ATTACHMENT 3

TO ENTERGY LETTER 2.14.023

PILGRIM RELIEF REQUEST PRR-25

Calculation Cover Page EC # 49514

Pilgrim Salt Service Water Discharge Piping Elbow (JF29-8-4) Wall Thinning Stress Analysis

Structural Integrity Associates Calculation No. 1400287.301, Rev. 0

(22 Pages)

☐ ANO-1 ☐ ANO-2 ☐ GGNS ☐ IP-2 ☐ IP-3 ☐ PLP
☐ JAF ☒ PNPS ☐ RBS ☐ VY ☐ W3
☐ NP-GGNS-3 ☐ NP-RBS-3

CALCULATION COVER PAGE	(1) **EC # 49514**	(2) **Page 1 of 22**

(3) Design Basis Calc. ☐ YES ☒ NO	(4) ☒ CALCULATION ☐ EC Markup
(5) **Calculation No: M1397**	(6) **Revision: 0**
(7) **Title: Pilgrim Salt Service Water Discharge Piping Elbow (JF29-8-4) Wall Thinning Stress Analysis**	(8) **Editorial** ☐ YES ☒ NO
(9) **System(s): 29**	(10) **Review Org (Department):**

(11) **Safety Class:** ☒ **Safety / Quality Related** ☐ **Augmented Quality Program** ☐ **Non-Safety Related**	(12) **Component/Equipment/Structure Type/Number:**	
	PIPE / JF29-8-4	
(13) **Document Type: CALC**		
(14) **Keywords (Description/Topical Codes):** **JF29-8-4, spool, SIA, Structural Integrity Associates, flaw, leak, rubber lining, 1400287.301, 1400287**		

REVIEWS

(15) Name/Signature/Date Structural Integrity Assoc. **Responsible Engineer**	(16) Name/Signature/Date John A. Tucker JAT 3-3-14 ☐ **Design Verifier** ☒ **Reviewer** ☐ Comments Attached	(17) Name/Signature/Date See IAS **Supervisor/Approval** ☐ Comments Attached

CALCULATION REFERENCE SHEET	CALCULATION NO: M1397 REVISION: 0

I. EC Markups Incorporated (N/A to NP calculations)
1.N/A
2.
3.
4.
5.

II. Relationships:	Sht	Rev	Input Doc	Output Doc	Impact Y/N	Tracking No.
1. Specification M300	2-12	109	×	☐	N	
2. M100-7250	-	5	×	☐	N	
3.			☐	☐		
4.			☐	☐		
5.			☐	☐		

III. CROSS REFERENCES:

1.PNPS Dwg M100-7250
2.ASME Code Case N-513-3
3.Flow of Fluids Through valves, Fittings and Pipe, Crane Co,., Technical Paper No. 410
4.
5.

IV. SOFTWARE USED:

Title: ANSYS Mechanical APDL and PrepPost Version/Release: 12.1x64, Nov 2009 Disk/CD No. --

V. DISK/CDS INCLUDED:

Title: N/A Version/Release________ Disk/CD No.______

VI. OTHER CHANGES:

Structural Integrity Associates, Inc.®

CALCULATION PACKAGE

File No.: 1400287.301

Project No.: 1400287

Quality Program: ☒ Nuclear ☐ Commercial

PROJECT NAME:
Pilgrim Leaking Elbow Evaluation Support

CONTRACT NO.:
10404807, Change Order No. 001

CLIENT:
Entergy Nuclear

PLANT:
Pilgrim Nuclear Power Station

CALCULATION TITLE:
Pilgrim Salt Service Water Discharge Piping Elbow (JF29-8-4 Spool) Wall Thinning Stress Analysis

Document Revision	Affected Pages	Revision Description	Project Manager Approval Signature & Date	Preparer(s) & Checker(s) Signatures & Date
0	1 - 16 A-1 - A-2 B-1 - B-2	Initial Issue	Eric Houston EJH 3/3/14	Richard Bax RLB 3/3/14 Jim Wu JW 3/3/14

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1.0 OBJECTIVE

A weeping flaw was identified in a 90° elbow at Pilgrim Nuclear Power Station. The leakage was identified in the Salt Service Water system, JF29-8-4 Spool [1]. Structural Integrity Associates (SI) was contracted to demonstrate the suitability for continued operation of the leaking elbow using methods consistent with an upcoming revision of Code Case N-513-3 [2]. The objective of this calculation is to develop a finite element model of the thinned elbow and determine the local stresses due to applied bending loads.

2.0 TECHNICAL APPROACH

A finite element model (FEM) of the leaking elbow will be developed using the ANSYS finite element software program [3]. Unit moment loads will then be applied to the model and stresses in the local region of the leak will be extracted for use in an evaluation of allowable through-wall flaw lengths, which will be documented in a later calculation.

3.0 ASSUMPTIONS / DESIGN INPUTS

The evaluated local thinning is from Reference [4] and is shown in Appendix B. The grid spacing is 0.75 inch [4]. The thinning data point locations for the Reference [4] values are shown in Figure 1.

Design input for the 90° elbow is taken from Reference [1] unless noted otherwise.

- Elbow Type: long radius (R) = 1.5•(Nominal Pipe Size) = 27 inches
- Outside diameter (OD): 18 inches
- Nominal wall thickness (t): Schedule 20 pipe = 0.312 inches [5]
- Elbow material: ASTM A-234, Grade WPB.

4.0 90° ELBOW FINITE ELEMENT MODEL DEVELOPMENT

A three-dimensional (3-D) FEM of the 90° elbow is developed with the ANSYS finite element analysis software package [3].

4.1 Geometry and Element Selection

The three-dimensional finite element model is constructed using ANSYS 8-node SOLID45 structural solid elements. The region of ultrasonic (UT) measurement consists of eight (8) axial grid blocks by sixty-one (61) circumferential grid blocks [4]. Reference [4b] indicates that the axial grid is centered across the axial position of the leak (see Figure 1). The axial position of the hole, relative to the elbow is provided in Reference [6] and shown in Figure 2. The remaining elbow region, which was not UT examined is assumed to have a wall thickness equal to the nominal wall thickness of the pipe, 0.312 inch.

