

NEBB Annual Meeting 2013

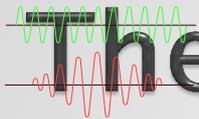
Vibration and Sound Testing/Analysis/Commissioning

Benefits to owners

VIBRATION and SOUND

THE COST OF HAVING TOO MUCH AND
THE BENEFITS OF SOLVING IT

The Sign of Vibration



- ▶ Noisy unit can create audible noise in tenant spaces
- ▶ Early Breakdown & unscheduled manpower
- ▶ High initial costs for repairs
- ▶ Unhappy Customers not renewed Leases
- ▶ Increased office paperwork (parts ordering, sales allowances, factory conflicts)
- ▶ Lower profit on jobs
- ▶ Lost future Sales

WHY COMMISSION YOUR EQUIPMENT

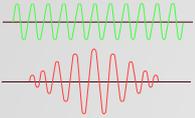
- ▶ IT SAVES **MONEY!!!!**
- ▶ CHECKS EQUIPMENT INTEGRITY BEFORE TURN OVER AND/OR DURING WARRANTY EQUIPMENT—THIS GIVES A “BASELINE” COMPARISON TO FUTURE TESTING TO DETERMINE IF EQUIPMENT IS DEGRADING AND WHEN TO SCHEDULE REPAIRS TO BE PERFORMED MOST COST EFFECTIVELY

Vibration Analysis–Benefits \$\$

- ▶ Early Equipment Fault Diagnosis
- ▶ Ability to Baseline Equipment Vibration
- ▶ Ability to Balance Rotating Equipment
- ▶ Ability to Align Equipment Properly
- ▶ Ability to Check for Proper Unit Installation
- ▶ Ability to Check While a Rebuild/Overhaul is in Progress.
- ▶ Your Customer will be Confident in Your Ability.

Sound Analysis – Benefits \$\$ before construction

- ▶ Determine if adjacent tenant spaces are in conflict best determined during design commissioning phase
- ▶ Cost to remediate high
 - 4 to 20 times what would have been original costs
 - Loss of facility usage during remediation
 - Uncompensated loss of time for tenant, building owner and contractors
- ▶ Your Customer will be Confident in Your Ability.



Costs of Startup Failure mid 1990's

- ▶ Mechanical Contractor ▶ \$5,000
- ▶ Replace Original Parts ▶ \$3,500
- ▶ VA Diagnosis & Balance ▶ \$1,000
- ▶ Purchase new parts ▶ \$250
- ▶ Paperwork ▶ \$500
- ▶ Good will loss ▶ \$\$\$\$
- ▶ Total Measurable Costs ▶ \$10,250

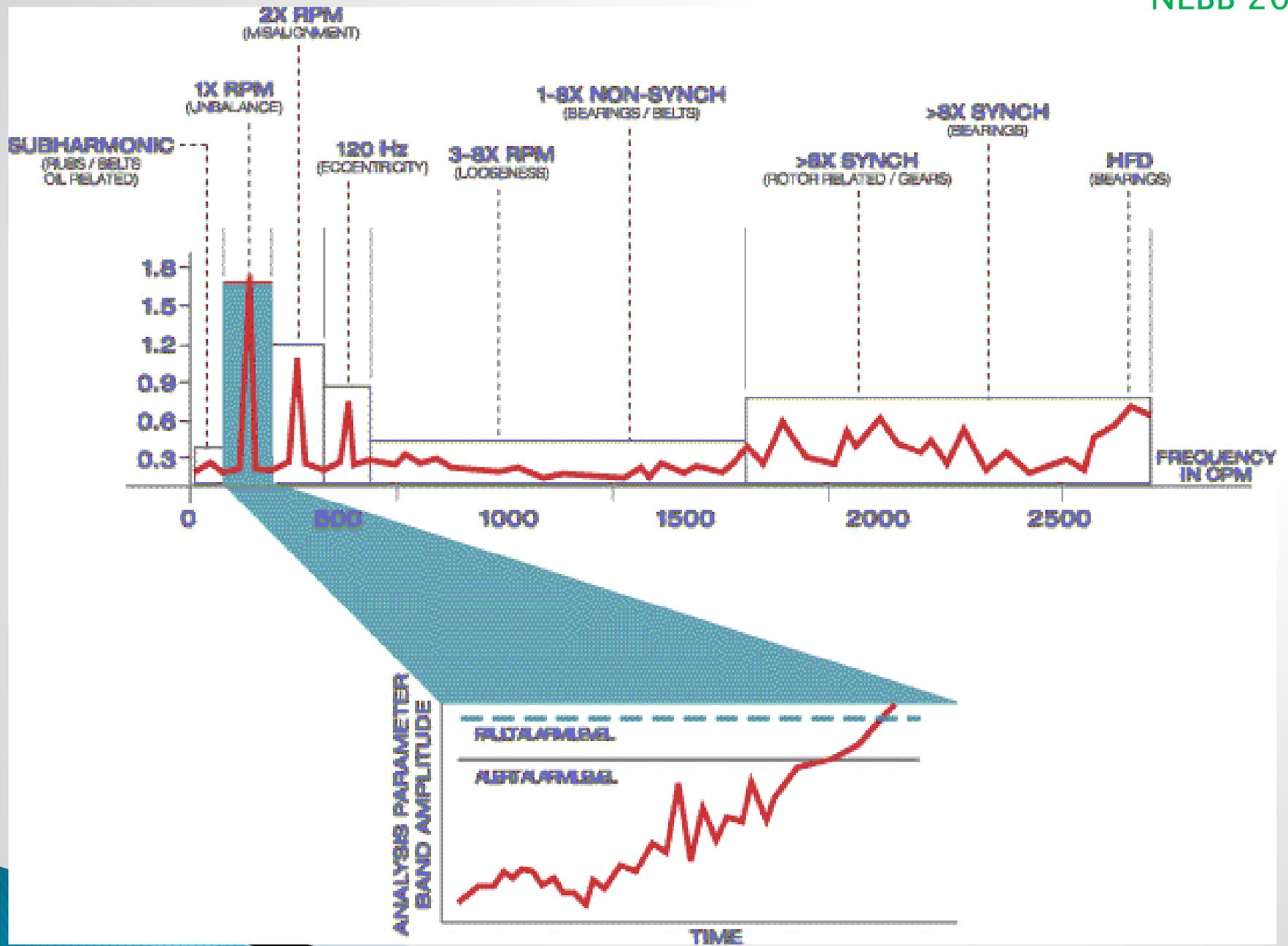
**very old numbers– meant to be generic

The Sign of NO Vibration and Acceptable Noise

- ▶ Quiet/Smooth Equipment Operation
- ▶ Minimum Wear to Rotating Parts
Maximum Life Expectancy on HVAC Unit
- ▶ Good Customer Relationships
- ▶ Repeat Sales
- ▶ Happy Bldg. Occupants / Happy Bldg. Owners

