Welcome to Vibrationdata

Acoustics • Shock • Vibration • Signal Processing **December 2005 Newsletter**

Merry Christmas, Happy Hanukkah, Joyous Kwanza, Merry Winter Solstice, Happy Ramadan!

This month's newsletter features four articles. The first article gives on account of the Long Range Acoustic Device, which was recently used to thwart an attack by pirates on a cruise ship.

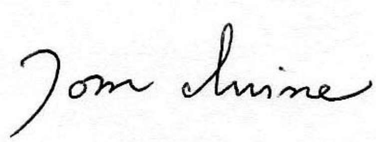
The second article discusses the acceleration levels experienced by American football players. Football is a very popular sport in America, but the potential for concussions and other injuries is very sobering.

The third article presents some reverberation data that I collected during a simple experiment. A balloon pop was used to excite a racquet ball court, producing a sustained echo effect.

The fourth article describes several damping systems that are used to attenuate vibration in the Taipei 101 building in Taiwan. This building must withstand both seismic and wind excitation.

Have a Happy New Year as well!

Sincerely,



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Feature Articles

Please visit: http://www.vibrationdata.com

Long Range Acoustic Device (LRAD™)

By Tom Irvine

Figure 1. LRAD

Introduction

American Technology Corporation in San Diego has developed the LRAD long-range hailing and warning acoustic device for crowd control and for protection against pirates at sea.

The LRAD is a "non-lethal weapon" developed for the U.S. Navy after the deadly attach against the USS Cole in Yemen in 2000.

Woody Norris is the inventor of the LRAD, as well as the chairman of American Technology Corporation.

"We've devised a system with a multiplicity of individual speakers that are phased so sound that would normally go off to the side or up or down, cancels out, while sound directly in front is reinforced," Norris explained. "It's kind of like the way a lens magnifies a beam of light."

The LRAD has a diameter of 33 inches. It is designed to communicate with authority and exceptionally high intelligibility in a 15-30° beam. It can issue a verbal challenge with instructions in excess of 500 meters.

Recorded messages can be selected and transmitted over LRAD in multiple languages. The maximum level for voice communication is 120 dB at one meter.

The LRAD also has the capability of following up with a high-pitched warning tone to "influence behavior."

The LRAD's maximum volume is 150 dB at 1 meter for warning tones. This level will cause permanent damage to hearing. The beam does not harm the operator, however.

The volume is 105 dB at 300 meters. This level is comparable to subway noise or construction noise, but the LRAD warning tone has a much higher frequency.

The shrill tone of the LRAD is similar to that of a smoke detector. A smoke alarm, however, outputs a level of 80 to 90 dB. The amplitude of the LRAD is thus substantially louder.

The tone wails at between 2100 and 3100 Hz, which is the most sensitive part of most people's hearing range.

Seabourn Spirit

The Seabourn Spirit is luxury cruise ship that was attacked by pirates off the eastern coast of Africa on November 5, 2005.

The 440-foot Seabourn Spirit was carrying 208 passengers and a crew of 161.

The Spirit was about 100 miles off the coast of Somalia when pirates fired rocket-propelled grenades and machine guns, as they tried to get onboard.

Figure 2. Seabourn Spirit

Figure 3. Armed Pirates, Photo Courtesy of AP

The gunmen, shown in Figure 3, never got close enough to board the cruise ship, but one crewmember was injured by shrapnel. None of the passengers were hurt.

The ship's crew used the LRAD sonic weapon to repel the attackers.

The crew also fended off the pirates with water hoses.

Furthermore, the Seabourn Spirit escaped the attack by shifting to high speed and changing course, the cruise line said.

This was the first attack on a cruise ship since Palestinian terrorists hijacked the Achille Lauro in the Mediterranean in 1985 and killed a wheelchair-bound American.

Additional Uses

LRAD systems were at hand outside of the Republican National Convention in New York City in 2004. NYPD officers were concerned about controlling protestors. The officers apparently did not need to activate the devices, however.

The devices were also deployed against looters in New Orleans after hurricane Katrina struck in 2005.

