VIBRATION ANALYSIS

HOW TO START A PREDICTIVE MAINTENANCE PROGRAM

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Types of Maintenance Systems

* Reactive
* Proactive
  - Preventive
  - Predictive
  - Root Cause Analysis

There is a place for reactive maintenance

* Non critical equipment
* Equipment that does not significantly affect production
* Equipment with adequate spares
* Inexpensive (disposable) equipment
* Machinery that does not impact safety

Preventive Maintenance

* Routinely replace components based on machine history

* Some maintenance is non-intrusive (oil leaks, structural cracks, excessive noise, heat, missing fasteners, worn brushes can be detected without disturbing machinery)

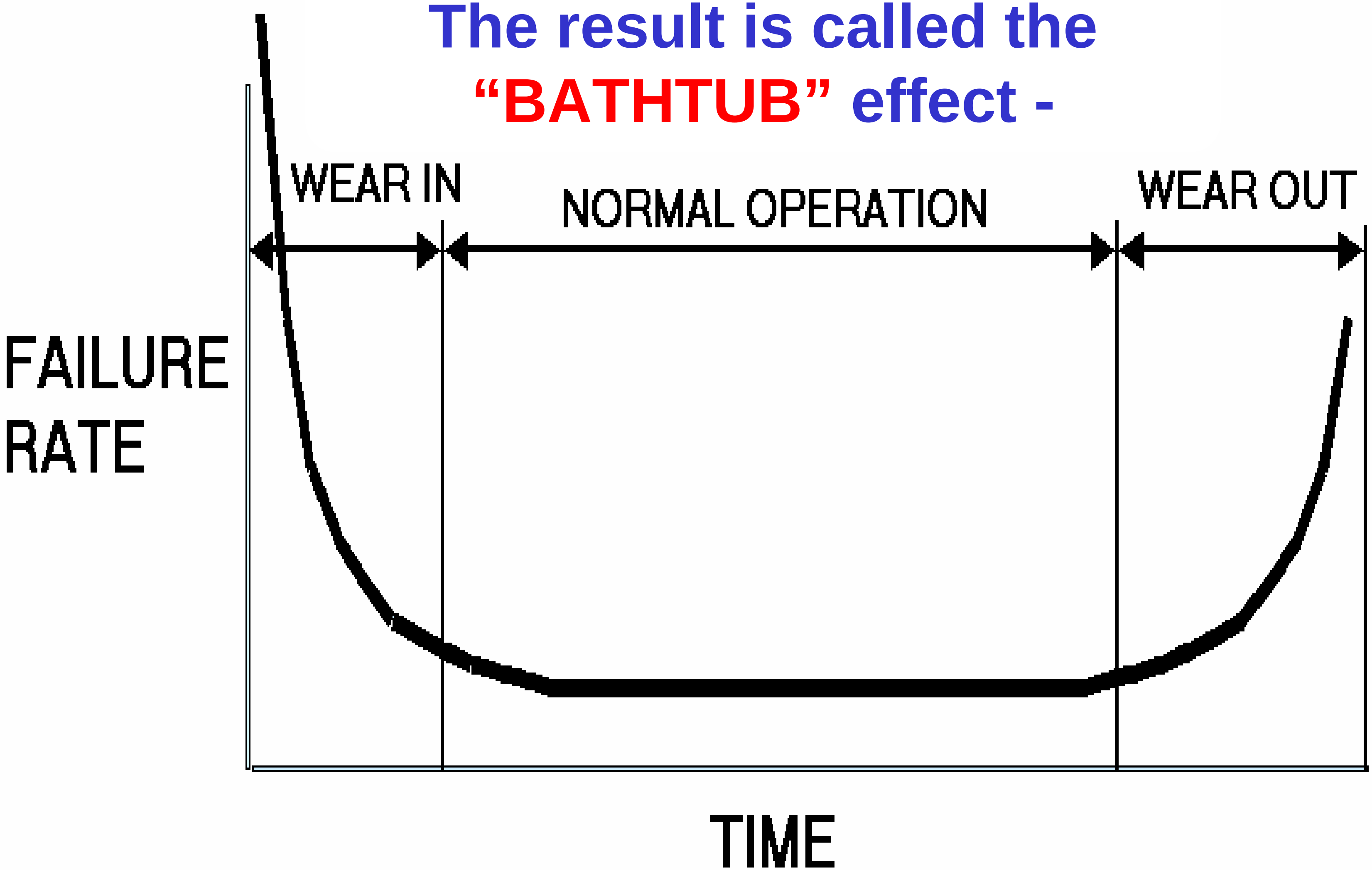
* Replacing parts, however, can be hard on machinery and introduce new problems

A study carried out some years ago by two major US airline companies found that whenever intrusive maintenance is performed, problems are often introduced.

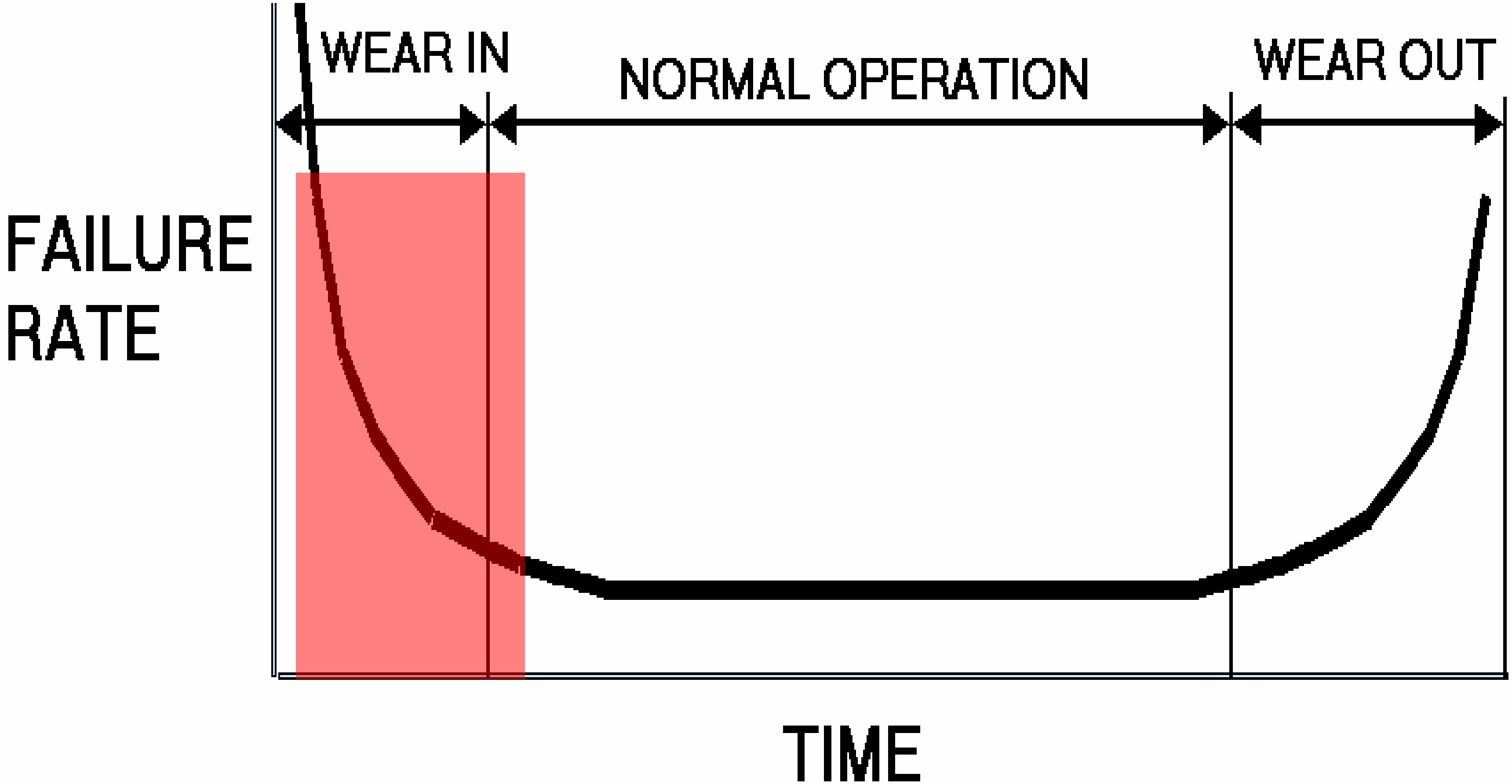
Contributing factors include -

- **Defective parts**
- **Misalignment**
- **Unbalance**
- **Incorrect assembly**

