ENCLOSURE 2

ATTACHMENT 3

"Structural Design Evaluation of Quad Cities New Dryer Instrumentation Mast," GENE-0000-0034-6964-01R2-NP, Revision 2, Non-Proprietary, dated April 2005

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Structural Design Evaluation of Quad Cities New Dryer Instrumentation Mast

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Revision Status

Revision	Date	Description
0	Dec. 2004	Issued
1	Feb. 2005	Issued with additional references
2	April 2005	Issued with additional information to response to customer's comments

Table of Contents

1.0 Introduction

1.1 Description

The dryer mast is used to support the conduit tubes for instrumentation sensor wires. The dryer mast includes a 4 inch tube which is connected to the dryer top hood through 3 stabilizer support brackets as shown in Figure 1-1. There are 12 conduit tubes, which are attached to the dryer mast through the dryer stiffening plates. These conduit tubes are used to protect Inconel alloy sensor wires of [[ ]] for the strain gauges and [[ ]] for the pressure gauges and accelerometers.

1.2 Scope

The scope of this analysis is the dryer mast from dryer top hood connecting plate, 4" mast tube and all the conduit tubes for instrumentation sensors to the seal weld at the tube sealing cap. The RPV flange and the penetration bolt analyses are excluded from the scope of this analysis. The pressure boundary as shown in Figure 1-2 is the ASME Class 1. Per ASME Section III paragraph NB-3630(d)(1), for Class 1 piping of 1 in. nominal pipe size or less may be analyzed in accordance with the NC-3600 Class 2 component. The conduit tube below the seal header is not a pressure boundary. Since the mast is considered as a continuation of the dryer, it is considered as an ASME Class component, and this analysis will show that the NC-3600 requirements are satisfied. The stabilizer support brackets and the supporting plates to support the conduit tubes are under the jurisdiction boundary of the ASME Section NF Code.

1.3 Purpose

During operation, differential thermal expansion due to the dryer mast having a higher coefficient of thermal expansion than the reactor pressure vessel (RPV) induces the load in the dryer mast. Also pressure and steam flow velocities acting across the dryer mast, as well as seismic acceleration, act to increase the load and stress.

The 0.375" diameter conduit tubes and the 4"diameter mast tube are in tube schedule. However, these tubes are called piping in the ASME code. Because the purpose of this analysis is to show that these components meet the NC-3600 piping code requirement, the conduit tube is referred to as a pipe throughout this report.

The purpose of this report is to analytically demonstrate the structural integrity of the dryer mast design including conduit pipes meeting NC-3600 design requirements. The load combinations for the design requirements and operating condition include gravitational, thermal, pressure, steady state drag forces, fluid-induced vibration, and earthquake loads.

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FIGURE 1-1. Dryer Mast Pipe With Stabilizer Support Brackets

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FIGURE 1-2. Penetration Assembly and Interface Area for 0.375 inch Conduit Pipe

2.0 Conclusions and Interface Requirements

ANSYS finite element code and PISYS07D were used to evaluate the dynamic and static response of the dryer mast. ANSYS was used to evaluate the response of the stabilizer supports and PISYS07D was used for the piping system. The output from PISYSO7D program with ANSI713D program is used to calculate stresses in accordance with the ASME NC-3600 Piping code. Six load combinations were evaluated for each component as described in Table B-1.

2.1 Code Compliance

Results of the analysis in Appendix C show that the requirements (equations) of ASME Section III Class II Components and NC-3600 have been met for all the pipe components. A summary of pipe stresses for the dryer mast and conduit is presented in Appendix D. Two tables are provided for each section. The first table tabulates the summary of stresses in the ANSI7 joint input sequence. The second table arranges the stress ratios from the highest stress to the lowest stress value

Within the scope of this report, design of the dryer mast meets the requirements of ASME Section III NF-3600. The stress ratios for each location are summarized in Appendix C. The dryer mast pipe, conduit pipes, and stabilizer supports have adequate margins for primary and secondary stresses.

2.2 Design Margin

The maximum stress ratios (max calculated stress/allowable) for each load combination for the various component types are tabulated below from Appendix D. Load combination and acceptance criteria are presented in Table B-1 Appendix B.