Furthermore, the U.S. military is using LRAD systems to deter insurgents in Iraq, particularly in Falluja and Baghdad.

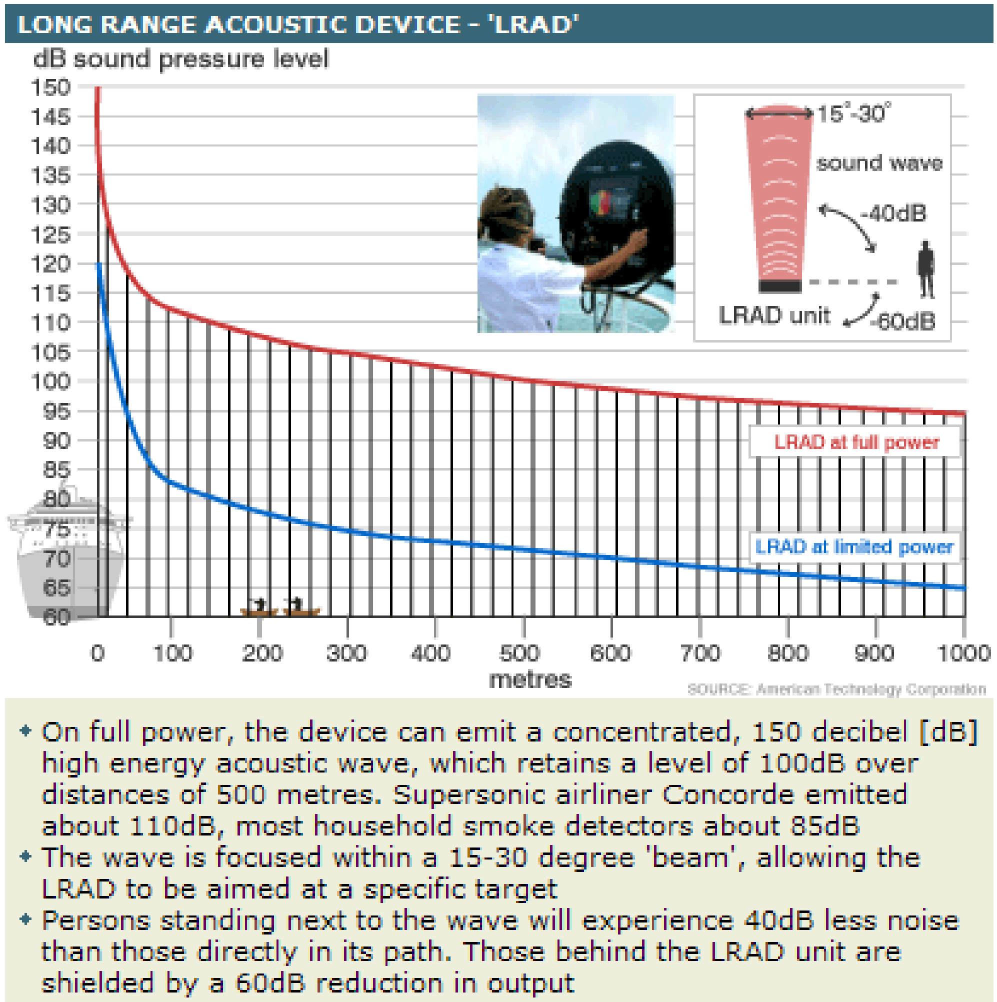
LONG RANGE ACOUSTIC DEVICE - 'LRAD'
dB sound pressure level
150
145
140
135
130
125
120
115
110
105
100
95
90
85
80
75
70
65
60
15°-30°
sound wave
-40dB
LRAD unit
-60dB
LRAD at full power
LRAD at limited power
0
100
200
300
400
500
600
700
800
900
1000
metres
SOURCE: American Technology Corporation
On full power, the device can emit a concentrated, 150 decibel [dB] high energy acoustic wave, which retains a level of 100dB over distances of 500 metres. Supersonic airliner Concorde emitted about 110dB, most household smoke detectors about 85dB
The wave is focused within a 15-30 degree 'beam', allowing the LRAD to be aimed at a specific target
Persons standing next to the wave will experience 40dB less noise than those directly in its path. Those behind the LRAD unit are shielded by a 60dB reduction in output

Figure 4.