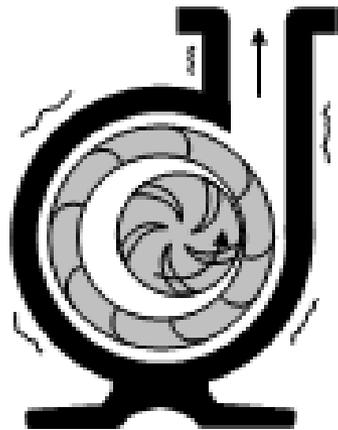
Vibration Analysis Program

- ▶ How to Establish a Workable Program?
 - Start with baseline commissioning
 - Setup Procedures
 - Measurements are taken and Spec's are to be met on all chiller overhauls. Fan/pump aligned & other checks performed.
 - Customer Noise and Vibration Complaints are directed to the VA group to see if they can diagnose the problem.
 - Training_Etc.

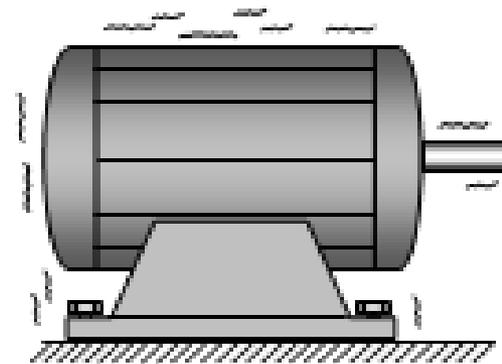


- ▶ Why is Monitoring Vibration Important?
- ▶ Monitoring machine vibration and using the information you obtain saves money!
- ▶ How is this possible?

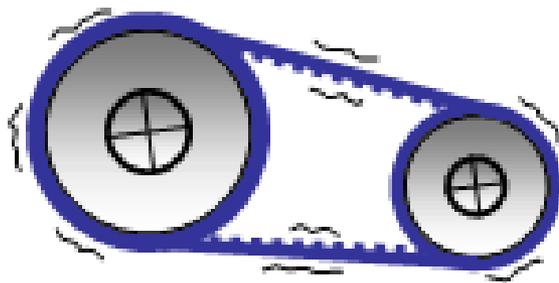
- ▶ Machine vibration can take various forms. A machine component may vibrate over large or small distances, quickly or slowly, and with or without perceptible sound or heat. Machine vibration can often be intentionally designed and so have a functional purpose.
- ▶ At other times machine vibration can be unintended and lead to machine damage.
- ▶ Most times machine vibration is unintended and undesirable. This is about the monitoring of undesirable machine vibration.
- ▶ Shown below are some examples of undesirable machine vibration.



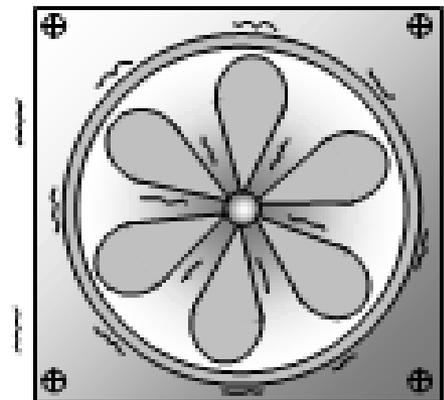
Vibrating Pumps



Vibrating Motors



Vibrating Belts

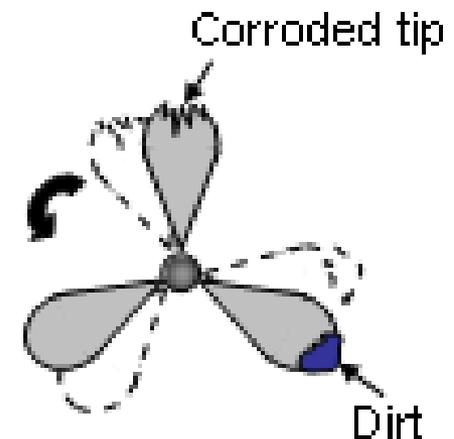
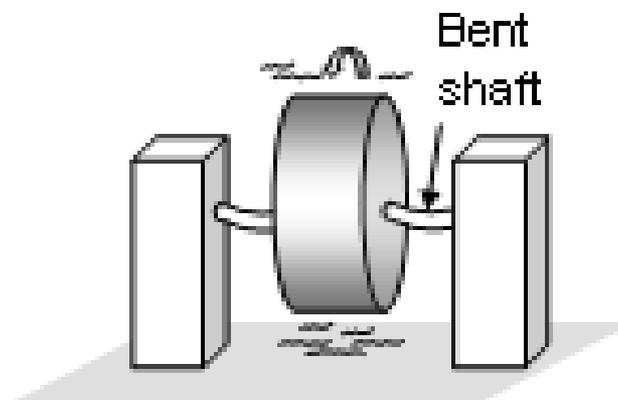
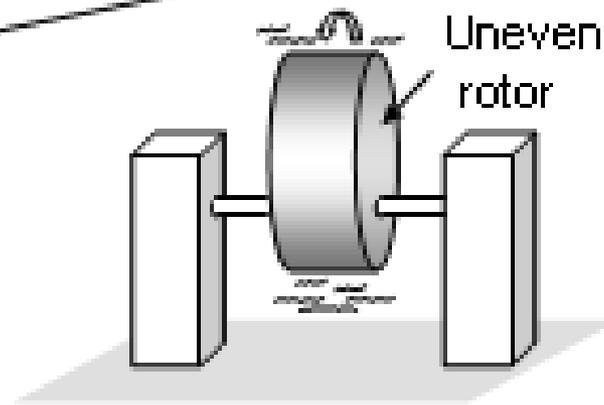


