March 1993

GENERAL VIBRATION MONITORING

Coupling between a Storage Ring Tunnel I-Beam Support Structure and the Tunnel/ Basemat

by

J. A. Jendrzejczyk, M. W. Wambsganss, and R. K. Smith

The primary objective of this study was to measure the coupling between a specific I-beam support structure, cantilevered from the infield side of the storage ring tunnel, and the storage ring tunnel/basemat. The support structure is mechanically connected to the side of the tunnel. It has the potential for a large resonant response and coupling to the storage ring basemat through its mechanical mounting or through the many pipes and ducts fastened to it. Impact excitation force was used to determine the lowest resonant frequency of the structure. Ambient vibration was used as the excitation source for studying the coupling.

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APS VIBRATION MONITORING

Location: EAA/STORAGE RING

Date: 2/3/93

Time: 14:00-21:30

File #: 10

Objective: To measure vibration response/coupling between cantilever I beam structure and storage ring

Site/Location Conditions: Site quiet, cold, dry. About 60°F in EAA area

Instrumentation:

<u>Storage Device:</u>	<u>Transducer:</u>	<u>Mount:</u>
FM tape <u> x </u>	S-500 <u> x </u>	Single <u> x </u>
On line <u> </u>	383C <u> </u>	Biaxial <u> </u>
Other <u> </u>	Other <u> </u>	Triaxial <u> x </u>

Orientation and Identification:

<u>Ch. #</u>	<u>Acc. Loc.</u>	<u>Orientation</u>	<u>Scale/Range</u>	<u>Approx. Noise Floor</u>
1	On I beam	Y, Vertical	0.2	NA
2	On I beam	Z, Horizontal	0.2	NA
3	On I beam	X, Horizontal	0.2	NA
4	Top surface of storage ring roof	Y, Vertical	0.2	NA
5	Top surface of storage ring roof	X, Horizontal	0.2	NA
6	Top surface of storage ring roof	Z, Horizontal	0.2	NA
7	On storage ring floor, in tunnel	Y, Horizontal	0.2	NA

DISCLAIMER

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Comments/Conclusions: See Attachment 1

Other Attachments:

Table 1. Observed frequencies

Fig. 1. Seismometer locations

Fig. 2. File 10, Photo of seismometer location

Fig. 3. RMS displacement response, 1-100 Hz

Fig. 4. RMS displacement response, 4-100 Hz

Fig. 5. RMS displacement response, 10-100 Hz

Fig. 6. RMS displacement response, 20-100 Hz

Fig. 7. RMS displacement response, 26-27.5 Hz

Fig. 8. Power spectral density plot, Time = 17:09

Fig. 9. Power spectral density plot, Time = 17:39

Attachment 1

Observations/Conclusions

Measurement Locations

Figure 1 is a schematic showing the seismometer locations on the I-beam structure and on the storage ring tunnel roof and basemat. The seismometers which are located on the storage ring tunnel roof and basemat are in the same position as they were for the study reported in APS/IN/VIB-93-4. A photograph of the I-beam mounted seismometers is shown in Fig. 2.

RMS Displacements

The RMS displacement response vs. time plots are shown in Figs. 3-7. The results given in Figs. 3-7 correspond to frequency ranges of 1-100, 4-100, 10-100, 20-100, and 26.0-27.5 Hz, respectively, and are discussed below.

1-100 Hz (Fig. 3)

Considering the minimal site activity at the time the measurements were made, the motion of the I-beam structure is very large, averaging approximately 0.8 mm RMS in the X-direction. Although the basic trend of the RMS displacements of the I-beam and of the storage ring tunnel roof and

basemat are similar, the vibration amplitudes on the tunnel roof and basemat are significantly less.

4-100 Hz (Fig. 4)

RMS displacement amplitudes in the 4-100 Hz range, as measured on the I-beam in the X- and Z-directions, are similar in magnitude to those of the 1-100 Hz range. However, there is some amplitude reduction in the Y-direction, indicating that there is a large low frequency contribution to the Y-direction motion. With the low frequency contribution (1-4 Hz) removed, a cyclic response is observed, primarily in the Y-direction, in the measurements on the storage ring tunnel roof and basemat. The RMS displacements of both the storage ring tunnel roof and basemat are approximately equal during the times when the cyclic response is observed; at other times, the response of basemat is slightly lower.

