Vibration Isolation of Screw Chillers

Jerry G. Lilly

JGL Acoustics, Inc.

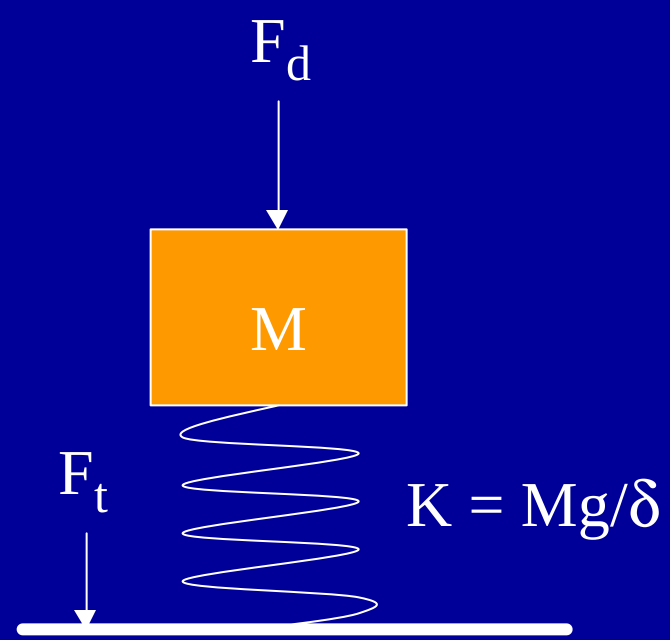
Issaquah, WA

Topics of Discussion

- Brief review of elementary vibration isolation theory
- Screw chiller vibration and noise characteristics
- Case History

Vibration Isolation

- Oscillating force F_d is internal to mass M
- Isolator has stiffness K = weight/static deflection (δ)
- Goal is to minimize the transmitted force into the building, F_t



Natural Frequency

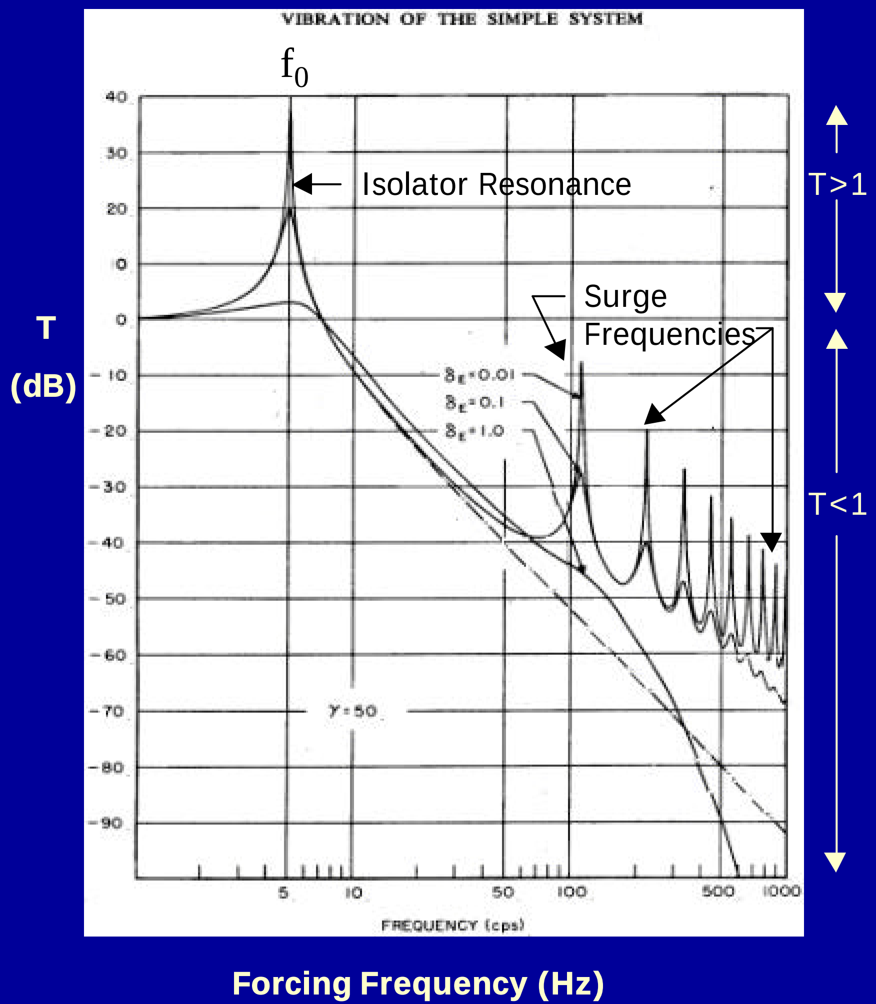
- The natural frequency f_0 is the frequency of oscillation after impact
- f_0 can be measured by displacing the mass M and letting it oscillate to its final rest position

$$f_0 = 3.13 \, [1/d]^{1/2}$$

where d is the static deflection of the isolator in inches

Transmissibility

- Transmissibility T is the ratio of F_t/F_d
- Performance is very poor at the isolator resonance - vibration is amplified by isolator
- Performance is good above 3 times f_0, except at surge frequencies where T is increased



Surge Frequencies

- Internal reflections build up creating surge frequency f_s
- Surge frequencies occur in all isolator types, but are most prominent in steel springs

$$f_s = nKS_s / \delta_s \text{ (Hz)}$$

$n = 1, 2, 3, \ldots$

$K = 0.0384$

S_s = solid stress (psi)

δ_s = solid deflection (in.)

