0.7	1	32.264	27.349	36.056	30.600
48	50	0.8	1	28.366	22.482	29.368	32.656
49	50	0.9	1	23.751	16.769	22.592	34.590
50	50	1	1	19.025	10.472	17.927	36.421
51	100	0.1	1	32.048	35.984	26.366	33.498
52	100	0.2	1	59.366	54.024	62.585	46.284
53	100	0.3	1	78.652	63.826	93.458	56.234
54	100	0.4	1	89.961	67.652	113.516	64.672
55	100	0.5	1	94.053	66.821	121.046	72.128
56	100	0.6	1	92.018	62.285	116.732	78.884
57	100	0.7	1	85.146	54.812	103.049	85.104
58	100	0.8	1	74.859	45.059	83.933	90.900
59	100	0.9	1	62.680	33.607	64.568	96.348
60	100	1	1	50.209	20.988	51.236	101.504
61	20	0.1	0.3	1.635	3.021	0.815	1.744
62	20	0.2	0.3	3.029	4.535	1.936	2.385
63	20	0.3	0.3	4.013	5.358	2.890	2.887
64	20	0.4	0.3	4.590	5.680	3.511	3.314
65	20	0.5	0.3	4.798	5.610	3.744	3.691
66	20	0.6	0.3	4.694	5.229	3.610	4.034
67	20	0.7	0.3	4.344	4.602	3.187	4.350
68	20	0.8	0.3	3.819	3.783	2.596	4.644
69	20	0.9	0.3	3.198	2.821	1.997	4.920
70	20	1	0.3	2.561	1.762	1.585	5.182
71	50	0.1	0.3	5.897	7.573	3.268	6.431
72	50	0.2	0.3	10.924	11.370	7.757	8.965
73	50	0.3	0.3	14.472	13.433	11.583	10.926
74	50	0.4	0.3	16.553	14.238	14.069	12.586
75	50	0.5	0.3	17.306	14.063	15.003	14.050
76	50	0.6	0.3	16.932	13.108	14.468	15.376
77	50	0.7	0.3	15.667	11.536	12.772	16.597
78	50	0.8	0.3	13.774	9.483	10.403	17.733
79	50	0.9	0.3	11.534	7.073	8.003	18.801
80	50	1	0.3	9.239	4.417	6.350	19.811
81	100	0.1	0.3	15.562	15.178	9.339	17.754
82	100	0.2	0.3	28.828	22.787	22.169	24.925
83	100	0.3	0.3	38.193	26.921	33.105	30.451
84	100	0.4	0.3	43.684	28.535	40.210	35.118
85	100	0.5	0.3	45.671	28.184	42.878	39.234
86	100	0.6	0.3	44.683	26.271	41.349	42.958
87	100	0.7	0.3	41.346	23.119	36.502	46.383
88	100	0.8	0.3	36.351	19.005	29.731	49.572
89	100	0.9	0.3	30.437	14.175	22.872	52.569
90	100	1	0.3	24.381	8.853	18.149	55.403
91	20	0.1	3	6.509	15.745	5.934	8.133
92	20	0.2	3	12.057	23.638	14.087	9.623
93	20	0.3	3	15.974	27.927	21.036	10.912
94	20	0.4	3	18.271	29.601	25.550	12.064
95	20	0.5	3	19.102	29.237	27.245	13.114
96	20	0.6	3	18.689	27.253	26.274	14.087
97	20	0.7	3	17.293	23.983	23.194	14.997
98	20	0.8	3	15.204	19.715	18.892	15.855
99	20	0.9	3	12.731	14.705	14.533	16.668
100	20	1	3	10.197	9.183	11.532	17.444
101	50	0.1	3	23.476	39.471	23.783	24.985
102	50	0.2	3	43.488	59.259	56.453	31.849
103	50	0.3	3	57.616	70.010	84.301	37.477
104	50	0.4	3	65.900	74.207	102.394	42.364
105	50	0.5	3	68.897	73.295	109.187	46.742
106	50	0.6	3	67.407	68.319	105.295	50.744
107	50	0.7	3	62.372	60.123	92.953	54.453
108	50	0.8	3	54.837	49.424	75.710	57.925
109	50	0.9	3	45.916	36.863	58.242	61.200
110	50	1	3	36.780	23.021	46.216	64.309
111	100	0.1	3	61.954	79.106	67.970	63.074
112	100	0.2	3	114.765	118.764	161.343	83.897
113	100	0.3	3	152.049	140.312	240.931	100.494
114	100	0.4	3	173.911	148.723	292.640	114.714
115	100	0.5	3	181.821	146.895	312.055	127.356
116	100	0.6	3	177.887	136.923	300.932	138.852
117	100	0.7	3	164.602	120.496	265.657	149.466
118	100	0.8	3	144.716	99.054	216.378	159.375
119	100	0.9	3	121.173	73.880	166.455	168.703
120	100	1	3	97.062	46.139	132.084	177.542

Unreinforced Fabricated Tee (UFT) - Sketch 2.3 - Branch Torsional K

Item #	D/T	d/D	t/T	PRG kt	Wais kt	PRG (kib)(iib)/ (itb)(2/3)^2	Wais (kib)(iib)/ (itb)(2/3)^2
1	20	0.1	0.1	1.000	1.000	0.007	0.670
2	20	0.2	0.2	1.000	1.000	0.039	0.816
3	20	0.3	0.3	1.000	1.000	0.108	0.783
4	20	0.4	0.4	1.000	1.000	0.213	0.761
5	20	0.5	0.5	1.000	1.019	0.354	0.745
6	20	0.6	0.6	1.000	1.497	0.530	0.731
7	20	0.7	0.7	1.000	2.072	0.763	0.916
8	20	0.8	0.8	1.916	2.746	1.110	1.196
9	20	0.9	0.9	3.628	3.521	1.668	1.514
10	20	1	1	6.423	4.398	2.539	1.869
11	50	0.1	0.1	1.000	1.000	0.014	0.885
12	50	0.2	0.2	1.000	1.000	0.086	0.826
13	50	0.3	0.3	1.000	1.000	0.239	0.794
14	50	0.4	0.4	1.000	1.000	0.474	0.771
15	50	0.5	0.5	1.000	1.221	0.785	0.754
16	50	0.6	0.6	1.000	1.794	1.176	1.077
17	50	0.7	0.7	1.988	2.484	1.693	1.466
18	50	0.8	0.8	4.100	3.292	2.464	1.915
19	50	0.9	0.9	7.763	4.221	3.702	2.425
20	50	1	1	13.741	5.272	5.634	2.994
21	100	0.1	0.1	1.000	1.000	0.025	0.893
22	100	0.2	0.2	1.000	1.000	0.158	0.834
23	100	0.3	0.3	1.000	1.000	0.437	0.801
24	100	0.4	0.4	1.000	1.000	0.866	0.779
25	100	0.5	0.5	1.000	1.401	1.435	1.068
26	100	0.6	0.6	1.533	2.058	2.149	1.538
27	100	0.7	0.7	3.534	2.849	3.094	2.094
28	100	0.8	0.8	7.288	3.777	4.503	2.735
29	100	0.9	0.9	13.799	4.842	6.767	3.462
30	100	1	1	24.427	6.048	10.297	4.275
31	20	0.1	1	1.000	1.000	0.037	1.433
32	20	0.2	1	1.000	1.000	0.137	1.153
33	20	0.3	1	1.000	1.000	0.275	1.015
34	20	0.4	1	1.000	1.056	0.436	0.927
35	20	0.5	1	1.000	1.495	0.607	0.864
36	20	0.6	1	1.000	1.985	0.789	0.969
37	20	0.7	1	1.000	2.524	1.007	1.182
38	20	0.8	1	1.916	3.107	1.321	1.403
39	20	0.9	1	3.628	3.732	1.811	1.632
40	20	1	1	6.423	4.398	2.539	1.869
41	50	0.1	1	1.000	1.000	0.083	1.451
42	50	0.2	1	1.000	1.000	0.303	1.168
43	50	0.3	1	1.000	1.000	0.611	1.028
44	50	0.4	1	1.000	1.266	0.968	0.939
45	50	0.5	1	1.000	1.792	1.348	1.228
46	50	0.6	1	1.000	2.380	1.752	1.552
47	50	0.7	1	1.988	3.026	2.236	1.892
48	50	0.8	1	4.100	3.725	2.932	2.247
49	50	0.9	1	7.763	4.475	4.019	2.614
50	50	1	1	13.741	5.272	5.634	2.994
51	100	0.1	1	1.000	1.000	0.151	1.466
52	100	0.2	1	1.000	1.000	0.554	1.179
53	100	0.3	1	1.000	1.000	1.117	1.038
54	100	0.4	1	1.000	1.452	1.769	1.316
55	100	0.5	1	1.000	2.055	2.463	1.753
56	100	0.6	1	1.533	2.730	3.201	2.216
57	100	0.7	1	3.534	3.471	4.086	2.702
58	100	0.8	1	7.288	4.273	5.359	3.208
59	100	0.9	1	13.799	5.133	7.346	3.733
60	100	1	1	24.427	6.048	10.297	4.275
61	20	0.1	0.3	1.000	1.000	0.015	1.106
62	20	0.2	0.3	1.000	1.000	0.053	0.890
63	20	0.3	0.3	1.000	1.000	0.108	0.783
64	20	0.4	0.3	1.000	1.000	0.171	0.716

Item #	D/T	d/D	t/T	PRG kt	Wais kt	PRG (kib)(iib)/ (itb)(2/3)^2	Wais (kib)(iib)/ (itb)(2/3)^2
65	20	0.5	0.3	1.000	1.000	0.237	0.667
66	20	0.6	0.3	1.000	1.020	0.309	0.630
67	20	0.7	0.3	1.000	1.297	0.394	0.600
68	20	0.8	0.3	1.916	1.597	0.517	0.593
69	20	0.9	0.3	3.628	1.918	0.708	0.690
70	20	1	0.3	6.423	2.260	0.993	0.790
71	50	0.1	0.3	1.000	1.000	0.032	1.120
72	50	0.2	0.3	1.000	1.000	0.119	0.901
73	50	0.3	0.3	1.000	1.000	0.239	0.794
74	50	0.4	0.3	1.000	1.000	0.379	0.725
75	50	0.5	0.3	1.000	1.000	0.527	0.676
76	50	0.6	0.3	1.000	1.223	0.685	0.656
77	50	0.7	0.3	1.988	1.555	0.874	0.800
78	50	0.8	0.3	4.100	1.914	1.146	0.950
79	50	0.9	0.3	7.763	2.299	1.572	1.105
80	50	1	0.3	13.741	2.709	2.203	1.266
81	100	0.1	0.3	1.000	1.000	0.059	1.131
82	100	0.2	0.3	1.000	1.000	0.217	0.910
83	100	0.3	0.3	1.000	1.000	0.437	0.801
84	100	0.4	0.3	1.000	1.000	0.692	0.732
85	100	0.5	0.3	1.000	1.056	0.963	0.741
86	100	0.6	0.3	1.533	1.403	1.252	0.937
87	100	0.7	0.3	3.534	1.783	1.598	1.142
88	100	0.8	0.3	7.288	2.196	2.095	1.357
89	100	0.9	0.3	13.799	2.638	2.872	1.578
90	100	1	0.3	24.427	3.108	4.026	1.807
91	20	0.1	3	1.000	1.000	0.039	1.815
92	20	0.2	3	1.000	1.000	0.143	1.460
93	20	0.3	3	1.000	1.239	0.288	1.285
94	20	0.4	3	1.000	1.938	0.456	1.262
95	20	0.5	3	1.000	2.744	0.635	1.681
96	20	0.6	3	1.000	3.645	0.825	2.126
97	20	0.7	3	1.000	4.633	1.053	2.592
98	20	0.8	3	1.916	5.704	1.380	3.077
99	20	0.9	3	3.628	6.852	1.893	3.581
100	20	1	3	6.423	8.073	2.653	4.100
101	50	0.1	3	1.000	1.000	0.087	1.838
102	50	0.2	3	1.000	1.000	0.317	1.479
103	50	0.3	3	1.000	1.485	0.639	1.396
104	50	0.4	3	1.000	2.324	1.012	2.021
105	50	0.5	3	1.000	3.290	1.408	2.693
106	50	0.6	3	1.000	4.370	1.830	3.404
107	50	0.7	3	1.988	5.555	2.336	4.151
108	50	0.8	3	4.100	6.839	3.064	4.928
109	50	0.9	3	7.763	8.215	4.200	5.734
110	50	1	3	13.741	9.679	5.887	6.566
111	100	0.1	3	1.000	1.000	0.158	1.856
112	100	0.2	3	1.000	1.000	0.579	1.493
113	100	0.3	3	1.000	1.703	1.167	1.994
114	100	0.4	3	1.000	2.666	1.849	2.886
115	100	0.5	3	1.000	3.774	2.574	3.845
116	100	0.6	3	1.533	5.012	3.345	4.861
117	100	0.7	3	3.534	6.372	4.270	5.927
118	100	0.8	3	7.288	7.845	5.599	7.038
119	100	0.9	3	13.799	9.423	7.676	8.189
120	100	1	3	24.427	11.103	10.760	9.377

Unreinforced Fabricated Tee (UFT) - Sketch 2.3 - Header Inplane K

Item #	D/T	d/D	t/T	PRG kih	Wais kih
1	20	0.1	0.1		
2	20	0.2	0.2		
3	20	0.3	0.3	1.000	1.000
4	20	0.4	0.4	1.000	1.000
5	20	0.5	0.5	1.000	1.000
6	20	0.6	0.6	1.000	1.000
7	20	0.7	0.7	1.000	1.325
8	20	0.8	0.8	1.235	1.883
9	20	0.9	0.9	2.182	2.566
10	20	1	1	3.630	3.385
11	50	0.1	0.1		
12	50	0.2	0.2		
13	50	0.3	0.3	1.000	1.000
14	50	0.4	0.4	1.000	1.000
15	50	0.5	0.5	1.000	1.000
16	50	0.6	0.6	1.000	1.105
17	50	0.7	0.7	1.000	1.658
18	50	0.8	0.8	1.900	2.355
19	50	0.9	0.9	3.357	3.211
20	50	1	1	5.584	4.236
21	100	0.1	0.1		
22	100	0.2	0.2		
23	100	0.3	0.3	1.000	1.000
24	100	0.4	0.4	1.000	1.000
25	100	0.5	0.5	1.000	1.000
26	100	0.6	0.6	1.000	1.310
27	100	0.7	0.7	1.381	1.964
28	100	0.8	0.8	2.632	2.791
29	100	0.9	0.9	4.650	3.804
30	100	1	1	7.734	5.019
31	20	0.1	1		
32	20	0.2	1		
33	20	0.3	1	1.000	1.000
34	20	0.4	1	1.000	1.000
35	20	0.5	1	1.000	1.000
36	20	0.6	1	1.000	1.000
37	20	0.7	1	1.000	1.218
38	20	0.8	1	1.112	1.786
39	20	0.9	1	2.077	2.503
40	20	1	1	3.630	3.385
41	50	0.1	1		
42	50	0.2	1		
43	50	0.3	1	1.000	1.000
44	50	0.4	1	1.000	1.000
45	50	0.5	1	1.000	1.000
46	50	0.6	1	1.000	1.000
47	50	0.7	1	1.000	1.524
48	50	0.8	1	1.711	2.234
49	50	0.9	1	3.195	3.132
50	50	1	1	5.584	4.236
51	100	0.1	1		
52	100	0.2	1		
53	100	0.3	1	1.000	1.000
54	100	0.4	1	1.000	1.000
55	100	0.5	1	1.000	1.000
56	100	0.6	1	1.000	1.160
57	100	0.7	1	1.168	1.805
58	100	0.8	1	2.370	2.647
59	100	0.9	1	4.425	3.710
60	100	1	1	7.734	5.019
61	20	0.1	0.3		
62	20	0.2	0.3		
63	20	0.3	0.3	1.000	1.000
64	20	0.4	0.3	1.000	1.000
65	20	0.5	0.3	1.000	1.000
66	20	0.6	0.3	1.000	1.041
67	20	0.7	0.3	1.000	1.619
68	20	0.8	0.3	1.959	2.374
69	20	0.9	0.3	3.657	3.328
70	20	1	0.3	6.392	4.501
71	50	0.1	0.3		
72	50	0.2	0.3		
73	50	0.3	0.3	1.000	1.000
74	50	0.4	0.3	1.000	1.000
75	50	0.5	0.3	1.000	1.000
76	50	0.6	0.3	1.000	1.302
77	50	0.7	0.3	1.485	2.026
78	50	0.8	0.3	3.013	2.971
79	50	0.9	0.3	5.626	4.164
80	50	1	0.3	9.833	5.632
81	100	0.1	0.3		
82	100	0.2	0.3		
83	100	0.3	0.3	1.000	1.000
84	100	0.4	0.3	1.000	1.000
85	100	0.5	0.3	1.000	1.000
86	100	0.6	0.3	1.000	1.543
87	100	0.7	0.3	2.057	2.400
88	100	0.8	0.3	4.174	3.520
89	100	0.9	0.3	7.792	4.933
90	100	1	0.3	13.620	6.673
91	20	0.1	3		
92	20	0.2	3		
93	20	0.3	3	1.000	1.000
94	20	0.4	3	1.000	1.000
95	20	0.5	3	1.000	1.000
96	20	0.6	3	1.000	1.000
97	20	0.7	3	1.000	1.000
98	20	0.8	3	1.000	1.377
99	20	0.9	3	1.239	1.930
100	20	1	3	2.166	2.611
101	50	0.1	3		
102	50	0.2	3		
103	50	0.3	3	1.000	1.000
104	50	0.4	3	1.000	1.000
105	50	0.5	3	1.000	1.000
106	50	0.6	3	1.000	1.000
107	50	0.7	3	1.000	1.175
108	50	0.8	3	1.021	1.723
109	50	0.9	3	1.906	2.415
110	50	1	3	3.332	3.266
111	100	0.1	3		
112	100	0.2	3		
113	100	0.3	3	1.000	1.000
114	100	0.4	3	1.000	1.000
115	100	0.5	3	1.000	1.000
116	100	0.6	3	1.000	1.000
117	100	0.7	3	1.000	1.392
118	100	0.8	3	1.414	2.041
119	100	0.9	3	2.640	2.861
120	100	1	3	4.615	3.870

Unreinforced Fabricated Tee (UFT) - Sketch 2.3 - Header Torsional K

Item #	D/T	d/D	t/T	PRG kth	Wais kth
1	20	0.1	0.1		
2	20	0.2	0.2		
3	20	0.3	0.3	1.000	1.000
4	20	0.4	0.4	1.000	1.000
5	20	0.5	0.5	1.000	1.000
6	20	0.6	0.6	1.000	1.135
7	20	0.7	0.7	1.000	1.661
8	20	0.8	0.8	1.264	2.310
9	20	0.9	0.9	2.882	3.090
10	20	1	1	6.026	4.008
11	50	0.1	0.1		
12	50	0.2	0.2		
13	50	0.3	0.3	1.000	1.000
14	50	0.4	0.4	1.000	1.000
15	50	0.5	0.5	1.000	1.000
16	50	0.6	0.6	1.000	1.515
17	50	0.7	0.7	1.014	2.217
18	50	0.8	0.8	2.582	3.083
19	50	0.9	0.9	5.890	4.124
20	50	1	1	12.314	5.349
21	100	0.1	0.1		
22	100	0.2	0.2		
23	100	0.3	0.3	1.000	1.000
24	100	0.4	0.4	1.000	1.000
25	100	0.5	0.5	1.000	1.201
26	100	0.6	0.6	1.000	1.884
27	100	0.7	0.7	1.741	2.758
28	100	0.8	0.8	4.434	3.835
29	100	0.9	0.9	10.113	5.130
30	100	1	1	21.144	6.655
31	20	0.1	1		
32	20	0.2	1		
33	20	0.3	1	1.000	1.000
34	20	0.4	1	1.000	1.000
35	20	0.5	1	1.000	1.000
36	20	0.6	1	1.000	1.000
37	20	0.7	1	1.000	1.505
38	20	0.8	1	1.057	2.172
39	20	0.9	1	2.649	3.001
40	20	1	1	6.026	4.008
41	50	0.1	1		
42	50	0.2	1		
43	50	0.3	1	1.000	1.000
44	50	0.4	1	1.000	1.000
45	50	0.5	1	1.000	1.000
46	50	0.6	1	1.000	1.316
47	50	0.7	1	1.000	2.009
48	50	0.8	1	2.160	2.899
49	50	0.9	1	5.414	4.005
50	50	1	1	12.314	5.349
51	100	0.1	1		
52	100	0.2	1		
53	100	0.3	1	1.000	1.000
54	100	0.4	1	1.000	1.000
55	100	0.5	1	1.000	1.000
56	100	0.6	1	1.000	1.637
57	100	0.7	1	1.309	2.499
58	100	0.8	1	3.709	3.606
59	100	0.9	1	9.296	4.983
60	100	1	1	21.144	6.655
61	20	0.1	0.3		
62	20	0.2	0.3		
63	20	0.3	0.3	1.000	1.000
64	20	0.4	0.3	1.000	1.000
65	20	0.5	0.3	1.000	1.000
66	20	0.6	0.3	1.000	1.374
67	20	0.7	0.3	1.000	2.098
68	20	0.8	0.3	2.770	3.028

Item #	D/T	d/D	t/T	PRG kth	Wais kth
69	20	0.9	0.3	6.941	4.184
70	20	1	0.3	15.787	5.588
71	50	0.1	0.3		
72	50	0.2	0.3		
73	50	0.3	0.3	1.000	1.000
74	50	0.4	0.3	1.000	1.000
75	50	0.5	0.3	1.000	1.112
76	50	0.6	0.3	1.000	1.834
77	50	0.7	0.3	1.997	2.801
78	50	0.8	0.3	5.660	4.041
79	50	0.9	0.3	14.184	5.584
80	50	1	0.3	32.262	7.458
81	100	0.1	0.3		
82	100	0.2	0.3		
83	100	0.3	0.3	1.000	1.000
84	100	0.4	0.3	1.000	1.000
85	100	0.5	0.3	1.000	1.383
86	100	0.6	0.3	1.031	2.282
87	100	0.7	0.3	3.430	3.484
88	100	0.8	0.3	9.719	5.027
89	100	0.9	0.3	24.355	6.947
90	100	1	0.3	55.399	9.278
91	20	0.1	3		
92	20	0.2	3		
93	20	0.3	3	1.000	1.000
94	20	0.4	3	1.000	1.000
95	20	0.5	3	1.000	1.000
96	20	0.6	3	1.000	1.000
97	20	0.7	3	1.000	1.111
98	20	0.8	3	1.000	1.604
99	20	0.9	3	1.100	2.216
100	20	1	3	2.502	2.960
101	50	0.1	3		
102	50	0.2	3		
103	50	0.3	3	1.000	1.000
104	50	0.4	3	1.000	1.000
105	50	0.5	3	1.000	1.000
106	50	0.6	3	1.000	1.000
107	50	0.7	3	1.000	1.483
108	50	0.8	3	1.000	2.140
109	50	0.9	3	2.248	2.958
110	50	1	3	5.113	3.950
111	100	0.1	3		
112	100	0.2	3		
113	100	0.3	3	1.000	1.000
114	100	0.4	3	1.000	1.000
115	100	0.5	3	1.000	1.000
116	100	0.6	3	1.000	1.208
117	100	0.7	3	1.000	1.845
118	100	0.8	3	1.540	2.663
119	100	0.9	3	3.860	3.680
120	100	1	3	8.780	4.914

Extruded Welding Tee (EXT) - Sketch 2.4 - Branch Inplane SIF

Item #	D/T	d/D	t/T	PRG iib	B31.3 iib WTEE	NB-3683.9 i	B31.3 iib EXT
1	20	0.1	0.1	1.000	1.000	1.555	1.000
2	20	0.2	0.2	1.000	1.000	1.555	1.000
3	20	0.3	0.3	1.123	1.000	1.555	1.000
4	20	0.4	0.4	1.356	1.000	1.555	1.319
5	20	0.5	0.5	1.568	1.000	1.555	1.639
6	20	0.6	0.6	1.763	1.034	1.555	1.955
7	20	0.7	0.7	1.945	1.207	1.555	2.267
8	20	0.8	0.8	2.040	1.379	1.555	2.575
9	20	0.9	0.9	2.209	1.551	1.555	2.880
10	20	1	1	2.432	1.724	1.555	3.181
11	50	0.1	0.1	1.000	1.000	2.864	1.000
12	50	0.2	0.2	1.581	1.000	2.864	1.189
13	50	0.3	0.3	2.069	1.000	2.864	1.772
14	50	0.4	0.4	2.500	1.186	2.864	2.348
15	50	0.5	0.5	2.891	1.482	2.864	2.916
16	50	0.6	0.6	3.252	1.779	2.864	3.478
17	50	0.7	0.7	3.588	2.075	2.864	4.033
18	50	0.8	0.8	3.904	2.372	2.864	4.582
19	50	0.9	0.9	4.203	2.668	2.864	5.124
20	50	1	1	4.488	2.964	2.864	5.659
21	100	0.1	0.1	1.577	1.000	4.547	1.000
22	100	0.2	0.2	2.510	1.000	4.547	1.858
23	100	0.3	0.3	3.286	1.368	4.547	2.769
24	100	0.4	0.4	3.970	1.824	4.547	3.669
25	100	0.5	0.5	4.591	2.279	4.547	4.558
26	100	0.6	0.6	5.163	2.735	4.547	5.435
27	100	0.7	0.7	5.698	3.191	4.547	6.302
28	100	0.8	0.8	6.201	3.647	4.547	7.159
29	100	0.9	0.9	6.676	4.103	4.547	8.005
30	100	1	1	7.128	4.559	4.547	8.842
31	20	0.1	1	1.000	1.724	1.555	3.352
32	20	0.2	1	1.146	1.724	1.555	3.332
33	20	0.3	1	1.233	1.724	1.555	3.312
34	20	0.4	1	1.354	1.724	1.555	3.292
35	20	0.5	1	1.565	1.724	1.555	3.273
36	20	0.6	1	1.761	1.724	1.555	3.254
37	20	0.7	1	1.943	1.724	1.555	3.236
38	20	0.8	1	2.040	1.724	1.555	3.217
39	20	0.9	1	2.209	1.724	1.555	3.199
40	20	1	1	2.432	1.724	1.555	3.181
41	50	0.1	1	1.852	2.964	2.864	5.975
42	50	0.2	1	2.112	2.964	2.864	5.938
43	50	0.3	1	2.272	2.964	2.864	5.901
44	50	0.4	1	2.498	2.964	2.864	5.865
45	50	0.5	1	2.889	2.964	2.864	5.829
46	50	0.6	1	3.250	2.964	2.864	5.794
47	50	0.7	1	3.587	2.964	2.864	5.760
48	50	0.8	1	3.903	2.964	2.864	5.726
49	50	0.9	1	4.203	2.964	2.864	5.692
50	50	1	1	4.488	2.964	2.864	5.659
51	100	0.1	1	2.959	4.559	4.547	9.345
52	100	0.2	1	3.352	4.559	4.547	9.285
53	100	0.3	1	3.606	4.559	4.547	9.227
54	100	0.4	1	3.968	4.559	4.547	9.169
55	100	0.5	1	4.589	4.559	4.547	9.112
56	100	0.6	1	5.162	4.559	4.547	9.057
57	100	0.7	1	5.697	4.559	4.547	9.002
58	100	0.8	1	6.200	4.559	4.547	8.948
59	100	0.9	1	6.676	4.559	4.547	8.894
60	100	1	1	7.128	4.559	4.547	8.842
61	20	0.1	0.3	1.000	1.000	1.555	1.008
62	20	0.2	0.3	1.000	1.000	1.555	1.002
63	20	0.3	0.3	1.123	1.000	1.555	1.000
64	20	0.4	0.3	1.357	1.000	1.555	1.000
65	20	0.5	0.3	1.569	1.000	1.555	1.000
66	20	0.6	0.3	1.765	1.000	1.555	1.000
67	20	0.7	0.3	1.948	1.000	1.555	1.000
68	20	0.8	0.3	2.040	1.000	1.555	1.000
69	20	0.9	0.3	2.209	1.000	1.555	1.000
70	20	1	0.3	2.437	1.724	1.555	3.188
71	50	0.1	0.3	1.000	1.000	2.864	1.794
72	50	0.2	0.3	1.581	1.000	2.864	1.783
73	50	0.3	0.3	2.069	1.000	2.864	1.772
74	50	0.4	0.3	2.500	1.000	2.864	1.761
75	50	0.5	0.3	2.892	1.000	2.864	1.750
76	50	0.6	0.3	3.253	1.000	2.864	1.740
77	50	0.7	0.3	3.590	1.000	2.864	1.729
78	50	0.8	0.3	3.907	1.000	2.864	1.719
79	50	0.9	0.3	4.207	1.000	2.864	1.709
80	50	1	0.3	4.492	2.964	2.864	5.664
81	100	0.1	0.3	1.577	1.368	4.547	2.805
82	100	0.2	0.3	2.510	1.368	4.547	2.787
83	100	0.3	0.3	3.286	1.368	4.547	2.769
84	100	0.4	0.3	3.970	1.368	4.547	2.752
85	100	0.5	0.3	4.591	1.368	4.547	2.735
86	100	0.6	0.3	5.164	1.368	4.547	2.718
87	100	0.7	0.3	5.699	1.368	4.547	2.702
88	100	0.8	0.3	6.203	1.368	4.547	2.685
89	100	0.9	0.3	6.679	1.368	4.547	2.669
90	100	1	0.3	7.131	4.559	4.547	8.846
91	20	0.1	3	2.082	5.171	1.555	9.996
92	20	0.2	3	2.474	5.171	1.555	9.936
93	20	0.3	3	2.661	5.171	1.555	9.877
94	20	0.4	3	2.802	5.171	1.555	9.820
95	20	0.5	3	2.917	5.171	1.555	9.763
96	20	0.6	3	3.015	5.171	1.555	9.707
97	20	0.7	3	3.099	5.171	1.555	9.652
98	20	0.8	3	3.175	5.171	1.555	9.597
99	20	0.9	3	3.243	5.171	1.555	9.544
100	20	1	3	3.305	1.724	1.555	3.164
101	50	0.1	3	4.022	8.893	2.864	17.881
102	50	0.2	3	4.557	8.893	2.864	17.770
103	50	0.3	3	4.902	8.893	2.864	17.660
104	50	0.4	3	5.162	8.893	2.864	17.552
105	50	0.5	3	5.374	8.893	2.864	17.446
106	50	0.6	3	5.553	8.893	2.864	17.341
107	50	0.7	3	5.709	8.893	2.864	17.238
108	50	0.8	3	5.848	8.893	2.864	17.137
109	50	0.9	3	5.973	8.893	2.864	17.037
110	50	1	3	6.088	2.964	2.864	5.646
111	100	0.1	3	6.385	13.677	4.547	27.998
112	100	0.2	3	7.233	13.677	4.547	27.820
113	100	0.3	3	7.781	13.677	4.547	27.645
114	100	0.4	3	8.194	13.677	4.547	27.473
115	100	0.5	3	8.530	13.677	4.547	27.303
116	100	0.6	3	8.815	13.677	4.547	27.137
117	100	0.7	3	9.063	13.677	4.547	26.972
118	100	0.8	3	9.283	13.677	4.547	26.811
119	100	0.9	3	9.482	13.677	4.547	26.652
120	100	1	3	9.664	4.559	4.547	8.832

Extruded Welding Tee (EXT) - Sketch 2.4 - Branch Outplane SIF

Item #	D/T	d/D	t/T	PRG iob	B31.3 iob WTEE	NB-3683.9 i	B31.3 iob EXT
1	20	0.1	0.1	1.006	1.140	1.555	1.234
2	20	0.2	0.2	1.740	1.140	1.555	1.234
3	20	0.3	0.3	2.117	1.140	1.555	1.233
4	20	0.4	0.4	2.428	1.140	1.555	1.626
5	20	0.5	0.5	2.696	1.140	1.555	2.019
6	20	0.6	0.6	2.934	1.179	1.555	2.406
7	20	0.7	0.7	3.148	1.375	1.555	2.789
8	20	0.8	0.8	3.344	1.572	1.555	3.167
9	20	0.9	0.9	3.524	1.768	1.555	3.540
10	20	1	1	3.691	1.965	1.555	3.908
11	50	0.1	0.1	1.852	1.221	2.864	1.278
12	50	0.2	0.2	3.207	1.221	2.864	1.518
13	50	0.3	0.3	3.901	1.221	2.864	2.263
14	50	0.4	0.4	4.475	1.448	2.864	2.997
15	50	0.5	0.5	4.971	1.810	2.864	3.722
16	50	0.6	0.6	5.411	2.172	2.864	4.438
17	50	0.7	0.7	5.807	2.534	2.864	5.144
18	50	0.8	0.8	6.169	2.895	2.864	5.842
19	50	0.9	0.9	6.502	3.257	2.864	6.532
20	50	1	1	6.812	3.619	2.864	7.212
21	100	0.1	0.1	3.464	1.260	4.547	1.298
22	100	0.2	0.2	5.091	1.260	4.547	2.411
23	100	0.3	0.3	6.194	1.724	4.547	3.592
24	100	0.4	0.4	7.106	2.298	4.547	4.759
25	100	0.5	0.5	7.894	2.873	4.547	5.910
26	100	0.6	0.6	8.592	3.447	4.547	7.047
27	100	0.7	0.7	9.222	4.022	4.547	8.170
28	100	0.8	0.8	9.797	4.596	4.547	9.279
29	100	0.9	0.9	10.328	5.171	4.547	10.374
30	100	1	1	10.820	5.745	4.547	11.456
31	20	0.1	1	1.183	1.965	1.555	4.136
32	20	0.2	1	1.736	1.965	1.555	4.109
33	20	0.3	1	2.112	1.965	1.555	4.083
34	20	0.4	1	2.423	1.965	1.555	4.057
35	20	0.5	1	2.692	1.965	1.555	4.031
36	20	0.6	1	2.930	1.965	1.555	4.006
37	20	0.7	1	3.146	1.965	1.555	3.981
38	20	0.8	1	3.342	1.965	1.555	3.956
39	20	0.9	1	3.523	1.965	1.555	3.932
40	20	1	1	3.691	1.965	1.555	3.908
41	50	0.1	1	2.179	3.619	2.864	7.634
42	50	0.2	1	3.203	3.619	2.864	7.584
43	50	0.3	1	3.898	3.619	2.864	7.535
44	50	0.4	1	4.472	3.619	2.864	7.487
45	50	0.5	1	4.968	3.619	2.864	7.439
46	50	0.6	1	5.408	3.619	2.864	7.392
47	50	0.7	1	5.805	3.619	2.864	7.346
48	50	0.8	1	6.167	3.619	2.864	7.301
49	50	0.9	1	6.502	3.619	2.864	7.256
50	50	1	1	6.812	3.619	2.864	7.212
51	100	0.1	1	3.460	5.745	4.547	12.126
52	100	0.2	1	5.088	5.745	4.547	12.047
53	100	0.3	1	6.191	5.745	4.547	11.969
54	100	0.4	1	7.103	5.745	4.547	11.892
55	100	0.5	1	7.891	5.745	4.547	11.816
56	100	0.6	1	8.590	5.745	4.547	11.742
57	100	0.7	1	9.221	5.745	4.547	11.669
58	100	0.8	1	9.796	5.745	4.547	11.597
59	100	0.9	1	10.327	5.745	4.547	11.526
60	100	1	1	10.820	5.745	4.547	11.456
61	20	0.1	0.3	1.006	1.140	1.555	1.244
62	20	0.2	0.3	1.740	1.140	1.555	1.236
63	20	0.3	0.3	2.117	1.140	1.555	1.233
64	20	0.4	0.3	2.429	1.140	1.555	1.232
65	20	0.5	0.3	2.698	1.140	1.555	1.232
66	20	0.6	0.3	2.937	1.140	1.555	1.231
67	20	0.7	0.3	3.152	1.140	1.555	1.231
68	20	0.8	0.3	3.349	1.140	1.555	1.230
69	20	0.9	0.3	3.531	1.140	1.555	1.229
70	20	1	0.3	3.699	1.965	1.555	3.917
71	50	0.1	0.3	2.276	1.221	2.864	2.292
72	50	0.2	0.3	3.206	1.221	2.864	2.277
73	50	0.3	0.3	3.901	1.221	2.864	2.263
74	50	0.4	0.3	4.476	1.221	2.864	2.248
75	50	0.5	0.3	4.972	1.221	2.864	2.234
76	50	0.6	0.3	5.413	1.221	2.864	2.220
77	50	0.7	0.3	5.810	1.221	2.864	2.206
78	50	0.8	0.3	6.173	1.221	2.864	2.192
79	50	0.9	0.3	6.507	1.221	2.864	2.179
80	50	1	0.3	6.817	3.619	2.864	7.219
81	100	0.1	0.3	3.623	1.724	4.547	3.640
82	100	0.2	0.3	5.091	1.724	4.547	3.616
83	100	0.3	0.3	6.194	1.724	4.547	3.592
84	100	0.4	0.3	7.107	1.724	4.547	3.569
85	100	0.5	0.3	7.895	1.724	4.547	3.547
86	100	0.6	0.3	8.594	1.724	4.547	3.524
87	100	0.7	0.3	9.225	1.724	4.547	3.502
88	100	0.8	0.3	9.800	1.724	4.547	3.481
89	100	0.9	0.3	10.331	1.724	4.547	3.459
90	100	1	0.3	10.821	5.745	4.547	11.461
91	20	0.1	3	2.082	5.895	1.555	12.328
92	20	0.2	3	2.474	5.895	1.555	12.248
93	20	0.3	3	2.661	5.895	1.555	12.170
94	20	0.4	3	2.802	5.895	1.555	12.093
95	20	0.5	3	2.917	5.895	1.555	12.017
96	20	0.6	3	3.015	5.895	1.555	11.942
97	20	0.7	3	3.126	5.895	1.555	11.869
98	20	0.8	3	3.322	5.895	1.555	11.797
99	20	0.9	3	3.502	5.895	1.555	11.725
100	20	1	3	3.669	1.965	1.555	3.885
101	50	0.1	3	4.022	10.858	2.864	22.842
102	50	0.2	3	4.557	10.858	2.864	22.693
103	50	0.3	3	4.902	10.858	2.864	22.547
104	50	0.4	3	5.162	10.858	2.864	22.403
105	50	0.5	3	5.374	10.858	2.864	22.261
106	50	0.6	3	5.553	10.858	2.864	22.122
107	50	0.7	3	5.791	10.858	2.864	21.984
108	50	0.8	3	6.152	10.858	2.864	21.849
109	50	0.9	3	6.486	10.858	2.864	21.716
110	50	1	3	6.795	3.619	2.864	7.195
111	100	0.1	3	6.385	17.236	4.547	36.330
112	100	0.2	3	7.233	17.236	4.547	36.093
113	100	0.3	3	7.781	17.236	4.547	35.860
114	100	0.4	3	8.194	17.236	4.547	35.630
115	100	0.5	3	8.530	17.236	4.547	35.404
116	100	0.6	3	8.815	17.236	4.547	35.182
117	100	0.7	3	9.209	17.236	4.547	34.963
118	100	0.8	3	9.784	17.236	4.547	34.748
119	100	0.9	3	10.314	17.236	4.547	34.535
120	100	1	3	10.806	5.745	4.547	11.442

Extruded Welding Tee (EXT) - Sketch 2.4 - Branch Torsional SIF

Item #	D/T	d/D	t/T	PRG itb	B31.3 iob WTEE	NB-3683.9 i	B31.3 iob EXT
1	20	0.1	0.1	1.000	1.140	1.555	1.234
2	20	0.2	0.2	1.000	1.140	1.555	1.234
3	20	0.3	0.3	1.000	1.140	1.555	1.233
4	20	0.4	0.4	1.000	1.140	1.555	1.626
5	20	0.5	0.5	1.000	1.140	1.555	2.019
6	20	0.6	0.6	1.000	1.179	1.555	2.406
7	20	0.7	0.7	1.255	1.375	1.555	2.789
8	20	0.8	0.8	1.703	1.572	1.555	3.167
9	20	0.9	0.9	2.231	1.768	1.555	3.540
10	20	1	1	2.839	1.965	1.555	3.908
11	50	0.1	0.1	1.000	1.221	2.864	1.278
12	50	0.2	0.2	1.000	1.221	2.864	1.518
13	50	0.3	0.3	1.000	1.221	2.864	2.263
14	50	0.4	0.4	1.000	1.448	2.864	2.997
15	50	0.5	0.5	1.208	1.810	2.864	3.722
16	50	0.6	0.6	1.835	2.172	2.864	4.438
17	50	0.7	0.7	2.611	2.534	2.864	5.144
18	50	0.8	0.8	3.545	2.895	2.864	5.842
19	50	0.9	0.9	4.637	3.257	2.864	6.532
20	50	1	1	5.690	3.619	2.864	7.212
21	100	0.1	0.1	1.000	1.260	4.547	1.298
22	100	0.2	0.2	1.000	1.260	4.547	2.411
23	100	0.3	0.3	1.000	1.724	4.547	3.592
24	100	0.4	0.4	1.262	2.298	4.547	4.759
25	100	0.5	0.5	2.104	2.873	4.547	5.910
26	100	0.6	0.6	3.194	3.447	4.547	7.047
27	100	0.7	0.7	4.512	4.022	4.547	8.170
28	100	0.8	0.8	5.856	4.596	4.547	9.279
29	100	0.9	0.9	7.365	5.171	4.547	10.374
30	100	1	1	9.037	5.745	4.547	11.456
31	20	0.1	1	1.000	1.965	1.555	4.136
32	20	0.2	1	1.000	1.965	1.555	4.109
33	20	0.3	1	1.000	1.965	1.555	4.083
34	20	0.4	1	1.000	1.965	1.555	4.057
35	20	0.5	1	1.000	1.965	1.555	4.031
36	20	0.6	1	1.022	1.965	1.555	4.006
37	20	0.7	1	1.391	1.965	1.555	3.981
38	20	0.8	1	1.817	1.965	1.555	3.956
39	20	0.9	1	2.300	1.965	1.555	3.932
40	20	1	1	2.839	1.965	1.555	3.908
41	50	0.1	1	1.000	3.619	2.864	7.634
42	50	0.2	1	1.000	3.619	2.864	7.584
43	50	0.3	1	1.000	3.619	2.864	7.535
44	50	0.4	1	1.000	3.619	2.864	7.487
45	50	0.5	1	1.477	3.619	2.864	7.439
46	50	0.6	1	2.099	3.619	2.864	7.392
47	50	0.7	1	2.840	3.619	2.864	7.346
48	50	0.8	1	3.686	3.619	2.864	7.301
49	50	0.9	1	4.637	3.619	2.864	7.256
50	50	1	1	5.690	3.619	2.864	7.212
51	100	0.1	1	1.000	5.745	4.547	12.126
52	100	0.2	1	1.000	5.745	4.547	12.047
53	100	0.3	1	1.000	5.745	4.547	11.969
54	100	0.4	1	1.646	5.745	4.547	11.892
55	100	0.5	1	2.572	5.745	4.547	11.816
56	100	0.6	1	3.335	5.745	4.547	11.742
57	100	0.7	1	4.511	5.745	4.547	11.669
58	100	0.8	1	5.855	5.745	4.547	11.597
59	100	0.9	1	7.365	5.745	4.547	11.526
60	100	1	1	9.037	5.745	4.547	11.456
61	20	0.1	0.3	1.000	1.140	1.555	1.244
62	20	0.2	0.3	1.000	1.140	1.555	1.236
63	20	0.3	0.3	1.000	1.140	1.555	1.233
64	20	0.4	0.3	1.000	1.140	1.555	1.232
65	20	0.5	0.3	1.000	1.140	1.555	1.232
66	20	0.6	0.3	1.000	1.140	1.555	1.231
67	20	0.7	0.3	1.000	1.140	1.555	1.231
68	20	0.8	0.3	1.282	1.140	1.555	1.230
69	20	0.9	0.3	1.622	1.140	1.555	1.229
70	20	1	0.3	2.003	1.965	1.555	3.917
71	50	0.1	0.3	1.000	1.221	2.864	2.292
72	50	0.2	0.3	1.000	1.221	2.864	2.277
73	50	0.3	0.3	1.000	1.221	2.864	2.263
74	50	0.4	0.3	1.000	1.221	2.864	2.248
75	50	0.5	0.3	1.042	1.221	2.864	2.234
76	50	0.6	0.3	1.500	1.221	2.864	2.220
77	50	0.7	0.3	2.042	1.221	2.864	2.206
78	50	0.8	0.3	2.668	1.221	2.864	2.192
79	50	0.9	0.3	3.376	1.221	2.864	2.179
80	50	1	0.3	4.168	3.619	2.864	7.219
81	100	0.1	0.3	1.000	1.724	4.547	3.640
82	100	0.2	0.3	1.000	1.724	4.547	3.616
83	100	0.3	0.3	1.000	1.724	4.547	3.592
84	100	0.4	0.3	1.161	1.724	4.547	3.569
85	100	0.5	0.3	1.814	1.724	4.547	3.547
86	100	0.6	0.3	2.612	1.724	4.547	3.524
87	100	0.7	0.3	3.556	1.724	4.547	3.502
88	100	0.8	0.3	4.644	1.724	4.547	3.481
89	100	0.9	0.3	5.878	1.724	4.547	3.459
90	100	1	0.3	7.257	5.745	4.547	11.461
91	20	0.1	3	1.000	5.895	1.555	12.328
92	20	0.2	3	1.000	5.895	1.555	12.248
93	20	0.3	3	1.000	5.895	1.555	12.170
94	20	0.4	3	1.000	5.895	1.555	12.093
95	20	0.5	3	1.000	5.895	1.555	12.017
96	20	0.6	3	1.406	5.895	1.555	11.942
97	20	0.7	3	1.913	5.895	1.555	11.869
98	20	0.8	3	2.499	5.895	1.555	11.797
99	20	0.9	3	3.163	5.895	1.555	11.725
100	20	1	3	3.905	1.965	1.555	3.885
101	50	0.1	3	1.000	10.858	2.864	22.842
102	50	0.2	3	1.000	10.858	2.864	22.693
103	50	0.3	3	1.000	10.858	2.864	22.547
104	50	0.4	3	1.300	10.858	2.864	22.403
105	50	0.5	3	2.032	10.858	2.864	22.261
106	50	0.6	3	2.926	10.858	2.864	22.122
107	50	0.7	3	3.982	10.858	2.864	21.984
108	50	0.8	3	5.201	10.858	2.864	21.849
109	50	0.9	3	6.583	10.858	2.864	21.716
110	50	1	3	8.127	3.619	2.864	7.195
111	100	0.1	3	1.000	17.236	4.547	36.330
112	100	0.2	3	1.000	17.236	4.547	36.093
113	100	0.3	3	1.273	17.236	4.547	35.860
114	100	0.4	3	2.264	17.236	4.547	35.630
115	100	0.5	3	3.537	17.236	4.547	35.404
116	100	0.6	3	5.094	17.236	4.547	35.182
117	100	0.7	3	6.933	17.236	4.547	34.963
118	100	0.8	3	9.056	17.236	4.547	34.748
119	100	0.9	3	11.461	17.236	4.547	34.535
120	100	1	3	14.150	5.745	4.547	11.442

Extruded Welding Tee (EXT) - Sketch 2.4 - Header Inplane SIF

Item #	D/T	d/D	t/T	PRG iih	B31.3 iih WTEE	NB-3683.9 i	B31.3 iih EXT
1	20	0.1	0.1	2.034	1.724	1.555	3.361
2	20	0.2	0.2	2.320	1.724	1.555	3.340
3	20	0.3	0.3	2.499	1.724	1.555	3.319
4	20	0.4	0.4	2.627	1.724	1.555	3.298
5	20	0.5	0.5	2.717	1.724	1.555	3.278
6	20	0.6	0.6	2.792	1.724	1.555	3.258
7	20	0.7	0.7	2.857	1.724	1.555	3.238
8	20	0.8	0.8	2.915	1.724	1.555	3.219
9	20	0.9	0.9	2.967	1.724	1.555	3.200
10	20	1	1	3.014	1.724	1.555	3.181
11	50	0.1	0.1	2.804	2.964	2.864	5.982
12	50	0.2	0.2	3.199	2.964	2.864	5.944
13	50	0.3	0.3	3.446	2.964	2.864	5.906
14	50	0.4	0.4	3.626	2.964	2.864	5.869
15	50	0.5	0.5	3.767	2.964	2.864	5.833
16	50	0.6	0.6	3.882	2.964	2.864	5.797
17	50	0.7	0.7	3.978	2.964	2.864	5.762
18	50	0.8	0.8	4.060	2.964	2.864	5.727
19	50	0.9	0.9	4.131	2.964	2.864	5.693
20	50	1	1	4.193	2.964	2.864	5.659
21	100	0.1	0.1	3.574	4.559	4.547	9.350
22	100	0.2	0.2	4.078	4.559	4.547	9.290
23	100	0.3	0.3	4.393	4.559	4.547	9.231
24	100	0.4	0.4	4.623	4.559	4.547	9.172
25	100	0.5	0.5	4.803	4.559	4.547	9.115
26	100	0.6	0.6	4.950	4.559	4.547	9.059
27	100	0.7	0.7	5.073	4.559	4.547	9.003
28	100	0.8	0.8	5.178	4.559	4.547	8.949
29	100	0.9	0.9	5.268	4.559	4.547	8.895
30	100	1	1	5.347	4.559	4.547	8.842
31	20	0.1	1	1.000	1.724	1.555	3.352
32	20	0.2	1	1.002	1.724	1.555	3.332
33	20	0.3	1	1.333	1.724	1.555	3.312
34	20	0.4	1	1.630	1.724	1.555	3.292
35	20	0.5	1	1.902	1.724	1.555	3.273
36	20	0.6	1	2.155	1.724	1.555	3.254
37	20	0.7	1	2.393	1.724	1.555	3.236
38	20	0.8	1	2.618	1.724	1.555	3.217
39	20	0.9	1	2.832	1.724	1.555	3.199
40	20	1	1	3.014	1.724	1.555	3.181
41	50	0.1	1	1.000	2.964	2.864	5.975
42	50	0.2	1	1.384	2.964	2.864	5.938
43	50	0.3	1	1.841	2.964	2.864	5.901
44	50	0.4	1	2.250	2.964	2.864	5.865
45	50	0.5	1	2.626	2.964	2.864	5.829
46	50	0.6	1	2.975	2.964	2.864	5.794
47	50	0.7	1	3.304	2.964	2.864	5.760
48	50	0.8	1	3.615	2.964	2.864	5.726
49	50	0.9	1	3.910	2.964	2.864	5.692
50	50	1	1	4.193	2.964	2.864	5.659
51	100	0.1	1	1.079	4.559	4.547	9.345
52	100	0.2	1	1.765	4.559	4.547	9.285
53	100	0.3	1	2.348	4.559	4.547	9.227
54	100	0.4	1	2.870	4.559	4.547	9.169
55	100	0.5	1	3.349	4.559	4.547	9.112
56	100	0.6	1	3.794	4.559	4.547	9.057
57	100	0.7	1	4.213	4.559	4.547	9.002
58	100	0.8	1	4.610	4.559	4.547	8.948
59	100	0.9	1	4.987	4.559	4.547	8.894
60	100	1	1	5.347	4.559	4.547	8.842
61	20	0.1	0.3	1.148	1.724	1.555	3.359
62	20	0.2	0.3	1.879	1.724	1.555	3.339
63	20	0.3	0.3	2.499	1.724	1.555	3.319
64	20	0.4	0.3	2.905	1.724	1.555	3.299
65	20	0.5	0.3	3.248	1.724	1.555	3.280
66	20	0.6	0.3	3.558	1.724	1.555	3.261
67	20	0.7	0.3	3.844	1.724	1.555	3.242
68	20	0.8	0.3	4.109	1.724	1.555	3.224
69	20	0.9	0.3	4.358	1.724	1.555	3.205
70	20	1	0.3	4.594	1.724	1.555	3.188
71	50	0.1	0.3	1.583	2.964	2.864	5.981
72	50	0.2	0.3	2.590	2.964	2.864	5.943
73	50	0.3	0.3	3.446	2.964	2.864	5.906
74	50	0.4	0.3	4.192	2.964	2.864	5.870
75	50	0.5	0.3	4.687	2.964	2.864	5.834
76	50	0.6	0.3	5.134	2.964	2.864	5.799
77	50	0.7	0.3	5.545	2.964	2.864	5.765
78	50	0.8	0.3	5.928	2.964	2.864	5.731
79	50	0.9	0.3	6.288	2.964	2.864	5.697
80	50	1	0.3	6.628	2.964	2.864	5.664
81	100	0.1	0.3	2.018	4.559	4.547	9.349
82	100	0.2	0.3	3.302	4.559	4.547	9.289
83	100	0.3	0.3	4.393	4.559	4.547	9.231
84	100	0.4	0.3	5.370	4.559	4.547	9.173
85	100	0.5	0.3	6.184	4.559	4.547	9.116
86	100	0.6	0.3	6.774	4.559	4.547	9.060
87	100	0.7	0.3	7.317	4.559	4.547	9.005
88	100	0.8	0.3	7.822	4.559	4.547	8.951
89	100	0.9	0.3	8.297	4.559	4.547	8.898
90	100	1	0.3	8.745	4.559	4.547	8.846
91	20	0.1	3	1.000	1.724	1.555	3.332
92	20	0.2	3	1.000	1.724	1.555	3.312
93	20	0.3	3	1.000	1.724	1.555	3.292
94	20	0.4	3	1.000	1.724	1.555	3.273
95	20	0.5	3	1.067	1.724	1.555	3.254
96	20	0.6	3	1.209	1.724	1.555	3.236
97	20	0.7	3	1.343	1.724	1.555	3.217
98	20	0.8	3	1.470	1.724	1.555	3.199
99	20	0.9	3	1.590	1.724	1.555	3.181
100	20	1	3	1.705	1.724	1.555	3.164
101	50	0.1	3	1.000	2.964	2.864	5.960
102	50	0.2	3	1.000	2.964	2.864	5.923
103	50	0.3	3	1.037	2.964	2.864	5.887
104	50	0.4	3	1.268	2.964	2.864	5.851
105	50	0.5	3	1.479	2.964	2.864	5.815
106	50	0.6	3	1.676	2.964	2.864	5.780
107	50	0.7	3	1.861	2.964	2.864	5.746
108	50	0.8	3	2.036	2.964	2.864	5.712
109	50	0.9	3	2.203	2.964	2.864	5.679
110	50	1	3	2.363	2.964	2.864	5.646
111	100	0.1	3	1.000	4.559	4.547	9.333
112	100	0.2	3	1.000	4.559	4.547	9.273
113	100	0.3	3	1.324	4.559	4.547	9.215
114	100	0.4	3	1.619	4.559	4.547	9.158
115	100	0.5	3	1.889	4.559	4.547	9.101
116	100	0.6	3	2.140	4.559	4.547	9.046
117	100	0.7	3	2.377	4.559	4.547	8.991
118	100	0.8	3	2.600	4.559	4.547	8.937
119	100	0.9	3	2.813	4.559	4.547	8.884
120	100	1	3	3.017	4.559	4.547	8.832

Extruded Welding Tee (EXT) - Sketch 2.4 - Header Outplane SIF

Item #	D/T	d/D	t/T	PRG ioh	B31.3 ioh WTEE	NB-3683.9 i	B31.3 ioh EXT
1	20	0.1	0.1	1.000	1.965	1.555	4.148
2	20	0.2	0.2	1.000	1.965	1.555	4.120
3	20	0.3	0.3	1.000	1.965	1.555	4.092
4	20	0.4	0.4	1.000	1.965	1.555	4.064
5	20	0.5	0.5	1.000	1.965	1.555	4.037
6	20	0.6	0.6	1.000	1.965	1.555	4.011
7	20	0.7	0.7	1.000	1.965	1.555	3.985
8	20	0.8	0.8	1.301	1.965	1.555	3.959
9	20	0.9	0.9	1.805	1.965	1.555	3.933
10	20	1	1	2.476	1.965	1.555	3.908
11	50	0.1	0.1	1.000	3.619	2.864	7.643
12	50	0.2	0.2	1.000	3.619	2.864	7.592
13	50	0.3	0.3	1.000	3.619	2.864	7.542
14	50	0.4	0.4	1.000	3.619	2.864	7.492
15	50	0.5	0.5	1.000	3.619	2.864	7.444
16	50	0.6	0.6	1.107	3.619	2.864	7.396
17	50	0.7	0.7	1.412	3.619	2.864	7.349
18	50	0.8	0.8	1.929	3.619	2.864	7.303
19	50	0.9	0.9	2.677	3.619	2.864	7.257
20	50	1	1	3.672	3.619	2.864	7.212
21	100	0.1	0.1	1.000	5.745	4.547	12.133
22	100	0.2	0.2	1.000	5.745	4.547	12.053
23	100	0.3	0.3	1.000	5.745	4.547	11.974
24	100	0.4	0.4	1.000	5.745	4.547	11.897
25	100	0.5	0.5	1.180	5.745	4.547	11.820
26	100	0.6	0.6	1.491	5.745	4.547	11.745
27	100	0.7	0.7	1.903	5.745	4.547	11.671
28	100	0.8	0.8	2.599	5.745	4.547	11.598
29	100	0.9	0.9	3.606	5.745	4.547	11.527
30	100	1	1	4.947	5.745	4.547	11.456
31	20	0.1	1	1.000	1.965	1.555	4.136
32	20	0.2	1	1.000	1.965	1.555	4.109
33	20	0.3	1	1.000	1.965	1.555	4.083
34	20	0.4	1	1.000	1.965	1.555	4.057
35	20	0.5	1	1.000	1.965	1.555	4.031
36	20	0.6	1	1.000	1.965	1.555	4.006
37	20	0.7	1	1.000	1.965	1.555	3.981
38	20	0.8	1	1.113	1.965	1.555	3.956
39	20	0.9	1	1.677	1.965	1.555	3.932
40	20	1	1	2.476	1.965	1.555	3.908
41	50	0.1	1	1.000	3.619	2.864	7.634
42	50	0.2	1	1.000	3.619	2.864	7.584
43	50	0.3	1	1.000	3.619	2.864	7.535
44	50	0.4	1	1.000	3.619	2.864	7.487
45	50	0.5	1	1.000	3.619	2.864	7.439
46	50	0.6	1	1.000	3.619	2.864	7.392
47	50	0.7	1	1.100	3.619	2.864	7.346
48	50	0.8	1	1.650	3.619	2.864	7.301
49	50	0.9	1	2.486	3.619	2.864	7.256
50	50	1	1	3.672	3.619	2.864	7.212
51	100	0.1	1	1.000	5.745	4.547	12.126
52	100	0.2	1	1.000	5.745	4.547	12.047
53	100	0.3	1	1.000	5.745	4.547	11.969
54	100	0.4	1	1.000	5.745	4.547	11.892
55	100	0.5	1	1.000	5.745	4.547	11.816
56	100	0.6	1	1.043	5.745	4.547	11.742
57	100	0.7	1	1.482	5.745	4.547	11.669
58	100	0.8	1	2.223	5.745	4.547	11.597
59	100	0.9	1	3.350	5.745	4.547	11.526
60	100	1	1	4.947	5.745	4.547	11.456
61	20	0.1	0.3	1.000	1.965	1.555	4.146
62	20	0.2	0.3	1.000	1.965	1.555	4.119
63	20	0.3	0.3	1.000	1.965	1.555	4.092
64	20	0.4	0.3	1.000	1.965	1.555	4.066
65	20	0.5	0.3	1.000	1.965	1.555	4.040
66	20	0.6	0.3	1.000	1.965	1.555	4.014
67	20	0.7	0.3	1.123	1.965	1.555	3.989
68	20	0.8	0.3	1.457	1.965	1.555	3.965
69	20	0.9	0.3	1.913	1.965	1.555	3.941
70	20	1	0.3	2.524	1.965	1.555	3.917
71	50	0.1	0.3	1.000	3.619	2.864	7.641
72	50	0.2	0.3	1.000	3.619	2.864	7.591
73	50	0.3	0.3	1.000	3.619	2.864	7.542
74	50	0.4	0.3	1.000	3.619	2.864	7.493
75	50	0.5	0.3	1.000	3.619	2.864	7.446
76	50	0.6	0.3	1.207	3.619	2.864	7.399
77	50	0.7	0.3	1.787	3.619	2.864	7.353
78	50	0.8	0.3	2.584	3.619	2.864	7.307
79	50	0.9	0.3	3.525	3.619	2.864	7.263
80	50	1	0.3	4.652	3.619	2.864	7.219
81	100	0.1	0.3	1.000	5.745	4.547	12.132
82	100	0.2	0.3	1.000	5.745	4.547	12.052
83	100	0.3	0.3	1.000	5.745	4.547	11.974
84	100	0.4	0.3	1.000	5.745	4.547	11.897
85	100	0.5	0.3	1.181	5.745	4.547	11.822
86	100	0.6	0.3	1.694	5.745	4.547	11.747
87	100	0.7	0.3	2.408	5.745	4.547	11.674
88	100	0.8	0.3	3.612	5.745	4.547	11.602
89	100	0.9	0.3	5.442	5.745	4.547	11.531
90	100	1	0.3	7.386	5.745	4.547	11.461
91	20	0.1	3	1.000	1.965	1.555	4.109
92	20	0.2	3	1.000	1.965	1.555	4.083
93	20	0.3	3	1.000	1.965	1.555	4.057
94	20	0.4	3	1.000	1.965	1.555	4.031
95	20	0.5	3	1.000	1.965	1.555	4.006
96	20	0.6	3	1.000	1.965	1.555	3.981
97	20	0.7	3	1.000	1.965	1.555	3.956
98	20	0.8	3	1.000	1.965	1.555	3.932
99	20	0.9	3	1.000	1.965	1.555	3.908
100	20	1	3	1.148	1.965	1.555	3.885
101	50	0.1	3	1.000	3.619	2.864	7.614
102	50	0.2	3	1.000	3.619	2.864	7.564
103	50	0.3	3	1.000	3.619	2.864	7.516
104	50	0.4	3	1.000	3.619	2.864	7.468
105	50	0.5	3	1.000	3.619	2.864	7.420
106	50	0.6	3	1.000	3.619	2.864	7.374
107	50	0.7	3	1.000	3.619	2.864	7.328
108	50	0.8	3	1.000	3.619	2.864	7.283
109	50	0.9	3	1.152	3.619	2.864	7.239
110	50	1	3	1.702	3.619	2.864	7.195
111	100	0.1	3	1.000	5.745	4.547	12.110
112	100	0.2	3	1.000	5.745	4.547	12.031
113	100	0.3	3	1.000	5.745	4.547	11.953
114	100	0.4	3	1.000	5.745	4.547	11.877
115	100	0.5	3	1.000	5.745	4.547	11.801
116	100	0.6	3	1.000	5.745	4.547	11.727
117	100	0.7	3	1.000	5.745	4.547	11.654
118	100	0.8	3	1.030	5.745	4.547	11.583
119	100	0.9	3	1.553	5.745	4.547	11.512
120	100	1	3	2.293	5.745	4.547	11.442

Extruded Welding Tee (EXT) - Sketch 2.4 - Header Torsional SIF

Item #	D/T	d/D	t/T	PRG ith	B31.3 ioh WTEE	NB-3683.9 i	B31.3 ioh EXT
1	20	0.1	0.1	1.000	1.965	1.555	4.148
2	20	0.2	0.2	1.000	1.965	1.555	4.120
3	20	0.3	0.3	1.143	1.965	1.555	4.092
4	20	0.4	0.4	1.490	1.965	1.555	4.064
5	20	0.5	0.5	1.745	1.965	1.555	4.037
6	20	0.6	0.6	1.899	1.965	1.555	4.011
7	20	0.7	0.7	2.037	1.965	1.555	3.985
8	20	0.8	0.8	2.164	1.965	1.555	3.959
9	20	0.9	0.9	2.280	1.965	1.555	3.933
10	20	1	1	2.388	1.965	1.555	3.908
11	50	0.1	0.1	1.000	3.619	2.864	7.643
12	50	0.2	0.2	1.200	3.619	2.864	7.592
13	50	0.3	0.3	1.743	3.619	2.864	7.542
14	50	0.4	0.4	2.271	3.619	2.864	7.492
15	50	0.5	0.5	2.788	3.619	2.864	7.444
16	50	0.6	0.6	3.297	3.619	2.864	7.396
17	50	0.7	0.7	3.758	3.619	2.864	7.349
18	50	0.8	0.8	3.992	3.619	2.864	7.303
19	50	0.9	0.9	4.207	3.619	2.864	7.257
20	50	1	1	4.408	3.619	2.864	7.212
21	100	0.1	0.1	1.000	5.745	4.547	12.133
22	100	0.2	0.2	1.651	5.745	4.547	12.053
23	100	0.3	0.3	2.397	5.745	4.547	11.974
24	100	0.4	0.4	3.123	5.745	4.547	11.897
25	100	0.5	0.5	3.835	5.745	4.547	11.820
26	100	0.6	0.6	4.535	5.745	4.547	11.745
27	100	0.7	0.7	5.226	5.745	4.547	11.671
28	100	0.8	0.8	5.909	5.745	4.547	11.598
29	100	0.9	0.9	6.586	5.745	4.547	11.527
30	100	1	1	7.001	5.745	4.547	11.456
31	20	0.1	1	1.000	1.965	1.555	4.136
32	20	0.2	1	1.000	1.965	1.555	4.109
33	20	0.3	1	1.000	1.965	1.555	4.083
34	20	0.4	1	1.000	1.965	1.555	4.057
35	20	0.5	1	1.232	1.965	1.555	4.031
36	20	0.6	1	1.469	1.965	1.555	4.006
37	20	0.7	1	1.703	1.965	1.555	3.981
38	20	0.8	1	1.934	1.965	1.555	3.956
39	20	0.9	1	2.163	1.965	1.555	3.932
40	20	1	1	2.388	1.965	1.555	3.908
41	50	0.1	1	1.000	3.619	2.864	7.634
42	50	0.2	1	1.000	3.619	2.864	7.584
43	50	0.3	1	1.014	3.619	2.864	7.535
44	50	0.4	1	1.503	3.619	2.864	7.487
45	50	0.5	1	2.041	3.619	2.864	7.439
46	50	0.6	1	2.620	3.619	2.864	7.392
47	50	0.7	1	3.143	3.619	2.864	7.346
48	50	0.8	1	3.569	3.619	2.864	7.301
49	50	0.9	1	3.991	3.619	2.864	7.256
50	50	1	1	4.408	3.619	2.864	7.212
51	100	0.1	1	1.000	5.745	4.547	12.126
52	100	0.2	1	1.000	5.745	4.547	12.047
53	100	0.3	1	1.394	5.745	4.547	11.969
54	100	0.4	1	2.068	5.745	4.547	11.892
55	100	0.5	1	2.807	5.745	4.547	11.816
56	100	0.6	1	3.604	5.745	4.547	11.742
57	100	0.7	1	4.451	5.745	4.547	11.669
58	100	0.8	1	5.345	5.745	4.547	11.597
59	100	0.9	1	6.281	5.745	4.547	11.526
60	100	1	1	7.001	5.745	4.547	11.456
61	20	0.1	0.3	1.000	1.965	1.555	4.146
62	20	0.2	0.3	1.000	1.965	1.555	4.119
63	20	0.3	0.3	1.143	1.965	1.555	4.092
64	20	0.4	0.3	1.696	1.965	1.555	4.066
65	20	0.5	0.3	2.254	1.965	1.555	4.040
66	20	0.6	0.3	2.687	1.965	1.555	4.014
67	20	0.7	0.3	3.116	1.965	1.555	3.989
68	20	0.8	0.3	3.539	1.965	1.555	3.965
69	20	0.9	0.3	3.957	1.965	1.555	3.941
70	20	1	0.3	4.370	1.965	1.555	3.917
71	50	0.1	0.3	1.000	3.619	2.864	7.641
72	50	0.2	0.3	1.000	3.619	2.864	7.591
73	50	0.3	0.3	1.743	3.619	2.864	7.542
74	50	0.4	0.3	2.584	3.619	2.864	7.493
75	50	0.5	0.3	3.508	3.619	2.864	7.446
76	50	0.6	0.3	4.504	3.619	2.864	7.399
77	50	0.7	0.3	5.563	3.619	2.864	7.353
78	50	0.8	0.3	6.522	3.619	2.864	7.307
79	50	0.9	0.3	7.293	3.619	2.864	7.263
80	50	1	0.3	8.054	3.619	2.864	7.219
81	100	0.1	0.3	1.000	5.745	4.547	12.132
82	100	0.2	0.3	1.375	5.745	4.547	12.052
83	100	0.3	0.3	2.397	5.745	4.547	11.974
84	100	0.4	0.3	3.555	5.745	4.547	11.897
85	100	0.5	0.3	4.826	5.745	4.547	11.822
86	100	0.6	0.3	6.195	5.745	4.547	11.747
87	100	0.7	0.3	7.652	5.745	4.547	11.674
88	100	0.8	0.3	9.188	5.745	4.547	11.602
89	100	0.9	0.3	10.797	5.745	4.547	11.531
90	100	1	0.3	12.474	5.745	4.547	11.461
91	20	0.1	3	1.000	1.965	1.555	4.109
92	20	0.2	3	1.000	1.965	1.555	4.083
93	20	0.3	3	1.000	1.965	1.555	4.057
94	20	0.4	3	1.000	1.965	1.555	4.031
95	20	0.5	3	1.000	1.965	1.555	4.006
96	20	0.6	3	1.000	1.965	1.555	3.981
97	20	0.7	3	1.000	1.965	1.555	3.956
98	20	0.8	3	1.110	1.965	1.555	3.932
99	20	0.9	3	1.241	1.965	1.555	3.908
100	20	1	3	1.371	1.965	1.555	3.885
101	50	0.1	3	1.000	3.619	2.864	7.614
102	50	0.2	3	1.000	3.619	2.864	7.564
103	50	0.3	3	1.000	3.619	2.864	7.516
104	50	0.4	3	1.000	3.619	2.864	7.468
105	50	0.5	3	1.245	3.619	2.864	7.420
106	50	0.6	3	1.561	3.619	2.864	7.374
107	50	0.7	3	1.810	3.619	2.864	7.328
108	50	0.8	3	2.056	3.619	2.864	7.283
109	50	0.9	3	2.299	3.619	2.864	7.239
110	50	1	3	2.539	3.619	2.864	7.195
111	100	0.1	3	1.000	5.745	4.547	12.110
112	100	0.2	3	1.000	5.745	4.547	12.031
113	100	0.3	3	1.000	5.745	4.547	11.953
114	100	0.4	3	1.261	5.745	4.547	11.877
115	100	0.5	3	1.712	5.745	4.547	11.801
116	100	0.6	3	2.198	5.745	4.547	11.727
117	100	0.7	3	2.715	5.745	4.547	11.654
118	100	0.8	3	3.260	5.745	4.547	11.583
119	100	0.9	3	3.655	5.745	4.547	11.512
120	100	1	3	4.037	5.745	4.547	11.442

Extruded Welding Tee (EXT) - Sketch 2.4 - Branch Inplane K

Item #	D/T	d/D	t/T	PRG kib	PRG UFT kib	Wais UFT kib
1	20	0.1	0.1	1.000	1.000	1.507
2	20	0.2	0.2	1.000	1.721	1.977
3	20	0.3	0.3	1.000	2.274	2.316
4	20	0.4	0.4	1.000	2.550	2.592
5	20	0.5	0.5	1.000	2.627	2.828
6	20	0.6	0.6	1.000	2.623	3.037
7	20	0.7	0.7	1.000	2.689	3.226
8	20	0.8	0.8	1.000	2.991	3.399
9	20	0.9	0.9	1.000	3.718	3.559
10	20	1	1	1.708	5.071	3.709
11	50	0.1	0.1	1.000	1.892	2.803
12	50	0.2	0.2	1.000	3.682	3.676
13	50	0.3	0.3	1.000	4.866	4.307
14	50	0.4	0.4	1.000	5.456	4.820
15	50	0.5	0.5	1.000	5.619	5.259
16	50	0.6	0.6	1.000	5.613	5.648
17	50	0.7	0.7	1.033	5.752	5.999
18	50	0.8	0.8	1.251	6.399	6.320
19	50	0.9	0.9	1.921	7.954	6.618
20	50	1	1	3.458	10.848	6.896
21	100	0.1	0.1	1.000	3.363	4.481
22	100	0.2	0.2	1.000	6.546	5.877
23	100	0.3	0.3	1.000	8.650	6.886
24	100	0.4	0.4	1.299	9.699	7.706
25	100	0.5	0.5	1.560	9.989	8.408
26	100	0.6	0.6	1.670	9.977	9.030
27	100	0.7	0.7	1.761	10.225	9.591
28	100	0.8	0.8	2.133	11.376	10.105
29	100	0.9	0.9	3.276	14.140	10.581
30	100	1	1	5.897	19.284	11.026
31	20	0.1	1	1.000	2.732	6.029
32	20	0.2	1	1.000	3.787	5.208
33	20	0.3	1	1.000	4.103	4.781
34	20	0.4	1	1.000	3.995	4.500
35	20	0.5	1	1.000	3.689	4.293
36	20	0.6	1	1.000	3.370	4.131
37	20	0.7	1	1.000	3.202	3.999
38	20	0.8	1	1.000	3.337	3.887
39	20	0.9	1	1.054	3.915	3.792
40	20	1	1	1.708	5.071	3.709
41	50	0.1	1	1.000	5.846	11.210
42	50	0.2	1	1.292	8.102	9.685
43	50	0.3	1	1.741	8.778	8.891
44	50	0.4	1	1.904	8.548	8.367
45	50	0.5	1	1.829	7.892	7.983
46	50	0.6	1	1.632	7.209	7.681
47	50	0.7	1	1.475	6.850	7.435
48	50	0.8	1	1.563	7.139	7.229
49	50	0.9	1	2.135	8.376	7.051
50	50	1	1	3.458	10.848	6.896
51	100	0.1	1	1.037	10.392	17.923
52	100	0.2	1	2.203	14.403	15.485
53	100	0.3	1	2.969	15.604	14.215
54	100	0.4	1	3.246	15.195	13.378
55	100	0.5	1	3.119	14.030	12.763
56	100	0.6	1	2.783	12.815	12.281
57	100	0.7	1	2.516	12.178	11.888
58	100	0.8	1	2.666	12.690	11.558
59	100	0.9	1	3.640	14.889	11.274
60	100	1	1	5.897	19.284	11.026
61	20	0.1	0.3	1.000	1.515	2.920
62	20	0.2	0.3	1.000	2.099	2.523
63	20	0.3	0.3	1.000	2.274	2.316
64	20	0.4	0.3	1.000	2.215	2.180
65	20	0.5	0.3	1.000	2.045	2.080
66	20	0.6	0.3	1.000	1.868	2.001
67	20	0.7	0.3	1.000	1.775	1.937
Item #	D/T	d/D	t/T	PRG kib	PRG UFT kib	Wais UFT kib
68	20	0.8	0.3	1.000	1.850	1.883
69	20	0.9	0.3	1.000	2.170	1.837
70	20	1	0.3	1.000	2.811	1.797
71	50	0.1	0.3	1.000	3.241	5.431
72	50	0.2	0.3	1.000	4.492	4.692
73	50	0.3	0.3	1.000	4.866	4.307
74	50	0.4	0.3	1.000	4.738	4.053
75	50	0.5	0.3	1.000	4.375	3.867
76	50	0.6	0.3	1.000	3.996	3.721
77	50	0.7	0.3	1.000	3.798	3.602
78	50	0.8	0.3	1.000	3.957	3.502
79	50	0.9	0.3	1.000	4.643	3.416
80	50	1	0.3	1.037	6.014	3.341
81	100	0.1	0.3	1.000	5.761	8.683
82	100	0.2	0.3	1.000	7.985	7.501
83	100	0.3	0.3	1.000	8.650	6.886
84	100	0.4	0.3	1.000	8.423	6.481
85	100	0.5	0.3	1.000	7.777	6.183
86	100	0.6	0.3	1.000	7.104	5.949
87	100	0.7	0.3	1.000	6.751	5.759
88	100	0.8	0.3	1.000	7.035	5.599
89	100	0.9	0.3	1.092	8.254	5.461
90	100	1	0.3	1.769	10.690	5.341
91	20	0.1	3	1.000	4.681	11.680
92	20	0.2	3	1.914	6.488	10.091
93	20	0.3	3	2.579	7.029	9.263
94	20	0.4	3	2.820	6.845	8.718
95	20	0.5	3	2.710	6.320	8.317
96	20	0.6	3	2.418	5.773	8.003
97	20	0.7	3	2.186	5.485	7.747
98	20	0.8	3	2.316	5.716	7.532
99	20	0.9	3	3.162	6.707	7.347
100	20	1	3	5.123	8.687	7.185
101	50	0.1	3	1.824	10.014	21.719
102	50	0.2	3	3.875	13.880	18.764
103	50	0.3	3	5.223	15.037	17.226
104	50	0.4	3	5.711	14.643	16.211
105	50	0.5	3	5.488	13.520	15.466
106	50	0.6	3	4.896	12.350	14.882
107	50	0.7	3	4.426	11.735	14.406
108	50	0.8	3	4.690	12.229	14.005
109	50	0.9	3	6.404	14.349	13.662
110	50	1	3	10.374	18.584	13.361
111	100	0.1	3	3.111	17.802	34.725
112	100	0.2	3	6.608	24.675	30.001
113	100	0.3	3	8.906	26.732	27.541
114	100	0.4	3	9.739	26.031	25.919
115	100	0.5	3	9.358	24.034	24.727
116	100	0.6	3	8.349	21.954	23.793
117	100	0.7	3	7.547	20.862	23.032
118	100	0.8	3	7.997	21.740	22.392
119	100	0.9	3	10.920	25.508	21.842
120	100	1	3	17.690	33.037	21.362

Extruded Welding Tee (EXT) - Sketch 2.4 - Branch Outplane K

Item #	D/T	d/D	t/T	PRG kob	PRG UFT kob	Wais UFT kob
1	20	0.1	0.1	1.000	1.000	1.374
2	20	0.2	0.2	1.000	2.375	3.391
3	20	0.3	0.3	1.000	4.013	5.358
4	20	0.4	0.4	1.000	5.454	6.981
5	20	0.5	0.5	1.009	6.519	8.091
6	20	0.6	0.6	1.150	7.115	8.595
7	20	0.7	0.7	1.204	7.222	8.448
8	20	0.8	0.8	1.167	6.879	7.642
9	20	0.9	0.9	1.047	6.182	6.202
10	20	1	1	1.000	5.275	4.177
11	50	0.1	0.1	1.000	3.050	3.445
12	50	0.2	0.2	1.095	8.565	8.501
13	50	0.3	0.3	2.069	14.472	13.433
14	50	0.4	0.4	3.038	19.672	17.500
15	50	0.5	0.5	3.846	23.513	20.283
16	50	0.6	0.6	4.384	25.664	21.547
17	50	0.7	0.7	4.588	26.048	21.178
18	50	0.8	0.8	4.445	24.812	19.158
19	50	0.9	0.9	3.988	22.296	15.549
20	50	1	1	3.297	19.025	10.472
21	100	0.1	0.1	1.000	8.050	6.904
22	100	0.2	0.2	3.014	22.602	17.038
23	100	0.3	0.3	5.692	38.193	26.921
24	100	0.4	0.4	8.359	51.915	35.072
25	100	0.5	0.5	10.582	62.052	40.651
26	100	0.6	0.6	12.060	67.727	43.183
27	100	0.7	0.7	12.622	68.742	42.443
28	100	0.8	0.8	12.229	65.479	38.397
29	100	0.9	0.9	10.971	58.841	31.162
30	100	1	1	9.070	50.209	20.988
31	20	0.1	1	1.000	3.367	7.162
32	20	0.2	1	1.437	6.237	10.753
33	20	0.3	1	1.810	8.263	12.704
34	20	0.4	1	1.993	9.451	13.465
35	20	0.5	1	2.019	9.881	13.300
36	20	0.6	1	1.917	9.667	12.397
37	20	0.7	1	1.720	8.945	10.910
38	20	0.8	1	1.458	7.865	8.968
39	20	0.9	1	1.163	6.585	6.689
40	20	1	1	1.000	5.275	4.177
41	50	0.1	1	3.218	12.144	17.955
42	50	0.2	1	5.477	22.495	26.956
43	50	0.3	1	6.897	29.804	31.847
44	50	0.4	1	7.596	34.089	33.756
45	50	0.5	1	7.693	35.639	33.341
46	50	0.6	1	7.306	34.868	31.078
47	50	0.7	1	6.554	32.264	27.349
48	50	0.8	1	5.556	28.366	22.482
49	50	0.9	1	4.431	23.751	16.769
50	50	1	1	3.297	19.025	10.472
51	100	0.1	1	8.853	32.048	35.984
52	100	0.2	1	15.069	59.366	54.024
53	100	0.3	1	18.975	78.652	63.826
54	100	0.4	1	20.898	89.961	67.652
55	100	0.5	1	21.164	94.053	66.821
56	100	0.6	1	20.100	92.018	62.285
57	100	0.7	1	18.032	85.146	54.812
58	100	0.8	1	15.286	74.859	45.059
59	100	0.9	1	12.190	62.680	33.607
60	100	1	1	9.070	50.209	20.988
61	20	0.1	0.3	1.000	1.635	3.021
62	20	0.2	0.3	1.000	3.029	4.535
63	20	0.3	0.3	1.000	4.013	5.358
64	20	0.4	0.3	1.000	4.590	5.680
65	20	0.5	0.3	1.000	4.798	5.610
66	20	0.6	0.3	1.000	4.694	5.229
67	20	0.7	0.3	1.000	4.344	4.602
68	20	0.8	0.3	1.000	3.819	3.783
69	20	0.9	0.3	1.000	3.198	2.821
70	20	1	0.3	1.000	2.561	1.762
71	50	0.1	0.3	1.000	5.897	7.573
72	50	0.2	0.3	1.643	10.924	11.370
73	50	0.3	0.3	2.069	14.472	13.433
74	50	0.4	0.3	2.279	16.553	14.238
75	50	0.5	0.3	2.308	17.306	14.063
76	50	0.6	0.3	2.192	16.932	13.108
77	50	0.7	0.3	1.966	15.667	11.536
78	50	0.8	0.3	1.667	13.774	9.483
79	50	0.9	0.3	1.329	11.534	7.073
80	50	1	0.3	1.000	9.239	4.417
81	100	0.1	0.3	2.656	15.562	15.178
82	100	0.2	0.3	4.521	28.828	22.787
83	100	0.3	0.3	5.692	38.193	26.921
84	100	0.4	0.3	6.269	43.684	28.535
85	100	0.5	0.3	6.349	45.671	28.184
86	100	0.6	0.3	6.030	44.683	26.271
87	100	0.7	0.3	5.409	41.346	23.119
88	100	0.8	0.3	4.586	36.351	19.005
89	100	0.9	0.3	3.657	30.437	14.175
90	100	1	0.3	2.721	24.381	8.853
91	20	0.1	3	2.533	6.509	15.745
92	20	0.2	3	4.312	12.057	23.638
93	20	0.3	3	5.430	15.974	27.927
94	20	0.4	3	5.980	18.271	29.601
95	20	0.5	3	6.056	19.102	29.237
96	20	0.6	3	5.752	18.689	27.253
97	20	0.7	3	5.160	17.293	23.983
98	20	0.8	3	4.374	15.204	19.715
99	20	0.9	3	3.489	12.731	14.705
100	20	1	3	2.596	10.197	9.183
101	50	0.1	3	9.653	23.476	39.471
102	50	0.2	3	16.432	43.488	59.259
103	50	0.3	3	20.692	57.616	70.010
104	50	0.4	3	22.789	65.900	74.207
105	50	0.5	3	23.079	68.897	73.295
106	50	0.6	3	21.918	67.407	68.319
107	50	0.7	3	19.663	62.372	60.123
108	50	0.8	3	16.669	54.837	49.424
109	50	0.9	3	13.293	45.916	36.863
110	50	1	3	9.891	36.780	23.021
111	100	0.1	3	26.558	61.954	79.106
112	100	0.2	3	45.206	114.765	118.764
113	100	0.3	3	56.925	152.049	140.312
114	100	0.4	3	62.693	173.911	148.723
115	100	0.5	3	63.491	181.821	146.895
116	100	0.6	3	60.299	177.887	136.923
117	100	0.7	3	54.095	164.602	120.496
118	100	0.8	3	45.859	144.716	99.054
119	100	0.9	3	36.571	121.173	73.880
120	100	1	3	27.211	97.062	46.139

Extruded Welding Tee (EXT) - Sketch 2.4 - Branch Torsional K

Item #	D/T	d/D	t/T	PRG ktb	Wais UFT ktb
1	20	0.1	0.1	1.000	1.000
2	20	0.2	0.2	1.000	1.000
3	20	0.3	0.3	1.000	1.000
4	20	0.4	0.4	1.000	1.000
5	20	0.5	0.5	1.000	1.019
6	20	0.6	0.6	1.000	1.497
7	20	0.7	0.7	1.000	2.072
8	20	0.8	0.8	1.000	2.746
9	20	0.9	0.9	1.000	3.521
10	20	1	1	1.000	4.398
11	50	0.1	0.1	1.000	1.000
12	50	0.2	0.2	1.000	1.000
13	50	0.3	0.3	1.000	1.000
14	50	0.4	0.4	1.000	1.000
15	50	0.5	0.5	1.000	1.221
16	50	0.6	0.6	1.000	1.794
17	50	0.7	0.7	1.000	2.484
18	50	0.8	0.8	1.000	3.292
19	50	0.9	0.9	1.000	4.221
20	50	1	1	1.908	5.272
21	100	0.1	0.1	1.000	1.000
22	100	0.2	0.2	1.000	1.000
23	100	0.3	0.3	1.000	1.000
24	100	0.4	0.4	1.000	1.000
25	100	0.5	0.5	1.000	1.401
26	100	0.6	0.6	1.000	2.058
27	100	0.7	0.7	1.000	2.849
28	100	0.8	0.8	1.000	3.777
29	100	0.9	0.9	1.601	4.842
30	100	1	1	3.253	6.048
31	20	0.1	1	1.000	1.000
32	20	0.2	1	1.000	1.000
33	20	0.3	1	1.000	1.000
34	20	0.4	1	1.000	1.056
35	20	0.5	1	1.000	1.495
36	20	0.6	1	1.000	1.985
37	20	0.7	1	1.000	2.524
38	20	0.8	1	1.000	3.107
39	20	0.9	1	1.000	3.732
40	20	1	1	1.000	4.398
41	50	0.1	1	1.000	1.000
42	50	0.2	1	1.000	1.000
43	50	0.3	1	1.000	1.000
44	50	0.4	1	1.000	1.266
45	50	0.5	1	1.000	1.792
46	50	0.6	1	1.000	2.380
47	50	0.7	1	1.000	3.026
48	50	0.8	1	1.000	3.725
49	50	0.9	1	1.043	4.475
50	50	1	1	1.908	5.272
51	100	0.1	1	1.000	1.000
52	100	0.2	1	1.000	1.000
53	100	0.3	1	1.000	1.000
54	100	0.4	1	1.000	1.452
55	100	0.5	1	1.000	2.055
56	100	0.6	1	1.000	2.730
57	100	0.7	1	1.000	3.471
58	100	0.8	1	1.145	4.273
59	100	0.9	1	1.779	5.133
60	100	1	1	3.253	6.048
61	20	0.1	0.3	1.000	1.000
62	20	0.2	0.3	1.000	1.000
63	20	0.3	0.3	1.000	1.000
64	20	0.4	0.3	1.000	1.000
65	20	0.5	0.3	1.000	1.000
66	20	0.6	0.3	1.000	1.020
67	20	0.7	0.3	1.000	1.297
68	20	0.8	0.3	1.000	1.597
69	20	0.9	0.3	1.000	1.918
70	20	1	0.3	1.000	2.260
71	50	0.1	0.3	1.000	1.000
72	50	0.2	0.3	1.000	1.000
73	50	0.3	0.3	1.000	1.000
74	50	0.4	0.3	1.000	1.000
75	50	0.5	0.3	1.000	1.000
76	50	0.6	0.3	1.000	1.223
77	50	0.7	0.3	1.000	1.555
78	50	0.8	0.3	1.000	1.914
79	50	0.9	0.3	1.000	2.299
80	50	1	0.3	1.000	2.709
81	100	0.1	0.3	1.000	1.000
82	100	0.2	0.3	1.000	1.000
83	100	0.3	0.3	1.000	1.000
84	100	0.4	0.3	1.000	1.000
85	100	0.5	0.3	1.000	1.056
86	100	0.6	0.3	1.000	1.403
87	100	0.7	0.3	1.000	1.783
88	100	0.8	0.3	1.000	2.196
89	100	0.9	0.3	1.000	2.638
90	100	1	0.3	1.000	3.108
91	20	0.1	3	1.000	1.000
92	20	0.2	3	1.000	1.000
93	20	0.3	3	1.000	1.239
94	20	0.4	3	1.000	1.938
95	20	0.5	3	1.000	2.744
96	20	0.6	3	1.000	3.645
97	20	0.7	3	1.000	4.633
98	20	0.8	3	1.000	5.704
99	20	0.9	3	1.546	6.852
100	20	1	3	2.826	8.073
101	50	0.1	3	1.000	1.000
102	50	0.2	3	1.000	1.000
103	50	0.3	3	1.000	1.485
104	50	0.4	3	1.000	2.324
105	50	0.5	3	1.000	3.290
106	50	0.6	3	1.000	4.370
107	50	0.7	3	1.647	5.555
108	50	0.8	3	2.014	6.839
109	50	0.9	3	3.130	8.215
110	50	1	3	5.723	9.679
111	100	0.1	3	1.000	1.000
112	100	0.2	3	1.000	1.000
113	100	0.3	3	1.000	1.703
114	100	0.4	3	1.000	2.666
115	100	0.5	3	1.000	3.774
116	100	0.6	3	1.533	5.012
117	100	0.7	3	2.809	6.372
118	100	0.8	3	3.434	7.845
119	100	0.9	3	5.338	9.423
120	100	1	3	9.760	11.103

Extruded Welding Tee (EXT) - Sketch 2.4 - Header Inplane K

Item #	D/T	d/D	t/T	PRG kih	PRG UFT kih	Wais UFT kih
1	20	0.1	0.1	1.000	1.000	1.000
2	20	0.2	0.2	1.000	1.000	1.000
3	20	0.3	0.3	1.000	1.000	1.000
4	20	0.4	0.4	1.000	1.000	1.000
5	20	0.5	0.5	1.000	1.000	1.000
6	20	0.6	0.6	1.000	1.000	1.000
7	20	0.7	0.7	1.000	1.000	1.325
8	20	0.8	0.8	1.000	1.235	1.883
9	20	0.9	0.9	1.000	2.182	2.566
10	20	1	1	1.136	3.630	3.385
11	50	0.1	0.1	1.000	1.000	1.000
12	50	0.2	0.2	1.000	1.000	1.000
13	50	0.3	0.3	1.000	1.000	1.000
14	50	0.4	0.4	1.000	1.000	1.000
15	50	0.5	0.5	1.000	1.000	1.000
16	50	0.6	0.6	1.000	1.000	1.105
17	50	0.7	0.7	1.000	1.000	1.658
18	50	0.8	0.8	1.000	1.900	2.355
19	50	0.9	0.9	1.396	3.357	3.211
20	50	1	1	2.364	5.584	4.236
21	100	0.1	0.1	1.000	1.000	1.000
22	100	0.2	0.2	1.000	1.000	1.000
23	100	0.3	0.3	1.000	1.000	1.000
24	100	0.4	0.4	1.000	1.000	1.000
25	100	0.5	0.5	1.000	1.000	1.000
26	100	0.6	0.6	1.000	1.000	1.310
27	100	0.7	0.7	1.000	1.381	1.964
28	100	0.8	0.8	1.349	2.632	2.791
29	100	0.9	0.9	2.430	4.650	3.804
30	100	1	1	4.116	7.734	5.019
31	20	0.1	1	1.000	1.000	1.000
32	20	0.2	1	1.000	1.000	1.000
33	20	0.3	1	1.000	1.000	1.000
34	20	0.4	1	1.000	1.000	1.000
35	20	0.5	1	1.000	1.000	1.000
36	20	0.6	1	1.000	1.000	1.000
37	20	0.7	1	1.000	1.000	1.218
38	20	0.8	1	1.000	1.112	1.786
39	20	0.9	1	1.000	2.077	2.503
40	20	1	1	1.136	3.630	3.385
41	50	0.1	1	1.000	1.000	1.000
42	50	0.2	1	1.000	1.000	1.000
43	50	0.3	1	1.000	1.000	1.000
44	50	0.4	1	1.000	1.000	1.000
45	50	0.5	1	1.000	1.000	1.000
46	50	0.6	1	1.000	1.000	1.000
47	50	0.7	1	1.000	1.000	1.524
48	50	0.8	1	1.000	1.711	2.234
49	50	0.9	1	1.396	3.195	3.132
50	50	1	1	2.364	5.584	4.236
51	100	0.1	1	1.000	1.000	1.000
52	100	0.2	1	1.000	1.000	1.000
53	100	0.3	1	1.000	1.000	1.000
54	100	0.4	1	1.000	1.000	1.000
55	100	0.5	1	1.000	1.000	1.000
56	100	0.6	1	1.000	1.000	1.160
57	100	0.7	1	1.000	1.168	1.805
58	100	0.8	1	1.349	2.370	2.647
59	100	0.9	1	2.430	4.425	3.710
60	100	1	1	4.116	7.734	5.019
61	20	0.1	0.3	1.000	1.000	1.000
62	20	0.2	0.3	1.000	1.000	1.000
63	20	0.3	0.3	1.000	1.000	1.000
64	20	0.4	0.3	1.000	1.000	1.000
65	20	0.5	0.3	1.000	1.000	1.000
66	20	0.6	0.3	1.000	1.000	1.041
67	20	0.7	0.3	1.000	1.000	1.619

Item #	D/T	d/D	t/T	PRG kih	PRG UFT kih	Wais UFT kih
68	20	0.8	0.3	1.000	1.959	2.374
69	20	0.9	0.3	1.000	3.657	3.328
70	20	1	0.3	1.136	6.392	4.501
71	50	0.1	0.3	1.000	1.000	1.000
72	50	0.2	0.3	1.000	1.000	1.000
73	50	0.3	0.3	1.000	1.000	1.000
74	50	0.4	0.3	1.000	1.000	1.000
75	50	0.5	0.3	1.000	1.000	1.000
76	50	0.6	0.3	1.000	1.000	1.302
77	50	0.7	0.3	1.000	1.485	2.026
78	50	0.8	0.3	1.000	3.013	2.971
79	50	0.9	0.3	1.396	5.626	4.164
80	50	1	0.3	2.364	9.833	5.632
81	100	0.1	0.3	1.000	1.000	1.000
82	100	0.2	0.3	1.000	1.000	1.000
83	100	0.3	0.3	1.000	1.000	1.000
84	100	0.4	0.3	1.000	1.000	1.000
85	100	0.5	0.3	1.000	1.000	1.000
86	100	0.6	0.3	1.000	1.000	1.543
87	100	0.7	0.3	1.000	2.057	2.400
88	100	0.8	0.3	1.349	4.174	3.520
89	100	0.9	0.3	2.430	7.792	4.933
90	100	1	0.3	4.116	13.620	6.673
91	20	0.1	3	1.000	1.000	1.000
92	20	0.2	3	1.000	1.000	1.000
93	20	0.3	3	1.000	1.000	1.000
94	20	0.4	3	1.000	1.000	1.000
95	20	0.5	3	1.000	1.000	1.000
96	20	0.6	3	1.000	1.000	1.000
97	20	0.7	3	1.000	1.000	1.000
98	20	0.8	3	1.000	1.000	1.377
99	20	0.9	3	1.000	1.239	1.930
100	20	1	3	1.136	2.166	2.611
101	50	0.1	3	1.000	1.000	1.000
102	50	0.2	3	1.000	1.000	1.000
103	50	0.3	3	1.000	1.000	1.000
104	50	0.4	3	1.000	1.000	1.000
105	50	0.5	3	1.000	1.000	1.000
106	50	0.6	3	1.000	1.000	1.000
107	50	0.7	3	1.000	1.000	1.175
108	50	0.8	3	1.000	1.021	1.723
109	50	0.9	3	1.396	1.906	2.415
110	50	1	3	2.364	3.332	3.266
111	100	0.1	3	1.000	1.000	1.000
112	100	0.2	3	1.000	1.000	1.000
113	100	0.3	3	1.000	1.000	1.000
114	100	0.4	3	1.000	1.000	1.000
115	100	0.5	3	1.000	1.000	1.000
116	100	0.6	3	1.000	1.000	1.000
117	100	0.7	3	1.000	1.000	1.392
118	100	0.8	3	1.349	1.414	2.041
119	100	0.9	3	2.430	2.640	2.861
120	100	1	3	4.116	4.615	3.870

Extruded Welding Tee (EXT) - Sketch 2.4 - Header Torsional K

Item #	D/T	d/D	t/T	PRG kth	Wais UFT kth
1	20	0.1	0.1	1.000	1.000
2	20	0.2	0.2	1.000	1.000
3	20	0.3	0.3	1.000	1.000
4	20	0.4	0.4	1.000	1.000
5	20	0.5	0.5	1.000	1.000
6	20	0.6	0.6	1.000	1.135
7	20	0.7	0.7	1.000	1.661
8	20	0.8	0.8	1.000	2.310
9	20	0.9	0.9	1.000	3.090
10	20	1	1	1.000	4.008
11	50	0.1	0.1	1.000	1.000
12	50	0.2	0.2	1.000	1.000
13	50	0.3	0.3	1.000	1.000
14	50	0.4	0.4	1.000	1.000
15	50	0.5	0.5	1.000	1.000
16	50	0.6	0.6	1.000	1.515
17	50	0.7	0.7	1.000	2.217
18	50	0.8	0.8	1.000	3.083
19	50	0.9	0.9	1.000	4.124
20	50	1	1	1.497	5.349
21	100	0.1	0.1	1.000	1.000
22	100	0.2	0.2	1.000	1.000
23	100	0.3	0.3	1.000	1.000
24	100	0.4	0.4	1.000	1.000
25	100	0.5	0.5	1.000	1.201
26	100	0.6	0.6	1.000	1.884
27	100	0.7	0.7	1.000	2.758
28	100	0.8	0.8	1.000	3.835
29	100	0.9	0.9	1.543	5.130
30	100	1	1	2.813	6.655
31	20	0.1	1	1.000	1.000
32	20	0.2	1	1.000	1.000
33	20	0.3	1	1.000	1.000
34	20	0.4	1	1.000	1.000
35	20	0.5	1	1.000	1.000
36	20	0.6	1	1.000	1.000
37	20	0.7	1	1.000	1.505
38	20	0.8	1	1.000	2.172
39	20	0.9	1	1.000	3.001
40	20	1	1	1.000	4.008
41	50	0.1	1	1.000	1.000
42	50	0.2	1	1.000	1.000
43	50	0.3	1	1.000	1.000
44	50	0.4	1	1.000	1.000
45	50	0.5	1	1.000	1.000
46	50	0.6	1	1.000	1.316
47	50	0.7	1	1.000	2.009
48	50	0.8	1	1.000	2.899
49	50	0.9	1	1.000	4.005
50	50	1	1	1.497	5.349
51	100	0.1	1	1.000	1.000
52	100	0.2	1	1.000	1.000
53	100	0.3	1	1.000	1.000
54	100	0.4	1	1.000	1.000
55	100	0.5	1	1.000	1.000
56	100	0.6	1	1.000	1.637
57	100	0.7	1	1.000	2.499
58	100	0.8	1	1.000	3.606
59	100	0.9	1	1.543	4.983
60	100	1	1	2.813	6.655
61	20	0.1	0.3	1.000	1.000
62	20	0.2	0.3	1.000	1.000
63	20	0.3	0.3	1.000	1.000
64	20	0.4	0.3	1.000	1.000
65	20	0.5	0.3	1.000	1.000
66	20	0.6	0.3	1.000	1.374
67	20	0.7	0.3	1.000	2.098

Item #	D/T	d/D	t/T	PRG kth	Wais UFT kth
68	20	0.8	0.3	1.000	3.028
69	20	0.9	0.3	1.000	4.184
70	20	1	0.3	1.000	5.588
71	50	0.1	0.3	1.000	1.000
72	50	0.2	0.3	1.000	1.000
73	50	0.3	0.3	1.000	1.000
74	50	0.4	0.3	1.000	1.000
75	50	0.5	0.3	1.000	1.112
76	50	0.6	0.3	1.000	1.834
77	50	0.7	0.3	1.000	2.801
78	50	0.8	0.3	1.000	4.041
79	50	0.9	0.3	1.000	5.584
80	50	1	0.3	1.497	7.458
81	100	0.1	0.3	1.000	1.000
82	100	0.2	0.3	1.000	1.000
83	100	0.3	0.3	1.000	1.000
84	100	0.4	0.3	1.000	1.000
85	100	0.5	0.3	1.000	1.383
86	100	0.6	0.3	1.000	2.282
87	100	0.7	0.3	1.000	3.484
88	100	0.8	0.3	1.000	5.027
89	100	0.9	0.3	1.543	6.947
90	100	1	0.3	2.813	9.278
91	20	0.1	3	1.000	1.000
92	20	0.2	3	1.000	1.000
93	20	0.3	3	1.000	1.000
94	20	0.4	3	1.000	1.000
95	20	0.5	3	1.000	1.000
96	20	0.6	3	1.000	1.000
97	20	0.7	3	1.000	1.111
98	20	0.8	3	1.000	1.604
99	20	0.9	3	1.000	2.216
100	20	1	3	1.000	2.960
101	50	0.1	3	1.000	1.000
102	50	0.2	3	1.000	1.000
103	50	0.3	3	1.000	1.000
104	50	0.4	3	1.000	1.000
105	50	0.5	3	1.000	1.000
106	50	0.6	3	1.000	1.000
107	50	0.7	3	1.000	1.483
108	50	0.8	3	1.000	2.140
109	50	0.9	3	1.000	2.958
110	50	1	3	1.497	3.950
111	100	0.1	3	1.000	1.000
112	100	0.2	3	1.000	1.000
113	100	0.3	3	1.000	1.000
114	100	0.4	3	1.000	1.000
115	100	0.5	3	1.000	1.000
116	100	0.6	3	1.000	1.208
117	100	0.7	3	1.000	1.845
118	100	0.8	3	1.000	2.663
119	100	0.9	3	1.543	3.680
120	100	1	3	2.813	4.914

Welded Contour Insert (SWP) - Sketch 2.5 - Branch Inplane SIF

Item #	D/T	d/D	t/T	PRG iib	B31.3 iib	NB-3683.9 i
1	20	0.1	0.1	1.000	1.000	1.555
2	20	0.2	0.2	1.000	1.000	1.555
3	20	0.3	0.3	1.000	1.000	1.555
4	20	0.4	0.4	1.000	1.000	1.555
5	20	0.5	0.5	1.000	1.000	1.555
6	20	0.6	0.6	1.036	1.034	1.555
7	20	0.7	0.7	1.187	1.207	1.555
8	20	0.8	0.8	1.335	1.379	1.555
9	20	0.9	0.9	1.481	1.551	1.555
10	20	1	1	1.625	1.724	1.555
11	50	0.1	0.1	1.000	1.000	2.864
12	50	0.2	0.2	1.000	1.000	2.864
13	50	0.3	0.3	1.037	1.000	2.864
14	50	0.4	0.4	1.336	1.186	2.864
15	50	0.5	0.5	1.626	1.482	2.864
16	50	0.6	0.6	1.909	1.779	2.864
17	50	0.7	0.7	2.186	2.075	2.864
18	50	0.8	0.8	2.459	2.372	2.864
19	50	0.9	0.9	2.727	2.668	2.864
20	50	1	1	2.992	2.964	2.864
21	100	0.1	0.1	1.000	1.000	4.547
22	100	0.2	0.2	1.152	1.000	4.547
23	100	0.3	0.3	1.647	1.368	4.547
24	100	0.4	0.4	2.121	1.824	4.547
25	100	0.5	0.5	2.581	2.279	4.547
26	100	0.6	0.6	3.030	2.735	4.547
27	100	0.7	0.7	3.471	3.191	4.547
28	100	0.8	0.8	3.903	3.647	4.547
29	100	0.9	0.9	4.330	4.103	4.547
30	100	1	1	4.750	4.559	4.547
31	20	0.1	1	1.000	1.724	1.555
32	20	0.2	1	1.216	1.724	1.555
33	20	0.3	1	1.308	1.724	1.555
34	20	0.4	1	1.378	1.724	1.555
35	20	0.5	1	1.434	1.724	1.555
36	20	0.6	1	1.482	1.724	1.555
37	20	0.7	1	1.524	1.724	1.555
38	20	0.8	1	1.561	1.724	1.555
39	20	0.9	1	1.594	1.724	1.555
40	20	1	1	1.625	1.724	1.555
41	50	0.1	1	1.852	2.964	2.864
42	50	0.2	1	2.240	2.964	2.864
43	50	0.3	1	2.409	2.964	2.864
44	50	0.4	1	2.537	2.964	2.864
45	50	0.5	1	2.641	2.964	2.864
46	50	0.6	1	2.730	2.964	2.864
47	50	0.7	1	2.806	2.964	2.864
48	50	0.8	1	2.875	2.964	2.864
49	50	0.9	1	2.936	2.964	2.864
50	50	1	1	2.992	2.964	2.864
51	100	0.1	1	3.137	4.559	4.547
52	100	0.2	1	3.555	4.559	4.547
53	100	0.3	1	3.825	4.559	4.547
54	100	0.4	1	4.028	4.559	4.547
55	100	0.5	1	4.193	4.559	4.547
56	100	0.6	1	4.333	4.559	4.547
57	100	0.7	1	4.455	4.559	4.547
58	100	0.8	1	4.563	4.559	4.547
59	100	0.9	1	4.661	4.559	4.547
60	100	1	1	4.750	4.559	4.547
61	20	0.1	0.3	1.000	1.000	1.555
62	20	0.2	0.3	1.000	1.000	1.555
63	20	0.3	0.3	1.000	1.000	1.555
64	20	0.4	0.3	1.000	1.000	1.555
65	20	0.5	0.3	1.000	1.000	1.555
66	20	0.6	0.3	1.000	1.000	1.555
67	20	0.7	0.3	1.000	1.000	1.555

Item #	D/T	d/D	t/T	PRG iib	B31.3 iib	NB-3683.9 i
68	20	0.8	0.3	1.000	1.000	1.555
69	20	0.9	0.3	1.000	1.000	1.555
70	20	1	0.3	1.000	1.724	1.555
71	50	0.1	0.3	1.000	1.000	2.864
72	50	0.2	0.3	1.000	1.000	2.864
73	50	0.3	0.3	1.037	1.000	2.864
74	50	0.4	0.3	1.092	1.000	2.864
75	50	0.5	0.3	1.137	1.000	2.864
76	50	0.6	0.3	1.175	1.000	2.864
77	50	0.7	0.3	1.208	1.000	2.864
78	50	0.8	0.3	1.238	1.000	2.864
79	50	0.9	0.3	1.264	1.000	2.864
80	50	1	0.3	1.288	2.964	2.864
81	100	0.1	0.3	1.351	1.368	4.547
82	100	0.2	0.3	1.531	1.368	4.547
83	100	0.3	0.3	1.647	1.368	4.547
84	100	0.4	0.3	1.734	1.368	4.547
85	100	0.5	0.3	1.805	1.368	4.547
86	100	0.6	0.3	1.865	1.368	4.547
87	100	0.7	0.3	1.918	1.368	4.547
88	100	0.8	0.3	1.965	1.368	4.547
89	100	0.9	0.3	2.007	1.368	4.547
90	100	1	0.3			
91	20	0.1	3	2.082	5.171	1.555
92	20	0.2	3	2.624	5.171	1.555
93	20	0.3	3	2.822	5.171	1.555
94	20	0.4	3	2.972	5.171	1.555
95	20	0.5	3	3.094	5.171	1.555
96	20	0.6	3	3.197	5.171	1.555
97	20	0.7	3	3.287	5.171	1.555
98	20	0.8	3	3.367	5.171	1.555
99	20	0.9	3	3.439	5.171	1.555
100	20	1	3			
101	50	0.1	3	4.177	8.893	2.864
102	50	0.2	3	4.833	8.893	2.864
103	50	0.3	3	5.199	8.893	2.864
104	50	0.4	3	5.475	8.893	2.864
105	50	0.5	3	5.699	8.893	2.864
106	50	0.6	3	5.890	8.893	2.864
107	50	0.7	3	6.055	8.893	2.864
108	50	0.8	3	6.203	8.893	2.864
109	50	0.9	3	6.335	8.893	2.864
110	50	1	3			
111	100	0.1	3	6.772	13.677	4.547
112	100	0.2	3	7.672	13.677	4.547
113	100	0.3	3	8.252	13.677	4.547
114	100	0.4	3	8.691	13.677	4.547
115	100	0.5	3	9.047	13.677	4.547
116	100	0.6	3	9.349	13.677	4.547
117	100	0.7	3	9.612	13.677	4.547
118	100	0.8	3	9.846	13.677	4.547
119	100	0.9	3	10.057	13.677	4.547
120	100	1	3			

Welded Contour Insert (SWP) - Sketch 2.5 - Branch Outplane SIF

Item #	D/T	d/D	t/T	PRG iob	B31.3 iob	NB-3683.9 i
1	20	0.1	0.1	1.000	1.140	1.555
2	20	0.2	0.2	1.000	1.140	1.555
3	20	0.3	0.3	1.000	1.140	1.555
4	20	0.4	0.4	1.131	1.140	1.555
5	20	0.5	0.5	1.334	1.140	1.555
6	20	0.6	0.6	1.527	1.179	1.555
7	20	0.7	0.7	1.711	1.375	1.555
8	20	0.8	0.8	1.889	1.572	1.555
9	20	0.9	0.9	2.061	1.768	1.555
10	20	1	1	2.228	1.965	1.555
11	50	0.1	0.1	1.000	1.221	2.864
12	50	0.2	0.2	1.247	1.221	2.864
13	50	0.3	0.3	1.684	1.221	2.864
14	50	0.4	0.4	2.083	1.448	2.864
15	50	0.5	0.5	2.457	1.810	2.864
16	50	0.6	0.6	2.812	2.172	2.864
17	50	0.7	0.7	3.152	2.534	2.864
18	50	0.8	0.8	3.479	2.895	2.864
19	50	0.9	0.9	3.796	3.257	2.864
20	50	1	1	4.104	3.619	2.864
21	100	0.1	0.1	1.185	1.260	4.547
22	100	0.2	0.2	1.980	1.260	4.547
23	100	0.3	0.3	2.673	1.724	4.547
24	100	0.4	0.4	3.307	2.298	4.547
25	100	0.5	0.5	3.901	2.873	4.547
26	100	0.6	0.6	4.464	3.447	4.547
27	100	0.7	0.7	5.003	4.022	4.547
28	100	0.8	0.8	5.523	4.596	4.547
29	100	0.9	0.9	6.026	5.171	4.547
30	100	1	1	6.515	5.745	4.547
31	20	0.1	1	1.000	1.965	1.555
32	20	0.2	1	1.228	1.965	1.555
33	20	0.3	1	1.427	1.965	1.555
34	20	0.4	1	1.587	1.965	1.555
35	20	0.5	1	1.724	1.965	1.555
36	20	0.6	1	1.844	1.965	1.555
37	20	0.7	1	1.953	1.965	1.555
38	20	0.8	1	2.051	1.965	1.555
39	20	0.9	1	2.143	1.965	1.555
40	20	1	1	2.228	1.965	1.555
41	50	0.1	1	1.852	3.619	2.864
42	50	0.2	1	2.262	3.619	2.864
43	50	0.3	1	2.629	3.619	2.864
44	50	0.4	1	2.924	3.619	2.864
45	50	0.5	1	3.176	3.619	2.864
46	50	0.6	1	3.397	3.619	2.864
47	50	0.7	1	3.597	3.619	2.864
48	50	0.8	1	3.779	3.619	2.864
49	50	0.9	1	3.947	3.619	2.864
50	50	1	1	4.104	3.619	2.864
51	100	0.1	1	3.137	5.745	4.547
52	100	0.2	1	3.591	5.745	4.547
53	100	0.3	1	4.173	5.745	4.547
54	100	0.4	1	4.641	5.745	4.547
55	100	0.5	1	5.041	5.745	4.547
56	100	0.6	1	5.393	5.745	4.547
57	100	0.7	1	5.709	5.745	4.547
58	100	0.8	1	5.998	5.745	4.547
59	100	0.9	1	6.266	5.745	4.547
60	100	1	1	6.515	5.745	4.547
61	20	0.1	0.3	1.000	1.140	1.555
62	20	0.2	0.3	1.000	1.140	1.555
63	20	0.3	0.3	1.000	1.140	1.555
64	20	0.4	0.3	1.017	1.140	1.555
65	20	0.5	0.3	1.104	1.140	1.555
66	20	0.6	0.3	1.181	1.140	1.555
67	20	0.7	0.3	1.251	1.140	1.555

Item #	D/T	d/D	t/T	PRG iob	B31.3 iob	NB-3683.9 i
68	20	0.8	0.3	1.314	1.140	1.555
69	20	0.9	0.3	1.373	1.140	1.555
70	20	1	0.3	1.427	1.965	1.555
71	50	0.1	0.3	1.121	1.221	2.864
72	50	0.2	0.3	1.449	1.221	2.864
73	50	0.3	0.3	1.684	1.221	2.864
74	50	0.4	0.3	1.873	1.221	2.864
75	50	0.5	0.3	2.034	1.221	2.864
76	50	0.6	0.3	2.176	1.221	2.864
77	50	0.7	0.3	2.304	1.221	2.864
78	50	0.8	0.3	2.420	1.221	2.864
79	50	0.9	0.3	2.528	1.221	2.864
80	50	1	0.3	2.629	3.619	2.864
81	100	0.1	0.3	1.780	1.724	4.547
82	100	0.2	0.3	2.300	1.724	4.547
83	100	0.3	0.3	2.673	1.724	4.547
84	100	0.4	0.3	2.973	1.724	4.547
85	100	0.5	0.3	3.229	1.724	4.547
86	100	0.6	0.3	3.454	1.724	4.547
87	100	0.7	0.3	3.657	1.724	4.547
88	100	0.8	0.3	3.842	1.724	4.547
89	100	0.9	0.3	4.013	1.724	4.547
90	100	1	0.3			
91	20	0.1	3	2.082	5.895	1.555
92	20	0.2	3	2.624	5.895	1.555
93	20	0.3	3	2.822	5.895	1.555
94	20	0.4	3	2.972	5.895	1.555
95	20	0.5	3	3.094	5.895	1.555
96	20	0.6	3	3.197	5.895	1.555
97	20	0.7	3	3.287	5.895	1.555
98	20	0.8	3	3.367	5.895	1.555
99	20	0.9	3	3.439	5.895	1.555
100	20	1	3			
101	50	0.1	3	4.177	10.858	2.864
102	50	0.2	3	4.833	10.858	2.864
103	50	0.3	3	5.199	10.858	2.864
104	50	0.4	3	5.475	10.858	2.864
105	50	0.5	3	5.699	10.858	2.864
106	50	0.6	3	5.890	10.858	2.864
107	50	0.7	3	6.055	10.858	2.864
108	50	0.8	3	6.203	10.858	2.864
109	50	0.9	3	6.335	10.858	2.864
110	50	1	3			
111	100	0.1	3	6.772	17.236	4.547
112	100	0.2	3	7.672	17.236	4.547
113	100	0.3	3	8.252	17.236	4.547
114	100	0.4	3	8.691	17.236	4.547
115	100	0.5	3	9.047	17.236	4.547
116	100	0.6	3	9.349	17.236	4.547
117	100	0.7	3	9.612	17.236	4.547
118	100	0.8	3	9.846	17.236	4.547
119	100	0.9	3	10.057	17.236	4.547
120	100	1	3			