	Level A (Sustained)	Level B (Occasional)	Thermal +FIV	Thermal +Sustained	Level C	Level D
Conduit Pipe (Pressure Boundary)	[[					
Dryer Mast Pipe						
Stabilizer Support						]]

[[

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Figure 2.3 Interface location for the Conduit Pipe With RPV

2.3 Interface Requirements

2.3.1 Penetration Bolt Force and Moments

The external forces and moments on top of the penetration bolt are summarized in Appendix F-1. These external forces and moments are provided to the responsible engineering group to address the stresses in the penetration bolt and RPV flange.

Figure 2.3 presents the interface for the conduit pipe with RPV top flange including penetration bolt assembly. The forces and moments for the RPV top flange are calculated for the location of node 32 in Figure 2.3. Nodes 25 and 26 are for the coupling tube location in Figure 2.3.

2.3.2 Conduit supports

As shown in Figure 1-1, these conduit pipes are laterally supported by the plates, which are welded to the 4" mast tube. Due to thermal expansion of the conduit from the top of the penetration bolt, the support plate should allow the conduit to move in the axial direction. Refer to the Figure A-1 in Appendix A, which shows that the conduit tube at the bottom should have a [[ ]] to absorb the thermal movement, from node 1 to 2N in this figure.

2.3.3 Dryer top hood support bolt loads

Refer to Figures A-2 and A-3 for the node number in the dryer mast model. All the support loads are tabulated in Appendix F-2.

3.0 References:

1. ASME Section III, Class II Components, NC-3600, 1995 Edition.
2. Mechanics of Fluids, Merle C. Potter and David C. Wiggert, Prentice Hall, 1991.
3. ANSYS Release 6.1, ANSYS, Incorporated, 2001.

4.0 Input Data

The geometries of the dryer mast design with conduit pipe were obtained from the mast drawings.

4.1 Mechanical Properties

The dryer mast, conduit pipes, and stiffening plates are composed of stainless steel alloy SA240, 304 L. The material properties for SA240, 304 L are presented in Tables 4.1. The dimensional properties of the piping system are presented in Table 4.2.

It should be mentioned that the plate material for the 4 inch dryer mast is specified as stainless steel alloy ASTM A312 type 304 L. This material is identical with the same heat treatment conditions as SA240, 304 L.

4.2 Dryer Mast Configurations

ANSYS finite element model and PISYS07D isometric joint diagrams showing the piping configurations are found in Appendix A.

4.3 Operating and Design Temperatures

The operating and design temperatures for the dryer mast design are 550 F and 575 F, respectively.

4.4 Loads

The static and dynamic loads acting on the dryer mast design are defined in Table 4.3.

4.4.1 Design Pressure and Acoustic Pressure

The design pressure load acting on the dryer mast is 1250 psi (see Table 4.2). The acoustic differential pressure across the conduit and dyer mast piping is negligible. Also the peak frequency of the acoustic excitation force is significantly higher than the first mode frequency of the conduit pipe [[ ]]. Therefore, the acoustic pressure associated with FIV load is not considered in this analysis.

4.4.2 Dead Weight

The dead weight loads acting on the dryer mast are defined in Table 4.2. The weight of conduit and dryer mast pipes and instrumentation wires are shown in Table 4.2.

4.4.3 Drag Force and Vortex Shedding

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The flow over the cylinder creates unsteady Strouhal and buffeting lifting force (F_L') perpendicular to the flow direction and Strouhal and buffeting drag force (F_D') in the direction of the flow. These unsteady forces are a small fraction of the drag force.

The first natural frequency of the dryer mast is [[ ]], which is significantly lower than the vortex shedding frequency at the top of the dryer. Therefore, the flow velocity does not have enough energy to cause significant fatigue damage.

4.4.4 Seismic Load

The seismic coefficients are [[ ]] in the horizontal directions and [[ ]] in the vertical direction for the operating Base Earthquake (OBE). The seismic coefficients for safety shutdown (SSE) are twice of the OBE.

4.4.5 Thermal Expansion Load

During operation, differential thermal expansion due to the dryer mast having a higher coefficient of thermal expansion than the reactor pressure vessel (RPV) induces the load in the dryer mast. Thermal expansion load is calculated from 75 deg. F to design temperature of 575 deg. F. The relative anchor displacements between the top hood of the dryer and the RPV flange are also included in the analysis.

