Availability 301
Improving Availability by Detection and Monitoring

In this course:

Overview

Best in class availability is at least 4% higher than that achieved by 75% of the process industry—potentially offering as much as two weeks per year of additional production time and 2% of annual revenue to operating profit. Benchmarks across chemical, petrochemical, power, pulp and paper, and other industries demonstrate that effective monitoring and prediction combined with proper maintenance practices can increase availability.

Detecting or predicting conditions that lead to failure, and taking corrective action before an early failure starts, can reduce or eliminate many apparently random failures, and close the financial gap created by low availability.

Detecting and predicting conditions that lead to failure requires the use of equipment-specific monitoring and diagnostic techniques. Frequently, multiple techniques are required to give complete diagnostic coverage. With complete coverage, unscheduled downtime can be minimized or eliminated, scheduled downtime can be shortened, equipment damage and repair cost can be reduced, and equipment life can be extended.

In this course, you will learn how to use monitoring and prediction to detect and eliminate problematic conditions before they lead to failure and loss of availability.

Hint

As you go through the topics in this course, watch for answers to these questions:

- Which rotating equipment diagnostic technologies are complementary?
- What are the reasons for monitoring process equipment?
- In what ways can valves and instruments impact process availability?

Assets for Monitoring

Appropriate assets for monitoring failure conditions include:

- Rotating Equipment
- Process Equipment
- Valves
- Instruments

You will now study the main monitoring technologies for each of these assets.

Rotating Equipment

Detecting and predicting wear or failure conditions in rotating equipment maximizes availability while minimizing maintenance cost. Eliminating unscheduled shutdowns and reducing collateral damage caused by failure improves availability. This is accomplished by monitoring for maintenance need, and eliminating unneeded maintenance.


Rotating Equipment

These results are best accomplished by a combination of technologies such as:

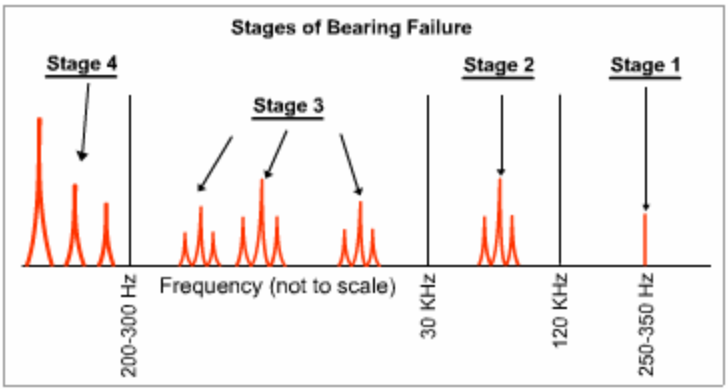
- **Vibration Monitoring**
- **Lube Oil Analysis**
- **Thermography**

Rotating Equipment >> Vibration Monitoring

Vibration monitoring is a powerful monitoring technology. It can be Continuous or Walk-around.

Vibration monitoring uses vibration sensors that attach to the rotating equipment using techniques ranging from magnetic to stud mounted. The frequency response of a vibration sensor is determined by sensor weight and type of mounting. Lighter sensors and more rigid mounting deliver better high frequency response. For example, light stud mounted sensors give better high frequency response than heavier

magnetically mounted sensors. High frequency response is important as an early stage bearing failure produces very high frequency noise.



Stage 1 failure - 250-350 KHz
Noise evaluated by stress wave analysis.

Stage 2 failure - 30-120 KHz
Bearing component "ring."

Stage 3 failure - 1-30 KHz
Bearing defect frequencies – REPLACE BEARING NOW!

Stage 4 failure – 1x-4x
Vibration grows. High frequency noise becomes random. Failure with collateral damage imminent.

Stress waves analysis can detect stage 1 bearing failure, when up to 20% of bearing life remains. This analysis is important because collateral damage is minor and sufficient lead-time exists to order parts and to schedule maintenance.

Rotating Equipment >> Lube Oil Analysis

Lube oil analysis combines wear particle analysis, chemistry, and contamination analysis.

Wear particle analysis can detect the onset of many wear conditions earlier than vibration analysis. It can also isolate problems within the equipment to a specific bearing, race, gear, and so on.

Chemistry determines if the lube oil has the correct characteristics such as viscosity for the application. An incorrect lubricant is one of the causes of seal failure. If a lubricant is incompatible with seals, it may cause seal deterioration, and eventually, leakage.

