# ENCLOSURE 2

## Attachment 6

## Exelon Report Number AM-2005-007, "AM-2005-007 Assessment of the Revised QC1 Minimum Error ACM Loads Using All Main Steam Line Strain Gages," Revision 0, dated August 2, 2005

# AM-2005-007 Assessment of the Revised QC1 Minimum Error ACM Loads Using All Main Steam Line Strain Gages

*Document Number AM-2005-007*
*Revision 0*

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# Abstract

This report documents an assessment of the minimum error acoustic circuit model loads that were developed by CDI using different main steam (MS) line pressure inputs. The assessment examines the differences between these two load cases to determine which would produce bounding dryer stresses.

# 1. Introduction

This report assesses the magnitudes and frequency content of the steam dryer pressure loads predicted by the CDI minimum error acoustic circuit model (ACM) for Quad Cities Unit 1 (QC1) as reported in Reference 1. Two sets of dryer pressure loads developed using the same acoustic circuit model with different main steam line pressure inputs were compared and assessed to determine which load case is bounding. Details of the CDI minimum error acoustic circuit model are found in Reference 2, Section 5.6. The difference between the two pressure load cases being compared is the treatment of the failed strain gage data used to develop the main steam line pressures. A detailed description of the differences in the main steam line pressures used to develop these two load cases is found in Reference 1.

The load case identified as TC15a in Reference 1 has been used in the finite element analysis of the dryer to qualify the dryer skirt. The GE finite element analysis results are designated as QC1B. The load case identified as TC15a_3 in Reference 1 represents the dryer loads that best represent the pressures acting on the Unit 1 dryer. This is based on the conclusions developed in References 2 and 3 for the acoustic circuit model, and the recommendations for defining the QC1 main steam line pressure input to these models given in Reference 4.

The purpose of this assessment is to determine which of the two load cases would produce bounding dryer stresses. It will examine the differences in pressures at specified locations on the dryer to determine changes in pressure magnitudes and frequencies. The pressure loads on the dryer skirt and outer hoods are the specific locations to examine, as these are the locations of the largest pressures and highest stresses on the dryer.

# 2. Description of Assessment Criteria

The purpose of this assessment is to determine the relative magnitudes and frequencies of the two load cases. The locations of primary interest are:

1) Skirt Locations P22, P24, and P25
2) Dryer external locations P3, P12, P20, and P21 (these are the highest load points opposite the nozzles)
3) Other external dryer locations may also be reviewed as necessary
4) Internal pressures at P13, P14 will be compared in combination with P3 and P20 to establish hood differential pressure behavior.

These locations were chosen because they best represent the pressure loads acting on the skirt (i.e., P22, P24 andP25) and the largest pressure loads acting on the outer hoods (i.e., P3, P12, P20 and P21).

The following criteria were applied for the initial comparison:

1) Root mean square (RMS) pressures – TC15a case should be within -5% or greater than the TC15a_3 load case.
2) Peak pressures – TC15a case should be within -3% or greater than the TC15a_3 load case.
3) Differential pressure indications should be conservative for TC15a case relative to TC15a_3 load case.
4) Power Spectral Densities (PSDs) will be compared at critical structural frequencies for the elements in question: For the skirt, this frequency is 33 Hz +/- 5Hz. For the hood, the frequencies of interest are 80-110 Hz, 140 Hz +/- 5Hz, and 155 Hz +/- 5hz. The expectation is that the TC15a case will show comparable or conservative PSD amplitude values compared to the TC15a_3 load case.

If these criteria are satisfied, the TC15a load case is considered to be an acceptable load definition for determining the FIV stresses in the dryer.

