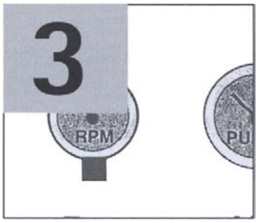

How to prevent machinery failures

- Introduction
- Component function awareness – 'What should it do?'
- Component condition monitoring – 'What is it doing?'
- Preventive (PM) and predictive maintenance (PDM)
- Troubleshooting
- Reliability, everyone's responsibility

Introduction

The five (5) machinery failure classifications are presented in Figure 3.1.

Failure classifications

- Process condition changes
- Improper assembly/maintenance/installation
- Improper operating procedures
- Design deficiencies
- Component wearout

Figure 3.1 Failure classifications

The details concerning each of these failure classifications were discussed in the previous chapter. How can these failure causes be prevented?

Re-examination of the details concerning each failure classification shows that the solution to the prevention of each failure cause is identical. This fact is presented in Figure 3.2.

Prevent machinery failures by ...

- Component function awareness (what should it do?)
- Component condition monitoring (what is it doing?)
- Using predictive maintenance techniques
- Teamwork – reliability is everyone's responsibility

Figure 3.2 Prevent machinery failures by ...

Let's now examine each of the action items noted above in detail.

Component function awareness – 'What should it do?'

Component (machinery part) function awareness allows you to determine what the component is supposed to do. It is obvious that a certain amount of knowledge is required to accomplish this fact. Remember, you may not have all of the knowledge required. **OBTAIN IT!** Figure 3.3 presents sources of where the information may be obtained.

What is it supposed to do?

- Thoroughly understand the function of each component by:
- Reading the instruction book
- Asking questions of:
  - Site reliability group
  - Site technical group
  - Machinists
  - Operators
- Referring to reference books
- Organizing 'mini' information sessions for operators and machinists

Figure 3.3 What is it supposed to do?

Figure 3.4 presents the important principle of knowledge base. The greater this base, the more effective predictive maintenance and root cause analysis procedures will be.

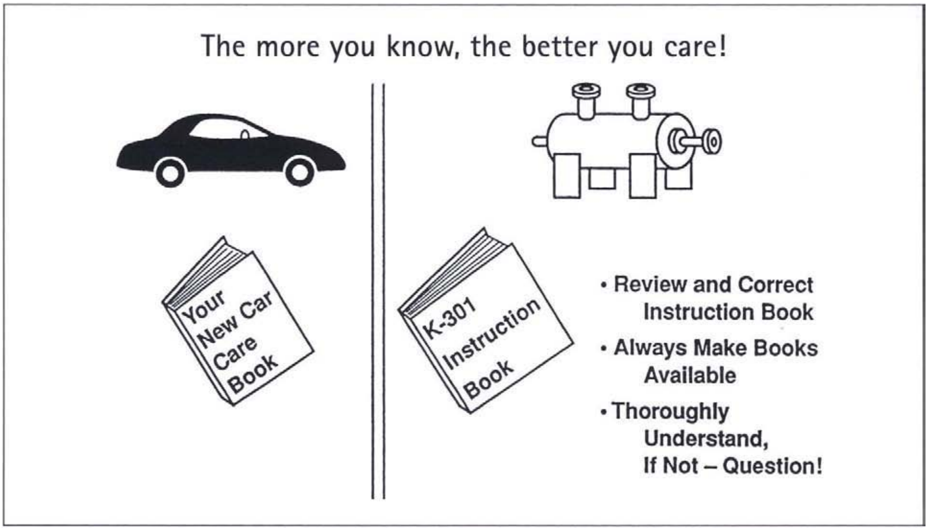

Figure 3.4 The more you know, the better you care!

One final word. Do not be afraid to admit to management that you do not know certain aspects of a problem. But be sure to state that you will find out. After all, management must understand that this is a learning process and does require time.

To aid in the understanding of component function definition, we have included an example for an anti-friction bearing in Figure 3.5.

Component function example

An anti-friction bearing continuously supports all *static and dynamic forces* of a rotor by providing sufficient *bearing area* and requires *oil flow* to remove the generated *frictional heat.*

This statement then defines the items that must be monitored to determine the bearing's condition:

- Static and dynamic forces
- Bearing area
- Oil flow
- Frictional heat

Figure 3.5 Component function example

Naturally, we cannot measure directly all of the items noted in Figure 3.5. However, based on the instruments and measuring devices available on site, what can be measured to assure the component (bearing) is performing correctly?