Football Player Head Acceleration

By Tom Irvine

Introduction

Biomechanics professor Stefan Duma of Virginia Tech has been measuring the head acceleration sustained by football players. He has collected data from specially designed helmets.

Duma is particularly concerned with concussions resulting from head impacts.

Helmet System

The helmets contain the Head Impact Telemetry System, or HIT System, produced by Simbex of Lebanon, N.H. Six MEMS accelerometers are spring-loaded inside each helmet to record the severity and frequency of individual head impacts in real time, thus creating an "impact history" for each wearer. Impact information detected by sensors is transmitted wirelessly to a laptop computer housed in a compact, sideline console.

Concussions by Position

Duma determined the following list of head impact frequency by position with the first having the highest frequency:

1. Offensive linemen
2. Defensive linemen
3. Running backs
4. Linebackers
5. Wide receivers
6. Defensive backs
7. Quarterbacks

The careers of two prominent NFL quarterbacks were cut short by concussions, even though the quarterback position has the least frequency in the impact list.

San Francisco 49ers Steve Young played in only three games in 1999 before suffering a season-ending blow to the head against the Cardinals on Sept. 27. It was Young's fourth concussion in three years.

Troy Aikman was one of the most dominant professional football players in the United States during the 1990s, leading the Dallas Cowboys to three Super Bowl championships. Aikman sustained ten concussions and several injuries in his career, forcing him to retire in 2001.

Concussions

Concussions are the result of an electrical discharge that sweeps through the brain after a heavy blow to the head. The injured region will quickly try to repair itself, rerouting functions in a hypermetabolic state that temporarily impairs memory and the ability to make calculations.

The effect of a concussion may not be readily apparent, unlike other sports injuries.

"With athletes, 90 percent of the time they are still walking around after a concussion," said Dr. Julian Bates, a neurological consultant with the NFL Players Association and former team physician for the Pittsburgh Steelers.

Unfortunately, players are reluctant to report their concussions because they are conditioned to shrug off injuries.

Concussions are thus difficult to diagnose.

Headaches and dizziness are short-term symptoms of concussions, in addition to memory loss.

Long term effects include an increased risk for the following disorders:

1. Clinical depression
2. Stroke
3. Alzheimer's disease
4. Parkinson's disease

Death and Paralysis

As troubling as concussions may be, they are far from the worst possible consequence.

Frederick Mueller is head of the department of exercise and sports science at the University of North Carolina. Mueller said "Every year we have six or eight players die from head injuries. We also have a large number who have permanent brain damage or permanent paralysis."

The six to eight deaths include high school, college and professional leagues.

Acceleration Levels

One of Duma's studies showed that the average impact is 40 G. This level is similar to the force generated by a boxer's gloved punch.

The hardest hits measured more than 130 G. "An impact of 120 G would be like a severe car accident which you could survive if you were wearing a seatbelt," Duma said.

Furthermore, linemen may experience 50 or 60 significant blows during a game.

The direction of the blow is just as important in causing a concussion as the force of the impact. A player who sustains a 130 G frontal impact might walk away from the play without a concussion. On the other hand, the same player could experience a 70 or 80 G lateral or posterior blow that could leave him with concussion symptoms.

Conclusion

Duma hopes that this acceleration data will lead to the design of safer helmets.

As an alternative, the HIT system can be used to determine when a player should be brought out of a game.

Simple Measurement of Room Reverberation Time

By Tom Irvine

Figure 1. Racquetball Court

Introduction

Reverberation is the echo effect which occurs in a room due to sound reflection.

Measurement

Reverberation time is measured by exciting a room with an impulse source. The response is measured by a microphone. The time required for the sound pressure level to decay by 60 dB is taken as the reverberation time, designated RT60. Extrapolation can be used if a full 60 dB decay cannot be measured.