# 3. Assessment of TC15a and TC15a_3 Load Cases

The summary pressures and PSDs for the two load cases are documented in Reference 1. To assess these results, Table 1 below provides the minimum, maximum, and RMS pressures for both load cases at each of the QC2 dryer pressure transducer locations.

| Pressure Sensor Number | TC15a: Minimum psi | TC15a_3: Minimum psi | % Change Minimum | TC15a: Maximum psi | TC15a_3: Maximum psi | % Change Maximum | TC15a: RMS psi | TC15a_3: RMS psi | % Change RMS |
|---|---|---|---|---|---|---|---|---|---|
| P1 | -1.342 | -1.355 | -0.959 | 1.341 | 1.440 | -6.875 | 0.438 | 0.464 | -5.603 |
| P2 | -1.028 | -1.121 | -8.296 | 1.010 | 1.140 | -11.404 | 0.224 | 0.270 | -17.037 |
| P3 | -1.938 | -1.776 | 9.122 | 1.830 | 1.688 | 8.412 | 0.504 | 0.467 | 7.923 |
| P4 | -0.723 | -0.777 | -6.950 | 0.755 | 0.728 | 3.709 | 0.177 | 0.182 | -2.747 |
| P5 | -1.038 | -0.766 | 35.509 | 0.813 | 0.799 | 1.752 | 0.199 | 0.194 | 2.577 |
| P6 | -1.301 | -1.164 | 11.770 | 1.267 | 1.171 | 8.198 | 0.347 | 0.312 | 11.218 |
| P7 | -1.054 | -1.125 | -6.311 | 1.038 | 1.179 | -11.959 | 0.338 | 0.386 | -12.435 |
| P8 | -0.837 | -0.678 | 23.451 | 0.809 | 0.713 | 13.464 | 0.182 | 0.161 | 13.043 |
| P9 | -1.674 | -1.550 | 8.000 | 1.695 | 1.562 | 8.515 | 0.510 | 0.518 | -1.544 |
| P10 | -1.322 | -1.361 | -2.866 | 1.364 | 1.393 | -2.082 | 0.436 | 0.458 | -4.803 |
| P11 | -0.946 | -0.789 | 19.899 | 0.866 | 0.848 | 2.123 | 0.209 | 0.193 | 8.290 |
| P12 | -2.335 | -2.069 | 12.856 | 2.231 | 2.116 | 5.435 | 0.678 | 0.741 | -8.502 |
| P13 | -0.549 | -0.355 | 54.648 | 0.403 | 0.343 | 17.493 | 0.106 | 0.087 | 21.839 |
| P14 | -0.461 | -0.452 | 1.991 | 0.512 | 0.489 | 4.703 | 0.114 | 0.106 | 7.547 |
| P15 | -2.027 | -2.012 | 0.746 | 1.896 | 1.882 | 0.744 | 0.569 | 0.572 | -0.524 |
| P16 | -0.366 | -0.304 | 20.395 | 0.289 | 0.262 | 10.305 | 0.078 | 0.063 | 23.810 |
| P17 | -1.160 | -1.112 | 4.317 | 1.135 | 1.014 | 11.933 | 0.275 | 0.287 | -4.181 |
| P18 | -1.691 | -1.617 | 4.576 | 1.696 | 1.701 | -0.294 | 0.501 | 0.517 | -3.095 |
| P19 | Not functional | | | | | | | | |
| P20 | -3.342 | -3.503 | -4.596 | 3.621 | 3.781 | -4.232 | 1.075 | 1.124 | -4.359 |
| P21 | -1.641 | -1.503 | 9.182 | 1.461 | 1.462 | -0.068 | 0.407 | 0.395 | 3.038 |
| P22 | -1.439 | -1.407 | 2.274 | 1.527 | 1.351 | 13.027 | 0.435 | 0.445 | -2.247 |
| P23 | -0.332 | -0.251 | 32.271 | 0.257 | 0.204 | 25.980 | 0.073 | 0.056 | 30.357 |
| P24 | -1.138 | -1.029 | 10.593 | 1.193 | 1.125 | 6.044 | 0.280 | 0.257 | 8.949 |
| P25 | -1.342 | -1.260 | 6.508 | 1.348 | 1.258 | 7.154 | 0.328 | 0.295 | 11.186 |
| P26 | -0.294 | -0.238 | 23.529 | 0.280 | 0.245 | 14.286 | 0.077 | 0.064 | 20.313 |
| P27 | -0.335 | -0.242 | 38.430 | 0.285 | 0.231 | 23.377 | 0.074 | 0.059 | 25.424 |
| | | | | | | | | | |
| Average | -1.218 | -1.147 | 6.168 | 1.189 | 1.159 | 2.646 | 0.332 | 0.334 | -0.450 |
| | | | | | | | | | |
| P3-P13 | -1.984 | -1.928 | 2.905 | 1.952 | 1.973 | -1.064 | 0.553 | 0.511 | 8.219 |
| P20-P14 | -3.660 | -3.821 | -4.214 | 3.877 | 4.096 | -5.347 | 1.148 | 1.204 | -4.651 |

