Westinghouse Non-Proprietary Class 3

WCAP-17611-NP
Revision 1

August 2012

Peach Bottom Unit 2 and Unit 3 Replacement Steam Dryer Four-Line Subscale Acoustic Test Data Evaluation and Derivation of CLTP-to-EPU Scaling Spectra

Enclosure B.5

WCAP-17611-NP
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Peach Bottom Unit 2 and Unit 3 Replacement Steam Dryer Four-Line Subscale Acoustic Test Data Evaluation and Derivation of CLTP-to-EPU Scaling Spectra

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August 2012

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EXECUTIVE SUMMARY

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]a

The main purpose of the test program was [

]a

[

]a,b

[

]a,b

[

]a,b

[

]a,b

ACRONYMS AND ABBREVIATIONS

BWR	boiling water reactor
CLTP	current licensed thermal power
DAS	data acquisition system
DS	downstream (used only in figures and tables)
EPU	extended power uprate
EPU*1.02	102 percent of extended power uprate
HPCI	high-pressure coolant injection
MSIV	main steam isolation valve
MSL	main steam line
NRC	Nuclear Regulatory Commission
OEM	original equipment manufacturer
PBAPS	Peach Bottom Atomic Power Station
PSD	power spectral density
PVC	polyvinyl chloride
RMS	root mean square
RPV	reactor pressure vessel
RSD	replacement steam dryer
SRV	safety relief valve
SSV	safety spring valve
STI	Stellar Technologies, Inc.
TSV	turbine stop valve
US	upstream (used only in figures and tables)

TRADEMARKS

1 BACKGROUND AND PURPOSE

[

]a,d

In order to uprate the plant power, the United States Nuclear Regulatory Commission (NRC) requires that the structural integrity of the steam dryer be evaluated with regard to possible acoustic pressure loads. This requirement is detailed in Reference 2. In order to evaluate the structural integrity of the steam dryer, [

]a

The main purpose of this testing program was [

]a

[

]a

The results presented in this report are based on testing performed in accordance with the test plans (References 6 and 7).

A secondary purpose of the testing was [

]b,d

2 INPUTS TO TESTING

2.1 PLANT OPERATING CONDITIONS

The plant operating conditions were provided by Exelon in References 1 and 8 [

]^{a}

[

]^{a}

Table 2-1 Plant Operating Conditions				
[				
				]^{a,b}

2.2 PRETEST PREDICTIONS

[

]^{a,b}

Table 2-2 [	]^{a,b}
[	
	]^{a,b}

[

]a,b

Table 2-3 [ ]a				
[				
				]a,b

3 TESTING METHODOLOGY

The testing was performed per the test plans, documented in Reference 6 for Unit 2, and Reference 7 for Unit 3, and is summarized in the following sections.

3.1 PHYSICAL TEST SYSTEM

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]a,b

[

]a

a.b.d

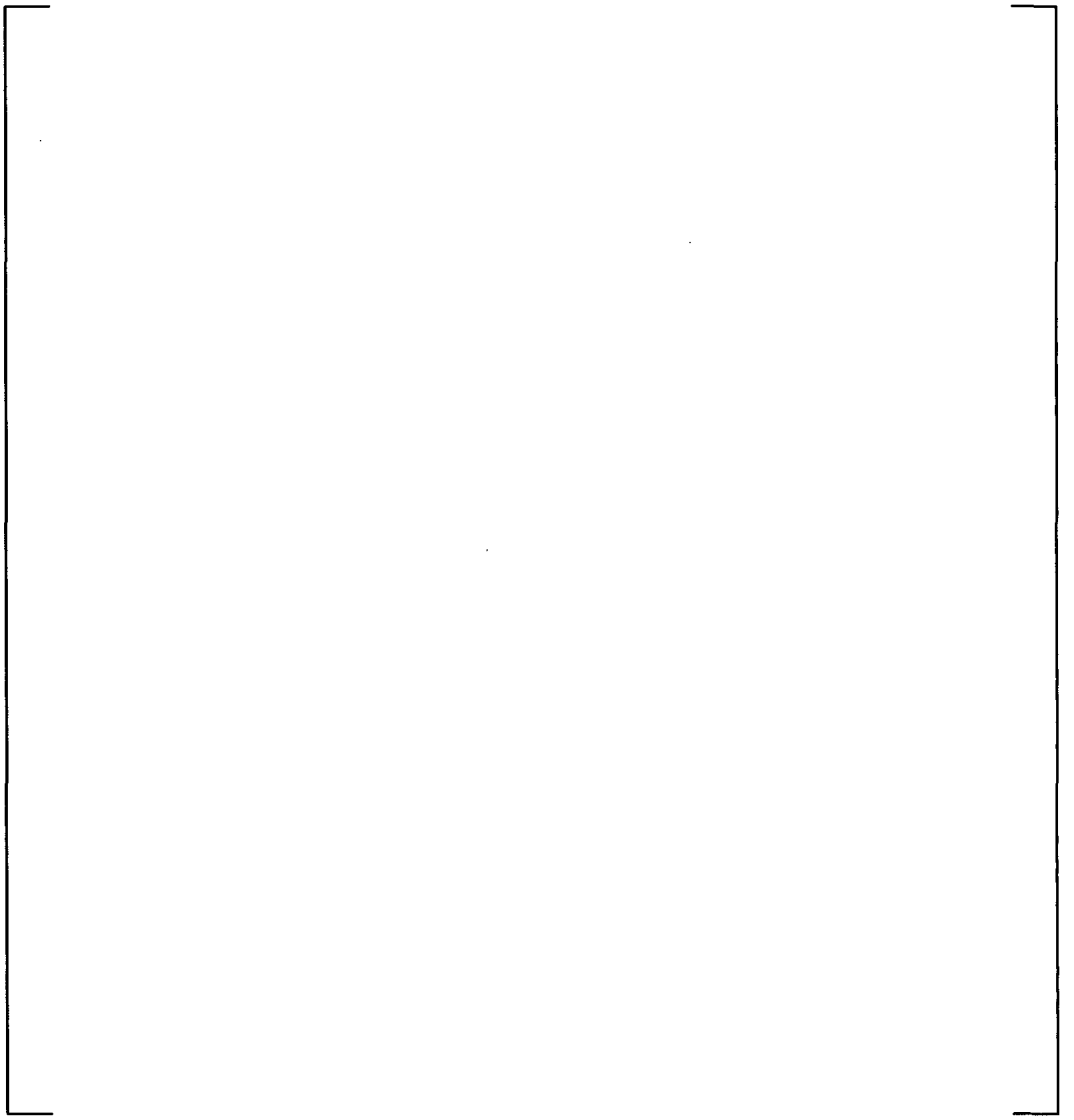


Figure 3-1 [ ][a]

a,b,d

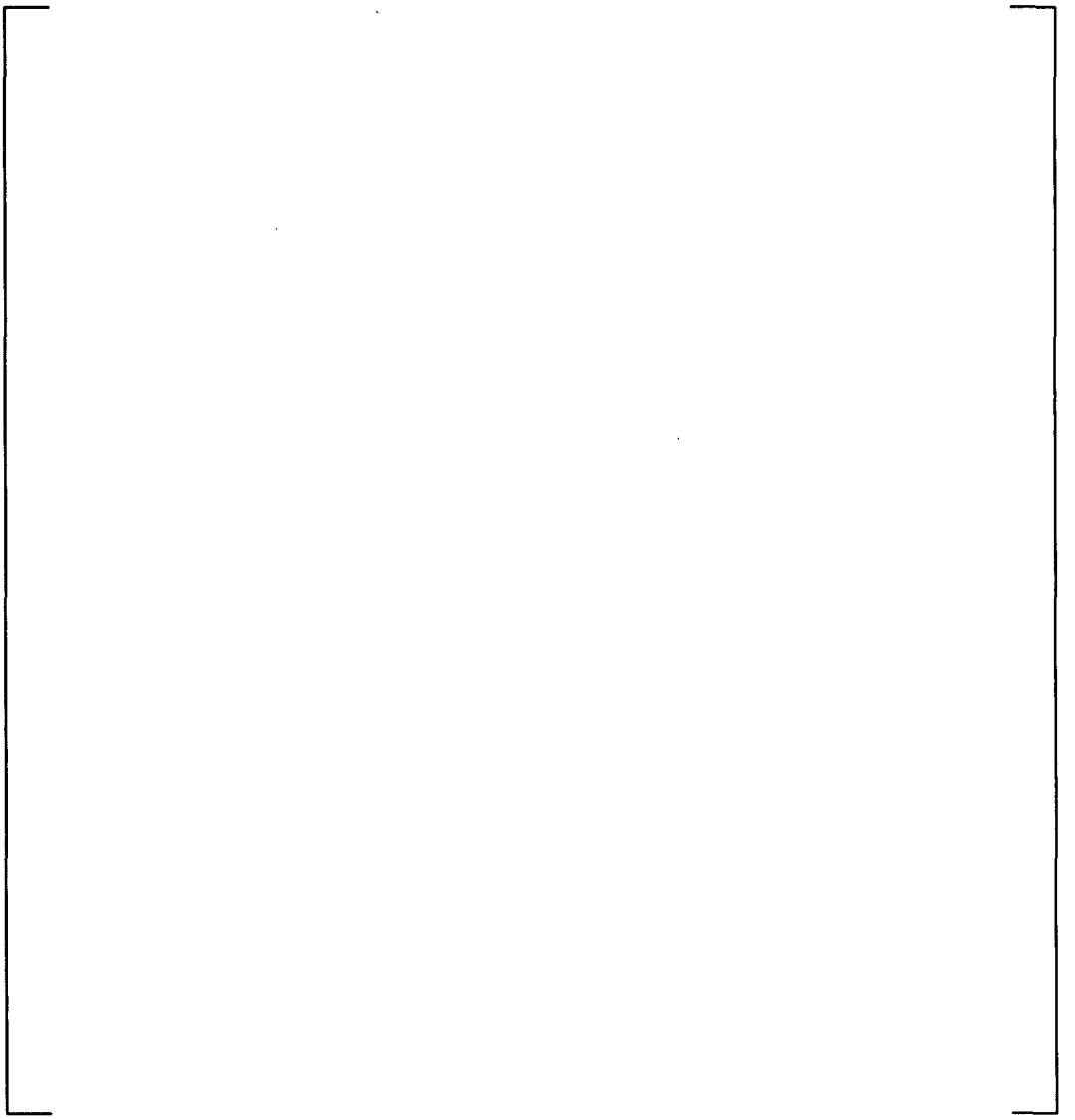


Figure 3-2 [ ][a]

[

]a,d

[

]a,d

[

]a

[ ]a

[

]a

[a

]

Figure 3-3 Peach Bottom Unit 3 Physical Test Setup, [ ]a

[

]a

a

Figure 3-4 Peach Bottom Unit 3 Physical Test Setup, [ ]a

[

]a

[a

Figure 3-5 Peach Bottom Unit 2 Physical Test Setup, [ ][a]