5.0 Load Combinations and Acceptance Criteria

The load combination and acceptance criteria for the dryer mast design are shown in Table B-1 Appendix B.

6.0 Methods

6.1 Modeling Techniques

6.1.1 PISYS07D Modeling

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6.1.2 ANSYS Modeling

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6.1.3. Boundary Conditions

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6.2 Analysis

ANSYS finite element code and PISYS07D were used to calculate the dynamic and static response of the dryer mast. ANSYS was used to evaluate the response of the stabilizer supports and PISYS07D was used for the piping system. The output from PISYS07D program with ANSI713D program is used to calculate stresses in accordance with ASME NC-3600 code. Six load combinations were evaluated for each component as described in Table b-1 Appendix B.

6.3 Computer Programs

The computer programs used in the piping stress analysis are described below. All of these programs meet GE Quality Control Standards. All programs have been approved for production use after independent review and verification. Any changes to these programs require verification and approval in accordance with GE Quality Assurance Program. The programs listed below operate on a DEC/Alpha Station running DEC UNIX.

6.3.1 PISYS07D

GE's proprietary computer program, PISYS07D, was used to calculate the response of the piping system to all of the static and dynamic loads.

6.3.2 ANSI713D

The output from the PISYS07D program was evaluated by another GE proprietary computer program, ANSI713D. The ANSI713D program calculates stresses and cumulative usage factors, as applicable, for Class 1, 2 and 3 and ASME B31.1 piping components in accordance with applicable codes. This program also calculates combined loads on piping equipment and compares them with the allowable loads where applicable.

7.0 Evaluation of Results

7.1 Modal Analysis Results

ANSYS finite element modal analysis is presented in Appendix E. Modal Analysis results indicate that the first bending mode occurs at [[ ]]. This bending mode is associated with the bending of conduit pipe at the mast dryer pipe attached area.

7.2 Stress Analysis Results

7.2.1 Piping Stress Analysis Results

7.2.1.1 Pressure Design

The minimum wall requirement of NC-3133.8 for the 0.375 inch tube and 0.568 inch coupling tube under external pressure is determined in accordance with Fig. NC-3133.8-1. Based on this figure, the minimum wall tube and coupling wall tube under external pressure can be calculated below.

[[

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The calculated required minimum pipe wall and nominal pipe wall values are provided in Table 4.2. It can be seen that the minimum thickness for these components are greater than the calculated minimum wall thickness. Thus the code requirement has been met.

7.2.1.2 Stress Analysis Results

The piping was analyzed in accordance with the requirements of ASME NC-3600 Piping Code by the PISYS computer programs. This program produces structural solutions based on the applied loading, inputs, and modeling techniques described in the previous sections. The solutions are post-processed to be compared to the material allowable values. The interface loads (forces and moments) acting on the pipe are also generated.

The detailed stress analysis results meeting NC-3650 equations are listed in Appendix C. It is noted that the pressure stresses listed for each component are the longitudinal stress in the Code equations. The pressure acting on the conduit is external pressure. Because the stress analysis from the NC-3600 equations uses an absolute sum, only positive values are listed. A summary of pipe stresses for the dryer mast and conduit are presented in Appendix D. Two tables are provided for each section. The first table tabulates the summary of stresses in the ANSI7 joint input sequence. The second table arranges the stress ratios from the highest stress to the lowest stress value. The external forces and moments on the top flange and the reaction loads at the dryer interface are summarized in Appendix F.

7.2.2 Stabilizer Bracket Stress Analysis Results

The results of stress analysis for the stabilizer brackets are presented in Appendix G. The node number for theses brackets are presented in Figures A-2 and A-3.

7.2.2 Weld Stress Analysis Results

7.2.2.1 Support Bracket

The support bracket is [[ ]] and it is welded to the dryer mast tube (4 inch diameter) using a [[ ]] weld. The weld strength capability is calculated as:

[[

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Using the minimum weld shear strength of 30X0.3= 9 ksi with the combined bending and shear stress results in load capability of [[ ]] for each side of the bracket. Each side of the bracket supports six conduit pipes. The actual loads for these six conduit pips at support bracket are significantly less than [[ ]]. Therefore, there is significant margin of safety for the welded region.