Skirt pressures for assessment
Outer Hood pressures for assessment

**Table 1: Pressure Comparisons for TC15a and TC15a_3 Load Cases**

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The table contains the percent difference of the TC15a load case to the TC15a_3 load case. Positive percentages indicate that TC15a pressures are greater than the TC15a_3 pressures for the RMS and maximum pressures. A positive percentage also indicates that TC15a minimum pressures are smaller than the TC15a_3 minimum pressures. Positive percent changes indicate that TC15a bounds the TC15a_3 load case for the pressure being evaluated.

The percent changes at the skirt locations, P22, P24, and P25, meet the assessment criteria provided in Section 2. The minimum pressures for the TC15a load case are smaller than the minimum pressures for the TC15a_3 load case by approximately 2% to 10%. The maximum pressures for TC15a are larger than the maximum pressures for the TC15a_3 load case by approximately 6% to 13%. The RMS pressures for TC15a are generally larger than the maximum pressures for the TC15a_3 load case by approximately 8% to 11%, however one location is less by 2.2%.

Reviewing the frequency content of the skirt pressures at the P22, P24 and P25 locations in Figures 1 through 3 below, the TC15a load case clearly envelops all frequencies at these three locations with one minor exception at approximately 180 Hz.

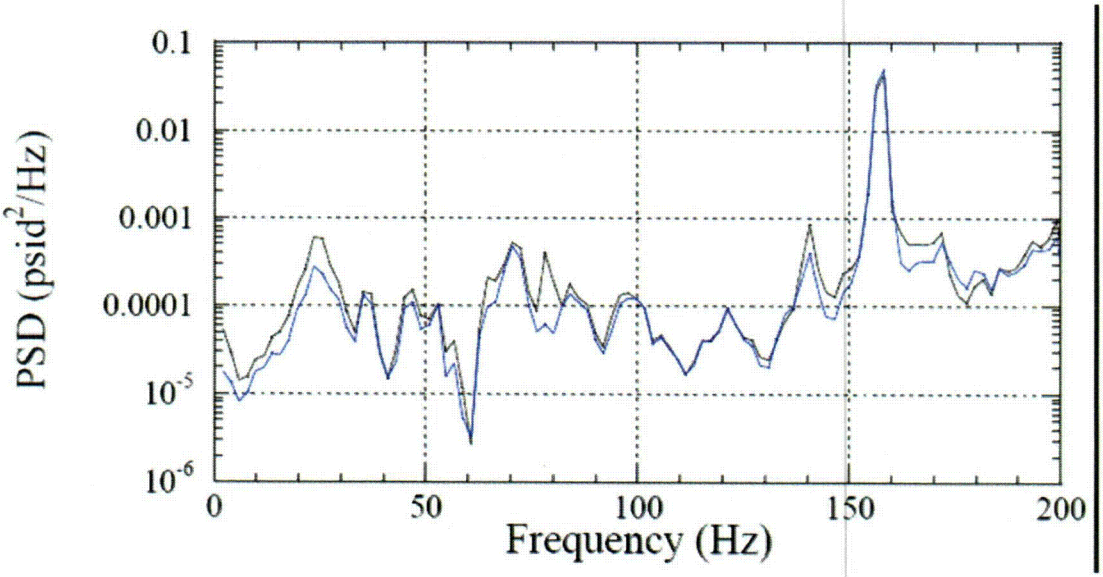


**Figure 1: P22 PSD – Black Curve is TC15a & Blue Curve is TC15a_3**

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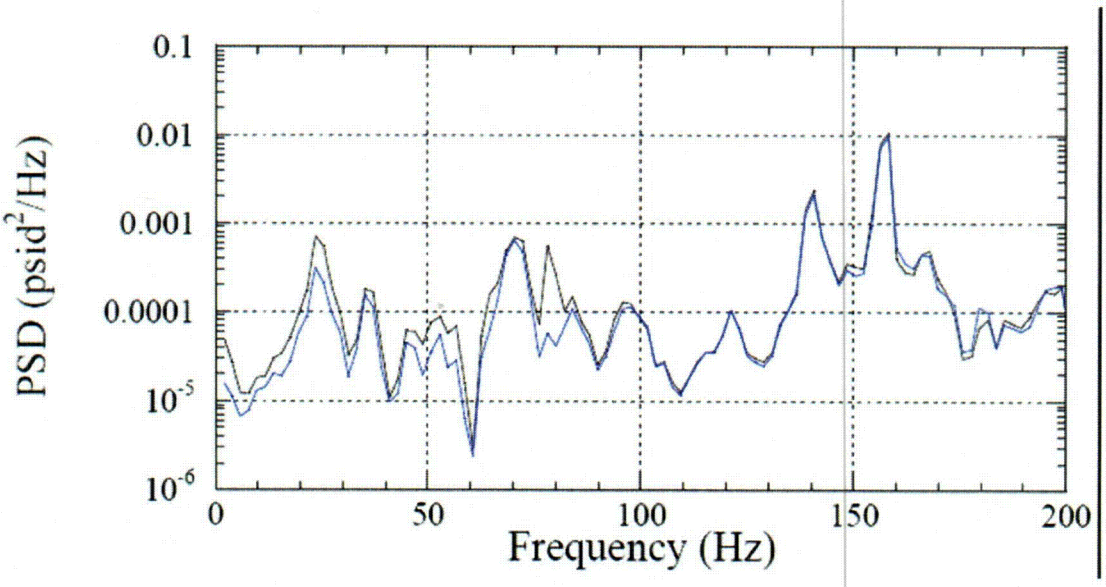


**Figure 2: P24 PSD – Black Curve is TC15a & Blue Curve is TC15a_3**

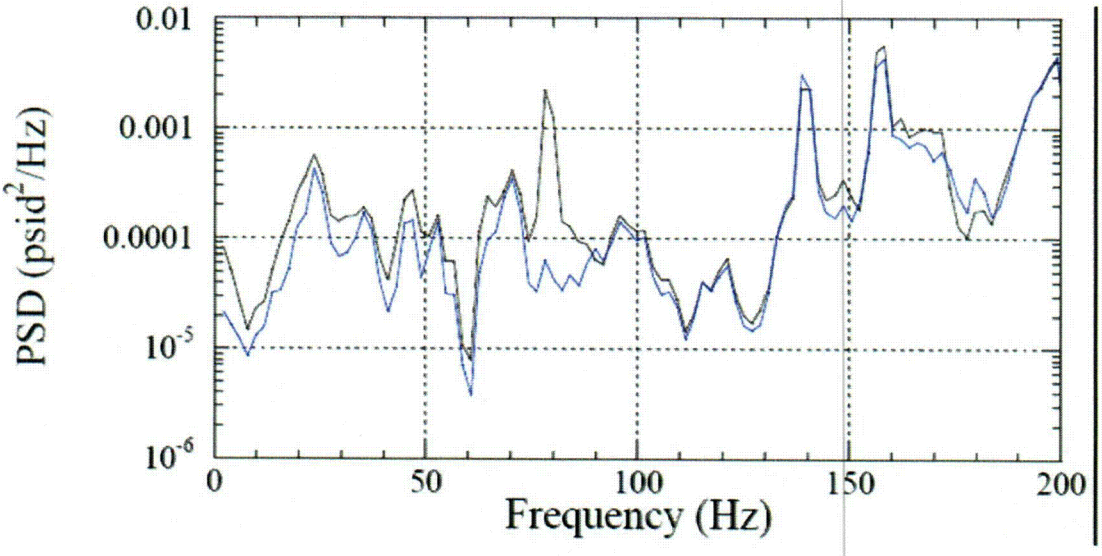


**Figure 3: P25 PSD – Black Curve is TC15a & Blue Curve is TC15a_3**

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For the outer hood pressure comparisons, the assessment is not as conclusive as it was for the skirt comparisons. The TC15a maximum and minimum pressures for the P3, P12, and P21 locations are clearly bounding the pressures from the TC15a_3 load case. The TC15a maximum, minimum and RMS pressures for the P20 location are less than the TC15a_3 by approximately 5% for each. The P3-P13 differential pressure satisfies the assessment criteria and is bounding for the minimum and RMS pressures. The TC15a maximum, minimum and RMS pressures for the P20-P14 differential pressure are less than the TC15a_3 pressures by approximately 5% for each. With the exception of the TC15a_3 pressures at the P20 nozzle, the TC15a pressures at the other nozzles and generally for the rest of the dryer locations bound the TC15a_3 pressures.