Welded Contour Insert (SWP) - Sketch 2.5 - Branch Torsional SIF

Item #	D/T	d/D	t/T	PRG itb	B31.3 iob	NB-3683.9 i
1	20	0.1	0.1	1.000	1.140	1.555
2	20	0.2	0.2	1.000	1.140	1.555
3	20	0.3	0.3	1.000	1.140	1.555
4	20	0.4	0.4	1.000	1.140	1.555
5	20	0.5	0.5	1.000	1.140	1.555
6	20	0.6	0.6	1.000	1.179	1.555
7	20	0.7	0.7	1.000	1.375	1.555
8	20	0.8	0.8	1.250	1.572	1.555
9	20	0.9	0.9	1.620	1.768	1.555
10	20	1	1	2.042	1.965	1.555
11	50	0.1	0.1	1.000	1.221	2.864
12	50	0.2	0.2	1.000	1.221	2.864
13	50	0.3	0.3	1.000	1.221	2.864
14	50	0.4	0.4	1.000	1.448	2.864
15	50	0.5	0.5	1.000	1.810	2.864
16	50	0.6	0.6	1.223	2.172	2.864
17	50	0.7	0.7	1.716	2.534	2.864
18	50	0.8	0.8	2.303	2.895	2.864
19	50	0.9	0.9	2.984	3.257	2.864
20	50	1	1	3.762	3.619	2.864
21	100	0.1	0.1	1.000	1.260	4.547
22	100	0.2	0.2	1.000	1.260	4.547
23	100	0.3	0.3	1.000	1.724	4.547
24	100	0.4	0.4	1.000	2.298	4.547
25	100	0.5	0.5	1.300	2.873	4.547
26	100	0.6	0.6	1.941	3.447	4.547
27	100	0.7	0.7	2.725	4.022	4.547
28	100	0.8	0.8	3.655	4.596	4.547
29	100	0.9	0.9	4.736	5.171	4.547
30	100	1	1	5.972	5.745	4.547
31	20	0.1	1	1.000	1.965	1.555
32	20	0.2	1	1.000	1.965	1.555
33	20	0.3	1	1.000	1.965	1.555
34	20	0.4	1	1.000	1.965	1.555
35	20	0.5	1	1.000	1.965	1.555
36	20	0.6	1	1.022	1.965	1.555
37	20	0.7	1	1.380	1.965	1.555
38	20	0.8	1	1.598	1.965	1.555
39	20	0.9	1	1.819	1.965	1.555
40	20	1	1	2.042	1.965	1.555
41	50	0.1	1	1.000	3.619	2.864
42	50	0.2	1	1.000	3.619	2.864
43	50	0.3	1	1.000	3.619	2.864
44	50	0.4	1	1.000	3.619	2.864
45	50	0.5	1	1.477	3.619	2.864
46	50	0.6	1	2.127	3.619	2.864
47	50	0.7	1	2.541	3.619	2.864
48	50	0.8	1	2.943	3.619	2.864
49	50	0.9	1	3.350	3.619	2.864
50	50	1	1	3.762	3.619	2.864
51	100	0.1	1	1.000	5.745	4.547
52	100	0.2	1	1.000	5.745	4.547
53	100	0.3	1	1.000	5.745	4.547
54	100	0.4	1	1.646	5.745	4.547
55	100	0.5	1	2.572	5.745	4.547
56	100	0.6	1	3.405	5.745	4.547
57	100	0.7	1	4.034	5.745	4.547
58	100	0.8	1	4.672	5.745	4.547
59	100	0.9	1	5.318	5.745	4.547
60	100	1	1	5.972	5.745	4.547
61	20	0.1	0.3	1.000	1.140	1.555
62	20	0.2	0.3	1.000	1.140	1.555
63	20	0.3	0.3	1.000	1.140	1.555
64	20	0.4	0.3	1.000	1.140	1.555
65	20	0.5	0.3	1.000	1.140	1.555
66	20	0.6	0.3	1.000	1.140	1.555
67	20	0.7	0.3	1.000	1.140	1.555
68	20	0.8	0.3	1.000	1.140	1.555
69	20	0.9	0.3	1.000	1.140	1.555
70	20	1	0.3	1.000	1.965	1.555
71	50	0.1	0.3	1.000	1.221	2.864
72	50	0.2	0.3	1.000	1.221	2.864
73	50	0.3	0.3	1.000	1.221	2.864
74	50	0.4	0.3	1.000	1.221	2.864
75	50	0.5	0.3	1.000	1.221	2.864
76	50	0.6	0.3	1.000	1.221	2.864
77	50	0.7	0.3	1.000	1.221	2.864
78	50	0.8	0.3	1.000	1.221	2.864
79	50	0.9	0.3	1.000	1.221	2.864
80	50	1	0.3	1.001	3.619	2.864
81	100	0.1	0.3	1.000	1.724	4.547
82	100	0.2	0.3	1.000	1.724	4.547
83	100	0.3	0.3	1.000	1.724	4.547
84	100	0.4	0.3	1.000	1.724	4.547
85	100	0.5	0.3	1.000	1.724	4.547
86	100	0.6	0.3	1.000	1.724	4.547
87	100	0.7	0.3	1.073	1.724	4.547
88	100	0.8	0.3	1.243	1.724	4.547
89	100	0.9	0.3	1.414	1.724	4.547
90	100	1	0.3			
91	20	0.1	3	1.000	5.895	1.555
92	20	0.2	3	1.000	5.895	1.555
93	20	0.3	3	1.000	5.895	1.555
94	20	0.4	3	1.000	5.895	1.555
95	20	0.5	3	1.000	5.895	1.555
96	20	0.6	3	1.406	5.895	1.555
97	20	0.7	3	1.913	5.895	1.555
98	20	0.8	3	2.499	5.895	1.555
99	20	0.9	3	3.163	5.895	1.555
100	20	1	3			
101	50	0.1	3	1.000	10.858	2.864
102	50	0.2	3	1.000	10.858	2.864
103	50	0.3	3	1.000	10.858	2.864
104	50	0.4	3	1.300	10.858	2.864
105	50	0.5	3	2.032	10.858	2.864
106	50	0.6	3	2.926	10.858	2.864
107	50	0.7	3	3.982	10.858	2.864
108	50	0.8	3	5.201	10.858	2.864
109	50	0.9	3	6.583	10.858	2.864
110	50	1	3			
111	100	0.1	3	1.000	17.236	4.547
112	100	0.2	3	1.000	17.236	4.547
113	100	0.3	3	1.273	17.236	4.547
114	100	0.4	3	2.264	17.236	4.547
115	100	0.5	3	3.537	17.236	4.547
116	100	0.6	3	5.094	17.236	4.547
117	100	0.7	3	6.933	17.236	4.547
118	100	0.8	3	9.056	17.236	4.547
119	100	0.9	3	11.461	17.236	4.547
120	100	1	3			

Welded Contour Insert (SWP) - Sketch 2.5 - Header Inplane SIF

Item #	D/T	d/D	t/T	PRG iih	B31.3 iih	NB-3683.9 i
1	20	0.1	0.1	1.413	1.724	1.555
2	20	0.2	0.2	1.623	1.724	1.555
3	20	0.3	0.3	1.760	1.724	1.555
4	20	0.4	0.4	1.864	1.724	1.555
5	20	0.5	0.5	1.949	1.724	1.555
6	20	0.6	0.6	2.021	1.724	1.555
7	20	0.7	0.7	2.085	1.724	1.555
8	20	0.8	0.8	2.141	1.724	1.555
9	20	0.9	0.9	2.192	1.724	1.555
10	20	1	1	2.239	1.724	1.555
11	50	0.1	0.1	1.947	2.964	2.864
12	50	0.2	0.2	2.236	2.964	2.864
13	50	0.3	0.3	2.425	2.964	2.864
14	50	0.4	0.4	2.569	2.964	2.864
15	50	0.5	0.5	2.686	2.964	2.864
16	50	0.6	0.6	2.786	2.964	2.864
17	50	0.7	0.7	2.873	2.964	2.864
18	50	0.8	0.8	2.951	2.964	2.864
19	50	0.9	0.9	3.021	2.964	2.864
20	50	1	1	3.085	2.964	2.864
21	100	0.1	0.1	2.481	4.559	4.547
22	100	0.2	0.2	2.850	4.559	4.547
23	100	0.3	0.3	3.091	4.559	4.547
24	100	0.4	0.4	3.274	4.559	4.547
25	100	0.5	0.5	3.423	4.559	4.547
26	100	0.6	0.6	3.550	4.559	4.547
27	100	0.7	0.7	3.662	4.559	4.547
28	100	0.8	0.8	3.761	4.559	4.547
29	100	0.9	0.9	3.850	4.559	4.547
30	100	1	1	3.932	4.559	4.547
31	20	0.1	1	1.000	1.724	1.555
32	20	0.2	1	1.000	1.724	1.555
33	20	0.3	1	1.000	1.724	1.555
34	20	0.4	1	1.157	1.724	1.555
35	20	0.5	1	1.359	1.724	1.555
36	20	0.6	1	1.550	1.724	1.555
37	20	0.7	1	1.732	1.724	1.555
38	20	0.8	1	1.906	1.724	1.555
39	20	0.9	1	2.075	1.724	1.555
40	20	1	1	2.239	1.724	1.555
41	50	0.1	1	1.000	2.964	2.864
42	50	0.2	1	1.000	2.964	2.864
43	50	0.3	1	1.297	2.964	2.864
44	50	0.4	1	1.595	2.964	2.864
45	50	0.5	1	1.873	2.964	2.864
46	50	0.6	1	2.136	2.964	2.864
47	50	0.7	1	2.386	2.964	2.864
48	50	0.8	1	2.627	2.964	2.864
49	50	0.9	1	2.860	2.964	2.864
50	50	1	1	3.085	2.964	2.864
51	100	0.1	1	1.000	4.559	4.547
52	100	0.2	1	1.234	4.559	4.547
53	100	0.3	1	1.653	4.559	4.547
54	100	0.4	1	2.033	4.559	4.547
55	100	0.5	1	2.387	4.559	4.547
56	100	0.6	1	2.722	4.559	4.547
57	100	0.7	1	3.042	4.559	4.547
58	100	0.8	1	3.349	4.559	4.547
59	100	0.9	1	3.645	4.559	4.547
60	100	1	1	3.932	4.559	4.547
61	20	0.1	0.3	1.000	1.724	1.555
62	20	0.2	0.3	1.314	1.724	1.555
63	20	0.3	0.3	1.760	1.724	1.555
64	20	0.4	0.3	2.165	1.724	1.555
65	20	0.5	0.3	2.542	1.724	1.555
66	20	0.6	0.3	2.898	1.724	1.555
67	20	0.7	0.3	3.239	1.724	1.555

Item #	D/T	d/D	t/T	PRG iih	B31.3 iih	NB-3683.9 i
68	20	0.8	0.3	3.566	1.724	1.555
69	20	0.9	0.3	3.881	1.724	1.555
70	20	1	0.3	4.187	1.724	1.555
71	50	0.1	0.3	1.099	2.964	2.864
72	50	0.2	0.3	1.811	2.964	2.864
73	50	0.3	0.3	2.425	2.964	2.864
74	50	0.4	0.3	2.983	2.964	2.864
75	50	0.5	0.3	3.503	2.964	2.864
76	50	0.6	0.3	3.994	2.964	2.864
77	50	0.7	0.3	4.463	2.964	2.864
78	50	0.8	0.3	4.914	2.964	2.864
79	50	0.9	0.3	5.348	2.964	2.864
80	50	1	0.3	5.770	2.964	2.864
81	100	0.1	0.3	1.401	4.559	4.547
82	100	0.2	0.3	2.308	4.559	4.547
83	100	0.3	0.3	3.091	4.559	4.547
84	100	0.4	0.3	3.802	4.559	4.547
85	100	0.5	0.3	4.465	4.559	4.547
86	100	0.6	0.3	5.091	4.559	4.547
87	100	0.7	0.3	5.689	4.559	4.547
88	100	0.8	0.3	6.263	4.559	4.547
89	100	0.9	0.3	6.817	4.559	4.547
90	100	1	0.3	7.354	4.559	4.547
91	20	0.1	3	1.000	1.724	1.555
92	20	0.2	3	1.000	1.724	1.555
93	20	0.3	3	1.000	1.724	1.555
94	20	0.4	3	1.000	1.724	1.555
95	20	0.5	3	1.000	1.724	1.555
96	20	0.6	3	1.000	1.724	1.555
97	20	0.7	3	1.000	1.724	1.555
98	20	0.8	3	1.077	1.724	1.555
99	20	0.9	3	1.172	1.724	1.555
100	20	1	3	1.264	1.724	1.555
101	50	0.1	3	1.000	2.964	2.864
102	50	0.2	3	1.000	2.964	2.864
103	50	0.3	3	1.000	2.964	2.864
104	50	0.4	3	1.000	2.964	2.864
105	50	0.5	3	1.058	2.964	2.864
106	50	0.6	3	1.206	2.964	2.864
107	50	0.7	3	1.348	2.964	2.864
108	50	0.8	3	1.484	2.964	2.864
109	50	0.9	3	1.615	2.964	2.864
110	50	1	3	1.743	2.964	2.864
111	100	0.1	3	1.000	4.559	4.547
112	100	0.2	3	1.000	4.559	4.547
113	100	0.3	3	1.000	4.559	4.547
114	100	0.4	3	1.148	4.559	4.547
115	100	0.5	3	1.348	4.559	4.547
116	100	0.6	3	1.537	4.559	4.547
117	100	0.7	3	1.718	4.559	4.547
118	100	0.8	3	1.891	4.559	4.547
119	100	0.9	3	2.059	4.559	4.547
120	100	1	3	2.221	4.559	4.547

Welded Contour Insert (SWP) - Sketch 2.5 - Header Outplane SIF

Item #	D/T	d/D	t/T	PRG ioh	B31.3 ioh	NB-3683.9 i
1	20	0.1	0.1	1.000	1.965	1.555
2	20	0.2	0.2	1.000	1.965	1.555
3	20	0.3	0.3	1.000	1.965	1.555
4	20	0.4	0.4	1.000	1.965	1.555
5	20	0.5	0.5	1.000	1.965	1.555
6	20	0.6	0.6	1.000	1.965	1.555
7	20	0.7	0.7	1.000	1.965	1.555
8	20	0.8	0.8	1.023	1.965	1.555
9	20	0.9	0.9	1.209	1.965	1.555
10	20	1	1	1.404	1.965	1.555
11	50	0.1	0.1	1.000	3.619	2.864
12	50	0.2	0.2	1.000	3.619	2.864
13	50	0.3	0.3	1.000	3.619	2.864
14	50	0.4	0.4	1.000	3.619	2.864
15	50	0.5	0.5	1.000	3.619	2.864
16	50	0.6	0.6	1.000	3.619	2.864
17	50	0.7	0.7	1.104	3.619	2.864
18	50	0.8	0.8	1.334	3.619	2.864
19	50	0.9	0.9	1.577	3.619	2.864
20	50	1	1	1.831	3.619	2.864
21	100	0.1	0.1	1.000	5.745	4.547
22	100	0.2	0.2	1.000	5.745	4.547
23	100	0.3	0.3	1.000	5.745	4.547
24	100	0.4	0.4	1.000	5.745	4.547
25	100	0.5	0.5	1.000	5.745	4.547
26	100	0.6	0.6	1.084	5.745	4.547
27	100	0.7	0.7	1.349	5.745	4.547
28	100	0.8	0.8	1.631	5.745	4.547
29	100	0.9	0.9	1.928	5.745	4.547
30	100	1	1	2.239	5.745	4.547
31	20	0.1	1	1.000	1.965	1.555
32	20	0.2	1	1.000	1.965	1.555
33	20	0.3	1	1.000	1.965	1.555
34	20	0.4	1	1.000	1.965	1.555
35	20	0.5	1	1.000	1.965	1.555
36	20	0.6	1	1.000	1.965	1.555
37	20	0.7	1	1.000	1.965	1.555
38	20	0.8	1	1.000	1.965	1.555
39	20	0.9	1	1.143	1.965	1.555
40	20	1	1	1.404	1.965	1.555
41	50	0.1	1	1.000	3.619	2.864
42	50	0.2	1	1.000	3.619	2.864
43	50	0.3	1	1.000	3.619	2.864
44	50	0.4	1	1.000	3.619	2.864
45	50	0.5	1	1.000	3.619	2.864
46	50	0.6	1	1.000	3.619	2.864
47	50	0.7	1	1.000	3.619	2.864
48	50	0.8	1	1.185	3.619	2.864
49	50	0.9	1	1.491	3.619	2.864
50	50	1	1	1.831	3.619	2.864
51	100	0.1	1	1.000	5.745	4.547
52	100	0.2	1	1.000	5.745	4.547
53	100	0.3	1	1.000	5.745	4.547
54	100	0.4	1	1.000	5.745	4.547
55	100	0.5	1	1.000	5.745	4.547
56	100	0.6	1	1.000	5.745	4.547
57	100	0.7	1	1.117	5.745	4.547
58	100	0.8	1	1.449	5.745	4.547
59	100	0.9	1	1.823	5.745	4.547
60	100	1	1	2.239	5.745	4.547
61	20	0.1	0.3	1.000	1.965	1.555
62	20	0.2	0.3	1.000	1.965	1.555
63	20	0.3	0.3	1.000	1.965	1.555
64	20	0.4	0.3	1.000	1.965	1.555
65	20	0.5	0.3	1.000	1.965	1.555
66	20	0.6	0.3	1.000	1.965	1.555
67	20	0.7	0.3	1.205	1.965	1.555

Item #	D/T	d/D	t/T	PRG ioh	B31.3 ioh	NB-3683.9 i
68	20	0.8	0.3	1.720	1.965	1.555
69	20	0.9	0.3	2.164	1.965	1.555
70	20	1	0.3	2.657	1.965	1.555
71	50	0.1	0.3	1.000	3.619	2.864
72	50	0.2	0.3	1.000	3.619	2.864
73	50	0.3	0.3	1.000	3.619	2.864
74	50	0.4	0.3	1.000	3.619	2.864
75	50	0.5	0.3	1.000	3.619	2.864
76	50	0.6	0.3	1.257	3.619	2.864
77	50	0.7	0.3	1.729	3.619	2.864
78	50	0.8	0.3	2.243	3.619	2.864
79	50	0.9	0.3	2.822	3.619	2.864
80	50	1	0.3	3.466	3.619	2.864
81	100	0.1	0.3	1.000	5.745	4.547
82	100	0.2	0.3	1.000	5.745	4.547
83	100	0.3	0.3	1.000	5.745	4.547
84	100	0.4	0.3	1.000	5.745	4.547
85	100	0.5	0.3	1.097	5.745	4.547
86	100	0.6	0.3	1.565	5.745	4.547
87	100	0.7	0.3	2.114	5.745	4.547
88	100	0.8	0.3	2.743	5.745	4.547
89	100	0.9	0.3	3.451	5.745	4.547
90	100	1	0.3	4.238	5.745	4.547
91	20	0.1	3	1.000	1.965	1.555
92	20	0.2	3	1.000	1.965	1.555
93	20	0.3	3	1.000	1.965	1.555
94	20	0.4	3	1.000	1.965	1.555
95	20	0.5	3	1.000	1.965	1.555
96	20	0.6	3	1.000	1.965	1.555
97	20	0.7	3	1.000	1.965	1.555
98	20	0.8	3	1.000	1.965	1.555
99	20	0.9	3	1.000	1.965	1.555
100	20	1	3	1.000	1.965	1.555
101	50	0.1	3	1.000	3.619	2.864
102	50	0.2	3	1.000	3.619	2.864
103	50	0.3	3	1.000	3.619	2.864
104	50	0.4	3	1.000	3.619	2.864
105	50	0.5	3	1.000	3.619	2.864
106	50	0.6	3	1.000	3.619	2.864
107	50	0.7	3	1.000	3.619	2.864
108	50	0.8	3	1.000	3.619	2.864
109	50	0.9	3	1.000	3.619	2.864
110	50	1	3	1.023	3.619	2.864
111	100	0.1	3	1.000	5.745	4.547
112	100	0.2	3	1.000	5.745	4.547
113	100	0.3	3	1.000	5.745	4.547
114	100	0.4	3	1.000	5.745	4.547
115	100	0.5	3	1.000	5.745	4.547
116	100	0.6	3	1.000	5.745	4.547
117	100	0.7	3	1.000	5.745	4.547
118	100	0.8	3	1.000	5.745	4.547
119	100	0.9	3	1.018	5.745	4.547
120	100	1	3	1.251	5.745	4.547

Welded Contour Insert (SWP) - Sketch 2.5 - Header Torsional SIF

Item #	D/T	d/D	t/T	PRG ith	B31.3 ioh	NB-3683.9 i
1	20	0.1	0.1	1.000	1.965	1.555
2	20	0.2	0.2	1.000	1.965	1.555
3	20	0.3	0.3	1.000	1.965	1.555
4	20	0.4	0.4	1.057	1.965	1.555
5	20	0.5	0.5	1.182	1.965	1.555
6	20	0.6	0.6	1.294	1.965	1.555
7	20	0.7	0.7	1.398	1.965	1.555
8	20	0.8	0.8	1.495	1.965	1.555
9	20	0.9	0.9	1.585	1.965	1.555
10	20	1	1	1.671	1.965	1.555
11	50	0.1	0.1	1.000	3.619	2.864
12	50	0.2	0.2	1.200	3.619	2.864
13	50	0.3	0.3	1.686	3.619	2.864
14	50	0.4	0.4	1.947	3.619	2.864
15	50	0.5	0.5	2.176	3.619	2.864
16	50	0.6	0.6	2.384	3.619	2.864
17	50	0.7	0.7	2.575	3.619	2.864
18	50	0.8	0.8	2.753	3.619	2.864
19	50	0.9	0.9	2.920	3.619	2.864
20	50	1	1	3.078	3.619	2.864
21	100	0.1	0.1	1.000	5.745	4.547
22	100	0.2	0.2	1.651	5.745	4.547
23	100	0.3	0.3	2.397	5.745	4.547
24	100	0.4	0.4	3.090	5.745	4.547
25	100	0.5	0.5	3.455	5.745	4.547
26	100	0.6	0.6	3.785	5.745	4.547
27	100	0.7	0.7	4.088	5.745	4.547
28	100	0.8	0.8	4.370	5.745	4.547
29	100	0.9	0.9	4.635	5.745	4.547
30	100	1	1	4.886	5.745	4.547
31	20	0.1	1	1.000	1.965	1.555
32	20	0.2	1	1.000	1.965	1.555
33	20	0.3	1	1.000	1.965	1.555
34	20	0.4	1	1.000	1.965	1.555
35	20	0.5	1	1.000	1.965	1.555
36	20	0.6	1	1.003	1.965	1.555
37	20	0.7	1	1.170	1.965	1.555
38	20	0.8	1	1.337	1.965	1.555
39	20	0.9	1	1.504	1.965	1.555
40	20	1	1	1.671	1.965	1.555
41	50	0.1	1	1.000	3.619	2.864
42	50	0.2	1	1.000	3.619	2.864
43	50	0.3	1	1.000	3.619	2.864
44	50	0.4	1	1.231	3.619	2.864
45	50	0.5	1	1.539	3.619	2.864
46	50	0.6	1	1.847	3.619	2.864
47	50	0.7	1	2.155	3.619	2.864
48	50	0.8	1	2.462	3.619	2.864
49	50	0.9	1	2.770	3.619	2.864
50	50	1	1	3.078	3.619	2.864
51	100	0.1	1	1.000	5.745	4.547
52	100	0.2	1	1.000	5.745	4.547
53	100	0.3	1	1.394	5.745	4.547
54	100	0.4	1	1.954	5.745	4.547
55	100	0.5	1	2.443	5.745	4.547
56	100	0.6	1	2.932	5.745	4.547
57	100	0.7	1	3.420	5.745	4.547
58	100	0.8	1	3.909	5.745	4.547
59	100	0.9	1	4.397	5.745	4.547
60	100	1	1	4.886	5.745	4.547
61	20	0.1	0.3	1.000	1.965	1.555
62	20	0.2	0.3	1.000	1.965	1.555
63	20	0.3	0.3	1.000	1.965	1.555
64	20	0.4	0.3	1.220	1.965	1.555
65	20	0.5	0.3	1.525	1.965	1.555
66	20	0.6	0.3	1.830	1.965	1.555
67	20	0.7	0.3	2.136	1.965	1.555

Item #	D/T	d/D	t/T	PRG ith	B31.3 ioh	NB-3683.9 i
68	20	0.8	0.3	2.441	1.965	1.555
69	20	0.9	0.3	2.746	1.965	1.555
70	20	1	0.3	3.051	1.965	1.555
71	50	0.1	0.3	1.000	3.619	2.864
72	50	0.2	0.3	1.000	3.619	2.864
73	50	0.3	0.3	1.686	3.619	2.864
74	50	0.4	0.3	2.248	3.619	2.864
75	50	0.5	0.3	2.810	3.619	2.864
76	50	0.6	0.3	3.372	3.619	2.864
77	50	0.7	0.3	3.934	3.619	2.864
78	50	0.8	0.3	4.496	3.619	2.864
79	50	0.9	0.3	5.058	3.619	2.864
80	50	1	0.3	5.620	3.619	2.864
81	100	0.1	0.3	1.000	5.745	4.547
82	100	0.2	0.3	1.375	5.745	4.547
83	100	0.3	0.3	2.397	5.745	4.547
84	100	0.4	0.3	3.555	5.745	4.547
85	100	0.5	0.3	4.460	5.745	4.547
86	100	0.6	0.3	5.352	5.745	4.547
87	100	0.7	0.3	6.244	5.745	4.547
88	100	0.8	0.3	7.136	5.745	4.547
89	100	0.9	0.3	8.028	5.745	4.547
90	100	1	0.3	8.920	5.745	4.547
91	20	0.1	3	1.000	1.965	1.555
92	20	0.2	3	1.000	1.965	1.555
93	20	0.3	3	1.000	1.965	1.555
94	20	0.4	3	1.000	1.965	1.555
95	20	0.5	3	1.000	1.965	1.555
96	20	0.6	3	1.000	1.965	1.555
97	20	0.7	3	1.000	1.965	1.555
98	20	0.8	3	1.000	1.965	1.555
99	20	0.9	3	1.000	1.965	1.555
100	20	1	3	1.000	1.965	1.555
101	50	0.1	3	1.000	3.619	2.864
102	50	0.2	3	1.000	3.619	2.864
103	50	0.3	3	1.000	3.619	2.864
104	50	0.4	3	1.000	3.619	2.864
105	50	0.5	3	1.000	3.619	2.864
106	50	0.6	3	1.066	3.619	2.864
107	50	0.7	3	1.244	3.619	2.864
108	50	0.8	3	1.422	3.619	2.864
109	50	0.9	3	1.599	3.619	2.864
110	50	1	3	1.777	3.619	2.864
111	100	0.1	3	1.000	5.745	4.547
112	100	0.2	3	1.000	5.745	4.547
113	100	0.3	3	1.000	5.745	4.547
114	100	0.4	3	1.128	5.745	4.547
115	100	0.5	3	1.410	5.745	4.547
116	100	0.6	3	1.693	5.745	4.547
117	100	0.7	3	1.975	5.745	4.547
118	100	0.8	3	2.257	5.745	4.547
119	100	0.9	3	2.539	5.745	4.547
120	100	1	3	2.821	5.745	4.547

Welded Contour Insert (SWP) - Sketch 2.5 - Branch Inplane K

Item #	D/T	d/D	t/T	PRG kib	PRG UFT kib	Wais UFT kib
1	20	0.1	0.1	1.000	1.000	1.507
2	20	0.2	0.2	1.000	1.721	1.977
3	20	0.3	0.3	1.000	2.274	2.316
4	20	0.4	0.4	1.000	2.550	2.592
5	20	0.5	0.5	1.000	2.627	2.828
6	20	0.6	0.6	1.000	2.623	3.037
7	20	0.7	0.7	1.000	2.689	3.226
8	20	0.8	0.8	1.000	2.991	3.399
9	20	0.9	0.9	1.182	3.718	3.559
10	20	1	1	2.120	5.071	3.709
11	50	0.1	0.1	1.000	1.892	2.803
12	50	0.2	0.2	1.000	3.682	3.676
13	50	0.3	0.3	1.000	4.866	4.307
14	50	0.4	0.4	1.000	5.456	4.820
15	50	0.5	0.5	1.135	5.619	5.259
16	50	0.6	0.6	1.218	5.613	5.648
17	50	0.7	0.7	1.288	5.752	5.999
18	50	0.8	0.8	1.561	6.399	6.320
19	50	0.9	0.9	2.393	7.954	6.618
20	50	1	1	4.293	10.848	6.896
21	100	0.1	0.1	1.000	3.363	4.481
22	100	0.2	0.2	1.000	6.546	5.877
23	100	0.3	0.3	1.102	8.650	6.886
24	100	0.4	0.4	1.609	9.699	7.706
25	100	0.5	0.5	1.936	9.989	8.408
26	100	0.6	0.6	2.077	9.977	9.030
27	100	0.7	0.7	2.197	10.225	9.591
28	100	0.8	0.8	2.662	11.376	10.105
29	100	0.9	0.9	4.080	14.140	10.581
30	100	1	1	7.320	19.284	11.026
31	20	0.1	1	1.000	2.732	6.029
32	20	0.2	1	1.000	3.787	5.208
33	20	0.3	1	1.064	4.103	4.781
34	20	0.4	1	1.165	3.995	4.500
35	20	0.5	1	1.121	3.689	4.293
36	20	0.6	1	1.003	3.370	4.131
37	20	0.7	1	1.000	3.202	3.999
38	20	0.8	1	1.000	3.337	3.887
39	20	0.9	1	1.313	3.915	3.792
40	20	1	1	2.120	5.071	3.709
41	50	0.1	1	1.000	5.846	11.210
42	50	0.2	1	1.597	8.102	9.685
43	50	0.3	1	2.155	8.778	8.891
44	50	0.4	1	2.359	8.548	8.367
45	50	0.5	1	2.271	7.892	7.983
46	50	0.6	1	2.030	7.209	7.681
47	50	0.7	1	1.840	6.850	7.435
48	50	0.8	1	1.951	7.139	7.229
49	50	0.9	1	2.658	8.376	7.051
50	50	1	1	4.293	10.848	6.896
51	100	0.1	1	1.282	10.392	17.923
52	100	0.2	1	2.724	14.403	15.485
53	100	0.3	1	3.674	15.604	14.215
54	100	0.4	1	4.023	15.195	13.378
55	100	0.5	1	3.872	14.030	12.763
56	100	0.6	1	3.462	12.815	12.281
57	100	0.7	1	3.138	12.178	11.888
58	100	0.8	1	3.328	12.690	11.558
59	100	0.9	1	4.533	14.889	11.274
60	100	1	1	7.320	19.284	11.026
61	20	0.1	0.3	1.000	1.515	2.920
62	20	0.2	0.3	1.000	2.099	2.523
63	20	0.3	0.3	1.000	2.274	2.316
64	20	0.4	0.3	1.000	2.215	2.180
65	20	0.5	0.3	1.000	2.045	2.080
66	20	0.6	0.3	1.000	1.868	2.001
67	20	0.7	0.3	1.000	1.775	1.937

Item #	D/T	d/D	t/T	PRG kib	PRG UFT kib	Wais UFT kib
68	20	0.8	0.3	1.000	1.850	1.883
69	20	0.9	0.3	1.000	2.170	1.837
70	20	1	0.3	1.000	2.811	1.797
71	50	0.1	0.3	1.000	3.241	5.431
72	50	0.2	0.3	1.000	4.492	4.692
73	50	0.3	0.3	1.000	4.866	4.307
74	50	0.4	0.3	1.000	4.738	4.053
75	50	0.5	0.3	1.000	4.375	3.867
76	50	0.6	0.3	1.000	3.996	3.721
77	50	0.7	0.3	1.000	3.798	3.602
78	50	0.8	0.3	1.000	3.957	3.502
79	50	0.9	0.3	1.000	4.643	3.416
80	50	1	0.3	1.288	6.014	3.341
81	100	0.1	0.3	1.000	5.761	8.683
82	100	0.2	0.3	1.000	7.985	7.501
83	100	0.3	0.3	1.102	8.650	6.886
84	100	0.4	0.3	1.207	8.423	6.481
85	100	0.5	0.3	1.162	7.777	6.183
86	100	0.6	0.3	1.039	7.104	5.949
87	100	0.7	0.3	1.000	6.751	5.759
88	100	0.8	0.3	1.000	7.035	5.599
89	100	0.9	0.3	1.360	8.254	5.461
90	100	1	0.3	2.196	10.690	5.341
91	20	0.1	3	1.114	4.681	11.680
92	20	0.2	3	2.367	6.488	10.091
93	20	0.3	3	3.192	7.029	9.263
94	20	0.4	3	3.495	6.845	8.718
95	20	0.5	3	3.364	6.320	8.317
96	20	0.6	3	3.008	5.773	8.003
97	20	0.7	3	2.726	5.485	7.747
98	20	0.8	3	2.891	5.716	7.532
99	20	0.9	3	3.939	6.707	7.347
100	20	1	3	6.360	8.687	7.185
101	50	0.1	3	2.255	10.014	21.719
102	50	0.2	3	4.792	13.880	18.764
103	50	0.3	3	6.464	15.037	17.226
104	50	0.4	3	7.077	14.643	16.211
105	50	0.5	3	6.812	13.520	15.466
106	50	0.6	3	6.091	12.350	14.882
107	50	0.7	3	5.520	11.735	14.406
108	50	0.8	3	5.854	12.229	14.005
109	50	0.9	3	7.975	14.349	13.662
110	50	1	3	12.878	18.584	13.361
111	100	0.1	3	3.845	17.802	34.725
112	100	0.2	3	8.172	24.675	30.001
113	100	0.3	3	11.023	26.732	27.541
114	100	0.4	3	12.068	26.031	25.919
115	100	0.5	3	11.615	24.034	24.727
116	100	0.6	3	10.387	21.954	23.793
117	100	0.7	3	9.414	20.862	23.032
118	100	0.8	3	9.983	21.740	22.392
119	100	0.9	3	13.600	25.508	21.842
120	100	1	3	21.960	33.037	21.362

Welded Contour Insert (SWP) - Sketch 2.5 - Branch Outplane K

Item #	D/T	d/D	t/T	PRG kob	PRG UFT kob	Wais UFT kob
1	20	0.1	0.1	1.000	1.000	1.374
2	20	0.2	0.2	1.000	2.375	3.391
3	20	0.3	0.3	1.100	4.013	5.358
4	20	0.4	0.4	1.630	5.454	6.981
5	20	0.5	0.5	2.082	6.519	8.091
6	20	0.6	0.6	2.395	7.115	8.595
7	20	0.7	0.7	2.531	7.222	8.448
8	20	0.8	0.8	2.480	6.879	7.642
9	20	0.9	0.9	2.256	6.182	6.202
10	20	1	1	1.903	5.275	4.177
11	50	0.1	0.1	1.000	3.050	3.445
12	50	0.2	0.2	2.199	8.565	8.501
13	50	0.3	0.3	4.191	14.472	13.433
14	50	0.4	0.4	6.210	19.672	17.500
15	50	0.5	0.5	7.933	23.513	20.283
16	50	0.6	0.6	9.126	25.664	21.547
17	50	0.7	0.7	9.646	26.048	21.178
18	50	0.8	0.8	9.450	24.812	19.158
19	50	0.9	0.9	8.597	22.296	15.549
20	50	1	1	7.253	19.025	10.472
21	100	0.1	0.1	1.761	8.050	6.904
22	100	0.2	0.2	6.049	22.602	17.038
23	100	0.3	0.3	11.530	38.193	26.921
24	100	0.4	0.4	17.085	51.915	35.072
25	100	0.5	0.5	21.825	62.052	40.651
26	100	0.6	0.6	25.105	67.727	43.183
27	100	0.7	0.7	26.536	68.742	42.443
28	100	0.8	0.8	25.997	65.479	38.397
29	100	0.9	0.9	23.651	58.841	31.162
30	100	1	1	19.954	50.209	20.988
31	20	0.1	1	1.680	3.367	7.162
32	20	0.2	1	2.885	6.237	10.753
33	20	0.3	1	3.666	8.263	12.704
34	20	0.4	1	4.074	9.451	13.465
35	20	0.5	1	4.164	9.881	13.300
36	20	0.6	1	3.991	9.667	12.397
37	20	0.7	1	3.616	8.945	10.910
38	20	0.8	1	3.100	7.865	8.968
39	20	0.9	1	2.507	6.585	6.689
40	20	1	1	1.903	5.275	4.177
41	50	0.1	1	6.400	12.144	17.955
42	50	0.2	1	10.994	22.495	26.956
43	50	0.3	1	13.971	29.804	31.847
44	50	0.4	1	15.526	34.089	33.756
45	50	0.5	1	15.867	35.639	33.341
46	50	0.6	1	15.209	34.868	31.078
47	50	0.7	1	13.779	32.264	27.349
48	50	0.8	1	11.812	28.366	22.482
49	50	0.9	1	9.552	23.751	16.769
50	50	1	1	7.253	19.025	10.472
51	100	0.1	1	17.607	32.048	35.984
52	100	0.2	1	30.247	59.366	54.024
53	100	0.3	1	38.434	78.652	63.826
54	100	0.4	1	42.713	89.961	67.652
55	100	0.5	1	43.650	94.053	66.821
56	100	0.6	1	41.842	92.018	62.285
57	100	0.7	1	37.908	85.146	54.812
58	100	0.8	1	32.496	74.859	45.059
59	100	0.9	1	26.278	62.680	33.607
60	100	1	1	19.954	50.209	20.988
61	20	0.1	0.3	1.000	1.635	3.021
62	20	0.2	0.3	1.000	3.029	4.535
63	20	0.3	0.3	1.100	4.013	5.358
64	20	0.4	0.3	1.222	4.590	5.680
65	20	0.5	0.3	1.249	4.798	5.610
66	20	0.6	0.3	1.197	4.694	5.229
67	20	0.7	0.3	1.085	4.344	4.602

Item #	D/T	d/D	t/T	PRG kob	PRG UFT kob	Wais UFT kob
68	20	0.8	0.3	1.000	3.819	3.783
69	20	0.9	0.3	1.000	3.198	2.821
70	20	1	0.3	1.000	2.561	1.762
71	50	0.1	0.3	1.920	5.897	7.573
72	50	0.2	0.3	3.298	10.924	11.370
73	50	0.3	0.3	4.191	14.472	13.433
74	50	0.4	0.3	4.658	16.553	14.238
75	50	0.5	0.3	4.760	17.306	14.063
76	50	0.6	0.3	4.563	16.932	13.108
77	50	0.7	0.3	4.134	15.667	11.536
78	50	0.8	0.3	3.544	13.774	9.483
79	50	0.9	0.3	2.866	11.534	7.073
80	50	1	0.3	2.176	9.239	4.417
81	100	0.1	0.3	5.282	15.562	15.178
82	100	0.2	0.3	9.074	28.828	22.787
83	100	0.3	0.3	11.530	38.193	26.921
84	100	0.4	0.3	12.814	43.684	28.535
85	100	0.5	0.3	13.095	45.671	28.184
86	100	0.6	0.3	12.553	44.683	26.271
87	100	0.7	0.3	11.372	41.346	23.119
88	100	0.8	0.3	9.749	36.351	19.005
89	100	0.9	0.3	7.884	30.437	14.175
90	100	1	0.3	5.986	24.381	8.853
91	20	0.1	3	5.039	6.509	15.745
92	20	0.2	3	8.656	12.057	23.638
93	20	0.3	3	10.999	15.974	27.927
94	20	0.4	3	12.223	18.271	29.601
95	20	0.5	3	12.491	19.102	29.237
96	20	0.6	3	11.974	18.689	27.253
97	20	0.7	3	10.848	17.293	23.983
98	20	0.8	3	9.299	15.204	19.715
99	20	0.9	3	7.520	12.731	14.705
100	20	1	3	5.710	10.197	9.183
101	50	0.1	3	19.200	23.476	39.471
102	50	0.2	3	32.983	43.488	59.259
103	50	0.3	3	41.912	57.616	70.010
104	50	0.4	3	46.577	65.900	74.207
105	50	0.5	3	47.600	68.897	73.295
106	50	0.6	3	45.628	67.407	68.319
107	50	0.7	3	41.338	62.372	60.123
108	50	0.8	3	35.436	54.837	49.424
109	50	0.9	3	28.656	45.916	36.863
110	50	1	3	21.760	36.780	23.021
111	100	0.1	3	52.822	61.954	79.106
112	100	0.2	3	90.740	114.765	118.764
113	100	0.3	3	115.303	152.049	140.312
114	100	0.4	3	128.138	173.911	148.723
115	100	0.5	3	130.951	181.821	146.895
116	100	0.6	3	125.526	177.887	136.923
117	100	0.7	3	113.725	164.602	120.496
118	100	0.8	3	97.488	144.716	99.054
119	100	0.9	3	78.835	121.173	73.880
120	100	1	3	59.863	97.062	46.139

Welded Contour Insert (SWP) - Sketch 2.5 - Branch Torsional K

Item #	D/T	d/D	t/T	PRG ktb	Wais UFT ktb
1	20	0.1	0.1	1.000	1.000
2	20	0.2	0.2	1.000	1.000
3	20	0.3	0.3	1.000	1.000
4	20	0.4	0.4	1.000	1.000
5	20	0.5	0.5	1.000	1.019
6	20	0.6	0.6	1.000	1.497
7	20	0.7	0.7	1.000	2.072
8	20	0.8	0.8	1.000	2.746
9	20	0.9	0.9	1.000	3.521
10	20	1	1	1.060	4.398
11	50	0.1	0.1	1.000	1.000
12	50	0.2	0.2	1.000	1.000
13	50	0.3	0.3	1.000	1.000
14	50	0.4	0.4	1.000	1.000
15	50	0.5	0.5	1.000	1.221
16	50	0.6	0.6	1.000	1.794
17	50	0.7	0.7	1.000	2.484
18	50	0.8	0.8	1.000	3.292
19	50	0.9	0.9	1.083	4.221
20	50	1	1	2.146	5.272
21	100	0.1	0.1	1.000	1.000
22	100	0.2	0.2	1.000	1.000
23	100	0.3	0.3	1.000	1.000
24	100	0.4	0.4	1.000	1.000
25	100	0.5	0.5	1.000	1.401
26	100	0.6	0.6	1.000	2.058
27	100	0.7	0.7	1.000	2.849
28	100	0.8	0.8	1.050	3.777
29	100	0.9	0.9	1.847	4.842
30	100	1	1	3.660	6.048
31	20	0.1	1	1.000	1.000
32	20	0.2	1	1.000	1.000
33	20	0.3	1	1.000	1.000
34	20	0.4	1	1.000	1.056
35	20	0.5	1	1.000	1.495
36	20	0.6	1	1.000	1.985
37	20	0.7	1	1.000	2.524
38	20	0.8	1	1.000	3.107
39	20	0.9	1	1.000	3.732
40	20	1	1	1.060	4.398
41	50	0.1	1	1.000	1.000
42	50	0.2	1	1.000	1.000
43	50	0.3	1	1.000	1.000
44	50	0.4	1	1.000	1.266
45	50	0.5	1	1.000	1.792
46	50	0.6	1	1.000	2.380
47	50	0.7	1	1.000	3.026
48	50	0.8	1	1.000	3.725
49	50	0.9	1	1.204	4.475
50	50	1	1	2.146	5.272
51	100	0.1	1	1.000	1.000
52	100	0.2	1	1.000	1.000
53	100	0.3	1	1.000	1.000
54	100	0.4	1	1.000	1.452
55	100	0.5	1	1.000	2.055
56	100	0.6	1	1.000	2.730
57	100	0.7	1	1.027	3.471
58	100	0.8	1	1.313	4.273
59	100	0.9	1	2.053	5.133
60	100	1	1	3.660	6.048
61	20	0.1	0.3	1.000	1.000
62	20	0.2	0.3	1.000	1.000
63	20	0.3	0.3	1.000	1.000
64	20	0.4	0.3	1.000	1.000
65	20	0.5	0.3	1.000	1.000
66	20	0.6	0.3	1.000	1.020
67	20	0.7	0.3	1.000	1.297
68	20	0.8	0.3	1.000	1.597
69	20	0.9	0.3	1.000	1.918
70	20	1	0.3	1.000	2.260
71	50	0.1	0.3	1.000	1.000
72	50	0.2	0.3	1.000	1.000
73	50	0.3	0.3	1.000	1.000
74	50	0.4	0.3	1.000	1.000
75	50	0.5	0.3	1.000	1.000
76	50	0.6	0.3	1.000	1.223
77	50	0.7	0.3	1.000	1.555
78	50	0.8	0.3	1.000	1.914
79	50	0.9	0.3	1.000	2.299
80	50	1	0.3	1.000	2.709
81	100	0.1	0.3	1.000	1.000
82	100	0.2	0.3	1.000	1.000
83	100	0.3	0.3	1.000	1.000
84	100	0.4	0.3	1.000	1.000
85	100	0.5	0.3	1.000	1.056
86	100	0.6	0.3	1.000	1.403
87	100	0.7	0.3	1.000	1.783
88	100	0.8	0.3	1.000	2.196
89	100	0.9	0.3	1.000	2.638
90	100	1	0.3	1.098	3.108
91	20	0.1	3	1.000	1.000
92	20	0.2	3	1.000	1.000
93	20	0.3	3	1.000	1.239
94	20	0.4	3	1.000	1.938
95	20	0.5	3	1.000	2.744
96	20	0.6	3	1.000	3.645
97	20	0.7	3	1.000	4.633
98	20	0.8	3	1.141	5.704
99	20	0.9	3	1.783	6.852
100	20	1	3	3.180	8.073
101	50	0.1	3	1.000	1.000
102	50	0.2	3	1.000	1.000
103	50	0.3	3	1.000	1.485
104	50	0.4	3	1.000	2.324
105	50	0.5	3	1.000	3.290
106	50	0.6	3	1.000	4.370
107	50	0.7	3	1.806	5.555
108	50	0.8	3	2.310	6.839
109	50	0.9	3	3.611	8.215
110	50	1	3	6.439	9.679
111	100	0.1	3	1.000	1.000
112	100	0.2	3	1.000	1.000
113	100	0.3	3	1.000	1.703
114	100	0.4	3	1.000	2.666
115	100	0.5	3	1.000	3.774
116	100	0.6	3	1.533	5.012
117	100	0.7	3	3.080	6.372
118	100	0.8	3	3.939	7.845
119	100	0.9	3	6.158	9.423
120	100	1	3	10.980	11.103

Welded Contour Insert (SWP) - Sketch 2.5 - Header Inplane K

Item #	D/T	d/D	t/T	PRG kih	PRG UFT kih	Wais UFT kih
1	20	0.1	0.1	1.000	1.000	1.000
2	20	0.2	0.2	1.000	1.000	1.000
3	20	0.3	0.3	1.000	1.000	1.000
4	20	0.4	0.4	1.000	1.000	1.000
5	20	0.5	0.5	1.000	1.000	1.000
6	20	0.6	0.6	1.000	1.000	1.000
7	20	0.7	0.7	1.000	1.000	1.325
8	20	0.8	0.8	1.000	1.235	1.883
9	20	0.9	0.9	1.000	2.182	2.566
10	20	1	1	1.245	3.630	3.385
11	50	0.1	0.1	1.000	1.000	1.000
12	50	0.2	0.2	1.000	1.000	1.000
13	50	0.3	0.3	1.000	1.000	1.000
14	50	0.4	0.4	1.000	1.000	1.000
15	50	0.5	0.5	1.000	1.000	1.000
16	50	0.6	0.6	1.000	1.000	1.105
17	50	0.7	0.7	1.000	1.000	1.658
18	50	0.8	0.8	1.000	1.900	2.355
19	50	0.9	0.9	1.588	3.357	3.211
20	50	1	1	2.689	5.584	4.236
21	100	0.1	0.1	1.000	1.000	1.000
22	100	0.2	0.2	1.000	1.000	1.000
23	100	0.3	0.3	1.000	1.000	1.000
24	100	0.4	0.4	1.000	1.000	1.000
25	100	0.5	0.5	1.000	1.000	1.000
26	100	0.6	0.6	1.000	1.000	1.310
27	100	0.7	0.7	1.000	1.381	1.964
28	100	0.8	0.8	1.577	2.632	2.791
29	100	0.9	0.9	2.842	4.650	3.804
30	100	1	1	4.813	7.734	5.019
31	20	0.1	1	1.000	1.000	1.000
32	20	0.2	1	1.000	1.000	1.000
33	20	0.3	1	1.000	1.000	1.000
34	20	0.4	1	1.000	1.000	1.000
35	20	0.5	1	1.000	1.000	1.000
36	20	0.6	1	1.000	1.000	1.000
37	20	0.7	1	1.000	1.000	1.218
38	20	0.8	1	1.000	1.112	1.786
39	20	0.9	1	1.000	2.077	2.503
40	20	1	1	1.245	3.630	3.385
41	50	0.1	1	1.000	1.000	1.000
42	50	0.2	1	1.000	1.000	1.000
43	50	0.3	1	1.000	1.000	1.000
44	50	0.4	1	1.000	1.000	1.000
45	50	0.5	1	1.000	1.000	1.000
46	50	0.6	1	1.000	1.000	1.000
47	50	0.7	1	1.000	1.000	1.524
48	50	0.8	1	1.000	1.711	2.234
49	50	0.9	1	1.588	3.195	3.132
50	50	1	1	2.689	5.584	4.236
51	100	0.1	1	1.000	1.000	1.000
52	100	0.2	1	1.000	1.000	1.000
53	100	0.3	1	1.000	1.000	1.000
54	100	0.4	1	1.000	1.000	1.000
55	100	0.5	1	1.000	1.000	1.000
56	100	0.6	1	1.000	1.000	1.160
57	100	0.7	1	1.000	1.168	1.805
58	100	0.8	1	1.577	2.370	2.647
59	100	0.9	1	2.842	4.425	3.710
60	100	1	1	4.813	7.734	5.019
61	20	0.1	0.3	1.000	1.000	1.000
62	20	0.2	0.3	1.000	1.000	1.000
63	20	0.3	0.3	1.000	1.000	1.000
64	20	0.4	0.3	1.000	1.000	1.000
65	20	0.5	0.3	1.000	1.000	1.000
66	20	0.6	0.3	1.000	1.000	1.041
67	20	0.7	0.3	1.000	1.000	1.619

Item #	D/T	d/D	t/T	PRG kih	PRG UFT kih	Wais UFT kih
68	20	0.8	0.3	1.000	1.959	2.374
69	20	0.9	0.3	1.000	3.657	3.328
70	20	1	0.3	1.245	6.392	4.501
71	50	0.1	0.3	1.000	1.000	1.000
72	50	0.2	0.3	1.000	1.000	1.000
73	50	0.3	0.3	1.000	1.000	1.000
74	50	0.4	0.3	1.000	1.000	1.000
75	50	0.5	0.3	1.000	1.000	1.000
76	50	0.6	0.3	1.000	1.000	1.302
77	50	0.7	0.3	1.000	1.485	2.026
78	50	0.8	0.3	1.000	3.013	2.971
79	50	0.9	0.3	1.588	5.626	4.164
80	50	1	0.3	2.689	9.833	5.632
81	100	0.1	0.3	1.000	1.000	1.000
82	100	0.2	0.3	1.000	1.000	1.000
83	100	0.3	0.3	1.000	1.000	1.000
84	100	0.4	0.3	1.000	1.000	1.000
85	100	0.5	0.3	1.000	1.000	1.000
86	100	0.6	0.3	1.000	1.000	1.543
87	100	0.7	0.3	1.000	2.057	2.400
88	100	0.8	0.3	1.577	4.174	3.520
89	100	0.9	0.3	2.842	7.792	4.933
90	100	1	0.3	4.813	13.620	6.673
91	20	0.1	3	1.000	1.000	1.000
92	20	0.2	3	1.000	1.000	1.000
93	20	0.3	3	1.000	1.000	1.000
94	20	0.4	3	1.000	1.000	1.000
95	20	0.5	3	1.000	1.000	1.000
96	20	0.6	3	1.000	1.000	1.000
97	20	0.7	3	1.000	1.000	1.000
98	20	0.8	3	1.000	1.000	1.377
99	20	0.9	3	1.000	1.239	1.930
100	20	1	3	1.245	2.166	2.611
101	50	0.1	3	1.000	1.000	1.000
102	50	0.2	3	1.000	1.000	1.000
103	50	0.3	3	1.000	1.000	1.000
104	50	0.4	3	1.000	1.000	1.000
105	50	0.5	3	1.000	1.000	1.000
106	50	0.6	3	1.000	1.000	1.000
107	50	0.7	3	1.000	1.000	1.175
108	50	0.8	3	1.000	1.021	1.723
109	50	0.9	3	1.588	1.906	2.415
110	50	1	3	2.689	3.332	3.266
111	100	0.1	3	1.000	1.000	1.000
112	100	0.2	3	1.000	1.000	1.000
113	100	0.3	3	1.000	1.000	1.000
114	100	0.4	3	1.000	1.000	1.000
115	100	0.5	3	1.000	1.000	1.000
116	100	0.6	3	1.000	1.000	1.000
117	100	0.7	3	1.000	1.000	1.392
118	100	0.8	3	1.414	1.414	2.041
119	100	0.9	3	2.640	2.640	2.861
120	100	1	3	4.615	4.615	3.870

Welded Contour Insert (SWP) - Sketch 2.5 - Header Torsional K

Item #	D/T	d/D	t/T	PRG kth	PRG UFT kth	Wais UFT kth
1	20	0.1	0.1	1.000	1.000	1.000
2	20	0.2	0.2	1.000	1.000	1.000
3	20	0.3	0.3	1.000	1.000	1.000
4	20	0.4	0.4	1.000	1.000	1.000
5	20	0.5	0.5	1.000	1.000	1.000
6	20	0.6	0.6	1.000	1.000	1.135
7	20	0.7	0.7	1.000	1.000	1.661
8	20	0.8	0.8	1.000	1.264	2.310
9	20	0.9	0.9	1.000	2.882	3.090
10	20	1	1	1.000	6.026	4.008
11	50	0.1	0.1	1.000	1.000	1.000
12	50	0.2	0.2	1.000	1.000	1.000
13	50	0.3	0.3	1.000	1.000	1.000
14	50	0.4	0.4	1.000	1.000	1.000
15	50	0.5	0.5	1.000	1.000	1.000
16	50	0.6	0.6	1.000	1.000	1.515
17	50	0.7	0.7	1.000	1.014	2.217
18	50	0.8	0.8	1.000	2.582	3.083
19	50	0.9	0.9	1.026	5.890	4.124
20	50	1	1	1.871	12.314	5.349
21	100	0.1	0.1	1.000	1.000	1.000
22	100	0.2	0.2	1.000	1.000	1.000
23	100	0.3	0.3	1.000	1.000	1.000
24	100	0.4	0.4	1.000	1.000	1.000
25	100	0.5	0.5	1.000	1.000	1.201
26	100	0.6	0.6	1.000	1.000	1.884
27	100	0.7	0.7	1.000	1.741	2.758
28	100	0.8	0.8	1.000	4.434	3.835
29	100	0.9	0.9	1.929	10.113	5.130
30	100	1	1	3.516	21.144	6.655
31	20	0.1	1	1.000	1.000	1.000
32	20	0.2	1	1.000	1.000	1.000
33	20	0.3	1	1.000	1.000	1.000
34	20	0.4	1	1.000	1.000	1.000
35	20	0.5	1	1.000	1.000	1.000
36	20	0.6	1	1.000	1.000	1.000
37	20	0.7	1	1.000	1.000	1.505
38	20	0.8	1	1.000	1.057	2.172
39	20	0.9	1	1.000	2.649	3.001
40	20	1	1	1.000	6.026	4.008
41	50	0.1	1	1.000	1.000	1.000
42	50	0.2	1	1.000	1.000	1.000
43	50	0.3	1	1.000	1.000	1.000
44	50	0.4	1	1.000	1.000	1.000
45	50	0.5	1	1.000	1.000	1.000
46	50	0.6	1	1.000	1.000	1.316
47	50	0.7	1	1.000	1.000	2.009
48	50	0.8	1	1.000	2.160	2.899
49	50	0.9	1	1.026	5.414	4.005
50	50	1	1	1.871	12.314	5.349
51	100	0.1	1	1.000	1.000	1.000
52	100	0.2	1	1.000	1.000	1.000
53	100	0.3	1	1.000	1.000	1.000
54	100	0.4	1	1.000	1.000	1.000
55	100	0.5	1	1.000	1.000	1.000
56	100	0.6	1	1.000	1.000	1.637
57	100	0.7	1	1.000	1.309	2.499
58	100	0.8	1	1.000	3.709	3.606
59	100	0.9	1	1.929	9.296	4.983
60	100	1	1	3.516	21.144	6.655
61	20	0.1	0.3	1.000	1.000	1.000
62	20	0.2	0.3	1.000	1.000	1.000
63	20	0.3	0.3	1.000	1.000	1.000
64	20	0.4	0.3	1.000	1.000	1.000
65	20	0.5	0.3	1.000	1.000	1.000
66	20	0.6	0.3	1.000	1.000	1.374
67	20	0.7	0.3	1.000	1.000	2.098

Item #	D/T	d/D	t/T	PRG kth	PRG UFT kth	Wais UFT kth
68	20	0.8	0.3	1.000	2.770	3.028
69	20	0.9	0.3	1.000	6.941	4.184
70	20	1	0.3	1.000	15.787	5.588
71	50	0.1	0.3	1.000	1.000	1.000
72	50	0.2	0.3	1.000	1.000	1.000
73	50	0.3	0.3	1.000	1.000	1.000
74	50	0.4	0.3	1.000	1.000	1.000
75	50	0.5	0.3	1.000	1.000	1.112
76	50	0.6	0.3	1.000	1.000	1.834
77	50	0.7	0.3	1.000	1.997	2.801
78	50	0.8	0.3	1.000	5.660	4.041
79	50	0.9	0.3	1.026	14.184	5.584
80	50	1	0.3	1.871	32.262	7.458
81	100	0.1	0.3	1.000	1.000	1.000
82	100	0.2	0.3	1.000	1.000	1.000
83	100	0.3	0.3	1.000	1.000	1.000
84	100	0.4	0.3	1.000	1.000	1.000
85	100	0.5	0.3	1.000	1.000	1.383
86	100	0.6	0.3	1.000	1.031	2.282
87	100	0.7	0.3	1.000	3.430	3.484
88	100	0.8	0.3	1.000	9.719	5.027
89	100	0.9	0.3	1.929	24.355	6.947
90	100	1	0.3	3.516	55.399	9.278
91	20	0.1	3	1.000	1.000	1.000
92	20	0.2	3	1.000	1.000	1.000
93	20	0.3	3	1.000	1.000	1.000
94	20	0.4	3	1.000	1.000	1.000
95	20	0.5	3	1.000	1.000	1.000
96	20	0.6	3	1.000	1.000	1.000
97	20	0.7	3	1.000	1.000	1.111
98	20	0.8	3	1.000	1.000	1.604
99	20	0.9	3	1.000	1.100	2.216
100	20	1	3	1.000	2.502	2.960
101	50	0.1	3	1.000	1.000	1.000
102	50	0.2	3	1.000	1.000	1.000
103	50	0.3	3	1.000	1.000	1.000
104	50	0.4	3	1.000	1.000	1.000
105	50	0.5	3	1.000	1.000	1.000
106	50	0.6	3	1.000	1.000	1.000
107	50	0.7	3	1.000	1.000	1.483
108	50	0.8	3	1.000	1.000	2.140
109	50	0.9	3	1.026	2.248	2.958
110	50	1	3	1.871	5.113	3.950
111	100	0.1	3	1.000	1.000	1.000
112	100	0.2	3	1.000	1.000	1.000
113	100	0.3	3	1.000	1.000	1.000
114	100	0.4	3	1.000	1.000	1.000
115	100	0.5	3	1.000	1.000	1.000
116	100	0.6	3	1.000	1.000	1.208
117	100	0.7	3	1.000	1.000	1.845
118	100	0.8	3	1.000	1.540	2.663
119	100	0.9	3	1.929	3.860	3.680
120	100	1	3	3.516	8.780	4.914

Integrally Reinforced Weld-On Fitting (OLET) - Sketch 2.6 - Branch Inplane SIF

Item #	D/T	d/D	t/T	PRG iib	B31.3 iib	Ncib
1	20	0.1	0.1	1.000	1.133	1.500
2	20	0.2	0.2	1.000	1.133	1.500
3	20	0.3	0.3	1.000	1.133	1.500
4	20	0.4	0.4	1.000	1.133	1.500
5	20	0.5	0.5	1.000	1.133	2.092
6	20	0.6	0.6	1.038	1.133	2.750
7	20	0.7	0.7	1.236	1.319	3.466
8	20	0.8	0.8	1.503	1.508	4.235
9	20	0.9	0.9	1.904	1.696	5.053
10	20	1	1	2.520	1.885	3.551
11	50	0.1	0.1	1.000	1.217	1.500
12	50	0.2	0.2	1.000	1.217	1.500
13	50	0.3	0.3	1.009	1.217	1.791
14	50	0.4	0.4	1.424	1.389	2.758
15	50	0.5	0.5	1.808	1.736	3.854
16	50	0.6	0.6	2.180	2.083	5.066
17	50	0.7	0.7	2.597	2.430	6.384
18	50	0.8	0.8	3.158	2.777	7.800
19	50	0.9	0.9	4.000	3.124	9.308
20	50	1	1	5.057	3.472	6.541
21	100	0.1	0.1	1.000	1.257	1.500
22	100	0.2	0.2	1.025	1.257	1.548
23	100	0.3	0.3	1.768	1.653	2.843
24	100	0.4	0.4	2.496	2.204	4.378
25	100	0.5	0.5	3.171	2.755	6.118
26	100	0.6	0.6	3.822	3.306	8.042
27	100	0.7	0.7	4.553	3.858	10.135
28	100	0.8	0.8	5.536	4.409	12.382
29	100	0.9	0.9	7.013	4.960	14.775
30	100	1	1	8.564	5.511	10.383
31	20	0.1	1	1.000	1.885	1.871
32	20	0.2	1	1.392	1.885	2.647
33	20	0.3	1	1.601	1.885	3.241
34	20	0.4	1	1.695	1.885	3.743
35	20	0.5	1	1.722	1.885	4.185
36	20	0.6	1	1.730	1.885	4.584
37	20	0.7	1	1.766	1.885	4.951
38	20	0.8	1	1.879	1.885	5.293
39	20	0.9	1	2.116	1.885	5.614
40	20	1	1	2.520	1.885	3.551
41	50	0.1	1	1.852	3.472	3.447
42	50	0.2	1	2.807	3.472	4.875
43	50	0.3	1	3.362	3.472	5.971
44	50	0.4	1	3.560	3.472	6.894
45	50	0.5	1	3.617	3.472	7.708
46	50	0.6	1	3.634	3.472	8.444
47	50	0.7	1	3.710	3.472	9.121
48	50	0.8	1	3.947	3.472	9.750
49	50	0.9	1	4.433	3.472	10.342
50	50	1	1	5.057	3.472	6.541
51	100	0.1	1	3.137	5.511	5.472
52	100	0.2	1	4.754	5.511	7.739
53	100	0.3	1	5.750	5.511	9.478
54	100	0.4	1	6.241	5.511	10.944
55	100	0.5	1	6.341	5.511	12.236
56	100	0.6	1	6.370	5.511	13.404
57	100	0.7	1	6.505	5.511	14.478
58	100	0.8	1	6.920	5.511	15.478
59	100	0.9	1	7.508	5.511	16.416
60	100	1	1	8.564	5.511	10.383
61	20	0.1	0.3	1.000	1.133	1.500
62	20	0.2	0.3	1.000	1.133	1.500
63	20	0.3	0.3	1.000	1.133	1.500
64	20	0.4	0.3	1.000	1.133	1.500
65	20	0.5	0.3	1.000	1.133	1.500
66	20	0.6	0.3	1.000	1.133	1.500
67	20	0.7	0.3	1.000	1.133	1.500

Item #	D/T	d/D	t/T	PRG iib	B31.3 iib	Ncib
68	20	0.8	0.3	1.000	1.133	1.588
69	20	0.9	0.3	1.000	1.133	1.684
70	20	1	0.3	1.000	1.885	3.551
71	50	0.1	0.3	1.000	1.217	1.500
72	50	0.2	0.3	1.000	1.217	1.500
73	50	0.3	0.3	1.009	1.217	1.791
74	50	0.4	0.3	1.068	1.217	2.068
75	50	0.5	0.3	1.085	1.217	2.312
76	50	0.6	0.3	1.090	1.217	2.533
77	50	0.7	0.3	1.113	1.217	2.736
78	50	0.8	0.3	1.184	1.217	2.925
79	50	0.9	0.3	1.333	1.217	3.103
80	50	1	0.3	1.591	3.472	6.541
81	100	0.1	0.3	1.127	1.653	1.642
82	100	0.2	0.3	1.538	1.653	2.322
83	100	0.3	0.3	1.768	1.653	2.843
84	100	0.4	0.3	1.872	1.653	3.283
85	100	0.5	0.3	1.902	1.653	3.671
86	100	0.6	0.3	1.911	1.653	4.021
87	100	0.7	0.3	1.951	1.653	4.343
88	100	0.8	0.3	2.076	1.653	4.643
89	100	0.9	0.3	2.338	1.653	4.925
90	100	1	0.3	2.789		
91	20	0.1	3	2.082	5.654	5.614
92	20	0.2	3	3.154	5.654	7.940
93	20	0.3	3	3.815	5.654	9.724
94	20	0.4	3	4.169	5.654	11.229
95	20	0.5	3	4.320	5.654	12.554
96	20	0.6	3	4.373	5.654	13.752
97	20	0.7	3	4.431	5.654	14.854
98	20	0.8	3	4.599	5.654	15.880
99	20	0.9	3	4.981	5.654	16.843
100	20	1	3	5.683		
101	50	0.1	3	4.177	10.415	10.342
102	50	0.2	3	6.329	10.415	14.625
103	50	0.3	3	7.655	10.415	17.912
104	50	0.4	3	8.366	10.415	20.683
105	50	0.5	3	8.669	10.415	23.125
106	50	0.6	3	8.774	10.415	25.332
107	50	0.7	3	8.890	10.415	27.362
108	50	0.8	3	9.228	10.415	29.251
109	50	0.9	3	9.995	10.415	31.025
110	50	1	3	11.402		
111	100	0.1	3	7.073	16.532	16.416
112	100	0.2	3	10.718	16.532	23.216
113	100	0.3	3	12.964	16.532	28.434
114	100	0.4	3	14.167	16.532	32.833
115	100	0.5	3	14.680	16.532	36.708
116	100	0.6	3	14.858	16.532	40.212
117	100	0.7	3	15.056	16.532	43.434
118	100	0.8	3	15.627	16.532	46.433
119	100	0.9	3	16.927	16.532	49.249
120	100	1	3	19.309		

Integrally Reinforced Weld-On Fitting (OLET) - Sketch 2.6 - Branch Outplane SIF

Item #	D/T	d/D	t/T	PRG iob	B31.3 iob	Ncib
1	20	0.1	0.1	1.000	1.133	1.500
2	20	0.2	0.2	1.000	1.133	1.500
3	20	0.3	0.3	1.000	1.133	1.500
4	20	0.4	0.4	1.448	1.133	1.500
5	20	0.5	0.5	2.130	1.133	2.092
6	20	0.6	0.6	2.837	1.133	2.750
7	20	0.7	0.7	3.489	1.319	3.466
8	20	0.8	0.8	3.997	1.508	4.235
9	20	0.9	0.9	4.256	1.696	5.053
10	20	1	1	3.109	1.885	3.551
11	50	0.1	0.1	1.000	1.217	1.500
12	50	0.2	0.2	1.000	1.217	1.500
13	50	0.3	0.3	1.804	1.217	1.791
14	50	0.4	0.4	3.069	1.389	2.758
15	50	0.5	0.5	4.516	1.736	3.854
16	50	0.6	0.6	6.014	2.083	5.066
17	50	0.7	0.7	7.397	2.430	6.384
18	50	0.8	0.8	8.474	2.777	7.800
19	50	0.9	0.9	9.021	3.124	9.308
20	50	1	1	6.590	3.472	6.541
21	100	0.1	0.1	1.000	1.257	1.500
22	100	0.2	0.2	1.459	1.257	1.548
23	100	0.3	0.3	3.185	1.653	2.843
24	100	0.4	0.4	5.417	2.204	4.378
25	100	0.5	0.5	7.973	2.755	6.118
26	100	0.6	0.6	10.616	3.306	8.042
27	100	0.7	0.7	13.059	3.858	10.135
28	100	0.8	0.8	14.960	4.409	12.382
29	100	0.9	0.9	14.635	4.960	14.775
30	100	1	1	11.634	5.511	10.383
31	20	0.1	1	1.000	1.885	1.871
32	20	0.2	1	1.949	1.885	2.647
33	20	0.3	1	2.837	1.885	3.241
34	20	0.4	1	3.619	1.885	3.743
35	20	0.5	1	4.261	1.885	4.185
36	20	0.6	1	4.728	1.885	4.584
37	20	0.7	1	4.985	1.885	4.951
38	20	0.8	1	4.997	1.885	5.293
39	20	0.9	1	4.728	1.885	5.614
40	20	1	1	3.109	1.885	3.551
41	50	0.1	1	2.103	3.472	3.447
42	50	0.2	1	4.133	3.472	4.875
43	50	0.3	1	6.013	3.472	5.971
44	50	0.4	1	7.671	3.472	6.894
45	50	0.5	1	9.033	3.472	7.708
46	50	0.6	1	10.023	3.472	8.444
47	50	0.7	1	10.567	3.472	9.121
48	50	0.8	1	10.592	3.472	9.750
49	50	0.9	1	10.024	3.472	10.342
50	50	1	1	6.590	3.472	6.541
51	100	0.1	1	3.460	5.511	5.472
52	100	0.2	1	6.694	5.511	7.739
53	100	0.3	1	9.966	5.511	9.478
54	100	0.4	1	13.024	5.511	10.944
55	100	0.5	1	15.615	5.511	12.236
56	100	0.6	1	17.486	5.511	13.404
57	100	0.7	1	18.386	5.511	14.478
58	100	0.8	1	18.062	5.511	15.478
59	100	0.9	1	16.261	5.511	16.416
60	100	1	1	11.634	5.511	10.383
61	20	0.1	0.3	1.000	1.133	1.500
62	20	0.2	0.3	1.000	1.133	1.500
63	20	0.3	0.3	1.000	1.133	1.500
64	20	0.4	0.3	1.086	1.133	1.500
65	20	0.5	0.3	1.278	1.133	1.500
66	20	0.6	0.3	1.418	1.133	1.500
67	20	0.7	0.3	1.495	1.133	1.500

Item #	D/T	d/D	t/T	PRG iob	B31.3 iob	Ncib
68	20	0.8	0.3	1.499	1.133	1.588
69	20	0.9	0.3	1.419	1.133	1.684
70	20	1	0.3	1.000	1.885	3.551
71	50	0.1	0.3	1.000	1.217	1.500
72	50	0.2	0.3	1.240	1.217	1.500
73	50	0.3	0.3	1.804	1.217	1.791
74	50	0.4	0.3	2.301	1.217	2.068
75	50	0.5	0.3	2.710	1.217	2.312
76	50	0.6	0.3	3.007	1.217	2.533
77	50	0.7	0.3	3.170	1.217	2.736
78	50	0.8	0.3	3.178	1.217	2.925
79	50	0.9	0.3	3.007	1.217	3.103
80	50	1	0.3	1.977	3.472	6.541
81	100	0.1	0.3	1.127	1.653	1.642
82	100	0.2	0.3	2.189	1.653	2.322
83	100	0.3	0.3	3.185	1.653	2.843
84	100	0.4	0.3	4.063	1.653	3.283
85	100	0.5	0.3	4.784	1.653	3.671
86	100	0.6	0.3	5.308	1.653	4.021
87	100	0.7	0.3	5.597	1.653	4.343
88	100	0.8	0.3	5.610	1.653	4.643
89	100	0.9	0.3	5.309	1.653	4.925
90	100	1	0.3	3.490		
91	20	0.1	3	2.977	5.654	5.614
92	20	0.2	3	5.848	5.654	7.940
93	20	0.3	3	8.510	5.654	9.724
94	20	0.4	3	10.856	5.654	11.229
95	20	0.5	3	12.783	5.654	12.554
96	20	0.6	3	14.184	5.654	13.752
97	20	0.7	3	14.955	5.654	14.854
98	20	0.8	3	14.990	5.654	15.880
99	20	0.9	3	14.185	5.654	16.843
100	20	1	3	9.326		
101	50	0.1	3	6.310	10.415	10.342
102	50	0.2	3	12.398	10.415	14.625
103	50	0.3	3	18.040	10.415	17.912
104	50	0.4	3	23.014	10.415	20.683
105	50	0.5	3	27.098	10.415	23.125
106	50	0.6	3	30.068	10.415	25.332
107	50	0.7	3	31.702	10.415	27.362
108	50	0.8	3	31.777	10.415	29.251
109	50	0.9	3	30.071	10.415	31.025
110	50	1	3	19.771		
111	100	0.1	3	10.379	16.532	16.416
112	100	0.2	3	20.081	16.532	23.216
113	100	0.3	3	29.898	16.532	28.434
114	100	0.4	3	39.071	16.532	32.833
115	100	0.5	3	46.844	16.532	36.708
116	100	0.6	3	52.459	16.532	40.212
117	100	0.7	3	55.158	16.532	43.434
118	100	0.8	3	54.185	16.532	46.433
119	100	0.9	3	48.782	16.532	49.249
120	100	1	3	34.903		

Integrally Reinforced Weld-On Fitting (OLET) - Sketch 2.6 - Branch Torsional SIF

Item #	D/T	d/D	t/T	PRG itb	B31.3 iib	Ncib
1	20	0.1	0.1	1.000	1.133	1.500
2	20	0.2	0.2	1.000	1.133	1.500
3	20	0.3	0.3	1.000	1.133	1.500
4	20	0.4	0.4	1.000	1.133	1.500
5	20	0.5	0.5	1.000	1.133	2.092
6	20	0.6	0.6	1.000	1.133	2.750
7	20	0.7	0.7	1.042	1.319	3.466
8	20	0.8	0.8	1.555	1.508	4.235
9	20	0.9	0.9	2.215	1.696	5.053
10	20	1	1	2.278	1.885	3.551
11	50	0.1	0.1	1.000	1.217	1.500
12	50	0.2	0.2	1.000	1.217	1.500
13	50	0.3	0.3	1.000	1.217	1.791
14	50	0.4	0.4	1.000	1.389	2.758
15	50	0.5	0.5	1.000	1.736	3.854
16	50	0.6	0.6	1.209	2.083	5.066
17	50	0.7	0.7	1.919	2.430	6.384
18	50	0.8	0.8	2.865	2.777	7.800
19	50	0.9	0.9	4.079	3.124	9.308
20	50	1	1	4.197	3.472	6.541
21	100	0.1	0.1	1.000	1.257	1.500
22	100	0.2	0.2	1.000	1.257	1.548
23	100	0.3	0.3	1.000	1.653	2.843
24	100	0.4	0.4	1.000	2.204	4.378
25	100	0.5	0.5	1.110	2.755	6.118
26	100	0.6	0.6	1.919	3.306	8.042
27	100	0.7	0.7	3.047	3.858	10.135
28	100	0.8	0.8	4.548	4.409	12.382
29	100	0.9	0.9	6.476	4.960	14.775
30	100	1	1	6.662	5.511	10.383
31	20	0.1	1	1.000	1.885	1.871
32	20	0.2	1	1.000	1.885	2.647
33	20	0.3	1	1.000	1.885	3.241
34	20	0.4	1	1.000	1.885	3.743
35	20	0.5	1	1.000	1.885	4.185
36	20	0.6	1	1.022	1.885	4.584
37	20	0.7	1	1.391	1.885	4.951
38	20	0.8	1	1.817	1.885	5.293
39	20	0.9	1	2.300	1.885	5.614
40	20	1	1	2.278	1.885	3.551
41	50	0.1	1	1.000	3.472	3.447
42	50	0.2	1	1.000	3.472	4.875
43	50	0.3	1	1.000	3.472	5.971
44	50	0.4	1	1.000	3.472	6.894
45	50	0.5	1	1.399	3.472	7.708
46	50	0.6	1	2.015	3.472	8.444
47	50	0.7	1	2.742	3.472	9.121
48	50	0.8	1	3.581	3.472	9.750
49	50	0.9	1	4.533	3.472	10.342
50	50	1	1	4.197	3.472	6.541
51	100	0.1	1	1.000	5.511	5.472
52	100	0.2	1	1.000	5.511	7.739
53	100	0.3	1	1.000	5.511	9.478
54	100	0.4	1	1.421	5.511	10.944
55	100	0.5	1	2.221	5.511	12.236
56	100	0.6	1	3.198	5.511	13.404
57	100	0.7	1	4.353	5.511	14.478
58	100	0.8	1	5.685	5.511	15.478
59	100	0.9	1	7.195	5.511	16.416
60	100	1	1	6.662	5.511	10.383
61	20	0.1	0.3	1.000	1.133	1.500
62	20	0.2	0.3	1.000	1.133	1.500
63	20	0.3	0.3	1.000	1.133	1.500
64	20	0.4	0.3	1.000	1.133	1.500
65	20	0.5	0.3	1.000	1.133	1.500
66	20	0.6	0.3	1.000	1.133	1.500
67	20	0.7	0.3	1.000	1.133	1.500

Item #	D/T	d/D	t/T	PRG itb	B31.3 iib	Ncib
68	20	0.8	0.3	1.000	1.133	1.588
69	20	0.9	0.3	1.000	1.133	1.684
70	20	1	0.3	1.000	1.885	3.551
71	50	0.1	0.3	1.000	1.217	1.500
72	50	0.2	0.3	1.000	1.217	1.500
73	50	0.3	0.3	1.000	1.217	1.791
74	50	0.4	0.3	1.000	1.217	2.068
75	50	0.5	0.3	1.000	1.217	2.312
76	50	0.6	0.3	1.000	1.217	2.533
77	50	0.7	0.3	1.000	1.217	2.736
78	50	0.8	0.3	1.074	1.217	2.925
79	50	0.9	0.3	1.360	1.217	3.103
80	50	1	0.3	1.259	3.472	6.541
81	100	0.1	0.3	1.000	1.653	1.642
82	100	0.2	0.3	1.000	1.653	2.322
83	100	0.3	0.3	1.000	1.653	2.843
84	100	0.4	0.3	1.000	1.653	3.283
85	100	0.5	0.3	1.000	1.653	3.671
86	100	0.6	0.3	1.000	1.653	4.021
87	100	0.7	0.3	1.306	1.653	4.343
88	100	0.8	0.3	1.706	1.653	4.643
89	100	0.9	0.3	2.159	1.653	4.925
90	100	1	0.3	1.999		
91	20	0.1	3	1.000	5.654	5.614
92	20	0.2	3	1.000	5.654	7.940
93	20	0.3	3	1.000	5.654	9.724
94	20	0.4	3	1.000	5.654	11.229
95	20	0.5	3	1.000	5.654	12.554
96	20	0.6	3	1.406	5.654	13.752
97	20	0.7	3	1.913	5.654	14.854
98	20	0.8	3	2.499	5.654	15.880
99	20	0.9	3	3.163	5.654	16.843
100	20	1	3	3.905		
101	50	0.1	3	1.000	10.415	10.342
102	50	0.2	3	1.000	10.415	14.625
103	50	0.3	3	1.000	10.415	17.912
104	50	0.4	3	1.300	10.415	20.683
105	50	0.5	3	2.032	10.415	23.125
106	50	0.6	3	2.926	10.415	25.332
107	50	0.7	3	3.982	10.415	27.362
108	50	0.8	3	5.201	10.415	29.251
109	50	0.9	3	6.583	10.415	31.025
110	50	1	3	8.127		
111	100	0.1	3	1.000	16.532	16.416
112	100	0.2	3	1.000	16.532	23.216
113	100	0.3	3	1.273	16.532	28.434
114	100	0.4	3	2.264	16.532	32.833
115	100	0.5	3	3.537	16.532	36.708
116	100	0.6	3	5.094	16.532	40.212
117	100	0.7	3	6.933	16.532	43.434
118	100	0.8	3	9.056	16.532	46.433
119	100	0.9	3	11.461	16.532	49.249
120	100	1	3	14.150		

Integrally Reinforced Weld-On Fitting (OLET) - Sketch 2.6 - Header Inplane SIF

Item #	D/T	d/D	t/T	PRG iih	B31.3 iih	WRC 329 Eq. 45
1	20	0.1	0.1	1.698	1.885	2.100
2	20	0.2	0.2	1.951	1.885	2.100
3	20	0.3	0.3	2.116	1.885	2.100
4	20	0.4	0.4	2.241	1.885	2.100
5	20	0.5	0.5	2.343	1.885	2.100
6	20	0.6	0.6	2.430	1.885	2.228
7	20	0.7	0.7	2.506	1.885	2.599
8	20	0.8	0.8	2.574	1.885	2.971
9	20	0.9	0.9	2.635	1.885	3.342
10	20	1	1	2.692	1.885	3.713
11	50	0.1	0.1	2.518	3.472	2.100
12	50	0.2	0.2	2.893	3.472	2.100
13	50	0.3	0.3	3.137	3.472	2.100
14	50	0.4	0.4	3.323	3.472	2.736
15	50	0.5	0.5	3.475	3.472	3.420
16	50	0.6	0.6	3.604	3.472	4.104
17	50	0.7	0.7	3.716	3.472	4.788
18	50	0.8	0.8	3.817	3.472	5.472
19	50	0.9	0.9	3.908	3.472	6.156
20	50	1	1	3.991	3.472	6.840
21	100	0.1	0.1	3.393	5.511	2.100
22	100	0.2	0.2	3.897	5.511	2.172
23	100	0.3	0.3	4.227	5.511	3.257
24	100	0.4	0.4	4.477	5.511	4.343
25	100	0.5	0.5	4.681	5.511	5.429
26	100	0.6	0.6	4.855	5.511	6.515
27	100	0.7	0.7	5.007	5.511	7.600
28	100	0.8	0.8	5.143	5.511	8.686
29	100	0.9	0.9	5.265	5.511	9.772
30	100	1	1	5.377	5.511	10.858
31	20	0.1	1	1.500	1.885	2.100
32	20	0.2	1	1.500	1.885	2.100
33	20	0.3	1	1.651	1.885	2.100
34	20	0.4	1	1.906	1.885	2.100
35	20	0.5	1	2.131	1.885	2.100
36	20	0.6	1	2.335	1.885	2.228
37	20	0.7	1	2.506	1.885	2.599
38	20	0.8	1	2.574	1.885	2.971
39	20	0.9	1	2.635	1.885	3.342
40	20	1	1	2.692	1.885	3.713
41	50	0.1	1	1.500	3.472	2.100
42	50	0.2	1	1.945	3.472	2.100
43	50	0.3	1	2.382	3.472	2.100
44	50	0.4	1	2.750	3.472	2.736
45	50	0.5	1	3.075	3.472	3.420
46	50	0.6	1	3.368	3.472	4.104
47	50	0.7	1	3.638	3.472	4.788
48	50	0.8	1	3.817	3.472	5.472
49	50	0.9	1	3.908	3.472	6.156
50	50	1	1	3.991	3.472	6.840
51	100	0.1	1	1.815	5.511	2.100
52	100	0.2	1	2.566	5.511	2.172
53	100	0.3	1	3.143	5.511	3.257
54	100	0.4	1	3.629	5.511	4.343
55	100	0.5	1	4.057	5.511	5.429
56	100	0.6	1	4.445	5.511	6.515
57	100	0.7	1	4.801	5.511	7.600
58	100	0.8	1	5.132	5.511	8.686
59	100	0.9	1	5.265	5.511	9.772
60	100	1	1	5.377	5.511	10.858
61	20	0.1	0.3	1.500	1.885	2.100
62	20	0.2	0.3	1.951	1.885	2.100
63	20	0.3	0.3	2.116	1.885	2.100
64	20	0.4	0.3	2.241	1.885	2.100
65	20	0.5	0.3	2.343	1.885	2.100
66	20	0.6	0.3	2.430	1.885	2.228
67	20	0.7	0.3	2.506	1.885	2.599

Item #	D/T	d/D	t/T	PRG iih	B31.3 iih	WRC 329 Eq. 45
68	20	0.8	0.3	2.574	1.885	2.971
69	20	0.9	0.3	2.635	1.885	3.342
70	20	1	0.3	2.692	1.885	3.713
71	50	0.1	0.3	2.096	3.472	2.100
72	50	0.2	0.3	2.893	3.472	2.100
73	50	0.3	0.3	3.137	3.472	2.100
74	50	0.4	0.3	3.323	3.472	2.736
75	50	0.5	0.3	3.475	3.472	3.420
76	50	0.6	0.3	3.604	3.472	4.104
77	50	0.7	0.3	3.716	3.472	4.788
78	50	0.8	0.3	3.817	3.472	5.472
79	50	0.9	0.3	3.908	3.472	6.156
80	50	1	0.3	3.991	3.472	6.840
81	100	0.1	0.3	2.766	5.511	2.100
82	100	0.2	0.3	3.897	5.511	2.172
83	100	0.3	0.3	4.227	5.511	3.257
84	100	0.4	0.3	4.477	5.511	4.343
85	100	0.5	0.3	4.681	5.511	5.429
86	100	0.6	0.3	4.855	5.511	6.515
87	100	0.7	0.3	5.007	5.511	7.600
88	100	0.8	0.3	5.143	5.511	8.686
89	100	0.9	0.3	5.265	5.511	9.772
90	100	1	0.3	5.377	5.511	10.858
91	20	0.1	3	1.500	1.885	2.100
92	20	0.2	3	1.500	1.885	2.100
93	20	0.3	3	1.500	1.885	2.100
94	20	0.4	3	1.500	1.885	2.100
95	20	0.5	3	1.500	1.885	2.100
96	20	0.6	3	1.590	1.885	2.228
97	20	0.7	3	1.717	1.885	2.599
98	20	0.8	3	1.835	1.885	2.971
99	20	0.9	3	1.947	1.885	3.342
100	20	1	3	2.052	1.885	3.713
101	50	0.1	3	1.500	3.472	2.100
102	50	0.2	3	1.500	3.472	2.100
103	50	0.3	3	1.622	3.472	2.100
104	50	0.4	3	1.872	3.472	2.736
105	50	0.5	3	2.093	3.472	3.420
106	50	0.6	3	2.293	3.472	4.104
107	50	0.7	3	2.477	3.472	4.788
108	50	0.8	3	2.648	3.472	5.472
109	50	0.9	3	2.809	3.472	6.156
110	50	1	3	2.960	3.472	6.840
111	100	0.1	3	1.500	5.511	2.100
112	100	0.2	3	1.747	5.511	2.172
113	100	0.3	3	2.140	5.511	3.257
114	100	0.4	3	2.471	5.511	4.343
115	100	0.5	3	2.762	5.511	5.429
116	100	0.6	3	3.026	5.511	6.515
117	100	0.7	3	3.268	5.511	7.600
118	100	0.8	3	3.494	5.511	8.686
119	100	0.9	3	3.706	5.511	9.772
120	100	1	3	3.906	5.511	10.858

Integrally Reinforced Weld-On Fitting (OLET) - Sketch 2.6 - Header Outplane SIF

Item #	D/T	d/D	t/T	PRG ioh	B31.3 ioh
1	20	0.1	0.1	1.000	1.885
2	20	0.2	0.2	1.000	1.885
3	20	0.3	0.3	1.000	1.885
4	20	0.4	0.4	1.000	1.885
5	20	0.5	0.5	1.000	1.885
6	20	0.6	0.6	1.000	1.885
7	20	0.7	0.7	1.000	1.885
8	20	0.8	0.8	1.094	1.885
9	20	0.9	0.9	1.667	1.885
10	20	1	1	2.476	1.885
11	50	0.1	0.1	1.000	3.472
12	50	0.2	0.2	1.000	3.472
13	50	0.3	0.3	1.000	3.472
14	50	0.4	0.4	1.000	3.472
15	50	0.5	0.5	1.000	3.472
16	50	0.6	0.6	1.000	3.472
17	50	0.7	0.7	1.064	3.472
18	50	0.8	0.8	1.623	3.472
19	50	0.9	0.9	2.471	3.472
20	50	1	1	3.672	3.472
21	100	0.1	0.1	1.000	5.511
22	100	0.2	0.2	1.000	5.511
23	100	0.3	0.3	1.000	5.511
24	100	0.4	0.4	1.000	5.511
25	100	0.5	0.5	1.000	5.511
26	100	0.6	0.6	1.000	5.511
27	100	0.7	0.7	1.433	5.511
28	100	0.8	0.8	2.186	5.511
29	100	0.9	0.9	3.330	5.511
30	100	1	1	4.947	5.511
31	20	0.1	1	1.000	1.885
32	20	0.2	1	1.000	1.885
33	20	0.3	1	1.000	1.885
34	20	0.4	1	1.000	1.885
35	20	0.5	1	1.000	1.885
36	20	0.6	1	1.000	1.885
37	20	0.7	1	1.000	1.885
38	20	0.8	1	1.094	1.885
39	20	0.9	1	1.667	1.885
40	20	1	1	2.476	1.885
41	50	0.1	1	1.000	3.472
42	50	0.2	1	1.000	3.472
43	50	0.3	1	1.000	3.472
44	50	0.4	1	1.000	3.472
45	50	0.5	1	1.000	3.472
46	50	0.6	1	1.000	3.472
47	50	0.7	1	1.064	3.472
48	50	0.8	1	1.623	3.472
49	50	0.9	1	2.471	3.472
50	50	1	1	3.672	3.472
51	100	0.1	1	1.000	5.511
52	100	0.2	1	1.000	5.511
53	100	0.3	1	1.000	5.511
54	100	0.4	1	1.000	5.511
55	100	0.5	1	1.000	5.511
56	100	0.6	1	1.000	5.511
57	100	0.7	1	1.433	5.511
58	100	0.8	1	2.186	5.511
59	100	0.9	1	3.330	5.511
60	100	1	1	4.947	5.511
61	20	0.1	0.3	1.000	1.885
62	20	0.2	0.3	1.000	1.885
63	20	0.3	0.3	1.000	1.885
64	20	0.4	0.3	1.000	1.885
65	20	0.5	0.3	1.000	1.885
66	20	0.6	0.3	1.000	1.885
67	20	0.7	0.3	1.000	1.885

Item #	D/T	d/D	t/T	PRG ioh	B31.3 ioh
68	20	0.8	0.3	1.094	1.885
69	20	0.9	0.3	1.667	1.885
70	20	1	0.3	2.476	1.885
71	50	0.1	0.3	1.000	3.472
72	50	0.2	0.3	1.000	3.472
73	50	0.3	0.3	1.000	3.472
74	50	0.4	0.3	1.000	3.472
75	50	0.5	0.3	1.000	3.472
76	50	0.6	0.3	1.000	3.472
77	50	0.7	0.3	1.064	3.472
78	50	0.8	0.3	1.623	3.472
79	50	0.9	0.3	2.471	3.472
80	50	1	0.3	3.672	3.472
81	100	0.1	0.3	1.000	5.511
82	100	0.2	0.3	1.000	5.511
83	100	0.3	0.3	1.000	5.511
84	100	0.4	0.3	1.000	5.511
85	100	0.5	0.3	1.000	5.511
86	100	0.6	0.3	1.000	5.511
87	100	0.7	0.3	1.433	5.511
88	100	0.8	0.3	2.186	5.511
89	100	0.9	0.3	3.330	5.511
90	100	1	0.3	4.947	5.511
91	20	0.1	3	1.000	1.885
92	20	0.2	3	1.000	1.885
93	20	0.3	3	1.000	1.885
94	20	0.4	3	1.000	1.885
95	20	0.5	3	1.000	1.885
96	20	0.6	3	1.000	1.885
97	20	0.7	3	1.000	1.885
98	20	0.8	3	1.000	1.885
99	20	0.9	3	1.000	1.885
100	20	1	3	1.148	1.885
101	50	0.1	3	1.000	3.472
102	50	0.2	3	1.000	3.472
103	50	0.3	3	1.000	3.472
104	50	0.4	3	1.000	3.472
105	50	0.5	3	1.000	3.472
106	50	0.6	3	1.000	3.472
107	50	0.7	3	1.000	3.472
108	50	0.8	3	1.000	3.472
109	50	0.9	3	1.152	3.472
110	50	1	3	1.702	3.472
111	100	0.1	3	1.000	5.511
112	100	0.2	3	1.000	5.511
113	100	0.3	3	1.000	5.511
114	100	0.4	3	1.000	5.511
115	100	0.5	3	1.000	5.511
116	100	0.6	3	1.000	5.511
117	100	0.7	3	1.000	5.511
118	100	0.8	3	1.030	5.511
119	100	0.9	3	1.553	5.511
120	100	1	3	2.293	5.511

Integrally Reinforced Weld-On Fitting (OLET) - Sketch 2.6 - Header Torsional SIF

Item #	D/T	d/D	t/T	PRG ith	B31.3 iih	PRG UFT ith
1	20	0.1	0.1	1.000	1.885	1.000
2	20	0.2	0.2	1.000	1.885	1.000
3	20	0.3	0.3	1.000	1.885	1.143
4	20	0.4	0.4	1.044	1.885	1.490
5	20	0.5	0.5	1.418	1.885	1.829
6	20	0.6	0.6	1.820	1.885	2.163
7	20	0.7	0.7	2.248	1.885	2.493
8	20	0.8	0.8	2.699	1.885	2.819
9	20	0.9	0.9	3.141	1.885	3.141
10	20	1	1	3.461	1.885	3.461
11	50	0.1	0.1	1.000	3.472	1.000
12	50	0.2	0.2	1.000	3.472	1.200
13	50	0.3	0.3	1.063	3.472	1.743
14	50	0.4	0.4	1.577	3.472	2.271
15	50	0.5	0.5	2.141	3.472	2.788
16	50	0.6	0.6	2.748	3.472	3.297
17	50	0.7	0.7	3.395	3.472	3.799
18	50	0.8	0.8	4.076	3.472	4.296
19	50	0.9	0.9	4.788	3.472	4.788
20	50	1	1	5.275	3.472	5.275
21	100	0.1	0.1	1.000	5.511	1.000
22	100	0.2	0.2	1.000	5.511	1.651
23	100	0.3	0.3	1.453	5.511	2.397
24	100	0.4	0.4	2.154	5.511	3.123
25	100	0.5	0.5	2.925	5.511	3.835
26	100	0.6	0.6	3.754	5.511	4.535
27	100	0.7	0.7	4.637	5.511	5.226
28	100	0.8	0.8	5.568	5.511	5.909
29	100	0.9	0.9	6.543	5.511	6.586
30	100	1	1	7.256	5.511	7.256
31	20	0.1	1	1.000	1.885	1.000
32	20	0.2	1	1.000	1.885	1.000
33	20	0.3	1	1.000	1.885	1.000
34	20	0.4	1	1.000	1.885	1.000
35	20	0.5	1	1.339	1.885	1.339
36	20	0.6	1	1.719	1.885	1.719
37	20	0.7	1	2.123	1.885	2.123
38	20	0.8	1	2.549	1.885	2.549
39	20	0.9	1	2.996	1.885	2.996
40	20	1	1	3.461	1.885	3.461
41	50	0.1	1	1.000	3.472	1.000
42	50	0.2	1	1.000	3.472	1.000
43	50	0.3	1	1.014	3.472	1.014
44	50	0.4	1	1.503	3.472	1.503
45	50	0.5	1	2.041	3.472	2.041
46	50	0.6	1	2.620	3.472	2.620
47	50	0.7	1	3.236	3.472	3.236
48	50	0.8	1	3.886	3.472	3.886
49	50	0.9	1	4.566	3.472	4.566
50	50	1	1	5.275	3.472	5.275
51	100	0.1	1	1.000	5.511	1.000
52	100	0.2	1	1.000	5.511	1.000
53	100	0.3	1	1.394	5.511	1.394
54	100	0.4	1	2.068	5.511	2.068
55	100	0.5	1	2.807	5.511	2.807
56	100	0.6	1	3.604	5.511	3.604
57	100	0.7	1	4.451	5.511	4.451
58	100	0.8	1	5.345	5.511	5.345
59	100	0.9	1	6.281	5.511	6.281
60	100	1	1	7.256	5.511	7.256
61	20	0.1	0.3	1.000	1.885	1.000
62	20	0.2	0.3	1.000	1.885	1.000
63	20	0.3	0.3	1.000	1.885	1.143
64	20	0.4	0.3	1.044	1.885	1.696
65	20	0.5	0.3	1.418	1.885	2.302
66	20	0.6	0.3	1.820	1.885	2.955
67	20	0.7	0.3	2.248	1.885	3.650

Item #	D/T	d/D	t/T	PRG ith	B31.3 iih	PRG UFT ith
68	20	0.8	0.3	2.699	1.885	4.382
69	20	0.9	0.3	3.171	1.885	5.150
70	20	1	0.3	3.664	1.885	5.949
71	50	0.1	0.3	1.000	3.472	1.000
72	50	0.2	0.3	1.000	3.472	1.000
73	50	0.3	0.3	1.063	3.472	1.743
74	50	0.4	0.3	1.577	3.472	2.584
75	50	0.5	0.3	2.141	3.472	3.508
76	50	0.6	0.3	2.748	3.472	4.504
77	50	0.7	0.3	3.395	3.472	5.563
78	50	0.8	0.3	4.076	3.472	6.680
79	50	0.9	0.3	4.790	3.472	7.849
80	50	1	0.3	5.534	3.472	9.068
81	100	0.1	0.3	1.000	5.511	1.000
82	100	0.2	0.3	1.000	5.511	1.375
83	100	0.3	0.3	1.453	5.511	2.397
84	100	0.4	0.3	2.154	5.511	3.555
85	100	0.5	0.3	2.925	5.511	4.826
86	100	0.6	0.3	3.754	5.511	6.195
87	100	0.7	0.3	4.637	5.511	7.652
88	100	0.8	0.3	5.568	5.511	9.188
89	100	0.9	0.3	6.543	5.511	10.797
90	100	1	0.3	7.559	5.511	12.474
91	20	0.1	3	1.000	1.885	1.000
92	20	0.2	3	1.000	1.885	1.000
93	20	0.3	3	1.000	1.885	1.000
94	20	0.4	3	1.000	1.885	1.000
95	20	0.5	3	1.000	1.885	1.000
96	20	0.6	3	1.048	1.885	1.048
97	20	0.7	3	1.295	1.885	1.295
98	20	0.8	3	1.555	1.885	1.555
99	20	0.9	3	1.827	1.885	1.827
100	20	1	3	2.111	1.885	2.111
101	50	0.1	3	1.000	3.472	1.000
102	50	0.2	3	1.000	3.472	1.000
103	50	0.3	3	1.000	3.472	1.000
104	50	0.4	3	1.000	3.472	1.000
105	50	0.5	3	1.245	3.472	1.245
106	50	0.6	3	1.598	3.472	1.598
107	50	0.7	3	1.974	3.472	1.974
108	50	0.8	3	2.370	3.472	2.370
109	50	0.9	3	2.785	3.472	2.785
110	50	1	3	3.218	3.472	3.218
111	100	0.1	3	1.000	5.511	1.000
112	100	0.2	3	1.000	5.511	1.000
113	100	0.3	3	1.000	5.511	1.000
114	100	0.4	3	1.261	5.511	1.261
115	100	0.5	3	1.712	5.511	1.712
116	100	0.6	3	2.198	5.511	2.198
117	100	0.7	3	2.715	5.511	2.715
118	100	0.8	3	3.260	5.511	3.260
119	100	0.9	3	3.831	5.511	3.831
120	100	1	3	4.426	5.511	4.426

Integrally Reinforced Weld-On Fitting (OLET) - Sketch 2.6 - Branch Inplane K

Item #	D/T	d/D	t/T	PRG kib	Wais UFT kib	Widera UFT kib
1	20	0.1	0.1	1.000	1.507	0.859
2	20	0.2	0.2	1.000	1.977	1.749
3	20	0.3	0.3	1.000	2.316	2.342
4	20	0.4	0.4	1.000	2.592	2.619
5	20	0.5	0.5	1.000	2.828	2.661
6	20	0.6	0.6	1.000	3.037	2.616
7	20	0.7	0.7	1.000	3.226	2.676
8	20	0.8	0.8	1.000	3.399	3.071
9	20	0.9	0.9	1.000	3.559	4.060
10	20	1	1	1.100	3.709	5.929
11	50	0.1	0.1	1.000	2.803	1.792
12	50	0.2	0.2	1.000	3.676	3.647
13	50	0.3	0.3	1.000	4.307	4.884
14	50	0.4	0.4	1.000	4.820	5.460
15	50	0.5	0.5	1.000	5.259	5.548
16	50	0.6	0.6	1.084	5.648	5.454
17	50	0.7	0.7	1.189	5.999	5.580
18	50	0.8	0.8	1.402	6.320	6.404
19	50	0.9	0.9	1.861	6.618	8.467
20	50	1	1	2.750	6.896	12.364
21	100	0.1	0.1	1.000	4.481	3.124
22	100	0.2	0.2	1.000	5.877	6.358
23	100	0.3	0.3	1.229	6.886	8.516
24	100	0.4	0.4	1.667	7.706	9.520
25	100	0.5	0.5	1.969	8.408	9.673
26	100	0.6	0.6	2.167	9.030	9.509
27	100	0.7	0.7	2.379	9.591	9.729
28	100	0.8	0.8	2.803	10.105	11.166
29	100	0.9	0.9	3.722	10.581	14.762
30	100	1	1	5.500	11.026	21.557
31	20	0.1	1	1.000	6.029	3.599
32	20	0.2	1	1.000	5.208	4.759
33	20	0.3	1	1.000	4.781	4.953
34	20	0.4	1	1.000	4.500	4.630
35	20	0.5	1	1.000	4.293	4.095
36	20	0.6	1	1.000	4.131	3.594
37	20	0.7	1	1.000	3.999	3.341
38	20	0.8	1	1.000	3.887	3.528
39	20	0.9	1	1.000	3.792	4.335
40	20	1	1	1.100	3.709	5.929
41	50	0.1	1	1.110	11.210	7.505
42	50	0.2	1	1.758	9.685	9.923
43	50	0.3	1	2.048	8.891	10.329
44	50	0.4	1	2.084	8.367	9.655
45	50	0.5	1	1.969	7.983	8.539
46	50	0.6	1	1.806	7.681	7.494
47	50	0.7	1	1.699	7.435	6.966
48	50	0.8	1	1.752	7.229	7.358
49	50	0.9	1	2.068	7.051	9.040
50	50	1	1	2.750	6.896	12.364
51	100	0.1	1	2.220	17.923	13.085
52	100	0.2	1	3.516	15.485	17.302
53	100	0.3	1	4.097	14.215	18.008
54	100	0.4	1	4.168	13.378	16.833
55	100	0.5	1	3.938	12.763	14.888
56	100	0.6	1	3.612	12.281	13.066
57	100	0.7	1	3.399	11.888	12.146
58	100	0.8	1	3.504	11.558	12.828
59	100	0.9	1	4.136	11.274	15.762
60	100	1	1	5.500	11.026	21.557
61	20	0.1	0.3	1.000	2.920	1.702
62	20	0.2	0.3	1.000	2.523	2.251
63	20	0.3	0.3	1.000	2.316	2.342
64	20	0.4	0.3	1.000	2.180	2.190
65	20	0.5	0.3	1.000	2.080	1.937
66	20	0.6	0.3	1.000	2.001	1.700
67	20	0.7	0.3	1.000	1.937	1.580
68	20	0.8	0.3	1.000	1.883	1.669
69	20	0.9	0.3	1.000	1.837	2.050
70	20	1	0.3	1.000	1.797	2.804
71	50	0.1	0.3	1.000	5.431	3.549
72	50	0.2	0.3	1.000	4.692	4.693
73	50	0.3	0.3	1.000	4.307	4.884
74	50	0.4	0.3	1.000	4.053	4.566
75	50	0.5	0.3	1.000	3.867	4.038
76	50	0.6	0.3	1.000	3.721	3.544
77	50	0.7	0.3	1.000	3.602	3.294
78	50	0.8	0.3	1.000	3.502	3.479
79	50	0.9	0.3	1.000	3.416	4.275
80	50	1	0.3	1.000	3.341	5.847
81	100	0.1	0.3	1.000	8.683	6.188
82	100	0.2	0.3	1.055	7.501	8.182
83	100	0.3	0.3	1.229	6.886	8.516
84	100	0.4	0.3	1.250	6.481	7.961
85	100	0.5	0.3	1.181	6.183	7.040
86	100	0.6	0.3	1.084	5.949	6.179
87	100	0.7	0.3	1.020	5.759	5.744
88	100	0.8	0.3	1.051	5.599	6.066
89	100	0.9	0.3	1.241	5.461	7.454
90	100	1	0.3	1.650	5.341	10.194
91	20	0.1	3	1.332	11.680	7.128
92	20	0.2	3	2.110	10.091	9.425
93	20	0.3	3	2.458	9.263	9.810
94	20	0.4	3	2.501	8.718	9.170
95	20	0.5	3	2.363	8.317	8.110
96	20	0.6	3	2.167	8.003	7.118
97	20	0.7	3	2.039	7.747	6.616
98	20	0.8	3	2.102	7.532	6.988
99	20	0.9	3	2.481	7.347	8.586
100	20	1	3	3.300	7.185	11.743
101	50	0.1	3	3.329	21.719	14.863
102	50	0.2	3	5.274	18.764	19.653
103	50	0.3	3	6.145	17.226	20.456
104	50	0.4	3	6.252	16.211	19.121
105	50	0.5	3	5.906	15.466	16.911
106	50	0.6	3	5.418	14.882	14.842
107	50	0.7	3	5.098	14.406	13.796
108	50	0.8	3	5.256	14.005	14.571
109	50	0.9	3	6.203	13.662	17.904
110	50	1	3	8.250	13.361	24.487
111	100	0.1	3	6.659	34.725	25.915
112	100	0.2	3	10.548	30.001	34.265
113	100	0.3	3	12.290	27.541	35.665
114	100	0.4	3	12.504	25.919	33.338
115	100	0.5	3	11.813	24.727	29.484
116	100	0.6	3	10.836	23.793	25.877
117	100	0.7	3	10.196	23.032	24.054
118	100	0.8	3	10.512	22.392	25.405
119	100	0.9	3	12.407	21.842	31.216
120	100	1	3	16.500	21.362	42.693

Integrally Reinforced Weld-On Fitting (OLET) - Sketch 2.6 - Branch Outplane K

Item #	D/T	d/D	t/T	PRG kob	Wais UFT kob	Widera UFT kob
1	20	0.1	0.1	1.000	1.374	0.316
2	20	0.2	0.2	1.000	3.391	1.365
3	20	0.3	0.3	1.000	5.358	2.890
4	20	0.4	0.4	1.498	6.981	4.499
5	20	0.5	0.5	2.011	8.091	5.815
6	20	0.6	0.6	2.387	8.595	6.562
7	20	0.7	0.7	2.561	8.448	6.616
8	20	0.8	0.8	2.503	7.642	6.046
9	20	0.9	0.9	2.219	6.202	5.148
10	20	1	1	1.758	4.177	4.473
11	50	0.1	0.1	1.000	3.445	1.268
12	50	0.2	0.2	1.584	8.501	5.469
13	50	0.3	0.3	3.387	13.433	11.583
14	50	0.4	0.4	5.404	17.500	18.029
15	50	0.5	0.5	7.252	20.283	23.303
16	50	0.6	0.6	8.608	21.547	26.296
17	50	0.7	0.7	9.238	21.178	26.513
18	50	0.8	0.8	9.028	19.158	24.229
19	50	0.9	0.9	8.002	15.549	20.631
20	50	1	1	6.342	10.472	17.927
21	100	0.1	0.1	1.000	6.904	3.623
22	100	0.2	0.2	4.181	17.038	15.630
23	100	0.3	0.3	8.939	26.921	33.105
24	100	0.4	0.4	14.260	35.072	51.527
25	100	0.5	0.5	19.139	40.651	66.598
26	100	0.6	0.6	22.718	43.183	75.155
27	100	0.7	0.7	24.380	42.443	75.774
28	100	0.8	0.8	23.825	38.397	69.247
29	100	0.9	0.9	21.117	31.162	58.963
30	100	1	1	16.736	20.988	51.236
31	20	0.1	1	1.035	7.162	2.302
32	20	0.2	1	2.196	10.753	5.464
33	20	0.3	1	3.131	12.704	8.160
34	20	0.4	1	3.746	13.465	9.911
35	20	0.5	1	4.022	13.300	10.568
36	20	0.6	1	3.978	12.397	10.192
37	20	0.7	1	3.659	10.910	8.997
38	20	0.8	1	3.129	8.968	7.328
39	20	0.9	1	2.465	6.689	5.637
40	20	1	1	1.758	4.177	4.473
41	50	0.1	1	3.733	17.955	9.225
42	50	0.2	1	7.922	26.956	21.898
43	50	0.3	1	11.291	31.847	32.700
44	50	0.4	1	13.509	33.756	39.719
45	50	0.5	1	14.505	33.341	42.354
46	50	0.6	1	14.347	31.078	40.844
47	50	0.7	1	13.198	27.349	36.056
48	50	0.8	1	11.285	22.482	29.368
49	50	0.9	1	8.891	16.769	22.592
50	50	1	1	6.342	10.472	17.927
51	100	0.1	1	9.851	35.984	26.366
52	100	0.2	1	20.906	54.024	62.585
53	100	0.3	1	29.798	63.826	93.458
54	100	0.4	1	35.651	67.652	113.516
55	100	0.5	1	38.278	66.821	121.046
56	100	0.6	1	37.863	62.285	116.732
57	100	0.7	1	34.829	54.812	103.049
58	100	0.8	1	29.781	45.059	83.933
59	100	0.9	1	23.464	33.607	64.568
60	100	1	1	16.736	20.988	51.236
61	20	0.1	0.3	1.000	3.021	0.815
62	20	0.2	0.3	1.000	4.535	1.936
63	20	0.3	0.3	1.000	5.358	2.890
64	20	0.4	0.3	1.124	5.680	3.511
65	20	0.5	0.3	1.206	5.610	3.744
66	20	0.6	0.3	1.193	5.229	3.610
67	20	0.7	0.3	1.098	4.602	3.187
68	20	0.8	0.3	1.000	3.783	2.596
69	20	0.9	0.3	1.000	2.821	1.997
70	20	1	0.3	1.000	1.762	1.585
71	50	0.1	0.3	1.120	7.573	3.268
72	50	0.2	0.3	2.377	11.370	7.757
73	50	0.3	0.3	3.387	13.433	11.583
74	50	0.4	0.3	4.053	14.238	14.069
75	50	0.5	0.3	4.351	14.063	15.003
76	50	0.6	0.3	4.304	13.108	14.468
77	50	0.7	0.3	3.959	11.536	12.772
78	50	0.8	0.3	3.385	9.483	10.403
79	50	0.9	0.3	2.667	7.073	8.003
80	50	1	0.3	1.903	4.417	6.350
81	100	0.1	0.3	2.955	15.178	9.339
82	100	0.2	0.3	6.272	22.787	22.169
83	100	0.3	0.3	8.939	26.921	33.105
84	100	0.4	0.3	10.695	28.535	40.210
85	100	0.5	0.3	11.484	28.184	42.878
86	100	0.6	0.3	11.359	26.271	41.349
87	100	0.7	0.3	10.449	23.119	36.502
88	100	0.8	0.3	8.934	19.005	29.731
89	100	0.9	0.3	7.039	14.175	22.872
90	100	1	0.3	5.021	8.853	18.149
91	20	0.1	3	3.105	15.745	5.934
92	20	0.2	3	6.589	23.638	14.087
93	20	0.3	3	9.392	27.927	21.036
94	20	0.4	3	11.237	29.601	25.550
95	20	0.5	3	12.065	29.237	27.245
96	20	0.6	3	11.934	27.253	26.274
97	20	0.7	3	10.977	23.983	23.194
98	20	0.8	3	9.387	19.715	18.892
99	20	0.9	3	7.395	14.705	14.533
100	20	1	3	5.275	9.183	11.532
101	50	0.1	3	11.199	39.471	23.783
102	50	0.2	3	23.765	59.259	56.453
103	50	0.3	3	33.874	70.010	84.301
104	50	0.4	3	40.528	74.207	102.394
105	50	0.5	3	43.514	73.295	109.187
106	50	0.6	3	43.042	68.319	105.295
107	50	0.7	3	39.593	60.123	92.953
108	50	0.8	3	33.855	49.424	75.710
109	50	0.9	3	26.673	36.863	58.242
110	50	1	3	19.025	23.021	46.216
111	100	0.1	3	29.553	79.106	67.970
112	100	0.2	3	62.717	118.764	161.343
113	100	0.3	3	89.394	140.312	240.931
114	100	0.4	3	106.953	148.723	292.640
115	100	0.5	3	114.835	146.895	312.055
116	100	0.6	3	113.588	136.923	300.932
117	100	0.7	3	104.487	120.496	265.657
118	100	0.8	3	89.343	99.054	216.378
119	100	0.9	3	70.391	73.880	166.455
120	100	1	3	50.209	46.139	132.084

Integrally Reinforced Weld-On Fitting (OLET) - Sketch 2.6 - Branch Torsional K

Item #	D/T	d/D	t/T	PRG ktb	Wais UFT ktb
1	20	0.1	0.1	1.000	1.000
2	20	0.2	0.2	1.000	1.000
3	20	0.3	0.3	1.000	1.000
4	20	0.4	0.4	1.000	1.000
5	20	0.5	0.5	1.000	1.019
6	20	0.6	0.6	1.000	1.497
7	20	0.7	0.7	1.000	2.072
8	20	0.8	0.8	1.000	2.746
9	20	0.9	0.9	1.000	3.521
10	20	1	1	1.000	4.398
11	50	0.1	0.1	1.000	1.000
12	50	0.2	0.2	1.000	1.000
13	50	0.3	0.3	1.000	1.000
14	50	0.4	0.4	1.000	1.000
15	50	0.5	0.5	1.000	1.221
16	50	0.6	0.6	1.000	1.794
17	50	0.7	0.7	1.000	2.484
18	50	0.8	0.8	1.000	3.292
19	50	0.9	0.9	1.206	4.221
20	50	1	1	2.000	5.272
21	100	0.1	0.1	1.000	1.000
22	100	0.2	0.2	1.000	1.000
23	100	0.3	0.3	1.000	1.000
24	100	0.4	0.4	1.000	1.000
25	100	0.5	0.5	1.000	1.401
26	100	0.6	0.6	1.000	2.058
27	100	0.7	0.7	1.124	2.849
28	100	0.8	0.8	1.577	3.777
29	100	0.9	0.9	2.413	4.842
30	100	1	1	4.000	6.048
31	20	0.1	1	1.000	1.000
32	20	0.2	1	1.000	1.000
33	20	0.3	1	1.000	1.000
34	20	0.4	1	1.000	1.056
35	20	0.5	1	1.000	1.495
36	20	0.6	1	1.000	1.985
37	20	0.7	1	1.000	2.524
38	20	0.8	1	1.000	3.107
39	20	0.9	1	1.000	3.732
40	20	1	1	1.000	4.398
41	50	0.1	1	1.000	1.000
42	50	0.2	1	1.000	1.000
43	50	0.3	1	1.000	1.000
44	50	0.4	1	1.000	1.266
45	50	0.5	1	1.000	1.792
46	50	0.6	1	1.000	2.380
47	50	0.7	1	1.000	3.026
48	50	0.8	1	1.000	3.725
49	50	0.9	1	1.340	4.475
50	50	1	1	2.000	5.272
51	100	0.1	1	1.000	1.000
52	100	0.2	1	1.000	1.000
53	100	0.3	1	1.000	1.000
54	100	0.4	1	1.000	1.452
55	100	0.5	1	1.000	2.055
56	100	0.6	1	1.391	2.730
57	100	0.7	1	1.606	3.471
58	100	0.8	1	1.971	4.273
59	100	0.9	1	2.681	5.133
60	100	1	1	4.000	6.048
61	20	0.1	0.3	1.000	1.000
62	20	0.2	0.3	1.000	1.000
63	20	0.3	0.3	1.000	1.000
64	20	0.4	0.3	1.000	1.000
65	20	0.5	0.3	1.000	1.000
66	20	0.6	0.3	1.000	1.020
67	20	0.7	0.3	1.000	1.297

Item #	D/T	d/D	t/T	PRG ktb	Wais UFT ktb
68	20	0.8	0.3	1.000	1.597
69	20	0.9	0.3	1.000	1.918
70	20	1	0.3	1.000	2.260
71	50	0.1	0.3	1.000	1.000
72	50	0.2	0.3	1.000	1.000
73	50	0.3	0.3	1.000	1.000
74	50	0.4	0.3	1.000	1.000
75	50	0.5	0.3	1.000	1.000
76	50	0.6	0.3	1.000	1.223
77	50	0.7	0.3	1.000	1.555
78	50	0.8	0.3	1.000	1.914
79	50	0.9	0.3	1.000	2.299
80	50	1	0.3	1.000	2.709
81	100	0.1	0.3	1.000	1.000
82	100	0.2	0.3	1.000	1.000
83	100	0.3	0.3	1.000	1.000
84	100	0.4	0.3	1.000	1.000
85	100	0.5	0.3	1.000	1.056
86	100	0.6	0.3	1.000	1.403
87	100	0.7	0.3	1.000	1.783
88	100	0.8	0.3	1.000	2.196
89	100	0.9	0.3	1.000	2.638
90	100	1	0.3	1.200	3.108
91	20	0.1	3	1.000	1.000
92	20	0.2	3	1.000	1.000
93	20	0.3	3	1.000	1.239
94	20	0.4	3	1.000	1.938
95	20	0.5	3	1.000	2.744
96	20	0.6	3	1.000	3.645
97	20	0.7	3	1.000	4.633
98	20	0.8	3	1.183	5.704
99	20	0.9	3	1.608	6.852
100	20	1	3	2.400	8.073
101	50	0.1	3	1.000	1.000
102	50	0.2	3	1.000	1.000
103	50	0.3	3	1.000	1.485
104	50	0.4	3	1.000	2.324
105	50	0.5	3	1.000	3.290
106	50	0.6	3	1.000	4.370
107	50	0.7	3	1.988	5.555
108	50	0.8	3	2.956	6.839
109	50	0.9	3	4.021	8.215
110	50	1	3	6.000	9.679
111	100	0.1	3	1.000	1.000
112	100	0.2	3	1.000	1.000
113	100	0.3	3	1.000	1.703
114	100	0.4	3	1.000	2.666
115	100	0.5	3	1.000	3.774
116	100	0.6	3	1.533	5.012
117	100	0.7	3	3.534	6.372
118	100	0.8	3	5.913	7.845
119	100	0.9	3	8.042	9.423
120	100	1	3	12.000	11.103

Integrally Reinforced Weld-On Fitting (OLET) - Sketch 2.6 - Header Inplane K

Item #	D/T	d/D	t/T	PRG kih	Wais UFT kih
1	20	0.1	0.1	1.000	1.000
2	20	0.2	0.2	1.000	1.000
3	20	0.3	0.3	1.000	1.000
4	20	0.4	0.4	1.000	1.000
5	20	0.5	0.5	1.000	1.000
6	20	0.6	0.6	1.000	1.000
7	20	0.7	0.7	1.000	1.325
8	20	0.8	0.8	1.000	1.883
9	20	0.9	0.9	1.000	2.566
10	20	1	1	1.581	3.385
11	50	0.1	0.1	1.000	1.000
12	50	0.2	0.2	1.000	1.000
13	50	0.3	0.3	1.000	1.000
14	50	0.4	0.4	1.000	1.000
15	50	0.5	0.5	1.000	1.000
16	50	0.6	0.6	1.000	1.105
17	50	0.7	0.7	1.000	1.658
18	50	0.8	0.8	1.000	2.355
19	50	0.9	0.9	1.476	3.211
20	50	1	1	2.500	4.236
21	100	0.1	0.1	1.000	1.000
22	100	0.2	0.2	1.000	1.000
23	100	0.3	0.3	1.000	1.000
24	100	0.4	0.4	1.000	1.000
25	100	0.5	0.5	1.000	1.000
26	100	0.6	0.6	1.000	1.310
27	100	0.7	0.7	1.000	1.964
28	100	0.8	0.8	1.159	2.791
29	100	0.9	0.9	2.088	3.804
30	100	1	1	3.536	5.019
31	20	0.1	1	1.000	1.000
32	20	0.2	1	1.000	1.000
33	20	0.3	1	1.000	1.000
34	20	0.4	1	1.000	1.000
35	20	0.5	1	1.000	1.000
36	20	0.6	1	1.000	1.000
37	20	0.7	1	1.000	1.218
38	20	0.8	1	1.000	1.786
39	20	0.9	1	1.000	2.503
40	20	1	1	1.581	3.385
41	50	0.1	1	1.000	1.000
42	50	0.2	1	1.000	1.000
43	50	0.3	1	1.000	1.000
44	50	0.4	1	1.000	1.000
45	50	0.5	1	1.000	1.000
46	50	0.6	1	1.000	1.000
47	50	0.7	1	1.000	1.524
48	50	0.8	1	1.000	2.234
49	50	0.9	1	1.476	3.132
50	50	1	1	2.500	4.236
51	100	0.1	1	1.000	1.000
52	100	0.2	1	1.000	1.000
53	100	0.3	1	1.000	1.000
54	100	0.4	1	1.000	1.000
55	100	0.5	1	1.000	1.000
56	100	0.6	1	1.000	1.160
57	100	0.7	1	1.000	1.805
58	100	0.8	1	1.159	2.647
59	100	0.9	1	2.088	3.710
60	100	1	1	3.536	5.019
61	20	0.1	0.3	1.000	1.000
62	20	0.2	0.3	1.000	1.000
63	20	0.3	0.3	1.000	1.000
64	20	0.4	0.3	1.000	1.000
65	20	0.5	0.3	1.000	1.000
66	20	0.6	0.3	1.000	1.041
67	20	0.7	0.3	1.000	1.619

Item #	D/T	d/D	t/T	PRG kih	Wais UFT kih
68	20	0.8	0.3	1.000	2.374
69	20	0.9	0.3	1.000	3.328
70	20	1	0.3	1.581	4.501
71	50	0.1	0.3	1.000	1.000
72	50	0.2	0.3	1.000	1.000
73	50	0.3	0.3	1.000	1.000
74	50	0.4	0.3	1.000	1.000
75	50	0.5	0.3	1.000	1.000
76	50	0.6	0.3	1.000	1.302
77	50	0.7	0.3	1.000	2.026
78	50	0.8	0.3	1.000	2.971
79	50	0.9	0.3	1.476	4.164
80	50	1	0.3	2.500	5.632
81	100	0.1	0.3	1.000	1.000
82	100	0.2	0.3	1.000	1.000
83	100	0.3	0.3	1.000	1.000
84	100	0.4	0.3	1.000	1.000
85	100	0.5	0.3	1.000	1.000
86	100	0.6	0.3	1.000	1.543
87	100	0.7	0.3	1.000	2.400
88	100	0.8	0.3	1.159	3.520
89	100	0.9	0.3	2.088	
90	100	1	0.3	3.536	
91	20	0.1	3	1.000	1.000
92	20	0.2	3	1.000	1.000
93	20	0.3	3	1.000	1.000
94	20	0.4	3	1.000	1.000
95	20	0.5	3	1.000	1.000
96	20	0.6	3	1.000	1.000
97	20	0.7	3	1.000	1.000
98	20	0.8	3	1.000	1.377
99	20	0.9	3	1.000	1.930
100	20	1	3	1.581	
101	50	0.1	3	1.000	1.000
102	50	0.2	3	1.000	1.000
103	50	0.3	3	1.000	1.000
104	50	0.4	3	1.000	1.000
105	50	0.5	3	1.000	1.000
106	50	0.6	3	1.000	1.000
107	50	0.7	3	1.000	1.175
108	50	0.8	3	1.000	1.723
109	50	0.9	3	1.476	2.415
110	50	1	3	2.500	
111	100	0.1	3	1.000	1.000
112	100	0.2	3	1.000	1.000
113	100	0.3	3	1.000	1.000
114	100	0.4	3	1.000	1.000
115	100	0.5	3	1.000	1.000
116	100	0.6	3	1.000	1.000
117	100	0.7	3	1.000	1.392
118	100	0.8	3	1.159	2.041
119	100	0.9	3	2.088	2.861
120	100	1	3	3.536	

Item #	D/T	d/D	t/T	PRG kth	Wais UFT kth
1	20	0.1	0.1	1.000	1.000
2	20	0.2	0.2	1.000	1.000
3	20	0.3	0.3	1.000	1.000
4	20	0.4	0.4	1.000	1.000
5	20	0.5	0.5	1.000	1.000
6	20	0.6	0.6	1.000	1.135
7	20	0.7	0.7	1.000	1.661
8	20	0.8	0.8	1.000	2.310
9	20	0.9	0.9	1.000	3.090
10	20	1	1	1.000	4.008
11	50	0.1	0.1	1.000	1.000
12	50	0.2	0.2	1.000	1.000
13	50	0.3	0.3	1.000	1.000
14	50	0.4	0.4	1.000	1.000
15	50	0.5	0.5	1.000	1.000
16	50	0.6	0.6	1.000	1.515
17	50	0.7	0.7	1.000	2.217
18	50	0.8	0.8	1.000	3.083
19	50	0.9	0.9	1.371	4.124
20	50	1	1	2.500	5.349
21	100	0.1	0.1	1.000	1.000
22	100	0.2	0.2	1.000	1.000
23	100	0.3	0.3	1.000	1.000
24	100	0.4	0.4	1.000	1.000
25	100	0.5	0.5	1.000	1.201
26	100	0.6	0.6	1.000	1.884
27	100	0.7	0.7	1.000	2.758
28	100	0.8	0.8	1.401	3.835
29	100	0.9	0.9	2.743	5.130
30	100	1	1	5.000	6.655
31	20	0.1	1	1.000	1.000
32	20	0.2	1	1.000	1.000
33	20	0.3	1	1.000	1.000
34	20	0.4	1	1.000	1.000
35	20	0.5	1	1.000	1.000
36	20	0.6	1	1.000	1.000
37	20	0.7	1	1.000	1.505
38	20	0.8	1	1.000	2.172
39	20	0.9	1	1.000	3.001
40	20	1	1	1.000	4.008
41	50	0.1	1	1.000	1.000
42	50	0.2	1	1.000	1.000
43	50	0.3	1	1.000	1.000
44	50	0.4	1	1.000	1.000
45	50	0.5	1	1.000	1.000
46	50	0.6	1	1.000	1.316
47	50	0.7	1	1.000	2.009
48	50	0.8	1	1.000	2.899
49	50	0.9	1	1.371	4.005
50	50	1	1	2.500	5.349
51	100	0.1	1	1.000	1.000
52	100	0.2	1	1.000	1.000
53	100	0.3	1	1.000	1.000
54	100	0.4	1	1.000	1.000
55	100	0.5	1	1.000	1.000
56	100	0.6	1	1.000	1.637
57	100	0.7	1	1.000	2.499
58	100	0.8	1	1.401	3.606
59	100	0.9	1	2.743	4.983
60	100	1	1	5.000	6.655
61	20	0.1	0.3	1.000	1.000
62	20	0.2	0.3	1.000	1.000
63	20	0.3	0.3	1.000	1.000
64	20	0.4	0.3	1.000	1.000
65	20	0.5	0.3	1.000	1.000
66	20	0.6	0.3	1.000	1.374
67	20	0.7	0.3	1.000	2.098

Item #	D/T	d/D	t/T	PRG kth	Wais UFT kth
68	20	0.8	0.3	1.000	3.028
69	20	0.9	0.3	1.000	4.184
70	20	1	0.3	1.000	5.588
71	50	0.1	0.3	1.000	1.000
72	50	0.2	0.3	1.000	1.000
73	50	0.3	0.3	1.000	1.000
74	50	0.4	0.3	1.000	1.000
75	50	0.5	0.3	1.000	1.112
76	50	0.6	0.3	1.000	1.834
77	50	0.7	0.3	1.000	2.801
78	50	0.8	0.3	1.000	4.041
79	50	0.9	0.3	1.371	5.584
80	50	1	0.3	2.500	7.458
81	100	0.1	0.3	1.000	1.000
82	100	0.2	0.3	1.000	1.000
83	100	0.3	0.3	1.000	1.000
84	100	0.4	0.3	1.000	1.000
85	100	0.5	0.3	1.000	1.383
86	100	0.6	0.3	1.000	2.282
87	100	0.7	0.3	1.000	3.484
88	100	0.8	0.3	1.401	5.027
89	100	0.9	0.3	2.743	
90	100	1	0.3	5.000	
91	20	0.1	3	1.000	1.000
92	20	0.2	3	1.000	1.000
93	20	0.3	3	1.000	1.000
94	20	0.4	3	1.000	1.000
95	20	0.5	3	1.000	1.000
96	20	0.6	3	1.000	1.000
97	20	0.7	3	1.000	1.111
98	20	0.8	3	1.000	1.604
99	20	0.9	3	1.000	2.216
100	20	1	3	1.000	
101	50	0.1	3	1.000	1.000
102	50	0.2	3	1.000	1.000
103	50	0.3	3	1.000	1.000
104	50	0.4	3	1.000	1.000
105	50	0.5	3	1.000	1.000
106	50	0.6	3	1.000	1.000
107	50	0.7	3	1.000	1.483
108	50	0.8	3	1.000	2.140
109	50	0.9	3	1.371	2.958
110	50	1	3	2.500	
111	100	0.1	3	1.000	1.000
112	100	0.2	3	1.000	1.000
113	100	0.3	3	1.000	1.000
114	100	0.4	3	1.000	1.000
115	100	0.5	3	1.000	1.000
116	100	0.6	3	1.000	1.208
117	100	0.7	3	1.000	1.845
118	100	0.8	3	1.401	2.663
119	100	0.9	3	2.743	3.680
120	100	1	3	5.000	

ANNEX D – RELATIVE COMPARISONS BETWEEN COMPONENTS

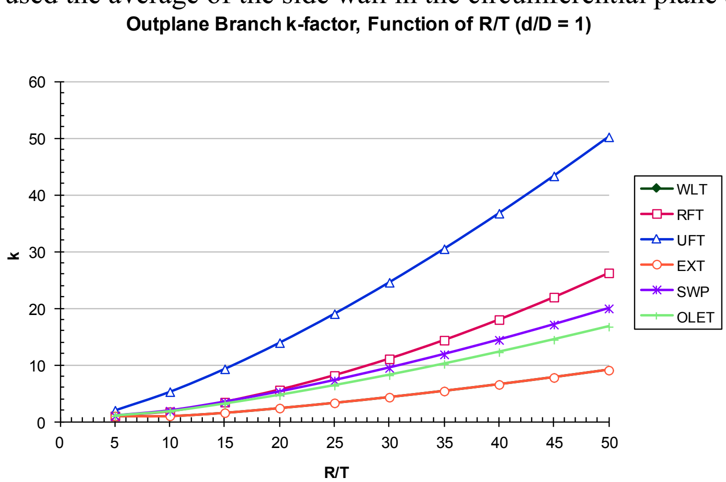
The comparisons in this annex are intended to provide additional verification of the branch connection relationships developed for this project. SIFs and k-factors for each branch connection type (Sketches 2.1 through 2.6 in Annex A in this report) are compared so that the anticipated relationship between branch connection types is maintained through the full parameter range. Additional discussion regarding comparisons of Sketch 2.1 and Sketch 2.3 i-factor equations as they apply to BPVC Section III are given at the end of this Annex.

