S&A

SPECTRA 2.0 QUALITY ASSURANCE MANUAL

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1. INTRODUCTION

This report describes the analytical capabilities and theoretical foundations of the SPECTRA 2.0 software package. It also verifies its correct operation as required by Stevenson & Associates Quality Assurance program. Operational requirements are also detailed.

SPECTRA is a Windows based program developed by Stevenson & Associates (S&A). It has the capability to create, manipulate and perform conversion operations on time history, power spectrum and response spectrum data records. It also effectively manages large databases containing these records by providing features for data import, labeling, and fast retrieval of records. Refer to the SPECTRA User Manual for a complete description of its capabilities.

Section 2 presents the programs analytical capabilities and their theoretical foundations. Section 3 specifies operational requirements, both system requirements and functional requirements. Section 4 presents the Software Verification and Validation Plan (SVVP). Section 5 then provides the results of the verification testing.

2. ANALYTICAL CAPABILITIES

2.1. Definitions, Acronyms, and Abbreviations

PC Acronym for IBM compatible personal computer.
RAM Acronym for PC central processor Random Access Memory.
DOS Acronym for Disk Operating System.
FFT Acronym for Fast Fourier Transform.
PSD Acronym for power spectral density. The mean squared value per unit frequency of a waveform.
PS Acronym for Power Spectrum. It is obtained by integrating the PSD over finite frequency bands. One sided PS are used.
SDOF Acronym for Single Degree of Freedom systems.
RS Acronym for Response Spectrum. A table of the maximum response, as a function of oscillator frequency, of an array of single-degree-of freedom damped oscillators subjected to the same base excitation.
TH Acronym for Time History of the base acceleration.
Octave When the ratio between two frequencies is two they are said to be an octave apart.
PVRC Pressure Vessel Research Committee of the Welding Research Council.

2.2. Data Conversion Capabilities

Each of the record types that SPECTRA operates with, PS, RS and TH, is a different way of representing dynamic motion. By default, SPECTRA assumes that all data records contain accleration data. The program has the capability to convert from one type of representation to another with its data conversion utilities.

Conversions may or may not involve an approximation, it depends on the specific conversion operation. In all cases there are also conversion parameters that allows the user to control aspects of the operation. These parameters are identified in Section 3.3 (Functional Requirements).

Since there are three types of data records, there are six type conversion operations available to the user. In addition there are internal conversion operations, transparent to the user, that SPECTRA performs when changing from PS to PSD format and vice versa.

2.3. Theoretical Foundation

2.3.1. PSD to PS Conversion

A SPECTRA database contains PS instead of PSD and hence it is necessary at times to convert a PSD to PS. In this discussion it is assumed that the PSD is defined at n points (f_0,PSD_0), (f_1,PSD_1), (f_2,PSD_2),...,(f_i,PSD_i),...(f_{n-1},PSD_{n-1}) and the output PS values are required at m frequency points defined by the sequence $fout_0$, $fout_1$, $fout_2$, ...$fout_{m-1}$.

An Energy Integral E_i can be defined at each point f_0, f_1, f_2, ...,f_r,..., f_{n-1} by the following recursive set of expressions.

(2.1) $E(f_0) = PSD_0 \frac{(f_1 - f_0)}{2}$ for i = 0

(2.2) $E(f_i) = E(f_{i-1}) + PSD_i \frac{(f_{i+1} - f_{i-i})}{2}$ for 0 < i < n-1

(2.3) $E(f_{n-1}) = E(f_{n-2}) + PSD_{n-1} \frac{(f_{n-1} - f_{n-2})}{2}$ for i = n-1

At an output frequency point f_{out_r}, the Energy is determined by linear interpolation. A PSD defined frequency f_i is found such that (2.4) is satisfied. The energy value is then computed using (2.5).

(2.4) $f_{i-i} < f_{out_r} < f_i$

(2.5) $E(f_{out_r}) = E_{i-1} + \frac{(E_i - E_{i-1})}{(f_i - f_{i-1})}(f_r - f_{i-1})$

PS values are then computed using expressions (2.6) and (2.7).

(2.6) $PS(f_{out_0}) = E(f_{out_0})$

(2.7) $PS(f_{out_r}) = E(f_{out_r}) - E(f_{out_{r-1}})$ for r=1,2, ...,m

2.3.2. PS to PSD Conversion

To compute PSD given a set of PS values, Equations (2.1) through (2.7) are inverted for the PSD values. Equations (2.6) and (2.7) are used to compute an Energy Integral in terms of the given PS values. Equations (2.1), (2.2) and (2.3) are then used to compute the PSD values from the Energy Integral.

2.3.3. PS to RS Conversion

To determine RS from a PS, the following formula is used:

(2.8) $$R(\omega_0) = \left\{ -2m_0 \ln\left[\frac{-\pi}{T}\left(\frac{m_0}{m_2}\right)^{1/2} \ln(1-r) \right] \right\}^{1/2}$$

(2.9) $$m_n = m_n(\omega_0) = \int_{-\infty}^{\infty} \omega^n |H_0(\omega)|^2 S(\omega)d\omega, \qquad n = 0,2,4$$

(2.10) $$|H_0(\omega)|^2 = \frac{\omega_0^4 + 4\omega_0^2\xi_e^2\omega^2}{\left(\omega_0^2 - \omega^2\right)^2 + 4\omega_0^2\xi_e^2\omega^2}$$

where

T = effective earthquake duration
r = probability of exceedance
$S(\omega)$ represents the PSD at frequency ω
ω = frequency in radians/second.
$\xi_e = \xi + \frac{2}{\omega T}$

ξ = Damping ratio as a fraction of the critical damping.
$R(\omega_0)$ = Response Spectrum.

This procedure is straight forward to apply but involves an approximation. It deviates from the exact solution when (2.11) is small or when (2.12) is close to 1.

(2.11) $$N=\frac{1}{\pi}\left(\frac{m_4}{m_2}\right)^{1/2} T$$

(2.12 $$\varepsilon=\left(1-\frac{m_2^2}{m_0 m_4}\right)^{1/2}$$

2.3.4. RS to PS Conversion

An iterative process is used to provide sucessive approximations of the PSD consistent with the target RS. This is followed by a PSD to PS conversion. From the given response spectrum $R(\omega)_0$, an initial guess for the PSD is calculated using the relationships

(2.13) $$S(\omega)_1=\frac{2\xi_e}{\pi\omega}R^2(\omega)_0\left\{-2\ln\left[-\frac{\pi}{\omega T}\ln(1-r)\right]\right\}^{-1}$$

(2.14) $$\xi_e=\xi+\frac{2}{\omega T}$$

where ξ = damping ratio of $R(\omega)_0$.

Corresponding to the PSD $S(\omega)_1$ a response spectrum $R(\omega)_1$ is computed using Eqns. (2.8)-(2.10). The next guess at the PSD is made using Eqn (2.15) for i=1.

(2.15) $$S(\omega)_{i+1} = S(\omega)_i\left(\frac{R(\omega)_0}{R(w)_i}\right)$$

When $R(\omega)_i$ matches the original $R(\omega)_0$, then $S(\omega)_i$ is the consistent PSD that we seek. In general a perfect match is not made, rather an acceptable error or iteration limit is reached.

2.3.5. TH to PS Conversion

To obtain the PS from a set of TH points, the Fourier coefficients are computed using an FFT algorithm. The Fourier coefficients are then converted to PS values. For a set of N TH points, the Fourier Coefficients F_k are determined using the expressions

(2.16) $$F(0)=\frac{1}{N}\sum_{j=0}^{N-1}TH(j)$$

(2.17) $$F(k)=\frac{1}{N}\sum_{j=0}^{N-1}TH(j)e^{-2\pi ikj/N}, \qquad k=1...N/2$$

where $i^2 = -1$.

The Fourier coefficients are complex and have a real part and an imaginary part. SPECTRA database stores PS instead of the Fourier coefficients. In this discussion it is assumed that the Fourier coefficients are defined at points (f_0,F_0), (f_1,F_1), (f_2,F_2),...,(f_i,F_i),...(f_n,F_n) and the output PS values are required at m frequency points defined by the sequence $f_{o1}, f_{o2}, ..., f_{or}, ...f_{m-1}$. An Energy Integral E_i can be defined at each point by the following recursive set of expressions

(2.18) $E(f_0) = F_0^2$ for $i = 0$

(2.19) $E(f_i) = E(f_{i-1}) + (Re_i^2 + Im_i^2)/2$ for $0 < i < n/2$

where Re_i and Im_i are the real and imaginary parts cf the i^{th} Fourier coefficient.

At an output frequency point f_{out_r} the Energy is determined by linear interpolation. A frequency f_i is found such that (2.20) is satisfied, and the energy is computed using the expression (2.21).

(2.20) $f_{i-i} < f_{out_r} < f_i$

(2.21) $E(f_{out_r}) = E_{i-1} + \frac{(E_i - E_{i-1})}{(f_i - f_{i-1})}(f_{out_r} - f_{i-1})$

PS values are then computed using the following expressions.

(2.22) $PS(f_{out_0}) = E(f_{out_0})$

(2.23) $PS(f_{out_r}) = E(f_{out_r}) - E(f_{out_{r-1}})$ for $r=1,2, ...,m$.

2.3.6. PS to TH Conversion

The PS values are converted to Fourier coefficients by generating random phase angles for the spectral values.

(2.24) Ordinate $r_i = \sqrt{2Ps_i}$

(2.25) Phase Angle $\theta_i = \frac{\pi}{2}random(i)$

The range of random(i) is between 0 and 4.0, such that the phase angle θ_i has a range between 0 and 2π. The complex Fourier coefficient is then calclated using (2.26)-(2.28). The TH is then obtained using an inverse Fourier transform.

(2.26) Real Part $Re_i = r_i Cos(\theta_i)$

(2.27) Imaginary Part $Im_i = r_i Sin(\theta_i)$

(2.28) Complex Fourier Coefficient $F_i = Re_i + iIm_i$

The PS to TH conversion is not unique. i.e the same PS can yield any number of time histories.

2.3.7. TH to RS Conversion

Response spectra are plots of the maximum response of a simple oscillator to a component of the ground motion, plotted as functions of the natural frequency and damping of the oscillator. The digital computation of RS requires the step-wise solution of the equations of motion of the oscillator while monitoring of the maximum value of the response at each step of the integration.

For a viscously damped, simple oscillator subjected to the base acceleration a(t) , the equation of motion is given by

(2.29) $m\ddot{x} + c\dot{x} + kx = -ma(t)$

in which m = mass of the oscillator, c= damping coefficient , k = stiffness of the restoring element and x is displacement relative to the base. Dividing by m, the equation becomes

(2.30) $\ddot{x} + 2\beta\omega\dot{x} + \omega^2 x = -a(t)$

in which β = ratio of actual damping to the critical damping and

(2.31) $\omega^2 = \frac{k}{m}$

(2.32) $c = 2m\omega\beta$

Assuming that the base acceleration (TH) can be represented by a piecewise linear function, the above equation becomes

(2.33) $\ddot{x} + 2\beta\omega\dot{x} + \omega^2 x = -a_i - \frac{\Delta a_i}{\Delta t_i}(t - t_i) \qquad t_i \le t \le t_{i-1}$

with

(2.34) $\Delta t_i = t_{i+1} - t_i$

(2.35) $\Delta a_i = a_{i+1} - a_i$

The solution of Equation (2.30) for $t_i \le t \le t_{i+1}$ is given by

(2.36) $x = e^{-\beta\omega(t-t_i)}[C_1 \mathrm{Sin}\omega_d (t-t_i) + C_2 \mathrm{Cos}\omega_d (t-t_i)] - \frac{a_i}{\omega^2} + \frac{2\beta\Delta a_i}{\omega^3 \Delta t_i} - \frac{1}{\omega^2}\frac{\Delta a_i}{\Delta t_i}(t-t_i)$

where

(2.36a) $\omega_d = \omega\sqrt{1-\beta^2}$

and C_1 and C_2 are constants of integration.

Setting $x = x_i$ and $\dot{x} = \dot{x}_i$ at $t = t_i$ and solving for C_1 and C_2, it can be shown that

(2.37a) $C_1 = \frac{1}{\omega_d}\left(\beta\omega x_i + \dot{x}_i - \frac{2\beta^2-1}{\omega^2}\frac{\Delta a_i}{\Delta t_i} + \frac{\beta}{\omega}a_i\right)$

(2.37b) $$C_2 = x_i - \frac{2\beta}{\omega^3}\frac{\Delta a_i}{\Delta t_i} + \frac{a_i}{\omega^2}$$

Substitution of these values of C_1 and C_2 into Equation (2.36) yields the values of x and $\dot{x}$ at $t = t_{i+1}$.

(2.37c) $$\begin{Bmatrix} x \\ \dot{x} \end{Bmatrix}_{i+1} = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{12} \end{bmatrix} \begin{Bmatrix} x \\ \dot{x} \end{Bmatrix}_i + \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{12} \end{bmatrix} \begin{Bmatrix} a_i \\ a_{i+1} \end{Bmatrix}$$

(2.37d) $$a_{11} = e^{-\beta\omega\Delta t_i}\left[\frac{\beta\omega}{\omega_d} \text{Sin}\omega_d \Delta t_i + \text{Cos}\omega_d \Delta t_i\right]$$

(2.37e) $$a_{12} = \frac{e^{-\beta\omega\Delta t_i}}{\omega_d} \text{Sin}\omega_d \Delta t_i$$

(2.37f) $$a_{21} = -\frac{\omega^2 e^{-\beta\omega\Delta t_i}}{\omega_d} \text{Sin}\omega_d \Delta t_i$$

(2.37g) $$a_{22} = e^{-\beta\omega\Delta t_i}\left[-\frac{\beta\omega}{\omega_d} \text{Sin}\omega_d \Delta t_i + \text{Cos}\omega_d \Delta t_i\right]$$

(2.37h) $$b_{11} = e^{-\beta\omega\Delta t_i}\left[\left(\frac{2\beta^2-1}{\omega^2\Delta t_i} + \frac{\beta}{\omega}\right)\frac{\text{Sin}\omega_d \Delta t_i}{\omega_d} + \left(\frac{2\beta}{\omega^3\Delta t_i} + \frac{1}{\omega^2}\right)\text{Cos}\omega_d \Delta t_i\right] - \frac{2\beta}{\omega^3\Delta t_i}$$

(2.37i) $$b_{12} = -e^{-\beta\omega\Delta t_i}\left[\left(\frac{2\beta^2-1}{\omega^2\Delta t_i}\right)\frac{\text{Sin}\omega_d \Delta t_i}{\omega_d} + \left(\frac{2\beta}{\omega^3\Delta t_i}\right)\text{Cos}\omega_d \Delta t_i\right] + \frac{2\beta}{\omega^3\Delta t_i} - \frac{1}{\omega^2}$$

(2.37j) $$b_{21} = e^{-\beta\omega\Delta t_i}\left(\frac{2\beta^2-1}{\omega^2\Delta t_i} + \frac{\beta}{\omega}\right)\left(\text{Cos}\omega_d \Delta t_i - \frac{\beta\omega}{\omega_d}\text{Sin}\omega_d \Delta t_i\right)$$
$$- e^{-\beta\omega\Delta t_i}\left(\frac{2\beta}{\omega^3\Delta t_i} + \frac{1}{\omega^2}\right)\left(\omega_d \text{Sin}\omega_d \Delta t_i + \beta\omega \text{Cos}\omega_d \Delta t_i\right) + \frac{1}{\omega^2\Delta t_i}$$

(2.37k) $$b_{22} = -e^{-\beta\omega\Delta t_i}\frac{2\beta^2-1}{\omega^2\Delta t_i}\left(\text{Cos}\omega_d \Delta t_i - \frac{\beta\omega}{\omega_d}\text{Sin}\omega_d \Delta t_i\right)$$
$$+ e^{-\beta\omega\Delta t_i}\frac{2\beta}{\omega^3\Delta t_i}\left(\omega_d \text{Sin}\omega_d \Delta t_i + \beta\omega \text{Cos}\omega_d \Delta t_i\right) - \frac{1}{\omega^2\Delta t_i}$$

Starting at time t=0, a stepwise integration is carried out using relations 2.37 to determine the relative displacement and velocity. Using this procedure the maximum relative displacement for a given frequency is determined. The corresponding maximum acceleration is then assumed to be ω^2(Maximum Displacement).

To avoid missing any peaks, each time interval is divided into sub-divisions such that the minimum time step is 1/10f, where f is the oscillator frequency in Hertz. This ensures that the oscillator response is computed at least 10 time points per oscillator cycle. At 0.2 Hz, the response is computed at least once each 1/(0.2*10) = 0.5 seconds. At 34 Hz, the response is computed at least once each 1/(34*10)= .00294 seconds.

Equations (2.33) to (2.37) are exact for a piecewise liner base motion. The base acceleration of Equation 2.33 is the linearly interpolated input TH.

2.3.8. RS to TH Conversion

The RS to TH conversion is iterative. An RS calculated from the trial TH is compared to the target RS. The target RS is obtained by interpolating the original RS values at the 75 default RS frequencies (See Table 1 of Ref. 9). If the Original values are defined at the 75 default frequencies, then the target RS is the same as the original RS.

An initial PSD is obtained from the original RS using expression (2.13). After a PSD to PS conversion, a PS to TH conversion yields a trial TH. The RS corresponding to the trial TH is calculated to check whether it envelopes the target RS. As per the guidelines in Reference 1, each calculated RS of the artificial TH is considered to envelope the original RS when no more than five points fall below, and no more than 10 percent below, the Original RS. When the calculated RS does not envelope the target RS, the PSD is updated depending on the ratio of the calculated RS to the target RS using the following expression (2.38)

(2.38) $$PSD_{new}(f) = PSD_{old}(f)\left(\text{Factor}\frac{Rs_T(f)}{Rs_C(f)}\right)^{2.5}$$

(2.39) Factor = max(1.0,min(1.05+nPtsBelow*.005)),

where RS_T is the target RS, RS_C is the RS calculated from the TH obtained from PSD_{OLD}, and where nPtsBelow refers to the number of points of RS_C that fall below the target RS.

3. OPERATIONAL REQUIREMENTS

3.1. Scope

These requirements address Version 2.0 of the SPECTRA software package.

3.2. System Requirements

SPECTRA requires an IBM compatible PC with at least 4 MB of RAM. The resident operating systems must be DOS 5.0 or higher and Microsoft Windows 3.1 must be active. The system may be configured with a 80386 or 80486 microprocessor. A comparable math co-processor (80387) must be installed for the 80386 CPU. It supports major graphics conventions including CGA, EGA, VGA and Hercules graphics cards. SPECTRA is written in C and ASSEMBLY languages.

3.3. Functional Requirements

The the input parameters for the analytical (data conversion) utilities are provided in this section. The equations in which this parameters are used may be found in Section 2.

3.3.1. PS to RS Conversion

The following quantities are needed.
(a) Duration. This is the effective earthquake duration in seconds. SPECTRA provides a default value of 15 seconds.
(b) Probability of Exceedance. This is the probability that an actual RS will exceed the calculated RS. SPECTRA uses a default value of 0.15. The probability of exceedance can take values greater than zero but less than one.
(c) Damping Ratios. The user can specify up to 12 RS curves of different damping for which to calculate the output RS. Each RS curve is characterized by a unique damping ratio. The damping ratio is the fraction of the critical damping. The damping ratio can be any number greater than zero.
(d) PVRC Damping. Instead of using constant damping the user may optionally specify PVRC damping. PVRC damping (see Reference 2) is defined as a function of frequency as follows:
from 0 Hz to 10 Hz , damping ratio = 0.05,
10 to 20 Hz, ratio varies linearly from .05 at 10Hz to .02 at 20 Hz.,
above 20 Hz, the damping ratio = 0.02.
Figure 3-1 shows the frequency dependency of the damping ratios.
(e) RS output frequencies. These are the frequencies at which the output RS frequencies are provided. SPECTRA uses 75 default frequencies that satisfy the requirements laid out in Reference 6. The user may type in a different set of frequencies if desired.

3.3.2. PS to TH Conversion

The quantities required are llisted below.
(a) Number of TH points. The number of points at which TH is computed. Any number up to 8192 is allowable. However, as this algorithm uses FFT conversion, a power of 2 will give optimal speed in the conversion. The SPECTRA default value is 1024.

(b) Time Step. The time step (increment) in seconds.
(c) Random Seed. A seed number that is used to obtain a set of random numbers. The random numbers are used to generate phase angles as this information is not available in the PS.
(d) Intensity Type. A time window that is applied to the time history. The intensity type can be either constant or trilinear. If Trilinear Intensity is chosen, tRise and tLevel; need to be additionally specified (See Figure 3-2).

3.3.3. RS to PS Conversion

For a given record, the RS curve with the lowest damping ratio is converted to PS as this provides the most accuracy. The following quantities are required.
(a) Duration. See discussion in Section 2.3 above.
(b) Probability of Exceedance. See discussion in Section 2.3 above.
(c) Output PS frequencies The frequency values at which PS values are computed. The default values are the frequencies used in any previous RS to PS conversion for the record in consideration. If such frequencies are not available for the record, SPECTRA generates frequencies at equal geometric intervals between the lowest and highest RS frequencies at the rate of 24 frequencies per octave.

3.3.4. RS to TH Conversion

The quantities required are the same as those discussed in PS to TH Conversion (Section 2.3)

3.3.5. TH to PS Conversion

Fourier coefficients are computed from zero to the Nyquist frequency in equal increments. PS The frequency spacing at which PS is output needs to be specified in Hz. is output at equal frequency intervals (specified by the user) and represents the incremental energy in the frequency band.

3.3.6. TH to RS Conversion

For a given TH it is possible to generate up to 12 RS curves. Each RS curve is characterized by a unique damping ratio and an associated set of output frequencies.
(a) Damping Ratios. The damping ratios can be any positive numbers and represent the fraction of actual damping to the critical damping. The frequencies can be any positive numbers greater than zero. The user can specify PVRC damping instead of constant damping for an RS curve.
(b) Default RS output frequencies: These are the frequencies at which the output RS values are calculated. SPECTRA uses 75 default frequencies that satisfy the requirements laid out in Reference 6. A list of these frequencies is provided in Table 1 of Appendix A of SPECTRA user's manual (Ref. 3).

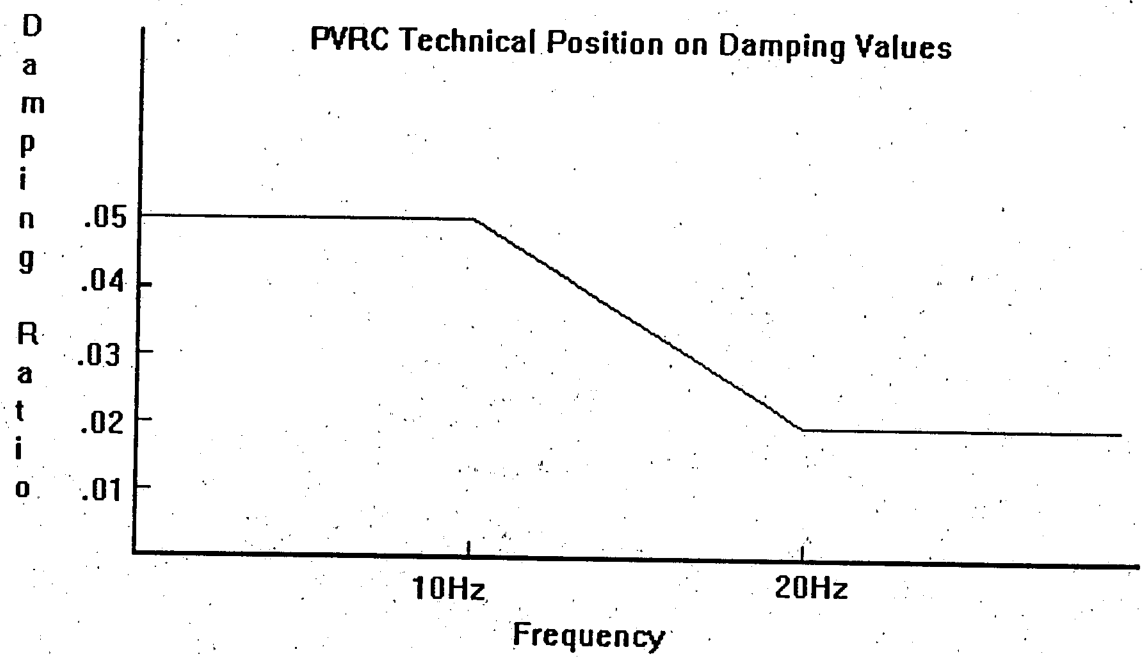


Figure 3-1

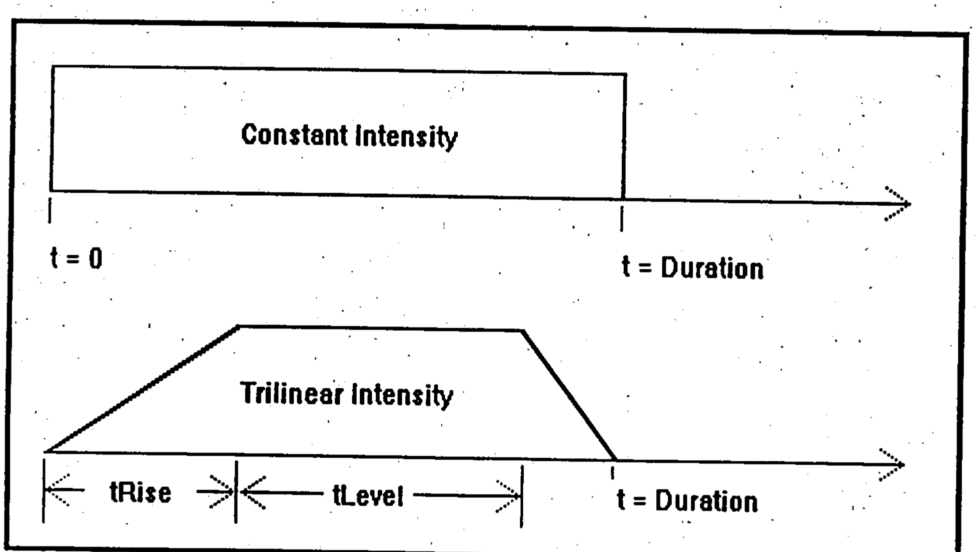


Figure 3-2

4. SOFTWARE VERIFICATION AND VALIDATION PLAN

4.1. Software Description

4.1.1. Program Identification

This software verification and validation plan (SVVP) addresses version 2.0 of the SPECTRA software package.

4.1.2. Originators

The SVVP developer is Stevenson & Associates (S&A), 10 State Street, Woburn, Massachusetts 01801, Phone:(617) 932-9580. S&A is also the sole developer of the SPECTRA software package.

4.2. Test Description

4.2.1. Requirements to Be Tested

The following features of the SPECTRA program will be checked.

Case 1. Data Import for PS Data.
Case 2. Data Import for RS Data.
Case 3. Data Import for TH Data.
Case 4. Unit Conversions for PS Data.
Case 5. Unit Conversions for RS Data.
Case 6. Unit Conversions for TH Data.
Case 7. PS to RS Conversion
Case 8. RS to PS Conversion
Case 9. TH to PS Conversion
Case 10. PS to TH Conversion
Case 11. TH to RS Conversion
Case 12. RS to TH Conversion
Case 13. Broadening Response Spectrum
Case 14. Enveloping RS Curves
Case 15. Copy List Data to the Clipboard
Case 16. Custom Formatting in *EasyPlot*

4.2.2. Acceptance Criteria for Each Requirement

Acceptability for Cases 1 to 6 can be confirmed by inspection of the relevant data. For Cases 7 through 12 (type conversion utilities), correct operation of SPECTRA will be demonstrated by comparing the product of conversion to results of other QA verified software, to analytically derived results, or to results of previously verified utilities of SPECTRA. The EDASP software package will be used extensively for verification. EDASP is an S&A product that has previously been verified [4]. Cases 13 and 14 will be verified by inspection plots of the resulting data. Acceptability of Case 15 is demonstrated by inspection of the relevant data copied to the Clipboard. Acceptability of Case 16 is demonstrated by inspection of the plotted SPECTRA record data using the *EasyPlot program* [12].