The frequency comparisons for the outer hood locations opposite the main steam nozzles are presented in Figures 4 through 7 below. Reviewing these figures the following conclusions are drawn.

1. P3 – TC15a bounds the TC15a_3 pressures at all frequencies except a minor difference at approximately 180 Hz. This has not been a frequency of concern for the design of the dryer and magnitudes are greater at other frequencies that are more significant to the dryer.
2. P12 – TC15a bounds the TC15a_3 pressures at all frequencies except minor differences at approximately 150 Hz and 180 Hz. These have not been frequencies of concern for the design of the dryer and magnitudes are greater at other frequencies that are more significant to the dryer.
3. P20 – TC15a bounds the TC15a_3 pressures at all frequencies except minor differences at approximately 15 Hz and 50 Hz. These have not been frequencies of concern for the design of the dryer and magnitudes are greater at other frequencies that are more significant to the dryer.
4. P21 – TC15a bounds the TC15a_3 pressures at all frequencies.

The frequency content comparisons for the P3-P13 and P20-P14 differential pressures are presented in Figures 8 and 9 below. Reviewing these figures the following conclusions can be drawn:

1. P3-P13 – TC15a bounds the TC15a_3 pressures at all frequencies except minor differences at approximately 80 Hz and 180 Hz. The 180 Hz has not been a frequency of concern for the design of the dryer and magnitudes at other more significant frequencies to dryer are greater. The 80 Hz difference is very minor and would be enveloped by a much larger pressure at approximately 78 Hz.
2. P20-P14 – TC15a bounds the TC15a_3 pressures at all frequencies except a minor difference at approximately 10 Hz to 15 Hz. This has not been a frequency range of concern for the design of the dryer and magnitudes are greater at other frequencies that are more significant to the dryer.