The equations and nomenclature used to develop each of the graphs below are found in Annex G.

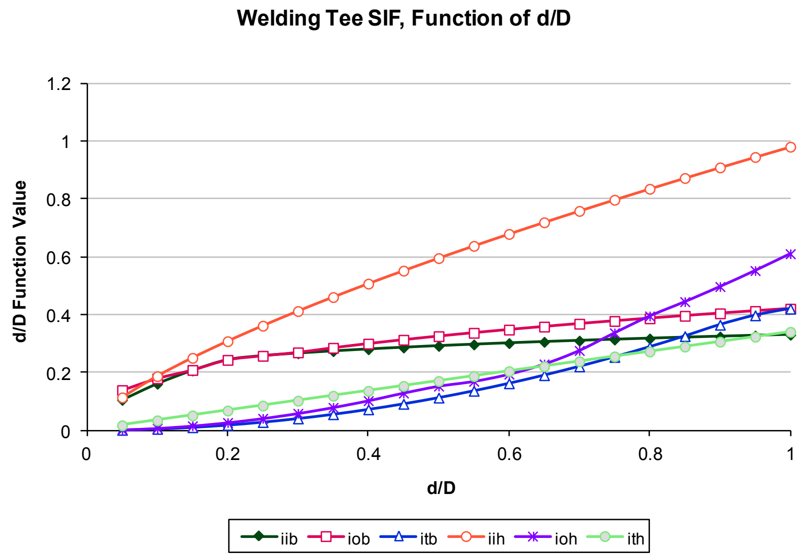
Each Sketch type in Annex A is identified by the mneumonic given in the table below:

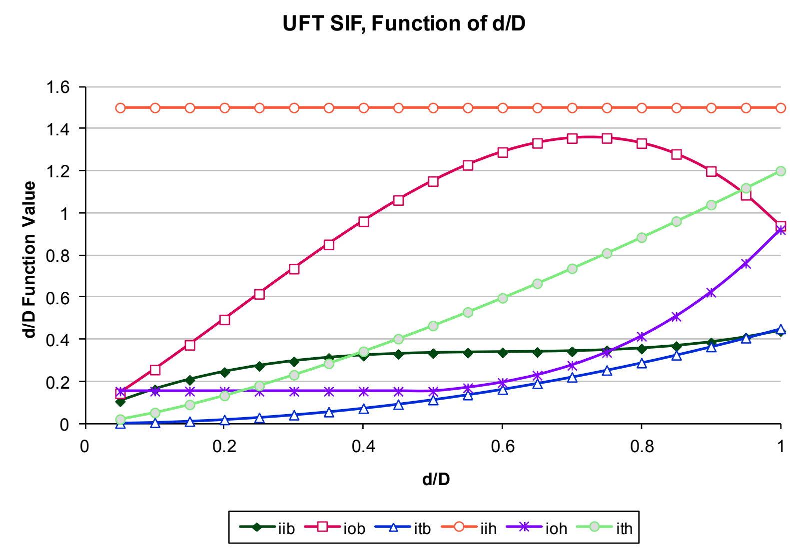
Sketch	Description	Mneumonic
Sketch 2.1	Welding tee per ASME B16.9	WLT
Sketch 2.2	Reinforced fabricated tee	RFT
Sketch 2.3	Unreinforced fabricated tee	UFT
Sketch 2.4	Extruded outlet	EXT
Sketch 2.5	Welded-in contour insert	SWP
Sketch 2.6	Integrally reinforced branch weld-on fitting	OLET

For example, the graph below shows the out-of-plane branch k-factor for Sketches 2.1 through 2.6. The unreinforced fabricated tee (Sketch 2.3), mneumonic UFT has the highest k-factor (is the most flexible) for loads on the branch in the out-of-plane direction when d/D=1, t/T=1 and the pad thickness of any pad reinforced tee is equal to the thickness of the run pipe. The reinforced fabricated tee and the integrally reinforced branch weld-on fitting have the next highest k-factor. B16.9 welding tees and extruded outlets, (which can be geometrically identical), have the lowest k-factor for all R/T ranges since they can have both contoured crotch radii and significantly thicker average tee body thicknesses. The k-factors for this component and all fittings show the same relationship to each other through the R/T range. Various approaches have been used to established the average tee body thickness. Markl used the average of the side wall in the circumferential plane and the crotch thickness.



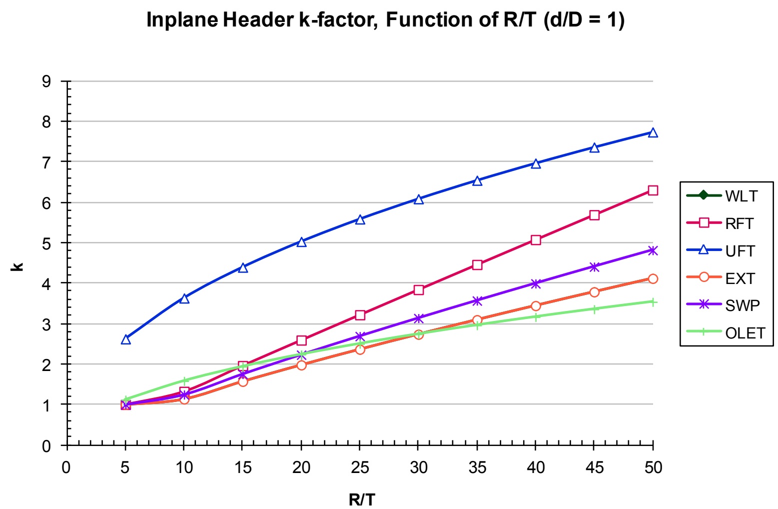
Comparisons are also made for each directional d/D function for a given fitting. The Sketch 2.1 (B16.9 welding tee), and Sketch 2.3 (unreinforced fabricated tee), d/D functions are shown below. The d/D function for the Sketch 2.1 welding tee SIFs is a function of d/D raised to a power. There is no curve maxima for any of the coefficients as suggested by WRC 346 [6]. The same is true for the Sketch 2.3 SIF functions except for the out-of-plane loading on the branch as suggested by WRC 329 [76]. A d/D function in a SIF equation might appear as $1.3 + 0.8d/D + 1.4(d/D)^2 – 1.2(d/D)^4$ for example.

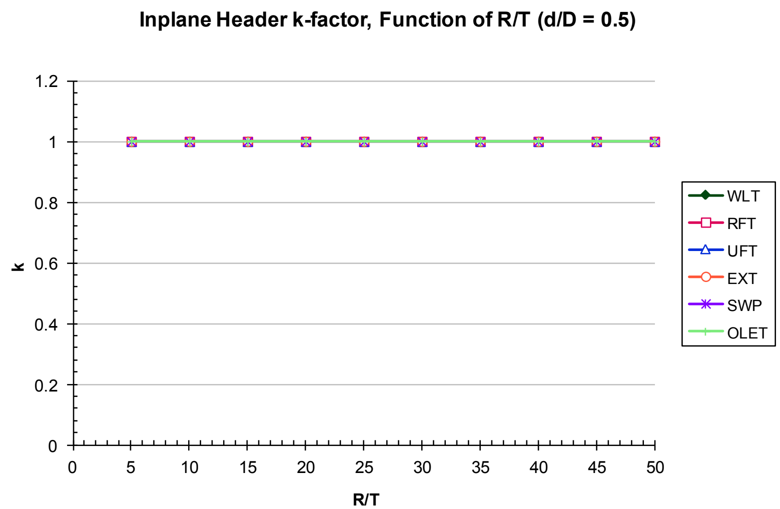


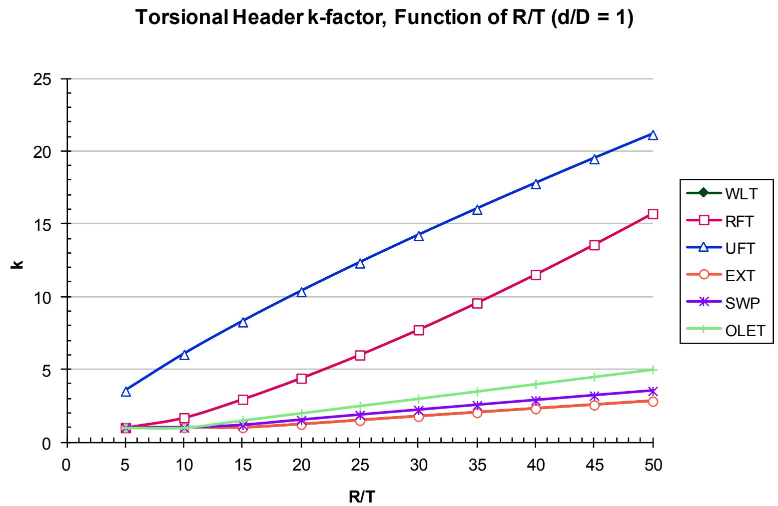


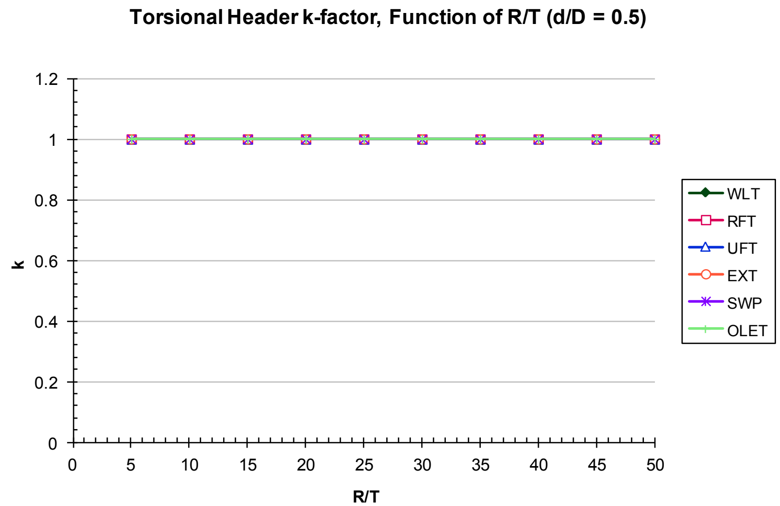
The term "run" and "header" are used interchangeably throughout this annex. Where iih appears for example, it refers to the in-plane stress intensification factor for the header or the run.

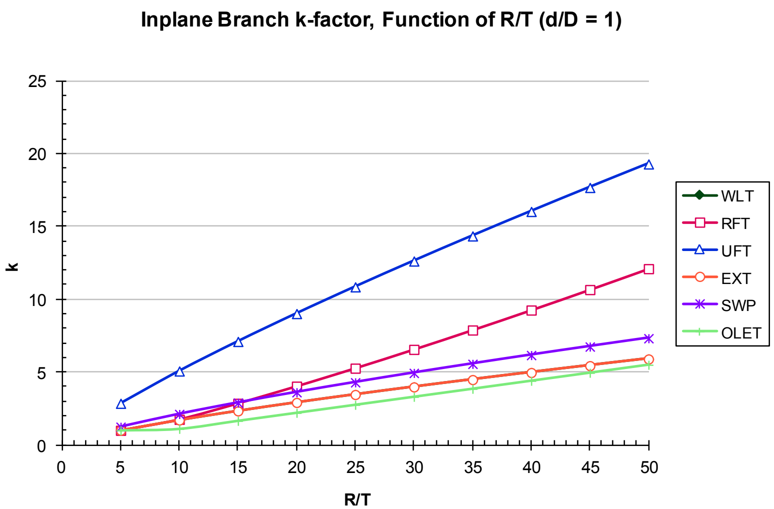
(i_{ih} and i_{oh} should be switched in the above chart. The SIF i_{oh} is not a function of d/D.)

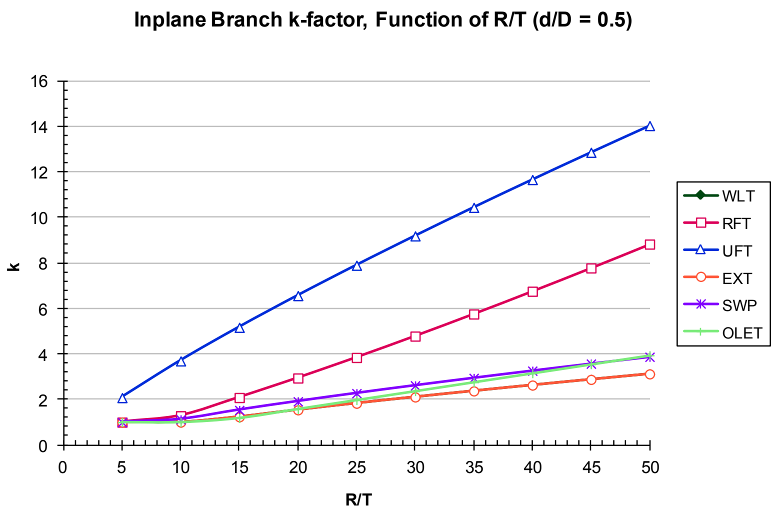

Inplane Header k-factor, Function of R/T (d/D = 1)
k
R/T
WLT
RFT
UFT
EXT
SWP
OLET

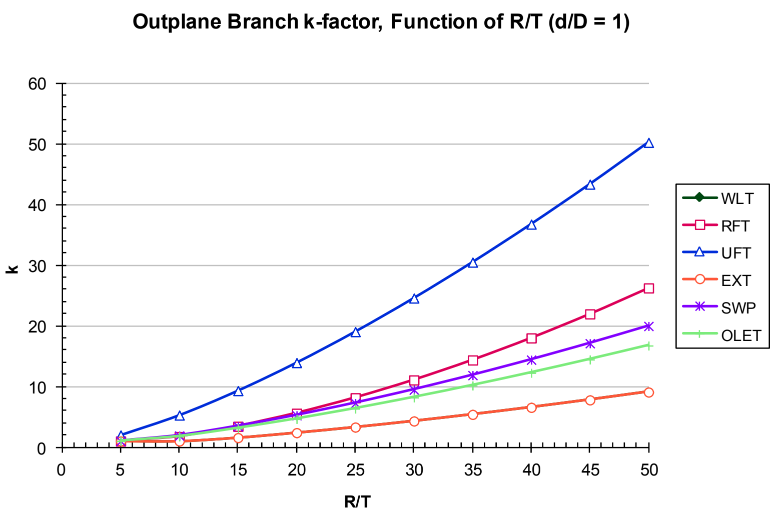

Inplane Header k-factor, Function of R/T (d/D = 0.5)
k
R/T
WLT
RFT
UFT
EXT
SWP
OLET

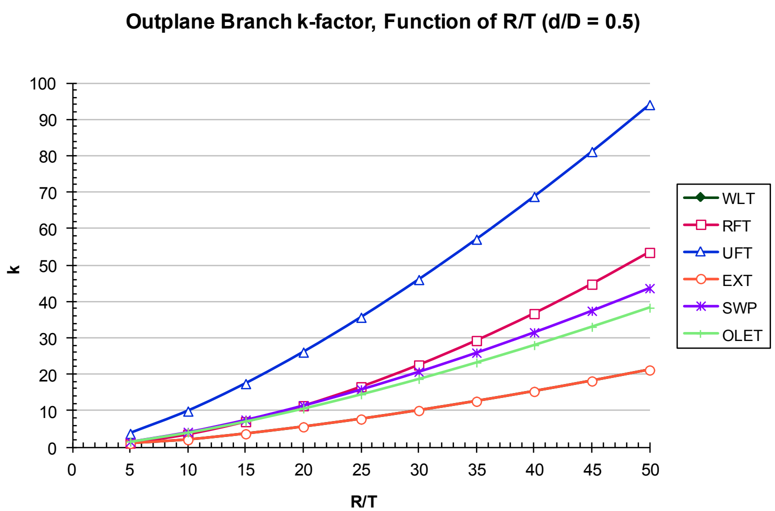

Torsional Header k-factor, Function of R/T (d/D = 1)
k
R/T
WLT
RFT
UFT
EXT
SWP
OLET


Torsional Header k-factor, Function of R/T (d/D = 0.5)
k
R/T
WLT
RFT
UFT
EXT
SWP
OLET

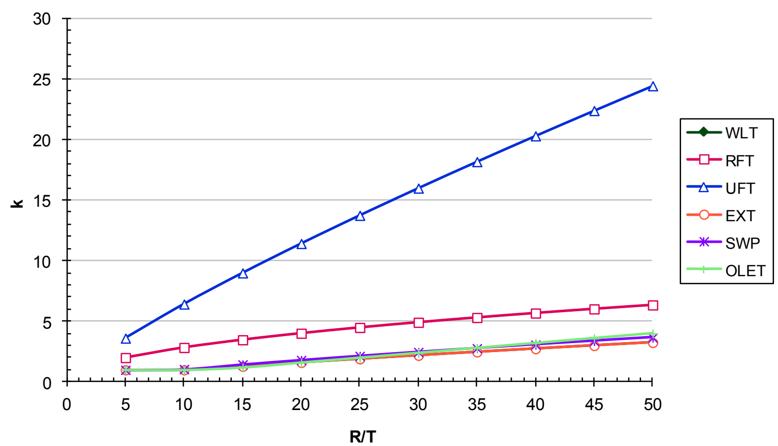

Inplane Branch k-factor, Function of R/T (d/D = 1)
k
R/T
0
5
10
15
20
25
30
35
40
45
50
WLT
RFT
UFT
EXT
SWP
OLET


Inplane Branch k-factor, Function of R/T (d/D = 0.5)
k
R/T
0
2
4
6
8
10
12
14
16
WLT
RFT
UFT
EXT
SWP
OLET

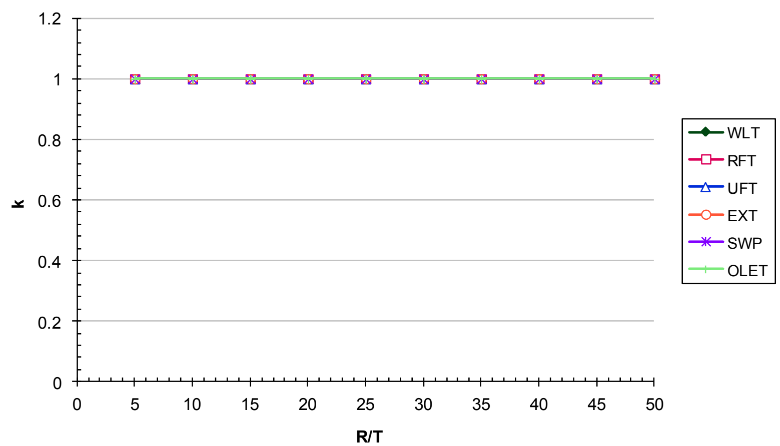

Outplane Branch k-factor, Function of R/T (d/D = 1)
k
R/T
0
10
20
30
40
50
60
WLT
RFT
UFT
EXT
SWP
OLET


Outplane Branch k-factor, Function of R/T (d/D = 0.5)
k
R/T
0
10
20
30
40
50
60
70
80
90
100
WLT
RFT
UFT
EXT
SWP
OLET

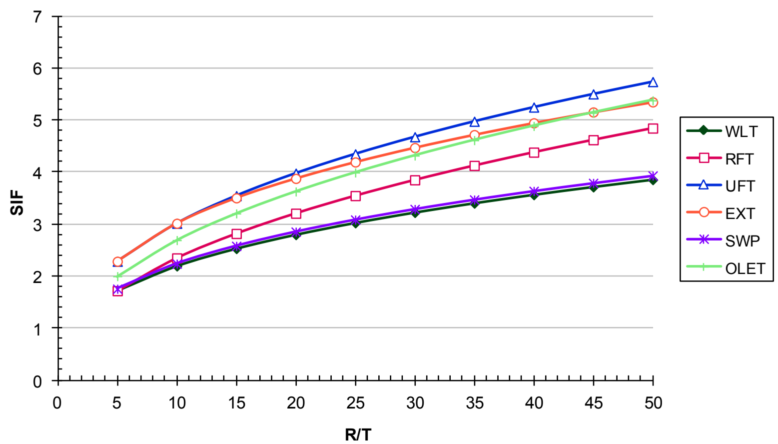
Torsional Branch k-factor, Function of R/T (d/D = 1)



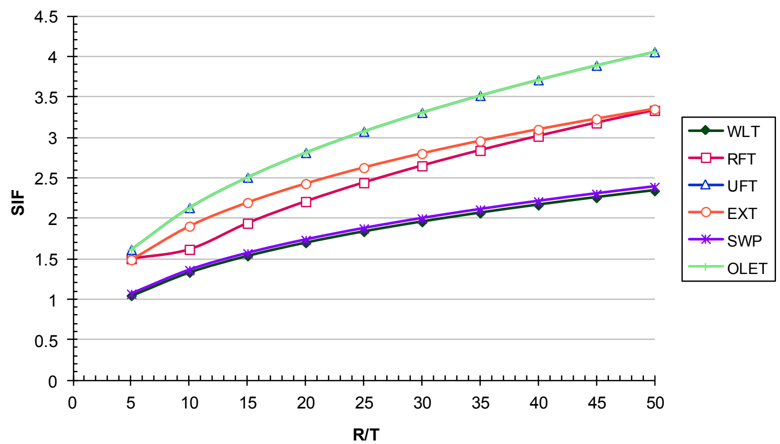
Torsional Branch k-factor, Function of R/T (d/D = 0.5)

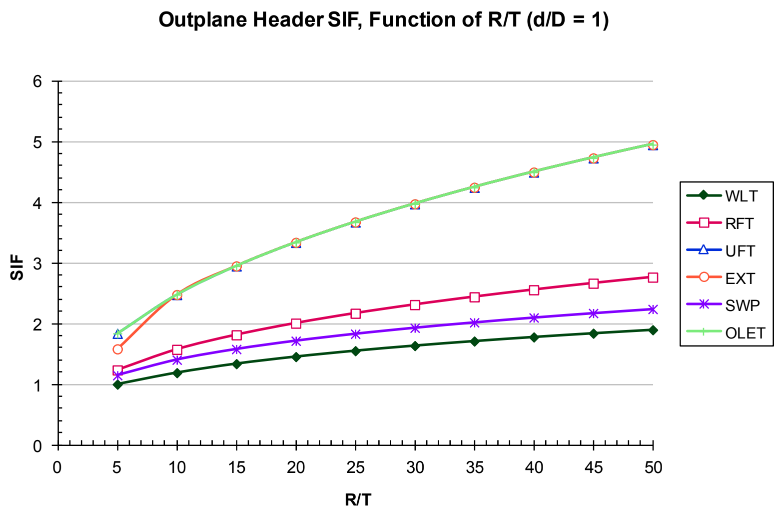


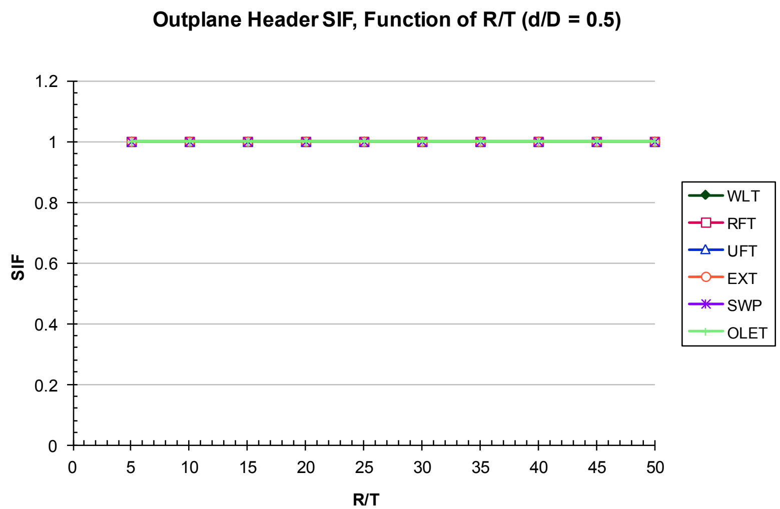
Inplane Header SIF, Function of R/T (d/D = 1)

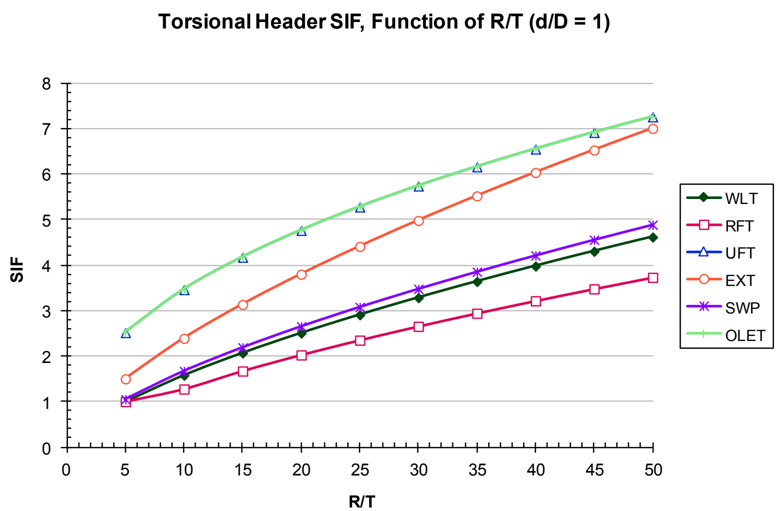


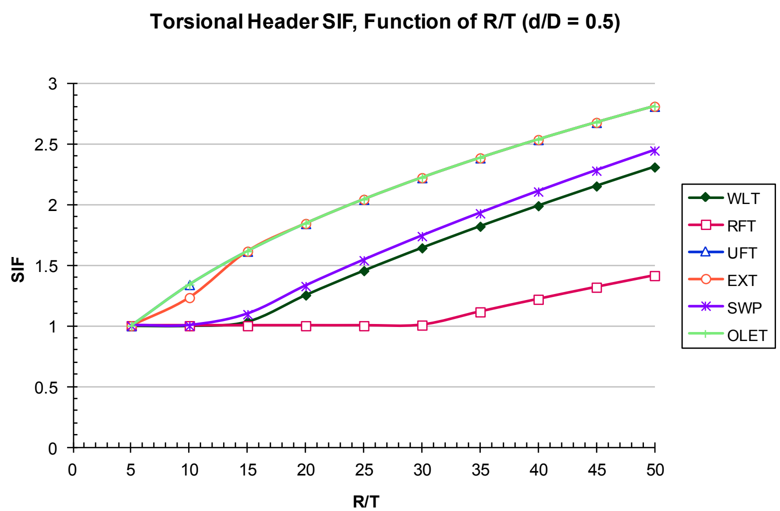
Inplane Header SIF, Function of R/T (d/D = 0.5)

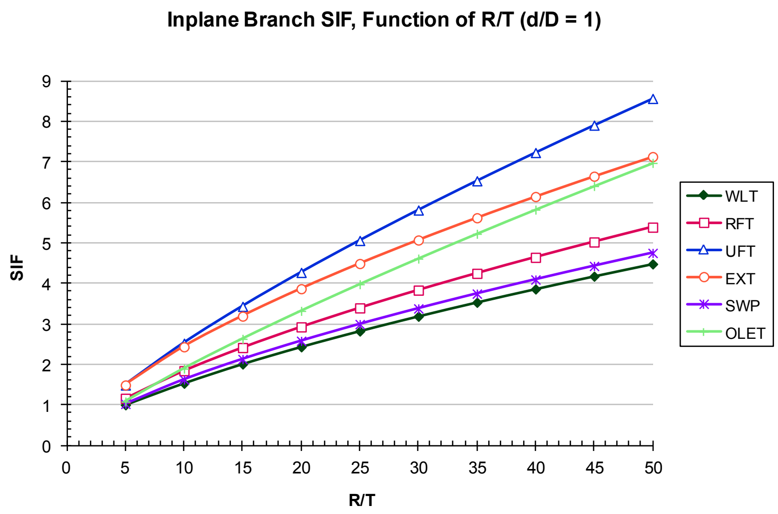


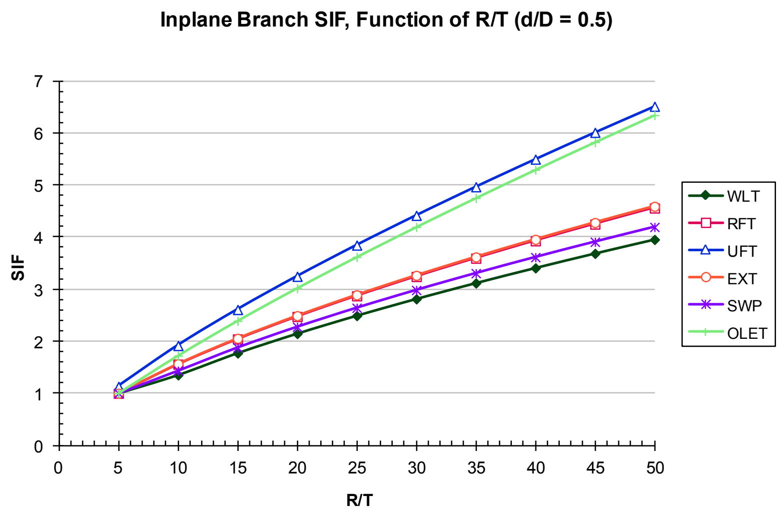

Outplane Header SIF, Function of R/T (d/D = 1)
SIF
R/T
WLT
RFT
UFT
EXT
SWP
OLET

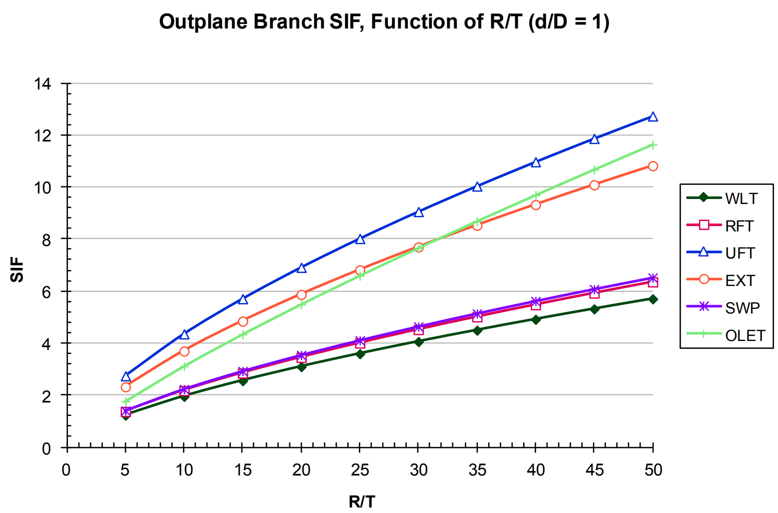

Outplane Header SIF, Function of R/T (d/D = 0.5)
SIF
R/T
WLT
RFT
UFT
EXT
SWP
OLET

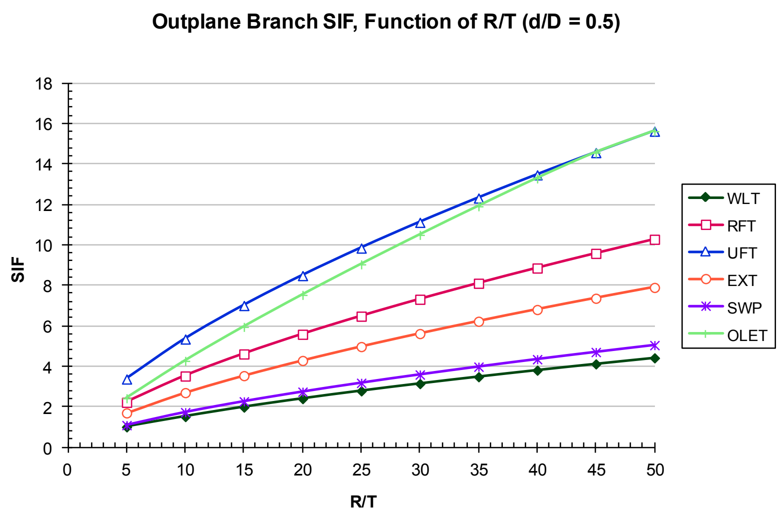

Torsional Header SIF, Function of R/T (d/D = 1)
SIF
R/T
WLT
RFT
UFT
EXT
SWP
OLET

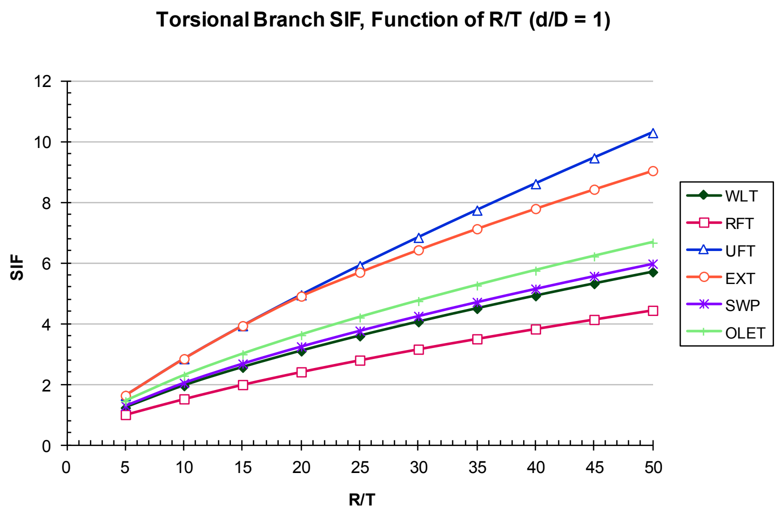

Torsional Header SIF, Function of R/T (d/D = 0.5)
SIF
R/T
WLT
RFT
UFT
EXT
SWP
OLET

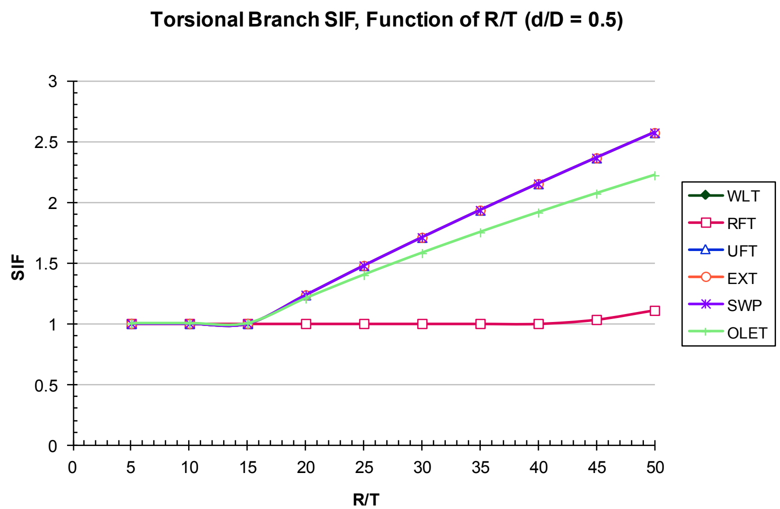

Inplane Branch SIF, Function of R/T (d/D = 1)
SIF
R/T
WLT
RFT
UFT
EXT
SWP
OLET

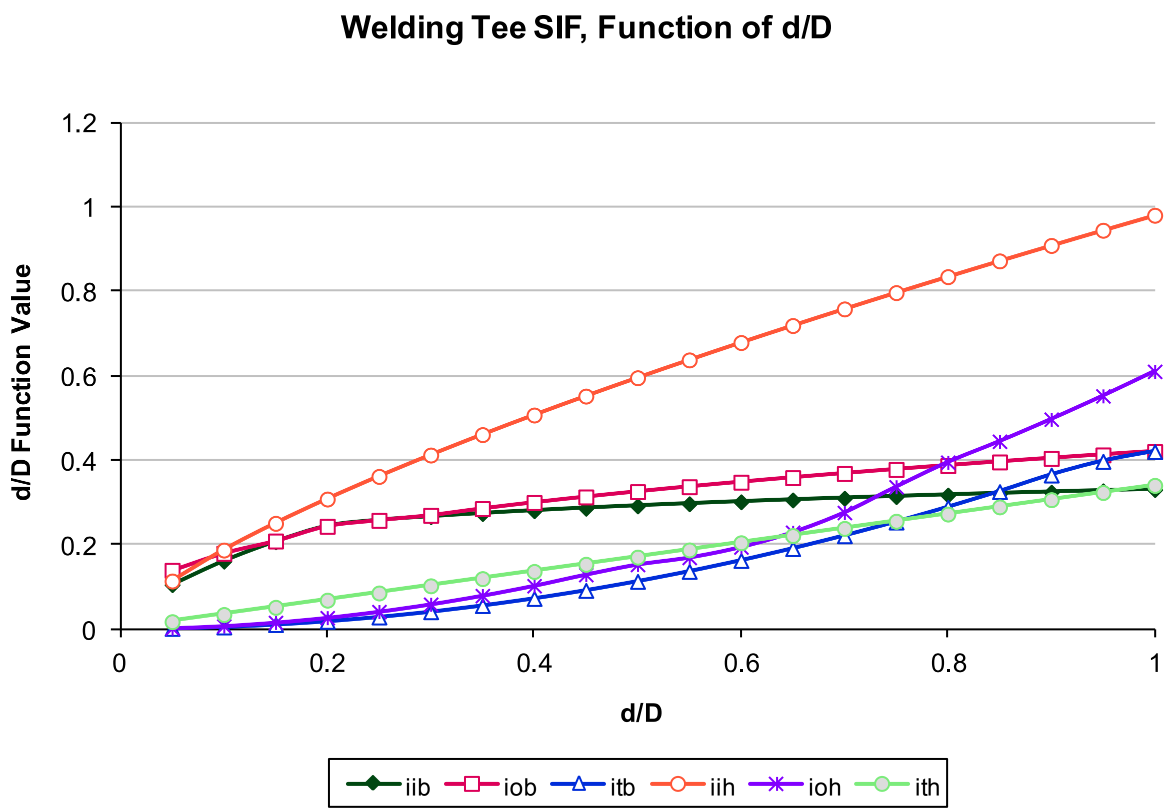

Inplane Branch SIF, Function of R/T (d/D = 0.5)
SIF
R/T
WLT
RFT
UFT
EXT
SWP
OLET

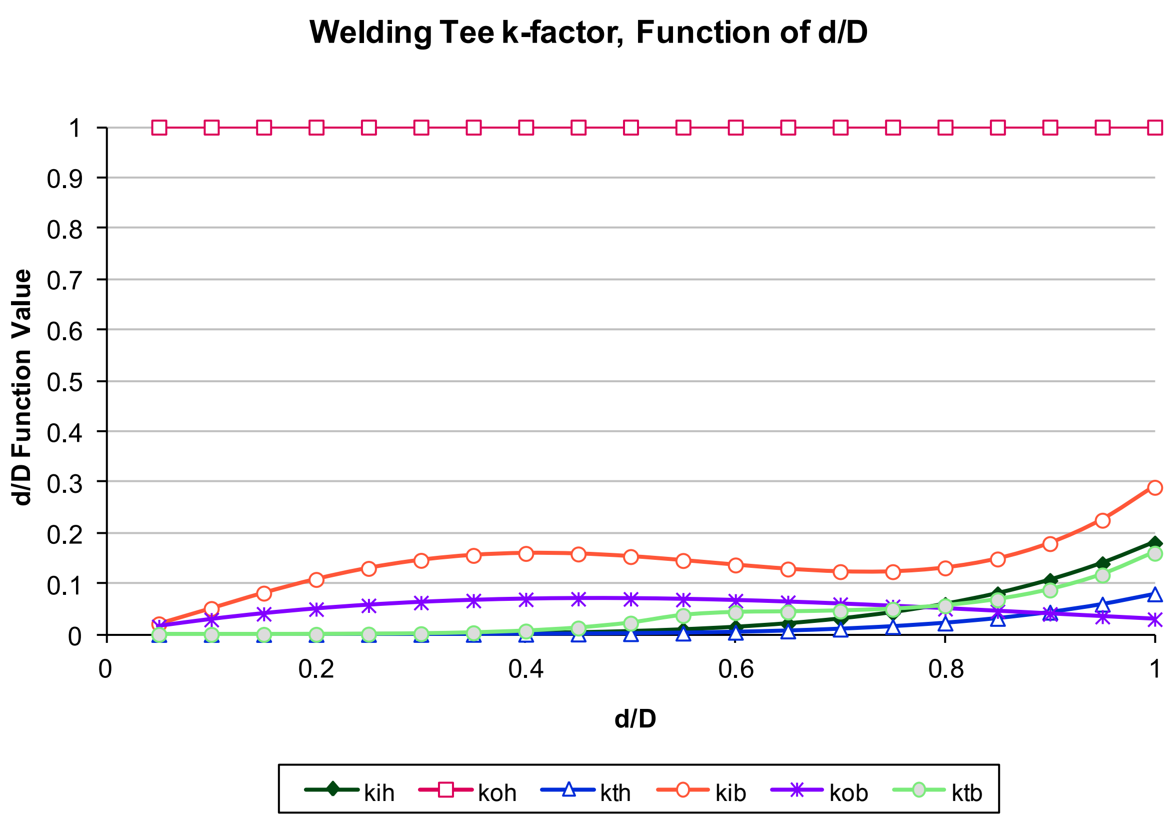

Outplane Branch SIF, Function of R/T (d/D = 1)
SIF
R/T
WLT
RFT
UFT
EXT
SWP
OLET

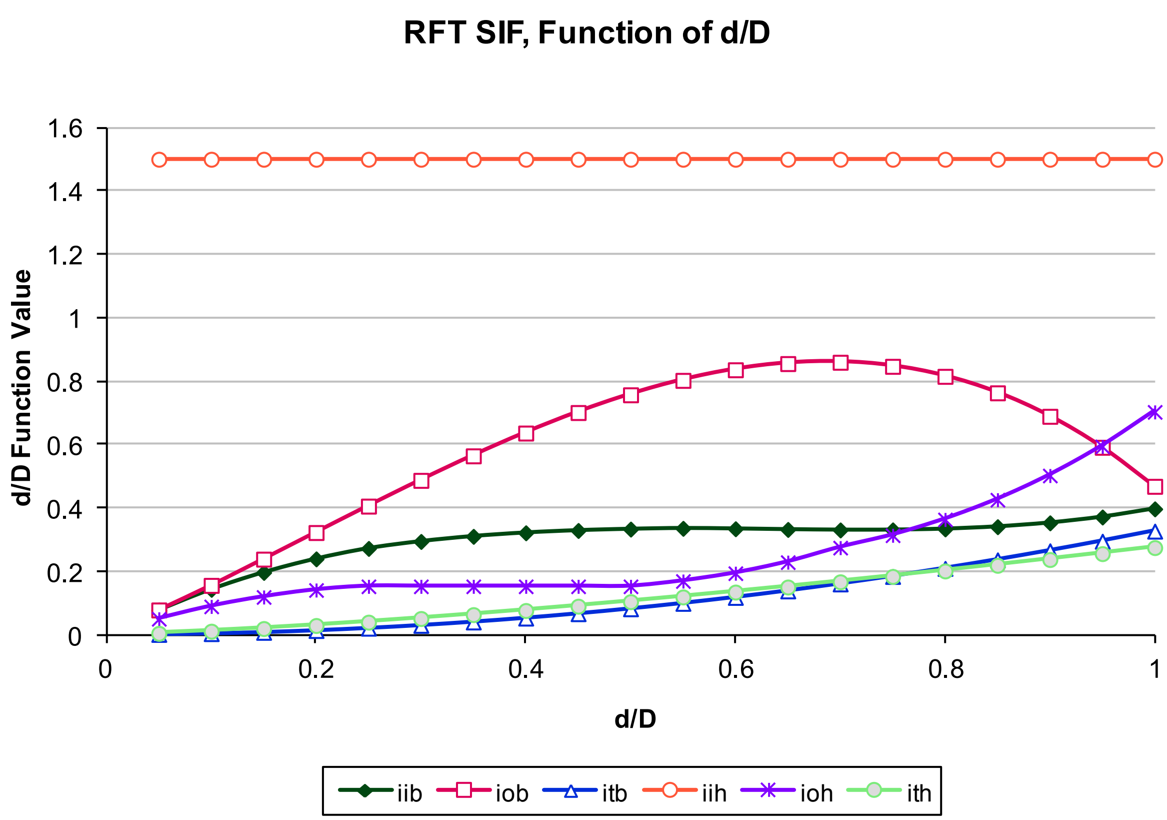

Outplane Branch SIF, Function of R/T (d/D = 0.5)
SIF
R/T
WLT
RFT
UFT
EXT
SWP
OLET

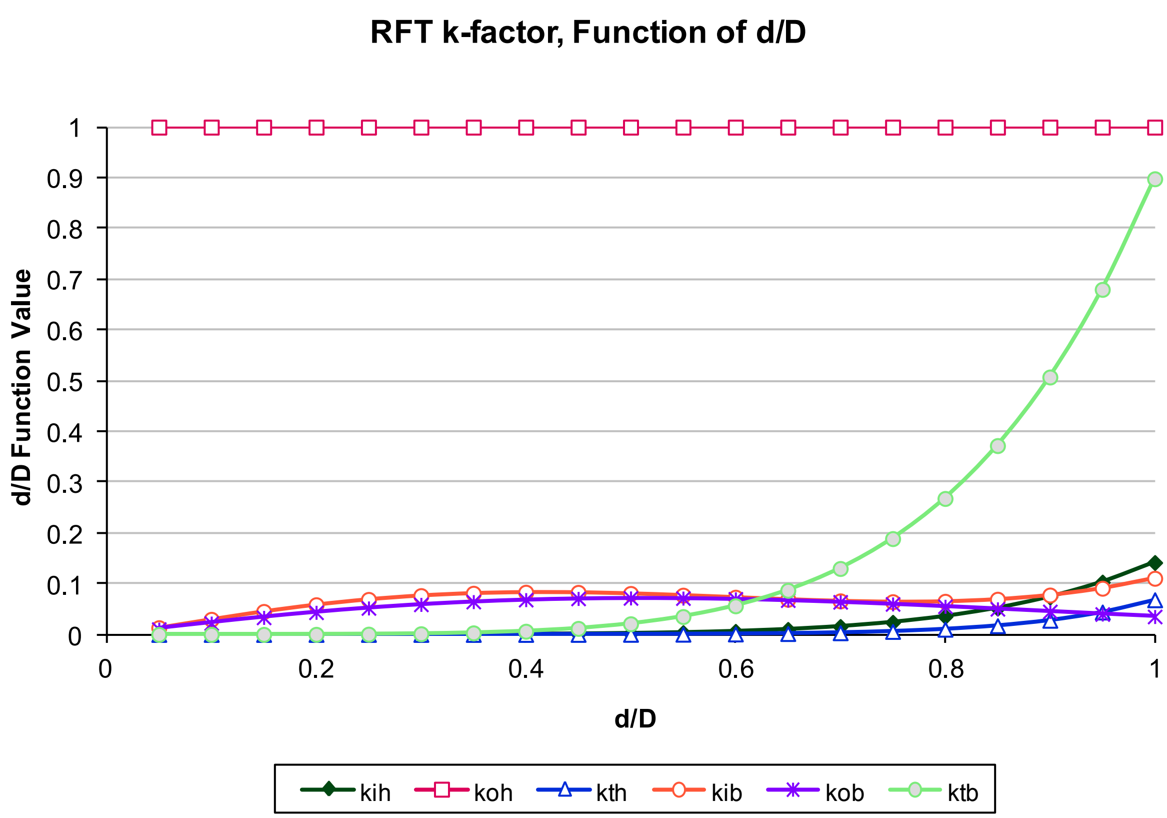

Torsional Branch SIF, Function of R/T (d/D = 1)
SIF
R/T
0
2
4
6
8
10
12
5
10
15
20
25
30
35
40
45
50
WLT
RFT
UFT
EXT
SWP
OLET

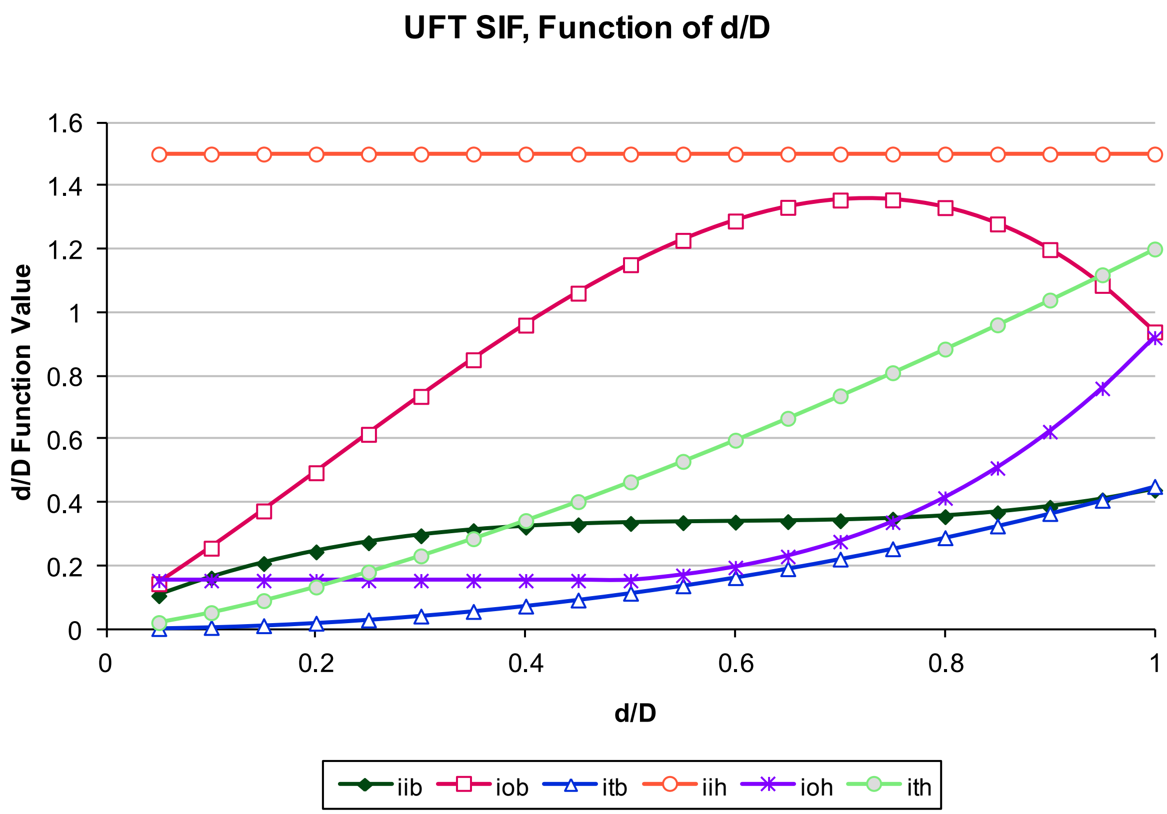

Torsional Branch SIF, Function of R/T (d/D = 0.5)
SIF
R/T
0
0.5
1
1.5
2
2.5
3
5
10
15
20
25
30
35
40
45
50
WLT
RFT
UFT
EXT
SWP
OLET

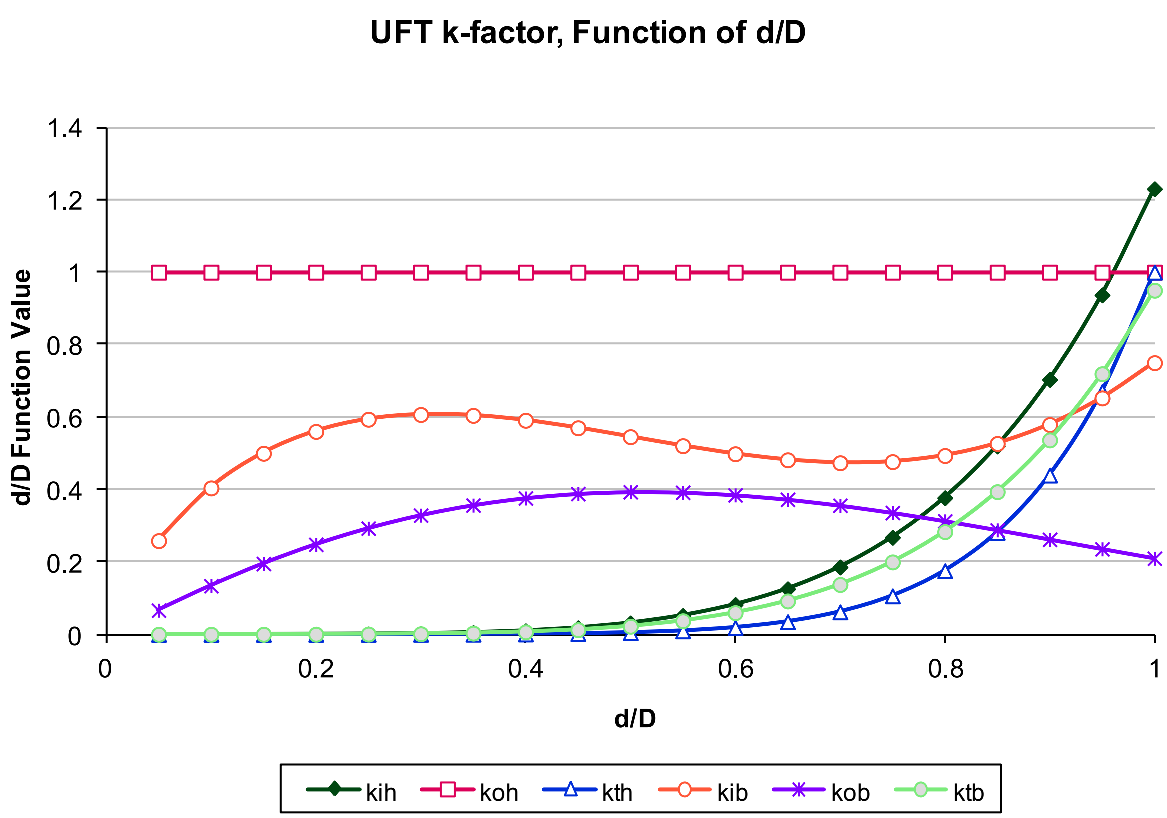

Welding Tee SIF, Function of d/D
d/D Function Value
1.2
1
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
1
d/D
iib
iob
itb
iih
ioh
ith


Welding Tee k-factor, Function of d/D
d/D Function Value
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.2
0.4
0.6
0.8
1
d/D
kih
koh
kth
kib
kob
ktb

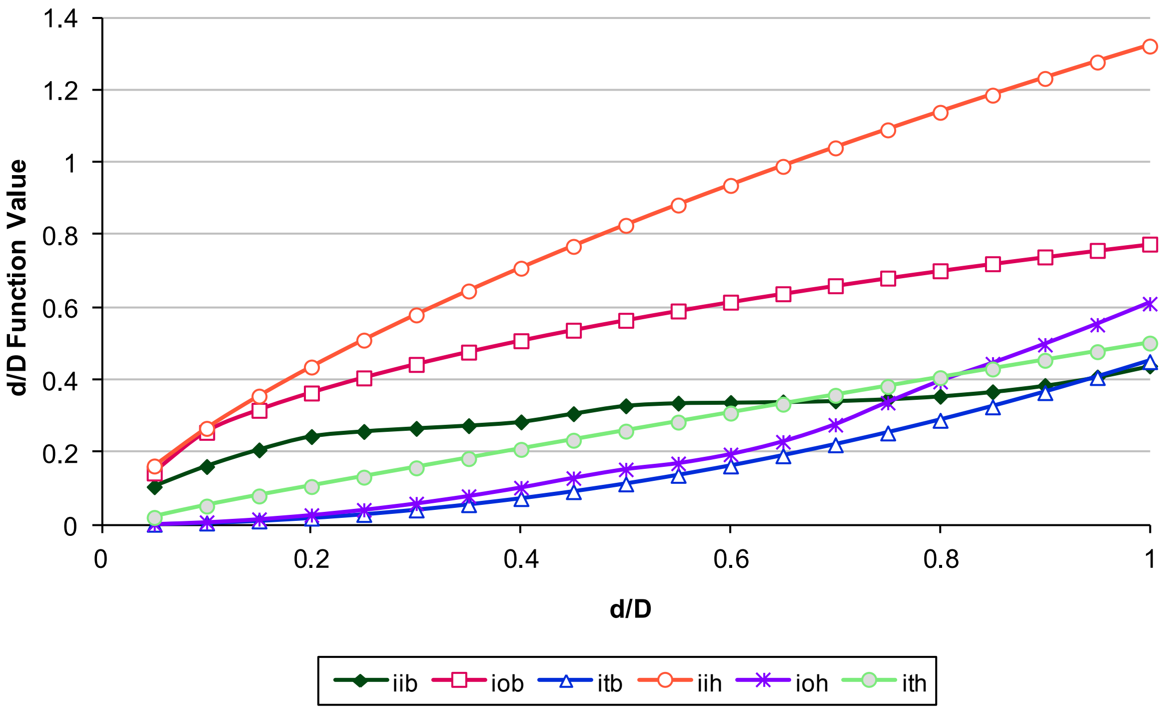

RFT SIF, Function of d/D
d/D Function Value
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
1
d/D
iib
iob
itb
iih
ioh
ith


RFT k-factor, Function of d/D
d/D Function Value
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.2
0.4
0.6
0.8
1
d/D
kih
koh
kth
kib
kob
ktb

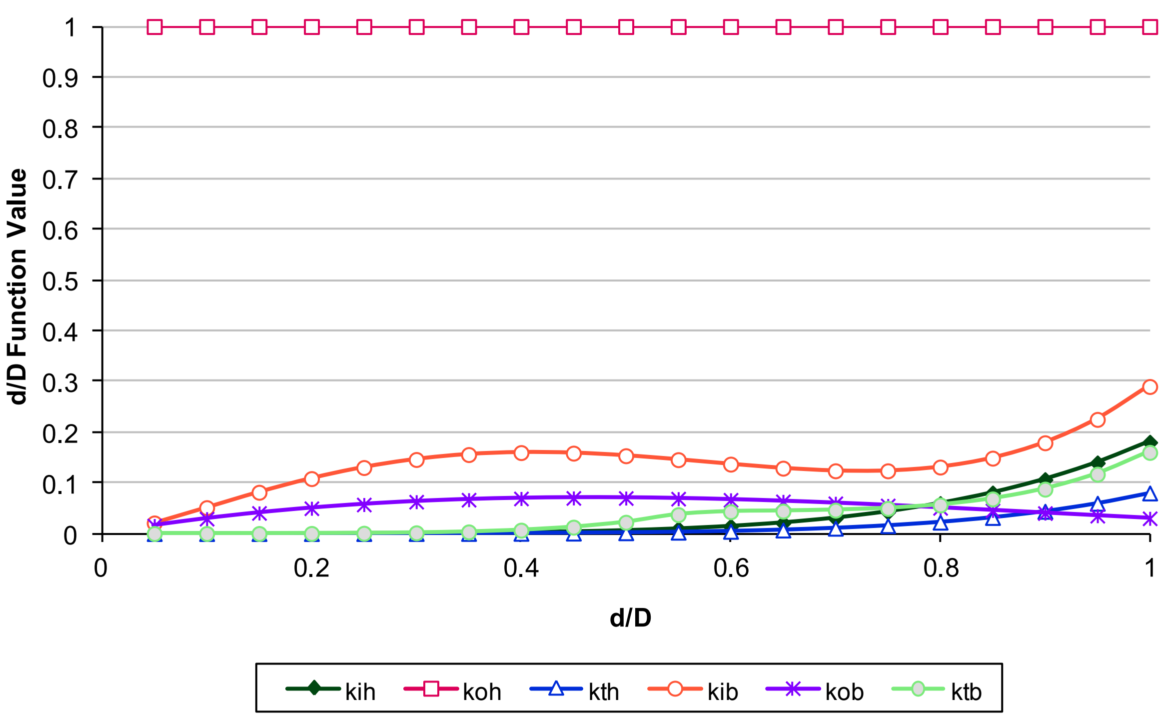

UFT SIF, Function of d/D
d/D Function Value
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
1
d/D
iib
iob
itb
iih
ioh
ith


UFT k-factor, Function of d/D
d/D Function Value
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
1
d/D
kih
koh
kth
kib
kob
ktb

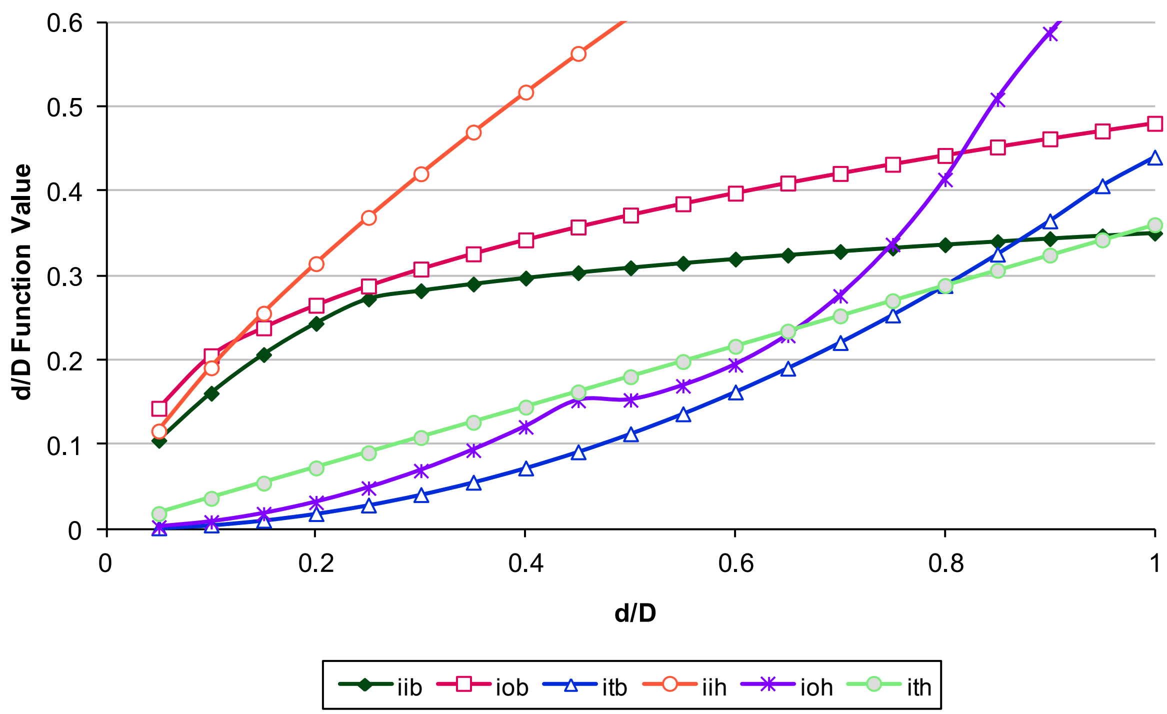
Extruded Tee SIF, Function of d/D



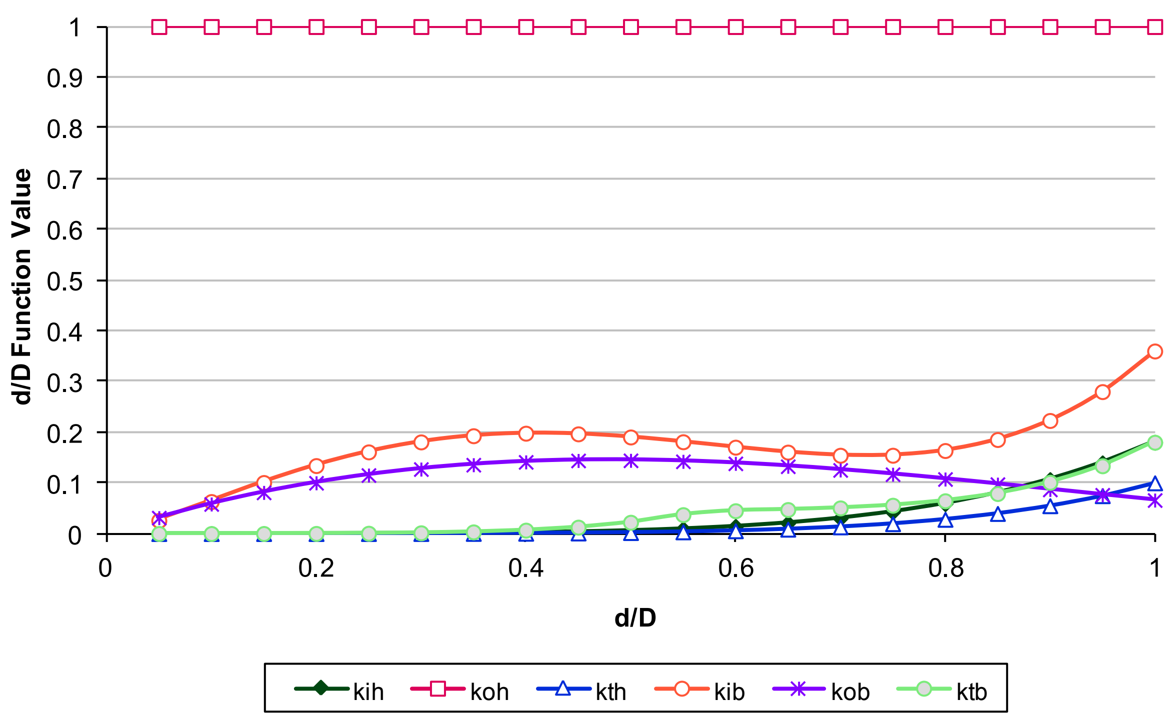
Extruded Tee k-factor, Function of d/D

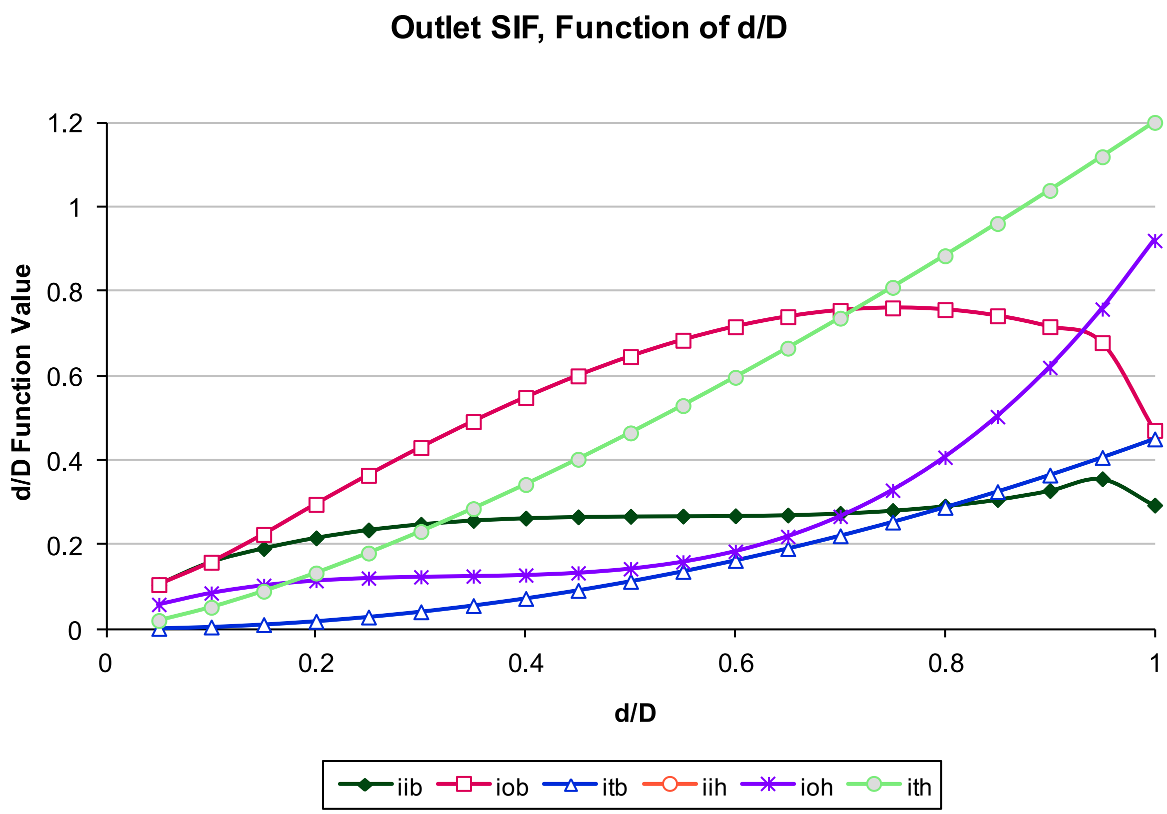


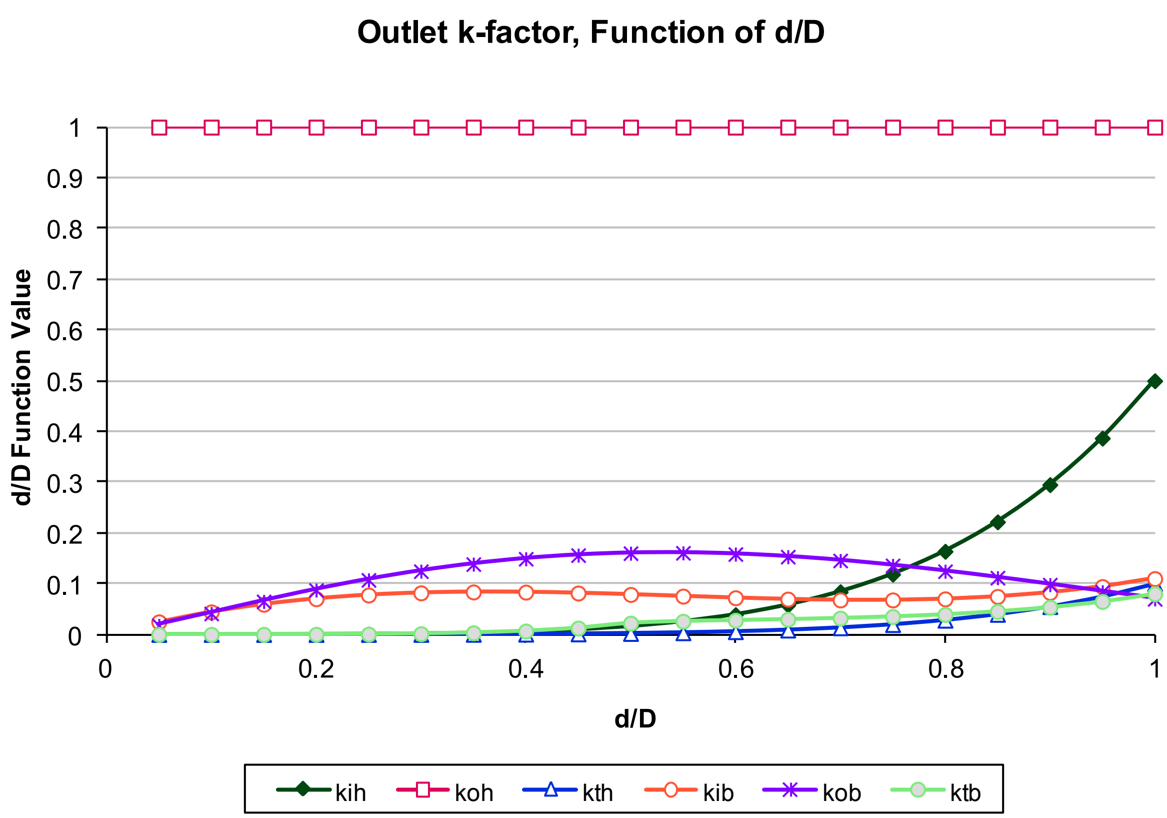
Welded-in Contour SIF, Function of d/D



Welded-in Contour k-factor, Function of d/D




Outlet SIF, Function of d/D
d/D Function Value
1.2
1
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
1
d/D
iib
iob
itb
iih
ioh
ith


Outlet k-factor, Function of d/D
d/D Function Value
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.2
0.4
0.6
0.8
1
d/D
kih
koh
kth
kib
kob
ktb

The collected Markl-type test data showing relationships between the different branch connection types as a function of geometry is included in the 6 plots below for i_{ib} and i_{ob} for each of the six branch connection Sketches 2.1 through 2.6. There are three plots for i_{ib} and three plots for i_{ob}. The first plot includes test results for branch components that have t/T values less than 1.1. The second plot contains all tests where t/T is greater than 1.1 and the third plot is for all tests for any t/T.

i_{ib}, t/T Range 0-1.1:

toT Range 0 1.1 | iib

d/D	Type	D/T 0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100
0-0.2	UFT								2.35	2.67	4.20
	EXT										
	PAD										
	OLT										
	SWP										
	B16										
0.2-0.4	UFT			2.05		2.75					
	EXT		0.85								
	PAD			1.46				1.19			
	OLT										
	SWP										
	B16										
0.4-0.6	UFT								2.25		5.64
	EXT										
	PAD				2.99						
	OLT			0.81	1.28						
	SWP			1.00	0.98						
	B16										
0.6-0.8	UFT		3.10	1.85		3.47					
	EXT		1.35								
	PAD										
	OLT										
	SWP				1.47						
	B16										
0.8-1	UFT		2.51	4.04		6.12			2.51	9.66	
	EXT										
	PAD		1.52	3.04	2.20						
	OLT		1.82								
	SWP										
	B16	1.24	1.29		1.66						2.14

i_{ib}, t/T Range 1.1-100:

toT Range 1.1 100 | iib

d/D	Type	D/T 0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100
0-0.2	UFT										
	EXT										
	PAD										
	OLT										
	SWP										
	B16										
0.2-0.4	UFT										
	EXT										
	PAD										
	OLT										
	SWP										
	B16										
0.4-0.6	UFT										
	EXT										
	PAD										
	OLT										
	SWP										
	B16										
0.6-0.8	UFT										
	EXT										
	PAD										
	OLT										
	SWP										
	B16										
0.8-1	UFT		2.16								
	EXT										
	PAD										
	OLT										
	SWP										
	B16										

iib, t/T Range 0-100:

toT Range 0 100 iib

	D/T																			
d/D	0-10		10-20		20-30		30-40		40-50		50-60		60-70		70-80		80-90		90-100	
0-0.2	UFT		UFT		UFT		UFT		UFT		UFT		UFT		UFT	2.35	UFT	2.67	UFT	4.20
	EXT		EXT		EXT		EXT		EXT		EXT		EXT		EXT		EXT		EXT	
	PAD		PAD		PAD		PAD		PAD		PAD		PAD		PAD		PAD		PAD	
	OLT		OLT		OLT		OLT		OLT		OLT		OLT		OLT		OLT		OLT	
	SWP		SWP		SWP		SWP		SWP		SWP		SWP		SWP		SWP		SWP	
	B16		B16		B16		B16		B16		B16		B16		B16		B16		B16	
0.2-0.4	UFT		UFT		UFT	2.05	UFT		UFT	2.75	UFT		UFT		UFT		UFT		UFT	
	EXT		EXT	0.85	EXT		EXT		EXT		EXT		EXT		EXT		EXT		EXT	
	PAD		PAD		PAD	1.46	PAD		PAD		PAD		PAD	1.19	PAD		PAD		PAD	
	OLT		OLT		OLT		OLT		OLT		OLT		OLT		OLT		OLT		OLT	
	SWP		SWP		SWP		SWP		SWP		SWP		SWP		SWP		SWP		SWP	
	B16		B16		B16		B16		B16		B16		B16		B16		B16		B16	
0.4-0.6	UFT		UFT		UFT		UFT		UFT		UFT		UFT		UFT	2.25	UFT		UFT	5.64
	EXT		EXT		EXT		EXT		EXT		EXT		EXT		EXT		EXT		EXT	
	PAD		PAD		PAD		PAD	2.99	PAD		PAD		PAD		PAD		PAD		PAD	
	OLT		OLT		OLT	0.81	OLT	1.28	OLT		OLT		OLT		OLT		OLT		OLT	
	SWP		SWP		SWP	1.00	SWP	0.98	SWP		SWP		SWP		SWP		SWP		SWP	
	B16		B16		B16		B16		B16		B16		B16		B16		B16		B16	
0.6-0.8	UFT		UFT	3.10	UFT	1.85	UFT		UFT	3.47	UFT		UFT		UFT		UFT		UFT	
	EXT		EXT	1.35	EXT		EXT		EXT		EXT		EXT		EXT		EXT		EXT	
	PAD		PAD		PAD		PAD		PAD		PAD		PAD		PAD		PAD		PAD	
	OLT		OLT		OLT		OLT		OLT		OLT		OLT		OLT		OLT		OLT	
	SWP		SWP		SWP		SWP	1.47	SWP		SWP		SWP		SWP		SWP		SWP	
	B16		B16		B16		B16		B16		B16		B16		B16		B16		B16	
0.8-1	UFT		UFT	2.51	UFT	4.04	UFT		UFT	6.12	UFT		UFT		UFT	2.51	UFT	9.66	UFT	
	EXT		EXT		EXT		EXT		EXT		EXT		EXT		EXT		EXT		EXT	
	PAD		PAD	1.52	PAD	3.04	PAD	2.20	PAD		PAD		PAD		PAD		PAD		PAD	
	OLT		OLT	1.82	OLT		OLT		OLT		OLT		OLT		OLT		OLT		OLT	
	SWP		SWP		SWP		SWP		SWP		SWP		SWP		SWP		SWP		SWP	
	B16	1.24	B16	1.29	B16		B16	1.66	B16		B16		B16		B16		B16		B16	2.14

iob, t/T Range 0-1.1:

toT Range 0 1.1 iob

	D/T																			
d/D	0-10		10-20		20-30		30-40		40-50		50-60		60-70		70-80		80-90		90-100	
0-0.2	UFT		UFT		UFT		UFT		UFT		UFT		UFT		UFT	5.25	UFT		UFT	7.00
	EXT		EXT		EXT		EXT		EXT		EXT		EXT		EXT		EXT		EXT	
	PAD		PAD		PAD		PAD		PAD		PAD		PAD		PAD	2.25	PAD		PAD	
	OLT		OLT		OLT		OLT		OLT		OLT		OLT		OLT		OLT		OLT	
	SWP		SWP		SWP		SWP		SWP		SWP		SWP		SWP		SWP		SWP	
	B16		B16		B16		B16		B16		B16		B16		B16		B16		B16	
0.2-0.4	UFT		UFT		UFT	3.10	UFT		UFT	3.58	UFT		UFT		UFT		UFT		UFT	
	EXT	1.20	EXT	1.23	EXT		EXT		EXT		EXT		EXT		EXT		EXT		EXT	
	PAD		PAD		PAD	1.95	PAD		PAD		PAD		PAD	4.34	PAD	3.25	PAD		PAD	
	OLT		OLT		OLT	3.19	OLT		OLT		OLT		OLT		OLT		OLT		OLT	
	SWP		SWP		SWP		SWP		SWP		SWP		SWP		SWP		SWP		SWP	
	B16		B16		B16		B16		B16		B16		B16		B16		B16		B16	
0.4-0.6	UFT		UFT		UFT		UFT		UFT		UFT		UFT		UFT	5.00	UFT		UFT	18.87
	EXT		EXT	1.48	EXT		EXT		EXT		EXT		EXT		EXT		EXT		EXT	
	PAD		PAD		PAD		PAD	3.47	PAD		PAD		PAD		PAD	3.75	PAD		PAD	
	OLT		OLT		OLT	3.47	OLT	3.76	OLT		OLT		OLT		OLT		OLT		OLT	
	SWP		SWP		SWP	1.90	SWP	2.58	SWP		SWP		SWP		SWP		SWP		SWP	
	B16		B16		B16		B16	1.02	B16		B16		B16		B16		B16		B16	
0.6-0.8	UFT		UFT	4.40	UFT	5.84	UFT		UFT		UFT		UFT		UFT		UFT		UFT	
	EXT		EXT	2.35	EXT		EXT		EXT		EXT		EXT		EXT		EXT		EXT	
	PAD		PAD		PAD	2.79	PAD	3.91	PAD		PAD		PAD		PAD		PAD		PAD	
	OLT		OLT	2.12	OLT	4.54	OLT		OLT		OLT		OLT		OLT		OLT		OLT	
	SWP		SWP		SWP		SWP	2.70	SWP		SWP		SWP		SWP		SWP		SWP	
	B16		B16	1.29	B16		B16		B16		B16		B16		B16		B16		B16	
0.8-1	UFT		UFT	2.84	UFT		UFT	8.337	UFT		UFT		UFT		UFT	6.00	UFT		UFT	
	EXT	1.49	EXT		EXT		EXT		EXT		EXT		EXT		EXT		EXT		EXT	
	PAD		PAD	1.52	PAD		PAD	2.42	PAD		PAD		PAD		PAD		PAD		PAD	
	OLT		OLT	1.66	OLT	5.19	OLT		OLT		OLT		OLT		OLT		OLT		OLT	
	SWP		SWP		SWP		SWP		SWP		SWP		SWP		SWP		SWP		SWP	
	B16		B16	1.85	B16		B16		B16		B16		B16		B16		B16		B16	

iob, t/T Range 1.1-100:

toT Range 1.1 100 — iob

d/D	D/T 0-10		10-20		20-30		30-40		40-50		50-60		60-70		70-80		80-90		90-100	
0-0.2	UFT		UFT		UFT		UFT		UFT		UFT		UFT		UFT		UFT		UFT	
	EXT		EXT		EXT		EXT		EXT		EXT		EXT		EXT		EXT		EXT	
	PAD		PAD		PAD		PAD		PAD		PAD		PAD		PAD		PAD		PAD	
	OLT		OLT		OLT		OLT		OLT		OLT		OLT		OLT		OLT		OLT	
	SWP		SWP		SWP		SWP		SWP		SWP		SWP		SWP		SWP		SWP	
	B16		B16		B16		B16		B16		B16		B16		B16		B16		B16	
0.2-0.4	UFT		UFT		UFT		UFT		UFT		UFT		UFT		UFT		UFT		UFT	
	EXT		EXT		EXT		EXT		EXT		EXT		EXT		EXT		EXT		EXT	
	PAD		PAD		PAD		PAD		PAD		PAD		PAD		PAD		PAD		PAD	
	OLT		OLT		OLT		OLT		OLT		OLT		OLT		OLT		OLT		OLT	
	SWP		SWP		SWP		SWP		SWP		SWP		SWP		SWP		SWP		SWP	
	B16		B16		B16		B16		B16		B16		B16		B16		B16		B16	
0.4-0.6	UFT		UFT		UFT		UFT		UFT		UFT		UFT		UFT		UFT		UFT	
	EXT		EXT		EXT		EXT		EXT		EXT		EXT		EXT		EXT		EXT	
	PAD		PAD		PAD		PAD		PAD		PAD		PAD		PAD		PAD		PAD	
	OLT		OLT		OLT		OLT		OLT		OLT		OLT		OLT		OLT		OLT	
	SWP		SWP		SWP		SWP		SWP		SWP		SWP		SWP		SWP		SWP	
	B16		B16		B16		B16		B16		B16		B16		B16		B16		B16	
0.6-0.8	UFT		UFT		UFT		UFT		UFT		UFT		UFT		UFT		UFT		UFT	
	EXT		EXT		EXT		EXT		EXT		EXT		EXT		EXT		EXT		EXT	
	PAD		PAD		PAD		PAD		PAD		PAD		PAD		PAD		PAD		PAD	
	OLT		OLT		OLT		OLT		OLT		OLT		OLT		OLT		OLT		OLT	
	SWP		SWP		SWP		SWP		SWP		SWP		SWP		SWP		SWP		SWP	
	B16		B16		B16		B16		B16		B16		B16		B16		B16		B16	
0.8-1	UFT		UFT		UFT		UFT		UFT		UFT		UFT		UFT		UFT		UFT	
	EXT		EXT		EXT		EXT		EXT		EXT		EXT		EXT		EXT		EXT	
	PAD		PAD		PAD		PAD		PAD		PAD		PAD		PAD		PAD		PAD	
	OLT		OLT		OLT		OLT		OLT		OLT		OLT		OLT		OLT		OLT	
	SWP		SWP		SWP		SWP		SWP		SWP		SWP		SWP		SWP		SWP	
	B16		B16		B16		B16		B16		B16		B16		B16		B16		B16	

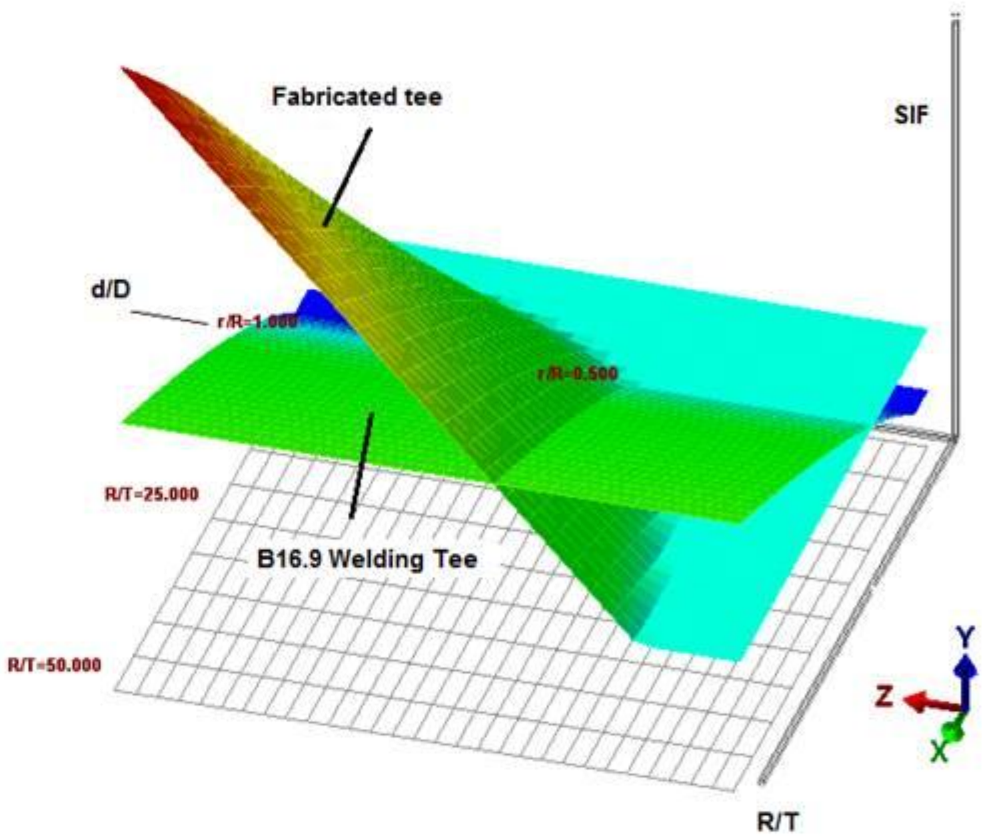
iob, t/T Range 0-100:

toT Range 0 100 — iob

d/D	D/T 0-10		10-20		20-30		30-40		40-50		50-60		60-70		70-80		80-90		90-100	
0-0.2	UFT		UFT		UFT		UFT		UFT		UFT		UFT		UFT	5.25	UFT		UFT	7.00
	EXT		EXT		EXT		EXT		EXT		EXT		EXT		EXT		EXT		EXT	
	PAD		PAD		PAD		PAD		PAD		PAD		PAD		PAD	2.25	PAD		PAD	
	OLT		OLT		OLT		OLT		OLT		OLT		OLT		OLT		OLT		OLT	
	SWP		SWP		SWP		SWP		SWP		SWP		SWP		SWP		SWP		SWP	
	B16		B16		B16		B16		B16		B16		B16		B16		B16		B16	
0.2-0.4	UFT		UFT		UFT	3.10	UFT		UFT	3.58	UFT		UFT		UFT		UFT		UFT	
	EXT	1.20	EXT	1.23	EXT		EXT		EXT		EXT		EXT		EXT		EXT		EXT	
	PAD		PAD		PAD	1.95	PAD		PAD		PAD		PAD	4.34	PAD	3.25	PAD		PAD	
	OLT		OLT		OLT	3.19	OLT		OLT		OLT		OLT		OLT		OLT		OLT	
	SWP		SWP		SWP		SWP		SWP		SWP		SWP		SWP		SWP		SWP	
	B16		B16		B16		B16		B16		B16		B16		B16		B16		B16	
0.4-0.6	UFT		UFT		UFT		UFT		UFT		UFT		UFT		UFT	5.00	UFT		UFT	18.87
	EXT		EXT	1.48	EXT		EXT		EXT		EXT		EXT		EXT		EXT		EXT	
	PAD		PAD		PAD		PAD	3.47	PAD		PAD		PAD		PAD	3.75	PAD		PAD	
	OLT		OLT		OLT	3.47	OLT	3.76	OLT		OLT		OLT		OLT		OLT		OLT	
	SWP		SWP		SWP	1.90	SWP	2.58	SWP		SWP		SWP		SWP		SWP		SWP	
	B16		B16		B16		B16	1.02	B16		B16		B16		B16		B16		B16	
0.6-0.8	UFT		UFT	4.40	UFT	5.84	UFT		UFT		UFT		UFT		UFT		UFT		UFT	
	EXT		EXT	2.35	EXT		EXT		EXT		EXT		EXT		EXT		EXT		EXT	
	PAD		PAD		PAD	2.79	PAD	3.91	PAD		PAD		PAD		PAD		PAD		PAD	
	OLT		OLT	2.12	OLT	4.54	OLT		OLT		OLT		OLT		OLT		OLT		OLT	
	SWP		SWP		SWP		SWP	2.70	SWP		SWP		SWP		SWP		SWP		SWP	
	B16		B16	1.29	B16		B16		B16		B16		B16		B16		B16		B16	
0.8-1	UFT		UFT	2.84	UFT		UFT	8.337	UFT		UFT		UFT		UFT	6.00	UFT		UFT	
	EXT	1.49	EXT		EXT		EXT		EXT		EXT		EXT		EXT		EXT		EXT	
	PAD		PAD	1.52	PAD		PAD	2.42	PAD		PAD		PAD		PAD		PAD		PAD	
	OLT		OLT	1.66	OLT	5.19	OLT		OLT		OLT		OLT		OLT		OLT		OLT	
	SWP		SWP		SWP		SWP		SWP		SWP		SWP		SWP		SWP		SWP	
	B16		B16	1.85	B16		B16		B16		B16		B16		B16		B16		B16	

BPVC Section III NC Fabricated and B16.9 Welding Tee Comparisons for Low d/D Ratios

The objective is to determine when there should be a constant ratio between i-factors and k-factors for different branch connection products. When the i-factor and k-factor equations are curve fit to match the test data over certain parameter ranges, exponents on coefficients like (d/D), (R/T) and (t/T) can have large effects on the relationship between the product forms once the parameters get away from the test ranges. This evaluation started with Table D-1 B31.3 and concluded with the B16.9 tee and the fabricated tee i-factor equations in table NC-3673.2(b)-1 to look at how these relationships were established in the current code. Noticing that the NC fabricated tee and welding tee i-factor curves for thru-run loads cross at d/D=0.418 an evaluation of the full parameter range associated with the ST-LLC 0702 project equations was undertaken. The results of this review were included as additions to Note 10 which prescribe minimum relationships between certain of the i-factor and k-factor components. A rough plot of the fabricated tee and B16.9 tee i-factor surfaces from NC-3673.2(b)-1 are shown below. (t/T=d/D).



A relationship between the different components for fixed T_p and r_x values in B31.3 are in Table G-1 below.

Table G-1 B31.3 Outplane i-factor Constants for Noted Geometry Assumptions

$$\text{Stress} = iM/Z = [0.9/(h^{2/3})]\ M/Z = 0.9\ (x)(R/T)^{2/3}\ M/Z$$

Description	x	x
Welding tee	$(1/3.1)^{2/3}$	0.47
Unreinforced fabricated tee	1	1
Welded-in contour insert	$(1/3.1)^{2/3}$	0.47
Branch welded-on fitting	$(1/3.3)^{2/3}$	0.45
Pad Reinforced tee	Note 1	0.5
Extruded tee	Note 2	0.86

Note 1 – Assume $T_p = T$
Note 2 – Assume $r_x \approx d/8$

The same comparison was made for some of the NC components where noticeably different slopes existed for the i-factor curves.

The nomenclature used below will be that from this projct report and from 2007 BPVC Section III, Division 1 – NC-3500. [NC]

It seems reasonable that in all cases where the i-factors for both components are greater than 1, (or as it turns out for NC – 2.1), the unreinforced tee run i-factor would be greater than the B16.9 tee run i-factor since the UFT includes a weld and a sharper geometric "corner" along the intersection penetration line. Tested B16.9 tees in Markl's day also had average crotch and side-wall thicknesses equal to 1.6T, and so the nominal stress in the body away from the run girth weld drops considerably in the welding tee when compared to the UFT where the body thickness is everywhere = T.

For the NC-3673.2(b)-1 welding tee h=4.4t/r. ($t=t_n$ in NC and is the thickness of the matching pipe.)
For checking run legs of fabricated tees from Fig. NC-3673.2(b)-1: $i=0.8(R/T)^{2/3}(r/R)$; 2.1 minimum.
A point of interest in the parameter space exists when the i-factor for thru-run loads for the welding tee is equal to the i-factor for thru-run loads for the unreinforced fabricated tee.

For the welding tee if h is substituted into the equation for i:
NC-3673.2(b)-1 Welding tee $i = 0.9/h^{2/3}$; h=4.4t/r; $i=(0.9)/\ [\ (4.4)^{2/3}\ (R/T)^{2/3}]. = 0.335\ (R/T)^{2/3}$. There is no t/T factor in this equation since t/T is only included for the branch side equation. The unreinforced fabricated tee run stress intensification equation (UFT) i-factor gets smaller as r/R gets smaller.

Of interest is the occasion where the UFT will have an i-factor that is smaller than the welding tee and still within the parameter ranges for B31/NC and is in a practical B16.9 welding tee size range.

One point of interest in the parameter space is found where the run i-factor for the UFT and the WLT are the same: 0.8(r/R)=0.335; r/R = 0.335/0.8 = 0.418. At an r/R=0.418 a UFT appears to the NC-3673.2(b)-1 Code user as a component that is equally strong as a welding tee, and at r/R < 0.418 the UFT for thru-run moments shows to be a component that is stronger in fatigue than a B16.9 welding tee.

The ratio of the fabricated tee to B16.9 welding tee i-factor ratio for thru-run moments is:

i-factor(Fabricated Tee) / i-factor(B16.9 Tee) = 0.8(r/R) / 0.335

The lowest ratio occurs for the smallest value of r/R, which for B16.9 tees is approximately 0.25:

i-factor(Fabricated Tee) / i-factor(B16.9 Tee) = 0.8(r/R) / 0.335 = (0.8)(0.25) / 0.335 = 0.597

The question becomes whether the i-factor for a fabricated tee can be 60% of the i-factor for a welding tee, or if it is possible that this would provide incorrect design guidance.

When r/R=0.25, the fabricated tee i-factor is the minimum allowed of 2.1 when $R/T = [(2.1)/[(0.25)(0.8)]^{3/2} = 34.023$. The i-factor for the welding tee would be 0.335(34.023)2/3 = 3.517. At this point the B16.9 welding tee "peak" stress due to a thru-run load would be 3.517/2.1 = 1.67 times as high as the stress in a comparable fabricated tee of matching thickness.

An incorrect design could occur if the analyst mistakenly assumed that a fabricated tee would be as strong as a welding tee for loads through the run when $r/R \leq 0.418$ and assumed that fabricated tees might be less expensive or were more readily available.

In most cases in the nuclear industry this thought process is believed to be unlikely, although the potential for incorrect guidance could be corrected by providing a lower bound for the B16.9 welding tee i-factor that is equal to the i-factor for the fabricated tee. (This is what was done for rhis project since the equations and conditional requirements are more comprehensive.) It is believed that for nuclear power plant NC and ND piping systems most B16.9 ferrous and non-ferrous welding tees are closer to Markl B16.9 tees in thickness than they are to the PRG measured stainless welding tees and so there is little potential for confusion. Markl tees had an averaged sidewall and crotch thickness equal to 1.6 times the matching pipe thickness. PRG measured stainless B16.9 tees have a maximum tee body wall thickness of 99% of the nominal matching pipe wall. (See Annex A.)

ANNEX E - AUTOMATICALLY GENERATED TEST COMPARISON TABLES

This document contains automatically generated tables and charts using Microsoft Word and Microsoft Excel. Links to external data sets can result in changes to this document when it is opened if the references have changed. The comparisons to the ASME ST-LLC 07-02 project equations are also updated when the ST-LLC 07-02 Project equations are modified. ST-LLC 07-02 R70 equations and all reference equations are found in Annex G.

This document was produced so that:
1) All SIF and flexibility factor data suited for use to develop equations for branch connections in piping systems could be collected into one document along with all references to that data.
2) Notes that indicate the overall applicability of the equations could be provided along with the test data as further investigations are performed.
3) A mechanism could be provided that allows automatic regeneration of the tables and comparisons when either the test data is updated, (as is the case for the ref. 91 thickness data), or when the equations are updated.
4) Automatic comparisons between test data and the ST-LLC 07-02 equations could be made.
5) FEA data sets could be included and used for comparisons when in the test data format.

Links to produce this document include:
1) **"i_k_factors.xla"** – ASME 07-02 Branch Connection SIF and k-factor equations and all ancillary equations used to produce Wais/Widera/B31/NC and DNV comparison plots and tables.
2) **"K Test Data.doc"** – Collected flexibility factor test data
3) **"SIF Test Data.doc"** – Collected SIF test data
4) **"EQuft.xls"** – Comparison plots of i-factors for unreinforced fabricated tees
5) "**EQpad.xls**" – Comparison plots of i-factors for pad reinforced fabricated tees
6) "**EQtee.xls"** – Comparison plots of i-factors for welding tees
7) "**EQext.xls**" – Comparison plots of i-factors for extruded tees
8) "**EQolet.xls" –** Comparison plots of i-factors for integrally reinforced branch welded-on fittings
9) **"EQswp.xls**" – Comparison plots of i-factors for welded-in contour inserts
10) "**General Flexibility Test Data.xls**" – Comparison plots of flexibility factor test data

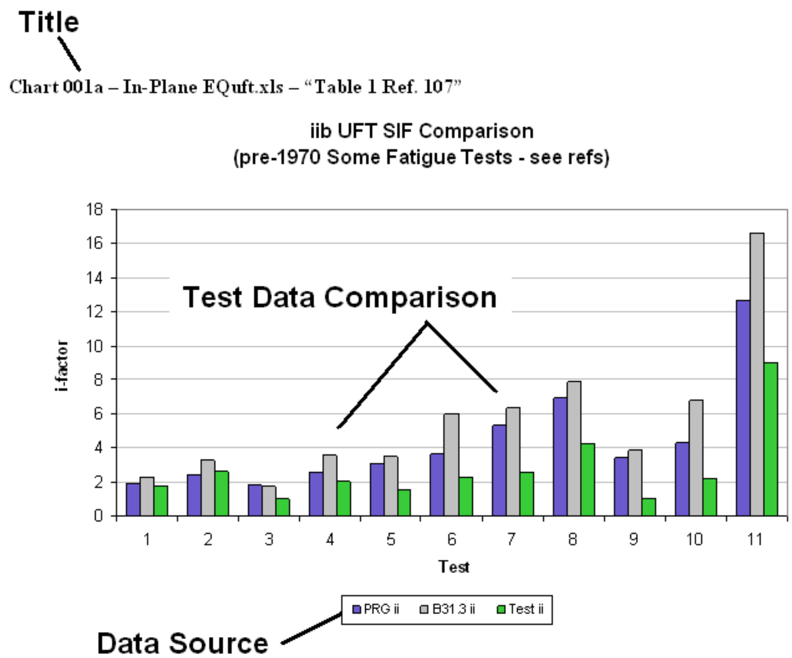
Considerable pertinent details for branch connection tests are provided in WRC 329 (ref. 54). Those details are not reproduced here.

When a reference is made to a "PRG" test or calculated result it refers to the applicable version of the ASME ST-LLC 07-02 project guidelines.

The collected i-factor (SIF) and k-factor test data is undergoing further review. It is anticipated that a final version of the data presented in Annex F will be released as a separate document and will include some additional flexibility factor data.

How to use this document:

Each comparison has a bar graph or plot of comparison values followed occasionally by additional notes and references that are used to produce the graph. Values referenced to B31, NC, NB, Wais or Widera are computed using the equations used in Annex G for the respective term. For example, in the iib table comparison below, the B31.3 iib equation used to produce the comparison values is found in Annex G Section 3.10 on p. 22.



The complete list of i-factor and k-factor references is found in Annex F. Those used for the test comparisons are extracted and printed below the table showing the comparison. Each unique test found in the literature has a separate row in the Annex F compilation. The "item #" in column 1 corresponds with the horizontal axis in the comparison table. Each test has a reference # that corresponds with the type of fitting tested. The reference number for each item in the comparison table is shown in column 2 below. The source of the test data is in the third column. All references are given in Annex J.

