March 7, 2006

Mr. Robert McCullough
Smith College Physical Plant
126 West Street
Northampton, MA 01063

Subject: Baseline Vibration Survey
Smith College – Sabin-Reed Hall

Dear Mr. McCullough,

On February 16, 2006, Cavanaugh Tocci Associates, Inc. visited the Smith College Campus in Northampton, Massachusetts. During this visit, we conducted a survey of vibration in Sabin-Reed Hall. It is our understanding that many vibration sensitive laboratories in this building will be relocated to the new Science and Engineering Building. This survey has been conducted to quantify existing laboratory vibration levels and to identify potential issues associated with relocation. The report discusses applicable criteria for vibration sensitive applications, and summarizes the results of these measurements.

**General Criteria for Vibration Sensitive Spaces**

Vibration limits for building spaces are often expressed as constant velocity limits (μinches/second). Where sensitive laboratory equipment is of concern, typical limits range from 2000 μin/sec for general-purpose benchtop equipment, to less than 125 μin/sec for the most sensitive equipment (SEM, NMR, Cell implant, etc). Note that these criteria apply at the base of the instrument and not at the floor. Generic guidelines are listed below:
2000 μin/sec: Acceptable for most: Bench microscopes at 400x magnification, Optical and other precision balances, Coordinate measuring machines, Optical comparators.

1000 μin/sec: Acceptable for most: Bench microscopes at magnification greater than 400x, Optical equipment on isolation tables

500 μin/sec: Acceptable for most: Electron microscopes at up to 30,000x magnification, Microtomes, Magnetic resonance imagers,

250 μin/sec: Acceptable for most: Electron microscopes at greater than 30,000x magnification, Mass spectrometers, Cell implant equipment,

125 μin/sec: Acceptable for most: Unisolated laser optical research,

Vibration Measurements

Vibration measurements were conducted in seven laboratories that are located on the 2nd, 3rd, and 4th floors of Sabin-Reed Hall. These locations were selected as the most vibration sensitive laboratories in Sabine-Reed Hall. These laboratories are listed below, and photographs are included in Appendix A.

- Room 220: Organic Chemistry NMR
- Room 305: Cell Biology Benchtop Microscopes
- Room 308: Developmental Biology Benchtop Microscopes
- Room 338: Biochemistry Benchtop Microscope
- Room 401: Microbiology & Immunology Benchtop Microscopes
- Room 444: Scanning Electron Microscope JEOL 6400
- Room 44X: Transmission Electron Microscope JEOL TEM-100CXII

Measurements of floor and benchtop vibration were obtained using three high sensitivity PCB 393 B12 seismic accelerometers that were oriented in three orthogonal directions (vertical, north-south, and east-west). In addition to floor and benchtop locations, measurements were also conducted on a vibration isolation platform that is used to support microscopes in Room 308, and at the top of the microscope in Room 338. Signals were analyzed using a Data Physics Quattro Frequency Analyzer. The measurements were conducted with without occupant activity (footfall) occurring within laboratory areas. Figures 1-14 are selected results of the vibration measurements. These plots are 1/3 octave band spectra and present the measured acceleration level (dB re: 1 μg) as function of frequency (Hz). To place measured vibration levels in perspective, the generic vibration criteria (VC) curves that are discussed above have been included with the data. Table 1 below summarizes the results for the measurements that are presented in the figures.
### Table 1: Summary of Vibration Measurements Maximum Velocity (µin/sec)

<table>
<thead>
<tr>
<th>Room #</th>
<th>Location</th>
<th>Vertical</th>
<th>N-S</th>
<th>E-W</th>
<th>Vertical with Occupant Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>220</td>
<td>Floor</td>
<td>602</td>
<td>55</td>
<td>65</td>
<td>1209</td>
</tr>
<tr>
<td>305</td>
<td>Floor</td>
<td>551</td>
<td>68</td>
<td>52</td>
<td>1928</td>
</tr>
<tr>
<td>305</td>
<td>Bench</td>
<td>506</td>
<td>853</td>
<td>225</td>
<td>4175</td>
</tr>
<tr>
<td>308</td>
<td>Floor</td>
<td>439</td>
<td>72</td>
<td>58</td>
<td>504</td>
</tr>
<tr>
<td>308</td>
<td>Bench</td>
<td>1641</td>
<td>411</td>
<td>474</td>
<td>1868</td>
</tr>
<tr>
<td>308</td>
<td>Isolated Plate</td>
<td>2735</td>
<td>601</td>
<td>486</td>
<td>3654</td>
</tr>
<tr>
<td>338</td>
<td>Floor</td>
<td>243</td>
<td>75</td>
<td>72</td>
<td>261</td>
</tr>
<tr>
<td>338</td>
<td>Bench</td>
<td>276</td>
<td>197</td>
<td>86</td>
<td>244</td>
</tr>
<tr>
<td>338</td>
<td>Microscope Top</td>
<td>1375</td>
<td>925</td>
<td>674</td>
<td>1514</td>
</tr>
<tr>
<td>401</td>
<td>Floor</td>
<td>266</td>
<td>71</td>
<td>93</td>
<td>280</td>
</tr>
<tr>
<td>401</td>
<td>Bench</td>
<td>343</td>
<td>748</td>
<td>289</td>
<td>756</td>
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<tr>
<td>444</td>
<td>Floor</td>
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<tr>
<td>444</td>
<td>SEM Platform</td>
<td>246</td>
<td>136</td>
<td>207</td>
<td>249</td>
</tr>
<tr>
<td>44X</td>
<td>Floor</td>
<td>722</td>
<td>56</td>
<td>80</td>
<td>726</td>
</tr>
</tbody>
</table>
Observations

Based on our review of the measured data, we have the following observations:

- Ambient floor vibration in Sabin-Reed Hall is most significant in the vertical direction. Maximum ambient velocity levels range between 243 and 722 µin/sec.