Component condition monitoring – 'What is it doing?'

In reference to the anti-friction bearing example, the component condition monitoring parameters are presented in Figure 3.6.

Component condition monitoring parameters (for anti-friction bearing)

- Bearing housing vibration
- Bearing housing temperature
- Lube oil condition
  - Viscosity
  - Water content
  - Oil particle content

Figure 3.6 Component condition monitoring parameters (for anti-friction bearing)

A similar exercise can be conducted for all of the major components and systems in any piece of equipment.

What are the major components and systems of any piece of rotating equipment? How many are there? And are the same components contained in any type of rotating equipment? The answers to these questions will be discussed in a later chapter of this book and form the principle of component condition monitoring.

In the next chapter, all of the parameters that should be monitored for each machinery component and its systems regardless of the type will be defined.

Preventive (PM) and predictive maintenance (PDM)

At this point, the distinctions between preventive maintenance (PM), predictive maintenance (PDM) and troubleshooting must be discussed.

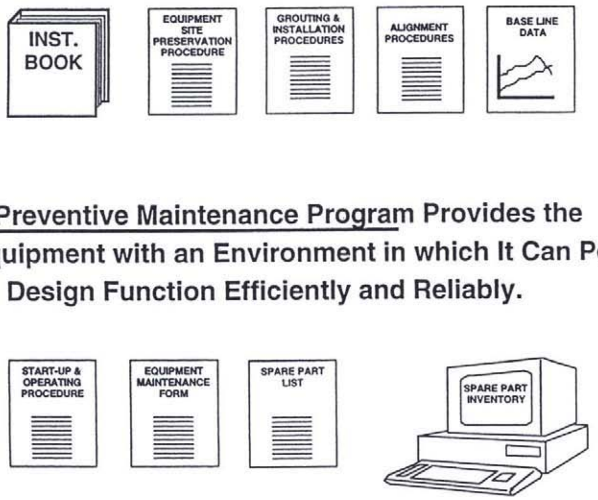

Figure 3.7 A typical preventive maintenance program (Courtesy of M.E. Crane Consultant)

Preventive maintenance

Preventive maintenance requires that maintenance be performed at predetermined intervals. It is time based. A most common preventive maintenance step is an automotive oil change. The objective of this action is to remove the oil from the engine before oil contamination and deterioration cause excessive wear to the engine components. Figure 3.7 presents the components of a typical site preventive maintenance program.

In our experience, a well-planned preventive maintenance program can truly be effective. However, the question must be asked, 'Is the maintenance performed always necessary?' Refer to Figure 3.8.

Preventive maintenance

- Preventive maintenance prevents but ... takes time.
- Is it always necessary?

Figure 3.8 Preventive maintenance

What is the basis for replacing components? Unnecessary component replacement exposes the machinery unit to a failure classification (improper assembly of components, improper installation, component malfunction, component improper storage procedures, etc.).

In addition, preventive maintenance can cause a mindset that automatically determines maintenance at every turnaround regardless of component condition. This can be a costly practice. A case history also demonstrates where preventive maintenance can lead if not properly monitored.

A centrifugal compressor in a large refinery was scheduled for maintenance during the upcoming turnaround. Maintenance planning had scheduled bearing inspection and change if necessary. During the turnaround when bearings were inspected, excessive clearances and signs of deterioration were found. Naturally the bearings were replaced. However, because the bearings were replaced, it was decided that the seals, which are more difficult to remove and inspect, be observed. Upon seal removal the seals were also in a distressed condition and needed to be replaced. Now the tough decisions had to be made. It was decided that the compressor would be dissembled to inspect interior condition for possible causes of seal and bearing failure. Upon disassembly, no significant abnormalities were found within the compressor and it was consequently reassembled.

This case history demonstrates how a standard preventive maintenance approach can lead to unnecessary maintenance and significant loss of revenue to the operating unit. In this case, the operating unit did not make use of site instrumentation. Nowhere had people answered the question 'What changed?'. This approach therefore led to unnecessary disassembly of the compressor. If bearing parameters (temperature, vibration, etc.) and seal parameters (inner and outer seal leakage) had been monitored for change, the conclusions of only bearing and seal change would have been made without unnecessary disassembly. Remember, to disassemble a compressor, significant additional tools and materials are required. Typical time for compressor disassembly can easily reach one week. It can be seen therefore, that the effective way to perform any maintenance activity is to thoroughly plan that activity based on condition changes to equipment. This leads us to the discussion of predictive maintenance.