An additional length of straight pipe is added to either end of the elbow in order to remove boundary condition end effects from the areas of interest. The wall thicknesses of the additional lengths of pipe are modeled using nominal wall thickness, 0.312 inch.

The leak location that is shown in Figure 2 is modeled as a square hole that is approximately 0.674 inches long axially by 0.464 inches long circumferentially. The elements originally modeled in the hole region are deactivated via the ANSYS EKILL command. The deactivated elements have near-zero stiffness contribution to the structure. The hole center axially between the Row 4, Column AO and Row 5 Column AO UT data points [4b] (see Appendix B).

Figure 3 shows a global view of the FEM solid model geometry. Figure 4 shows a view of the thinning in the solid model geometry with a detailed view of the leak region. Figure 5 shows a global view of the final finite element model mesh. The ANSYS input files that generate the FEM are listed in Appendix A.

4.2 Boundary Conditions

Two separate moment loads are applied to the FEM; an arbitrary unit 10,000 in-lb moment in the plane (moment about the global-z) of the elbow and an arbitrary unit 10,000 in-lb moment out of the plane (moment about the global-y) of the elbow (torsion loading is not evaluated). For the evaluations, one end of the attached piping is fixed in the axial and circumferential directions, and the CONTA175 and TARGE170 ANSYS elements are used in the application of a pilot node to apply the moment loading to the other free end of the attached piping. An example of the applied boundary conditions is shown in Figure 6.

The resulting peak hoop stresses in the elbow are shown in Figures 7 and 8 for the in-plane and out-of-plane moment loads, respectively. The resulting stresses from these moment evaluations will be scaled to the appropriate load combination piping resultant moments in a later calculation. The input files for the moment evaluation are listed in Appendix A.

5.0 RESULTS OF ANALYSIS

Linearized stresses are extracted at each of the grid locations provided in Reference [4] along the axial path of the elbow and through the leak location as shown in Figure 9. The extracted hoop membrane stress due to two moment loads are stored in the Excel spreadsheet, *Pilgrim-Results.xlsx*, and the results are shown in Table 1.

The input files for the post-processing as well as the output files are listed in Appendix A.

6.0 REFERENCES

1. Entergy Drawing No. M100-7250, Rev. E5, "Service Water System, E209N SSW Backwash Drain Piping," SI File No. 1400287.201.
2. ASME Code Case N-513-3, "Evaluation Criteria for Temporary Acceptance of Flaws in Moderate Energy Class 2 or 3 Piping Section XI, Division 1," Cases of ASME Boiler and Pressure Vessel Code, January 26, 2006.
3. ANSYS Mechanical APDL and PrepPost, Release 12.1 x64, ANSYS, Inc., November 2009.
4. Email from John Tucker (Entergy) to Eric Houston (SI), "Subject: FW: JF29-4-8," dated 2/25/14, with attached files, SI File No. 1400287.201.
    a) JF29-4-8 spool.JPG
    b) Spool JF29 4 8 012.xls
5. Flow of Fluids Through Valves, Fittings and Pipe, Crane Co., Technical Paper No. 410, 1976.
6. Email from Roger Metthe (Entergy) to Eric Houston (SI), "Subject: Pilgrim Hole Location Sketch," dated 2/25/14, with attached file, SI File No. 1400287.201.
    a) Pilgrim Hole Location Sketch.pdf

Table 1: Membrane Stresses along the Elbow through the Leak Location

UT Data Point[1]	Thickness Inches[2]	Membrane Hoop Stress, psi[3]	
		In-Plane (Global-Z)	Out-of-Plane (Global-Y)
Nominal	0.312	16	2
1, AO	0.352	17	25
2, AO	0.353	25	21
3, AO	0.361	21	61
4, AO[4]	0.051	352	165
5, AO[4]	0.064	281	52
6, AO	0.362	21	39
7, AO	0.343	36	23
8, AO	0.366	41	42
Nominal	0.312	16	3

Notes:

1) See Figure 9 for layout of UT Data Points and Figure 4 for relative location on the elbow.
2) UT data per Reference 4b and nominal thickness for 18 inch, Schedule 20 pipe.
3) The unit moment loadings where applied in arbitrary directions and thus the stress reported here are in terms of absolute values.
4) The modeled hole is centered between these two data points.