Furthermore, the sound pressure is typically bandpass filtered in terms of octave bands. The reverberation time for each band is then calculated.

Design Criteria

A moderate amount of reverberation enhances both symphony music and speech.

A solemn, slow organ melody is enhanced by long reverberation. Quick rhythmic music is better served by a shorter reverberation time. In general, music needs a greater amount of reverberation time than speech.

Excessive reverberation time can make speech unintelligible. Specifically, reverberation can mask "lower level consonants."

Churches and other auditoriums must often accommodate both speech and music. Thus, some compromise is needed.

Experiment

A balloon pop serves as a simple impulse source. This method was used to excite the acoustic modes of the racquetball court in Figure 1. The court consists of bare concrete surfaces. The floor is 40 feet by 20 feet. The ceiling is 20 feet high. The ceiling only covers about one-third of the top, however. Thus, the court is partially open at the top.

The choice of the court for this experiment was somewhat arbitrary. The same method could be used in an auditorium or a household room. Nevertheless, the court is an interesting test specimen due to its long reverberation time.

The resulting echo inside the court from the balloon pop was recorded on a tape recorder, which was later digitized in a computer via a sound card. The acoustic pressure time history is shown in Figure 2. The amplitude scale is uncalibrated. The portion of the signal prior to the main pulse is due partially to ambient environment noise and partially to spurious instrumentation noise.

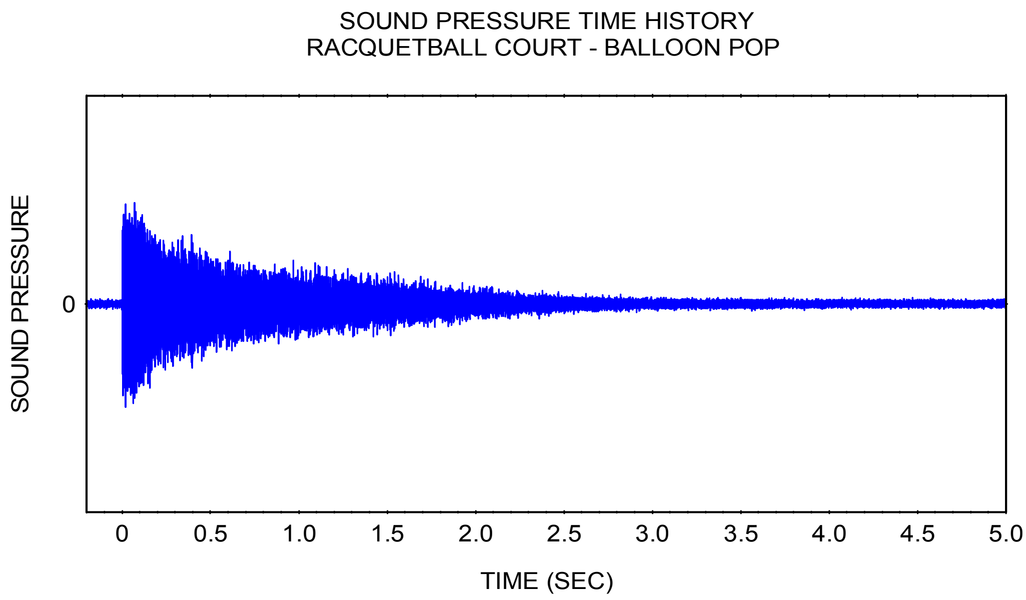

Figure 2.