Vibration Isolators

- Pad Mounts (5 Hz < f_0 < 20 Hz)
  Neoprene, Fiberglass, Cork (d < 0.15”)

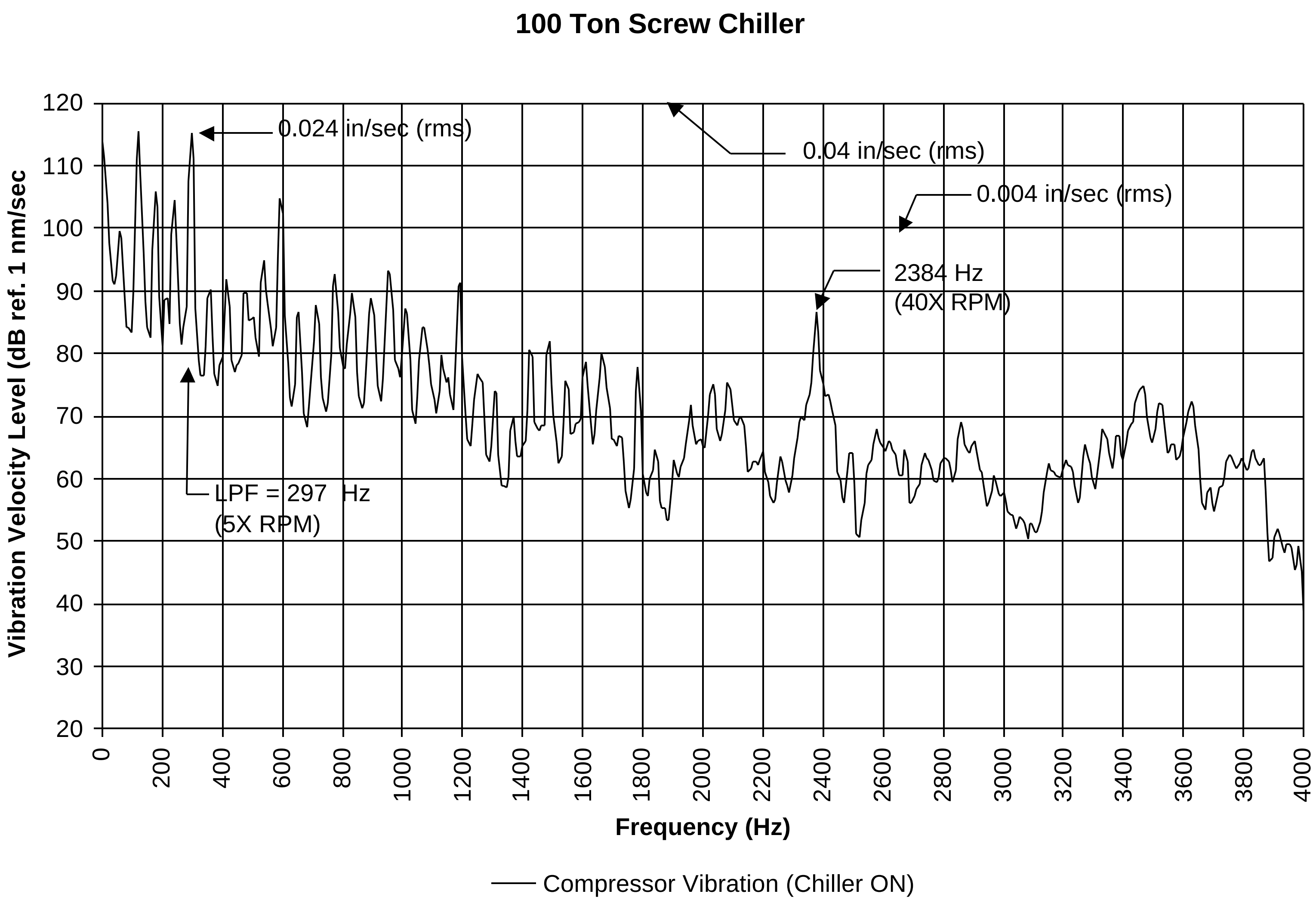
- Spring Mounts (2 Hz < f_0 < 5 Hz)
  Steel coils with rubber base (1” < d < 3”)

- Air Mounts (1.5 Hz < f_0 < 3 Hz)
  Pressurized air bag (2” < d < 5”)

Sources of Screw Chiller Vibration

- Screw Compressor
  - Motor Speed (3550 RPM = 59 Hz)
  - LPF = No. of lobes (RPM/60) Hz
  - Upper Harmonics (n = 2, 3, 4, ..., 20)
- Condenser Fans
  - Motor RPM (1140 RPM = 19 Hz)
  - BPF = No. of blades (RPM/60) Hz

Screw Chiller Vibration



Vibration Isolation Options

- Neoprene Pads: inadequate static deflection to control condenser fan vibration, marginal high frequency performance

- Steel Springs: good low frequency performance, surge frequencies may be a problem at high frequencies

- Air Mounts: best solution, most expensive

Case History: Air-Cooled Chiller

- new 100 ton screw chiller above existing administrative offices (retrofit project)
- Existing plywood roof deck with no concrete (roof could not support weight of chiller)
- Existing suspended acoustical tile ceiling below