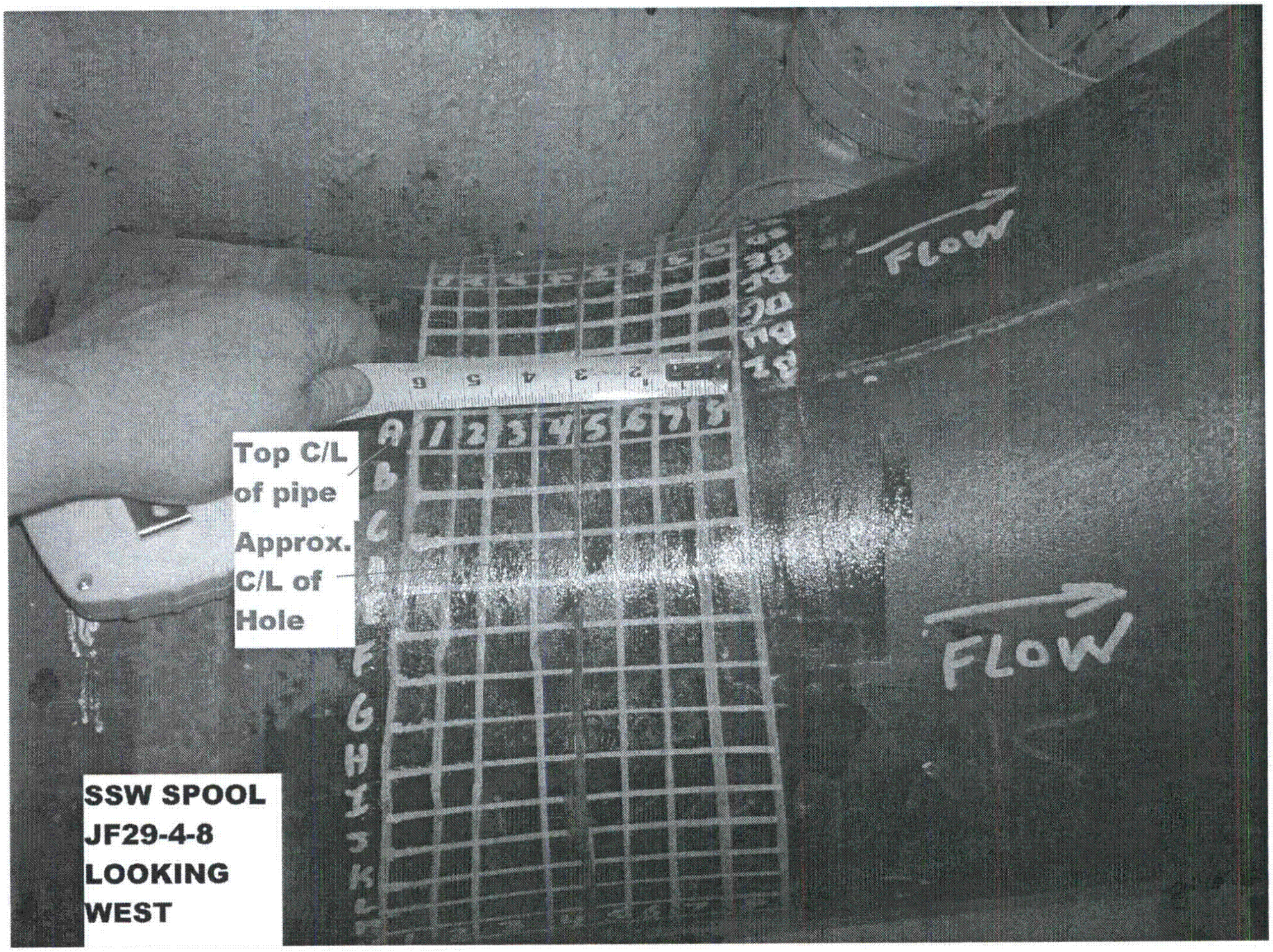

Figure 1: Photo of UT Grid

(From Reference 4a)

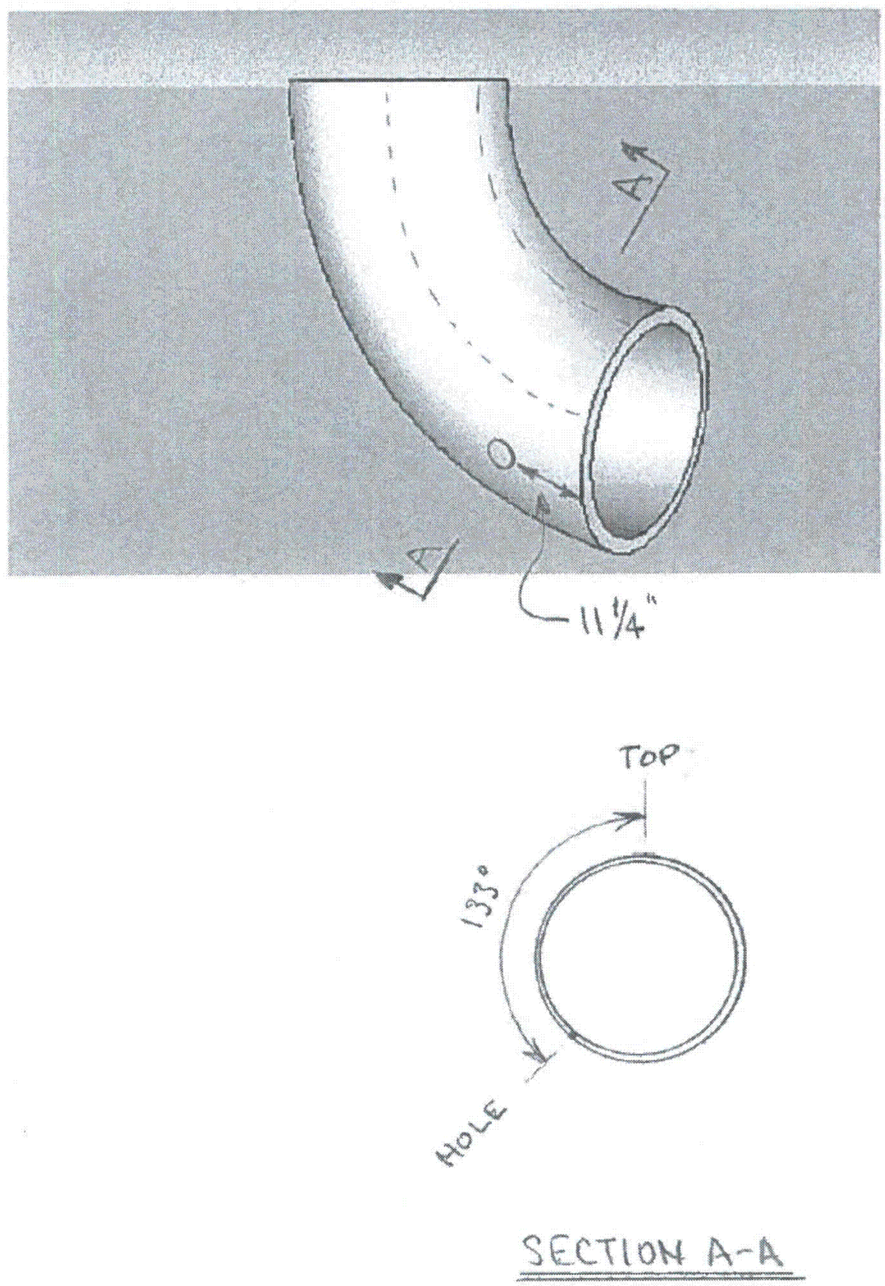

Figure 2: Leak Location

(From Reference 6a)