10-100 Hz (Fig. 5)

RMS displacement amplitudes in the 10-100 Hz range, as measured on the I-beam, are lower than those from the frequency ranges of 1-100 and 4-100 Hz. This is particularly the case in the X-direction, indicating a large low frequency X-direction displacement contribution. The cyclic response first observed in the 4-100 Hz plots is still present. Again, the response of both the storage ring tunnel roof and basemat are approximately equal at the times when the cyclic response is observed, and the basemat response is slightly lower at other times.

20-100 Hz (Fig. 6)

RMS displacement amplitudes in the 20-100 Hz, as measured on the I-beam, are lower than those from the frequency ranges of 1-100, 4-100, and 10-100 Hz. The largest reduction is in the X direction. From the observed amplitudes, one can conclude that there is very little coupling between the I-beam structure and the storage ring tunnel. However, there is good coupling between the storage ring tunnel roof and the basemat. This is an important consideration when locating vibration-producing equipment on the storage ring tunnel roof or when supporting equipment from the tunnel.

26-27.5 Hz (Fig. 7)

Impulse testing indicated a large resonant response of the I-beam structure at a frequency of 26.9 Hz. To study the effect of this large response on the storage ring tunnel structure, and to investigate the coupling effect, the plots of Fig. 7 were produced. The largest I-beam displacement response to ambient vibration excitation is in the Z-direction, with much lower amplitudes in the X- and Y-directions. There appears to be very little coupling between the I-beam structure and the storage ring tunnel/basemat. Although the measured RMS displacements on the storage ring tunnel roof and basemat are very small, the amplitude of the roof is smaller than that of the basemat; this is opposite to the results from the previous frequency ranges investigated (4-100, 10-100, and 20-100 Hz). This suggests that the observed behavior could be the result of exciting a particular mode of the storage ring tunnel by the excitation force produced by the motion of the I-beam structure.

Power Spectral Density Plots (Figs. 8 and 9)

Power spectral density plots at two selected times, 17:09 and 17:39, are shown in Figs. 8 and 9, respectively. Principal response frequencies are noted on these figures and are summarized in Table 1. In Table 1 an attempt is made to associate a measured frequency with a known or expected source. Several frequencies, in particular, 26.9, 42.2, and 73.1 Hz, were identified from impact testing as I-beam response frequencies. The 29.5-Hz response is attributed to rotating machinery, nominally 1800-RPM equipment, which, due to magnetic "slip" inherent in motors, results in a rotational speed of 1770-RPM. A of 59.3-Hz frequency response, corresponding to nominally 3600 RPM rotating machinery, was observed on the storage ring tunnel roof at 16:10. No similar frequency response was observed on this set of data, suggesting the response is cyclic, such as, a building heater cycling on and off. A small 120-Hz electrical response was observed at all locations. This response is caused by the magnetization force generated by motors, transformers, and other electrical equipment. Several other frequencies are observed, but since their displacement response is very small, no attempt was made to identify them.

Conclusions

- Based on ambient excitation, coupling between the I-beam structure and the storage ring tunnel is small. However, this situation could change, as the addition of piping and ductwork could increase the coupling.
- The largest contribution to the total RMS displacement response is from frequencies less than 10 Hz. Above 10 Hz the measured RMS

displacement response to the ambient excitation, present at the time of the tests, is acceptable relative to established APS vibration criteria.

- Above 20 Hz, excluding the 26-27.5 Hz response, the motion of the storage ring basemat follows that of the storage ring tunnel roof, indicating that there is good coupling between the tunnel roof and storage ring basemat. This must be taken into consideration when installing equipment, with the potential for acting as a vibration excitation source, on the storage ring tunnel roof.
- The storage ring basemat motion is larger than the storage ring roof motion for the 26.9-Hz frequency response. This is possibly a function of the location of the excitation source (the I-beam structure) relative to the measurement location on the storage ring basemat; when vibrating in a particular mode, the displacement amplitude will vary with location. Consequently, another factor to consider when placing vibration-generating equipment on the storage ring tunnel is the location of that equipment relative to the vibration mode shape. This, in turn, implies the need to understand and characterize the modes of vibration. This requires an independent excitation source with variable excitation frequency.
- If the response frequencies of the I-beam structure change due to additional equipment being mounted to it, the resonant frequencies of the structure can be expected to change. If, as a result of such a frequency shift, a resonant frequency should now coincide with a large ambient excitation frequency, large unacceptable motion of the storage ring basemat may occur. An example of this would be if the 26.9-Hz resonant response frequency would be increased to coincide with the

29.5-Hz rotational frequency. Damping, of course, is also a consideration, as it will determine the response amplitude at resonance.