CHRT001

Cols:

1 2 3 4 5 6 7 8 9 10 11

Item #	#	Ref	ID	Do	T	do	t	Auxiliary Data	Results	Notes
1	3-37	80,94	20x12 UFT	20	1	12.75	0.687	Model R strain gage and fatigue tests on model R. N=80,000 S=6300 Fig.29 Ref93	iib=3.5/2 iob=8.6/2	See Line 2 in Table 3, WRC 329. Fatigue Test iob=3.9. See p.124 of Ref 94 for measured stress divided by 2 comparison with test i-factor.
2	3-38	80,94	20x20 UFT	20	1.	20	1.		iib=5.2/2 iob=5.3/2	
3	3-30	80,94	56x12 UFT	56	2.08	12.75	0.843	Strain gage extrapolation to fillet	iib=2.1/2 iob=3.8/2	s/S=0.46 iax=C2/2=4.6/2 Stress recorded in cylinder only
4	3-29	80,94	56x12 UFT	56	1.312	12.75	0.875	Strain gage extrapolation to fillet	iib=4.1/2 iob=6.2/2	s/S=0.29 ixx=C2/2 iax=C2/2=9.8/2=4.9 Stress recorded in cylinder only. Iax=F/A (See Note 2 Table 21 Ref 94). F=axial force A=2□rt. Axial iax provided for information when given in Table 21 from Ref 94.
5	3-36	80,94	48x6 UFT	48	0.625	6.625	0.28	Drawn? See WRC 60	iib=3.1 iob=4.4	
6	3-31	80,94	24x4 UFT	24	0.312	4.5	0.237	Strain gage extrapolation to fillet	Iib=4.5/2 iob=10./2	
7	3-32	80,94	24x12 UFT	24	0.313	12.75	0.250	Strain gage extrapolation to fillet	iib=5.1/2 iob=12./2	
8	3-33	80,94	24x24 UFT	24	0.312	24	0.312	Strain gage extrapolation to fillet	iib=8.4/2 iob=14./2	
9	3-34	80,94	36x4 UFT	36	0.375	4.5	0.375	Strain gage extrapolation to fillet	iib=2.1/2 iob=3.5/2	Ixx=C2/2 iax=C2/2=8.1/2
10	3-35	80,94	36x6 UFT	36	0.375	6.625	0.280	Strain gage extrapolation to fillet	iib=4.7/2 iob=10.5/2	Ixx=C2/2 iax=C2/2=16.7/2
11	3-39	80,94	24x12 UFT	24	0.1	12.75	0.1		iib=18/2 iob=90./2	WRC 108

CHRT001

Chart 001a – In-Plane EQuft.xlsm – "Table 1 Ref. 107"

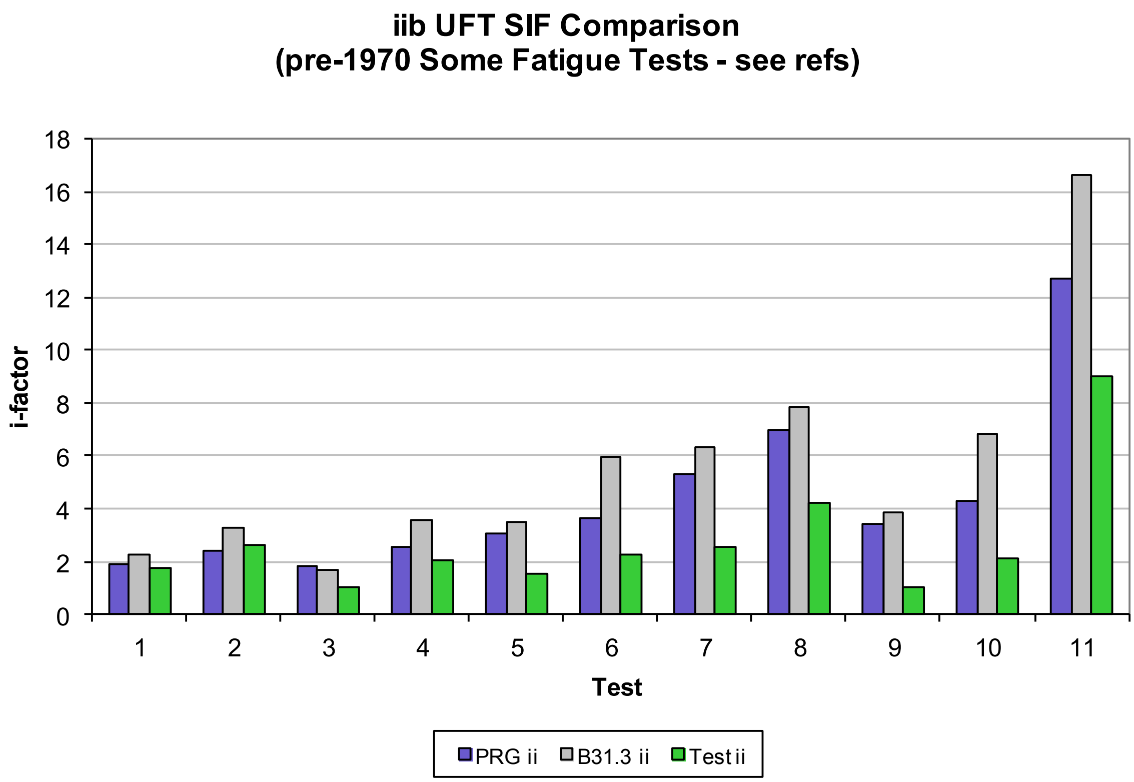


Chart 001b – Out-of-Plane EQuft.xlsm – "Table 1 Ref. 107"

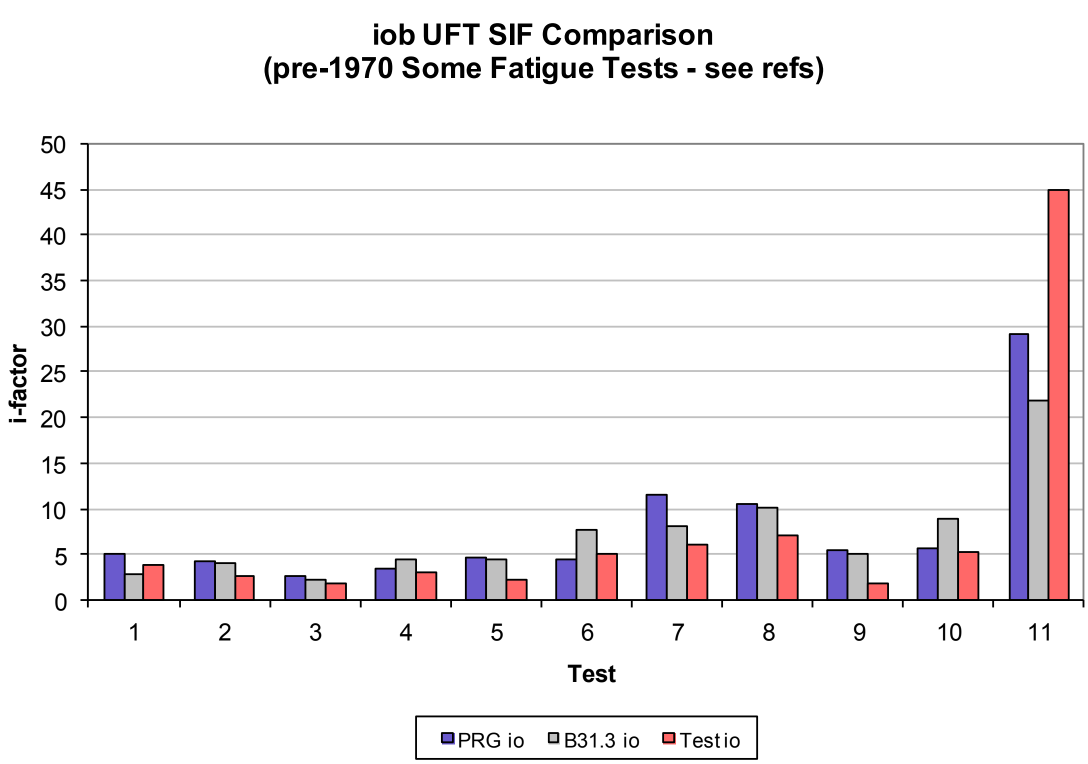


Chart 001 Notes:

1) Test 11 is from Riley, WRC 108. (ref.[34]).
2) Data above referenced as Table 1[, in "Stress Intensification Factors and Stress Indices for Sweepolets", E.C. Rodabaugh, Aug. 20, 1970, ref. [35][107]. The data is also reproduced and discussed in detail in the "Phase Report No. 5 on Stresses at Nozzles in Cylindrical Shells Loaded with Pressure, Moment or Thrust, December 22, 1967", E.C.Rodabaugh, T.J.Atterbury, ref.[7].

3) Some test data is taken from strain gage results extrapolated to the toe of the fillet weld. Test 11 is taken from WRC 108. Test 10 is not extrapolated. Tests 1 and 5 are believed to be drawn tees and not unreinforced fabricated tees.

4) Tests in Chart001 were conducted prior to 1967 and some were based on strain gage extrapolated results but were included here since they were used with 1960's review literature to evaluate i-factors in and around the release of Code Case 53.

5) Elastic results were obtained for model R and it was subsequently cycled. Model R is shown in Fig. 13 of WRC 329 and in Figure 32 of ref. [7]. The measured elastic stress location is at approximately the fatigue crack. (The fatigue crack occurred just above the weld.) The measured elastic stress divided by the nominal branch stress (M/Z) = 8.6. The test i-factor is 3.9. 8.6/3.9 = 2.2. This ratio tends to support the use of $i=C_2K_2/2$; $K_2=1$ as recommended in EPRI TR-110996.

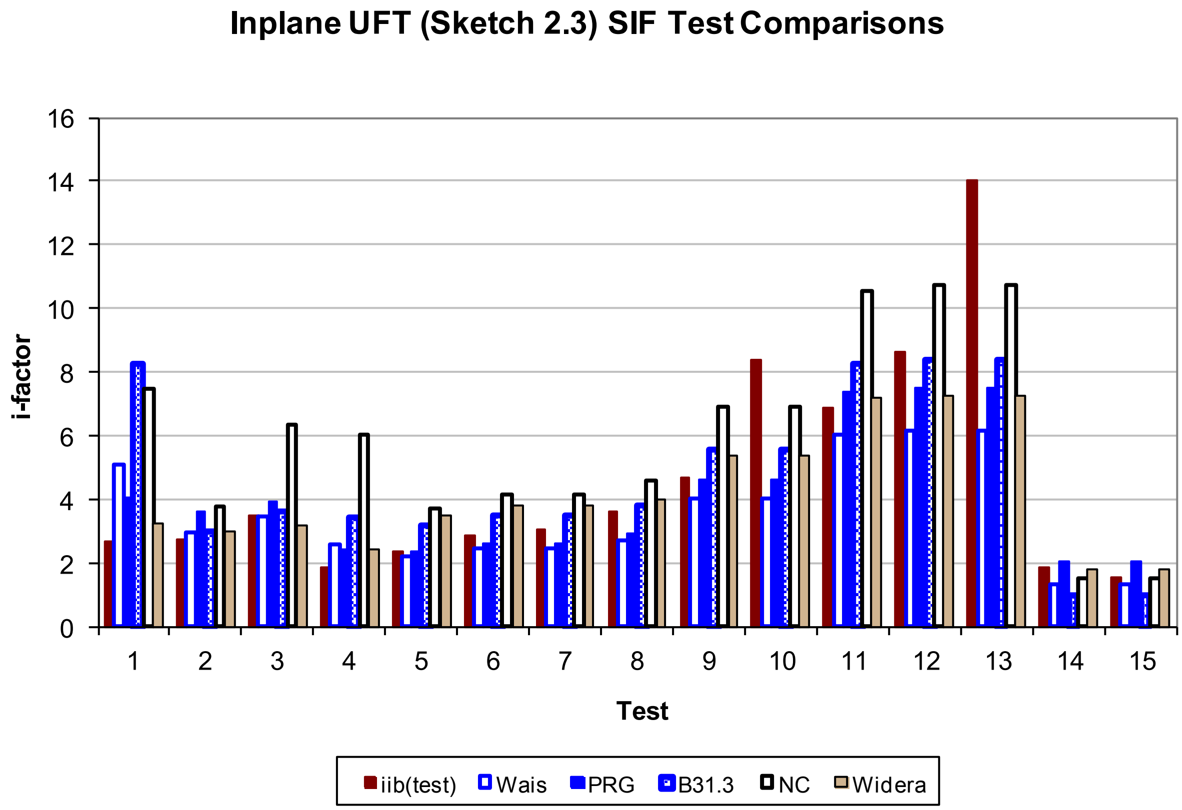
The electronically collected data from the 11 tests points given in Chart 001 is presented in the CHRT001 table below. These automatically generated tables are updated by Microsoft Word when this document is opened.

CHRT001

Item #	#	Ref	ID	Do	T	do	t	Auxiliary Data	Results	Notes
1	3-37	80,94	20x12 UFT	20	1	12.75	0.687	Model R strain gage and fatigue tests on model R. N=80,000 S=6300 Fig.29 Ref93	iib=3.5/2 iob=8.6/2	See Line 2 in Table 3, WRC 329. Fatigue Test iob=3.9. See p.124 of Ref 94 for measured stress divided by 2 comparison with test i-factor.
2	3-38	80,94	20x20 UFT	20	1.	20	1.		iib=5.2/2 iob=5.3/2	
3	3-30	80,94	56x12 UFT	56	2.08	12.75	0.843	Strain gage extrapolation to fillet	iib=2.1/2 iob=3.8/2	s/S=0.46 iax=C2/2=4.6/2 Stress recorded in cylinder only
4	3-29	80,94	56x12 UFT	56	1.312	12.75	0.875	Strain gage extrapolation to fillet	iib=4.1/2 iob=6.2/2	s/S=0.29 ixx=C2/2 iax=C2/2=9.8/2=4.9 Stress recorded in cylinder only. Iax=F/A (See Note 2 Table 21 Ref 94). F=axial force A=2∟rt. Axial iax provided for information when given in Table 21 from Ref 94.
5	3-36	80,94	48x6 UFT	48	0.625	6.625	0.28	Drawn? See WRC 60	iib=3.1 iob=4.4	
6	3-31	80,94	24x4 UFT	24	0.312	4.5	0.237	Strain gage extrapolation to fillet	Iib=4.5/2 iob=10./2	
7	3-32	80,94	24x12 UFT	24	0.313	12.75	0.250	Strain gage extrapolation to fillet	iib=5.1/2 iob=12./2	
8	3-33	80,94	24x24 UFT	24	0.312	24	0.312	Strain gage extrapolation to fillet	iib=8.4/2 iob=14./2	
9	3-34	80,94	36x4 UFT	36	0.375	4.5	0.375	Strain gage extrapolation to fillet	iib=2.1/2 iob=3.5/2	Ixx=C2/2 iax=C2/2=8.1/2
10	3-35	80,94	36x6 UFT	36	0.375	6.625	0.280	Strain gage extrapolation to fillet	iib=4.7/2 iob=10.5/2	Ixx=C2/2 iax=C2/2=16.7/2
11	3-39	80,94	24x12 UFT	24	0.1	12.75	0.1		iib=18/2 iob=90./2	WRC 108

CHRT001

Chart 002 - EQuft.xlsm – "Inplane Branch SIF Tests"



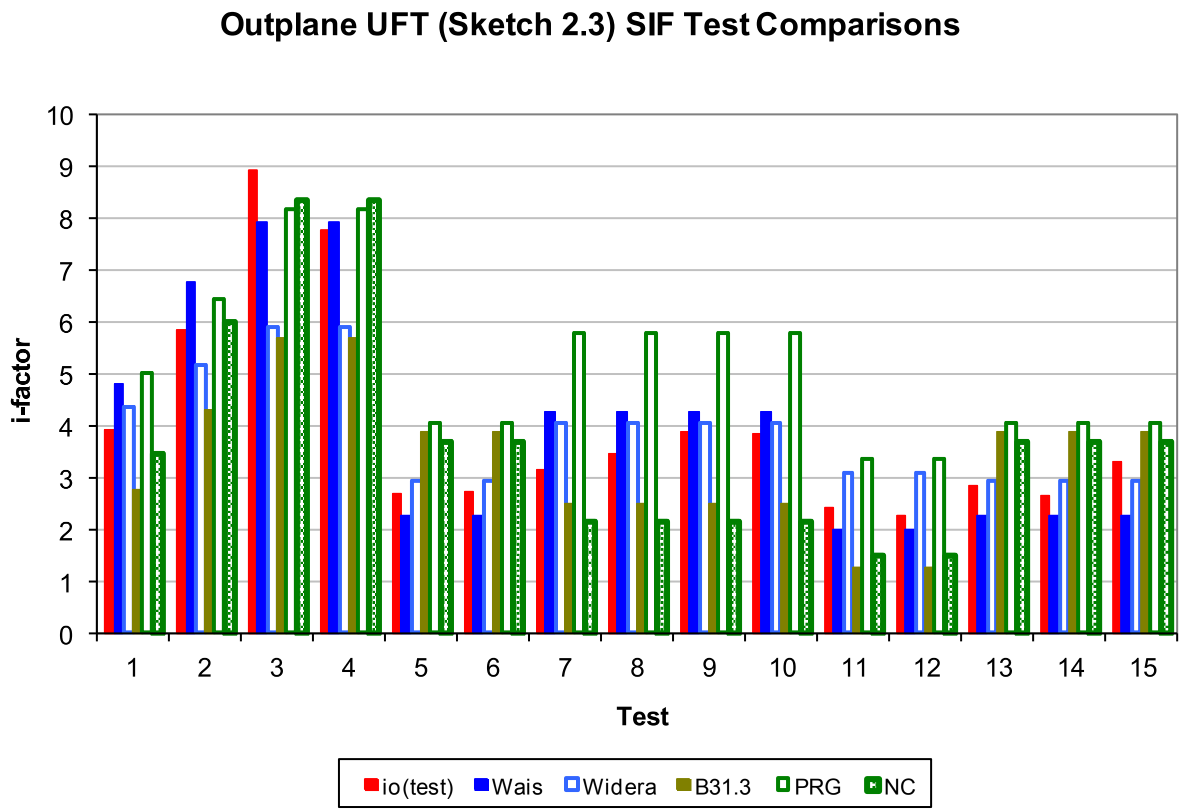
Notes:

1) Test 9/10 and 12/13 are the Markl thin walled 4" pipe tests. The thickness of the 4" pipe was 0.1" and 0.053 in. respectively. See references [25] through [29] for more details. The thicknesses of tests 14 and 15 are from EPRI TR-1006227 ref. 91 and are discussed in detail in more detail in Annex H.

CHRT001

Item #	#	Ref	ID	Do	T	do	t	Auxiliary Data	Results	Notes
1	3-52	84	20x4 UFT	19.803	0.239	4.0945	0.239		iib=2.67	R/T=41.4 r/R=0.197 t/T=1 Line 3 Table 3 WRC 329. Ref 84 is Decock model machined on outside and inside.
2	3-53	84	20x8 UFT	19.803	0.3937	7.4507	0.1969		iib=2.75	R/T=24.6 r/R=0.375 t/T=0.5 Line 4 Table 3 WRC 329. Ref 84 is Decock model machined on outside and inside.
3	3-54	84	20x14 UFT	19.803	0.3937	13.858	0.239		iib=3.47	R/T=24.6 r/R=0.702 t/T=0.6 Line 5 Table 3 WRC 329. Ref 84 is Decock model machined on outside and inside.
4	3-48	79	8x6 UFT	8.625	0.322	6.625	0.280	Nio=5410 Sio=7515	iib=1.85 iob=5.842	Line 1 & 2 Table 5 WRC 329
5	3-6	5	4x4 UFT	4.5	0.237	4.5	0.337	N=155,000 S=10,400	iib=2.158	Sch 40 Run Sch 80 Branch in Ref 5 Fig. 16.
5	3-7	5	4x4 UFT	4.5	0.237	4.5	0.237	N=3500 S=19,900	iib=2.407	Line 1 Table 2 WRC 329
5	3-8	5	4x4 UFT	4.5	0.237	4.5	0.237	N=4500 S=19,900	iib=2.289	Line 2 Table 2 WRC 329
5	3-9	5	4x4 UFT	4.5	0.237	4.5	0.237	N=7000 S=19,900	iib=2.096	Line 3 Table 2 WRC 329
5	3-10	5	4x4 UFT	4.5	0.237	4.5	0.237	N=8200 S=19,900	iib=2.030	Line 4 Table 2 WRC 329
5	3-11	5	4x4 UFT	4.5	0.237	4.5	0.237	N=25,000 S=13,000	iib=2.487	Line 6 Table 2 WRC 329
5	3-12	5	4x4 UFT	4.5	0.237	4.5	0.237	N=27,500 S=13,200	iib=2.403	Line 7 Table 2 WRC 329
5	3-13	5	4x4 UFT	4.5	0.237	4.5	0.237	N=28,000 S=15,700	iib=2.013	Line 5 Table 2 WRC 329
5	3-14	5	4x4 UFT	4.5	0.237	4.5	0.237	N=31,000 S=13,200	iib=2.346	Line 8 Table 2 WRC 329
5	3-15	5	4x4 UFT	4.5	0.237	4.5	0.237	N=32,000 S13,200	iib=2.331	Line 9 Table 2 WRC 329
5	3-16	5	4x4 UFT	4.5	0.237	4.5	0.237	N=86,000 S=10,000	iib=2.525	Line 10 Table 2 WRC 329
5	3-17	5	4x4 UFT	4.5	0.237	4.5	0.237	N=155,000 S=8800	iib=2.550	Line 11 Table 2 WRC 329
5	3-18	5	4x4 UFT	4.5	0.237	4.5	0.237	N=241,000 S=8500	iib=2.417	Line 12 Table 2 WRC 329
5	3-19	5	4x4 UFT	4.5	0.237	4.5	0.237	N=241,500 S=8600	iib=2.388	Line 13 Table 2 WRC 329
5	3-20	5	4x4 UFT	4.5	0.237	4.5	0.237	N=250,000 S=8700	iib=2.345	Not shown in Table 2 WRC 329
6	3-21	5	4x4 UFT	4.5	0.203	4.5	0.203	N=1600 S=19,400	iib=2.888	Line 14 Table 2 WRC 329
7	3-22	5	4x4 UFT	4.5	0.203	4.5	0.203	N=140,000 S=760	iib=3.014	Line 15 Table 2 WRC 329
8	3-51	83	6x6 UFT	6.625	0.265	6.625	0.265		iib=3.62	R/T=12, r/R=1, t/T=1, 5 tests (Ea. Test reported below. Blair vibration tests. Header ends pinned. Test pressurized to about 18,000 psi hoop stress. Tests run between 1936 and 1946.
9	3-24	5	4x4 UFT	4.5	0.100	4.5	0.100	N=150 S=20,600	iib=4.366	Line 16 Table 2 WRC 329
10	3-23	5	4x4 UFT	4.5	0.100	4.5	0.100	N=975 S=7850	iib=7.879	Line 17 Table 2 WRC 329. For these tests Markl states “The exploratory pairs of tests carried out with fittings of only 0.100 in. and 0.053 in. wall, on the other hand, do not fit too well, which might reflect the effect of the actual size of the intersection weld which could assume importance in view of the light wall.”
11	3-55	84	20x20 UFT	19.803	0.239	19.803	0.239		iib=6.90	R/T=41.4 r/R=1.0 t/T=1.0 Line 6 Table 3 WRC 329. Ref 84 is Decock model machined on outside and inside.
12	3-25	5	4x4 UFT	4.5	0.053	4.5	0.053	N=260 S=9500	iib=8.481	Line 18 Table 2 WRC 329
13	3-26	5	4x4 UFT	4.5	0.053	4.5	0.053	N=1350 S=4260	iib=13.605	Line 19 Table 2 WRC 329
14	3-44	91	8x2 UFT E	8.625	0.322	2.5	0.065	N=1919, Neq=535	iib=1.87	Mtr Tr=0.322 (Report Tr=0.188)
15	3-45	91	8x2 UFT F	8.625	0.322	2.5	0.065	N=2884 Neq=858	iib=1.54	Mtr Tr=0.322 (Report Tr=0.188)

Chart 003 - EQuft.xlsm – "Outplane Branch SIF Tests"



Notes:

1) Items 7 to 10 are associated both with the MTR issues described in Annex H, and the Hinnant-Paulin adjustment to i-factor equations described in Ref. [19] p.12. It is believed that the run pipe and wall thicknesses described for the item 7 to 10 tests are as reported below and in EPRI TR-110996.
2) The Ref [19] adjustment to the 7-to-10 Test items shown in the chart above are given below:

Item#	i	N	Hinnant K	i-adj	07-10(R70)
7	3.15	459	1.6871	5.3145	5.8
8	3.45	754	1.5775	5.4424	5.8
9	3.88	923	1.5349	5.9555	5.8
10	3.84	1816	1.4006	5.3782	5.8

CHRT003

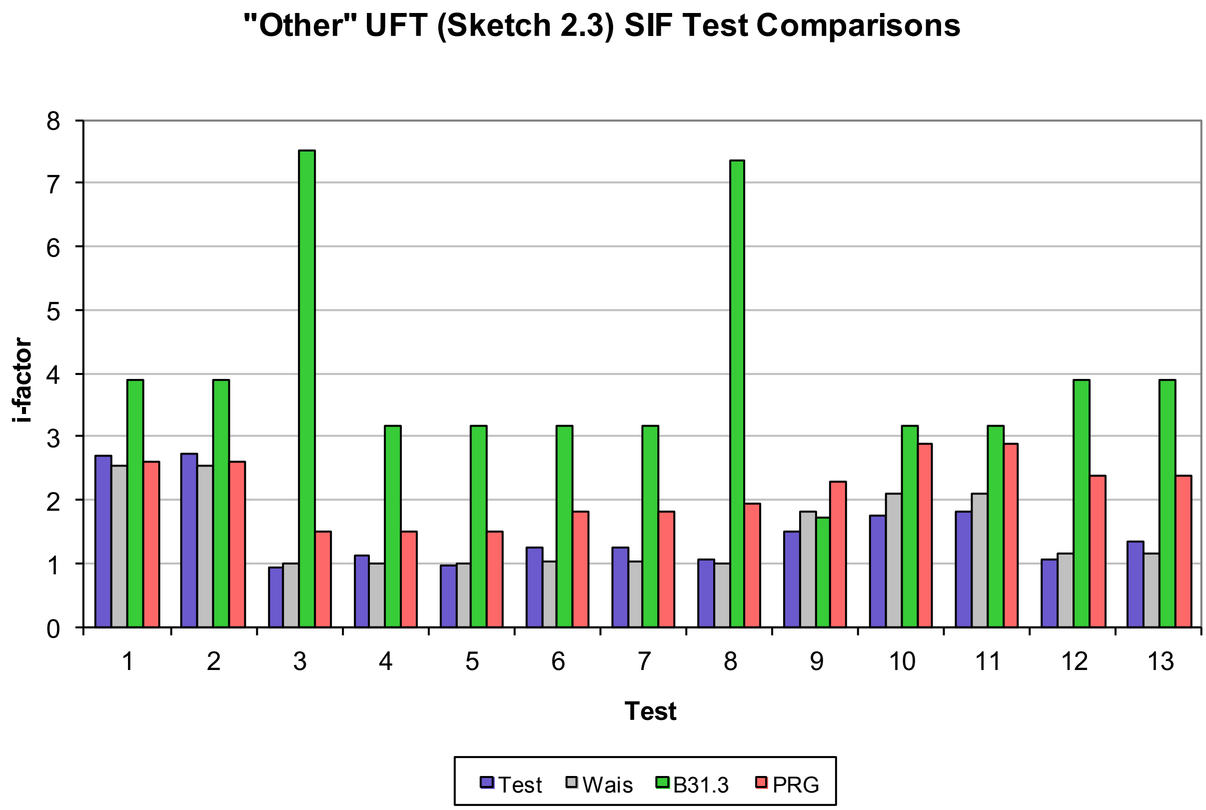
Item #	#	Ref	ID	Do	T	do	t	Auxiliary Data	Results	Notes
1	3-37	80,94	20x12 UFT	20	1	12.75	0.687	Model R strain gage and fatigue tests on model R. N=80,000 S=6300 Fig.29 Ref93	iib=3.5/2 iob=8.6/2	See Line 2 in Table 3, WRC 329. Fatigue Test iob=3.9. See p.124 of Ref 94 for measured stress divided by 2 comparison with test i-factor.
2	3-48	79	8x6 UFT	8.625	0.322	6.625	0.280	Nio=5410 Sio=7515	iib=1.85 iob=5.842	Line 1 & 2 Table 5 WRC 329
3	3-49	79	12x10 UFT	12.75	0.375	10.75	0.365	N=212 S=9399	iob=8.929	Line 3 Table 5 WRC 329
4	3-50	79	12x10 UFT	12.75	0.375	10.75	0.365	N=6130 S=5529	iob=7.745	Line 4 Table 5 WRC 329
5	3-28	5	4x4 UFT	4.5	0.237	4.5	0.237	N=77,000 S=9900	iob=2.608 itb=2.608	Line 21 Table 2 WRC 329 See Table 2.1 in 110996. Itb=iob. Isn't moment arm different in this case? Should this really be called a torsional load test?
6	3-27	5	4x4 UFT	4.5	0.237	4.5	0.237	N=6000 S=15,500	iob=2.775 itb=2.775	Line 20 Table 2 WRC 329 See Table 2.1 in 110996. Itb=iob. Isn't moment arm different in this case.
7	3-40	65	8x2 UFT A	8.625	0.188	2.5	0.065	N=459 S=22,800	iob=3.15	
8	3-41	65	8x2 UFT B	8.625	0.188	2.5	0.065	N=754 S=18,900	iob=3.45	
9	3-42	65	8x2 UFT C	8.625	0.188	2.5	0.065	N=923 S=16,100	iob=3.88	
10	3-43	65	8x2 UFT D	8.625	0.188	2.5	0.065	N=1816 S=14,200	iob=3.84	
11	3-46	91	8x2 UFT G	8.625	0.322	2.5	0.065	N=1168 Neq=546	iob=2.4	Mtr Tr=0.322 (Report Tr=0.188)
12	3-47	91	8x2 UFT H	8.625	0.322	2.5	0.065	N=1225 Neq=1225	iob=2.28	Mtr Tr=0.322 (Report Tr=0.188)
13	3-67	95	4x4 UFT	4.5	0.237	4.5	0.237	N=2835 S=35,2100	iob=2.84	D=1.44
14	3-68	95	4x4 UFT	4.5	0.237	4.5	0.237	N=3955 S=35,210	iob=2.66	D=1.44
15	3-69	95	4x4 UFT	4.5	0.237	4.5	0.237	N=23,370 S=19,830	iob=3.30	D=0.86"

The Equation from Ref. [19] to find the Hinnant-K used in the above table for the i-factor adjustment is:

$$K_{SIF} = \frac{1895\ ksi \cdot N^{-\frac{1}{2.982}}}{490 \cdot N^{-\frac{1}{5}}} = 3.867 \cdot N^{-0.135} \qquad (5)$$

It is believed that if a larger number of cycles were used for the items 7-to-10 testing, i-factors found by Ref [19] and by FEA would be realized, and that for these small d/D and t/T geometries, they would be closer to 6 than 4.

Chart 004 - EQuft.xlsm – "Other SIF Tests"



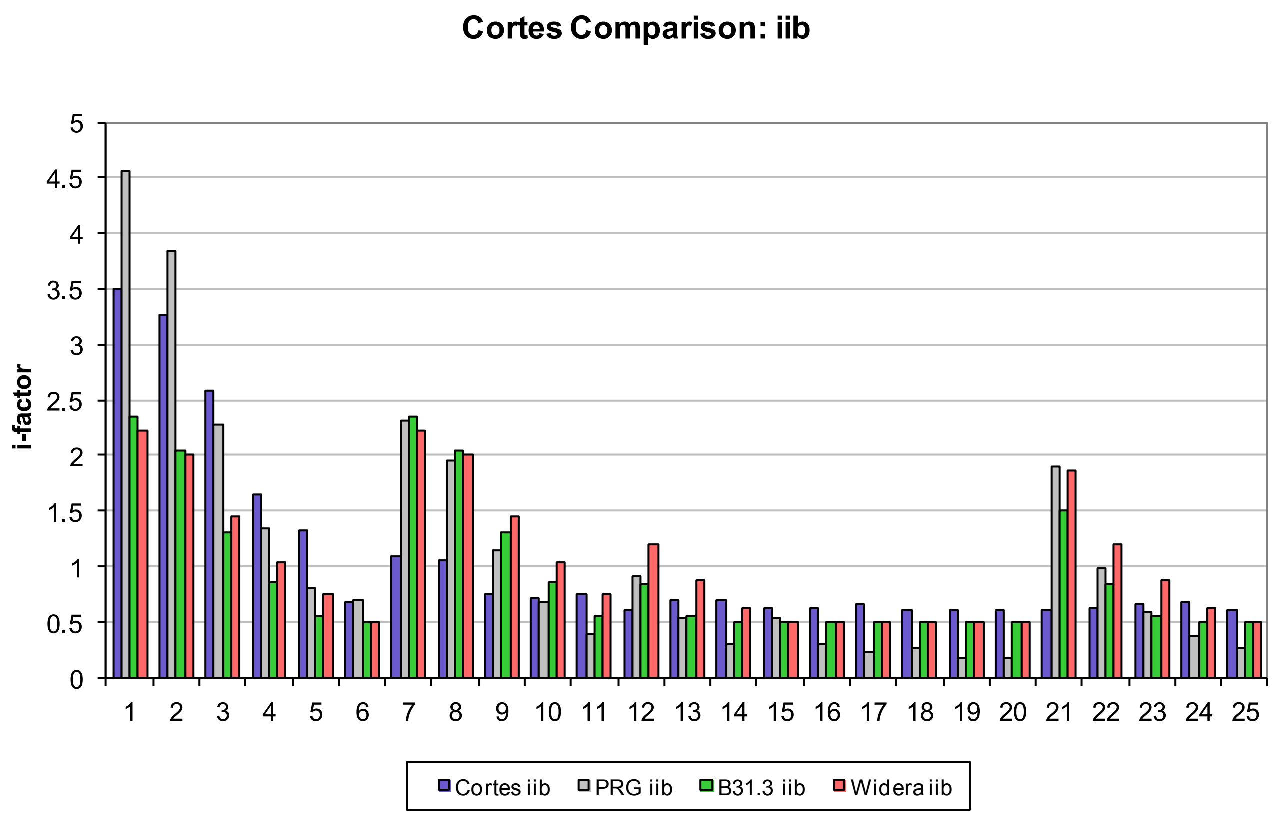
Notes:

1) Tests 1 and 2 in this group are Markl test where a torsional load is induced in the branch by applying a lateral load through the run.

CHRT004

Item #	#	Ref	ID	Do	T	do	t	Auxiliary Data	Results	Notes
1	3-28	5	4x4 UFT	4.5	0.237	4.5	0.237	N=77,000 S=9900	iob=2.608 itb=2.608	Line 21 Table 2 WRC 329 See Table 2.1 in 110996. Itb=iob. Isn't moment arm different in this case? Should this really be called a torsional load test?
2	3-27	5	4x4 UFT	4.5	0.237	4.5	0.237	N=6000 S=15,500	iob=2.775 itb=2.775	Line 20 Table 2 WRC 329 See Table 2.1 in 110996. Itb=iob. Isn't moment arm different in this case.
3	3-63	92	4x0.5 UFT	4.148	0.0612	0.5	0	N=370 S=40400	iir=1.86	
4	3-62	92	4x1 UFT	4.5	0.246	1.0	0.5	N=1246 S=52,100	iir<1.13	See WRC doc and add notes here.
5	3-51	83	6x6 UFT	6.625	0.265	6.625	0.265		iib=3.62	R/T=12, r/R=1, t/T=1, 5 tests (Ea. Test reported below. Blair vibration tests. Header ends pinned. Test pressurized to about 18,000 psi hoop stress. Tests run between 1936 and 1946.
6	3-58	92	4x1 UFT	4.533	0.234	1.0	0.1	N=2428 S=41,200	iir=1.25	
7	3-59	92	4x1 UFT	4.533	0.237	1.0	0.1	N=546 S=56,600	iir=1.23	
8	3-65	92	4x1 UFT	4.146	0.0599	1.0	0.11	N=1909 S=51600	iir=1.05	
9	3-64	92	4x1 UFT	4.138	0.0562	1.0	0.05	N=915 S=41,600	iir=1.51	
10	3-1	5	4x4 UFT	4.5	0.337	4.5	0.237	N=8500 S=23,000	iir=1.74	Line 22 Table 2 WRC 329. Markl added for UFTs that, "The data taken from Blair's paper fall well in line and also serve to indicate that it makes little difference, if any, whether the branch is set onto the run or into it."
11	3-2	5	4x4 UFT	4.5	0.237	4.5	0.337	N=120,000 S=13,000	Iir=1.82	Line 23 Table 2 WRC 329
12	3-3	5	4x4 UFT	4.5	0.237	4.5	0.237	N=6500 S=40,000	ior=1.06	Line 24 Table 2 WRC 329
13	3-4	5	4x4 UFT	4.5	0.237	4.5	0.237	N=320,000 S=14,500	ior=1.34	Line 25 Table 2 WRC 329

Chart 005a - EQuft.xlsm – "Cortes SIF Comparisons"



Notes:

1) Cortes FEA results are included in this survey because they were included in WRC 329 (ref. 54) and because it is believed that they played a role in the development of the BPVC Section III rules for branch connections. The Cortes results also provide estimates of i-factors for thru-run loading.

2) THE MAJORITY OF MODELS IN THIS SURVEY HAVE I-FACTORS LESS THAN 1.0

Cortes Model Data

	A	B	C	D	E	F	G	H	I	J	K	O	P	Q
1														
2														
3														
4		Note (2)								Note (1)				
5														
6		Model	D/T	d/D	t/T	di	t	tn	r/rp	factor		iob	itb	iib
7	1	UA	100	0.5	0.5							8.3	0.695	3.5
8	2	UB	80	0.5	0.5							7.525	0.66	3.27
9	3	UC	40	0.5	0.5							5.425	0.625	2.585
10	4	UD	20	0.5	0.5							2.885	0.695	1.64
11	5	UE	10	0.5	0.5							1.75	0.715	1.32
12	6	UF	10	0.08	0.08							0.635	0.51	0.68
13														
14	7	S1A	100	0.5	0.5	5	0.05	0.434	0.8606	0.8691		5.535	0.58	1.095
15	8	S1B	80	0.5	0.5	5	0.0625	0.5012	0.8434	0.8538		4.92	0.58	1.045
16	9	S1C	40	0.5	0.5	5	0.125	0.7838	0.7803	0.7994		2.82	0.585	0.755
17	10	S1D	20	0.5	0.5	5	0.25	1.224	0.7049	0.7385		1.405	0.58	0.71
18	11	S1E	10	0.5	0.5	5	0.5	1.9158	0.6228	0.6794		0.78	0.565	0.745
19	12	S1F	40	0.32	0.3[illegible]	3.2	0.08	0.64	0.7321	0.7500		1.28	0.53	0.61
20	13	S1G	20	0.32	0.32	3.2	0.16	0.988	0.6491	0.6801		0.715	0.535	0.685
21	14	S1H	10	0.32	0.32	3.2	0.32	1.5236	0.5635	0.6147		0.695	0.525	0.685
22	15	S1I	40	0.16	0.16	1.6	0.04	0.4694	0.6460	0.6617		0.62	0.51	0.615
23	16	S1J	20	0.16	0.16	1.6	0.08	0.7128	0.5553	0.5817		0.63	0.51	0.625
24	17	S1K	10	0.16	0.16	1.6	0.16	1.0788	0.4684	0.5110		0.665	0.515	0.66
25	18	S1L	40	0.08	0.08	0.8	0.02	0.3446	0.5506	0.5641		0.61	0.505	0.61
26	19	S1M	20	0.08	0.08	0.8	0.04	0.5158	0.4586	0.4805		0.605	0.505	0.605
27	20	S1N	10	0.08	0.08	0.8	0.08	0.7238	0.3915	0.4271		0.605	0.51	0.6
28								X Note (3)	T Note (3)	rp Note (3)	factor Note (3)			
29	21	P30A	100	0.32	0.32	3.2	0.032	0.4298	0.1	2.0009	0.8156	1.86	0.54	0.595
30	22	P30B	40	0.32	0.32	3.2	0.08	0.6796	0.25	2.2074	0.7611	0.92	0.54	0.62
31	23	P30C	20	0.32	0.32	3.2	0.16	0.9611	0.5	2.4168	0.7282	0.695	0.535	0.66
32	24	P30D	10	0.32	0.32	3.2	0.32	1.3593	1	2.6706	0.7189	0.665	0.525	0.675
33	25	P30E	10	0.08	0.08	0.8	0.08	0.6796	1	0.7909	0.6069	0.6	0.505	0.6

36	
37	Note (1) The PRG SIF function for Sketch 2.3 includes the r/rp term for iob as (di+t)/(di+2t). For the Model Types S, the multiplier should be the actual r/rp term. To
38	get this term from the existing PRG SIF function, the function multiplier (di+t)/(di+2t) must be multiplied by (di+2t)/(di+2tn), which is "factor".
39	
40	Note (2) Data taken from ORNL/NUREG 4. iob, itb and iib are from Sbar/2.
41	
42	Note (3) X and T are taken from Table 5 in ORNL/NUREG 4. rp is calculated from di/2 + X - T/2tan30. 30 deg is used for the hub angle for all P30 models.
43	The factor is (di+2t)/(2rp), since this must be multiplied by the PRG_BR_io function to effect the r/rp term in the standard function.
44	
45	Note (4) Sbar from Cortes is the outside surface stress from the brick finite element analysis on the program Cortes. All intersections have r2 defined. See NUREG 4.

Notes:

1) The Cortes model data can be found in WRC 329 (ref. [1]), and in Bryson's "Stresses in Reinforced Nozzle-Cylinder Attachments Under Internal Pressure Loading Analyzed by the Finite Element Method – A Parameter Study," (ref [31]).

Chart 005b - EQuft.xlsm – "Cortes SIF Comparisons"

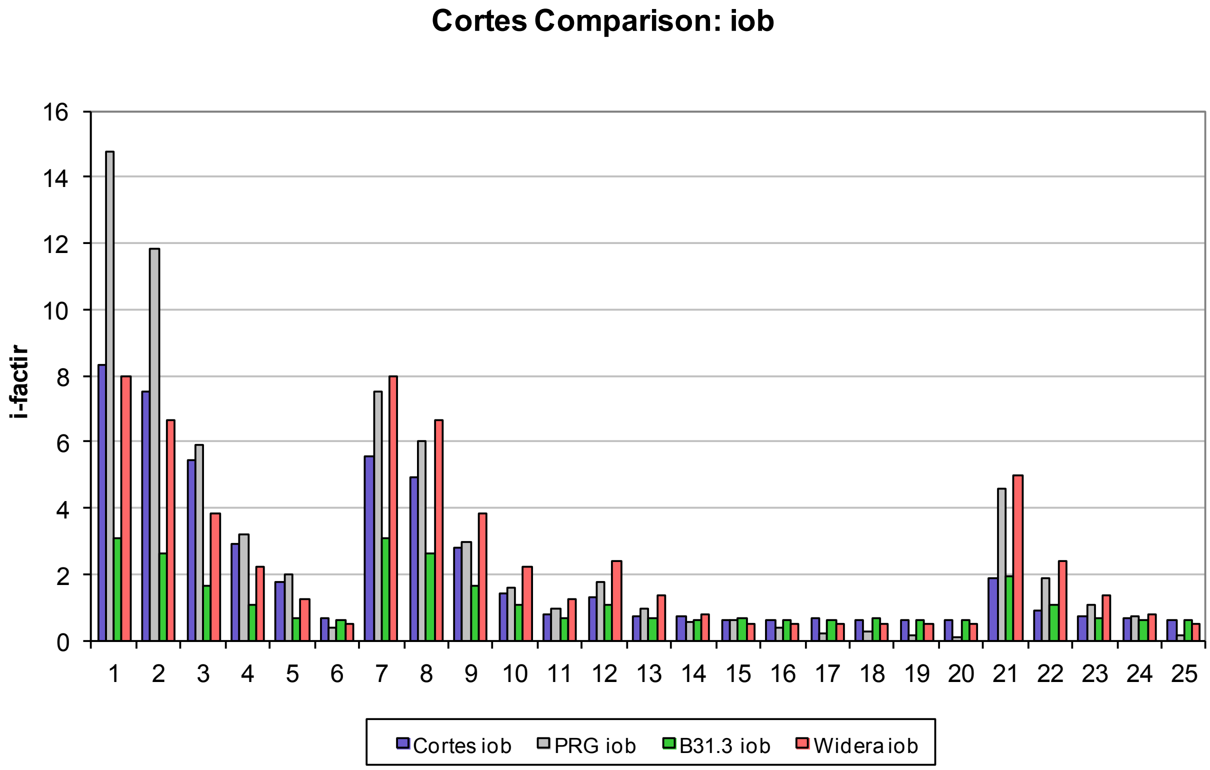


Chart 005c - EQuft.xlsm – "Cortes SIF Comparisons"

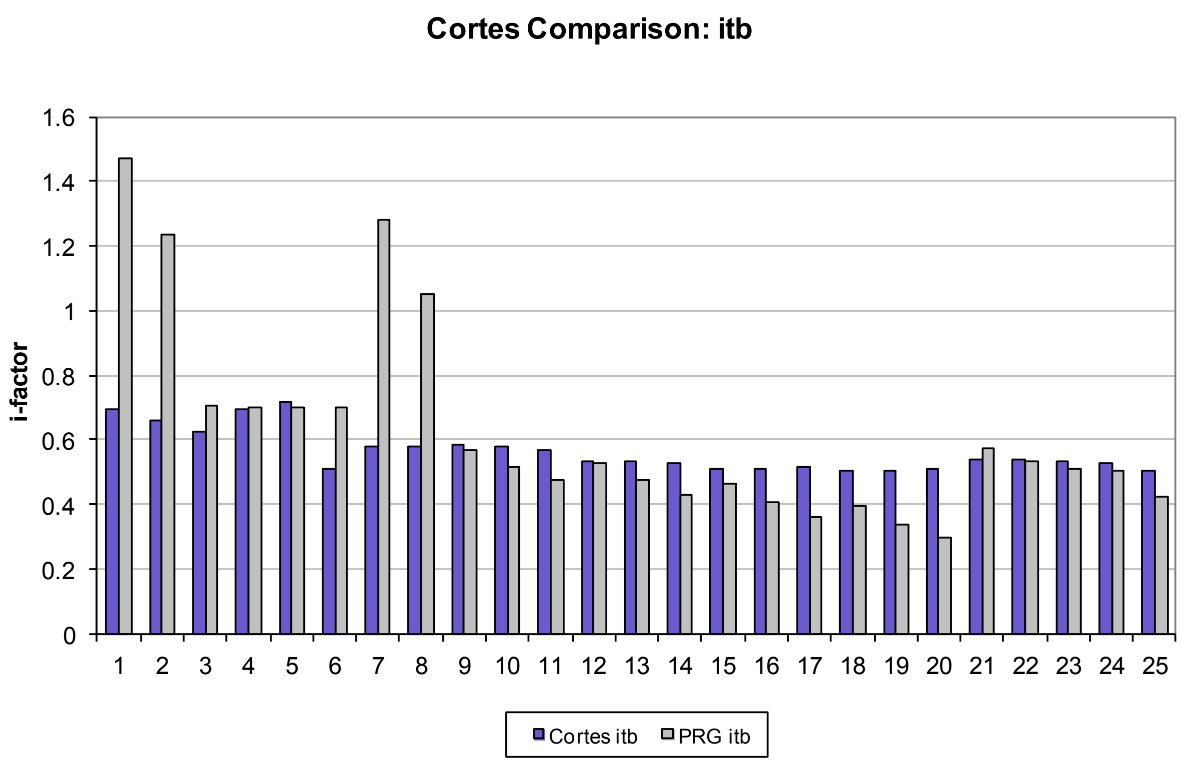


Chart 005d - EQuft.xlsm – "Cortes SIF Comparisons"

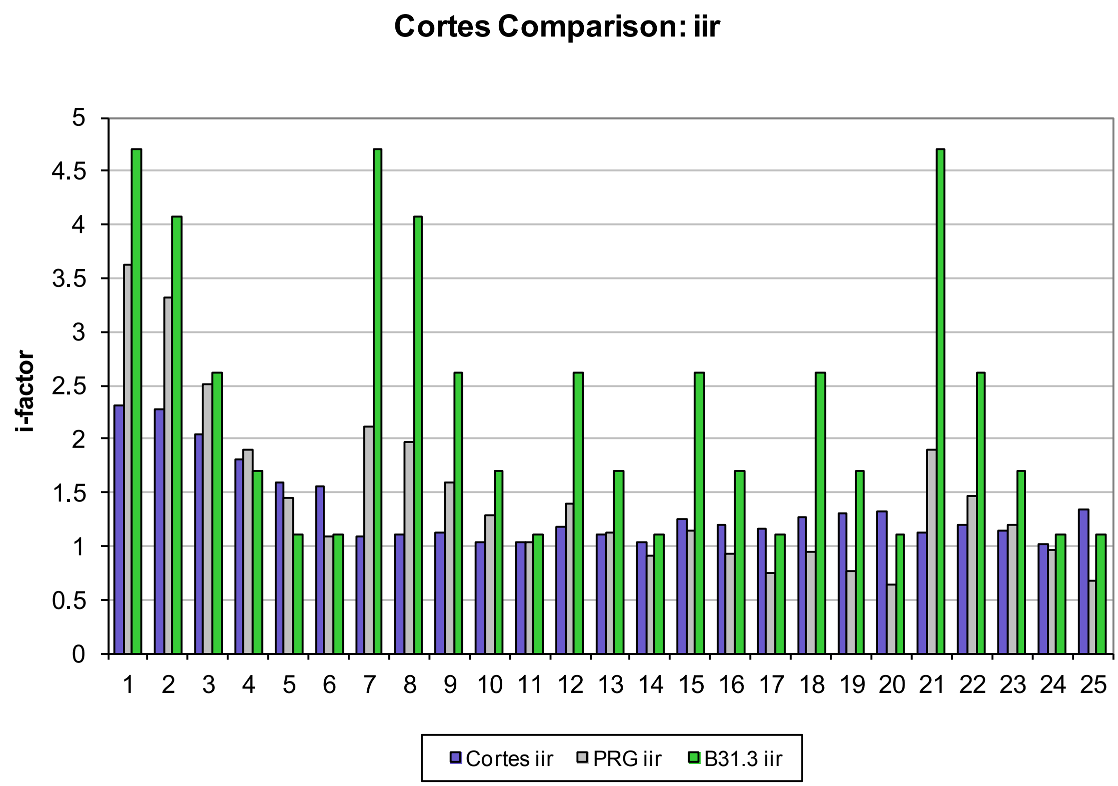


Chart 005e - EQuft.xlsm – "Cortes SIF Comparisons"

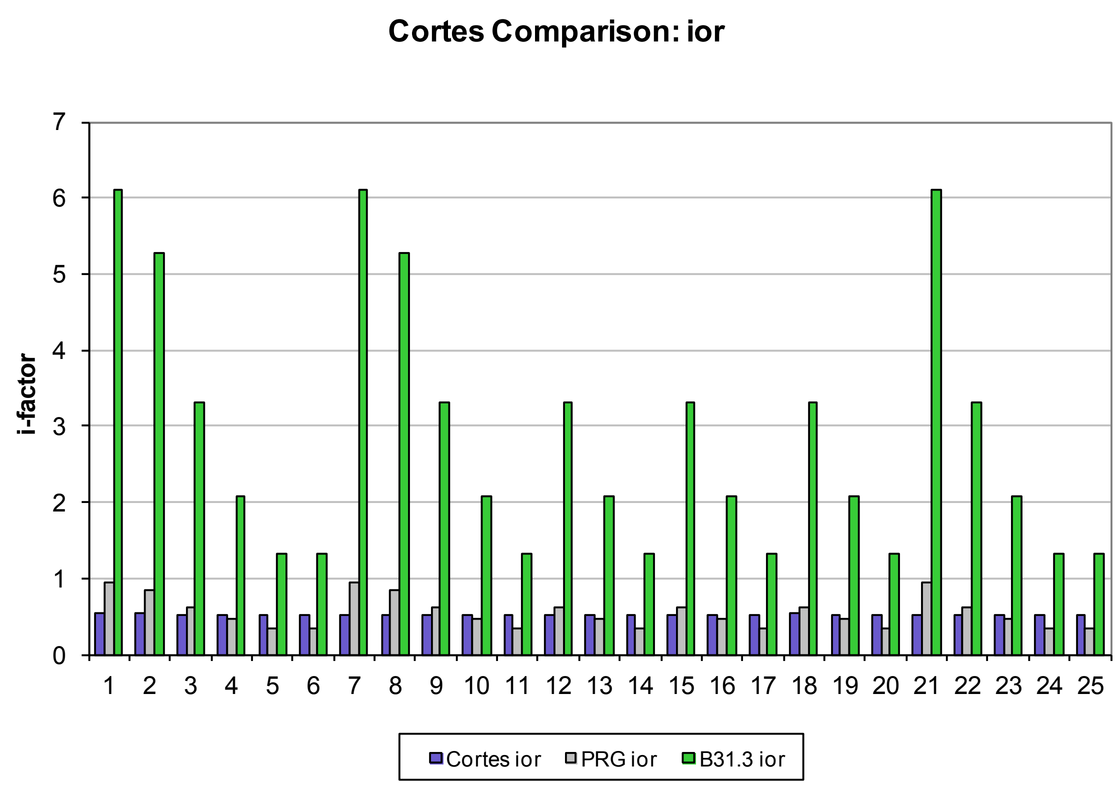


Chart 005f - EQuft.xlsm – "Cortes SIF Comparisons"

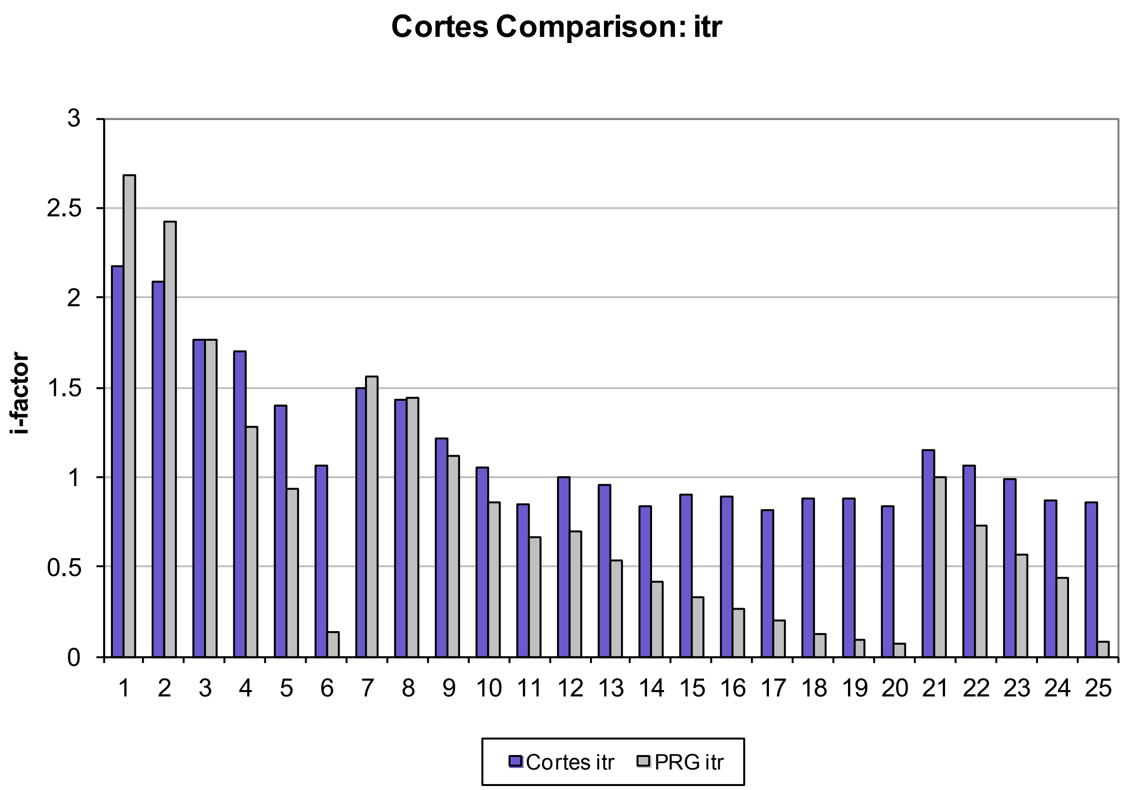


Chart 006a - EQuft.xlsm – "Cortes k-factor Comparisons"

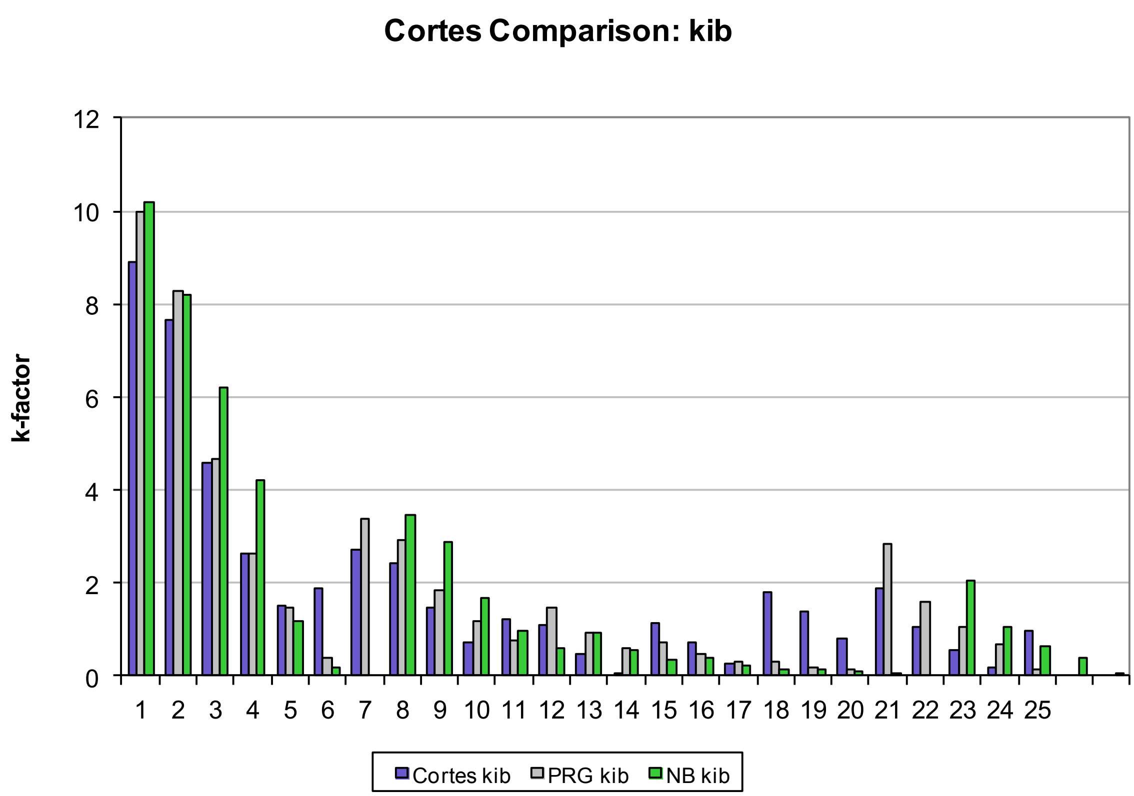
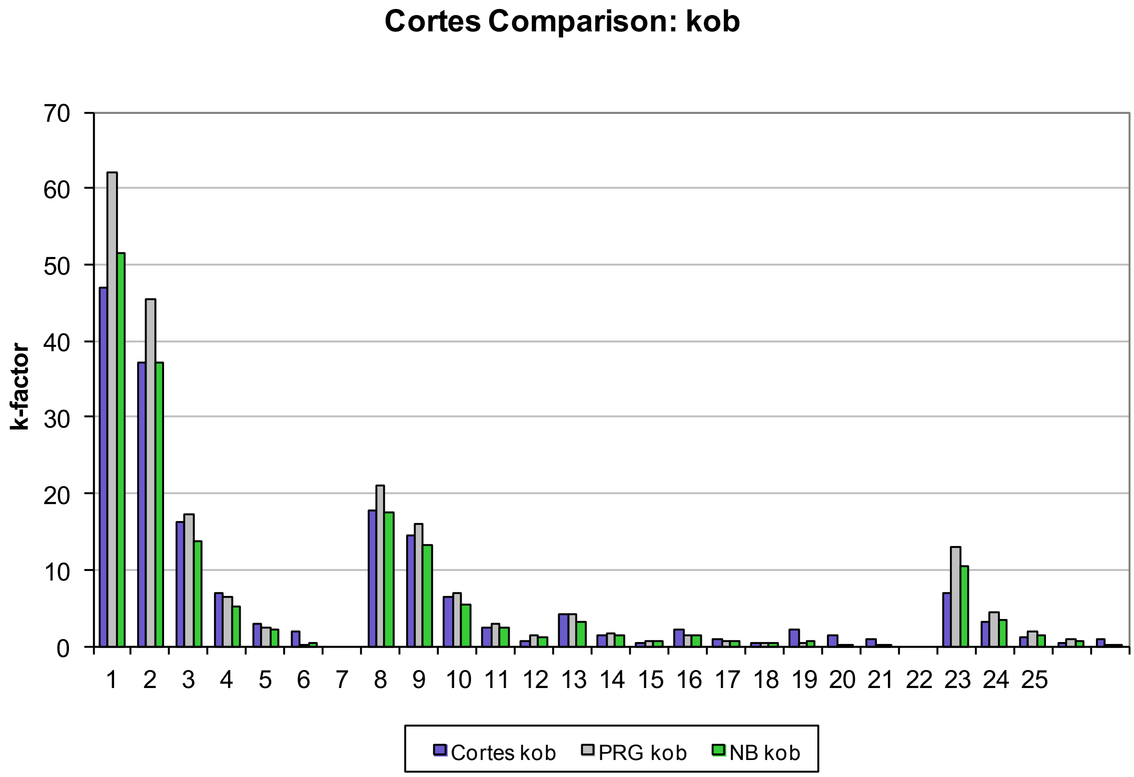


Chart 006b - EQuft.xlsm – "Cortes k-factor Comparisons"



Some FEA Comparisons:

Charts 007 through 019 show a comparison of a variety of FEA runs compared to various methods. The FEA results are produced using shell FEA models as described in Wais [2] and Widera [14], Part 3. Lengths in the FEA models were developed following the guidelines suggested by Widera. For each model t/T=1. Equations used to develop each point in the curves below are found in Annex G. For example, the B31.3 io equation used in Chart 007 on the following page is found in Annex G Section 3.10 on p. 22. ST-LLC-07-02 SIF and k-factor equations for each branch connection given in Table 1 of Annex A is also given in Annex G in the major section labels. For example, the ST-LLC 07-02 io equation used in Chart 007 is found in Annex G Section 3.1 on p. 12.

The Charts 007 through 019 show how the expressions developed by Wais [2], Widera [14], Part 3, and for the ST-LLC-07-02 project show similar trends for the directional i-factor and k-factor components for both run and branch side loadings.

Chart 007 - EQuft.xlsm – "DoT=50 doD=.04-1"

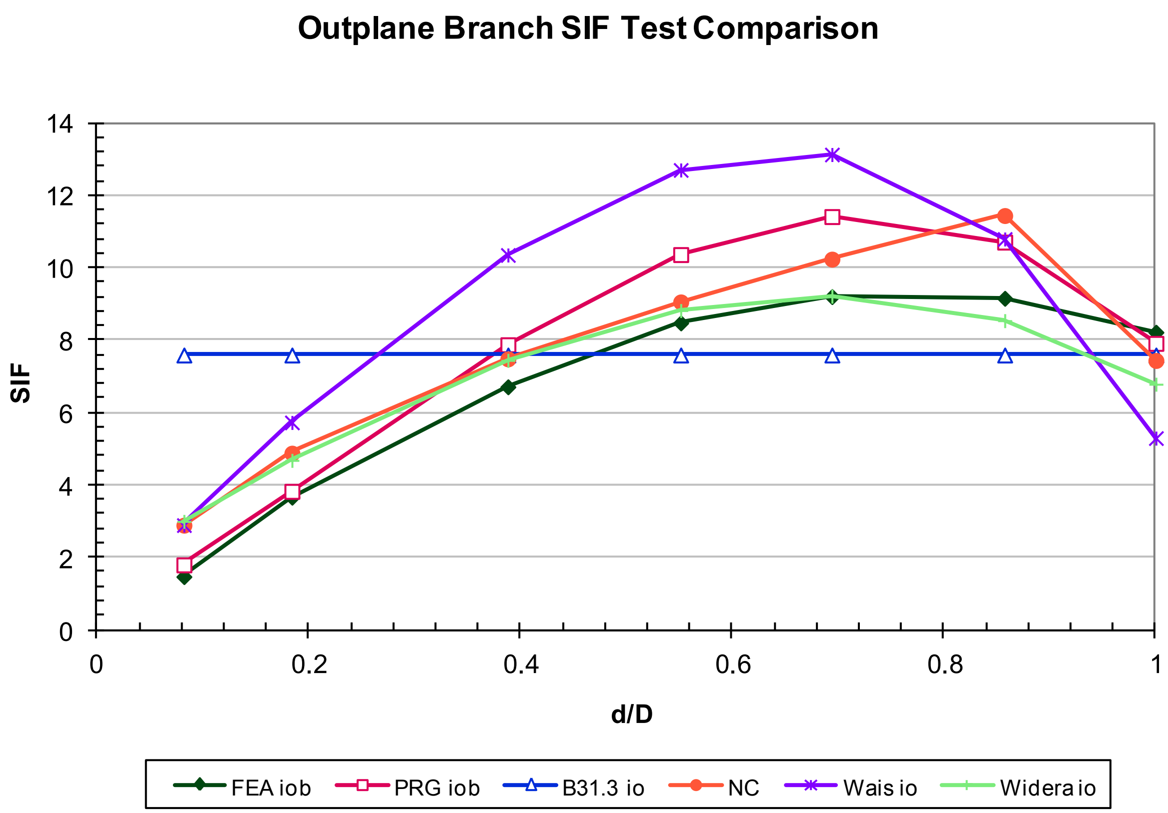


Chart 008 - EQuft.xlsm – "DoT=50 doD=.04-1"

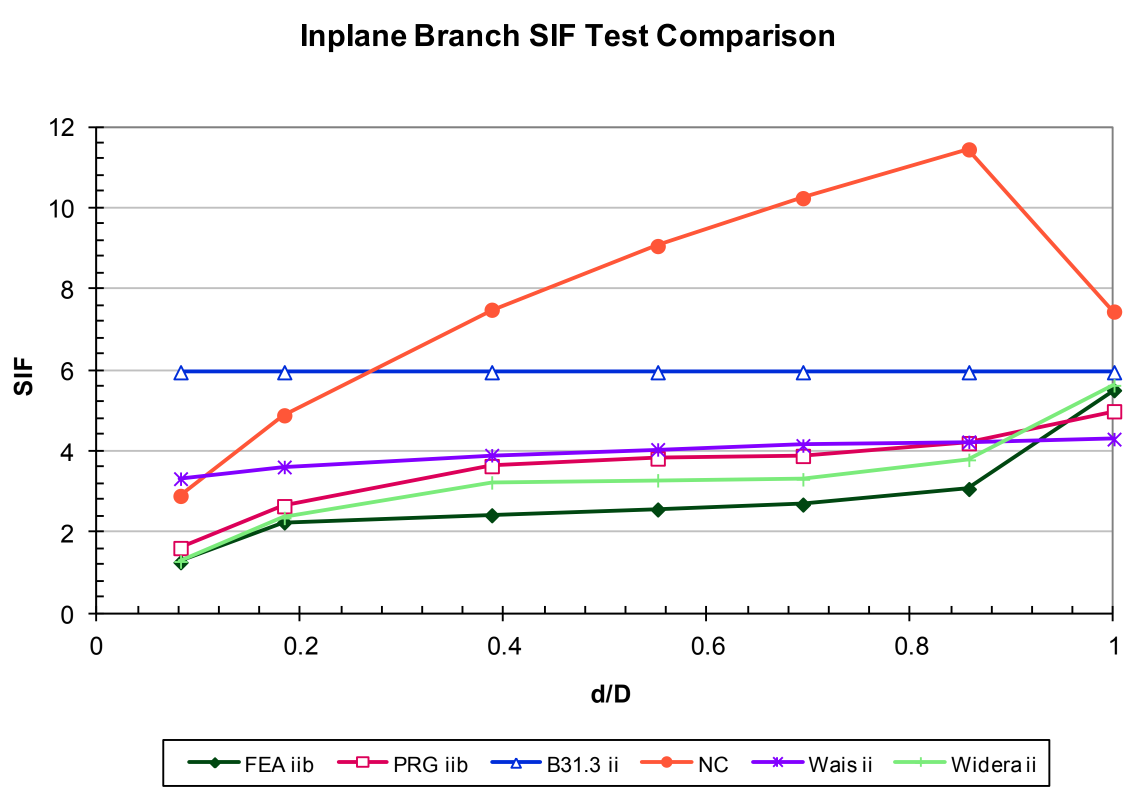


Chart 009 - EQuft.xlsm – "DoT=50 doD=.04-1"

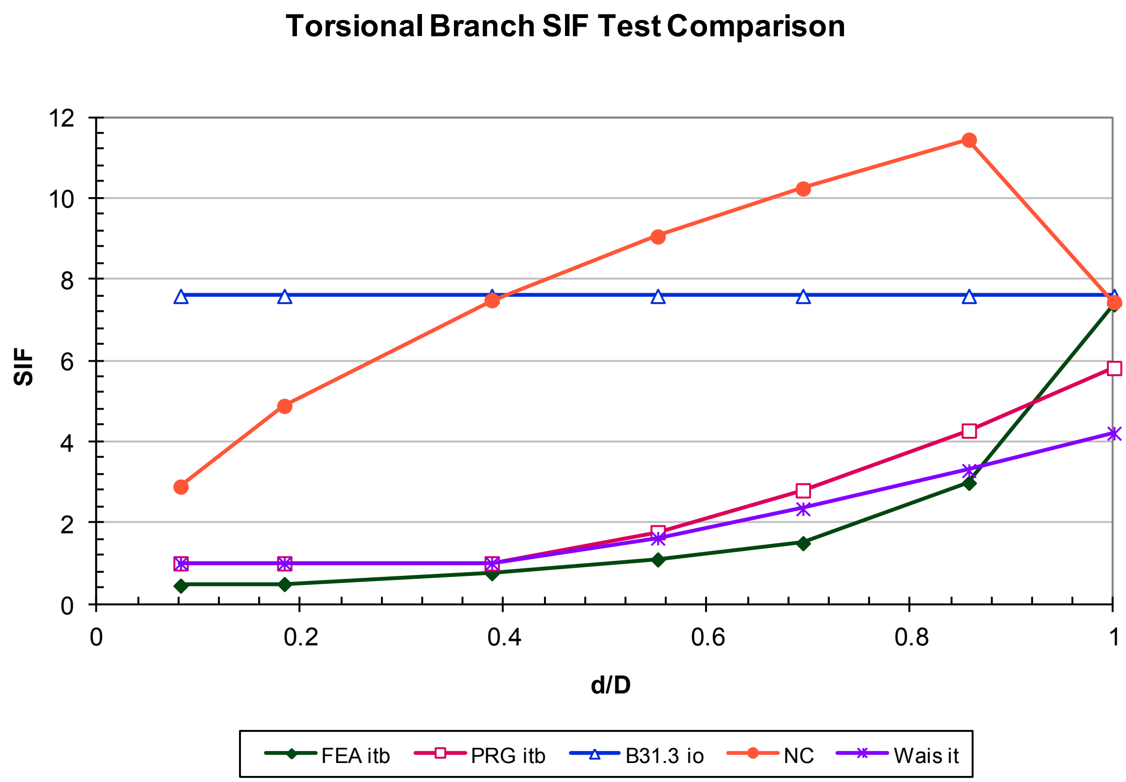


Chart 010 - EQuft.xlsm – "DoT=50 doD=.04-1"

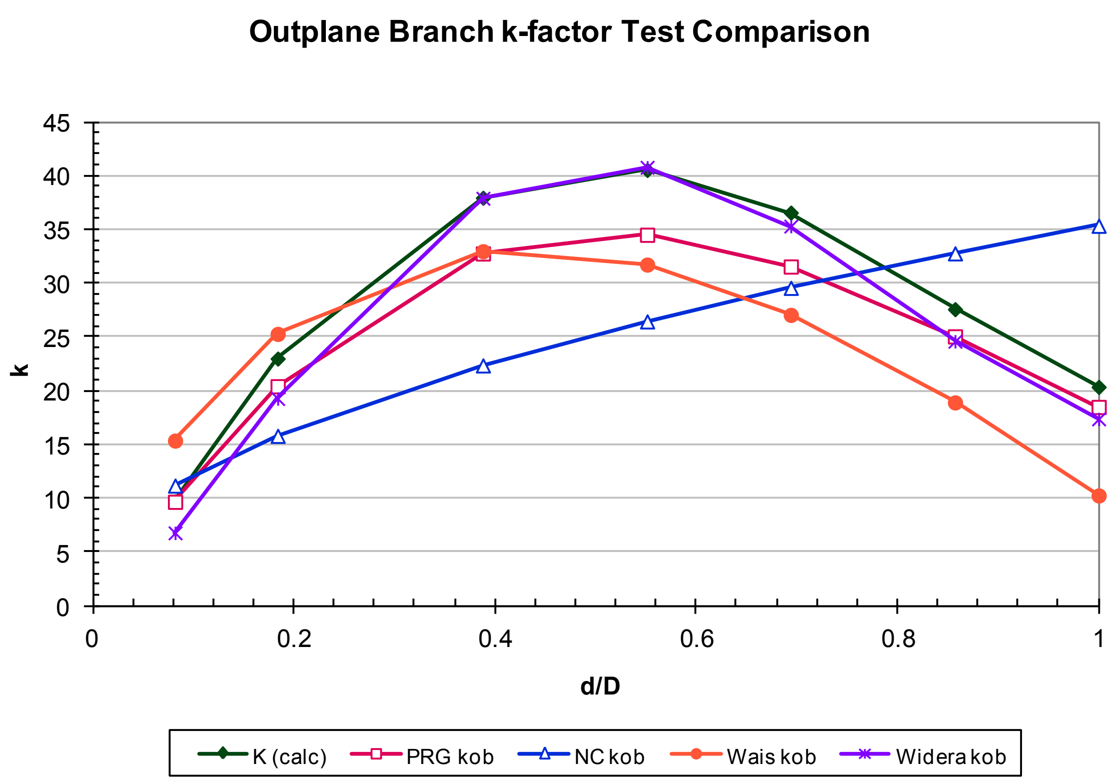


Chart 012 - EQuft.xlsm – "DoT=50 doD=.04-1"

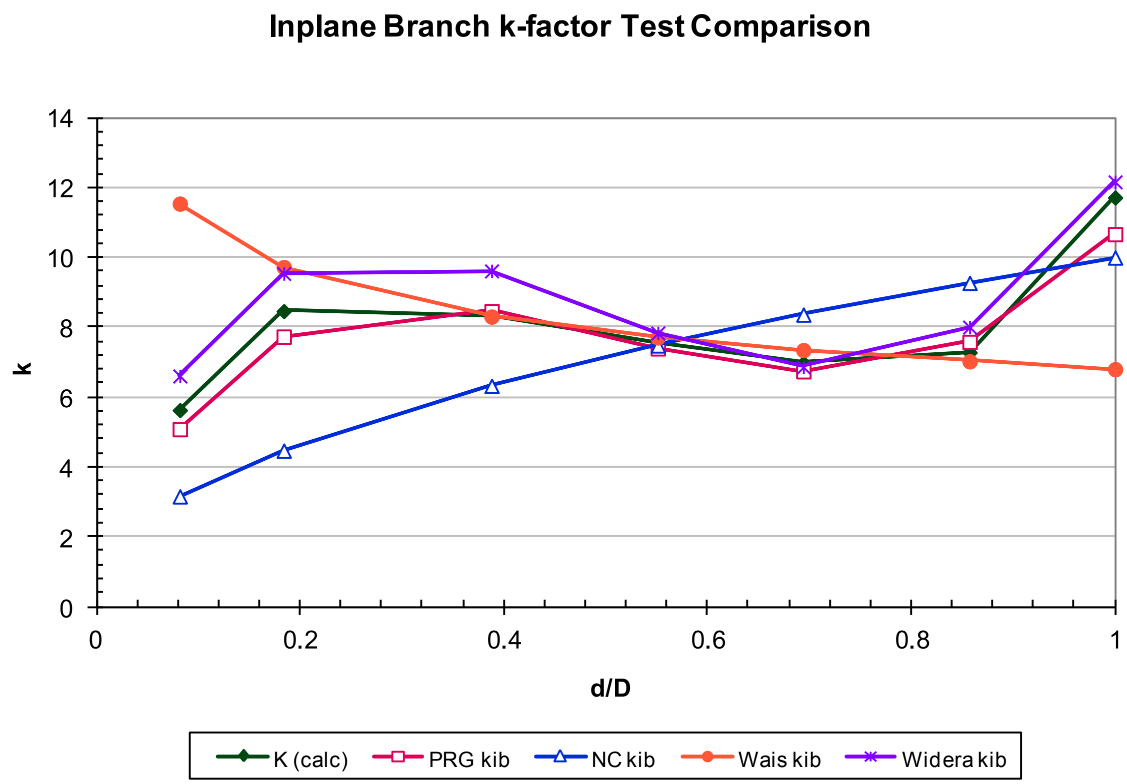


Chart 013 - EQuft.xlsm – "DoT=50 doD=.04-1"

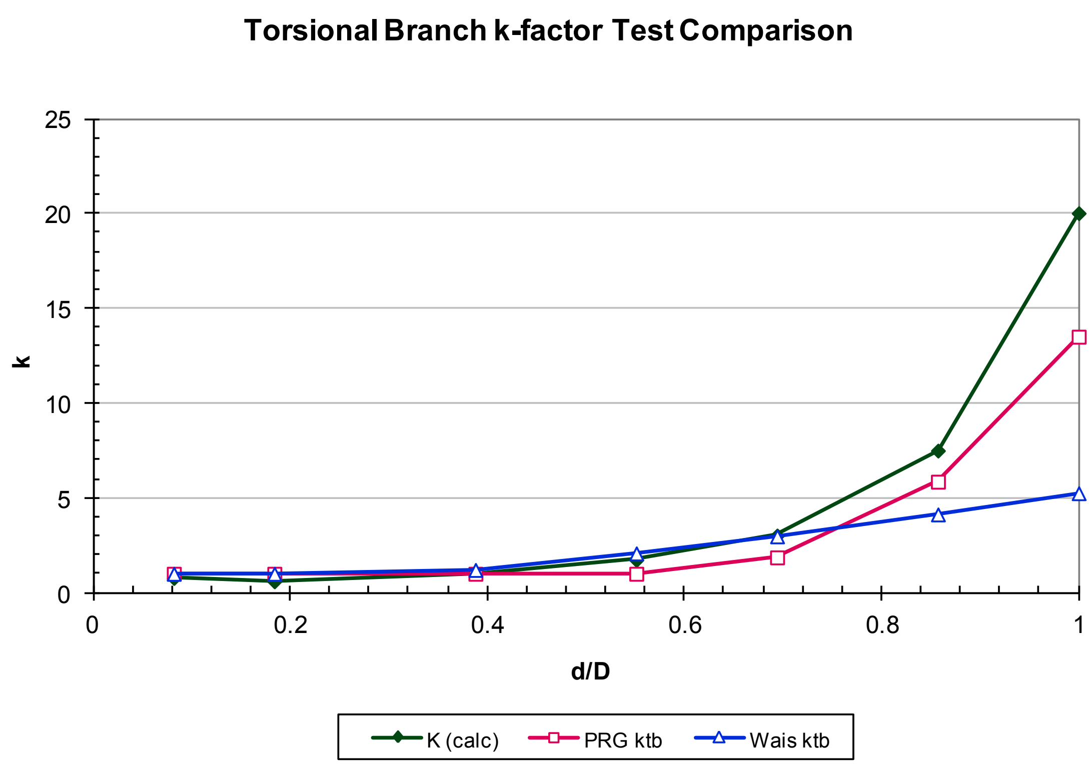


Chart 014 - EQuft.xlsm – "DoT=50 doD=.04-1"

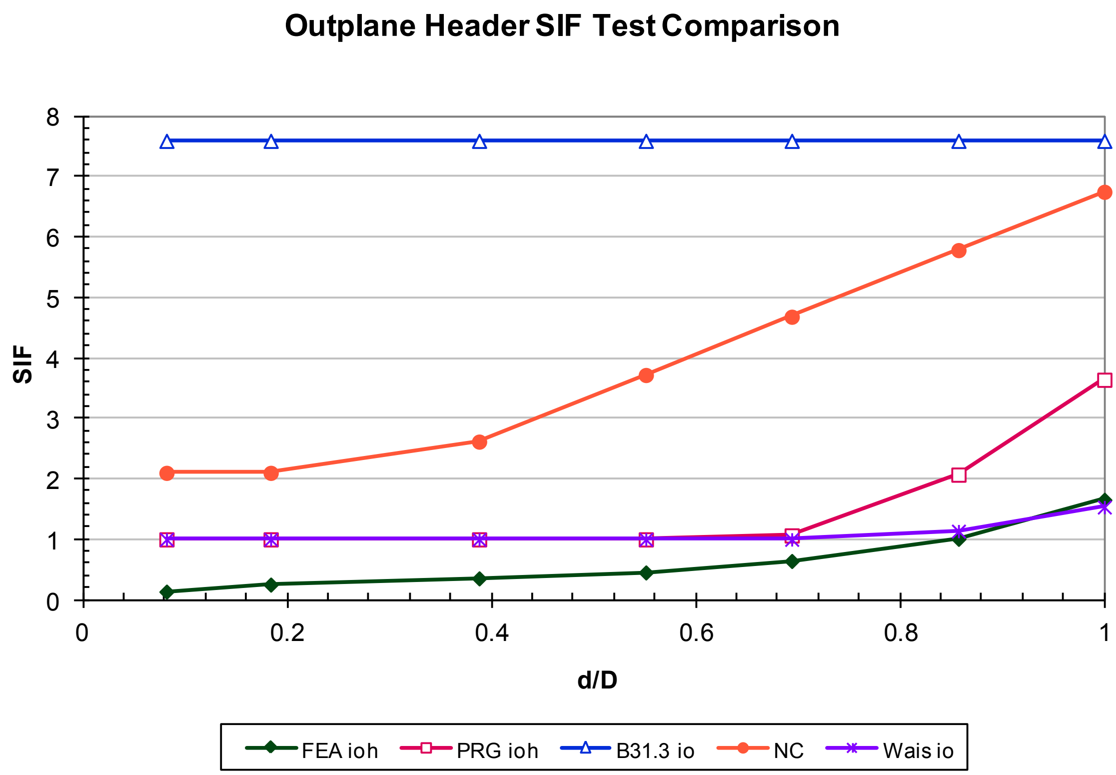


Chart 015 - EQuft.xlsm – "DoT=50 doD=.04-1"

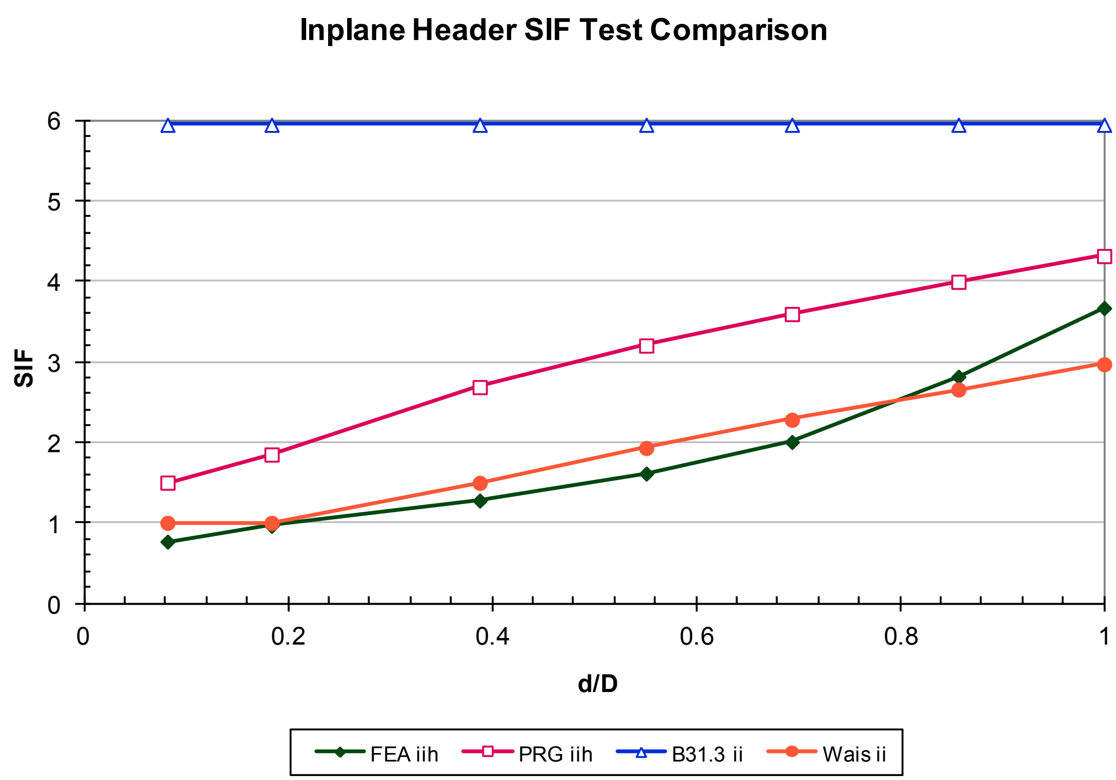


Chart 016 - EQuft.xlsm – “DoT=50 doD=.04-1”

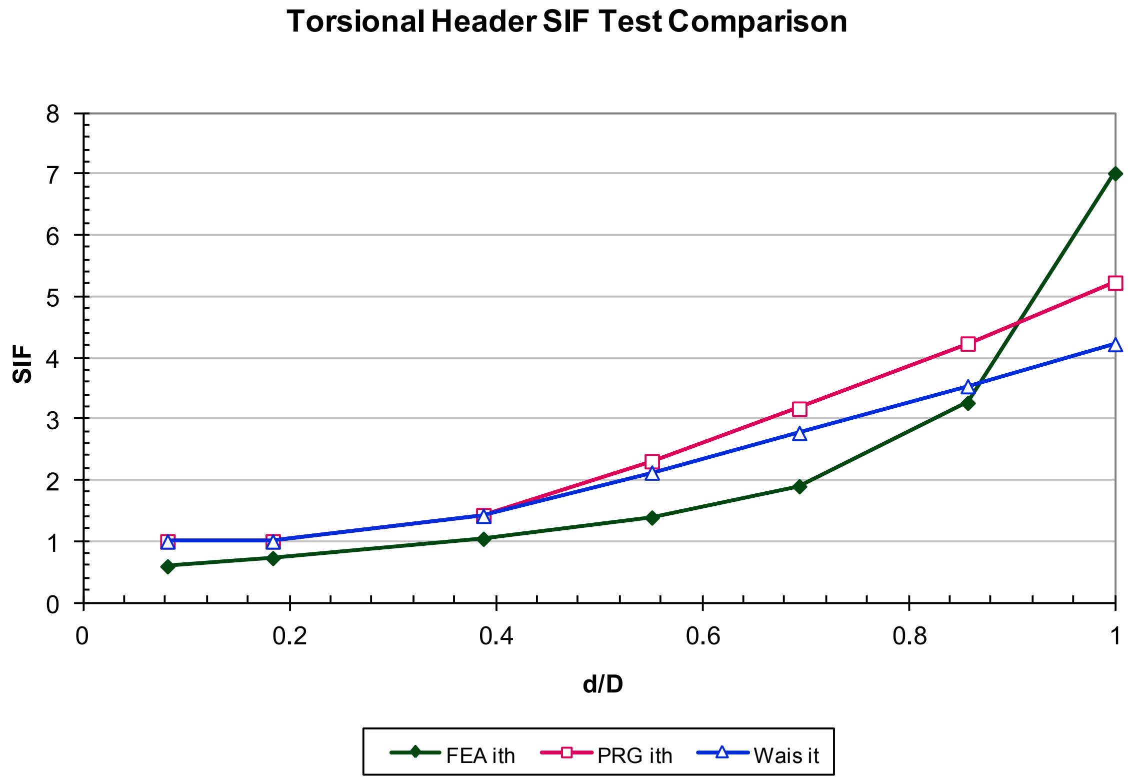


Chart 017 - EQuft.xlsm – “DoT=50 doD=.04-1”

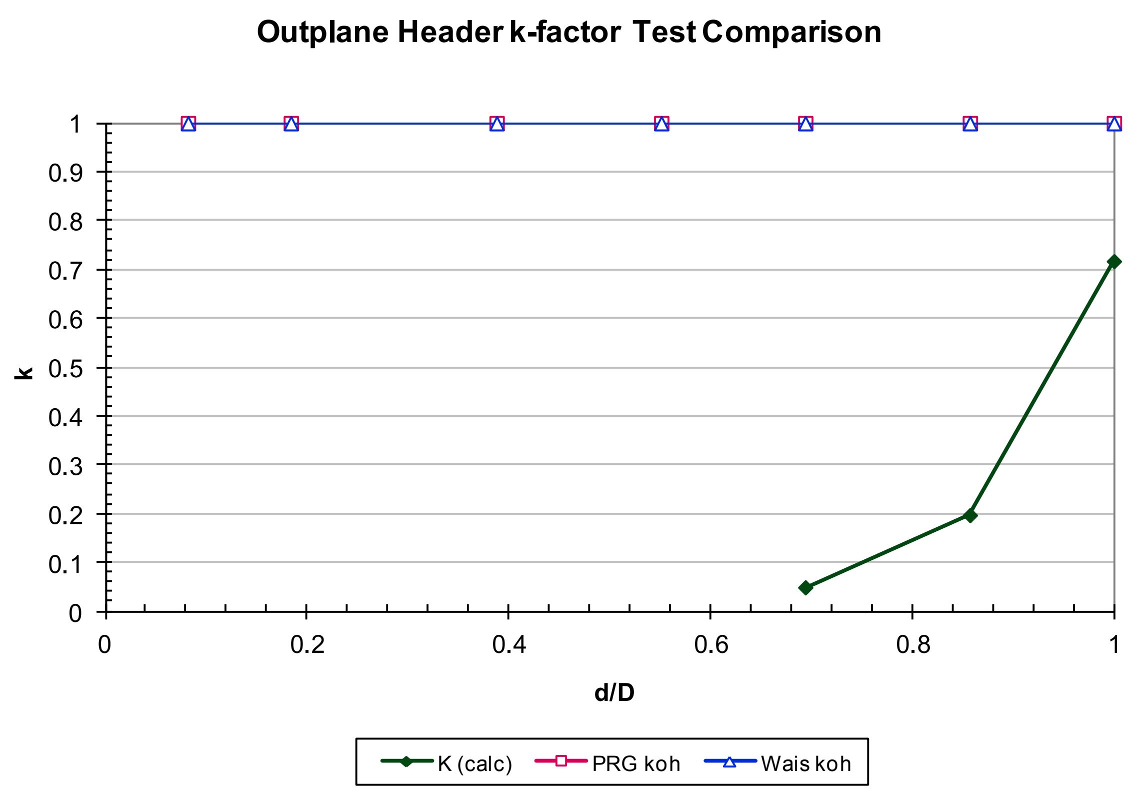


Chart 018 - EQuft.xlsm – "DoT=50 doD=.04-1"

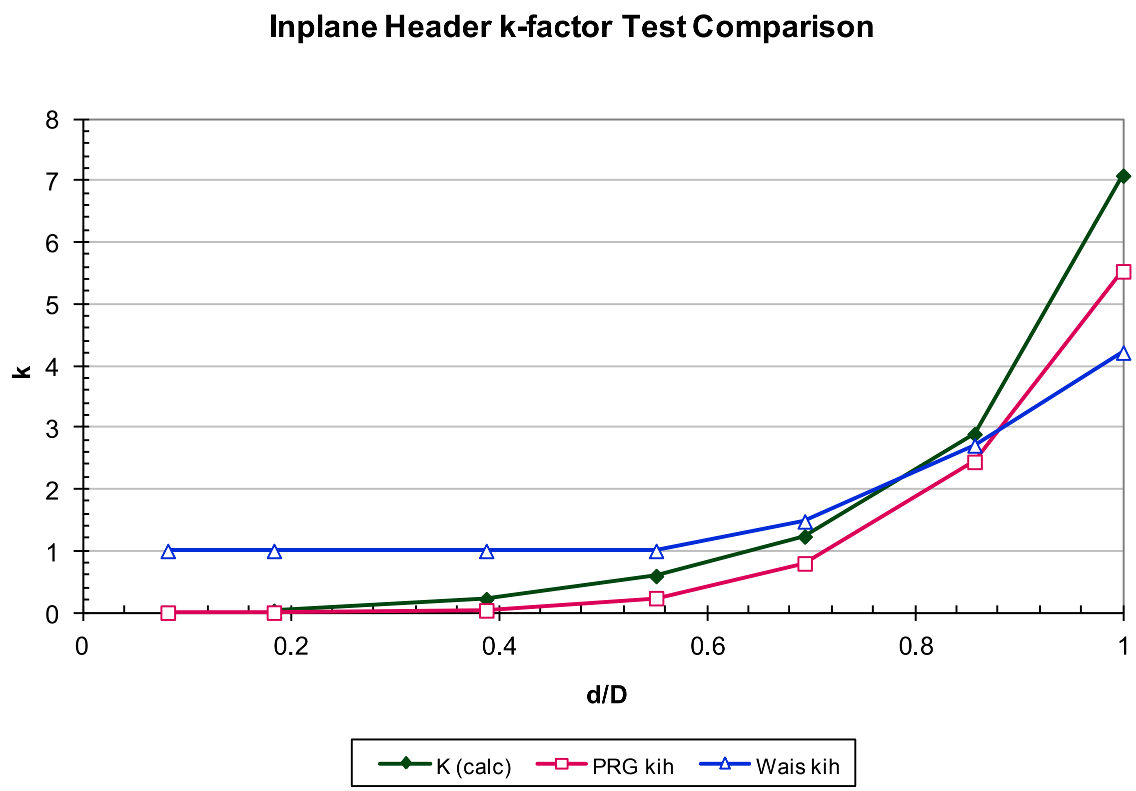


Chart 019 - EQuft.xlsm – "DoT=50 doD=.04-1"

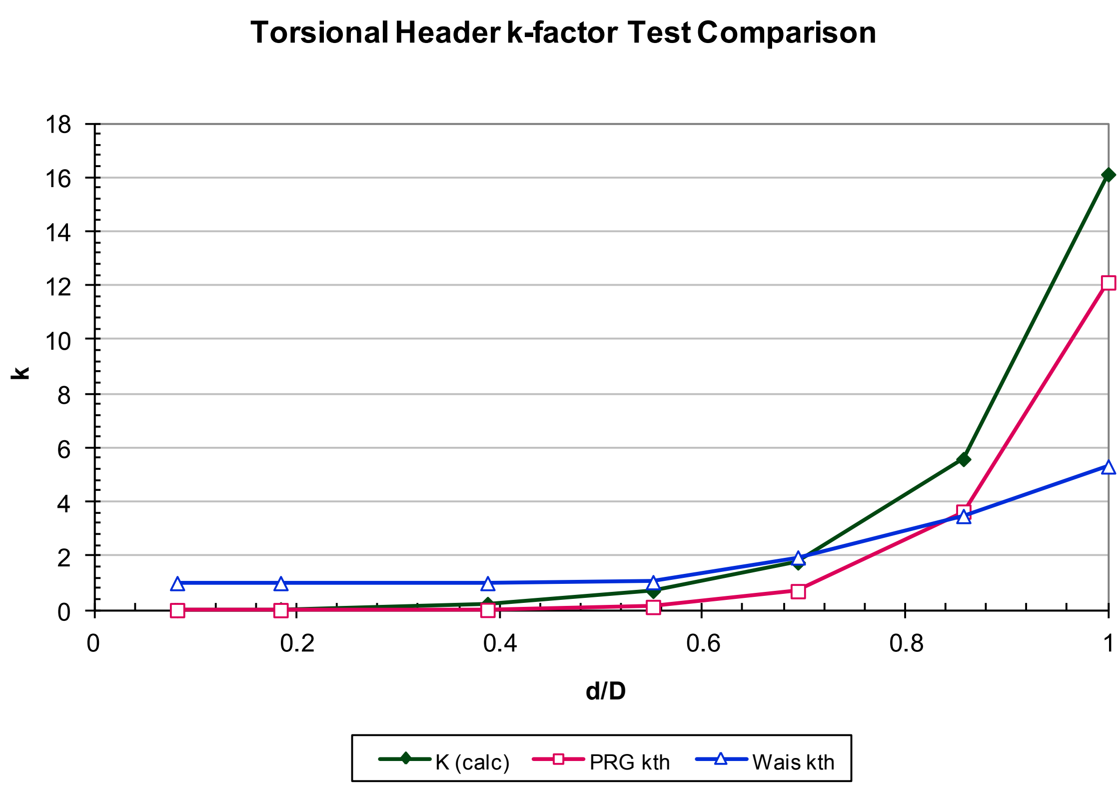
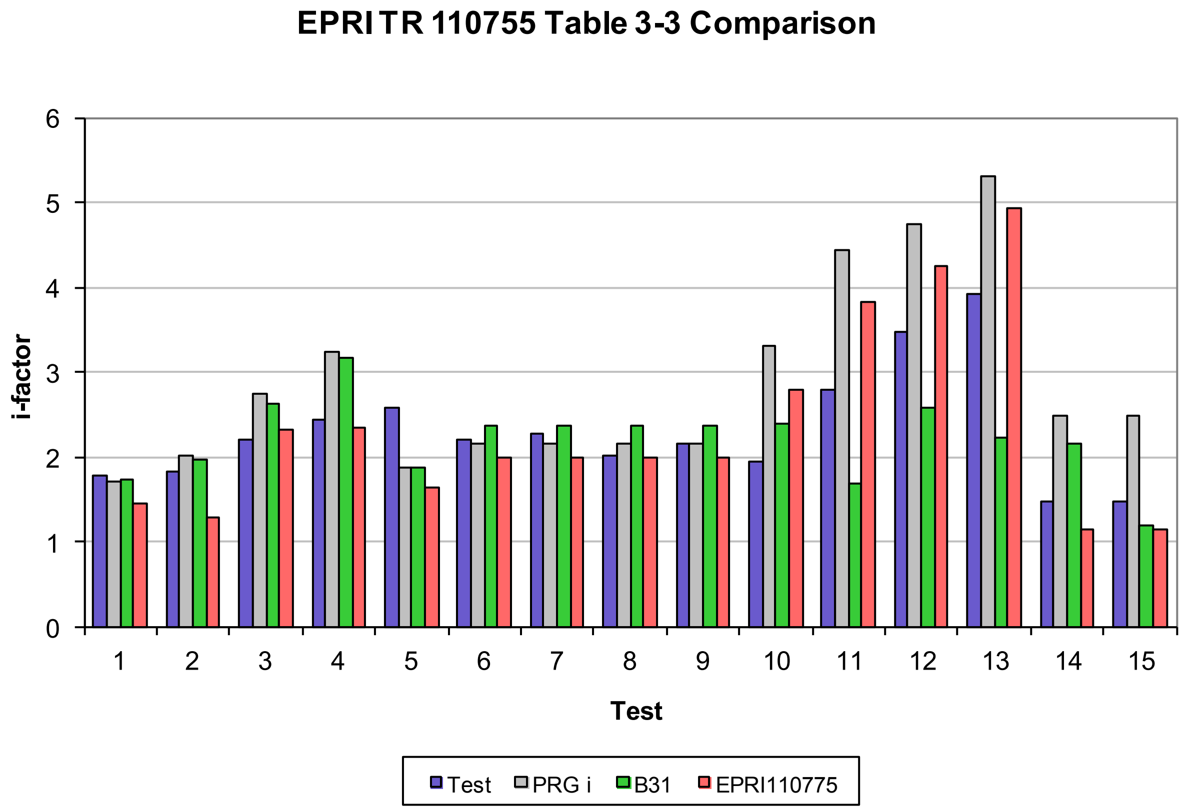


Chart 020 - EQpad.xlsm – "Pad SIF EPRI T3-3"



Notes:

1) EPRI TR-110755 (ref.[6]) test data is given in the table immediately below because it's easier to read than CHRT005 on the following page. The first five tests in the spreadsheet below are reported by Markl[27]. Tests E through P reported on rows 9 through 18 are from EPRI results reported in ref.[6]. See references in CHRT005 for more information. Annex H also discusses discrepancies found in EPRI TR-110755 regarding reported thicknesses and addresses numerical results in more detail.

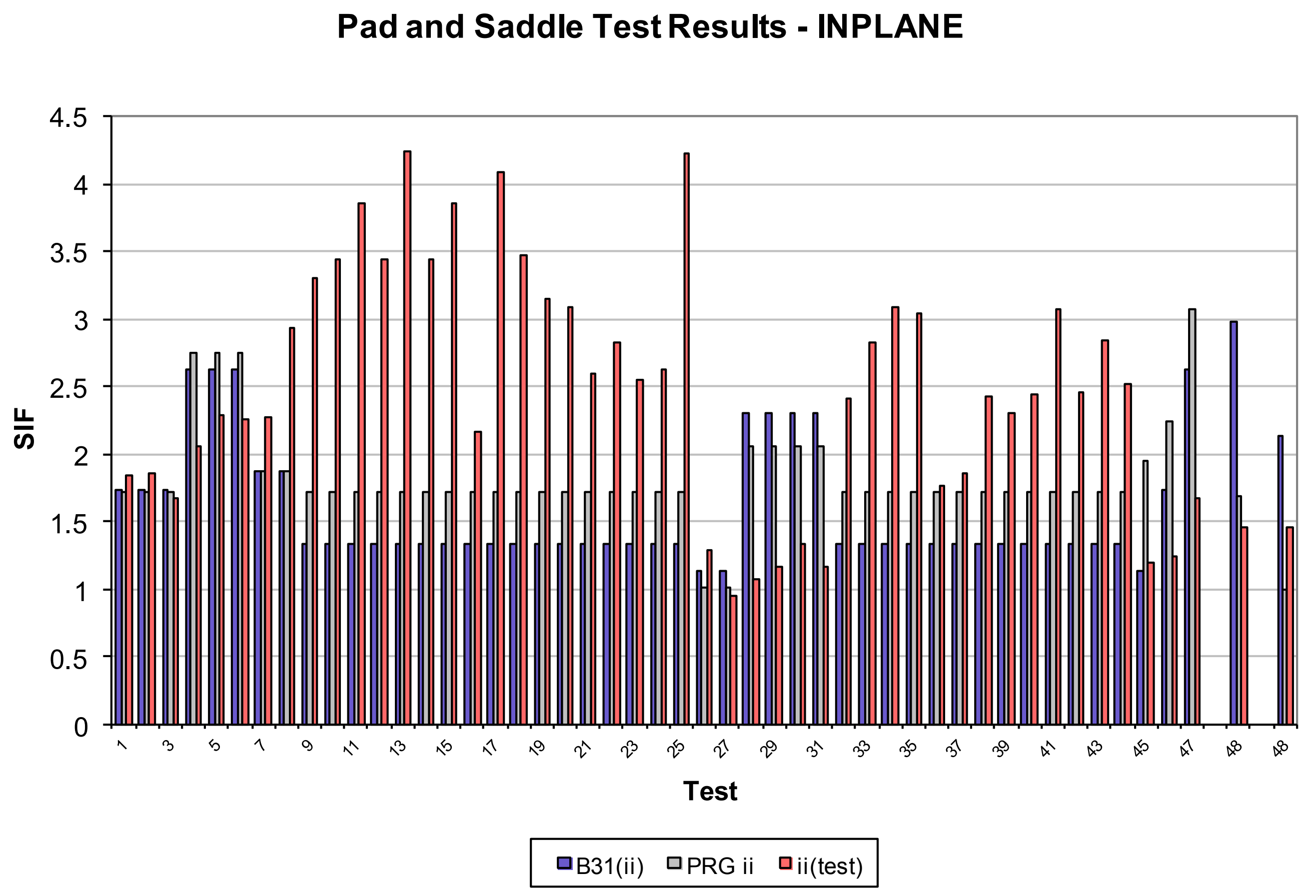
	A	B	C	D	E	F	G	H	I	J	K	L	M	
1	EPRI TR 110755 Table 3-3 Comparison													
2														
3		Test	Load	T	T*	R/T	r/t	r/R	R	r	t	Te	itest	i
4		1	ii	0.237	0.356	8.99	8.99	1	2.1306	2.13063	0.237	0.238	1.78	
5		2	io	0.237	0.356	8.99	8.99	1	2.1306	2.13063	0.237	0.238	1.83	
6		3	ii	0.12	0.18	18.25	18.25	1	2.19	2.19	0.12	0.12	2.21	
7		4	io	0.12	0.18	18.25	18.25	1	2.19	2.19	0.12	0.12	2.43	
8		5	ii	0.26	0.416	12	12	1	3.12	3.12	0.26	0.312	2.58	
9		E	ii	0.25	0.375	16.75	8.99	0.509	4.1875	2.13144	0.237	0.25	2.2	
10		F	ii	0.25	0.375	16.75	8.99	0.509	4.1875	2.13144	0.237	0.25	2.26	
11		G	ii	0.25	0.375	16.75	8.99	0.509	4.1875	2.13144	0.237	0.25	2.01	
12		H	ii	0.25	0.375	16.75	8.99	0.509	4.1875	2.13144	0.237	0.25	2.16	
13		K1	io	0.322	0.483	12.89	7.6	0.396	4.1506	1.64363	0.216	0.322	1.95	
14		K2	io	0.322	0.483	12.89	11.33	0.764	4.1506	3.17104	0.28	0.322	2.78	
15		K3	io	0.375	0.563	16.5	11.33	0.513	6.1875	3.17419	0.28	0.376	3.47	
16		K4	io	0.375	0.563	16.5	12.89	0.671	6.1875	4.15181	0.322	0.376	3.91	
17		O	io	0.322		12.89	18.73	0.293	4.1515	1.2175	0.065	0.188	1.47	
18		P	io	0.322		12.89	18.73	0.293	4.1515	1.2175	0.065	0.188	1.46	

CHRT005

Item #	#	Ref	ID	Do	T	do	t	Auxiliary Data	Results	Notes
1	2-29	5	4x4 PAD	4.5	0.237	4.5	0.237	N=800 S=35,000	iib=1.839	Line 2 Table 4 WRC 329 te/T=1
1	2-30	5	4x4 PAD	4.5	0.237	4.5	0.237	N=4000 S=25,000	iib=1.866	Line 2 Table 4 WRC 329 te/T=1
1	2-31	5	4x4 PAD	4.5	0.237	4.5	0.237	N=220,000 S=12,500	iib=1.674	Line 2 Table 4 WRC 329 te/T=1
2	2-32	5	4x4 PAD	4.5	0.237	4.5	0.237	N=700 S=35,000	iob=1.888	Line 1 Table 4 WRC 329 te/T=1
2	2-33	5	4x4 PAD	4.5	0.237	4.5	0.237	N=3800 S=25,000	iob=1.885	Line 1 Table 4 WRC 329 te/T=1
2	2-34	5	4x4 PAD	4.5	0.237	4.5	0.237	N=220,000 S=12,500	iob=1.674	Line 1 Table 4 WRC 329 te/T=1
3	2-38	5	4x4 PAD	4.5	0.120	4.5	0.120	N=700 S=32,000	iib=2.06	Line 3 Table 4 WRC 329 te/T=1
3	2-39	5	4x4 PAD	4.5	0.120	4.5	0.120	N=2400 S=22,500	iib=2.296	Line 3 Table 4 WRC 329 te/T=1
3	2-40	5	4x4 PAD	4.5	0.120	4.5	0.120	N=75,000 N=11,500	iib=2.257	Line 3 Table 4 WRC 329 te/T=1
4	2-35	5	4x4 PAD	4.5	0.120	4.5	0.120	N=430 S=32,000	iob=2.288	Line 4 Table 4 WRC 329 te/T=1
4	2-36	5	4x4 PAD	4.5	0.120	4.5	0.120	N=1600 S=23,000	iob=2.436	Line 4 Table 4 WRC 329 te/T=1
4	2-37	5	4x4 PAD	4.5	0.120	4.5	0.120	N=41,000 S=11,500	iob=2.546	Line 4 Table 4 WRC 329 te/T=1
5	2-41	83	6x6 PAD	6.5	0.25	6.5	0.25	N=1,468,000 S=5640	iib=2.538	Line 7 Table 4 WRC 329 te/T=1.25 Blair CR-1 Blair concerned about behavior in this test. Blair tests were approx 30Hz shaker tests. Both legs of run clamped. Run length=22" approx. Surface to load=44.75". Tested in between 1936 and 1946
5	2-42	83	6x6 PAD	6.5	0.25	6.5	0.25	N=340,000 S=5840	iib=3.284	Line 7 Table 4 WRC 329 te/T=1.25 Blair CR-2
6	2-49	90	8x4 PAD E	8.625	0.25	4.5	0.237	N=1260 S=26,773	iib=2.20	PadOD=6 PadT=0.25
7	2-50	90	8x4 PAD F	8.625	0.25	4.5	0.237	N=1901 S=23,997	iib=2.26	PadOD=7 PadT=0.25
8	2-51	90	8x4 PAD G	8.625	0.25	4.5	0.237	N=1366 S=28,752	iib=2.01	PadOD=9.5 PadT=0.25
9	2-52	90	8x4 PAD H	8.625	0.25	4.5	0.237	N=1075 S=28,133	iib=2.16	PadOD=7.5 PadT=0.25
10	2-43	79	8x3 PAD K1	8.625	0.322	3.5	0.216	N=51,638 S=14,331	iob=1.951	Line 6 Table 5 WRC 329
11	2-44	79	8x6 PAD K2	8.625	0.322	6.625	0.280	N=7541 S=14,752	iob=2.785	Line 5 Table 5 WRC 329
12	2-45	79	12x6 PAD K3	12.75	0.375	6.625	0.280	N=2829 S=14,408	iob=3.469	Line 8 Table 5 WRC 329
13	2-46	79	12x8 PAD K4	12.75	0.375	8.625	0.322	N=1056 S=15,589	iob=3.905	Line 7 Table 5 WRC 329
14	2-47	91	8x2 PAD O	8.625	0.322	2.5	0.065	N=697 Neq=697 S=45,046	iob=1.47	MTR AppA suggests 8" t=0.355"; dimensions for 2"
15	2-48	91	8x2 PAD P	8.625	0.322	2.5	0.065	N=223 Neq=223 S=57,012	iib=1.46	Report: Pad OD=5. Tp=0.188 Mtr Tr=0.322

CHRT005

Chart 021 - EQpad.xlsm – "Pad SIF Tests Inplane"



Notes:

1) Many of these tests were conducted using a dynamic shaker similar to the Blair tests (ref. [36]) cited in Markl's work (ref.[28],[27]). See CHRT006 for the number of cycles to failure used in the reported i-factor test. The number of cycles to failure were in the hundreds of thousands and millions of cycles, (see CHRT006 below.) Hinnant in ref. [19] showed that the Markl evaluation could be excessively conservative in these high cycle ranges and proposed a correction to SIFs computed using the Markl equation. The high cycle pad and saddle SIFs presented in Charts 021 through 026 are given using Markl's and Hinnant's equations. In the high cycle range the Hinnant adjusted ST-LLC 07-02 equations [19] perform considerably better than the Markl equations.