[a

Figure 3-6 Peach Bottom Unit 3 Physical Test Setup, [ ][a]

[

]a

a

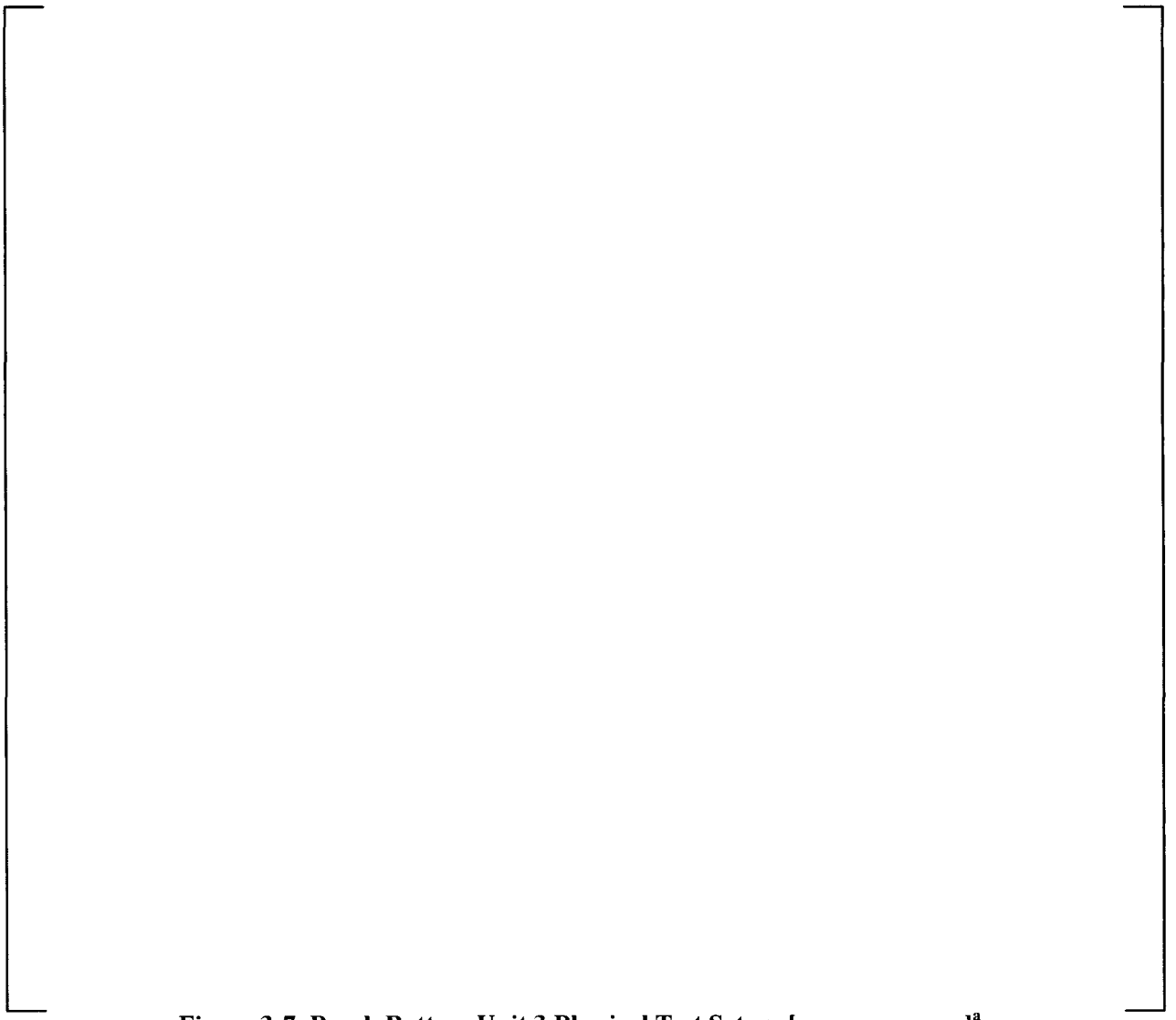
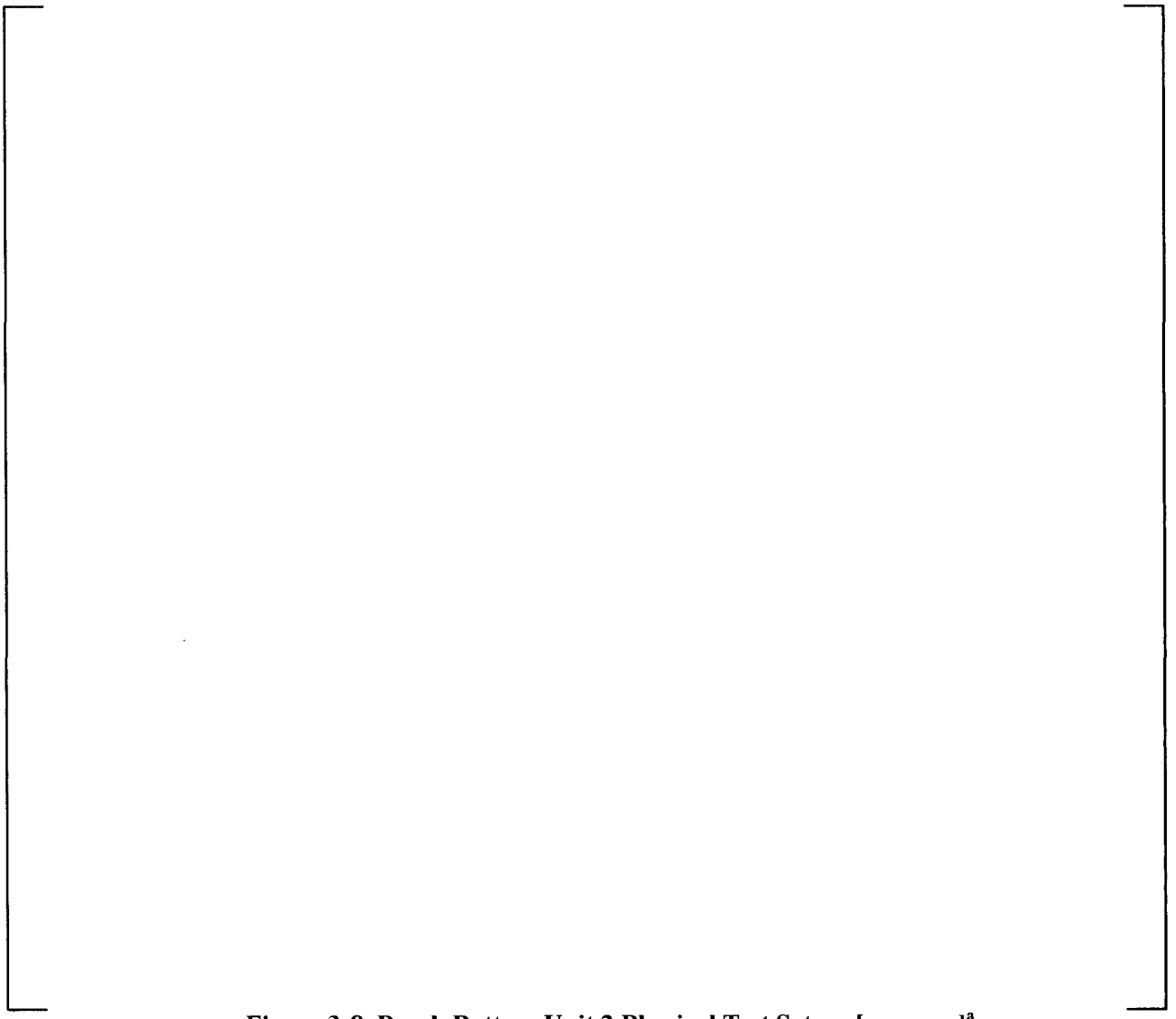


