

Equipment Troubleshooting

Equipment Can't Talk, But People Can And Should

Summary

When the real reasons for equipment problems are known the professional troubleshooter can recommend and implement corrective actions that will prevent further similar problems and allow increased mean time between failures.

Common shortcomings of equipment troubleshooting are discussed. A case study consisting of a pump motor (bearing) failure is followed, using Equifactor® and human performance root cause analysis to find the real reasons and root causes for the equipment downtime and component failure.

SI04003
System Improvements Inc.
13 pages
February 2004

SKF Reliability Systems
@ptitudeXchange
5271 Viewridge Court
San Diego, CA 92123
United States
tel. +1 858 496 3554
fax +1 858 496 3555
email: info@aptitudexchange.com
Internet: www.aptitudexchange.com

@ptitudeXchange

Use of this document is governed by the terms
and conditions contained in @ptitudeXchange.
Copying or distribution of this document is prohibited.

Introduction

Industry has done a very good job at determining how to fix equipment and to keep equipment up and running. And yet, how often do we look at a failed piece of equipment or equipment that has never worked quite right:

- Blaming the manufacturer for the problems
- Telling people it has always worked that way (problem? What problem?)
- Assuming that someone else will fix it (operations or maintenance)
- Asking Mr. Machinery to fix it (the person who has been around for 30 years)

As we all know, equipment can not talk back and so we may not take the time to conduct a thorough troubleshooting and failure analysis effort to determine the actual path to failure and identify human performance issues and root causes of our equipment problems. To be determined are:

- Failure Mode
- Failure Agent
- Failure Classification

Then the professional troubleshooter can better collect necessary information that will help perform better root cause failure analysis and subsequently identify the real human performance root causes that often are the underlying reasons causing equipment problem(s). When the real reasons for the equipment problems are known the professional troubleshooter can recommend and implement corrective actions that will prevent further similar problems and allow increased mean time between failures.

A case study will be provided to show common shortcomings of equipment troubleshooting, followed by a case study

using Equifactor® and human performance root cause analysis to find the real reasons and root causes for equipment and component downtime and failures.

Troubleshooting Objectives

Most people recognize that the primary objective of conducting machinery troubleshooting is to prevent the equipment and machinery from repeat incidents. Although this may sound obvious, I would suggest that we might not be as effective at accomplishing this as desired. One of the reasons may be that in our troubleshooting efforts we do not always take the time to document our efforts. As a result, when we have a failure and we review the machinery history for the equipment or machinery, the entry looks something like the following:

3-25-01 Compressor failed

3-26-01 Compressor online

Unfortunately, this does not indicate what was done during the troubleshooting process and whether actions that were taken were effective or ineffective. A process that makes the documentation easier while conducting the troubleshooting is a desired goal.

Additionally, if a decision is made to purchase a new piece of equipment or upgrade an existing piece, it is beneficial to have previous problems documented in order that the bid specification for the new or upgraded piece of equipment can be better written. This will provide for the new or upgraded equipment to be better suited for the desired service.

Traps

Too often, what may prevent us from fully realizing our troubleshooting potential are some common troubleshooting *traps*.

The first of these is the “Everyone’s job and no ones’ job.” This is where the Operations

group decide that it is too difficult for them to fix and the Maintenance group decide that it is too minor for them to get involved. The result is often just replacing the item or addressing the symptoms only.

The second trap is the “Mr. Machinery.” This is where a facility may rely on a certain individual that has been at the facility for a long time. This is not necessarily adverse, it can be a problem if this individual has not kept up with current technology.

The third trap is “Telephone troubleshooting.” This occurs when the troubleshooter attempts to solve the problem by interviewing people over the phone and not taking the opportunity to look at the failed equipment in person.

The fourth and final trap is “Familiarity.” This situation can arise if a person becomes very familiar with a piece of equipment or machinery and begins to assume that the

current problem is the same as the last time whether or not it in fact is or not.

Systematic Troubleshooting

In order to effectively conduct troubleshooting and avoid the above-mentioned traps, one should follow a logical process. A logical process should be able to determine “what” happened, “why” it happened and then develop effective fixes.

What Happened?

The “what” happened can effectively be portrayed by creating a sequence of events chart. This provides a graphical presentation of what happened to those reviewing the incident. A common technique is to put the incident or problem in a circle, the actions or events into boxes and amplifying information in ovals often called conditions. Let’s take a look at an incident (Figure 1) that occurred to a cooling pump motor.