The result is called the “BATHTUB” effect -



Every time you perform intrusive maintenance the machine goes through the "WEAR IN" period



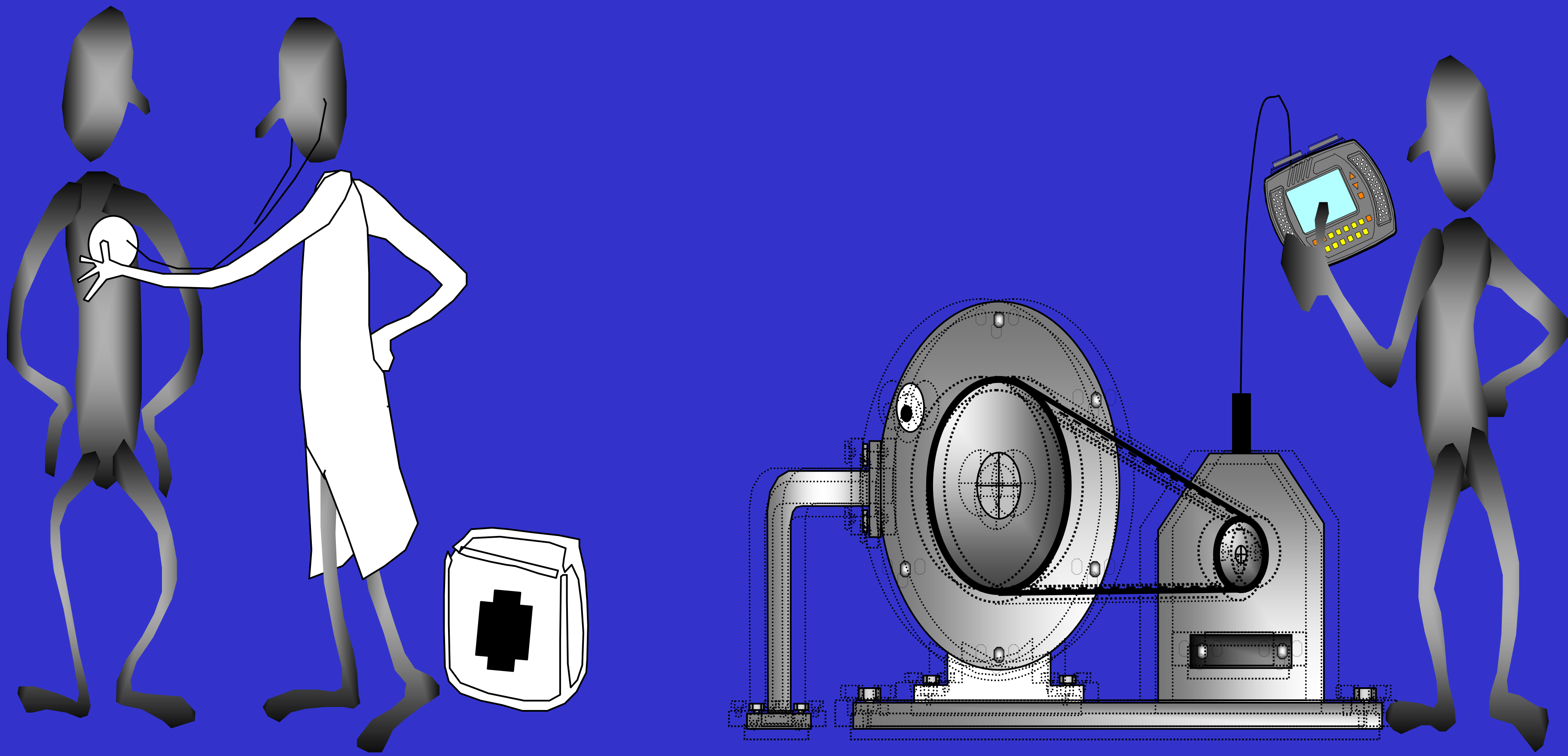
Lets consider the second type of PROACTIVE maintenance -

<u>PREDICTIVE</u> maintenance

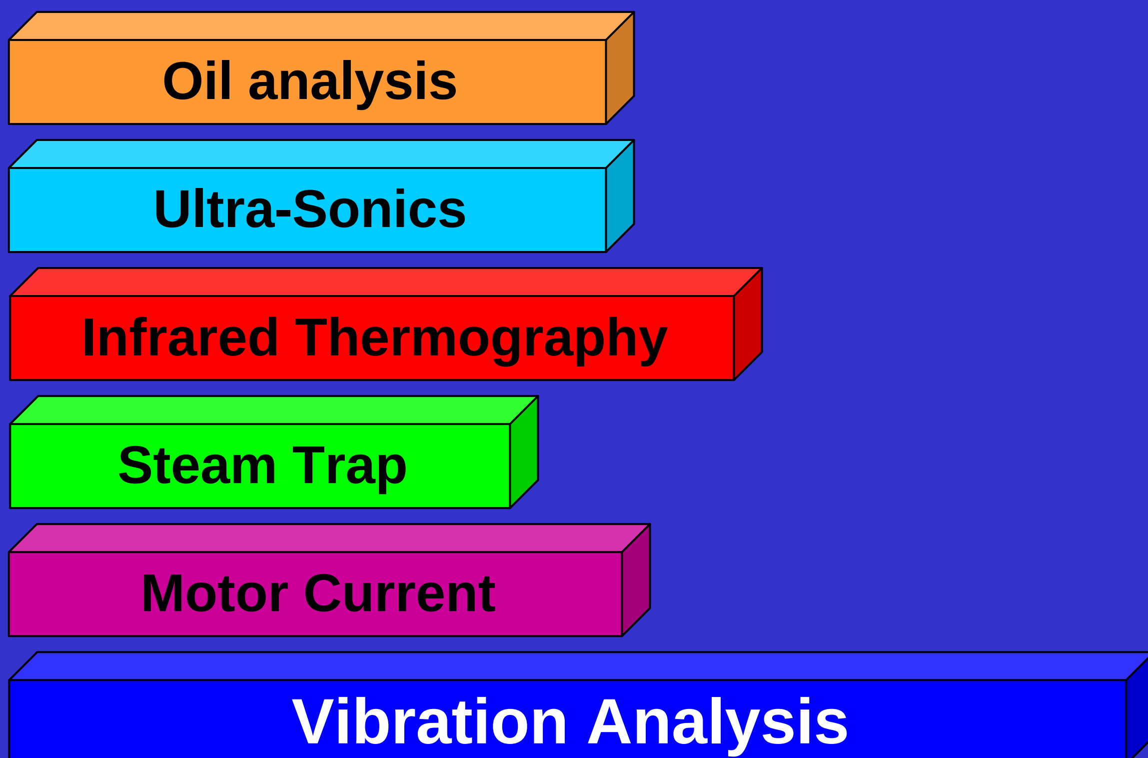
PREDICTIVE maintenance involves regular monitoring to detect changes in a machine's operating condition

Predictive Maintenance might better be called "condition Monitoring"