Vibrating Fans

- ▶ What Causes Machine Vibration?
- ▶ Almost all machine vibration is due to one or more of these causes:
 - ▶ (a) Repeating forces
 - ▶ (b) Looseness
 - ▶ (c) Resonance
- ▶ Imagine a boat anchored in a bay. Waves are slapping the sides of the boat, and as long as the waves continue to act on the boat we would expect the boat to rock.
- ▶ The boat would be rocking because the waves would be exerting a repeating force on the boat – a force of a pattern repeated over and over again.
- ▶ Most machine vibration is due to repeating forces similar to those causing the boat to rock. Repeating forces such as these act on machine components and cause the machine to vibrate.
- ▶ Where do the repeating forces that cause machine vibration come from?

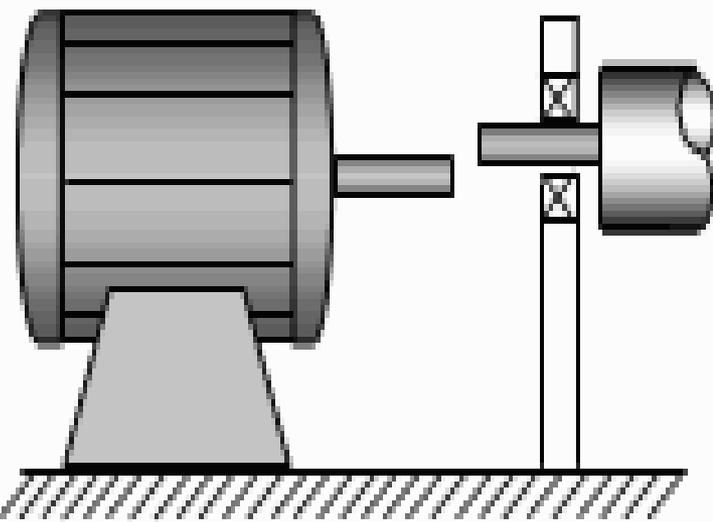
- ▶ Repeating forces in machines are mostly due to the rotation of imbalanced, misaligned, worn, or improperly driven machine components.
- ▶ Examples of these four types of repeating forces are shown below.

Imbalanced machine components contain 'heavy spots' which when rotated, exert a repeating force on the machine. Imbalance is often caused by machining errors, non-uniform material density, variation in bolt sizes, air cavities in cast parts, missing balance weights, incorrect balancing, uneven electric motor windings, and broken, deformed, corroded, or dirty fan blades.

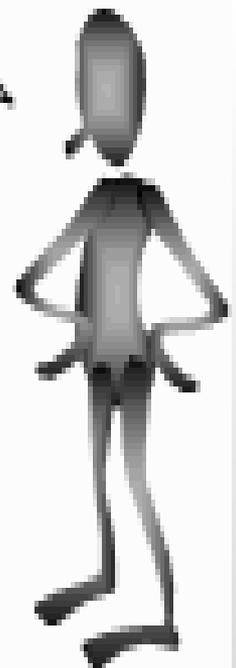
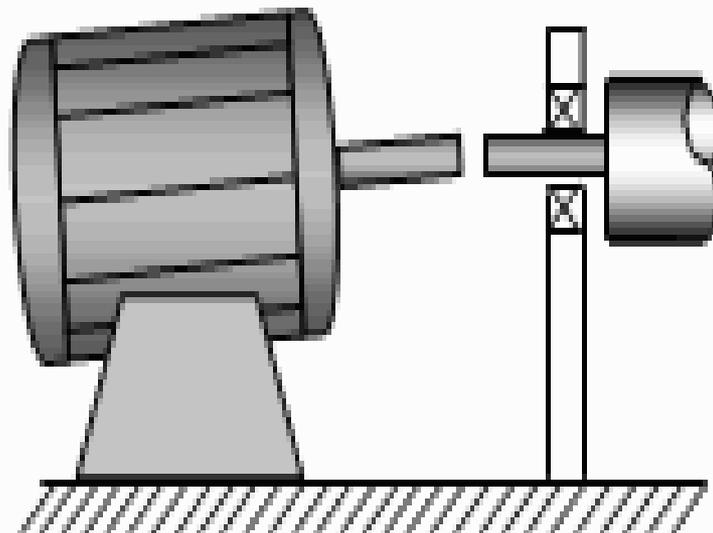


Misaligned machine components create "bending moments" which when rotated, exert a repeating force on the machine. Misalignment is often caused by inaccurate assembly, uneven floors, thermal expansion, distortions due to fastening torque, and improper mounting of couplings.

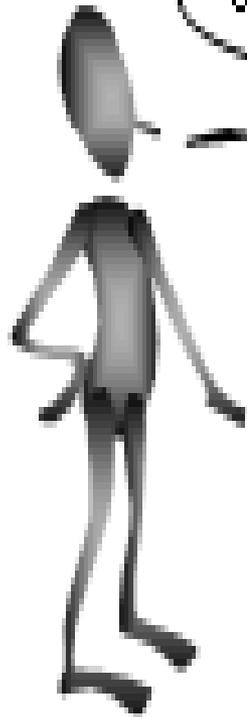
Parallel misalignment



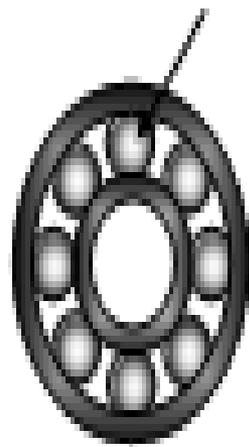
Angular misalignment



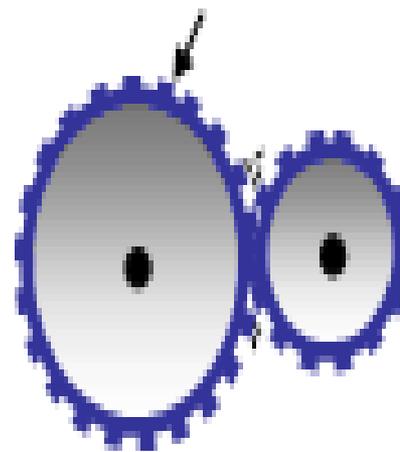
Worn machine components exert a repeating force on the machine because of the rubbing of uneven worn surfaces. Wear in roller bearings, gears, and belts is often due to improper mounting, poor lubrication, manufacturing defects, and overloading.