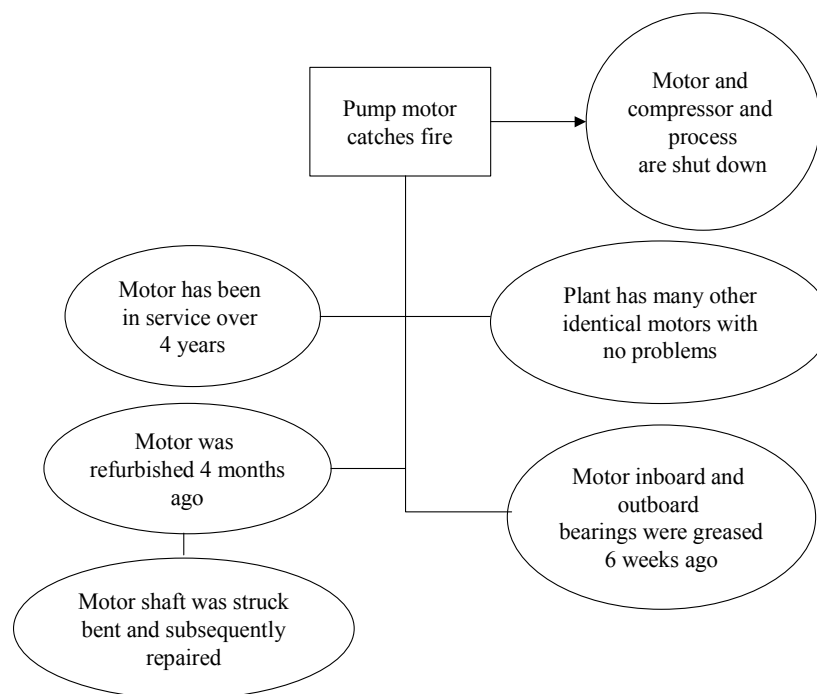


Figure 1 The Incident.

This pump has been in operation for over four years. Four months ago it was taken out of service and refurbished. Six weeks ago it was greased as per the manufacturers recommendations. One the day of the incident, the pump motor began to smoke eventually catching fire. After disassembly of the motor we find that the inboard bearing is burned and melted. The outboard bearing appears to be in good condition. We can put this into a sequence of events chart and then begin to troubleshoot using a combination of brainstorming and a cause and effect technique.

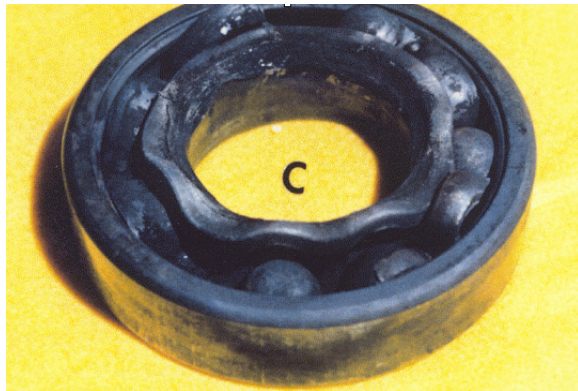


Figure 2: Inboard Motor Shaft Bearing.

Symptoms Identification

For a good process of troubleshooting, all symptoms should be listed. These can include operator observations in the field, such as:

- Smell / odor: gas, acid leakage, acrid burning
- Touch: overheating, vibration
- Sound: abnormal noise, knocking, rubbing
- Sight: direct observation and indirect observation

Also symptoms can be collected by operator observations in the control room, such as by direct observation: vapor, fume, fluid, leakage, smoke. Indirect observations could include:

Changes in indicator readings:

- Pressure
- Temperature
- Flow
- Position speed

Changes in performance:

- Pressure ratios
- Temperature ratios
- Power demand
- Product loss efficiencies

Why it Happened - Option 1

Returning to the bearing example, if we are able to gather the right people we should be able to develop a reasonable list of possibilities for the burned bearing by brainstorming (Figure 3). Some may include:

- Lubrication problems
- Loading problems
- Misalignment problems
- Clearance problems
- Friction problems

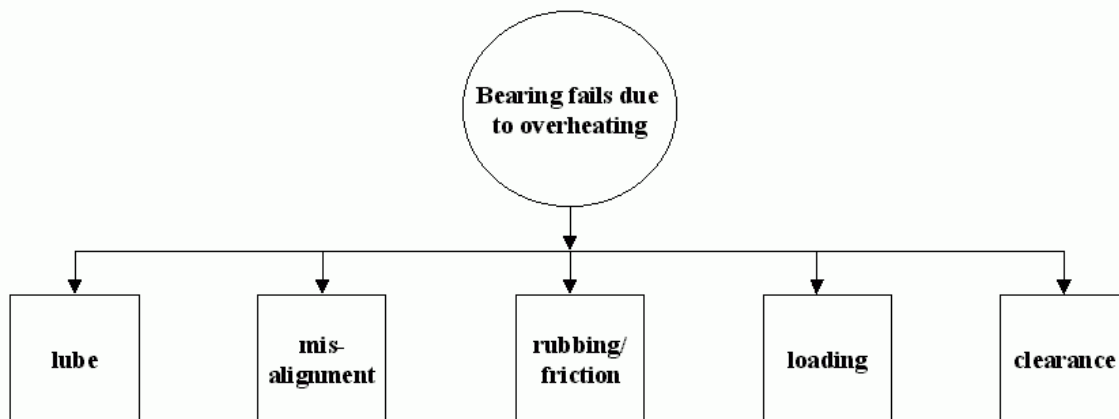


Figure 3 What Happened (Option 1)

Below each of these general categories we could also postulate additional detailed possibilities (Figure 4). Specifically under the lubrication category we could list:

- Insufficient lubrication
- Over lubrication

- Incorrect lubrication

We could continue to drill deeper under each of the general categories as the group that we have gathered continues to brainstorm based on their collective knowledge and experience. This would hopefully get us to at least several different possibilities regarding the root cause.