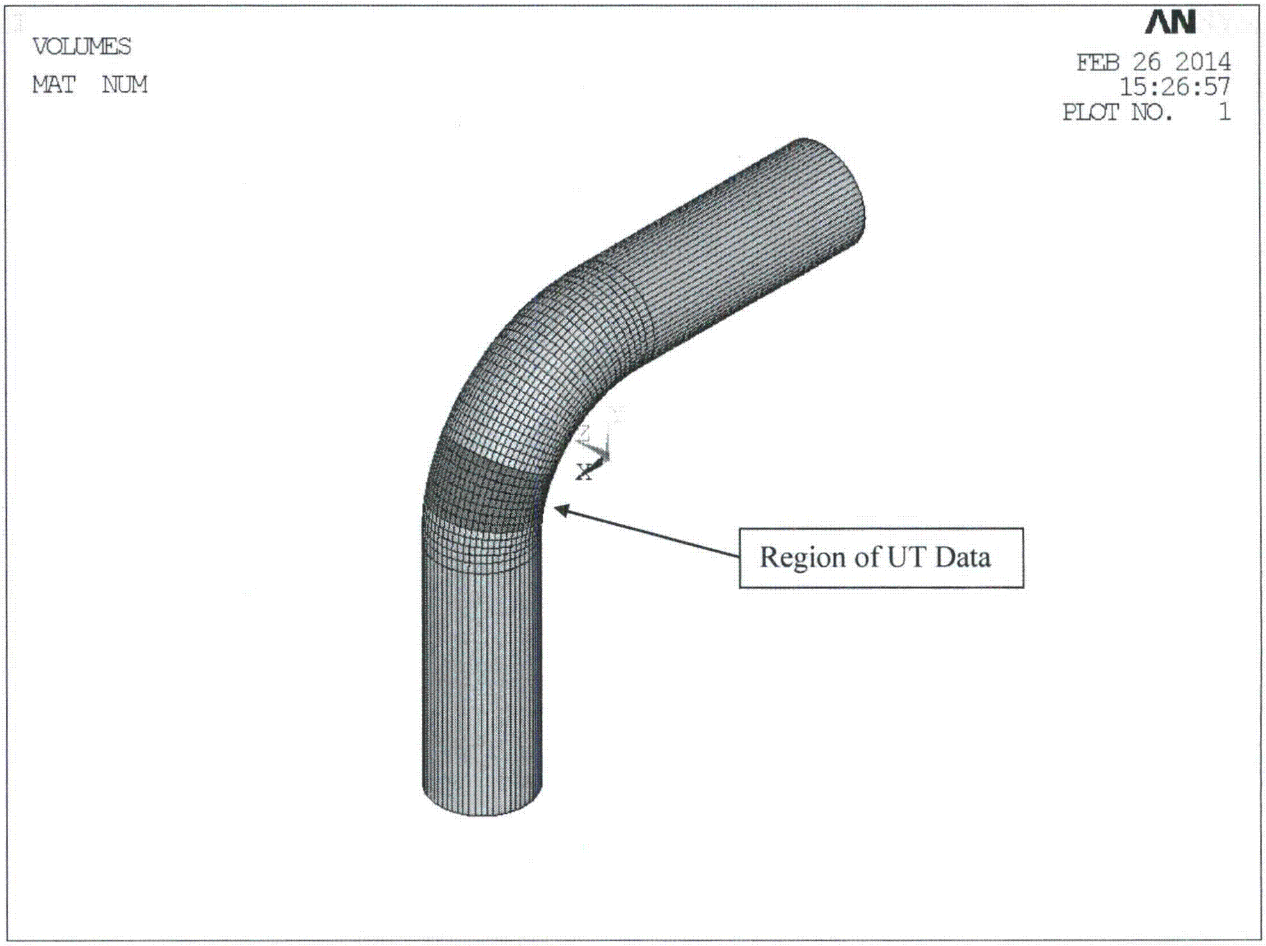

Figure 3: Model Geometry, Global View

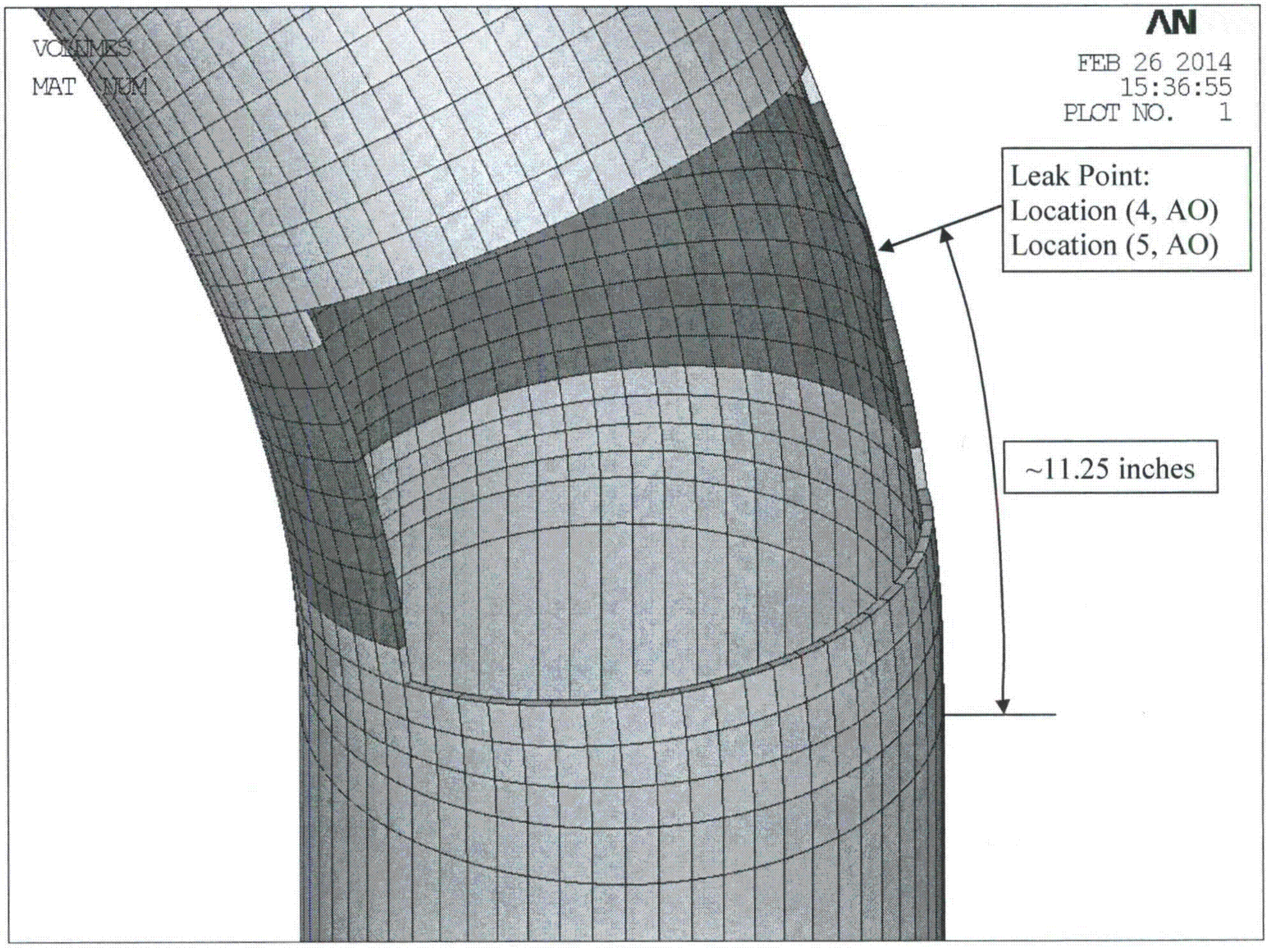

Figure 4: Model Geometry, Thinning View