Contamination analysis finds contaminates such as water in lubricating oil.

The following table shows seven basic lubricated wear mechanisms listed in percentage order. The percentage figures show how common each of these is compared to the others for industrial machinery.

Basic Lubricated Wear Mechanisms	Percentage
Abrasive wear due to particulate contamination	46%
Fatigue wear due to cyclic loading	17%
Adhesive wear due to machine design tolerances	13%
Corrosive wear due to contamination with moisture and air	9%
Fretting wear due to chemical attack combined with oscillating motion	9%
Erosive wear due to particulate contaminants	6%
Cavitation wear due to implosion of bubbles	<1%

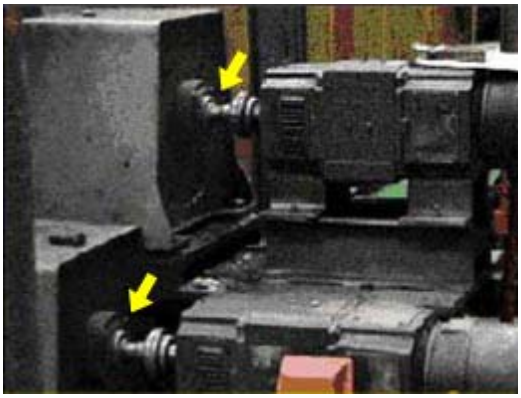
It is important to note that 70% of the wear mechanisms are due to contamination. Chemistry and contamination analysis detects these problems. The other 30% are due to mechanical effects. Wear particle analysis detects these problems as well as the products of contamination-induced wear. Wear particle analysis, chemistry, and contamination analysis are all needed to provide complete analysis coverage.

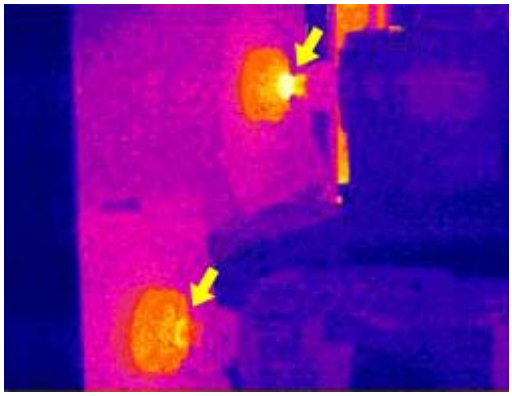
Rotating Equipment >> Thermography

Thermography detects hot spots appearing in a variety of equipment.

Presence of hot spots can mean insulation breakdown, poor electrical connections, or excess friction. These conditions may be caused by lube problems, alignment problems, cooling problems, and so on. The problems often start as efficiency problems. If left uncorrected, they can lead to downtime.

The arrows in the photo and thermography image below show the location of hotspots in rotating equipment.