4.3. Test Cases

Each of the test cases is described in the following sections and the expected output results are given for each. The SPECTRA database SPQA2V0 was created to store the records used in the test cases.

4.3.1. Case 1: Data Import for PS Data

A set of 15 PS values is stored in the file PS001.PS on the SPECTRA QA disk. A record is created by importing the PS values stored in the file PS001.PS. The record is shown in Figure 4-1. The SPECTRA Table Editor is used to view the PS values stored in the record. Figure 4-2 shows a listing of the file PS001.PS as well as a screen bitmap of the Table Editor. The data in the file listing should match the data in the Table Editor.

4.3.2. Case 2: Data Import for RS Data

Two RS curves are stored in file RS001.RS on the SPECTRA QA disk. A record is created by importing the RS values stored in the file RS001.RS. The record is shown in Figure 4-3. The SPECTRA Table Editor is used to view the RS values stored in the record. Figure 4-4 shows a listing of the file RS001.RS as well as a screen bitmap of the Table Editor. The data in the file listing should match the data in the Table Editor.

4.3.3. Case 3: Data Import for TH Data

A set of 17 TH values is stored in the file TH001.TH on the SPECTRA QA disk. A record is created by importing the TH values stored in the file TH001.TH. The record is shown in Figure 4-5. The SPECTRA Table Editor is used to view the TH values stored in the record. Figure 4-6 shows a listing of the file TH001.TH as well as a screen bitmap of the Table Editor. The data in the file listing should match the data in the Table Editor.

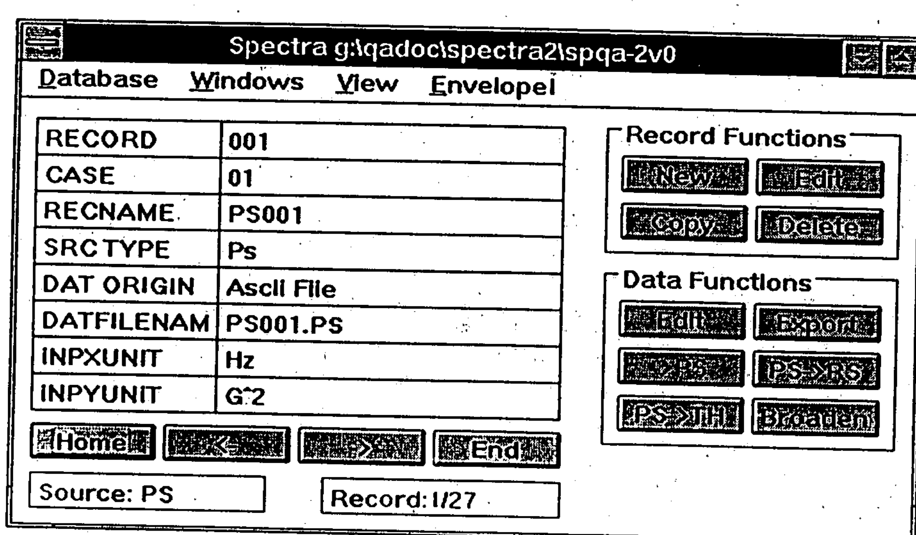


Figure 4-1

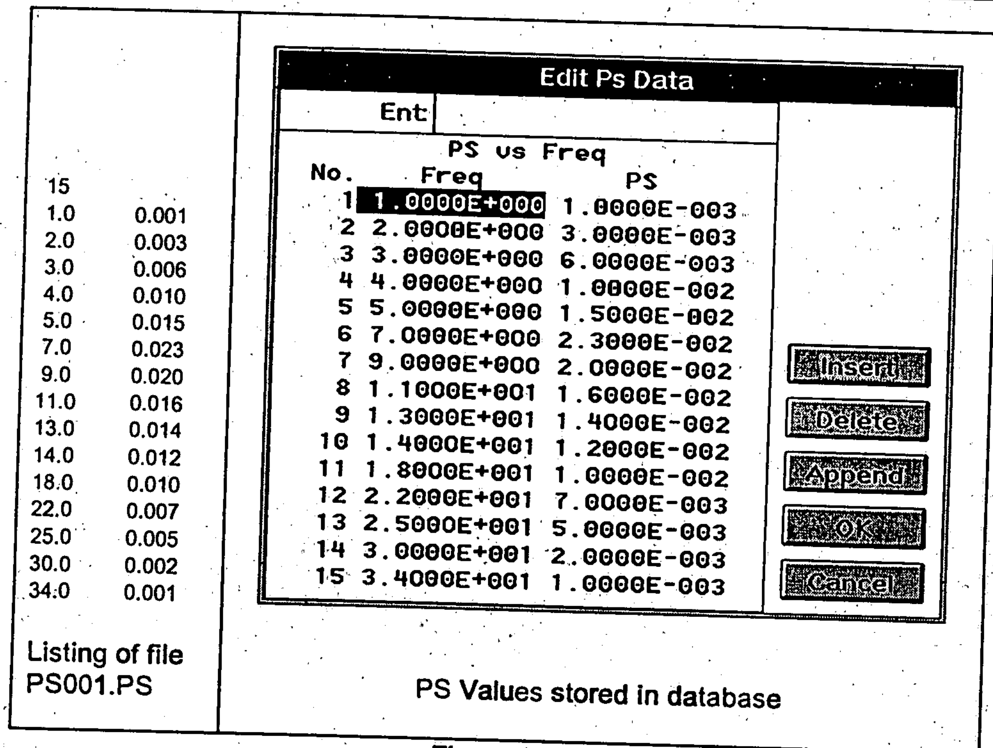


Figure 4-2

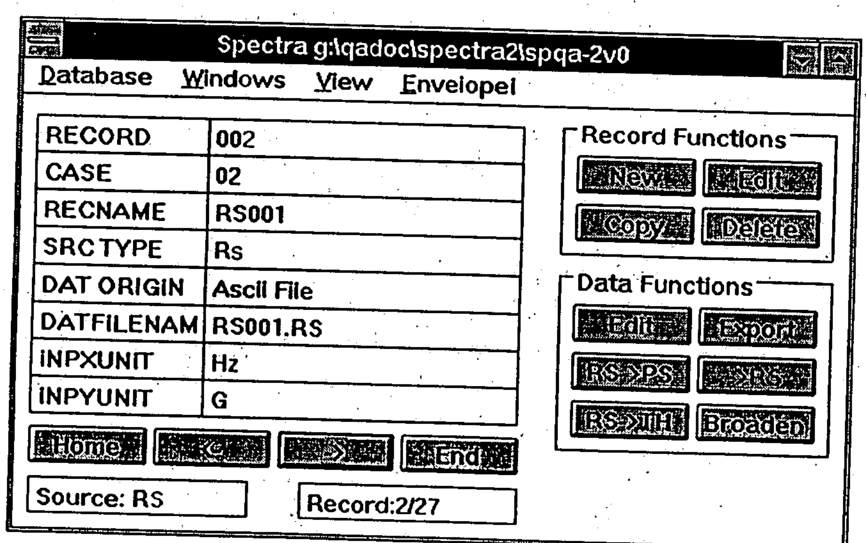
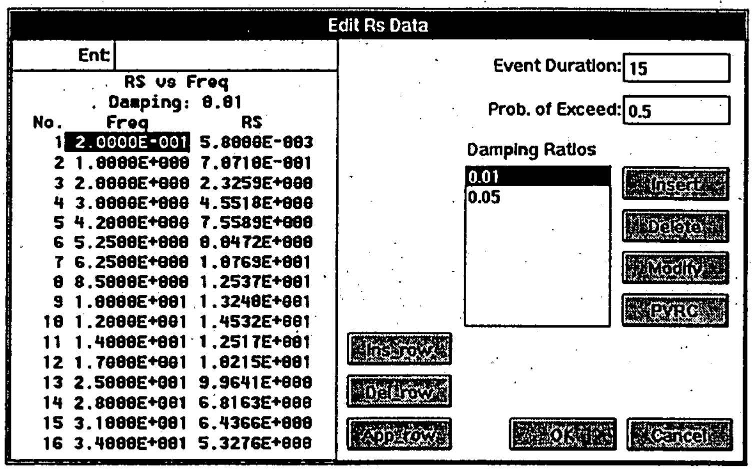


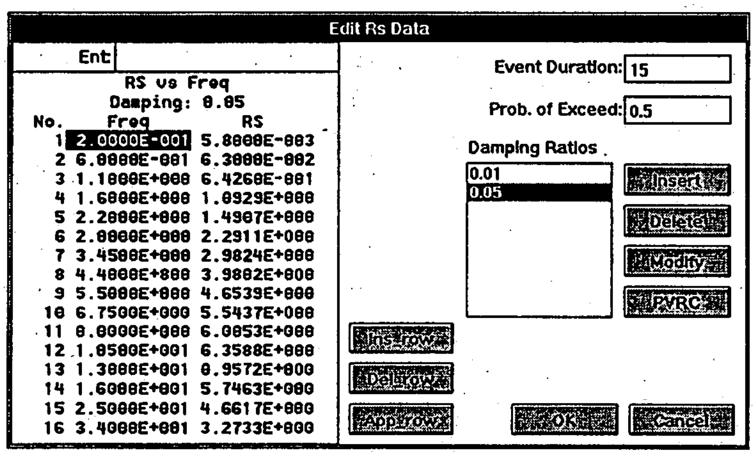
Figure 4-3

2	
16	0.010000
0.2	0.0058
1	0.7071
2	2.3259
3	4.5518
4.2	7.5589
5.25	8.9472
6.25	10.769
8.5	12.537
10	13.240
12	14.532
14	12.517
17	10.215
25	9.0641
28	6.8163
31	6.4366
34	5.3276
16	0.0500
0.2	0.0058
0.6	0.0639
1.1	0.6426
1.6	1.0929
2.2	1.4907
2.8	2.2911
3.45	2.9824
4.4	3.9802
5.5	4.6539
6.75	5.5437
8	6.0053
10.5	6.3588
13	6.9572
16	5.7463
25	4.6617
34	3.2733

Listing of file RS001.RS



RS Curve for Damping Ratio = 0.01



RS Curve for Damping Ratio = 0.05

Figure 4-4

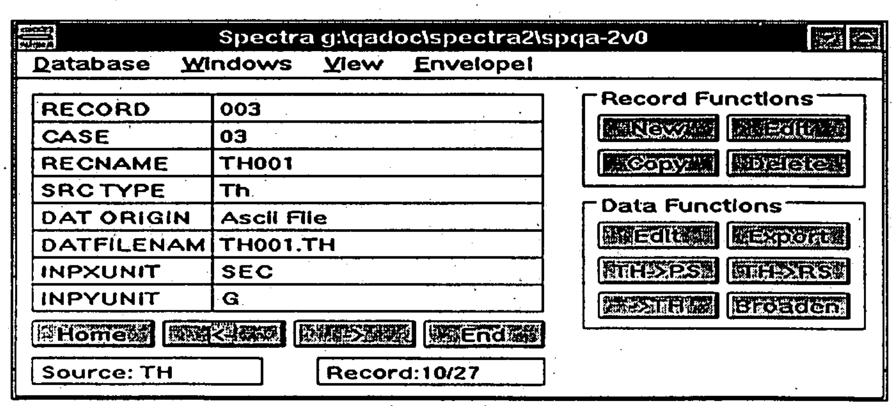


Figure 4-5

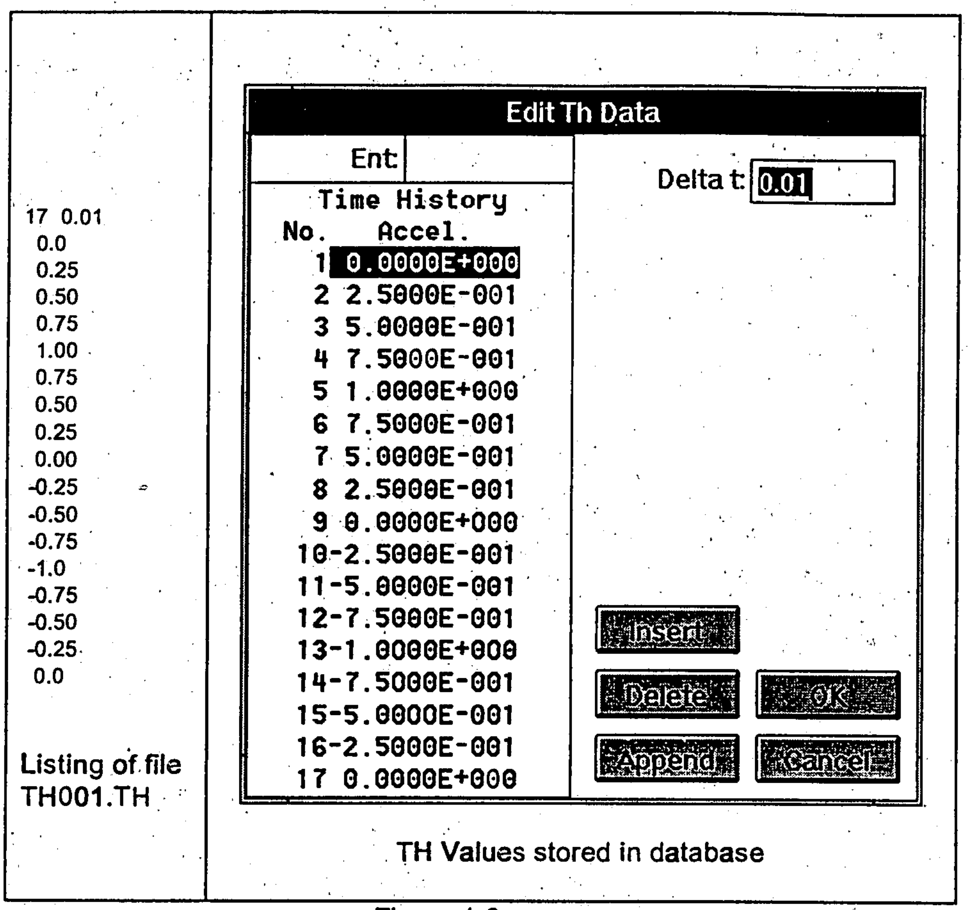

17 0.01
0.0
0.25
0.50
0.75
1.00
0.75
0.50
0.25
0.00
-0.25
-0.50
-0.75
-1.0
-0.75
-0.50
-0.25
0.0
Listing of file TH001.TH
Edit Th Data
Ent:
Delta t: 0.01
Time History
No. Accel.
1 0.0000E+000
2 2.5000E-001
3 5.0000E-001
4 7.5000E-001
5 1.0000E+000
6 7.5000E-001
7 5.0000E-001
8 2.5000E-001
9 0.0000E+000
10-2.5000E-001
11-5.0000E-001
12-7.5000E-001
13-1.0000E+000
14-7.5000E-001
15-5.0000E-001
16-2.5000E-001
17 0.0000E+000
Insert
Delete
OK
Append
Cancel
TH Values stored in database

Figure 4-6

4.3.4. Case 4: Units Conversions for PS Data

Internally, PS data is stored as a set of acceleration power vs. frequency using native units of G^2 for power and Hz for frequency. Data imported from ASCII files can be converted to SPECTRA's native units. When creating a new record using an ASCII file one can specify the units in which the PS values are defined, and they will be converted. To verify correct operation, the file from case 1, PS001.PS, is imported by specifying different x Units (rad/sec, sec) and y-Units (G^2, mm^2/sec^4, cm^2/sec4, m^2/sec^4, $inches^2/sec^4$, $feet^2/sec^4$). The expected results are described below.

<u>Case 4a. Units Conversion for PS Data; x-Units:rad/sec,y-Units:G^2.</u>
The entries in the first column of the Table Editor should be 1/2π times the corresponding entries in the first column of the file listing. The entries in the second column of the Table Editor should be identical to the corresponding entries in the file listing.

<u>Case 4b. Units Conversion for PS Data; x-Units:sec, y-Units:G^2</u>
As period is the reciprocal of cycles/sec, the entries in the first column of the Table Editor will be the reciprocals of the entries in the file listing. SPECTRA stores the PS curves in ascending order of frequencies, so the order in which the PS points are stored is reversed. The second column of the TableEditor should have the same values as the second column of the file listing in reverse order.

<u>Case 4c. Units Conversion for PS Data; x-Units:Hz, y-Units:mm^2/sec^4.</u>
The first column of the Table Editor should have the same values as in the file listing. The second column of the Table Editor should be $(1/(32.174*12*25.4))^2$= 1.0398E-08 times the entries in the file listing.

<u>Case 4d. Units Conversion for PS Data; x-Units:Hz, y-Units:cm^2/sec^4.</u>
The first column of the Table Editor should have the same values as in the file listing. The second column of the Table Editor should be $(1/(32.174*12*2.54))^2$= 1.0398E-06 times the entries in the file listing.

<u>Case 4e. Units Conversion for PS Data; x-Units:Hz, y-Units:m^2/sec^4.</u>
The first column of the Table Editor should have the same values as in the file listing. The second column of the Table Editor should be $(1/(32.174*12*.0254))^2$= 1.0398E-02 times the entries in the file listing.

<u>Case 4f. Units Conversion for PS Data, x-Units:Hz, y-Units:in^2/sec^4.</u>
The first column of the Table Editor should have the same values as in the file listing. The second column of the Table Editor should be $(1/(32.174*12))^2$=6.7085E-06 times the entries in the file listing.

<u>Case 4g. Units Conversion for PS Data, x-Units:Hz, y-Units:ft^2/sec^4.</u>
The first column of the Table Editor should have the same values as in the file listing. The second column of the Table Editor should be $(1/(32.174))^2$=9.66028E-04 times the entries in the file listing.

4.3.5. Case 5: Units Conversions for RS Data
Internally RS data is stored as a set of acceleration vs. frequency points. SPECTRA native units are G's for acceleration and Hz for corresponding frequencies. Data imported from ASCII files can be converted to SPECTRA native units. When creating a new record using an ASCII file, the units in which the RS values are defined can be specified. Using the 1% damping Rs curve from the file RS001.RS, a file RS002.RS is created. To verify correct operation, the file RS002.RS, is imported by specifying different x Units (rad/sec, sec) and y-Units (G, mm/sec^2, cm/sec^2, m/sec^2, $inches/sec^2$, $feet/sec^2$). The expected results are described below.

Case 5a. Units Conversion for RS Data; x-Units:rad/sec,y-Units:G.
The entries in the first column of the Table Editor should be $1/2\pi$ times the corresponding entries in the first column of the file listing. The entries in the second column of the Table Editor should be identical to the corresponding entries in the file listing.

Case 5b. Units Conversion for RS Data; x-Units:sec,y-Units:G.
As period is the reciprocal of cycles/sec, the entries in the first column of the Table Editor will be the reciprocals of the entries in the file listing. SPECTRA stores the RS curves in ascending order of frequencies, so the order in which the RS points are stored is reversed.

Case 5c. Units Conversion for RS Data; x-Units:Hz,y-Units:mm/sec^2.
The first column of the Table Editor should have the same values as in the file listing. The second column of the Table Editor should be 1/(32.174*12*25.4) = 1.0197E-04 times the entries in the file listing.

Case 5d. Units Conversion for RS Data; x-Units:Hz,y-Units:cm/sec^2.
The first column of the Table Editor should have the same values as in the file listing. The second column of the Table Editor should be 1/(32.174*12*2.54) = 1.0197E-03 times the entries in the file listing.

Case 5e. Units Conversion for RS Data; x-Units:Hz,y-Units:m/sec^2.
The first column of the Table Editor should have the same values as in the file listing. The second column of the Table Editor should be 1/(32.174*12*.0254) = 1.0197E-01 times the entries in the file listing.

Case 5f. Units Conversion for RS Data; x-Units:Hz,y-Units:in/sec^2.
The first column of the Table Editor should have the same values as in the file listing. The second column of the Table Editor should be 1/(32.174*12) =2.59008E-03 times the entries in the file listing.

Case 5g. Units Conversion for RS Data; x-Units:Hz,y-Units:ft/sec^2.
The first column of the Table Editor should have the same values as in the file listing. The second column of the Table Editor should be 1/(32.174) = 3.1081E-02 times the entries in the file listing.

4.3.6. Case 6: Units Conversions for TH Data
TH data is stored as a set of acceleration time history values at successive and equally spaced time intervals. SPECTRA native units are G s for the acceleration values; the time increment is assumed to be given in seconds. . Data imported from ASCII files can be converted to SPECTRA native units. When creating a new record from an ASCII file the units in which the TH values are defined can be specified. To verify correct operation, the file from case 3, TH001.TH, is imported by specifying different y-Units (mm/sec^2, cm/sec^2, m/sec^2, inches/sec^2, feet/sec^2). The expected results are listed below.

Case 6a. Units Conversion for TH Data; x-Units:sec,y-Units:mm/sec^2.
The first column of the Table Editor should have the same values as in the file listing. The second column of the Table Editor should be 1/(32.174*12*25.4) = 1.0197E-04 times the entries in the file listing.

Case 6b. Units Conversion for TH Data; x-Units:sec,y-Units:cm/sec^2.
The first column of the Table Editor should have the same values as in the file listing. The second column of the Table Editor should be 1/(32.174*12*2.54) = 1.0197E-03 times the entries in the file listing.

Case 6c. Units Conversion for TH Data; x-Units:sec,y-Units:m/sec^2.
The first column of the Table Editor should have the same values as in the file listing. The second column of the Table Editor should be 1/(32.174*12*0.0254) = 1.0197E-01 times the entries in the file listing.

Case 6d. Units Conversion for TH Data; x-Units:sec,y-Units:in/sec^2.
The first column of the Table Editor should have the same values as in the file listing. The second column of the Table Editor should be 1/(32.174*12) = 2.59008E-03 times the entries in the file listing.

Case 6e. Units Conversion for TH Data; x-Units:sec,y-Units:ft/sec^2.
The first column of the Table Editor should have the same values as in the file listing. The second column of the Table Editor should be 1/(32.174) = 3.1081E-02 times the entries in the file listing.

4.3.7. Case 7: PS to RS Conversion

Case 7a. Regulatory Guide 1.60 Motion

The U.S. Regulatory Guide 1.60 motion (ref. 5), defined in terms of an RS for various dampings, is used in Case 7a. At the specified dampings, the spectrum is defined by six control points as shown in Table 4-1. Between these points, the spectra is to be interpreted in a log-log fashion.

Freq.(Hz)	0.5%	2%	5%	7%	10%
0.2	0.471	0.368	0.302	0.277	0.250
0.25	0.736	0.575	0.471	0.432	0.391
2.5	5.95	4.25	3.13	2.72	2.28
9.0	4.96	3.54	2.61	2.27	1.9
33.0	1.0	1.0	1.0	1.0	1.0
34.0	1.0	1.0	1.0	1.0	1.0

Table 4-1. REG GUIDE 1.60 Horizontal Response Spectra (1g ZPA).

Seventy-five point response spectra were manually created and stored in ASCII file NRC160H.RS. The 75 frequencies correspond to those listed in reference 6. A SPECTRA record was created by importing the ASCII file into SPQA2V0. The record is identified in Figure 4-7 and plotted in Figure 4-8. The five curves correspond to the five damping ratios 0.5%, 2%, 5%, 7% and 10%. Notice that on a log-log scale the RS curves are linear.

The PSD values corresponding to the 5% response spectra curve are stored in file NRC160H.RSE. It is in EDASP format and was created by using EDASP's RS to PSD conversion utility. (Prob. of Exceed=0.15, duration = 15 seconds, cutoff frequency = 34Hz). The program CNVED2SP.EXE is used to convert the PSD values to a corresponding PS which was stored in the SPECTRA compatible ASCII file NRC160X.PS. A record was created by importing the file NRC160X.PS. The record is identifed in Figure 4-9. The PS curve is plotted in Figure 4-10.

The ASCII file NRC160X.RS contains the EDASP generated 5% RS data that is consistent with the EDASP PSD. A record was created in SPQA2V0 by importing this file. The record is identified in Figure 4-11. The RS curve is plotted in Figure 4-12.

Expected Results (Case 7a)

The result of converting the PS from the record shown in Figure 4-9 should be close to the 5% damping RS Curve shown in Figure 4-8. The results should match exactly with those obtained using EDASP (Figure 4-12).