Table 1. Observed frequencies

X, I beam	Y, I beam	Z, I beam	X, St.Ring,Top	X, St.Ring,Top	Z, St.Ring,Top	Y, St Rng Flr	Comments
2.96	2.96	2.96	2.96	2.96	2.96	2.96	Storage Ring Tunnel?
8.06	7.68	8.06	8.06	8.06	8.06	8.06	Storage Ring Tunnel?
					10.2		Previously Observed, Unknown Source
		13.9					
	15						
18.3	18.6			18.3	18.3	18.2	
20.7							
23.3							
26.9		26.9	26.9	26.9	26.9	26.9	Z Dir. I-Beam Structure
		31.7					
29.5			29.5	29.5	29.5	29.5	Rotational Frequency
32							
34.2	35.7	35.3		34.2		34.2	
42.2	42.2		42.2	42.2	42.2		I Beam-Structure
49.5		45.5	49.5	49.5	49.5	49.5	
		50.6					
					54.2		
60			60	60	60	60	Power Line Frequency
68.7	68.7	68.8	68.7	68.7	68.7	68.7	
73.1	73.1	73.1	73.1	73.1	73.1		Y Dir. I-Beam Structure
80.8							
96.4	96.7	96.8					
	105						
112	112	113					I-Beam Structure Response Freq. ?
117	117	117					C 58/Building Response ?
120	120	120	120	120	120	120	Power Line Freq.,120 Hz "Buzz"