Figure 3-7 Peach Bottom Unit 3 Physical Test Setup, [ ]a

[

]a



a

Figure 3-8 Peach Bottom Unit 2 Physical Test Setup, [ ]a

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]a

a

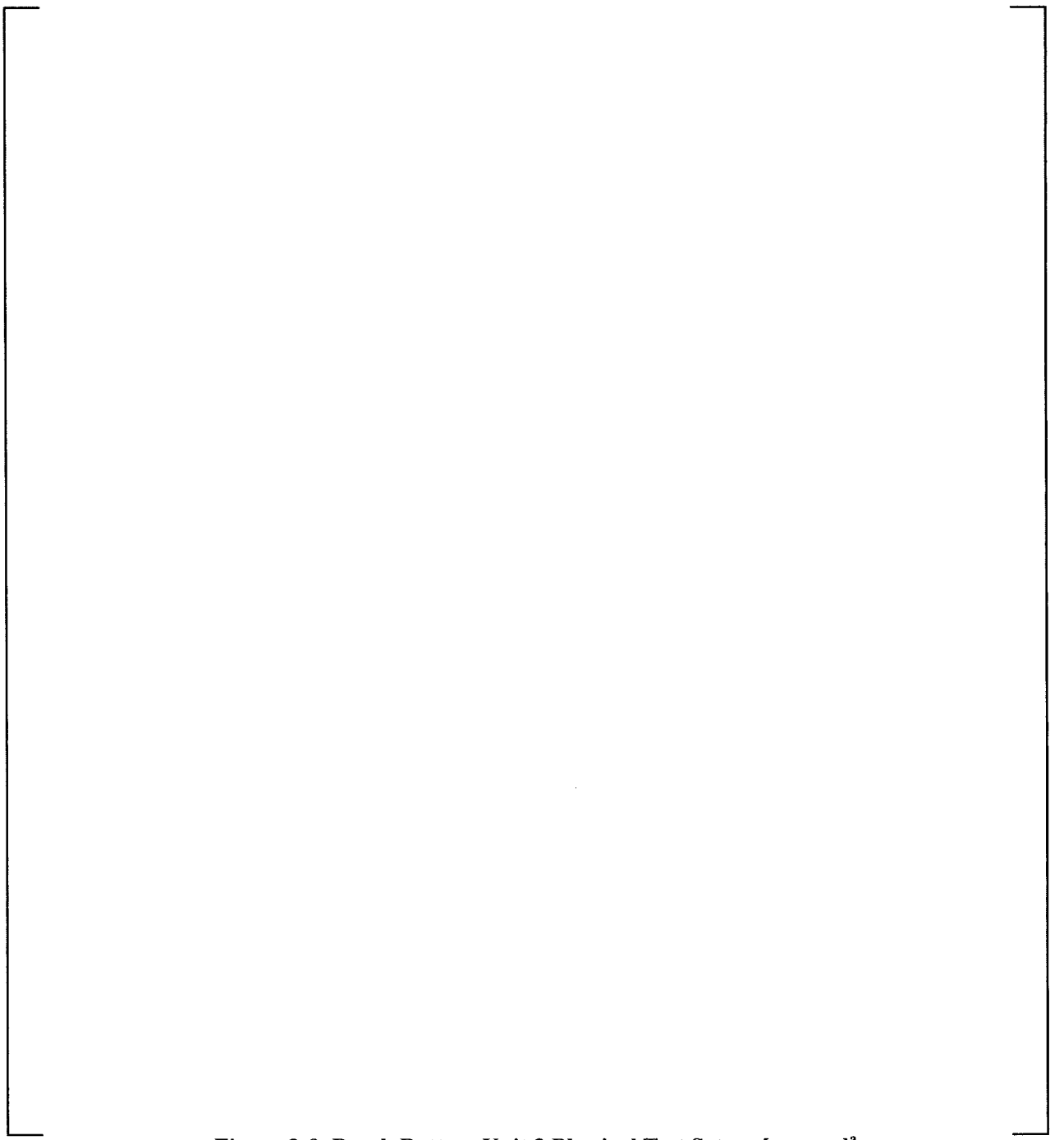
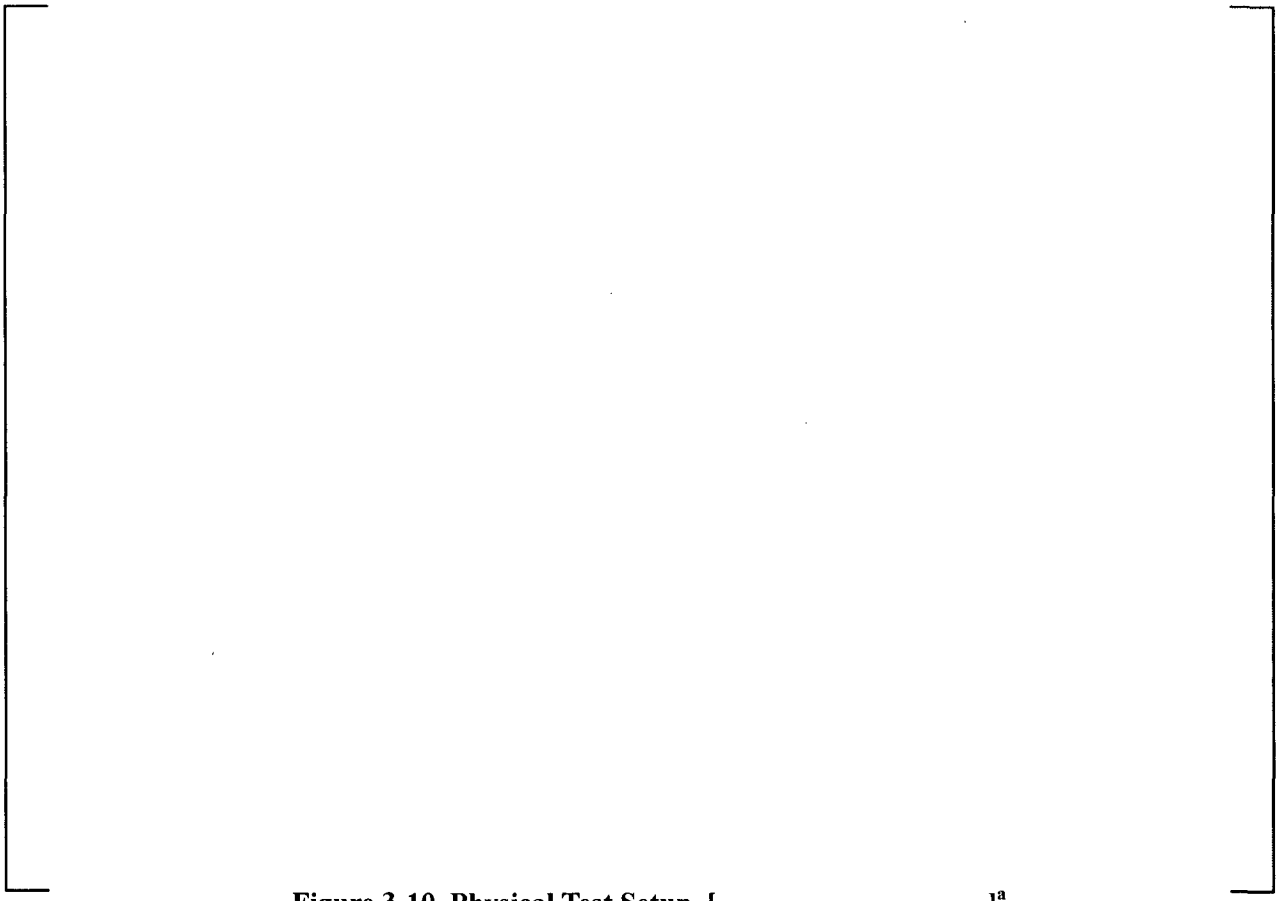


Figure 3-9 Peach Bottom Unit 3 Physical Test Setup, [ ]a

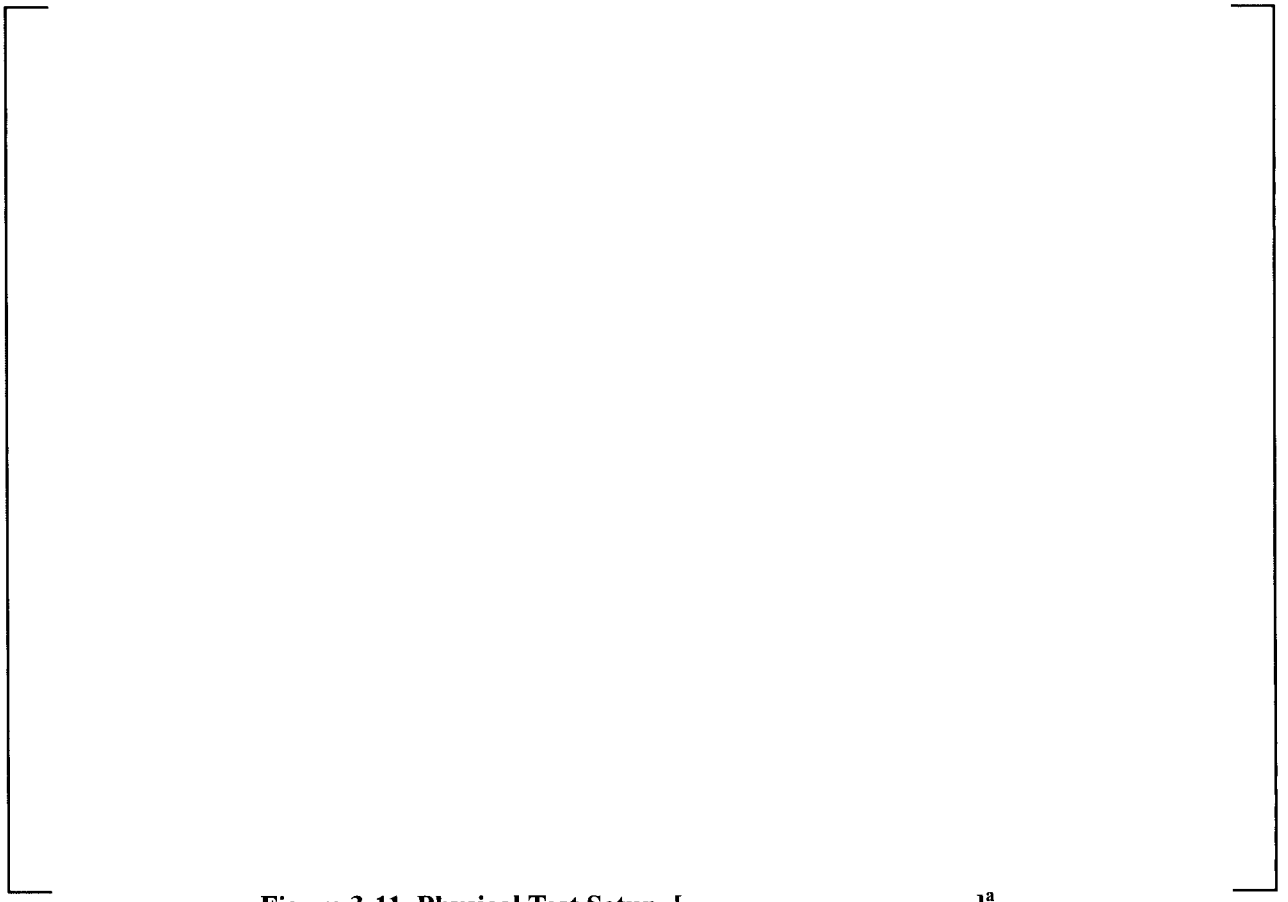
[

]a



a

Figure 3-10 Physical Test Setup, [ ]a

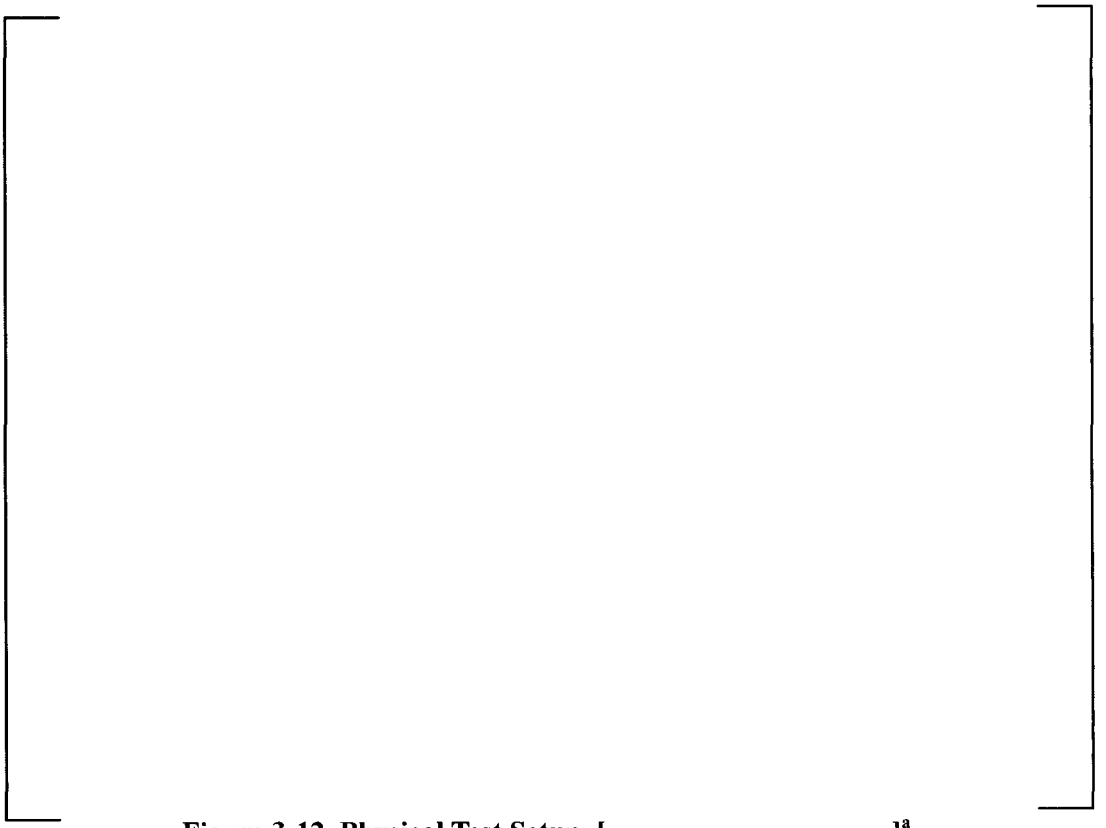


a

Figure 3-11 Physical Test Setup, [ ][a]

[

]a



a

Figure 3-12 Physical Test Setup, [ ]a

3.2 PROCEDURAL OVERVIEW

The testing procedure is documented in Reference 6 for Unit 2 and Reference 7 for Unit 3. The testing procedure is the same for both units and is summarized in this section.