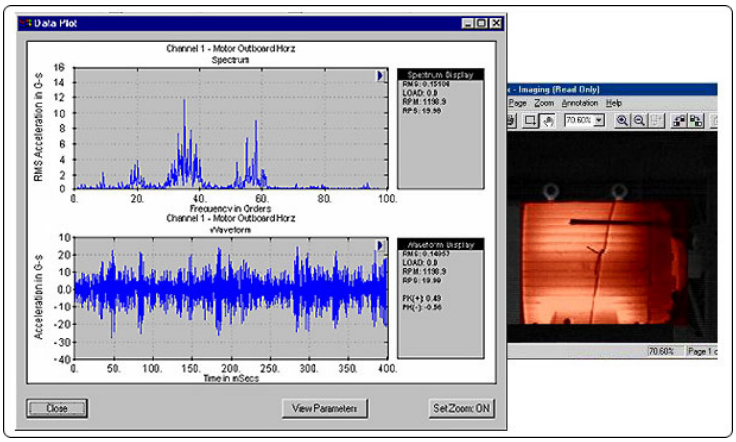




Rotating Equipment >> Combining Monitoring Technologies

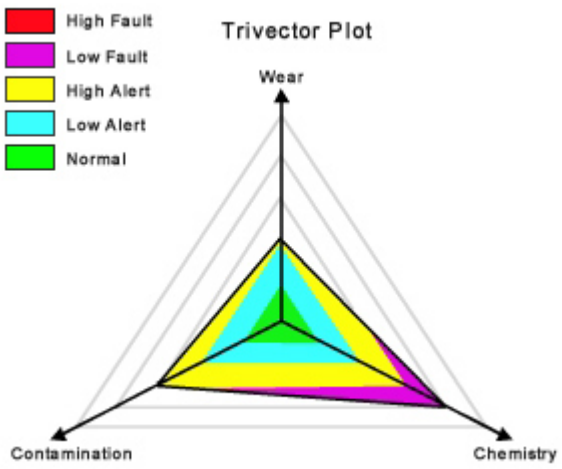
The best monitoring program uses multiple technologies. Online vibration monitoring and lube oil analysis are good examples of highly complementary technologies. Each technology has areas of strong diagnostic performance where the other technology has limitations or does not apply. Vibration monitoring shows conditions including imbalance, misalignment, cracked shafts, and machine resonance. Lube analysis shows early wear, lubricant contamination, and chemistry problems. Combination of these technologies detects more types of problems, predicts more future failures, and helps to determine the root cause more specifically then either technology alone so that future problems are avoided.

Monitor all critical rotating equipment to optimize availability. Since rotating equipment requires several technologies for complete diagnostics, use multiple technologies to get complete predictive diagnostic information.



Vibration analysis brings a broad range of tools including Fast Fourier Transforms, time waveform, phase analysis, stress wave analysis, and others to diagnose equipment condition.

The upper plot shows the frequency vibration signature associated with bearing failure. The lower plot shows accelerations of over 20 G's, causing severe equipment stress.



Lube oil analysis Tri-vector Plot combines contamination, oil chemistry, and wear analysis in a single severity plot. This sample shows water contamination and oil chemistry problems. Lubricant change is recommended.

Monitor more candidate assets to reduce both maintenance costs and eliminate collateral damage.

The PlantWeb Advantage

AMS Suite: Machinery Health Manager provides comprehensive multi-vector rotating equipment diagnostics that include vibration monitoring, lube oil analysis, motor diagnostics, and thermography. These diagnostics can be used to eliminate downtime and keep equipment operating at high efficiency. Emerson provides comprehensive machinery health management services to complement our technology.

Process Equipment

Process equipment ranges from boilers, columns, reactors and heat exchangers, to pumps, turbines, compressors, and other rotating equipment.

Process equipment monitoring is frequently performed to improve the efficiency of process equipment, and thereby minimize production cost. It helps to improve availability in three areas:

- **Shortening Scheduled Maintenance**

  If candidate assets are monitored, and their performance is determined to be good, then scheduled maintenance can frequently be delayed. This delay results in fewer hours lost to maintenance in a given time period.

- **Determining Maintenance Effectiveness**

  If the assets are monitored, maintenance effectiveness can be determined. For example, after maintenance, a heat exchanger suffered rapid loss of efficiency and capacity. Because of the efficiency drop, maintenance personnel inspected the heat exchanger and determined that the problem was torn sealant strips. If left undetected, the ongoing deterioration would cause the process to be heat capacity limited, resulting in an unscheduled shutdown.

- **Delaying Needed Maintenance**

  Needed maintenance can be delayed as long as it is economically attractive to do so. For example, after predicting the drop in efficiency of a heat exchanger, it was determined that the heat exchanger

would cause process downtime due to insufficient capacity in about two months. An economic analysis determined that the optimum time for maintenance was just before the process became capacity limited by the heat exchanger since ongoing production at reduced efficiency was more profitable than an earlier shutdown. Consequently, an unscheduled shutdown was avoided, and scheduled maintenance time was minimized and optimally scheduled.

The PlantWeb Advantage

AMS Suite: Equipment Performance Monitor provides performance monitoring for a broad variety of process equipment ranging from heat exchangers and boilers to pumps, compressors, and turbines. These diagnostics can determine the performance and health of process equipment by indicating if equipment is suffering conditions that could cause downtime. They can also determine the cost of performance problems, and notify you if deteriorating equipment health can impact availability or throughput.

Process Equipment >> Excess Variability

Swings in temperature and pressure can cause stress and lead to premature deterioration of the process equipment. Monitoring for and correcting excess variability to reduce these swings reduces equipment stress and extends equipment life.