Figure 5: Finite Element Model

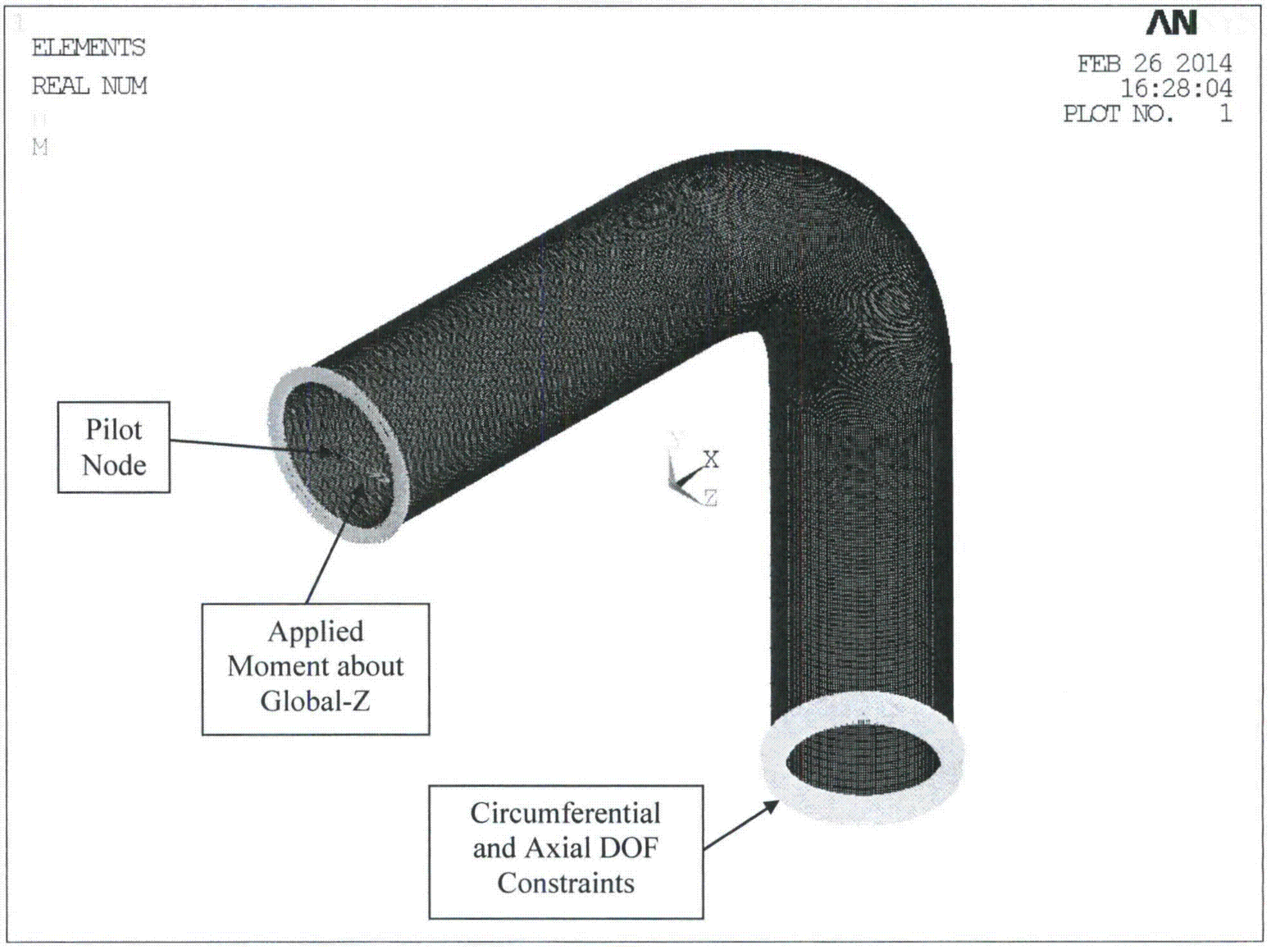

Figure 6: Loads and Boundary Condition Application for Global-Z Moment