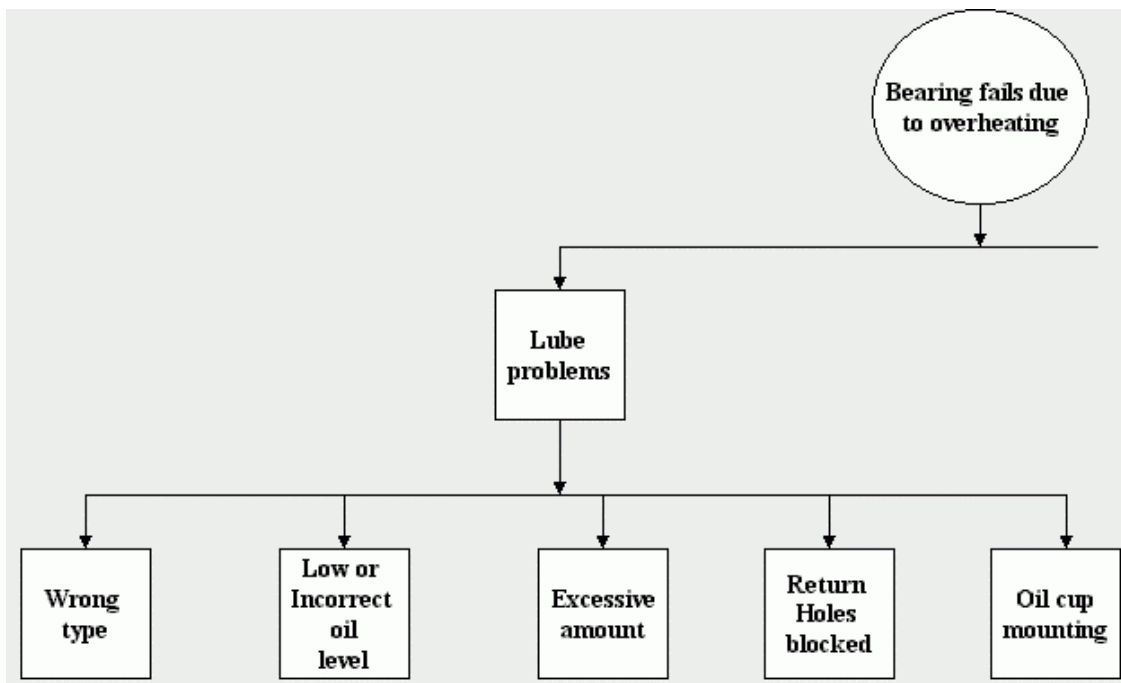


Figure 4 Additional Detailed Possibilities (Lube Problems).

Why it Happened - Option 2

Another approach to the troubleshooting process could include gathering the right people but in addition, this group could also use pre-developed and/or existing *checklists* that contain the most common symptoms of bearing problems and then include the possible causes for each of the listed symptoms. An advantage of using well developed checklists is the tendency of people to forget one or two symptoms and/or to

forget possible causes of the symptoms. Also, if the right people can not be gathered you may have to rely on people with less experience and knowledge. By using checklists one can ensure that each and every troubleshooter is relying on the best available information obtained to create the checklists. Example checklists, or "troubleshooting tables" are included in the Equifactor® guide. The tables cover generic equipment, valves, components, and electrical problems.