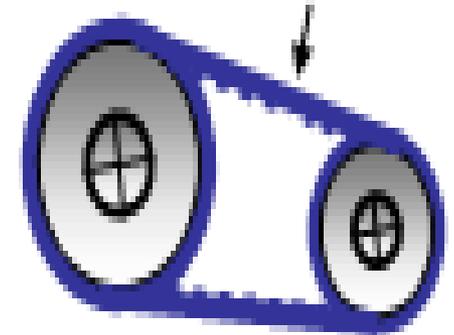
Worn rollers



Worn teeth



Worn belt



Improperly driven machine components exert a repeating force on the machine because of intermittent power supply. Examples include pumps receiving air in pulses, internal combustion engines with misfiring cylinders, and intermittent brush-commutator contact in DC motors.

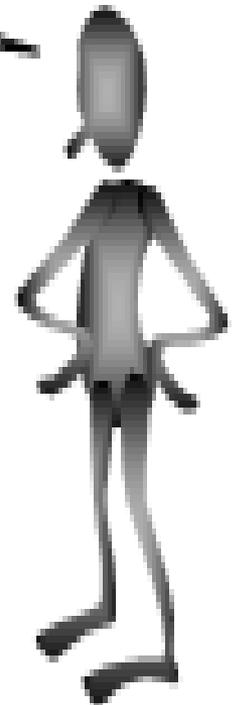
Uneven
air supply



Misfiring
cylinder



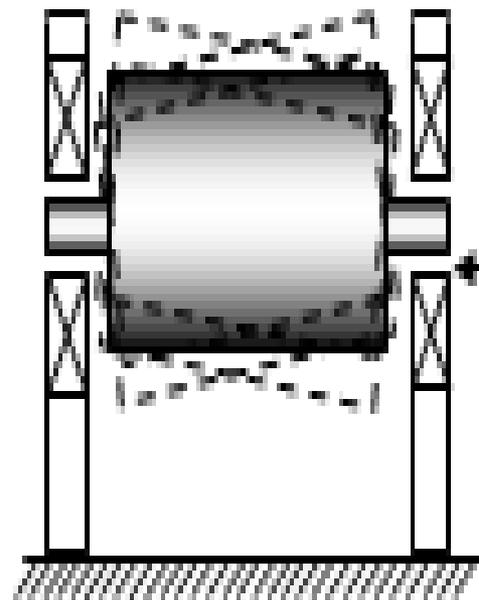
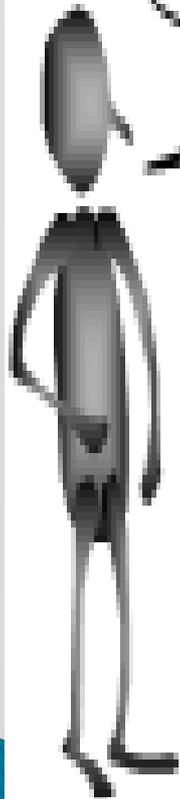
Intermittent
brush
contact



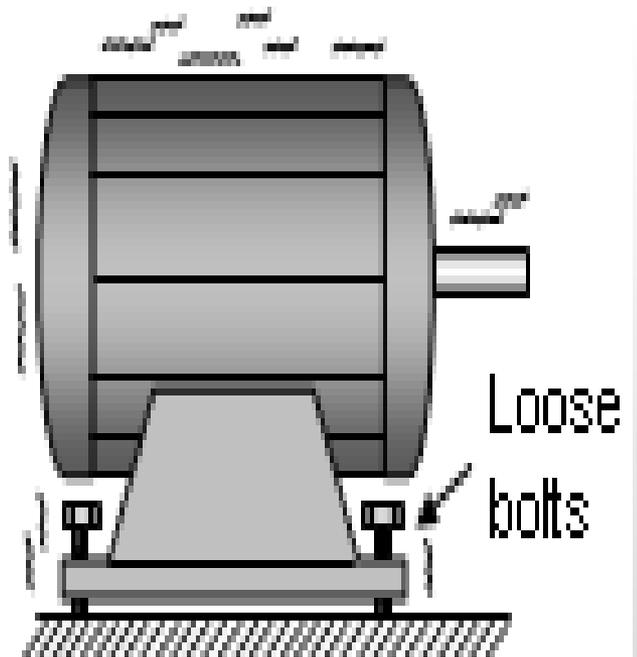
Looseness

- ▶ Looseness of machine parts causes a machine to vibrate. If parts become loose, vibration that is normally of tolerable levels may become unrestrained and excessive.

Looseness can cause vibration in both rotating and non-rotating machinery. Looseness is often due to excessive bearing clearances, loose mounting bolts, mismatched parts, corrosion, and cracked structures.