Many types of process equipment, including boilers, heat exchangers, and cokers demonstrate life extension due to reduction of variability achieved with improved instruments, valves, and process control. This extends the interval between needed maintenance, and postpones asset replacement, leading to increased availability.

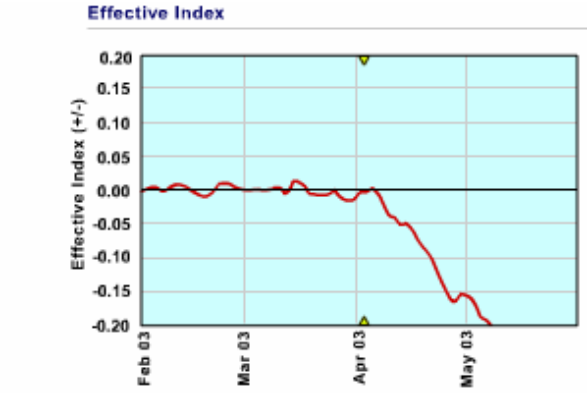
Example

A hydrocracker was experiencing temperature swings of +/- 4^{o} F. So its valves, instruments, and controls were upgraded to cut temperature variation to +/- 0.5^{o} F and to improve throughput. An unexpected benefit of upgrading was the extension of catalyst life by an average of three months. This benefit extended the interval between shutdowns.

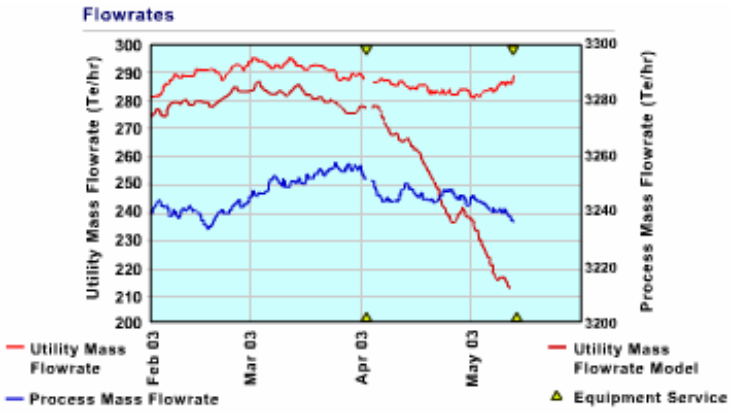
Process Equipment >> Advantages of Monitoring

Monitoring process equipment such as boilers, turbines, heat exchangers, and pumps provides multiple advantages. These advantages can include higher throughput, lower utility and energy use, and optimized run-versus-maintain decisions.

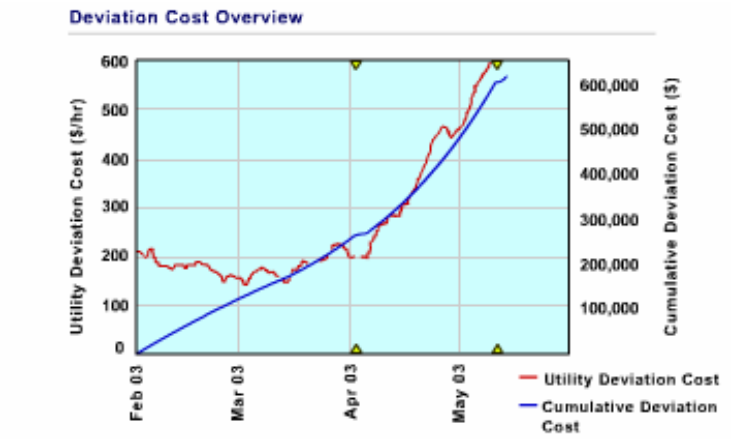
The graphs that follow illustrate the advantages of monitoring process equipment.



This graph shows heat exchanger efficiency dropping significantly. This drop may lead the process to become heat-limited and force a production slowdown or shutdown.



This graph shows increase in **utility** use while **throughput** and **heat** drop. Trending this allows you to predict when the unit will become heat-limited, allowing the unit to stay in operation until maintenance is absolutely required.



This graph shows the **hourly** and **cumulative** cost of reduced efficiency. This allows a run-versus-maintain decision to be made based on cost and profitability.

Valves

Valves are complex high precision mechanical devices subject to wear and many failure modes. Traditionally valve operation was verified by confirming (often visually) the valve's actual position. If the valve position was close to the analog output, and the process variable changed with valve position, the valve was assumed to be operating correctly. This assumption is not necessarily true.