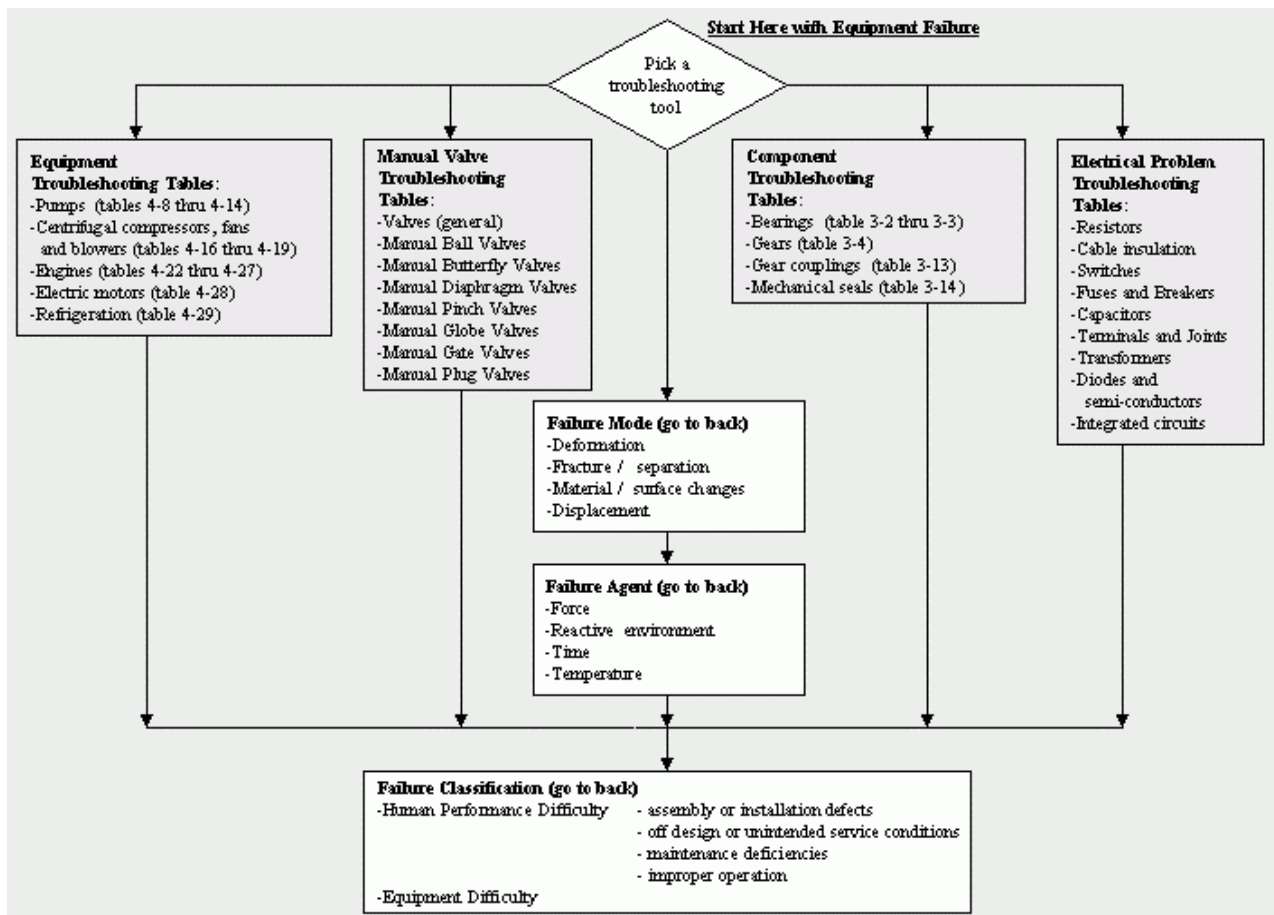


Figure 5: Equifactor® Troubleshooting Guide.

Continuing with the bearing example, the Equifactor® table for bearings was used. Various causes for overheated bearing are rejected, based on investigation. Finally, measurements taken after the failure of the

bearing found that the shaft clearance was excessive (0.007 negative). The housing surrounding the bearing outer ring was made too tight, increasing friction heat, thermal expansion, etc. (too tight interference fit).