Excessive
clearance



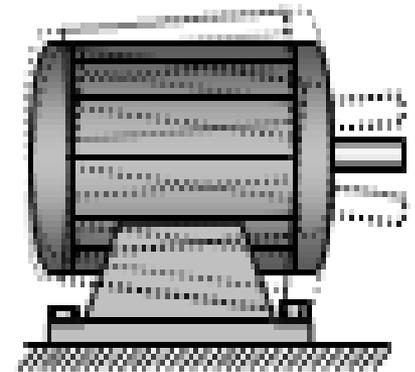
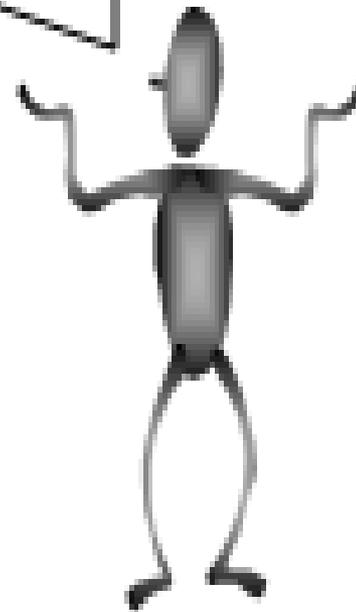
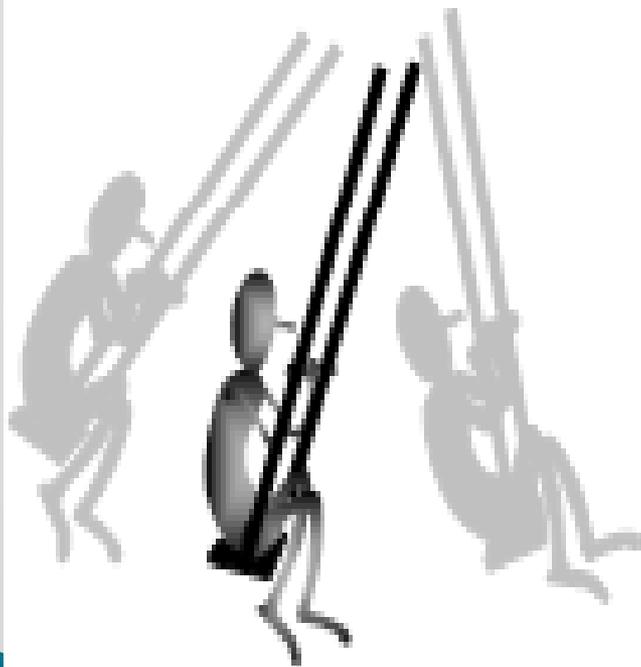
Loose
bolts

Resonance

- ▶ Imagine a child swinging freely on a swing, that is, without the child propelling himself or anyone pushing him. If we observe the motion closely we will see the child swinging at a particular rate. For example, we may see that it consistently takes him three seconds to complete one cycle of swinging.
- ▶ The rate of the child's free-swinging is in fact a physical property of the child-swing system – much as the weight of the child is a physical property of the child. It is the rate at which the child will tend to swing while seated on that particular swing.

RESONANCE

Just as a swing has a natural swinging rate, machines have natural oscillation rates.



RESONANCE

- ▶ Machines also tend to vibrate at certain oscillation rates. The oscillation rate at which a machine tends to vibrate is called its natural oscillation rate.
- ▶ A machine left to vibrate freely will tend to vibrate at its natural oscillation rate.
- ▶ Most machines have more than one natural oscillation rate.
- ▶ In general, the more complex the machine, the more natural oscillation rates it has.

RESONANCE

- ▶ Now consider again the child on the swing.
- ▶ If we aided the swinging motion by repeatedly pushing the child, we would expect the child to swing higher and higher over time.
- ▶ We would however only cause the child to swing higher and higher if we pushed with the right rhythm.
- ▶ If our pushing rhythm is such that he is sometimes pushed down while he is ascending, we would not expect him to swing properly.
- ▶ To make him swing higher and higher, our pushing rhythm would in fact need to be in harmony with his natural oscillation rate.
- ▶ For example, we could push him every time – or every alternate time – he reaches his highest point. Only by pushing the child at a rate which is in harmony with his natural or preferred oscillation rate can we cause him to quickly swing higher and higher.

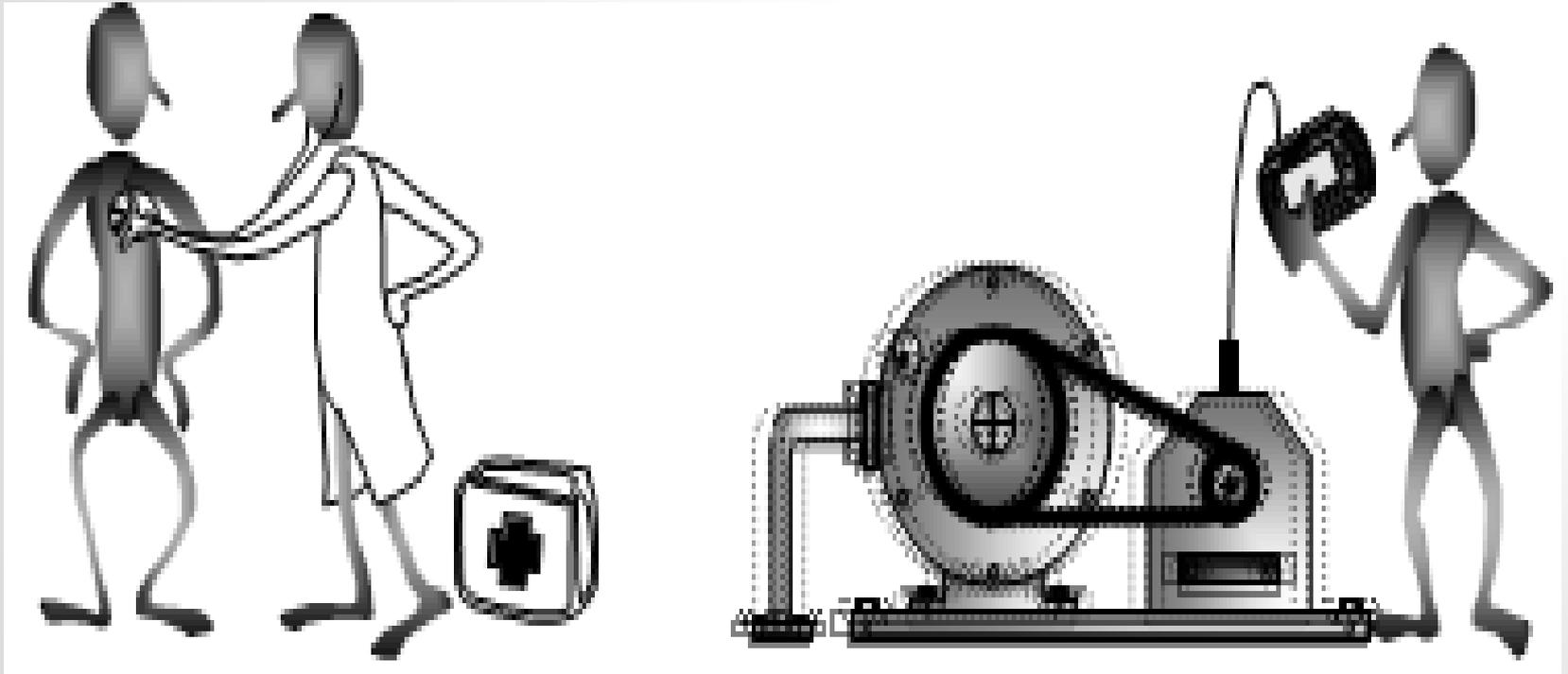
- ▶ What happens if a machine is 'pushed' by a repeating force with a rhythm matching the natural oscillation rate of the machine?