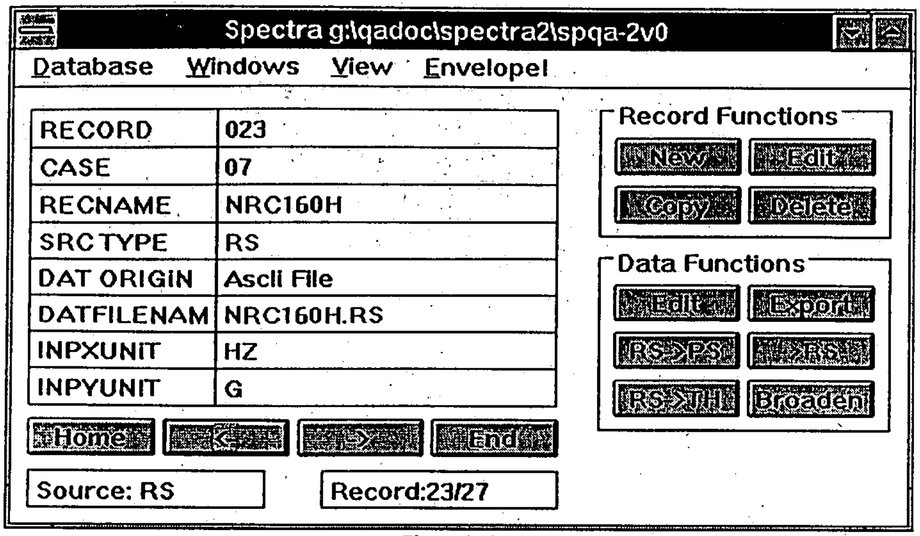


Figure 4-7

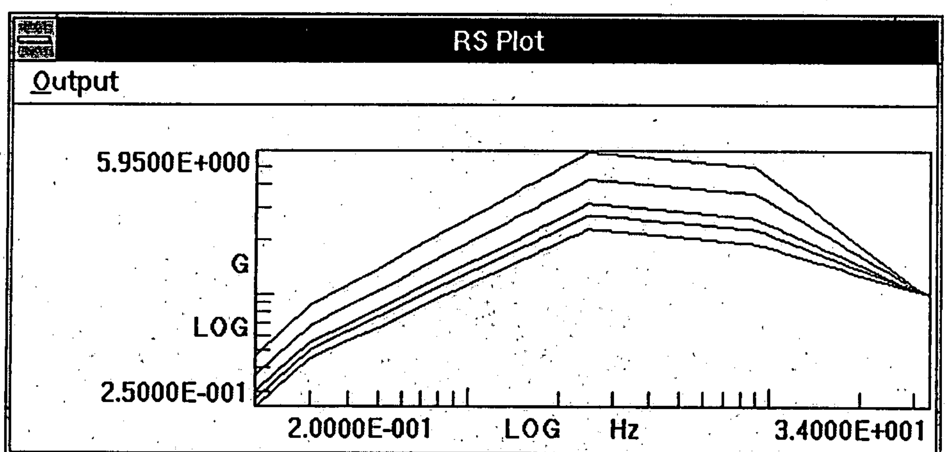


Figure 4-8

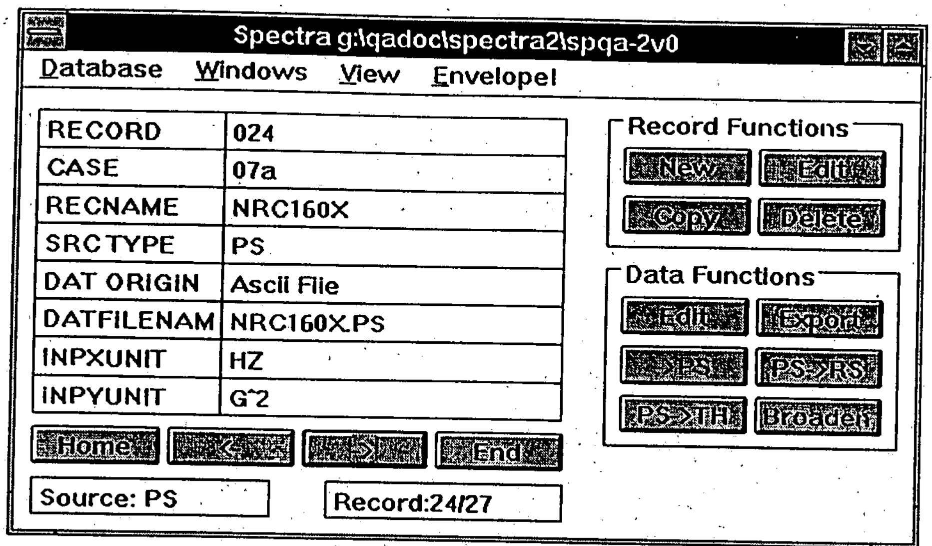


Figure 4-9

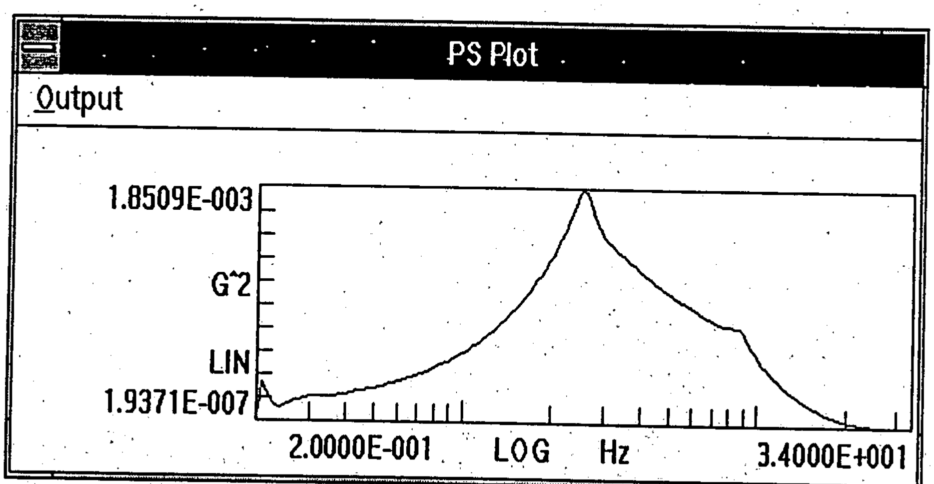


Figure 4-10

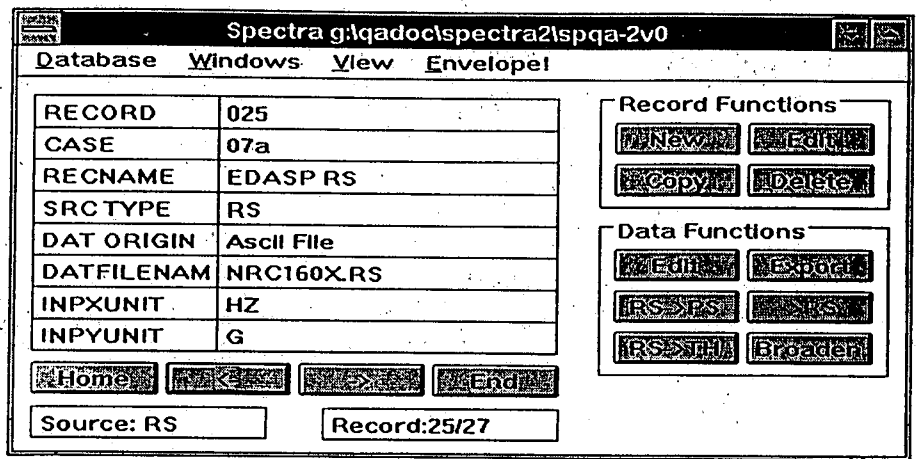


Figure 4-11

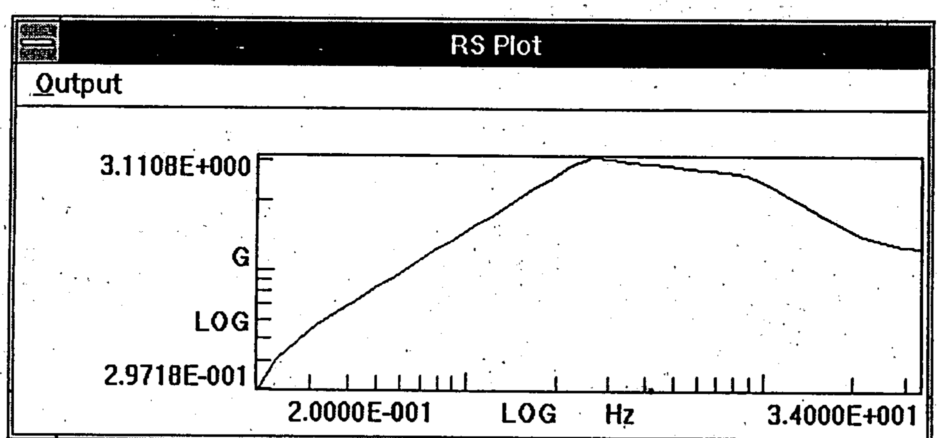


Figure 4-12

Case 7b. Smooth PS

A smooth PS curve is generated using the equation

(4.1) $$PS(f) = \left[\frac{(f-f_1)(f_n-f)}{(f_n+f^2)}\right]^2$$ where $f_1 = 0.2$ and $f_n = 34.0$ Hz..

The results of an PS to RS conversion (using the SPECTRA program) are compared to results obtained using the EDASP program. The PS data is stored in the record shown in Figure 4-13. It is plotted in Figure 4-14.

The PS data from the above record was exported to the EDASP format file CASE7bED.RS. The PSD to RS conversion utility of EDASP is used, and the resulting RS data is stored in file 7bEDASP.RSE. The data is converted to SPECTRA format (using the program CNVED2SP.EXE) and the results stored in file 7bEDASP.RS. The RS data in file 7bEDASP.RS is imported to the record shown in Figure 4-15 and displayed in Figure 4-16.

The following parameters are used for the PS to RS conversion.
SPECTRA:
Damping = 0.05
Prob. of Exceedance = 0.5
Frequencies: Default SPECTRA frequencies.
SPECTRA uses 24 divisions per octave.

EDASP:
Damping = 0.05
Prob. of Exceedance = 0.5
Divisions per Octave = 24

<u>Expected Results (Case 7b)</u>
The RS data values stored in the record shown in Figure 4-13 should match those stored in the record of Figure 4-15.

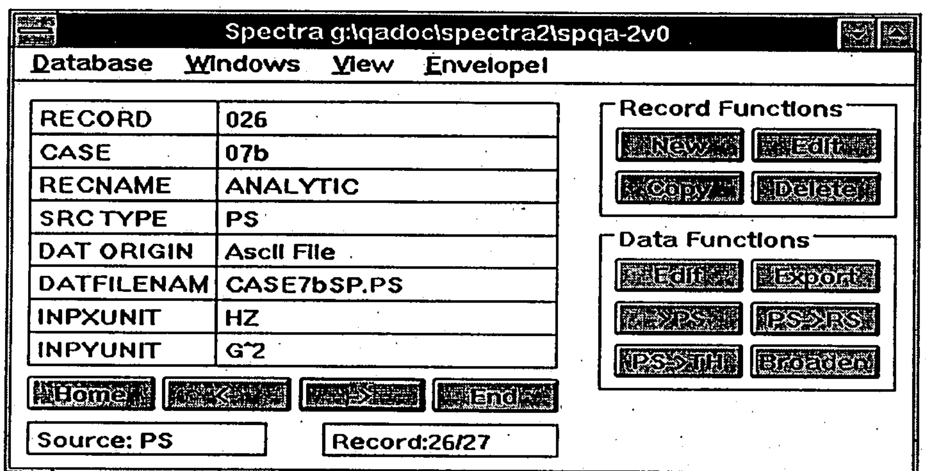


Figure 4-13

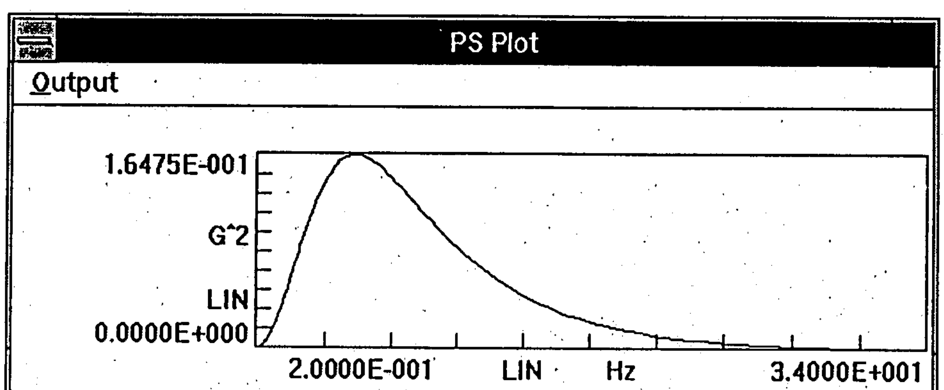


Figure 4-14

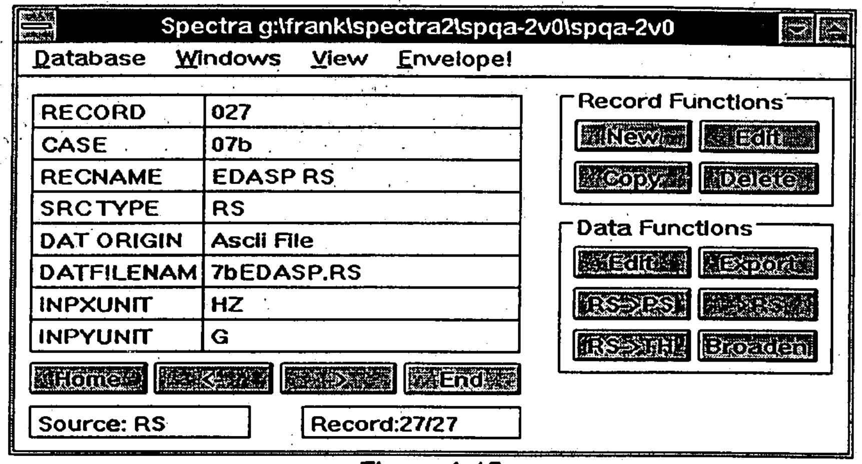


Figure 4-15

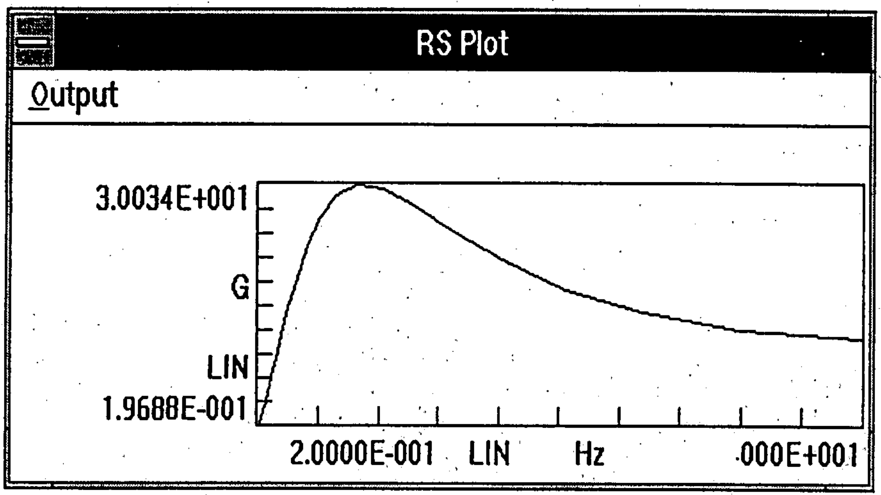


Figure 4-16

4.3.8. Case 8: RS to PS Conversion

Case 8a. REG Guide 1.60 Spectrum.
The RS to PS conversion is self-checking in that the RS corresponding to the resultant PS is compared with the original RS. Note that the PS to RS conversion process is independently verified. As a further check the results obtained from an RS to PS conversion are compared with results obtained using the EDASP program.

The data described in Case 7 (NRC160H.RS) was used for the verification. The PS data stored in file NRC160X.PS is in a format compatible for SPECTRA.

A SPECTRA record was created using the 5% damped RS data. (The Copy command is used to create a new record with the RS data. Edit (Data) is then used to delete the 0.5%, 2%, 7% and 10% damping curves from the record RS data). The record is identified in Figure 4-17.

The SPECTRA RS to PS utility was used to convert the RS to a PSD.

Expected Results (Case 8a)
A RS to PS conversion on the record described in Figure 4-17 with the following parameters should yield a PS curve that matches with the one stored in the file NRC160X.PS.

Probability of Exceedance	= 0.15
Excitation Duration	= 15.0 seconds
Iteration cycles	= 5
Frequencies	= SPECTRA default frequencies.

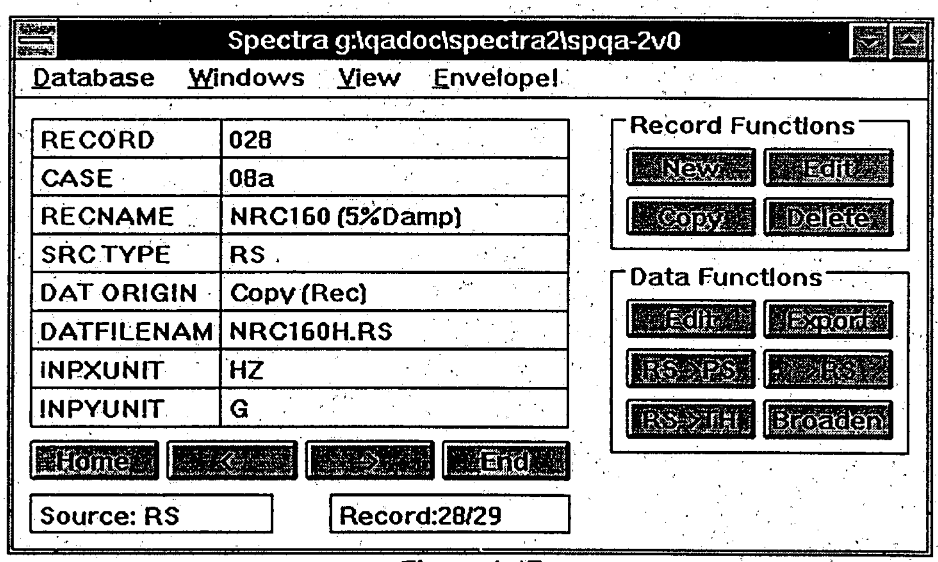


Figure 4-17

Case 8b. Smooth Spectrum.
The RS data in record identified in Figure 4-18 was converted to PS using the SPECTRA program and the results compared to EDASP results. The RS data in the record is shown plotted in Figure 4-19.

The RS data from the above record was exported to an EDASP format file CASE8bED.RS. The data from this file is converted to a PSD using the RS to PSD utility of EDASP, and the results are stored in file 8bEDASP.RSE. The following input parameters are used in the RS to PSD conversions.

SPECTRA input parameters.

Damping Ratio	= 0.05
Probability of Exceedance	= 0.5
Duration	= 15.0 seconds
Iteration cycles	= 5
Frequencies	= SPECTRA default frequencies.

EDASP Input Parameters.
Input File Name: CASE8bED.RS

Damping Ratio	= 0.05
Division/Octave	= 21.0
Prob. of Exceedance	= 0.5
Max # of Iterations	= 25
Conv. Tolerance	= 0.001

Expected Results (Case 8b)
The PSD values stored in file CASE8bED.Sp (SPECTRA results) should match PSD values stored in file 8bEDASP.RSE (EDASP results).

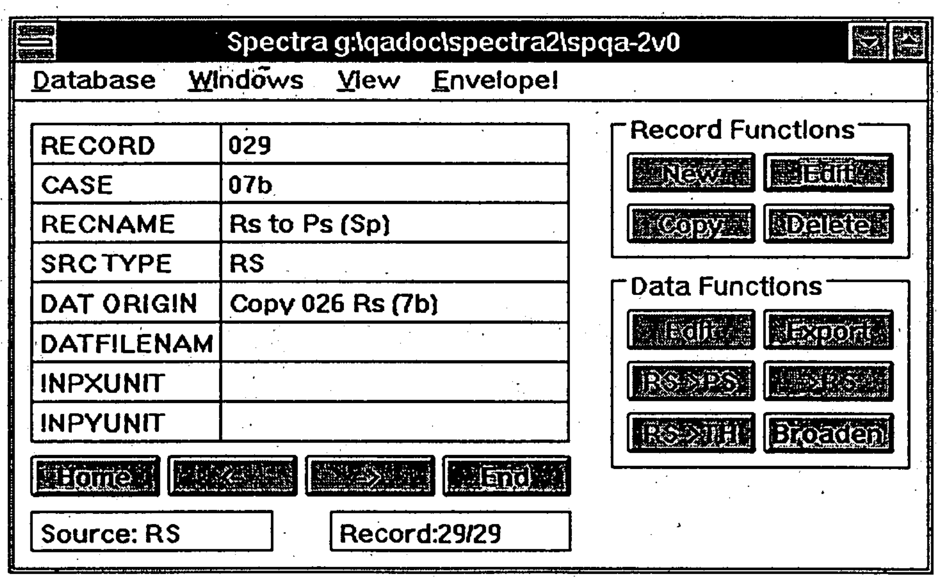


Figure 4-18

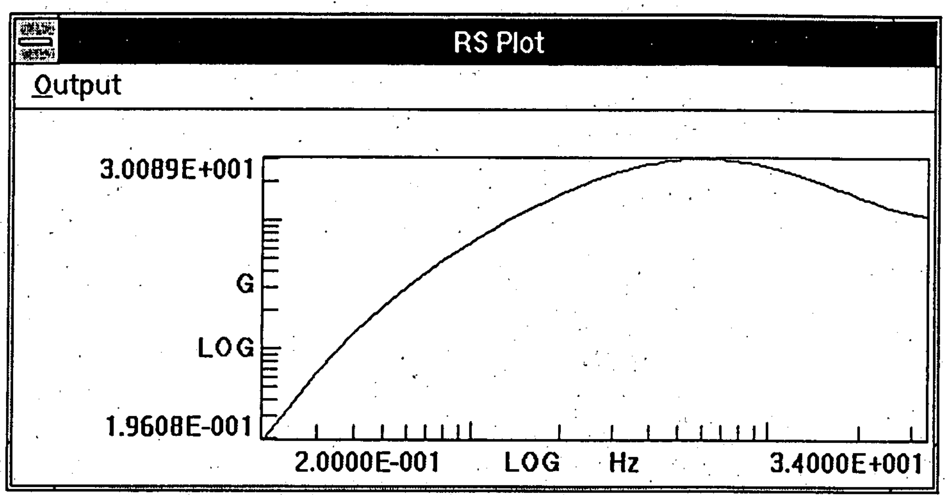

RS Plot
Output
3.0089E+001
G
LOG
1.9608E-001
2.0000E-001
LOG
Hz
3.4000E+001

Figure 4-19

4.3.9. Case 9: TH to PS Conversion.

Case 9a. Earthquake Motion
The results of a TH to PS conversion obtained using SPECTRA are compared to those obtained using the Subroutines described in Reference 8. The TH used for the comparison is stored in file DUKE.TH.

The Fourier components of the time history given in file DUKE.TH are obtained using the program TESTFFT.EXE described in Reference 8. The Fourier components are stored in file DUKE.FS. The Fourier components stored in file DUKE.FS are then converted to PS using the program FS2PS.EXE . (The program FS2PS.EXE converts a set of Fourier components to corresponding PS values.) The resulting PS is stored in file DUKE387.PS.

A SPECTRA record is created using the file DUKE.TH. The record is identified in Figure 4-20 and the corresponding TH is plotted in Figure 4-21. The SPECTRA utility for TH to PS conversion is used to convert the time history to PS.

Expected Results. (Case 9a)
The result of converting the TH should match the PS values stored in file DUKE387.PS.

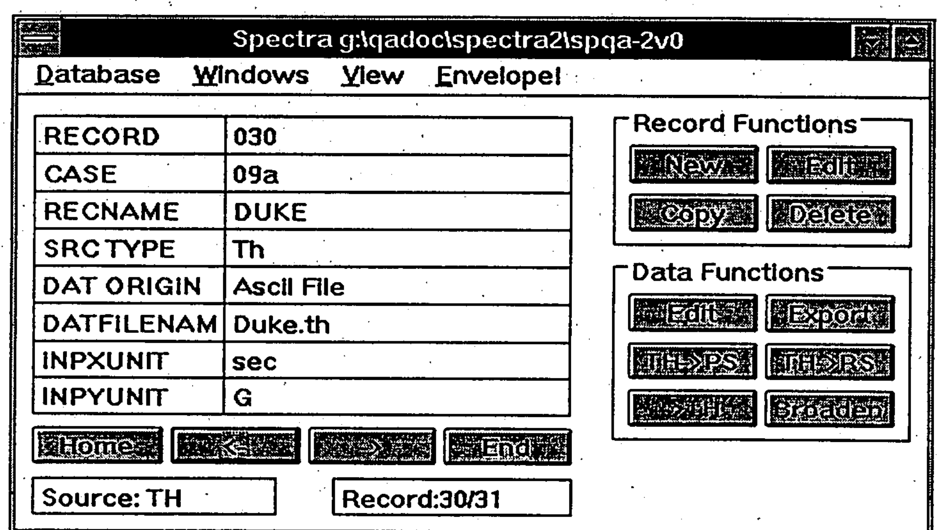


Figure 4-20

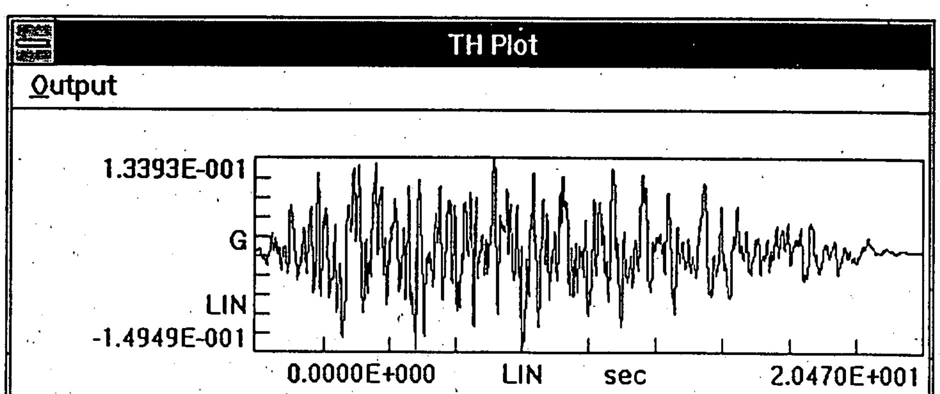


Figure 4-21

Case 9b. Sine Wave

An approximation of 10Hz sine wave is created using 1024 points at 0.014662 second intervals, for a total duration of 15 seconds. The time history is stored in the record shown in Figure 4-22 and plotted in Figure 4-23. A TH to PS conversion was then performed using a frequency spacing of 0.125Hz.

Expected Results (Case 9b)

The calculated PS should correspond to a one sided PS of a pure tone with unit amplitude, a value of 0.5 G at 10Hz for the ideal case. Leakage will cause part of the PS value to spill to nearby frequencies. Therefore, the sum of the PS values at frequencies near 10Hz should be close to 0.5.

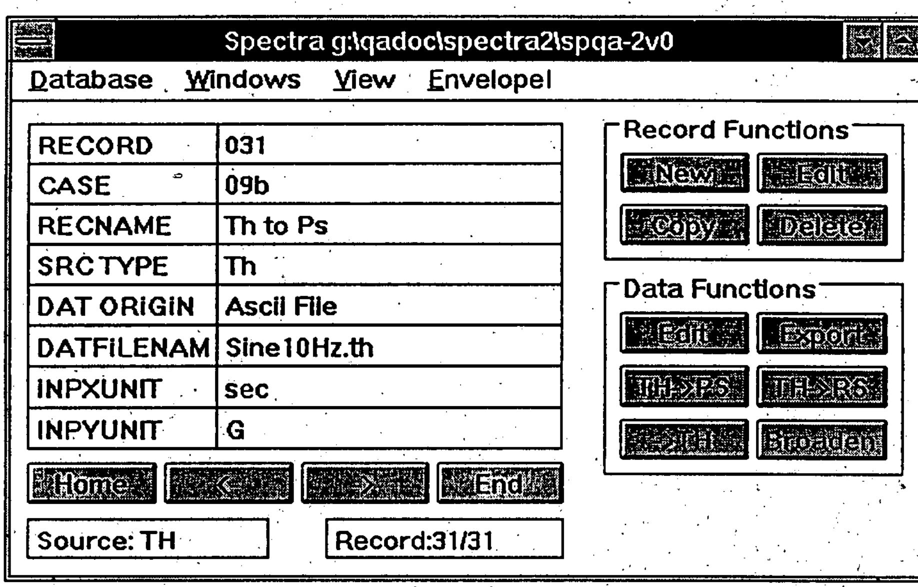


Figure 4-22

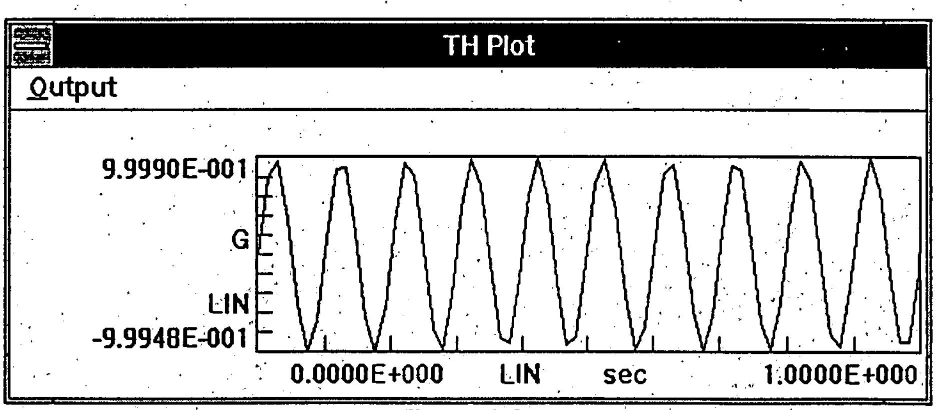


Figure 4-23

4.3.10. Case 10: PS to TH Conversion

Case 10a. Earthquake Motion
The PS to TH conversion was used to generate a set of TH values from the PS data in file DUKE387.PS. The record identified in Figure 4-24 contains the PS data.

The SPECTRA utility for PS to TH conversion was used to generate a time history with the following parameters.

Number of Points	= 2048
Time Step	= .01sec
Random Seed	= 23456
Intensity Type	= Constant

The resultant TH was copied to a new record shown in Figure 4-25. The TH to PS conversion utility was then used (with a frequency spacing of 0.5Hz) to generate a corresponding PS.

Expected Results (Case 10a)
The PS values stored in record shown in Figure 4-25 should match those stored in file DUKE387.PS.