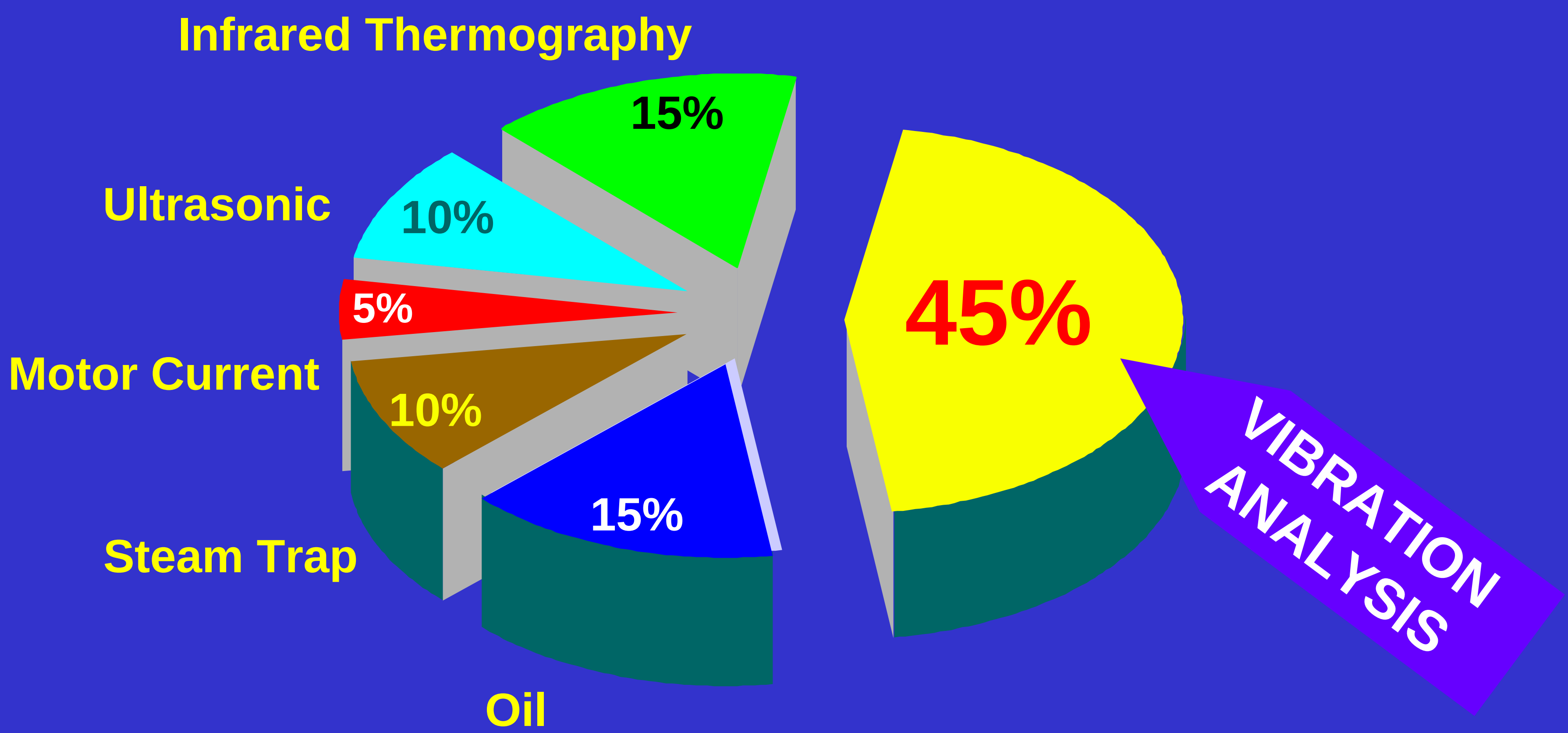
It is much like going to the doctor for a regular checkup



PROACTIVE MAINTENANCE makes use of many technologies



One technology is distinctly MORE EFFECTIVE



Run to Failure

“If it ain’t broke, don’t fix it”

* Ends up “broke”- often with expensive consequences

Preventive Maintenance

“If it ain’t broke, fix it anyway”

* Sometimes new problems are introduced (bathtub curve) and failures may actually increase. Unused good performance time is given up.

Predictive Maintenance

If it is running fine and going to continue to do so, “do not disturb”. Only when it is “thinking about” having problems do you fix it.

*** You get the most life out of the machine parts with the least disruption to production**

Why Vibration Monitoring?

Vibration monitoring detects more problems than the next three predictive maintenance techniques combined.

Why Now?

Vibration monitoring equipment technology improvements have made the equipment much less expensive and easier to operate than in the past.

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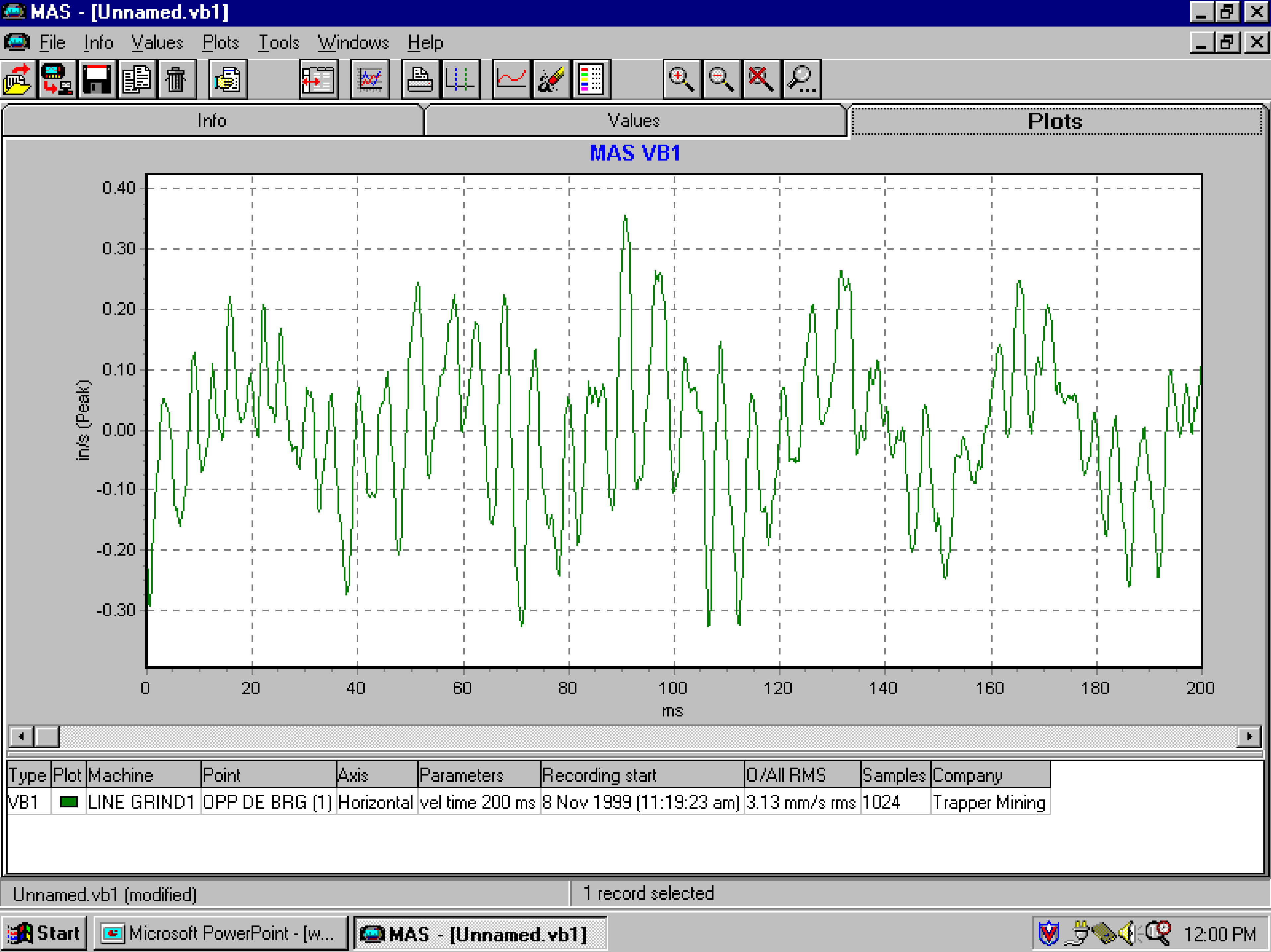
VIBRATION ANALYSIS