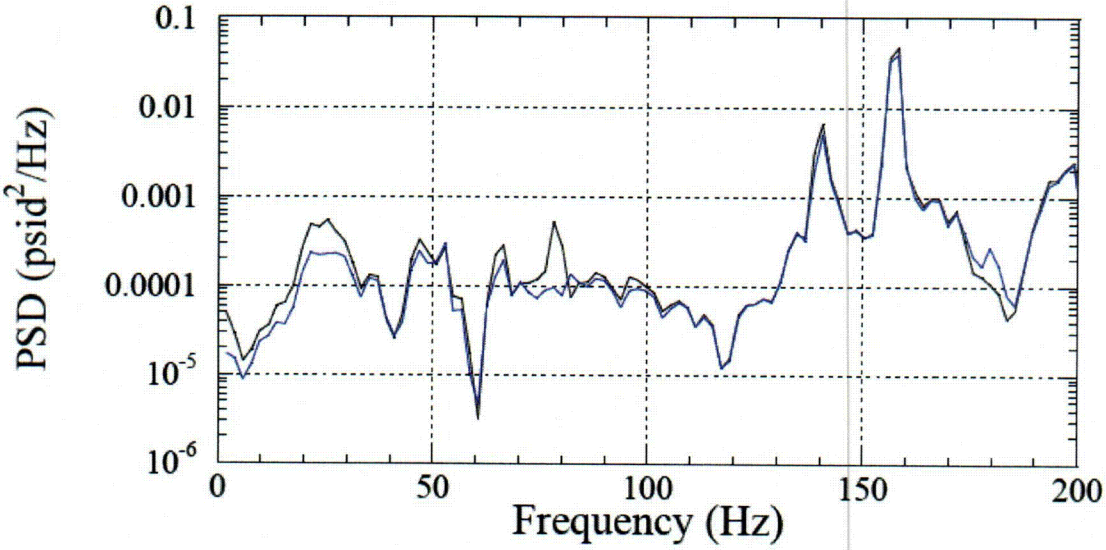


**Figure 4: P3 PSD – Black Curve is TC15a & Blue Curve is TC15a_3**

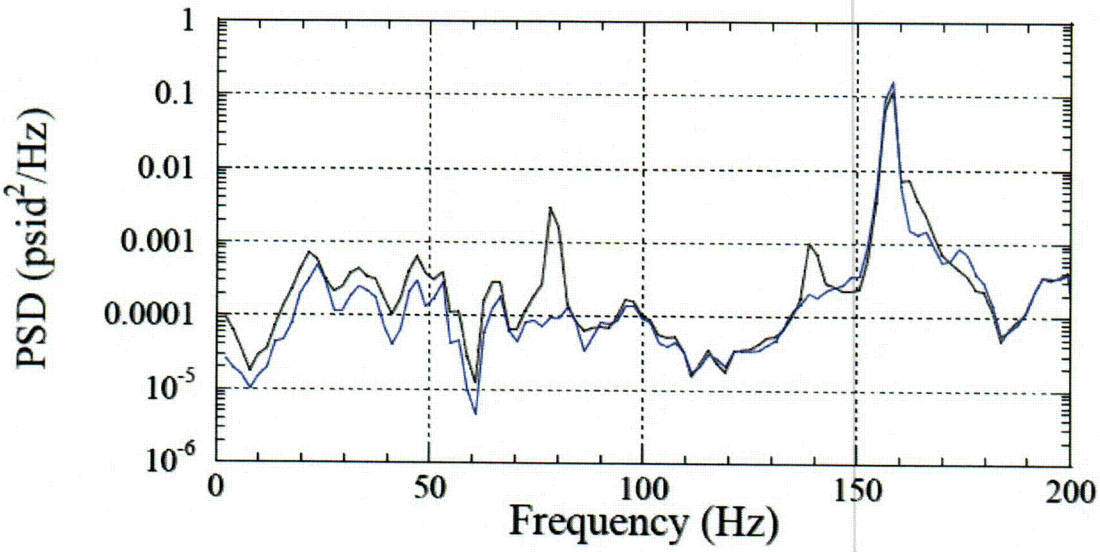


**Figure 5: P12 PSD – Black Curve is TC15a & Blue Curve is TC15a_3**

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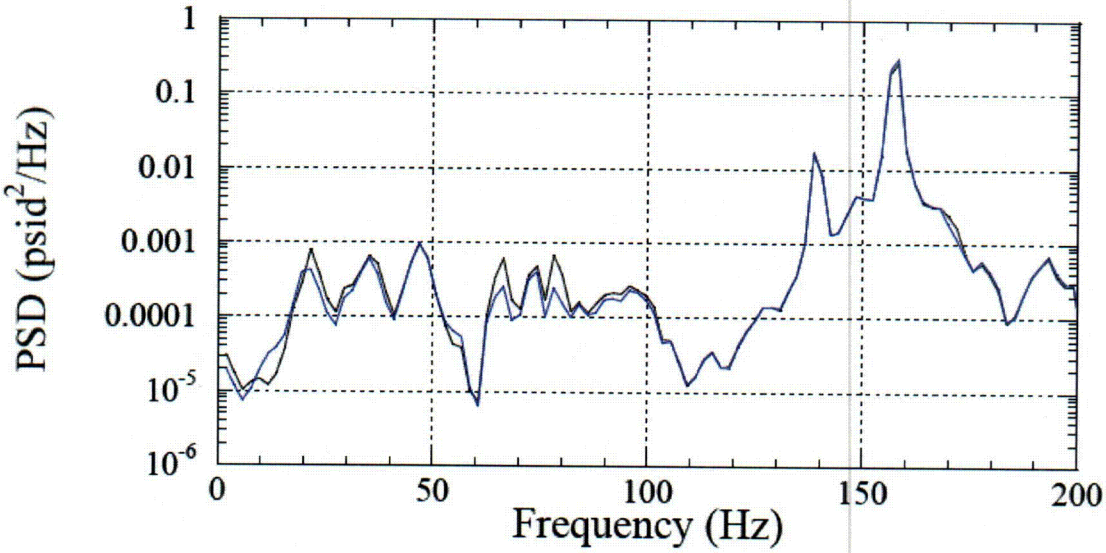