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]a

[

]a

[

]a

[

]a

[

]a

[

]a

[

]a

3.3 INSTRUMENTATION AND DATA ACQUISITION SPECIFICATION

[

]^{a} The instrumentation for both units is summarized in Table 3-1. [

]^{a}

Table 3-1 Instrumentation Log

Channel	Location	Transducer	Manufacturer	Model No.
[				
				]^{a}

[

]^{a}

[

]^{a}

3.4 SHAKEDOWN TESTING

In the test plans (References 6 and 7), [
]a

1. [
]a This was done by inspection of the results by the test engineer.

2. [ ]a

3. [
]a

[

]a

[

]a

3.5 PRODUCTION TESTING

[
]a The Unit 2 test logs are shown in Table 5-3 and Table 5-4. The Unit 3 test logs are shown in Table 5-5, Table 5-6, and Table 5-7.

[

]a

[

]a

4 DATA PROCESSING METHODOLOGY

The data processing performed during the testing is described in the test plans (References 6 and 7), and is the same for Peach Bottom Unit 2 and Unit 3.

4.1 DATA FILTERING AND SELECTION

[

]a

[

]a

4.2 DERIVATION OF THE MACH NUMBER

[

]a

The derivation of the Mach number was performed with Equation (4-1).

$$\left[\right]^{a} \tag{4-1}$$

where,

[

]a

The acoustic speed in air is a function of temperature. The derivation of the acoustic speed is shown in Equation (4-2). This equation is found in Reference 9.

$$c_{air} = \sqrt{\gamma * R * T} \tag{4-2}$$

where,

c_{air} is the acoustic speed in air.

γ is the ratio of specific heats (1.4 for air).

R is the universal gas constant ($1718 * \frac{ft}{s^2 * Rankine}$ for air).

T is the absolute temperature in Rankine.

4.3 FREQUENCY SCALING

[

]^{a}

[ ] a (4-3)

where,

[

]^{a,b}

[

]^{a}

4.4 DERIVATION OF THE SIDE BRANCH NATURAL FREQUENCIES

The side branch natural frequencies were derived [

]^{a}

[

]a

Table 4-1 [		]a,b
[		
		]a,b

[

]a

4.5 DERIVATION OF THE POWER SPECTRAL DENSITIES

The PSDs were derived using Welch's modified periodogram method. Averaging was used, and the number of points selected for each ensemble were selected to yield a frequency resolution of 1 Hz (full scale). A Hanning window was used to reduce spectral leakage, and 50 percent overlap was used to increase the number of averages.

4.6 DERIVATION OF THE RMS PRESSURES

The derivation of the RMS pressures is shown in Equation (4-4).

$$\left[\qquad\qquad\right]^{a} \tag{4-4}$$

where,

[

]a

By applying Equation (4-4), [

]a

[

]a

[

]a

$$\left[\qquad\qquad\right] \text{ a} \tag{4-5}$$

where,

[

]a

[

]a

4.7 DERIVATION OF THE CLTP-TO-EPU SCALING SPECTRA

[

]a This is shown in Equation (4-6), and discussed in Reference 3.

[ ] a (4-6)

where,

[ ] a

[

]a

[ ] (4-7)

a

where,

[ ] a

[

]a

5 RESULTS

5.1 TEST LOGS

Table 5-1 and Table 5-2 show the test logs from the shakedown runs for Peach Bottom Unit 2 and Unit 3, respectively. [

]^{a}

Table 5-1 Shakedown Testing Log, Peach Bottom Unit 2

Date (DD/MM/YYYY)	Time (HH:MM:SS)	Filename	Orifice Diameter, in.	Mach No.	% CLTP
[					
					]^{a,b}

Table 5-2 Shakedown Testing Log, Peach Bottom Unit 3

Date (DD/MM/YYYY)	Time (HH:MM:SS)	Filename	Orifice Diameter, in.	Mach No.	% CLTP
[					
					]^{a,b}

[

]^{a}

[

]^{d}

Table 5-3 Production Run Logs, Peach Bottom Unit 2 [					][d]
Date (DD/MM/YYYY)	**Time (HH:MM:SS)**	**Filename**	**Orifice Diameter, in.**	**Mach No.**	**% CTLP**
[					
					][b]

Table 5-4 Production Run Log, Peach Bottom Unit 2 [ ]d					
Date (DD/MM/YYYY)	Time (HH:MM:SS)	Filename	Orifice Diameter, in.	Mach No.	% CTLP
[					
					]b

Table 5-5, Table 5-6, and Table 5-7 show the test logs for the production runs for the Peach Bottom Unit 3 test setup. [

]a

Table 5-5 Production Run Log, Peach Bottom Unit 3 [ ]d					
Date (DD/MM/YYYY)	Time (HH:MM:SS)	Filename	Orifice Diameter, in.	Mach No.	% CLTP
[					
					]b

Table 5-5 Production Run Log, Peach Bottom Unit 3 [					]^{d}
Date (DD/MM/YYYY)	**Time (HH:MM:SS)**	**Filename**	**Orifice Diameter, in.**	**Mach No.**	**% CLTP**
[					
					]^{b}

Table 5-5 Production Run Log, Peach Bottom Unit 3 [ ]^{d}

Date (DD/MM/YYYY)	Time (HH:MM:SS)	Filename	Orifice Diameter, in.	Mach No.	% CLTP
[					
					]^{b}

Table 5-6 Production Run Log, Peach Bottom Unit 3 [					]^{d}
Date (DD/MM/YYYY)	**Time (HH:MM:SS)**	**Filename**	**Orifice Diameter, in.**	**Mach No.**	**% CLTP**
[					
					]^{b}

Table 5-6 Production Run Log, Peach Bottom Unit 3 [					]^{d}
Date (DD/MM/YYYY)	Time (HH:MM:SS)	Filename	Orifice Diameter, in.	Mach No.	% CLTP
[					
					]^{b}

Table 5-7 Production Run Log, Peach Bottom Unit 3 [					]^{d}
Date (DD/MM/YYYY)	Time (HH:MM:SS)	Filename	Orifice Diameter, in.	Mach No.	% CLTP
[					
					]^{b}

5.2 MACH NUMBER COMPARISONS

[

]^{a}

b

Figure 5-1 [ ]^{a,b}, Peach Bottom Unit 2

Figure 5-2 [ ]^{a,b}, Peach Bottom Unit 3

[

]^{a}

$$[\quad]^{a,b} \qquad (5\text{-}1)$$

$$[\quad]^{a,b} \qquad (5\text{-}2)$$

where,

[ ]^{a}

5.3 NATURAL FREQUENCIES OF THE SIDE BRANCHES

[

]a

Table 5-8 [ ]a, Peach Bottom Unit 2

[			]a
[			
			]b

Table 5-9 [ ]a, Peach Bottom Unit 3

[			]a
[			
			]b

[

]a,b

5.4 ASSESSMENT OF THE MSL ACOUSTIC SIGNATURES

[

]a

[

]a,b

[

]a

b

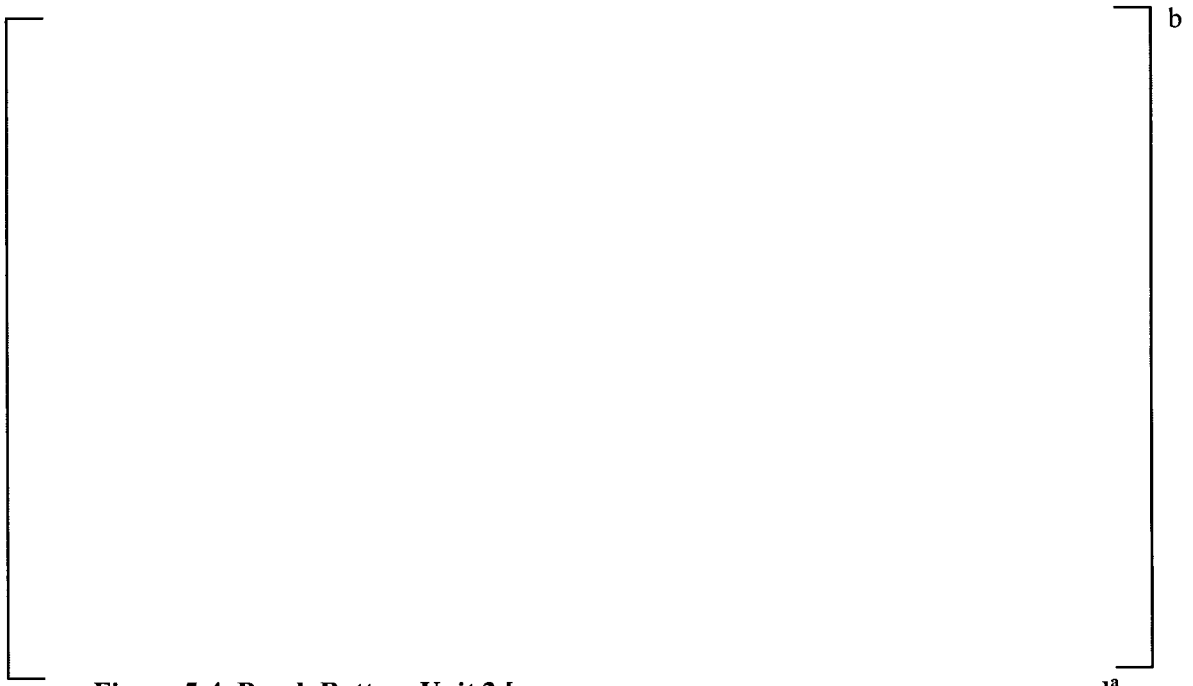
Figure 5-3 Peach Bottom Unit 2 [ ]a

[

]b

[

]a



b

Figure 5-4 Peach Bottom Unit 2 [ ]a

[

]b

[

]a

Figure 5-5 Peach Bottom Unit 2 [ ]a

[

]b

[

]a

b

Figure 5-6 Peach Bottom Unit 2 [ ]a

[

]b

[

]a,b

[

]a

[

]b

Figure 5-7 Peach Bottom Unit 3 [ ]a

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]b

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]a

b

Figure 5-8 Peach Bottom Unit 3 [ ]a

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b

Figure 5-9 Peach Bottom Unit 3 [ ]a

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Figure 5-10 Peach Bottom Unit 3 [ ]a