7.2.2.2 BASE Bracket

The base bracket is 1 inch thick and it is welded to the dryer using [[ ]]. The weld strength capability is calculated as:

[[

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Maximum combined shear and tension stress= [[ ]]

Using the minimum weld shear strength of $30 \times 0.3 = 9$ ksi , there is significant margin of safety for the welded region

7.2.2.3 Short and Long Gussets

The stresses for the short and long gussets are very small compared to weld strength capability.

7.2.3 Support Bracket Bolt Stress Analysis Results

The support brackets are used to attach the dryer mast to the dryer using [[ ]] bolts made of the ASTM A479, 304 L. The tensile strength capability of the [[ ]] bolts in each bracket is:

[[ ]]

The loads for the support bracket attached to the dryer are presented in Appendix F. These loads and combined resultant loads are significantly less than the tension capability of [[ ]].

List of Tables

Table 4.1 Material Properties

Material	Material No.	Temp (°F)	$\alpha^{(8)}$ X 10^{-6} (°F)	$S_c^{(7)}$ (Ksi)	$S_h^{(3)}$ (Ksi)	$S_y^{(4)}$ (ksi)	Modulus of Elasticity (ksi)
SA213 and 240, 304L or ASTM A312 type 304 L *(Dryer Mast Pipe, Conduit Pipes, Stabilizer Supports)*	1	575(1) 550(2)	9.45	25	14.1	14.6 25.0	25.9E+6(5) 28.3E+6(6)

1. Design Temperature
2. Operating Temperature
3. Sh = Allowable Stress at Design Temperature
4. S_y = Yield stress
5. Ec = Modulus of Elasticity at 70°F
6. Eh = Modulus of Elasticity at Operating Temperature
7. Sc = Allowable stress at 70°F
8. α = Mean Coefficient of Expansion at Operating Temperature

Table 4.2 Dimensional Properties for Dryer and Conduit Pipes

Pipe Line	Conduit Pipe	Dryer Mast Pipe	Coupling Tube
Pipe Line	Tube	Tube	Tube
Nom. tube Size – takeoff (in)	0.375	4.0	0.568
Nom. tube OD (in)	0.375	4.0	0.568
Nom. tube ID (in)	0.275	3.364	0.440
Nom. Wall t_{nom} (in)	0.050	0.318	0.064
Tube min. wall,	0.044		0.056
Tube Schedule			
Material Type	1	1	1
Required min. wall, tmc per Code	0.035	-------	0.053
Design Press. (psi)	1250	0	1250
Design Temp. (°F)	575	575	575
Tube weight (lbm/ft)	0.174	12.60	0.66
Wires Weight (lbm/ft) for 3 wires	0.520		1.06
Pipe Weight Total (lbm/ft)	0.226	12.60	

For material type, please see section 4.1.

Table 4.3 Definition of Loads

Load Type	Cases(3)	Ident(3)	Direction(1)	Description
Pressure		PD		Design Pressure
Thermal	1	TE1		Thermal Expansion Loads
Weight	1	WT1	Y	Dead Weight
OBEI	1, 2	OBEI	X, Z	Operating Basis Earthquake - Inertia Effect
SSEI	1, 2	SSEI	X, Z	Safe Shutdown Earthquake - Inertia Effect

1) X, Y and Z directions correspond to the global X, Y and Z directions shown on the stress isometric diagrams in Appendix A.

Table 4.4 Nomenclature and Units for Appendices

ANC	=	Anchor identification in structural analysis
COMB	=	Service level equation number as shown on load combination table
D_X, D_Y, D_Z	=	Global displacement in X, Y, Z directions (inch)
FA, FB, FC*	=	Local force A, B, C directions (lbs)
F/M	=	Force (Newton) and moment (lbs-in)
FX, FY, FZ	=	Global force in X, Y, Z directions (lbs)
GGD	=	Guide identification in structural analysis (Global coordinates)
GUD	=	Guide identification in structural analysis (Local coordinates)
HAN	=	Spring Hanger identification in structural analysis
LOAD	=	Calculated load (lbs)
MA, MB, MC*	=	Local moment in A, B, C directions (lb-in)
MX, MY, MZ	=	Global moment in X, Y, Z directions (lb-in)

* There are two types of elements that the PISYS computer program uses to form the pipe model. One is the straight or tangent element and the other is a planar bend element. Each element has local coordinate axes that orient the element in the global coordinate system and identify force and moment components at a joint with respect to element axis. Joint displacements and rotations are in global coordinates. The convention for the orientation of local axes is as follows:

1. Tangent elements parallel to the global Y-axis (vertical axis) have their local B-axis diverted to and in the same direction as the global Z-axis.