Predictive maintenance

Predictive maintenance is based on component condition monitoring and trending. Figure 3.9 presents the definition of predictive maintenance.

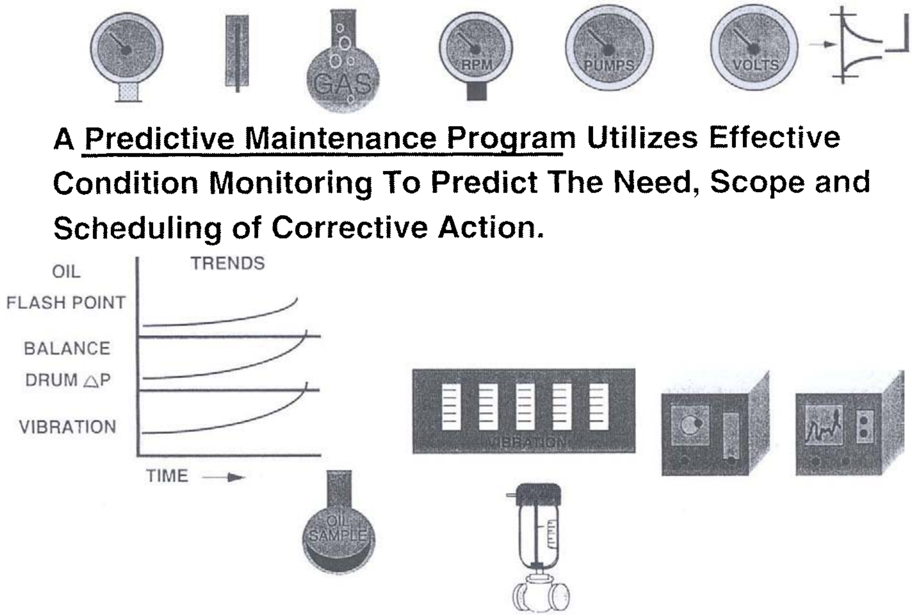

Figure 3.9 A predictive maintenance program (Courtesy of M.E. Crane Consultant)

Troubleshooting

Wherever I travel, worldwide, Troubleshooting is the 'keyword'. More recently, other 'keywords' have emerged:

- Failure analysis
- Root cause analysis
- Reliability centered maintenance (RCM)

Regardless of the 'keyword', it's still troubleshooting. This term is defined in Figure 3.10.

Definition
Troubleshoot – to **discover** and **eliminate (root)** causes of trouble

Figure 3.10 Definition

What are the requirements to accomplish an effective troubleshooting exercise? These facts are presented in Figure 3.11.

- Troubleshooting requires that all **abnormal** conditions be defined
- However, to determine **abnormal** conditions, the **normal** conditions must be known
- Therefore **baseline (normal)** conditions must be known

Figure 3.11 An effective troubleshooting exercise

Do these requirements sound familiar? They certainly should. These are the requirements for predictive maintenance! The differences between these two terms are presented in Figure 3.12.

Predictive maintenance and troubleshooting

- **Predictive maintenance** requires baseline and trend data to predict the root cause of the **change in condition**.
- **Troubleshooting** requires baseline and trend data to predict the root cause of **failure**

Figure 3.12 Predictive maintenance and troubleshooting

Therefore, if we use site-wide predictive maintenance techniques, we can *potentially* detect a *change in condition* before failure. Please refer to Figure 3.13.

Troubleshooting ...

Is predictive maintenance after a failure!

Figure 3.13 Troubleshooting ...

Notice that in the discussion above, the word 'potentially' was in italics.

Remember that the majority of rotating equipment in any plant is general purpose or spared equipment that is not continuously monitored in the control room DCS system. This equipment is also the source of most reliability problems ('Bad Actors'). How can this equipment be effectively monitored?

Let's now discuss the final topic in this chapter.

Reliability, everyone's responsibility

Please refer again to Figure 3.4 of this chapter and review the analogy between your vehicle and site machinery. You'll have fewer problems if you and the mechanic (operators and machinists) know more and – work as a team!

Reliability must be everyone's responsibility. The entire plant operations, maintenance and engineering departments must be aware of the reliability program philosophy and must be able to implement it. Having operators and machinists equipped and trained in the use of simple vibration instruments (vibration pens), oil condition monitors and laser temperature guns will significantly increase the reliability of general purpose (spared) equipment thru the implementation of an effective predictive maintenance program.