Seismometer Layout, File # 10

Fig. 1. Seismometer locations

Fig. 2 File 10, Photo of seismometer location

STORAGE RING/EAA DISPLACEMENT AMBIENT EXCITATION, Condition 2

1-100 Hz Measurement date : 2/3/93 File 10

Fig. 3. RMS displacement response, 1-100 Hz

STORAGE RING/EAA DISPLACEMENT

AMBIENT EXCITATION, Condition 2

1-100 Hz Measurement date : 2/3/93 File 10

Fig. 3. RMS displacement response, 1-100 Hz

STORAGE RING/EAA DISPLACEMENT

AMBIENT EXCITATION, Condition 2

1-100 Hz Measurement date : 2/3/93

File 10

Fig. 3. RMS displacement response, 1-100 Hz

STORAGE RING/EAA DISPLACEMENT

AMBIENT EXCITATION, Condition 2

1-100 Hz Measurement date : 2/3/93 File 10

Fig. 3. RMS displacement response, 1-100 Hz

STORAGE RING/EAA DISPLACEMENT AMBIENT EXCITATION, Condition 2

1-100 Hz Measurement date : 2/3/93 File 10

Fig. 3. RMS displacement response, 1-100 Hz

STORAGE RING/EAA DISPLACEMENT

AMBIENT EXCITATION, Condition 2

4-100 Hz

Measurement date: 2/3/93

File 10

Fig. 4. RMS displacement response, 4-100 Hz

STORAGE RING/EAA DISPLACEMENT

AMBIENT EXCITATION, Condition 2

4-100 Hz

Measurement date: 2/3/93

File 10

Fig. 4. RMS displacement response, 4-100 Hz

STORAGE RING/EAA DISPLACEMENT AMBIENT EXCITATION, Condition 2

4-100 Hz

Measurement date: 2/3/93

File 10

Fig. 4. RMS displacement response, 4-100 Hz

STORAGE RING/EAA DISPLACEMENT

AMBIENT EXCITATION, Condition 2

4-100 Hz

Measurement date: 2/3/93

File 10

Fig. 4. RMS displacement response, 4-100 Hz

STORAGE RING/EAA DISPLACEMENT

AMBIENT EXCITATION, Condition 2

4-100 Hz

Measurement date: 2/3/93

File 10

Fig. 4. RMS displacement response, 4-100 Hz

STORAGE RING/EAA DISPLACEMENT

AMBIENT EXCITATION, Condition 2

10-100 Hz

Measurement date: 2/3/93

File 10

Fig. 5. RMS displacement response, 10-100 Hz

STORAGE RING/EAA DISPLACEMENT

AMBIENT EXCITATION, Condition 2

10-100 Hz

Measurement date: 2/3/93

File 10

Fig. 5. RMS displacement response, 10-100 Hz

STORAGE RING/EAA DISPLACEMENT AMBIENT EXCITATION, Condition 2

10-100 Hz Measurement date: 2/3/93 File 10

Fig. 5. RMS displacement response, 10-100 Hz

STORAGE RING/EAA DISPLACEMENT AMBIENT EXCITATION, Condition 2

Fig. 5. RMS displacement response, 10-100 Hz

STORAGE RING/EAA DISPLACEMENT

AMBIENT EXCITATION, Condition 2

Fig. 5. RMS displacement response, 10-100 Hz

STORAGE RING/EAA DISPLACEMENT

AMBIENT EXCITATION, Condition 2

20-100 Hz

Measurement date: 2/3/93

File 10

Fig. 6. RMS displacement response, 20-100 Hz

STORAGE RING/EAA DISPLACEMENT

AMBIENT EXCITATION, Condition 2

Fig. 6. RMS displacement response, 20-100 Hz

STORAGE RING/EAA DISPLACEMENT

AMBIENT EXCITATION, Condition 2

20-100 Hz Measurement date: 2/3/93 File 10

Fig. 6. RMS displacement response, 20-100 Hz

STORAGE RING/EAA DISPLACEMENT

AMBIENT EXCITATION, Condition 2

Fig. 6. RMS displacement response, 20-100 Hz

STORAGE RING/EAA DISPLACEMENT

AMBIENT EXCITATION, Condition 2

26-27.6 Hz

Measurement date: 2/3/93

File 10

Fig. 7. RMS displacement response, 26-27.5 Hz

STORAGE RING/EAA DISPLACEMENT

AMBIENT EXCITATION, Condition 2

Fig. 7. RMS displacement response, 26-27.5 Hz

STORAGE RING/EAA DISPLACEMENT

AMBIENT EXCITATION, Condition 2

26-27.6 Hz

Measurement date: 2/3/93

File 10

Fig. 7. RMS displacement response, 26-27.5 Hz

STORAGE RING/EAA DISPLACEMENT

AMBIENT EXCITATION, Condition 2

26-27.6 Hz

Measurement date: 2/3/93

File 10

Fig. 7. RMS displacement response, 26-27.5 Hz

STORAGE RING/EAA DISPLACEMENT

Ambient Excitation, Condition 2

File 10

Measurement date: 2/3/93

Time: 17:09

Fig. 8. Power spectral density plot, Time = 17:09

STORAGE RING/EAA DISPLACEMENT

Ambient Excitation, Condition 2

File 10

Measurement date: 2/3/93

Time: 17:09

Fig. 8. Power spectral density plot, Time = 17:09

STORAGE RING/EAA DISPLACEMENT

Ambient Excitation, Condition 2

Measurement date: 2/3/93 Time: 17:09

File 10

Fig. 8. Power spectral density plot, Time = 17:09

STORAGE RING/EAA DISPLACEMENT

Ambient Excitation, Condition 2

File 10

Measurement date: 2/3/93

Time: 17:09

Fig. 8. Power spectral density plot, Time = 17:09

STORAGE RING/EAA DISPLACEMENT

Ambient Excitation, Condition 2

File 10

Measurement date: 2/3/93

Time: 17:09

Fig. 8. Power spectral density plot, Time = 17:09

STORAGE RING/EAA DISPLACEMENT

Ambient Excitation, Condition 2

File 10

Measurement date: 2/3/93

Time: 17:09

Fig. 8. Power spectral density plot, Time = 17:09

STORAGE RING/EAA DISPLACEMENT

Ambient Excitation, Condition 2

File 10

Measurement date: 2/3/93 Time: 17:09

Fig. 8. Power spectral density plot, Time = 17:09

STORAGE RING/EAA DISPLACEMENT

Ambient Excitation, Condition 2

File 10

Measurement date: 2/3/93

Time: 17:39

Fig. 9. Power spectral density plot, Time = 17:39

STORAGE RING/EAA DISPLACEMENT

Ambient Excitation, Condition 2

File 10

Measurement date: 2/3/93 Time: 17:39

Fig. 9. Power spectral density plot, Time = 17:39

STORAGE RING/EAA DISPLACEMENT

Ambient Excitation, Condition 2

File 10

Measurement date: 2/3/93 Time: 17:39

Fig. 9. Power spectral density plot, Time = 17:39

STORAGE RING/EAA DISPLACEMENT

Ambient Excitation, Condition 2

File 10

Measurement date: 2/3/93

Time: 17:39

Fig. 9. Power spectral density plot, Time = 17:39

STORAGE RING/EAA DISPLACEMENT

Ambient Excitation, Condition 2

File 10

Measurement date: 2/3/93

Time: 17:39

Fig. 9. Power spectral density plot, Time = 17:39

STORAGE RING/EAA DISPLACEMENT

Ambient Excitation, Condition 2

File 10

Measurement date: 2/3/93

Time: 17:39

Fig. 9. Power spectral density plot, Time = 17:39

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11 / 29 / 93

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