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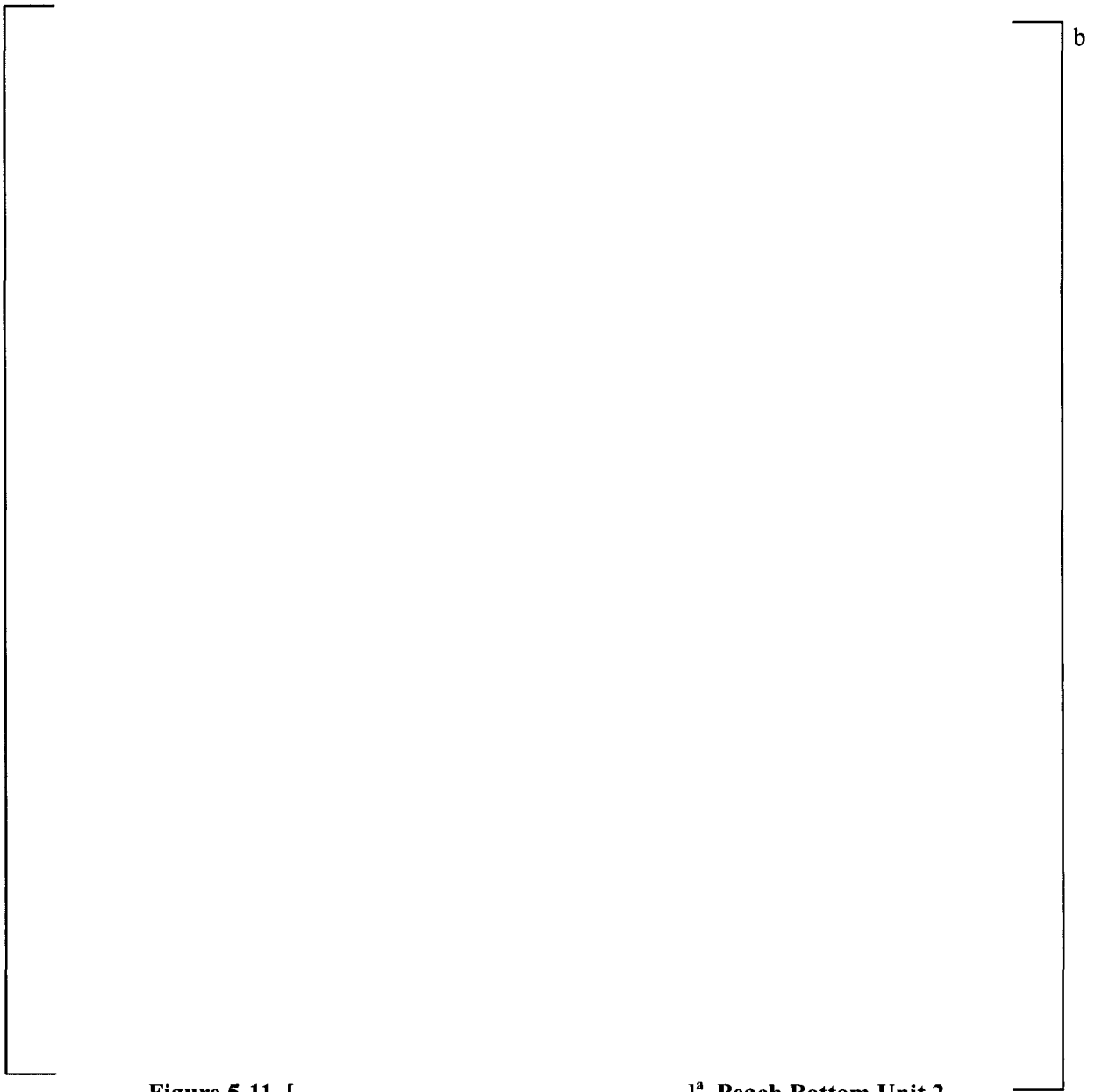
]b