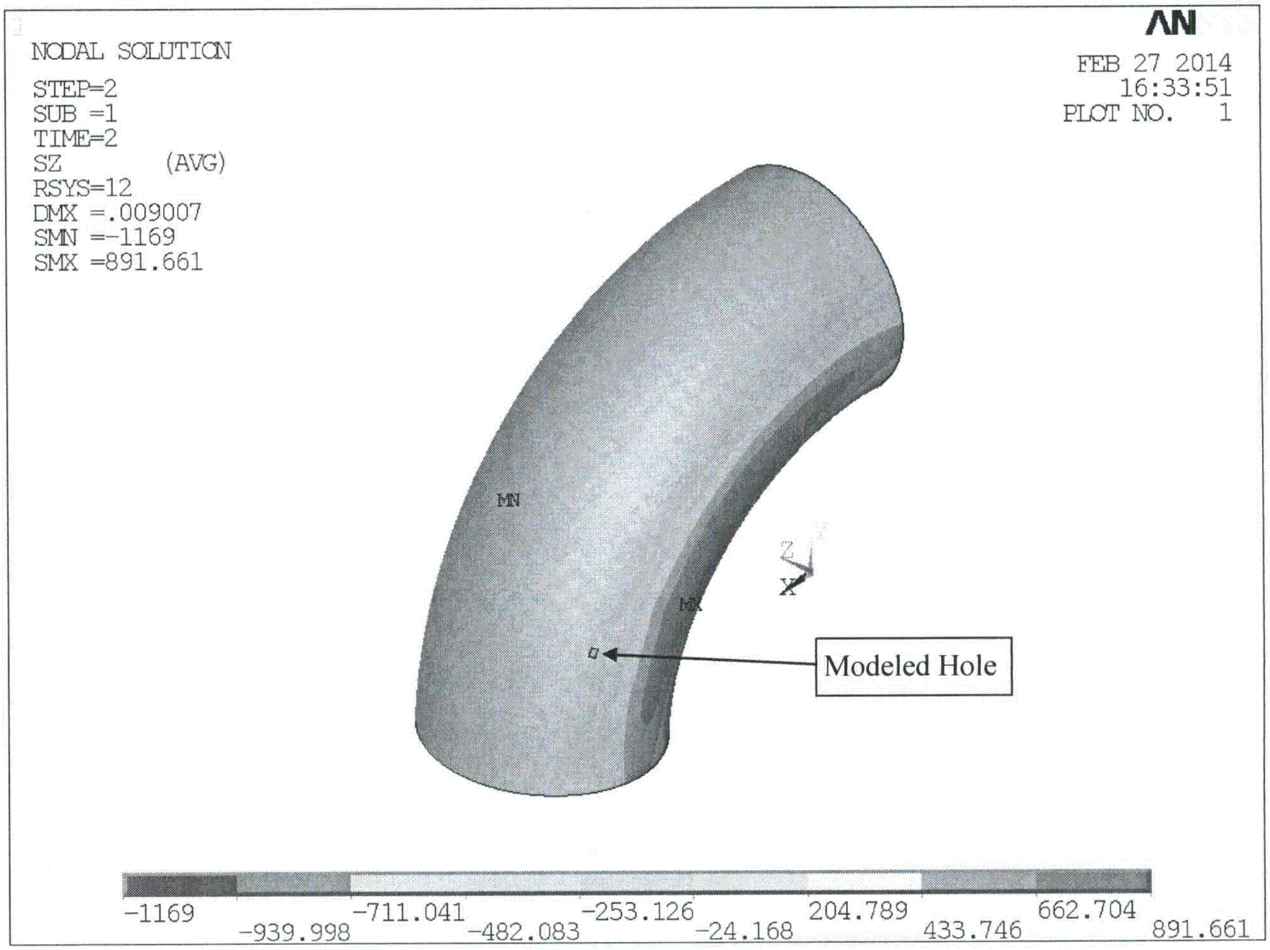

Figure 7: Total Hoop Stress Results due to In-Plane (Global-Z) Unit Moment

(Units are in terms of psi)

