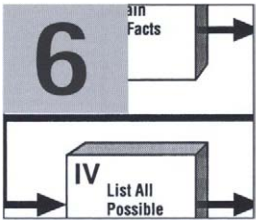

Root cause analysis example problem

- Introduction
- Example case history
- Answers and comments for the example case history

Introduction

In the previous chapter, the root cause analysis procedure was defined and discussed. In this chapter, an example is presented that will enable you to implement the procedure. The example is arranged to allow you to perform each step and then either immediately review the comments for that section (Considerations) or to proceed to the next step of the example. It is suggested that you attempt to complete the entire procedure the first time and then review the specific comments for each section. Answers for each section are contained in the back of this chapter.

The procedure outline from Chapter 5 is presented in Figure 6.1. Be sure to follow each step in order and to refer to the details for each step in Chapter 5 to assure completeness.

Example case history

The example case history is noted below. This is an actual problem that was encountered and resulted in multiple shutdowns of a process unit and loss of MM$ of profit.

Read the case history carefully and be sure to review all details. Also make a list of the questions that you would want to ask and to what

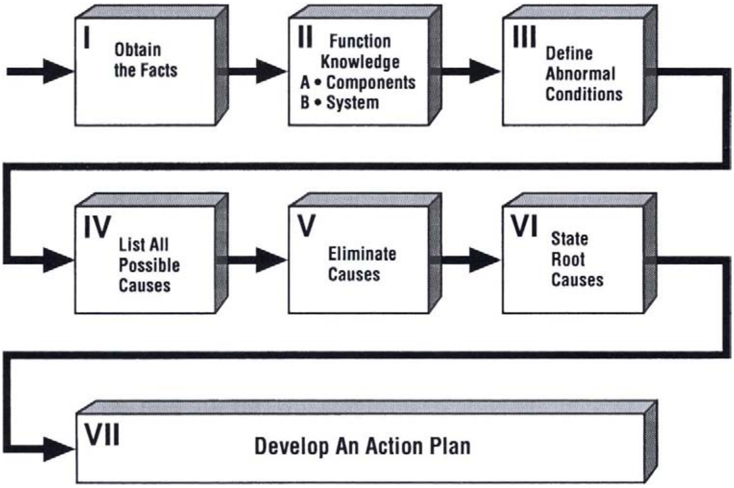

Figure 6.1 The troubleshooting process

group in the plant (Operations, maintenance and engineering) you would direct your questions.

Title:	**Example troubleshooting problem**
Purpose:	To learn that troubleshooting should follow through logical steps, and requires knowledge of equipment and supporting system function and *practice*.
Task:	Read the following case history and list any required questions. Follow the troubleshooting guidelines previously discussed. Complete *all* required steps, note *all* information required and state: ■ Root cause ■ Action plan
Given:	Case history:

A two (2) stage motor driven positive displacement diaphragm compressor and an identical spare were installed in a chemical plant. Specifics are as follows:

I. Mechanical details (Figure 1)

A. Motor driven through a belt
B. 400 rpm compressor speed
C. Sleeve bearings – pressure lube
D. Self contained oil system in sump
E. No auxiliary pump (Manufacturer's proven design that had good field operating experience)
F. Main pump driven off the shaft