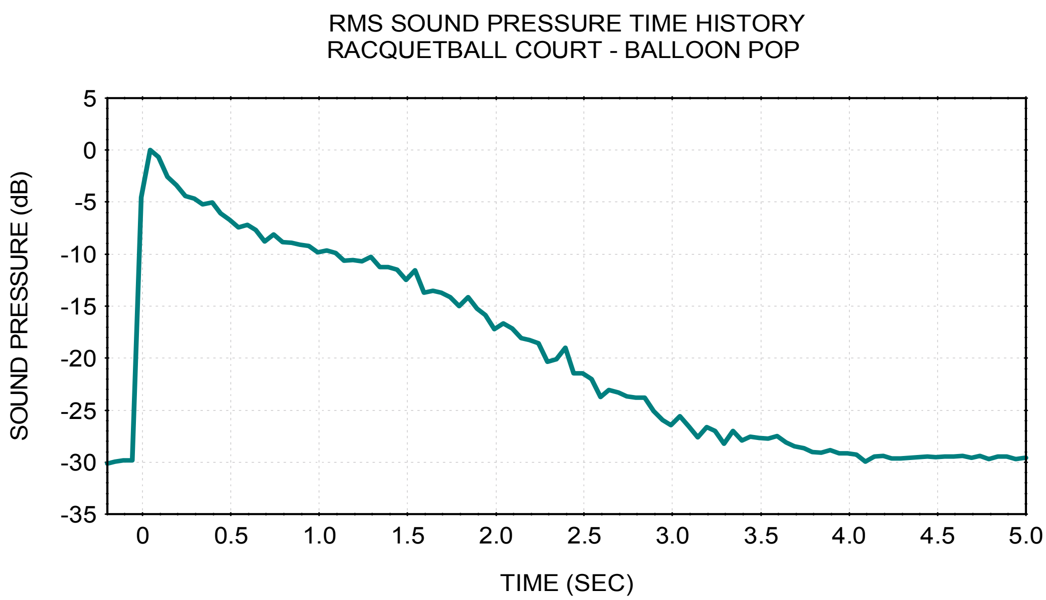

Figure 3.

The RMS time history in Figure 3 represents the entire frequency bandwidth. The curve is normalized so that its peak value is zero dB. For calculation purposes, the ideal decay slope would be a straight line. The measured data departs somewhat from this ideal. The time required for a 30 dB decay is about 4.0 seconds. The RT60 value is thus 8.0 seconds.

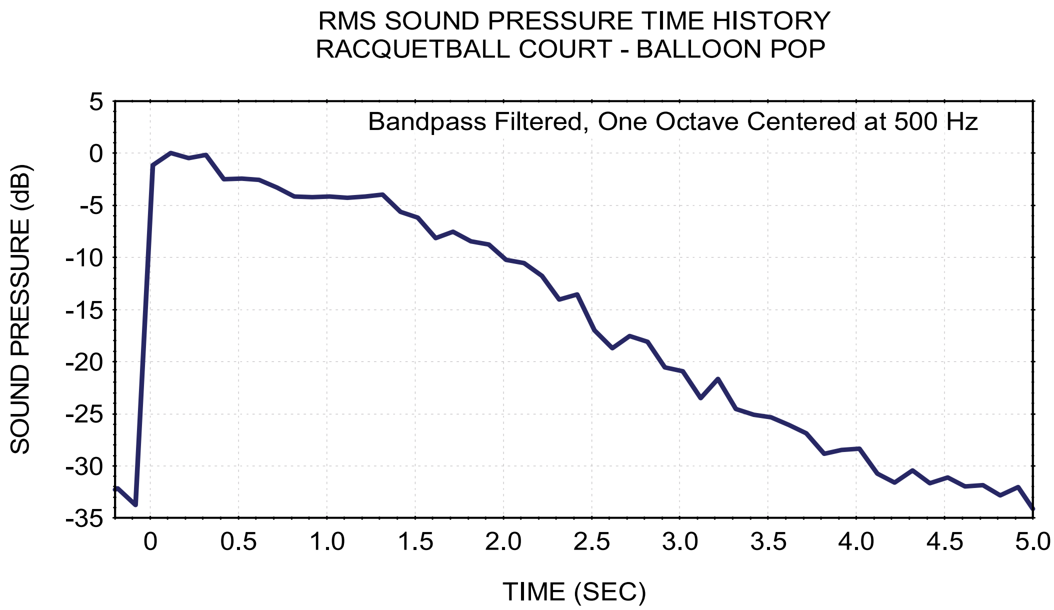

Figure 4.

The RT60 for the band centered at 500 Hz is also about 8.0 seconds. Again, the curve is normalized.