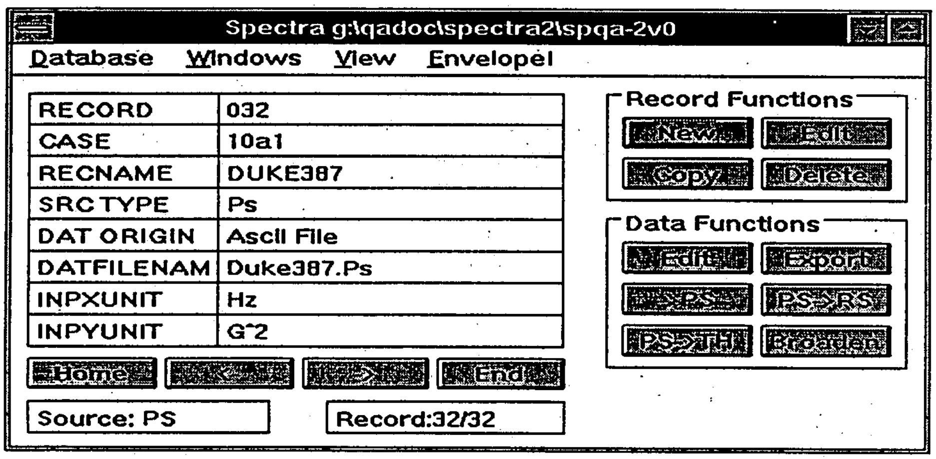


Figure 4-24

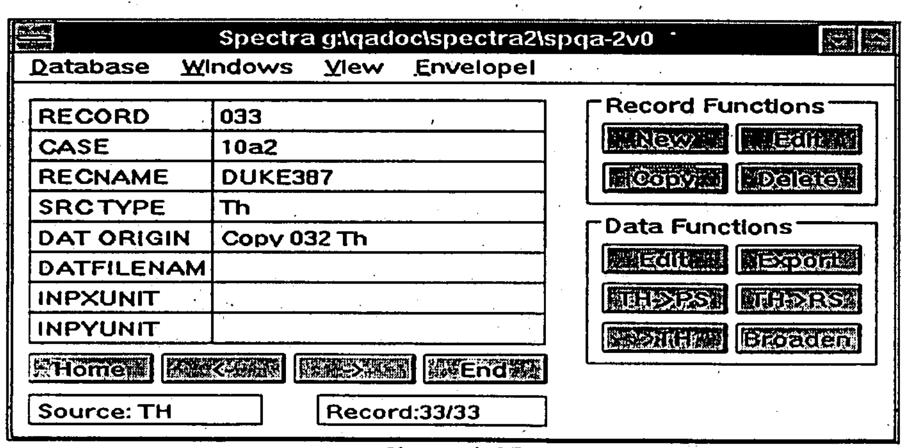


Figure 4-25

Case 10b. Sine Wave
The PS data from case 9b is used as input to a PS to TH conversion. The result should be a 10Hz time history. The PS data is stored in the record shown in Figure 4-26., and plotted in Figure 4-27. The conversion parameters used were

Number of Points = 1024
Time Increment = 0.014662
Random Seed = 123456
Intensity Type = Constant.

Expected Results (Case 10b)
The PS to TH conversion should produce a 10 Hz tone.

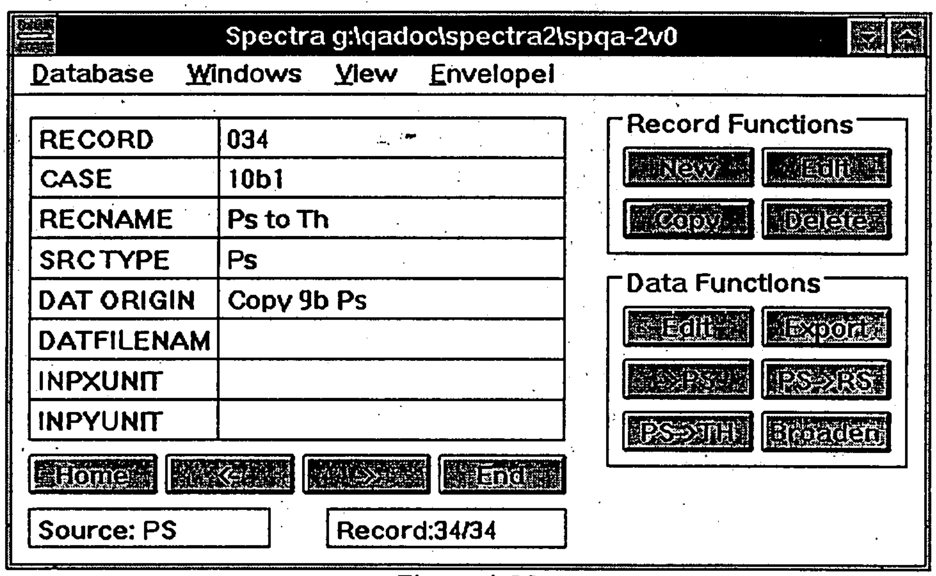


Figure 4-26

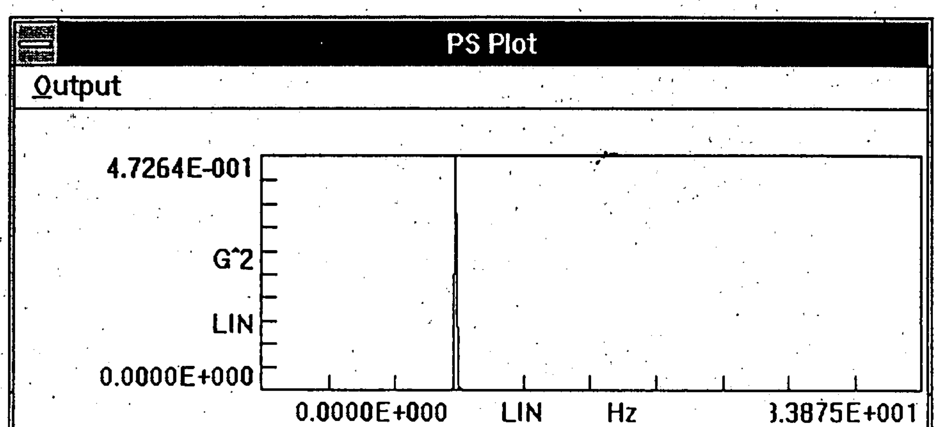


Figure 4-27

4.3.11. Case 11: TH to RS Conversion.

Case 11a. Random Motion.

A set of TH values was generated using a random number generator. The amplitude of the generated TH has a Gaussian distribution with zero mean and unit variance. The TH values are stored in file RANDOM.TH.

The number of TH points is 601 at equally spaced intervals of 0.025 seconds. The maximum TH amplitude is 2.91. A source TH record is created using the TH data in file RANDOM.TH, shown in Figure 4-28. The TH curve is plotted in Figure 4-29.

TH to RS conversion was used to obtain the corresponding RS with a damping ratio of 0.05. The RS values are calculated at the 75 default frequencies described in Section 2.4.7. The results of the TH to RS conversion using SPECTRA, are exported to file RANDSPEC.RS.

The RS values obtained using SPECTRA are compared with those obtained using the EDASP program. The TH points used for EDASP are stored in file RANDEDSP.TH. The results of the EDASP program are stored in file RANDEDSP.RS. To compare EDASP results with SPECTRA it is necessary to generate additional TH points by linear interpolation of TH values for the following reason.

If TH values are specified at a set of time points t_i, SPECTRA checks for RS peaks that might occur within t_i and t_{i+1} depending on the oscillator frequency. When calculating the RS for the oscillator frequency f, SPECTRA subdivides the interval t_i to t_{i+1} into nSubDivisions to ensure that at least 10 points are checked for each complete cycle.

EDASP assumes that the RS peaks will occur either at t_i or t_{i+1}. At higher oscillator frequencies this assumption may not be true as the peak could occur at an intermediate point. To make EDASP results comparable to SPECTRA at frequencies up to 34 Hz, it is necessary to have TH values at intervals of 1/340 = .002941 seconds. Linear interpolation is used to calculate TH values at .002941 second intervals and the resulting TH is stored in file RANDEDSP.TH. EDASP is then used to compute the 5% RS corresponding to this interpolated TH.

Expected Results (Case 11a)

The RS stored in the record shown in Figure 4-28 should match that given in file RANDEDSP.RS.

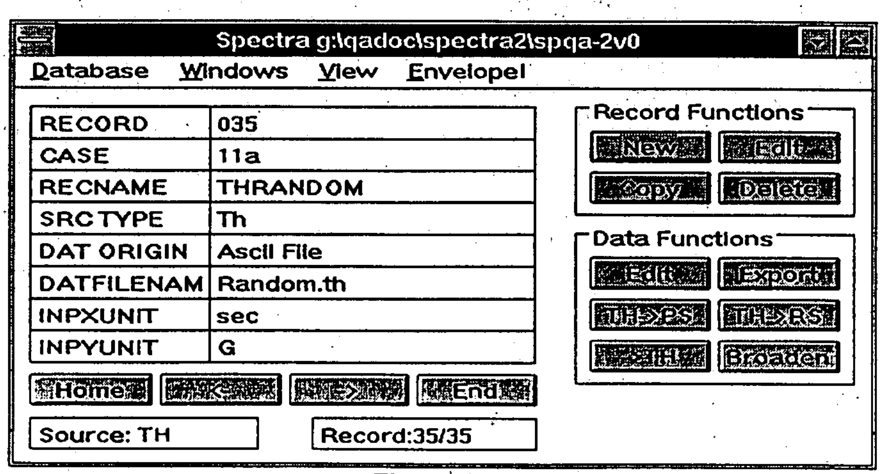


Figure 4-28

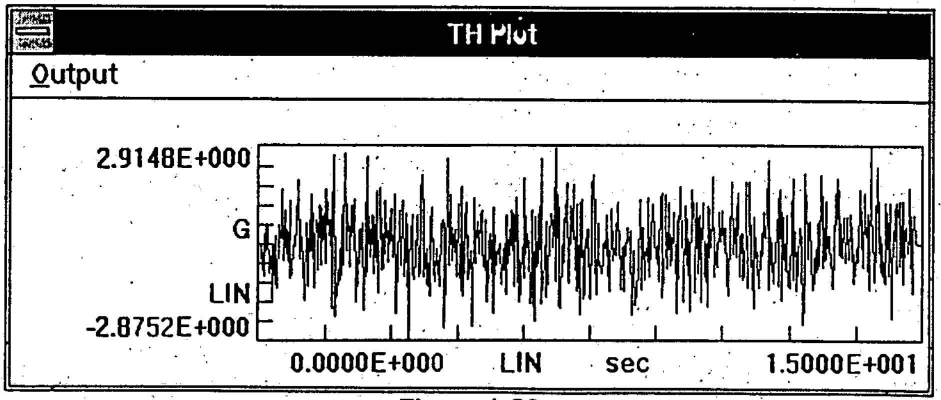

TH Plot
Output
2.9148E+000
G
LIN
-2.8752E+000
0.0000E+000
LIN
sec
1.5000E+001

Figure 4-29

4.3.11.1. Case 11b

The RS corresponding to a unit amplitude 10Hz sine wave is computed with SPECTRA's TH to RS utility. The results are compared to a hand calculation. The 10 Hz TH data is stored in the record shown in Figure 4-30.

Expected Results (Case 11b)

From reference 13 p. 128, the steady state response of a SDOF oscillator to sinusoidal base motion is

$$(4.2) \qquad A_s = \frac{A_f\sqrt{1+(2\beta r)^2}}{\sqrt{(1-r^2)^2+(2\beta\rho)^2}}$$

where

A_f = forcing amplitude
ρ = ratio of forcing frequency/natural frequency
β = Damping ratio as a percentage of critical.
A_s = response amplitude.

Because Eqn. (4.2) is for the steady state response, the RS values will tend to deviate from the predicted SDOF response. In addition there are errors associated with the discretization process. However, for cases where the steady state dominates, this estimated value should be close to the actual RS. A resonant case with significant damping should provide a good match. Therefore the value of a 5% damped RS at f=10Hz should produce a value equal to A_s ϕoρ r=1 and β =0.05, which is A_s = 10.05 g.

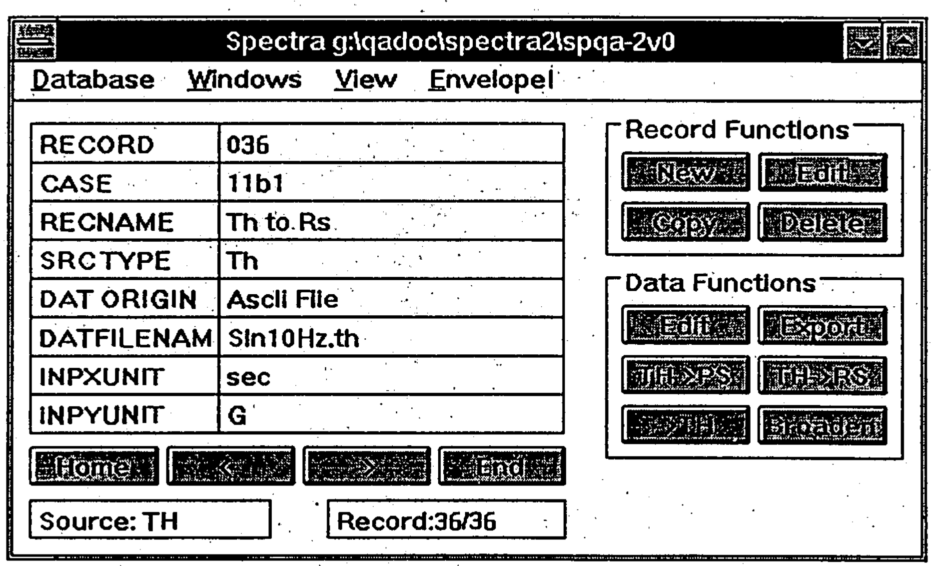


Figure 4-30

4.3.12. Case 12: RS to TH Conversion

<u>Case 12. Regulatory Guide 1.60 Spectrum</u>
The RS to TH conversion is self-checking in that the RS corresponding to the resultant TH is compared with the original RS.

A record was created using the 2% damped NRC160 RS data, identified in Figure 4-31. The RS to TH utility is used to obtain the corresponding TH. Parameters used are

Number of Points = 1024
Time Step = 1/68 seconds = 0.014705 seconds.
Random Seed = 123456
Intensity Type = Constant
Iteration Cycles = 2

The resultant TH was copied to a new record, shown in Figure 4-32.

<u>Expected Results (Case 12)</u>
The original RS and an RS calculated from the output TH should match well. Note that the TH to RS conversion process is independently verified.

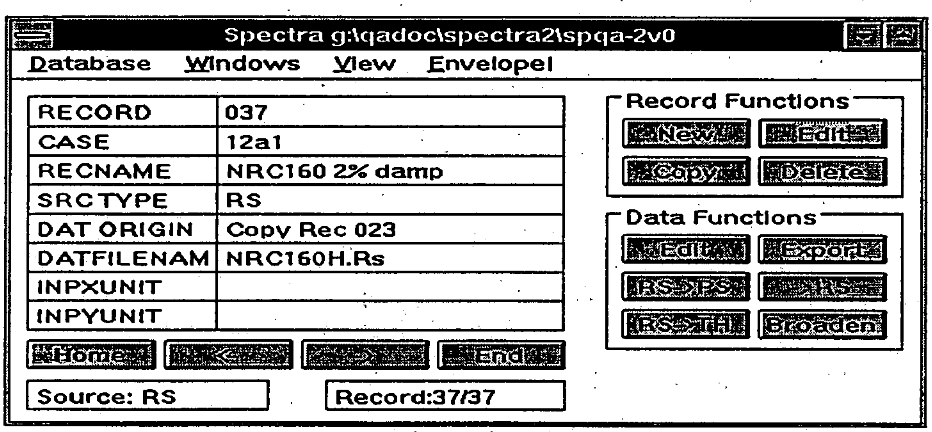


Figure 4-31

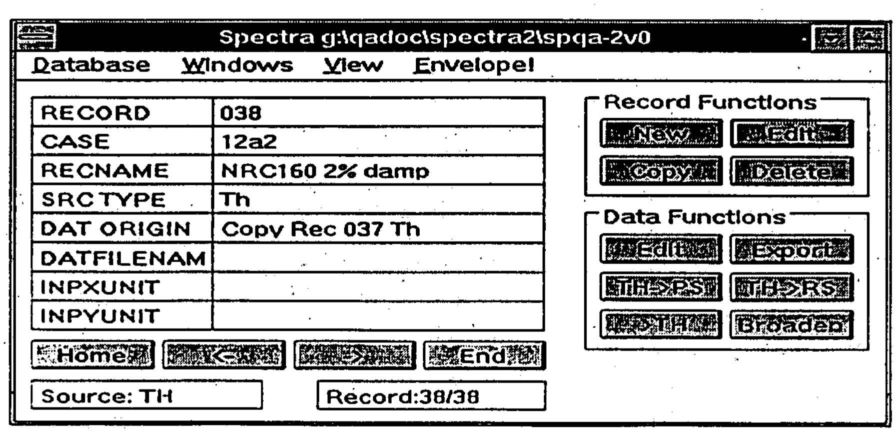


Figure 4-32

4.3.13. Case 13: Broadening RS

SPECTRA allows the user to broaden RS by a specified broadening factor. The broadened RS is stored as (calculated)RS. The user can copy the broadened RS to create a new record.

Three SPECTRA records are created from RS data in file RS51X.RS, RS52X.RS and RS53X.RS. The RS curves in each record are broadened by a factor of 0.15. The (original)RS values and the broadened RS values are stored in records shown in Figures 4-33, 4-35, and 4-37. and the plots in Figures 4-34, 4-36, and 4-38, respectively.

<u>Expected Results. Case 13</u>

The results obtained from the SPECTRA should match those described on page 26 of the EDASP Verification Manual (Reference 4). The (original)RS curves are stored in the above records as source RS and the broadened RS are stored as calculated RS.

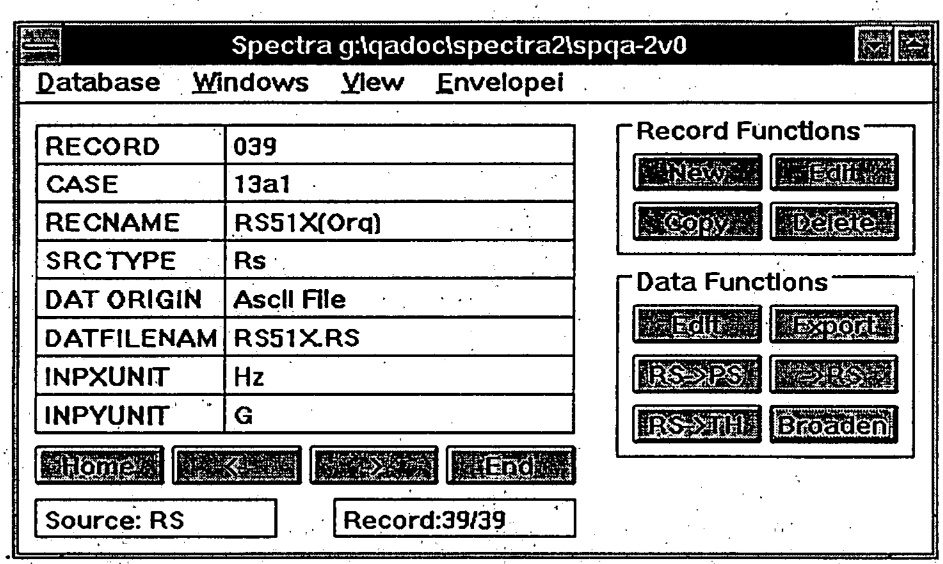


Figure 4-33

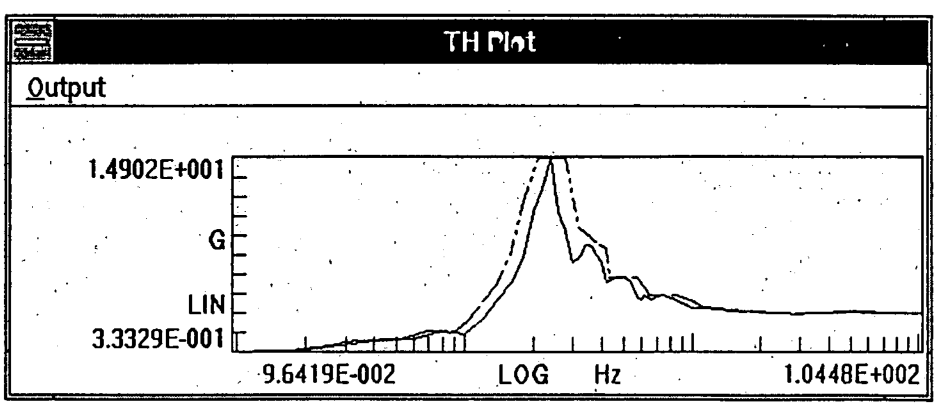


Figure 4-34

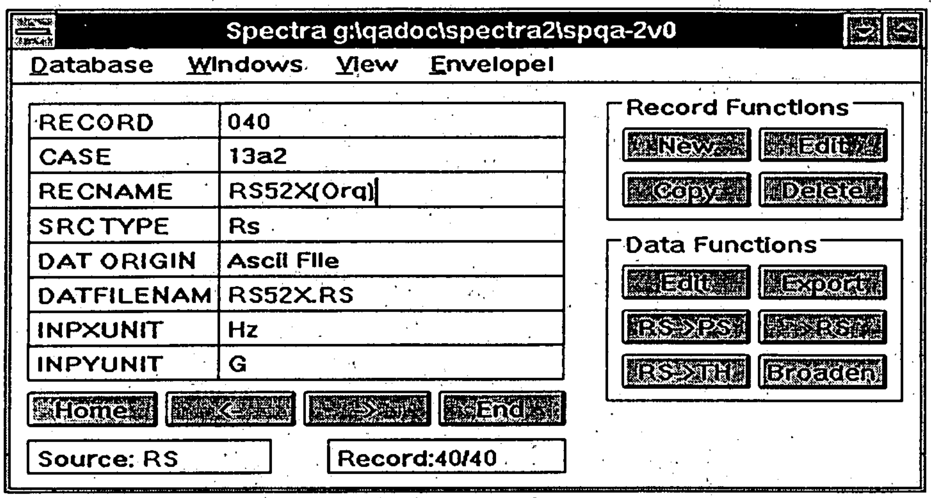


Figure 4-35

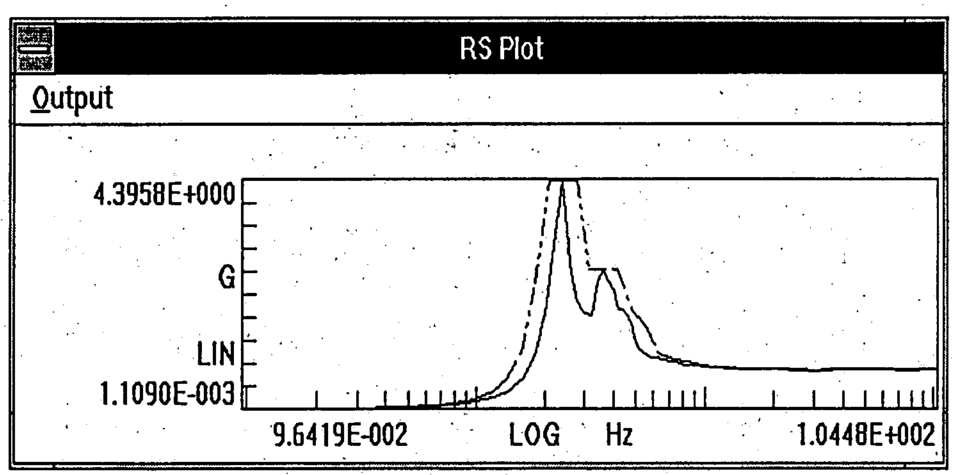


Figure 4-36

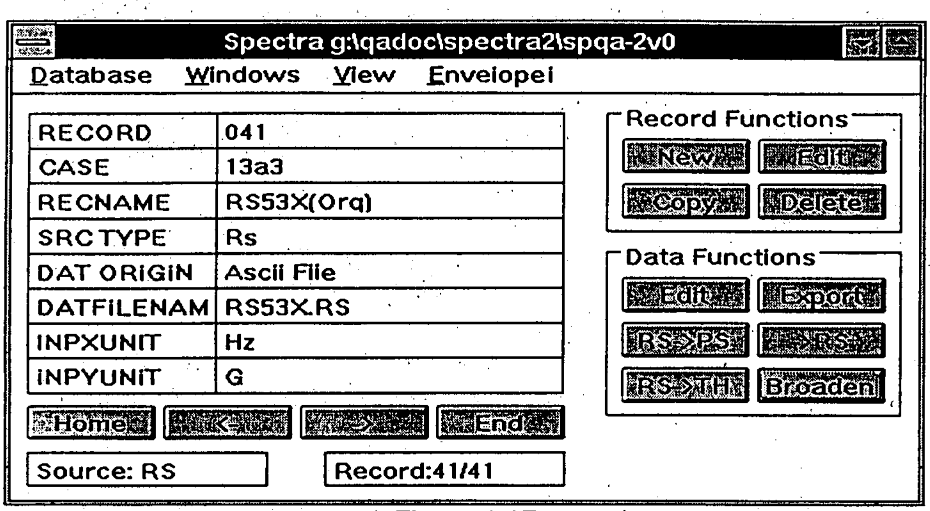


Figure 4-37

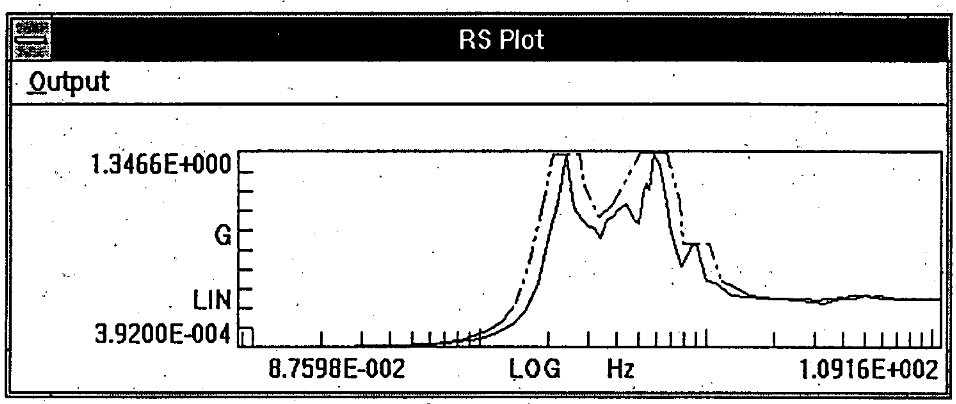


Figure 4-38

4.3.14. Case 14: Enveloping RS.

SPECTRA can be used to obtain the envelope of two or more RS curves from one or more databases. To verify the process, two RS curves are enveloped. One RS curve represents the NRC 0.5% damping curve stored in record listed in Figure-4-7. The other is the 5% damping RS curve corresponding to the record described in Figure 4-3. Figure 4-39 shows the two RS curves plotted together. and Figure 4-40 shows the corresponding envelope. The envelope is stored in the database in the record described in Figure 4-41.

Expected Results:
A visual inspection should indicate that each ordinate of the envelope curve is equal to the greater of the corresponding ordinates of the 2 constituent curves.