Plots Made with Vibration Analyzers

In the “Time Domain”

* Plots vibration amplitude Vs time (Time Waveform)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In the “Time Domain”

* Plots vibration amplitude Vs time (Time Waveform)

Typical problems detected

* Broken gear teeth

* AC motor problems

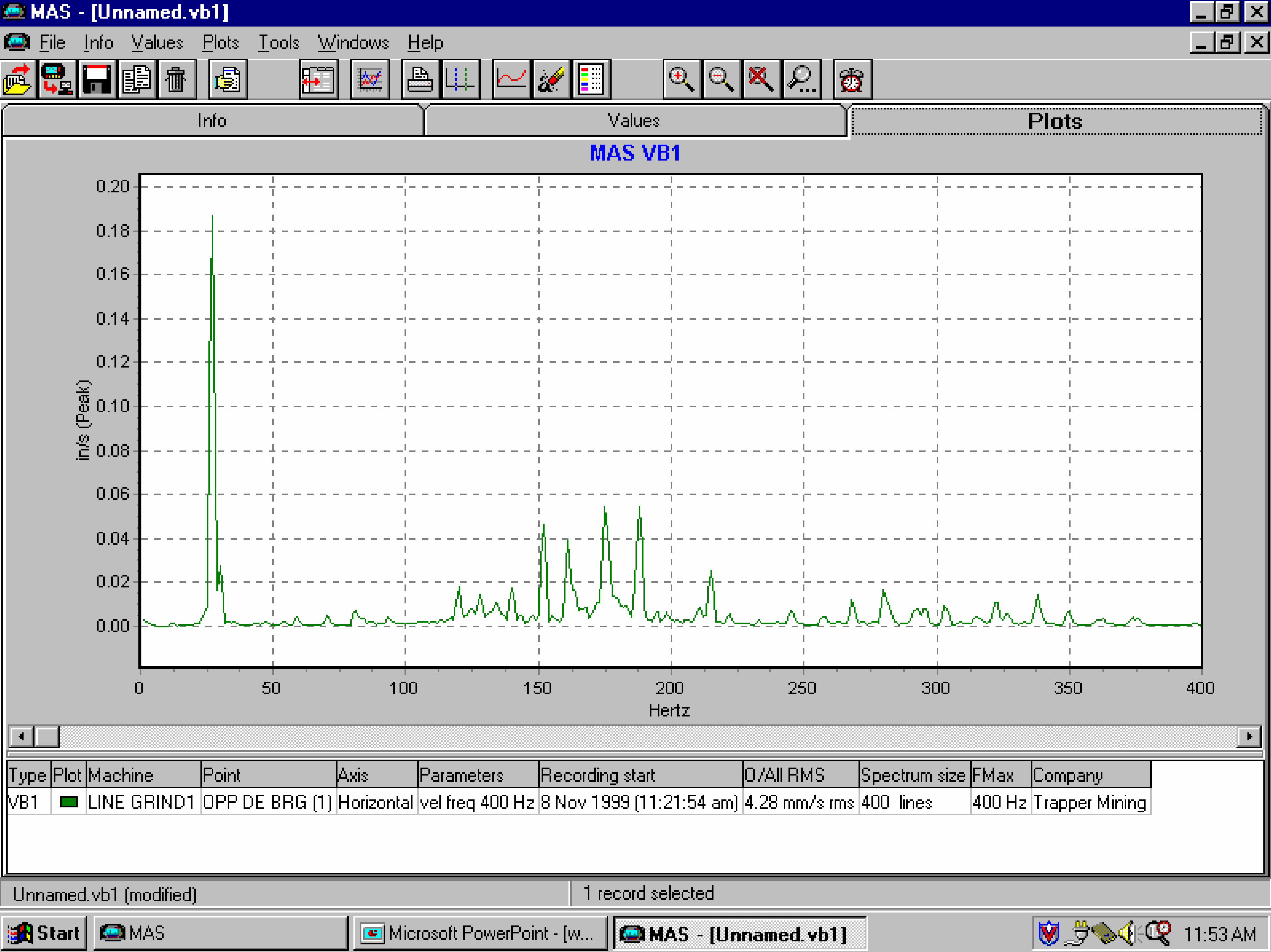
* Amplitude modulation (interaction of two close frequencies)

* Frequency modulation (frequency varies cyclically with time)

Plots Made with Vibration Analyzers

In the "Frequency Domain"

* Plots vibration amplitude Vs frequency (frequency spectrum) Information is converted in the analyzer using a mathematical function called a Fast Fourier Transform or FFT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Plots Made with Vibration Analyzers

In the "Frequency Domain"

Frequency of the peaks indicate the <u>cause</u> of the problem

Amplitude of the peaks indicate the <u>severity</u> of the problem

In the “Frequency Domain”

Typical problems detected

* Unbalance
* Misalignment
* Mechanical looseness
* DC motor problems (SCR drives)
* Antifriction bearing problems
* Gear problems
* Pump and fan problems
* Bent shaft
* Soft foot
* Oil whip, oil whirl or shaft rub (sleeve bearings)

Setting up a Vibration Monitoring Program

Selecting Equipment to Monitor

List Your Machines

Selecting Equipment to Monitor

Categorize Your Machines

* Critical
* Essential
* Non- Critical

Selecting Equipment to Monitor

Critical Machines

* Safety critical- catastrophic failure would endanger humans or the environment

* Process critical- machines that must run 24 hours per day

* These should definitely be in a predictive maintenance program

Selecting Equipment to Monitor

Essential Machines

* One of a kind with no spares

* Machines with intermittent use, but must have guaranteed availability (like emergency generators, some compressors)

* Machines where the cost to repair is extremely high

* These should would be the next priority in a predictive maintenance program

Selecting Equipment to Monitor

Non-Essential Machines

* Have little impact on production
* Spare parts or replacement equipment is readily available
* Repairs are not difficult or expensive
* These would not be candidates for a predictive maintenance program

Selecting Equipment to Monitor

Within each category they should be further ranked by asking:

* Is the machine fully spared, partially spared or not spared?

* If spared, how long would it take for the spare to be put on line ?

* To what level would plant production be reduced if this machine failed?

* How much lead time is required for repair of this machine?

* How costly is the repair/replacement of this machine?

* Is the spare in good enough shape to continue production for a substantial length of time?

*Does quality suffer due to poor performance or loss of this machine?

Selecting Equipment to Monitor

* Machines that have a chronic maintenance history/or recurring problems (these may require root cause analysis)

* Machines with excessive replacement component or repair lead time

* Machines that must be scheduled for repair far in advance

* Machines under warranty and/or an insurance liability

Potential Equipment to Monitor

Main MG Set

* Rotating unbalance
* Resonant frequencies
* Electrical faults - generators
* Electrical faults- synchronous motor
* Antifriction thrust bearings
* Coupling eccentricity

Potential Equipment to Monitor

Swing MG Set

* Rotating unbalance
* Resonant frequencies
* Electrical faults - generators
* <u>Electrical faults- induction motor</u>
* <u>Ball bearings</u>
* Coupling eccentricity

Potential Equipment to Monitor

Motion drive motors

* Rotating unbalance
* Resonant frequencies
* Electrical faults
* <u>Misalignment</u>
* Antifriction bearings
* <u>Soft foot mounting (improper shimming)</u>
* <u>Blower problems</u>
* <u>Brakes</u>

Potential Equipment to Monitor

Gear boxes

* Rotating unbalance
* Resonant frequencies
* Gear teeth problems
* Misalignment
* Antifriction bearings
* Eccentric gears or bent shafts

Potential Equipment to Monitor

Since the motion drives are more complex, we will investigate the swing drive as an example

Potential Equipment to Monitor

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* Motors
* Bearings
* Gear mesh
* Alignment

Six Steps to Analyzing Vibration

1. Familiarize yourself with the equipment. What is inside?

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5. Identify other vibrations present