[

]^{a,b}



b

Figure 5-11 [ ]^{a}, Peach Bottom Unit 2

[ ]b

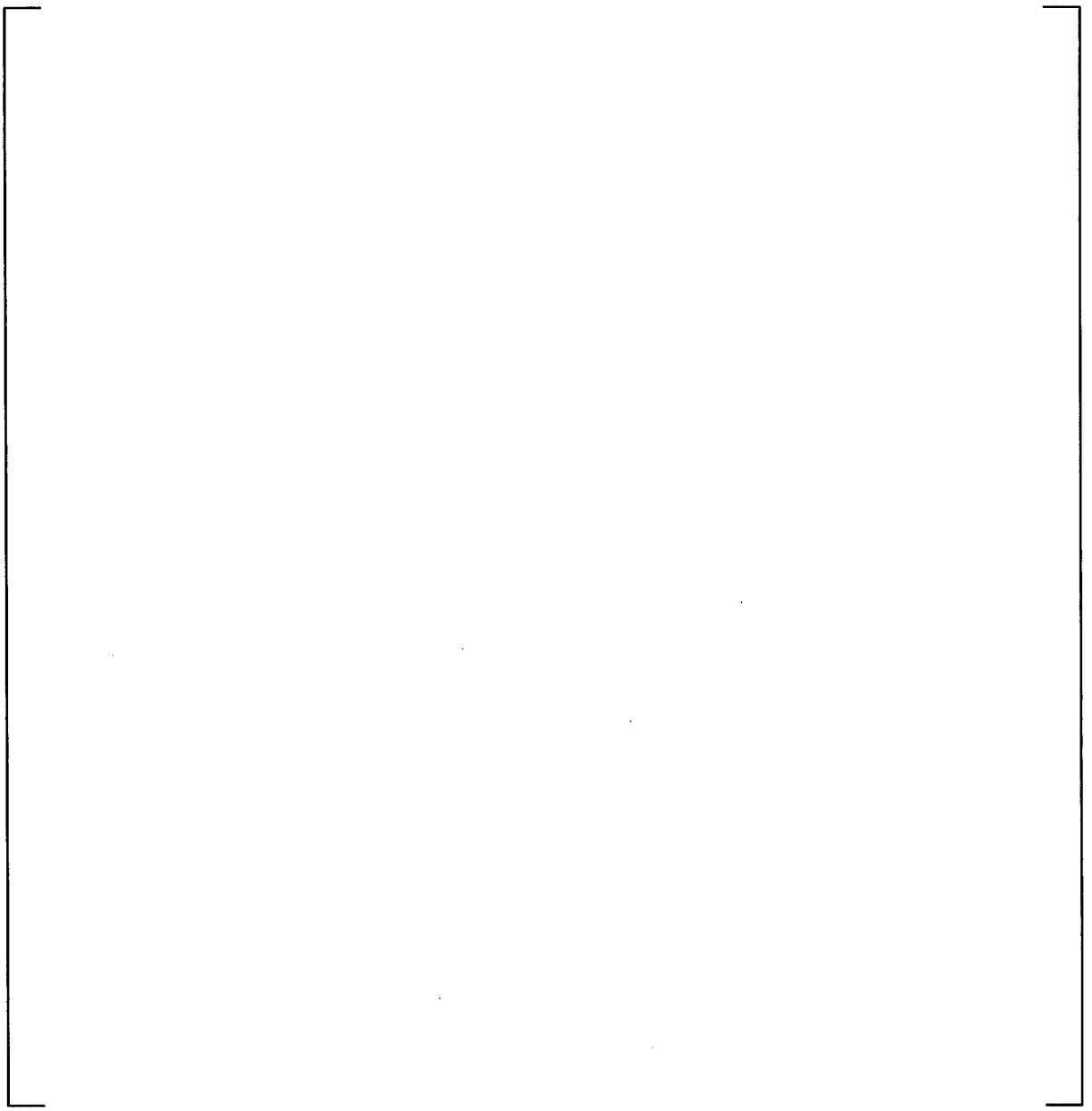


Figure 5-12 [ ]a, Peach Bottom Unit 3

[

]a,b

[

]a

5.5 RMS PRESSURE TRENDS

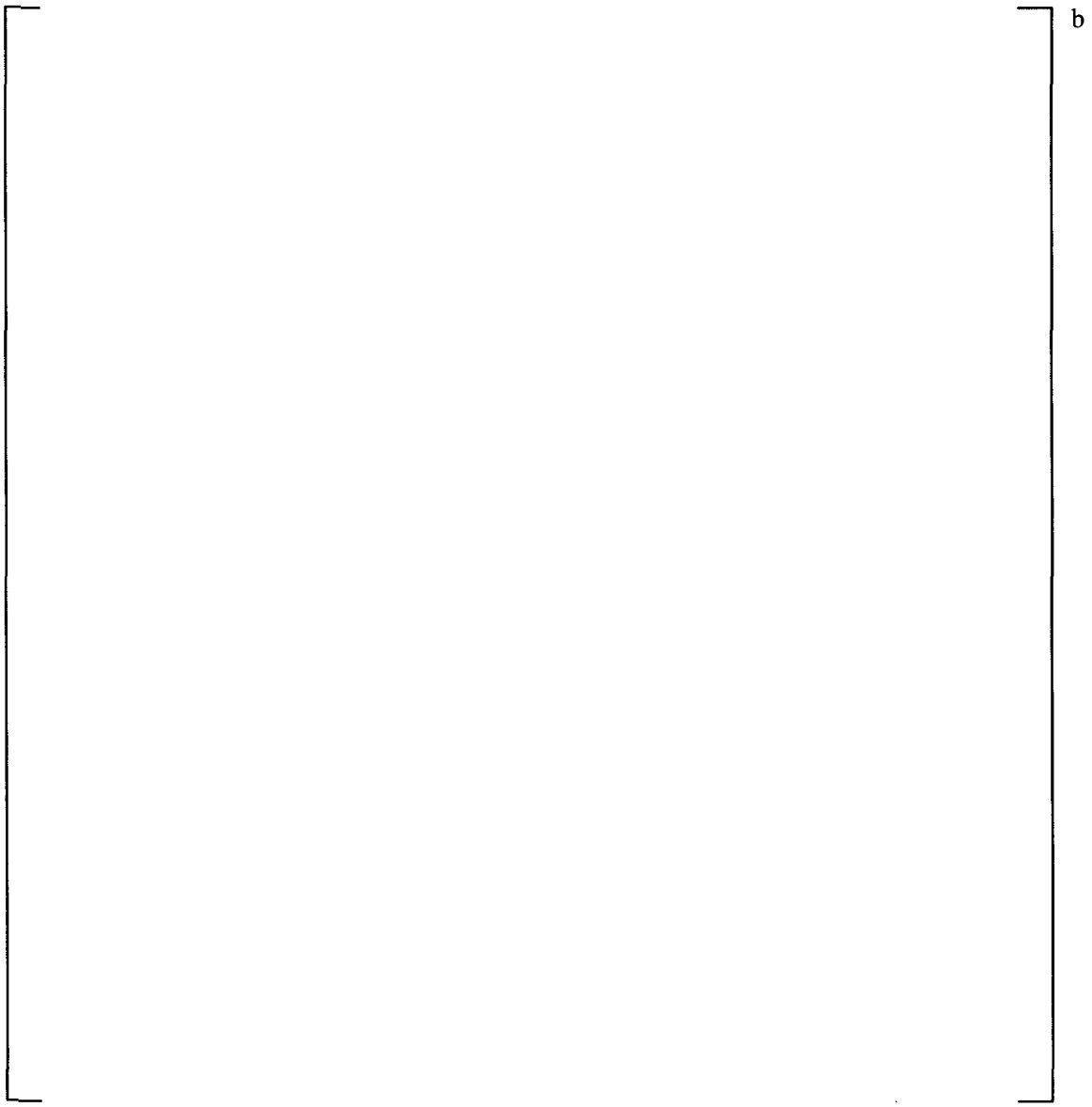
[

]^{a,b}

5.5.1 Total RMS Pressure Trend

[

]^{a,d}



b

Figure 5-13 [ ]^{a}, Peach Bottom Unit 2

[ ]b

Figure 5-14 [ ]a, Peach Bottom Unit 3

[

]a,b

[

]a

5.5.2 RMS Pressure Trend for the Target Rock SRV

[

]a,d

[b

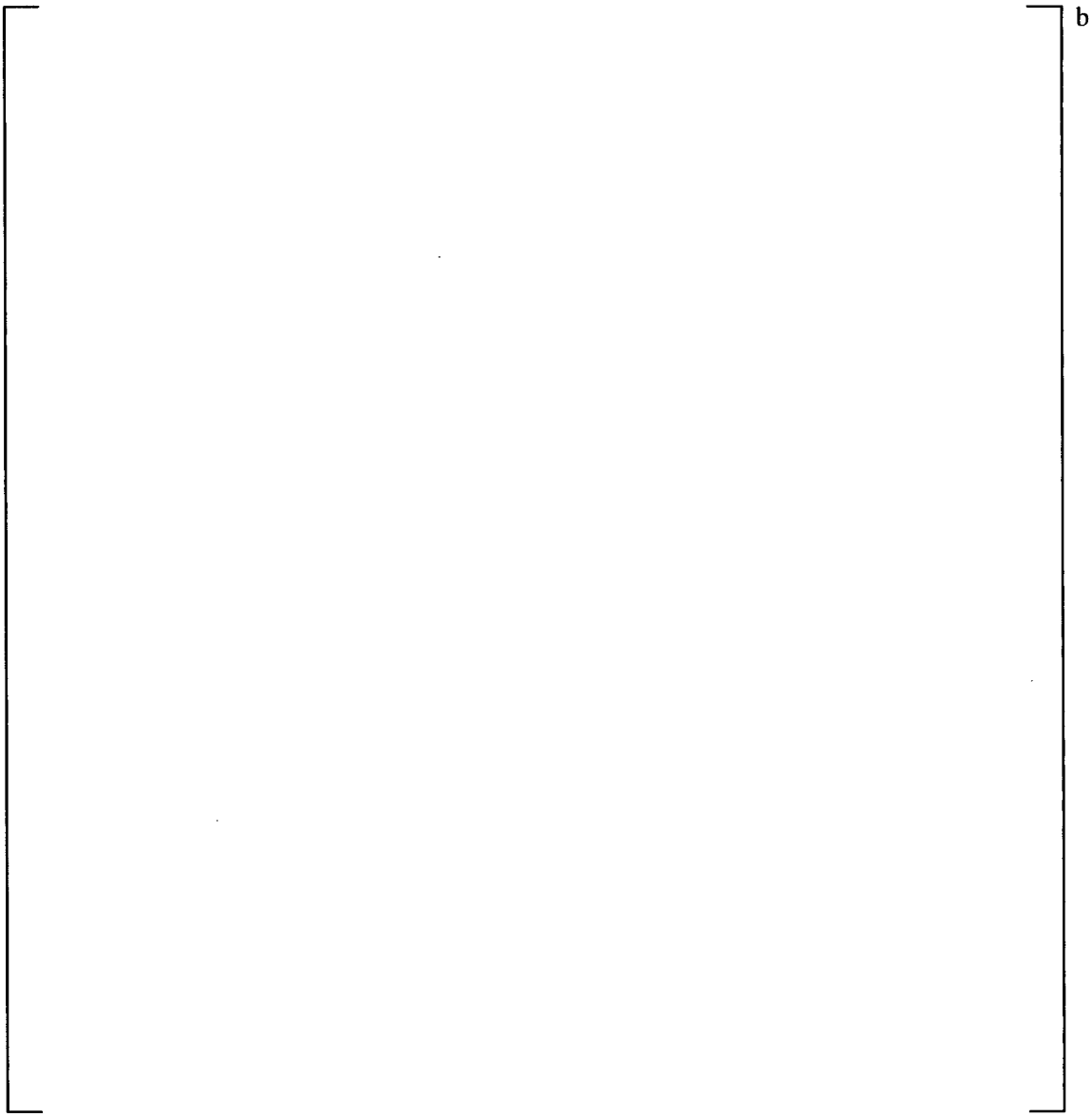
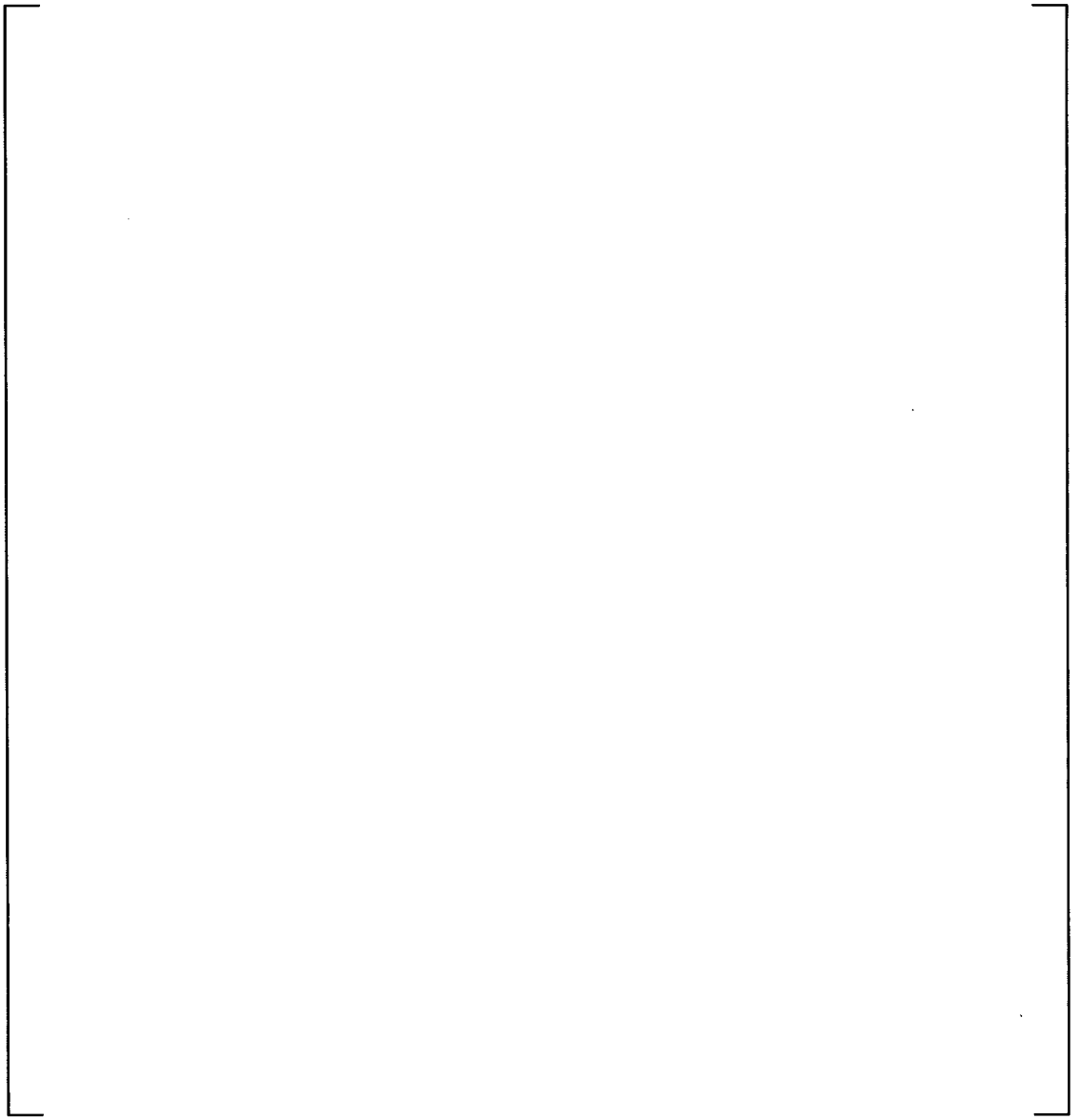


Figure 5-15 [ ]^{a}, Peach Bottom Unit 2

[b



]