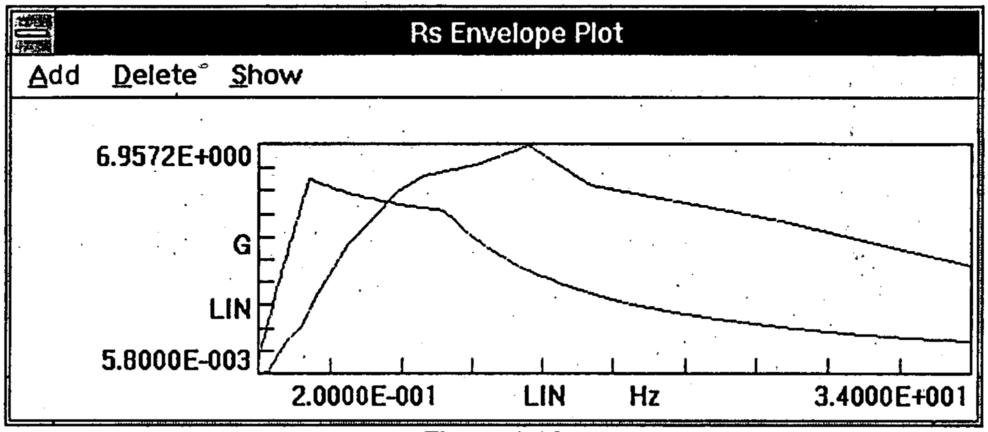


Figure 4-39

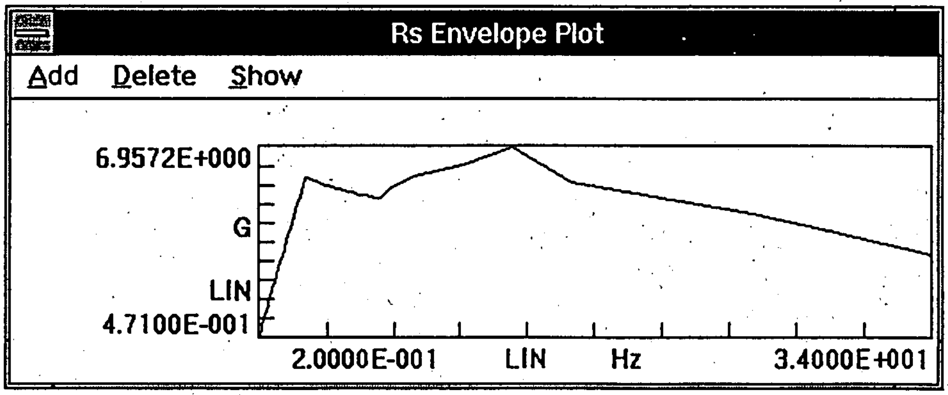


Figure 4-40

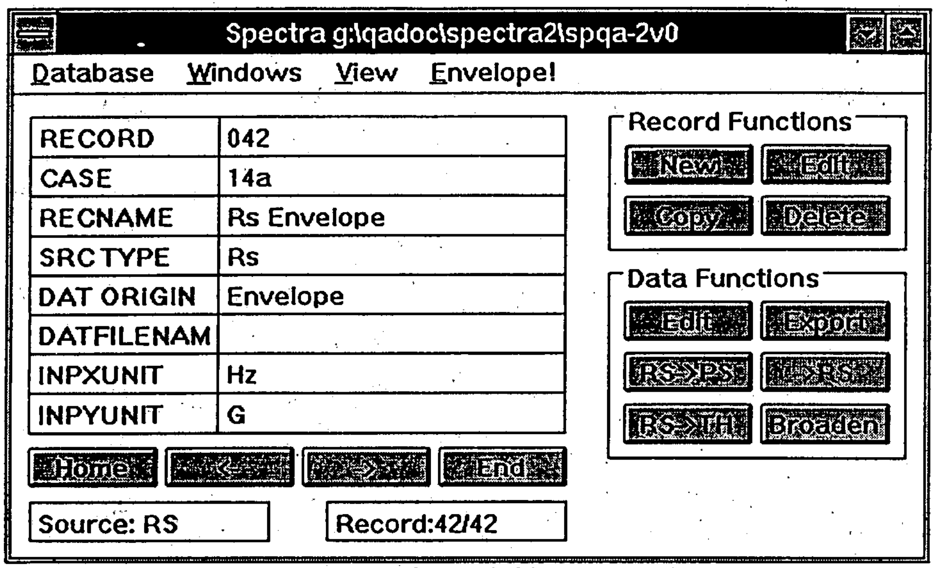


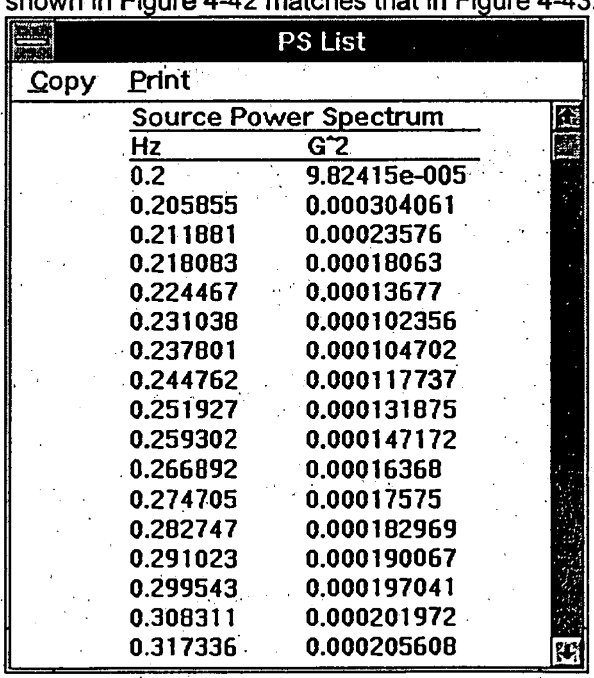
Figure 4-41

4.3.15. Case 15: Copy List Data to the Clipboard

Ps, Rs and Th List data is copied to the Clipboard from the SPECTRA records. The List data copied to the Clipboard should match the data in the SPECTRA records.

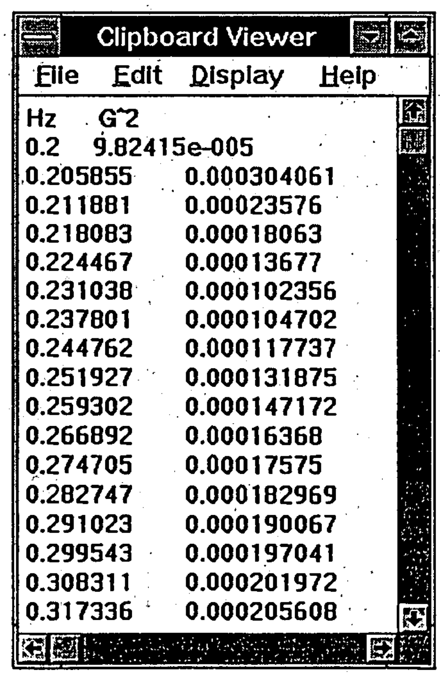
Case 15a. Copy Ps List Data

The Ps List data stored in the record identified in Figure 4-9 is copied to the clipboard. The Ps List data shown in Figure 4-42 matches that in Figure 4-43.



Hz	G^2
0.2	9.82415e-005
0.205855	0.000304061
0.211881	0.00023576
0.218083	0.00018063
0.224467	0.00013677
0.231038	0.000102356
0.237801	0.000104702
0.244762	0.000117737
0.251927	0.000131875
0.259302	0.000147172
0.266892	0.00016368
0.274705	0.00017575
0.282747	0.000182969
0.291023	0.000190067
0.299543	0.000197041
0.308311	0.000201972
0.317336	0.000205608

Figure 4-42



Hz	G^2
0.2	9.82415e-005
0.205855	0.000304061
0.211881	0.00023576
0.218083	0.00018063
0.224467	0.00013677
0.231038	0.000102356
0.237801	0.000104702
0.244762	0.000117737
0.251927	0.000131875
0.259302	0.000147172
0.266892	0.00016368
0.274705	0.00017575
0.282747	0.000182969
0.291023	0.000190067
0.299543	0.000197041
0.308311	0.000201972
0.317336	0.000205608

Figure 4-43

Case 15b. Copy Th List Data

The Th List data stored in the record identified in Figure 4-5 is copied to the Clipboard. The Th List data shown in Figure 4-44 matches that in Figure 4-45.

TH List

Copy Print

sec	G
0	0
0.01	0.25
0.02	0.5
0.03	0.75
0.04	1
0.05	0.75
0.06	0.5
0.07	0.25
0.08	0
0.09	-0.25
0.1	-0.5
0.11	-0.75
0.12	-1
0.13	-0.75
0.14	-0.5
0.15	-0.25

Figure 4-44

Clipboard Viewer

File Edit Display Help

sec	G
0	0
0.01	0.25
0.02	0.5
0.03	0.75
0.04	1
0.05	0.75
0.06	0.5
0.07	0.25
0.08	0
0.09	-0.25
0.1	-0.5
0.11	-0.75
0.12	-1
0.13	-0.75
0.14	-0.5
0.15	-0.25

Figure 4-45

Case 15c. Copy Rs List Data

An x-axis tolerance of 0.015 Hz is applied to the Rs List calculated data stored in the record identified in Figure 4-17 prior to being copied to the Clipboard. The Rs List calculated data (prior to application of the tolerance) is shown in Figure 4-46. Figure 4-47.displays the same spectrum subsequent to the application of the tolerance. Note that the larger of the two response (y-axis) values is chosen for closely spaced frequency (x-axis) values within 0.015 Hz as shown in Figure 4-47: 0.321109g's being chosen as the larger of the two response values corresponding to 0.2Hz and 0.205821Hz; 0.361389g's being chosen as the larger of the two response values corresponding to 0.0.211812Hz and 0.217978 Hz; etc.

RS List

Copy Print

Calculated Response Spectrum

Hz	G
0.2	0.295636
0.205821	0.321109
0.211812	0.343089
0.217978	0.361389
0.224322	0.377095
0.230852	0.391765
0.237571	0.406656
0.244486	0.422407
0.251602	0.43912
0.258926	0.456578
0.266463	0.474455
0.274218	0.492433
0.2822	0.51023
0.290414	0.527581
0.298867	0.544245
0.307567	0.560082
0.316519	0.575148
0.325732	0.589682
0.335213	0.603971
0.34497	0.618222
0.355011	0.632529
0.365345	0.646926
0.375979	0.661487

Figure 4-46

Clipboard Viewer

File Edit Display Help

(Hz)	5.0% (G)
0.2	0.321109
0.211812	0.361389
0.224322	0.391765
0.237571	0.422407
0.251602	0.456578
0.266463	0.492433
0.2822	0.527581
0.298867	0.560082
0.316519	0.589682
0.335213	0.618222
0.355011	0.632529
0.365345	0.646926
0.375979	0.661487

Figure 4-47

4.3.16. Custom Formatting in *EasyPlot*

Selected response spectra from the record shown in Figure 4-7 is plotted using the *EasyPlot* program (ref. 12).. The custom formatting options employed in this case include selecting a plot title, 1/2%,2% and 7% damped spectra for plotting, a database field position file (sampl02.txt) which has selected the 2nd, 3rd and 4th database field labels and their values for printing, and the default options for the *EasyPlot* template and EasyPlot Parameter file identification. The SPECTRA EasyPlot Parameter dialog box used in the formatting is shown in Figure 4-48. Figure 4-49 demonstrates the acceptability of this case.

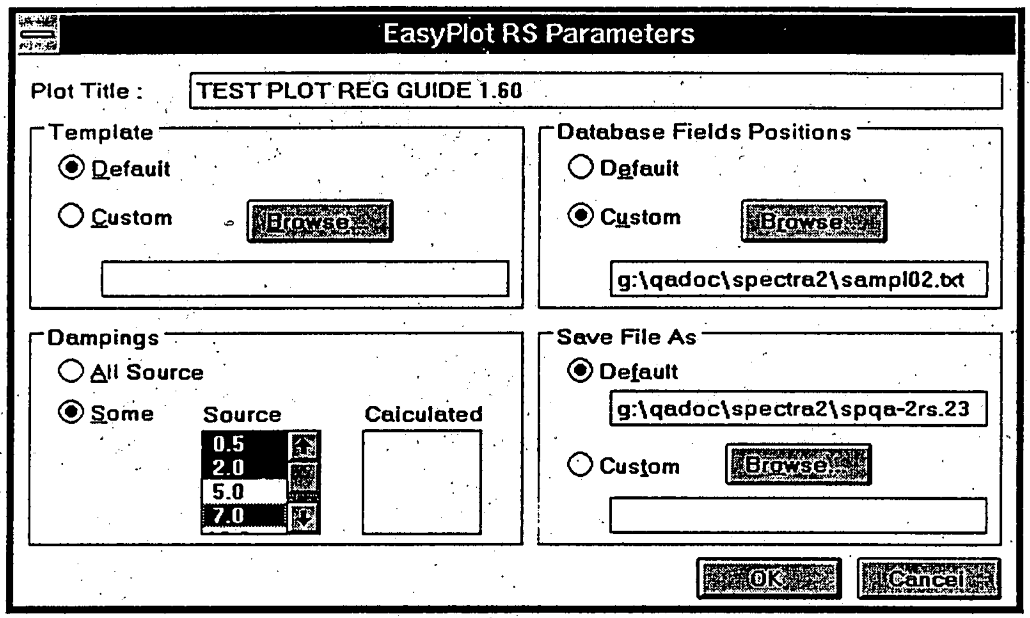


Figure 4-48

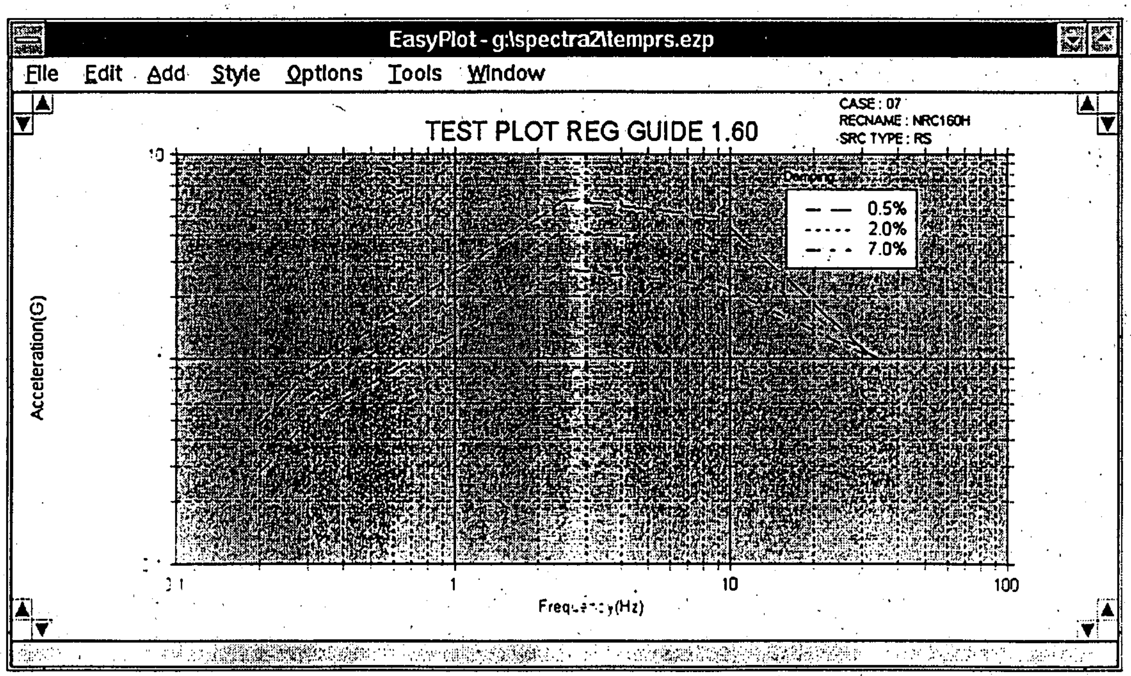


Figure 4-49

5. QA VERIFICATION

This section presents the results of the test cases layed out in Section 4. The SPECTRA database SPQA2VO contains all SPECTRA records referenced in the verification process. The ASCII based text files used are stored along with SPQA2VO. The data is kept on file at S&A's offices.

Cases 1 through 6 lend to straightforward verification. In those cases inspection of data adequately confirms correct operation of SPECTRA. Verification of Cases 7 to 12 relies on other QA qualified programs or on calculations. Cases 13, 14, 15, and 16 are verified by inspection.

The EDASP [4] program is used to verify the PS to RS, RS to PS, and TH to RS functions. EDASP has been qualified for use under S&A's Quality Assurance program and has been used extensively by nuclear engineers since 1984. SPECTRA and EDASP use similar algorithms for the above conversions and results should be generally the same except for minor differences in the discretization process.

The program 387FFT [8] is used to verify the results of the TH to PS conversion. 387FFT is a library of FFT related functions for use on IBM compatible computers using the Intel 8087/287/387 co-processor chip.

5.1. Case 1

Inspection of Figure 4-2 confirms that the data has been correctly imported.

5.2. Case 2

Inspection of Figure 4-4 confirms that the data has been correctly imported.

5.3. Case 3

Inspection of Figure 4-6 confirms that the data has been correctly imported.

5.4. Case 4

Figures 5-1 to 5-7 show the results of importing PS data with units conversion. Inspection of the figures verifies that SPECTRA has correctly converted the data to the native units Hertz and G^2. The imported data is stored as records 10 to 16 in SPQA2VO.

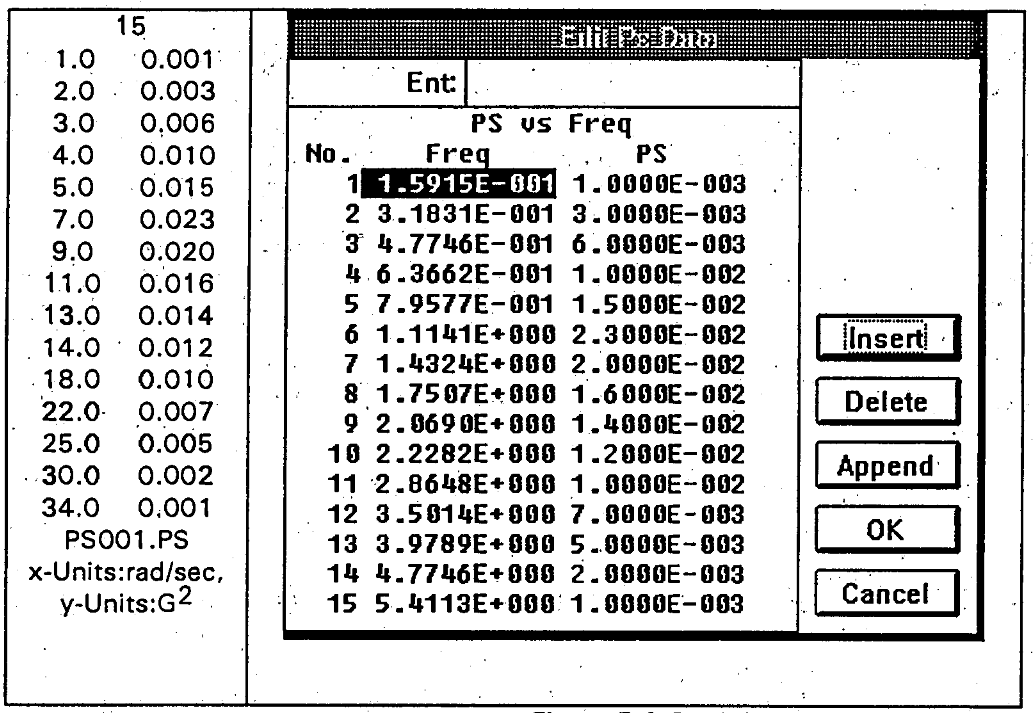
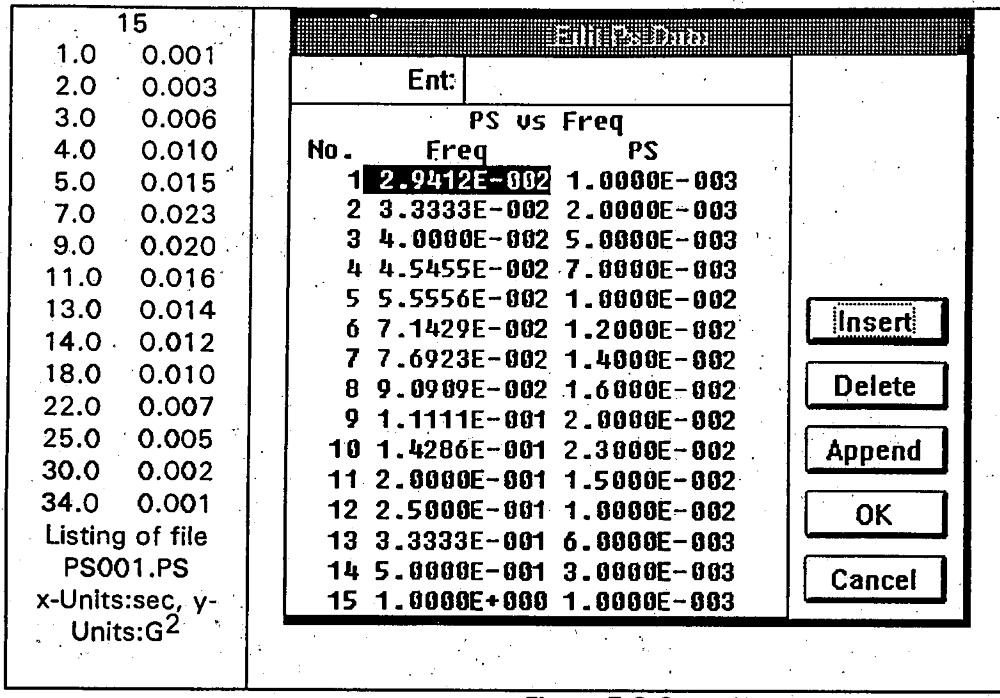


Figure 5-1 Case 4a



15	
1.0	0.001
2.0	0.003
3.0	0.006
4.0	0.010
5.0	0.015
7.0	0.023
9.0	0.020
11.0	0.016
13.0	0.014
14.0	0.012
18.0	0.010
22.0	0.007
25.0	0.005
30.0	0.002
34.0	0.001

Listing of file PS001.PS x-Units:sec, y-Units:G^2

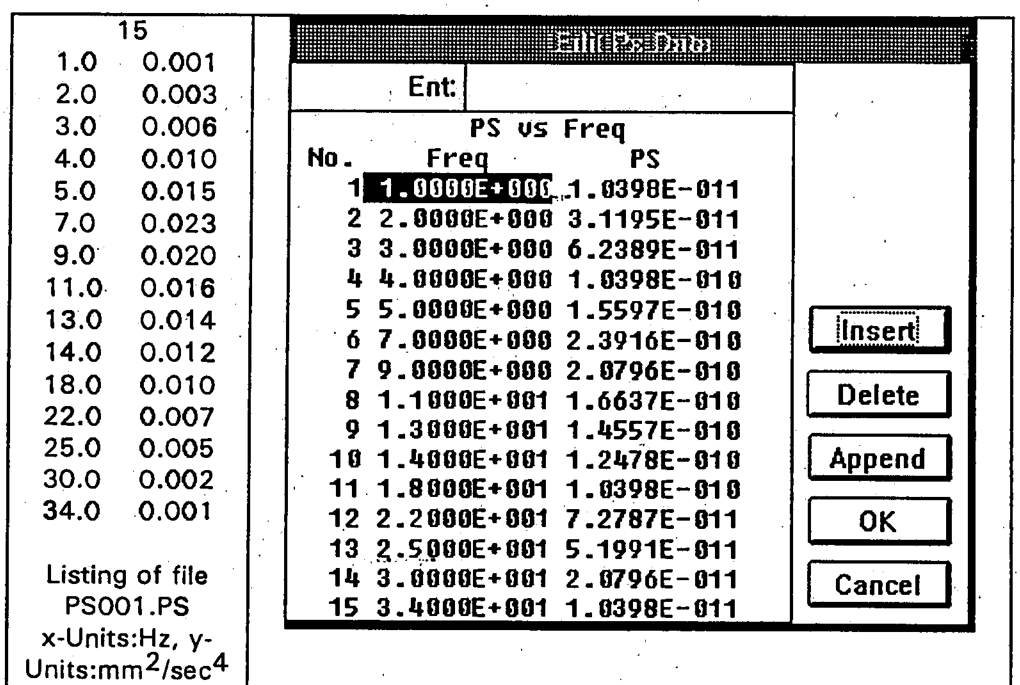
Ent:

PS vs Freq

No.	Freq	PS
1	2.9412E-002	1.0000E-003
2	3.3333E-002	2.0000E-003
3	4.0000E-002	5.0000E-003
4	4.5455E-002	7.0000E-003
5	5.5556E-002	1.0000E-002
6	7.1429E-002	1.2000E-002
7	7.6923E-002	1.4000E-002
8	9.0909E-002	1.6000E-002
9	1.1111E-001	2.0000E-002
10	1.4286E-001	2.3000E-002
11	2.0000E-001	1.5000E-002
12	2.5000E-001	1.0000E-002
13	3.3333E-001	6.0000E-003
14	5.0000E-001	3.0000E-003
15	1.0000E+000	1.0000E-003

Insert Delete Append OK Cancel

Figure 5-2 Case 4b



15	
1.0	0.001
2.0	0.003
3.0	0.006
4.0	0.010
5.0	0.015
7.0	0.023
9.0	0.020
11.0	0.016
13.0	0.014
14.0	0.012
18.0	0.010
22.0	0.007
25.0	0.005
30.0	0.002
34.0	0.001

Listing of file PS001.PS x-Units:Hz, y-Units:mm^2/sec^4

Ent:

PS vs Freq

No.	Freq	PS
1	1.0000E+000	1.0398E-011
2	2.0000E+000	3.1195E-011
3	3.0000E+000	6.2389E-011
4	4.0000E+000	1.0398E-010
5	5.0000E+000	1.5597E-010
6	7.0000E+000	2.3916E-010
7	9.0000E+000	2.0796E-010
8	1.1000E+001	1.6637E-010
9	1.3000E+001	1.4557E-010
10	1.4000E+001	1.2478E-010
11	1.8000E+001	1.0398E-010
12	2.2000E+001	7.2787E-011
13	2.5000E+001	5.1991E-011
14	3.0000E+001	2.0796E-011
15	3.4000E+001	1.0398E-011

Insert Delete Append OK Cancel

Figure 5-3 Case 4c

15	
1.0	0.001
2.0	0.003
3.0	0.006
4.0	0.010
5.0	0.015
7.0	0.023
9.0	0.020
11.0	0.016
13.0	0.014
14.0	0.012
18.0	0.010
22.0	0.007
25.0	0.005
30.0	0.002
34.0	0.001

Listing of file PS001.PS x-Units:Hz, y-Units:cm^2/sec^4

Edit Ps Data

Ent:

PS vs Freq

No.	Freq	PS
1	1.0000E+000	1.0398E-009
2	2.0000E+000	3.1195E-009
3	3.0000E+000	6.2389E-009
4	4.0000E+000	1.0398E-008
5	5.0000E+000	1.5597E-008
6	7.0000E+000	2.3916E-008
7	9.0000E+000	2.0796E-008
8	1.1000E+001	1.6637E-008
9	1.3000E+001	1.4557E-008
10	1.4000E+001	1.2478E-008
11	1.8000E+001	1.0398E-008
12	2.2000E+001	7.2787E-009
13	2.5000E+001	5.1991E-009
14	3.0000E+001	2.0796E-009
15	3.4000E+001	1.0398E-009

Insert
Delete
Append
OK
Cancel

Figure 5-4 Case 4d

15	
1.0	0.001
2.0	0.003
3.0	0.006
4.0	0.010
5.0	0.015
7.0	0.023
9.0	0.020
11.0	0.016
13.0	0.014
14.0	0.012
18.0	0.010
22.0	0.007
25.0	0.005
30.0	0.002
34.0	0.001

Listing of file PS001.PS x-Units:Hz, y-Units:m^2/sec^4

Edit Ps Data

Ent:

PS vs Freq

No.	Freq	PS
1	1.0000E+000	1.0398E-005
2	2.0000E+000	3.1195E-005
3	3.0000E+000	6.2389E-005
4	4.0000E+000	1.0398E-004
5	5.0000E+000	1.5597E-004
6	7.0000E+000	2.3916E-004
7	9.0000E+000	2.0796E-004
8	1.1000E+001	1.6637E-004
9	1.3000E+001	1.4557E-004
10	1.4000E+001	1.2478E-004
11	1.8000E+001	1.0398E-004
12	2.2000E+001	7.2787E-005
13	2.5000E+001	5.1991E-005
14	3.0000E+001	2.0796E-005
15	3.4000E+001	1.0398E-005

Insert
Delete
Append
OK
Cancel

Figure 5-5 Case 4e

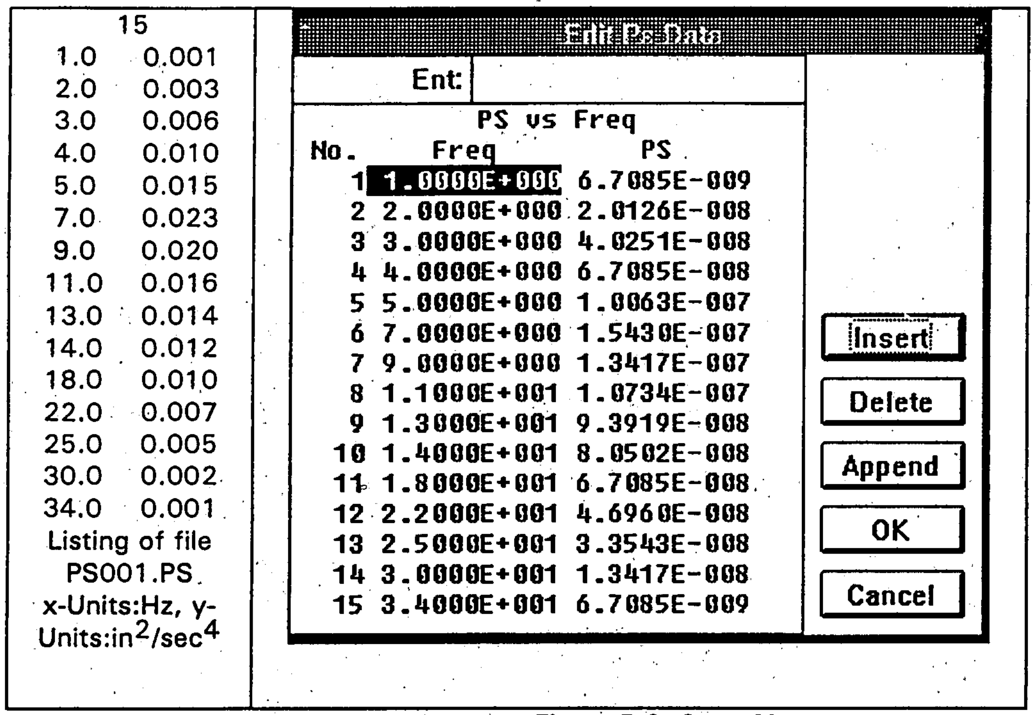


Figure 5-6 Case 4f

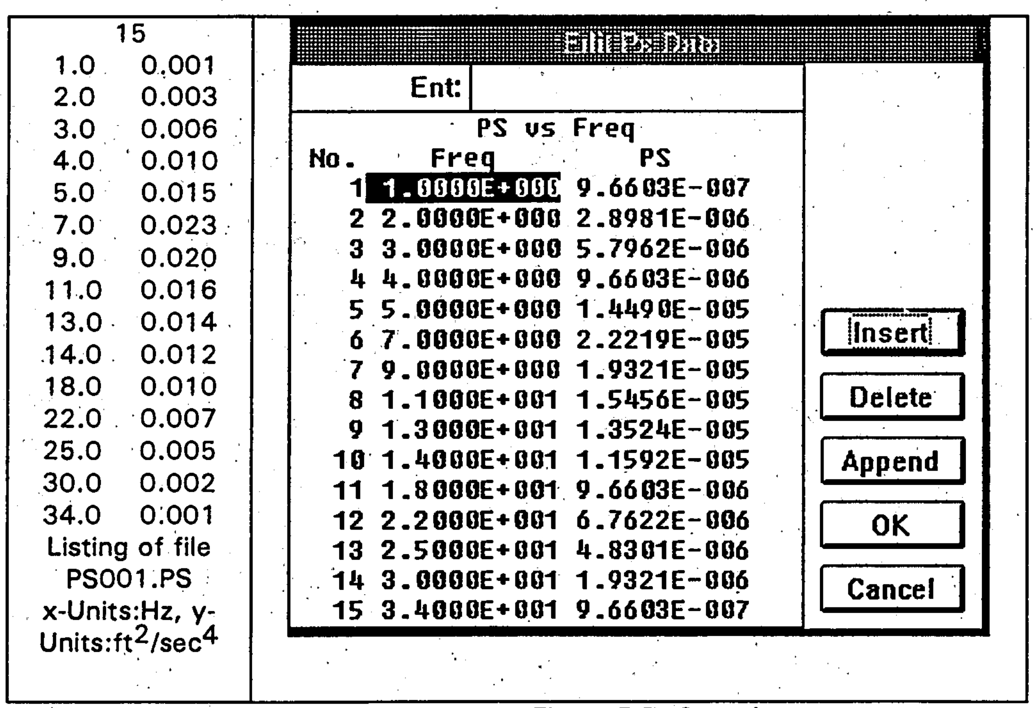


Figure 5-7 Case 4g

5.5: Case 5

Figures 5-8 to 5-14 show the results of importing RS data with units conversion. Inspection of the Figures verifies that SPECTRA has correctly converted the data to the native units of Hertz and G. The imported data is stored as records 11 to 17 in SPQA2V0.

1	
16	0.0100
0.2	0.1
1	1.000
2	2.325
3	4.551
4.2	7.558
5.25	8.947
6.25	10.00
8.5	12.53
10	13.24
12	14.53
14	12.51
17	10.21
25	9.064
28	6.816
31	6.436
34	5.327

Listing of file RS002.RS x-Units:rad/sec; y-Units:G

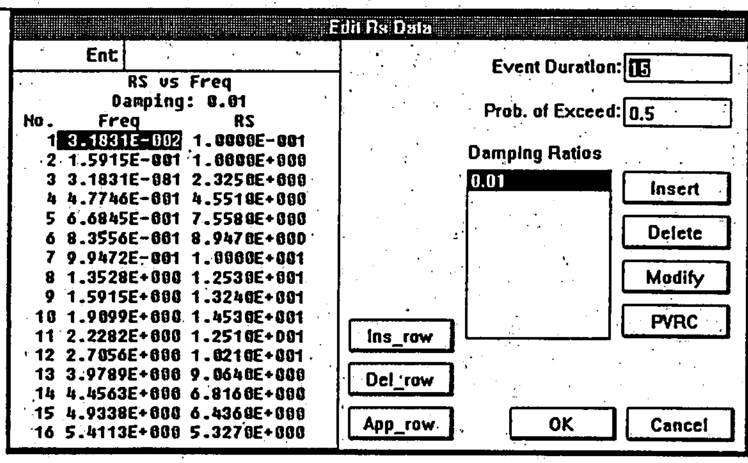


Figure 5-8 Case 5a

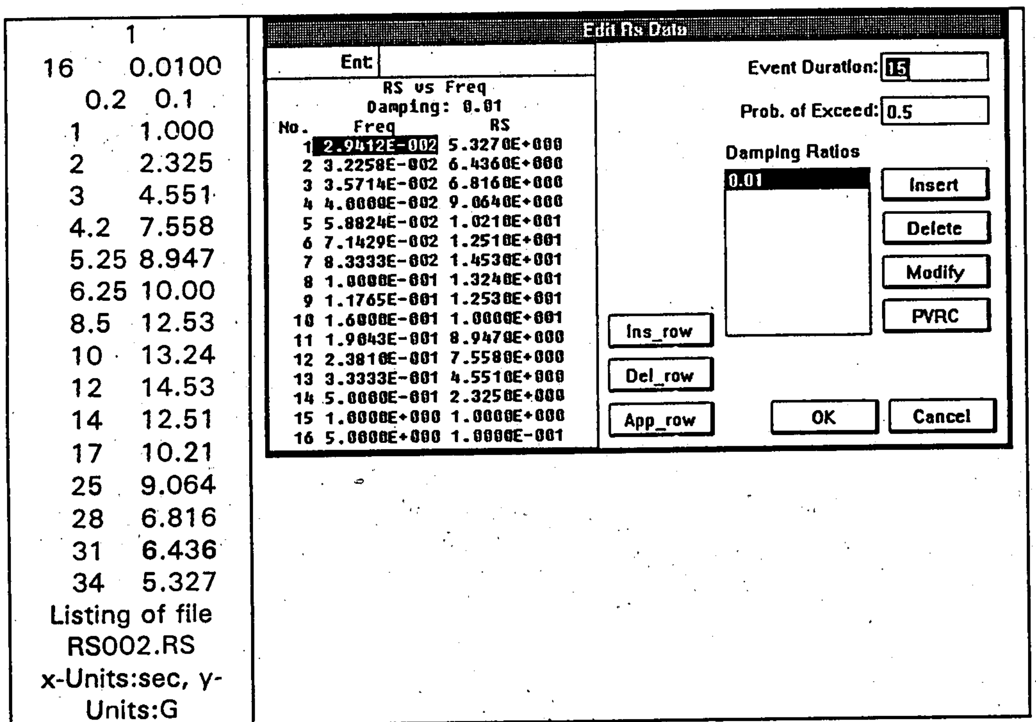


Figure 5-9 Case 5b

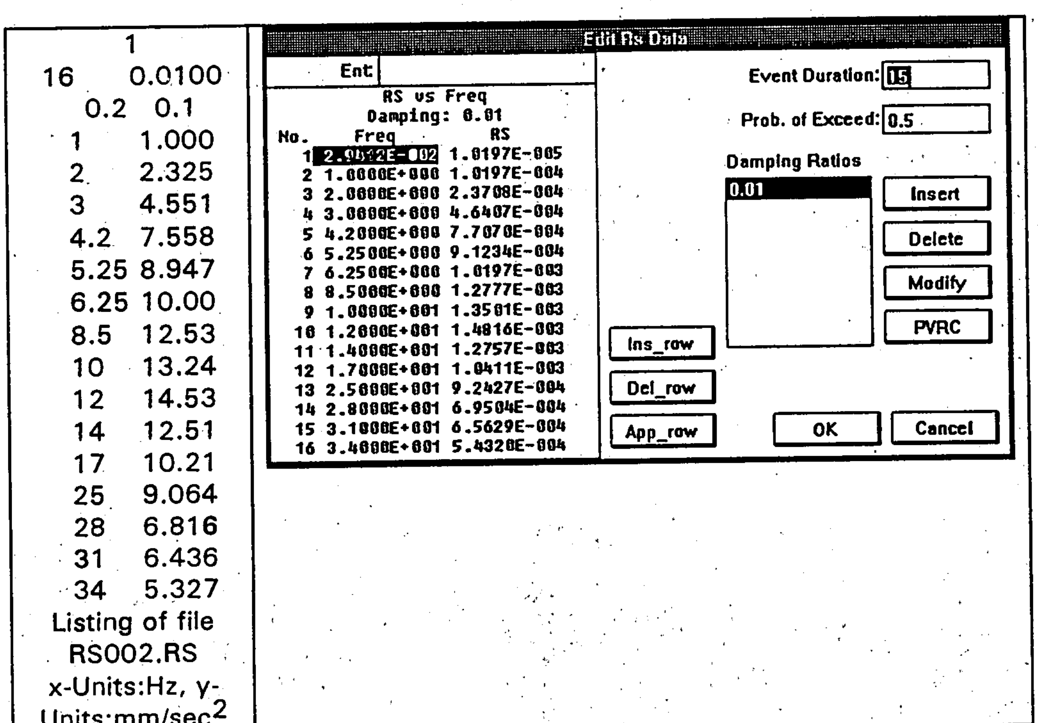


Figure 5-10 Case 5c

	1
16	0.0100
0.2	0.1
1	1.000
2	2.325
3	4.551
4.2	7.558
5.25	8.947
6.25	10.00
8.5	12.53
10	13.24
12	14.53
14	12.51
17	10.21
25	9.064
28	6.816
31	6.436
34	5.327

Listing of file RS002.RS x-Units:Hz, y-Units:cm/sec^2

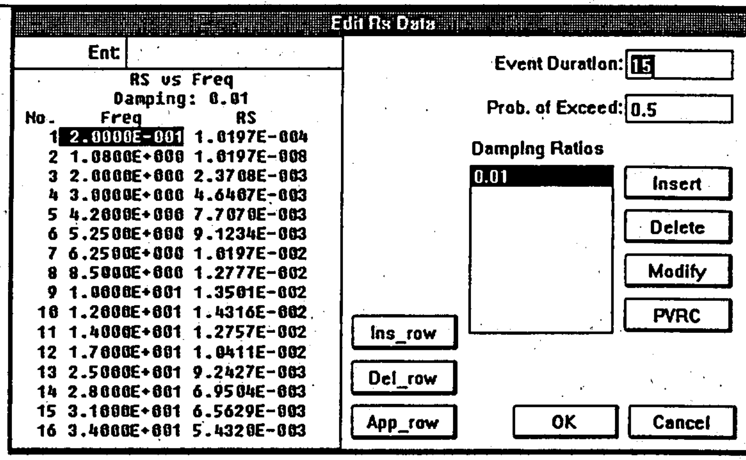


Figure 5-11 Case 5d

	1
16	0.0100
0.2	0.1
1	1.000
2	2.325
3	4.551
4.2	7.558
5.25	8.947
6.25	10.00
8.5	12.53
10	13.24
12	14.53
14	12.51
17	10.21
25	9.064
28	6.816
31	6.436
34	5.327

Listing of file RS002.RS x-Units:Hz, y-Units:m/sec^2

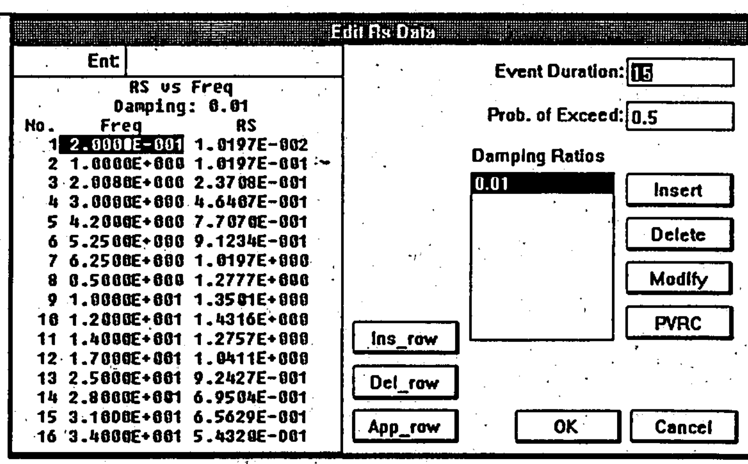


Figure 5-12 Case 5e

1
16 0.0100
0.2 0.1
1 1.000
2 2.325
3 4.551
4.2 7.558
5.25 8.947
6.25 10.00
8.5 12.53
10 13.24
12 14.53
14 12.51
17 10.21
25 9.064
28 6.816
31 6.436
34 5.327
Listing of file RS002.RS
x-Units:Hz, y-Units:in/sec^2

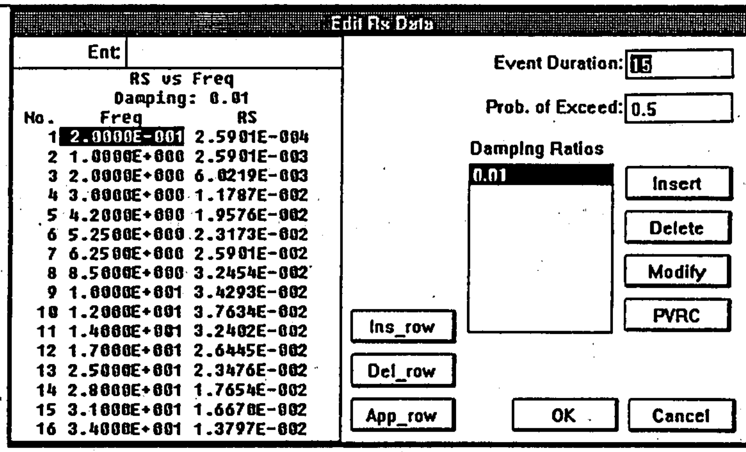


Figure 5-13 Case 5f

1
16 0.0100
0.2 0.1
1 1.000
2 2.325
3 4.551
4.2 7.558
5.25 8.947
6.25 10.00
8.5 12.53
10 13.24
12 14.53
14 12.51
17 10.21
25 9.064
28 6.816
31 6.436
34 5.327

Listing of file RS002.RS
x-Units:Hz, y-Units:ft/sec^2

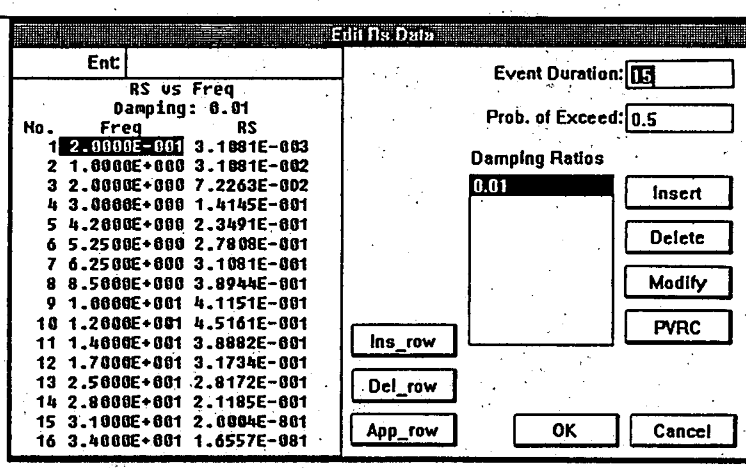


Figure 5-14 Case 5g

5.6. Case 6

Figures 5-15 to 5-19 show the results of importing TH data with units conversion. Inspection of the Figures verifies that SPECTRA has correctly converted the data to the native units seconds and G. The imported data is stored as records 18 to 22 in SPQA2V0.

17 0.01
0.0
0.25
0.50
0.75
1.00
0.75
0.50
0.25
0.00
-0.25
-0.50
-0.75
-1.0
-0.75
-0.50
-0.25
0.0

Listing of file TH001.TH x-Units:sec, y-Units:mm/sec^2

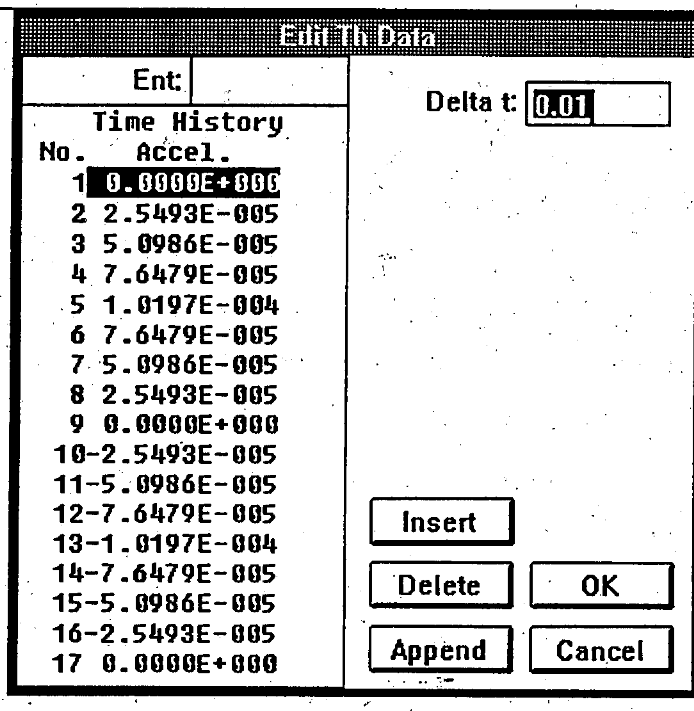


Figure 5-15 Case 6a

17 0.01
0.0
0.25
0.50
0.75
1.00
0.75
0.50
0.25
0.00
-0.25
-0.50
-0.75
-1.0
-0.75
-0.50
-0.25
0.0
Listing of file TH001.TH x-Units:sec, y-Units:cm/sec^2

Edit Th Data

Ent:

Delta t: 0.01

No.	Time History Accel.
1	0.0000E+000
2	2.5493E-004
3	5.0986E-004
4	7.6479E-004
5	1.0197E-003
6	7.6479E-004
7	5.0986E-004
8	2.5493E-004
9	0.0000E+000
10	-2.5493E-004
11	-5.0986E-004
12	-7.6479E-004
13	-1.0197E-003
14	-7.6479E-004
15	-5.0986E-004
16	-2.5493E-004
17	0.0000E+000

Insert Delete OK Append Cancel

Figure 5-16 Case 6b

17 0.01
0.0
0.25
0.50
0.75
1.00
0.75
0.50
0.25
0.00
-0.25
-0.50
-0.75
-1.0
-0.75
-0.50
-0.25
0.0
Listing of file TH001.TH x-Units:sec, y-Units:m/sec^2

Edit Th Data

Ent:

Delta t: 0.01

No.	Time History Accel.
1	0.0000E+000
2	2.5493E-002
3	5.0986E-002
4	7.6479E-002
5	1.0197E-001
6	7.6479E-002
7	5.0986E-002
8	2.5493E-002
9	0.0000E+000
10	-2.5493E-002
11	-5.0986E-002
12	-7.6479E-002
13	-1.0197E-001
14	-7.6479E-002
15	-5.0986E-002
16	-2.5493E-002
17	0.0000E+000

Insert Delete OK Append Cancel

Figure 5-17 Case 6c

17 0.01
0.0
0.25
0.50
0.75
1.00
0.75
0.50
0.25
0.00
-0.25
-0.50
-0.75
-1.0
-0.75
-0.50
-0.25
0.0
Listing of file THO01.TH x-Units:sec, y-Units:in/sec^2

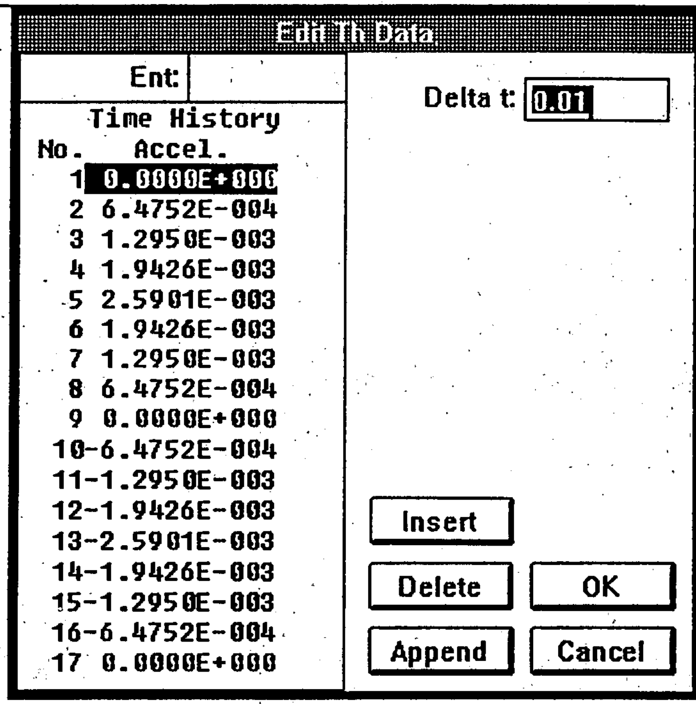


Figure 5-18 Case 6d

17 0.01
0.0
0.25
0.50
0.75
1.00
0.75
0.50
0.25
0.00
-0.25
-0.50
-0.75
-1.0
-0.75
-0.50
-0.25
0.0
Listing of file THO01.TH x-Units:sec, y-Units:ft/sec^2

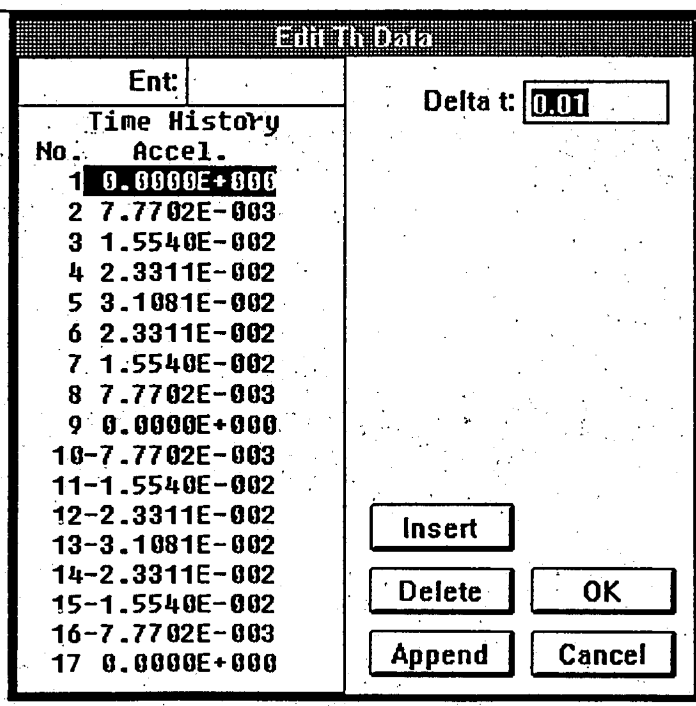


Figure 5-19 Case 6e

5.7. Case 7 PS to RS Conversion

Case 7a.

As discussed in Section 4.3.7, a PS to RS conversion is made on the record shown in Figure 4-9. The following parameters are used for the conversion.

Damping Ratio = 0.05
Event Duration = 15
Prob. of Exceedance = 0.15
Frequencies : SPECTRA Default frequencies.

The RS curve that is obtained is shown plotted along with the original 5% NRC160 damping curve in Figure 5-20. The plot shows good agreement between the two curves except at the higher end of the frequency scale. This is due to the fact that the NRC160 spectra have sharp slope discontinuities and as such no PS distribution with a finite frequency band can reproduce the RS values exactly.

Figure 5-21 compares results of a PS to RS conversion using SPECTRA with those obtained using the EDASP program. Because of the similarity between the two programs, close agreement is expected. Inspection of Figure 5-21 verifies this.