Six Steps to Analyzing Vibration

1. Familiarize yourself with the equipment. What is inside?
2. Calculate the important speeds and frequencies
3. Locate 1X in the spectrum
4. Identify the signature vibration patterns
5. Identify other vibrations present
6. Evaluate the equipment and make a recommendation

Familiarize yourself with the equipment (Page 752 Dragline)

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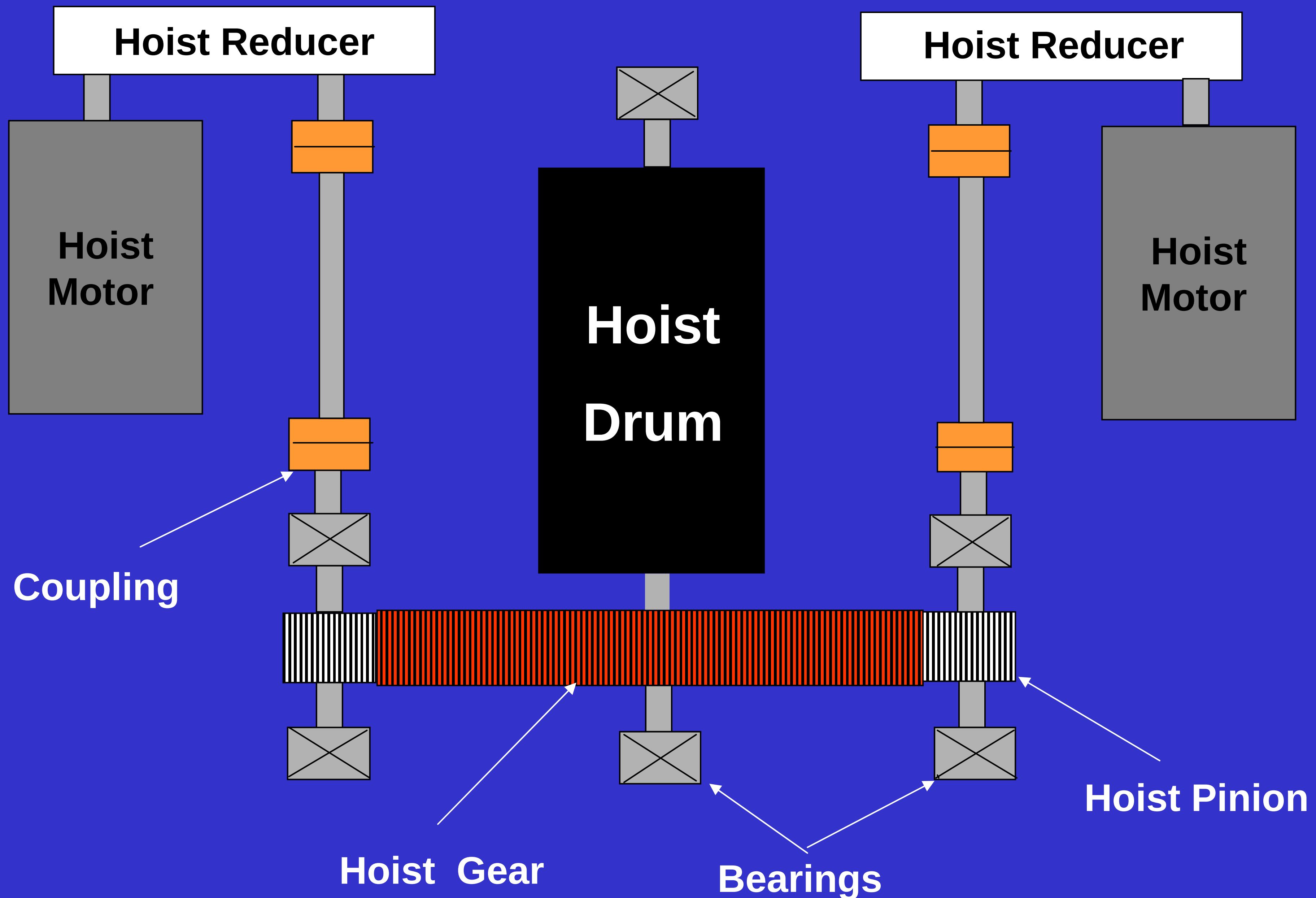
a. Reviewed P&H (Page) drawings of machinery layout