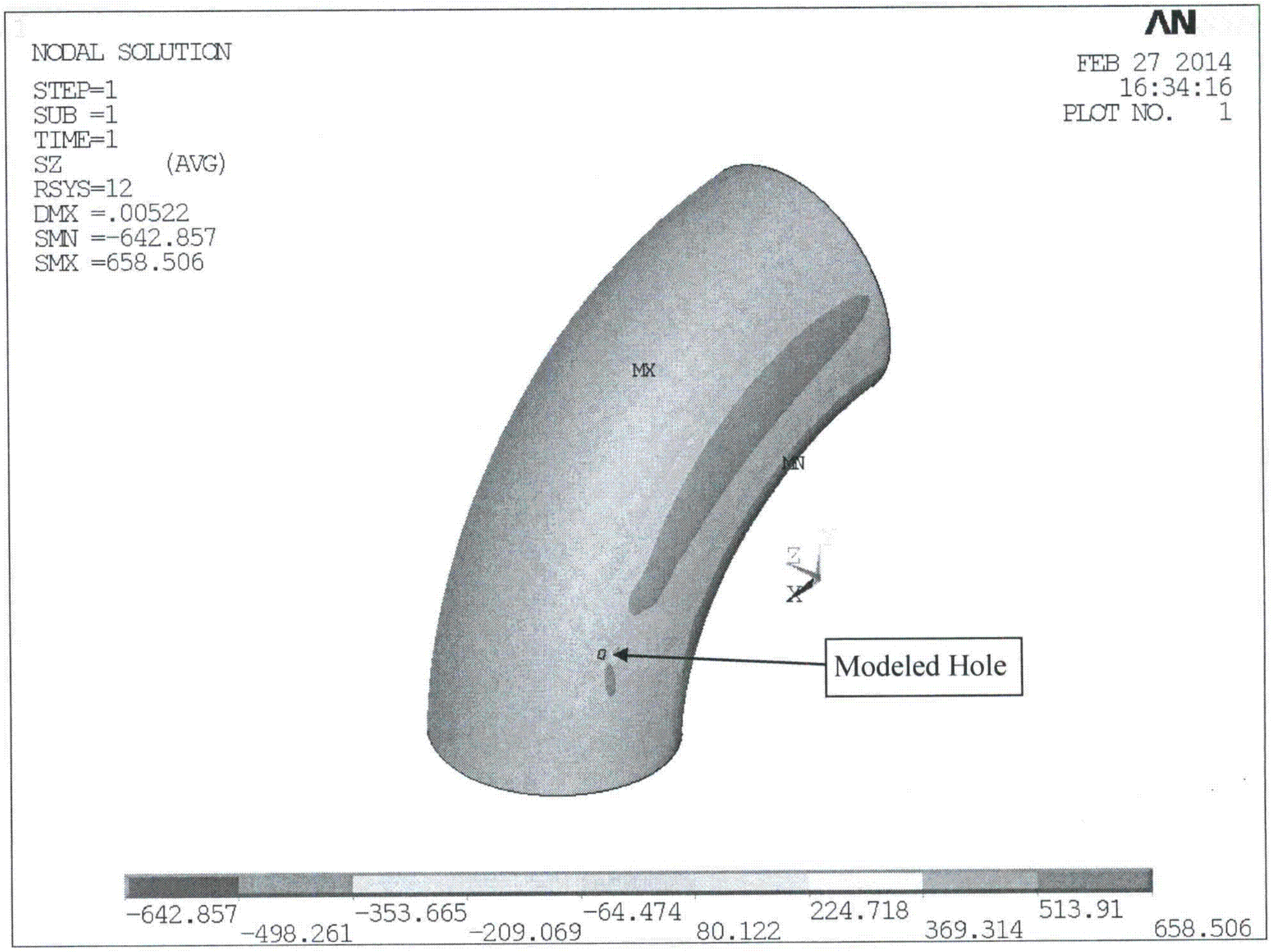

Figure 8: Total Hoop Stress Results due to Out-of-Plane (Global-Y) Unit Moment

(Units are in terms of psi)

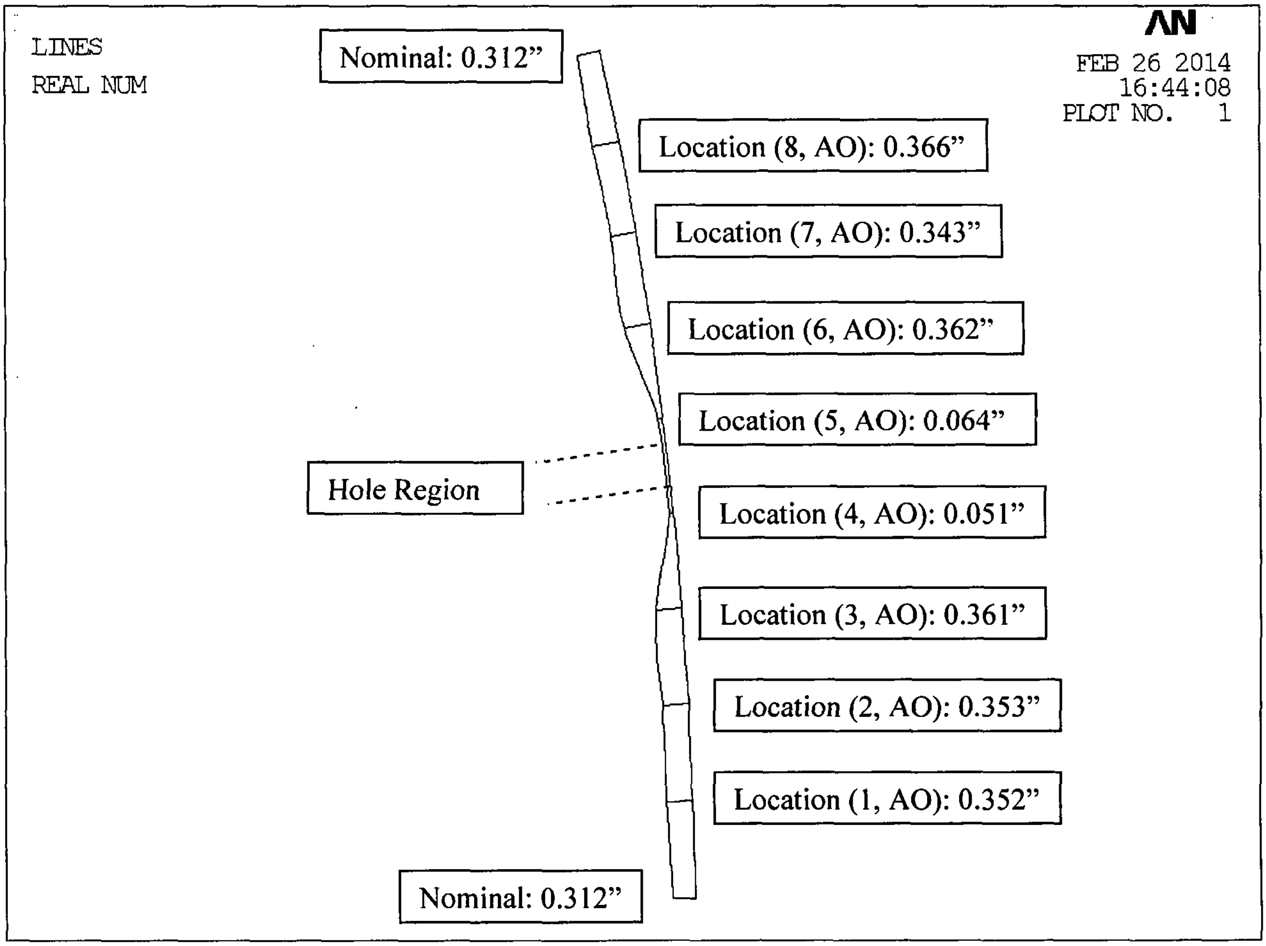

Figure 9: Linearized Path Locations

APPENDIX A

COMPUTER FILES

FILENAME	DESCRIPTION
geom-pil.inp	ANSYS input file to generate finite element model.
pilgrim.prn	ASCI file called by geom-pil.inp containing UT data. Generated in Excel spreadsheet *Thickness Data.xls.*
load-pil-M.inp	ANSYS input file to run two 10,000 in-lb moment evaluations.
post-pil-M.inp	ANSYS input file to extract linearized stress results for two 10,000 in-lb moment evaluations.
Pilgrim-Unit-In.out	Output file containing linearized stress results for 10,000 in-lb in-plane moment (about Global-Z) evaluation.
Pilgrim-Unit-Out.out	Output file containing linearized stress results for 10,000 in-lb out-of-plane moment (about Global-Y) evaluation.
Thickness Data.xls	Excel file with final UT data.
Pilgrim-Results.xlsx	Compilation of the linearized stress results.