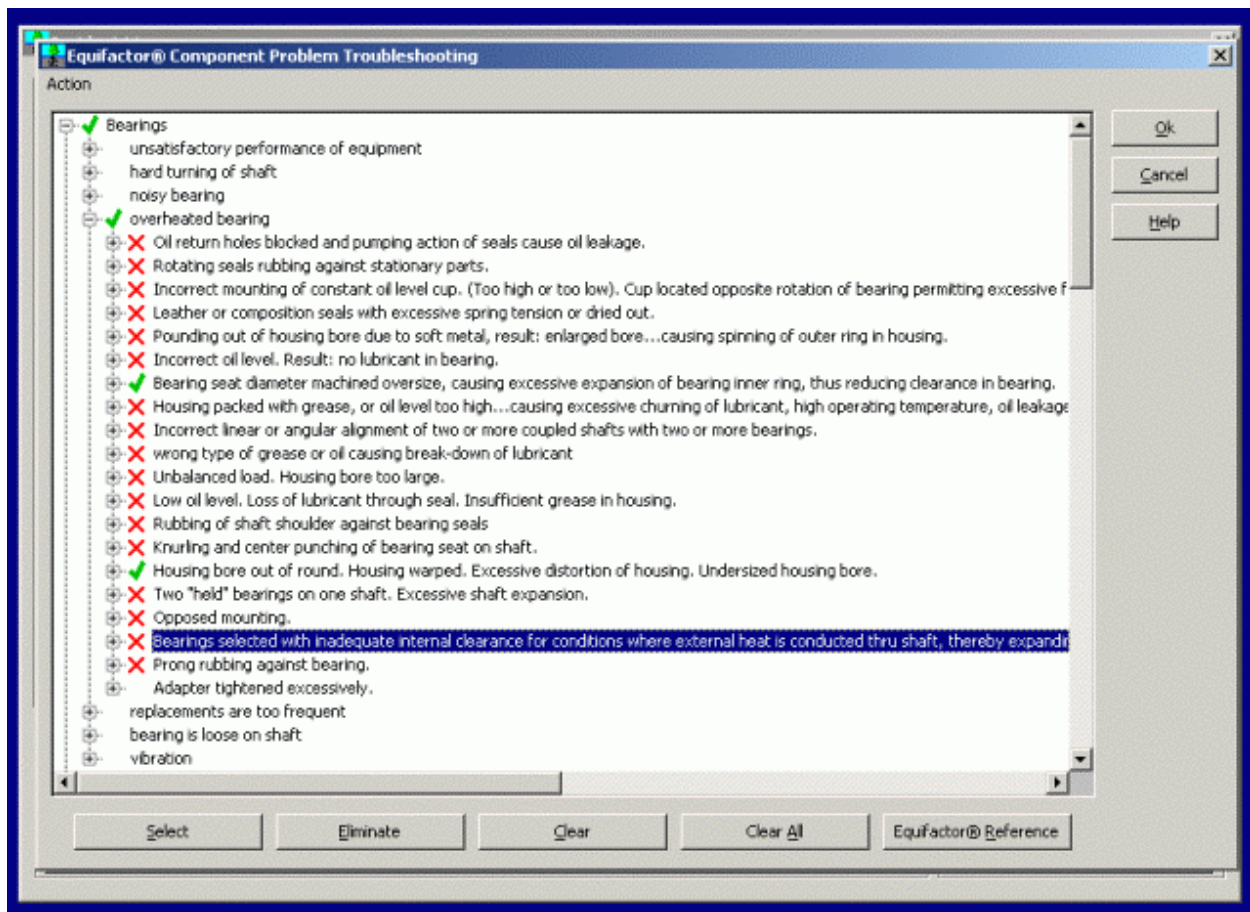


Figure 6: Checking Possible Causes For Bearing Overheating.

Path To Failure

If checklists are not available, one can still use a process to determine the “path to failure” to better understand the manner and conditions that existed to create the failure or poorly performing equipment or machinery.

The first step is to determine the *Failure Mode*. This is the appearance, manner or form

in which a machinery component or unit failure manifests itself. The general categories of failure modes include: deformation, fracture, surface/material changes and displacement. Below each of the general categories we can list more specific forms of each (Figure 7).

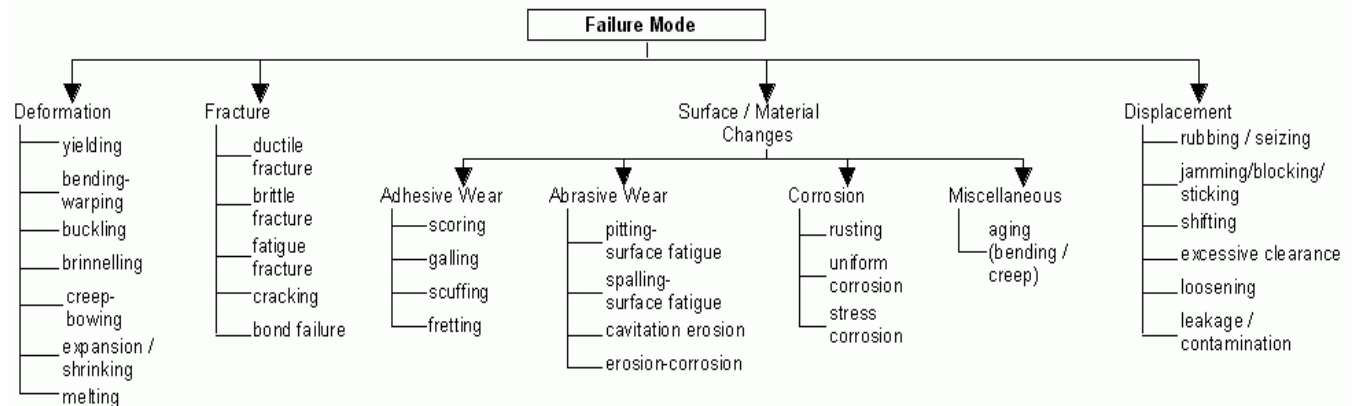


Figure 7 Mechanical Failure Modes.

After the failure mode we would proceed to the *failure agents* (Figure 8). The failure agent is the catalyst that allowed the failure mode to occur. The failure modes consist of: Force, Reactive Environment, Time, Temperature ("FRETT"). One of these will be the primary often creating secondary and tertiary failure agents that are exhibited. It is similar to asking why as in option 1 above, only now we have a more structured and systematic process that anyone can use and document.

- Force - Did a component fail due to application of excessive force? (due to possible misalignment, thermal expansion and contraction, overloading etc.)
- Reactive Environment - Did a component fail due an environment that is not conducive to the material of the equipment or component such as brass and seawater?

- Time - Did equipment or a component fail due to reaching its end of expected life? Did the equipment or component reach or exceed the working life of similar equipment or components?
- Temperature - Did equipment or a component fail due to excessive temperature, either hot or cold?

After the failure agent we proceed to determine the *failure classification* (Figure 9). This is where we determine whether the issue is strictly an "equipment difficulty" or whether there may be a "human performance difficulty" associated with it. Too often, many troubleshooters' stop at this point. They are missing a valuable opportunity to take their troubleshooting to another level. This is where we now involve the people talking back part of the investigation.