- ▶ A similar situation will arise – the machine will vibrate more and more strongly due to the repeating force encouraging the machine to vibrate at a rate it is most natural with.
- ▶ The machine will vibrate vigorously and excessively, not only because it is doing so at a rate it 'prefers' but also because it is receiving external aid to do so.
- ▶ A machine vibrating in such a manner is said to be experiencing **resonance.**

- ▶ A repeating force causing resonance may be small and may originate from the motion of a good machine component.
- ▶ Such a mild repeating force would not be a problem until it begins to cause resonance.
- ▶ Resonance, however, should always be avoided as it causes rapid and severe damage.
- ▶ For example, whole bridges have collapsed due to their natural oscillation rates being excited by the mere rhythm of soldiers marching in unison across the bridges.

Why Monitor Machine Vibration?

- ▶ To do a good job of monitoring machine vibration and to fully reap the benefits, we must understand the answers to the above question.
- ▶ Monitoring the vibration characteristics of a machine gives us an understanding of the 'health' condition of the machine.
- ▶ We can use this information to detect problems that might be developing.



- ▶ Why be concerned about the condition of a machine?
- ▶ Why not just continue to run the machine until it breaks down and then repair it?
- ▶ Operating a machine until it breaks down might be acceptable if the machine were a 'disposable' one. Most machines, however, are not 'disposable' due to their cost.

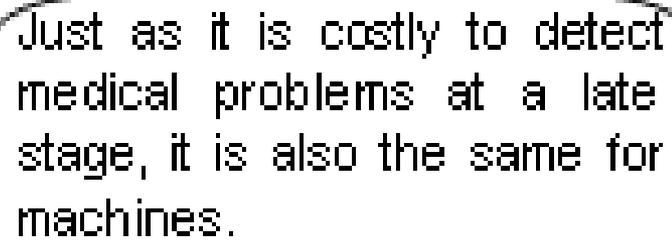
- ▶ If we regularly monitor the conditions of machines we will find any problems that might be developing, therefore we can correct the problems even as they arise.
- ▶ In contrast, if we do not monitor machines to detect unwanted vibration the machines are more likely to be operated until they break down.

- ▶ Because machine vibration monitoring finds potentially damaging vibration, we can prevent problems arising and this saves a lot of time, money, and frustration.
- ▶ How?

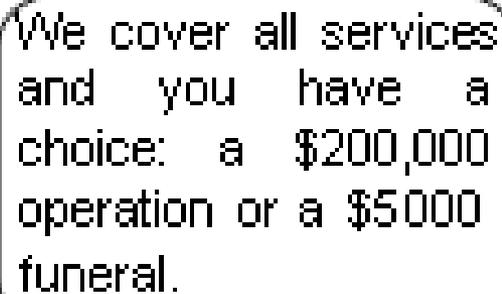
- ▶ Below we discuss some common problems that can be avoided by monitoring machine vibration.
- ▶ These problems are worth avoiding as the costs of dealing with them are large and far exceed the cost of reasonably priced machine vibration monitoring programs.

Severe Machine Damage

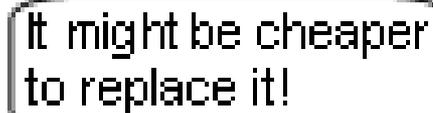
- ▶ Machine vibration that is not detected early enough will often lead to severe machine damage requiring costly repairs or even total machine replacement.
- ▶ However, if the condition of a machine is monitored regularly, potential problems can be detected – and corrected – at an early stage when the repair required is simpler, faster, and cheaper.
- ▶ This is similar to our own health. Regular visits to a doctor help us to detect problems early and so avoid the large costs of remedying severe health damage.



Just as it is costly to detect medical problems at a late stage, it is also the same for machines.