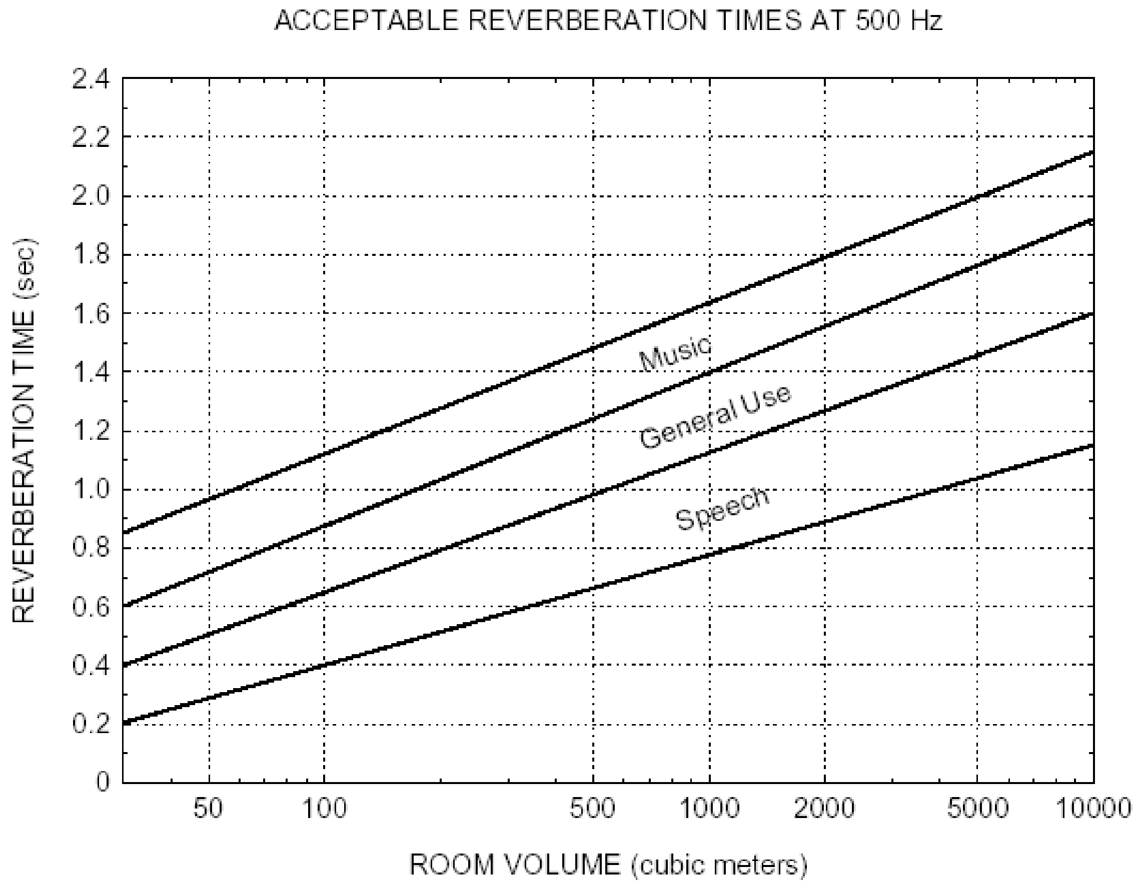

Figure 5.

The racquetball court has a volume of 16000 ft^3, or 453 m^3. Again, it has an RT60 reverberation time of 8.0 seconds at 500 Hz. The maximum acceptable reverberation time for this space is about 1.5 seconds for music and 1.0 seconds for speech.

Clearly, the racquetball court is unacceptable for speech or music, although this was obvious without the experiment.

The Reference for Figure 5 is:

Anonymous, Pocket Handbook Noise, Vibration, Light, Thermal Comfort, Bruel & Kjaer, Denmark, 1986.

Taipei 101 Building Tuned Mass Damper by Tom Irvine

Figure 1. Taipei 101 Building

Figure 2. Steel Sphere

Introduction

The Taipei 101 building is the tallest skyscraper in Taipei, Taiwan. It has 101 floors above ground and 5 floors below ground. Its height is 508 meters (1667 feet).