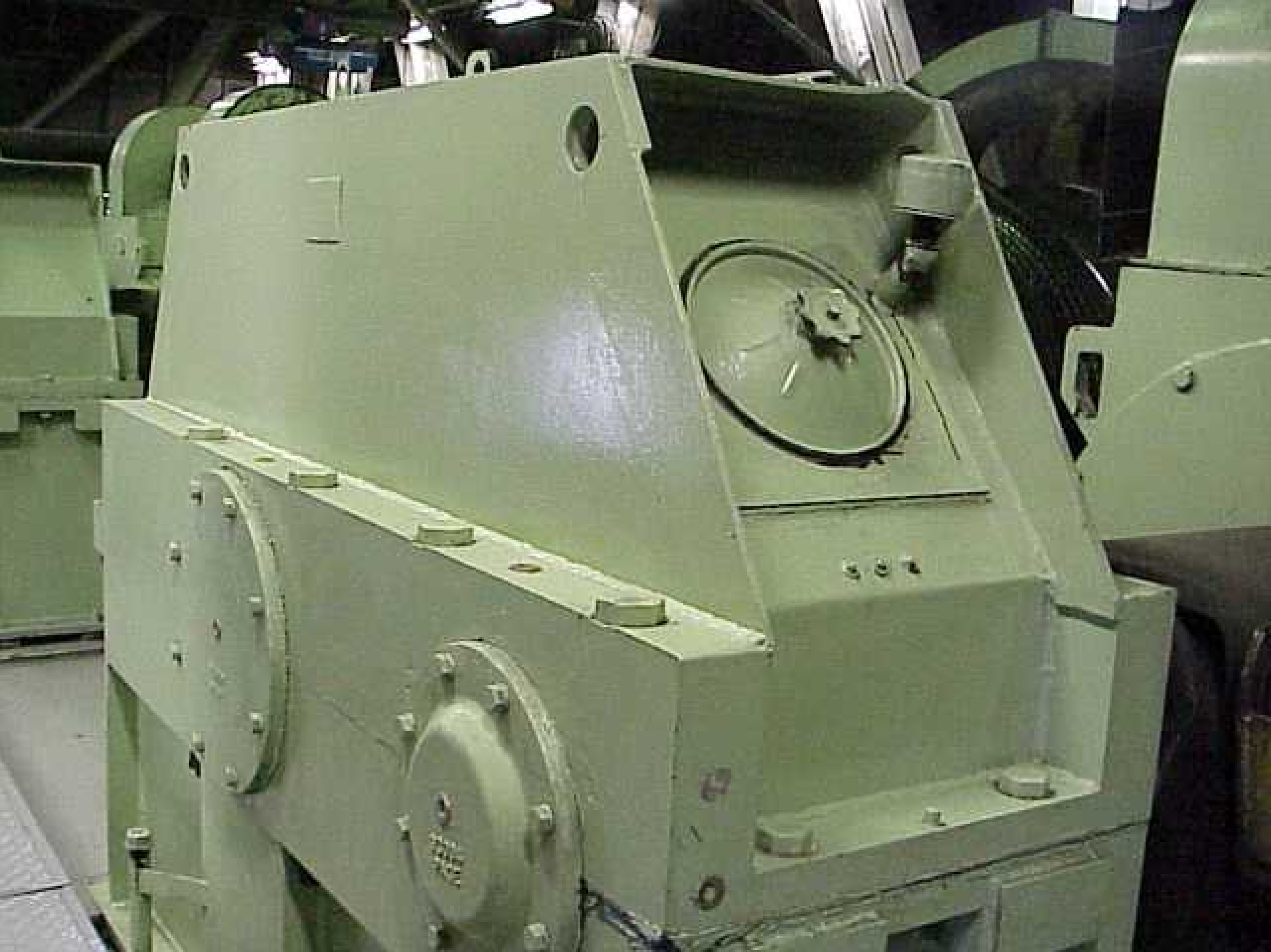
Hoist Motion



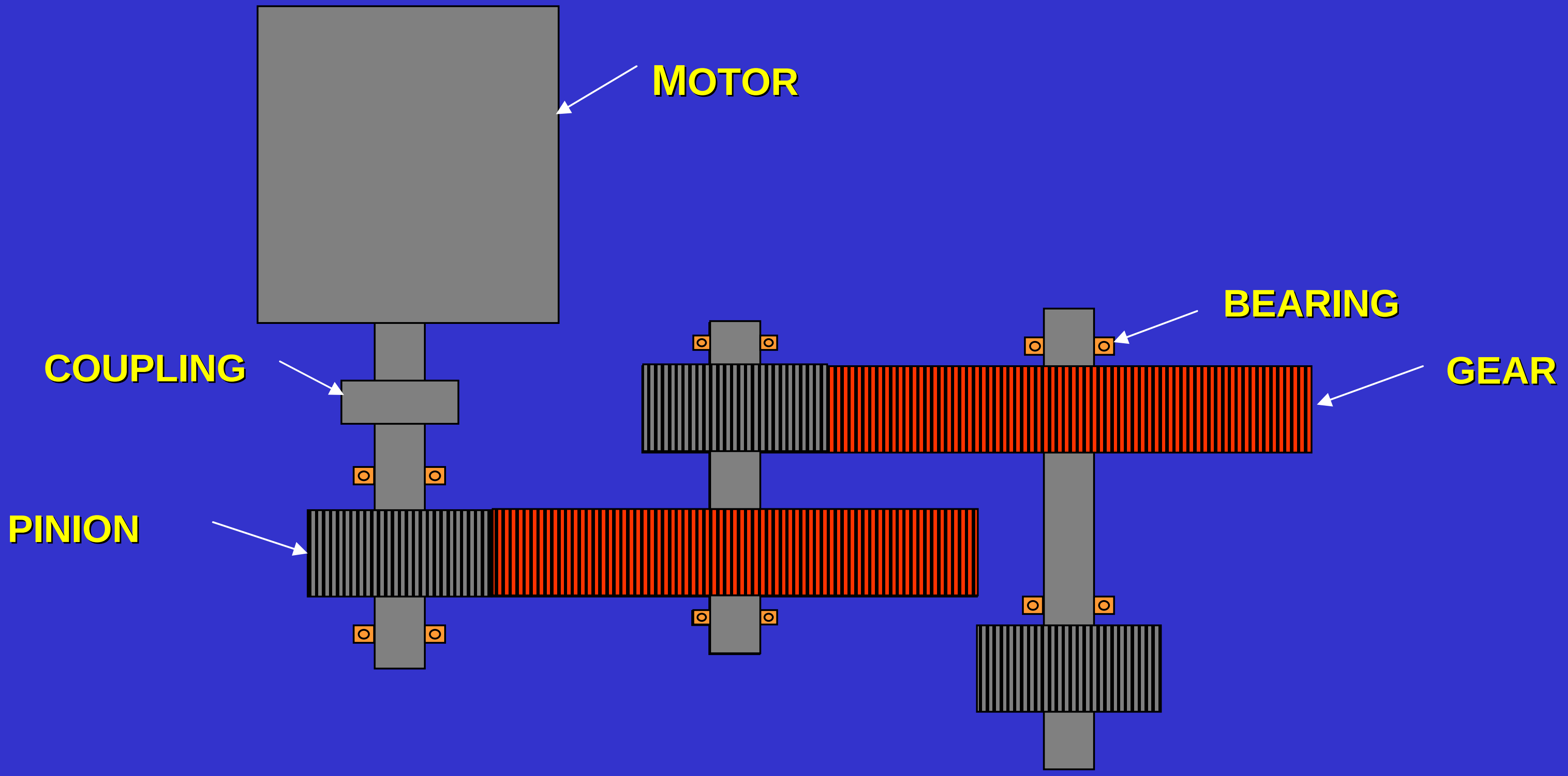
Familiarize yourself with the equipment (Page 752 Dragline)

a. Reviewed P&H (Page) drawings of machinery layout

b. Reviewed OEM drawings of gearboxes



Swing Motion



Familiarize yourself with the equipment (Page 752 Dragline)

a. Reviewed P&H (Page) drawings of machinery layout

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c. Gathered part numbers of gears, shafts, bearings etc. from OEM drawings

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e. Determined the number of teeth on all gears

Inspect spare or used gears at the mine


5054-0012
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Familiarize yourself with the equipment (Page 752 Dragline)

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2

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Inspected spare or used gears at the mine

Obtained information from the OEM

Familiarize yourself with the equipment (Page 752 Dragline)

f. Determined bearing fault frequencies (BPFI, BPFO, BSF, FTF)

The bearing manufacturers know this and it is becoming more available, but is not universally, easily available today

* "Bearing Expert" in the analyzer software (Timken)

  Currently contains 1,000,000 bearing numbers with data on approximately 120,000

* One bearing manufacturer sent diskettes with their bearing information (Torrington)

* NTN said info soon on web site. Obtained by phone

Bearing Fault Frequencies- (e.g. Torrington HM256810CD (Cup))

BPFI- Ball Pass Frequency Inner race (e.g.. 19.441)

BPFO- Ball Pass Frequency Outer race (e.g. 16.559)

BSF- Ball Spin Frequency (e.g. 6.075)

FTF- Fundamental Train Frequency -cage rotation (e.g. 0.46)

Six Steps to Analyzing Vibration

1. Familiarize yourself with the equipment. What is inside?

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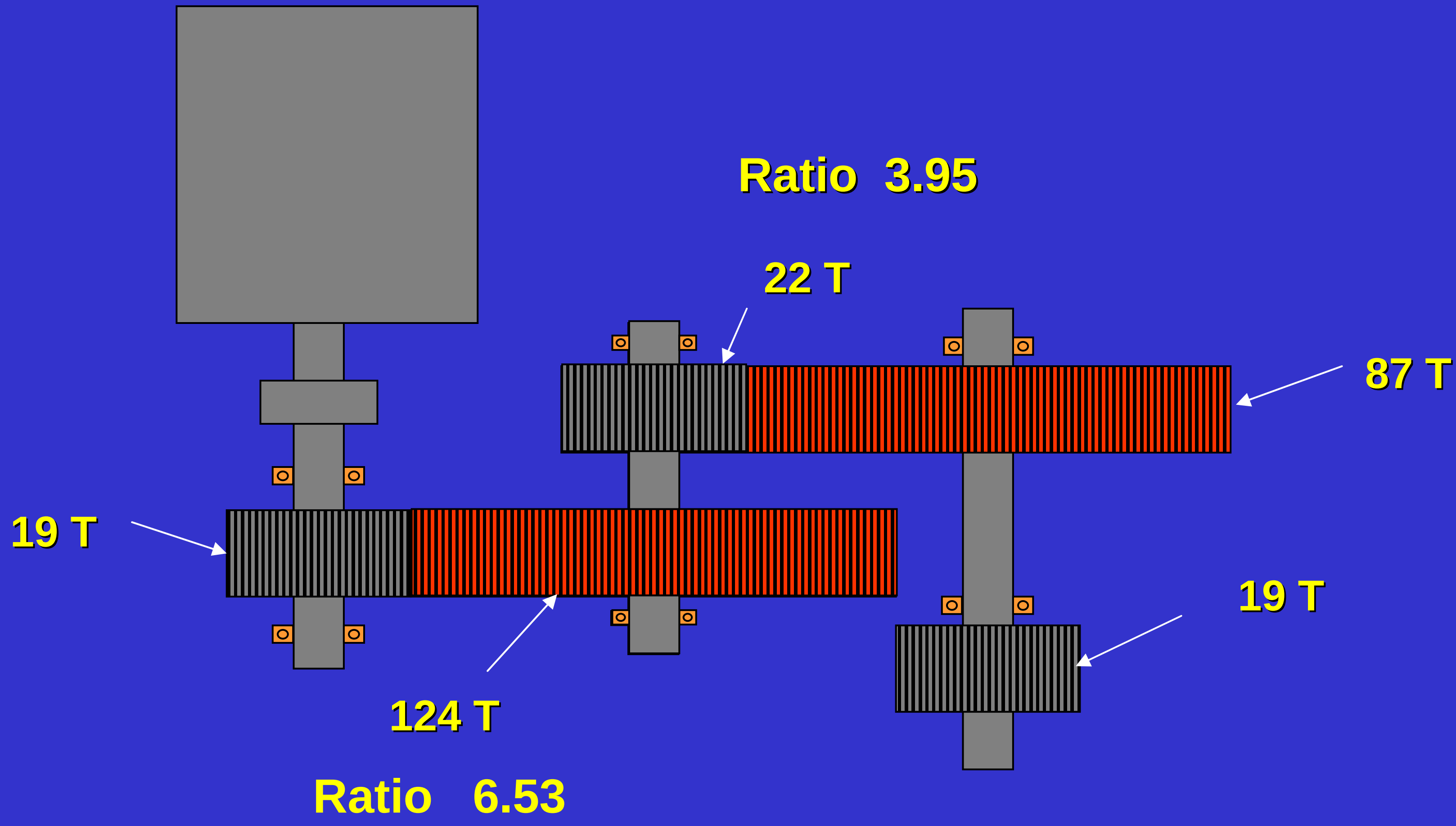
Swing Motion