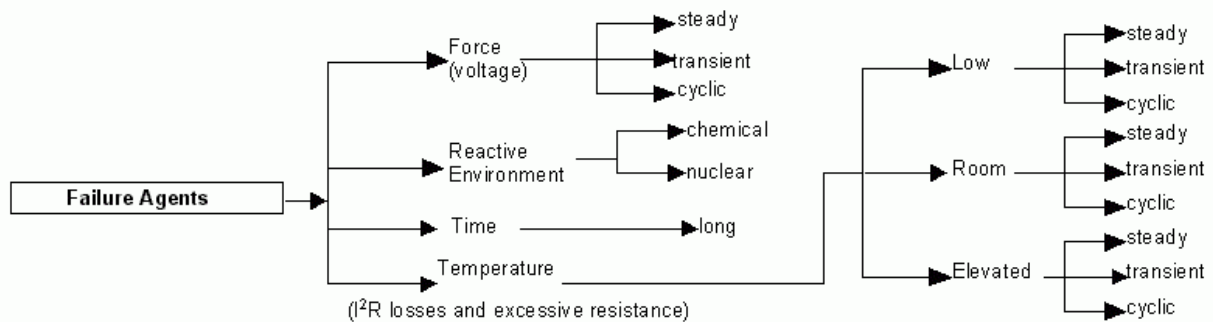


Figure 8 Failure Agents.

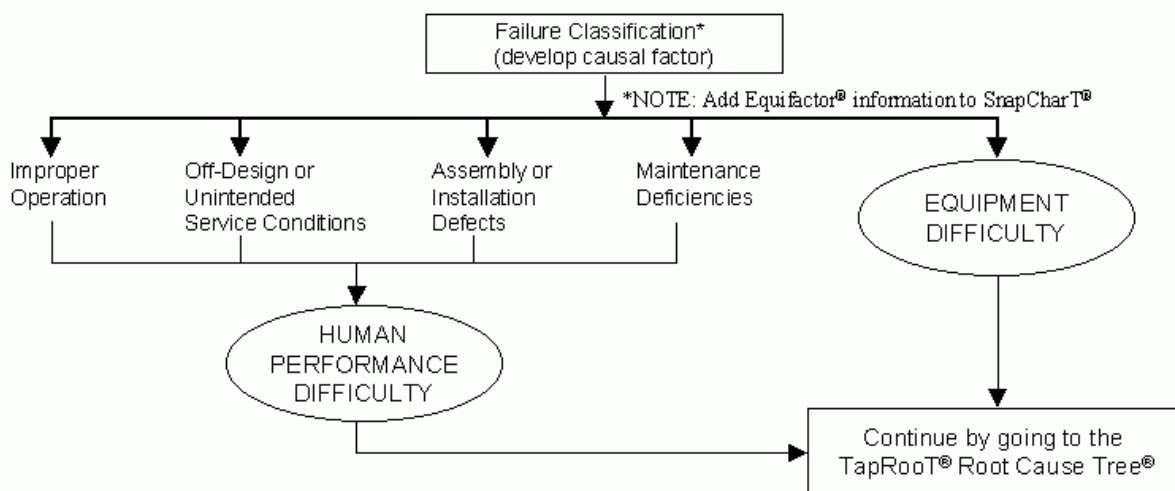


Figure 9 Failure Classification.

Human Performance

If it is determined that there was human performance involved in the equipment issue, the troubleshooter will then need to step out of the equipment analysis role and begin to set up interviews with people who have interacted with the equipment or machinery in question.

To begin the process of finding the human performance root causes we can use the Root Cause Tree® (See Figure 10). This will allow us to get the human performance “why” part

of the investigation. The process starts by answering the 15 questions on the front of the Root Cause Tree®. This will help the troubleshooter better determine which of the basic cause categories are applicable and which basic cause categories are not applicable for the equipment issue being investigated.

Once the 15 questions have been answered, YES or NO, the troubleshooter will turn to the back of the Root Cause Tree® and analyze the basic cause categories identified by the 15

questions from the front of the Root Cause Tree®. Under each of the basic cause categories there are root causes the troubleshooter should evaluate to determine if they apply to the equipment issue (See Figure 11).

An example might be where a person was performing maintenance and the procedure was not specific enough causing the maintenance person to have to interpret the intent of the procedure and subsequently making an incorrect interpretation causing the equipment to fail or not work properly.