CHRT006

Item #	#	Ref	ID	Do	T	do	t	Auxiliary Data	Results	Notes
1	2-29	5	4x4 PAD	4.5	0.237	4.5	0.237	N=800 S=35,000	iib=1.839	Line 2 Table 4 WRC 329 te/T=1
2	2-30	5	4x4 PAD	4.5	0.237	4.5	0.237	N=4000 S=25,000	iib=1.866	Line 2 Table 4 WRC 329 te/T=1
3	2-31	5	4x4 PAD	4.5	0.237	4.5	0.237	N=220,000 S=12,500	iib=1.674	Line 2 Table 4 WRC 329 te/T=1
4	2-38	5	4x4 PAD	4.5	0.120	4.5	0.120	N=700 S=32,000	iib=2.06	Line 3 Table 4 WRC 329 te/T=1
5	2-39	5	4x4 PAD	4.5	0.120	4.5	0.120	N=2400 S=22,500	iib=2.296	Line 3 Table 4 WRC 329 te/T=1
6	2-40	5	4x4 PAD	4.5	0.120	4.5	0.120	N=75,000 N=11,500	iib=2.257	Line 3 Table 4 WRC 329 te/T=1
7	2-41	83	6x6 PAD	6.5	0.25	6.5	0.25	N=1,468,000 S=5640	iib=2.538	Line 7 Table 4 WRC 329 te/T=1.25 Blair CR-1 Blair concerned about behavior in this test. Blair tests were approx 30Hz shaker tests. Both legs of run clamped. Run length=22" approx. Surface to load=44.75". Tested in between 1936 and 1946
8	2-42	83	6x6 PAD	6.5	0.25	6.5	0.25	N=340,000 S=5840	iib=3.284	Line 7 Table 4 WRC 329 te/T=1.25 Blair CR-2
9	2-53	77	16x6 PAD	16	0.5	6.625	0.280	N=650,000 S=5100	iib=3.304	Tp=0.5
10	2-54	77	16x6 PAD	16	0.5	6.625	0.280	N=1,400,000 S=4200	iib=3.447	Tp=0.5
11	2-55	77	16x6 PAD	16	0.5	6.625	0.280	N=1,700,000 S=3600	iib=3.862	Tp=0.5
12	2-56	77	16x6 PAD	16	0.5	6.625	0.280	N=10,000,000 S=2700	iib=3.612	Tp=0.5
13	2-57	77	16x6 PAD	16	0.5	6.625	0.280	N=350,000 S=4500	iib=4.238	Tp=0.5
14	2-58	77	16x6 PAD	16	0.5	6.625	0.280	N=1,000,000 S=4500	iib=3.435	Tp=0.5
15	2-59	77	16x6 PAD	16	0.5	6.625	0.280	N=4,300,000 S=3000	iib=3.849	Tp=0.5
16	2-60	77	16x6 PAD	16	0.5	6.625	0.280	N=13,000,000 S=2700	iib=2.163	Tp=0.5
17	2-61	77	16x6 PAD	16	0.5	6.625	0.280	N=19,000,000 S=2100	iib=4.085	Tp=0.5
18	2-62	77	16x6 PAD	16	0.5	6.625	0.280	N=950,000 S=4500	iib=3.471	Tp=0.5
19	2-63	77	16x6 PAD	16	0.5	6.625	0.280	N=2,800,000 S=4000	iib=3.145	Tp=0.5
20	2-64	77	16x6 PAD	16	0.5	6.625	0.280	N=13,000,000 S=3000	iib=3.085	Tp=0.5
21	2-69	77	16x6 PAD	16	0.5	6.625	0.280	N=3,800,000 S=4500	iib=2.630	Weld ground Tp=0.5
22	2-70	77	16x6 PAD	16	0.5	6.625	0.280	N=3,600,000 S=4200	iib=2.833	Weld ground Tp=0.5
23	2-71	77	16x6 PAD	16	0.5	6.625	0.280	N=8,000,000 S=4000	iib=2.550	Weld ground Tp=0.5
24	2-72	77	16x6 PAD	16	0.5	6.625	0.280	N=18,000,000 S=3300	iib=2.628	Weld ground Tp=0.5
25	2-73	77	16x6 PAD	16	0.5	6.625	0.280	N=2,700,000 S=3000	iib=4.224	Weld ground Tp=0.5
26	2-1	5	4x4 SDL	4.5	0.237	4.5	0.237	N=10,000 S=30,000	iib=1.294	Line 6 Table 4 WRC 329 te/T=2.1
27	2-2	5	4x4 SDL	4.5	0.237	4.5	0.237	N=120,000 S=25,000	iib=0.945	Line 6 Table 4 WRC 329 te/T=2.1
28	2-5	76	24x8 SDL	24	0.353	8.625	0.318	N=520 S=65,000	iib=1.079	
29	2-6	76	24x8 SDL	24	0.353	8.625	0.318	N=6000 S=37,000	iib=1.162	
30	2-7	76	24x8 SDL	24	0.353	8.625	0.318	N=50,000 S=21,000	iib=1.340	
31	2-8	76	24x8 SDL	24	0.353	8.625	0.318	N=126,000 S=20,000	iib=1.170	
32	2-11	77	16x6 SDL	16	0.5	6.625	0.280	N=1,400,000 S=6000	iib=2.409	
33	2-12	77	16x6 SDL	16	0.5	6.625	0.280	N=5,500,000 S=3900	iib=2.819	
34	2-13	77	16x6 SDL	16	0.5	6.625	0.280	N=8,000,000 S=3300	iib=3.091	
35	2-14	77	16x6 SDL	16	0.5	6.625	0.280	N=10,000,000 S=3200	iib=3.048	
36	2-15	77	16x6 SDL	16	0.5	6.625	0.280	N=1,600,000 S=8000	iib=1.759	
37	2-16	77	16x6 SDL	16	0.5	6.625	0.280	N=3,200,000 S=6600	iib=1.856	
38	2-17	77	16x6 SDL	16	0.5	6.625	0.280	N=5,600,000 S=4500	iib=2.434	
39	2-18	77	16x6 SDL	16	0.5	6.625	0.280	N=7,300,000 S=4500	iib=2.308	
40	2-19	77	16x6 SDL	16	0.5	6.625	0.280	N=10,000,000 S=4000	iib=2.438	
41	2-20	77	16x6 SDL	16	0.5	6.625	0.280	N=9,500,000 S=3200	iib=3.079	
42	2-21	77	16x6 SDL	16	0.5	6.625	0.280	N=3,200,000 S=5000	iib=2.450	
43	2-22	77	16x6 SDL	16	0.5	6.625	0.280	N=2,600,000 S=4500	iib=2.838	
44	2-23	77	16x6 SDL	16	0.5	6.625	0.280	N=4,700,000, S=4500	iib=2.521	
45	2-74	5	4x4 SDL	4.5	0.237	4.5	0.237	N=18,000 S=29,000	iir=1.1905	Tp=0.5
46	2-76	5	4x4 Pad	4.5	0.237	4.5	0.237	N=30,000 S=25,000	iir=1.2468	Tp=0.237
47	2-78	5	4x4 Pad	4.5	0.120	4.5	0.120	N=11,500 S=22,500	iir=1.6782	Tp=0.120
48	2-48	91	8x2 PAD P	8.625	0.322	2.5	0.065	N=223 Neq=223 S=57,012	iib=1.46	Report: Pad OD=5. Tp=0.188 Mtr Tr=0.322

CHRT006

Chart 022 - EQpad.xlsm – "Pad SIF Tests Inplane"

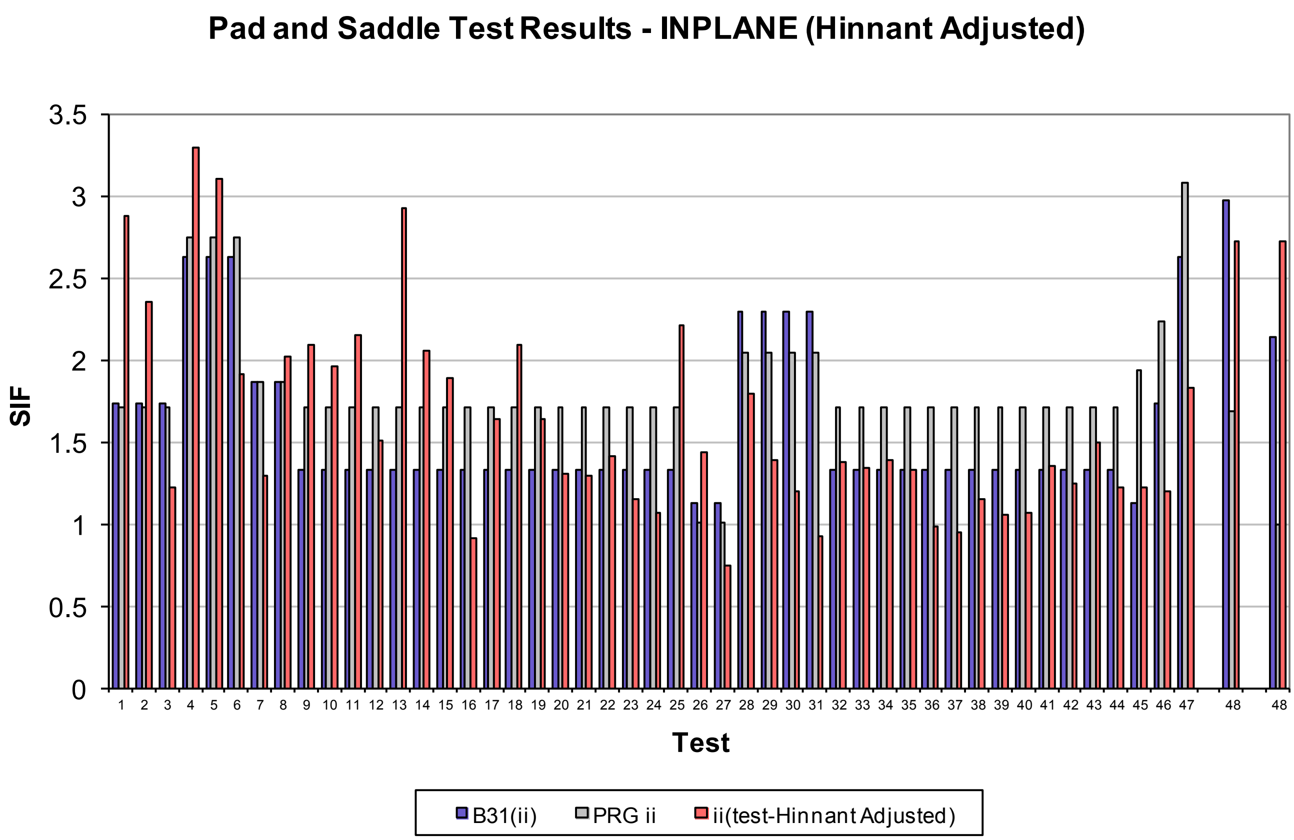
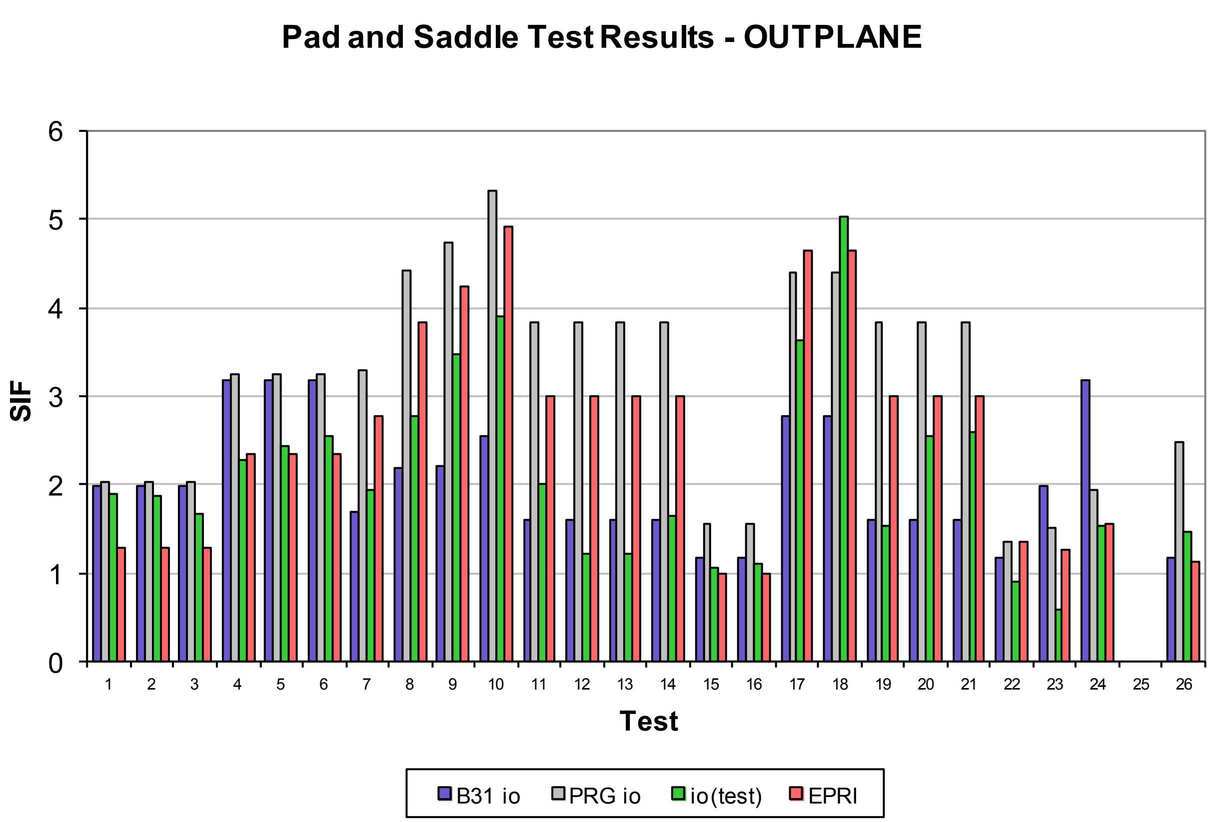


Chart 023 - EQpad.xlsm – "Pad SIF Tests Outplane"



CHRT007

Item #	#	Ref	ID	Do	T	do	t	Auxiliary Data	Results	Notes
1	2-32	5	4x4 PAD	4.5	0.237	4.5	0.237	N=700 S=35,000	iob=1.888	Line 1 Table 4 WRC 329 te/T=1
2	2-33	5	4x4 PAD	4.5	0.237	4.5	0.237	N=3800 S=25,000	iob=1.885	Line 1 Table 4 WRC 329 te/T=1
3	2-34	5	4x4 PAD	4.5	0.237	4.5	0.237	N=220,000 S=12,500	iob=1.674	Line 1 Table 4 WRC 329 te/T=1
4	2-35	5	4x4 PAD	4.5	0.120	4.5	0.120	N=430 S=32,000	iob=2.288	Line 4 Table 4 WRC 329 te/T=1
5	2-36	5	4x4 PAD	4.5	0.120	4.5	0.120	N=1600 S=23,000	iob=2.436	Line 4 Table 4 WRC 329 te/T=1
6	2-37	5	4x4 PAD	4.5	0.120	4.5	0.120	N=41,000 S=11,500	iob=2.546	Line 4 Table 4 WRC 329 te/T=1
7	2-43	79	8x3 PAD K1	8.625	0.322	3.5	0.216	N=51,638 S=14,331	iob=1.951	Line 6 Table 5 WRC 329
8	2-44	79	8x6 PAD K2	8.625	0.322	6.625	0.280	N=7541 S=14,752	iob=2.785	Line 5 Table 5 WRC 329
9	2-45	79	12x6 PAD K3	12.75	0.375	6.625	0.280	N=2829 S=14,408	iob=3.469	Line 8 Table 5 WRC 329
10	2-46	79	12x8 PAD K4	12.75	0.375	8.625	0.322	N=1056 S=15,589	iob=3.905	Line 7 Table 5 WRC 329
11	2-65	77	16x6 PAD	16	0.5	6.625	0.280	N=460,000: S=9000	iob=2.006	Tp=0.5
12	2-66	77	16x6 PAD	16	0.5	6.625	0.280	N=10,000,000 S=8000	iob=1.219	Tp=0.5
13	2-67	77	16x6 PAD	16	0.5	6.625	0.280	N=20,000,000 S=7000	iob=1.213	Tp=0.5
14	2-68	77	16x6 PAD	16	0.5	6.625	0.280	N=9,500,000 S=6000	iob=1.642	Tp=0.5
15	2-3	5	4x4 SDL	4.5	0.237	4.5	0.237	N=20,000 S=31,500	iob=1.056	Line 5 Table 4 WRC 329 te/T=2.1
16	2-4	5	4x4 SDL	4.5	0.237	4.5	0.237	N=80,000 S=23,000	iob=1.114	Line 5 Table 4 WRC 329 te/T=2.1
17	2-9	76	24x8 SDL	24	0.353	8.625	0.318	N=20, S=37,000	iob=3.637	
18	2-10	76	24x8 SDL	24	0.353	8.625	0.318	N=35,100 S=6000	iob=5.034	
19	2-24	77	16x6 SDL	16	0.5	6.625	0.280	N=3,100,000 S=8000	iob=1.541	
20	2-25	77	16x6 SDL	16	0.5	6.625	0.280	N=2,600,000 S=5000	iob=2.554	
21	2-26	77	16x6 SDL	16	0.5	6.625	0.280	N=9,500,000 S=3800	iob=2.593	
22	2-75	5	4x4 SDL	4.5	0.237	4.5	0.237	N=85,000 S=28,000	ior=0.9039	Tp=0.5
23	2-77	5	4x4 Pad	4.5	0.237	4.5	0.237	N=880,000 S=27,000	ior=0.5874	Tp=0.237
24	2-79	5	4x4 Pad	4.5	0.120	4.5	0.120	N=270,000 S=13,000	ior=1.5451	Tp=0.120
26	2-47	91	8x2 PAD O	8.625	0.322	2.5	0.065	N=697 Neq=697 S=45,046	iob=1.47	MTR AppA suggests 8" t=0.355"; dimensions for 2"

CHRT007

Chart 024 - EQpad.xlsm – "Pad SIF Tests Outplane"

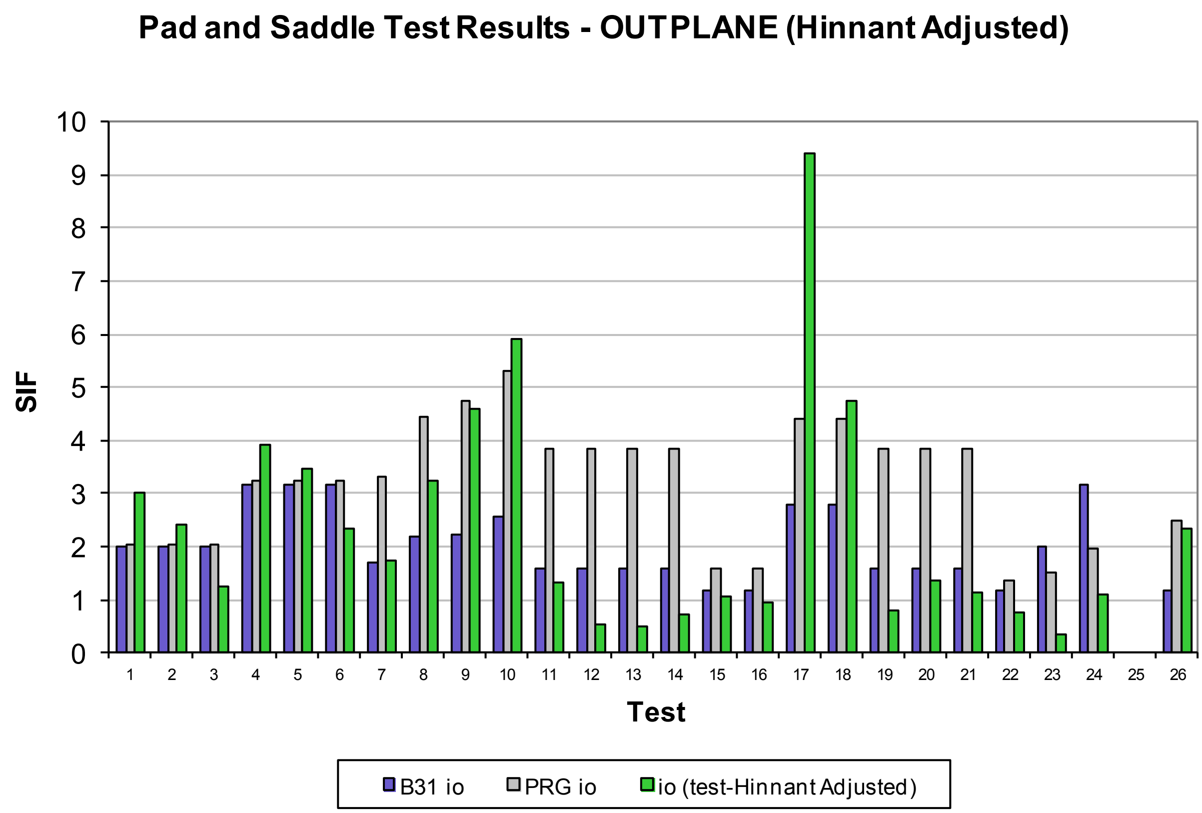
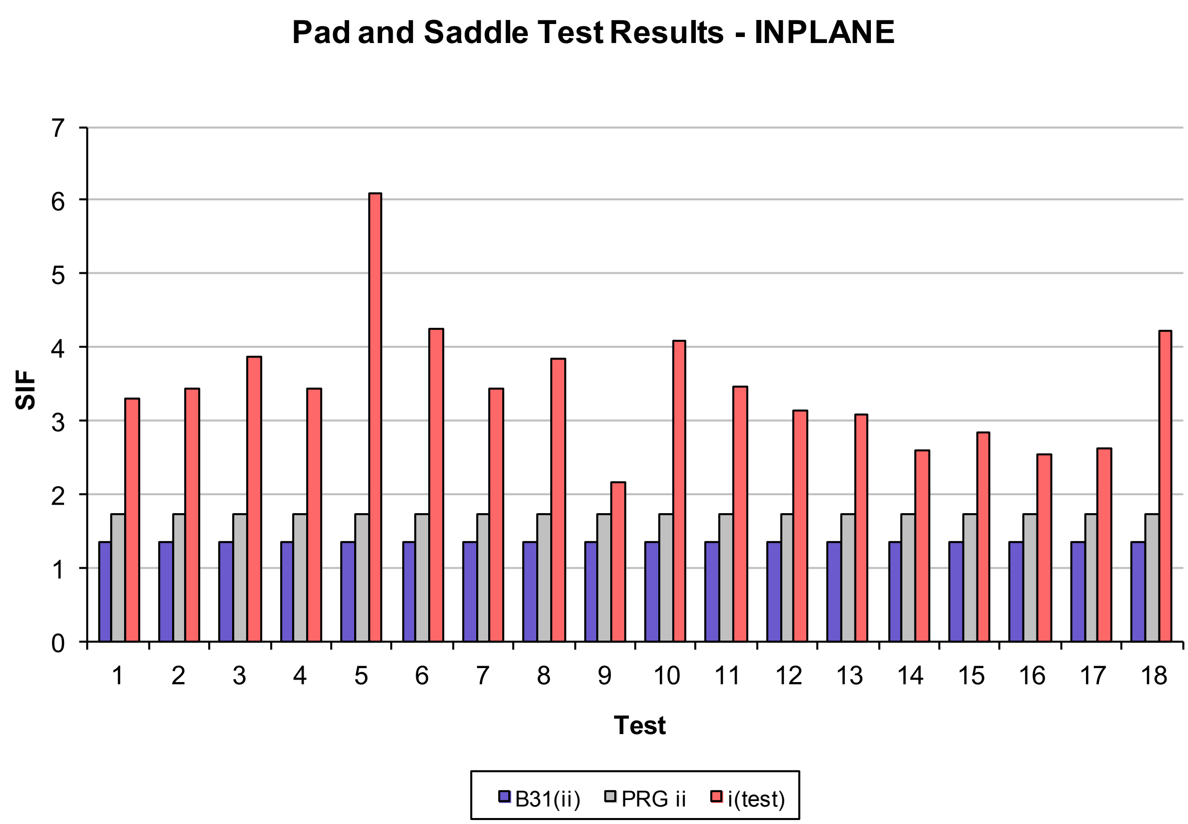


Chart 025 - EQpad.xlsm – "Pad Single Inplane Set"



CHRT008

Item #	#	Ref	ID	Do	T	do	t	Auxiliary Data	Results	Notes
1	2-53	77	16x6 PAD	16	0.5	6.625	0.280	N=650,000 S=5100	iib=3.304	Tp=0.5
2	2-54	77	16x6 PAD	16	0.5	6.625	0.280	N=1,400,000 S=4200	iib=3.447	Tp=0.5
3	2-55	77	16x6 PAD	16	0.5	6.625	0.280	N=1,700,000 S=3600	iib=3.862	Tp=0.5
4	2-56	77	16x6 PAD	16	0.5	6.625	0.280	N=10,000,000 S=2700	iib=3.612	Tp=0.5
5	???	77	16x6 PAD	16	0.5	6.625	0.280	N=10,000,000 S=1600	iib=6.096	Tp=0.5
6	2-57	77	16x6 PAD	16	0.5	6.625	0.280	N=350,000 S=4500	iib=4.238	Tp=0.5
7	2-58	77	16x6 PAD	16	0.5	6.625	0.280	N=1,000,000 S=4500	iib=3.435	Tp=0.5
8	2-59	77	16x6 PAD	16	0.5	6.625	0.280	N=4,300,000 S=3000	iib=3.849	Tp=0.5
9	2-60	77	16x6 PAD	16	0.5	6.625	0.280	N=13,000,000 S=2700	iib=2.163	Tp=0.5
10	2-61	77	16x6 PAD	16	0.5	6.625	0.280	N=19,000,000 S=2100	iib=4.085	Tp=0.5
11	2-62	77	16x6 PAD	16	0.5	6.625	0.280	N=950,000 S=4500	iib=3.471	Tp=0.5
12	2-63	77	16x6 PAD	16	0.5	6.625	0.280	N=2,800,000 S=4000	iib=3.145	Tp=0.5
13	2-64	77	16x6 PAD	16	0.5	6.625	0.280	N=13,000,000 S=3000	iib=3.085	Tp=0.5
14	2-69	77	16x6 PAD	16	0.5	6.625	0.280	N=3,800,000 S=4500	iib=2.630	Weld ground Tp=0.5
15	2-70	77	16x6 PAD	16	0.5	6.625	0.280	N=3,600,000 S=4200	iib=2.833	Weld ground Tp=0.5
16	2-71	77	16x6 PAD	16	0.5	6.625	0.280	N=8,000,000 S=4000	iib=2.550	Weld ground Tp=0.5
17	2-72	77	16x6 PAD	16	0.5	6.625	0.280	N=18,000,000 S=3300	iib=2.628	Weld ground Tp=0.5
18	2-73	77	16x6 PAD	16	0.5	6.625	0.280	N=2,700,000 S=3000	iib=4.224	Weld ground Tp=0.5

CHRT008

Chart 026 - EQpad.xlsm – "Pad Single Inplane Set"

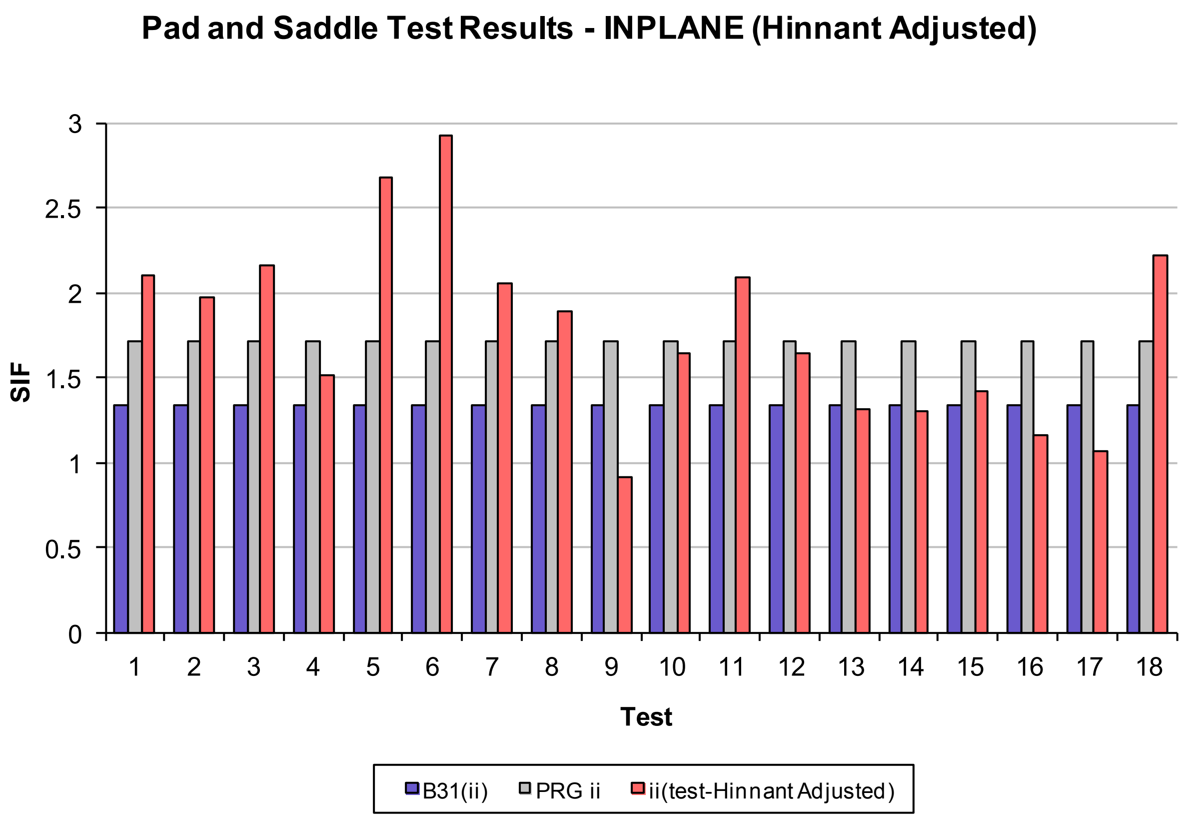
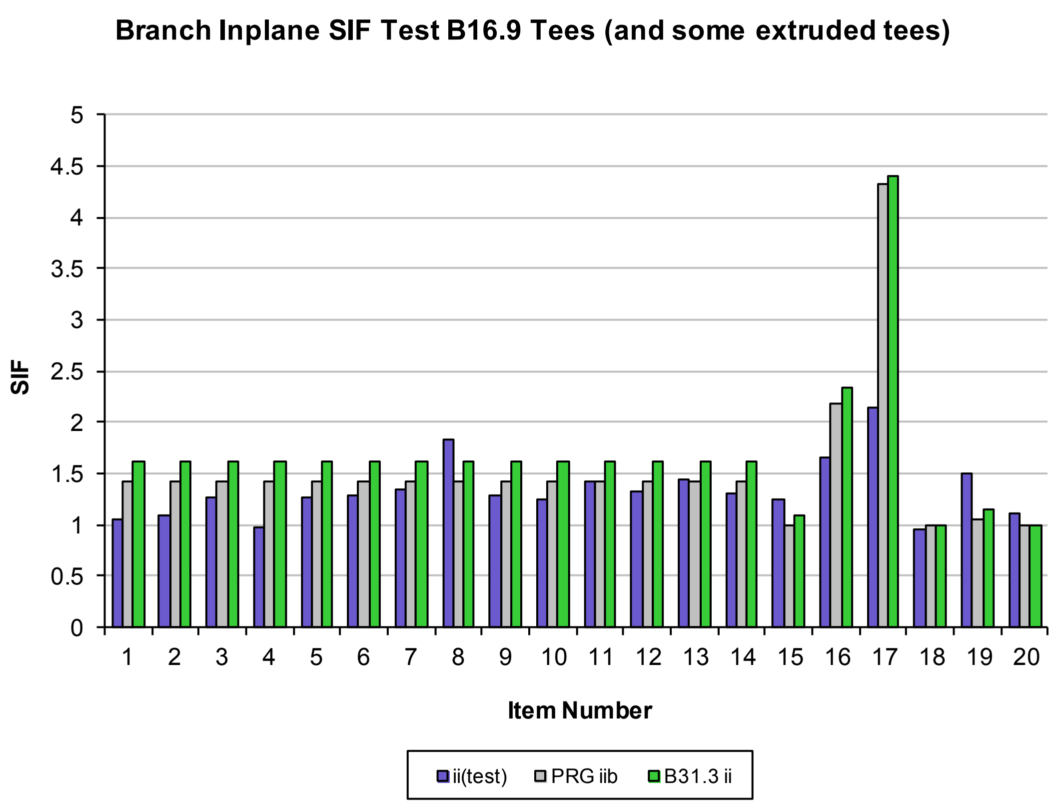


Chart 027 - EQtee.xlsm – "B16.9 SIF Tests"



Notes:

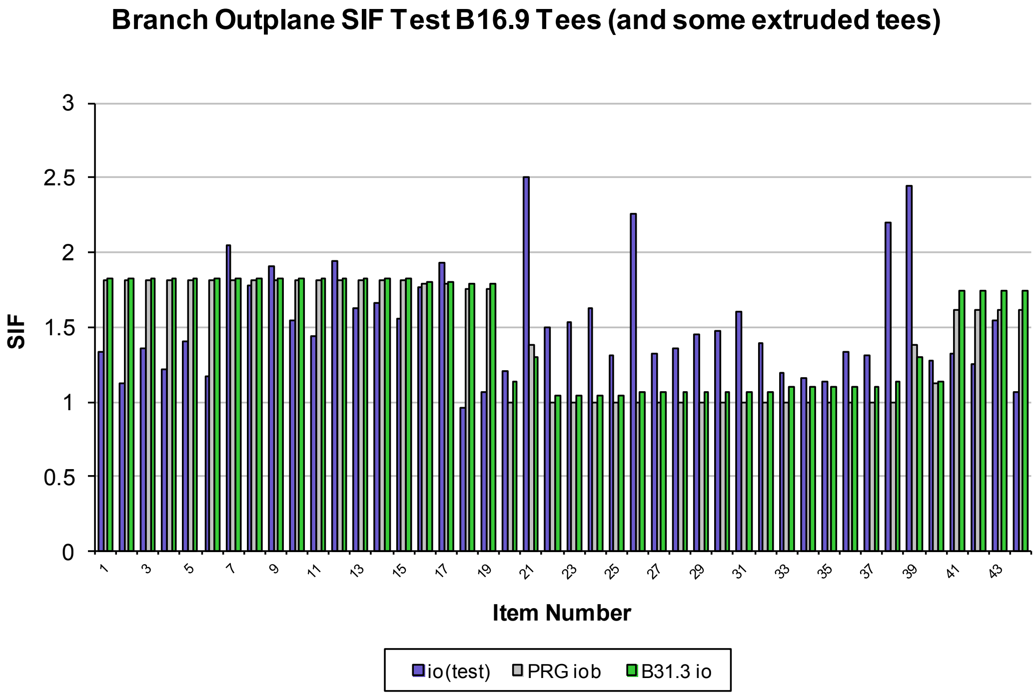
1) Some extruded tees are included in this list for comparison. Tests 18, 19, and 20 (4-2, 4-3, and 4-6) show test results that are up to 1.5 times higher than 07-02 and B31.3 predicted values. These are elastic test results divided by 1.8 and are tests that were run prior to 1967. Fatigue tests run for the 20x12(R) UFT model show an elastic to fatigue stress intensity ratio of 8.55/3.9=2.19.

CHRT009

Item #	#	Ref	ID	Do	T	do	t	Auxiliary Data	Results	Notes
1	1-1	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=4626 S=43,652	iib=1.0378	Markl description-Barrel-shape
2	1-2	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=16,342 S=32,614	iib=1.0792	Markl description-Barrel-shape
3	1-3	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=19,934 S=26,841	iib=1.2602	Markl description-Barrel-shape
4	1-4	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=213,895 S=16,776	iib=1.2544	Markl description-Barrel-shape
5	1-5	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=231,153 S=21,434	iib=0.9667	Markl description-Barrel-shape
6	1-6	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=0.75 N=7630 S=31,827	iib=1.2879	Markl description-conical
7	1-7	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=0.75 N=62,893 S=19,980	iib=1.3454	Markl description-conical
8	1-8	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=0.75 N=132,008 S=12,566	iib=1.8444	Markl description-conical
9	1-9	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=1347 S=45,030	iib=1.2876	Markl description-Cylindrical
10	1-10	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=1590 S=44,802	iib=1.2519	Markl description-Cylindrical
11	1-11	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=11,048 S=26,940	iib=1.4129	Markl description-Cylindrical
12	1-12	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=14,931 S=26,977	iib=1.3285	Markl description-Cylindrical
13	1-13	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=103,276 S=17,195	iib=1.4157	Markl description-Cylindrical
14	1-14	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=171,633 S=17,274	iib=1.2731	Markl description-Cylindrical
15	1-32	72	12x12 B16.9	12.75	1.312	12.75	1.312	N=11,475 S=30,500	iib=1.239	T-7 304L Pi=3,240 psig
16	1-35	73	24x24 B16.9	24	0.687	24	0.687	N=18,532 S=20,629	iib=1.664	T-10 A 212-61T GrB
17	1-36	73	24x24 B16.9	24	0.25	24	0.25	N=2344 S=24,202	iib=2.144	T-16 SA 312 304L
18	4-2	74	20x6 EXT	20	1	6.625	0.432		iib=0.94	
19	4-3	74	20x12 EXT	20	1	12.75	0.687	Test D strain gage	iib=1.5	Measured – NOT extrapolated Lax=8.7, Mt=-3.18. See ref for axial and torsional stress measurements. See 4-24. These may be the same geometry, but I think they represent a strain gage test and then a subsequent fatigue tests. Fatigue tests were run on L and D.
20	4-6	74	20x12 EXT	20	1	12.75	0.375	Test E strain gage	iib=1.11	

CHRT009

Chart 028 - EQtee.xlsm – “B16.9 SIF Tests”



Notes:

1) All Table 6 results from WRC 329 are from Taylor Forge extruded tees that were considerably thicker than nominal pipe. When actual thicknesses were used in the i-factor calculation (See WRC 329 Table 6, the Item 26 i-factor went from 2.26 to 1.55.).

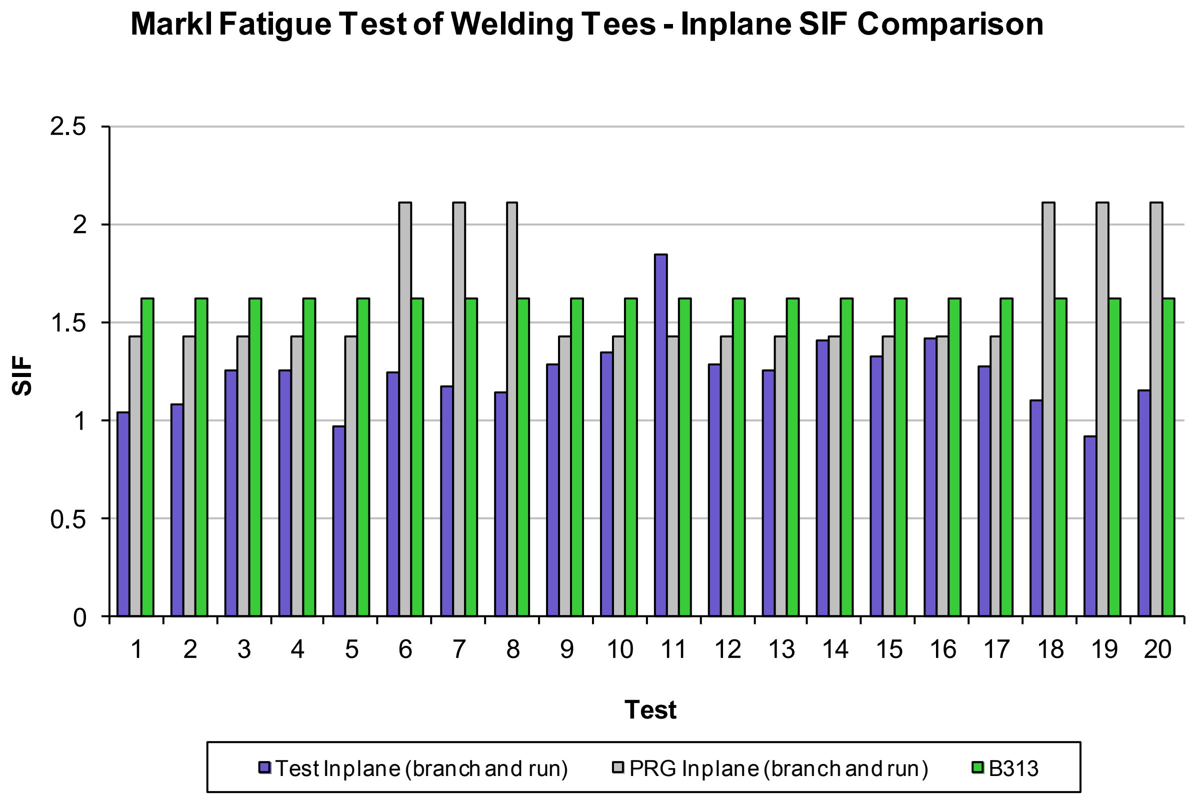
CHRT0010

Item #	#	Ref	ID	Do	T	do	t	Auxiliary Data	Results	Notes
1	1-15	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=1169 S=44,679	iob=1.3350	Markl description-Barrel-shape
2	1-16	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=4231 S=42,855	iob=1.0762	Markl description-Barrel-shape
3	1-17	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=12,557 S=27,233	iob=1.3623	Markl description-Barrel-shape
4	1-18	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=25,009 S=26,497	iob=1.2200	Markl description-Barrel-shape
5	1-19	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=97,544 S=17,338	iob=1.4201	Markl description-Barrel-shape
6	1-20	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=167,880 S=18,754	Iob=1.1778	Markl description-Barrel-shape
7	1-21	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=0.75 N=2103 S=25,038	iob=2.1183	Markl description-conical
8	1-22	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=0.75 N=58,050 S=15,251	iob=1.7910	Markl description-conical
9	1-23	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=0.75 N=549,414 S=9672	iob=1.8017	Markl description-conical
10	1-24	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=593 S=44,494	iob=1.5355	Markl description-Cylindrical
11	1-25	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=911 S=43,793	iob=1.4317	Markl description-Cylindrical
12	1-26	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=5573 S=21,857	iob=1.9969	Markl description-Cylindrical
13	1-27	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=15,951 S=21,330	iob=1.6581	Markl description-Cylindrical
14	1-28	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=325,237 S=11,706	iob=1.6532	Markl description-Cylindrical
15	1-29	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=604,644 S=11,112	iob=1.5384	Markl description-Cylindrical
16	1-30	72	12x12 B16.9	12.75	0.687	12.75	0.687	N=2062 S=30,200	iob=1.763	T-4 A106B Internal Pressure during test Pi= 1,925 psig r2=1.1
17	1-31	72	12x12 B16.9	12.75	0.687	12.75	0.687	N=1309 S=30,150	iob=1.934	T-6 A106B Pi=1,925 psig r2=2.3 to 3.0 in. (p57 TM 8965)
18	1-33	72	12x6 B16.9	12.75	0.406	6.625	0.280	N=8979 S=41,160	iob=0.964	T-8 304L Pi=950 psig r2=0.75 to 0.65 in.
19	1-34	72	12x6 B16.9	12.75	0.406	6.625	0.280	N=10,200 S=36,100	iob=1.071	T-15 304L Pi=950 psig
20	4-23	80	20x6 L EXT	20		6.5		N=50,000 S=23,000 fig29 Ref94	iob=1.2	R/T=9.5 r/R=0.326 t/T=0.432 Line 24 Table 3 WRC 329
21	4-24	80	20x12, D	20	1	12.75	0.687	N=20,000 S=13,000 fig29 Ref94	iob=2.5	R/T=9.5 r/R=0.635 t/T=0.687 Line 25 Table 3 WRC 329. This test prepared for comparison with elastic test 4-4.
22	4-7	75	4x4 EXT	5.0	0.480	5.0	0.480		iob=1.5	Body outside diameter=5.0 Line 1 Table 6 WRC 329
23	4-8	75	4x4 EXT	5.0	0.480	5.0	0.480		iob=1.53	Body outside diameter=5.0 Line 2 Table 6 WRC 329

24	4-9	75	4x4 EXT	5.0	0.480	5.0	0.480		iob=1.63	Body outside diameter=5.0 Line 3 Table 6 WRC 329
25	4-10	75	4x4 EXT	5.0	0.480	5.0	0.480		iob=1.31	Body outside diameter=5.0 Line 4 Table 6 WRC 329
26	4-11	75	6x4 EXT	6.625	0.562	4.5	0.237		iob=2.26	Body outside diameter=6.625 Line 5 Table 6 WRC 329
27	4-12	75	6x4 EXT	6.625	0.562	4.5	0.237		iob=1.32	Body outside diameter=6.625 Line 6 Table 6 WRC 329
28	4-13	75	6x4 EXT	6.625	0.562	4.5	0.237		iob=1.36	Body outside diameter=6.625 Line 7 Table 6 WRC 329
29	4-14	75	8x4 EXT	8.625	0.719	4.5	0.237		iob=1.45	Body outside diameter=8.625 Line 8 Table 6 WRC 329
30	4-15	75	8x4 EXT	8.625	0.719	4.5	0.237		iob=1.48	Body outside diameter=8.625 Line 9 Table 6 WRC 329
31	4-16	75	8x4 EXT	8.625	0.719	4.5	0.237		iob=1.60	Body outside diameter=8.625 Line 10 Table 6 WRC 329
32	4-17	75	8x4 EXT	8.625	0.719	4.5	0.237		iob=1.39	Body outside diameter=8.625 Line 11 Table 6 WRC 329
33	4-18	75	16x4 EXT	16	1.031	4.5	0.237		iob=1.19	Body outside diameter=16 Line 12 Table 6 WRC 329
34	4-19	75	16x4 EXT	16	1.031	4.5	0.237		iob=1.16	Body outside diameter=16 Line 13 Table 6 WRC 329
35	4-20	75	16x4 EXT	16	1.031	4.5	0.237		iob=1.14	Body outside diameter=16 Line 14 Table 6 WRC 329
36	4-21	75	16x4 EXT	16	1.031	4.5	0.237		iob=1.33	Body outside diameter=16 Line 15 Table 6 WRC 329
37	4-22	75	16x4 EXT	16	1.031	4.5	0.237		iob=1.31	Body outside diameter=16 Line 16 Table 6 WRC 329
38	4-1	74	20x6 EXT	20	1	6.625	0.432		iob=2.2	
39	4-4	74	20x12 EXT	20	1	12.75	0.687	Test D strain gage	iob=2.44	
40	4-5	74	20x12 EXT	20	1	12.75	0.375	Test E strain gage	iob=1.28	
41	1-37	97	4x3 B16.9 A	4.5	0.237	3.5	0.226	N=2225 S=39,600	iob=1.32	
42	1-38	97	4x3 B16.9 B	4.5	0.237	3.5	0.226	N=2612 S=40,600	iob=1.25	
43	1-39	97	4x3 B16.9 C	4.5	0.237	3.5	0.226	N=1030 S=39,600	iob=1.54	
44	1-40	97	4x3 B16.9 D	4.5	0.237	3.5	0.226	N=3143 S=46,100	iob=1.06	

CHRT0010

Chart 029 - EQtee.xlsm – "Markl Tee Tests"



Notes:

1)There are branch and run side i-factors in the test descriptions in CHRT0011. See the "Results" column for the i-factor load description.

CHRT0011

Item #	#	Ref	ID	Do	T	do	t	Auxiliary Data	Results	Notes
1	1-1	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=4626 S=43,652	iib=1.0378	Markl description-Barrel-shape
2	1-2	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=16,342 S=32,614	iib=1.0792	Markl description-Barrel-shape
3	1-3	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=19,934 S=26,841	iib=1.2602	Markl description-Barrel-shape
4	1-4	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=213,895 S=16,776	iib=1.2544	Markl description-Barrel-shape
5	1-5	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=231,153 S=21,434	iib=0.9667	Markl description-Barrel-shape
6	1-41	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=933 S=50,130	iir=1.2448	Markl description-Barrel-shape
7	1-42	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=33,235 S=25,984	iir=1.1753	Markl description-Barrel-shape
8	1-43	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=133,229 S=20,286	iir=1.1404	Markl description-Barrel-shape
9	1-6	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=0.75 N=7630 S=31,827	iib=1.2879	Markl description-conical
10	1-7	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=0.75 N=62,893 S=19,980	iib=1.3454	Markl description-conical
11	1-8	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=0.75 N=132,008 S=12,566	iib=1.8444	Markl description-conical
12	1-9	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=1347 S=45,030	iib=1.2876	Markl description-Cylindrical
13	1-10	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=1590 S=44,802	iib=1.2519	Markl description-Cylindrical
14	1-11	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=11,048 S=26,940	iib=1.4129	Markl description-Cylindrical
15	1-12	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=14,931 S=26,977	iib=1.3285	Markl description-Cylindrical
16	1-13	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=103,276 S=17,195	iib=1.4157	Markl description-Cylindrical
17	1-14	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=171,633 S=17,274	iib=1.2731	Markl description-Cylindrical
18	1-44	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=8354 S=36,501	iir=1.1028	Markl description-Cylindrical
19	1-45	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=80,279 S=27,701	iir=0.9242	Markl description-Cylindrical
20	1-46	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=296,483 S=17,084	iir=1.1539	Markl description-Cylindrical

CHRT0011

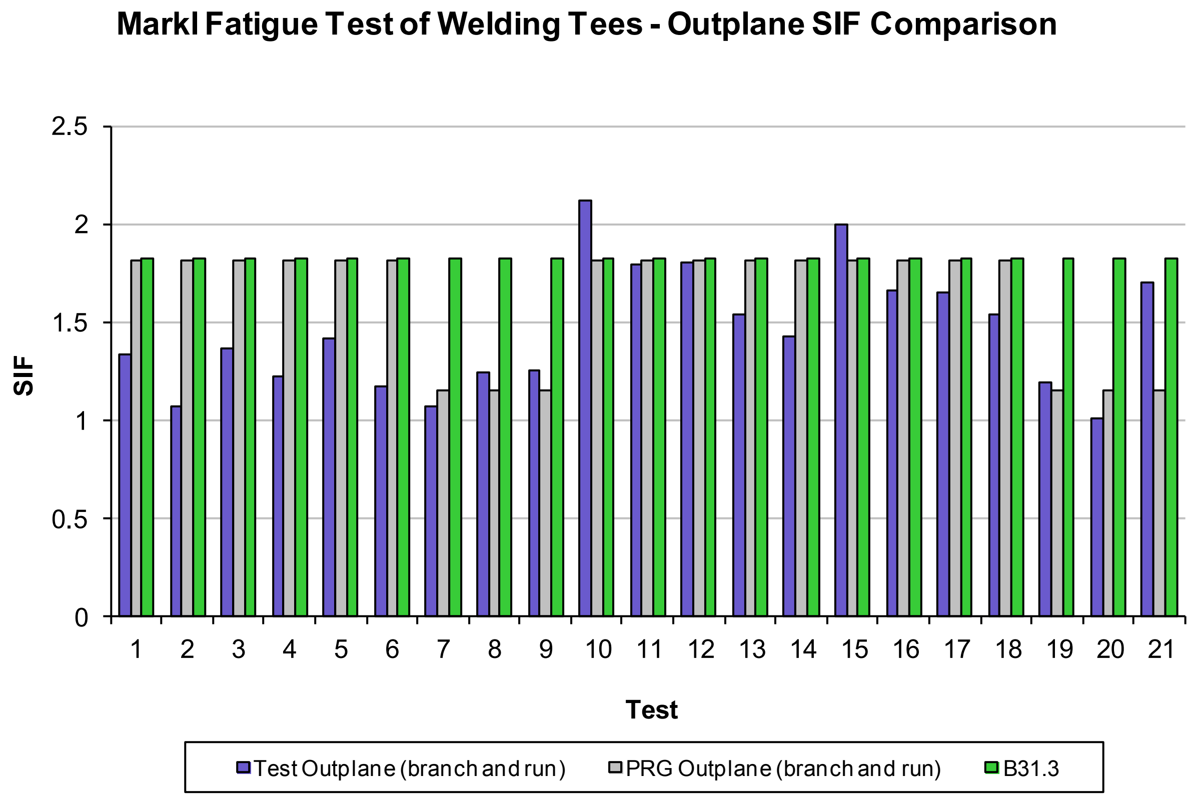
Test Data for Welding Tees Tabulated by Markl:

Row	Paper Figure No.	log(N) (by AutoCAD)	log(S) (by AutoCAD)	D/T	Direction	Loaded Thru	Type	Crotch Radius	Thickness inches	Failure Cycles	(M/Z) Alternating psi	Markl (i)	B313	TestRef
11	10	3.6652	4.64	17.9873418	In Plane	Branch	Tube Turns Barrel	1.125	0.237	4626	43652	1.03783	1.623036	1-1
12	10	4.2133	4.5134	17.9873418	In Plane	Branch	Tube Turns Barrel	1.125	0.237	16342	32614	1.07921	1.623036	1-2
13	10	4.2996	4.4288	17.9873418	In Plane	Branch	Tube Turns Barrel	1.125	0.237	19934	26841	1.260219	1.623036	1-3
14	10	5.3302	4.2247	17.9873418	In Plane	Branch	Tube Turns Barrel	1.125	0.237	213895	16776	1.254371	1.623036	1-4
15	10	5.3639	4.3311	17.9873418	In Plane	Branch	Tube Turns Barrel	1.125	0.237	231153	21434	0.966687	1.623036	1-5
16	10	2.9699	4.7001	17.9873418	In Plane	Run	Tube Turns Barrel	1.125	0.237	933	50130	1.244761	1.62303[illegible]	1-41
17	10	4.5216	4.4147	17.9873418	In Plane	Run	Tube Turns Barrel	1.125	0.237	33235	25984	1.175293	1.623036	1-42
18	10	5.1246	4.3072	17.9873418	In Plane	Run	Tube Turns Barrel	1.125	0.237	133229	20286	1.140371	1.623036	1-43
19	10	3.8825	4.5028	17.9873418	In Plane	Branch	Conical contour	0.75	0.237	7630	31827	1.287852	1.623036	1-6
20	10	4.7986	4.3006	17.9873418	In Plane	Branch	Conical contour	0.75	0.237	62893	19980	1.345383	1.623036	1-7
21	10	5.1206	4.0992	17.9873418	In Plane	Branch	Conical contour	0.75	0.237	132008	12566	1.844362	1.623036	1-8
22	10	3.1295	4.6535	17.9873418	In Plane	Branch	Conventional cylindrical tee	1	0.237	1347	45030	1.287556	1.623036	1-9
23	10	3.2015	4.6513	17.9873418	In Plane	Branch	Conventional cylindrical tee	1	0.237	1590	44802	1.25189	1.623036	1-10
24	10	4.0433	4.4304	17.9873418	In Plane	Branch	Conventional cylindrical tee	1	0.237	11048	26940	1.412883	1.623036	1-11
25	10	4.1741	4.431	17.9873418	In Plane	Branch	Conventional cylindrical tee	1	0.237	14931	26977	1.328453	1.623036	1-12
26	10	5.014	4.2354	17.9873418	In Plane	Branch	Conventional cylindrical tee	1	0.237	103276	17195	1.415683	1.623036	1-13
27	10	5.2346	4.2374	17.9873418	In Plane	Branch	Conventional cylindrical tee	1	0.237	171633	17274	1.273052	1.623036	1-14
28	10	3.9219	4.5623	17.9873418	In Plane	Run	Conventional cylindrical tee	1	0.237	8354	36501	1.102773	1.623036	1-44
29	10	4.9046	4.4425	17.9873418	In Plane	Run	Conventional cylindrical tee	1	0.237	80279	27701	0.924158	1.623036	1-45
30	10	5.472	4.2326	17.9873418	In Plane	Run	Conventional cylindrical tee	1	0.237	296483	17084	1.153894	1.623036	1-46
32	11	3.068	4.6501	17.9873418	Out of Plane	Branch	Tube Turns Barrel	1.125	0.237	1169	44679	1.334953	1.830714	1-15
33	11	3.6264	4.632	17.9873418	Out of Plane	Branch	Tube Turns Barrel	1.125	0.237	4231	42855	1.076183	1.830714	1-16
34	11	4.0989	4.4351	17.9873418	Out of Plane	Branch	Tube Turns Barrel	1.125	0.237	12557	27233	1.362342	1.830714	1-17
35	11	4.3981	4.4232	17.9873418	Out of Plane	Branch	Tube Turns Barrel	1.125	0.237	25009	26497	1.219961	1.830714	1-18
36	11	4.9892	4.239	17.9873418	Out of Plane	Branch	Tube Turns Barrel	1.125	0.237	97544	17338	1.420123	1.830714	1-19
37	11	5.225	4.2731	17.9873418	Out of Plane	Branch	Tube Turns Barrel	1.125	0.237	167880	18754	1.177785	1.830714	1-20
38	11	3.2086	4.7181	17.9873418	Out of Plane	Run	Tube Turns Barrel	1.125	0.237	1617	52252	1.069907	1.830714	1-47
39	11	4.4157	4.4096	17.9873418	Out of Plane	Run	Tube Turns Barrel	1.125	0.237	26044	25680	1.248608	1.830714	1-48
40	11	4.9592	4.2992	17.9873418	Out of Plane	Run	Tube Turns Barrel	1.125	0.237	91033	19916	1.253505	1.830714	1-49
41	11	3.3229	4.3986	17.9873418	Out of Plane	Branch	Conical contour	0.75	0.237	2103	25038	2.118293	1.830714	1-21
42	11	4.7638	4.1833	17.9873418	Out of Plane	Branch	Conical contour	0.75	0.237	58050	15251	1.791043	1.830714	1-22
43	11	5.7399	3.9855	17.9873418	Out of Plane	Branch	Conical contour	0.75	0.237	549414	9672	1.801715	1.830714	1-23
44	11	2.7731	4.6483	17.9873418	Out of Plane	Branch	Conventional cylindrical tee	1	0.237	593	44494	1.535487	1.830714	1-24
45	11	2.9596	4.6414	17.9873418	Out of Plane	Branch	Conventional cylindrical tee	1	0.237	911	43793	1.43168	1.830714	1-25
46	11	3.7461	4.3396	17.9873418	Out of Plane	Branch	Conventional cylindrical tee	1	0.237	5573	21857	1.996853	1.830714	1-26
47	11	4.2028	4.329	17.9873418	Out of Plane	Branch	Conventional cylindrical tee	1	0.237	15951	21330	1.658082	1.830714	1-27
48	11	5.5122	4.0684	17.9873418	Out of Plane	Branch	Conventional cylindrical tee	1	0.237	325237	11706	1.653203	1.830714	1-28
49	11	5.7815	4.0458	17.9873418	Out of Plane	Branch	Conventional cylindrical tee	1	0.237	604644	11112	1.538389	1.830714	1-29
50	11	3.9339	4.525	17.9873418	Out of Plane	Run	Conventional cylindrical tee	1	0.237	8588	33497	1.19505	1.830714	1-50
51	11	4.6421	4.4541	17.9873418	Out of Plane	Run	Conventional cylindrical tee	1	0.237	43863	28451	1.015421	1.830714	1-51
52	11	5.0156	4.1558	17.9873418	Out of Plane	Run	Conventional cylindrical tee	1	0.237	103657	14315	1.699206	1.830714	1-52

Notes:

1)Hinnant at PRG digitized much of the Markl branch connection test data given in refs. [27],[28] and used AutoCAD to read the fatigue test data points. It is believed that these points will provide accurate Markl experimental results. The AutoCAD processed results are reflected in the CHRT0010, CHRT0011, and CHRT0012 data from Markl.

Chart 030 - EQtee.xlsm – "Markl Tee Tests"



Notes:

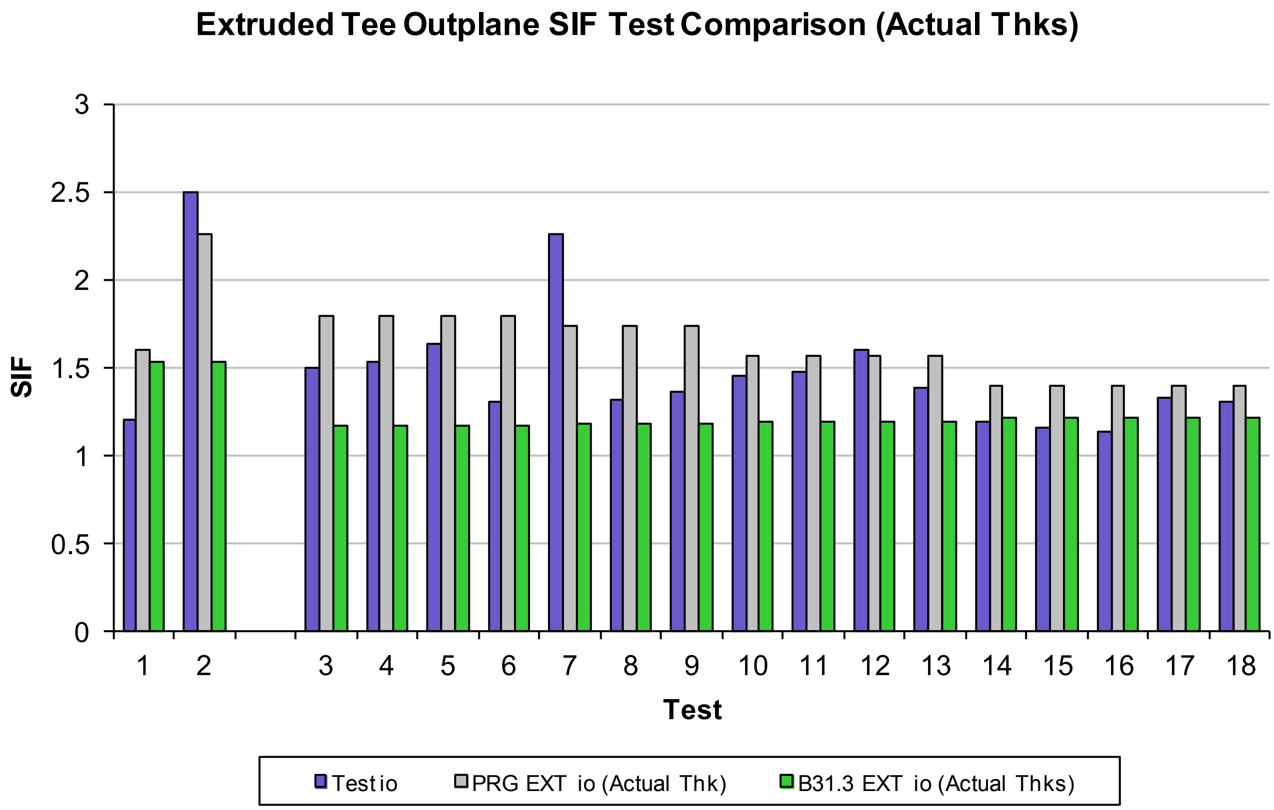
1)Branch and run side i-factors are contained in this test listing. See the CHRT0012 Result column for the load direction used in the test.

CHRT0012

Item #	#	Ref	ID	Do	T	do	t	Auxiliary Data	Results	Notes
1	1-15	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=1169 S=44,679	iob=1.3350	Markl description-Barrel-shape
2	1-16	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=4231 S=42,855	iob=1.0762	Markl description-Barrel-shape
3	1-17	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=12,557 S=27,233	iob=1.3623	Markl description-Barrel-shape
4	1-18	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=25,009 S=26,497	iob=1.2200	Markl description-Barrel-shape
5	1-19	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=97,544 S=17,338	iob=1.4201	Markl description-Barrel-shape
6	1-20	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=167,880 S=18,754	Iob=1.1778	Markl description-Barrel-shape
7	1-47	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=1617 S=52,252	ior=1.0699	Markl description-Barrel-shape
8	1-48	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=26,044 S=25,680	ior=1.2486	Markl description-Barrel-shape
9	1-49	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=91,033 S=19,916	ior=1.2535	Markl description-Barrel-shape
10	1-21	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=0.75 N=2103 S=25,038	iob=2.1183	Markl description-conical
11	1-22	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=0.75 N=58,050 S=15,251	iob=1.7910	Markl description-conical
12	1-23	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=0.75 N=549,414 S=9672	iob=1.8017	Markl description-conical
13	1-24	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=593 S=44,494	iob=1.5355	Markl description-Cylindrical
14	1-25	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=911 S=43,793	iob=1.4317	Markl description-Cylindrical
15	1-26	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=5573 S=21,857	iob=1.9969	Markl description-Cylindrical
16	1-27	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=15,951 S=21,330	iob=1.6581	Markl description-Cylindrical
17	1-28	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=325,237 S=11,706	iob=1.6532	Markl description-Cylindrical
18	1-29	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=604,644 S=11,112	iob=1.5384	Markl description-Cylindrical
19	1-50	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=8588 S=33,497	ior=1.1951	Markl description-Cylindrical
20	1-51	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=43,863 S=28,451	ior=1.0154	Markl description-Cylindrical
21	1-52	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=103,657 S=14,315	ior=1.6992	Markl description-Cylindrical

CHRT0012

Chart 031 - EQext.xlsm – "Extruded Tee Tests"



Notes:

1) See WRC 329 (ref. 54) for a discussion of results using actual body thicknesses.

2) Some data compiled from these 18 tests are given in the table below for convenience.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	AA	AB
1																								
2																						Note(A)	Actual T	
3				Nominal for "standard weight"														Note 2		Actual	Actual		B313	
4	Index #			Odr	Tr	Odb	Tb	r2	N	S	ii	io	Ref		d/D	D/T	t/T	rx/R	r/rp	Do	Tbody	rx	EXT-iob	TestRef
5	1	Ref=7	20x6,L	20	1	6.63	0.432					1.2	7 Table 3 WRC329		0.326	19	0.432	0.21	0.935	20	1	1.25	1.53586	4-23
6	2	Ref=7	20x12,D	20	1	12.8	0.432					2.5			0.635	19	0.687	0.21	0.946	20	1	1	1.53586	4-24
7																								
8	3		2 - 4x4	4.5	0.237	4.5	0.237					1.5			1	18.98734	1	0.117288		5	0.48	0.25	1.16758	4-7
9	4		3 - 4x4	4.5	0.237	4.5	0.237					1.53			1	18.98734	1	0.117288		5	0.48	0.25	1.16758	4-8
10	5		4 - 4x4	4.5	0.237	4.5	0.237					1.63			1	18.98734	1	0.117288		5	0.48	0.25	1.16758	4-9
11	6		5 - 4x4	4.5	0.237	4.5	0.237					1.31			1	18.98734	1	0.117288		5	0.48	0.25	1.16758	4-10
12	7		6 - 6x4	6.625	0.28	4.5	0.237					2.26			0.671868	23.66071	0.846429	0.078802		6.625	0.562	0.25	1.18344	4-11
13	8		7 - 6x4	6.625	0.28	4.5	0.237					1.32			0.671868	23.66071	0.846429	0.078802		6.625	0.562	0.25	1.18344	4-12
14	9		8 - 6x4	6.625	0.28	4.5	0.237					1.36			0.671868	23.66071	0.846429	0.078802		6.625	0.562	0.25	1.18344	4-13
15	10		9 - 8x4	8.625	0.322	4.5	0.237					1.45			0.513429	26.78571	0.736025	0.060219		8.625	0.719	0.25	1.18664	4-14
16	11		10 - 8x4	8.625	0.322	4.5	0.237					1.48			0.513429	26.78571	0.736025	0.060219		8.625	0.719	0.25	1.18664	4-15
17	12		11 - 8x4	8.625	0.322	4.5	0.237					1.6			0.513429	26.78571	0.736025	0.060219		8.625	0.719	0.25	1.18664	4-16
18	13		12 - 8x4	8.625	0.322	4.5	0.237					1.39			0.513429	26.78571	0.736025	0.060219		8.625	0.719	0.25	1.18664	4-17
19	14		13 - 16x4	16	0.375	4.5	0.237					1.19			0.272832	42.66667	0.632	0.032		16	1.031	0.25	1.21115	4-18
20	15		14 - 16x4	16	0.375	4.5	0.237					1.16			0.272832	42.66667	0.632	0.032		16	1.031	0.25	1.21115	4-19
21	16		15 - 16x4	16	0.375	4.5	0.237					1.14			0.272832	42.66667	0.632	0.032		16	1.031	0.25	1.21115	4-20
22	17		16 - 16x4	16	0.375	4.5	0.237					1.33			0.272832	42.66667	0.632	0.032		16	1.031	0.25	1.21115	4-21
23	18		17 - 16x4	16	0.375	4.5	0.237					1.31			0.272832	42.66667	0.632	0.032		16	1.031	0.25	1.21115	4-22

CHRT0013

Item #	#	Ref	ID	Do	T	do	t	Auxiliary Data	Results	Notes
1	4-23	80	20x6 L EXT	20		6.5		N=50,000 S=23,000 fig29 Ref94	iob=1.2	R/T=9.5 r/R=0.326 t/T=0.432 Line 24 Table 3 WRC 329
2	4-24	80	20x12, D	20	1	12.75	0.687	N=20,000 S=13,000 fig29 Ref94	iob=2.5	R/T=9.5 r/R=0.635 t/T=0.687 Line 25 Table 3 WRC 329. This test prepared for comparison with elastic test 4-4.
3	4-7	75	4x4 EXT	5.0	0.480	5.0	0.480		iob=1.5	Body outside diameter=5.0 Line 1 Table 6 WRC 329
4	4-8	75	4x4 EXT	5.0	0.480	5.0	0.480		iob=1.53	Body outside diameter=5.0 Line 2 Table 6 WRC 329
5	4-9	75	4x4 EXT	5.0	0.480	5.0	0.480		iob=1.63	Body outside diameter=5.0 Line 3 Table 6 WRC 329
6	4-10	75	4x4 EXT	5.0	0.480	5.0	0.480		iob=1.31	Body outside diameter=5.0 Line 4 Table 6 WRC 329
7	4-11	75	6x4 EXT	6.625	0.562	4.5	0.237		iob=2.26	Body outside diameter=6.625 Line 5 Table 6 WRC 329
8	4-12	75	6x4 EXT	6.625	0.562	4.5	0.237		iob=1.32	Body outside diameter=6.625 Line 6 Table 6 WRC 329
9	4-13	75	6x4 EXT	6.625	0.562	4.5	0.237		iob=1.36	Body outside diameter=6.625 Line 7 Table 6 WRC 329
10	4-14	75	8x4 EXT	8.625	0.719	4.5	0.237		iob=1.45	Body outside diameter=8.625 Line 8 Table 6 WRC 329
11	4-15	75	8x4 EXT	8.625	0.719	4.5	0.237		iob=1.48	Body outside diameter=8.625 Line 9 Table 6 WRC 329
12	4-16	75	8x4 EXT	8.625	0.719	4.5	0.237		iob=1.60	Body outside diameter=8.625 Line 10 Table 6 WRC 329
13	4-17	75	8x4 EXT	8.625	0.719	4.5	0.237		iob=1.39	Body outside diameter=8.625 Line 11 Table 6 WRC 329
14	4-18	75	16x4 EXT	16	1.031	4.5	0.237		iob=1.19	Body outside diameter=16 Line 12 Table 6 WRC 329
15	4-19	75	16x4 EXT	16	1.031	4.5	0.237		iob=1.16	Body outside diameter=16 Line 13 Table 6 WRC 329
16	4-20	75	16x4 EXT	16	1.031	4.5	0.237		iob=1.14	Body outside diameter=16 Line 14 Table 6 WRC 329
17	4-21	75	16x4 EXT	16	1.031	4.5	0.237		iob=1.33	Body outside diameter=16 Line 15 Table 6 WRC 329
18	4-22	75	16x4 EXT	16	1.031	4.5	0.237		iob=1.31	Body outside diameter=16 Line 16 Table 6 WRC 329

CHRT0013

Chart 032 - EQext.xlsm – "Extruded Tee Tests"

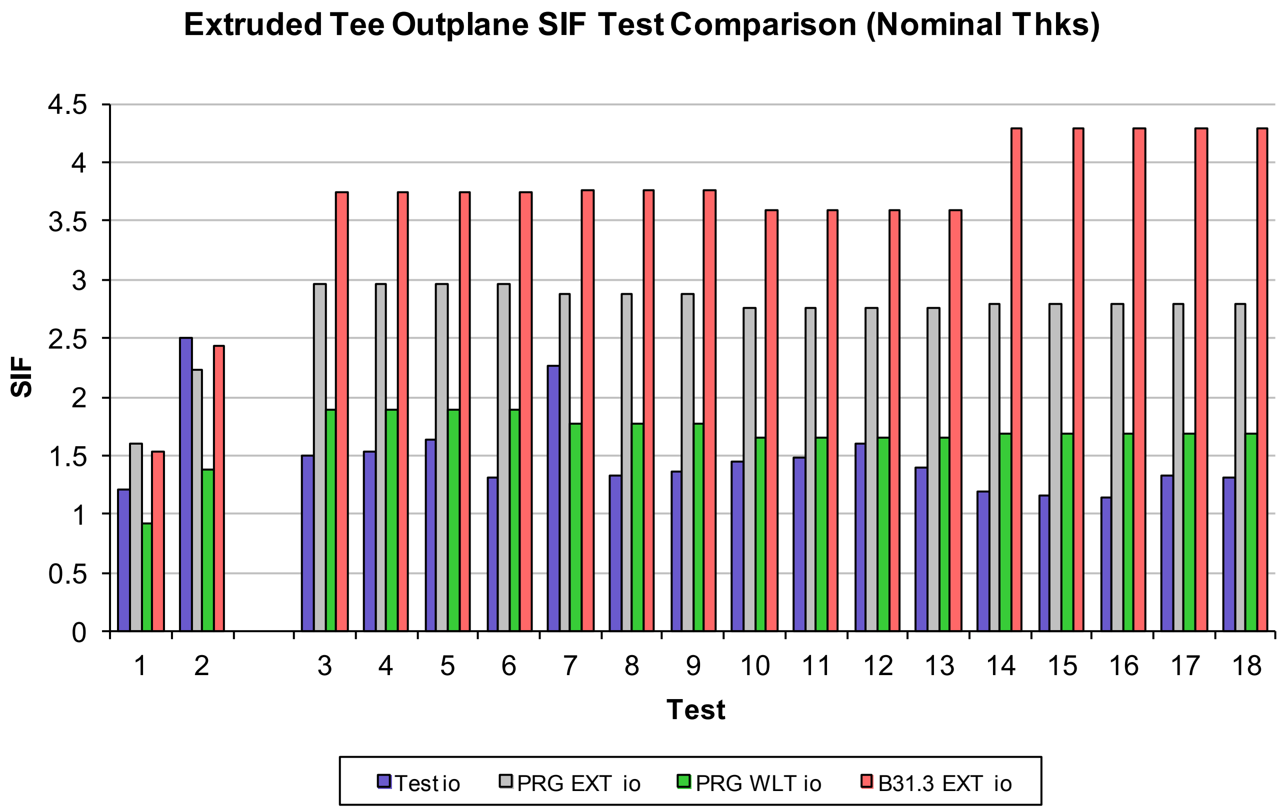
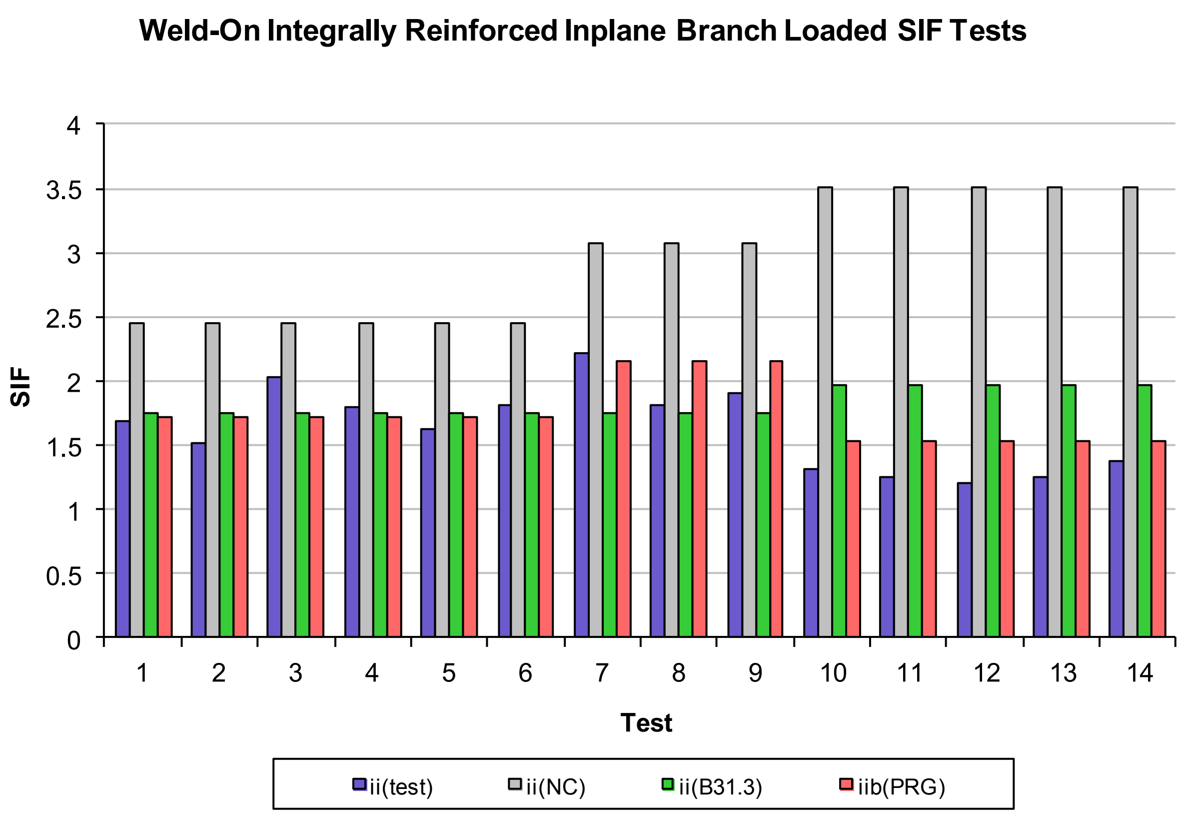


Chart 033 - EQolet.xlsm – "Olets iib"

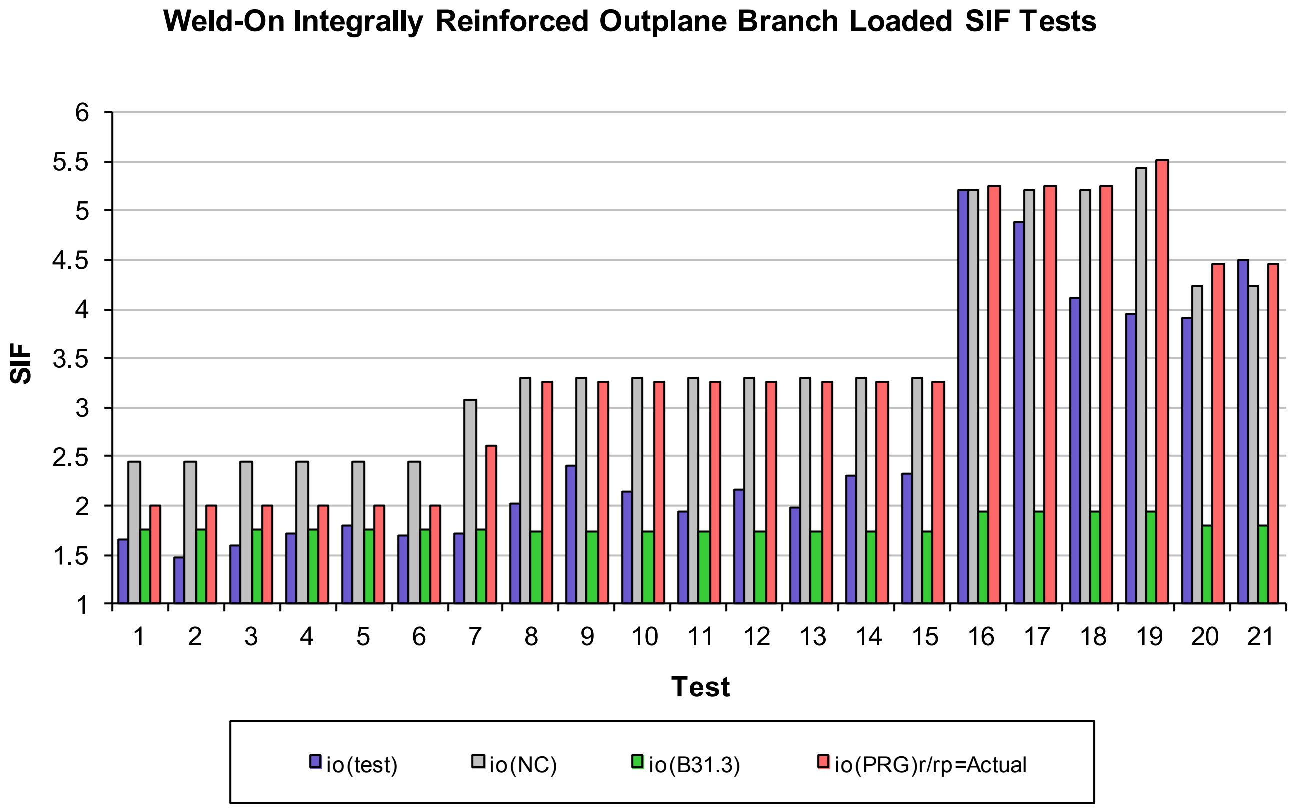


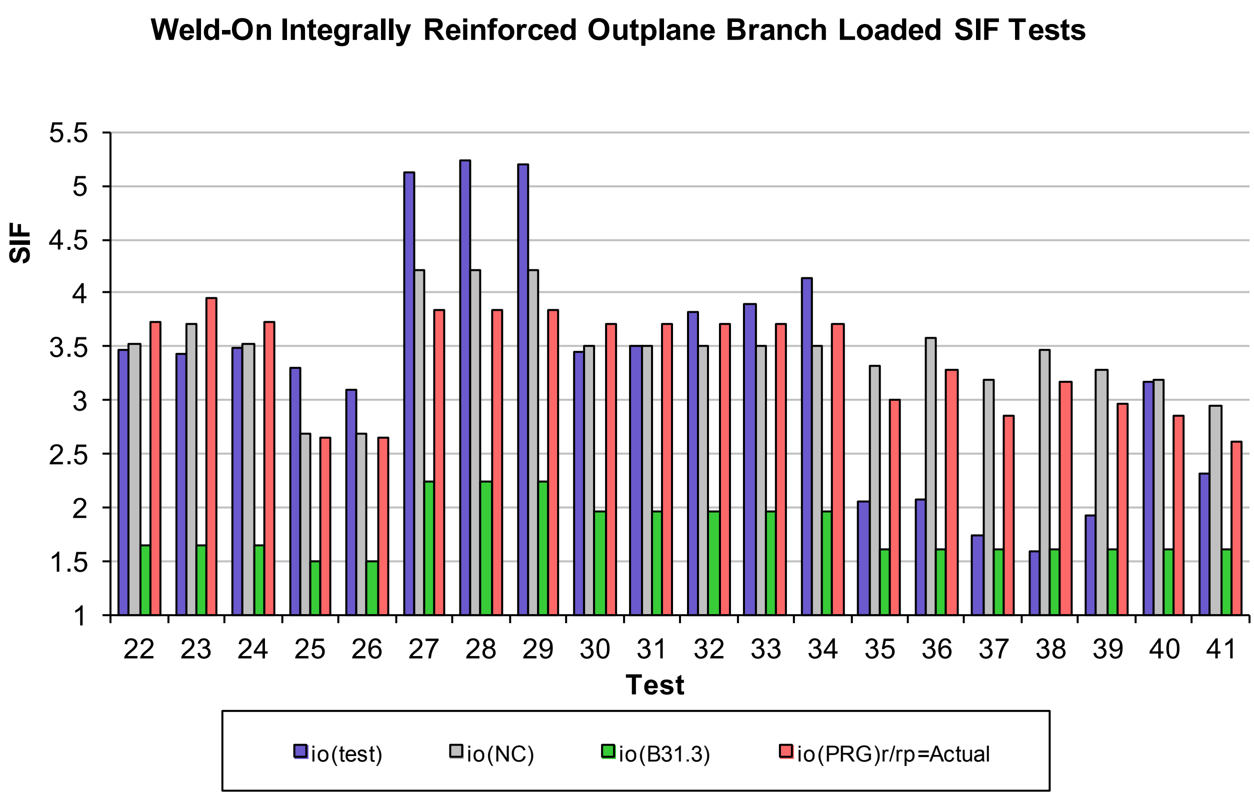
CHRT0014

Item #	#	Ref	ID	Do	T	do	t	Auxiliary Data	Results	Notes
1	6-1	81	4x4 OLET	4.5	0.237	4.5	0.237	N=390 S=43,900	iib=1.692	r/rp=0.63 Line 7 Table 3 WRC 329
2	6-2	81	4x4 OLET	4.5	0.237	4.5	0.237	N=1290 S=38,400	iib=1.523	r/rp=0.63 Line 7 Table 3 WRC 329
3	6-3	81	4x4 OLET	4.5	0.237	4.5	0.237	N=630 S=33,200	iib=2.033	r/rp=0.63 Line 7 Table 3 WRC 329
4	6-4	81	4x4 OLET	4.5	0.237	4.5	0.237	N=2930 S=27,600	iib=1.798	r/rp=0.63 Line 7 Table 3 WRC 329
5	6-5	81	4x4 OLET	4.5	0.237	4.5	0.237	N=14,240 S=22,300	iib=1.622	r/rp=0.63 Line 7 Table 3 WRC 329
6	6-6	81	4x4 OLET	4.5	0.237	4.5	0.237	N=36,310 S=16,500	iib=1.818	r/rp=0.63 Line 7 Table 3 WRC 329
7	6-31	87	4x4 OLET	4.5	0.237	4.5	0.237	N=1230 S=26,700	iib=2.211	Table 4.2-1 p 4-2 Target Test Report; Not in WRC 329
8	6-32	82	4x4 OLET	4.5	0.237	4.5	0.237	N=301 S=43,219	iib=1.810	p.34 Target Tech Report 9/6/77; Line 10 Table 3 WRC 329 ref 10; r/rp=0.79;
9	6-33	82	4x4 OLET	4.5	0.237	4.5	0.237	N=335 S=40,322	iib=1.899	p.34 Target Tech Report 9/6/77; Line 10 Table 3 WRC 329 ref 10; r/rp=0.79
10	6-21	86	12x6 OLET	12.75	0.375	6.625	0.280	N=362 S=57,200	iib=1.318	r/rp=0.675 Line 14 Table 3 WRC 329
11	6-22	86	12x6 OLET	12.75	0.375	6.625	0.280	N=2048 S=42,400	iib=1.258	r/rp=0.675 Line 14 Table 3 WRC 329
12	6-23	86	12x6 OLET	12.75	0.375	6.625	0.280	N=7851 S=33,900	iib=1.202	r/rp=0.675 Line 14 Table 3 WRC 329
13	6-24	86	12x6 OLET	12.75	0.375	6.625	0.280	N=26,597 S=25,400	iib=1.257	r/rp=0.675 Line 14 Table 3 WRC 329
14	6-25	86	12x6 OLET	12.75	0.375	6.625	0.280	N=41,597 S=21,200	iib=1.377	r/rp=0.675 Line 14 Table 3 WRC 329

CHRT0014

Chart 034a and Chart 034b - EQolet.xlsm – "Olets iob"





CHRT0015

Item #	#	Ref	ID	Do	T	do	t	Auxiliary Data	Results	Notes
1	6-7	81	4x4 OLET	4.5	0.237	4.5	0.237	N=216 S=50,700	iob=1.649	r/rp=0.63 Line 8 Table 3 WRC 329
2	6-8	81	4x4 OLET	4.5	0.237	4.5	0.237	N=1000 S=42,000	iob=1.465	r/rp=0.63 Line 8 Table 3 WRC 329
3	6-9	81	4x4 OLET	4.5	0.237	4.5	0.237	N=1403 S=35,900	iob=1.602	r/rp=0.63 Line 8 Table 3 WRC 329
4	6-10	81	4x4 OLET	4.5	0.237	4.5	0.237	N=2600 S=29,600	iob=1.717	r/rp=0.63 Line 8 Table 3 WRC 329
5	6-11	81	4x4 OLET	4.5	0.237	4.5	0.237	N=6100 S23,800	iob=1.801	r/rp=0.63 Line 8 Table 3 WRC 329
6	6-12	81	4x4 OLET	4.5	0.237	4.5	0.237	N=35,600 S=17,800	iob=1.692	r/rp=0.63 Line 8 Table 3 WRC 329
7	6-34	82	4x4 OLET	4.5	0.237	4.5	0.237	N=3330 S=28,061	iob=1.724	p.34 Target Tech Report 9/6/77; Line 9 Table 3 WRC 329 ref 10 ; r/rp=0.79
8	6-13	85	6x4 OLET	6.625	0.280	4.5	0.237	N=412 S=36,400	iob=2.019	As Welded Line 11 Table 3 WRC 329
9	6-14	85	6x4 OLET	6.625	0.280	4.5	0.237	N=1021 S=25,400	iob=2.413	As Welded Line 11 Table 3 WRC 329
10	6-15	85	6x4 OLET	6.625	0.280	4.5	0.237	N=37,027 S=13,900	iob=2.150	As Welded Line 11 Table 3 WRC 329
11	6-16	85	6x4 OLET	6.625	0.280	4.5	0.237	N=530 S=36,018	iob=1.940	Ground Line 12 Table 3 WRC 329
12	6-17	85	6x4 OLET	6.625	0.280	4.5	0.237	N=628 S=31,320	iob=2.157	Ground Line 12 Table 3 WRC 329
13	6-18	85	6x4 OLET	6.625	0.280	4.5	0.237	N=5676 S=21,924	iob=1.984	Ground Line 12 Table 3 WRC 329
14	6-19	85	6x4 OLET	6.625	0.280	4.5	0.237	N=10,559 S=16,617	iob=2.311	Ground Line 12 Table 3 WRC 329
15	6-20	85	6x4 OLET	6.625	0.280	4.5	0.237	N=14,717 S=15,399	iob=2.334	Ground Line 12 Table 3 WRC 329
16	6-36	79	8x6 OLET	8.625	0.322	6.625	0.280	N=331 S=14,762	iob=5.201	Line 16 Table 5 WRC 329 r/rp=0.832
17	6-37	79	8x6 OLET	8.625	0.322	6.625	0.280	N=3492 S=9800	iob=4.890	Line 17 Table 5 WRC 329 r/rp=0.832
18	6-38	79	8x6 OLET	8.625	0.322	6.625	0.280	N=6345 S=10350	iob=4.109	Line 18 Table 5 WRC 329 r/rp=0.832
19	6-39	79	8x6 OLET	8.625	0.322	6.625	0.280	N=3380 S=12,206	iob=3.952	Line 19 Table 5 WRC 329 r/rp=0.868
20	6-40	79	8x5 OLET	8.625	0.322	5.563	0.258	N=12,839 S=9430	iob=3.914	Line 15 Table 5 WRC 329 r/rp=0.801
21	6-41	79	8x5 OLET	8.625	0.322	5.563	0.258	N=4640 S=10,074	iob=4.494	Line 14 Table 5 WRC 329 r/rp=0.801
22	6-42	79	8x4 OLET	8.625	0.322	4.5	0.237	N=8870 S=11,448	iob=3.474	Line 11 Table 5 WRC 329 r/rp=0.812

23	6-43	79	8x4 OLET	8.625	0.322	4.5	0.237	N=3954 S=13,598	iob=3.438	Line 13 Table 5 WRC 329 r/rp=0.853 (50% reinf)
24	6-44	79	8x4 OLET	8.625	0.322	4.5	0.237	N=4310 S=13,167	iob=3.489	Line 12 Table 5 WRC 329 r/rp=0.812
25	6-45	79	8x3 OLET	8.625	0.322	3.5	0.216	N=12,310 S=11,306	iob=3.295	Line 9 Table 5 WRC 329 r/rp=0.773
26	6-46	79	8x3 OLET	8.625	0.322	3.5	0.216	N=4540 S=14,700	iob=3.093	Line 10 Table 5 WRC 329 r/rp=0.773
27	6-47	79	8x8 OLET	8.625	0.322	8.625	0.322	N=10,678 S=7474	iob=5.128	Line 20 Table 5 WRC 329 r/rp=0.852
28	6-48	79	8x8 OLET	8.625	0.322	8.625	0.322	N=1554 S=10,753	iob=5.240	Line 21 Table 5 WRC 329 r/rp=0.852
29	6-49	79	8x8 OLET	8.625	0.322	8.625	0.322	N=4516 S=8743	iob=5.207	Line 22 Table 5 WRC 329 r/rp=0.852
30	6-26	86	12x6 OLET	12.75	0.375	6.625	0.280	N=18 S=39,800	iob=3.453	r/rp=0.675 Line 13 Table 3 WRC 329
31	6-27	86	12x6 OLET	12.75	0.375	6.625	0.280	N=538 S=19,900	iob=3.501	r/rp=0.675 Line 13 Table 3 WRC 329
32	6-28	86	12x6 OLET	12.75	0.375	6.625	0.280	N=2607 S=13,300	iob=3.820	r/rp=0.675 Line 13 Table 3 WRC 329
33	6-29	86	12x6 OLET	12.75	0.375	6.625	0.280	N=5797 S=11,100	iob=3.901	r/rp=0.675 Line 13 Table 3 WRC 329
34	6-30	86	12x6 OLET	12.75	0.375	6.625	0.280	N=56,898 S=6630	iob=4.137	r/rp=0.675 Line 13 Table 3 WRC 329
35	6-51	98	4x3 OLET	4.5	0.237	3.5	0.216	N=1888 S=26,274	iob=2.063	r/rp=0.77271
36	6-52	98	4x3 OLET	4.5	0.237	3.5	0.216	N=3067 S=23,825	iob=2.064	r/rp=0.77271
37	6-53	98	4x3 OLET	4.5	0.237	3.5	0.216	N=1368 S=33,213	iob=1.74	r/rp=0.77271
38	6-54	98	4x3 OLET	4.5	0.237	3.5	0.216	N=1826 S=34,339	iob=1.589	r/rp=0.77271
39	6-55	98	4x3 OLET	4.5	0.237	3.5	0.216	N=5620 S=22,644	iob=1.924	r/rp=0.77271
40	6-56	98	4x3 OLET	4.5	0.237	3.5	0.216	N=1485 S=17,903	iob=3.176	r/rp=0.77271
41	6-57	98	4x3 OLET	4.5	0.237	3.5	0.216	N=1920 S=23,343	iob=2.314	r/rp=0.77271

CHRT0015

Chart 035 - EQolet.xlsm – “Olets iob” (cont.)

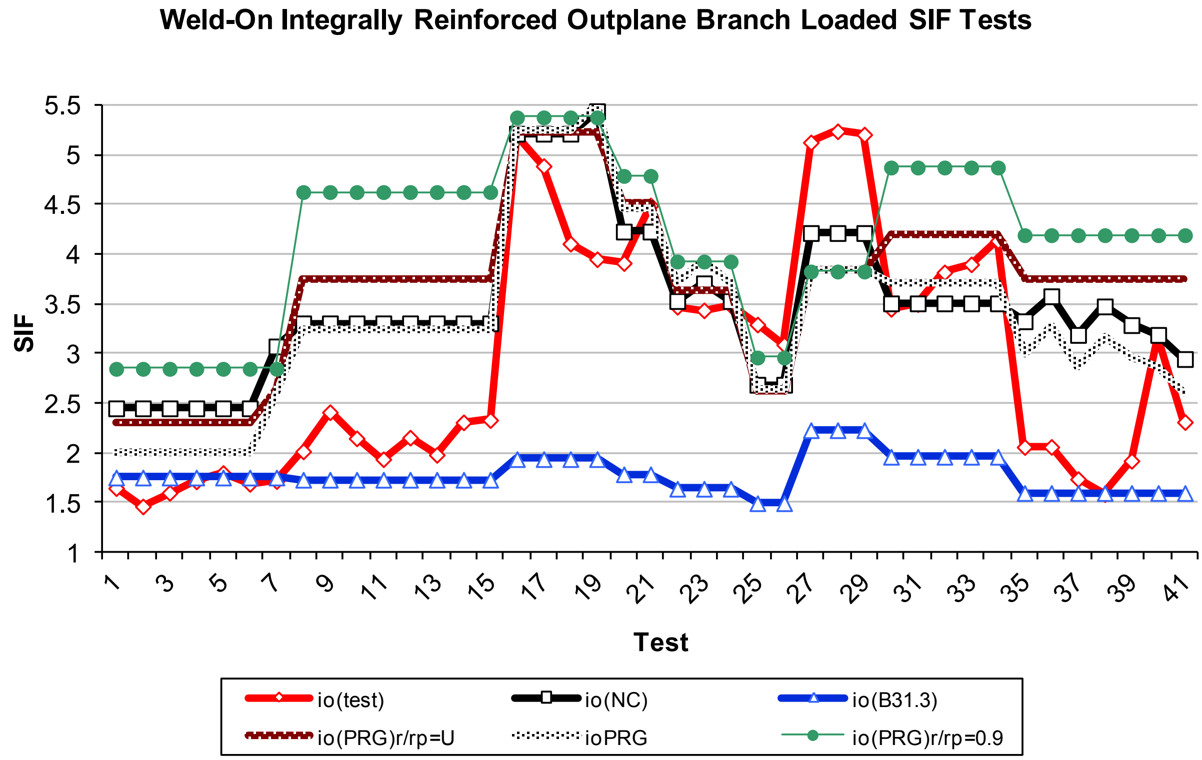
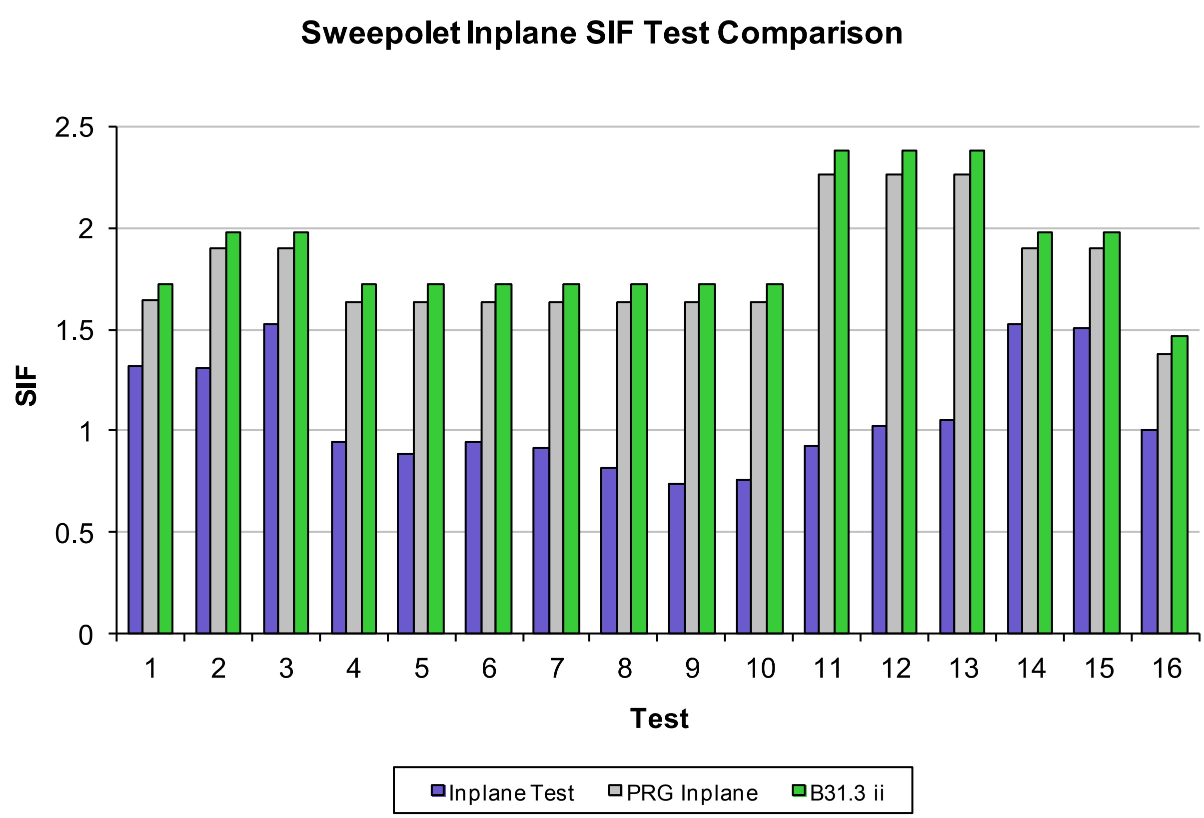


Chart 036 - EQswp.xlsm – “Swp SIF Tests”

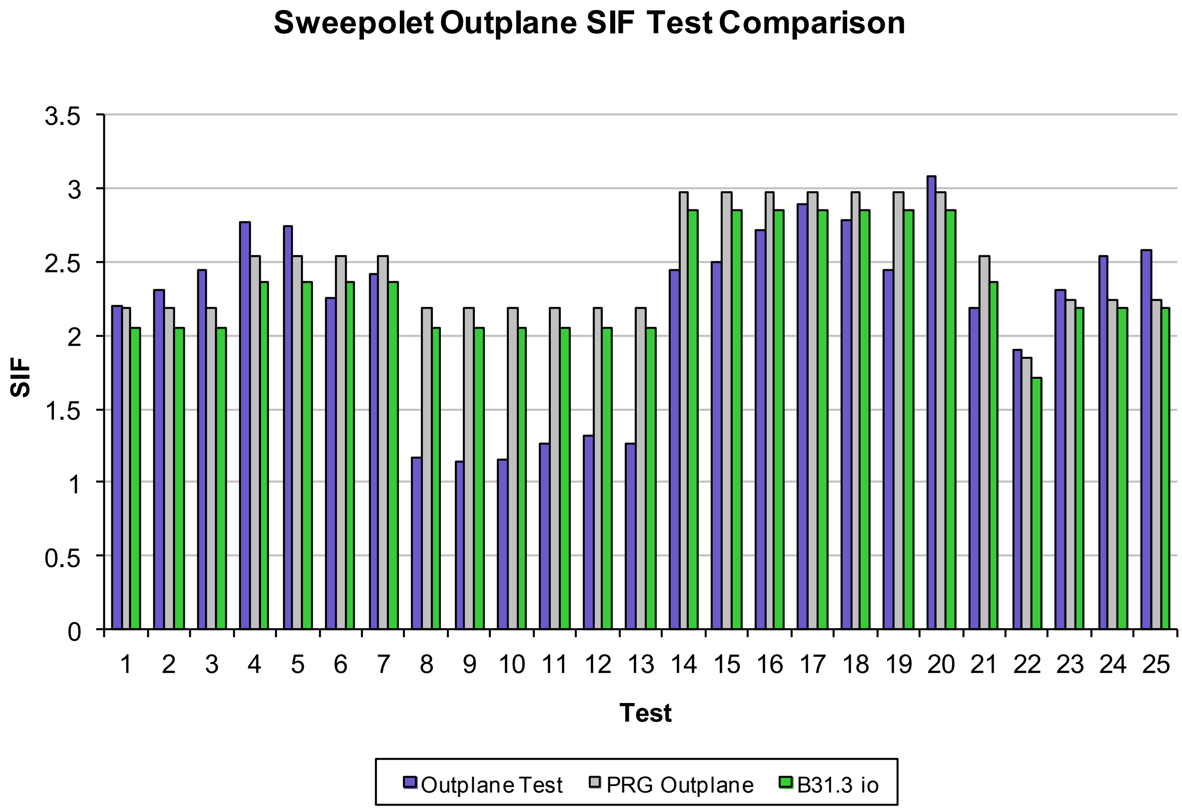


CHRT0016

Item #	#	Ref	ID	Do	T	do	t	Auxiliary Data	Results	Notes
1	5-30	79	12x6 INS	12.750	0.375	6.625	0.280	r2=0.5 N=5347 S=33,224	iib=1.325	Line 25 Table 5 WRC 329 (50% reinf)
2	5-37	79	12x8 INS	12.750	0.375	8.625	0.322	r2=0.625 N=5371 S=33,583	iib=1.309	Line 27 Table 5 WRC 329
3	5-38	79	12x8 INS	12.750	0.375	8.625	0.322	r2=0.625 N=3435 S=31,389	iib=1.532	Line 31 Table 5 WRC 329 (50% reinf)
4	5-16	81	12x6 INS	12.750	0.375	6.625	0.280	r2=1.688 N=444 S=76,200	iib=0.950	
5	5-17	81	12x6 INS	12.750	0.375	6.625	0.280	r2=1.688 N=659 S=75,700	iib=0.884	
6	5-18	81	12x6 INS	12.750	0.375	6.625	0.280	r2=1.688 N=5091 S=47,100	iib=0.944	
7	5-19	81	12x6 INS	12.750	0.375	6.625	0.280	r2=1.688 N=6191 S=46,700	iib=0.915	
8	5-20	81	12x6 INS	12.750	0.375	6.625	0.280	r2=1.688 N=42,363 S=35,700	iib=0.815	
9	5-21	81	12x6 INS	12.750	0.375	6.625	0.280	r2=1.688 N=67,780 S=35,600	iib=0.744	
10	5-22	81	12x6 INS	12.750	0.375	6.625	0.280	r2=1.688 N=310,111 S=25,600	iib=0.763	
11	5-8	81	14x10 INS	14	0.375	10.75	0.365	r2=3.75 N=605 S=73,100	iib=0.931	
12	5-9	81	14x10 INS	14	0.375	10.75	0.365	r2=3.75 N=5914 S=42,100	iib=1.024	
13	5-10	81	14x10 INS	14	0.375	10.75	0.365	r2=3.75 N=21,553 S=31,500	iib=1.057	
14	5-11	82	12x8 INS	12.75	0.375	8.625	0.322	r2=0.75 N=34,029 S=19,851	iib=1.531	Line 21 Table 3 WRC 329
15	5-12	82	12x8 INS	12.75	0.375	8.625	0.322	r2=0.75 N=15,495 S=23,632	iib=1.505	Line 21 Table 3 WRC 329
16	5-15	82	8x4 INS	8.625	0.322	4.5	0.237	r2=0.375 N=3858 S=46,894	iib=1.002	Line 23 Table 3 WRC 329

CHRT0016

Chart 037 - EQswp.xlsm – "Swp SIF Tests"



CHRT0017

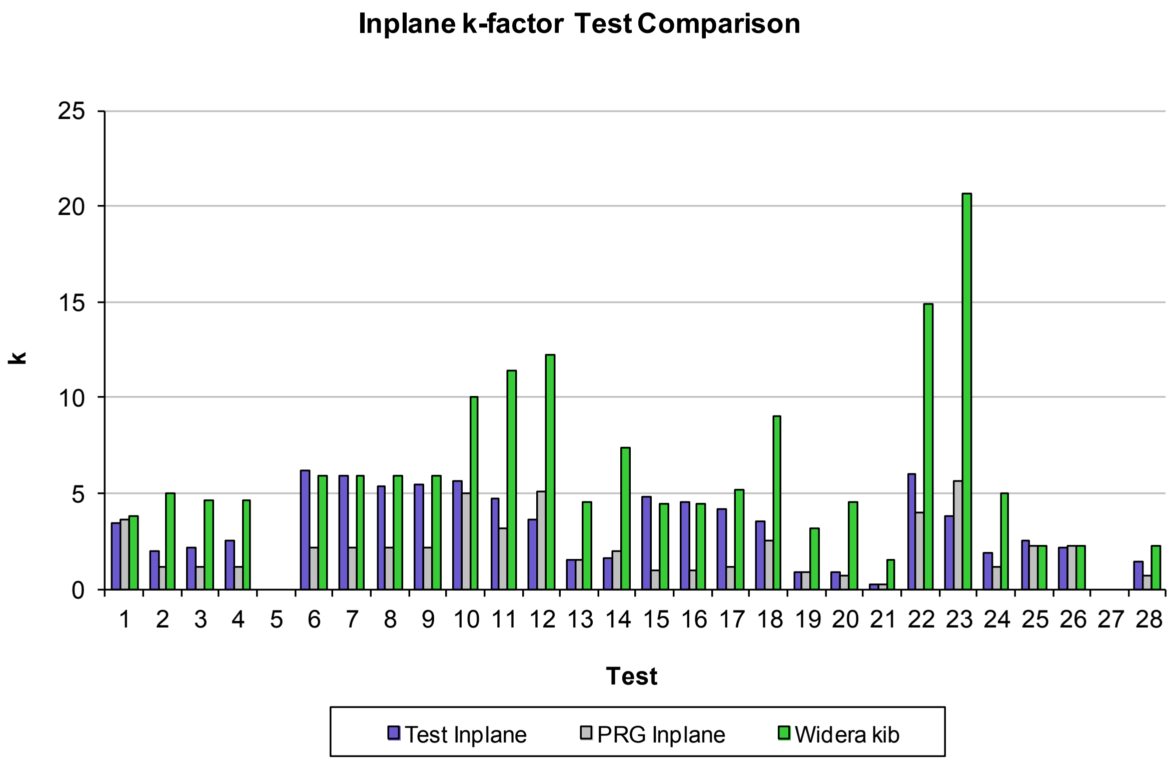
Item #	#	Ref	ID	Do	T	do	t	Auxiliary Data	Results	Notes
1	5-31	79	12x6 INS	12.750	0.375	6.625	0.280	r2=0.5 N=4445 S=20,769	iob=2.199	Line 23 Table 5 WRC 329
2	5-32	79	12x6 INS	12.750	0.375	6.625	0.280	r2=0.5 N=7655 S=17,728	iob=2.311	Line 24 Table 5 WRC 329
3	5-29	79	12x6 INS	12.750	0.375	6.625	0.280	r2=0.5 N=6760 S=17,237	iob=2.436	Line 26 Table 5 WRC 329 (50% reinf)
4	5-33	79	12x8 INS	12.750	0.375	8.625	0.322	r2=0.625 N=1840 S=19,701	iob=2.765	Line 28 Table 5 WRC 329
5	5-34	79	12x8 INS	12.750	0.375	8.625	0.322	r2=0.625 N=8510 S=14,631	iob=2.741	Line 29 Table 5 WRC 329
6	5-36	79	12x8 INS	12.750	0.375	8.625	0.322	r2=0.625 N=5460 S=19,445	iob=2.254	Line 30 Table 5 WRC 329
7	5-35	79	12x8 INS	12.750	0.375	8.625	0.322	r2=0.625 N=4525 S=18,862	iob=2.412	Line 32 Table 5 WRC 329 (50% reinf)
8	5-23	81	12x6 INS	12.750	0.375	6.625	0.280	r2=1.688 N=631 S=58,000	iob=1.163	
9	5-24	81	12x6 INS	12.750	0.375	6.625	0.280	r2=1.688 N=779 S=56,500	iob=1.145	
10	5-25	81	12x6 INS	12.750	0.375	6.625	0.280	r2=1.688 N=5309 S=38,100	iob=1.157	
11	5-26	81	12x6 INS	12.750	0.375	6.625	0.280	r2=1.688 N=32,490 S=24,200	iob=1.268	
12	5-27	81	12x6 INS	12.750	0.375	6.625	0.280	r2=1.688 N=55,316 S=20,900	iob=1.320	
13	5-28	81	12x6 INS	12.750	0.375	6.625	0.280	r2=1.688 N=117,588 S=18,700	iob=1.268	
14	5-1	81	14x10 INS	14	0.375	10.75	0.365	r2=3.75 N=140 S=37,300	iob=2.445	
15	5-2	81	14x10 INS	14	0.375	10.75	0.365	r2=3.75 N=215 S=33,500	iob=2.498	
16	5-3	81	14x10 INS	14	0.375	10.75	0.365	r2=3.75 N=1862 S=20,000	iob=2.717	
17	5-4	81	14x10 INS	14	0.375	10.75	0.365	r2=3.75 N=4546 S=15,700	iob=2.896	
18	5-5	81	14x10 INS	14	0.375	10.75	0.365	r2=3.75 N=49,915 S=10,100	iob=2.787	
19	5-6	81	14x10 INS	14	0.375	10.75	0.365	r2=3.75 N=238 S=33,500	iob=2.448	
20	5-7	81	14x10 INS	14	0.375	10.75	0.365	r2=3.75 N=30,374 S=10,100	iob=3.079	
21	5-13	82	12x8 INS	12.75	0.375	8.625	0.322	r2=0.75 N=1269 S=26,891	iob=2.182	Line 20 Table 3 WRC 329
22	5-14	82	8x4 INS	8.625	0.322	4.5	0.237	r2=0.375 N=758 S=34,273	iob=1.898	Line 22 Table 3 WRC 329
23	5-39	89	14x6 INS	14	0.375	6.625	0.280	r2=0.421 N=337 S=33,200	iob=2.304	Line 17 Table 3 WRC 329
24	5-40	89	14x6 INS	14	0.375	6.625	0.280	r2=0.421 N=1605 S=22,100	iob=2.533	Line 17 Table 3 WRC 329
25	5-41	89	14x6 INS	14	0.375	6.625	0.280	r2=0.421 N=6341 S=16,500	iob=2.578	Line 17 Table 3 WRC 329

CHRT0017

Test Data from Charts 036 and 037 is given below for convenience. Source data for each test is given in Column "C" of the spreadsheet below. This data is also reflected in the auto-generated tables CHRT0016 and CHRT0017 above.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
38																		
39					Nominal for "standard weight"							Test	Test					
40		Index #			Odr	Tr	Odb	Tb	r2	N	S	ii	io	Ref		d/D	D/T	t/T
41	INPLANE TESTS		TestRef															
42		1	5-30	12x6,50%	12.75	0.375	6.625	0.28	0.5			1.32				0.513	33	0.747
43		2	5-37	12x8	12.75	0.375	8.625	0.322	0.625			1.31				0.671	33	0.859
44		3	5-38	12x8,50%	12.75	0.375	8.625	0.322	0.625			1.53				0.671	33	0.859
45		4	5-16	12x6 Std	12.75	0.375	6.625	0.28	1.688	444	76200	0.95				0.5127	33	0.747
46		5	5-17	12x6 Std	12.75	0.375	6.625	0.28	1.688	659	75700	0.884				0.5127	33	0.747
47		6	5-18	12x6 Std	12.75	0.375	6.625	0.28	1.688	5091	47100	0.944				0.5127	33	0.747
48		7	5-19	12x6 Std	12.75	0.375	6.625	0.28	1.688	6191	46700	0.915				0.5127	33	0.747
49		8	5-20	12x6 Std	12.75	0.375	6.625	0.28	1.688	42363	35700	0.815				0.5127	33	0.747
50		9	5-21	12x6 Std	12.75	0.375	6.625	0.28	1.688	67780	35600	0.744				0.5127	33	0.747
51		10	5-22	12x6 Std	12.75	0.375	6.625	0.28	1.688	310111	25600	0.763				0.5127	33	0.747
52		11	5-8	14x10	14	0.375	10.75	0.365	3.75	605	73100	0.931				0.7622	36	0.973
53		12	5-9	14x10	14	0.375	10.75	0.365	3.75	5914	42100	1.024				0.7622	36	0.973
54		13	5-10	14x10	14	0.375	10.75	0.365	3.75	21553	31500	1.057				0.7622	36	0.973
55		14	5-11	12x8	12.75	0.375	8.625	0.322	0.75	34029	19851	1.531				0.6709	33	0.859
56		15	5-12	12x8	12.75	0.375	8.625	0.322	0.75	15495	23632	1.505				0.6709	33	0.859
57		16	5-15	8x4	8.625	0.322	4.5	0.237	0.375	3858	46894	1.002				0.5134	26	0.736
58																		
59	OUTPLANE TESTS																	
60		1	5-31	12x6	12.75	0.375	6.625	0.28	0.5	4445	20769		2.2			0.513	33	0.747
61		2	5-32	12x6	12.75	0.375	6.625	0.28	0.5	7655	17728		2.31			0.513	33	0.747
62		3	5-29	12x6,50%	12.75	0.375	6.625	0.28	0.5	6760	17237		2.44			0.513	33	0.747
63		4	5-33	12x8	12.75	0.375	8.625	0.322	0.625	1840	19701		2.77			0.671	33	0.859
64		5	5-34	12x8	12.75	0.375	8.625	0.322	0.625	8510	14631		2.74			0.671	33	0.859
65		6	5-36	12x8,100%	12.75	0.375	8.625	0.322	0.625	5460	19445		2.25			0.671	33	0.859
66		7	5-35	12x8,50%	12.75	0.375	8.625	0.322	0.625	4525	18862		2.41			0.671	33	0.859
67		8	5-23	12x6 Std	12.75	0.375	6.625	0.28	1.688	631	58000		1.163			0.5127	33	0.747
68		9	5-24	12x6 Std	12.75	0.375	6.625	0.28	1.688	779	56500		1.145			0.5127	33	0.747
69		10	5-25	12x6 Std	12.75	0.375	6.625	0.28	1.688	5309	38100		1.157			0.5127	33	0.747
70		11	5-26	12x6 Std	12.75	0.375	6.625	0.28	1.688	32490	24200		1.268			0.5127	33	0.747
71		12	5-27	12x6 Std	12.75	0.375	6.625	0.28	1.688	55316	20900		1.32			0.5127	33	0.747
72		13	5-28	12x6 Std	12.75	0.375	6.625	0.28	1.688	117588	18700		1.268			0.5127	33	0.747
73		14	5-1	14x10	14	0.375	10.75	0.365	3.75	140	37300		2.445			0.7622	36	0.973
74		15	5-2	14x10	14	0.375	10.75	0.365	3.75	215	33500		2.498			0.7622	36	0.973
75		16	5-3	14x10	14	0.375	10.75	0.365	3.75	1862	20000		2.717			0.7622	36	0.973
76		17	5-4	14x10	14	0.375	10.75	0.365	3.75	4546	15700		2.896			0.7622	36	0.973
77		18	5-5	14x10	14	0.375	10.75	0.365	3.75	49915	10100		2.787			0.7622	36	0.973
78		19	5-6	14x10	14	0.375	10.75	0.365	3.75	238	33500		2.448			0.7622	36	0.973
79		20	5-7	14x10	14	0.375	10.75	0.365	3.75	30374	10000		3.079			0.7622	36	0.973
80		21	5-13	12x8	12.75	0.375	8.625	0.322	0.75	1269	26891		2.182			0.6709	33	0.859
81		22	5-14	8x4	8.625	0.322	4.5	0.237	0.375	758	34273		1.898			0.5134	26	0.736
82		23	5-39	14x6	14	0.375	6.625	0.28	0.421	337	33200		2.304			0.4657	36	0.747
83		24	5-40	14x6	14	0.375	6.625	0.28	0.421	1605	22100		2.533			0.4657	36	0.747
84		25	5-41	14x6	14	0.375	6.625	0.28	0.421	6341	16500		2.578			0.4657	36	0.747
85																		

Chart 038 - General Flexibility Test Data.xlsm – "Flex Fact Comp for Plotting (2)" – Collection of variety of branch connection types. See references for details.