**Figure 6: P20 PSD – Black Curve is TC15a & Blue Curve is TC15a_3**

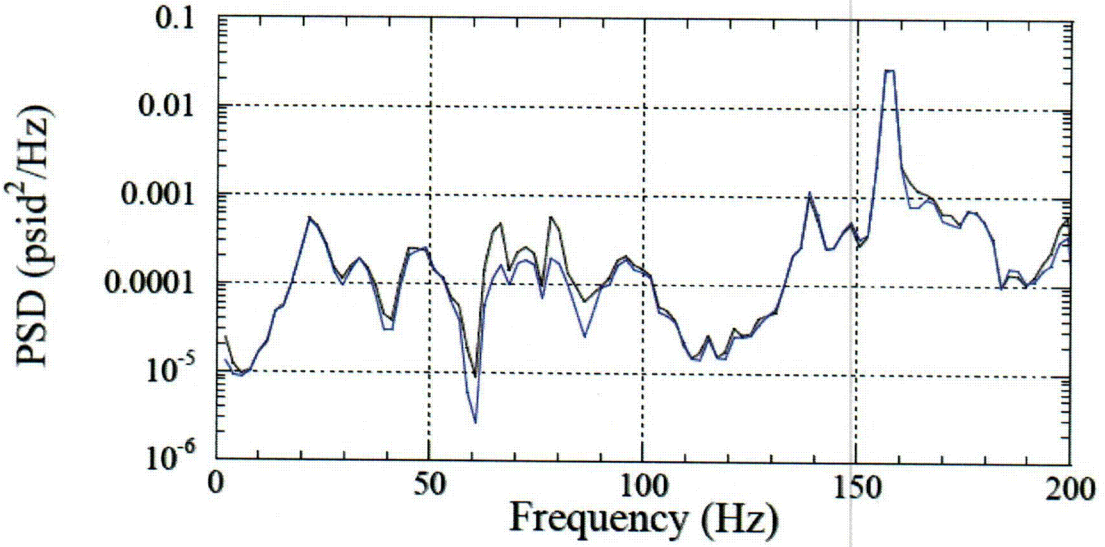


**Figure 7: P21 PSD – Black Curve is TC15a & Blue Curve is TC15a_3**

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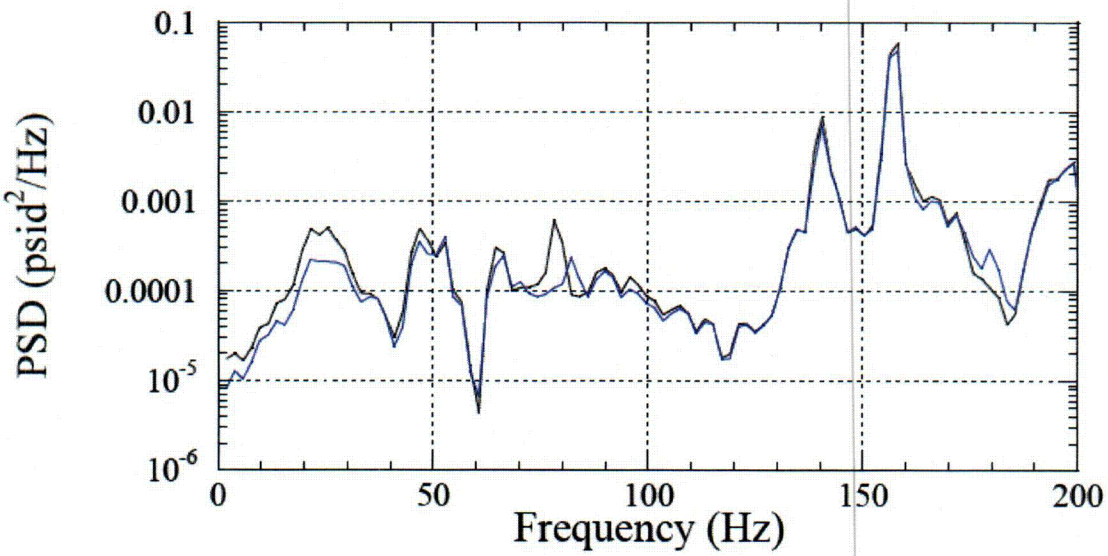