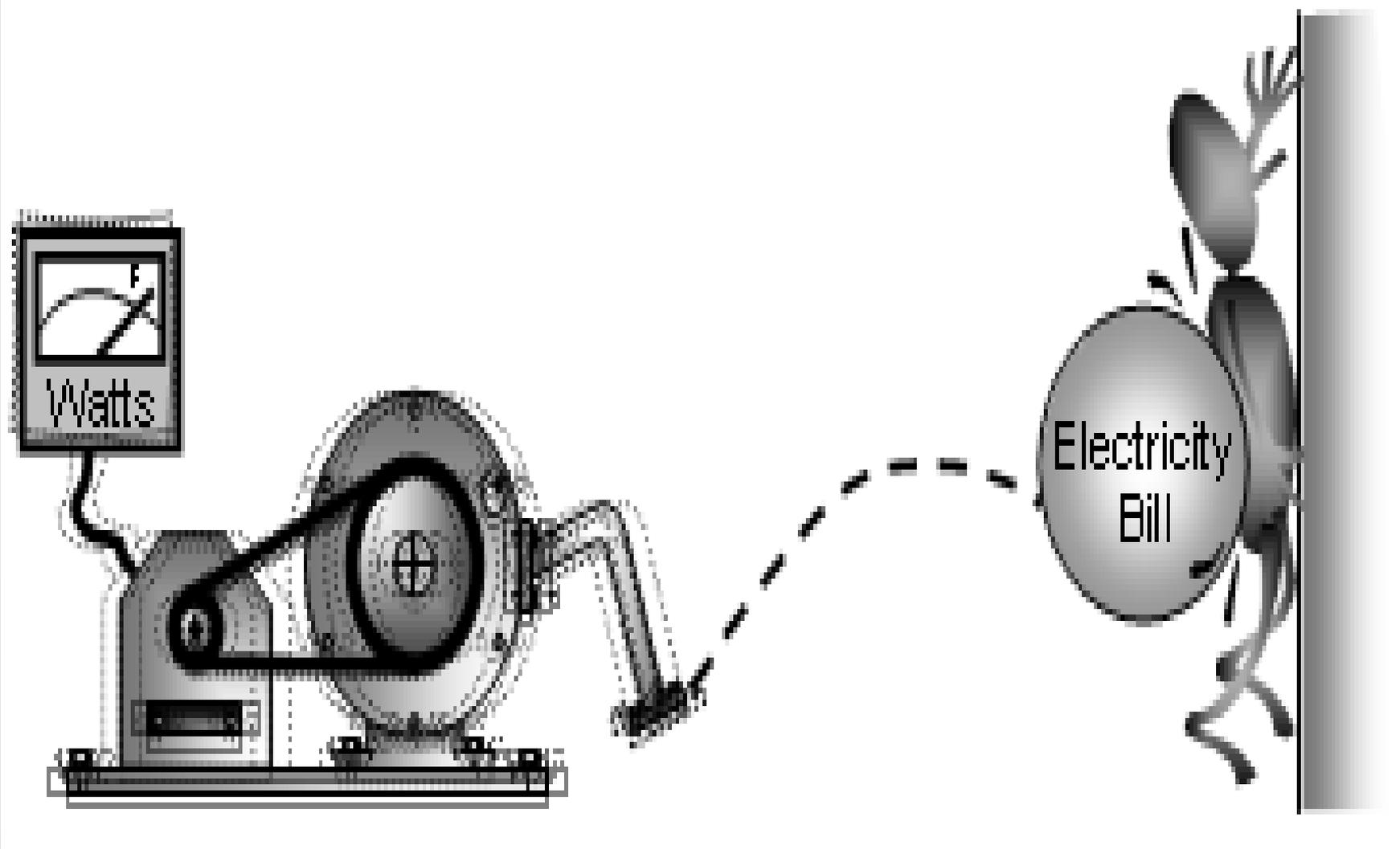
We cover all services and you have a choice: a \$200,000 operation or a \$5000 funeral.



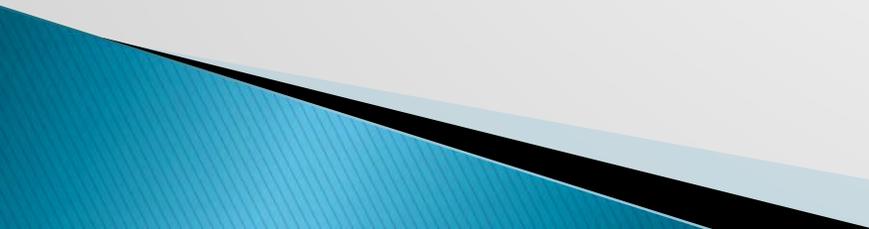
It might be cheaper to replace it!

High Power Consumption

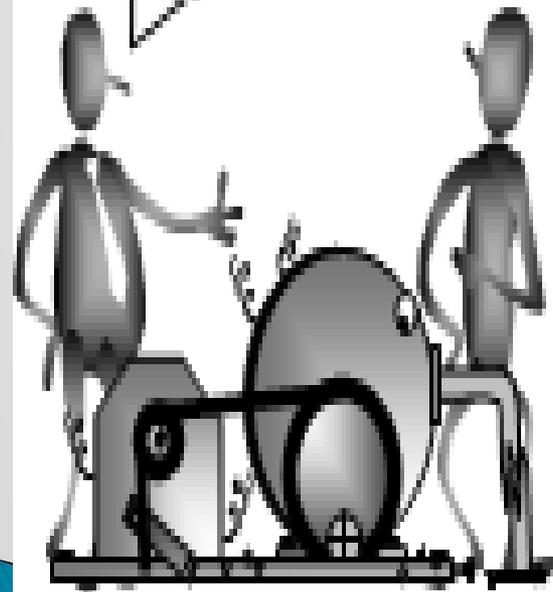
- ▶ A machine that is vibrating consumes more power. As well as the power required for the machine to perform its intended function, additional power is also required to sustain the vibration.
- ▶ We can minimize this problem by regularly monitoring and maintaining the machine.



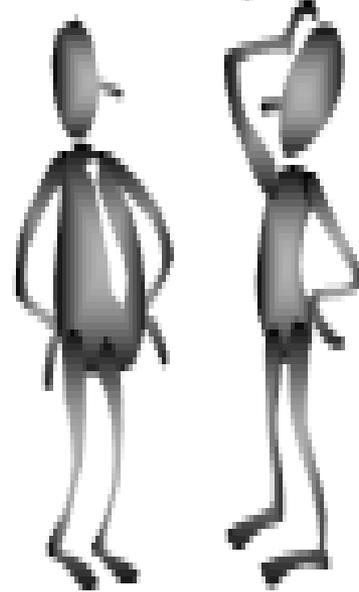
Machine Unavailability

- ▶ Because an unmonitored machine is more likely to break down, it is more often out of action.
 - ▶ However, the cost of procuring and operating a machine is normally justified by its availability to process goods efficiently, or by its availability to convert raw material into cash.
 - ▶ A machine should be consistently available to generate the money to justify its investment.
 - ▶ Regular monitoring helps ensure that a machine is always available to generate money.
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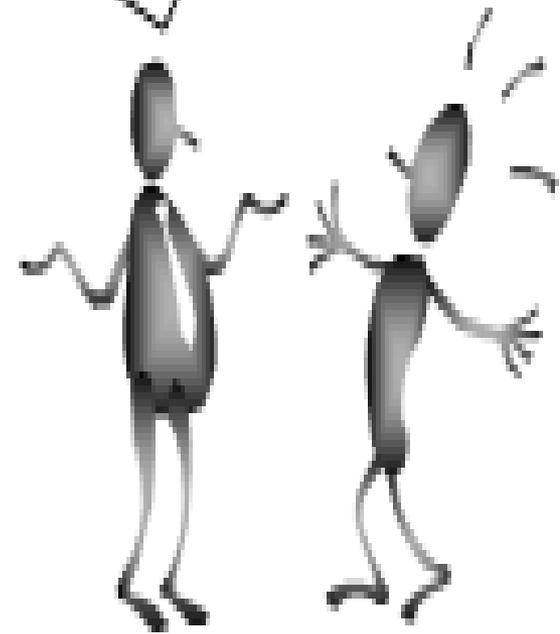
This is so often unavailable to make money it is actually losing money.