Monitoring can detect problems leading to several types of valve problems that impact availability. These include:

- **Failure on Demand**

  Causes for failure on demand range from loss of instrument air due to plugging or leaking, to sticking of on-off valves that remain unused for long periods. Diagnostics can detect these conditions before failure, allowing maintenance to be scheduled.

  High I/P drive signal can indicate a plugging air supply. Diagnostics can detect a high drive signal, and intelligent help can recommend proper corrective action. Procedures such as partial stroke testing can verify the availability of seldom-used valves. This test will stroke the valve by a small amount to establish valve movement and determine friction, ensuring that valves will work on demand.

- **Excess Valve Deadband**

  Excess valve deadband can cause plant trips. Excess friction means the valve needs a large input before it moves, resulting in a large process swing.

  Friction prevents control from correcting the swing before a constraint is exceeded, causing a trip. Valve diagnostics determine friction and deadband, and plot it over time. This enables predicting when friction or deadband will impact valve performance. It also indicates when valve performance is good, eliminating unneeded maintenance and scheduled downtime.

  Excess deadband reduces availability in another way. Off-specification product requiring reprocessing uses plant resources needed for production. Decrease in deadband reduces off-specification product and rework, increasing plant availability for incremental production.

- **Poor Process Control**

  Poor process control reduces valve life. If control or tuning is poor, valves cycle. This cycling will accelerate valve wear, causing premature valve failure. Monitoring for valve cycles and excess valve travel can detect cycling before valve wear becomes excessive.

Valves >> Advanced Diagnostics and Valve Availability

Advanced diagnostics and digital communications allow actual valve performance and condition to be monitored and increase valve availability through continuous online diagnostics.

Smart valve instruments can determine overall valve health and performance during normal operation, eliminating surprise failures and the need to remove a valve from service for diagnostics.

On-demand diagnostics with no process impact provide further diagnostic information.

The net result of using advanced diagnostics is prediction in advance of failure. Unneeded maintenance is thus eliminated, shortening or eliminating scheduled shutdowns.

The PlantWeb Advantage

Performance diagnostics in Emerson's **FIELDVUE DVC6000 digital valve controllers** can monitor and detect all the major valve conditions that impact availability. In addition, increased diagnostic sophistication of the **ValveLink** technology in our AMS Suite: Intelligent Device Manager software can determine the root cause of many valve conditions without the need for a human valve expert to interpret valve signature or other graphic information.

Finally, the diagnostic information is communicated with simple, easy to understand alerts to operators and maintenance personnel. These alerts notify Operations and Maintenance if maintenance is needed immediately to maintain production, and notify Maintenance if maintenance is required urgently so it can be scheduled before the need becomes critical.

Instruments

Instruments cause loss of availability when a valid process signal is lost. This loss can be absence of a signal, or a signal that appears valid but is actually invalid. In such cases, critical measurements are usually redundant because absence of a signal can be immediately detected, and correlation with other measurements sometimes compensates for the lost PV.

A reading that appears to be valid but is actually invalid is more difficult to determine. This confusion may lead to constraint violation and a trip. Common causes for this confusion are sensor drift, sensor aging or fouling, impulse leg plugging, and so on. Another cause is an analog signal that is stuck.

Device diagnostics can detect some invalid measurements, even if they are within an expected range.

Most intelligent devices have some level of diagnostics built-in. Best in class devices will have diagnostics delivering device status in plain language. Many devices have built-in test routines called "methods" that initiate, and in some cases completely run, on-demand diagnostics. Device diagnostics are generally low in cost or free, and are typically underused.

Instrument detection and prediction is expanding to include more sensor, installation, and process connection problems.

Example

A pressure transmitter will retain the pressure reading that was present when the impulse legs plugged. The actual pressure may be significantly different, but may not be detected until a safety system trip. This time lag would result in the product becoming off-specification, production efficiency being lost, and safety getting compromised.