Calculate Important Speeds and Frequencies (Swing Motor-Pin.Sft.)

Item	Freq	Speed	Mult.	Freq. (kCPM)	Freq. (Hz)
Blo Mtr.	1X	1750	1	1.75	29.17
Mtr/Pin Sft	1X	1000	1	1	16.67
S. Mtr.	BPFI	1000	8.3	8.3	138.33
S. Mtr.	BPFO	1000	5.7	5.7	95.00
S. Mtr.	BSF	1000	2.6	2.6	43.33
S.Mtr.	FTF	1000	0.41	0.4	6.83
S. Mtr	Slot	1000	58	58.0	966.67
Pin Sft.	BPFI	1000	17.296	17.3	288.27
Pin Sft.	BPFO	1000	14.704	14.7	245.07
Pin Sft.	BSF	1000	5.966	6.0	99.43
Pin Sft.	FTF	1000	0.459	0.5	7.65
# Pin Teeth	1st Mesh	1000	19	19	316.67

Calculate Important Speeds and Frequencies (First Reduction Shaft)

Gear Ratio 6.53 **Pinion Shaft 1000 RPM**

Item	Freq	Speed	Mult.	Freq. (kCPM)	Freq. (Hz)
# Gear Teeth	1st Mesh	153.23	124	19.00	316.67
1st Red. Sft.	1X	153.23	1	0.15	2.55
1st Red. Sft. Brg.	BPFI	153.23	13.356	2.05	34.11
1st Red. Sft. Brg.	BPFO	153.23	10.644	1.63	27.18
1st Red. Sft. Brg.	BSF	153.23	4.286	0.66	10.95
1st Red. Sft. Brg.	FTF	153.23	0.444	0.07	1.13
# Pin Teeth	2nd Msh	153.23	22	3.37	56.18