By some standards, the Taipei 101 building is the tallest building in the world. It is the tallest building in terms of ground to structural top.

However, the Sears Tower is taller in terms of ground to pinnacle height, at 529 meters (1703 feet).

The Taipei 101 building was opened on December 31, 2004.

Construction

The Taipei 101 building has a relatively stiff structure. The structural design utilizes steel supercolumns that contain reinforced concrete up to level 62, including a total of 95,000 tonnes of high strength steel (SM570M) and 23,900 m^3 of high-strength concrete (70 mPa).

The natural vibration period predicted during the design phase was 6.8 seconds, per Reference 1. The actual period of the constructed building is not immediately available.

The building must withstand both winds and earthquakes. The wind types include both moderate winds and typhoons. The building has several damping systems to attenuate the vibration from both winds and seismic excitation.

There are two concerns in this regard. One is to prevent structural fatigue. The other is to maintain occupant comfort. Note that some people may experience motion sickness if they are at the top of a tall swaying building.

Spherical Damper Design

The Taipei 101 building has a pendulum which serves as a passive tuned mass damper.

The pendulum is suspended between the 92nd floor and the 88th floor. It reduces 40% of the horizontal displacement from earthquakes and gales.

The pendulum consists of a sphere suspended by wire cables. The sphere is designed to swing back and forth up to 1.5 meters (5 feet) during a severe typhoon. Bumpers prevent the sphere from swinging further.

The sphere weighs 730 tons (660 metric tons). It consists of 41 circular steel plates that are welded together. It is painted gold. It is intended to be ornamental as well as functional. Furthermore, it is the world’s largest tuned mass damper in terms of size and weight.

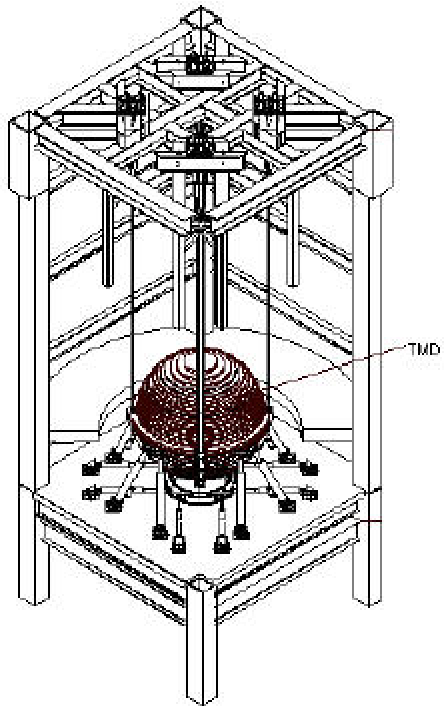

Figure 3. Spherical Damping System

The spherical tuned mass damper works as an inertial counterbalance to the swaying of the mass of the tower's superstructure.

Spherical Damper Natural Frequency

The pendulum's natural frequency fn is given by

$$fn = \frac{1}{2\pi}\sqrt{\frac{g}{L}} \quad (1)$$

where

g is the acceleration of gravity

L is the length from the pivot to the sphere center of mass

The period T is the inverse of the natural frequency.

$$T = 1/fn \quad (2)$$

The pendulum is tuned to match the natural period of the building. The theoretical cable length L is thus 11.5 meters (38 feet) per equations (1) and (2). The as-built length is not immediately available, but one source stated that the length could be adjusted as necessary to match the actual period of the building.

In addition, the sphere is connected to pistons which drive oil through small holes, thus providing viscous damping. The vibration energy is converted to heat by this damping.

Resulting Attenuation

The building spherical damper will reduce the peak acceleration of the top occupied floor from 7.9 milli-g to 5.0 milli-g, during the strongest wind storm expected to occur in half of a year, according to the Taipei local meteorological records.

Note that 1milli-g is 1/1000 of Earth's standard gravity.