Informing Plant Personnel

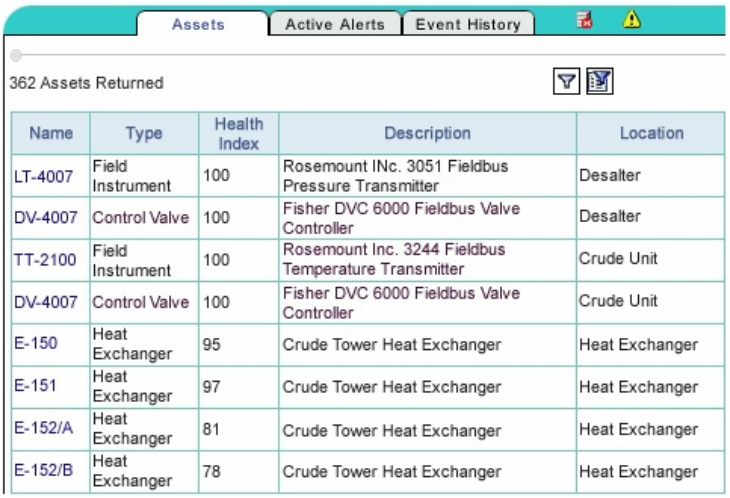
To increase availability, maintenance personnel should be aware of equipment deterioration and the severity of equipment condition so they can take corrective action before the problem leads to downtime. Alert messages such as "NVRAM checksum" or "error code 27" serve no purpose.

To help Maintenance establish priorities, plant asset monitoring systems should:

- **Interpret the severity of equipment alarms.**
- **Provide an overall health index.**
- **Indicate the urgency of the condition.**

This results in increasing maintenance efficiency and improving availability.

The information must be directed to the right individual. Advisory and maintenance issues are sent to the maintenance shop and not to the operator, unless there is an operational impact. Unneeded alarms and alerts distract the operator from more important issues, frequently causing operators to disable offending alarm and alert systems. Information should be sent to the operator only if a problem could affect the safe and effective operation of the process.



Assets | Active Alerts | Event History

362 Assets Returned

Name	Type	Health Index	Description	Location
LT-4007	Field Instrument	100	Rosemount INc. 3051 Fieldbus Pressure Transmitter	Desalter
DV-4007	Control Valve	100	Fisher DVC 6000 Fieldbus Valve Controller	Desalter
TT-2100	Field Instrument	100	Rosemount Inc. 3244 Fieldbus Temperature Transmitter	Crude Unit
DV-4007	Control Valve	100	Fisher DVC 6000 Fieldbus Valve Controller	Crude Unit
E-150	Heat Exchanger	95	Crude Tower Heat Exchanger	Heat Exchanger
E-151	Heat Exchanger	97	Crude Tower Heat Exchanger	Heat Exchanger
E-152/A	Heat Exchanger	81	Crude Tower Heat Exchanger	Heat Exchanger
E-152/B	Heat Exchanger	78	Crude Tower Heat Exchanger	Heat Exchanger

Asset health is recognized as very important to availability, throughput, quality, and operating cost. In the table, the column titled health index shows the health of a variety of plant assets.

Operators use this information to determine if equipment health may affect production. Maintenance uses this information to help establish maintenance priorities. This information can improve production levels, production cost, and availability.

The PlantWeb Advantage

PlantWeb Alert messages notify the right person to solve the problem. If a device has a maintenance issue, an alert is generated to the maintenance department. If the issue could affect operations, the alert is also sent to the operator. This gives the operator time to respond to equipment health conditions before plant operation is affected.

In addition, the **PlantWeb Asset Portal Application** tracks the health and performance of your plant assets ranging from transmitters and valves to rotating equipment and process equipment. An easy to understand "health index" and an "alert monitor" provides immediate feedback to both operators and maintenance personnel on the health of plant equipment.

Putting It All Together

Continuous monitoring can detect and predict conditions causing wear and failure. Needless maintenance can be eliminated with continuous monitoring, leading to reduced wear and degradation. The result is lower costs, longer equipment life, and higher availability.

How do you decide how much monitoring is needed? Equipment monitoring should be based on the criticality of the equipment to the process, and on the cost of repair if early failure conditions are not detected and corrected. The more important the equipment is to production, and the higher the cost of severe failure, the greater the need for equipment monitoring and failure prediction.

Finally, the **monitoring and predictive information needs to reach the right person**. Notify the operators, if the equipment condition could affect plant operation. Notify maintenance technicians of all conditions that could cause equipment deterioration. Clearly communicate the severity of the condition so that corrective action can be prioritized and scheduled.

By appropriate equipment monitoring, plant availability is becoming much more predictable and controllable. This can significantly increase profits and reduce both capital and operational cost.

[End of course]