Case History: Recommendations

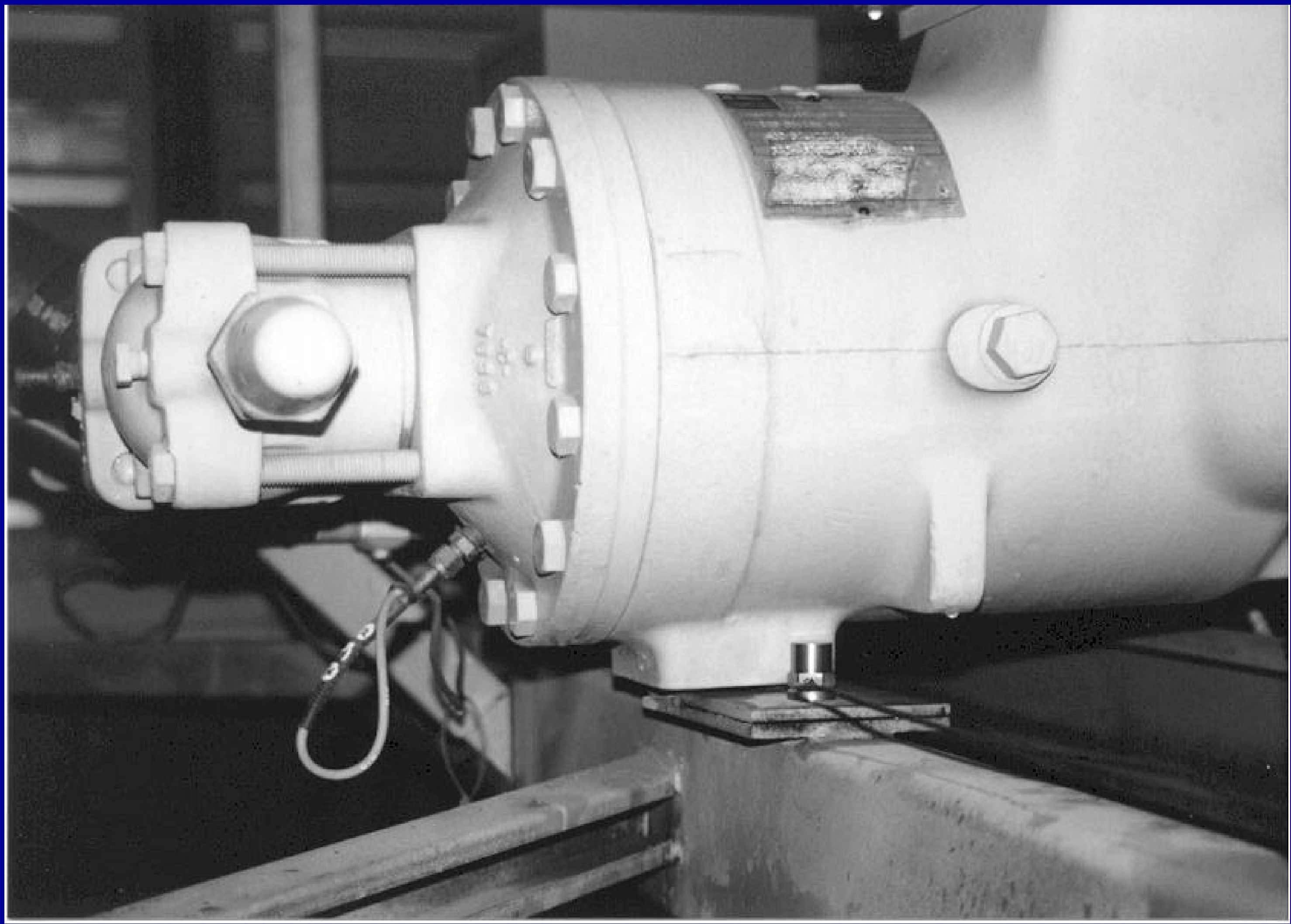
- Mount chiller on steel spring isolators (2” static deflection, seismic rated) on steel beams elevated 2” above roof
- Add 1.5” lightweight (50 pcf) topping slab
- Build noise barrier wall around unit to shield roof areas without the topping slab

Steel Spring Selection

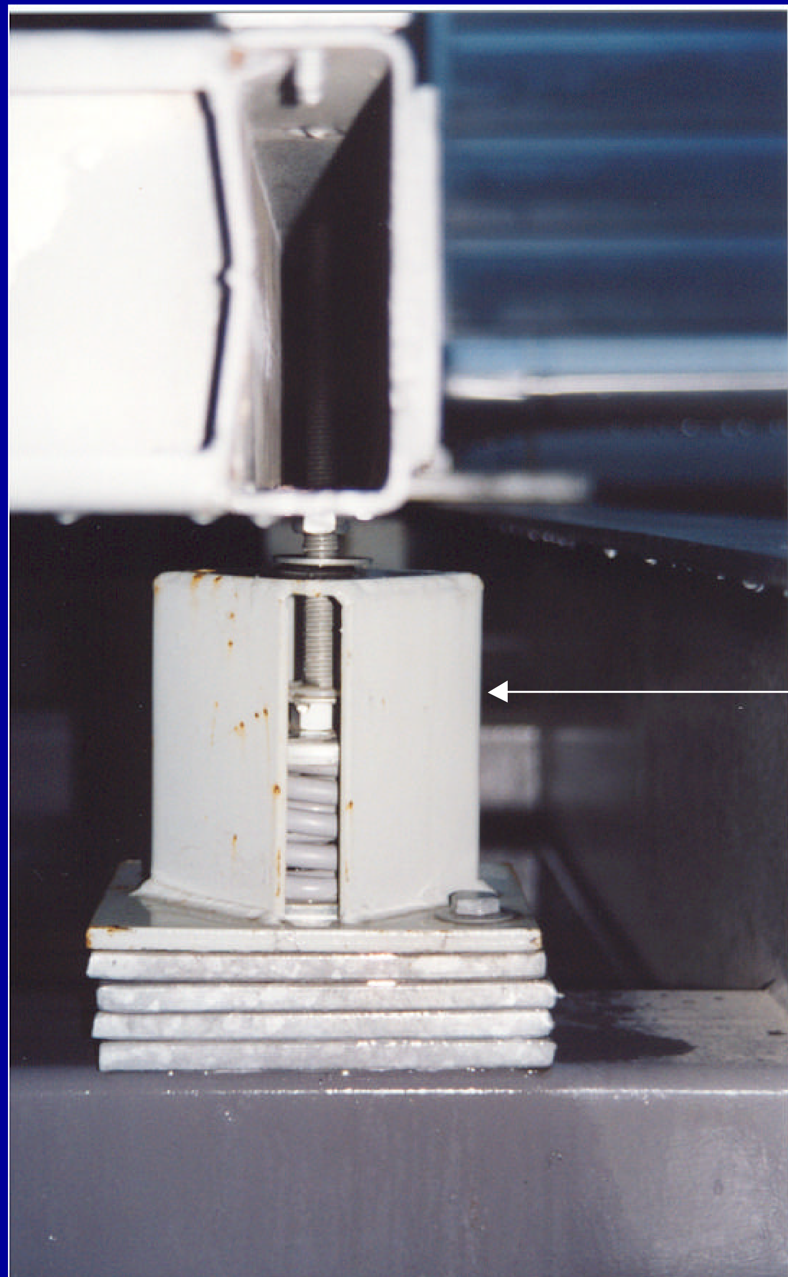
- 2” deflection springs (f_0 = 2.2 Hz) [auxiliary beams designed for 12 Hz]
- Primary Chiller Forcing Frequencies: 59 Hz, 178 Hz, 297 Hz, 594 Hz
- Spring Surge Frequencies: 186 Hz & 197 Hz, 157 Hz & 108 Hz

100 ton Screw Chiller (air-cooled)