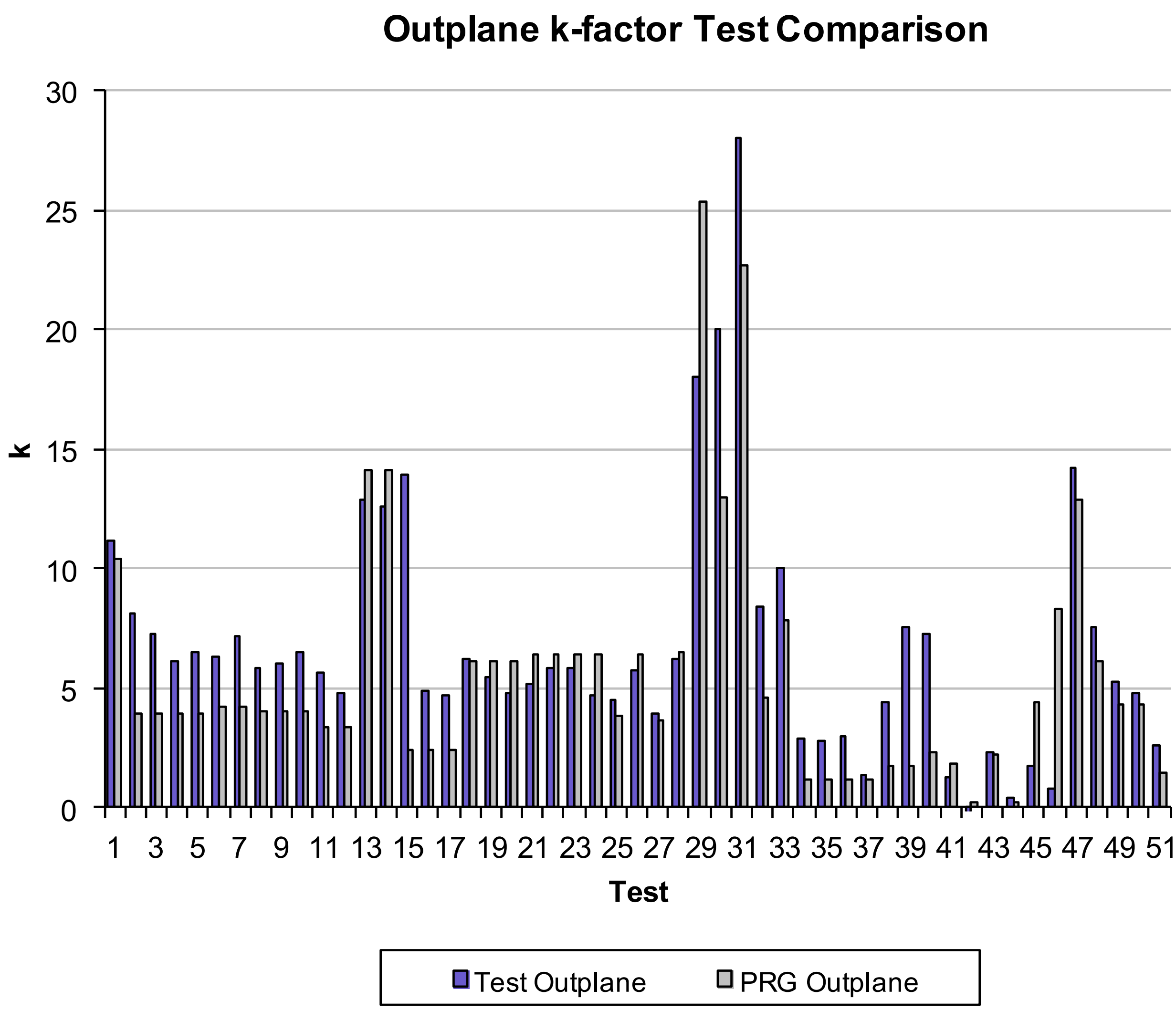


CHRT0018

Item #	#	Ref	ID	Do	T	do	t	Auxiliary Data	Results	Notes
1	3-48	79	8x6 UFT	8.625	0.322	6.625	0.280	N=5410 S=7515	kib=3.408 kob=11.189	Line 2 Table 5 WRC 329
2	5-30	79	12x6 INS	12.750	0.375	6.625	0.280	r2=0.5 N=5347 S=33,224	kib=1.933 (d)	Line 25 Table 5 WRC 329 (50% reinf)
3	5-37	79	12x8 INS	12.750	0.375	8.625	0.322	r2=0.625 N=5371 S=33,583	kib=2.147 (d)	Line 27 Table 5 WRC 329
4	5-38	79	12x8 INS	12.750	0.375	8.625	0.322	r2=0.625 N=3435 S=31,389	kib=2.517 (d)	Line 31 Table 5 WRC 329 (50% reinf)
6	2-49	90	8x4 PAD E	8.625	0.25	4.5	0.237	N=1260 S=26,773	kib=6.1802	
7	2-50	90	8x4 PAD F	8.625	0.25	4.5	0.237	N=1901 S=23,997	kib=5.8761	
8	2-51	90	8x4 PAD G	8.625	0.25	4.5	0.237	N=1366 S=28,752	kib=5.363	
9	2-52	90	8x4 PAD H	8.625	0.25	4.5	0.237	N=1075 S=28,133	kib=5.454	
10	2-85	71,94 ,106	24x12 PAD	24	0.312	12.75	0.25		kob=18 kib=5.6	
11	2-83	71,94 ,106	24x4 PAD	24	0.312	4.5	0.237		kob=20 kib=4.7	
12	2-84	71,94 ,106	24x8 PAD	24	0.312	8.625	0.25		kob=28 kib=3.6	
13	2-54	77	16x6 PAD	16	0.5	6.625	0.280	N=1,400,000 S=4200	kib=1.5	Tp=0.5
14	2-88	71	48x6 PAD	49.25	0.625	6.625	0.280		kob=10 kib=1.6	L1=41 L2=73 Dp=10.5 Tp=0.625
15	1-53	71	12x10	12.75	0.5	10.75	0.5		kib=4.8 kob=4.4	
16	1-54	71	12x10	12.75	0.5	10.75	0.5		kib=4.5 kob=7.6	
17	1-55	71	12x10	12.75	0.429	10.75	0.45		kib=4.2 kob=7.3	
18	1-35	73	24x24 B16.9	24	0.687	24	0.687	N=18,532 S=20,629	ktr=0.553 kor=-0.425 kir=2.409	T-10 A 212-61T GrB Table 14. 4785. See PRG est. for k-factor equations for these tee tests.
19	1-56	73	24x24x24	24	2.343	24	2.343		ktr=-1.587 kor=-0.305 kir=0.457	T-11 A105 Gr2 k's from Table 14 CR4785.
20	1-57	73	24x24x10	24	0.687	10.75	0.365		ktr=-1.105 kor=-0.425 kir=-0.142	T-12 A515 Gr70
21	1-58	73	24x24x10	24	2.343	10.75	1.125		ktr=-1.188 kor=-0.305 kir=-0.152	T-13 A105 Gr2
22	1-59	73	24x24x10	24	0.375	10.75	0.375		kib=6 kob=1.8	Tee Bored to Sch 20.
23	1-36	73	24x24 B16.9	24	0.25	24	0.25	N=2344 S=24,202	ktr=-0.531 kor=-0.813 kir=2.191	T-16 SA 312 304L ORNL T-16 was ordered as sched. 10, but was manufactured as sched. 20 and "through bored" to sched
24	5-16	81	12x6 INS	12.750	0.375	6.625	0.280	r2=1.688 N=444 S=76,200	kib=1.871	Ref 105 – k est. from test results in ref 105
25	3-44	91	8x2 UFT E	8.625	0.322	2.5	0.065	N=1919, Neq=535	kib=2.4813	MTR Annex A shows run wall=0.322. Report states that run wall is 0.188. Annex I in 07-02 report believes run wall is
26	3-45	91	8x2 UFT F	8.625	0.322	2.5	0.065	N=2884 Neq=858	kib=2.171	See Note 3-44
28	2-48	91	8x2 PAD P	8.625	0.322	2.5	0.065	N=223 Neq=223	kib=1.436	See note for 2-47

CHRT0018

Chart 039 - General Flexibility Test Data.xlsm – "Flex Fact Comp for Plotting (2)"



CHRT0019

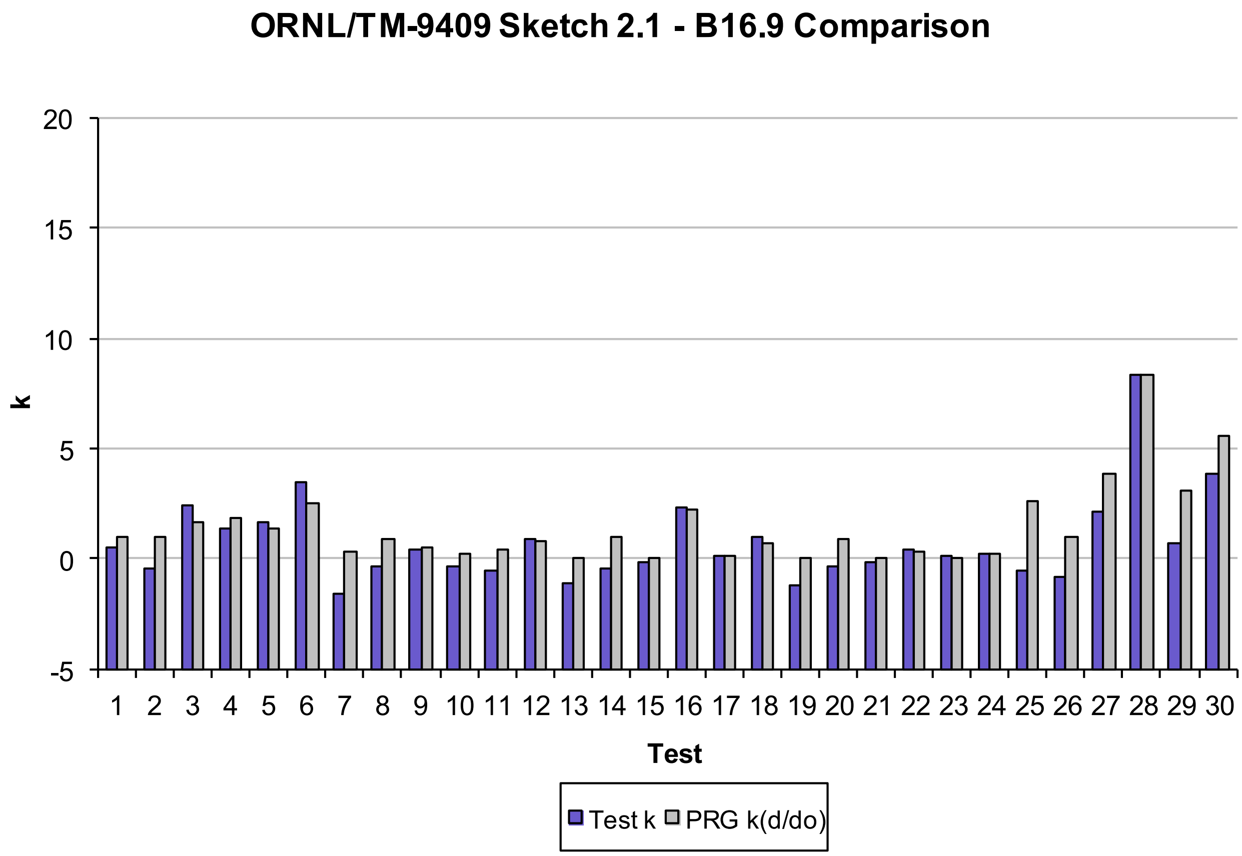
Item #	#	Ref	ID	Do	T	do	t	Auxiliary Data	Results	Notes
1	3-48	79	8x6 UFT	8.625	0.322	6.625	0.280	N=5410 S=7515	kib=3.408 kob=11.189	Line 2 Table 5 WRC 329
2	6-36	79	8x6 OLET	8.625	0.322	6.625	0.280	N=331 S=14,762	kob=8.153	Line 16 Table 5 WRC 329 r/rp=0.832
3	6-37	79	8x6 OLET	8.625	0.322	6.625	0.280	N=3492 S=9800	kob=7.329	Line 17 Table 5 WRC 329 r/rp=0.832
4	6-38	79	8x6 OLET	8.625	0.322	6.625	0.280	N=6345 S=10350	kob=6.175	Line 18 Table 5 WRC 329 r/rp=0.832
5	6-39	79	8x6 OLET	8.625	0.322	6.625	0.280	N=3380 S=12,206	kob=6.540	Line 18 Table 5 WRC 329 r/rp=0.868
6	6-40	79	8x5 OLET	8.625	0.322	5.563	0.258	N=12,839 S=9430	kob=6.311	Line 15 Table 5 WRC 329 r/rp=0.801
7	6-41	79	8x5 OLET	8.625	0.322	5.563	0.258	N=4640 S=10,074	kob=7.210	Line 14 Table 5 WRC 329 r/rp=0.801
8	6-42	79	8x4 OLET	8.625	0.322	4.5	0.237	N=8870 S=11,448	kob=5.895	Line 11 Table 5 WRC 329 r/rp=0.812
9	6-43	79	8x4 OLET	8.625	0.322	4.5	0.237	N=3954 S=13,598	kob=6.093	Line 13 Table 5 WRC 329 r/rp=0.853 (50% reinf)
10	6-44	79	8x4 OLET	8.625	0.322	4.5	0.237	N=4310 S=13,167	kob=6.548	Line 12 Table 5 WRC 329 r/rp=0.812
11	6-45	79	8x3 OLET	8.625	0.322	3.5	0.216	N=12,310 S=11,306	kob=5.679	Line 9 Table 5 WRC 329 r/rp=0.773
12	6-46	79	8x3 OLET	8.625	0.322	3.5	0.216	N=4540 S=14,700	kob=4.839	Line 10 Table 5 WRC 329 r/rp=0.773
13	3-49	79	12x10 UFT	12.75	0.375	10.75	0.365	N=212 S=9399	kob=12.912	Line 3 Table 5 WRC 329
14	3-50	79	12x10 UFT	12.75	0.375	10.75	0.365	N=6130 S=5529	kob=12.621	Line 4 Table 5 WRC 329
15	6-47	79	8x8 OLET	8.625	0.322	8.625	0.322	N=10,678 S=7474	kob=13.980	Line 20 Table 5 WRC 329 r/rp=0.852
16	6-48	79	8x8 OLET	8.625	0.322	8.625	0.322	N=1554 S=10,753	kob=4.911	Line 21 Table 5 WRC 329 r/rp=0.852
17	6-49	79	8x8 OLET	8.625	0.322	8.625	0.322	N=4516 S=8743	kob=4.757	Line 22 Table 5 WRC 329 r/rp=0.852
18	5-29	79	12x6 INS	12.750	0.375	6.625	0.280	r2=0.5 N=6760 S=17,237	kob=6.224	Line 26 Table 5 WRC 329 (50% reinf)
19	5-31	79	12x6 INS	12.750	0.375	6.625	0.280	r2=0.5 N=4445 S=20,769	kob=5.444	Line 23 Table 5 WRC 329
20	5-32	79	12x6 INS	12.750	0.375	6.625	0.280	r2=0.5 N=7655 S=17,728	kob=4.835	Line 24 Table 5 WRC 329
21	5-33	79	12x8 INS	12.750	0.375	8.625	0.322	r2=0.625 N=1840 S=19,701	kob=5.147	Line 28 Table 5 WRC 329
22	5-34	79	12x8 INS	12.750	0.375	8.625	0.322	r2=0.625 N=8510 S=14,631	kob=5.865	Line 29 Table 5 WRC 329

23	5-35	79	12x8 INS	12.750	0.375	8.625	0.322	r2=0.625 N=4525 S=18,862	kob=5.889	Line 32 Table 5 WRC 329 (50% reinf)
24	5-36	79	12x8 INS	12.750	0.375	8.625	0.322	r2=0.625 N=5460 S=19,445	kob=4.702	Line 30 Table 5 WRC 329
25	2-44	79	8x6 PAD K2	8.625	0.322	6.625	0.280	N=7541 S=14,752	kob=4.536	Line 5 Table 5 WRC 329
26	2-45	79	12x6 PAD K3	12.75	0.375	6.625	0.280	N=2829 S=14,408	kob=5.799	Line 8 Table 5 WRC 329
27	2-43	79	8x3 PAD K1	8.625	0.322	3.5	0.216	N=51,638 S=14,331	kob=3.9255	Line 6 Table 5 WRC 329
28	2-46	79	12x8 PAD K4	12.75	0.375	8.625	0.322	N=1056 S=15,589	kob=6.267	Line 7 Table 5 WRC 329
29	2-85	71,94,106	24x12 PAD	24	0.312	12.75	0.25		kob=18 kib=5.6	
30	2-83	71,94,106	24x4 PAD	24	0.312	4.5	0.237		kob=20 kib=4.7	
31	2-84	71,94,106	24x8 PAD	24	0.312	8.625	0.25		kob=28 kib=3.6	
32	2-53	77	16x6 PAD	16	0.5	6.625	0.280	N=650,000 S=5100	kob=8.4	Tp=0.5
33	2-88	71	48x6 PAD	49.25	0.625	6.625	0.280		kob=10 kib=1.6	L1=41 L2=73 Dp=10.5 Tp=0.625
34	1-37	97	4x3 B16.9 A	4.5	0.237	3.5	0.226	N=2225 S=39,600	kob=2.95 (do)	
35	1-38	97	4x3 B16.9 B	4.5	0.237	3.5	0.226	N=2612 S=40,600	kob=2.83 (do)	
36	1-39	97	4x3 B16.9 C	4.5	0.237	3.5	0.226	N=1030 S=39,600	kob=3.01 (do)	
37	1-40	97	4x3 B16.9 D	4.5	0.237	3.5	0.226	N=3143 S=46,100	kob=1.36 (do)	
38	1-53	71	12x10	12.75	0.5	10.75	0.5		kib=4.8 kob=4.4	
39	1-54	71	12x10	12.75	0.5	10.75	0.5		kib=4.5 kob=7.6	
40	1-55	71	12x10	12.75	0.429	10.75	0.45		kib=4.2 kob=7.3	
41	1-35	73	24x24 B16.9	24	0.687	24	0.687	N=18,532 S=20,629	ktr=0.553 kor=-0.425 kir=2.409 kob=1.333 ktb=1.641 kib=3.478	T-10 A 212-61T GrB Table 14. 4785. See PRG est. for k-factor equations for these tee tests.
42	1-56	73	24x24x24	24	2.343	24	2.343		ktr=-1.587 kor=-0.305 kir=0.457 kob=-0.375 ktb=-0.527 kib=0.866	T-11 A105 Gr2 k's from Table 14 CR4785.

43	1-57	73	24x24x10	24	0.687	10.75	0.365		ktr=-1.105 kor=-0.425 kir=-0.142 kob=2.316 ktb=0.131 kib=0.954	T-12 A515 Gr70
44	1-58	73	24x24x10	24	2.343	10.75	1.125		ktr=-1.188 kor=-0.305 kir=-0.152 kob=0.402 ktb=0.141 kib=0.261	T-13 A105 Gr2
45	1-59	73	24x24x10	24	0.375	10.75	0.375		kib=6 kob=1.8	Tee Bored to Sch 20.
46	1-36	73	24x24 B16.9	24	0.25	24	0.25	N=2344 S=24,202	ktr=-0.531 kor=-0.813 kir=2.191 kob=8.331 ktb=0.693 kib=3.891	T-16 SA 312 304L ORNL T-16 was ordered as sched. 10, but was manufactured as sched. 20 and "through bored" to sched 10 on the run. The displacement data ere analyzed as if the entire model was sched. 20 for T-16A and as if the entire model was sched 10 for T-16B.(Note C to Table 14 4785.)
47	3-40	65	8x2 UFT A	8.625	0.188	2.5	0.065	N=459 S=22,800	kob=13.8	
48	5-23	81	12x6 INS	12.750	0.375	6.625	0.280	r2=1.688 N=631 S=58,000	kob=7.61	Ref 105 – k est. from test results in ref 105
49	3-44	91	8x2 UFT E	8.625	0.322	2.5	0.065	N=1919, Neq=535	kib=2.4813	MTR Annex A shows run wall=0.322. Report states that run wall is 0.188. Annex I in 07-02 report believes run wall is 0.322.
50	3-45	91	8x2 UFT F	8.625	0.322	2.5	0.065	N=2884 Neq=858	kib=2.171	See Note 3-44
51	2-48	91	8x2 PAD P	8.625	0.322	2.5	0.065	N=223 Neq=223	kib=1.436	See note for 2-47

CHRT0019

Chart 040 - General Flexibility Test Data.xlsm – "ORNL-TM-9409"



Notes:

1) A separate Appendix has been provided for the some of the tee tests conducted by ORNL. All of these tests can be found in Ref. 73 ORNL/TM-9409.

2) There is some discussion of the discrepancies found in these tests in the CHRT0020 "Notes" column below.

CHRT0020

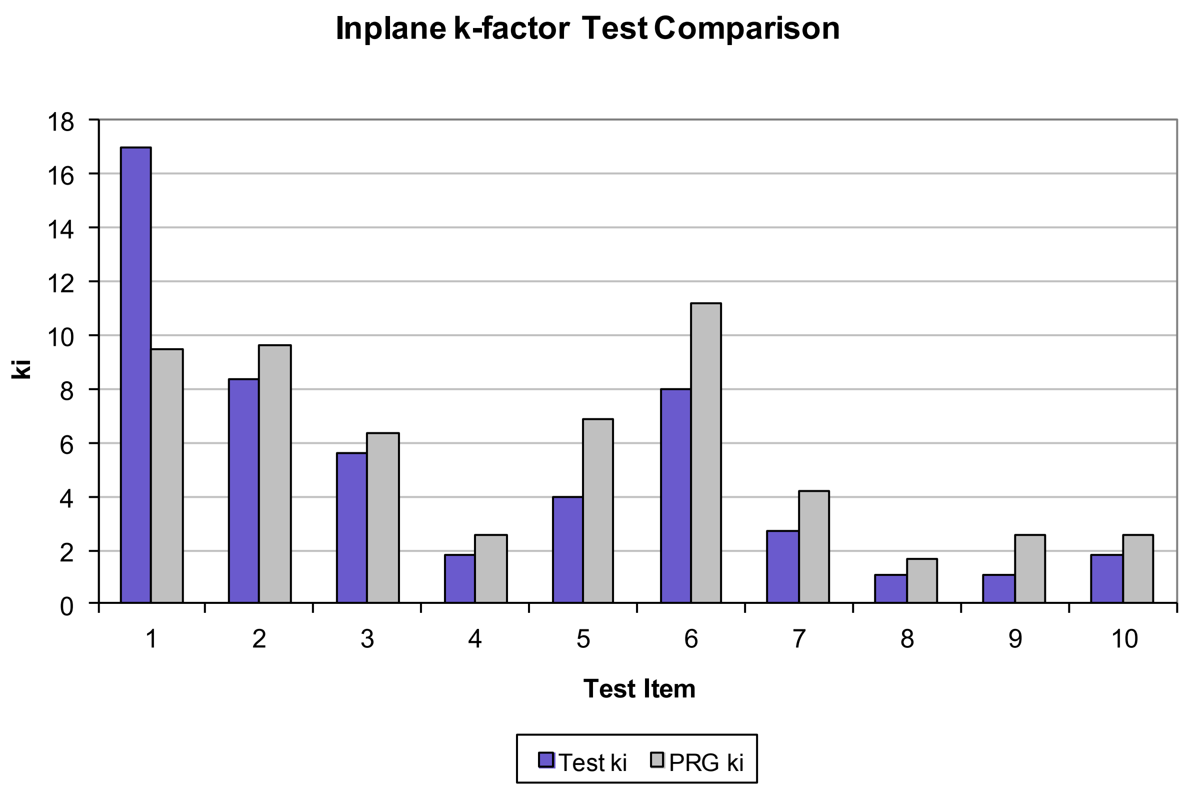
Item #	#	Ref	ID	Do	T	do	t	Auxiliary Data	Results	Notes
1	1-35	73	24x24 B16.9	24	0.687	24	0.687	N=18,532 S=20,629	ktr=0.553 kor=-0.425 kir=2.409 kob=1.333 ktb=1.641 kib=3.478	T-10 A 212-61T GrB Table 14. 4785. See PRG est. for k-factor equations for these tee tests.
2	1-35	73	24x24 B16.9	24	0.687	24	0.687	N=18,532 S=20,629	ktr=0.553 kor=-0.425 kir=2.409 kob=1.333 ktb=1.641 kib=3.478	T-10 A 212-61T GrB Table 14. 4785. See PRG est. for k-factor equations for these tee tests.
3	1-35	73	24x24 B16.9	24	0.687	24	0.687	N=18,532 S=20,629	ktr=0.553 kor=-0.425 kir=2.409 kob=1.333 ktb=1.641 kib=3.478	T-10 A 212-61T GrB Table 14. 4785. See PRG est. for k-factor equations for these tee tests.
4	1-35	73	24x24 B16.9	24	0.687	24	0.687	N=18,532 S=20,629	ktr=0.553 kor=-0.425 kir=2.409 kob=1.333 ktb=1.641 kib=3.478	T-10 A 212-61T GrB Table 14. 4785. See PRG est. for k-factor equations for these tee tests.
5	1-35	73	24x24 B16.9	24	0.687	24	0.687	N=18,532 S=20,629	ktr=0.553 kor=-0.425 kir=2.409 kob=1.333 ktb=1.641 kib=3.478	T-10 A 212-61T GrB Table 14. 4785. See PRG est. for k-factor equations for these tee tests.
6	1-35	73	24x24 B16.9	24	0.687	24	0.687	N=18,532 S=20,629	ktr=0.553 kor=-0.425 kir=2.409 kob=1.333 ktb=1.641 kib=3.478	T-10 A 212-61T GrB Table 14. 4785. See PRG est. for k-factor equations for these tee tests.
7	1-56	73	24x24x24	24	2.343	24	2.343		ktr=-1.587 kor=-0.305 kir=0.457 kob=-0.375 ktb=-0.527 kib=0.866	T-11 A105 Gr2 k's from Table 14 CR4785.
8	1-56	73	24x24x24	24	2.343	24	2.343		ktr=-1.587 kor=-0.305 kir=0.457 kob=-0.375 ktb=-0.527 kib=0.866	T-11 A105 Gr2 k's from Table 14 CR4785.
9	1-56	73	24x24x24	24	2.343	24	2.343		ktr=-1.587 kor=-0.305 kir=0.457 kob=-0.375 ktb=-0.527 kib=0.866	T-11 A105 Gr2 k's from Table 14 CR4785.
10	1-56	73	24x24x24	24	2.343	24	2.343		ktr=-1.587 kor=-0.305 kir=0.457 kob=-0.375 ktb=-0.527 kib=0.866	T-11 A105 Gr2 k's from Table 14 CR4785.
11	1-56	73	24x24x24	24	2.343	24	2.343		ktr=-1.587 kor=-0.305 kir=0.457 kob=-0.375 ktb=-0.527 kib=0.866	T-11 A105 Gr2 k's from Table 14 CR4785.
12	1-56	73	24x24x24	24	2.343	24	2.343		ktr=-1.587 kor=-0.305 kir=0.457 kob=-0.375 ktb=-0.527 kib=0.866	T-11 A105 Gr2 k's from Table 14 CR4785.
13	1-57	73	24x24x10	24	0.687	10.75	0.365		ktr=-1.105 kor=-0.425 kir=-0.142 kob=2.316 ktb=0.131 kib=0.954	T-12 A515 Gr70
14	1-57	73	24x24x10	24	0.687	10.75	0.365		ktr=-1.105 kor=-0.425 kir=-0.142 kob=2.316 ktb=0.131 kib=0.954	T-12 A515 Gr70

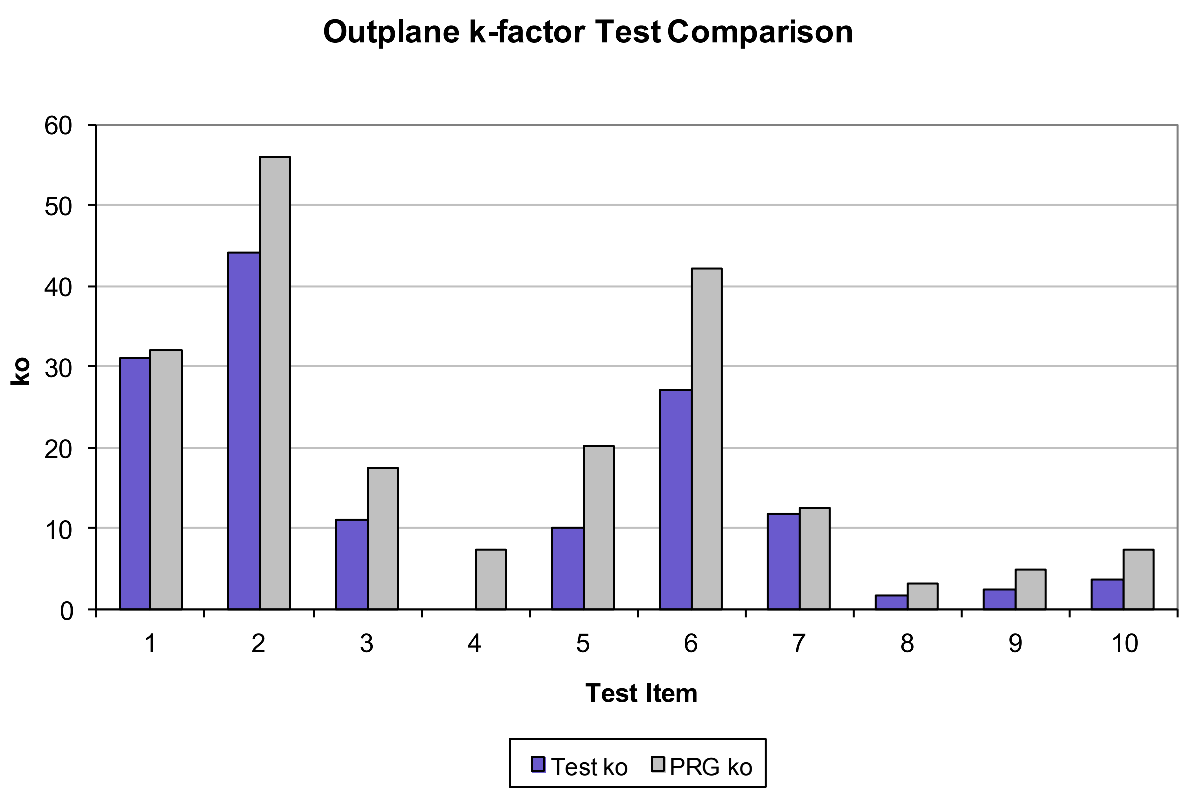
15	1-57	73	24x24x10	24	0.687	10.75	0.365		ktr=-1.105 kor=-0.425 kir=-0.142 kob=2.316 ktb=0.131 kib=0.954	T-12 A515 Gr70
16	1-57	73	24x24x10	24	0.687	10.75	0.365		ktr=-1.105 kor=-0.425 kir=-0.142 kob=2.316 ktb=0.131 kib=0.954	T-12 A515 Gr70
17	1-57	73	24x24x10	24	0.687	10.75	0.365		ktr=-1.105 kor=-0.425 kir=-0.142 kob=2.316 ktb=0.131 kib=0.954	T-12 A515 Gr70
18	1-57	73	24x24x10	24	0.687	10.75	0.365		ktr=-1.105 kor=-0.425 kir=-0.142 kob=2.316 ktb=0.131 kib=0.954	T-12 A515 Gr70
19	1-58	73	24x24x10	24	2.343	10.75	1.125		ktr=-1.188 kor=-0.305 kir=-0.152 kob=0.402 ktb=0.141 kib=0.261	T-13 A105 Gr2
20	1-58	73	24x24x10	24	2.343	10.75	1.125		ktr=-1.188 kor=-0.305 kir=-0.152 kob=0.402 ktb=0.141 kib=0.261	T-13 A105 Gr2
21	1-58	73	24x24x10	24	2.343	10.75	1.125		ktr=-1.188 kor=-0.305 kir=-0.152 kob=0.402 ktb=0.141 kib=0.261	T-13 A105 Gr2
22	1-58	73	24x24x10	24	2.343	10.75	1.125		ktr=-1.188 kor=-0.305 kir=-0.152 kob=0.402 ktb=0.141 kib=0.261	T-13 A105 Gr2
23	1-58	73	24x24x10	24	2.343	10.75	1.125		ktr=-1.188 kor=-0.305 kir=-0.152 kob=0.402 ktb=0.141 kib=0.261	T-13 A105 Gr2
24	1-58	73	24x24x10	24	2.343	10.75	1.125		ktr=-1.188 kor=-0.305 kir=-0.152 kob=0.402 ktb=0.141 kib=0.261	T-13 A105 Gr2
25	1-36	73	24x24 B16.9	24	0.25	24	0.25	N=2344 S=24,202	ktr=-0.531 kor=-0.813 kir=2.191 kob=8.331 ktb=0.693 kib=3.891	T-16 SA 312 304L ORNL T-16 was ordered as sched. 10, but was manufactured as sched. 20 and “through bored” to sched 10 on the run. The displacement data ere analyzed as if the entire model was sched. 20 for T-16A and as if the entire model was sched 10 for T-16B.(Note C to Table 14 4785.)
26	1-36	73	24x24 B16.9	24	0.25	24	0.25	N=2344 S=24,202	ktr=-0.531 kor=-0.813 kir=2.191 kob=8.331 ktb=0.693 kib=3.891	T-16 SA 312 304L ORNL T-16 was ordered as sched. 10, but was manufactured as sched. 20 and “through bored” to sched 10 on the run. The displacement data ere analyzed as if the entire model was sched. 20 for T-16A and as if the entire model was sched 10 for T-16B.(Note C to Table 14 4785.)
27	1-36	73	24x24 B16.9	24	0.25	24	0.25	N=2344 S=24,202	ktr=-0.531 kor=-0.813 kir=2.191 kob=8.331 ktb=0.693 kib=3.891	T-16 SA 312 304L ORNL T-16 was ordered as sched. 10, but was manufactured as sched. 20 and “through bored” to sched 10 on the run. The displacement data ere analyzed as if the entire model was sched. 20 for T-16A and as if the entire model was sched 10 for T-16B.(Note C to Table 14 4785.)

28	1-36	73	24x24 B16.9	24	0.25	24	0.25	N=2344 S=24,202	ktr=-0.531 kor=-0.813 kir=2.191 kob=8.331 ktb=0.693 kib=3.891	T-16 SA 312 304L ORNL T-16 was ordered as sched. 10, but was manufactured as sched. 20 and "through bored" to sched 10 on the run. The displacement data ere analyzed as if the entire model was sched. 20 for T-16A and as if the entire model was sched 10 for T-16B.(Note C to Table 14 4785.)
29	1-36	73	24x24 B16.9	24	0.25	24	0.25	N=2344 S=24,202	ktr=-0.531 kor=-0.813 kir=2.191 kob=8.331 ktb=0.693 kib=3.891	T-16 SA 312 304L ORNL T-16 was ordered as sched. 10, but was manufactured as sched. 20 and "through bored" to sched 10 on the run. The displacement data ere analyzed as if the entire model was sched. 20 for T-16A and as if the entire model was sched 10 for T-16B.(Note C to Table 14 4785.)
30	1-36	73	24x24 B16.9	24	0.25	24	0.25	N=2344 S=24,202	ktr=-0.531 kor=-0.813 kir=2.191 kob=8.331 ktb=0.693 kib=3.891	T-16 SA 312 304L ORNL T-16 was ordered as sched. 10, but was manufactured as sched. 20 and "through bored" to sched 10 on the run. The displacement data ere analyzed as if the entire model was sched. 20 for T-16A and as if the entire model was sched 10 for T-16B.(Note C to Table 14 4785.)

CHRT0020

Chart 041a and 041b - General Flexibility Test Data.xlsm – "NUREG CR/0778 Table 16"



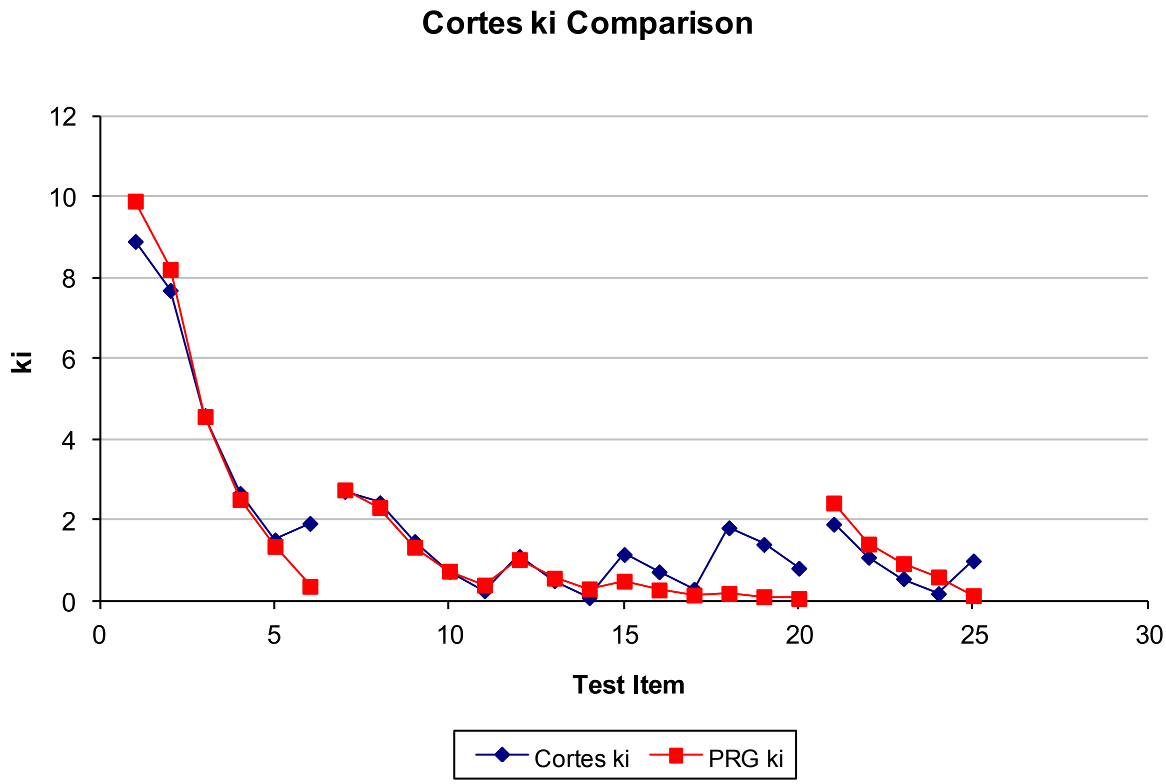


CHRT0021

Item #	#	Ref	ID	Do	T	do	t	Auxiliary Data	Results	Notes
1	3-31	80,94,101	24x4 UFT	24	0.312	4.5	0.237		Ko=31 ki=17	
2	3-32	80,101	24x12 UFT	24	0.313	12.75	0.250		Ko=44 ki=8.4	
3	3-36	80,101	48x6 UFT	48	0.625	6.625	0.28		Ko=11 ki=5.6	
4	3-37	80,101	20x12 UFT	20	1	12.75	0.687		Ki=1.8	See Line 2 in Table 3, WRC 329. Different value ??
5	3-34	80,101	36x4 UFT	36	0.375	4.5	0.375		Ko=10 ki=4	
6	3-35	80,101	36x6 UFT	36	0.375	6.625	0.280		Ko=27 ki=8	
7	4-25	101,102	16x6 EXT	16	0.5	6.625	0.280		Ko=11.8 ki=2.7	
8	4-26	101,102	16x6 EXT	16	1	6.625	0.280		Ko=1.7 ki=1.1	
9	4-23	80,101	20x6 L EXT	20		6.5			Ko=2.3 ki=1.1	R/T=9.5 r/R=0.326 t/T=0.432 Line 24 Table 3 WRC 329
10	4-24	80,101	20x12, D	20	1	12.75	0.687		Ko=3.5 ki=1.8	R/T=9.5 r/R=0.635 t/T=0.687 Line 25 Table 3 WRC 329

CHRT0021

Chart 042a and 042b - General Flexibility Test Data.xlsm – "Cortes k-fact"



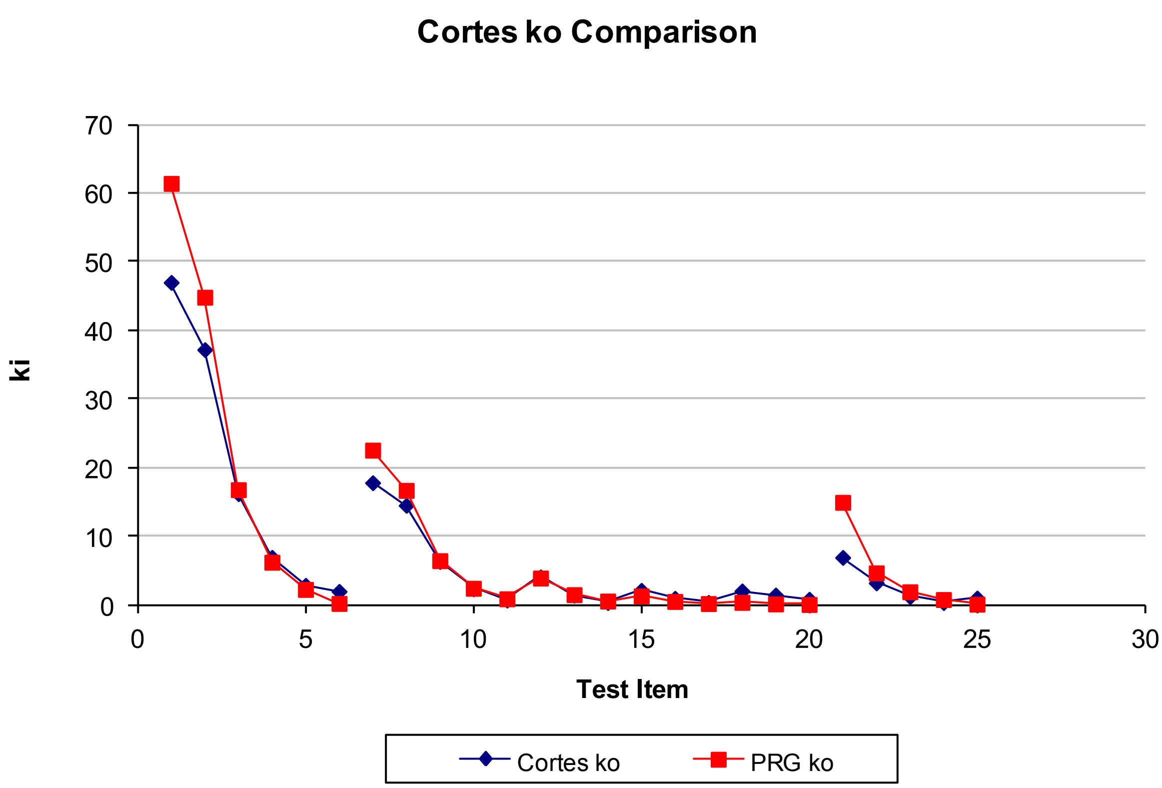
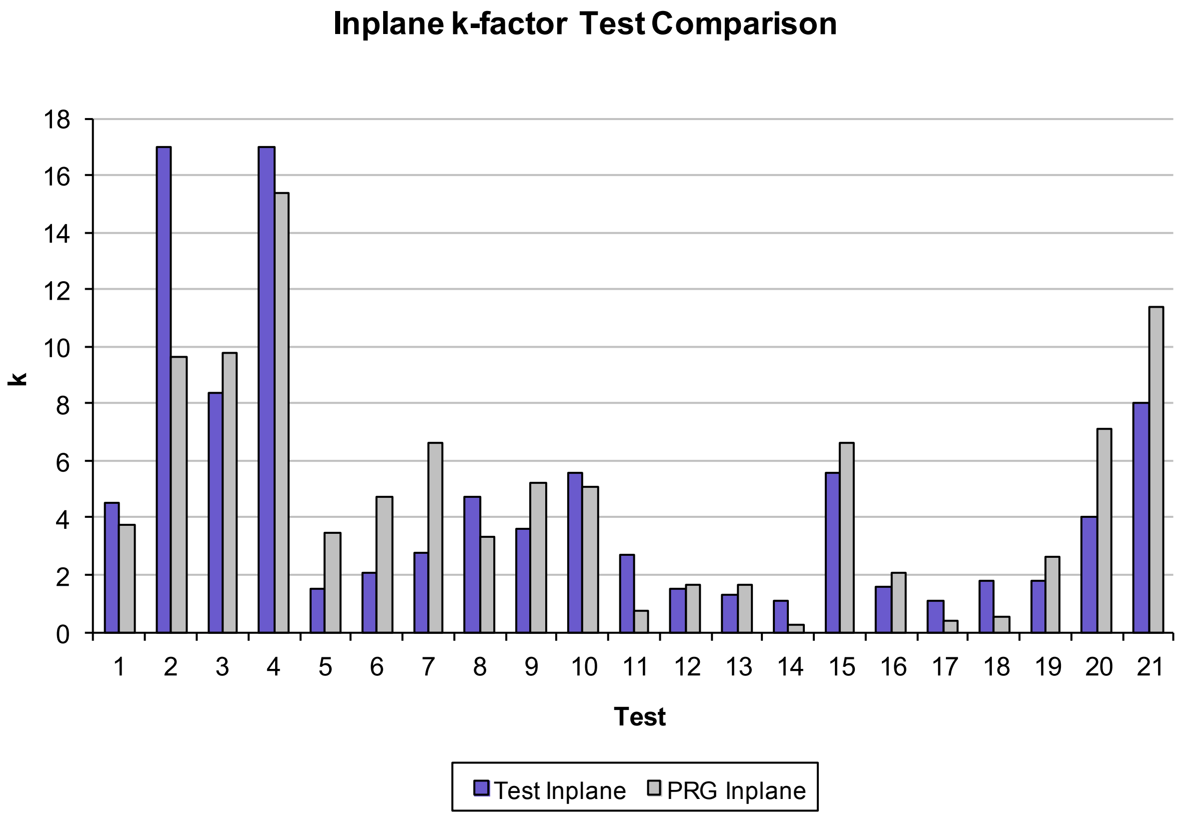


Chart 043 - General Flexibility Test Data.xlsm – "1967 test" ("Phase Report No. 6 Table 1, "Flexibility of Nozzles in Cylindrical Shells", December 22, 1967, E.C. Rodabaugh and T.J. Atterbury, Battelle Memorial Institute"[7])



CHRT0022

Item #	#	Ref	ID	Do	T	do	t	Auxiliary Data	Results	Notes
1	2-27	78,106	12x4 SDL	12.75	0.1875	4.5	0.165		kob=18	Line 8 Table 4 WRC 329 (2) Tests R/T=12.5 r/R=1 t/T=1 te/T=1.25 Dimensions from Table 13 of Nureg/CR-4785
2	3-31	80,94,101	24x4 UFT	24	0.312	4.5	0.237		Ko=31 ki=17	
3	3-32	80,101	24x12 UFT	24	0.313	12.75	0.250		Ko=44 ki=8.4	
4	3-33	80	24x24 UFT	24	0.312	24	0.312		Ko=16 ki=17	
5	2-80	71,94,106	24x4 SDL	24	0.312	4.5	0.237		kob=15 kib=1.5	L1=75 L2=150 Dp=9.625 Tp=0.344
6	2-81	71,94,106	24x8 SDL	24	0.312	8.625	0.25		kob=22 kib=2.1	L1=180 L2=45 Dp=17.25 Tp=0.438
7	2-82	71,94,106	24x12 SDL	24	0.312	12.75	0.25		kob=12 kib=2.8	Tp=0.438 Dp=23.75 L1=L2=109" (Distance from nozzle centerline to point of restraint on each end of run pipe.)
8	2-83	71,94,106	24x4 PAD	24	0.312	4.5	0.237		kob=20 kib=4.7	
9	2-84	71,94,106	24x8 PAD	24	0.312	8.625	0.25		kob=28 kib=3.6	
10	2-85	71,94,106	24x12 PAD	24	0.312	12.75	0.25		kob=18 kib=5.6	
11	4-25	101,102	16x6 EXT	16	0.5	6.625	0.280		Ko=11.8 ki=2.7	
12	2-53	77	16x6 PAD	16	0.5	6.625	0.280	N=650,000 S=5100	kob=8.4	Tp=0.5
12	2-54	77	16x6 PAD	16	0.5	6.625	0.280	N=1,400,000 S=4200	kib=1.5	Tp=0.5
13	2-11	77	16x6 SDL	16	0.5	6.625	0.280	N=1,400,000 S=6000	kob=3	L1=21 L2=21 Dp=11.625 Tp=0.5 Dimensions from Table 13 NUREG CR 4785
13	2-12	77	16x6 SDL	16	0.5	6.625	0.280	N=5,500,000 S=3900	kib=1.3	
14	4-26	101,102	16x6 EXT	16	1	6.625	0.280		Ko=1.7 ki=1.1	
15	3-36	80,101	48x6 UFT	48	0.625	6.625	0.28		Ko=11 ki=5.6	
16	2-88	71	48x6 PAD	49.25	0.625	6.625	0.280		kob=10 kib=1.6	L1=41 L2=73 Dp=10.5 Tp=0.625
17	4-23	80,101	20x6 L EXT	20		6.5			Ko=2.3 ki=1.1	R/T=9.5 r/R=0.326 t/T=0.432 Line 24 Table 3 WRC 329
18	4-24	80,101	20x12, D	20	1	12.75	0.687		Ko=3.5 ki=1.8	R/T=9.5 r/R=0.635 t/T=0.687 Line 25 Table 3 WRC 329
19	3-37	80,101	20x12 UFT	20	1	12.75	0.687		Ki=1.8	See Line 2 in Table 3, WRC 329. Different value ??
20	3-34	80,101	36x4 UFT	36	0.375	4.5	0.375		Ko=10 ki=4	
21	3-35	80,101	36x6 UFT	36	0.375	6.625	0.280		Ko=27 ki=8	

CHRT0022

Chart 044 - General Flexibility Test Data.xlsm – "Phase Report No. 6 Table 1, "Flexibility of Nozzles in Cylindrical Shells", December 22, 1967, E.C. Rodabaugh and T.J. Atterbury, Battelle Memorial Institute" [7]

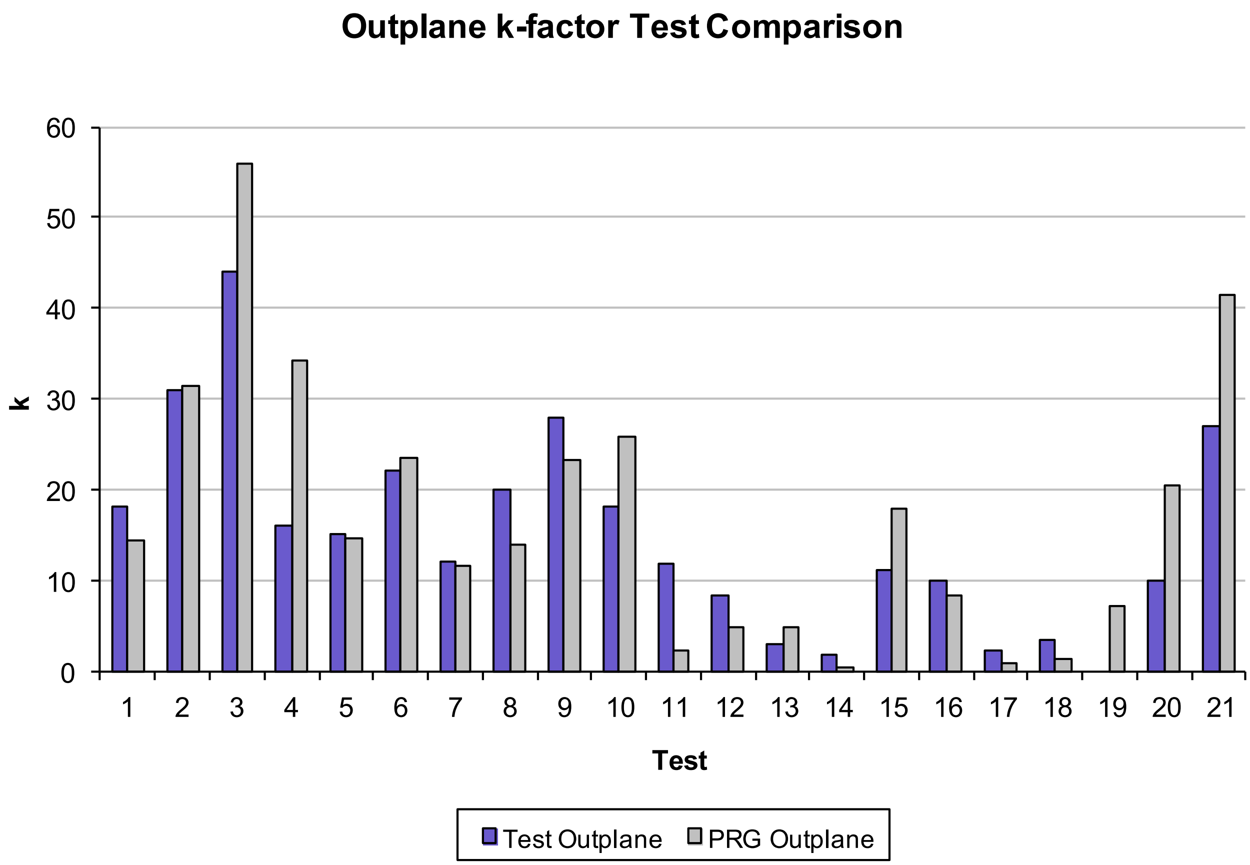
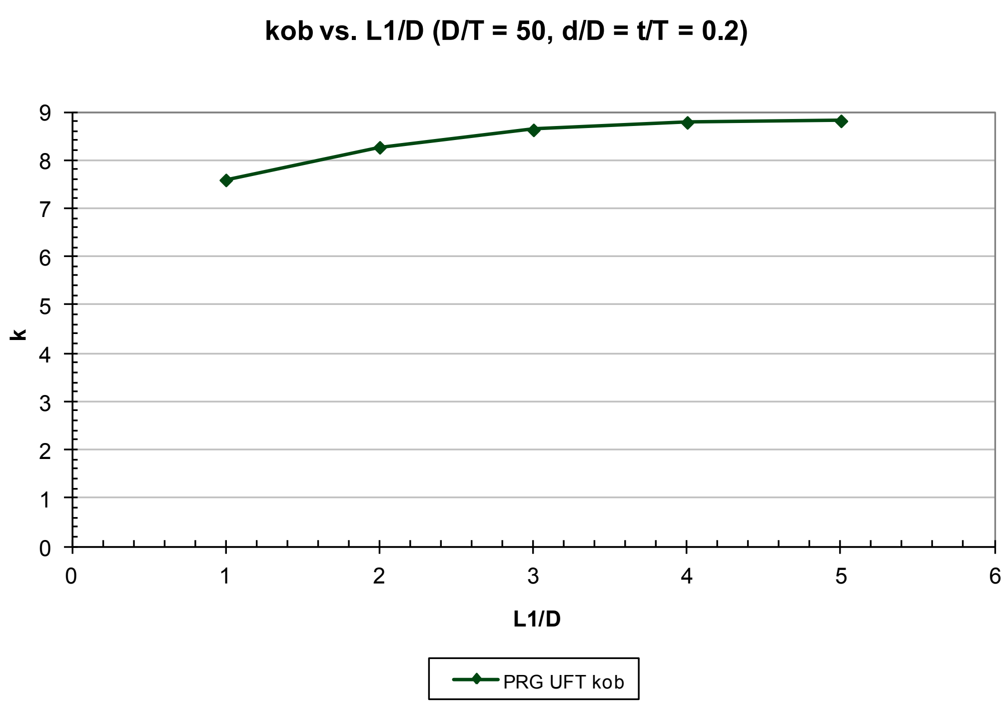


Chart 045 - EQuft.xlsm – "k vs. L1overD"



Charts 045 through 050 are intended to show the variation of flexibility factors as a function of attached pipe length when D/T=50. These results are based on shell FEA models and are not intended to be a complete survey of the affect length has on L_1 is the length of the run pipe from the branch centerline to the end of the run pipe on either side of the model.

Chart 046 - EQuft.xlsm – "k vs. L1overD"

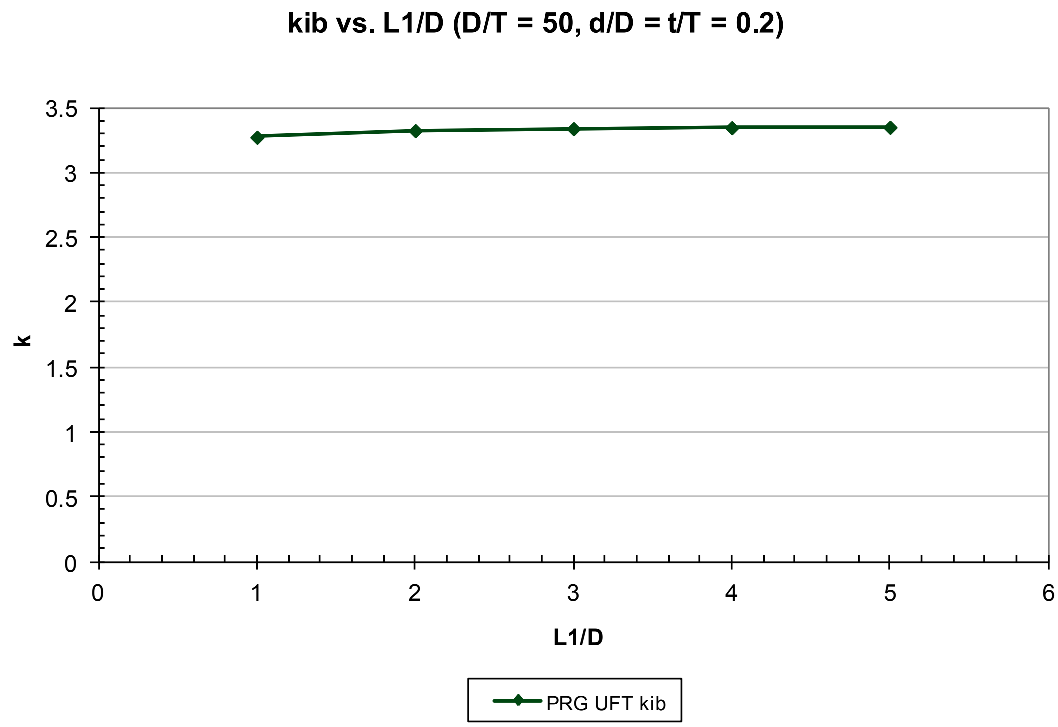


Chart 047 - EQuft.xlsm – "k vs. L1overD"

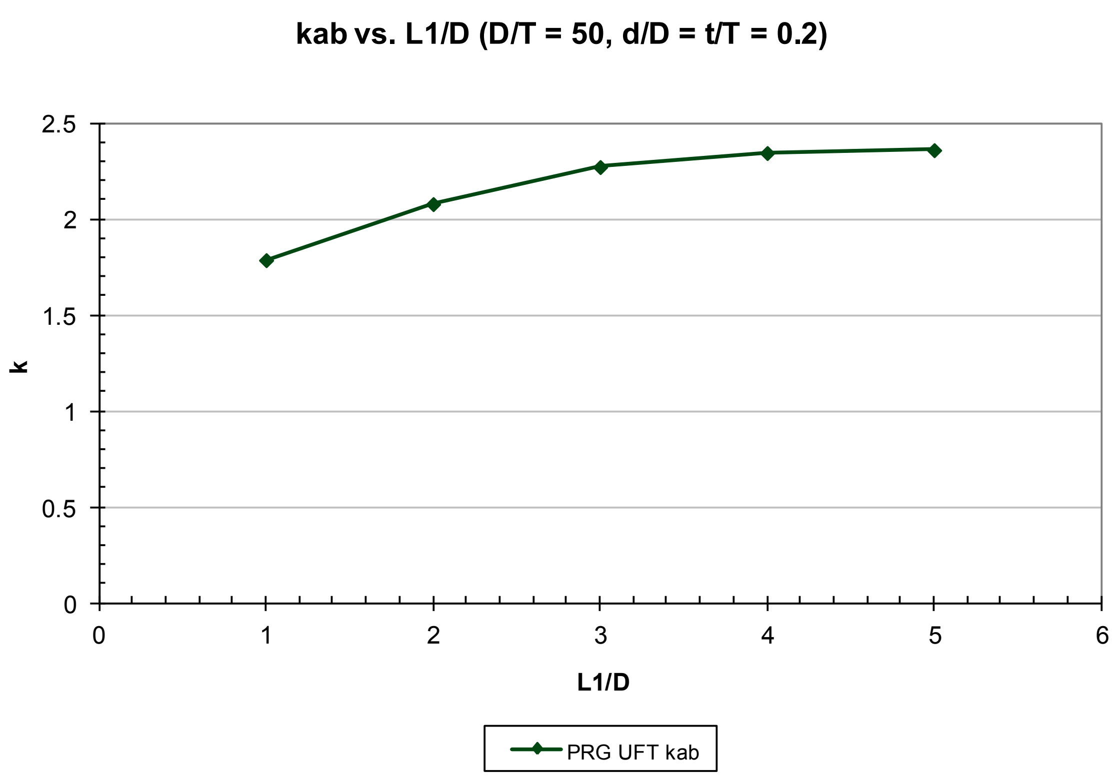


Chart 048 - EQuft.xlsm – "k vs. L1overD"

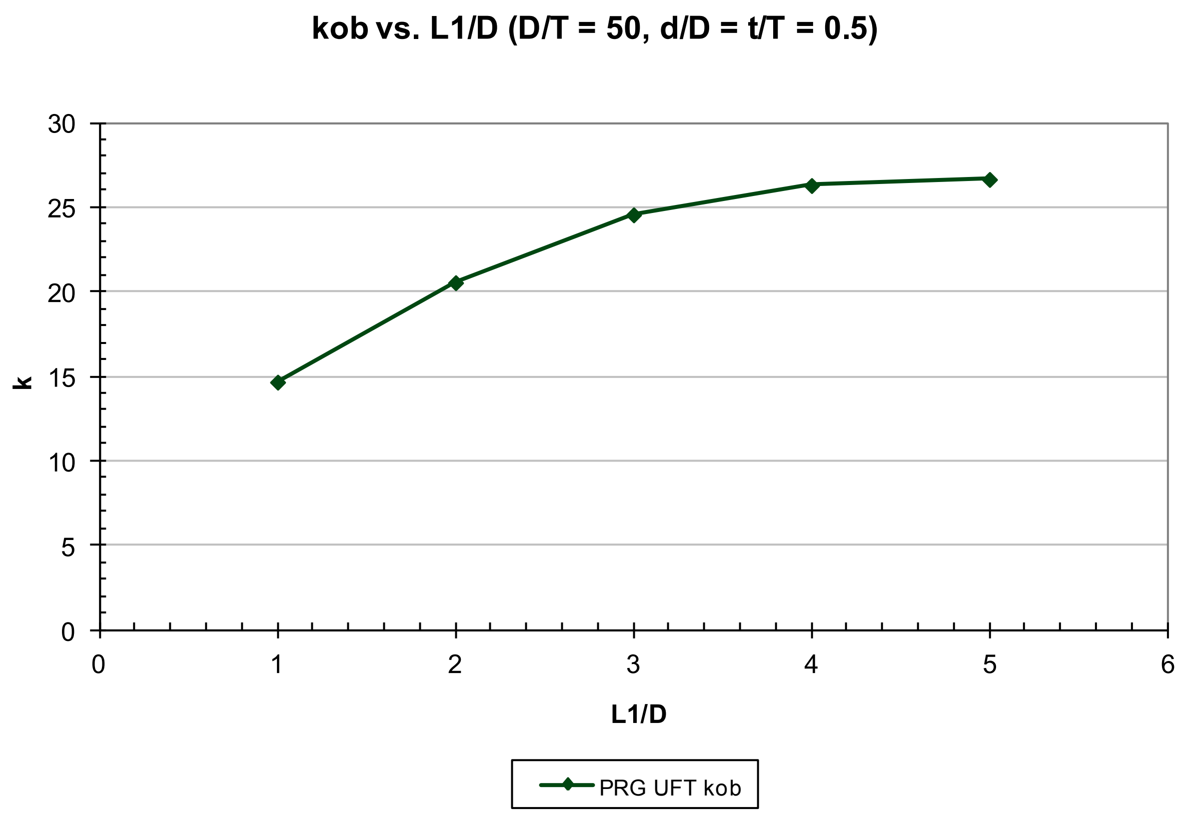


Chart 049 - EQuft.xlsm – "k vs. L1overD"

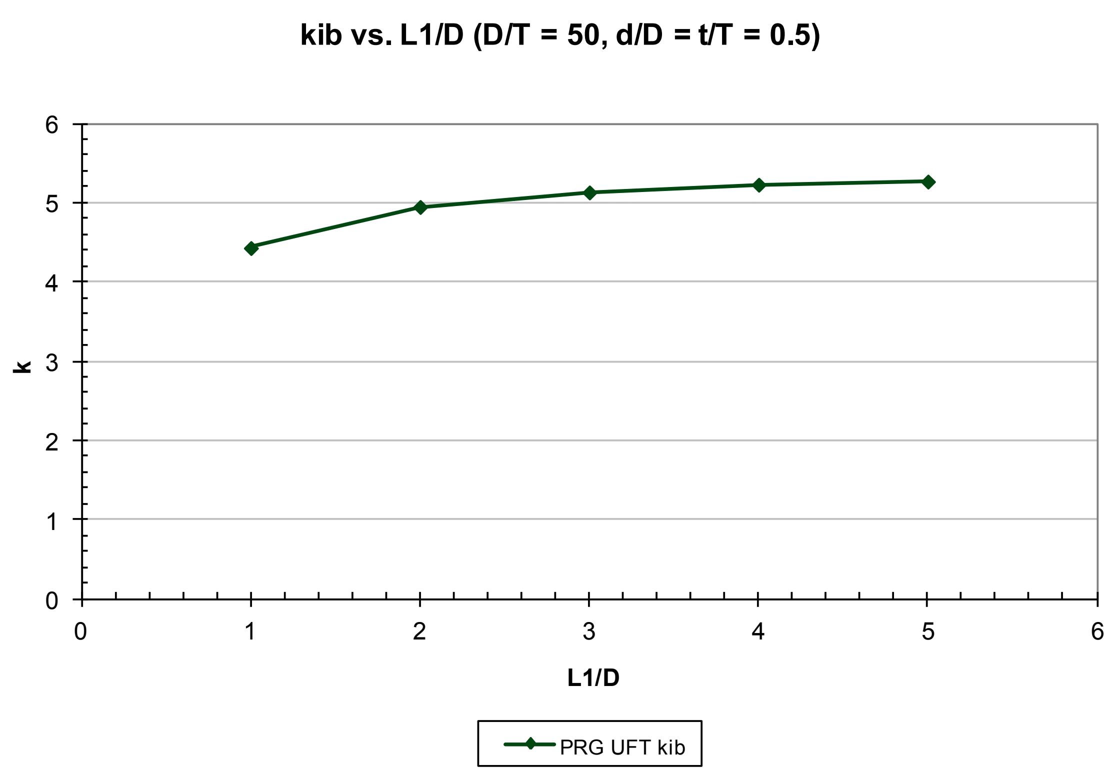


Chart 050 - EQuft.xlsm – "k vs. L1overD"

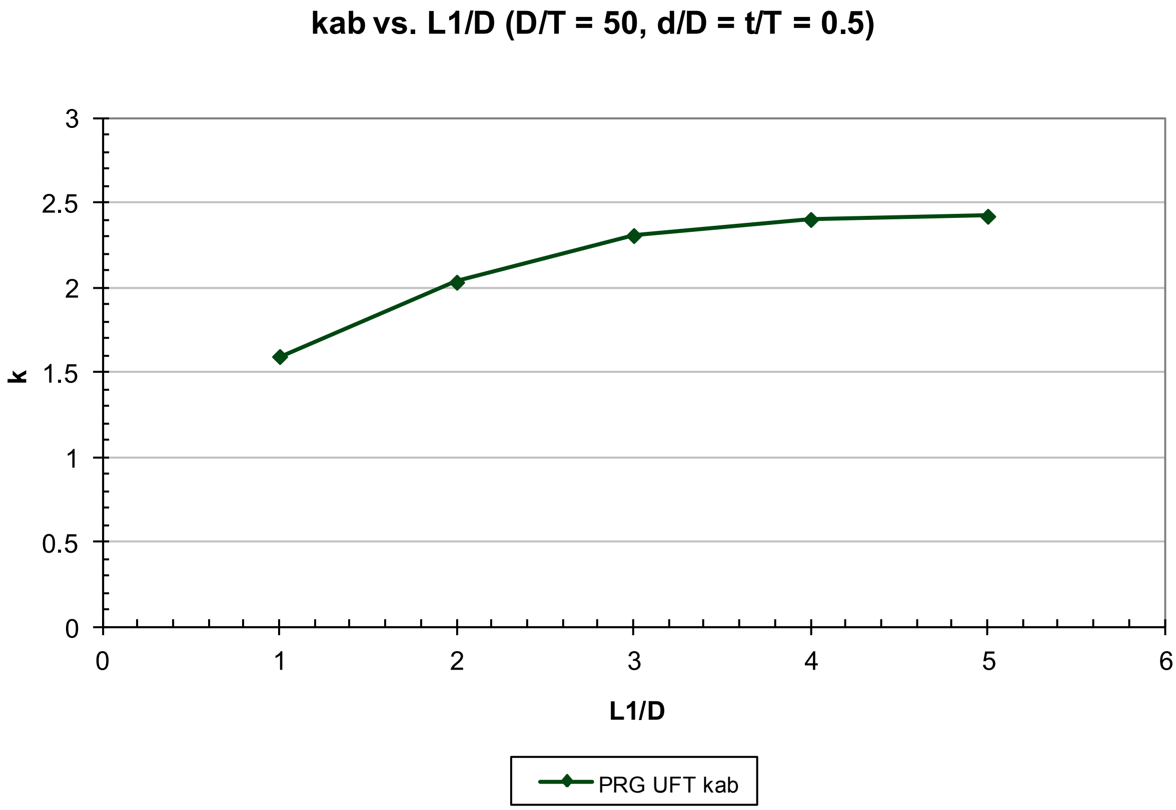
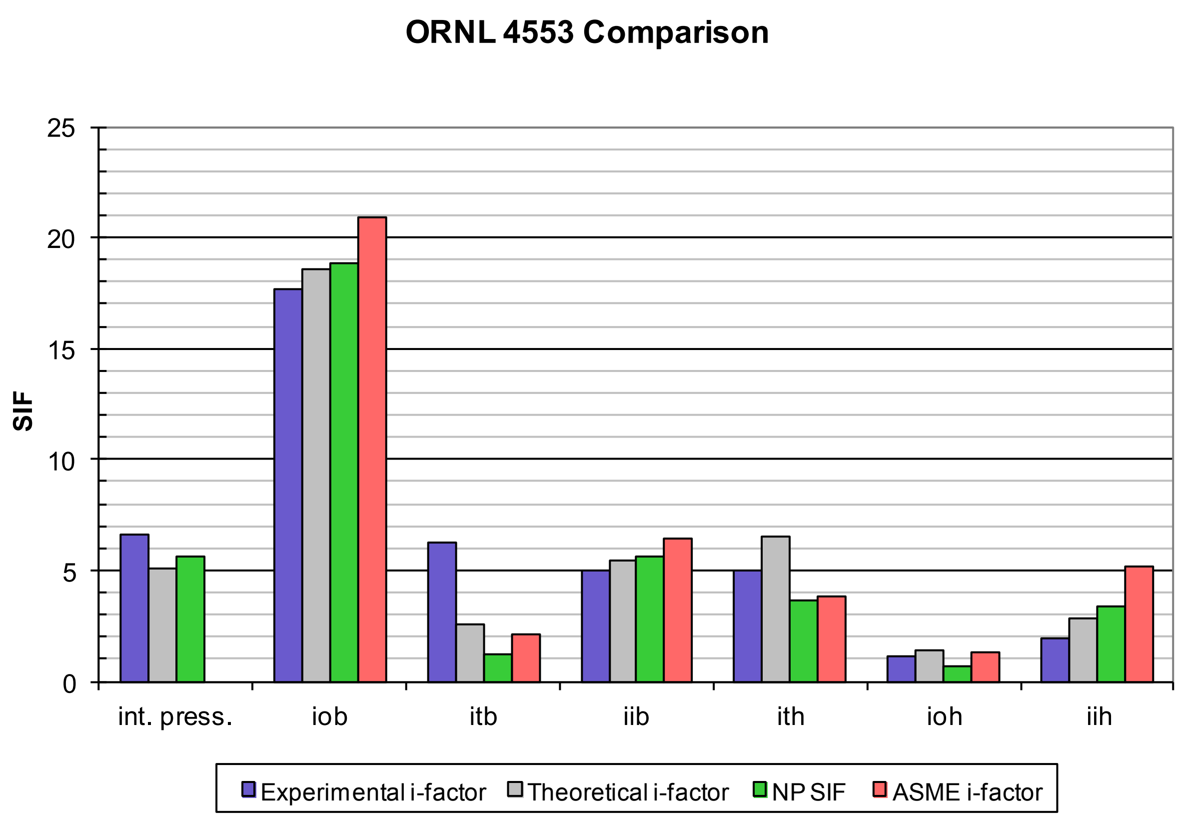


Chart 051 - EQuft.xlsm – "ORNL 4553 Comparison"



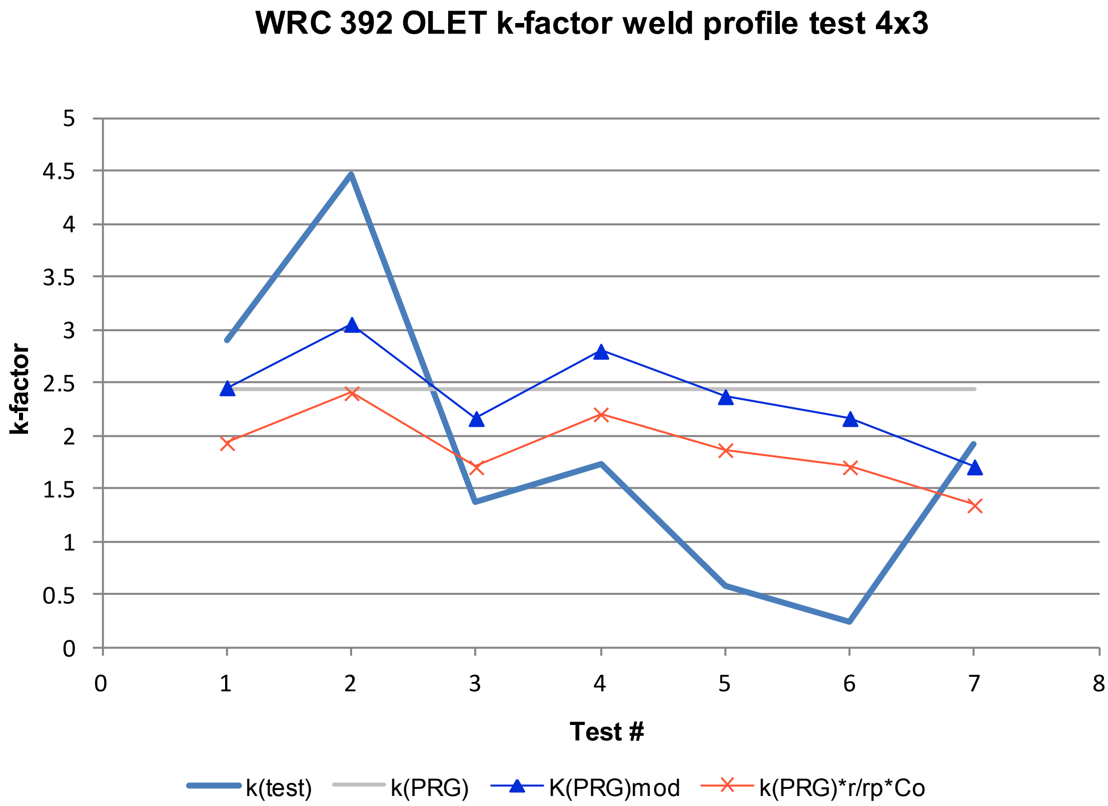
1) The ASME i-factors given above are from the ST-LLC 07-02 project equations in Annex A and G. NP results are from NozzlePRO shell results generated with ORNL 4553 test lengths entered into the model. The SCF (K_2) used by NozzlePRO to develop the plots shown above was 1.0 per the approach in EPRI 110996 ref. [2].

CHRT0023

Item #	#	Ref	ID	Do	T	do	t	Auxiliary Data	Results	Notes
1										
2	3-71		10x5 UFT	10	0.1	5	0.05		iob=18.867	Strain gage tests
3	3-72		10x5 UFT	10	0.1	5	0.05		itb=1.210	Strain gage tests
4	3-70		10x5 UFT	10	0.1	5	0.05		iib=5.637	Strain gage tests
5	3-75		10x5 UFT	10	0.1	5	0.05		ith=3.680	Strain gage tests
6	3-74		10x5 UFT	10	0.1	5	0.05		ioh=0.666	Strain gage tests
7	3-73		10x5 UFT	10	0.1	5	0.05		iih=3.377	Strain gage tests

CHRT0023

Chart 052 - General Flexibility Test Data.xlsm – "WRC 392 Olet k-factor"



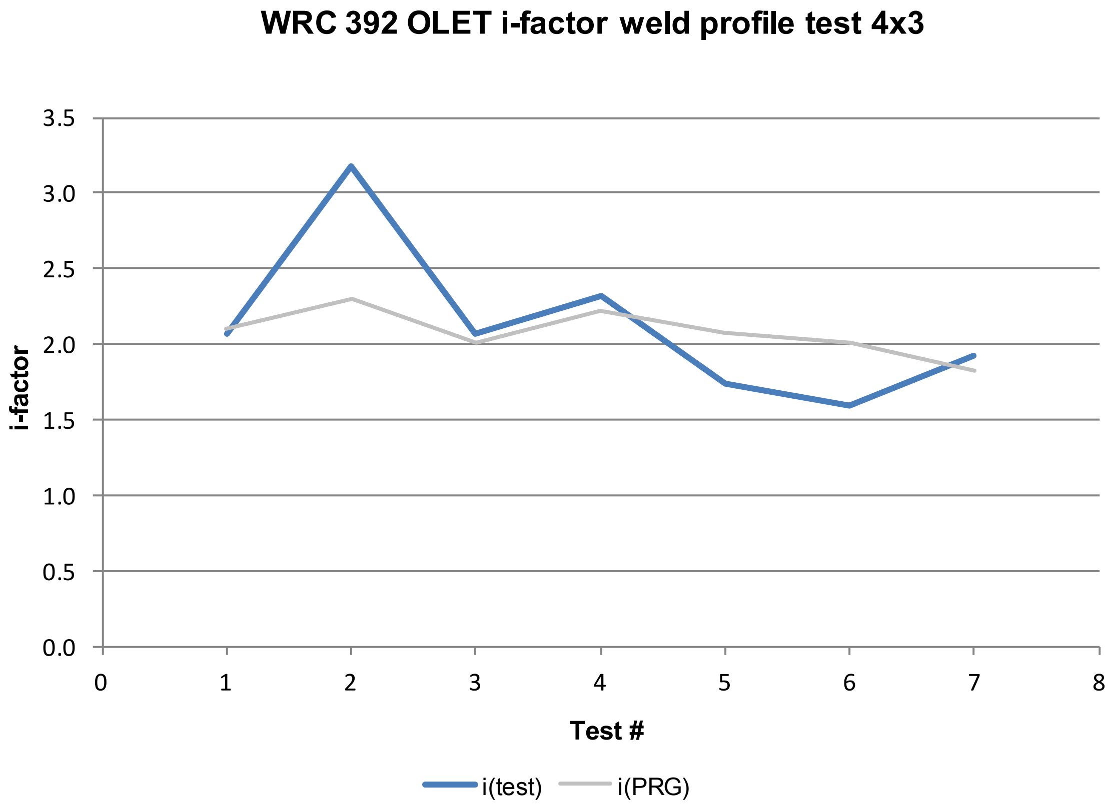
Notes:
1) k(PRG) series is 07-02 OLET (kob) * (d/d_o)
2) k(PRG)mod series is 07-02 OLET (kob) * (d/d_o) * [(r/rp)/0.64]^3
3) k(PRG)*r/rp*Co series is 07-02 OLET [(kob) * (d/d_o) * (r/rp)^3] * 3

CHRT0024

Item #	#	Ref	ID	Do	T	do	t	Auxiliary Data	Results	Notes
1	6-51	98	4x3 OLET	4.5	0.237	3.5	0.216	N=1888 S=26,274	kob=2.9	r/rp=0.64141
2	6-52	98	4x3 OLET	4.5	0.237	3.5	0.216	N=1485 S=17,903	kob=4.47	r/rp=0.68992
3	6-53	98	4x3 OLET	4.5	0.237	3.5	0.216	N=3067 S=23,825	kob=1.37	r/rp=0.61498
4	6-54	98	4x3 OLET	4.5	0.237	3.5	0.216	N=1920 S=23,343	kob=1.73	r/rp=0.67020
5	6-55	98	4x3 OLET	4.5	0.237	3.5	0.216	N=1368 S=33,213	kob=0.58	r/rp=0.63398
6	6-56	98	4x3 OLET	4.5	0.237	3.5	0.216	N=1826 S=34,339	kob=0.24	r/rp=0.61498
7	6-57	98	4x3 OLET	4.5	0.237	3.5	0.216	N=5620 S=22,644	kob=1.91	r/rp=0.56817

CHRT0024

Chart 053 - General Flexibility Test Data.xlsm – "WRC 392 Olet k-factor"

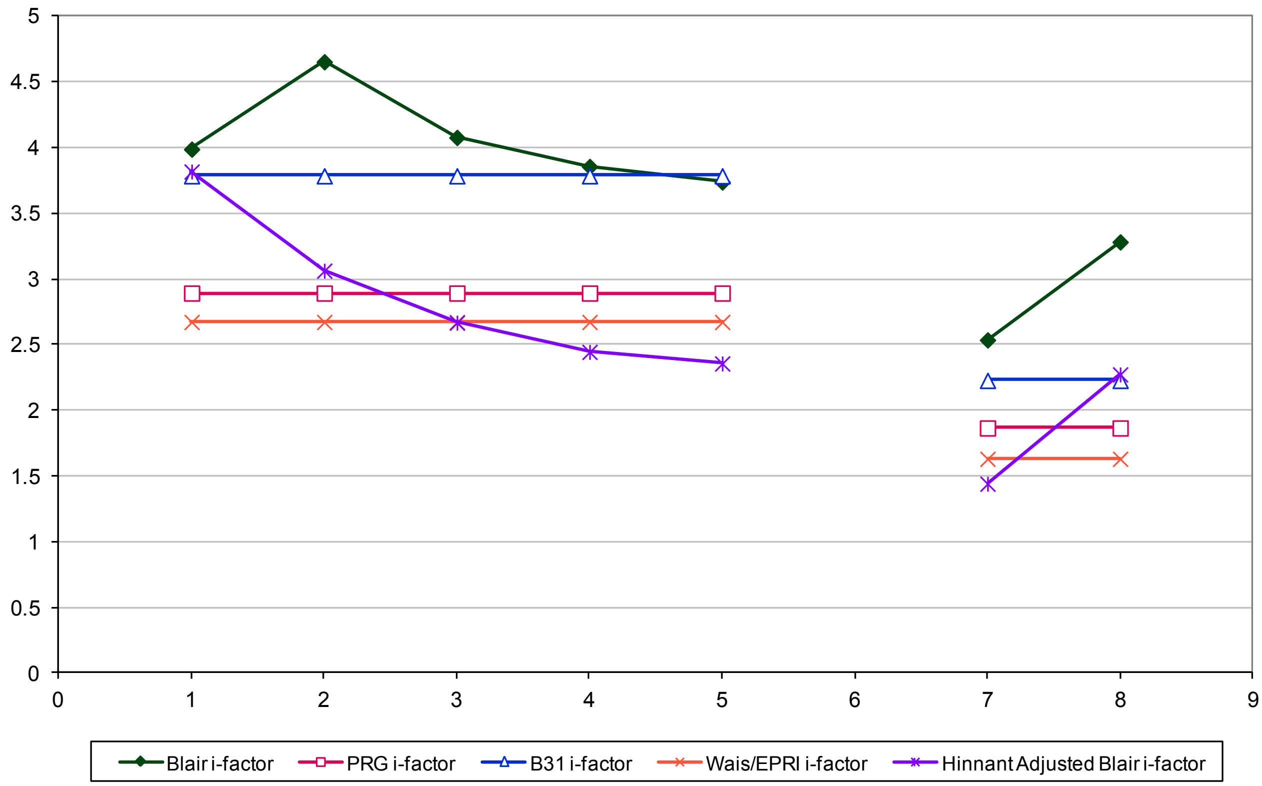


CHRT0025

Item #	#	Ref	ID	Do	T	do	t	Auxiliary Data	Results	Notes
1	6-51	98	4x3 OLET	4.5	0.237	3.5	0.216	N=1888 S=26,274	iob=2.063	r/rp=0.64141
2	6-52	98	4x3 OLET	4.5	0.237	3.5	0.216	N=1485 S=17,903	iob=3.176	r/rp=0.68992
3	6-53	98	4x3 OLET	4.5	0.237	3.5	0.216	N=3067 S=23,825	iob=2.064	r/rp=0.61498
4	6-54	98	4x3 OLET	4.5	0.237	3.5	0.216	N=1920 S=23,343	iob=2.314	r/rp=0.67020
5	6-55	98	4x3 OLET	4.5	0.237	3.5	0.216	N=1368 S=33,213	iob=1.740	r/rp=0.63398
6	6-56	98	4x3 OLET	4.5	0.237	3.5	0.216	N=1826 S=34,339	iob=1.589	r/rp=0.61498
7	6-57	98	4x3 OLET	4.5	0.237	3.5	0.216	N=5620 S=22,644	iob=1.924	r/rp=0.56817

CHRT0025

Chart 054a - General Flexibility Test Data.xlsm – “Blair”

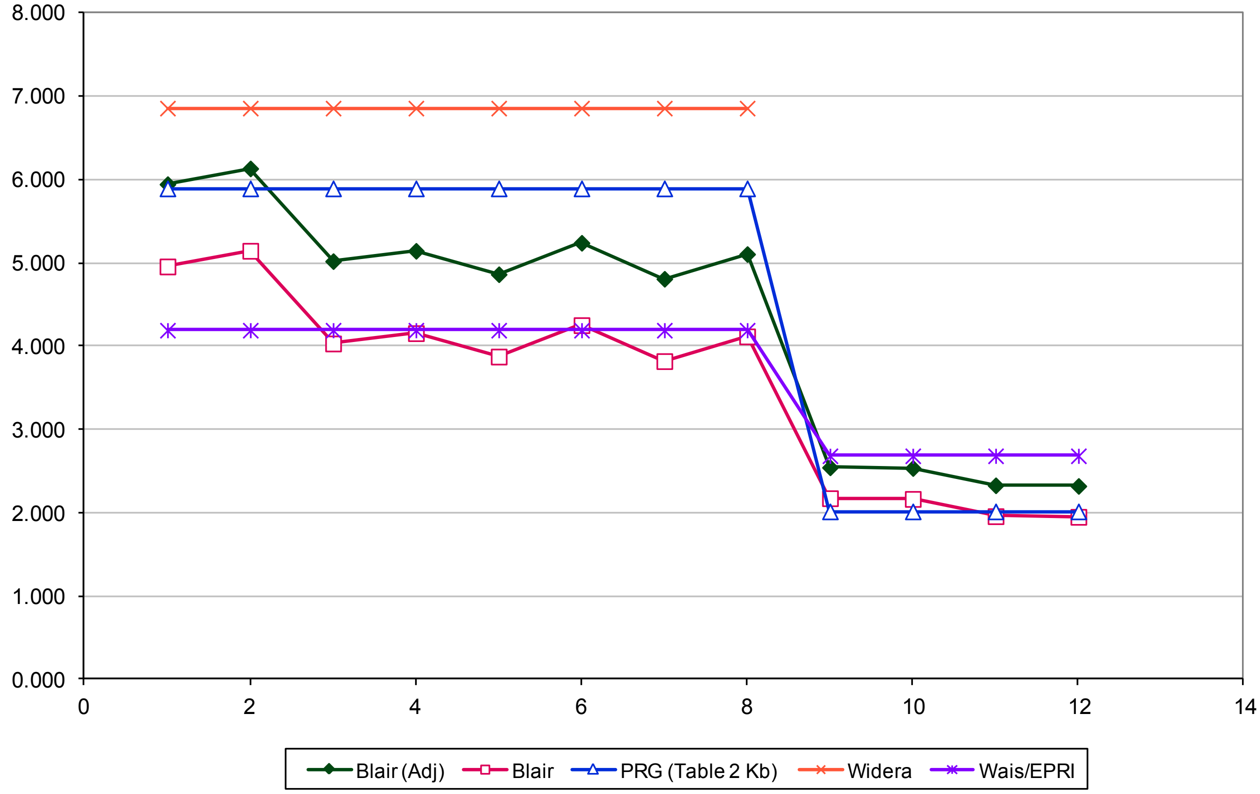


CHRT0026

Item #	#	Ref	ID	Do	T	do	t	Auxiliary Data	Results	Notes
1	3-51a	83	6x6 UFT	6.625	0.265	6.625	0.265	N=31000 S=7725	Iib=4.01	Set on Hinnint i-factor=3.837 [Blair cautions regarding defect in test]
2	3-51b	83	6x6 UFT	6.625	0.265	6.625	0.265	N=496000 S=3863	Iib=4.604	Set on Hinnant i-factor=3.031
3	3-51c	83	6x6 UFT	6.625	0.265	6.625	0.265	N=519000 S=4331	Iib=4.06951	Set on Hinnant i-factor=2.663
4	3-51d	83	6x6 UFT	6.625	0.265	6.625	0.265	N=655000 S=4448	Iiib=3.78221	Set in Hinnant i-factor=2.398
5	3-51e	83	6x6 UFT	6.625	0.265	6.625	0.265	N=683000 S=4448	Iiib=3.75	Set in Hinnant i-factor=2.365
7	2-41	83	6x6 PAD	6.5	0.25	6.5	0.25	N=1,468,000 S=5640	iib=2.538	Line 7 Table 4 WRC 329 te/T=1.25 Blair CR-1 Blair concerned about behavior in this test. Blair tests were approx 30Hz shaker tests. Both legs of run clamped. Run length=22" approx. Surface to load=44.75". Tested in between 1936 and 1946
8	2-42	83	6x6 PAD	6.5	0.25	6.5	0.25	N=340,000 S=5840	iib=3.284	Line 7 Table 4 WRC 329 te/T=1.25 Blair CR-2

CHRT0026

Chart 054b - General Flexibility Test Data.xlsm – "Blair"



ANNEX F - COMPILED SIF REFERENCES (R1)

#	Ref	ID	Do	T	do	t	Auxiliary data	Results	Notes
1-1	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=4626 S=43,652	iib=1.0378	Markl description-Barrel-shape
1-2	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=16,342 S=32,614	iib=1.0792	Markl description-Barrel-shape
1-3	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=19,934 S=26,841	iib=1.2602	Markl description-Barrel-shape
1-4	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=213,895 S=16,776	iib=1.2544	Markl description-Barrel-shape
1-5	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=231,153 S=21,434	iib=0.9667	Markl description-Barrel-shape
1-6	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=0.75 N=7630 S=31,827	iib=1.2879	Markl description-conical
1-7	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=0.75 N=62,893 S=19,980	iib=1.3454	Markl description-conical
1-8	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=0.75 N=132,008 S=12,566	iib=1.8444	Markl description-conical
1-9	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=1347 S=45,030	iib=1.2876	Markl description-Cylindrical
1-10	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=1590 S=44,802	iib=1.2519	Markl description-Cylindrical
1-11	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=11,048 S=26,940	iib=1.4129	Markl description-Cylindrical
1-12	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=14,931 S=26,977	iib=1.3285	Markl description-Cylindrical
1-13	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=103,276 S=17,195	iib=1.4157	Markl description-Cylindrical
1-14	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=171,633 S=17,274	iib=1.2731	Markl description-Cylindrical
1-15	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=1169 S=44,679	iob=1.3350	Markl description-Barrel-shape
1-16	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=4231 S=42,855	iob=1.0762	Markl description-Barrel-shape
1-17	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=12,557 S=27,233	iob=1.3623	Markl description-Barrel-shape
1-18	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=25,009 S=26,497	iob=1.2200	Markl description-Barrel-shape
1-19	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=97,544 S=17,338	iob=1.4201	Markl description-Barrel-shape
1-20	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=167,880 S=18,754	Iob=1.1778	Markl description-Barrel-shape
1-21	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=0.75 N=2103 S=25,038	iob=2.1183	Markl description-conical
1-22	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=0.75 N=58,050 S=15,251	iob=1.7910	Markl description-conical
1-23	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=0.75 N=549,414 S=9672	iob=1.8017	Markl description-conical
1-24	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=593 S=44,494	iob=1.5355	Markl description-Cylindrical
1-25	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=911 S=43,793	iob=1.4317	Markl description-Cylindrical
1-26	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=5573 S=21,857	iob=1.9969	Markl description-Cylindrical
1-27	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=15,951 S=21,330	iob=1.6581	Markl description-Cylindrical
1-28	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=325,237 S=11,706	iob=1.6532	Markl description-Cylindrical
1-29	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=604,644 S=11,112	iob=1.5384	Markl description-Cylindrical
1-30	72	12x12 B16.9	12.75	0.687	12.75	0.687	N=2062 S=30,200	iob=1.763	T-4 A106B Internal Pressure during test Pi= 1,925 psig r2=1.1
1-31	72	12x12 B16.9	12.75	0.687	12.75	0.687	N=1309 S=30,150	iob=1.934	T-6 A106B Pi=1,925 psig r2=2.3 to 3.0 in. (p57 TM 8965)
1-32	72	12x12 B16.9	12.75	1.312	12.75	1.312	N=11,475 S=30,500	iib=1.239	T-7 304L Pi=3,240 psig
1-33	72	12x6 B16.9	12.75	0.406	6.625	0.280	N=8979 S=41,160	iob=0.964	T-8 304L Pi=950 psig r2=0.75 to 0.65 in.
1-34	72	12x6 B16.9	12.75	0.406	6.625	0.280	N=10,200 S=36,100	iob=1.071	T-15 304L Pi=950 psig

1-35	73	24x24 B16.9	24	0.687	24	0.687	N=18,532 S=20,629	iib=1.664	T-10 A 212-61T GrB
1-36	73	24x24 B16.9	24	0.25	24	0.25	N=2344 S=24,202	iib=2.144	T-16 SA 312 304L
1-37	97	4x3 B16.9 A	4.5	0.237	3.5	0.226	N=2225 S=39,600	iob=1.32	
1-38	97	4x3 B16.9 B	4.5	0.237	3.5	0.226	N=2612 S=40,600	iob=1.25	
1-39	97	4x3 B16.9 C	4.5	0.237	3.5	0.226	N=1030 S=39,600	iob=1.54	
1-40	97	4x3 B16.9 D	4.5	0.237	3.5	0.226	N=3143 S=46,100	iob=1.06	
1-41	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=933 S=50,130	iir=1.2448	Markl description-Barrel-shape
1-42	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=33,235 S=25,984	iir=1.1753	Markl description-Barrel-shape
1-43	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=133,229 S=20,286	iir=1.1404	Markl description-Barrel-shape
1-44	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=8354 S=36,501	iir=1.1028	Markl description-Cylindrical
1-45	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=80,279 S=27,701	iir=0.9242	Markl description-Cylindrical
1-46	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=296,483 S=17,084	iir=1.1539	Markl description-Cylindrical
1-47	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=1617 S=52,252	ior=1.0699	Markl description-Barrel-shape
1-48	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=26,044 S=25,680	ior=1.2486	Markl description-Barrel-shape
1-49	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=91,033 S=19,916	ior=1.2535	Markl description-Barrel-shape
1-50	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=8588 S=33,497	ior=1.1951	Markl description-Cylindrical
1-51	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=43,863 S=28,451	ior=1.0154	Markl description-Cylindrical
1-52	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=103,657 S=14,315	ior=1.6992	Markl description-Cylindrical
1-53	71	12x10	12.75	0.5	10.75	0.5			
1-54	71	12x10	12.75	0.5	10.75	0.5			
1-55	71	12x10	12.75	0.429	10.75	0.45			
1-56	73	24x24x24	24	2.343	24	2.343			T-11 A105 Gr2
1-57	73	24x24x10	24	0.687	10.75	0.365			T-12 A515 Gr70
1-58	73	24x24x10	24	2.343	10.75	1.125			T-13 A105 Gr2
1-59	73	24x24x10	24	0.375	10.75	0.375			Bored to Sched 20
4-1	74	20x6 EXT	20	1	6.625	0.432		iob=2.2	
4-2	74	20x6 EXT	20	1	6.625	0.432		iib=0.94	
4-3	74	20x12 EXT	20	1	12.75	0.687	Test D strain gage	iib=1.5	Measured – NOT extrapolated Lax=8.7, Mt=-3.18. See ref for axial and torsional stress measurements. See 4-24. These may be the same geometry, but I think they represent a strain gage test and then a subsequent fatigue tests. Fatigue tests were run on L and D.
4-4	74	20x12 EXT	20	1	12.75	0.687	Test D strain gage	iob=2.44	
4-5	74	20x12 EXT	20	1	12.75	0.375	Test E strain gage	iob=1.28	
4-6	74	20x12 EXT	20	1	12.75	0.375	Test E strain gage	iib=1.11	
4-7	75	4x4 EXT	5.0	0.480	5.0	0.480		iob=1.5	Body outside diameter=5.0 Line 1 Table 6 WRC 329
4-8	75	4x4 EXT	5.0	0.480	5.0	0.480		iob=1.53	Body outside diameter=5.0 Line 2 Table 6 WRC 329

4-9	75	4x4 EXT	5.0	0.480	5.0	0.480		iob=1.63	Body outside diameter=5.0 Line 3 Table 6 WRC 329
4-10	75	4x4 EXT	5.0	0.480	5.0	0.480		iob=1.31	Body outside diameter=5.0 Line 4 Table 6 WRC 329
4-11	75	6x4 EXT	6.625	0.562	4.5	0.237		iob=2.26	Body outside diameter=6.625 Line 5 Table 6 WRC 329
4-12	75	6x4 EXT	6.625	0.562	4.5	0.237		iob=1.32	Body outside diameter=6.625 Line 6 Table 6 WRC 329
4-13	75	6x4 EXT	6.625	0.562	4.5	0.237		iob=1.36	Body outside diameter=6.625 Line 7 Table 6 WRC 329
4-14	75	8x4 EXT	8.625	0.719	4.5	0.237		iob=1.45	Body outside diameter=8.625 Line 8 Table 6 WRC 329
4-15	75	8x4 EXT	8.625	0.719	4.5	0.237		iob=1.48	Body outside diameter=8.625 Line 9 Table 6 WRC 329
4-16	75	8x4 EXT	8.625	0.719	4.5	0.237		iob=1.60	Body outside diameter=8.625 Line 10 Table 6 WRC 329
4-17	75	8x4 EXT	8.625	0.719	4.5	0.237		iob=1.39	Body outside diameter=8.625 Line 11 Table 6 WRC 329
4-18	75	16x4 EXT	16	1.031	4.5	0.237		iob=1.19	Body outside diameter=16 Line 12 Table 6 WRC 329
4-19	75	16x4 EXT	16	1.031	4.5	0.237		iob=1.16	Body outside diameter=16 Line 13 Table 6 WRC 329
4-20	75	16x4 EXT	16	1.031	4.5	0.237		iob=1.14	Body outside diameter=16 Line 14 Table 6 WRC 329
4-21	75	16x4 EXT	16	1.031	4.5	0.237		iob=1.33	Body outside diameter=16 Line 15 Table 6 WRC 329
4-22	75	16x4 EXT	16	1.031	4.5	0.237		iob=1.31	Body outside diameter=16 Line 16 Table 6 WRC 329
4-23	80	20x6 L EXT	20		6.5		N=50,000 S=23,000 fig29 Ref94	iob=1.2	R/T=9.5 r/R=0.326 t/T=0.432 Line 24 Table 3 WRC 329
4-24	80	20x12, D	20	1	12.75	0.687	N=20,000 S=13,000 fig29 Ref94	iob=2.5	R/T=9.5 r/R=0.635 t/T=0.687 Line 25 Table 3 WRC 329. This test prepared for comparison with elastic test 4-4.
4-25	101,102	16x6 EXT	16	0.5	6.625	0.280			
4-26	101,102	16x6 EXT	16	1	6.625	0.280			
2-1	5	4x4 SDL	4.5	0.237	4.5	0.237	N=10,000 S=30,000	iib=1.294	Line 6 Table 4 WRC 329 te/T=2.1
2-2	5	4x4 SDL	4.5	0.237	4.5	0.237	N=120,000 S=25,000	iib=0.945	Line 6 Table 4 WRC 329 te/T=2.1
2-3	5	4x4 SDL	4.5	0.237	4.5	0.237	N=20,000 S=31,500	iob=1.056	Line 5 Table 4 WRC 329 te/T=2.1
2-4	5	4x4 SDL	4.5	0.237	4.5	0.237	N=80,000 S=23,000	iob=1.114	Line 5 Table 4 WRC 329 te/T=2.1
2-5	76	24x8 SDL	24	0.353	8.625	0.318	N=520 S=65,000	iib=1.079	
2-6	76	24x8 SDL	24	0.353	8.625	0.318	N=6000 S=37,000	iib=1.162	
2-7	76	24x8 SDL	24	0.353	8.625	0.318	N=50,000 S=21,000	iib=1.340	
2-8	76	24x8 SDL	24	0.353	8.625	0.318	N=126,000 S=20,000	iib=1.170	
2-9	76	24x8 SDL	24	0.353	8.625	0.318	N=20, S=37,000	iob=3.637	
2-10	76	24x8 SDL	24	0.353	8.625	0.318	N=35,100 S=6000	iob=5.034	
2-11	77	16x6 SDL	16	0.5	6.625	0.280	N=1,400,000 S=6000	iib=2.409	
2-12	77	16x6 SDL	16	0.5	6.625	0.280	N=5,500,000 S=3900	iib=2.819	
2-13	77	16x6 SDL	16	0.5	6.625	0.280	N=8,000,000 S=3300	iib=3.091	
2-14	77	16x6 SDL	16	0.5	6.625	0.280	N=10,000,000 S=3200	iib=3.048	
2-15	77	16x6 SDL	16	0.5	6.625	0.280	N=1,600,000 S=8000	iib=1.759	
2-16	77	16x6 SDL	16	0.5	6.625	0.280	N=3,200,000 S=6600	iib=1.856	
2-17	77	16x6 SDL	16	0.5	6.625	0.280	N=5,600,000 S=4500	iib=2.434	

2-18	77	16x6 SDL	16	0.5	6.62 5	0.280	N=7,300,000 S=4500	iib=2.308	
2-19	77	16x6 SDL	16	0.5	6.62 5	0.280	N=10,000,000 S=4000	iib=2.438	
2-20	77	16x6 SDL	16	0.5	6.62 5	0.280	N=9,500,000 S=3200	iib=3.079	
2-21	77	16x6 SDL	16	0.5	6.62 5	0.280	N=3,200,000 S=5000	iib=2.450	
2-22	77	16x6 SDL	16	0.5	6.62 5	0.280	N=2,600,000 S=4500	iib=2.838	
2-23	77	16x6 SDL	16	0.5	6.62 5	0.280	N=4,700,000, S=4500	iib=2.521	
2-24	77	16x6 SDL	16	0.5	6.62 5	0.280	N=3,100,000 S=8000	iob=1.541	
2-25	77	16x6 SDL	16	0.5	6.62 5	0.280	N=2,600,000 S=5000	iob=2.554	
2-26	77	16x6 SDL	16	0.5	6.62 5	0.280	N=9,500,000 S=3800	iob=2.593	
2-27	78	12x4 SDL	12. 75	0.187 5	4.5	0.165		iob=4.34	Line 8 Table 4 WRC 329 (2) Tests R/T=12.5 r/R=1 t/T=1 te/T=1.25; Dimensions taken from Table 13; NUREG/CR-4785.
2-28	78	12x4 SDL	12. 75	0.187 5	4.5	0.165		iib=1.19	Line 9 Table 4 WRC 329 (2) Tests R/T=12.5 r/R=1 t/T=1 te/T=1.25
2-29	5	4x4 PAD	4.5	0.237	4.5	0.237	N=800 S=35,000	iib=1.839	Line 2 Table 4 WRC 329 te/T=1
2-30	5	4x4 PAD	4.5	0.237	4.5	0.237	N=4000 S=25,000	iib=1.866	Line 2 Table 4 WRC 329 te/T=1
2-31	5	4x4 PAD	4.5	0.237	4.5	0.237	N=220,000 S=12,500	iib=1.674	Line 2 Table 4 WRC 329 te/T=1
2-32	5	4x4 PAD	4.5	0.237	4.5	0.237	N=700 S=35,000	iob=1.888	Line 1 Table 4 WRC 329 te/T=1
2-33	5	4x4 PAD	4.5	0.237	4.5	0.237	N=3800 S=25,000	iob=1.885	Line 1 Table 4 WRC 329 te/T=1
2-34	5	4x4 PAD	4.5	0.237	4.5	0.237	N=220,000 S=12,500	iob=1.674	Line 1 Table 4 WRC 329 te/T=1
2-35	5	4x4 PAD	4.5	0.120	4.5	0.120	N=430 S=32,000	iob=2.288	Line 4 Table 4 WRC 329 te/T=1
2-36	5	4x4 PAD	4.5	0.120	4.5	0.120	N=1600 S=23,000	iob=2.436	Line 4 Table 4 WRC 329 te/T=1
2-37	5	4x4 PAD	4.5	0.120	4.5	0.120	N=41,000 S=11,500	iob=2.546	Line 4 Table 4 WRC 329 te/T=1
2-38	5	4x4 PAD	4.5	0.120	4.5	0.120	N=700 S=32,000	iib=2.06	Line 3 Table 4 WRC 329 te/T=1
2-39	5	4x4 PAD	4.5	0.120	4.5	0.120	N=2400 S=22,500	iib=2.296	Line 3 Table 4 WRC 329 te/T=1
2-40	5	4x4 PAD	4.5	0.120	4.5	0.120	N=75,000 N=11,500	iib=2.257	Line 3 Table 4 WRC 329 te/T=1
2-41	83	6x6 PAD	6.5	0.25	6.5	0.25	N=1,468,000 S=5640	iib=2.538	Line 7 Table 4 WRC 329 te/T=1.25 Blair CR-1 Blair concerned about behavior in this test. Blair tests were approx 30Hz shaker tests. Both legs of run clamped. Run length=22" approx. Surface to load=44.75". Tested in between 1936 and 1946
2-42	83	6x6 PAD	6.5	0.25	6.5	0.25	N=340,000 S=5840	iib=3.284	Line 7 Table 4 WRC 329 te/T=1.25 Blair CR-2
2-43	79	8x3 PAD K1	8.6 25	0.322	3.5	0.216	N=51,638 S=14,331	iob=1.951	Line 6 Table 5 WRC 329
2-44	79	8x6 PAD K2	8.6 25	0.322	6.62 5	0.280	N=7541 S=14,752	iob=2.785	Line 5 Table 5 WRC 329
2-45	79	12x6 PAD K3	12. 75	0.375	6.62 5	0.280	N=2829 S=14,408	iob=3.469	Line 8 Table 5 WRC 329
2-46	79	12x8 PAD K4	12. 75	0.375	8.62 5	0.322	N=1056 S=15,589	iob=3.905	Line 7 Table 5 WRC 329
2-47	91	8x2 PAD O	8.6 25	0.322	2.5	0.065	N=697 Neq=697 S=45,046	iob=1.47	MTR AppA suggests 8" t=0.355"; dimensions for 2"
2-48	91	8x2 PAD P	8.6 25	0.322	2.5	0.065	N=223 Neq=223 S=57,012	iib=1.46	Report: Pad OD=5. Tp=0.188 Mtr Tr=0.322
2-49	90	8x4 PAD E	8.6 25	0.25	4.5	0.237	N=1260 S=26,773	iib=2.20	PadOD=6 PadT=0.25
2-50	90	8x4 PAD F	8.6 25	0.25	4.5	0.237	N=1901 S=23,997	iib=2.26	PadOD=7 PadT=0.25
2-51	90	8x4 PAD G	8.6 25	0.25	4.5	0.237	N=1366 S=28,752	iib=2.01	PadOD=9.5 PadT=0.25

2-52	90	8x4 PAD H	8.625	0.25	4.5	0.237	N=1075 S=28,133	iib=2.16	PadOD=7.5 PadT=0.25
2-53	77	16x6 PAD	16	0.5	6.625	0.280	N=650,000 S=5100	iib=3.304	Tp=0.5
2-54	77	16x6 PAD	16	0.5	6.625	0.280	N=1,400,000 S=4200	iib=3.447	Tp=0.5
2-55	77	16x6 PAD	16	0.5	6.625	0.280	N=1,700,000 S=3600	iib=3.862	Tp=0.5
2-56	77	16x6 PAD	16	0.5	6.625	0.280	N=10,000,000 S=2700	iib=3.612	Tp=0.5
2-57	77	16x6 PAD	16	0.5	6.625	0.280	N=350,000 S=4500	iib=4.238	Tp=0.5
2-58	77	16x6 PAD	16	0.5	6.625	0.280	N=1,000,000 S=4500	iib=3.435	Tp=0.5
2-59	77	16x6 PAD	16	0.5	6.625	0.280	N=4,300,000 S=3000	iib=3.849	Tp=0.5
2-60	77	16x6 PAD	16	0.5	6.625	0.280	N=13,000,000 S=2700	iib=2.163	Tp=0.5
2-61	77	16x6 PAD	16	0.5	6.625	0.280	N=19,000,000 S=2100	iib=4.085	Tp=0.5
2-62	77	16x6 PAD	16	0.5	6.625	0.280	N=950,000 S=4500	iib=3.471	Tp=0.5
2-63	77	16x6 PAD	16	0.5	6.625	0.280	N=2,800,000 S=4000	iib=3.145	Tp=0.5
2-64	77	16x6 PAD	16	0.5	6.625	0.280	N=13,000,000 S=3000	iib=3.085	Tp=0.5
2-65	77	16x6 PAD	16	0.5	6.625	0.280	N=460,000: S=9000	iob=2.006	Tp=0.5
2-66	77	16x6 PAD	16	0.5	6.625	0.280	N=10,000,000 S=8000	iob=1.219	Tp=0.5
2-67	77	16x6 PAD	16	0.5	6.625	0.280	N=20,000,000 S=7000	iob=1.213	Tp=0.5
2-68	77	16x6 PAD	16	0.5	6.625	0.280	N=9,500,000 S=6000	iob=1.642	Tp=0.5
2-69	77	16x6 PAD	16	0.5	6.625	0.280	N=3,800,000 S=4500	iib=2.630	Weld ground Tp=0.5
2-70	77	16x6 PAD	16	0.5	6.625	0.280	N=3,600,000 S=4200	iib=2.833	Weld ground Tp=0.5
2-71	77	16x6 PAD	16	0.5	6.625	0.280	N=8,000,000 S=4000	iib=2.550	Weld ground Tp=0.5
2-72	77	16x6 PAD	16	0.5	6.625	0.280	N=18,000,000 S=3300	iib=2.628	Weld ground Tp=0.5
2-73	77	16x6 PAD	16	0.5	6.625	0.280	N=2,700,000 S=3000	iib=4.224	Weld ground Tp=0.5
2-74	5	4x4 SDL	4.5	0.237	4.5	0.237	N=18,000 S=29,000	iir=1.1905	Tp=0.5
2-75	5	4x4 SDL	4.5	0.237	4.5	0.237	N=85,000 S=28,000	ior=0.9039	Tp=0.5
2-76	5	4x4 Pad	4.5	0.237	4.5	0.237	N=30,000 S=25,000	iir=1.2468	Tp=0.237
2-77	5	4x4 Pad	4.5	0.237	4.5	0.237	N=880,000 S=27,000	ior=0.5874	Tp=0.237
2-78	5	4x4 Pad	4.5	0.120	4.5	0.120	N=11,500 S=22,500	iir=1.6782	Tp=0.120
2-79	5	4x4 Pad	4.5	0.120	4.5	0.120	N=270,000 S=13,000	ior=1.5451	Tp=0.120
2-80	71, 94	24x4 SDL	24	0.312	4.5	0.237		iob=C2/2=S'/S/2=4/2=2	Defs.p.106 Ref94.
2-81	71, 94	24x8 SDL	24	0.312	8.625	0.25		iob=C2/2=S'/S/2=7/2=3.5	
2-82	71, 94	24x12 SDL	24	0.312	12.75	0.25		iob=C2/2=S'/S/2=7/2=3.5	
2-83	71, 94	24x4 PAD	24	0.312	4.5	0.237		iob=C2/2=S'/S/2=5/2=2.5	
2-84	71, 94	24x8 PAD	24	0.312	8.625	0.25		iob=C2/2=S'/S/2=6/2=3.0	
2-85	71, 94	24x12 PAD	24	0.312	12.75	0.25		iob=C2/2=S'/S/2=8/2=4.0	

2-86	94	10x10 PAD						iob=C2/2=S'/S/2=2.0/2=1.0 iib=C2/2=S'/S/2=1.7/2=0.85	
2-87	78	24x4 SDL	24	0.1875	4.5	0.165			
2-88	71	48x6 PAD	49.25	0.625	6.625	0.280			L1=41 L2=73 Dp=10.5 Tp=0.625
3-1	5	4x4 UFT	4.5	0.337	4.5	0.237	N=8500 S=23,000	iir=1.74	Line 22 Table 2 WRC 329. Markl added for UFTs that, "The data taken from Blair's paper fall well in line and also serve to indicate that it makes little difference, if any, whether the branch is set onto the run or into it."
3-2	5	4x4 UFT	4.5	0.237	4.5	0.337	N=120,000 S=13,000	Iir=1.82	Line 23 Table 2 WRC 329
3-3	5	4x4 UFT	4.5	0.237	4.5	0.237	N=6500 S=40,000	ior=1.06	Line 24 Table 2 WRC 329
3-4	5	4x4 UFT	4.5	0.237	4.5	0.237	N=320,000 S=14,500	ior=1.34	Line 25 Table 2 WRC 329
3-5	5	4x4 UFT	4.5	0.337	4.5	0.237	N=150,000 S=10,600	iib=2.131	Sch 80 Run Sch40 Branch in Ref 5 Fig. 16. Markl also wrote about these tests in 5, "These variants were tested only under inplane bending, and the failures were found to be located similarly as in unreinforced fabricated intersections, i.e., they initiated as cracks across the weld jointing the branch to the run. In addition to failing in an identical fashion, the two variants ggave the saem average stress-intensification factors, which would indicate that the thickness at the intersection (which was identical for the two variants) is the controlling factor, and the distance the reinforcement is carried along the run or branch is of secondary importance only."
3-6	5	4x4 UFT	4.5	0.237	4.5	0.337	N=155,000 S=10,400	iib=2.158	Sch 40 Run Sch 80 Branch in Ref 5 Fig. 16.
3-7	5	4x4 UFT	4.5	0.237	4.5	0.237	N=3500 S=19,900	iib=2.407	Line 1 Table 2 WRC 329
3-8	5	4x4 UFT	4.5	0.237	4.5	0.237	N=4500 S=19,900	iib=2.289	Line 2 Table 2 WRC 329
3-9	5	4x4 UFT	4.5	0.237	4.5	0.237	N=7000 S=19,900	iib=2.096	Line 3 Table 2 WRC 329
3-10	5	4x4 UFT	4.5	0.237	4.5	0.237	N=8200 S=19,900	iib=2.030	Line 4 Table 2 WRC 329
3-11	5	4x4 UFT	4.5	0.237	4.5	0.237	N=25,000 S=13,000	iib=2.487	Line 6 Table 2 WRC 329
3-12	5	4x4 UFT	4.5	0.237	4.5	0.237	N=27,500 S=13,200	iib=2.403	Line 7 Table 2 WRC 329
3-13	5	4x4 UFT	4.5	0.237	4.5	0.237	N=28,000 S=15,700	iib=2.013	Line 5 Table 2 WRC 329
3-14	5	4x4 UFT	4.5	0.237	4.5	0.237	N=31,000 S=13,200	iib=2.346	Line 8 Table 2 WRC 329
3-15	5	4x4 UFT	4.5	0.237	4.5	0.237	N=32,000 S13,200	iib=2.331	Line 9 Table 2 WRC 329
3-16	5	4x4 UFT	4.5	0.237	4.5	0.237	N=86,000 S=10,000	iib=2.525	Line 10 Table 2 WRC 329
3-17	5	4x4 UFT	4.5	0.237	4.5	0.237	N=155,000 S=8800	iib=2.550	Line 11 Table 2 WRC 329
3-18	5	4x4 UFT	4.5	0.237	4.5	0.237	N=241,000 S=8500	iib=2.417	Line 12 Table 2 WRC 329
3-19	5	4x4 UFT	4.5	0.237	4.5	0.237	N=241,500 S=8600	iib=2.388	Line 13 Table 2 WRC 329
3-20	5	4x4 UFT	4.5	0.237	4.5	0.237	N=250,000 S=8700	iib=2.345	Not shown in Table 2 WRC 329
3-21	5	4x4 UFT	4.5	0.203	4.5	0.203	N=1600 S=19,400	iib=2.888	Line 14 Table 2 WRC 329
3-22	5	4x4 UFT	4.5	0.203	4.5	0.203	N=140,000 S=760	iib=3.014	Line 15 Table 2 WRC 329
3-23	5	4x4 UFT	4.5	0.100	4.5	0.100	N=975 S=7850	iib=7.879	Line 17 Table 2 WRC 329. For these tests Markl states "The exploratory pairs of tests carried out with fittings of only 0.100 in. and 0.053 in. wall, on the other hand, do not fit too well, which might reflect the effect of the actual size of the intersection weld which could assume importance in view of the light wall."