- With occupant activity, maximum vertical velocities measured on the floors range between 261 and 1,928 µin/sec. As expected, the highest levels associated with occupant activity occurred at the center of structural bays in larger “open” laboratories (room 305). Likewise, smaller rooms with CMU partitions and measurement points near columns barely respond to occupant activity, due to increased stiffness and damping properties.

- Measurements conducted on benchtops indicate the significant dynamic amplifications that can occur in laboratory casework. Note the high vertical velocity measured in Room 305 and 308 when there is occupant activity. Also, note the significant increase in horizontal vibration that occurs on the benchtops.

These measurements illustrate that although it important to set appropriate criteria for floor vibration (mainly associated with occupant activity), placement of sensitive equipment (e.g. near columns, etc.), and the type of casework used may be even more important with respect to vibration sensitive applications.

It has been a pleasure to perform this survey, if you have any questions, please do not hesitate to call me.

Yours Sincerely,
CAVANAUGH TOCCI ASSOCIATES, INC

Douglas H. Bell
DHB/dhb/Sabin-Reed Baseline Vibration
Room 220 (Floor) Inorganic Chemistry (NMR)

Sabin-Reed Hall, Smith College, Northampton, MA 2/16/06

Figure 1

Vertical Ambient
N-S Ambient
E-W Ambient
Vertical Walking
Room 305 (Floor) Cell Biology
Sabin-Reed Hall, Smith College, Northampton, MA 2/16/06

Figure 2
Figure 3

Room 305 (Bench) Cell Biology
Sabin-Reed Hall, Smith College, Northampton, MA 2/16/06

[Graph showing acceleration levels in decibels relative to 1 µg across different center frequencies (Hz) for various ambient and walking conditions, with lines marked VC-A 2000 µin/s, VC-B 1000 µin/s, VC-C 500 µin/s, VC-D 250 µin/s, VC-E 125 µin/s, and symbols for Vertical Ambient, N-S Ambient, E-W Ambient, Vertical Walking.

Legend:
- Vertical Ambient
- N-S Ambient
- E-W Ambient
- Vertical Walking

0 10 20 30 40 50 60 70
0 1 2 3 4 5 6 7
1/3 Octave Band Center Frequency (Hz)

Acceleration Level (dB re: 1 µg)
Figure 4

Room 308 (Floor) Developmental Biology & Embryology
Sabin-Reed Hall, Smith College, Northampton, MA 2/16/06

[Graph showing acceleration levels in 1/3 octave bands for different conditions]

Acceleration Level (dB re: 1 µg)

1/3 Octave Band Center Frequency (Hz)

Vertical Ambient
N-S Ambient
E-W Ambient
Vertical Walking
Figure 6

Room 308 (Isolated Platform) Developmental Biology & Embryology
Sabin-Reed Hall, Smith College, Northampton, MA 2/16/06

Vertical Ambient
N-S Ambient
E-W Ambient
Vertical Walking
Room 338 (Floor) Biochemistry
Sabin-Reed Hall, Smith College, Northampton, MA 2/16/06

Figure 7
Room 338 (Bench) Biochemistry
Sabin-Reed Hall, Smith College, Northampton, MA 2/16/06

VC-A 2000 µin/s
VC-B 1000 µin/s
VC-C 500 µin/s
VC-D 250 µin/s
VC-E 125 µin/s

1/3 Octave Band Center Frequency (Hz)

Acceleration Level (dB re: 1 µg)

Vertical Ambient
N-S Ambient
E-W Ambient
Vertical Walking

Figure 8
Room 338 (Microscope) Biochemistry

Sabin-Reed Hall, Smith College, Northampton, MA 2/16/06

Figure 9
Room 401 (Floor) - Microbiology and Immunology

Sabin-Reed Hall, Smith College, Northampton, MA 2/16/06

Vertical Ambient
N-S Ambient
E-W Ambient
Vertical Walking

Figure 10
Room 444 SEM (Floor) JEOL-6400

Sabin-Reed Hall, Smith College, Northampton, MA 2/16/06

Figure 12
Across Room 444 TEM (Floor) JEOL-100CXII

Sabin-Reed Hall, Smith College, Northampton, MA 2/16/06

Figure 14
Appendix A

Photographs of Vibration Measurement Locations
Room 220 – Organic Chemistry (NMR)

Room 305 – Cell Biology

Appendix Figure A-1
Room 308 – Developmental Biology & Embryology

Room 338 – Biochemistry

Appendix Figure A-2
Room 401 – Microbiology & Immunology

Room 444 – Scanning Electron Microscope

Appendix Figure A-3