How?



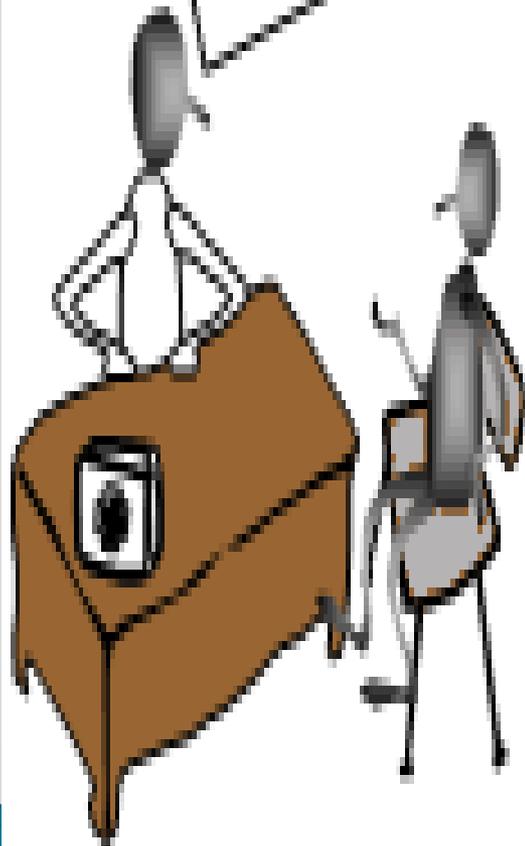
Its unavailability does not justify its initial cost, the floor space it occupies, the repairs required, and the business opportunities we miss out on!



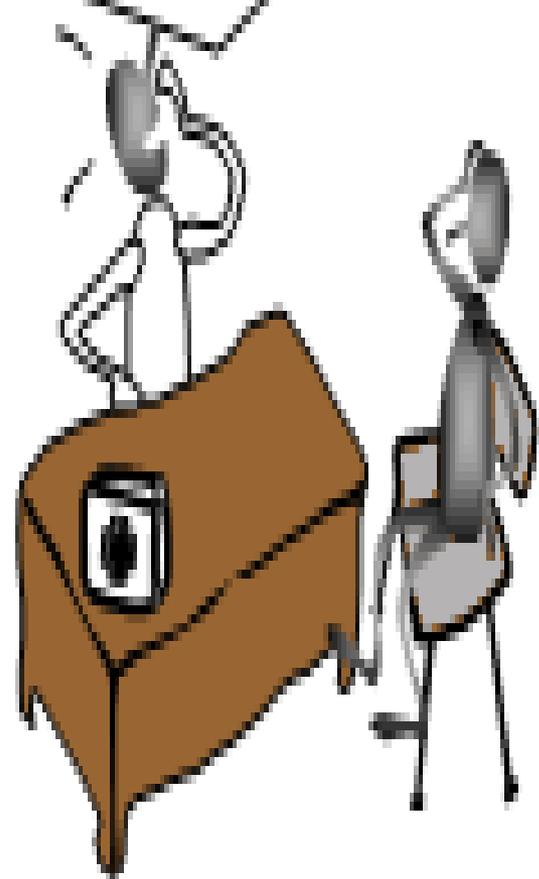
Unnecessary Maintenance

- ▶ To constantly ensure proper machine condition, some companies stop running machines according to predetermined schedules to adjust and replace parts regardless of whether or not the machines are malfunctioning.
- ▶ As a result, machines are often stopped unnecessarily to replace parts that are still good and to correct problems that do not exist.
- ▶ We can avoid such waste if the machines are regularly monitored and repaired only when necessary.

It's good that you're getting full checkups every week.



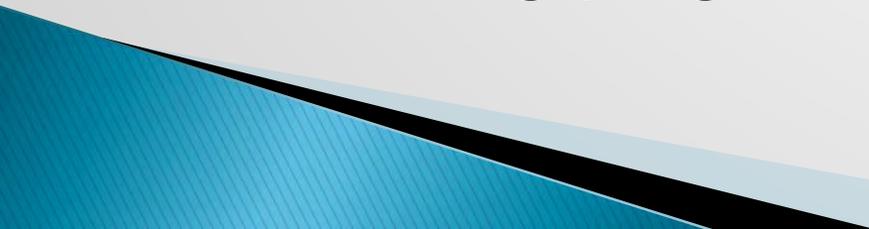
It's even better that you're making me rich unnecessarily!



Occupational Hazards

- ▶ Due to the noise and shaking they create, vibrating machines can cause occupational hazards and human discomfort.
- ▶ Human discomfort results in a loss to the company as workers who feel unwell will not be fully productive.
- ▶ Also, unexpected machine breakdowns leave workers with no work

Summary

- ▶ We identified the reasons for monitoring machine vibration regularly, as well as the consequences of not doing so.
 - ▶ By regularly monitoring the vibration characteristics of a machine we can detect and correct machine problems as they arise.
 - ▶ By correcting machine problems early we avoid many unpleasant and costly problems, some of which involve customers.
 - ▶ The cost of failing to monitor machine vibration far exceeds the cost of implementing a vibration monitoring program.
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Summary

- ▶ Cost to ignore acoustical issues before construction very significant
- ▶ Cost not just in materials but in management time dealing with or working the problem.
- ▶ Reputations suffer – even if you were not directly responsible. If you think there might be an issue say something.