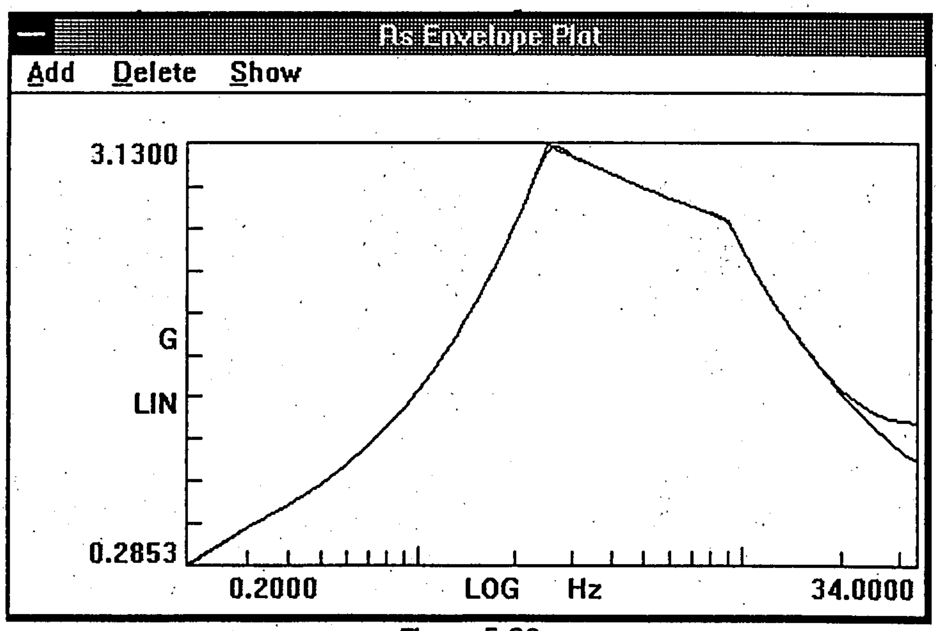


Figure 5-20

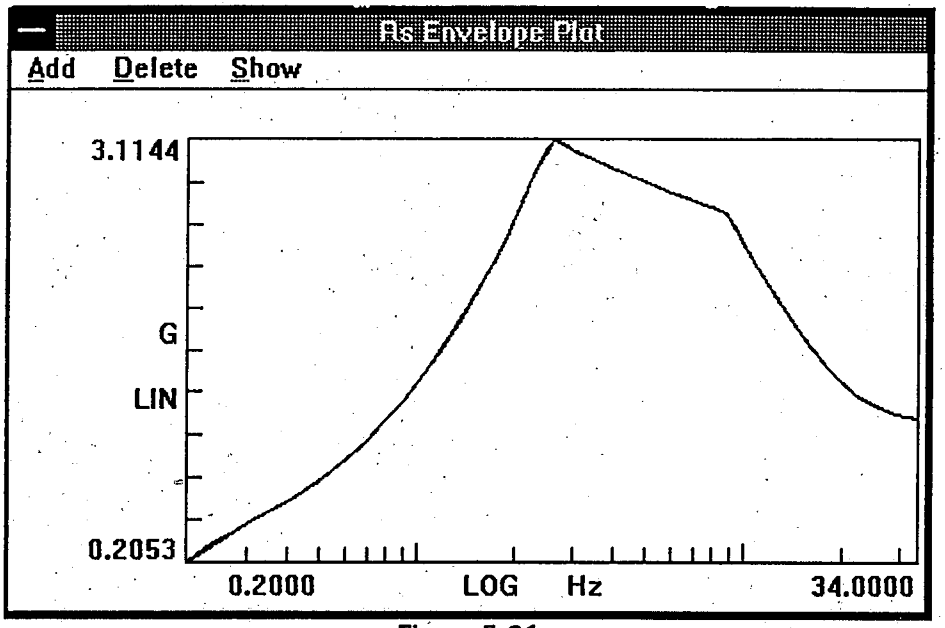


Figure 5-21

Case 7b

Figure 5-22 shows the RS values calculated using SPECTRA and EDASP. A visual inspection shows agreement between EDASP and SPECTRA results. Because of the similarity between the two programs, close agreement is expected. Inspection of Figure 5-22 verifies this.

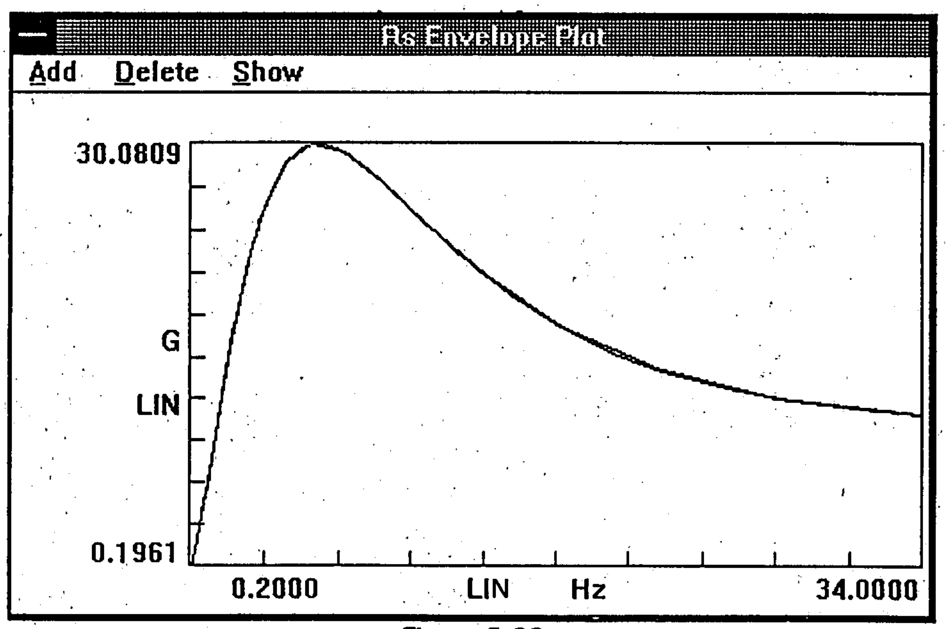


Figure 5-22

5.8. Case 8 RS to PS Conversion

Case 8a

The RS to PS conversion is made from the record described in Figure 4-8. The parameters used for the conversion are as follows:

Prob. of Exceedance = 0.15
Excitation Duration = 15 seconds
Frequencies : SPECTRA default frequencies for RS to PS conversion.
Iteration Cycles = 5

Figure 5-23 compares the SPECTRA and EDASP results for the RS to PS conversion. A visual comparison of Figure 5-23 shows good agreement between SPECTRA and EDASP results.

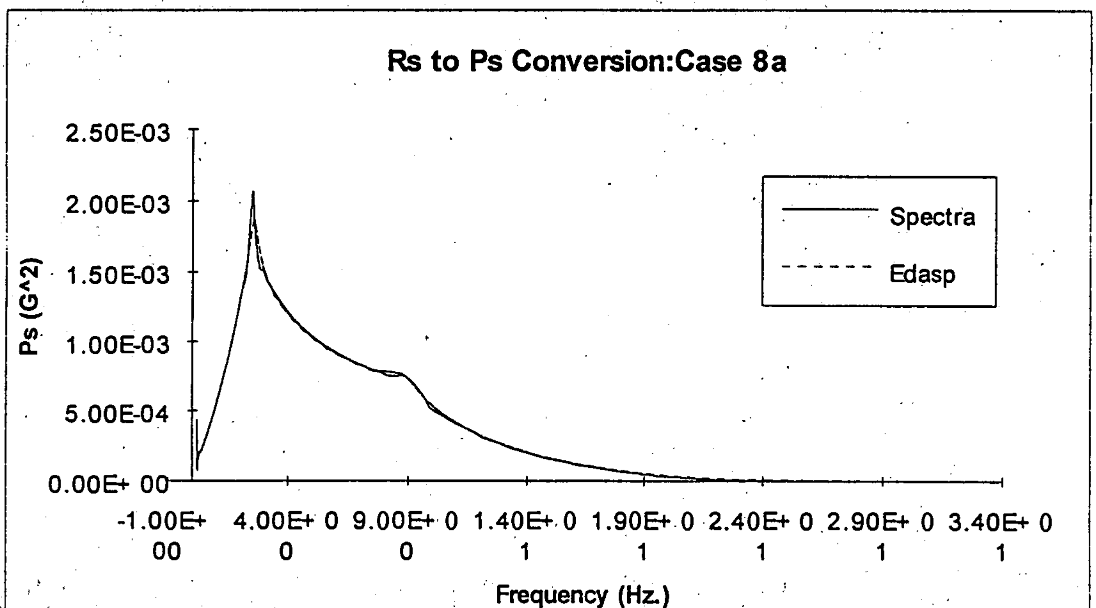


Figure 5-23

Case 8b

Figure 5-24 compares the SPECTRA and EDASP results of a RS to PS conversion. Visual inspection shows agreement between EDASP and SPECTRA results.

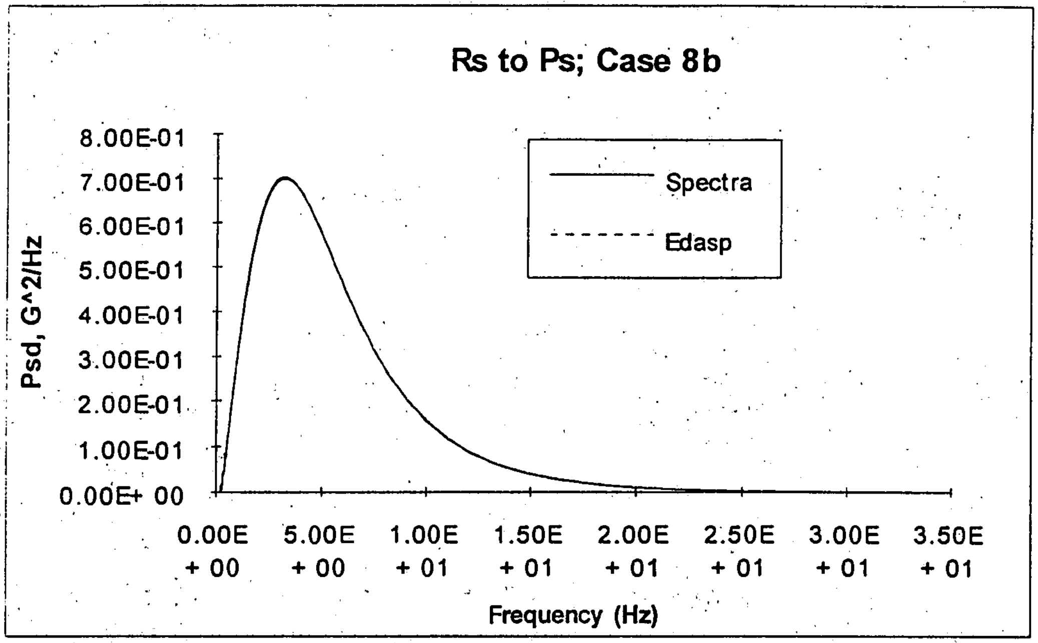

Rs to Ps; Case 8b
Psd, G^2/Hz
8.00E-01
7.00E-01
6.00E-01
5.00E-01
4.00E-01
3.00E-01
2.00E-01
1.00E-01
0.00E+ 00
Spectra
Edasp
0.00E + 00
5.00E + 00
1.00E + 01
1.50E + 01
2.00E + 01
2.50E + 01
3.00E + 01
3.50E + 01
Frequency (Hz)

Figure 5-24

5.9. Case 9 TH to PS Conversion

Case 9a

The TH to PS conversion is used on the record described in Figure 4-20. The frequency spacing used is 0.5Hz. The resulting PS is shown in Figure 5-25.

The results of using the Subroutines described in Reference 8 to obtain PS from the TH stored in file DUKE.TH are shown in Figure 5-26. The results are in agreement.

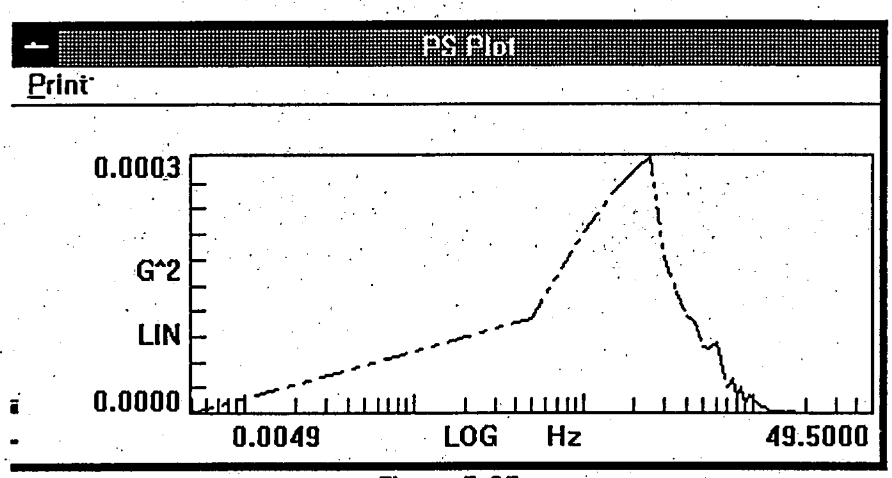


Figure 5-25

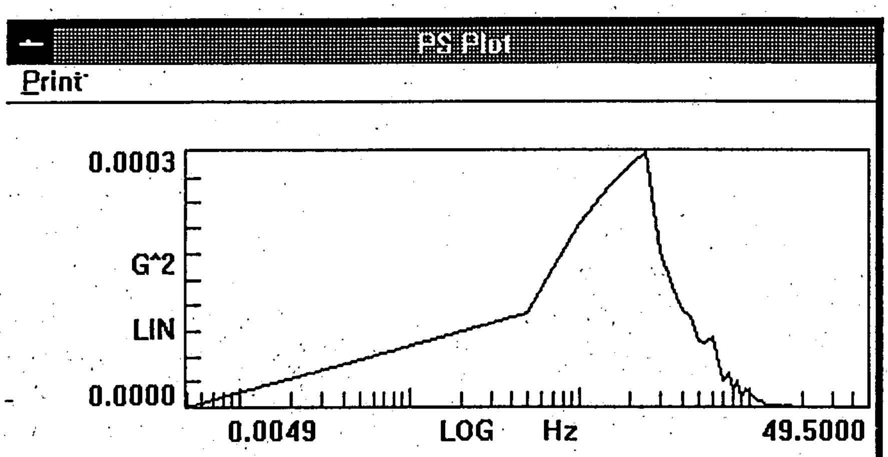


Figure 5-26

Case 9b

Figure 5-27 shows a partial list and Figure 5-28 a plot of the PS data obtained using SPECTRA and stored in the record shown in Figure 4-22

Inspection the figures indicates that the PS is concentrated at 10Hz with a small leakage to nearby frequencies. Adding the PS values at frequencies 9.75,9.875,10.0,10.125,10.25 we get a total of 0.495177G^2, which is close to the theoretical value of 0.5G^2, for a sine wave with an amplitude of 1G.

PS List

Copy Print

9	6.94661e-005
9.125	9.12855e-005
9.25	0.000126188
9.375	0.000182875
9.5	0.000286222
9.625	0.000506627
9.75	0.00112717
9.875	0.0047744
10	0.472636
10.125	0.0147878
10.25	0.00185186
10.375	0.000747204
10.5	0.000404954
10.625	0.00025404
10.75	0.000175034
10.875	0.000129074
11	9.90927e-005

Figure 5-27

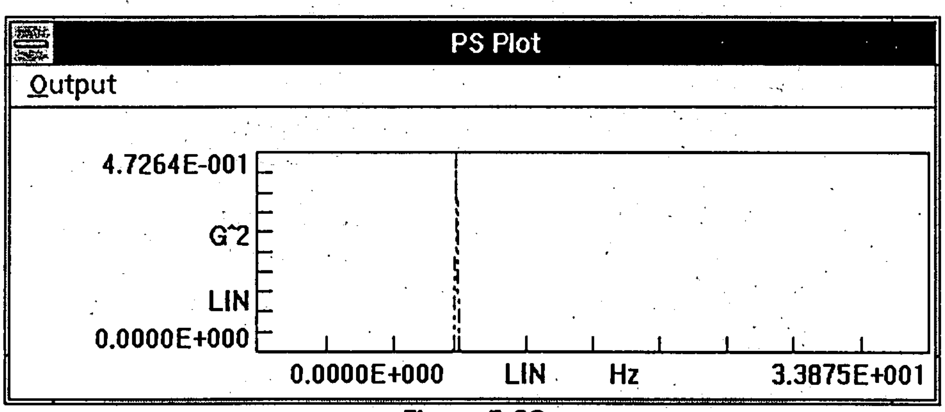


Figure 5-28

5.10. Case 10 PS to TH Conversion

Case 10a

The Original PS is stored in the record described in Figure 4-24 and is shown plotted in Figure 5-29. It represents the PS associated with the TH stored in the file DUKE.TH.

The Calculated PS is shown in Figure 5-30. It is obtained by using the TH to PS conversion on the record shown in Figure 4-25. The TH data in the record of Figure 4-25 is a result of a PS to TH conversion on the data shown in Figure 5-29. A comparison of Figure 5-29 and 5-30 shows that Original PS matches Calculated PS.

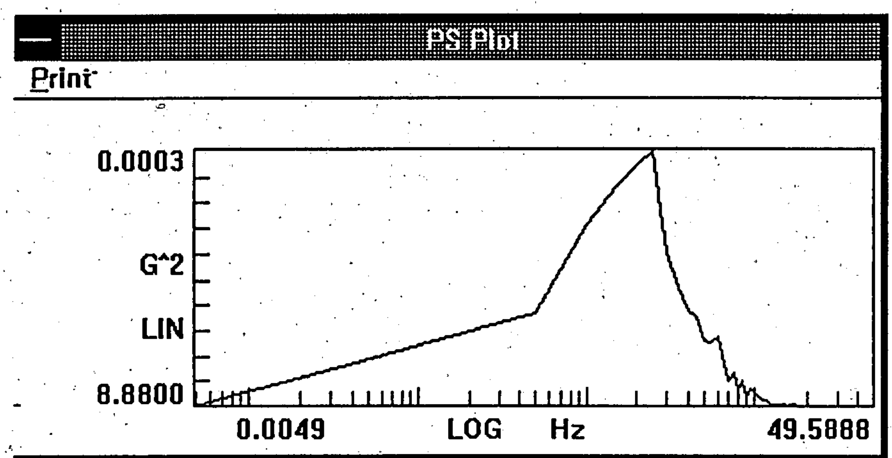


Figure 5-29

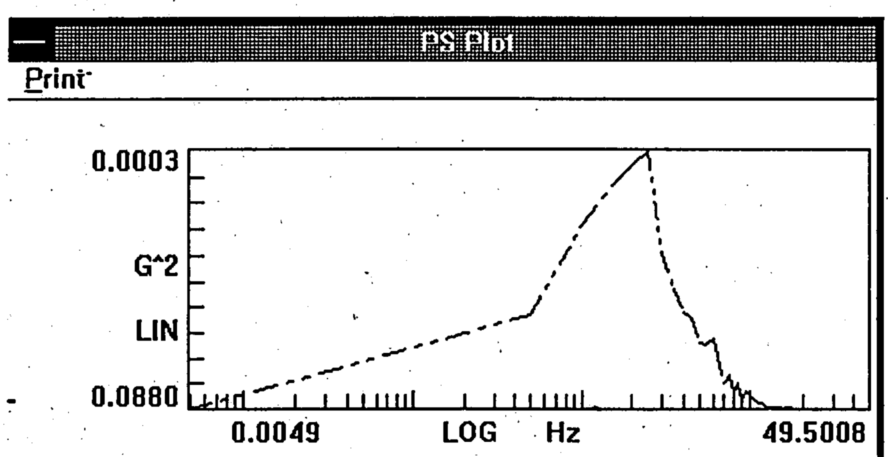


Figure 5-30

Case 10b

A partial plot of the TH data obtained from a PS to TH conversion on the record shown in Figure 4-26 is shown in Figure 5-31. The 1 second TH data shows 10 peaks, indicating that the TH has a dominant 10Hz frequency component. Due to identified magnitude errors and the randomly selected phase angles in a PS to TH conversion, we do not get back a pure sine wave.

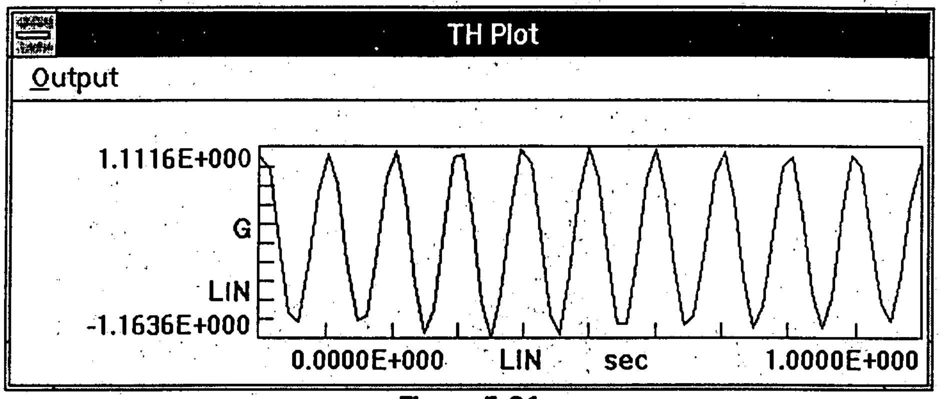

TH Plot
Output
1.1116E+000
G
LIN
-1.1636E+000
0.0000E+000
LIN
sec
1.0000E+000

Figure 5-31

5.11. Case 11 TH to RS Conversion

Case 11a

Figure 5-32 shows the RS plot for the TH stored in the record described in Figure 4-28. This RS is obtained using the SPECTRA TH to RS module with a damping ratio of 0.05. The RS data is also stored in the record shown in Figure 4-28 (as calculated data).

Figure 5-33 compares the RS obtained from SPECTRA with that obtained using EDASP . A linear y-scale is used in the plot to magnify any differences between the RS obtained using SPECTRA and that obtained using EDASP. The plot shows good agreement between the two curves.

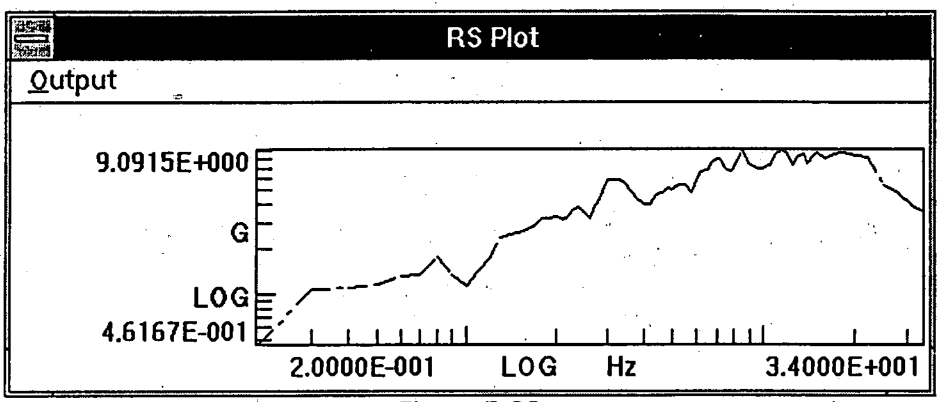


Figure 5-32

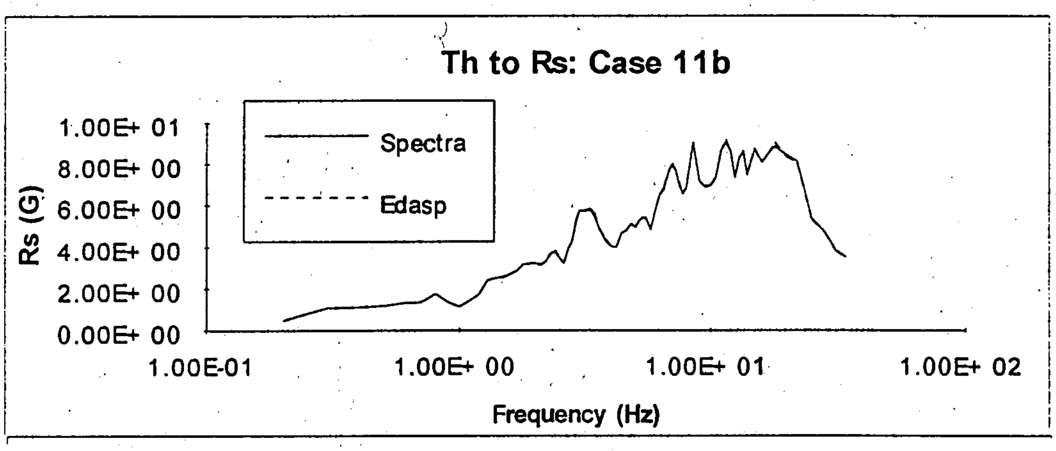


Figure 5-33

Case 11b

Equation (4.2) predicts steady state response, and does not include the transient effects. SPECTRA computes the actual maximum response, including the transient part, and hence should predicts higher RS values.

The excitation is a 10Hz sine wave so the transient effects will be small at 10Hz, and larger at other frequencies. When damping is higher, the transients decay faster and a better agreement is expected between SPECTRA and (4.2).

Using (4.2) for 5% damping and $A_f = 1.0$, a response value of 10.05 G is obtained for $r = 1.0$. An equivalent value from the listing of the TH to RS conversion in Figure 5-34 is 9.31 G (at f = 10 Hz). The 7% difference is mainly due to discretization, i.e., the input TH a is only a piece-wise linear approximation of a sine wave and the peak response value is not likely to be captured at response points.

RS List

Copy Print

9.5	6.7355
10	9.31244
10.5	7.34216
11	5.59614
11.5	4.53752
12	3.84235
12.5	3.39849
13	3.06811
13.5	2.82251
14	2.65388
14.5	2.39775
15	2.27917
16	2.15092
17	1.94649
18	1.79291
20	1.51207
22	1.47053
25	1.42201
28	1.36856
31	1.30841
34	1.26493

Figure 5-34

5.12. Case 12 RS to TH Conversion

Figure 5-35 shows a plot of RS original along with the RS that corresponds to the resulting TH. The original and calculated RS curves are stored in the record described in Figure 4-31. The plot shows the RS corresponding to the output TH generally matches the original RS.

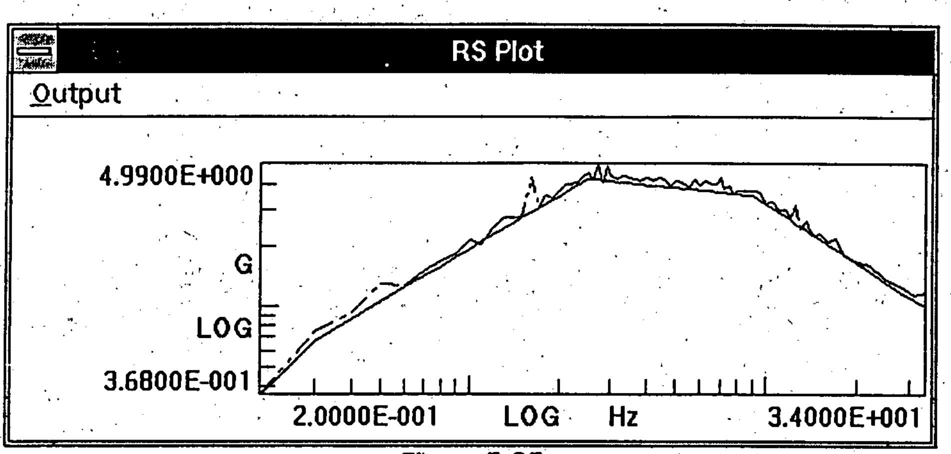


Figure 5-35

5.13. Case 13 Broadening RS

Case 13 is verified by inspection. The calculated RS shown plotted with the original RS in Figures 4-34, 4-36, and 4-38 verifies the correct operation of the broadening function.

5.14. Case 14 Enveloping RS

Case 14 is verified by inspection. The calculated RS shown plotted in Figure 4-40 envelopes the curves in 4-39.

5.15. Case 15 Copy List Data to the Clipboard

Case 15 (a, b and c) is verified by inspection. The Ps List data stored in the record identified in Figure 4-9 and shown in Figure 4-42 matches that copied to the Clipboard as shown in Figure 4-43. The Th List data stored in the record identified in Figure 4-5 and shown in Figure 4-44 matches that copied to the Clipboard as shown in Figure 4-45. The Rs List data stored in the record identified in Figure 4-17 and shown in Figure 4-46 has an X-axis tolerance of 0.15 Hz applied to it before being copied to the Clipboard as shown in figure 4-47. Visual inspection of the Rs List copy and x-axis tolerance operation shows it to be acceptable.

5.16. Case 16 Custom Formatting in *EasyPlot*

Case 16 is verified by inspection. The selected Rs data and plot formatting requirements as described in 4.3.16 manifest themselves acceptably as shown in Figure 4-49.