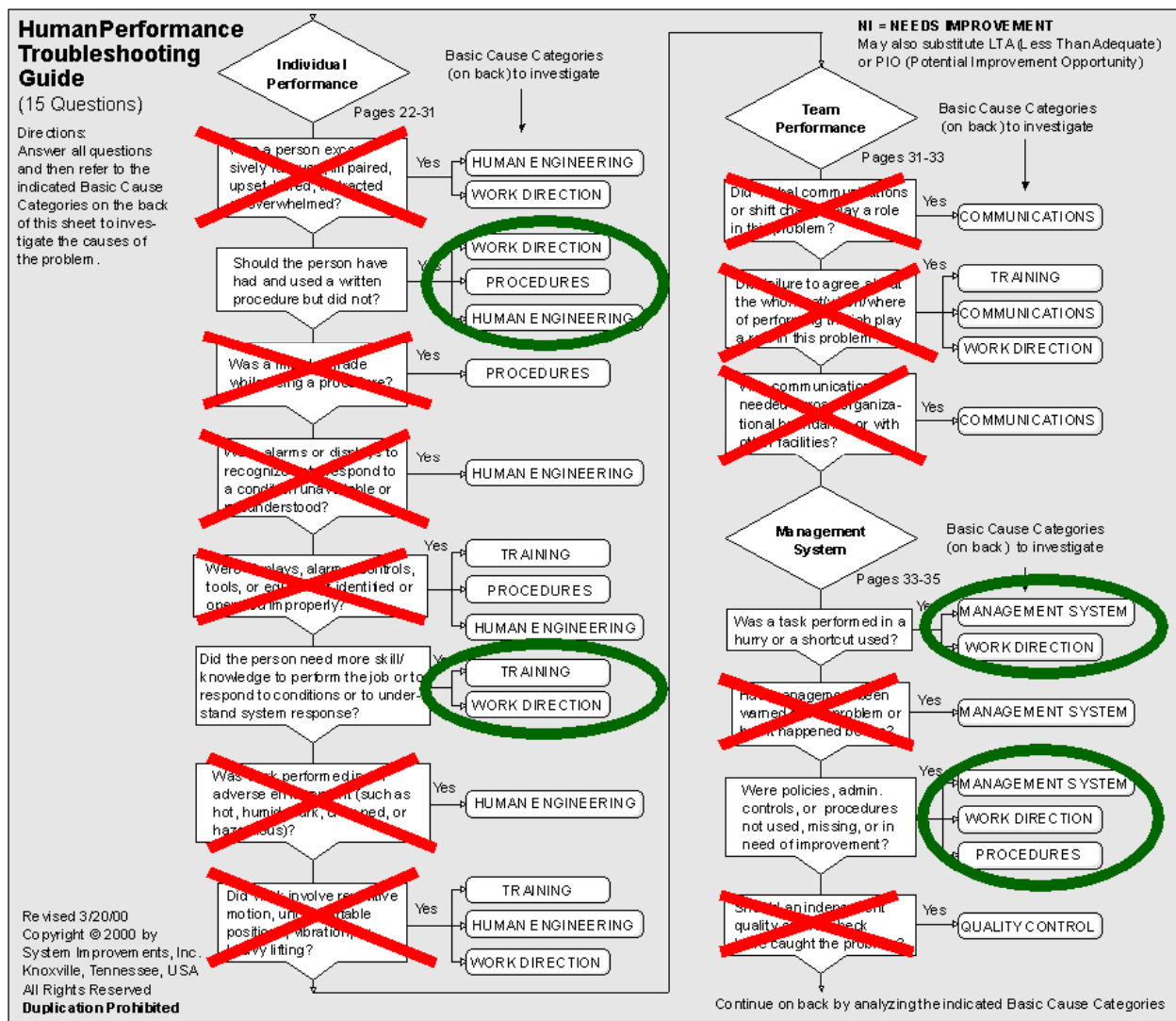


Figure 10 Root Cause Tree®

To adequately answer the 15 questions and then identify root causes from the Root Cause Tree® the troubleshooter will need to conduct interviews with the appropriate people. The 15 questions and the root causes on the Root Cause Tree® are designed to minimize if not eliminate the “blame” syndrome of many companies. This does not mean that we should

not hold people accountable for their actions, only that we need to look at our systems first to ensure that they are providing the people the tools they need to be successful in their jobs. Once we are confident that our systems are in order we can then have better justification in applying the appropriate discipline that is warranted for the situation.

Returning to the bearing example, four months ago this motor had been taken out of service for refurbishment. During the refurbishment process the motor shaft was struck, bent and repaired. The bearing housing was also refurbished. The shaft was repaired using a “weld-overlay method.”

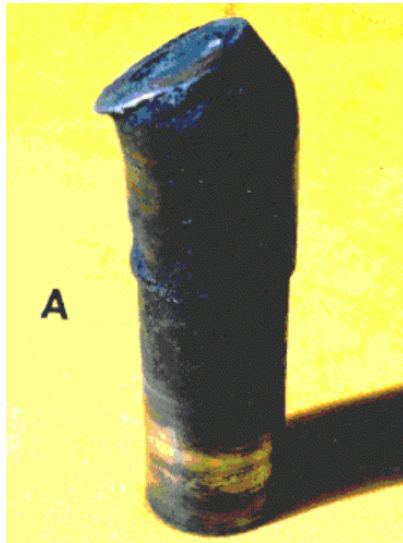


Figure 11: Full Length Of The Fractured Pump Side Of The Motor Shaft. The Larger Diameter Is The Weld Overlay. It Was Reported To Have Been Welded And Machined To Correct A Bend In The Shaft.

The bearing housing was repaired by “bushing it up” with a steel sleeve. Furthermore:

- No records were found of measurements taken before and after the fix at the repair shop.
- No mention was made of the difficulty experienced during installation of the bearing (due to excessive interference fit).