Figure 5-16 [ ]^{a}, Peach Bottom Unit 3

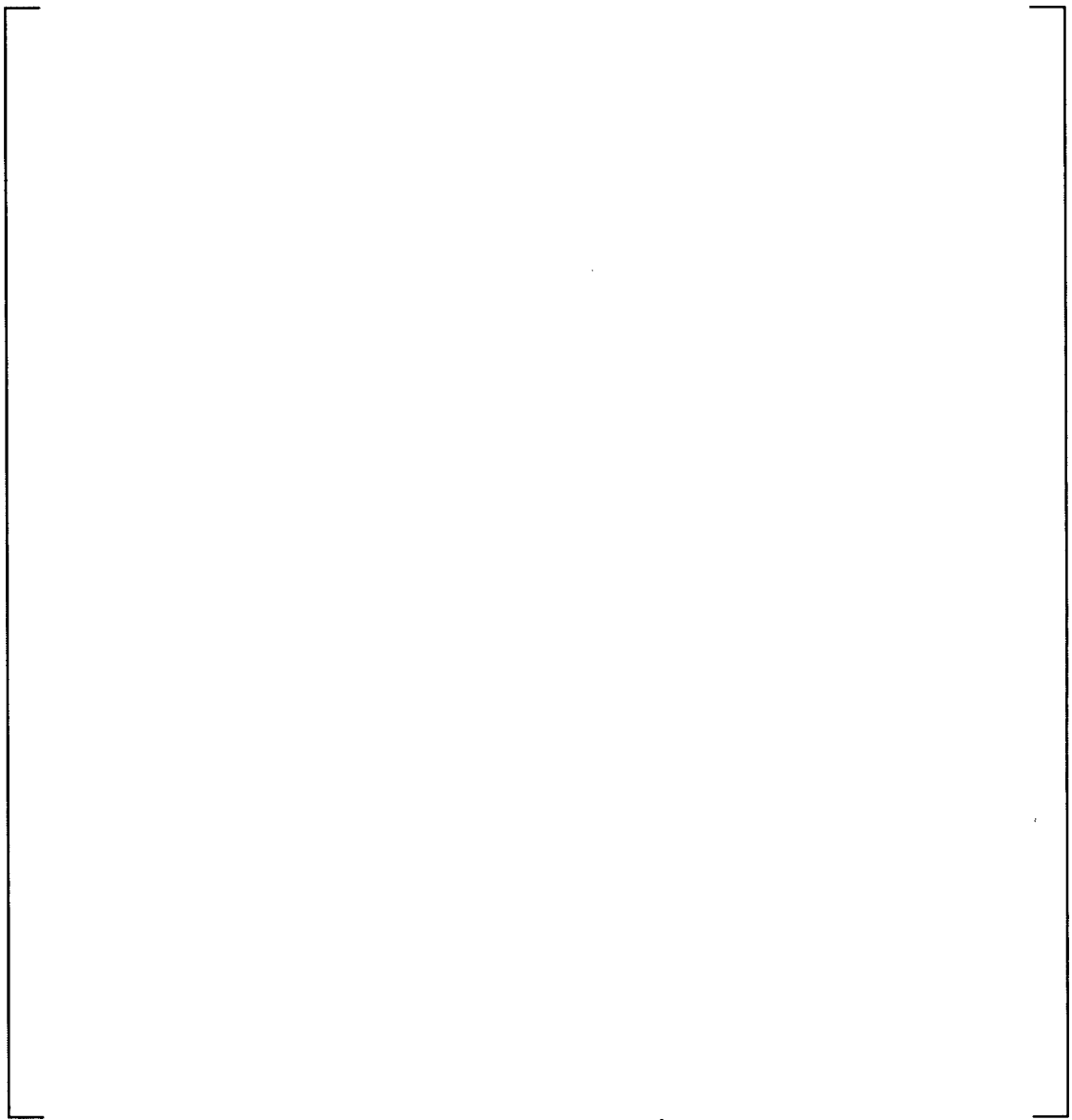
[

]^{b}

5.5.3 RMS Pressure Trend for the Dresser SSV

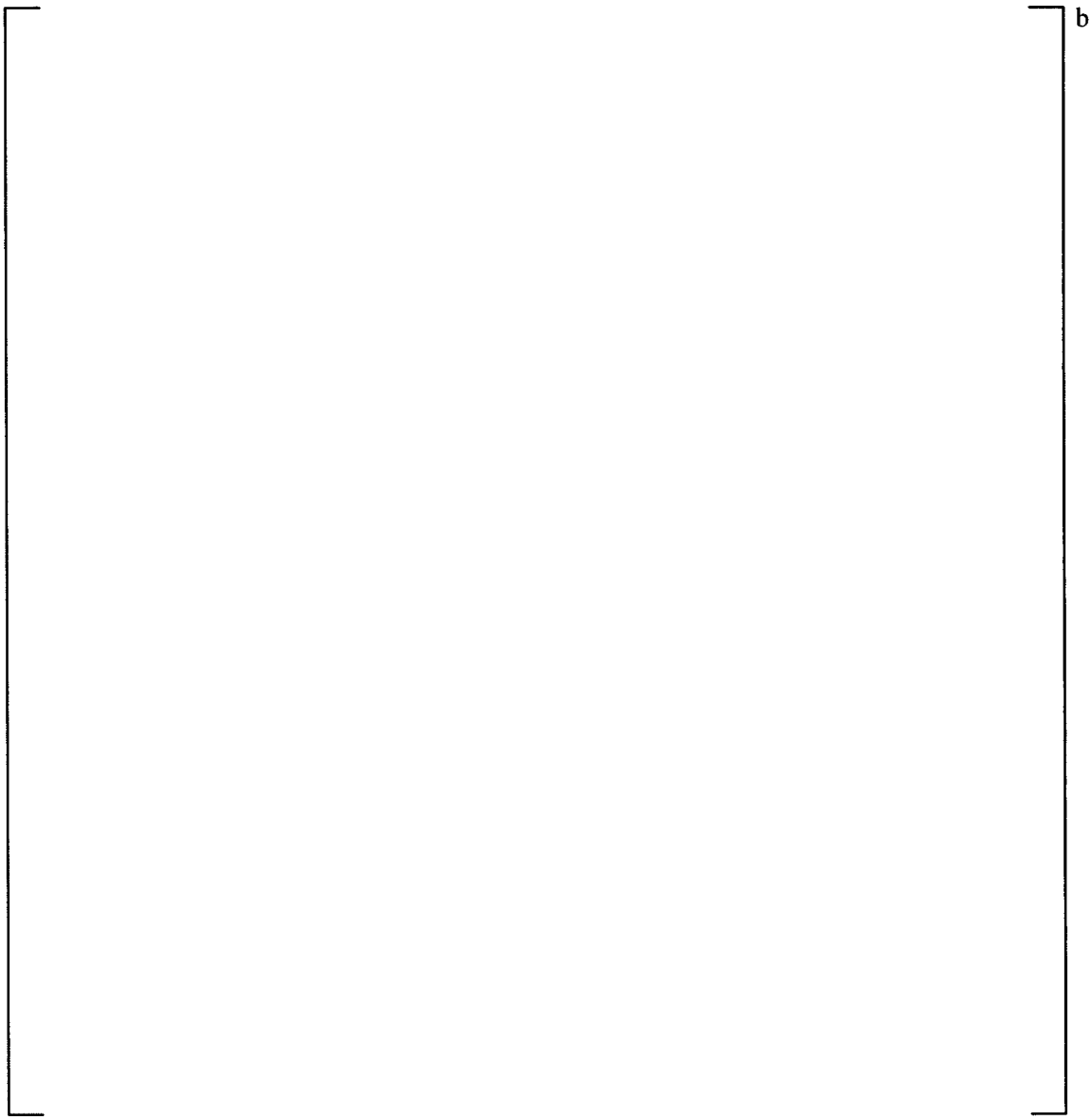
[

]^{a,d}



]^{b}

Figure 5-17 [ ]^{b} Peach Bottom Unit 2



b

Figure 5-18 [ ]^{a}, Peach Bottom Unit 3

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]^{b}

5.5.4 RMS Pressure Trend for the Blind-Flanged Standpipe

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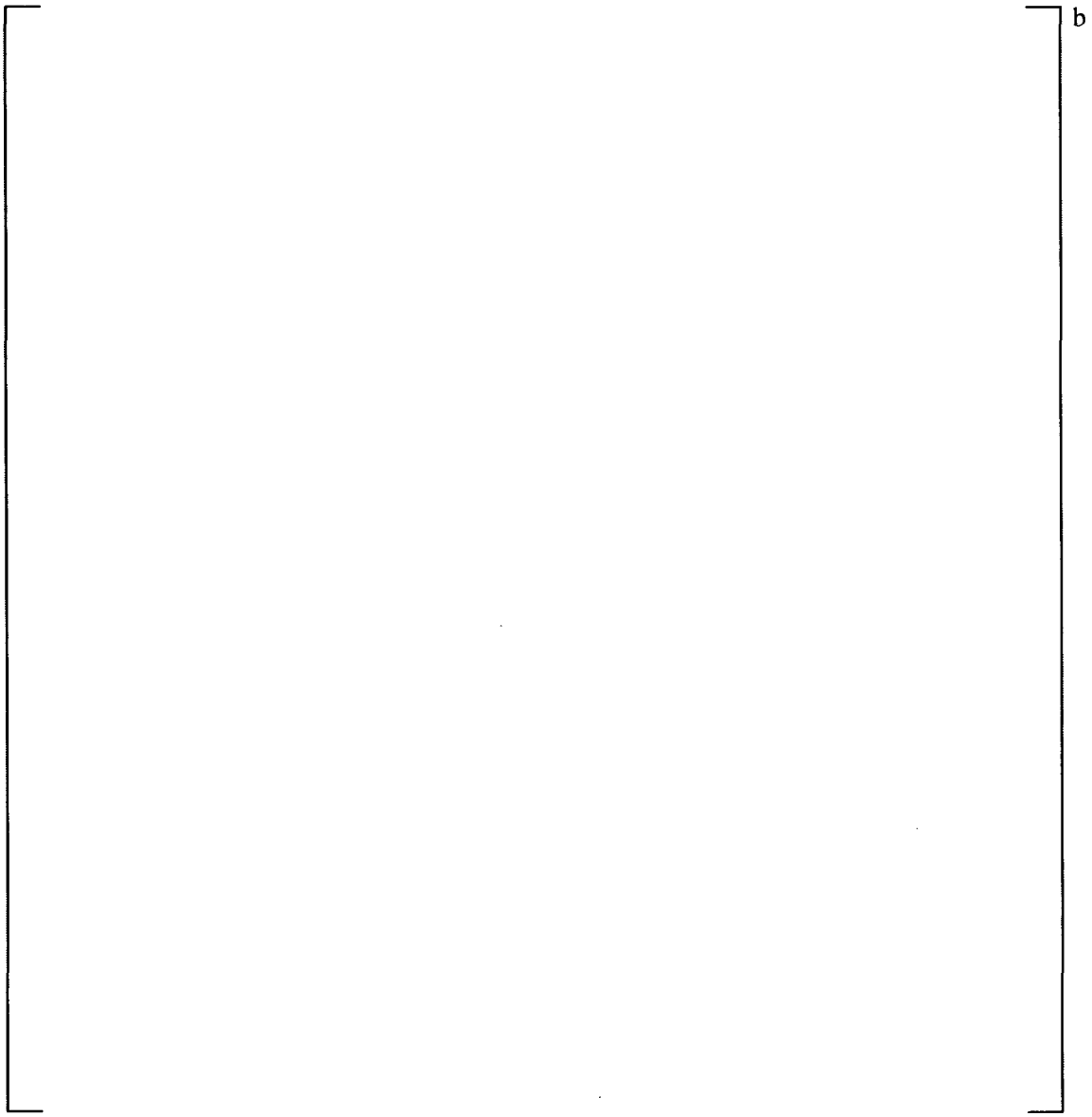
]^{a,d}