2. Tangent Elements not parallel to the global Y-axis have their local B-axis contained in a vertical (global) plane such that local B-axis projects positively on the positive global Y-axis.
3. For bend elements, the local B-axis is directed positively toward and intersects the center of curvature of the bend (i.e., radius vector).
4. The local A-axis is tangent to the arc of the bend or straight element and is directed positively from the FROM joint to the TO joint.

Appendices

Appendix A: Isometric Diagram and ANSYS Model

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Figure A-1: Conduit Pipe Iso-metric

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Figure A-2: ANSYS Finite Element Model of Short Stabilizer Brackets (node Number)

[[

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Figure A.3 ANSYS Finite Element Model of Long Stabilizer Bracket (node number)

[[

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Figure A-4: ANSYS Finite Element Model

Appendix B: Load Combinations and Acceptance Criteria

Table B-1 Load Combination and Criteria for Dryer Mast Design

Load Combination	Condition	Acceptance Criteria
PD + WT + FDRAG	Service Level A	EQ. 8 $\leq 1.5\ S_h$
PM + WT + FDRAG + OBEI	Service Level B	EQ. 9 $\leq 1.8\ S_h$, but not greater than $1.5\ S_y$
Thermal Expansion + FIV	Thermal +FIV	EQ. 10 $\leq S_A$
PD + WT + FDRAG + Thermal Expansion	Thermal+ Sustained	EQ. 11 $\leq (S_h + S_A)$
PM + WT + FDRAG + SSEI	Service Level D	EQ. 9 $\leq 3.0\ S_h$, but not greater than $2.0\ S_y$
PM + WT + FDRAG	Service Level C	EQ. 9 $\leq 2.25 S_h$ But not greater than $1.8\ S_y$

FDRAG = Steady state flow drag force due to 9.4 ft/sec flow.

PD= Design Pressure

PM= Operating Pressure

OBEI = Operation Base Earthquake (Inertia Effect)

SSEI = Safe Shutdown Earthquake (Inertia Effect)

S_A= Allowable Stress range for expansion stresses

S_h= Basic Material Allowable Stress at Design Temperature

S_y=Yield Strength Value, taken at average fluid temperature of transient under consideration