6. REFERENCES

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6.2. ASME Code Case N-411-1, Case of ASME Boiler and Pressure Vessel Code.

6.3. SPECTRA v1.0 User's Manual, Stevenson and Associates, Woburn, MA, January 1992.

6.4. EDASP 1.1 Theory and Verification Manual, Stevenson and Associates, Woburn, MA, September 1986.

6.5. "USNRC Regulatory Guide 1.60 -- Design Response Spectra for Seismic Design of Nuclear Power Plants", Revision 1, December 1973.

6.6. "USNRC Regulatory Guide 1.122 -- Development of Floor Design Response Spectra for Seismic Design of Floor-Supported Equipment Components", Revision 1, February 1978.

6.7. M.K, Kaul, "Stochastic Characterization of Earthquakes Through Their Response Spectrum," Earthquake Engineering and Structural Dynamics, Vol. 6, pp. 497-509, 1978.

6.8. 387FFT Version 1.0, Reference Manual, MicroWay.

6.9. "Recommended Minimum Power Spectral Density Functions Compatible with NRC Regulatory Guide 1.60 Response Spectrum", R.P. Kennedy and M. Shinozuka.

6.10. Stevenson & Associate Corporate Quality Assurance Program, Revision 8, Stevenson and Associates, Cleveland, Ohio, September 1989.

6.11. Vibration Analysis, R. Vierck, 2nd Edition, New York, 1979.

6.12 EasyPlot For Windows, Version 2.22-6, Release 1, by Stuart Karon, Copyright 1989-1993, Spiral Software, 15 Auburn Place, Brookline, MA 02146

ATTACHMENT III

Letter from C. R. Steinhardt (WPSC)

to

Document Control Desk (NRC)

Dated

December 20, 1996

Paul Smith President
The ***Readiness*** Operation, Inc.

Education

University of California - PhD in Civil/Structural Engineering, 1971
Lehigh University - Master of Science in Civil/Structural Engineering, 1964
University of Akron - Bachelor of Science in Civil Engineering, 1962

Licenses and Registrations

Civil Engineer - California C 24377

Professional History

The ***Readiness*** Operation, Inc, Oakland, California - President, 1989 to present
EQE, San Francisco, California - Senior VP, Board of Directors, 1984 - 1989
Lawrence Livermore National Laboratory, Livermore, California - Associate Program Leader for Seismic and Structural Safety, 1976 - 1984
EDS Nuclear (Impell), San Francisco, California - Supervising Engineer, 1974 - 1976
Auburn University, Alabama - Assistant Professor of Civil Engineering. 1971 - 1974
Marshall Spaceflight Center, Huntsville, Alabama - NASA-ASCE Fellow, 1972
University of California, Berkeley - Teaching and Research Assistant, 1967 - 1971
Bechtel, San Francisco, California - Civil/Structural Engineer, 1967
US Army, Fort Belvoir, Virginia - Engineering Officer, 1965 - 1967
Shell Oil, New Orleans, Louisiana - Civil/Structural Engineer, 1964-1965
Bethlehem Steel, Bethlehem, Pennsylvania - Civil/Strnctural Engineer, 1963
Burger Iron, Akron, Ohio - Structural Steel Designer/Drafter, 1952 - 1962

Experience

Dr Smith has over 40 years of experience in earthquake and structural engineering and in university teaching. He has managed large teams of research and design engineers on projects ranging from nuclear power plants to industrial, commercial, and public facilities. In recent years, he has developed a number of seismic training courses.

Dr Smith is currently performing Peer Reviews for USI A46 and the IPEEE for *Florida Power and Light*, *Philadelphia Electric*, and *Wisconsin Public Service*; participating in the implementation of the Seismic IPEEE for *Cleveland Electric Illuminating* and *New York Power Authority*; leading the development of a plant specific A46 and Seismic IPEEE program for *Florida Power Corp*, and consulting on A46 and the Seismic IPEEE for *Public Service Electric & Gas of NJ*, *Virginia Power*, and *Yankee Atomic*. Dr Smith was an invited participant in the 1991 *Workshop on Seismic Analysis of Gaseous Diffusion Plant Structures* in Paducah.

Dr Smith also organized a national workshop on the Seismic IPEEE, and has been the primary advocate of simplifying and reducing the costs of implementation of both A46 and the Seismic IPEEE.

In nuclear research, Dr Smith is best known as the developer and manager of NRC's *Seismic Safety Margins Research Program* (SSMRP). The SSMRP completed the seismic probabilistic risk analysis (PRA) efforts NRC began in the Reactor Safety Study, and developed Seismic PRA technology for the Seismic IPEEE. Dr Smith also initiated two well-known spin-offs from the SSMRP: (1) the Load Combination Program (which led the NRC to revise piping criteria and adopt the *leak before break* philosophy), and (2) the Seismic Hazard Characterization of the Eastern United States Program (to develop a more *stable* estimate of the earthquake hazard to benefit both NRC and the industry) which developed seismic hazard technology for Seismic PRAs for the Seismic IPEEE.

Dr Smith also suggested that NRC consider a seismic margin approach as an alternative to seismic PRAs, and then managed NRC's Seismic Design Margin Program (which developed NRC's Seismic Margin method for the Seismic IPEEE), after which the Electric Power Research Institute developed its method for Seismic Margin Assessments.

Prior to the SSMRP, Dr Smith participated in a number of NRC sponsored studies of seismic design margins. He has been at the forefront of assessing seismic margin and developing improved criteria for seismic design for some time.

Dr Smith also supervised efforts on the seismic, tornado, and hurricane analysis of the mooring system and breakwater for the Atlantic Generating Station (the floating nuclear power plant).

Dr Smith is one of the founders of using data from past earthquakes to address NRC Unresolved Safety Issue A46: ***Seismic Qualification of Equipment in Operating Plants***. His NUREG/CR-3017 was a key step in helping NRC issue its first written recognition (12/28/82) of the feasibility of using these data for A46 and for the seismic verification of equipment. In his five years at EQE, he was a consultant to the Seismic Qualification Utility Group on A46, and initiated many other applications of this new technology; for example, cable tray, conduit and piping systems, tanks, anchorage, and cranes, and is identified as one of the key contributors to SQUG's Generic Implementation Procedure. He helped develop and present training programs on SQUG/GIP technology, and is currently helping SQUG develop its training program for Replacement Items and Design Changes. As EQE's SQUG Program Manager, he personally convinced the SQUG Steering Group to accept the conduit/cable tray approach that was ultimately licensed, finalized development of SQUG's conduit/cable tray methodology, and obtained SSRAP and NRC approval of it. Recently (April 1993), Dr Smith was appointed to the ASME QME and IEEE Standards Special Working Group on the Standardization of SQUG Methodology.

Dr Smith has attended the SQUG Seismic Capability Engineer training course.

Dr Smith is one of the key developers of EPRI NP-6628: *Procedure for Seismic Evaluation and Design of Small Bore Piping (NCIG-14)*, which used earthquake experience data to justify a *"design by rule"* approach for piping. NRC is reviewing it now.

In the non-nuclear area, Dr Smith has varied experience in the structural design of buildings, bridges, and offshore structures.

Dr Smith has represented the US Government at a number of seminars and exchanges on earthquake engineering, including NRC scientific exchanges with Japan in 1979 and 1982, Korea in 1982, Europe in 1979 and 1983, and Taiwan in 1984.

Selected Publications

1. Publisher and Editor of the ***Earthquake Safety & Licensing Report***sm, *A monthly newsletter on (nuclear) industry earthquake safety*, ISSN 1045-7895.
2. *Seismic Qualification Using Earthquake Experience Data*, **Nuclear News**, June 1989.
3. *Correlation of Seismic Experience Data in Non-Nuclear Facilities with Seismic Equipment Qualification in Nuclear Plants (A-46)*, prepared for the U.S. Nuclear Regulatory Commission by Lawrence Livermore National Laboratory, **NUREG/CR-3017**, Nov. 1982.
4. *SQUG Cable Tray and Conduit Evaluation Procedure*, **Second Symposium on Current Issues Related to Nuclear Power Plant Structures, Equipment and Piping**, Orlando, December 1989.
5. *Procedure for Seismic Evaluation and Design of Small Bore Piping Developed by EPRI/NCIG*, **Third Symposium on Current Issues Related to Nuclear Power Plant Structures, Equipment and Piping**, Orlando, December 1990.
6. *Seismic Margins in Piping Systems*, in **Proceedings, 1990 Pressure Vessel And Piping Conference**, American Society of Mechanical Engineers, Nashville, 1990.

7. *Recommended Piping Seismic-Adequacy Criteria Based on Performance During and After Earthquakes*, **EPRI NP-5617** prepared for **Electric Power Research Institute**, 12/88.
8. *Independent Seismic Walkdown Review Team (ISWRT) Critique of SRS SQUG Type Seismic Program for Restart of K-Reactor at the Savannah River Site*, prepared by ISWRT for the **US Department of Energy**, February and April 1990.
9. Dr Smith is one of the significant contributors identified by SQUG for their *Generic Implementation Procedure (GIP) for Seismic Verification of Nuclear Plant Equipment*, **Seismic Qualification Utility Group (SQUG)**, February 14, 1992.
10. *Towards Future Antiseismic Criteria for Nuclear Plant Piping Systems*, published in ASME Special Publication: *Technology for the 90s*.
11. *Peer Review for USI A46 and the Seismic IPE*, ASME PVP 1993.

Training Courses Developed or Presented

"Overview of Seismic IPE and USI A-46." Developed and presented with Programmatic Solutions. One day course presented in open enrollment sessions.

"Training for Engineers and Designers in SQUG Methods." Developed and presented with Programmatic Solutions. Two day course presented on-site and in open enrollment.

"Using SQUG Methods for Modifications and Replacements." Developed and presented with Programmatic Solutions. Two day course presented on-site and in open enrollment.

"On-Site Overview of SQUG Methods and Their Use for Modification and Replacements." Developed and presented with Programmatic Solutions. Three hour on-site overview course for management presented on-site.

"Basic Seismic Engineering." Developed and presented with Programmatic Solutions. Two day course presented on-site and in open enrollment.

"Seismic IPE Workshop." Developed and presented with Programmatic Solutions. Two day workshop presented in open enrollment.

"Seismic Awareness Training," Developed with Programmatic Solutions. Three hour on-site course.

"Earthquake Awareness Training," Developed with Programmatic Solutions. Three-hour on-site course.

"SQUG Methods for European Reactors," Developed with Programmatic Solutions and hosted by CKTI VIBROSEISM. Two day course presented in St Petersburg, Russia in September 1993.

"Roundtable Workshops," Developed with Programmatic Solutions. Workshop #1 was held May 24, 1993 in the Newark, New Jersey area. The topic was: *Managing Your Seismic IPE and USI A46 Programs.*

SQUG

Certificate of Achievement

This is to Certify that

Paul Smith

has Completed lhe SQUG Walkdown Screening
and Seismic Evalualion Trainiug Course
Held August 10, 1992

Neil P. Smith

Neil P. Smith, Commonweaith Edison
SQUG Chairman

David A. Freed

David A. Freed, MPR Associates
SQUG Training Coordinator

R. P. Kassawara

Robert P. Kassawara, EPRI
SQUG Program Manager

11-26-1996 12:03PM FROM MPR ASSOCIATES INC 703 519 0224 P.2

SQUG

Certificate of Achievement

This is to Certify that

John D. Stevenson

has Completed the SQUG Walkdown Screening and
Seismic Evaluation Training Course
Held June 22-26, 1992

Neil P. Smith, Commonwealth Edison
SQUG Chairman

David A. Freed, MPR Associates
SQUG Training Coordinator

Robert P. Kassawara, EPRI
SQUG Program Manager

SQUG

Certificate of Achievement

This is to Certify that

Robert P. Kennedy

has Completed the SQUG Walkdown Screening
and Seismic Evaluation Training Course
Held June 22-26, 1992

Neil P. Smith, Commonwealth Edison
SQUG Chairman

David A. Freed, MPR Associates
SQUG Training Coordinator

Robert P. Kassawara, EPRI
SQUG Program Manager

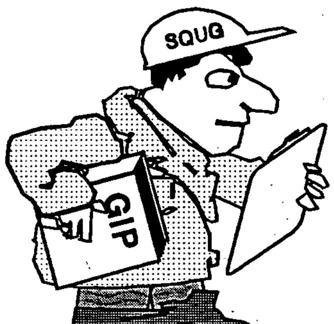
SQUG

Certificate of Achievement

This is to Certify that

Walter Djordjevic

has Completed the SQUG Walkdown Screening
and Seismic Evaluation Trainiug Course
Held April 6–10, 1992



Neil P. Smith, Commonwealth Edison
SQUG Chairman

David A. Freed, MPR Associates
SQUG Training Coordinator

Robert P. Kassawara, EPRI
SQUG Program Manager

SQUG

Certificate of Achievement

This is to Certify that

Patrick Finnemore

has Completed the SQUG Walkdown Screening
and Seismic Evaluation Training Course
Held September 14–18, 1992

David A. Freed, MPR Associates
SQUG Training Coordinator

Neil P. Smith, Commonwealth Edison
SQUG Chairman

Robert P. Kassawara, EPRI
SQUG Program Manager

SQUG

Certificate of Achievement

This is to Certify that

Greg Ridder

has Completed the SQUG Walkdown Screening
and Seismic Evaluation Training Course
Held June 22-26, 1992

Neil P. Smith, Commonwealth Edison
SQUG Chairman

David A. Freed, MPR Associates
SQUG Training Coordinator

Robert P. Kassawara, EPRI
SQUG Program Manager

ATTACHMENT IV

Letter from C. R. Steinhardt (WPSC)

to

Document Control Desk (NRC)

Dated

December 20, 1996

The *Readiness* Operation

When you need someone to count on.

December 5, 1996
1130010

Mr Walter Djordjevic
Vice President
Stevenson and Associates
10 State St
Woburn, MA 01801-6820

Dear Wally:

Re: Review of Kewaunee A46 Project Responding to NRC RAI

In accord with the October 8, 1996 letter from Greg Ridder, the proposal in my October 15, 1996 letter to you, and your October 31, 1996 letter to me, my review on the captioned project follows.

1. Section 1.2 of the A46 Summary Report contains the following:

'Separate, but related issues pertaining to methods of analysis for above-ground flexible tanks identified in USI A-40, "Seismic Design Criteria [4], and seismic adequacy of proximity items above and around important-to-safety equipment identified in USI A-17 [5] are explicitly addressed and resolved by implementation of the GIP.'

I assume this is not intended to imply that proximity issues were evaluated for all *important-to-safety* equipment identified in USI A-17. Instead, I believe the intent is to note that seismic proximity issues were evaluated for the A46 SSEL equipment.

In addition to the above, note that cable raceways were also added to NRC's original scope of A46. This was mostly to resolve some SEP issues.

2. Section 1.2 of the A46 Summary Report contains the following:

"By meeting seismic demand criteria, selected caveats to ensure similarity,..."

The more important function of caveats is "*dissimilarity*" not similarity. Many caveats identify equipment features that experience and judgment suggest are undesirable. Ensuring these features do not exist gives added confidence equipment will perform as intended during or after an earthquake. This is a key aspect of the experience approach.

3. Section 1.2 of the A46 Summary Report contains the following:

"Any deficiencies are documented on an Outlier Seismic Verification Sheets(s) (OSVS)"

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As noted later in the Report, an *"outlier"* is not necessarily a *"deficiency"* in the sense that a modification is required.

4. Section 2.2.1 of the A46 Summary Report contains the following:

"Equipment items which appear in the safe shutdown paths, but do not require a review for either seismic adequacy or relay chatter (i.e. inherently rugged equipment or passive equipment), were not identified."

If this means items such as a manually operated valve (that an operator needs to open or close after an earthquake to achieve safe shutdown) were not walked down to ensure they are not a seismic interaction source or target, then this needs to be explained and justified, in my opinion (even though the Kewaunee position is apparently consistent with the GIP – see GIP Section 3.3.5).

5. I haven't found anything in the Kewaunee information that suggests the following event (event #31279) is a issue at Kewaunee. However, I bring it to your attention because seismic interaction is a key A46 issue and because this condition was recently discovered at Susquehanna, Comanche Peak, Oyster Creek, Millstone, and South Texas:

"AT 1607 ON 11/5/96, IT WAS IDENTIFIED THAT THE UNIT 1 AND UNIT 2 CLASS 1E 4.16 kV WESTINGHOUSE SWITCHGEAR IS NOT SEISMICALLY QUALIFIED WITH ANY BREAKERS RACKED OUT AND INSTALLED IN THE CUBICLE OR RACKED INTO THE 'TEST' POSITION. IN ADDITION, WHEN THE BREAKERS ARE RACKED OUT AND LEFT WITHIN THE CUBICLE, THE SWITCHGEAR IS NOT OPERABLE. IT IS NORMAL OPERATING PRACTICE OF THE PLANT TO HAVE BREAKERS IN THIS UNQUALIFIED POSITION DURING ALL OPERATING CONDITIONS. THIS REPRESENTS A CONDITION THAT IS OUTSIDE THE DESIGN BASIS OF THE PLANT AND THEREFORE REQUIRES A 1 HOUR NOTIFICATION PER 10 CFR 50.72(b)(1)(ii)(B).

A TOTAL OF 7 BREAKERS ON BOTH UNITS WERE IDENTIFIED TO BE IN AN UNQUALIFIED POSITION. FIVE OF THE SEVEN BREAKERS WERE SPARE BREAKERS AND THE OTHER BREAKERS FED THE UNIT 2 MECHANICAL VACUUM PUMP AND THE UNIT 2 TURBINE BUILDING CHILLER. THESE BREAKERS WERE IMMEDIATELY PLACED IN THE RACKED IN POSITION. ALL INSTALLED 4.16 kV UNIT 1 AND UNIT 2 BREAKERS WERE INDEPENDENTLY VERIFIED TO BE FULLY RACKED IN."

6. The Screening Verification Data Sheets contain unclear nomenclature, typically when the equipment item is more than 40 feet above plant grade. The entry for the question "<40'?" is "N/A", but "NO" seems more appropriate (this is how the GIP has it), the entry for "Demand Spectra" is "ABS" (which, I assume refers to Amplified Bounding Spectra, that is, 1.5 x Bounding Spectra), and the entry for "Demand Spectra" is "CRS" (which, I assume refers to Floor Response Spectra or FRS).

7. Section 6 of the A46 Summary Report contains the following:

"The refueling water storage tank (RWST) is a vertical tank which did not meet the caveats; therefore, it was declared an outlier and was evaluated using the procedures of Appendix H - Flat Bottom Vertical Fluid Storage Tanks of EPRI Report NP-6041, Rev. 1 [15]."

Section 6.1 of the A46 Summary Report contains the following:

"For vertical tanks, Reference 15 provides guidelines for evaluating flat bottom vertical tanks using the Conservative Deterministic Failure Margin (CDFM) analysis approach."

The above does not convey that the RWST is an unusual (possibly unique) vertical tank. Nor does it explain why it does not meet the caveats. The tank is lightly anchored at its base (the SEWS says there are 8 7/8 inch anchor bolts, the calculation says they are 1 inch bolts) and apparently braced with four braces (at 90 degrees) at the top and at three intermediate elevations (apparently, a total of 20 lateral braces above the base). The braces are not rigidly connected, they have (apparently 1/8 inch) gaps. The tank is about 70 feet tall and 26 feet in diameter, which means a relatively large aspect ratio of $70/26 \sim 3$.

I found the tank calculation hard to follow.

One calculation result is that the top of the tank will displace laterally 1/8 inch under a spectral acceleration of 0.04g. This means the 1/8 inch gap at lateral supports will be closed in 0.04g spectral acceleration (and the calculation concludes the demand spectral acceleration will be much more than 0.04g in an SSE, for example, 0.26g or more). Thus, in an SSE the supports will be called upon to laterally restrain the tank.

Another calculation result is that the *"bottom of the tank will buckle"* at 0.04g spectral acceleration demand (where the SSE demand is 0.26g or more). The calculation assumes this buckling is acceptable, based on the following assumed behavior: *"When the tank base reaches its moment capacity (assuming the tank wall buckles), no additional force will be generated at the compression side of tank wall from the view point of vertical equilibrium condition. Additional horizontal seismic force will be transferred through its rings and lugs and bumper structures to its support structure."*

I have the following observations about this: (1) This behavior is assumed, whereas the reality of the behavior after a buckle might be more complex and problematic, and (2) What is the justification for assuming the acknowledged buckle does not cause a leak at the tank bottom (the location where tanks do leak in earthquakes, and which leaks evacuate the tanks surprisingly fast)?

I recommend that the predicted behavior of the tank in an SSE be described in words by the project staff, based on the calculation and other sources, and documented (possibly the length of a typewritten page or so). This might belong in Section 5 of the Report – see the following.

8. Section 6.1 of the A46 Summary Report also contains the following:

"The screening evaluations described in this section for verifying the seismic adequacy of tanks and heat exchangers which experience has shown can be vulnerable to seismic loadings. These evaluations include the following features:

- *Check that the shell of large, flat-bottom, vertical tanks will not buckle.*
- .
- .
- .

The Seismic Capability Engineers, Mr. W. Djordjevic and Dr. R. P. Kennedy, reviewed these evaluations to verify that they meet the intent of these guidelines."

Does this mean the Seismic Capability Engineers reviewed the calculation for the RWST and, although shell buckling is predicted at a low level of shaking, agree that the tank meets the intent of the guidelines? If so, then perhaps this should be documented in Section 5 of the Report. Are there aspects of the tank not discussed here that meet the intent, but neither the GIP nor EPRI guidelines, that aren't documented in Section 5?

9. The SEWS for Motor Control Center MCC52B contains the following:

"Weak link is the ¼" self-tap screws, per cabinet to base channel. GIP specifies 3/8". Self-tap screws are adequate per S&A calc. # C-017."

The GIP specifies 3/8" – but only for MCCs evaluated using GERS. The Reference Spectrum was used here, not GERS, so the 3/8" caveat does not apply. You might consider deleting reference to 3/8" to avoid a future misunderstanding. In addition, the calculations do not clearly show that the screws are the weak link. This comment is gratuitous, and might also be removed.

10. Calculation C-017 for MCC52B assumes the MCC center of gravity is 26 inches above the floor, but the photo suggests the MCC has a normal height (about 90 inches) which would put the center of gravity at about 45 inches rather than 26 inches. This should be checked, and the calculation revised if necessary.

In summary, the above comments are based on my review of the following:

- USI A-46 Seismic Evaluation Report, Kewaunee Nuclear Power Plant, Wisconsin Public Service Corporation, November, 1995.

- OSVS Rev 0, SEWS Rev 0, and Calculation C-018dated 5/24/94 for Refueling Water Storage Tank.

- SEWS Rev 0 and Calculation C-017 Rev 0 dated 9/2/94 for MCC52B

- SEWS Rev 1 for MCC62J.

- SEWS Rev 0 for BUS52

- OSVS Rev 0 and SEWS Rev 0 for RD106.

- SEWS Rev 0 for BUS5

- Calculation C-008 Rev 0 (Cable Tray and Conduit Supports Limited Analytical Review.

Sincerely,
The ***Readiness*** Operation, Inc.

Paul Smith

Paul Smith
President
paul.smith@trobb.com

xc Greg Ridder

ATTACHMENT V

Letter from C. R. Steinhardt (WPSC)

to

Document Control Desk (NRC)

Dated

December 20, 1996

RESPONSE TO PEER REVIEW COMMENTS PROVIDED IN ATTACHMENT IV

The following summary addresses the final peer review comments provided in Attachment IV. The peer reviewer comments are summarized for ease of review.

Comment 1: Was the USI A-17 proximity issue evaluated for all important-to-safety equipment or for USI A-46 equipment listed on the SSEL?

Response: Proximity reviews were limited to the USI A-46 SSEL equipment, as intended by the GIP.

Comment 2: Reviewer comment on semantics.

Response: No response necessary.

Comment 3: Reviewer comment on semantics.

Response: No response necessary.

Comment 4: Reviewer requests justification for not walking down inherently rugged equipment such as manually operated valves.

Response: The GIP (Section 3.3.5) is explicit in stating that such valves do not need to be walked down.

Comment 5: Reviewer noted a recent event reported at other nuclear plants regarding the seismic qualification of 4160V breakers placed in the disconnect or test positions.

Response: It is not normal operating practice at Kewaunee to place safety-related 4.16 kV breakers in the test or disconnect position for extended periods of time during normal plant operations. The breakers are normally either racked in or completely removed from the switchgear cubicle as necessary. In general, the breakers are placed in the test or disconnect positions only during plant shutdown or during surveillance testing when the entire switchgear assembly is taken out-of-service.

In addition, both the McGraw-Edison and Westinghouse 4.16 kV breakers are positively restrained inside the switchgear cubicle by a rugged latching mechanism when the breakers are placed in either the connect or test positions. The latching mechanism can only be disengaged by the use of a manual release lever. Therefore, placing the breakers in the test position does not present a seismic interaction concern.

Comment 6: *Explain the Screening Verification Data Sheets (SVDS) nomenclature.*

Response: The nomenclature CRS (conservative, design in-structure response spectrum) and ABS (1.5 times bounding spectrum) are standard GIP nomenclature (see page 4-65 of GIP-2). The <40' question is answered "N/A" (not applicable) when it is not applicable. So if the CRS is compared to the ABS for a particular equipment item, the so called 40 ft rule does not apply and the question is answered N/A.

Comment 7: *The reviewer requests a discussion of the evaluation of the refueling water storage tank (RWST). In particular;*

a) Explain why the tank does not meet the caveats and why the tank configuration is unusual.

b) SEWS state that the anchors are 7/8", the calculation states that they are 1".

c) Provide a justification for assuming the tank buckle does not cause a leak at the tank bottom.

d) Describe the predicted behavior of the tank.

Response: The response to the specific reviewer questions are as follows:

a) The RWST does not meet the criteria of Section 7 of the GIP because it is a braced tank with 16 lateral braces over the height. The GIP method which calculates frequencies and responses based on a free standing tank obviously would not apply. In addition, the fluid height-to-tank radius ratio (H=69.5', R=13') exceeds the upper end value of 5.0 given in Table 7-1 of the GIP. The fact that the tank is braced along its height is not necessarily unusual for a 70 ft tall tank.

b) The anchors were field verified as 1" diameter anchors. Therefore the calculation is correct.

c) The base of the tank reaches its buckling load (the so called "elephant foot" buckling phenomenon) as stated, but the lateral supports hold up the tank. The small gap (approximately 1/8") between the lateral support brace arms and the support pad face restricts tank movement, and very little non-elastic shortening can occur at the base of the tank. The strain at the base of the tank shell will be small, so a leak at the bottom is not credible.

d) The tank analysis is further described in the response to NRC Question 5 in Attachment I.

Comment 8: *Did the seismic review team review the results of the RWST tank evaluation, and are there other aspects of the tank not discussed in Section 6 of the Kewaunee Summary Report that meet the intent, but not the GIP or EPRI guidelines?*

Response: Yes, the seismic review team did review the results of the tank evaluation and agree with the conclusions. The RWST did not meet the basic assumptions of the GIP as stated and fully described in the response to comment 7.

Comment 9: *The reviewer suggests that two SRT comments provided in the SEWS for MCC52B, and a comment related to S&A calculation C-017, should be deleted.*

Response: WPSC will consider deleting or revising the comments as appropriate. S&A calculation C-017 is no longer valid and was previously withdrawn from the project record.

Comment 10: *The vertical center of gravity used in calculation C-017 for MCC52B appears to be in error.*

Response: Calculation C-017 is no longer valid and was previously withdrawn from the project record since it was originally performed to address an assumption that was later determined to be erroneous. The S&A calculation was never transmitted to WPSC and is not part of the permanent project record.