This performance is shown graphically in Figure 4, and contrasted against the ISO acceleration criteria, as well as the Taiwanese criteria of 5.0 cm/sec^2 (5.1milli-g).

An amplitude of 5 milli-g may seem negligibly small. The corresponding peak-to-peak displacement at a natural period of 6.8 seconds is 11.5 cm (4.5 inches), however.

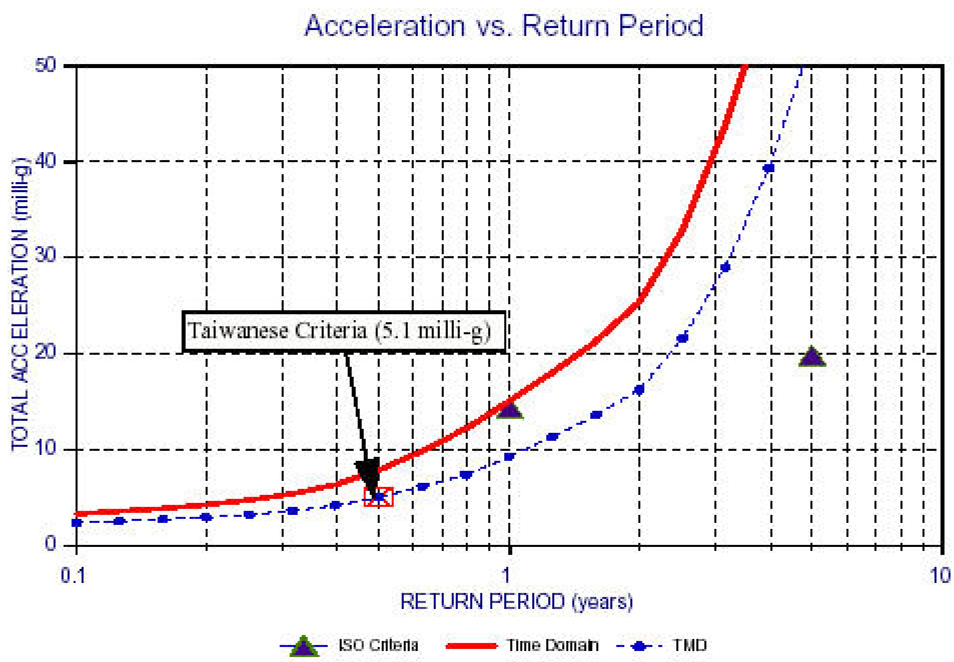

Figure 4.

Pinnacle Dampers

The slender Pinnacle has a number of vibration modes which may be exited by vortex induced oscillation at common wind speeds. Two particular frequencies of concern are at 0.86 Hz and 1.08 Hz.

These frequencies are too far apart to be effectively controlled by a single tuned mass damper. Therefore, two separate dampers have been designed, as shown in Figure 5 on the next page. Each damper is built to target a different structural frequency, and controls the amplitude in both principal perpendicular directions.

Reference

1. Tuned Mass Dampers Under Excessive Structural Excitation, T. Haskett, B. Breukelman, J. Robinson, J. Kottelenberg, Motioneering Inc., Guelph, Ontario, Canada N1K 1B8.

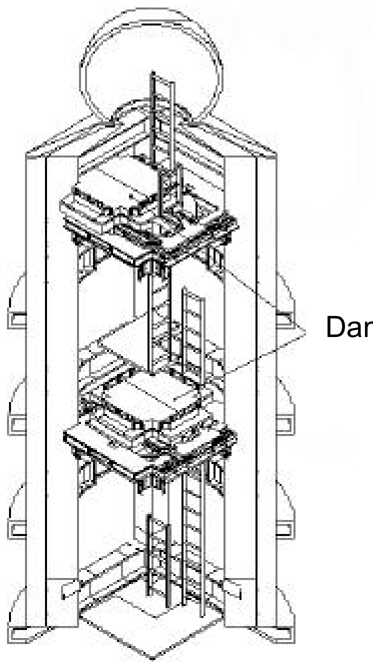

Figure 5. Pinnacle Dampers