APPENDIX B

JF29-8-4 SPOOL UT DATA

------------------------- File Header -------------------------

File Name : LF294 E 0.cmsd
Description :
Creation Date : 2014-02-25 10:20:02
Probe :
Cal Comment :
Inspector : R. AVERY   Company :
Instrument Type : DMS Go   Instrument S/N : USYGD 2015119
Min Alarm Val : 0.000   Max Alarm Val : 0.000
% Loss Alarm Val : 0.00   % Growth Alarm Val. : 0.00
Abs. Loss Alarm Val : 0.000   Abs. Growth Alarm Val. 0.000
Units : INCH   Velocity(in/us) : 0.2360

RESERVED   RESERVED
RESERVED   RESERVED

------------------------- File statistics -------------------------

Number of Readings : 400   Number of Lines : 000
Number of Obstructs : 0   Number of Alt. Bounds : 0
Range : 0.406   Points below MinAlarm : 0
Mean : 0.366   Standard Deviation : 0.047
Minimum Value : 0.051
Minimum Value Loc : 4/AO/1
Maximum Value : 0.437
Maximum Value Loc : F7 I

LOCATION	A	B	C	D	E	F	G	H	I	J	K		M	N
1	0.344	0.348	0.365	0.372	0.374	0.373	0.377	0.375	0.372	0.361	0.361	0.361	0.363	0.359
2	0.346	0.356	0.365	[illegible]	0.372	[illegible]	0.370	0.377	0.375	[illegible]	0.367	0.357	0.362	0.365
3	0.348	0.358	0.363	0.366	0.373	0.375	0.375	0.377	0.376	0.374	0.369	0.367	0.366	0.366
4	0.351	0.352	0.365	0.369	0.375	0.379	0.381	0.38	0.38	0.380	0.372	0.367	0.366	0.363
5	0.349	0.354	0.366	0.368	0.376	0.378	0.378	[illegible]	[illegible]	0.380	0.377	[illegible]	0.367	0.372
6	0.353	0.357	0.364	0.367	0.378	0.378	0.381	0.382	0.386	0.381	0.375	0.372	0.373	0.372
7	0.354	0.357	0.365	0.374	0.375	[illegible]	0.381	[illegible]	0.381	[illegible]	0.379	0.371	0.372	0.371
8	0.36	0.359	0.363	0.374	0.373	[illegible]	[illegible]	[illegible]	[illegible]	0.378	0.377	0.377	0.374	0.372

TOP OF PIPE

Direction of Flow ↑

N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD
0.359	0.367	0.371	0.380	0.386	0.398	0.400	0.379	0.413	0.419	0.425	0.427	0.421	0.417	0.415	0.417	0.413
0.365	0.372	[illegible]	[illegible]	0.392	0.390	0.401	0.409	0.411	0.415	0.421	0.420	0.420	0.421	0.422	0.417	0.414
0.366	0.373	0.380	0.383	0.391	0.400	0.405	0.410	0.415	0.420	0.429	0.437	0.428	0.422	0.417	0.418	0.410
0.363	0.374	0.382	0.383	0.396	0.400	0.405	0.409	0.413	0.425	0.427	0.429	0.423	0.421	0.416	0.419	0.413
0.372	0.373	0.384	0.385	0.400	0.403	0.407	0.412	0.416	0.425	0.428	0.425	0.431	0.427	0.425	0.425	0.421
0.372	0.380	0.389	0.393	0.404	0.407	0.414	0.421	0.419	0.429	0.437	0.433	0.430	0.426	0.425	0.422	0.423
0.371	0.380	0.387	0.390	0.400	0.406	0.412	0.416	0.419	[illegible]	[illegible]	[illegible]	[illegible]	0.427	0.425	[illegible]	0.425
0.372	0.383	0.387	0.396	0.401	0.407	0.412	0.418	0.422	0.426	0.428	0.427	0.437	0.421	0.419	0.422	0.421

AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP	AQ	AR	AS	AT	AU
0.401	0.403	0.395	0.391	0.396	0.396	0.397	0.397	0.380	0.369	0.352	0.318	0.344	0.342	0.330	0.326	0.315
0.405	0.390	0.392	0.399	0.397	0.390	0.396	0.390	0.371	0.304	[illegible]	0.347	[illegible]	[illegible]	0.321	0.337	0.311
0.401	0.394	0.390	0.388	0.389	0.393	0.390	0.393	0.369	0.309	0.351	0.317	0.358	0.345	0.330	0.327	0.308
0.403	0.391	0.383	0.383	0.383	0.387	0.389	0.389	0.363	0.100	0.051	0.109	0.356	0.339	0.336	0.327	0.308
0.411	0.373	0.383	0.380	0.381	0.385	0.390	0.394	0.152	0.087	0.064	0.083	0.354	0.315	0.325	0.325	0.316
0.403	0.390	0.380	0.382	0.383	0.389	0.388	0.392	0.108	0.352	0.352	0.352	0.353	0.334	0.298	0.292	0.317
0.414	0.390	0.385	0.386	0.383	0.390	0.390	0.390	0.350	0.300	0.340	0.342	[illegible]	0.321	0.290	0.337	0.321
0.413	0.401	0.392	0.388	0.381	0.385	0.388	0.392	0.358	0.386	0.356	0.360	0.356	0.345	0.345	0.348	0.327

AV	AW	AX	AY	AZ	BA	BB	BC	BD	BE	BF	BG	BH	BI
0.323	0.336	0.345	0.346	0.340	0.339	0.339	0.330	0.358	0.333	0.352	0.358	0.341	0.358
0.325	0.337	0.341	0.344	0.345	0.341	0.337	0.332	0.320	[illegible]	[illegible]	[illegible]	[illegible]	0.340
0.326	0.332	0.336	0.343	0.346	0.339	0.337	0.327	0.355	0.331	0.356	0.356	0.359	0.341
0.313	0.326	0.333	0.344	0.343	0.339	0.331	0.336	0.356	0.331	0.356	0.356	0.340	0.349
0.321	0.331	0.337	0.343	0.345	0.341	0.333	0.333	0.359	0.335	0.355	0.350	0.346	0.343
0.323	0.336	0.341	0.347	0.343	0.349	0.346	0.339	0.355	0.338	0.343	0.345	0.359	0.346
0.323	0.337	0.347	0.350	0.333	0.340	0.347	0.339	0.335	0.344	0.340	0.339	0.341	0.377
0.325	0.332	0.343	0.351	0.355	0.351	0.343	0.338	0.343	0.343	0.341	0.359	0.343	0.351