3-24	5	4x4 UFT	4.5	0.100	4.5	0.100	N=150 S=20,600	iib=4.366	Line 16 Table 2 WRC 329
3-25	5	4x4 UFT	4.5	0.053	4.5	0.053	N=260 S=9500	iib=8.481	Line 18 Table 2 WRC 329
3-26	5	4x4 UFT	4.5	0.053	4.5	0.053	N=1350 S=4260	iib=13.605	Line 19 Table 2 WRC 329
3-27	5	4x4 UFT	4.5	0.237	4.5	0.237	N=6000 S=15,500	iob=2.775 itb=2.775	Line 20 Table 2 WRC 329 See Table 2.1 in 110996. Itb=iob. Isn't moment arm different in this case.
3-28	5	4x4 UFT	4.5	0.237	4.5	0.237	N=77,000 S=9900	iob=2.608 itb=2.608	Line 21 Table 2 WRC 329 See Table 2.1 in 110996. Itb=iob. Isn't moment arm different in this case? Should this really be called a torsional load test?
3-29	80, 94	56x12 UFT	56	1.312	12.75	0.875	Strain gage extrapolation to fillet	iib=4.1/2 iob=6.2/2	s/S=0.29 $ixx=C_2/2$ $iax=C_2/2=9.8/2=4.9$ Stress recorded in cylinder only. Iax=F/A (See Note 2 Table 21 Ref 94). F=axial force $A=2\pi rt$. Axial iax provided for information when given in Table 21 from Ref 94.
3-30	80, 94	56x12 UFT	56	2.08	12.75	0.843	Strain gage extrapolation to fillet	iib=2.1/2 iob=3.8/2	s/S=0.46 $iax=C_2/2=4.6/2$ Stress recorded in cylinder only
3-31	80, 94	24x4 UFT	24	0.312	4.5	0.237	Strain gage extrapolation to fillet	Iib=4.5/2 iob=10./2	
3-32	80, 94	24x12 UFT	24	0.313	12.75	0.250	Strain gage extrapolation to fillet	iib=5.1/2 iob=12./2	
3-33	80, 94	24x24 UFT	24	0.312	24	0.312	Strain gage extrapolation to fillet	iib=8.4/2 iob=14./2	
3-34	80, 94	36x4 UFT	36	0.375	4.5	0.375	Strain gage extrapolation to fillet	iib=2.1/2 iob=3.5/2	$Ixx=C_2/2$ $iax=C_2/2=8.1/2$
3-35	80, 94	36x6 UFT	36	0.375	6.625	0.280	Strain gage extrapolation to fillet	iib=4.7/2 iob=10.5/2	$Ixx=C_2/2$ $iax=C_2/2=16.7/2$
3-36	80, 94	48x6 UFT	48	0.625	6.625	0.28	Drawn? See WRC 60	iib=3.1 iob=4.4	
3-37	80, 94	20x12 UFT	20	1	12.75	0.687	Model R strain gage and fatigue tests on model R. N=80,000 S=6300 Fig.29 Ref93	iib=3.5/2 iob=8.6/2	See Line 2 in Table 3, WRC 329. Fatigue Test iob=3.9. See p.124 of Ref 94 for measured stress divided by 2 comparison with test i-factor.
3-38	80, 94	20x20 UFT	20	1.	20	1.		iib=5.2/2 iob=5.3/2	
3-39	80, 94	24x12 UFT	24	0.1	12.75	0.1		iib=18/2 iob=90./2	WRC 108
3-40	65	8x2 UFT A	8.625	0.188	2.5	0.065	N=459 S=22,800	iob=3.15	
3-41	65	8x2 UFT B	8.625	0.188	2.5	0.065	N=754 S=18,900	iob=3.45	
3-42	65	8x2 UFT C	8.625	0.188	2.5	0.065	N=923 S=16,100	iob=3.88	
3-43	65	8x2 UFT D	8.625	0.188	2.5	0.065	N=1816 S=14,200	iob=3.84	
3-44	91	8x2 UFT E	8.625	0.322	2.5	0.065	N=1919, Neq=535	iib=1.87	Mtr Tr=0.322 (Report Tr=0.188)
3-45	91	8x2 UFT F	8.625	0.322	2.5	0.065	N=2884 Neq=858	iib=1.54	Mtr Tr=0.322 (Report Tr=0.188)
3-46	91	8x2 UFT G	8.625	0.322	2.5	0.065	N=1168 Neq=546	iob=2.4	Mtr Tr=0.322 (Report Tr=0.188)
3-47	91	8x2 UFT H	8.625	0.322	2.5	0.065	N=1225 Neq=1225	iob=2.28	Mtr Tr=0.322 (Report Tr=0.188)
3-48	79	8x6 UFT	8.625	0.322	6.625	0.280	Nio=5410 Sio=7515 Nii=3615 Sii = 25680	iib=1.85 iob=5.842	Line 1 & 2 Table 5 WRC 329
3-49	79	12x10 UFT	12.75	0.375	10.75	0.365	N=212 S=9399	iob=8.929	Line 3 Table 5 WRC 329
3-50	79	12x10 UFT	12.75	0.375	10.75	0.365	N=6130 S=5529	iob=7.745	Line 4 Table 5 WRC 329
3-51	83	6x6 UFT	6.625	0.265	6.625	0.265		iib=4.04 (avg)	R/T=12, r/R=1, t/T=1, 5 tests (Ea. Test reported below. Blair vibration tests. Header ends pinned. Test pressurized to about 18,000 psi hoop stress. Tests run between 1936 and 1946. Hinnant avg. iib omitting 3-51a = 2.614.
3-51a	83	6x6 UFT	6.625	0.265	6.625	0.265	N=31000 S=7725	Iib=4.01	Set on Hinnint i-factor=3.837 [Blair cautions regarding defect in test]
3-51b	83	6x6 UFT	6.625	0.265	6.625	0.265	N=496000 S=3863	Iib=4.604	Set on Hinnant i-factor=3.031

3-51c	83	6x6 UFT	6.625	0.265	6.625	0.265	N=519000 S=4331	Iib=4.06951	Set on Hinnant i-factor=2.663
3-51d	83	6x6 UFT	6.625	0.265	6.625	0.265	N=655000 S=4448	Iiib=3.78221	Set in Hinnant i-factor=2.398
3-51e	83	6x6 UFT	6.625	0.265	6.625	0.265	N=683000 S=4448	Iiib=3.75	Set in Hinnant i-factor=2.365
3-52	84	20x4 UFT	19.803	0.239	4.0945	0.239		iib=2.67	R/T=41.4 r/R=0.197 t/T=1 Line 3 Table 3 WRC 329. Ref 84 is Decock model machined on outside and inside.
3-53	84	20x8 UFT	19.803	0.3937	7.4507	0.1969		iib=2.75	R/T=24.6 r/R=0.375 t/T=0.5 Line 4 Table 3 WRC 329. Ref 84 is Decock model machined on outside and inside.
3-54	84	20x14 UFT	19.803	0.3937	13.858	0.239		iib=3.47	R/T=24.6 r/R=0.702 t/T=0.6 Line 5 Table 3 WRC 329. Ref 84 is Decock model machined on outside and inside.
3-55	84	20x20 UFT	19.803	0.239	19.803	0.239		iib=6.90	R/T=41.4 r/R=1.0 t/T=1.0 Line 6 Table 3 WRC 329. Ref 84 is Decock model machined on outside and inside.
3-56	92	4x0.5 UFT	4.53	0.24	0.5	0.	N=610 S=40,300	iir=1.68	
3-57	92	4x0.5 UFT	4.531	0.238	0.5	0.	N=2088 S=34,500	iir=1.54	
3-58	92	4x1 UFT	4.533	0.234	1.0	0.1	N=2428 S=41,200	iir=1.25	
3-59	92	4x1 UFT	4.533	0.237	1.0	0.1	N=546 S=56,600	iir=1.23	
3-60	92	4x1 UFT	4.533	0.238	1.0	0.25	N=2964 S=43,600	iir=1.14	
3-61	92	4x1 UFT	4.532	0.245	1.0	0.25	N>1000 S=63,600	iir<0.97	
3-62	92	4x1 UFT	4.5	0.246	1.0	0.5	N=1246 S=52,100	iir<1.13	See WRC doc and add notes here.
3-63	92	4x0.5 UFT	4.148	0.0612	0.5	0	N=370 S=40400	iir=1.86	
3-64	92	4x1 UFT	4.138	0.0562	1.0	0.05	N=915 S=41,600	iir=1.51	
3-65	92	4x1 UFT	4.146	0.0599	1.0	0.11	N=1909 S=51600	iir=1.05	
3-66	92	4x1 UFT	4.142	0.0578	1.0	0.50	N=1793 S=58,800	iir=0.93	
3-67	95	4x4 UFT	4.5	0.237	4.5	0.237	N=2835 S=35,2100	iob=2.84	D=1.44
3-68	95	4x4 UFT	4.5	0.237	4.5	0.237	N=3955 S=35,210	iob=2.66	D=1.44
3-69	95	4x4 UFT	4.5	0.237	4.5	0.237	N=23,370 S=19,830	iob=3.30	D=0.86”
3-70	110	10x5 UFT	10	0.1	5	0.05		iib=5.637	Strain gage tests
3-71	110	10x5 UFT	10	0.1	5	0.05		iob=18.867	Strain gage tests
3-72	110	10x5 UFT	10	0.1	5	0.05		itb=1.210	Strain gage tests
3-73	110	10x5 UFT	10	0.1	5	0.05		iih=3.377	Strain gage tests
3-74	110	10x5 UFT	10	0.1	5	0.05		ioh=0.666	Strain gage tests
3-75	110	10x5 UFT	10	0.1	5	0.05		ith=3.680	Strain gage tests
5-1	81	14x10 INS	14	0.375	10.75	0.365	r2=3.75 N=140 S=37,300	iob=2.445	
5-2	81	14x10 INS	14	0.375	10.75	0.365	r2=3.75 N=215 S=33,500	iob=2.498	
5-3	81	14x10 INS	14	0.375	10.75	0.365	r2=3.75 N=1862 S=20,000	iob=2.717	
5-4	81	14x10 INS	14	0.375	10.75	0.365	r2=3.75 N=4546 S=15,700	iob=2.896	
5-5	81	14x10 INS	14	0.375	10.75	0.365	r2=3.75 N=49,915 S=10,100	iob=2.787	
5-6	81	14x10 INS	14	0.375	10.75	0.365	r2=3.75 N=238 S=33,500	iob=2.448	
5-7	81	14x10 INS	14	0.375	10.75	0.365	r2=3.75 N=30,374 S=10,100	iob=3.079	

5-8	81	14x10 INS	14	0.375	10.75	0.365	r2=3.75 N=605 S=73,100	iib=0.931	
5-9	81	14x10 INS	14	0.375	10.75	0.365	r2=3.75 N=5914 S=42,100	iib=1.024	
5-10	81	14x10 INS	14	0.375	10.75	0.365	r2=3.75 N=21,553 S=31,500	iib=1.057	
5-11	82	12x8 INS	12.75	0.375	8.625	0.322	r2=0.75 N=34,029 S=19,851	iib=1.531	Line 21 Table 3 WRC 329
5-12	82	12x8 INS	12.75	0.375	8.625	0.322	r2=0.75 N=15,495 S=23,632	iib=1.505	Line 21 Table 3 WRC 329
5-13	82	12x8 INS	12.75	0.375	8.625	0.322	r2=0.75 N=1269 S=26,891	iob=2.182	Line 20 Table 3 WRC 329
5-14	82	8x4 INS	8.625	0.322	4.5	0.237	r2=0.375 N=758 S=34,273	iob=1.898	Line 22 Table 3 WRC 329
5-15	82	8x4 INS	8.625	0.322	4.5	0.237	r2=0.375 N=3858 S=46,894	iib=1.002	Line 23 Table 3 WRC 329
5-16	81	12x6 INS	12.750	0.375	6.625	0.280	r2=1.688 N=444 S=76,200	iib=0.950	
5-17	81	12x6 INS	12.750	0.375	6.625	0.280	r2=1.688 N=659 S=75,700	iib=0.884	
5-18	81	12x6 INS	12.750	0.375	6.625	0.280	r2=1.688 N=5091 S=47,100	iib=0.944	
5-19	81	12x6 INS	12.750	0.375	6.625	0.280	r2=1.688 N=6191 S=46,700	iib=0.915	
5-20	81	12x6 INS	12.750	0.375	6.625	0.280	r2=1.688 N=42,363 S=35,700	iib=0.815	
5-21	81	12x6 INS	12.750	0.375	6.625	0.280	r2=1.688 N=67,780 S=35,600	iib=0.744	
5-22	81	12x6 INS	12.750	0.375	6.625	0.280	r2=1.688 N=310,111 S=25,600	iib=0.763	
5-23	81	12x6 INS	12.750	0.375	6.625	0.280	r2=1.688 N=631 S=58,000	iob=1.163	
5-24	81	12x6 INS	12.750	0.375	6.625	0.280	r2=1.688 N=779 S=56,500	iob=1.145	
5-25	81	12x6 INS	12.750	0.375	6.625	0.280	r2=1.688 N=5309 S=38,100	iob=1.157	
5-26	81	12x6 INS	12.750	0.375	6.625	0.280	r2=1.688 N=32,490 S=24,200	iob=1.268	
5-27	81	12x6 INS	12.750	0.375	6.625	0.280	r2=1.688 N=55,316 S=20,900	iob=1.320	
5-28	81	12x6 INS	12.750	0.375	6.625	0.280	r2=1.688 N=117,588 S=18,700	iob=1.268	
5-29	79	12x6 INS	12.750	0.375	6.625	0.280	r2=0.5 N=6760 S=17,237	iob=2.436	Line 26 Table 5 WRC 329 (50% reinf)
5-30	79	12x6 INS	12.750	0.375	6.625	0.280	r2=0.5 N=5347 S=33,224	iib=1.325	Line 25 Table 5 WRC 329 (50% reinf)
5-31	79	12x6 INS	12.750	0.375	6.625	0.280	r2=0.5 N=4445 S=20,769	iob=2.199	Line 23 Table 5 WRC 329
5-32	79	12x6 INS	12.750	0.375	6.625	0.280	r2=0.5 N=7655 S=17,728	iob=2.311	Line 24 Table 5 WRC 329
5-33	79	12x8 INS	12.750	0.375	8.625	0.322	r2=0.625 N=1840 S=19,701	iob=2.765	Line 28 Table 5 WRC 329
5-34	79	12x8 INS	12.750	0.375	8.625	0.322	r2=0.625 N=8510 S=14,631	iob=2.741	Line 29 Table 5 WRC 329
5-35	79	12x8 INS	12.750	0.375	8.625	0.322	r2=0.625 N=4525 S=18,862	iob=2.412	Line 32 Table 5 WRC 329 (50% reinf)
5-36	79	12x8 INS	12.750	0.375	8.625	0.322	r2=0.625 N=5460 S=19,445	iob=2.254	Line 30 Table 5 WRC 329
5-37	79	12x8 INS	12.750	0.375	8.625	0.322	r2=0.625 N=5371 S=33,583	iib=1.309	Line 27 Table 5 WRC 329
5-38	79	12x8 INS	12.750	0.375	8.625	0.322	r2=0.625 N=3435 S=31,389	iib=1.532	Line 31 Table 5 WRC 329 (50% reinf)
5-39	89	14x6 INS	14	0.375	6.625	0.280	r2=0.421 N=337 S=33,200	iob=2.304	Line 17 Table 3 WRC 329
5-40	89	14x6 INS	14	0.375	6.625	0.280	r2=0.421 N=1605 S=22,100	iob=2.533	Line 17 Table 3 WRC 329
5-41	89	14x6 INS	14	0.375	6.625	0.280	r2=0.421 N=6341 S=16,500	iob=2.578	Line 17 Table 3 WRC 329
5-42	89	14x6 INS	14	0.375	6.625	0.280	r2=0.421 N=52,103 S=11,200	iob=2.492	Line 17 Table 3 WRC 329
5-43	89	14x6 INS	14	0.375	6.625	0.280	r2=0.421 N=330 S=33,200	iob=2.314	Line 18 Table 3 WRC 329
5-44	89	14x6 INS	14	0.375	6.625	0.280	r2=0.421 N=4047 S=16,600	iob=2.803	Line 18 Table 3 WRC 329

5-45	89	14x6 INS	14	0.375	6.625	0.280	r2= 0.421 N=19,546 S=11,100	iob=3.059	Line 18 Table 3 WRC 329
5-46	89	14x6 INS	14	0.375	6.625	0.280	r2=0.421 N=1034 S=61,200	iib=0.999	Line 19 Table 3 WRC 329
5-47	89	14x6 INS	14	0.375	6.625	0.280	r2=0.421 N=14,264 S=37300	iib=0.970	Line 19 Table 3 WRC 329
6-1	81	4x4 OLET	4.5	0.237	4.5	0.237	N=390 S=43,900	iib=1.692	r/rp=0.63 Line 7 Table 3 WRC 329
6-2	81	4x4 OLET	4.5	0.237	4.5	0.237	N=1290 S=38,400	iib=1.523	r/rp=0.63 Line 7 Table 3 WRC 329
6-3	81	4x4 OLET	4.5	0.237	4.5	0.237	N=630 S=33,200	iib=2.033	r/rp=0.63 Line 7 Table 3 WRC 329
6-4	81	4x4 OLET	4.5	0.237	4.5	0.237	N=2930 S=27,600	iib=1.798	r/rp=0.63 Line 7 Table 3 WRC 329
6-5	81	4x4 OLET	4.5	0.237	4.5	0.237	N=14,240 S=22,300	iib=1.622	r/rp=0.63 Line 7 Table 3 WRC 329
6-6	81	4x4 OLET	4.5	0.237	4.5	0.237	N=36,310 S=16,500	iib=1.818	r/rp=0.63 Line 7 Table 3 WRC 329
6-7	81	4x4 OLET	4.5	0.237	4.5	0.237	N=216 S=50,700	iob=1.649	r/rp=0.63 Line 8 Table 3 WRC 329
6-8	81	4x4 OLET	4.5	0.237	4.5	0.237	N=1000 S=42,000	iob=1.465	r/rp=0.63 Line 8 Table 3 WRC 329
6-9	81	4x4 OLET	4.5	0.237	4.5	0.237	N=1403 S=35,900	iob=1.602	r/rp=0.63 Line 8 Table 3 WRC 329
6-10	81	4x4 OLET	4.5	0.237	4.5	0.237	N=2600 S=29,600	iob=1.717	r/rp=0.63 Line 8 Table 3 WRC 329
6-11	81	4x4 OLET	4.5	0.237	4.5	0.237	N=6100 S23,800	iob=1.801	r/rp=0.63 Line 8 Table 3 WRC 329
6-12	81	4x4 OLET	4.5	0.237	4.5	0.237	N=35,600 S=17,800	iob=1.692	r/rp=0.63 Line 8 Table 3 WRC 329
6-13	85	6x4 OLET	6.625	0.280	4.5	0.237	N=412 S=36,400	iob=2.019	As Welded Line 11 Table 3 WRC 329
6-14	85	6x4 OLET	6.625	0.280	4.5	0.237	N=1021 S=25,400	iob=2.413	As Welded Line 11 Table 3 WRC 329
6-15	85	6x4 OLET	6.625	0.280	4.5	0.237	N=37,027 S=13,900	iob=2.150	As Welded Line 11 Table 3 WRC 329
6-16	85	6x4 OLET	6.625	0.280	4.5	0.237	N=530 S=36,018	iob=1.940	Ground Line 12 Table 3 WRC 329
6-17	85	6x4 OLET	6.625	0.280	4.5	0.237	N=628 S=31,320	iob=2.157	Ground Line 12 Table 3 WRC 329
6-18	85	6x4 OLET	6.625	0.280	4.5	0.237	N=5676 S=21,924	iob=1.984	Ground Line 12 Table 3 WRC 329
6-19	85	6x4 OLET	6.625	0.280	4.5	0.237	N=10,559 S=16,617	iob=2.311	Ground Line 12 Table 3 WRC 329
6-20	85	6x4 OLET	6.625	0.280	4.5	0.237	N=14,717 S=15,399	iob=2.334	Ground Line 12 Table 3 WRC 329
6-21	86	12x6 OLET	12.75	0.375	6.625	0.280	N=362 S=57,200	iib=1.318	r/rp=0.675 Line 14 Table 3 WRC 329
6-22	86	12x6 OLET	12.75	0.375	6.625	0.280	N=2048 S=42,400	iib=1.258	r/rp=0.675 Line 14 Table 3 WRC 329
6-23	86	12x6 OLET	12.75	0.375	6.625	0.280	N=7851 S=33,900	iib=1.202	r/rp=0.675 Line 14 Table 3 WRC 329
6-24	86	12x6 OLET	12.75	0.375	6.625	0.280	N=26,597 S=25,400	iib=1.257	r/rp=0.675 Line 14 Table 3 WRC 329
6-25	86	12x6 OLET	12.75	0.375	6.625	0.280	N=41,597 S=21,200	iib=1.377	r/rp=0.675 Line 14 Table 3 WRC 329
6-26	86	12x6 OLET	12.75	0.375	6.625	0.280	N=18 S=39,800	iob=3.453	r/rp=0.675 Line 13 Table 3 WRC 329
6-27	86	12x6 OLET	12.75	0.375	6.625	0.280	N=538 S=19,900	iob=3.501	r/rp=0.675 Line 13 Table 3 WRC 329
6-28	86	12x6 OLET	12.75	0.375	6.625	0.280	N=2607 S=13,300	iob=3.820	r/rp=0.675 Line 13 Table 3 WRC 329
6-29	86	12x6 OLET	12.75	0.375	6.625	0.280	N=5797 S=11,100	iob=3.901	r/rp=0.675 Line 13 Table 3 WRC 329
6-30	86	12x6 OLET	12.75	0.375	6.625	0.280	N=56,898 S=6630	iob=4.137	r/rp=0.675 Line 13 Table 3 WRC 329
6-31	87	4x4 OLET	4.5	0.237	4.5	0.237	N=1230 S=26,700	iib=2.211	Table 4.2-1 p 4-2 Target Test Report; Not in WRC 329
6-32	82	4x4 OLET	4.5	0.237	4.5	0.237	N=301 S=43,219	iib=1.810	p.34 Target Tech Report 9/6/77; Line 10 Table 3 WRC 329 ref 10; r/rp=0.79;
6-33	82	4x4 OLET	4.5	0.237	4.5	0.237	N=335 S=40,322	iib=1.899	p.34 Target Tech Report 9/6/77; Line 10 Table 3 WRC 329 ref 10; r/rp=0.79
6-34	82	4x4 OLET	4.5	0.237	4.5	0.237	N=3330 S=28,061	iob=1.724	p.34 Target Tech Report 9/6/77; Line 9 Table 3 WRC 329 ref 10 ; r/rp=0.79

6-35	88	8x4 OLET	8.625	0.322	4.5	0.237		iib = 0.81	R/T=12.9 r/R=0.513 t/T=0.736 r/rp=0.78 Line 15 Table 3 WRC 329 ref 10. (Did not find this test in Ref 87 Report)
6-36	79	8x6 OLET	8.625	0.322	6.625	0.280	N=331 S=14,762	iob=5.201	Line 16 Table 5 WRC 329 r/rp=0.832
6-37	79	8x6 OLET	8.625	0.322	6.625	0.280	N=3492 S=9800	iob=4.890	Line 17 Table 5 WRC 329 r/rp=0.832
6-38	79	8x6 OLET	8.625	0.322	6.625	0.280	N=6345 S=10350	iob=4.109	Line 18 Table 5 WRC 329 r/rp=0.832
6-39	79	8x6 OLET	8.625	0.322	6.625	0.280	N=3380 S=12,206	iob=3.952	Line 19 Table 5 WRC 329 r/rp=0.868
6-40	79	8x5 OLET	8.625	0.322	5.563	0.258	N=12,839 S=9430	iob=3.914	Line 15 Table 5 WRC 329 r/rp=0.801
6-41	79	8x5 OLET	8.625	0.322	5.563	0.258	N=4640 S=10,074	iob=4.494	Line 14 Table 5 WRC 329 r/rp=0.801
6-42	79	8x4 OLET	8.625	0.322	4.5	0.237	N=8870 S=11,448	iob=3.474	Line 11 Table 5 WRC 329 r/rp=0.812
6-43	79	8x4 OLET	8.625	0.322	4.5	0.237	N=3954 S=13,598	iob=3.438	Line 13 Table 5 WRC 329 r/rp=0.853 (50% reinf)
6-44	79	8x4 OLET	8.625	0.322	4.5	0.237	N=4310 S=13,167	iob=3.489	Line 12 Table 5 WRC 329 r/rp=0.812
6-45	79	8x3 OLET	8.625	0.322	3.5	0.216	N=12,310 S=11,306	iob=3.295	Line 9 Table 5 WRC 329 r/rp=0.773
6-46	79	8x3 OLET	8.625	0.322	3.5	0.216	N=4540 S=14,700	iob=3.093	Line 10 Table 5 WRC 329 r/rp=0.773
6-47	79	8x8 OLET	8.625	0.322	8.625	0.322	N=10,678 S=7474	iob=5.128	Line 20 Table 5 WRC 329 r/rp=0.852
6-48	79	8x8 OLET	8.625	0.322	8.625	0.322	N=1554 S=10,753	iob=5.240	Line 21 Table 5 WRC 329 r/rp=0.852
6-49	79	8x8 OLET	8.625	0.322	8.625	0.322	N=4516 S=8743	iob=5.207	Line 22 Table 5 WRC 329 r/rp=0.852
6-50									Not Used
6-51	98	4x3 OLET	4.5	0.237	3.5	0.216	N=1888 S=26,274	iob=2.063	r/rp=0.64141
6-52	98	4x3 OLET	4.5	0.237	3.5	0.216	N=1485 S=17,903	iob=3.176	r/rp=0.68992
6-53	98	4x3 OLET	4.5	0.237	3.5	0.216	N=3067 S=23,825	iob=2.064	r/rp=0.61498
6-54	98	4x3 OLET	4.5	0.237	3.5	0.216	N=1920 S=23,343	iob=2.314	r/rp=0.67020
6-55	98	4x3 OLET	4.5	0.237	3.5	0.216	N=1368 S=33,213	iob=1.740	r/rp=0.63398
6-56	98	4x3 OLET	4.5	0.237	3.5	0.216	N=1826 S=34,339	iob=1.589	r/rp=0.61498
6-57	98	4x3 OLET	4.5	0.237	3.5	0.216	N=5620 S=22,644	iob=1.924	r/rp=0.56817

General Notes

1) Vessolet in WFI test terminology are considered contoured inserts (Sketch 2.5)
2) Pipets are considered in WFI test terminology are considered to be welded on fittings.
3) Item numbers in the leftmost column of the "SIF References" table correspond to the applicable branch connection sketch number in the ASME ST-LLC 07-02 Table 1 recommendations in Annex A. For example, the item number 6-51 represents the 51st recorded test of a Sketch 2.6 Integrally reinforced branch welded-on fitting. The mnemonic INS is used as an abbreviation for Sketch 2.5 welded-in contour insert, UFT is used as an abbreviation for the Sketch 2.3 unreinforced fabricated tee, and SDL is used for the Sketch 2.2 reinforced fabricated tees when a saddle-type geometry is used for the reinforcement.
4) When the percentage of reinforcement is specified for a particular fitting this gives the amount of pressure design area that's provided by the fitting for the opening removed from the pipe.
4) Ref 1 Notes:Total reversed deflections in Markl tests for miters and elbows is up to 1.5 in. amplitude at anywhere between 75 and 1000 cycles per minute. For both the straight pipe and the elbow fittings, [the formula SN=245,000N^-0.2 may be considered applicable at least between limits of 500 and 500,000 cycles.]
5) Ref 5 Notes for Welding Tees: "While drawn tees must and do conform to certain dimensional and strength requirements set forth in ASA Standard B16.9, commercial products differ considerably in external contour and metal distribution." "For any one style of tee, the first and second loading positions [thru the branch, and thru the run with the branch fixed), gave practically identical results, so that there appeared to be no need for making a distinction in plotting the data. The third position (load only in the run with the branch end free) as a rule gave higher endurance strengths; data for it have been disregarded in arriving at the average stress-intensification factors shown, since it would complicate unduly application to piping stress analyses if separate values were to be specified." "For straight through tests (third position), failure occurred by cracking along the center or edge, or across the apex, of the weld attaching the branch to the run – [this indicates that for size-on-size tees, there is at least some effect on i-factor due to the weld – as expected." "The three types of tee selected for this study exhibited pronounced differences in endurance strength. In light of what was observed relative to location and nature of failures, the metal thickness availablein the crotch zone and the crotch radius were thought to be the controlling factors." "It was reasoned that a satisfactory correlation should be obtainable by considering the tee as if they had been elbows of an effective thickness te equal to the average of the crotch and side-wall thicknesses, and an effective bend radius Re equal to the sum of the pipe radius r and the crotch radius r_c." Markl's Eq. (9) for welding tees for h = c(teRe/r^2) = (te/t)^1.5 (te(r+r_c)/r^2 = (te/t)2.5 (t/r)(1+rc/r). Markl recommends the stress intensification factor as 0.9/(h^2/3), and h for welding tees in Chart 1 of Ref 2 is 4.4 t/r.
6)MTR's given for 8" pipe in TR110996 is 8x0.188 wall pipe. The MTR for tests reported in TR-1006227 shows 8" pipe with a 0.322" wall thickness (sch 7).For bends Markl [28] states, "It would appear, however, from the author's earlier investigation and a discussion fo Pardue and Vigness' paper by D.R. Zerno that if the inherent flexibility of a curved tube is to be fully utilized, a tangent length equal to at least two pipe diameters, preferably greater, must be present between its ends and adjoining flanges or anchors."
8)For tests around 2-57 (Ref. [37]) there are some data points that did not experience failure. i-factors are provided in table 5 of WRC 166 but they did not correspond with the Table 5 values or WRC 166 Eq. 1. This data and references for WRC 166 should be checked further.
9)Hinnant i-factors are calculated from 947,500 x N-0.335; psi, M/Z from moment amplitude (same as Markl)

ANNEX F2 - COMPLIED FLEXIBILITY FACTOR REFERENCES (R1)

#	Ref	ID	Do	T	do	t	Auxiliary data	Results	Notes
1-1	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=4626 S=43,652		
1-2	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=16,342 S=32,614		
1-3	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=19,934 S=26,841		
1-4	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=213,895 S=16,776		
1-5	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=231,153 S=21,434		
1-6	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=0.75 N=7630 S=31,827		
1-7	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=0.75 N=62,893 S=19,980		
1-8	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=0.75 N=132,008 S=12,566		
1-9	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=1347 S=45,030		
1-10	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=1590 S=44,802		
1-11	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=11,048 S=26,940		
1-12	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=14,931 S=26,977		
1-13	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=103,276 S=17,195		
1-14	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=171,633 S=17,274		
1-15	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=1169 S=44,679		
1-16	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=4231 S=42,855		
1-17	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=12,557 S=27,233		
1-18	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=25,009 S=26,497		
1-19	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=97,544 S=17,338		
1-20	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=167,880 S=18,754		
1-21	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=0.75 N=2103 S=25,038		
1-22	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=0.75 N=58,050 S=15,251		
1-23	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=0.75 N=549,414 S=9672		
1-24	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=593 S=44,494		
1-25	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=911 S=43,793		
1-26	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=5573 S=21,857		

1-27	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=15,951 S=21,330		
1-28	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=325,237 S=11,706		
1-29	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=604,644 S=11,112		
1-30	72	12x12 B16.9	12.75	0.687	12.75	0.687	N=2062 S=30,200		T-4 A106B
1-31	72	12x12 B16.9	12.75	0.687	12.75	0.687	N=1309 S=30,150		T-6 A106B
1-32	72	12x12 B16.9	12.75	1.312	12.75	1.312	N=11,475 S=30,500		T-7 304L
1-33	72	12x6 B16.9	12.75	0.406	6.625	0.280	N=8979 S=41,160		T-8 304L
1-34	72	12x6 B16.9	12.75	0.406	6.625	0.280	N=10,200 S=36,100		T-15 304L
1-35	73	24x24 B16.9	24	0.687	24	0.687	N=18,532 S=20,629	ktr=0.553 kor=-0.425 kir=2.409 kob=1.333 ktb=1.641 kib=3.478	T-10 A 212-61T GrB Table 14. 4785. See PRG est. for k-factor equations for these tee tests.
1-36	73	24x24 B16.9	24	0.25	24	0.25	N=2344 S=24,202	ktr=-0.531 kor=-0.813 kir=2.191 kob=8.331 ktb=0.693 kib=3.891	T-16 SA 312 304L ORNL T-16 was ordered as sched. 10, but was manufactured as sched. 20 and “through bored” to sched 10 on the run. The displacement data ere analyzed as if the entire model was sched. 20 for T-16A and as if the entire model was sched 10 for T-16B.(Note C to Table 14 4785.)
1-37	97	4x3 B16.9 A	4.5	0.237	3.5	0.226	N=2225 S=39,600	kob=2.95 (do)	
1-38	97	4x3 B16.9 B	4.5	0.237	3.5	0.226	N=2612 S=40,600	kob=2.83 (do)	
1-39	97	4x3 B16.9 C	4.5	0.237	3.5	0.226	N=1030 S=39,600	kob=3.01 (do)	
1-40	97	4x3 B16.9 D	4.5	0.237	3.5	0.226	N=3143 S=46,100	kob=1.36 (do)	
1-41	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=933 S=50,130		
1-42	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=33,235 S=25,984		
1-43	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=133,229 S=20,286		
1-44	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=8354 S=36,501		
1-45	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=80,279 S=27,701		
1-46	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=296,483 S=17,084		
1-47	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=1617 S=52,252		
1-48	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=26,044 S=25,680		
1-49	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1.125 N=91,033 S=19,916		
1-50	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=8588 S=33,497		

1-51	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=43,863 S=28,451		
1-52	5	4x4 B16.9	4.5	0.237	4.5	0.237	r2=1 N=103,657 S=14,315		
1-53	71	12x10	12.75	0.5	10.75	0.5		kib=4.8 kob=4.4	
1-54	71	12x10	12.75	0.5	10.75	0.5		kib=4.5 kob=7.6	
1-55	71	12x10	12.75	0.429	10.75	0.45		kib=4.2 kob=7.3	
1-56	73	24x24x24	24	2.343	24	2.343		ktr=-1.587 kor=-0.305 kir=0.457 kob=-0.375 ktb=-0.527 kib=0.866	T-11 A105 Gr2 k's from Table 14 CR4785.
1-57	73	24x24x10	24	0.687	10.75	0.365		ktr=-1.105 kor=-0.425 kir=-0.142 kob=2.316 ktb=0.131 kib=0.954	T-12 A515 Gr70
1-58	73	24x24x10	24	2.343	10.75	1.125		ktr=-1.188 kor=-0.305 kir=-0.152 kob=0.402 ktb=0.141 kib=0.261	T-13 A105 Gr2
1-59	73	24x24x10	24	0.375	10.75	0.375		kib=6 kob=1.8	Tee Bored to Sch 20.
4-1	74	20x6 EXT	20	1	6.625	0.432			
4-2	74	20x6 EXT	20	1	6.625	0.432			
4-3	74	20x12 EXT	20	1	12.75	0.687			
4-4	74	20x12 EXT	20	1	12.75	0.687			
4-5	74	20x12 EXT	20	1	12.75	0.375			
4-6	74	20x12 EXT	20	1	12.75	0.375			
4-7	75	5x5 EXT	5.0	0.480	5.0	0.480			
4-8	75	5x5 EXT	5.0	0.480	5.0	0.480			
4-9	75	5x5 EXT	5.0	0.480	5.0	0.480			
4-10	75	5x5 EXT	5.0	0.480	5.0	0.480			
4-11	75	6x4 EXT	6.625	0.562	4.5	0.237			
4-12	75	6x4 EXT	6.625	0.562	4.5	0.237			
4-13	75	6x4 EXT	6.625	0.562	4.5	0.237			
4-14	75	8x4 EXT	8.625	0.719	4.5	0.237			
4-15	75	8x4 EXT	8.625	0.719	4.5	0.237			

4-16	75	8x4 EXT	8.625	0.719	4.5	0.237			
4-17	75	8x4 EXT	8.625	0.719	4.5	0.237			
4-18	75	16x4 EXT	16	1.031	4.5	0.237			
4-19	75	16x4 EXT	16	1.031	4.5	0.237			
4-20	75	16x4 EXT	16	1.031	4.5	0.237			
4-21	75	16x4 EXT	16	1.031	4.5	0.237			
4-22	75	16x4 EXT	16	1.031	4.5	0.237			
4-23	80, 10	20x6 L EXT	20		6.5			ko=2.3 ki=1.1	R/T=9.5 r/R=0.326 t/T=0.432 Line 24 Table 3 WRC 329
4-24	80, 10	20x12, D	20	1	12.75	0.687		ko=3.5 ki=1.8	R/T=9.5 r/R=0.635 t/T=0.687 Line 25 Table 3 WRC 329
4-25	10 1.1	16x6 EXT	16	0.5	6.625	0.280		ko=11.8 ki=2.7	
4-26	10 1.1	16x6 EXT	16	1	6.625	0.280		ko=1.7 ki=1.1	
2-1	5	4x4 SDL	4.5	0.237	4.5	0.237	N=10,000 S=30,000		Line 6 Table 4 WRC 329 te/T=2.1
2-2	5	4x4 SDL	4.5	0.237	4.5	0.237	N=120,000 S=25,000		Line 6 Table 4 WRC 329 te/T=2.1
2-3	5	4x4 SDL	4.5	0.237	4.5	0.237	N=20,000 S=31,500		Line 5 Table 4 WRC 329 te/T=2.1
2-4	5	4x4 SDL	4.5	0.237	4.5	0.237	N=80,000 S=23,000		Line 5 Table 4 WRC 329 te/T=2.1
2-5	76	24x8 SDL	24	0.353	8.625	0.318	N=520 S=65,000		
2-6	76	24x8 SDL	24	0.353	8.625	0.318	N=6000 S=37,000		
2-7	76	24x8 SDL	24	0.353	8.625	0.318	N=50,000 S=21,000		
2-8	76	24x8 SDL	24	0.353	8.625	0.318	N=126,000 S=20,000		
2-9	76	24x8 SDL	24	0.353	8.625	0.318	N=20, S=37,000		
2-10	76	24x8 SDL	24	0.353	8.625	0.318	N=35,000 S=6000		
2-11	77	16x6 SDL	16	0.5	6.625	0.280	N=1,400,000 S=6000	kob=3	L1=21 L2=21 Dp=11.625 Tp=0.5 Dimensions from Table 13 NUREG CR 4785
2-12	77	16x6 SDL	16	0.5	6.625	0.280	N=5,500,000 S=3900	kib=1.3	
2-13	77	16x6 SDL	16	0.5	6.625	0.280	N=8,000,000 S=3300		
2-14	77	16x6 SDL	16	0.5	6.625	0.280	N=10,000,000 S=3200		
2-15	77	16x6 SDL	16	0.5	6.625	0.280	N=1,600,000 S=8000		
2-16	77	16x6 SDL	16	0.5	6.625	0.280	N=3,200,000 S=6600		
2-17	77	16x6 SDL	16	0.5	6.625	0.280	N=5,600,000 S=4500		
2-18	77	16x6 SDL	16	0.5	6.625	0.280	N=7,300,000 S=4500		

2-19	77	16x6 SDL	16	0.5	6.625	0.280	N=10,000,000 S=4000		
2-20	77	16x6 SDL	16	0.5	6.625	0.280	N=9,500,000 S=3200		
2-21	77	16x6 SDL	16	0.5	6.625	0.280	N=3,200,000 S=5000		
2-22	77	16x6 SDL	16	0.5	6.625	0.280	N=2,600,000 S=4500		
2-23	77	16x6 SDL	16	0.5	6.625	0.280	N=4,700,000, S=4500		
2-24	77	16x6 SDL	16	0.5	6.625	0.280	N=3,100,000 S=8000		
2-25	77	16x6 SDL	16	0.5	6.625	0.280	N=2,600,000 S=5000		
2-26	77	16x6 SDL	16	0.5	6.625	0.280	N=9,500,000 S=3800		
2-27	78, 10	12x4 SDL	12.75	0.1875	4.5	0.165		kob=18	Line 8 Table 4 WRC 329 (2) Tests R/T=12.5 r/R=1 t/T=1 te/T=1.25 Dimensions from Table 13 of Nureg/CR-4785
2-28	78, 10	12x4 SDL	12.75	0.1875	4.5	0.165		kib=4.5	Line 9 Table 4 WRC 329 (2) Tests R/T=12.5 r/R=1 t/T=1 te/T=1.25
2-29	5	4x4 PAD	4.5	0.237	4.5	0.237	N=800 S=35,000		Line 2 Table 4 WRC 329 te/T=1
2-30	5	4x4 PAD	4.5	0.237	4.5	0.237	N=4000 S=25,000		Line 2 Table 4 WRC 329 te/T=1
2-31	5	4x4 PAD	4.5	0.237	4.5	0.237	N=220,000 S=12,500		Line 2 Table 4 WRC 329 te/T=1
2-32	5	4x4 PAD	4.5	0.237	4.5	0.237	N=700 S=35,000		Line 1 Table 4 WRC 329 te/T=1
2-33	5	4x4 PAD	4.5	0.237	4.5	0.237	N=3800 S=25,000		Line 1 Table 4 WRC 329 te/T=1
2-34	5	4x4 PAD	4.5	0.237	4.5	0.237	N=220,000 S=12,500		Line 1 Table 4 WRC 329 te/T=1
2-35	5	4x4 PAD	4.5	0.120	4.5	0.120	N=430 S=32,000		Line 4 Table 4 WRC 329 te/T=1
2-36	5	4x4 PAD	4.5	0.120	4.5	0.120	N=1600 S=23,000		Line 4 Table 4 WRC 329 te/T=1
2-37	5	4x4 PAD	4.5	0.120	4.5	0.120	N=41,000 S=11,500		Line 4 Table 4 WRC 329 te/T=1
2-38	5	4x4 PAD	4.5	0.120	4.5	0.120	N=700 S=32,000		Line 3 Table 4 WRC 329 te/T=1
2-39	5	4x4 PAD	4.5	0.120	4.5	0.120	N=2400 S=22,500		Line 3 Table 4 WRC 329 te/T=1
2-40	5	4x4 PAD	4.5	0.120	4.5	0.120	N=75,000 N=11,500		Line 3 Table 4 WRC 329 te/T=1
2-41	83	6x6 PAD	6.5	0.25	6.5	0.25	N=1,468,000 S=5640	kib=2.178 (P=970 psi) kib=2.169 (P=0 psi)	Line 7 Table 4 WRC 329 te/T=1.25 Blair CR-1, k-based on mean branch diameter
2-42	83	6x6 PAD	6.5	0.25	6.5	0.25	N=340,000 S=5840	kib=1.962 (P=890 psi), kib=1.954 (P=0 psi)	Line 7 Table 4 WRC 329 te/T=1.25 Blair CR-2; k-based on mean branch diameter
2-43	79	8x3 PAD K1	8.625	0.322	3.5	0.216	N=51,638 S=14,331	kob=3.9255	Line 6 Table 5 WRC 329
2-44	79	8x6 PAD K2	8.625	0.322	6.625	0.280	N=7541 S=14,752	kob=4.536	Line 5 Table 5 WRC 329
2-45	79	12x6 PAD K3	12.75	0.375	6.625	0.280	N=2829 S=14,408	kob=5.799	Line 8 Table 5 WRC 329
2-46	79	12x8 PAD K4	12.75	0.375	8.625	0.322	N=1056 S=15,589	kob=6.267	Line 7 Table 5 WRC 329

2-47	91	8x2 PAD O	8.625	0.322	2.5	0.065	N=697 Neq=697	kob=2.627	MTR AppA suggests 8" t=0.322" Report states 8" wall=0.188" Annex I suggests that 0.322 is correct.
2-48	91	8x2 PAD P	8.625	0.322	2.5	0.065	N=223 Neq=223	kib=1.436	See note for 2-47
2-49	90	8x4 PAD E	8.625	0.25	4.5	0.237	N=1260 S=26,773	kib=6.1802	
2-50	90	8x4 PAD F	8.625	0.25	4.5	0.237	N=1901 S=23,997	kib=5.8761	
2-51	90	8x4 PAD G	8.625	0.25	4.5	0.237	N=1366 S=28,752	kib=5.363	
2-52	90	8x4 PAD H	8.625	0.25	4.5	0.237	N=1075 S=28,133	kib=5.454	
2-53	77	16x6 PAD	16	0.5	6.625	0.280	N=650,000 S=5100	kob=8.4	Tp=0.5
2-54	77	16x6 PAD	16	0.5	6.625	0.280	N=1,400,000 S=4200	kib=1.5	Tp=0.5
2-55	77	16x6 PAD	16	0.5	6.625	0.280	N=1,700,000 S=3600		Tp=0.5
2-56	77	16x6 PAD	16	0.5	6.625	0.280	N=10,000,000 S=2700		Tp=0.5
2-57	77	16x6 PAD	16	0.5	6.625	0.280	N=350,000 S=4500		Tp=0.5
2-58	77	16x6 PAD	16	0.5	6.625	0.280	N=1,000,000 S=4500		Tp=0.5
2-59	77	16x6 PAD	16	0.5	6.625	0.280	N=4,300,000 S=3000		Tp=0.5
2-60	77	16x6 PAD	16	0.5	6.625	0.280	N=13,000,000 S=2700		Tp=0.5
2-61	77	16x6 PAD	16	0.5	6.625	0.280	N=19,000,000 S=2100		Tp=0.5
2-62	77	16x6 PAD	16	0.5	6.625	0.280	N=950,000 S=4500		Tp=0.5
2-63	77	16x6 PAD	16	0.5	6.625	0.280	N=2,800,000 S=4000		Tp=0.5
2-64	77	16x6 PAD	16	0.5	6.625	0.280	N=13,000,000 S=3000		Tp=0.5
2-65	77	16x6 PAD	16	0.5	6.625	0.280	N=460,000: S=9000		Tp=0.5
2-66	77	16x6 PAD	16	0.5	6.625	0.280	N=10,000,000 S=8000		Tp=0.5
2-67	77	16x6 PAD	16	0.5	6.625	0.280	N=20,000,000 S=7000		Tp=0.5
2-68	77	16x6 PAD	16	0.5	6.625	0.280	N=9,500,000 S=6000		Tp=0.5
2-69	77	16x6 PAD	16	0.5	6.625	0.280	N=3,800,000 S=4500		Weld ground Tp=0.5
2-70	77	16x6 PAD	16	0.5	6.625	0.280	N=3,600,000 S=4200		Weld ground Tp=0.5
2-71	77	16x6 PAD	16	0.5	6.625	0.280	N=8,000,000 S=4000		Weld ground Tp=0.5
2-72	77	16x6 PAD	16	0.5	6.625	0.280	N=18,000,000 S=3300		Weld ground Tp=0.5
2-73	77	16x6 PAD	16	0.5	6.625	0.280	N=2,700,000 S=3000		Weld ground Tp=0.5
2-74	5	4x4 SDL	4.5	0.237	4.5	0.237	N=18,000 S=29,000		Tp=0.5
2-75	5	4x4 SDL	4.5	0.237	4.5	0.237	N=85,000 S=28,000		Tp=0.5

2-76	5	4x4 Pad	4.5	0.237	4.5	0.237	N=30,000 S=25,000		Tp=0.237
2-77	5	4x4 Pad	4.5	0.237	4.5	0.237	N=880,000 S=27,000		Tp=0.237
2-78	5	4x4 Pad	4.5	0.120	4.5	0.120	N=11,500 S=22,500		Tp=0.120
2-79	5	4x4 Pad	4.5	0.120	4.5	0.120	N=270,000 S=13,000		Tp=0.120
2-80	71, 94,	24x4 SDL	24	0.312	4.5	0.237		kob=15 kib=1.5	L1=75 L2=150 Dp=9.625 Tp=0.344
2-81	71, 94,	24x8 SDL	24	0.312	8.625	0.25		kob=22 kib=2.1	L1=180 L2=45 Dp=17.25 Tp=0.438
2-82	71, 94,	24x12 SDL	24	0.312	12.75	0.25		kob=12 kib=2.8	Tp=0.438 Dp=23.75 L1=L2=109" (Distance from nozzle centerline to point of restraint on each end of run pipe.)
2-83	71, 94,	24x4 PAD	24	0.312	4.5	0.237		kob=20 kib=4.7	
2-84	71, 94,	24x8 PAD	24	0.312	8.625	0.25		kob=28 kib=3.6	
2-85	71, 94,	24x12 PAD	24	0.312	12.75	0.25		kob=18 kib=5.6	
2-86	94	10x10 PAD							
2-87	78	24x4 SDL	24	0.1875	4.5	0.165		kob=18 kib=4.5	L1=L2=24 Dp=7.313 Tp=0.368
2-88	71	48x6 PAD	49.25	0.625	6.625	0.280		kob=10 kib=1.6	L1=41 L2=73 Dp=10.5 Tp=0.625
3-1	5	4x4 UFT	4.5	0.337	4.5	0.237	N=8500 S=23,000		Line 22 Table 2 WRC 329
3-2	5	4x4 UFT	4.5	0.237	4.5	0.337	N=120,000 S=13,000		Line 23 Table 2 WRC 329
3-3	5	4x4 UFT	4.5	0.237	4.5	0.237	N=6500 S=40,000		Line 24 Table 2 WRC 329
3-4	5	4x4 UFT	4.5	0.237	4.5	0.237	N=320,000 S=14,500		Line 25 Table 2 WRC 329
3-5	5	4x4 UFT	4.5	0.337	4.5	0.237	N=150,000 S=10,600		Sch 80 Run Sch40 Branch in Ref 5 Fig. 16
3-6	5	4x4 UFT	4.5	0.237	4.5	0.337	N=155,000 S=10,400		Sch 40 Run Sch 80 Branch in Ref 5 Fig. 16.
3-7	5	4x4 UFT	4.5	0.237	4.5	0.237	N=3500 S=19,900		Line 1 Table 2 WRC 329
3-8	5	4x4 UFT	4.5	0.237	4.5	0.237	N=4500 S=19,900		Line 2 Table 2 WRC 329
3-9	5	4x4 UFT	4.5	0.237	4.5	0.237	N=7000 S=19,900		Line 3 Table 2 WRC 329
3-10	5	4x4 UFT	4.5	0.237	4.5	0.237	N=8200 S=19,900		Line 4 Table 2 WRC 329
3-11	5	4x4 UFT	4.5	0.237	4.5	0.237	N=25,000 S=13,000		Line 6 Table 2 WRC 329
3-12	5	4x4 UFT	4.5	0.237	4.5	0.237	N=27,500 S=13,200		Line 7 Table 2 WRC 329
3-13	5	4x4 UFT	4.5	0.237	4.5	0.237	N=28,000 S=15,700		Line 5 Table 2 WRC 329
3-14	5	4x4 UFT	4.5	0.237	4.5	0.237	N=31,000 S=13,200		Line 8 Table 2 WRC 329
3-15	5	4x4 UFT	4.5	0.237	4.5	0.237	N=32,000 S13,200		Line 9 Table 2 WRC 329
3-16	5	4x4 UFT	4.5	0.237	4.5	0.237	N=86,000 S=10,000		Line 10 Table 2 WRC 329
3-17	5	4x4 UFT	4.5	0.237	4.5	0.237	N=155,000 S=8800		Line 11 Table 2 WRC 329

3-18	5	4x4 UFT	4.5	0.237	4.5	0.237	N=241,000 S=8500		Line 12 Table 2 WRC 329
3-19	5	4x4 UFT	4.5	0.237	4.5	0.237	N=241,500 S=8600		Line 13 Table 2 WRC 329
3-20	5	4x4 UFT	4.5	0.237	4.5	0.237	N=250,000 S=8700		Not shown in Table 2 WRC 329
3-21	5	4x4 UFT	4.5	0.203	4.5	0.203	N=1600 S=19,400		Line 14 Table 2 WRC 329
3-22	5	4x4 UFT	4.5	0.203	4.5	0.203	N=140,000 S=760		Line 15 Table 2 WRC 329
3-23	5	4x4 UFT	4.5	0.100	4.5	0.100	N=975 S=7850		Line 17 Table 2 WRC 329
3-24	5	4x4 UFT	4.5	0.100	4.5	0.100	N=150 S=20,600		Line 16 Table 2 WRC 329
3-25	5	4x4 UFT	4.5	0.053	4.5	0.053	N=260 S=9500		Line 18 Table 2 WRC 329
3-26	5	4x4 UFT	4.5	0.053	4.5	0.053	N=1350 S=4260		Line 19 Table 2 WRC 329
3-27	5	4x4 UFT	4.5	0.237	4.5	0.237	N=6000 S=15,500		Line 20 Table 2 WRC 329
3-28	5	4x4 UFT	4.5	0.237	4.5	0.237	N=77,000 S=9900		Line 21 Table 2 WRC 329
3-29	80	56x12 UFT	56	1.312	12.75	0.875			
3-30	80	56x12 UFT	56	2.0	12.75	0.843			
3-31	80, 94	24x4 UFT	24	0.312	4.5	0.237		ko=31 ki=17	
3-32	80, 10	24x12 UFT	24	0.313	12.75	0.250		ko=44 ki=8.4	
3-33	80	24x24 UFT	24	0.312	24	0.312		ko=16 ki=17	
3-34	80, 10	36x4 UFT	36	0.375	4.5	0.375		ko=10 ki=4	
3-35	80, 10	36x6 UFT	36	0.375	6.625	0.280		ko=27 ki=8	
3-36	80, 10	48x6 UFT	48	0.625	6.625	0.28		ko=11 ki=5.6	
3-37	80, 10	20x12 UFT	20	1	12.75	0.687		ki=1.8	See Line 2 in Table 3, WRC 329. Different value ??
3-38	80	20x20 UFT	20	1.	20	1.			
3-39	80	24x12 UFT	24	0.1	12.75	0.1			
3-40	65	8x2 UFT A	8.625	0.188	2.5	0.065	N=459 S=22,800	kob=13.8	
3-41	65	8x2 UFT B	8.625	0.188	2.5	0.065	N=754 S=18,900	kob=14.11	
3-42	65	8x2 UFT C	8.625	0.188	2.5	0.065	N=923 S=16,100	kob=16.3	
3-43	65	8x2 UFT D	8.625	0.188	2.5	0.065	N=1816 S=14,200	kob=12.76	
3-44	91	8x2 UFT E	8.625	0.322	2.5	0.065	N=1919, Neq=535	kib=2.4813	MTR Annex A shows run wall=0.322. Report states that run wall is 0.188. Annex I in 07-02 report believes run wall is 0.322.
3-45	91	8x2 UFT F	8.625	0.322	2.5	0.065	N=2884 Neq=858	kib=2.171	See Note 3-44
3-46	91	8x2 UFT G	8.625	0.322	2.5	0.065	N=1168 Neq=546	kob=5.303	See Note 3-44
3-47	91	8x2 UFT H	8.625	0.322	2.5	0.065	N=1225 Neq=1225	kob=4.783	See Note 3-44

3-48	79	8x6 UFT	8.625	0.322	6.625	0.280		kib=3.408 kob=11.189	Line 2 Table 5 WRC 329
3-49	79	12x10 UFT	12.75	0.375	10.75	0.365	N=212 S=9399	kob=12.912	Line 3 Table 5 WRC 329
3-50	79	12x10 UFT	12.75	0.375	10.75	0.365	N=6130 S=5529	kob=12.621	Line 4 Table 5 WRC 329
3-51	83	6x6 UFT	6.625	0.265	6.625	0.265			R/T=12, r/R=1, t/T=1, 5 tests (Ea test reported below. Blair) Each test had k factors calculated for ambient and for the test pressure.
3-51a	83	6x6 UFT	6.625	0.265	6.625	0.265	N=31000 S=7725		Set on
3-51b	83	6x6 UFT	6.625	0.265	6.625	0.265	N=496000 S=3863		Set on
3-51c	83	6x6 UFT	6.625	0.265	6.625	0.265	N=1038000 S=4331		Set on
3-51d	83	6x6 UFT	6.625	0.265	6.625	0.265	N=1310000 S=4448		Set in
3-51e	83	6x6 UFT	6.625	0.265	6.625	0.265	N=1366000 S=4448		Set in
3-52	84	20x4 UFT	19.803	0.239	4.0945	0.239			R/T=41.4 r/R=0.197 t/T=1 Line 3 Table 3 WRC 329. Ref 84 is Decock model machined on outside and inside.
3-53	84	20x8 UFT	19.803	0.3937	7.4507	0.1969			R/T=24.6 r/R=0.375 t/T=0.5 Line 4 Table 3 WRC 329. Ref 84 is Decock model machined on outside and inside.
3-54	84	20x14 UFT	19.803	0.3937	13.858	0.239			R/T=24.6 r/R=0.702 t/T=0.6 Line 5 Table 3 WRC 329. Ref 84 is Decock model machined on outside and inside.
3-55	84	20x20 UFT	19.803	0.239	19.803	0.239			R/T=41.4 r/R=1.0 t/T=1.0 Line 6 Table 3 WRC 329. Ref 84 is Decock model machined on outside and inside.
3-56	92	4x0.5 UFT	4.53	0.24	0.5	0.	N=610 S=40,300	ki=0	
3-57	92	4x0.5 UFT	4.531	0.238	0.5	0.	N=2088 S=34,500	ki=0	
3-58	92	4x1 UFT	4.533	0.234	1.0	0.1	N=2428 S=41,200	ki=0	
3-59	92	4x1 UFT	4.533	0.237	1.0	0.1	N=546 S=56,600	ki=0	
3-60	92	4x1 UFT	4.533	0.238	1.0	0.25	N=2964 S=43,600	ki=0	
3-61	92	4x1 UFT	4.532	0.245	1.0	0.25	N>1000 S=63,600	ki=0	
3-62	92	4x1 UFT	4.5	0.246	1.0	0.5	N=1246 S=52,100	ki=0	
3-63	92	4x0.5 UFT	4.148	0.0612	0.5	0	N=370 S=40400	ki=0	
3-64	92	4x1 UFT	4.138	0.0562	1.0	0.05	N=915 S=41,600	ki=0	
3-65	92	4x1 UFT	4.146	0.0599	1.0	0.11	N=1909 S=51600	ki=0	
3-66	92	4x1 UFT	4.142	0.0578	1.0	0.50	N=1793 S=58,800	ki=0	
3-67	95	4x4 UFT	4.5	0.237	4.5	0.237	N=2835 S=35,2100		D=1.44
3-68	95	4x4 UFT	4.5	0.237	4.5	0.237	N=3955 S=35,210		D=1.44
3-69	95	4x4 UFT	4.5	0.237	4.5	0.237	N=23,370 S=19,830		D=0.86”
3-70	110	10x5 UFT	10	0.1	5	0.05			Strain gage tests
3-71	110	10x5 UFT	10	0.1	5	0.05			Strain gage tests
3-72	110	10x5 UFT	10	0.1	5	0.05			Strain gage tests

3-73	110	10x5 UFT	10	0.1	5	0.05			Strain gage tests
3-74	110	10x5 UFT	10	0.1	5	0.05			Strain gage tests
3-75	110	10x5 UFT	10	0.1	5	0.05			Strain gage tests
5-1	81	14x10 INS	14	0.375	10.75	0.365	r2=3.75 N=140 S=37,300		
5-2	81	14x10 INS	14	0.375	10.75	0.365	r2=3.75 N=215 S=33,500		
5-3	81	14x10 INS	14	0.375	10.75	0.365	r2=3.75 N=1862 S=20,000		
5-4	81	14x10 INS	14	0.375	10.75	0.365	r2=3.75 N=4546 S=15,700		
5-5	81	14x10 INS	14	0.375	10.75	0.365	r2=3.75 N=49,915 S=10,100		
5-6	81	14x10 INS	14	0.375	10.75	0.365	r2=3.75 N=238 S=33,500		
5-7	81	14x10 INS	14	0.375	10.75	0.365	r2=3.75 N=30,374 S=10,100		
5-8	81	14x10 INS	14	0.375	10.75	0.365	r2=3.75 N=605 S=73,100		
5-9	81	14x10 INS	14	0.375	10.75	0.365	r2=3.75 N=5914 S=42,100		
5-10	81	14x10 INS	14	0.375	10.75	0.365	r2=3.75 N=21,553 S=31,500		
5-11	82	12x8 INS	12.75	0.375	8.625	0.322	r2=0.75 N=34,029 S=19,851		Line 21 Table 3 WRC 329
5-12	82	12x8 INS	12.75	0.375	8.625	0.322	r2=0.75 N=15,495 S=23,632		Line 21 Table 3 WRC 329
5-13	82	12x8 INS	12.75	0.375	8.625	0.322	r2=0.75 N=1269 S=26,891		Line 20 Table 3 WRC 329
5-14	82	8x4 INS	8.625	0.322	4.5	0.237	r2=0.375 N=758 S=34,273		Line 22 Table 3 WRC 329
5-15	82	8x4 INS	8.625	0.322	4.5	0.237	r2=0.375 N=3858 S=46,894		Line 23 Table 3 WRC 329
5-16	81	12x6 INS	12.750	0.375	6.625	0.280	r2=1.688 N=444 S=76,200	kib=1.871	Ref 105 – k est. from test results in ref 105
5-17	81	12x6 INS	12.750	0.375	6.625	0.280	r2=1.688 N=659 S=75,700		Ref 105
5-18	81	12x6 INS	12.750	0.375	6.625	0.280	r2=1.688 N=5091 S=47,100		Ref 105
5-19	81	12x6 INS	12.750	0.375	6.625	0.280	r2=1.688 N=6191 S=46,700		Ref 105
5-20	81	12x6 INS	12.750	0.375	6.625	0.280	r2=1.688 N=42,363 S=35,700		Ref 105
5-21	81	12x6 INS	12.750	0.375	6.625	0.280	r2=1.688 N=67,780 S=35,600		Ref 105
5-22	81	12x6 INS	12.750	0.375	6.625	0.280	r2=1.688 N=310,111 S=25,600		Ref 105
5-23	81	12x6 INS	12.750	0.375	6.625	0.280	r2=1.688 N=631 S=58,000	kob=7.61	Ref 105 – k est. from test results in ref 105
5-24	81	12x6 INS	12.750	0.375	6.625	0.280	r2=1.688 N=779 S=56,500		Ref 105
5-25	81	12x6 INS	12.750	0.375	6.625	0.280	r2=1.688 N=5309 S=38,100		Ref 105
5-26	81	12x6 INS	12.750	0.375	6.625	0.280	r2=1.688 N=32,490 S=24,200		Ref 105
5-27	81	12x6 INS	12.750	0.375	6.625	0.280	r2=1.688 N=55,316 S=20,900		Ref 105
5-28	81	12x6 INS	12.750	0.375	6.625	0.280	r2=1.688 N=117,588 S=18,700		Ref 105

5-29	79	12x6 INS	12.750	0.375	6.625	0.280	r2=0.5 N=6760 S=17,237	kob=6.224	Line 26 Table 5 WRC 329 (50% reinf)
5-30	79	12x6 INS	12.750	0.375	6.625	0.280	r2=0.5 N=5347 S=33,224	kib=1.933 (d)	Line 25 Table 5 WRC 329 (50% reinf)
5-31	79	12x6 INS	12.750	0.375	6.625	0.280	r2=0.5 N=4445 S=20,769	kob=5.444	Line 23 Table 5 WRC 329
5-32	79	12x6 INS	12.750	0.375	6.625	0.280	r2=0.5 N=7655 S=17,728	kob=4.835	Line 24 Table 5 WRC 329
5-33	79	12x8 INS	12.750	0.375	8.625	0.322	r2=0.625 N=1840 S=19,701	kob=5.147	Line 28 Table 5 WRC 329
5-34	79	12x8 INS	12.750	0.375	8.625	0.322	r2=0.625 N=8510 S=14,631	kob=5.865	Line 29 Table 5 WRC 329
5-35	79	12x8 INS	12.750	0.375	8.625	0.322	r2=0.625 N=4525 S=18,862	kob=5.889	Line 32 Table 5 WRC 329 (50% reinf)
5-36	79	12x8 INS	12.750	0.375	8.625	0.322	r2=0.625 N=5460 S=19,445	kob=4.702	Line 30 Table 5 WRC 329
5-37	79	12x8 INS	12.750	0.375	8.625	0.322	r2=0.625 N=5371 S=33,583	kib=2.147 (d)	Line 27 Table 5 WRC 329
5-38	79	12x8 INS	12.750	0.375	8.625	0.322	r2=0.625 N=3435 S=31,389	kib=2.517 (d)	Line 31 Table 5 WRC 329 (50% reinf)
5-39	89	14x6 INS	14	0.375	6.625	0.280	r2=0.421 N=337 S=33,200		Line 17 Table 3 WRC 329
5-40	89	14x6 INS	14	0.375	6.625	0.280	r2=0.421 N=1605 S=22,100		Line 17 Table 3 WRC 329
5-41	89	14x6 INS	14	0.375	6.625	0.280	r2=0.421 N=6341 S=16,500		Line 17 Table 3 WRC 329
5-42	89	14x6 INS	14	0.375	6.625	0.280	r2=0.421 N=52,103 S=11,200		Line 17 Table 3 WRC 329
5-43	89	14x6 INS	14	0.375	6.625	0.280	r2=0.421 N=330 S=33,200		Line 18 Table 3 WRC 329
5-44	89	14x6 INS	14	0.375	6.625	0.280	r2=0.421 N=4047 S=16,600		Line 18 Table 3 WRC 329
5-45	89	14x6 INS	14	0.375	6.625	0.280	r2= 0.421 N=19,546 S=11,100		Line 18 Table 3 WRC 329
5-46	89	14x6 INS	14	0.375	6.625	0.280	r2=0.421 N=1034 S=61,200		Line 19 Table 3 WRC 329
5-47	89	14x6 INS	14	0.375	6.625	0.280	r2=0.421 N=14,264 S=37300		Line 19 Table 3 WRC 329
6-1	81	4x4 OLET	4.5	0.237	4.5	0.237	N=390 S=43,900		r/rp=0.63 Line 7 Table 3 WRC 329
6-2	81	4x4 OLET	4.5	0.237	4.5	0.237	N=1290 S=38,400		r/rp=0.63 Line 7 Table 3 WRC 329
6-3	81	4x4 OLET	4.5	0.237	4.5	0.237	N=630 S=33,200		r/rp=0.63 Line 7 Table 3 WRC 329
6-4	81	4x4 OLET	4.5	0.237	4.5	0.237	N=2930 S=27,600		r/rp=0.63 Line 7 Table 3 WRC 329
6-5	81	4x4 OLET	4.5	0.237	4.5	0.237	N=14,240 S=22,300		r/rp=0.63 Line 7 Table 3 WRC 329
6-6	81	4x4 OLET	4.5	0.237	4.5	0.237	N=36,310 S=16,500		r/rp=0.63 Line 7 Table 3 WRC 329
6-7	81	4x4 OLET	4.5	0.237	4.5	0.237	N=216 S=50,700		r/rp=0.63 Line 8 Table 3 WRC 329
6-8	81	4x4 OLET	4.5	0.237	4.5	0.237	N=1000 S=42,000		r/rp=0.63 Line 8 Table 3 WRC 329
6-9	81	4x4 OLET	4.5	0.237	4.5	0.237	N=1403 S=35,900		r/rp=0.63 Line 8 Table 3 WRC 329
6-10	81	4x4 OLET	4.5	0.237	4.5	0.237	N=2600 S=29,600		r/rp=0.63 Line 8 Table 3 WRC 329
6-11	81	4x4 OLET	4.5	0.237	4.5	0.237	N=6100 S23,800		r/rp=0.63 Line 8 Table 3 WRC 329
6-12	81	4x4 OLET	4.5	0.237	4.5	0.237	N=35,600 S=17,800		r/rp=0.63 Line 8 Table 3 WRC 329

6-13	85	6x4 OLET	6.625	0.280	4.5	0.237	N=412 S=36,400		As Welded Line 11 Table 3 WRC 329
6-14	85	6x4 OLET	6.625	0.280	4.5	0.237	N=1021 S=25,400		As Welded Line 11 Table 3 WRC 329
6-15	85	6x4 OLET	6.625	0.280	4.5	0.237	N=37,027 S=13,900		As Welded Line 11 Table 3 WRC 329
6-16	85	6x4 OLET	6.625	0.280	4.5	0.237	N=530 S=36,018		Ground Line 12 Table 3 WRC 329
6-17	85	6x4 OLET	6.625	0.280	4.5	0.237	N=628 S=31,320		Ground Line 12 Table 3 WRC 329
6-18	85	6x4 OLET	6.625	0.280	4.5	0.237	N=5676 S=21,924		Ground Line 12 Table 3 WRC 329
6-19	85	6x4 OLET	6.625	0.280	4.5	0.237	N=10,559 S=16,617		Ground Line 12 Table 3 WRC 329
6-20	85	6x4 OLET	6.625	0.280	4.5	0.237	N=14,717 S=15,399		Ground Line 12 Table 3 WRC 329
6-21	86	12x6 OLET	12.75	0.375	6.625	0.280	N=362 S=57,200		r/rp=0.675 Line 14 Table 3 WRC 329
6-22	86	12x6 OLET	12.75	0.375	6.625	0.280	N=2048 S=42,400		r/rp=0.675 Line 14 Table 3 WRC 329
6-23	86	12x6 OLET	12.75	0.375	6.625	0.280	N=7851 S=33,900		r/rp=0.675 Line 14 Table 3 WRC 329
6-34	86	12x6 OLET	12.75	0.375	6.625	0.280	N=26,597 S=25,400		r/rp=0.675 Line 14 Table 3 WRC 329
6-25	86	12x6 OLET	12.75	0.375	6.625	0.280	N=41,597 S=21,200		r/rp=0.675 Line 14 Table 3 WRC 329
6-26	86	12x6 OLET	12.75	0.375	6.625	0.280	N=18 S=39,800		r/rp=0.675 Line 13 Table 3 WRC 329
6-27	86	12x6 OLET	12.75	0.375	6.625	0.280	N=538 S=19,900		r/rp=0.675 Line 13 Table 3 WRC 329
6-28	86	12x6 OLET	12.75	0.375	6.625	0.280	N=2607 S=13,300		r/rp=0.675 Line 13 Table 3 WRC 329
6-29	86	12x6 OLET	12.75	0.375	6.625	0.280	N=5797 S=11,100		r/rp=0.675 Line 13 Table 3 WRC 329
6-30	86	12x6 OLET	12.75	0.375	6.625	0.280	N=56,898 S=6630		r/rp=0.675 Line 13 Table 3 WRC 329
6-31	87	4x4 OLET	4.5	0.237	4.5	0.237	N=1230 S=26,700		Table 4.2-1 p 4-2 Target Test Report; Not in WRC 329
6-32	82	4x4 OLET	4.5	0.237	4.5	0.237	N=301 S=43,219		p.34 Target Tech Report 9/6/77; Line 10 Table 3 WRC 329 ref 10; r/rp=0.79;
6-33	82	4x4 OLET	4.5	0.237	4.5	0.237	N=335 S=40,322		p.34 Target Tech Report 9/6/77; Line 10 Table 3 WRC 329 ref 10; r/rp=0.79
6-34	82	4x4 OLET	4.5	0.237	4.5	0.237	N=3330 S=28,061		p.34 Target Tech Report 9/6/77; Line 9 Table 3 WRC 329 ref 10 ; r/rp=0.79
6-35	88	8x4 OLET	8.625	0.322	4.5	0.237			R/T=12.9 r/R=0.513 t/T=0.736 r/rp=0.78 Line 15 Table 3 WRC 329 ref 10. (Did not find this test in Ref 87 Report)
6-36	79	8x6 OLET	8.625	0.322	6.625	0.280	N=331 S=14,762	kob=8.153	Line 16 Table 5 WRC 329 r/rp=0.832
6-37	79	8x6 OLET	8.625	0.322	6.625	0.280	N=3492 S=9800	kob=7.329	Line 17 Table 5 WRC 329 r/rp=0.832
6-38	79	8x6 OLET	8.625	0.322	6.625	0.280	N=6345 S=10350	kob=6.175	Line 18 Table 5 WRC 329 r/rp=0.832
6-39	79	8x6 OLET	8.625	0.322	6.625	0.280	N=3380 S=12,206	kob=6.540	Line 18 Table 5 WRC 329 r/rp=0.868
6-40	79	8x5 OLET	8.625	0.322	5.563	0.258	N=12,839 S=9430	kob=6.311	Line 15 Table 5 WRC 329 r/rp=0.801
6-41	79	8x5 OLET	8.625	0.322	5.563	0.258	N=4640 S=10,074	kob=7.210	Line 14 Table 5 WRC 329 r/rp=0.801
6-42	79	8x4 OLET	8.625	0.322	4.5	0.237	N=8870 S=11,448	kob=5.895	Line 11 Table 5 WRC 329 r/rp=0.812

6-43	79	8x4 OLET	8.625	0.322	4.5	0.237	N=3954 S=13,598	kob=6.093	Line 13 Table 5 WRC 329 r/rp=0.853 (50% reinf)
6-44	79	8x4 OLET	8.625	0.322	4.5	0.237	N=4310 S=13,167	kob=6.548	Line 12 Table 5 WRC 329 r/rp=0.812
6-45	79	8x3 OLET	8.625	0.322	3.5	0.216	N=12,310 S=11,306	kob=5.679	Line 9 Table 5 WRC 329 r/rp=0.773
6-46	79	8x3 OLET	8.625	0.322	3.5	0.216	N=4540 S=14,700	kob=4.839	Line 10 Table 5 WRC 329 r/rp=0.773
6-47	79	8x8 OLET	8.625	0.322	8.625	0.322	N=10,678 S=7474	kob=13.980	Line 20 Table 5 WRC 329 r/rp=0.852
6-48	79	8x8 OLET	8.625	0.322	8.625	0.322	N=1554 S=10,753	kob=4.911	Line 21 Table 5 WRC 329 r/rp=0.852
6-49	79	8x8 OLET	8.625	0.322	8.625	0.322	N=4516 S=8743	kob=4.757	Line 22 Table 5 WRC 329 r/rp=0.852
6-50									Not Used
6-51	98	4x3 OLET	4.5	0.237	3.5	0.216	N=1888 S=26,274	kob=2.9	r/rp=0.64141
6-52	98	4x3 OLET	4.5	0.237	3.5	0.216	N=1485 S=17,903	kob=4.47	r/rp=0.68992
6-53	98	4x3 OLET	4.5	0.237	3.5	0.216	N=3067 S=23,825	kob=1.37	r/rp=0.61498
6-54	98	4x3 OLET	4.5	0.237	3.5	0.216	N=1920 S=23,343	kob=1.73	r/rp=0.67020
6-55	98	4x3 OLET	4.5	0.237	3.5	0.216	N=1368 S=33,213	kob=0.58	r/rp=0.63398
6-56	98	4x3 OLET	4.5	0.237	3.5	0.216	N=1826 S=34,339	kob=0.24	r/rp=0.61498
6-57	98	4x3 OLET	4.5	0.237	3.5	0.216	N=5620 S=22,644	kob=1.91	r/rp=0.56817

General Notes

1) Vessolet in WFI test terminology are considered contoured inserts

2) Pipets are considered in WFI test terminology are considered to be welded on fittings.

3) Item numbers in the leftmost column of the "SIF References" table correspond to the applicable branch connection sketch number in the ASME ST-LLC 07-02 Table 1 recommendations in Annex A. For example, the item number 6-51 represents the 51st recorded test of a Sketch 2.6 Integrally reinforced branch welded-on fitting. The mnemonic INS is used as an abbreviation for Sketch 2.5 welded-in contour insert, UFT is used as an abbreviation for the Sketch 2.3 unreinforced fabricated tee, and SDL is used for the Sketch 2.2 reinforced fabricated tees when a saddle-type geometry is used for the reinforcement.

4) When the percentage of reinforcement is specified for a particular fitting this gives the amount of pressure design area that's provided by the fitting for the opening removed from the pipe.

ANNEX G - SOURCE EQUATIONS FOR COMPARISON AND VERIFICATION

Contents:

Nomenclature:

D = mean diameter of matching pipe found from (D_o-T), in.(mm).
d = mean diameter of matching branch pipe found from (d_o-t), in.(mm)
d' = effective branch diameter, in.(mm)
i = stress intensification factor (SIF)
k = flexibility factor
r = mean radius of matching branch pipe found from (d_o-t)/2, in.(mm)
r_2 = radii used with Sketch 3.1, in.(mm)
R = mean radius of matching pipe found from (D_o-T)/2, in.(mm)
R_1 = bend radius of welding elbow or pipe bend, in.(mm)
r_p = radius to outside edge of fitting for Sketches 2.3 and 2.6 measured in longitudinal plane, in.(mm)
r_x = external crotch radius of welding tee per ASME B16.9, extruded outlet and welded-in contour insert [Sketches 2.1, 2.4 and 2.5], measured in the plane containing the centerline axes of the run and branch, in.(mm)
SIF = stress intensification factor
t = nominal wall thickness of matching branch pipe, in.(mm)
t' = effective branch thickness, in.(mm)
t_n = local branch pipe thickness used, in. (mm)
T = nominal wall thickness of the matching pipe for tees (Sketches 2.1 through 2.6), in.(mm)
T_c = crotch thickness in Sketches 2.1, 2.4 and 2.5 measured at the center of the crotch in the longitudinal plane, in.(mm)
t_p = reinforcement pad or saddle thickness, in.(mm)
Z = section modulus of pipe, in^3, (mm^3)
Z_b = section modulus of matching branch pipe, in^3, (mm^3)
toT = t/T expression used in source code for dimensionless parameter t/T.
doD = d/D expression used in source code for dimensionless parameter d/D.
DoT = D/T expression used in source code for dimensionless parameter D/T.

Discussion:

Equations used in the VBA source code below are taken from WRC 329, WRC 497, DNV [32], EPRI TR-110996, EPRI TR-110755, B31.3 and BPVC Section III NC and NB and are provided to establish a basis for comparisons. The charts, graphs and comparison tables in this Report's Annexes are produced using the functions found here.

The following paragraph from Appendix B Table 1 Note 10 is applied for the 07-02 equations where needed.

Sketch 2.1, 2.2, 2.4, 2.5 and 2.6 stress intensification factors i_{ib}, i_{ob}, i_{tb}, i_{ir}, i_{or}, and i_{tr}, and the flexibility factors k_{ib}, k_{ob}, k_{tb}, k_{ir}, k_{or}, and k_{tr} shall not be greater than the corresponding stress intensification and flexibility factors for Sketch 2.3 Fig.5(d) calculated using matching branch and run pipe dimensions and r_2=0. Sketch 2.4 and Sketch 2.5 stress intensification and flexibility factors shall not be less than the corresponding stress intensification and flexibility factors for Sketch 2.1 calculated using T_c = 1.1T. If i_{ob} is less than i_{ib} for any of Sketches 2.1 through 2.6 then use i_{ob}=i_{ib}. If i_{ir} is less than i_{or} for any of Sketches 2.1 through 2.6 then use i_{ir} = i_{or}.

For example, in the first function shown on page 3 below for the welding tee, the variable SIFchk is set equal to the SIF for the Sketch 2.3 unreinforced fabricated tee and the SIF for the welding tee compared to SIFchk. If the welding tee (Sketch 2.1) SIF is found greater than the unreinforced fabricated tee SIF, it is set equal to the fabricated tee SIF. These checks are provided to assure that consistency is maintained in the design process for the full range of parameters over which the equations are likely to be used.

```
Function PRG_tee_iib(doD As Double, DoT As Double, toT As Double) As Double
SIFchk = PRG_BR_ii(doD, DoT, toT)
RoT = DoT / 2
SIF = 0.33 * RoT ^ (2 / 3) * doD ^ 0.18 * toT ^ 0.7
PRG_tee_iib = SIF
If SIFchk < SIF Then
    SIF = SIFchk
    PRG_tee_iib = SIF
End If
End Function
```

1.1 Welding tee per ASME B16.9 Sketch 2.1 SIFs

```
Function PRG_tee_iib(doD As Double, DoT As Double, toT As Double) As Double
SIFchk = PRG_BR_ii(doD, DoT, toT)
RoT = DoT / 2
SIF = 0.33 * RoT ^ (2 / 3) * doD ^ 0.18 * toT ^ 0.7
PRG_tee_iib = SIF
If SIFchk < SIF Then
    SIF = SIFchk
    PRG_tee_iib = SIF
End If
End Function


Function PRG_tee_iob(doD As Double, DoT As Double, toT As Double) As Double
SIFiib = PRG_tee_iib(doD, DoT, toT)
SIFchk = PRG_BR_io(doD, DoT, toT)
RoT = DoT / 2
SIF = 0.42 * RoT ^ (2 / 3) * doD ^ 0.37 * toT ^ 0.37
PRG_tee_iob = SIF
If PRG_tee_iob < SIFiib Then
    PRG_tee_iob = SIFiib
    SIF = PRG_tee_iob
End If
If SIFchk < SIF Then
    SIF = SIFchk
    PRG_tee_iob = SIF
End If
End Function


Function PRG_tee_itb(doD As Double, DoT As Double, toT As Double) As Double
SIFchk = PRG_BR_it(doD, DoT, toT)
RoT = DoT / 2
SIF = 0.42 * RoT ^ (2 / 3) * doD ^ 1.1 * toT ^ 1.1
PRG_tee_itb = SIF
If SIFchk < SIF Then
    SIF = SIFchk
    PRG_tee_itb = SIF
End If
End Function


Function PRG_tee_iih(doD As Double, DoT As Double, toT As Double) As Double
SIFioh = PRG_tee_ioh(doD, DoT, toT)
SIFchk = PRG_Hdr_ii(doD, DoT, toT)
RoT = DoT / 2
SIF = 0.98 * RoT ^ (0.35) * doD ^ 0.72 * toT ^ (-0.52)
PRG_tee_iih = SIF
If PRG_tee_iih < SIFioh Then
    PRG_tee_iih = SIFioh
    SIF = PRG_tee_iih
End If
If SIFchk < SIF Then
    SIF = SIFchk
    PRG_tee_iih = SIF
End If
End Function


Function PRG_tee_ioh(doD As Double, DoT As Double, toT As Double) As Double
SIFchk = PRG_Hdr_io(doD, DoT, toT)
RoT = DoT / 2
SIF = 0.61 * RoT ^ 0.29 * doD ^ 1.95 * toT ^ (-0.53)
PRG_tee_ioh = SIF
If SIFchk < SIF Then
    SIF = SIFchk
    PRG_tee_ioh = SIF
End If
End Function


Function PRG_tee_ith(doD As Double, DoT As Double, toT As Double) As Double
```

```
SIFchk = PRG_Hdr_it(doD, DoT, toT)
RoT = DoT / 2
SIF = 0.34 * RoT ^ (2 / 3) * doD * toT ^ -0.5
PRG_tee_ith = SIF
If SIFchk < SIF Then
    SIF = SIFchk
    PRG_tee_ith = SIF
End If

End Function
```

1.2 Welding tee per ASME B16.9 Sketch 2.1 Flexibility Factors

```
Function PRG_tee_kib(doD As Double, DoT As Double, toT As Double) As Double
kchk = PRG_BR_ki(doD, DoT, toT)
RoT = DoT / 2
k = (1.91 * doD - 4.32 * doD ^ 2 + 2.7 * doD ^ 3) * RoT ^ 0.77 * doD ^ 0.47 * toT
PRG_tee_kib = k
If kchk < k Then
    k = kchk
    PRG_tee_kib = k
End If
End Function

Function PRG_tee_kob(doD As Double, DoT As Double, toT As Double) As Double
kchk = PRG_BR_ko(doD, DoT, toT)
RoT = DoT / 2
k = (0.34 * doD - 0.49 * doD ^ 2 + 0.18 * doD ^ 3) * RoT ^ 1.46 * toT
PRG_tee_kob = k
If kchk < k Then
    k = kchk
    PRG_tee_kob = k
End If
End Function


Function PRG_tee_ktb(doD As Double, DoT As Double, toT As Double) As Double
kchk = PRG_BR_kt(doD, DoT, toT)
RoT = DoT / 2
k = (1.08 * doD - 2.44 * doD ^ 2 + 1.52 * doD ^ 3) * RoT ^ 0.77 * doD ^ 1.61 * toT
PRG_tee_ktb = k
If kchk < k Then
    k = kchk
    PRG_tee_ktb = k
End If
End Function

Function PRG_tee_kih(doD As Double, DoT As Double, toT As Double) As Double
kchk = PRG_Hdr_ki(doD, DoT, toT)
RoT = DoT / 2
k = 0.18 * RoT ^ 0.8 * doD ^ 5
PRG_tee_kih = k
If kchk < k Then
    k = kchk
    PRG_tee_kih = k
End If
End Function

Function PRG_tee_koh(doD As Double, DoT As Double, toT As Double) As Double
kchk = PRG_Hdr_ko(doD, DoT, toT)
k = 1
PRG_tee_koh = k
If kchk < k Then
    k = kchk
    PRG_tee_koh = k
End If
End Function

Function PRG_tee_kth(doD As Double, DoT As Double, toT As Double) As Double
kchk = PRG_Hdr_kt(doD, DoT, toT)
RoT = DoT / 2
k = 0.08 * RoT ^ 0.91 * doD ^ 5.7
PRG_tee_kth = k
If kchk < k Then
    k = kchk
    PRG_tee_kth = k
End If
End Function
```

1.3 B31.3 B16.9 Welding Tee SIFs

```
Function B313_tee_iib(doD As Double, DoT As Double, toT As Double) As Double
RoT = DoT / 2
flexchar = 3.1 / RoT
iout = 0.9 / (flexchar ^ (2 / 3))
If iout < 1 Then iout = 1
iin = iout * 0.75 + 0.25
If iin < 1 Then iin = 1
If doD < 1 Then
   If iin < (1 / toT) Then
      iin = 1
    Else
      iin = iin * toT
   End If
End If
If iin < 1 Then iin = 1
B313_tee_iib = iin
End Function

Function B313_tee_iob(doD As Double, DoT As Double, toT As Double) As Double
RoT = DoT / 2
flexchar = 3.1 / RoT
iout = 0.9 / (flexchar ^ (2 / 3))
If iout < 1 Then iout = 1
iin = iout * 0.75 + 0.25
If iin < 1 Then iin = 1
If doD < 1 Then
   If iin < (1 / toT) Then
      iout = iout / iin
    Else
      iout = iout * toT
   End If
End If
If iout < 1 Then iout = 1
B313_tee_iob = iout
End Function

Function B313_tee_iih(doD As Double, DoT As Double, toT As Double) As Double
RoT = DoT / 2
flexchar = 3.1 / RoT
iout = 0.9 / (flexchar ^ (2 / 3))
If iout < 1 Then iout = 1
iin = iout * 0.75 + 0.25
If iin < 1 Then iin = 1
B313_tee_iih = iin
End Function

Function B313_tee_ioh(doD As Double, DoT As Double, toT As Double) As Double
RoT = DoT / 2
flexchar = 3.1 / RoT
iout = 0.9 / (flexchar ^ (2 / 3))
If iout < 1 Then iout = 1
B313_tee_ioh = iout
End Function
```

1.4 NB 3683 and NC 3673 Welding Tee SIFs

```
Function NB3683_tee_br(doD As Double, DoT As Double, toT As Double) As Double
RoT = DoT / 2
C2b = 0.67 * RoT ^ (2 / 3)
If C2b < 2# Then C2b = 2#
K2b = 1#
ibr = C2b * K2b / 2#
C2r = C2b
K2r = K2b
irun = ibr
ibranch = ibr
NB3683_tee_br = ibranch
End Function

Function NB3683_tee_hdr(doD As Double, DoT As Double, toT As Double) As Double
RoT = DoT / 2
C2b = 0.67 * RoT ^ (2 / 3)
If C2b < 2# Then C2b = 2#
K2b = 1#
ibr = C2b * K2b / 2#
C2r = C2b
K2r = K2b
irun = ibr
iheader = irun
NB3683_tee_hdr = iheader
End Function

Function NC3673_tee_br(doD, DoT, toT)
RoT = DoT / 2
hfact = 4.4 / RoT
NC3673_tee_br = 0.9 / hfact ^ (2 / 3) * toT
End Function

Function NC3673_tee_Hdr(doD, DoT, toT)
RoT = DoT / 2
hfact = 4.4 / RoT
NC3673_tee_Hdr = 0.9 / hfact ^ (2 / 3)
End Function
```

2.1 Reinforced fabricated tee Sketch 2.2 SIFs

```
Function PRG_iib_PAD(doD As Double, DoT As Double, toT As Double, tp As Double, R As Double, T As Double)
As Double
SIFchk = PRG_BR_ii(doD, DoT, toT)
RoT = DoT / 2
SIF = (3.33 * doD - 5.49 * doD ^ 2 + 2.94 * doD ^ 3) * ((T * R ^ (2 / 3)) / (T + 0.5 * tp) ^ (5 / 3)) *
toT ^ 0.3
PRG_iib_PAD = SIF
If SIFchk < SIF Then
    SIF = SIFchk
    PRG_iib_PAD = SIF
End If
End Function

Function PRG_iob_PAD(doD As Double, DoT As Double, toT As Double, tp As Double, R As Double, T As Double)
As Double
SIFiib = PRG_iib_PAD(doD, DoT, toT, tp, R, T)
SIFchk = PRG_BR_io(doD, DoT, toT)
RoT = DoT / 2
R = RoT * T
tpuse = tp
If tp > 1.5 * T Then tpuse = 1.5 * T
toTUSE = toT
If toTUSE < 0.85 Then toTUSE = 0.85
SIF = (2.86 * doD + 2.4 * doD ^ 2 - 4.34 * doD ^ 3) * (T * R ^ (2 / 3)) / ((T + 0.5 * tpuse) ^ (5 / 3))
* (toTUSE) ^ 0.3
If DoT >= 25 And doD < 1 And toT <= 0.85 Then
    If ((1.07 * toT - 1.08 * toT ^ 2 + 0.026) * (DoT ^ 0.34)) > 1 Then
        SIF = SIF * ((1.07 * toT - 1.08 * toT ^ 2 + 0.026) * (DoT ^ 0.34))
    End If
End If
PRG_iob_PAD = SIF
If PRG_iob_PAD < SIFiib Then
    PRG_iob_PAD = SIFiib
    SIF = PRG_iob_PAD
End If
If SIFchk < SIF Then
    SIF = SIFchk
    PRG_iob_PAD = SIF
End If
End Function

Function PRG_itb_PAD(doD As Double, DoT As Double, toT As Double, tp As Double, R As Double, T As Double)
As Double
SIFchk = PRG_BR_it(doD, DoT, toT)
RoT = DoT / 2
SIF = 0.6 * (1.07 * doD ^ 2) * ((T * R ^ (2 / 3)) / (T + 0.5 * tp) ^ (5 / 3)) * toT ^ 0.3
PRG_itb_PAD = SIF
If SIFchk < SIF Then
    SIF = SIFchk
    PRG_itb_PAD = SIF
End If
End Function

Function PRG_iih_PAD(doD As Double, DoT As Double, toT As Double, tp As Double, R As Double, T As Double)
As Double
SIFioh = PRG_ioh_PAD(doD, DoT, toT, tp, R, T)
SIFchk = PRG_Hdr_ii(doD, DoT, toT)
RoT = DoT / 2
SIF = doD ^ 0.54 * (R / (T + 0.5 * tp)) ^ 0.45 * toT ^ (-0.34)
If SIF < 1.5 Then SIF = 1.5
PRG_iih_PAD = SIF
If PRG_iih_PAD < SIFioh Then
    PRG_iih_PAD = SIFioh
    SIF = PRG_iih_PAD
End If
If SIFchk < SIF Then
    SIF = SIFchk
    PRG_iih_PAD = SIF
End If
End Function
```

```
Function PRG_ioh_PAD(doD As Double, DoT As Double, toT As Double, tp As Double, R As Double, T As Double)
As Double
SIFchk = PRG_Hdr_io(doD, DoT, toT)
RoT = DoT / 2
SIF = (1.29 * doD - 2.87 * doD ^ 2 + 2.39 * doD ^ 3) * (R / (T + 0.5 * tp)) ^ 0.35 * toT ^ (-0.25)
PRG_ioh_PAD = SIF
If SIFchk < SIF Then
    SIF = SIFchk
    PRG_ioh_PAD = SIF
End If
End Function

Function PRG_ith_PAD(doD As Double, DoT As Double, toT As Double, tp As Double, R As Double, T As Double)
As Double
SIFchk = PRG_Hdr_it(doD, DoT, toT)
RoT = DoT / 2
R = RoT * T
SIF = 0.36 * (R / (T + 0.5 * tp)) ^ (2 / 3) * doD ^ 1.4 * toT ^ (-0.6)
PRG_ith_PAD = SIF
If SIFchk < SIF Then
    SIF = SIFchk
    PRG_ith_PAD = SIF
End If
End Function
```

2.2 Reinforced fabricated tee Sketch 2.2 Flexibility Factors

```
Function PRG_kib_PAD(doD As Double, DoT As Double, toT As Double, tp As Double, R As Double, T As Double)
As Double
kchk = PRG_BR_ki(doD, DoT, toT)
RoT = DoT / 2
k = (1.29 * doD - 2.73 * doD ^ 2 + 1.62 * doD ^ 3) * (R / (T + 0.5 * tp)) ^ (1.2) * (toT) ^ 0.56 * doD ^
0.33
PRG_kib_PAD = k
If kchk < k Then
    k = kchk
    PRG_kib_PAD = k
End If
End Function

Function PRG_kob_PAD(doD As Double, DoT As Double, toT As Double, tp As Double, R As Double, T As Double)
As Double
kchk = PRG_BR_ko(doD, DoT, toT)
RoT = DoT / 2
k = (0.84 * doD - 1.27 * doD ^ 2 + 0.5 * doD ^ 3) * (R / (T + 0.5 * tp)) ^ (1.69) * (toT) ^ 0.68 * doD ^
0.21
PRG_kob_PAD = k
If kchk < k Then
    k = kchk
    PRG_kob_PAD = k
End If
End Function

Function PRG_ktb_PAD(doD As Double, DoT As Double, toT As Double, tp As Double, R As Double, T As Double)
As Double
kchk = PRG_BR_kt(doD, DoT, toT)
RoT = DoT / 2
Rm = RoT * T
RoTstar = Rm / (T + 0.5 * tp)
k = 1.1 * (RoTstar) ^ 0.5 * doD ^ 5.42
PRG_ktb_PAD = k
If kchk < k Then
    k = kchk
    PRG_ktb_PAD = k
End If
End Function

Function PRG_kih_PAD(doD As Double, DoT As Double, toT As Double, tp As Double, R As Double, T As Double)
As Double
kchk = PRG_Hdr_ki(doD, DoT, toT)
RoT = DoT / 2
k = 0.21 * (R / (T + 0.5 * tp)) ^ 0.97 * toT ^ (-0.65) * doD ^ 6.2
PRG_kih_PAD = k
If kchk < k Then
    k = kchk
    PRG_kih_PAD = k
End If
End Function

Function PRG_koh_PAD(doD As Double, DoT As Double, toT As Double, tp As Double, R As Double, T As Double)
As Double
kchk = PRG_Hdr_ko(doD, DoT, toT)
RoT = DoT / 2
k = 1
PRG_koh_PAD = k
If kchk < k Then
    k = kchk
    PRG_koh_PAD = k
End If
End Function

Function PRG_kth_PAD(doD As Double, DoT As Double, toT As Double, tp As Double, R As Double, T As Double)
As Double
kchk = PRG_Hdr_kt(doD, DoT, toT)
RoT = DoT / 2
k = 0.12 * (R / (T + 0.5 * tp)) ^ 1.39 * toT ^ (-0.74) * doD ^ (8.5)
PRG_kth_PAD = k
```

```
If kchk < k Then
    k = kchk
    PRG_kth_PAD = k
End If
End Function
```

2.3 B31 Reinforced fabricated tee SIFs

```
Function B31_iob_PAD(doD As Double, DoT As Double, toT As Double, T As Double, tp As Double) As Double
RoT = DoT / 2
R = RoT * T
iob = 0.9 * T * R ^ (2 / 3) / (T + 0.5 * tp) ^ (5 / 3)
If iob < 1 Then iob = 1
iib = 0.75 * iob + 0.25
If iib < 1 Then iib = 1
If doD < 1 Then
   If iib > (1 / toT) Then
      iob = iob * toT
   Else
      iob = iob / iib
   End If
End If
If iob < 1 Then iob = 1
B31_iob_PAD = iob
End Function

Function B31_iib_PAD(doD As Double, DoT As Double, toT As Double, T As Double, tp As Double) As Double
RoT = DoT / 2
R = RoT * T
iob = 0.9 * T * R ^ (2 / 3) / (T + 0.5 * tp) ^ (5 / 3)
If iob < 1 Then iob = 1
iib = 0.75 * iob + 0.25
If iib < 1 Then iib = 1
If doD < 1 Then
   If iib > (1 / toT) Then
      iib = iib * toT
   Else
      iib = 1
   End If
End If
If iib < 1 Then iib = 1
B31_iib_PAD = iib
End Function

Function B31_ioh_PAD(doD As Double, DoT As Double, toT As Double, T As Double, tp As Double) As Double
RoT = DoT / 2
R = RoT * T
ioh = 0.9 * T * R ^ (2 / 3) / (T + 0.5 * tp) ^ (5 / 3)
If ioh < 1 Then ioh = 1
B31_ioh_PAD = ioh
End Function

Function B31_iih_PAD(doD As Double, DoT As Double, toT As Double, T As Double, tp As Double) As Double
RoT = DoT / 2
R = RoT * T
iih = (0.9 * T * R ^ (2 / 3) / (T + 0.5 * tp) ^ (5 / 3)) * 0.75 + 0.25
If iih < 1 Then iih = 1
B31_iih_PAD = iih
End Function
```

2.4 EPRI TR-110755 Reinforced fabricated tee SIFs

```
' EPRI 110755 Wais/Rodabaugh Pad Equations


Function EPRI_iib(doD As Double, DoT As Double, toT As Double, T As Double, tp As Double) As Double
RoT = DoT / 2
Tstar = T + 0.5 * tp
RoT = RoT * T / Tstar
Lrot = 0.5 * doD / toT * DoT

SIF = 0.515 * RoT ^ 1.05 * Lrot ^ (-0.387) * doD ^ 0.49
If SIF < 1 Then SIF = 1
EPRI_iib = SIF
End Function

Function EPRI_iir(doD As Double, DoT As Double, toT As Double, T As Double, tp As Double) As Double
RoT = DoT / 2
Tstar = T + 0.5 * tp
RoT = RoT * T / Tstar
Lrot = 0.5 * doD / toT * DoT

SIF = 0.985 * RoT ^ (-0.137) * Lrot ^ (0.482) * doD ^ 0.241
If SIF < 1 Then SIF = 1
EPRI_iir = SIF
End Function

Function EPRI_iob(doD As Double, DoT As Double, toT As Double, T As Double, tp As Double) As Double
RoT = DoT / 2
Tstar = T + 0.5 * tp
RoT = RoT * T / Tstar
Lrot = 0.5 * doD / toT * DoT

SIF = 1.28 * (1.28 * doD - doD ^ 4) * RoT ^ (1.4) * Lrot ^ (-0.558) * doD ^ 0.406
If SIF < 1 Then SIF = 1
EPRI_iob = SIF
End Function

Function EPRI_ior(doD As Double, DoT As Double, toT As Double, T As Double, tp As Double) As Double
RoT = DoT / 2
Tstar = T + 0.5 * tp
RoT = RoT * T / Tstar
Lrot = 0.5 * doD / toT * DoT

SIF = 0.605 * RoT ^ (-0.237) * Lrot ^ (0.528) * doD ^ 1.42
If SIF < 1 Then SIF = 1
EPRI_ior = SIF
End Function

Function EPRI_itb(doD As Double, DoT As Double, toT As Double, T As Double, tp As Double) As Double
RoT = DoT / 2
Tstar = T + 0.5 * tp
RoT = RoT * T / Tstar
Lrot = 0.5 * doD / toT * DoT

SIF = 0.85 * RoT ^ (1) * Lrot ^ (-0.5) * doD ^ 2.1
If SIF < 1 Then SIF = 1
EPRI_itb = SIF
End Function

Function EPRI_itr(doD As Double, DoT As Double, toT As Double, T As Double, tp As Double) As Double
RoT = DoT / 2
Tstar = T + 0.5 * tp
RoT = RoT * T / Tstar
Lrot = 0.5 * doD / toT * DoT

SIF = 0.864 * RoT ^ (-0.0473) * Lrot ^ (0.543) * doD ^ 0.609
If SIF < 1 Then SIF = 1
EPRI_itr = SIF
End Function
```

2.5 EPRI TR-110755 Reinforced fabricated tee Flexibility Factors

```
Function EPRI_kib(doD As Double, DoT As Double, toT As Double, T As Double, tp As Double) As Double
RoT = DoT / 2
Tstar = T + 0.5 * tp
RoT = RoT * T / Tstar
Ldot = doD / toT * DoT

SIF = 0.488 * (RoT * 2) ^ (1.279) * Ldot ^ (-0.602) * doD ^ 0.391
If SIF < 1 Then SIF = 1
EPRI_kib = SIF
End Function

Function EPRI_kob(doD As Double, DoT As Double, toT As Double, T As Double, tp As Double) As Double
RoT = DoT / 2
Tstar = T + 0.5 * tp
RoT = RoT * T / Tstar
Ldot = doD / toT * DoT

SIF = 0.828 * (3 * doD - 3.75 * doD ^ 2 + doD ^ 3) * (2 * RoT) ^ (1.72) * Ldot ^ (-0.717) * doD ^ 0.5057
If SIF < 1 Then SIF = 1
EPRI_kob = SIF
End Function

Function EPRI_ktb(doD As Double, DoT As Double, toT As Double, T As Double, tp As Double) As Double
RoT = DoT / 2
Tstar = T + 0.5 * tp
RoT = RoT * T / Tstar
Ldot = doD / toT * DoT

SIF = 2.43 * (2 * RoT) ^ (0.751) * Ldot ^ (-0.553) * doD ^ 2.11
If SIF < 1 Then SIF = 1
EPRI_ktb = SIF
End Function

Function EPRI_kir(doD As Double, DoT As Double, toT As Double, T As Double, tp As Double) As Double
RoT = DoT / 2
Tstar = T + 0.5 * tp
RoT = RoT * T / Tstar
Ldot = doD / toT * DoT

SIF = 0.995 * (2 * RoT) ^ (0.675) * Ldot ^ (-0.25) * doD ^ 3.78
If SIF < 1 Then SIF = 1
EPRI_kir = SIF
End Function

Function EPRI_kor(doD As Double, DoT As Double, toT As Double, T As Double, tp As Double) As Double
RoT = DoT / 2
Tstar = T + 0.5 * tp
RoT = RoT * T / Tstar
Ldot = doD / toT * DoT

SIF = 0.0771 * (2 * RoT) ^ (-0.159) * Ldot ^ (1.305) * doD ^ 4.096
If SIF < 1 Then SIF = 1
EPRI_kor = SIF
End Function

Function EPRI_ktr(doD As Double, DoT As Double, toT As Double, T As Double, tp As Double) As Double
RoT = DoT / 2
Tstar = T + 0.5 * tp
RoT = RoT * T / Tstar
Ldot = doD / toT * DoT

SIF = 0.813 * (2 * RoT) ^ (0.982) * Ldot ^ (-0.349) * doD ^ 4.328
If SIF < 1 Then SIF = 1
EPRI_ktr = SIF
End Function
```

3.1 Unreinforced fabricated tee Sketch 2.3 SIFs

```
Function PRG_BR_ii(doD As Double, DoT As Double, toT As Double) As Double
RoT = DoT / 2
dovert = doD * DoT / toT
toverd = 1 / dovert
rorp = 1 / (1 + toverd)
toTUSE = toT
If toTUSE < 1 Then toTUSE = 1
SIF = (0.038 + 1.45 * doD - 2.39 * doD ^ 2 + 1.34 * doD ^ 3) * RoT ^ 0.76 * toTUSE ^ 0.74
PRG_BR_ii = SIF
End Function

Function PRG_BR_ii_rorp(doD As Double, DoT As Double, toT As Double, rorp As Double) As Double
RoT = DoT / 2
dovert = doD * DoT / toT
toverd = 1 / dovert
toTUSE = toT
If toTUSE < 1 Then toTUSE = 1
SIF = (0.038 + 1.45 * doD - 2.39 * doD ^ 2 + 1.34 * doD ^ 3) * RoT ^ 0.76 * toTUSE ^ 0.74
PRG_BR_ii_rorp = SIF
End Function

Function PRG_BR_io(doD As Double, DoT As Double, toT As Double) As Double
SIFiib = PRG_BR_ii(doD, DoT, toT)
RoT = DoT / 2
dovert = doD * DoT / toT
toverd = 1 / dovert
rorp = 1 / (1 + toverd)
toTUSE = toT
If toTUSE < 0.85 Then toTUSE = 0.85
SIF = (0.038 + 2 * doD + 2 * doD ^ 2 - 3.1 * doD ^ 3) * RoT ^ (2 / 3) * toTUSE
If DoT >= 25 And doD < 1 And toT <= 0.85 Then
    If ((0.75 * toT - 0.89 * toT ^ 2 + 0.18) * (DoT ^ 0.34)) > 1 Then
        SIF = SIF * ((0.75 * toT - 0.89 * toT ^ 2 + 0.18) * (DoT ^ 0.34))
    End If
End If
PRG_BR_io = SIF
If PRG_BR_io < SIFiib Then
    PRG_BR_io = SIFiib
    SIF = PRG_BR_io
End If
PRG_BR_io = SIF
End Function

Function PRG_BR_it(doD As Double, DoT As Double, toT As Double) As Double
RoT = DoT / 2
dovert = doD * DoT / toT
toverd = 1 / dovert
rorp = 1 / (1 + toverd)
SIF = 0.45 * RoT ^ 0.8 * toT ^ 0.29 * doD ^ 2
PRG_BR_it = SIF
End Function

Function PRG_BR_io_rorp(doD As Double, DoT As Double, toT As Double, rorpUSE As Double) As Double
SIFiib = PRG_BR_ii_rorp(doD, DoT, toT, rorpUSE)
RoT = DoT / 2
toTUSE = toT
If toTUSE < 0.85 Then toTUSE = 0.85
SIF = (0.038 + 2 * doD + 2 * doD ^ 2 - 3.1 * doD ^ 3) * RoT ^ (2 / 3) * toTUSE
If DoT >= 25 And doD < 1 And toT <= 0.85 Then
    If ((0.75 * toT - 0.89 * toT ^ 2 + 0.18) * (DoT ^ 0.34)) > 1 Then
        SIF = SIF * ((0.75 * toT - 0.89 * toT ^ 2 + 0.18) * (DoT ^ 0.34))
    End If
End If
PRG_BR_io_rorp = SIF
If PRG_BR_io_rorp < SIFiib Then
    PRG_BR_io_rorp = SIFiib
    SIF = PRG_BR_io_rorp
End If
PRG_BR_io_rorp = SIF
End Function
```

```
Function PRG_Hdr_ii_rorp(doD As Double, DoT As Double, toT As Double, rorpUSE As Double) As Double
SIFioh = PRG_Hdr_io(doD, DoT, toT)
RoT = DoT / 2
toTUSE = toT
SIF = 1.2 * doD ^ 0.5 * RoT ^ 0.4 * toT ^ (-0.35)
If SIF < 1.5 Then SIF = 1.5
PRG_Hdr_ii_rorp = SIF
If PRG_Hdr_ii_rorp < SIFioh Then
    PRG_Hdr_ii_rorp = SIFioh
    SIF = PRG_Hdr_ii_rorp
End If
PRG_Hdr_ii_rorp = SIF
End Function


Function PRG_Hdr_ii(doD As Double, DoT As Double, toT As Double) As Double
SIFioh = PRG_Hdr_io(doD, DoT, toT)
RoT = DoT / 2
dovert = doD * DoT / toT
toverd = 1 / dovert
rorp = 1 / (1 + toverd)
SIF = 1.2 * doD ^ 0.5 * RoT ^ 0.4 * toT ^ (-0.35)
If SIF < 1.5 Then SIF = 1.5
PRG_Hdr_ii = SIF
If PRG_Hdr_ii < SIFioh Then
    PRG_Hdr_ii = SIFioh
    SIF = PRG_Hdr_ii
End If
PRG_Hdr_ii = SIF
End Function

Function PRG_Hdr_io(doD As Double, DoT As Double, toT As Double) As Double
RoT = DoT / 2
doDUSE = doD
If doDUSE < 0.5 Then doDUSE = 0.5
toTUSE = toT
If toTUSE < 0.5 Then toTUSE = 0.5
SIF = (doDUSE - 2.7 * doDUSE ^ 2 + 2.62 * doDUSE ^ 3) * RoT ^ 0.43 * toTUSE ^ -0.7
PRG_Hdr_io = SIF
End Function

Function PRG_Hdr_it(doD As Double, DoT As Double, toT As Double) As Double
RoT = DoT / 2
toTUSE = toT
If toTUSE < 0.15 Then toTUSE = 0.15
SIF = 1.2 * RoT ^ 0.46 * toTUSE ^ -0.45 * doD ^ 1.37
PRG_Hdr_it = SIF
End Function
```

3.2 Unreinforced fabricated tee Sketch 2.3 Flexibility Factors

```
Function PRG_BR_ki(doD As Double, DoT As Double, toT As Double) As Double
RoT = DoT / 2
k = (3.15 * doD - 6.4 * doD ^ 2 + 4 * doD ^ 3) * RoT ^ 0.83 * toT ^ 0.49 * doD ^ -0.2
PRG_BR_ki = k
End Function

Function PRG_BR_ko(doD As Double, DoT As Double, toT As Double) As Double
RoT = DoT / 2
k = (2.05 * doD - 2.94 * doD ^ 2 + 1.1 * doD ^ 3) * RoT ^ 1.4 * toT ^ 0.6 * doD ^ 0.12
PRG_BR_ko = k
End Function

Function PRG_BR_kt(doD As Double, DoT As Double, toT As Double) As Double
RoT = DoT / 2
k = 0.95 * (RoT ^ 0.83) * (doD ^ 5.42)
PRG_BR_kt = k
End Function

Function PRG_Hdr_ki(doD As Double, DoT As Double, toT As Double) As Double
RoT = DoT / 2
k = 1.23 * RoT ^ 0.47 * toT ^ -0.47 * doD ^ 5.3
PRG_Hdr_ki = k
End Function

Function PRG_Hdr_ko(doD As Double, DoT As Double, toT As Double) As Double
k = 1
PRG_Hdr_ko = k
End Function

Function PRG_Hdr_kt(doD As Double, DoT As Double, toT As Double) As Double
RoT = DoT / 2
k = RoT ^ 0.78 * toT ^ -0.8 * doD ^ 7.8
PRG_Hdr_kt = k
End Function
```

3.3 Unreinforced fabricated tee (Locally Thickened) Sketch 2.3 SIFs

```
Function PRG_BR_iiNoz(doD As Double, DoT As Double, toT As Double, tnoT As Double) As Double
dnoD = doD - (toT / DoT) + (tnoT / DoT)
tnoLT = tnoT / toT
dnoLD = 1 - (toT / (DoT * doD)) + (tnoT / (DoT * doD))
xSIF = PRG_BR_ii(dnoD, DoT, tnoT) / (tnoLT * (dnoLD ^ 2))
If xSIF < 1.5 Then xSIF = 1.5
PRG_BR_iiNoz = xSIF
End Function

Function PRG_BR_ioNoz(doD As Double, DoT As Double, toT As Double, tnoT As Double) As Double
dnoD = doD - (toT / DoT) + (tnoT / DoT)
tnoLT = tnoT / toT
dnoLD = 1 - (toT / (DoT * doD)) + (tnoT / (DoT * doD))
xSIF = PRG_BR_io(dnoD, DoT, tnoT) / (tnoLT * (dnoLD ^ 2))
If xSIF < 1.5 Then xSIF = 1.5
PRG_BR_ioNoz = xSIF
End Function

Function PRG_BR_itNoz(doD As Double, DoT As Double, toT As Double, tnoT As Double) As Double
dnoD = doD - (toT / DoT) + (tnoT / DoT)
tnoLT = tnoT / toT
dnoLD = 1 - (toT / (DoT * doD)) + (tnoT / (DoT * doD))
xSIF = PRG_BR_it(dnoD, DoT, tnoT) / (tnoLT * (dnoLD ^ 2))
If xSIF < 1# Then xSIF = 1#
PRG_BR_itNoz = xSIF
End Function

Function PRG_Hdr_iiNoz(doD As Double, DoT As Double, toT As Double, tnoT As Double) As Double
dnoD = doD - (toT / DoT) + (tnoT / DoT)
tnoLT = tnoT / toT
xSIF = PRG_Hdr_ii(dnoD, DoT, tnoT)
If xSIF < 1.5 Then xSIF = 1.5
PRG_Hdr_iiNoz = xSIF
End Function

Function PRG_Hdr_ioNoz(doD As Double, DoT As Double, toT As Double, tnoT As Double) As Double
dnoD = doD - (toT / DoT) + (tnoT / DoT)
tnoLT = tnoT / toT
xSIF = PRG_Hdr_io(dnoD, DoT, tnoT)
If xSIF < 1# Then xSIF = 1#
PRG_Hdr_ioNoz = xSIF
End Function

Function PRG_Hdr_itNoz(doD As Double, DoT As Double, toT As Double, tnoT As Double) As Double
dnoD = doD - (toT / DoT) + (tnoT / DoT)
tnoLT = tnoT / toT
xSIF = PRG_Hdr_it(dnoD, DoT, tnoT)
If xSIF < 1.5 Then xSIF = 1.5
PRG_Hdr_itNoz = xSIF
End Function
```

3.4 Unreinforced fabricated tee (Locally Thickened) Sketch 2.3 Flexibility Factors

```
Function PRG_BR_kiNoz(doD As Double, DoT As Double, toT As Double, tnoT As Double) As Double
dnoD = doD - (toT / DoT) + (tnoT / DoT)
tnoLT = tnoT / toT
dnoLD = 1 - (toT / (DoT * doD)) + (tnoT / (DoT * doD))
xSIF = PRG_BR_ki(dnoD, DoT, tnoT) / (tnoLT * (dnoLD ^ 2))
If xSIF < 1# Then xSIF = 1#
PRG_BR_kiNoz = xSIF
End Function

Function PRG_BR_koNoz(doD As Double, DoT As Double, toT As Double, tnoT As Double) As Double
dnoD = doD - (toT / DoT) + (tnoT / DoT)
tnoLT = tnoT / toT
dnoLD = 1 - (toT / (DoT * doD)) + (tnoT / (DoT * doD))
xSIF = PRG_BR_ko(dnoD, DoT, tnoT) / (tnoLT * (dnoLD ^ 2))
If xSIF < 1# Then xSIF = 1#
PRG_BR_koNoz = xSIF
End Function

Function PRG_BR_ktNoz(doD As Double, DoT As Double, toT As Double, tnoT As Double) As Double
dnoD = doD - (toT / DoT) + (tnoT / DoT)
tnoLT = tnoT / toT
dnoLD = 1 - (toT / (DoT * doD)) + (tnoT / (DoT * doD))
xSIF = PRG_BR_kt(dnoD, DoT, tnoT) / (tnoLT * (dnoLD ^ 2))
If xSIF < 1# Then xSIF = 1#
PRG_BR_ktNoz = xSIF
End Function

Function PRG_Hdr_kiNoz(doD As Double, DoT As Double, toT As Double, tnoT As Double) As Double
dnoD = doD - (toT / DoT) + (tnoT / DoT)
tnoLT = tnoT / toT
xSIF = PRG_Hdr_ki(dnoD, DoT, tnoT)
If xSIF < 1# Then xSIF = 1#
PRG_Hdr_kiNoz = xSIF
End Function

Function PRG_Hdr_koNoz(doD As Double, DoT As Double, toT As Double, tnoT As Double) As Double
PRG_Hdr_koNoz = 1
End Function

Function PRG_Hdr_ktNoz(doD As Double, DoT As Double, toT As Double, tnoT As Double) As Double
dnoD = doD - (toT / DoT) + (tnoT / DoT)
tnoLT = tnoT / toT
xSIF = PRG_Hdr_kt(dnoD, DoT, tnoT)
If xSIF < 1# Then xSIF = 1#
PRG_Hdr_ktNoz = xSIF
End Function
```

3.5 EPRI TR-110996 Unreinforced fabricated tee SIFs

```
Function Wais_ib(doD As Double, DoT As Double, toT As Double) As Double
RoT = DoT / 2#
little_rot = doD * DoT / toT / 2#
SCF = 1.03 * RoT ^ 1.05 * little_rot ^ -0.387 * doD ^ 0.49
SIF = SCF / 2
If SIF < 1 Then SIF = 1
Wais_ib = SIF
End Function

Function Wais_iob(doD As Double, DoT As Double, toT As Double) As Double
small_dot = doD * DoT / toT
roR = doD
RoT = DoT / 2#
small_rot = small_dot / 2
iob = 1.28 * (1.28 * (roR) - (roR ^ 4)) * (RoT) ^ 1.4 * (small_rot) ^ (-0.558) * (roR) ^ 0.4057
If iob < 1# Then iob = 1
Wais_iob = iob
End Function

Function Wais_BR_it(doD As Double, DoT As Double, toT As Double) As Double
RoT = DoT / 2
roR = doD
Lrot = roR * RoT / toT
SIF = 0.85 * RoT * Lrot ^ -0.5 * roR ^ 2.1
If SIF < 1 Then SIF = 1
Wais_BR_it = SIF
End Function

Function Wais_ioh(doD As Double, DoT As Double, toT As Double) As Double
RoT = DoT / 2#
little_rot = doD * DoT / toT / 2#
SCF = 1.21 * RoT ^ (-0.237) * little_rot ^ 0.528 * doD ^ 1.42
SIF = SCF / 2#
If SIF < 1 Then SIF = 1
Wais_ioh = SIF
End Function

Function Wais_iih(doD As Double, DoT As Double, toT As Double) As Double
RoT = DoT / 2#
little_rot = doD * DoT / toT / 2#
SCF = 1.97 * (RoT ^ (-0.137)) * little_rot ^ 0.482 * doD ^ 0.241
SIF = SCF / 2#
If SIF < 1 Then SIF = 1
Wais_iih = SIF
End Function

Function Wais_ith(doD As Double, DoT As Double, toT As Double) As Double
RoT = DoT / 2#
little_rot = doD * DoT / toT / 2#
SCF = 1.73 * RoT ^ (-0.0473) * little_rot ^ 0.543 * doD ^ 0.6093
SIF = SCF / 2#
If SIF < 1 Then SIF = 1
Wais_ith = SIF
End Function
```