b

Figure 5-19 [ ]^{a}, Peach Bottom Unit 2

[ ]b

Figure 5-20 [ ]a, Peach Bottom Unit 3

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]b

[

]b

[

]b

5.6 EVALUATION OF THE IMPACT OF THE SUBSCALE [ ]d AND [ ]d

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]a,d

[

]d

[

]a,d

[

]^{a,d}

Figure 5-21 [ ]^{a}

Peach Bottom Unit 2

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]^{a,d}

Figure 5-22 [ ]^{a}

Peach Bottom Unit 3

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]^{b}

[ ]b

Figure 5-23 Peach Bottom Unit 2 [ ]a

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]b

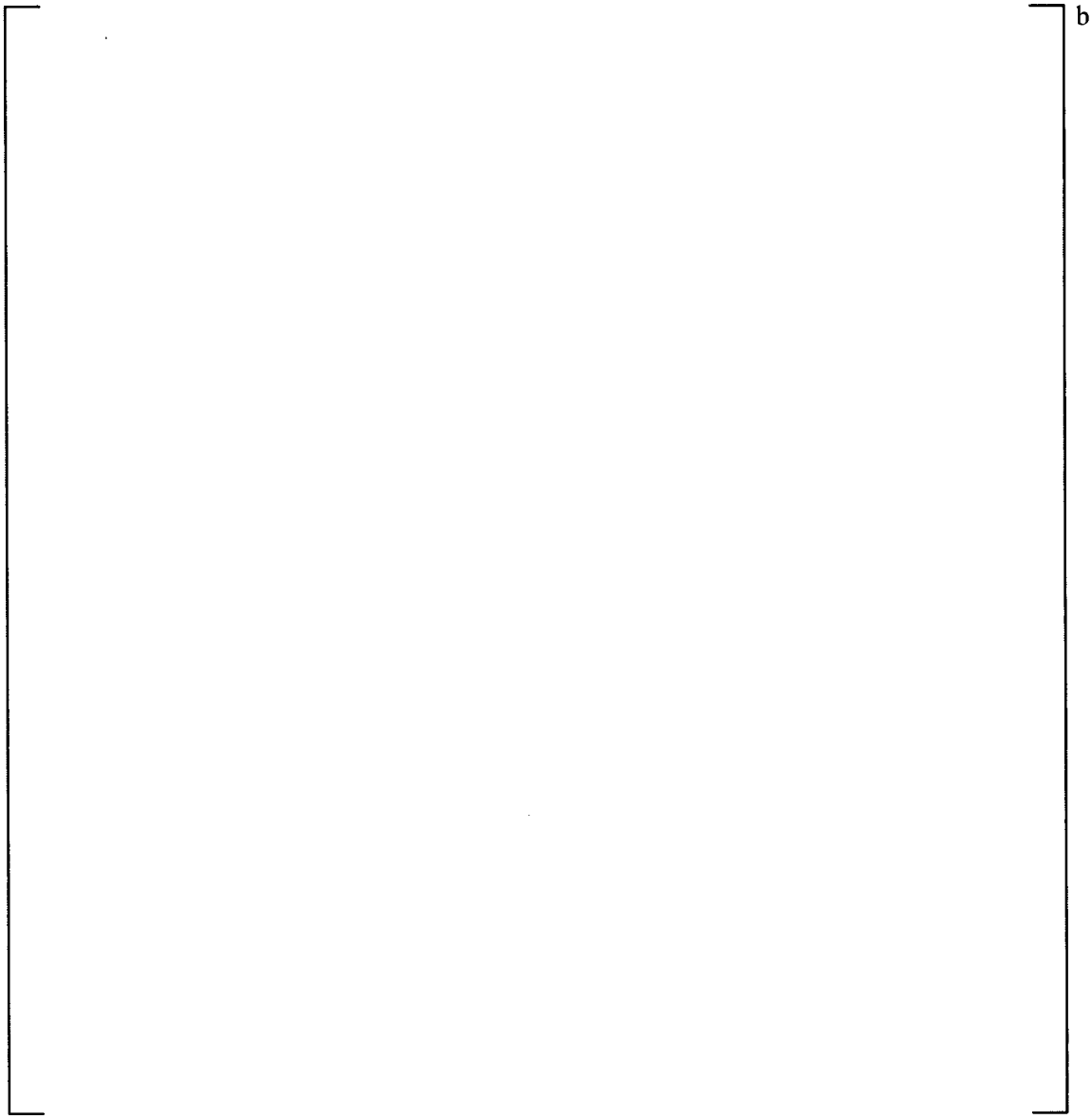

Figure 5-24 Peach Bottom Unit 3 [ ]^a

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]^a,b

6 CLTP-TO-EPU SCALING SPECTRA DERIVATION

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]^{a,b}

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]^{a}

[

]^{a,b}

[ ]b

Figure 6-1 Peach Bottom Unit 2 [ ]a

[ ]b

Figure 6-2 Peach Bottom Unit 3 [ ]a

[

]^{a}

$$\left[\right]^{a} \tag{6-1}$$

where,

[

]^{a,b}

[

]^{a,b}

[ ]b

Figure 6-3 Peach Bottom Unit 2 [ ]a

[ ]b

Figure 6-4 Peach Bottom Unit 2 [ ]a

Figure 6-5 Peach Bottom Unit 2 [ ]^{a}

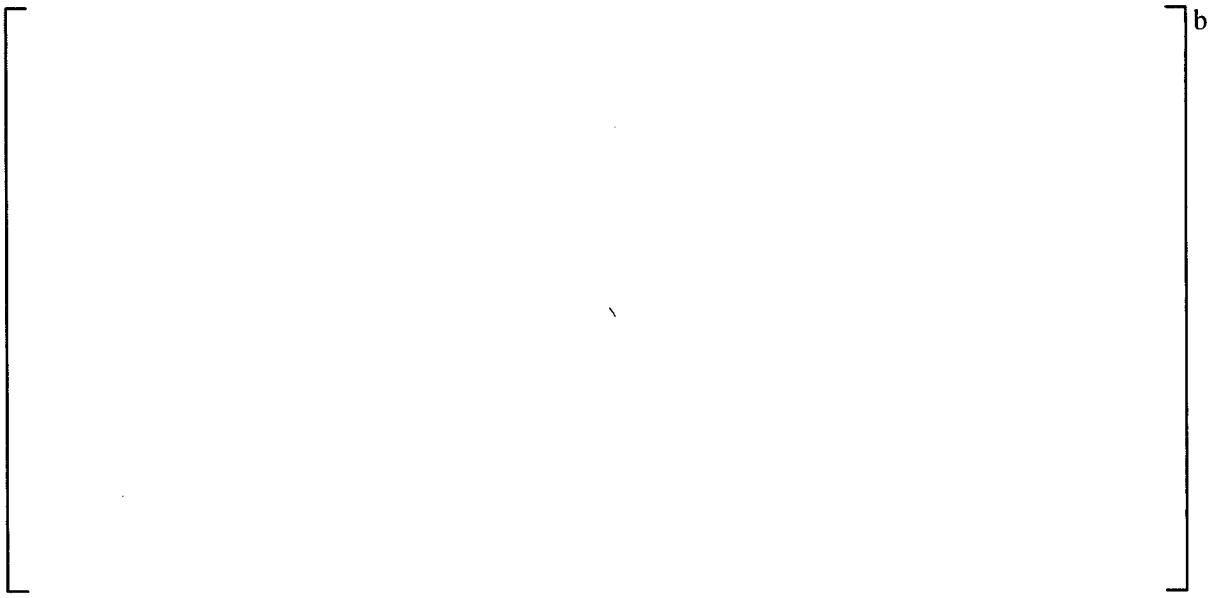

Figure 6-6 Peach Bottom Unit 2 [ ]^{a}

[

]a,b

Figure 6-7 Peach Bottom Unit 3 [ ]a

Figure 6-8 Peach Bottom Unit 3 [ ]a

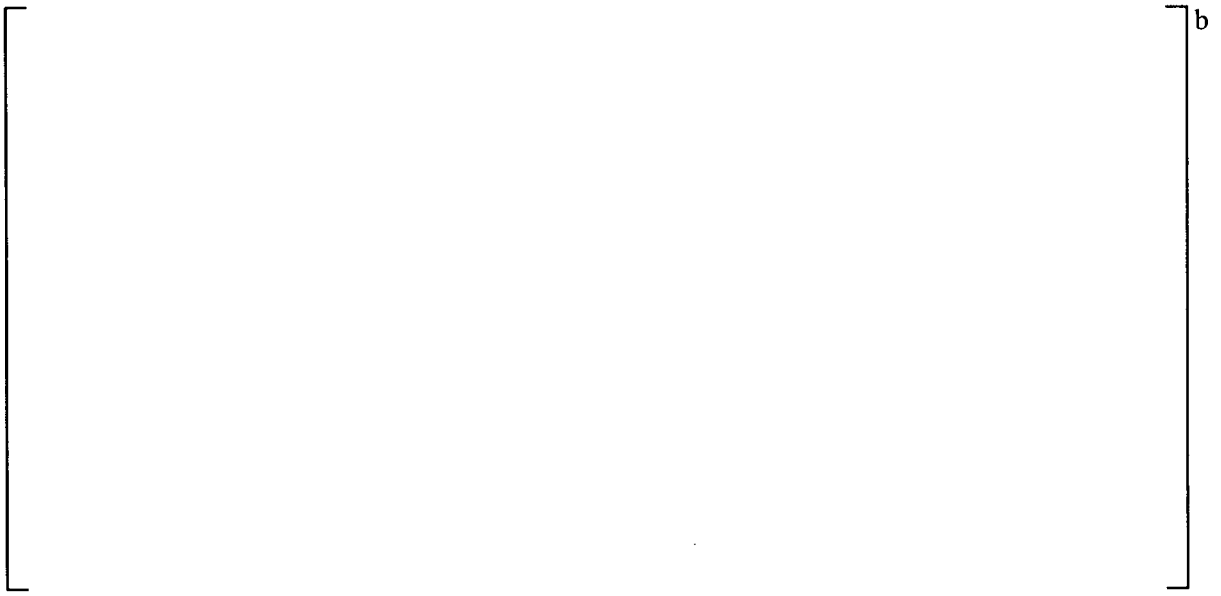

Figure 6-9 Peach Bottom Unit 3 [ ]^{a}

Figure 6-10 Peach Bottom Unit 3 [ ]^{a}

7 CONCLUSIONS

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[ ]a,d

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]b

[

]a,b

[

]a,b

8 REFERENCES

1. Exelon Technical Requirements Document, "Technical Requirements for the Replacement of Steam Dryers at Peach Bottom Atomic Power Station (PBAPS), LaSalle County Generating Station (LCGS), and Limerick Generating Station (LGS)," October 28, 2011.

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]^{a}

5. Westinghouse Letter [
]^{a}

6. Westinghouse Test Plan [
]^{a}

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]^{a}

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