Screw Compressor



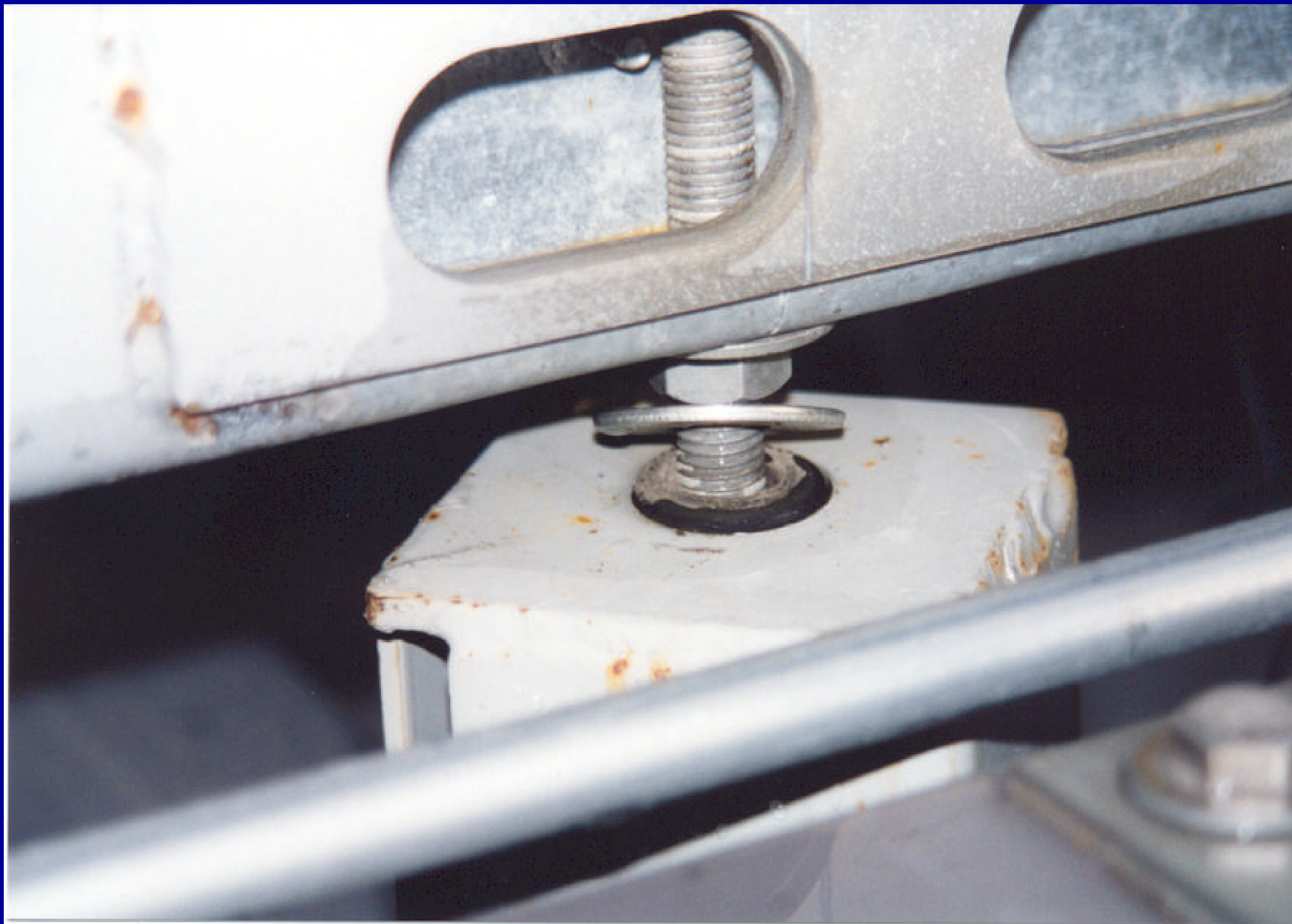
Chiller Base →



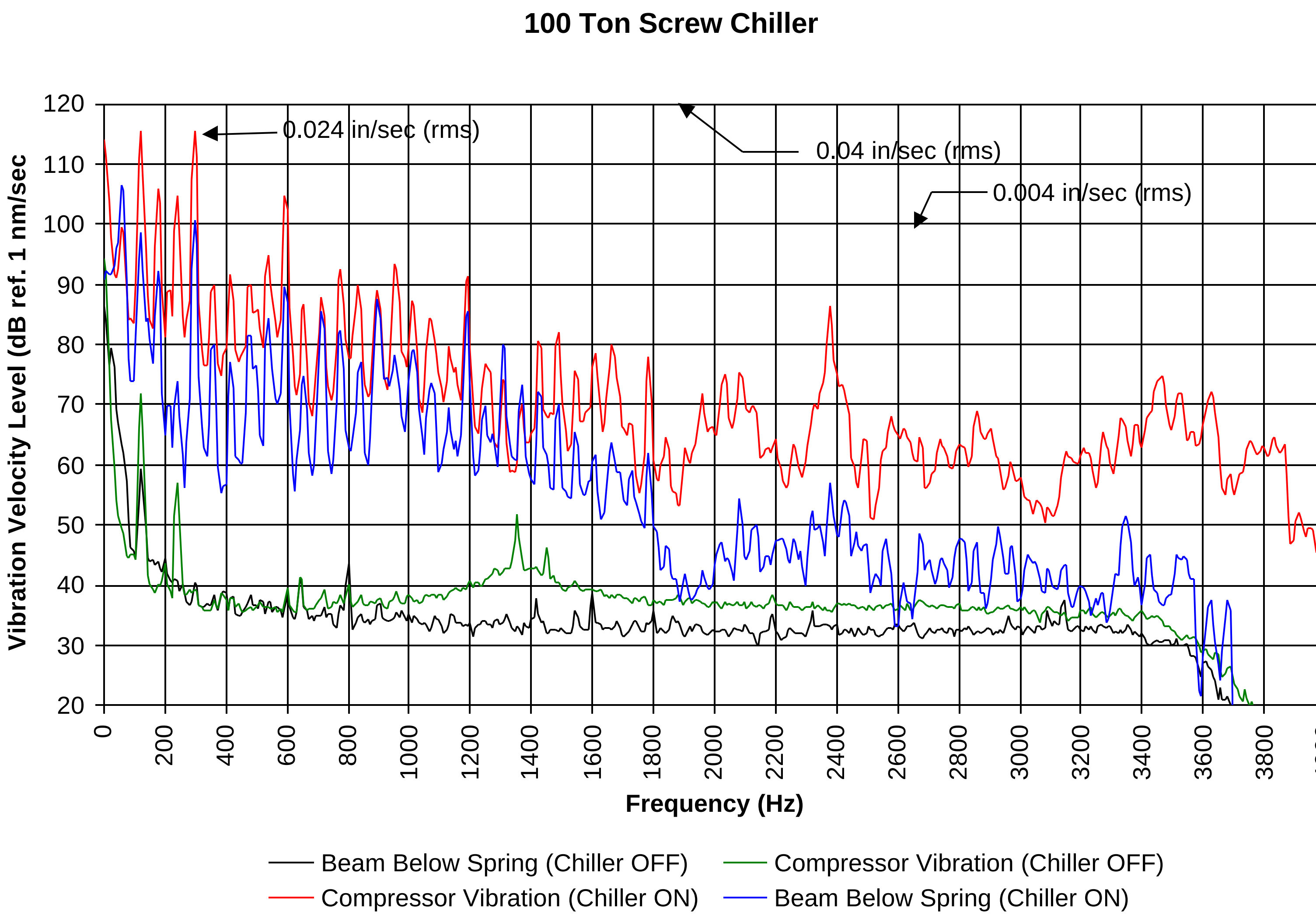
← Seismic Spring

(2 nested coils)

