Mechanical Vibration Testing
Reciprocating Pumps

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Condensate Injection Recip Pump

- Specific gravity : 0.44
- Vapor pressure : 554.7 PSIA
- Discharge Pressure : 5500 PSIA
- Speed : 240 RPM
- Quintuplex Design

Pump was purchased with a witnessed vibration test under suppliers vibration specification.

Specification’s vibration acceptance level was 0.25 in/sec for the pump and 0.30 in/sec for guards and spools.

Photo courtesy of FMC Industries
Available Standards

- **Balmac**
  - Equipment category definition is vague.
  - Acceptable vibration allowance varied by category.
- **ISO 108016-6:1995**
  - Equipment category definition is vague.
  - Acceptable vibration allowance varied by category.
- **API 674, 2nd Edition**
  - Does not specify any vibration acceptability tolerances.
Vibration Conversion Chart
### ISO 10816-6 Vibration Limits

**Table A.1 — Vibration classification numbers and guide values for reciprocating machines**

<table>
<thead>
<tr>
<th>Vibration severity grades</th>
<th>Maximum values of overall vibration measured on the machine structure</th>
<th>Machine vibration classification number</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Displacement $\mu m$ (r.m.s.)</td>
<td>Velocity mm/s (r.m.s.)</td>
</tr>
<tr>
<td>1.1</td>
<td>17.8</td>
<td>1.12</td>
</tr>
<tr>
<td>1.8</td>
<td>28.3</td>
<td>1.78</td>
</tr>
<tr>
<td>2.8</td>
<td>44.8</td>
<td>2.92</td>
</tr>
<tr>
<td>4.6</td>
<td>71.0</td>
<td>4.48</td>
</tr>
<tr>
<td>7.1</td>
<td>113</td>
<td>7.07</td>
</tr>
<tr>
<td>11</td>
<td>178</td>
<td>11.2</td>
</tr>
<tr>
<td>18</td>
<td>283</td>
<td>17.8</td>
</tr>
<tr>
<td>28</td>
<td>44.8</td>
<td>28.2</td>
</tr>
<tr>
<td>45</td>
<td>71.0</td>
<td>44.8</td>
</tr>
</tbody>
</table>

**Key to zones**

A: The vibration of newly commissioned machines would normally fall within this zone.
B: Machines with vibration within this zone are normally considered acceptable for long-term operation.
C: Machines with vibration within this zone are normally considered unsatisfactory for long-term continuous operation. Generally, the machine may be operated for a limited period in this condition until a suitable opportunity arises for remedial action.
D: Vibration values within this zone are normally considered to be of sufficient severity to cause damage to the machine.

**NOTE** — Vibration values for reciprocating machines may tend to be more constant over the life of the machine than for rotating machines. Therefore zones A and B are combined in this table. In future, when more experience is accumulated, guide values to differentiate between zones A and B may be provided.
Balmac Vibration Reference

Class-1: Individual components, integrally connected with the complete machine in its normal operating condition. Small Electric Motors, Precision Machines, Turbines

Class-2: Medium size machinery without special foundations, rigidly mounted engines, or machines on special foundation. Gear Boxes, Pumps, M-G Sets, Fans

Class-3: Large prime movers mounted on heavy, rigid foundations. Compressors, Blowers, Hammer mills, Engines

Class-4: Large prime movers mounted on relatively soft, light-weight structures. Crushers, Reciprocating Machinery, Vibrating Conveyors

<table>
<thead>
<tr>
<th>Vibration (ips)</th>
<th>Class-1</th>
<th>Class-2</th>
<th>Class-3</th>
<th>Class-4</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.01 ips</td>
<td>GOOD</td>
<td>GOOD</td>
<td>GOOD</td>
<td>GOOD</td>
</tr>
<tr>
<td>0.02 ips</td>
<td>GOOD</td>
<td>GOOD</td>
<td>GOOD</td>
<td>GOOD</td>
</tr>
<tr>
<td>0.03 ips</td>
<td>GOOD</td>
<td>GOOD</td>
<td>GOOD</td>
<td>GOOD</td>
</tr>
<tr>
<td>0.05 ips</td>
<td>FAIR</td>
<td>GOOD</td>
<td>GOOD</td>
<td>GOOD</td>
</tr>
<tr>
<td>0.08 ips</td>
<td>FAIR</td>
<td>FAIR</td>
<td>GOOD</td>
<td>GOOD</td>
</tr>
<tr>
<td>0.1 ips</td>
<td>ROUGH</td>
<td>FAIR</td>
<td>FAIR</td>
<td>GOOD</td>
</tr>
<tr>
<td>0.2 ips</td>
<td>N/A</td>
<td>ROUGH</td>
<td>FAIR</td>
<td>FAIR</td>
</tr>
<tr>
<td>0.4 ips</td>
<td>N/A</td>
<td>N/A</td>
<td>ROUGH</td>
<td>FAIR</td>
</tr>
<tr>
<td>0.6 ips</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>ROUGH</td>
</tr>
<tr>
<td>0.8 ips</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>1.0 ips</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>
Baseplate Stiffness Effects

Photo courtesy of FMC Industries
Baseplate Stiffness Effects

Photo courtesy of FMC Industries
Baseplate Stiffness Effects

Photo courtesy of FMC Industries
Bump Test

500 HP Test Stand – Impact Test Data
Frame 1Z

Natural Frequencies:
- 19.78 Hz
- 35.74 Hz
- 45.75 Hz

Operation Frequencies:
- 4 Hz (Running Speed)
- 20 Hz (5X Running Speed)

Photo courtesy of FMC Industries
Driveline Vibration

U-JOINT

Photo courtesy of FMC Industries
Driveline Vibration

500 HP Test Stand Piston Pump Spectrums & Waveforms

1X Pump Drive Bearing 1X

Analyse Spectrum
13-Jul-03 14:51:01
PK = 1530
LOAD = 103.0
RPM = 240. (4.00 Hz)

Analyse Waveform
13-Jul-03 14:51:01
RMS = 2116
PK(+/−) = 1.02/ 0.9290
CRESTF = 4.80

Photo courtesy of FMC Industries
Accepted Vibration Test

Pump passed

- Maximum vibration recorded
  - 0.33 in/sec
- Purchasers legacy vibration requirement
  - 0.40 in/sec
Recip pump vibration typically considered fluid induced, mechanical vibration must also be considered.

Vibration limits need to be set based on:
- Fluid being pumped
- Size of pump

Reduce all external vibration influences:
- Rigid base
- Direct drive line (w/flexible coupling)
Current Operation

- Pump completed final testing in January of 2010
- Pump is not installed and there is no further information on field performance with piping and pulsation dampeners.
Thank you!

QUESTIONS?