**Figure 8: P3-P13 PSD – Black Curve is TC15a & Blue Curve is TC15a_3**

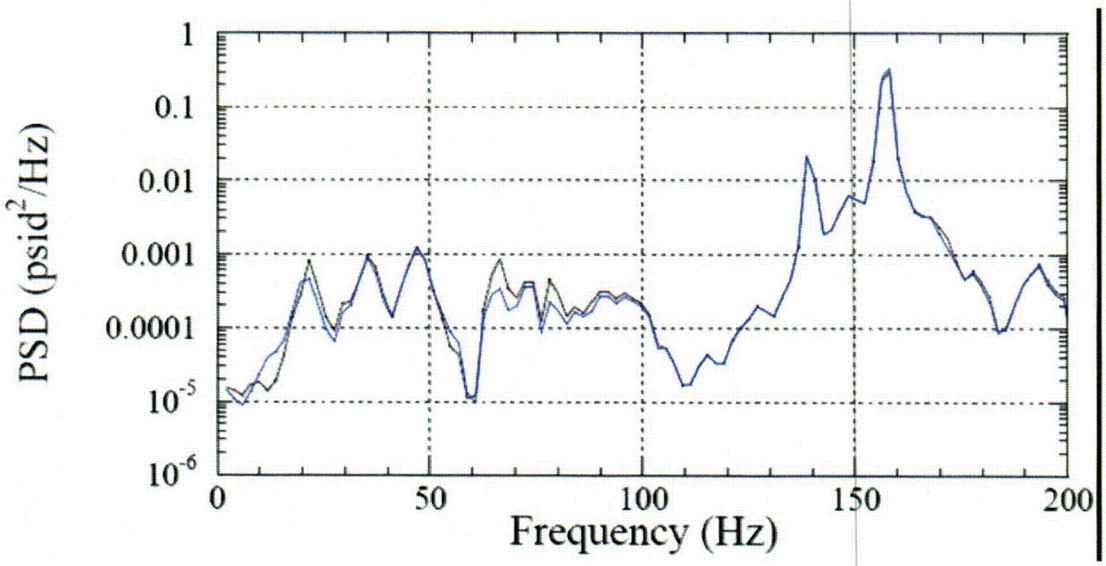


**Figure 9: P20-P14 PSD – Black Curve is TC15a & Blue Curve is TC15a_3**

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# 4. Conclusions and Recommendations

Based on the results of this assessment, the following conclusions are drawn.

1. The TC15a load case is bounding for the loading on the skirt when compared to the TC15a_3 load case. The pressures are bounding and the frequency content envelops that of TC15a_3 frequency content.

2. The TC15a load case is representative but not necessarily bounding for the loading on the outer hoods when compared to the TC15a_3 load case. The pressures generally bounding those from the TC15a_3 load case and the frequency content generally envelops that of TC15a_3 frequency content.

Based on these conclusions, it is recommended to qualify the skirt using the QC1B FEA results. All other dryer components should be qualified using the QC1D FEA results since that acoustic circuit model load case was developed using a validated acoustic circuit model, Reference 2 and Reference 3, with main steam line pressure inputs equivalent to those used in the TC15a_3 load case and satisfied the recommendations specified in Reference 4.

An additional recommendation is to perform a finite element analysis using the TC15a_3 load case. This load case is based on a validated acoustic circuit model using the best representation of main steam line pressure data as input, Reference 4; and it is less conservative than the load case used in the QC1D FEA.

# 5. References

1. "Test Condition TC15a Load Comparison for Quad Cities Unit 1," Continuum Dynamics, Inc. Technical Note No. 05-34, Revision 0, dated August 1, 2005.

2. "Evaluation of Continuum Dynamics, Inc. Steam Dryer Load Methodology Against Quad Cities Unit 2 In-Plant Data," Continuum Dynamics, Inc. Report No. 05-10, Revision 0, July 2005.

3. "Acoustic Circuit Benchmark Quad Cities Unit 2 Instrumented Steam Path Final Model Revision 930 MWe Power Level," Exelon Nuclear Asset Management Report AM-2005-004, Revision 0, July 2005.

4. "Comparison of Quad Cities Unit1 and Quad Cities Unit 2 Main Steam Line Strain gage Data," SIA Letter Report KKF-05-037, SIR-05-223 Revision 1, July18, 2005.