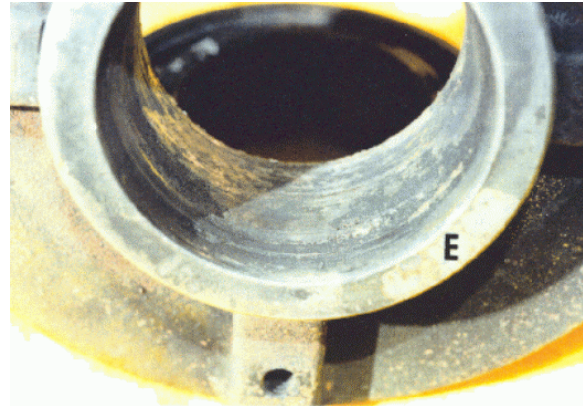


Figure 12: Mechanical Damaged Bushing From The Inboard Bearing Housing.

The sequence of events that happened can be added to the start made in Figure 1. The updated chart is depicted in Figure 13, using the SnapCharT® tool.

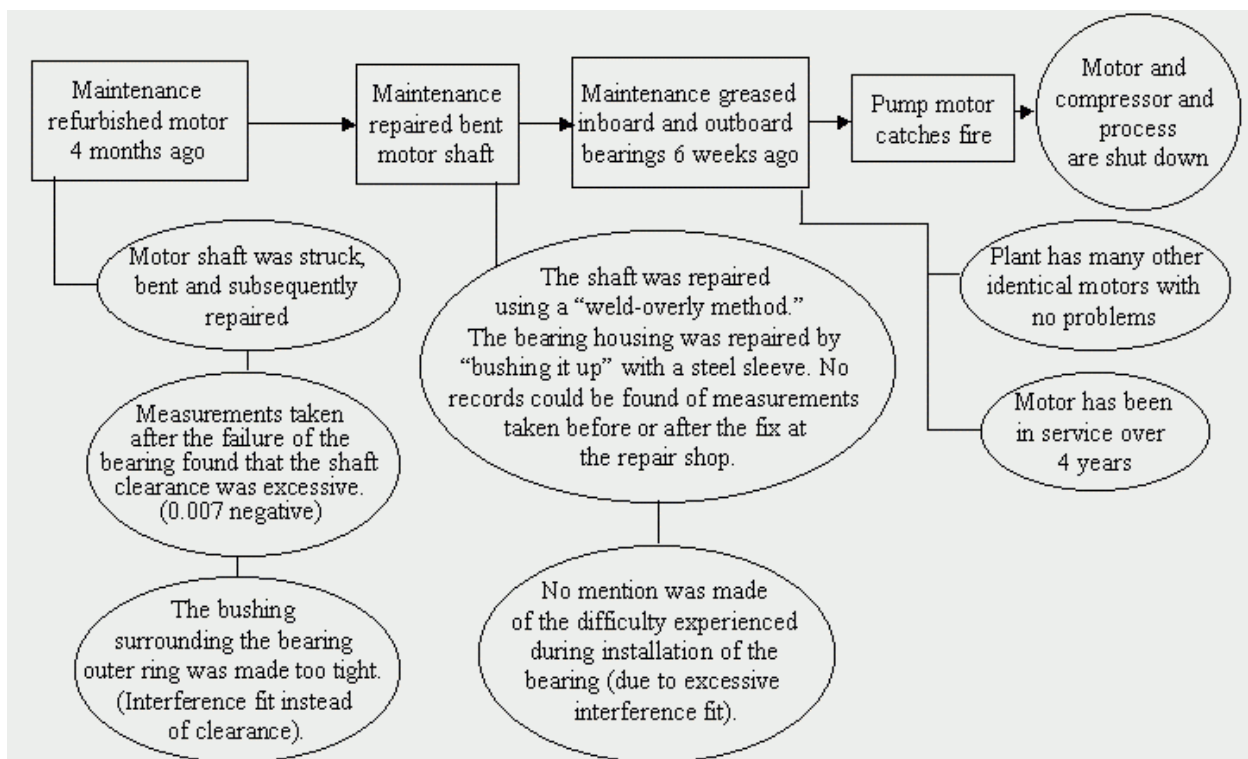


Figure 13: Updated Event Chart.

The problems definitely needed further investigation into human errors. This to prevent these problems from happening again. Following the Root Cause Tree® in Figure 10, various human performance basic causes were identified where it went wrong. Further investigation into the root causes showed non-existing procedures, lack of training, lack of standard and administration controls, and lack of supervision, see Figure 14.

Conclusions

The TapRoot® System and Equifactor® Equipment Troubleshooting processes provide a methodology to lead an investigator through the techniques/steps used to perform an in-depth investigation and troubleshooting of an

equipment's and incident's root causes or an in-depth audit or observation to proactively improve performance. TapRoot® and Equifactor® are an efficient, systematic set of tools that allow people to look at facts objectively, identify the problems and find the root causes of the problems.

For further information contact Andrew Marquardt of System Improvements, Inc. Phone: +1 (865)-539-2139.

<http://www.taproot.com>



Figure 14: Further Investigation Into The Basic Causes Of Human Errors.