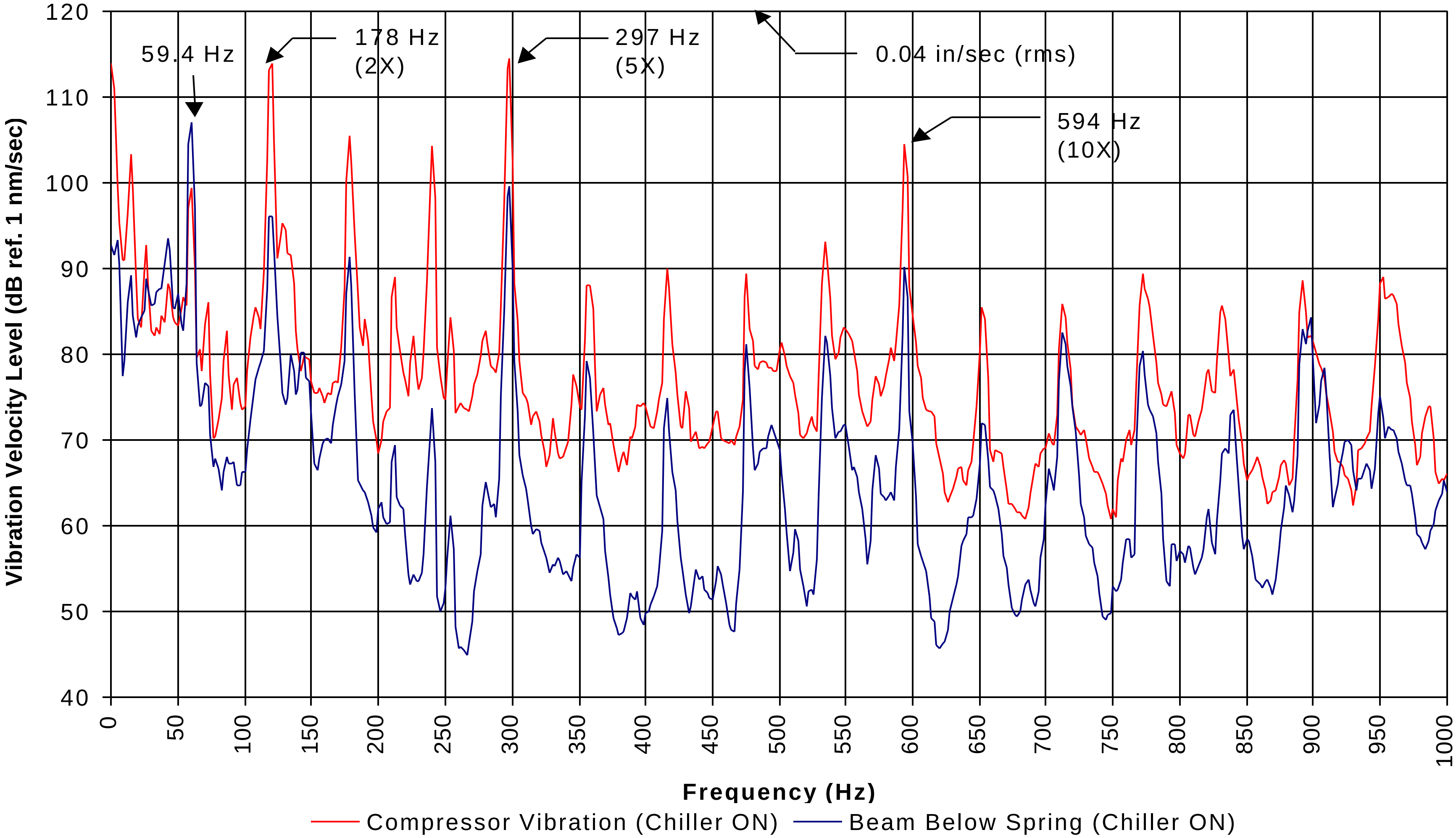
Structural Beam →



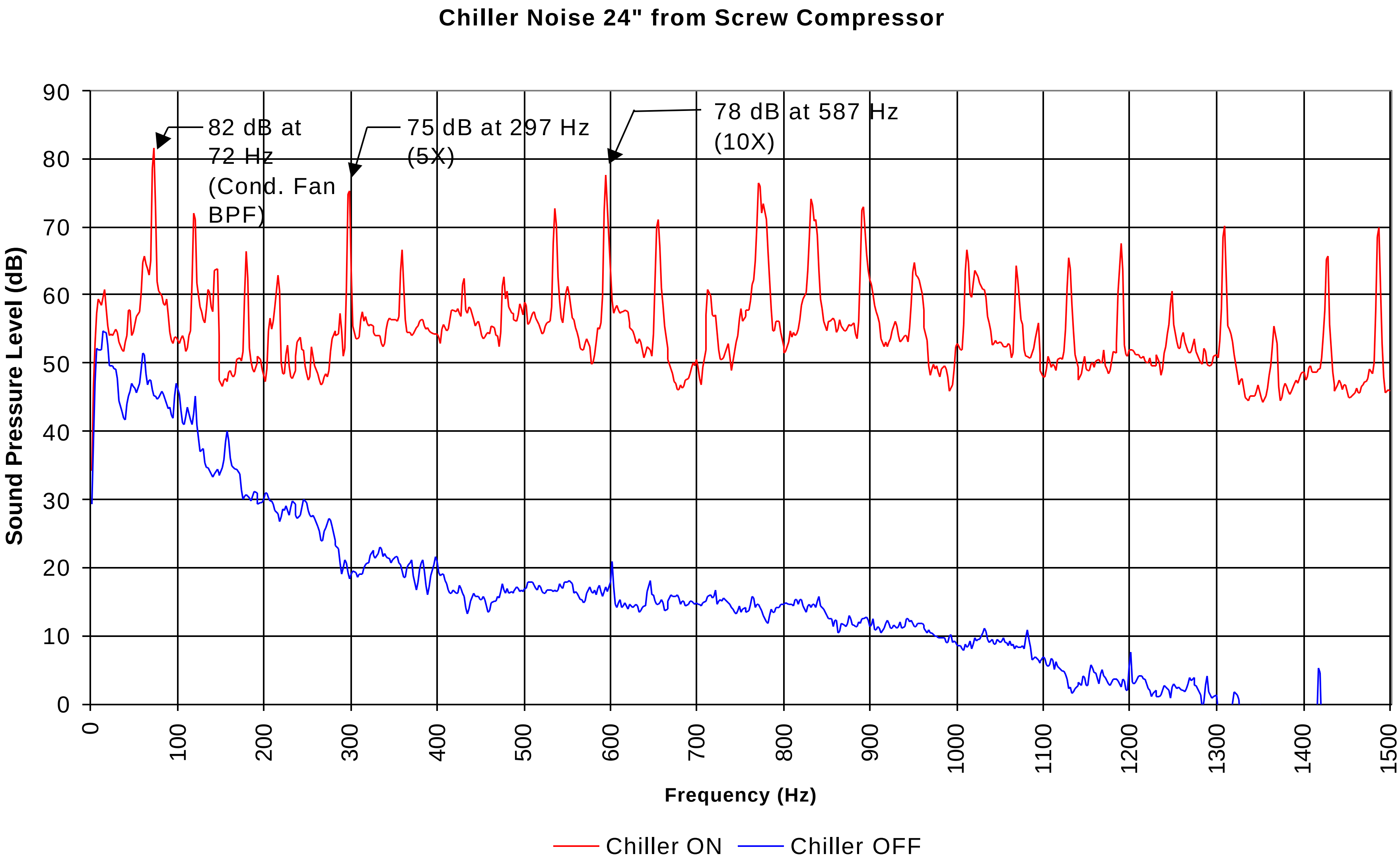
Screw Chiller Vibration



Screw Chiller Vibration

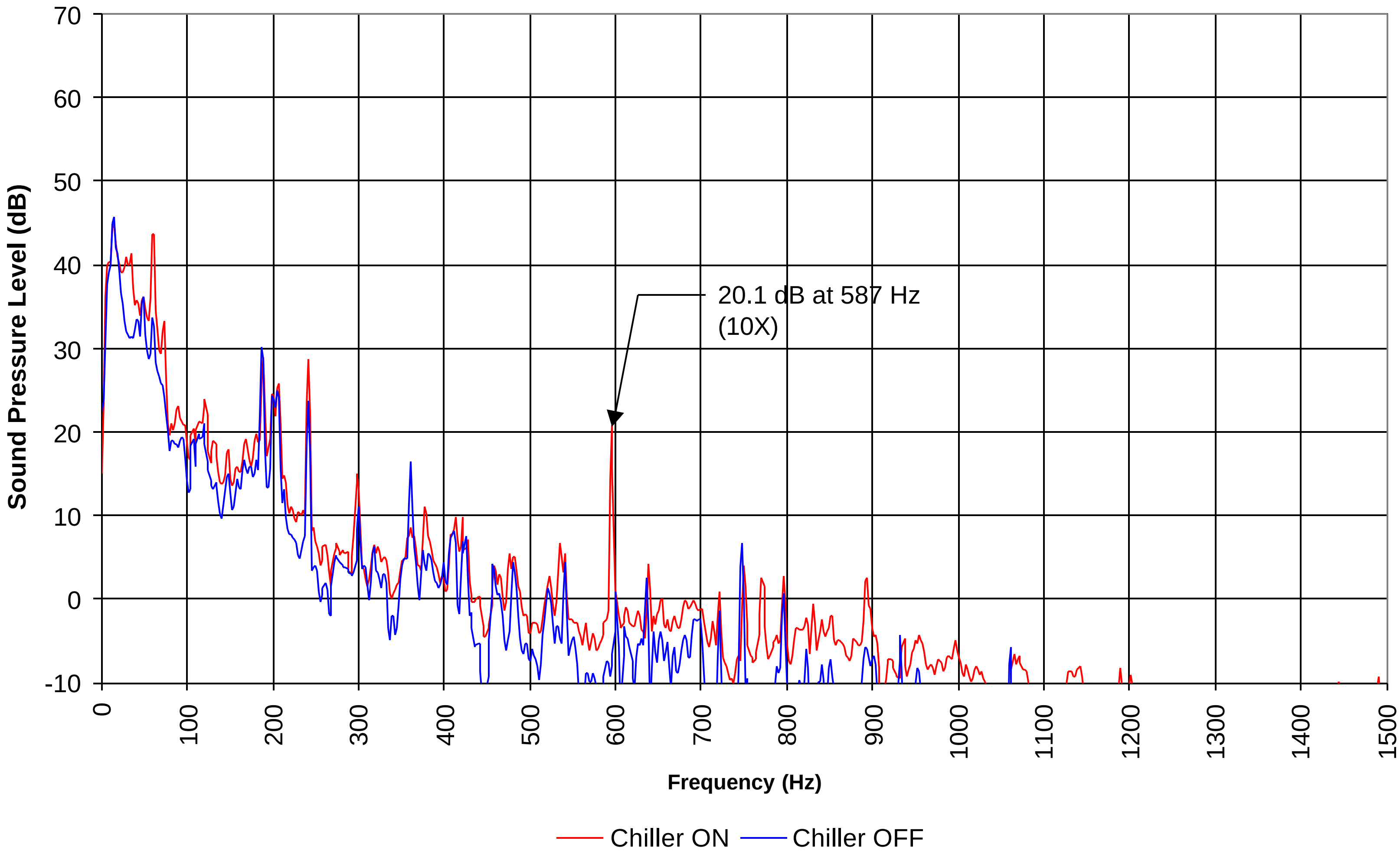


Screw Chiller Noise

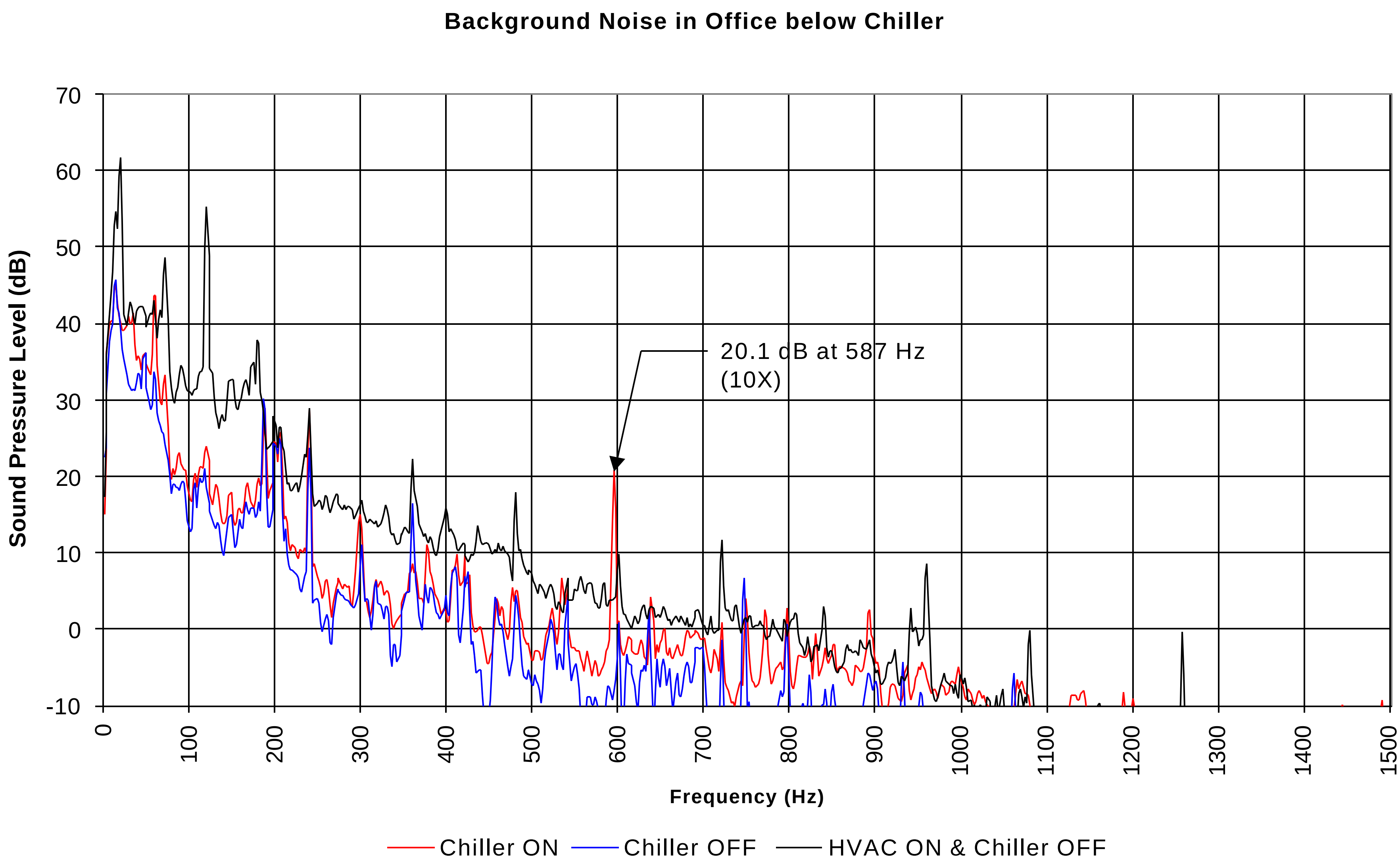


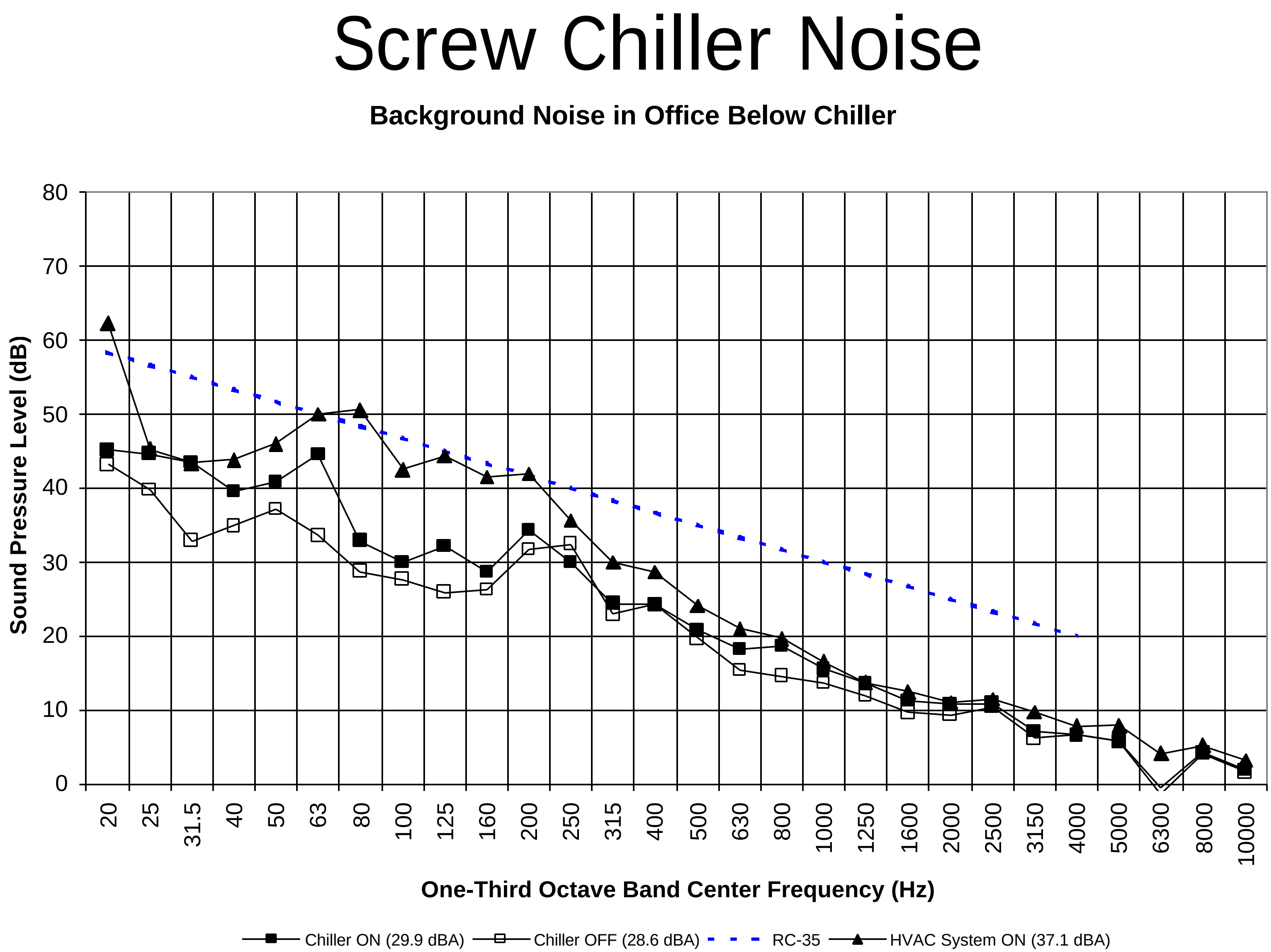
Screw Chiller Noise

Background Noise in Office below Chiller