Six Steps to Analyzing Vibration

1. Familiarize yourself with the equipment. What is inside?

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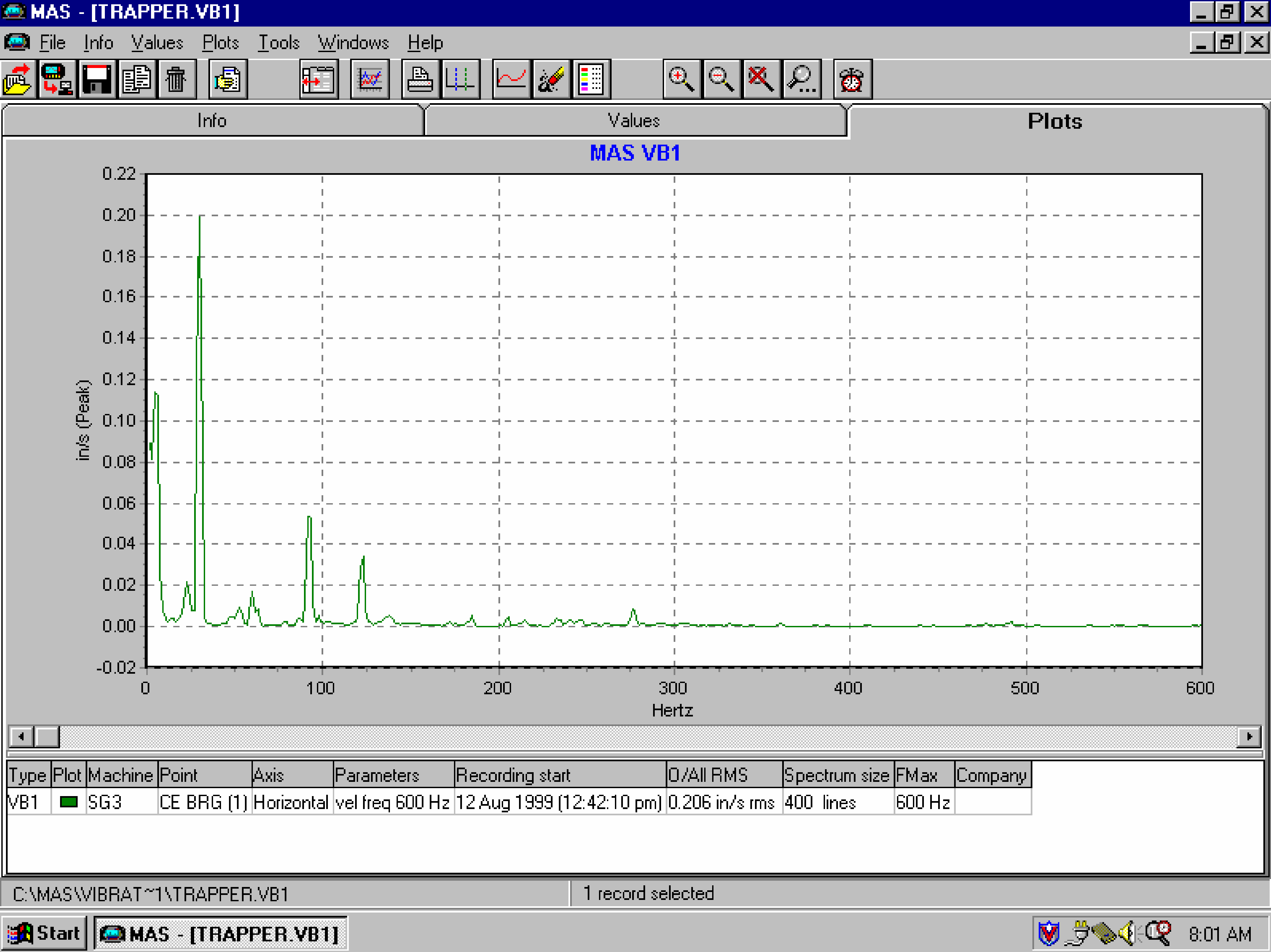
3. Locate 1X in the spectrum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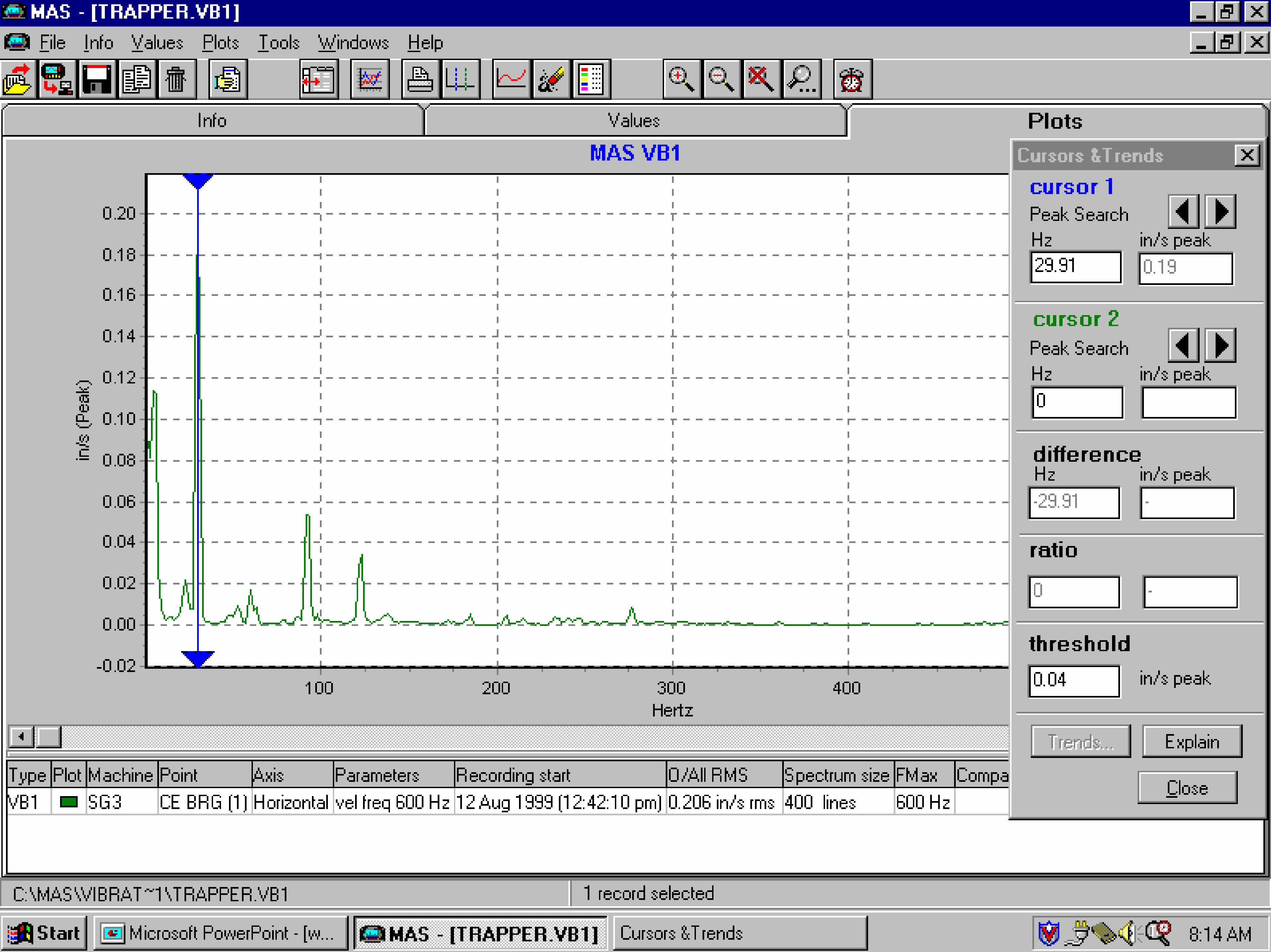
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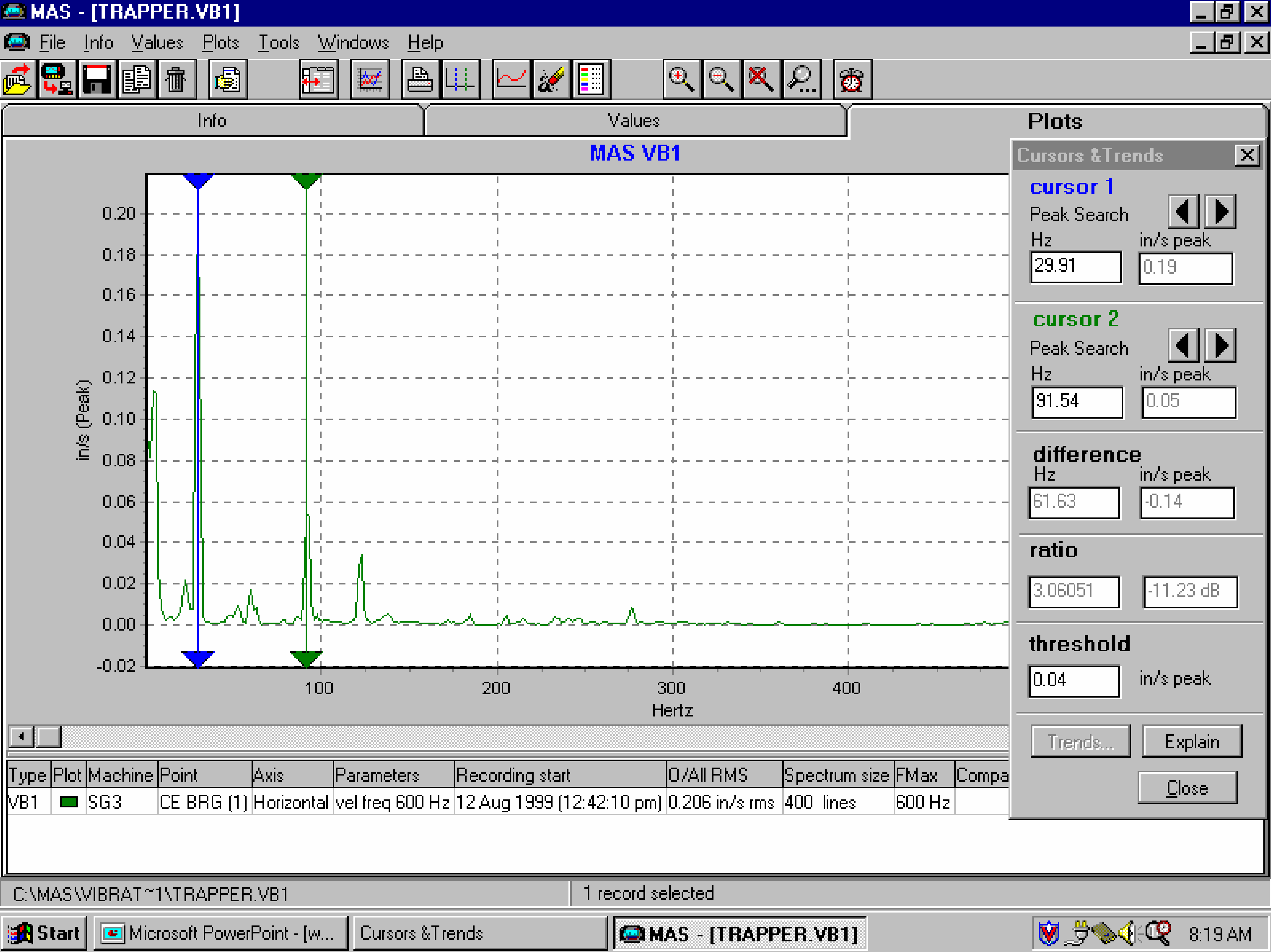
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Vibration Measurement- My Current Thoughts

* MG sets should be idling to avoid introducing vibration not related to the sets. Sets are constant speed, so taking measurements is easy.

* Swing motion should be run steadily at top speed as this is the easiest way to repeat speed on later measurements. Possibly run both directions in case one side of gear teeth only has problems.

* Hoist and drag. Run at top speed, empty bucket with machine not swinging. Limited time at top speed may be a challenge in getting readings.

* Bearings- Some applications have a variety of bearing vendors approved (e.g. Motors and generators). Fault frequencies may vary by vendor. When repairs are made obtain info on bearing vendor and bearing number.

Special Thanks To:

Trapper Mining Inc.

- Terry Wooten
- Ted Crook

P&H Mining Equipment

- Harvey Kallenberger
- Paul Todd

GE

- Dennis Buto
- Millis Parshall

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