3.6 EPRI TR-110996 Unreinforced fabricated tee Flexibility Factors

```
Function Wais_kib(doD As Double, DoT As Double, toT As Double) As Double
small_dot = doD * DoT / toT
roR = doD
RoT = DoT / 2#
small_rot = small_dot / 2
kib = 0.488 * DoT ^ 1.279 * doD ^ 0.391 * small_dot ^ -0.602
If kib < 1 Then kib = 1
Wais_kib = kib
End Function

Function Wais_kob(doD As Double, DoT As Double, toT As Double) As Double
small_dot = doD * DoT / toT
roR = doD
RoT = DoT / 2#
small_rot = small_dot / 2
kob = 0.828 * (3# * (roR) - 3.75 * (roR ^ 2) + (roR) ^ 3) * DoT ^ 1.72 * (small_dot) ^ (-0.717) * (roR)
^ 0.5057
If kob < 1 Then kob = 1
Wais_kob = kob
End Function

Function Wais_ktb(doD As Double, DoT As Double, toT As Double) As Double
small_dot = doD * DoT / toT
roR = doD
RoT = DoT / 2#
small_rot = small_dot / 2
ktb = 2.43 * DoT ^ 0.751 * doD ^ 2.11 * small_dot ^ -0.553
If ktb < 1 Then ktb = 1
Wais_ktb = ktb
End Function

Function Wais_kih(doD As Double, DoT As Double, toT As Double) As Double
small_dot = doD * DoT / toT
roR = doD
RoT = DoT / 2#
small_rot = small_dot / 2
kih = 1.627 * DoT ^ 0.008 * doD ^ 2.63 * small_dot ^ 0.2366
If kih < 1 Then kih = 1
Wais_kih = kih
End Function

Function Wais_koh(doD As Double, DoT As Double, toT As Double) As Double
small_dot = doD * DoT / toT
roR = doD
RoT = DoT / 2#
small_rot = small_dot / 2
koh = 0.128 * DoT ^ -1.085 * doD ^ 1.077 * small_dot ^ 1.305
If koh < 1 Then koh = 1
Wais_koh = koh
End Function

Function Wais_kth(doD As Double, DoT As Double, toT As Double) As Double
small_dot = doD * DoT / toT
roR = doD
RoT = DoT / 2#
small_rot = small_dot / 2
kth = 1.56 * DoT ^ 0.039 * doD ^ 2.47 * small_dot ^ 0.276
If kth < 1 Then kth = 1
Wais_kth = kth
End Function
```

3.7 WRC 497 Unreinforced fabricated tee SIFs and k-factors

```
Function Widera_iib(doD As Double, DoT As Double, toT As Double) As Double
SCFn = (-1.119 + 11.23 * doD - 19.67 * doD ^ 2 + 11.32 * doD ^ 3) * (DoT) ^ 0.476
SCFv = (-0.0022 + 4.729 * doD - 8.674 * doD ^ 2 + 5.237 * doD ^ 3) * DoT ^ 0.526 * toT ^ 0.812
SCF = SCFv
If SCFn > SCFv Then SCF = SCFn
SCF = SCF / 2
If SCF < 1 Then SCF = 1
Widera_iib = SCF
End Function

Function Widera_iob(doD As Double, DoT As Double, toT As Double) As Double
SCFn = (-0.863 + 5.559 * doD - 5.895 * doD ^ 2 + 1.78 * doD ^ 3) * (DoT) ^ 0.802 * toT ^ (-0.252)
SCFv = (0.0947 + 1.099 * doD - 0.2395 * doD ^ 2 - 0.541 * doD ^ 3) * DoT ^ 0.8972 * toT ^ 1.115
SCF = SCFv
If SCFn > SCFv Then SCF = SCFn
SCF = SCF / 2
If SCF < 1 Then SCF = 1
Widera_iob = SCF
End Function

Function Widera_kib(doD As Double, DoT As Double, toT As Double) As Double
k = 0.68 * (doD) ^ (-0.242) * DoT ^ 0.802 * toT ^ 0.622 * (3.437 * doD - 7.414 * (doD ^ 2) + 4.766 * doD
^ 3)
Widera_kib = k
End Function

Function Widera_kob(doD As Double, DoT As Double, toT As Double) As Double
k = 0.172 * (doD) ^ 0.538 * DoT ^ 1.515 * toT ^ 0.862 * (5.935 * doD - 10.454 * (doD ^ 2) + 4.797 * doD
^ 3)
Widera_kob = k
End Function
```

3.8 WRC 329 Eqs. 42, 45 and 46

```
Function WRC329Eq46(doD As Double, DoT As Double, toT As Double) As Double
RoT = DoT / 2
roR = doD
Lrot = roR * RoT / toT
SIF = 0.6 * RoT ^ (2 / 3) * (1 + 0.5 * roR ^ 3) * (1 / (1 + 1 / (Lrot * 2))) * toT
SIFiob = NCib(doD, DoT, toT)
If SIF > SIFiob Then SIF = SIFiob
If SIF < 1 Then SIF = 1
WRC329Eq46 = SIF
End Function

Function WRC329Eq42(doD As Double, DoT As Double, toT As Double) As Double
RoT = DoT / 2
roR = doD
Lrot = roR * RoT / toT
SIFiob = NCib(doD, DoT, toT)
SIF = SIFiob * roR
If SIF < 1 Then SIF = 1
WRC329Eq42 = SIF
End Function

Function WRC329Eq45(doD As Double, DoT As Double, toT As Double) As Double

RoT = DoT / 2
roR = doD
Lrot = roR * RoT / toT
SIFx = 0.8 * RoT ^ (2 / 3) * doD
If SIFx < 2.1 Then SIFx = 2.1
WRC329Eq45 = SIFx
End Function
```

3.9 NC-3673.2 (b) ib/ir; NB-3686.5 ki/ko

```
Function NCib(doD As Double, DoT As Double, toT As Double) As Double
rorp = 1# / (1# + toT / doD / DoT)
ibp9 = 1.5 * (DoT / 2) ^ (2# / 3#) * (doD) ^ 0.5 * (toT) * rorp
ib1 = 0.9 * (DoT / 2) ^ (2# / 3#) * rorp
If doD <= 0.9 Then
   ib = ibp9
Else
   ib = ibp9 + (doD - 0.9) / (0.1) * (ib1 - ibp9)
End If
If ib < 1.5 Then ib = 1.5
NCib = ib
End Function

Function NC_ioh(doD As Double, DoT As Double, toT As Double) As Double
RoT = DoT / 2
SIF = 0.8 * (RoT) ^ (2 / 3) * doD
If SIF < 2.1 Then SIF = 2.1
NC_ioh = SIF
End Function

Function NCkib(doD As Double, DoT As Double, toT As Double) As Double
k = 0.2 * (DoT + 1) * ((doD + toT / DoT) / (1 + 1 / DoT)) ^ 0.5 * toT ^ 0.5
NCkib = k
End Function

Function NCkob(doD As Double, DoT As Double, toT As Double) As Double
k = 0.1 * (DoT + 1) ^ 1.5 * ((doD + toT / DoT) / (1 + 1 / DoT)) ^ 0.5 * toT ^ 0.5
NCkob = k
End Function
```

3.10 B31.3 Sketch 2.3

```
Function B313_iib(doD As Double, DoT As Double, toT As Double) As Double
io = 0.9 * (DoT / 2#) ^ (2# / 3#)
If io < 1 Then io = 1
ii = 0.75 * io + 0.25
If ii < 1 Then ii = 1
If doD < 1 Then
    If ii < (1 / toT) Then
        ii = 1#
    Else
        ii = ii * toT
    End If
End If
If ii < 1 Then ii = 1
B313_iib = ii
End Function

Function B313_iob(doD As Double, DoT As Double, toT As Double) As Double
io = 0.9 * (DoT / 2#) ^ (2# / 3#)
If io < 1 Then io = 1
ii = 0.75 * io + 0.25
If ii < 1 Then ii = 1
If doD < 1 Then
    If ii < (1 / toT) Then
        io = io / ii
    Else
        io = io * toT
    End If
End If
If io < 1 Then io = 1
B313_iob = io
End Function

Function B313_iih(doD As Double, DoT As Double, toT As Double) As Double
io = 0.9 * (DoT / 2#) ^ (2# / 3#)
ii = 0.75 * io + 0.25
If ii < 1 Then ii = 1
B313_iih = ii
End Function

Function B313_ioh(doD As Double, DoT As Double, toT As Double) As Double
io = 0.9 * (DoT / 2#) ^ (2# / 3#)
If io < 1 Then io = 1
B313_ioh = io
End Function
```

3.11 DNV

```
Function DNV_iib_UFT(doD As Double, DoT As Double, toT As Double) As Double
beta = ((doD * DoT) + toT) / (DoT + 1)
gamma = (DoT + 1) / 2
tau = toT
SCF_Chord = 1.45 * beta * (tau ^ 0.85) * gamma ^ (1 - (0.68 * beta))
SCF_Brace = 1 + (0.65 * beta * (tau ^ 0.4) * gamma ^ (1.09 - (0.77 * beta)))
If SCF_Chord > SCF_Brace Then
    DNV_iib_UFT = SCF_Chord / 2
Else
    DNV_iib_UFT = SCF_Brace / 2
End If
End Function

Function DNV_iob_UFT(doD As Double, DoT As Double, toT As Double) As Double
beta = ((doD * DoT) + toT) / (DoT + 1)
gamma = (DoT + 1) / 2
tau = toT
SCF_Chord = gamma * tau * beta * (1.7 - (1.05 * beta ^ 3))
SCF_Brace = (tau ^ -0.54) * (gamma ^ -0.05) * (0.99 - (0.47 * beta) + (0.08 * beta ^ 4)) * SCF_Chord
If SCF_Chord > SCF_Brace Then
    DNV_iob_UFT = SCF_Chord / 2
Else
    DNV_iob_UFT = SCF_Brace / 2
End If

End Function
```

4.1 Extruded outlet Sketch 2.4 SIFs

```
Function PRG_ext_iib(doD As Double, DoT As Double, toT As Double, rx As Double) As Double
SIFchkL = PRG_tee_iib(doD, DoT, toT)
SIFchk = PRG_BR_ii(doD, DoT, toT)
RoT = DoT / 2
usetoT = toT
If usetoT < 1 Then usetoT = 1
userxoR = 0.05 * 2 * (doD + toT / DoT)
If rx > userxoR Then userxoR = rx
rxoLr = userxoR / doD
If rxoLr > 1 Then rxoLr = 1
SIF = (1 + userxoR) ^ (-2 / 3) * 0.56 * RoT ^ (2 / 3) * doD ^ 0.68
PRG_ext_iib = SIF
If SIFchk < SIF Then
    SIF = SIFchk
    PRG_ext_iib = SIF
End If
If SIF < SIFchkL Then
    SIF = SIFchkL
    PRG_ext_iib = SIF
End If
End Function

Function PRG_ext_iob(doD As Double, DoT As Double, toT As Double, rx As Double) As Double
SIFiib = PRG_ext_iib(doD, DoT, toT)
SIFchkL = PRG_tee_iob(doD, DoT, toT)
SIFchk = PRG_BR_io(doD, DoT, toT)
RoT = DoT / 2
usetoT = toT
If usetoT < 1 Then usetoT = 1
userxoR = 0.05 * 2 * (doD + toT / DoT)
If rx > userxoR Then userxoR = rx
rxoLr = userxoR / doD
If rxoLr > 1 Then rxoLr = 1
SIF = (1 + userxoR) ^ (-2 / 3) * 0.85 * RoT ^ (2 / 3) * doD ^ 0.5
PRG_ext_iob = SIF
If PRG_ext_iob < SIFiib Then
    PRG_ext_iob = SIFiib
    SIF = PRG_ext_iob
End If
If SIFchk < SIF Then
    SIF = SIFchk
    PRG_ext_iob = SIF
End If
If SIF < SIFchkL Then
    SIF = SIFchkL
    PRG_ext_iob = SIF
End If
End Function

Function PRG_ext_itb(doD As Double, DoT As Double, toT As Double, rx As Double) As Double
SIFchkL = PRG_tee_itb(doD, DoT, toT)
SIFchk = PRG_BR_it(doD, DoT, toT)
RoT = DoT / 2
userxoR = 0.05 * 2 * (doD + toT / DoT)
If rx > userxoR Then userxoR = rx
rxoLr = userxoR / doD
If rxoLr > 1 Then rxoLr = 1
SIF = (1 + userxoR) ^ (-2 / 3) * 0.71 * RoT ^ (2 / 3) * doD ^ 2
PRG_ext_itb = SIF
If SIFchk < SIF Then
    SIF = SIFchk
    PRG_ext_itb = SIF
End If
If SIF < SIFchkL Then
    SIF = SIFchkL
    PRG_ext_itb = SIF
End If
End Function
```

```
Function PRG_ext_iih(doD As Double, DoT As Double, toT As Double, rx As Double) As Double
SIFioh = PRG_ext_ioh(doD, DoT, toT)
SIFchkL = PRG_tee_iih(doD, DoT, toT)
SIFchk = PRG_Hdr_ii(doD, DoT, toT)
RoT = DoT / 2
userxoR = 0.05 * 2 * (doD + toT / DoT)
If rx > userxoR Then userxoR = rx
rxoLr = userxoR / doD
If rxoLr > 1 Then rxoLr = 1
SIF = (1 + userxoR) ^ (-2 / 3) * 1.45 * RoT ^ (0.35) * doD ^ 0.72 * toT ^ (-0.52)
PRG_ext_iih = SIF
If PRG_ext_iih < SIFioh Then
    PRG_ext_iih = SIFioh
    SIF = PRG_ext_iih
End If
If SIFchk < SIF Then
    SIF = SIFchk
    PRG_ext_iih = SIF
End If
If SIF < SIFchkL Then
    SIF = SIFchkL
    PRG_ext_iih = SIF
End If
End Function

Function PRG_ext_ioh(doD As Double, DoT As Double, toT As Double, rx As Double) As Double
SIFchkL = PRG_tee_ioh(doD, DoT, toT)
SIFchk = PRG_Hdr_io(doD, DoT, toT)
RoT = DoT / 2
userxoR = 0.05 * 2 * (doD + toT / DoT)
If rx > userxoR Then userxoR = rx
rxoLr = userxoR / doD
If rxoLr > 1 Then rxoLr = 1
SIF = (1 + userxoR) ^ (-2 / 3) * 0.58 * RoT ^ (2 / 3) * doD ^ 2.69
PRG_ext_ioh = SIF
If SIFchk < SIF Then
    SIF = SIFchk
    PRG_ext_ioh = SIF
End If
If SIF < SIFchkL Then
    SIF = SIFchkL
    PRG_ext_ioh = SIF
End If
End Function

Function PRG_ext_ith(doD As Double, DoT As Double, toT As Double, rx As Double) As Double
SIFchkL = PRG_tee_ith(doD, DoT, toT)
SIFchk = PRG_Hdr_it(doD, DoT, toT)
RoT = DoT / 2
userxoR = 0.05 * 2 * (doD + toT / DoT)
If rx > userxoR Then userxoR = rx
rxoLr = userxoR / doD
If rxoLr > 1 Then rxoLr = 1
SIF = (1 + userxoR) ^ (-2 / 3) * 0.55 * RoT ^ (2 / 3) * doD * toT ^ (-0.5)
PRG_ext_ith = SIF
If SIFchk < SIF Then
    SIF = SIFchk
    PRG_ext_ith = SIF
End If
If SIF < SIFchkL Then
    SIF = SIFchkL
    PRG_ext_ith = SIF
End If
End Function
```

4.2 Extruded outlet Sketch 2.4 Flexibility Factors

```
Function PRG_ext_kib(doD As Double, DoT As Double, toT As Double) As Double
kchkL = PRG_tee_kib(doD, DoT, toT)
kchk = PRG_BR_ki(doD, DoT, toT)
RoT = DoT / 2
k = (1.91 * doD - 4.32 * doD ^ 2 + 2.7 * doD ^ 3) * RoT ^ 0.77 * doD ^ 0.47 * toT
PRG_ext_kib = k
If kchk < k Then
    k = kchk
    PRG_ext_kib = k
End If
If k < kchkL Then
    k = kchkL
    PRG_ext_kib = k
End If
End Function

Function PRG_ext_kob(doD As Double, DoT As Double, toT As Double) As Double
kchkL = PRG_tee_kob(doD, DoT, toT)
kchk = PRG_BR_ko(doD, DoT, toT)
RoT = DoT / 2
k = (0.34 * doD - 0.49 * doD ^ 2 + 0.18 * doD ^ 3) * RoT ^ 1.46 * toT
PRG_ext_kob = k
If kchk < k Then
    k = kchk
    PRG_ext_kob = k
End If
If k < kchkL Then
    k = kchkL
    PRG_ext_kob = k
End If
End Function

Function PRG_ext_ktb(doD As Double, DoT As Double, toT As Double) As Double
kchkL = PRG_tee_ktb(doD, DoT, toT)
kchk = PRG_BR_kt(doD, DoT, toT)
RoT = DoT / 2
k = (1.08 * doD - 2.44 * doD ^ 2 + 1.52 * doD ^ 3) * RoT ^ 0.77 * doD ^ 1.79 * toT
PRG_ext_ktb = k
If kchk < k Then
    k = kchk
    PRG_ext_ktb = k
End If
If k < kchkL Then
    k = kchkL
    PRG_ext_ktb = k
End If
End Function

Function PRG_ext_kih(doD As Double, DoT As Double, toT As Double) As Double
kchkL = PRG_tee_kih(doD, DoT, toT)
kchk = PRG_Hdr_ki(doD, DoT, toT)
RoT = DoT / 2
k = 0.18 * RoT ^ 0.8 * doD ^ 5
PRG_ext_kih = k
If kchk < k Then
    k = kchk
    PRG_ext_kih = k
End If
If k < kchkL Then
    k = kchkL
    PRG_ext_kih = k
End If
End Function

Function PRG_ext_koh(doD As Double, DoT As Double, toT As Double) As Double
k = 1
PRG_ext_koh = k
End Function
```

```
Function PRG_ext_kth(doD As Double, DoT As Double, toT As Double) As Double
kchkL = PRG_tee_kth(doD, DoT, toT)
kchk = PRG_Hdr_kt(doD, DoT, toT)
RoT = DoT / 2
k = 0.08 * RoT ^ 0.91 * doD ^ 5.7
PRG_ext_kth = k
If kchk < k Then
    k = kchk
    PRG_ext_kth = k
End If
If k < kchkL Then
    k = kchkL
    PRG_ext_kth = k
End If
End Function
```

4.3 B31.3 Extruded outlet 2.4 SIFs

```
Function B313_ext_iib(doD As Double, DoT As Double, toT As Double) As Double
RoT = DoT / 2
flexchar = (1 + 0.1 * doD + 0.1 * toT / DoT) * 2 / DoT
iout = 0.9 / (flexchar ^ (2 / 3))
If iout < 1 Then iout = 1
iin = iout * 0.75 + 0.25
If iin < 1 Then iin = 1
If doD < 1 Then
   If iin < (1 / toT) Then
      iin = 1
    Else
      iin = iin * toT
   End If
End If
If iin < 1 Then iin = 1
B313_ext_iib = iin
End Function

Function B313_ext_iih(doD As Double, DoT As Double, toT As Double) As Double
RoT = DoT / 2
flexchar = (1 + 0.1 * doD + 0.1 * toT / DoT) * 2 / DoT
iout = 0.9 / (flexchar ^ (2 / 3))
If iout < 1 Then iout = 1
iin = iout * 0.75 + 0.25
If iin < 1 Then iin = 1
B313_ext_iih = iin
End Function

Function B313_ext_ioh(doD As Double, DoT As Double, toT As Double) As Double
RoT = DoT / 2
flexchar = (1 + 0.1 * doD + 0.1 * toT / DoT) * 2 / DoT
iout = 0.9 / (flexchar ^ (2 / 3))
If iout < 1 Then iout = 1
B313_ext_ioh = iout
End Function

Function B313_ext_iob(doD As Double, DoT As Double, toT As Double) As Double
RoT = DoT / 2
flexchar = (1 + 0.1 * doD + 0.1 * toT / DoT) * 2 / DoT
iout = 0.9 / (flexchar ^ (2 / 3))
If iout < 1 Then iout = 1
iin = iout * 0.75 + 0.25
If iin < 1 Then iin = 1
If doD < 1 Then
   If iin < (1 / toT) Then
      iout = iout / iin
    Else
      iout = iout * toT
   End If
End If
If iout < 1 Then iout = 1
B313_ext_iob = iout
End Function

Function B313_ext_iibrx(doD As Double, DoT As Double, toT As Double, rxoR As Double) As Double
RoT = DoT / 2
flexchar = (1 + rxoR) * 2 / DoT
iout = 0.9 / (flexchar ^ (2 / 3))
If iout < 1 Then iout = 1
iin = iout * 0.75 + 0.25
If iin < 1 Then iin = 1
If doD < 1 Then
   If iin < (1 / toT) Then
      iin = 1
    Else
      iin = iin * toT
   End If
End If
If iin < 1 Then iin = 1
B313_ext_iibrx = iin
```

```
End Function

Function B313_ext_iobrx(doD As Double, DoT As Double, toT As Double, rxoR As Double) As Double
RoT = DoT / 2
flexchar = (1 + rxoR) * 2 / DoT
iout = 0.9 / (flexchar ^ (2 / 3))
If iout < 1 Then iout = 1
iin = iout * 0.75 + 0.25
If iin < 1 Then iin = 1
If doD < 1 Then
   If iin < (1 / toT) Then
      iout = iout / iin
    Else
      iout = iout * toT
   End If
End If
If iout < 1 Then iout = 1
B313_ext_iobrx = iout
End Function
```

5.1 Welded-in contour insert Sketch 2.5 SIFs

```
Function PRG_SWP_iib(doD As Double, DoT As Double, toT As Double) As Double
SIFchkL = PRG_tee_iib(doD, DoT, toT)
SIFchk = PRG_BR_ii(doD, DoT, toT)
RoT = DoT / 2
SIF = 0.35 * RoT ^ (2 / 3) * doD ^ 0.18 * toT ^ 0.7
PRG_SWP_iib = SIF
If SIFchk < SIF Then
    SIF = SIFchk
    PRG_SWP_iib = SIF
End If
If SIF < SIFchkL Then
    SIF = SIFchkL
    PRG_SWP_iib = SIF
End If
End Function

Function PRG_SWP_iob(doD As Double, DoT As Double, toT As Double) As Double
SIFiib = PRG_SWP_iib(doD, DoT, toT)
SIFchkL = PRG_tee_iob(doD, DoT, toT)
SIFchk = PRG_BR_io(doD, DoT, toT)
RoT = DoT / 2
SIF = 0.48 * RoT ^ (2 / 3) * doD ^ 0.37 * toT ^ 0.37
PRG_SWP_iob = SIF
If PRG_SWP_iob < SIFiib Then
    PRG_SWP_iob = SIFiib
    SIF = PRG_SWP_iob
End If
If SIFchk < SIF Then
    SIF = SIFchk
    PRG_SWP_iob = SIF
End If
If SIF < SIFchkL Then
    SIF = SIFchkL
    PRG_SWP_iob = SIF
End If
End Function

Function PRG_SWP_itb(doD As Double, DoT As Double, toT As Double) As Double
SIFchkL = PRG_tee_itb(doD, DoT, toT)
SIFchk = PRG_BR_it(doD, DoT, toT)
RoT = DoT / 2
SIF = 0.44 * RoT ^ (2 / 3) * doD ^ 1.1 * toT ^ 1.1
PRG_SWP_itb = SIF
If SIFchk < SIF Then
    SIF = SIFchk
    PRG_SWP_itb = SIF
End If
If SIF < SIFchkL Then
    SIF = SIFchkL
    PRG_SWP_itp = SIF
End If
End Function

Function PRG_SWP_iih(doD As Double, DoT As Double, toT As Double) As Double
SIFioh = PRG_SWP_ioh(doD, DoT, toT)
SIFchkL = PRG_tee_iih(doD, DoT, toT)
SIFchk = PRG_Hdr_ii(doD, DoT, toT)
RoT = DoT / 2
SIF = RoT ^ (0.35) * doD ^ 0.72 * toT ^ (-0.52)
PRG_SWP_iih = SIF
If PRG_SWP_iih < SIFioh Then
    PRG_SWP_iih = SIFioh
    SIF = PRG_SWP_iih
End If
If SIFchk < SIF Then
    SIF = SIFchk
    PRG_SWP_iih = SIF
End If
If SIF < SIFchkL Then
    SIF = SIFchkL
```

```
    PRG_SWP_iih = SIF
End If
End Function

Function PRG_SWP_ioh(doD As Double, DoT As Double, toT As Double) As Double
SIFchkL = PRG_tee_ioh(doD, DoT, toT)
SIFchk = PRG_Hdr_io(doD, DoT, toT)
RoT = DoT / 2
SIF = 0.72 * RoT ^ 0.29 * doD ^ 1.95 * toT ^ -0.53
PRG_SWP_ioh = SIF
If SIFchk < SIF Then
    SIF = SIFchk
    PRG_SWP_ioh = SIF
End If
If SIF < SIFchkL Then
    SIF = SIFchkL
    PRG_SWP_ioh = SIF
End If
End Function

Function PRG_SWP_ith(doD As Double, DoT As Double, toT As Double) As Double
SIFchkL = PRG_tee_ith(doD, DoT, toT)
SIFchk = PRG_Hdr_it(doD, DoT, toT)
RoT = DoT / 2
SIF = 0.36 * RoT ^ (2 / 3) * doD * toT ^ -0.5
PRG_SWP_ith = SIF
If SIFchk < SIF Then
    SIF = SIFchk
    PRG_SWP_ith = SIF
End If
If SIF < SIFchkL Then
    SIF = SIFchkL
    PRG_SWP_ith = SIF
End If
End Function
```

5.2 Welded-in contour insert Sketch 2.5 Flexibility Factors

```
Function PRG_SWP_kib(doD As Double, DoT As Double, toT As Double) As Double
kchkL = PRG_tee_kib(doD, DoT, toT)
kchk = PRG_BR_ki(doD, DoT, toT)
RoT = DoT / 2
k = (2.36 * doD - 5.33 * doD ^ 2 + 3.33 * doD ^ 3) * RoT ^ 0.77 * doD ^ 0.47 * toT
PRG_SWP_kib = k
If kchk < k Then
    k = kchk
    PRG_SWP_kib = k
End If
If k < kchkL Then
    k = kchkL
    PRG_SWP_kib = k
End If
End Function

Function PRG_SWP_kob(doD As Double, DoT As Double, toT As Double) As Double
kchkL = PRG_tee_kob(doD, DoT, toT)
kchk = PRG_BR_ko(doD, DoT, toT)
RoT = DoT / 2
k = (1 + 0.1 * doD) * (0.67 * doD - 0.97 * doD ^ 2 + 0.36 * doD ^ 3) * RoT ^ 1.46 * toT
PRG_SWP_kob = k
If kchk < k Then
    k = kchk
    PRG_SWP_kob = k
End If
If k < kchkL Then
    k = kchkL
    PRG_SWP_kob = k
End If
End Function

Function PRG_SWP_ktb(doD As Double, DoT As Double, toT As Double) As Double
kchkL = PRG_tee_ktb(doD, DoT, toT)
kchk = PRG_BR_kt(doD, DoT, toT)
RoT = DoT / 2
k = (1.05 * doD - 2.36 * doD ^ 2 + 1.49 * doD ^ 3) * RoT ^ 0.77 * doD ^ 1.61 * toT
PRG_SWP_ktb = k
If kchk < k Then
    k = kchk
    PRG_SWP_ktb = k
End If
If k < kchkL Then
    k = kchkL
    PRG_SWP_ktb = k
End If
End Function

Function PRG_SWP_kih(doD As Double, DoT As Double, toT As Double) As Double
kchkL = PRG_tee_kih(doD, DoT, toT)
kchk = PRG_Hdr_ki(doD, DoT, toT)
RoT = DoT / 2
k = 0.18 * RoT ^ 0.84 * doD ^ 5
PRG_SWP_kih = k
If kchk < k Then
    k = kchk
    PRG_SWP_kih = k
End If
If k < kchkL Then
    k = kchkL
    PRG_SWP_kih = k
End If
End Function

Function PRG_SWP_koh(doD As Double, DoT As Double, toT As Double) As Double
k = 1
PRG_SWP_koh = k
End Function

Function PRG_SWP_kth(doD As Double, DoT As Double, toT As Double) As Double
```

```
kchkL = PRG_tee_kth(doD, DoT, toT)
kchk = PRG_Hdr_kt(doD, DoT, toT)
RoT = DoT / 2
k = 0.1 * RoT ^ 0.91 * doD ^ 5.7
PRG_SWP_kth = k
If kchk < k Then
    k = kchk
    PRG_SWP_kth = k
End If
If k < kchkL Then
    k = kchkL
    PRG_SWP_kth = k
End If
End Function
```

5.3 B31.3 Welded-in contour insert SIFs

```
Function B313_swp_iib(doD As Double, DoT As Double, toT As Double) As Double
RoT = DoT / 2
flexchar = 3.1 / RoT
iout = 0.9 / (flexchar ^ (2 / 3))
If iout < 1 Then iout = 1
iin = iout * 0.75 + 0.25
If iin < 1 Then iin = 1
If doD < 1 Then
   If iin < (1 / toT) Then
      iin = 1
    Else
      iin = iin * toT
   End If
End If
If iin < 1 Then iin = 1
B313_swp_iib = iin
End Function

Function B313_swp_iob(doD As Double, DoT As Double, toT As Double) As Double
RoT = DoT / 2
flexchar = 3.1 / RoT
iout = 0.9 / (flexchar ^ (2 / 3))
If iout < 1 Then iout = 1
iin = iout * 0.75 + 0.25
If iin < 1 Then iin = 1
If doD < 1 Then
   If iin < (1 / toT) Then
      iout = iout / iin
    Else
      iout = iout * toT
   End If
End If
If iout < 1 Then iout = 1
B313_swp_iob = iout
End Function
```

6.1 Integrally reinforced branch welded-on fittings Sketch 2.6 SIFs

```
Function PRG_OLET_iib(doD As Double, DoT As Double, toT As Double) As Double
SIFchk = PRG_BR_ii(doD, DoT, toT)
RoT = DoT / 2
rorp = 0.85
SIF = (0.08 + 1.28 * doD - 2.35 * doD ^ 2 + 1.45 * doD ^ 3) * RoT ^ 0.81 * toT * rorp
If doD > 0.99 Then SIF = SIF * 0.75
PRG_OLET_iib = SIF
If SIFchk < SIF Then
    SIF = SIFchk
    PRG_OLET_iib = SIF
End If
End Function

Function PRG_OLET_iob(doD As Double, DoT As Double, toT As Double) As Double
SIFiib = PRG_OLET_iib(doD, DoT, toT)
SIFchk = PRG_BR_io(doD, DoT, toT)
RoT = DoT / 2
rorp = 0.85
SIF = (1.83 * doD - 1.07 * doD ^ 3) * RoT ^ 0.82 * toT * rorp ^ 1.18
If doD > 0.99 Then SIF = SIF * 0.75
PRG_OLET_iob = SIF
If PRG_OLET_iob < SIFiib Then
    PRG_OLET_iob = SIFiib
    SIF = PRG_OLET_iob
End If
If SIFchk < SIF Then
    SIF = SIFchk
    PRG_OLET_iob = SIF
End If
End Function

Function PRG_OLET_itb(doD As Double, DoT As Double, toT As Double) As Double
SIFchk = PRG_BR_it(doD, DoT, toT)
RoT = DoT / 2
rorp = 0.85
SIF = 0.77 * RoT ^ (2 / 3) * toT * doD ^ 2 * rorp
If doD > 0.99 Then SIF = SIF * 0.75
PRG_OLET_itb = SIF
If SIFchk < SIF Then
    SIF = SIFchk
    PRG_OLET_itb = SIF
End If
End Function

Function PRG_OLET_iib_rorp(doD As Double, DoT As Double, toT As Double, rorpUSE As Double) As Double
SIFchk = PRG_BR_ii(doD, DoT, toT)
RoT = DoT / 2
SIF = (0.08 + 1.28 * doD - 2.35 * doD ^ 2 + 1.45 * doD ^ 3) * RoT ^ 0.81 * toT * rorpUSE
PRG_OLET_iib_rorp = SIF
If SIFchk < SIF Then
    SIF = SIFchk
    PRG_OLET_iib_rorp = SIF
End If
End Function

Function PRG_OLET_iob_rorp(doD As Double, DoT As Double, toT As Double, rorpUSE As Double) As Double
SIFiib = PRG_OLET_iib_rorp(doD, DoT, toT, rorpUSE)
SIFchk = PRG_BR_io(doD, DoT, toT)
RoT = DoT / 2
SIF = (1.83 * doD - 1.07 * doD ^ 3) * RoT ^ 0.82 * toT * rorpUSE ^ 1.18
If doD > 0.99 Then SIF = SIF * 0.75
PRG_OLET_iob_rorp = SIF
If PRG_OLET_iob_rorp < SIFiib Then
    PRG_OLET_iob_rorp = SIFiib
    SIF = PRG_OLET_iob_rorp
End If
If SIFchk < SIF Then
    SIF = SIFchk
    PRG_OLET_iob_rorp = SIF
End If
```

```
End Function

Function PRG_OLET_itb_rorp(doD As Double, DoT As Double, toT As Double, rorpUSE As Double) As Double
SIFchk = PRG_BR_it(doD, DoT, toT)
RoT = DoT / 2
SIF = 0.77 * RoT ^ (2 / 3) * toT * doD ^ 2 * rorpUSE
If doD > 0.99 Then SIF = SIF * 0.75
PRG_OLET_itb_rorp = SIF
If SIFchk < SIF Then
    SIF = SIFchk
    PRG_OLET_itb_rorp = SIF
End If
End Function

Function PRG_OLET_iih(doD As Double, DoT As Double, toT As Double) As Double
SIFioh = PRG_OLET_ioh(doD, DoT, toT)
SIFchk = PRG_Hdr_ii(doD, DoT, toT)
RoT = DoT / 2
SIF = RoT ^ 0.43 * doD ^ 0.2
If SIF < 1.5 Then SIF = 1.5
PRG_OLET_iih = SIF
If PRG_OLET_iih < SIFioh Then
    PRG_OLET_iih = SIFioh
    SIF = PRG_OLET_iih
End If
If SIFchk < SIF Then
    SIF = SIFchk
    PRG_OLET_iih = SIF
End If
End Function

Function PRG_OLET_ioh(doD As Double, DoT As Double, toT As Double) As Double
SIFchk = PRG_Hdr_io(doD, DoT, toT)
RoT = DoT / 2
SIF = (0.02 + 0.88 * doD - 2.56 * doD ^ 2 + 2.58 * doD ^ 3) * RoT ^ 0.43
PRG_OLET_ioh = SIF
If SIFchk < SIF Then
    SIF = SIFchk
    PRG_OLET_ioh = SIF
End If
End Function

Function PRG_OLET_ith(doD As Double, DoT As Double, toT As Double) As Double
SIFchk = PRG_Hdr_it(doD, DoT, toT)
RoT = DoT / 2
SIF = 1.3 * RoT ^ (0.45) * doD ^ 1.37
PRG_OLET_ith = SIF
If SIFchk < SIF Then
    SIF = SIFchk
    PRG_OLET_ith = SIF
End If
End Function
```

6.2 Integrally reinforced branch welded-on fittings Sketch 2.6 Flexibility Factors

```
Function PRG_OLET_kib(doD As Double, DoT As Double, toT As Double) As Double
kchk = PRG_BR_ki(doD, DoT, toT)
RoT = DoT / 2
k = (0.55 * doD - 1.13 * doD ^ 2 + 0.69 * doD ^ 3) * RoT * toT
PRG_OLET_kib = k
If kchk < k Then
    k = kchk
    PRG_OLET_kib = k
End If
End Function

Function PRG_OLET_kob(doD As Double, DoT As Double, toT As Double) As Double
kchk = PRG_BR_ko(doD, DoT, toT)
RoT = DoT / 2
k = (1.03 * doD - 1.55 * doD ^ 2 + 0.59 * doD ^ 3) * RoT ^ 1.4 * toT * doD ^ 0.33
PRG_OLET_kob = k
If kchk < k Then
    k = kchk
    PRG_OLET_kob = k
End If
End Function

Function PRG_OLET_ktb(doD As Double, DoT As Double, toT As Double) As Double
kchk = PRG_BR_kt(doD, DoT, toT)
RoT = DoT / 2
k = (0.37 * doD - 0.75 * doD ^ 2 + 0.46 * doD ^ 3) * RoT * toT * doD ^ 1.2
PRG_OLET_ktb = k
If kchk < k Then
    k = kchk
    PRG_OLET_ktb = k
End If
End Function

Function PRG_OLET_kih(doD As Double, DoT As Double, toT As Double) As Double
kchk = PRG_Hdr_ki(doD, DoT, toT)
RoT = DoT / 2
k = 0.5 * RoT ^ 0.5 * doD ^ 5
PRG_OLET_kih = k
If kchk < k Then
    k = kchk
    PRG_OLET_kih = k
End If
End Function

Function PRG_OLET_koh(doD As Double, DoT As Double, toT As Double) As Double
k = 1
PRG_OLET_koh = k
End Function

Function PRG_OLET_kth(doD As Double, DoT As Double, toT As Double) As Double
kchk = PRG_Hdr_kt(doD, DoT, toT)
RoT = DoT / 2
k = 0.1 * RoT * doD ^ 5.7
PRG_OLET_kth = k
If kchk < k Then
    k = kchk
    PRG_OLET_kth = k
End If
End Function
```

6.3 B31.3 Integrally reinforced branch welded-on fittings

```
Function B313_iihOlet(doD As Double, DoT As Double, toT As Double) As Double
io = 0.9 * (DoT / 2# / 3.3) ^ (2# / 3#)
ii = io
If io < 1 Then io = 1
If ii < 1 Then ii = 1
B313_iihOlet = ii
End Function

Function B313_iohOlet(doD As Double, DoT As Double, toT As Double) As Double
io = 0.9 * (DoT / 2# / 3.3) ^ (2# / 3#)
ii = io
If io < 1 Then io = 1
If ii < 1 Then ii = 1
B313_iohOlet = io
End Function

Function B313_iibOlet(doD As Double, DoT As Double, toT As Double) As Double
B313_iibOlet = B313_iobOlet(doD, DoT, toT)
End Function

Function B313_iobOlet(doD As Double, DoT As Double, toT As Double) As Double
io = 0.9 * (DoT / 2# / 3.3) ^ (2# / 3#)
ii = 0.75 * io + 0.25
If doD < 1 Then
    If ii < (1 / toT) Then
        io = io / ii
        ii = 1#
    Else
        ii = ii * toT
        io = io * toT
    End If
End If
If io < 1 Then io = 1
If ii < 1 Then ii = 1
B313_iobOlet = io
End Function

Function WeldOn_io(doD As Double, DoT As Double, toT As Double, rorp As Double) As Double
If doD <= 0.9 Then
    ro_or = 1# + toT / (doD * DoT)
    SIF = 1.5 * (DoT / 2) ^ (2 / 3) * (doD) ^ 0.5 * toT * rorp
Else
    doDUSE = 0.9
    ro_or = 1# + toT / (doDUSE * DoT)
    SIF09 = 1.5 * (DoT / 2) ^ (2 / 3) * (doDUSE) ^ 0.5 * toT * rorp

    sif10 = 0.9 * (DoT / 2) ^ (2 / 3) * rorp
    If doD < 1 Then
        SIF = (sif10 - SIF09) / 0.1 * (doD - 0.9) + SIF09
    Else
        SIF = sif10
    End If
End If
If SIF < 1.5 Then SIF = 1.5
WeldOn_io = SIF
End Function
```

7.0 Utility Functions

```
Function rorpx(doD As Double, DoT As Double, toT As Double) As Double
RoT = DoT / 2
dovert = doD * DoT / toT
toverd = 1 / dovert
rorpx = 1 / (1 + toverd)
End Function
```

ANNEX H - CALCULATIONS TO REVIEW SOME ASPECTS OF EPRI TR-1006227

Summary:
The EPRI document TR-1006227, titled "Investigation of Stress Intensification Factors and Directionality of Loading for Branch connections" contains inplane and outplane fatigue tests for 8x2 unreinforced and pad reinforced fabricated tees. The report also contains tests for skewed fatigue loadings and results from finite element analyses.

Section 3 – "Experimental Loading" of the TR-1006227 document describes the test program and indicates that the run pipe is 8.625 inch outside diameter with a 0.188 inch wall thickness. The report also indicates that the Material Test Records for the pipe are included in Appendix A. The material described in Appendix A is for 8.625 x 0.322 inch pipe.

The calculations and review included here attempts to determine which pipe wall thickness was used in the test. The determination is attempted by comparing dates from similar EPRI reports, by comparing results in TR-1006227 with shell finite element results and by comparing with identical specimen fatigue tests documented in EPRI 110996.

Comparing single data points or tests do not provide enough information to draw a definitive conclusion. Trends developed between the different test results for both the SIF and flexibility factors suggest that there was some material difference between the reported identical outplane 8x2 unreinforced fabricated tee test assemblies described in EPRI documents 110996 and TR-1006227.

Notes:

1) Dates on reports and MTR's suggest that 0.322 wall run pipe was available for the TR-1006227 tests.
2) The assembly stiffness is controlled by:
    a. The stiffness of the 2" branch pipe
    b. The local stiffness of the 8x2 intersection
3) The stiffness of the 2" branch pipe is a function of the branch pipe length cubed ($\delta = FL^3/(3EI)$)
4) The calculated beam stiffness contribution to the assembly stiffness ranges from 1.2 to 2.2 times the measured assembly stiffness suggesting that a stiffness contribution due to local deflection of the 8" pipe surface should be discernable from the test results, although perhaps with only order of magnitude accuracy since the results are sensitive to the branch length which varies slightly between tests. (See "L" in Fig 5, Chart A, and Table 8.)
5) The reported i-factors and load-deflection slopes for reportedly "identical" tests in EPRI documents TR-1006227 and TR-110996 show differences in i-factors and k-factors that are difficult to resolve without assuming that there is a geometry difference of some kind. (See Table 2.)
6) Even though k-factors are shown to be sensitive to dimensions that are potentially not well known, this sensitivity does not affect i-factors that are a function of load and cycles. There is some degree of uncertainty introduced in the i-factors due to the low cycle nature of some of the tests.
7) Chart A (included below) suggests that the (4) outplane unreinforced fabricated tee tests reported in EPRI 110996 likely came from a run pipe with a 0.188" wall while the (2) outplane unreinforced fabricated tee tests reported in TR-1006227 likely came from a run pipe with a 0.322" wall.

Details:
Wais conducted a number of fatigue tests for EPRI in the period from 1996 through 2002. Details of some of these tests are listed in Table 1 below:

Table 1 – Selected Test Pipe and Dates

Document	Title	Report Date	8" Mtr Date	8" Pipe (Reported)	Mtr 8" Pipe
110996	Wais,E.A., and Rodabaugh,E.C., *Stress Intensification Factors and Flexibility Factors for Unreinforced Branch Connections*, TR_110996 Final Report, Issued November 1998.	Nov 1998	Jan 1997	8x0.188	8x0.188
110755	Wais, E. A., and Rodabaugh, E.C., *Stress Intensification Factors and Flexibility Factors for Pad-Reinforced Branch Connections*, EPRI report TR-110755, 1998.	Nov 1998	Jul 1996	8x0.25	8x0.25
1006227	Wais, E. A., and Rodabaugh, E.C., *Investigation of Stress Intensification Factors and Directionality of Loading for Branch Connections,* EPRI report TR-1006227, 2001.	Sept 2001	Jul 2000	8x0.188	8x0.322

The EPRI TR-1006227 report includes results from outplane tests of two 8x2 unreinforced fabricated tees whose assemblies are identical to four reported EPRI 110996 outplane tests of 8x2 unreinforced fabricated tees (UFT). The comparable results for these outplane SIF tests are given in Table 2 below:

Table 2 – EPRI TR-110996 and TR-1006227 Results Comparison

Test Reference	Test i-factor	Load-Deflection Slope	Test k-factor (Calculated)	Cycles to Failure (N)	Test i Adjusted per Hinnant [19]
110996 A	3.150	124	13.43	459	5.33
110996 B	3.450	125	13.43	754	5.45
110996 C	3.880	123	13.43	923	5.97
110996 D	3.840	123	13.43	1816	5.39
1006227 Outplane UFT #1	2.4	225	6.49	546	3.964
1006227 Outplane UFT #2	2.28	237	6.525	1225	3.376
Average	3.167				4.913
Std Dev	0.6952				1.007
110996 A	3.150	124	13.43	459	5.33
110996 B	3.450	125	13.43	754	5.45
110996 C	3.880	123	13.43	923	5.97
110996 D	3.840	123	13.43	1816	5.39
Average	3.58				5.53
Std Dev	0.346				0.294
1006227 Outplane UFT #1	2.4	225	6.49	546	3.964
1006227 Outplane UFT #2	2.28	237	6.525	1225	3.376
Average	2.34				3.67
Std Dev	0.085				0.415

The EPRI 1006227 report in Section 3.4 on page 3-2 states, "The unreinforced configuration is identical to that used in the tests discussed in TR-110996 [10]." Dimensions and figures from each of the documents are shown below. Reinforced fabricated tees (RFT) were also evaluated in TR-1006227, and some of these results are reported here also for comparison.

The test k-factors presented below were calculated by PRG and are found by:

1) Estimating the stiffness of the beam model assembly used in the test, and
2) Calculating the k-factor from: $k = (1/K_{test} – 1/K_{beam}) (EI/(L^2 d)$

k – branch connection flexibility factor
K_{test} – assembly stiffness reported in EPRI test report
K_{beam} – assembly stiffness calculated using only 6dof beam elements and no local intersection stiffnesses
E – modulus of elasticity
I – moment of inertia of the branch pipe
L – distance measured along the centerline of the branch pipe from the point of application of the load to the surface of the run pipe.
d – diameter of the branch pipe

These results can be compared to finite element calculations for the 8x2 pipe intersection for the two different run pipe wall thicknesses:

Table 3 – FEA Results for Comparison with i- and k-factors from 8x2 UFT Fatigue Tests

Pipe	FEA i-factor (FE/Pipe 7.0)	FEA k-factor (FE/Pipe 7.0)	Widera i-factor [14] [1]	Wais i-factor Ref [10]	PRG [Report] i-factor (R70)
8x0.322 x 2x0.065	2.495	3.108	3.09	2.001	3.35
8x0.188 x 2x0.065	4.453	9.348	4.047	4.2546	5.803

[1] The i-factor is found from shell finite element models in a manner similar to that used by Wais [10].

An example of a shell FEA model used in this evaluation is shown below in Figure A. FE/Pipe V.7 was used for this calculation.

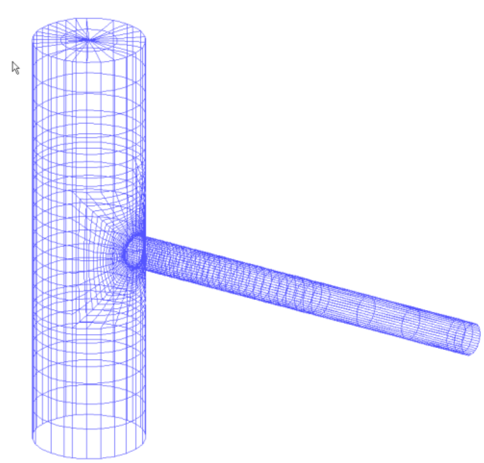


Figure A – Example of Shell FEA Model Used in Comparison Calculations

A picture of the test facility is included on the front of the EPRI TR-1006227 document and gives an idea of the test configuration used.

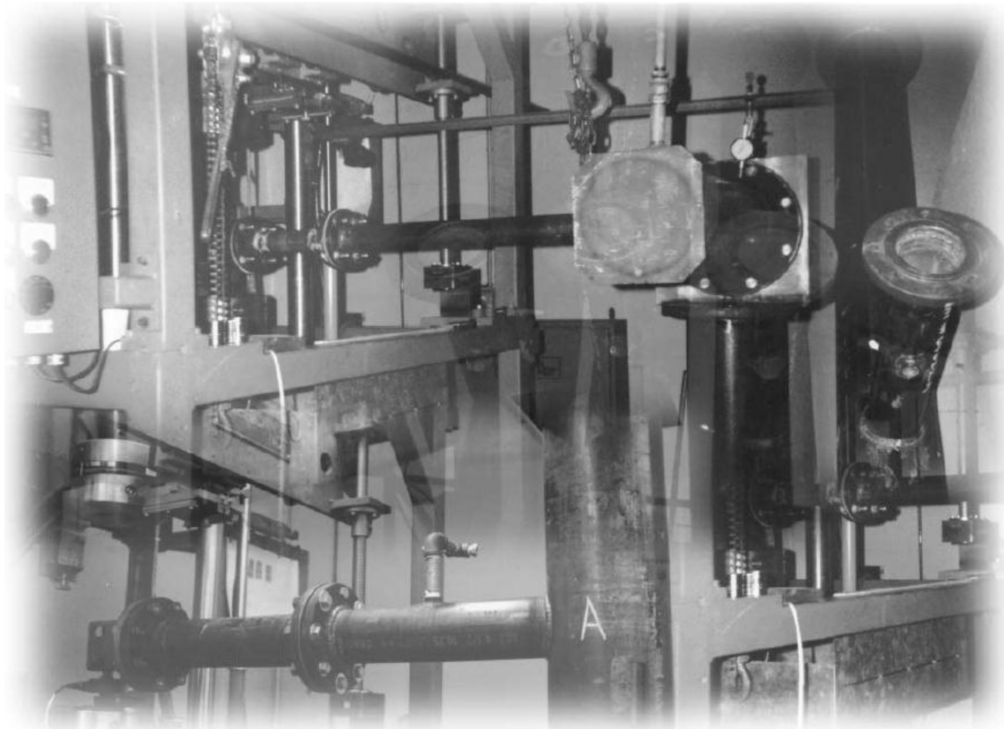


Figure B – Picture from Front of EPRI 1006227 Showing Test Assemblies

A figure from a companion paper [2] written by Wais and Rodabaugh to describe the TR-110996 document tests is reproduced below. This figure is identical to Fig. 2-2 in TR-110996.

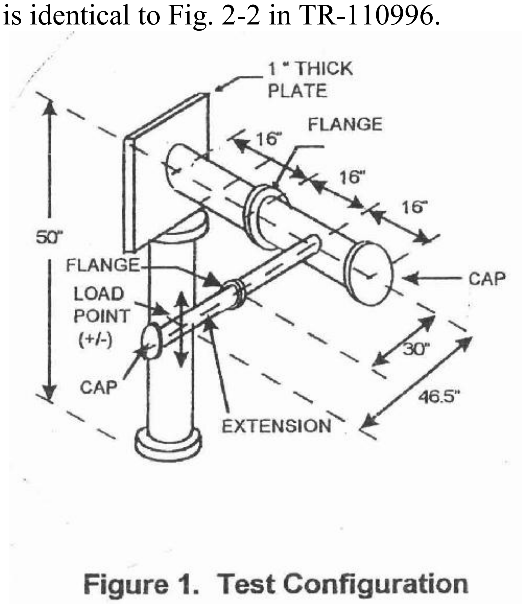


Figure C – EPRI 110996 Test Assembly Sketch from Ref. [2]

The stiffness results are sensitive to the length of the branch pipe, shown in Figure C from the centerline in the figure above as 46.5". The actual dimension for the length used in each of the load deflection tests is given in EPRI 110996, and TR-1006227 test reports. The actual dimensions were used for the stiffness calculations made here.

A sketch from the TR-1006227 document in Figure D below does not appear to include the additional 16" extension of 8" pipe seen in the figure above. This is not considered significant however, since the flexibility of the smaller 2" pipe and the local intersection have a much greater affect on the displacement of the assembly than the thickness of the 8" pipe.

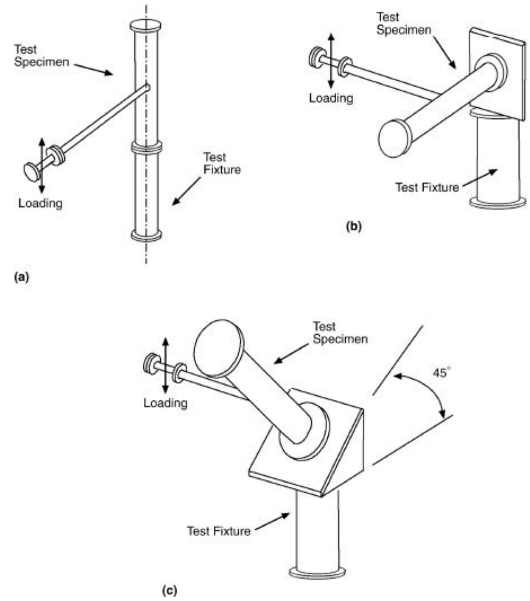


Figure 3-1
Test Configuration (a) In-Plane Loading, (b) Out-of-Plane Loading, and (c) Combined In-Plane and Out-of-Plane Loading

Figure D – Test Assembly Sketch from TR-1006227

The following sketch from TR-1006227 shows dimensions equivalent to those in the 110996 document.

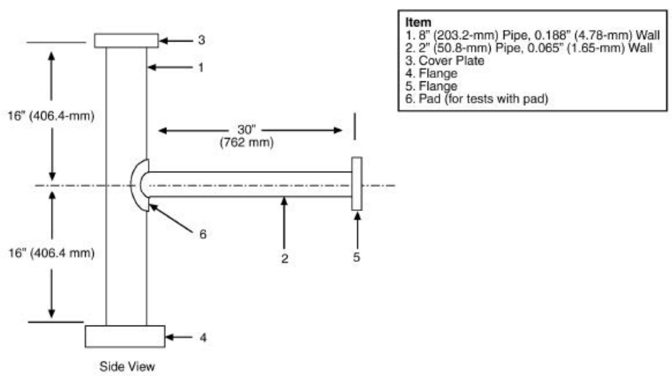


Figure 3-2
Test Specimens

Figure E – Detailed Dimensions of Assembly from TR-1006227

The local test "stiffness" of the assembly can be read from the load deflection diagrams recorded for the SIF test. These assembly stiffnesses are given below from TR-1006227:

Table 4 – Load-Deflection Results from TR-1006227

	Load Deflection Slopes Specimen #1					Load Deflection slopes Specimen #2				
	Test#1	Test#2	Test#3	Test#4	Fat#1	Test #1	Test#2	Test#3	Test#4	Fat#1
UFT inpl	299	311	302	308	305	316	330	303	324	318
UFT outp	218	237	211	235	225	228	246	222	251	237
RFT outp	305	311	283	295	298					
RFT inpl	358	365	332	347	351					

There are 4 sequences of loading for each test model, two in the positive direction and two in the negative. These are labeled Test#1 through Test#4. The Fat# given in Table 4 is the load deflection slope used for the fatigue test and is the average of the four load-deflection tests. There were two models for each loading direction for the UFT, and one model for each loading direction for the RFT.

Stiffnesses were computed for the UFT and RFT assemblies using shell FEA models. The model has the same dimensions as given Figure 3-2 above although the length to the point of application of the load is taken for each test from TR-1006227. This distance from the surface of the run pipe to the point of application of the load is given as the dimension "L" in Table 5 below.

Table 5 – FEA Assembly Stiffness Compared to Measured Assembly Stiffness

	A	B	C	D	E	F	G
1					From		
2				1006227	Surface		
3		Dir	Ref	Ktest	L	Kfea	%Error
4		inplane	UFT 188	305	40.9065	261	0.1543
5		inplane	UFT 322	305	40.9065	352	-0.1420
6		inplane	RFT 188 Tp=.188	351	41.2815	349	0.0053
7		inplane	RFT 322	351	41.2815	416	-0.1686
8							
9				1006227			
10		Dir	Ref	Ktest	L	Kfea	
11		outplane	UFT 188	225	39.9065	151	0.3956
12		outplane	UFT 322	225	39.9065	284	-0.2335
13		outplane	RFT 188	298	41.7815	247	0.1868
14		outplane	RFT 322	298	41.7815	362	-0.1934
15							
16							
17		Dir	110996	Specimen	Ktest		
18		outplane	UFT 188	A	124		
19		outplane	UFT 188	B	125		
20		outplane	UFT 188	C	123		
21		outplane	UFT 188	D	123		
22							

The results from Table 5 calculations seem inconclusive. Table 5 Rows 4 and 5 suggest that the FEA shell model stiffness of the test assembly with a 0.188 wall run pipe thickness is 15% lower than the tested stiffness, while the FEA shell model stiffness of the test assembly with a 0.322 wall run pipe thickness is 14% higher than the tested stiffness. One might expect the shell FEA model would have a higher assembly stiffness because there is no local base flexibilities included in the model. PRG experience with 4x4 UFT Markl-style tests does not support this general trend however. A 10% difference in stiffness between shell calculated and measured results from fabricated piping component tests is not unexpected.

The flexibility calculations for FEA models with 0.125" fillet legs along both the branch and run pipe are given for the 0.188 wall run pipe assembly in Table 6 below for comparison. In this case, the inplane test stiffness (row 48 in Table 6 below), matches the FEA model with a 0.188 run pipe wall to within 0.7%, and changes the outplane test stiffness comparison to 18.6% from 39% shown above.

Table 6 – Adjusted FEA Assembly Stiffnesses for 0.125" Weld Length and 0.188 Wall Run Pipe

	A	B	C	D	E	F	G
45							
46		Add 0.125" Weld Leg			From		
47				1006227	Surface		
48		Dir	Ref	Ktest	L	Kfea	%Error
49		inplane	UFT 188	305	40.9065	303	0.0071
50		inplane	RFT 188 Tp=.188	351	41.2815	370	-0.0537
51							
52				1006227			
53		Dir	Ref	Ktest	L	Kfea	
54		outplane	UFT 188	225	39.9065	187	0.1864
55		outplane	RFT 188	298	41.7815	270	0.0981
56							

If the TR-1006227 test was actually performed with 0.322 wall pipe, the test assembly stiffness can be replicated by using 0.188 wall pipe with a 0.125" wall weld. This perspective is important when evaluating the "identical"

110996 test results that show an identical test assembly stiffness of 125 lb/in., instead of the 225 lb/in. that was matched above.

A Table 6a could be produced for the 0.322 wall pipe that would include a base stiffness. The additional flexibility is needed for the 0.322 wall pipe since the FEA calculation shows a 23% stiffer assembly for the outplane test.

Flexibility Calculations (k-factors):
The equation relating the local stiffness of the intersection to the total displacement at the point of application of the load through the branch and the flexibility factor (k) is:

$k = (1/K_{test} - 1/K_{beam})\ (EI/(L^2\ d)$

$I = \pi/64(2.5^4 - 2.37^4) = 0.36878$ in.^4

$k = (1/K_{test} - 1/K_{beam})(29e6)(0.36878)/(L^2x2.5)$

Table 7 – Computed k-Factors for TR-1006227 Test

	A	B	C	D	E	F	G	H	I	J
24										
25		1006227			UFT	UFT	UFT			
26		Dir		L	Kbeam	Ktest	k-factor	E	I	d
27		outplane	Beam 188	39.9065	492.997	225	6.490	2.90E+07	0.36878	2.5
28		outplane	Beam 322	39.9065	496.1646	225	6.525	2.90E+07	0.36878	2.5
29								2.90E+07	0.36878	2.5
30		inplane	Beam 188	40.9065	460.0303	305	2.825	2.90E+07	0.36878	2.5
31		inplane	Beam 322	40.9065	462.1478	305	2.850	2.90E+07	0.36878	2.5
32										
33		1006227			RFT	RFT	RFT			
34		Dir		L	Kbeam	Ktest	k-factor	E	I	d
35		outplane	Beam 188	41.7815	430.2278	298	2.527	2.90E+07	0.36878	2.5
36		outplane	Beam 322	41.7815	432.8367	298	2.562	2.90E+07	0.36878	2.5
37								2.90E+07	0.36878	2.5
38		inplane	Beam 188	41.2815	447.7178	351	1.545	2.90E+07	0.36878	2.5
39		inplane	Beam 322	41.2815	449.7596	351	1.570	2.90E+07	0.36878	2.5
40										
41		1006227			RFT	RFT	RFT			
42		Dir		L	Kbeam	Ktest	k-factor	E	I	d
43		outplane	Beam 188	42.2815	408.0267	124	13.433	2.90E+07	0.36878	2.5

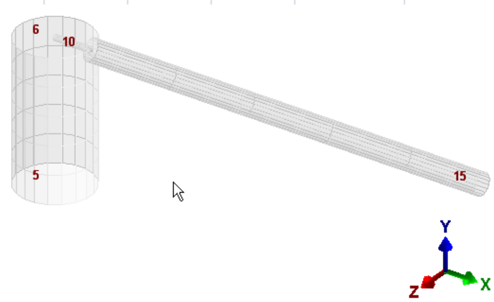


Figure F – Beam Model Layout (FE/Pipe V.7)

The length of the FEA shell models can be varied to determine which run pipe thickness likely corresponds with the tests reported. It is most likely that the length of the branch pipe used for all tests is in the range of 39 to 42 inches when measured from the surface of the run pipe. The assembly stiffnesses for the two outplane 8x2 UFT tests reported in TR-1006227 are 225 and 237 lb/in. The assembly stiffnesses for the four outplane 8x2 UFT tests reported in 110996 average 123.75 lb/in. The blue line in Chart A shows the calculated assembly stiffness as a function of the branch length for 0.322 wall run pipe FEA models, while the red line shows the calculated assembly stiffness as a function of the branch length for 0.188 wall run pipe FEA models.

Chart A shows that a 225 lb/in. assembly most likely comes from a 0.322 wall run pipe with a 44 in. length. Chart A also shows that a 124 lb/in. assembly most likely comes from a 0.188 wall run pipe with a 43 in. length. Chart A shows that if a 225 lb/in. assembly stiffness came from a 0.188 wall run pipe assembly, the length of the branch pipe to the point of application of the load would have to be approximately 33 in. in length.

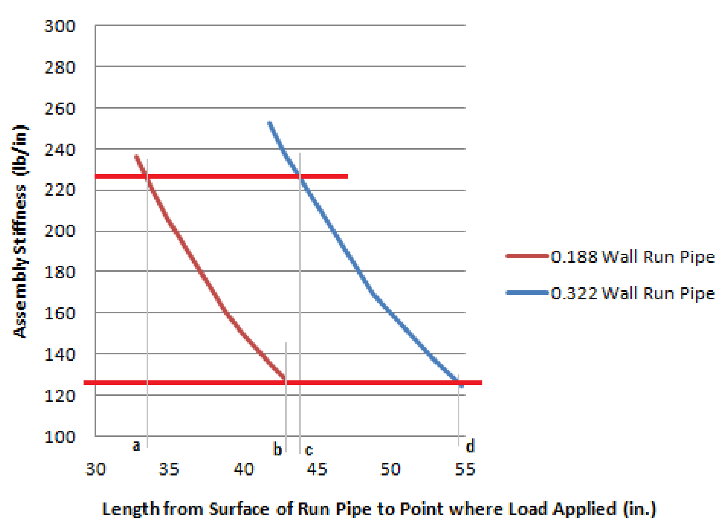
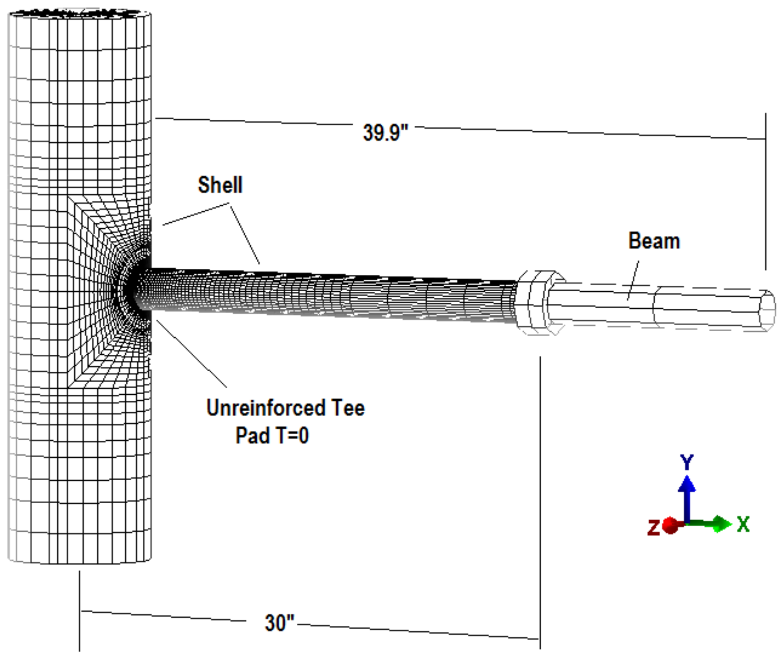


Chart A – FEA Assembly Stiffness From Shell FEA Analysis

Table 8 – FEA Model Sensitivity to Branch Pipe Length for Different Run Pipe Thicknesses

L Measured from Surface of Run Pipe			
No Weld in FEA Model			
Outplane Tests 8x2			
	0.188		0.322
L	K(FEA)		K(FEA)
32.8	235.8491		
33.8	220.3128		433.8395
34.8	206.1856		
38.8	160.7459		
39.8	151.607		
40.8	143.1844		
41.8	135.3913		252.589
42.8	128.1887		237.6991
48.8			169.1189
52.8			137.6462
54.8			124.7661

To make sure the results presented above are not sensitive to the branch model used, the shell model was modified to include the intermediate flange 30” from the centerline of the run pipe along the branch. This FEA model is shown below and should be compared to the 284 lb/in. assembly stiffness recorded for the branch length of 39.9 in. from the surface of the run pipe to the point of application of the load given in Table 5. The stiffness from detailed branch model below is 286.6 lb/in. and compares well with the results from FEA models that have a consistent branch wall throughout the entire branch length (Fig. A).



The lowest number of cycles to failure in the Markl test in the 110996 outplane i-factor test was 459. Hinnant and Paulin suggested that low cycle Markl tests might produce i-factors that are too low because the Markl girth butt weld curve is itself too low in the low cycle range. If this affect is present an additional uncertainty is involved in the i-factor development.

The Hinnant adjustment for i-factors given in Ref [19] is: $i_{adjusted} = i(1895/490)N^{-0.135}$.

Due to the magnitude of the i-factor and k-factor differences between the two identical tests being compared (110996 outplane UFT 8x2 test and TR-1006227 outplane UFT 8x2 test), and their calculated differences, it is believed likely that 0.322 wall pipe was used for some families of the tests reported in the TR-1006227 document.

ANNEX I - PRG UNREINFORCED FABRICATED TEE AND BLAIR (1936-1945) FATIGUE TESTS

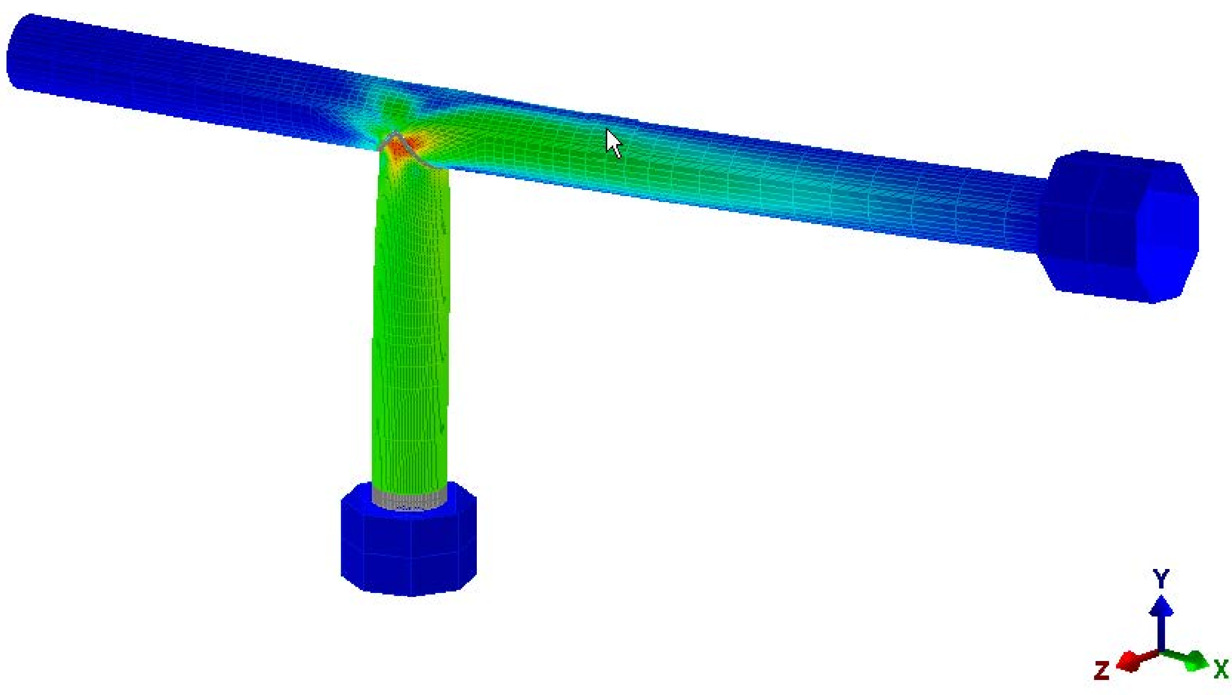
Chris Hinnant at PRG conducted several SIF tests on 4x4 standard wall unreinforced fabricated tee intersections on the Markl fatigue test frame at the PRG offices in Houston, Texas in 2006. This is the same test frame used by Kahn for his 1987 fatigue tests of piping components, [23][24][34] The results of those tests are included below along with some discussion of the stiffnesses found for those assemblies. In the ten year period from 1936 to 1945 Blair [36] conducted a series of fatigue tests on unreinforced, pad reinforced and triform intersections. The Blair tests are cited by Markl [27], but are presented in more detail here. The Hinnant/PRG test details have not been previously published.

The two unreinforced fabricated tees in the PRG Hinnant tests (Sketch 2.3) were intended to be identical. The outplane stiffness of the assembly was found from the load-deflection test. The stiffnesses from the test are given in the following table:

Test	Stiffness
#1	1700 lb/in.
#2	1640 lb/in.

The average stiffness is 1670 lb/in. and the standard deviation is 30 lb/in. The measured stiffnesses are within 1.8% of each other.

A shell model of the tested intersection is shown below. The stiffness with and without a weld leg is 1521 and 1596 lb/in.



Out-of-plane Fatigue Test #1
Conducted on December 3, 2006

A 4"x4" SCH 40 unreinforced tee intersection was tested to failure by alternating bending stress applied thru the run pipe. The fully reversed displacement was applied to one end of the run pipe, the branch pipe was rigidly fixed to the testing frame, and the other end of run pipe was free.

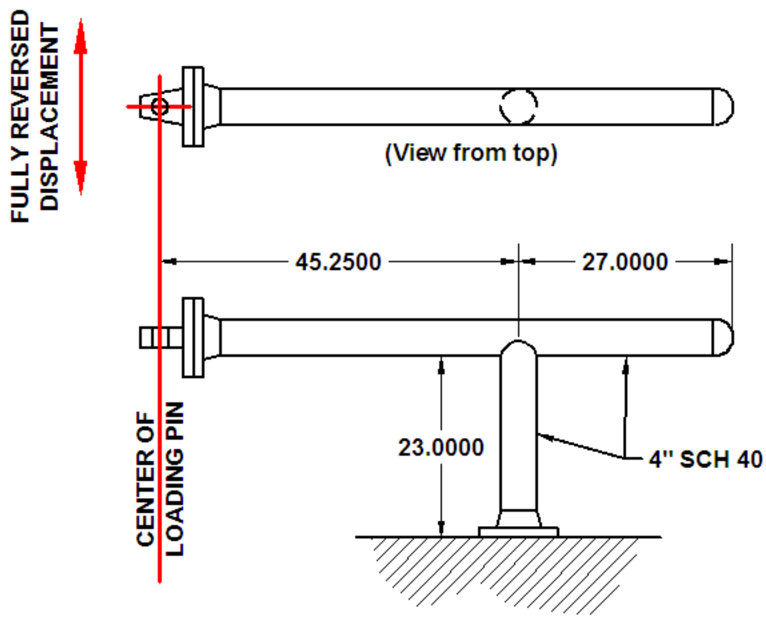
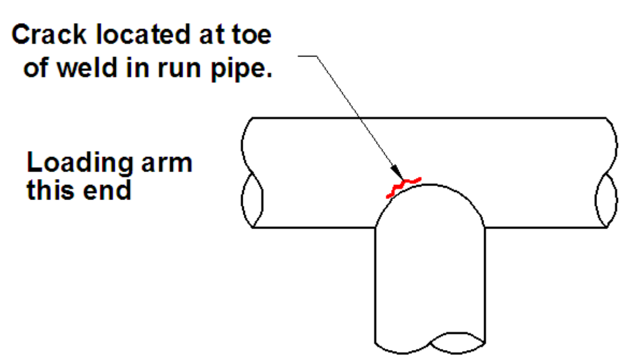


Figure 1 – Out-of-plane bending test geometry.

The load deflection curve for the geometry was determined to be that shown in Figure 2. The measured system stiffness is approximately 1,700 lbf/in. The stiffness as measured by linear elastic FEA is 1521/1596 lbf/in using 8 noded solid elements. A beam model of the same system yielded a linear elastic stiffness in excess of 2,000 lbf/in.

The first failure occurred in the run pipe at the toe of the weld joining the branch pipe to the run pipe. This failure occurred at 2,835 cycles. The second failure occurred at the same location, but on the other side of the junction with a cycle life of 3,956 cycles.



An alternating displacement of 0.72" was applied during the testing. This corresponds to an alternating load of approximately 1,225 lbf. With a lever arm of 45.25" from the loading pin to the middle of the branch pipe, this results in a nominal alternating bending stress of 17,245 psi. (The distance to the crack would have been a little less.)

The local alternating stress measured by strain gauges directly adjacent to the failure site was 96,352 psi. This stress was measured approximately 0.125” from the failure site.

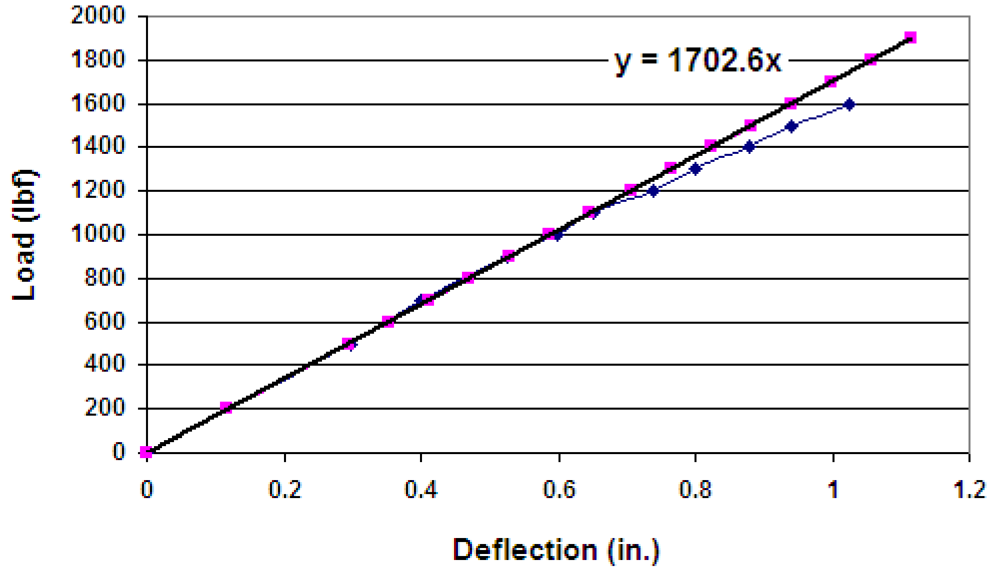


Figure 2 – Load deflection curve for out-of-plane bending test.

Based on the alternating nominal bending stress of 17,245 psi, the piping SIF associated with the two failures are:

$$i_f * 17245 = 245{,}000 * (2835^{-0.20}) \qquad \therefore \; i_f = 2.897$$

$$i_f * 17245 = 245{,}000 * (3731^{-0.20}) \qquad \therefore \; i_f = 2.742$$

The predicted SIF using design formulas developed by Markl:

$$SIF = \frac{0.90}{\left(\frac{t}{r_M}\right)^{2/3}} = \frac{0.90}{\left(\frac{0.237}{2.1315}\right)^{2/3}} = 3.89$$

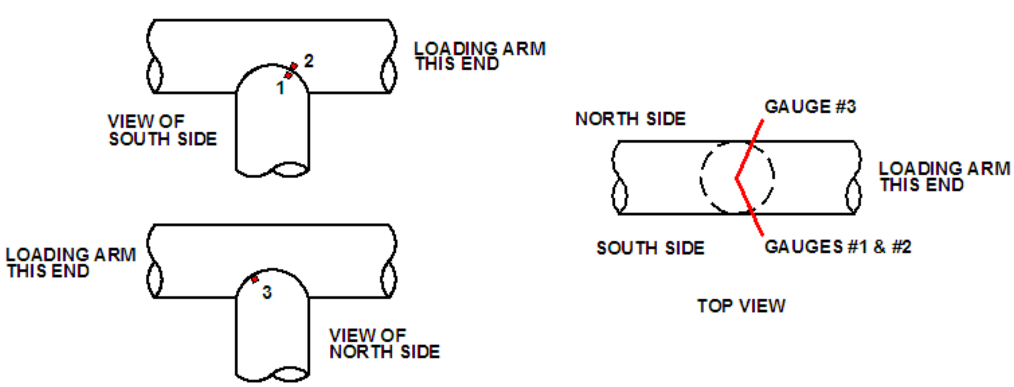


Figure 3 – Location of strain gauges for out-of-plane test #1.

Strain Gauge	Location	Maximum Measured Stress Range for 2 x 0.72" = 1.44" Displacement Range
1	Branch pipe adjacent to toe of weld near failure site (south side)	105,116 psi
2	Run pipe adjacent to toe of weld at failure site (south side)	192,705 psi
3	Branch pipe adjacent to toe of weld near failure site (north side)	111,202 psi

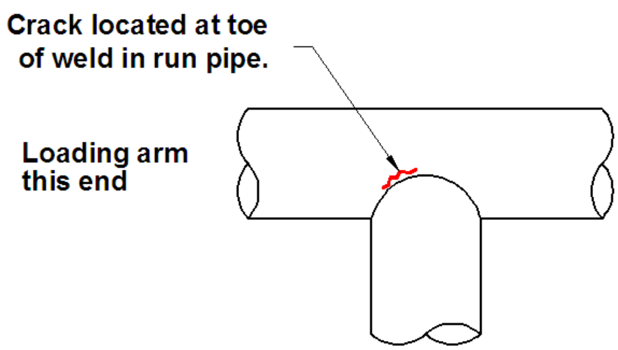
Out-of-plane Fatigue Test #2

Conducted on December 5, 2006

A 4"x4" SCH 40 unreinforced tee intersection was tested to failure by alternating bending stress applied thru the run pipe. The fully reversed displacement was applied to one end of the run pipe, the branch pipe was rigidly fixed to the testing frame, and the other end of run pipe was free.

The load deflection curve for the geometry was determined to be that shown in Figure 2. The measured system stiffness is approximately 1,640 lbf/in.

The first failure occurred on the south side of the specimen in the run pipe adjacent to the toe of the weld joining the branch pipe to the run pipe at 23,371 cycles.



An alternating displacement of 0.43" was applied during the testing. This corresponds to an alternating load of approximately 705 lbf. With a lever arm of 45.25" from the loading pin to the middle of the branch pipe, this results in a nominal alternating bending stress of 9,925 psi.

The local <u>alternating</u> stress measured by strain gauges directly adjacent to the failure site was 57,741 psi. This stress was measured approximately 0.125" from the failure site.

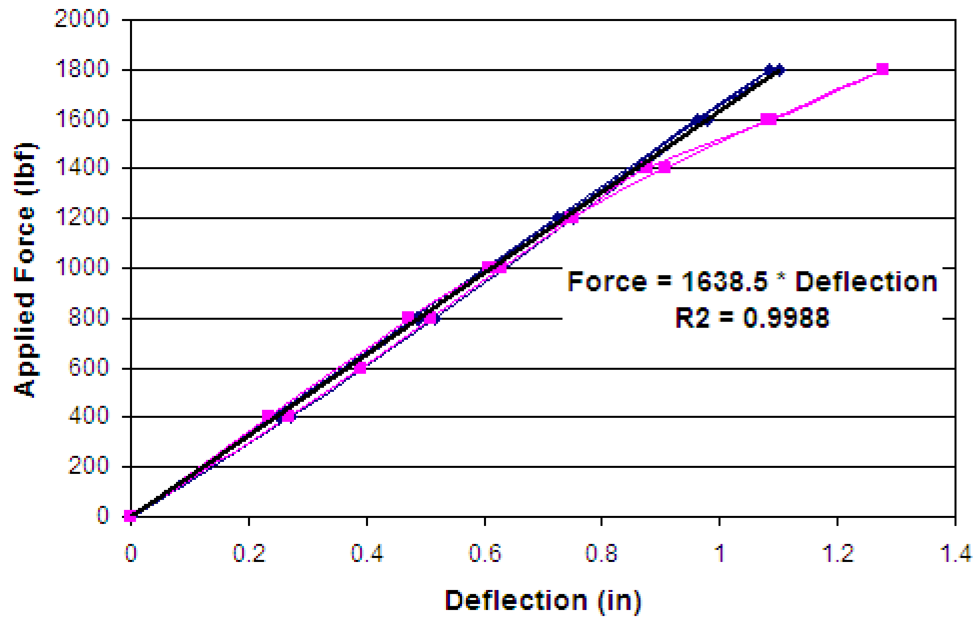


Figure 4 – Load deflection curve for out-of-plane bending test.

Based on the alternating nominal bending stress of 9,925 psi, the piping SIF associated with the two failures are:

$$i_f * 9{,}925 = 245{,}000 * (23371^{-0.20}) \qquad \therefore\ i_f = 3.30$$

The predicted SIF using design formulas developed by Markl would predict a SIF of:

$$SIF = \frac{0.90}{\left(\frac{t}{r_M}\right)^{2/3}} = \frac{0.90}{\left(\frac{0.237}{2.1315}\right)^{2/3}} = 3.89$$

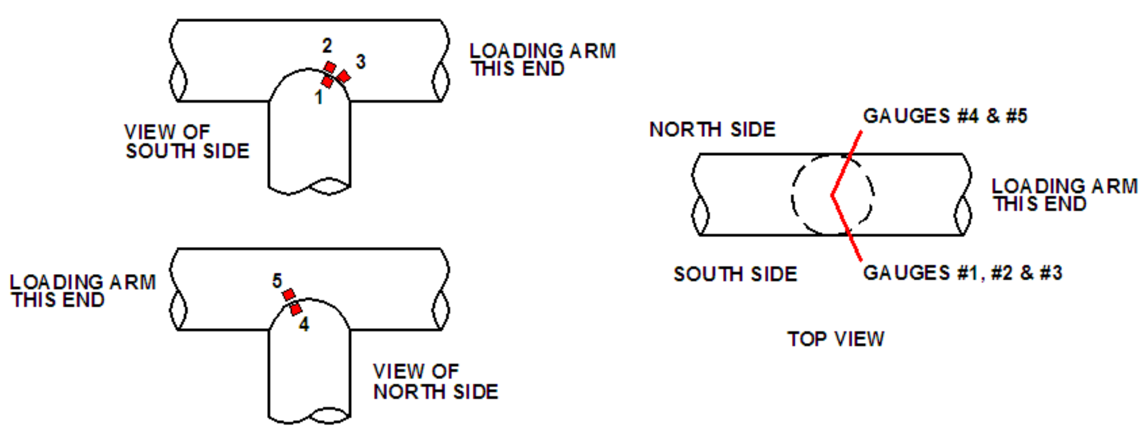


Figure 5 – Location of strain gauges for out-of-plane test #2.

Strain Gauge	Location	Maximum Measured Stress Range for 2 x 0.425” = 0.85” Displacement Range
1	Branch pipe adjacent to toe of weld near failure site (South side)	60,611
2	Run pipe adjacent to toe of weld at failure site (South side)	115,482
3	Run pipe adjacent to toe of weld at failure site (South side)	99,679
4	Branch pipe adjacent to toe of weld near failure site (North side)	55,720
5	Run pipe adjacent to toe of weld at failure site (North side)	72,091

PRG Out-of-plane Fatigue Tests Strain Gage Results

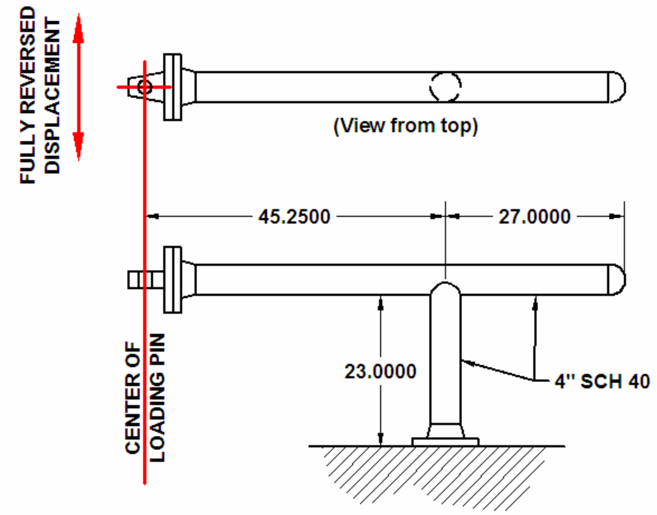
FEA Shell Results

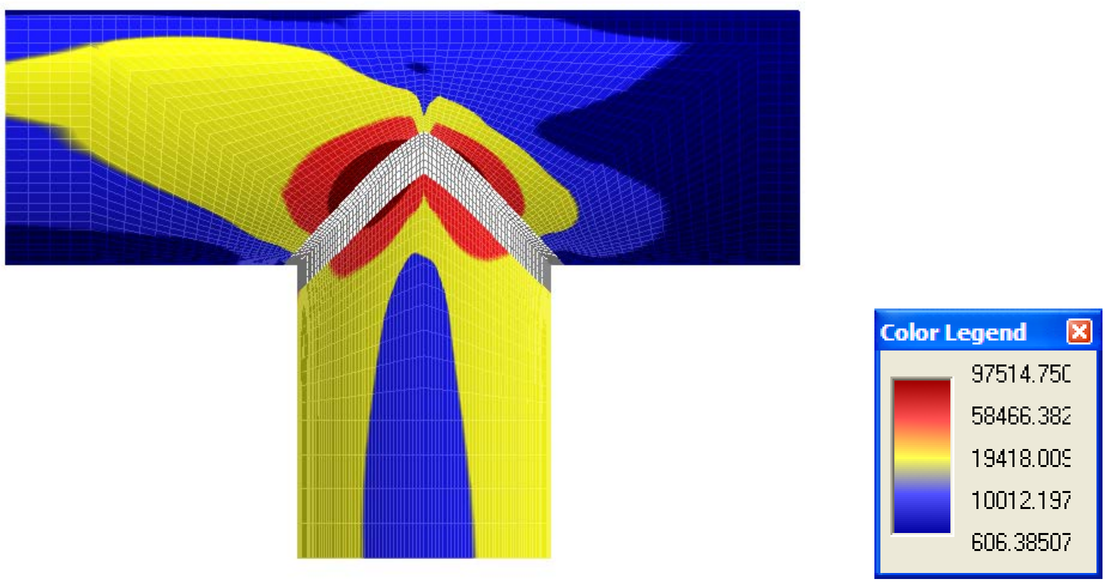
Applied force in FEA model = 0.7547 inches

Displacement at point of load = 1225 lbf

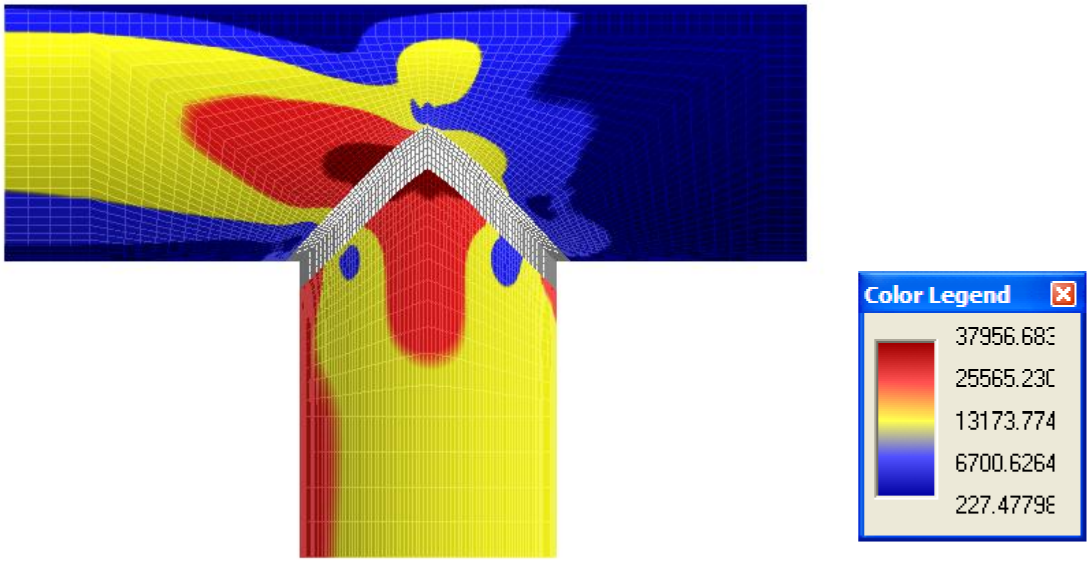
Moment arm to failure site = 45.25 inches

FEA models include weld leg length of 0.125 inches.

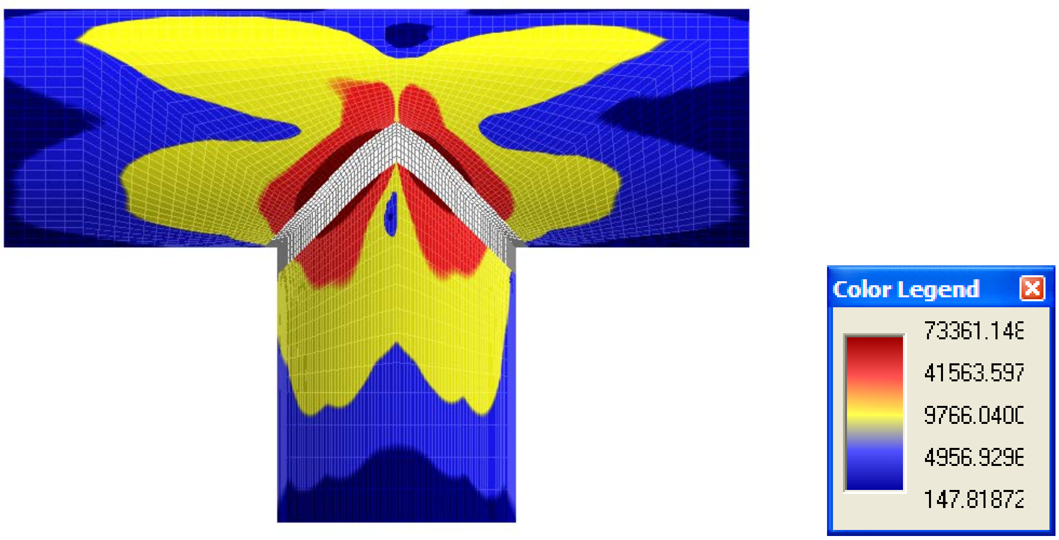




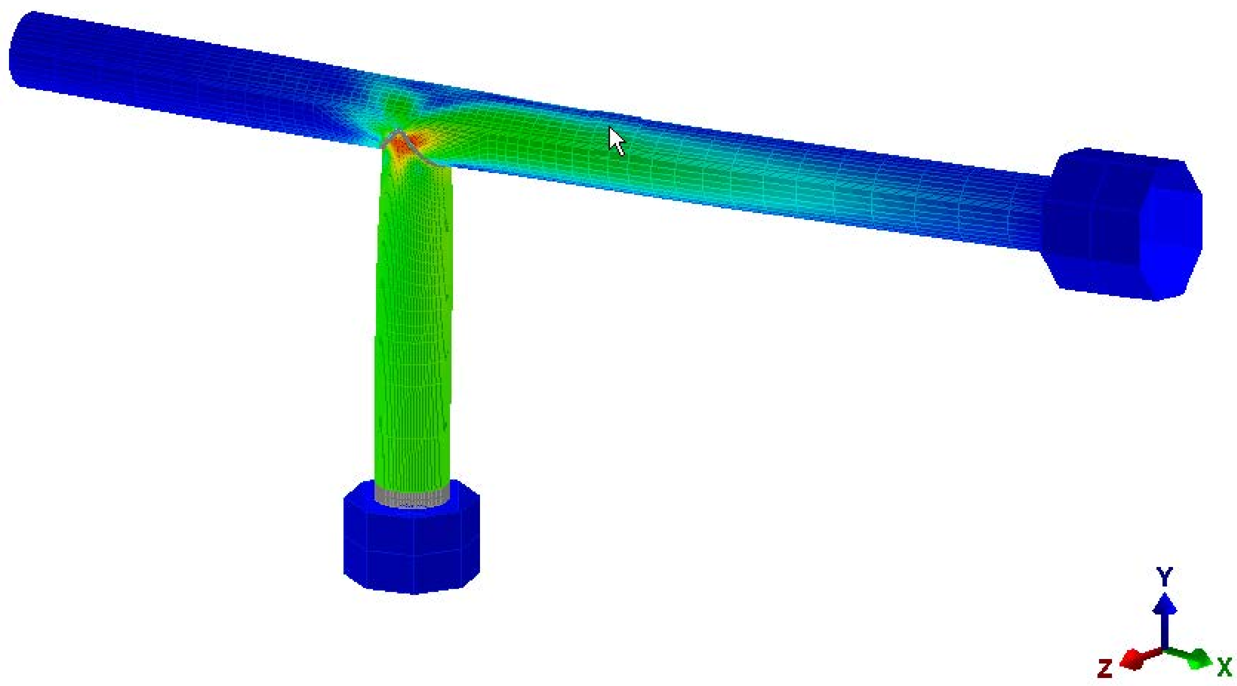
Alternating PL+Pb+Q at Crack Site = 97,514 psi



Alternating Maximum membrane stress at crack site = 30,854 psi



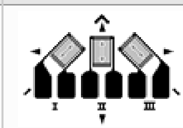
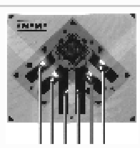
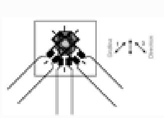
Alternating Maximum bending stress at crack site = 73,361 psi



Shell model (+beams for flanges and load end).

K(no weld) = 1521 lb/in.   K(weld leg=0.125) = 1596 lb/in.

Strain gages used in the test are Vishay 060WR shown below with a gage length of 0.06 inch.

Pattern	Datasheet	Strain Gage Pattern Image	Gage Geometry	Gage Series	Gage Resistance	Gage Length	Overall Pattern Length	Grid Width	Overall Pattern Width	Matrix Length	Matrix Width
031RB	Datasheet		RR	EA	120	0.031	0.085	0.031	0.175	0.19	0.24
				EP							
				SA							
031WW	Datasheet		RR	L2A	350	0.031	0.206	0.070	0.227	0.28	0.32
				C2A	120						
					350						
				L2A	120						
060WR	Datasheet		RR	SK	1000	0.06	0.240	0.060	0.300	0.24	0.30
				WK							
				SK	120						
				WK							
				SK	350						
				WK							
				SA	120						
				WA							

Blair (1936-1946) Fatigue Tests:

The Blair tests documented in reference [36] provide some of the earliest fatigue and load-deflection tests for unreinforced and pad reinforced branch connections in piping systems. The Blair tests of interest used 6.5 x 0.26" wall pipe. Over the ten year period from 1936 through 1946 Blair conducted dynamic shaker tests and a variety of load deflection tests on the unreinforced, pad reinforced and various triform and stiffened intersections.

This annex is not intended to provide a thorough discussion of the Blairs tests or results, but was included as a brief introduction to provide some additional information regarding the Blair tests sited by Markl [27].

The details of Blair's tests that apply to i-factor and k-factor development for branch connections are given below.

1)The Blair tests were vibration tests and static tests. A photograph of Blair's tests is included here. From the outside point of the run pipe to the point of application of the load is 44.75". From the centerline of the branch to the point of support is scaled from the photograph to be 22".

2)Blair tests labeled Ui 1, Ui 2 were set in nozzles. Uo 0, Uo1, Uo2 were set-on nozzles. CR types were compensating rings with pad reinforcement: CR 1, CR 2.

3)Blair tests were pressurized during vibration tests, and were principally in-plane load tests.

4)Tests were conducted over the 10 years: 1935 to 1945. The results and discussion were published in July of 1946 and over a number of volumes following the July publication. The report is in several parts.

5)There were anomalous results for the two CR tests. Each of the CR test specimens were of identical 6.5x0.26" pad reinforced (Blair's compensating ring) geometries. One of the tests produced Luder's lines in the epoxy coating when it was not pressurized instead of when it was pressurized (CR1). The other test (CR2) produced Luder's lines in the epoxy sooner when it was pressurized as Blair expected. The difference in these behaviors, Blair speculated was due to differences in thickness or fabrication not detected on inspection.

6)Blair's blind branch test was an interesting test suggesting that there is a point where increasing the thickness of the nozzle damages the junction due to the large increase in discontinuity. The i-factor that results is in between the unreinforced and pad reinforced tests. The flexibility of the blind branch test is shown to be twice that of the unreinforced tests and about four times that of the pad reinforced test which seems inconsistent with the specimen description. The run pipe internal opening was not removed, and a solid plug was included in the branch.

Blair gives displacements, loads and the load deflection diagram for his tests. To compute equivalent double pinned end run branch flexibility factors, a compatible beam model of the Blair system was constructed. A static load of 10,000 pounds was applied on the horizontal plane at the point of load application in the Blair models. The displacement results are given below for the beam model without any local flexibilities. The stiffness is 10,000/0.6603 = 15,144 lb./in.

Displacement Solution (Rotation in Degrees)

Load Case: 1 Type: SUSTAINED (Wgt) Fw

	X	Y	Z	RX	RY	RZ
5.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0438
10.0	0.0007	0.0000	0.0000	0.0000	0.0000	-0.1566
10.0	0.0007	0.0000	0.0000	0.0000	0.0000	-0.1566
15.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0438
10.0	0.0007	0.0000	0.0000	0.0000	0.0000	-0.1566
20.0	0.6603	0.0000	0.0000	0.0000	0.0000	-1.0725

Some extracted data from the Blair paper is given below. For clarification and nomenclature see ref. [36].

Taken from Blair Table VI

Test	Do	T	do	t	Q Factor	Alt Load	Z	Moment Arm	Alt Stress due to load	Cycles to Failure	Markl i-factor	Blair Sv Long Stress	Blair Stress Markl i-factor	R/T	d/D	t/T	PRG i-factor	Blair SRF
Uo-0	6.5	0.26	6.5	0.26		1320	7.646	44.75	7725.6082	31000	4.008308	7760	3.990543	24	1	1	2.77605	1.00445
Uo-1	6.5	0.26	6.5	0.26		660	7.646	44.75	3862.8041	496000	4.604337	3820	4.655929	24	1	1	2.77605	0.98892
Uo-2	6.5	0.26	6.5	0.26		740	7.646	44.75	4331.0228	1038000	3.542714	4320	3.551754	24	1	1	2.77605	0.99745
Ui-1	6.5	0.26	6.5	0.26		760	7.646	44.75	4448.0774	1310000	3.292604	4360	3.359119	24	1	1	2.77605	0.9802
Ui-2	6.5	0.26	6.5	0.26		760	7.646	44.75	4448.0774	1366000	3.265154	4460	3.256425	24	1	1	2.77605	1.00268
CR 1	6.5	0.26	6.5	0.26	1.17	960	7.646	44.75	5618.6241	1468000	2.54795	5640	2.538293	24	1	1	1.84629	1.0038
CR 2	6.5	0.26	6.5	0.26	1.23	1000	7.646	44.75	5852.7335	340000	3.277265	5840	3.284411	24	1	1	1.84629	0.99782
S1	6.5	0.26	6.5	0.26						12930000		8420	1.100359	Did not break				
S2	6.5	0.26	6.5	0.26						1650000		12680	1.102935					
S3	6.5	0.26	6.5	0.26						2990000		11500	1.079777					
BB	6.5	0.26	6.5	0.26						171000		7040	3.126038					

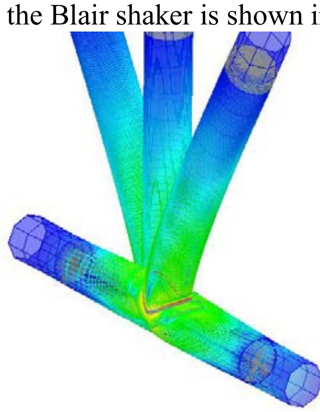
Test	Do	T	do	t	M@PL	P@PL	d@pl	M/d	Stress@pl	Amp d in vibrat	Blair Stress@PL	Blair/ (M/Z	Force from Moment	F/d	F/d (FEA)	F=10000 dact	F=10000 dbeam	d due to local K	Klocal in.lb/rad	k-flex (inplane)
Uo-0	6.5	0.26	6.5	0.26	80600	1700	0.26	310000	10541.46	0.19	10600	1.00555	1801.117	6927.37	15144.631	1.443548	0.6603	0.78325	25567400	4.51703
Uo-1	6.5	0.26	6.5	0.26	103000	1010	0.35	294286	13471.096	0.1	13400	0.99472	2301.676	6576.22	15144.631	1.520631	0.6603	0.86033	23276650	4.96157
					113800	0	0.395	288101	14883.599	0.1	14800	0.99438	2543.017	6438.02	15144.631	1.553273	0.6603	0.89297	22425783	5.14982
Uo-2	6.5	0.26	6.5	0.26	80600	1460	0.245	328980	10541.46	0.1	10600	1.00555	1801.117	7351.5	15144.631	1.360267	0.6603	0.69997	28609395	4.03674
					100400	0	0.31	323871	13131.049	0.1	13200	1.00525	2243.575	7237.34	15144.631	1.381723	0.6603	0.72142	27758502	4.16048
Ui-1	6.5	0.26	6.5	0.26	94000	980	0.28	335714	12294.01	0.1	12200	0.99235	2100.559	7502	15144.631	1.332979	0.6603	0.67268	29769969	3.87937
					105600	0	0.33	320000	13811.143	0.1	13800	0.99919	2359.777	7150.84	15144.631	1.398438	0.6603	0.73814	27129939	4.25688
Ui-2	6.5	0.26	6.5	0.26	89600	1430	0.265	338113	11718.546	0.1	11800	1.00695	2002.235	7555.6	15144.631	1.323521	0.6603	0.66322	30194488	3.82483
					107400	0	0.33	325455	14046.56	0.1	14000	0.99669	2400	7272.73	15144.631	1.375	0.6603	0.7147	28019624	4.12171
CR 1	6.5	0.26	6.5	0.26	174600	970	0.405	431111	22835.47	0.1	22800	0.99845	3901.676	9633.77	15144.631	1.038015	0.6603	0.37772	53017753	2.1783
					125200	0	0.29	431724	16374.575	0.1	16400	1.00155	2797.765	9647.47	15144.631	1.036542	0.6603	0.37624	53225450	2.1698
CR 2	6.5	0.26	6.5	0.26	161000	890	0.36	447222	21056.762	0.1	21000	0.9973	3597.765	9993.79	15144.631	1.000621	0.6603	0.34032	58843322	1.96265
					206000	0	0.46	447826	26942.192	0.1	26800	0.99472	4603.352	10007.3	15144.631	0.999272	0.6603	0.33897	59077547	1.95487
BB					168000	1150	0.83	202410					3754.19	4523.12	15144.631	2.210863	0.6603	1.55056	12915066	8.94218

Estimated natural frequencies from shell model with boundary conditions taken from scaled photograph are given below. The natural frequencies were calculated to assure that 2nd or higher modes in the Blair assembly were sufficiently removed from the motor excitation frequency so that a static load assumption was valid. Blair reports the rotational speed of the eccentric masses. For the CR1 and CR2 tests the excitation frequency was 30 and 35 Hz respectively.

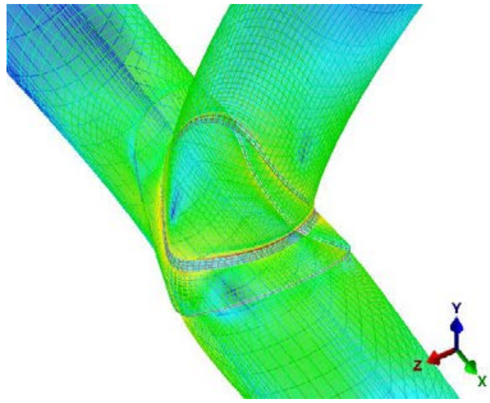
```
Natural Frequencies

Mode:   1   Frequency:    78.2176 Hz.
Mode:   2   Frequency:   205.3081 Hz.
Mode:   3   Frequency:   322.0869 Hz.
Mode:   4   Frequency:   493.8637 Hz.
Mode:   5   Frequency:   501.8342 Hz.
Mode:   6   Frequency:   579.1557 Hz.
```

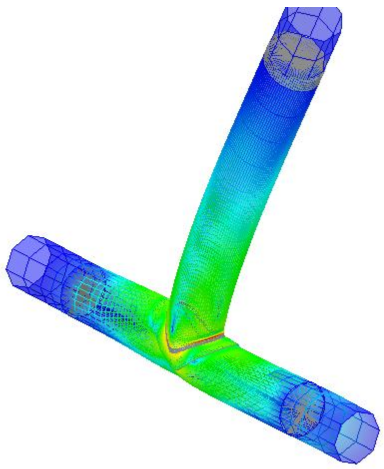
The back-and-forth first mode excited by the Blair shaker is shown in the figure below.



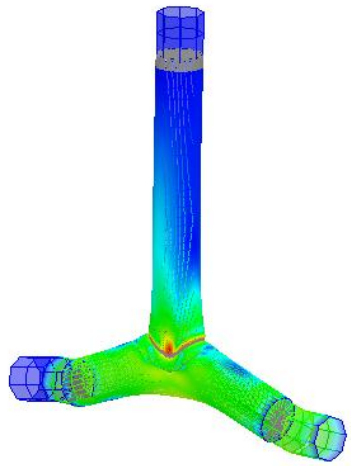
The radial bulging described in the Blair paper may be the same as that shown in the exaggerated finite element model of the first mode displacement shown below.



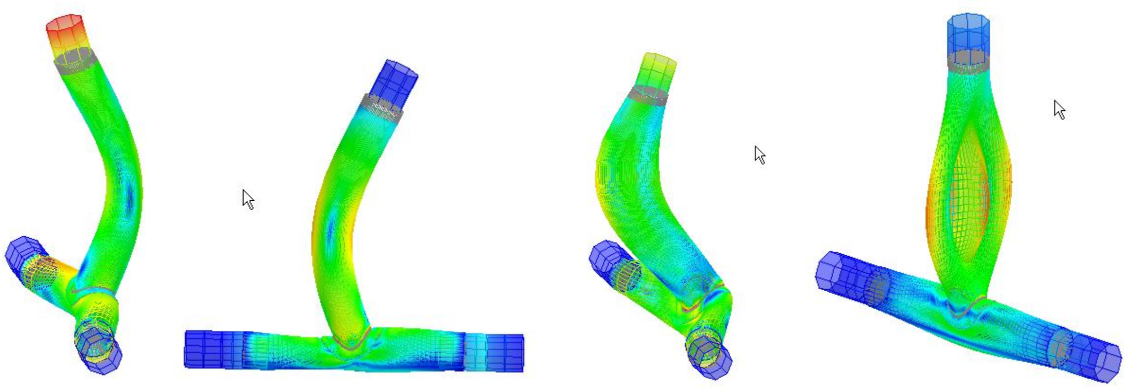
Shapes for modes 1 through 6 of the Blair test are shown below:



1st mode at 78Hz.



Mode at 205 Hz. (2nd mode)



3rd 4th 5th and 6th modes.

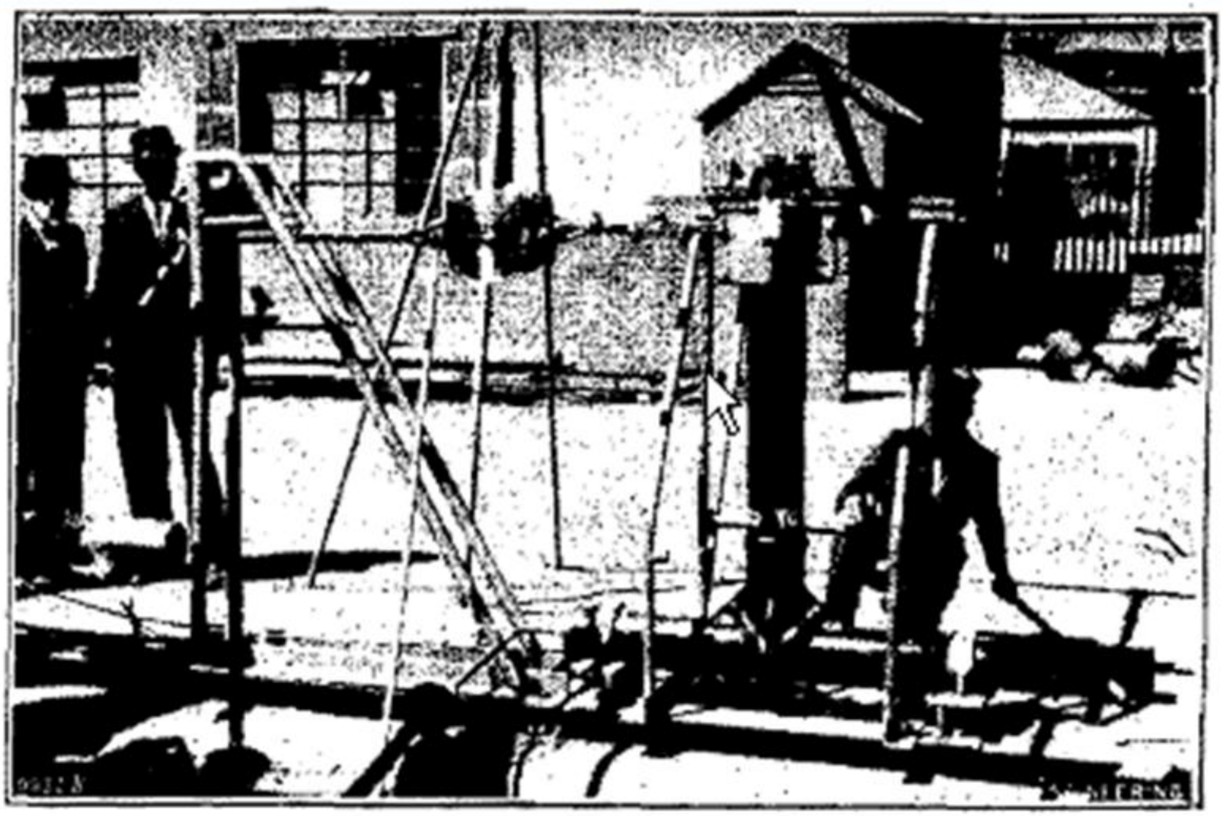
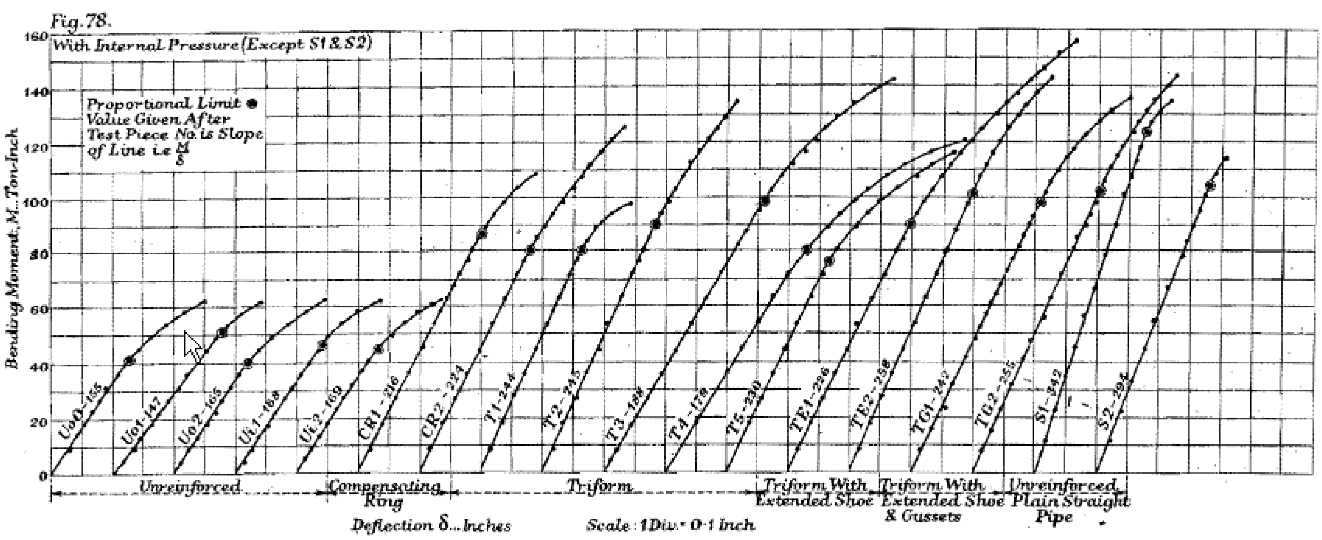
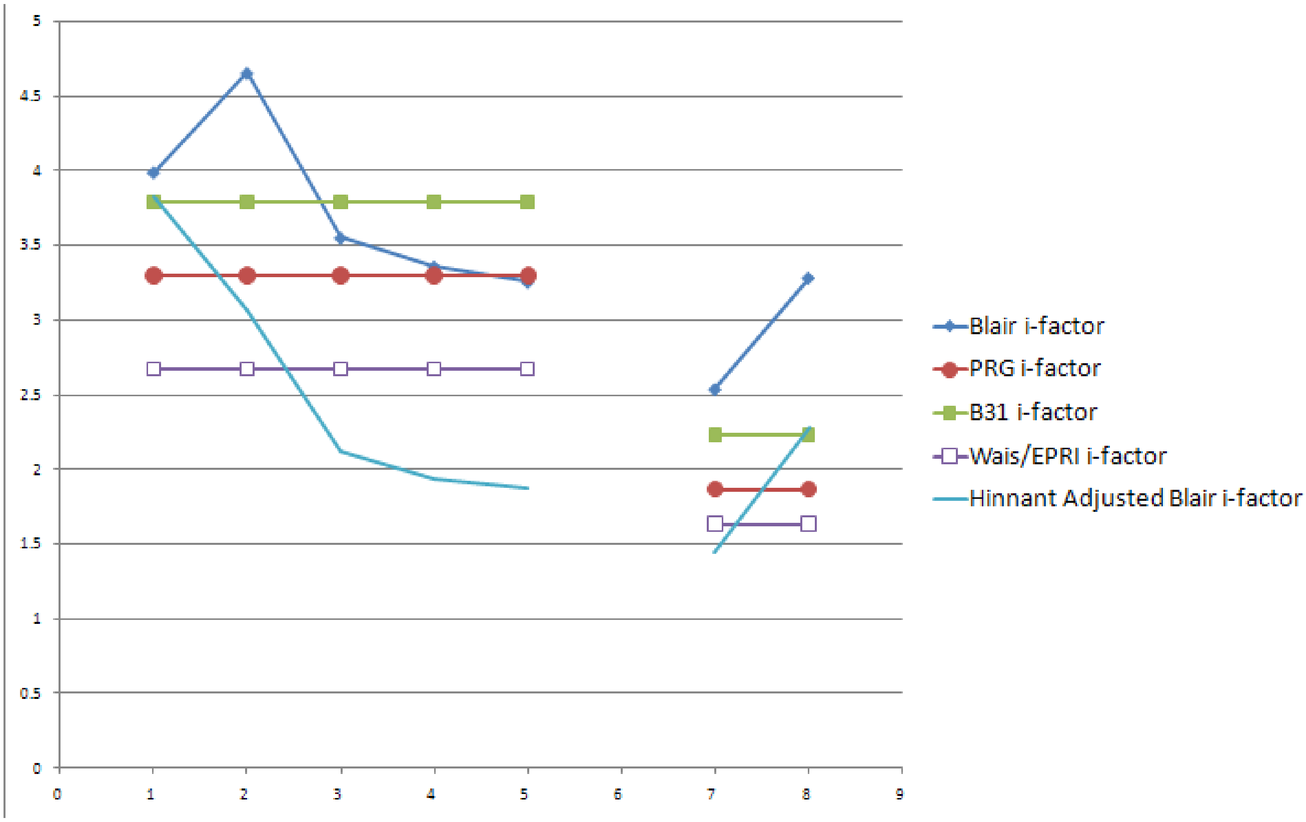


FIG. 66. TEST BED, SHOWING TEST-PIECE TG 2 UNDER STATIC BENDING TEST.



Load Deflection curves from Blair.



i-factor Comparisons – Blair Tests with PRG, Wais and B31.
(See Annex E for latest comparisons.)

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