Screw Chiller Noise





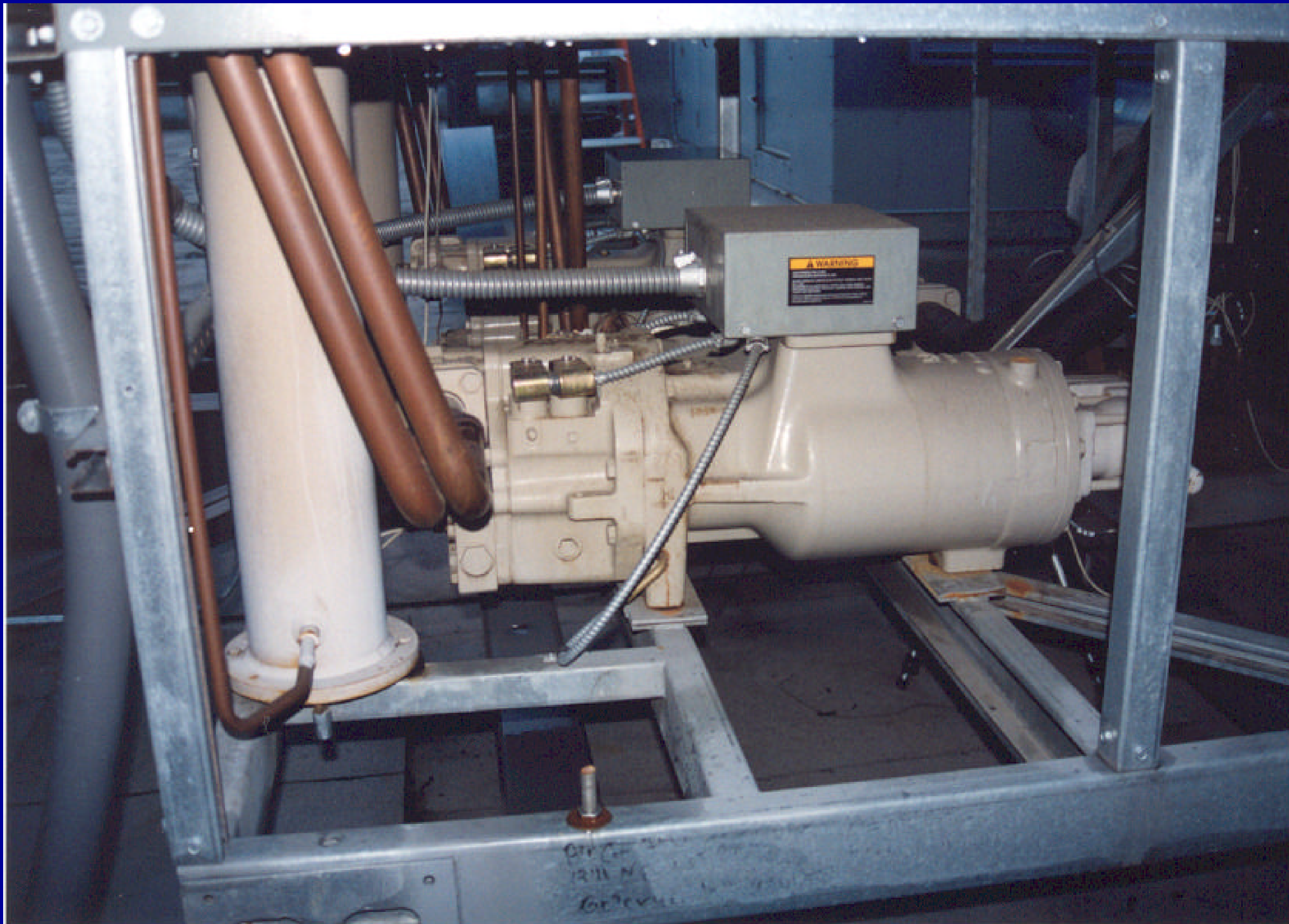
Screw Chiller Noise
Background Noise in Office Below Chiller
Sound Pressure Level (dB)
80
70
60
50
40
30
20
10
0
20
25
31.5
40
50
63
80
100
125
160
200
250
315
400
500
630
800
1000
1250
1600
2000
2500
3150
4000
5000
6300
8000
10000
One-Third Octave Band Center Frequency (Hz)
Chiller ON (29.9 dBA)
Chiller OFF (28.6 dBA)
RC-35
HVAC System ON (37.1 dBA)

Case History: Summary

- Screw chiller is not audible in the office space when HVAC system is operating
- Steel springs can effectively isolate the low frequency vibration of the condenser fans and the screw compressor tones as long as the surge frequencies do not match the driving frequencies

Conclusions

- Screw chillers generate noise and vibration at specific frequencies (integer multiples of LPF)
- Steel springs can effectively isolate the low frequency vibration of the condenser fans
- Be aware of surge frequencies in steel springs - do not use if they fall within 5% of the primary screw compressor frequencies


WARNING