WT=Dead Weight

Appendix C: Details of Piping Stress Analysis to Meet NC-3600

Appendix C-1 Pressure Boundary Conduit Pipe (0375 inch O.D.)

```
DATE 12-16-2004 RESUL1                                                          PAGE    9
□     QC dry mast conduit       QC dry mast conduit
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[[

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DATE 12-16-2004 RESUL1 PAGE 10

□ QC dry mast conduit QC dry mast conduit

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DATE 12-16-2004 RESUL1 PAGE 11

☐ QC dry mast conduit QC dry mast conduit

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QC dry mast conduit QC dry mast conduit

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DATE 12-16-2004 RESUL1 PAGE 14

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□ QC dry mast conduit QC dry mast conduit

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DATE 12-16-2004 RESUL1 PAGE 16

QC dry mast conduit QC dry mast conduit

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DATE 12-16-2004 RESUL1 PAGE 17

☐ QC dry mast conduit QC dry mast conduit

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Appendix C-2 Non-Pressure Boundary Conduit Pipe (0375 inch O.D.)

DATE 12-16-2004 RESUL1 PAGE 28
☐ QC dry mast conduit QC dry mast conduit

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□ QC dry mast conduit QC dry mast conduit

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☐ QC dry mast conduit QC dry mast conduit

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☐ QC dry mast conduit QC dry mast conduit

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DATE 12-16-2004 RESUL1 PAGE 32

☐ QC dry mast conduit QC dry mast conduit

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Appendix C-3 Non-Pressure Boundary Conduit Pipe (4.0 inch O.D.)

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DATE 12-16-2004 RESUL1                                                             PAGE   43
□    QC dry mast conduit       QC dry mast 4"-Tube
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[[

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DATE 12-16-2004 RESUL1 PAGE 44

QC dry mast conduit QC dry mast 4"-Tube

[[

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QC dry mast conduit QC dry mast 4"-Tube

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DATE 12-16-2004 RESUL1 PAGE 46

☐ QC dry mast conduit QC dry mast 4"-Tube

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DATE 12-16-2004 RESUL1 PAGE 47

☐ QC dry mast conduit QC dry mast 4"-Tube

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☐ QC dry mast conduit QC dry mast 4"-Tube

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Appendix C-4 Pressure Boundary Conduit Pipe (0375 inch O.D.) Forces, moments and displacements

FROM JOINT NO	TYPE	CASE NO	FORCES FA	FORCES FB	FORCES FC	MOMENTS MA	MOMENTS MB	MOMENTS MC	DEFLECTIONS X	DEFLECTIONS Y	DEFLECTIONS Z	TO JOINT NO

[[

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DATE 12-16-2004 COORD PAGE 5
QC dry mast conduit QC dry mast conduit

FROM JOINT NO	TYPE	CASE NO	FA	FORCES FB	FC	MA	MOMENTS MB	MC	X	DEFLECTIONS Y	Z	TO JOINT NO

[[

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DATE 12-16-2004 COORD PAGE 6
QC dry mast conduit QC dry mast conduit

FROM JOINT NO	TYPE	CASE NO	FA	FORCES FB	FC	MA	MOMENTS MB	MC	X	DEFLECTIONS Y	Z	TO JOINT NO

[[

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Appendix D: Summary of Stresses to Meet NC-3600

Arranged From Input Sequences

0.375 inch Conduit Pipe Pressure Boundary

[[

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0.375 inch Conduit Pipe non Pressure Boundary

DATE 12-16-2004 FINAL PAGE 33

□ QC dry mast conduit QC dry mast conduit

[[

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Arranged From Highest Stress to Lowest stress

0.375 inch Conduit Pipe pressure boundary

[[

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0.375 inch Conduit Pipe non pressure boundary

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□ QC dry mast conduit QC dry mast conduit

[[

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4 inch Dryer Mast pipe

DATE 12-16-2004 FINAL PAGE 50

☐ QC dry mast conduit QC dry mast 4"-Tube

[[

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Appendix E: List of Natural Frequencies

List of natural frequencies

```
*** FREQUENCIES FROM BLOCK LANCZOS           ITERATION ***

  MODE    FREQUENCY (HERTZ)


   FREQUENCY RANGE REQUESTED=   5.00000       5000.00
```
[[

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```
     Block Lanczos CP Time (sec) =          0.437
Block Lanczos ELAPSED Time (sec) =          0.437
```

Appendix F: External Forces and Moments

F-1 External Forces and Moments on the Penetration Bolts Per Conduit

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[[

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F-2 Reaction Loads at Dryer Mast/Dryer Interface

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Service Level A

[[

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Service Level B

[[

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Load Case 3, FIV + thermal expansion

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Load Case 4, Sustained +thermal expansion

[[

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Service Level C

[[

]]

Service Level D

[[

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Appendix G: Principal Stresses for Stabilizer Brackets

(See Figures G-1, G-2 and G-3 for location of maximum stresses)

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Figure G-1, Location of Maximum Principal Stresses for Stabilizer Brackets

<u>Service Level A</u>
MAXIMUM VALUE

ELEM	[[ ]]
VALUE	[[ ]]
Stress Ratio	[[ ]]

<u>Service Level B</u>
MAXIMUM VALUES

ELEM	[[ ]]
VALUE	[[ ]]
Stress Ratio	[[ ]]

<u>FIV+ thermal expansion</u>
MAXIMUM VALUES

ELEM	[[ ]]
VALUE	[[ ]]
Stress Ratio	[[ ]]

<u>Thermal expansion +sustained</u>
MAXIMUM VALUES

ELEM	[[ ]]
VALUE	[[ ]]
Stress Ratio	[[ ]]

<u>Service Level C</u>
MAXIMUM VALUES

ELEM	[[ ]]
VALUE	[[ ]]
Stress Ratio	[[ ]]

<u>Service Level D</u>
MAXIMUM VALUES

ELEM	[[ ]]
VALUE	[[ ]]
Stress Ratio	[[ ]]

[[

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Figure G-2, Short Stabilizer Bracket (element no.)

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Figure G-3, Long Stabilizer Bracket (element no.)