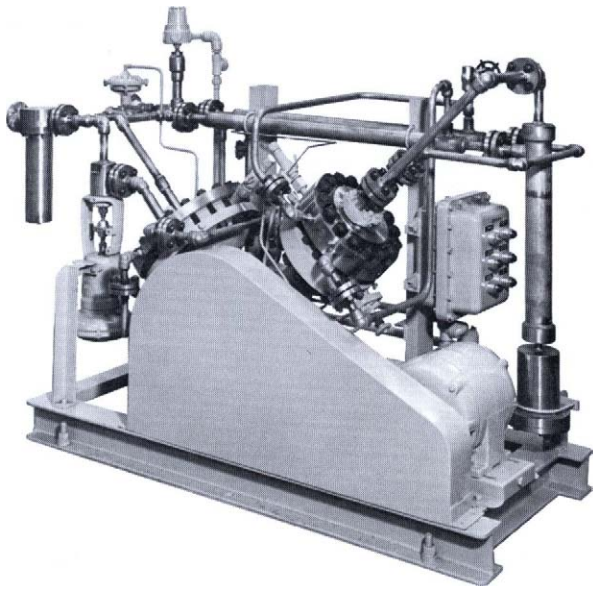

Figure 6.2

II. Performance details
P_1 = 80 psia
P_2 (final) = 330–400 psia
Intercooled
T_1 = 100ºF
T_2 (final) = 275ºF
Gas = dry nitrogen
Acfm (inlet) = 20 ft.^{3}/minute

III. Process system details (Figure 2)
The subject compressor supplies N_2 at approximately 300 psi, to catalyst feeder, to allow dry (non-stick) feed of catalyst to the reactor. Feed is continuous. Design of system incorporates a receiver downstream of compressor to hold excess quantity of N_2. Low and high pressure switch turn compressor on and off as required. The volume of the receiver, is 200 ft.^{3}. Approximate required feed rate to catalyst feeders = 1 acfm.

Pressure switches set at:

- Start compressor 300 psig
- Stop compressor 355 psig

IV. Additional facts
A. Unit was started up new.
B. Compressor ran well for first two weeks.

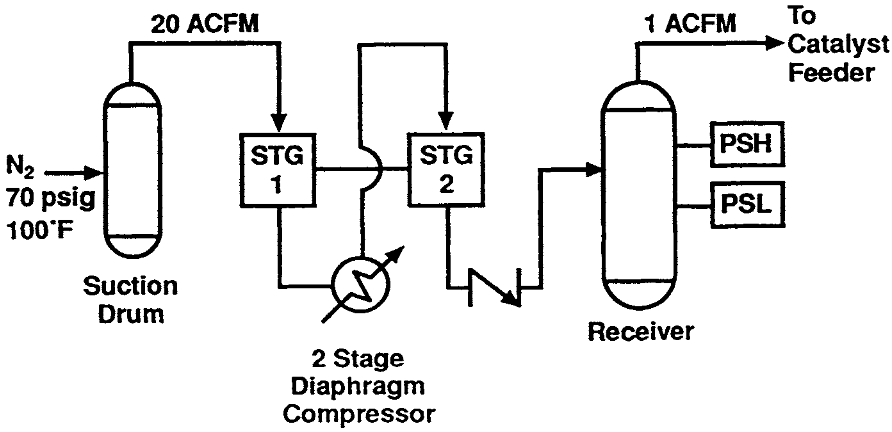

Figure 6.3

C. After this time, both compressors continuously suffered bearing failures.
D. Bearings were totally black.
E. Babbitt was not found on bearing shells.
F. All clearances on bearings ok when installed.
G. Babbitt material per specification.
H. No abnormal vibration prior to failure.
I. All pressures and temperatures OK. Note: since this is a small unit, it is not supplied with vibration and bearing temperature monitoring.

Step 1 – Fact finding

This step forms the foundation for the procedure and determines its effectiveness.

Apparent problem: ______________________________

Affected components: ______________________________

____

____

Facts: ______________ ______________

______________ ______________

______________ ______________

______________ ______________

______________ ______________

Additional questions:

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Considerations:

Be sure to:

- First determine the apparent problem from the facts presented. What is it? It may be necessary to change the apparent problem during the procedure based on the information gathered.
- Next, determine the affected components(s). What are they?
- If the information presented in the case history requires questions, ask them of the appropriate plant group (s). Asking the same question of different groups can be helpful.
- Review the apparent affected components(s) damage details thoroughly.
- Now obtain all the facts. Use the failure classification list contained in Chapter 2 as a checklist to assure that questions are asked concerning all the failure classifications. Also refer to the Fact list contained in Chapter 5.
- In addition, a good example of questions to ask is contained in the site study questionnaire contained at the back of Chapter 8.

Step 2 – Component and system function knowledge

This step requires the most work and the greatest knowledge base. Next to insufficient fact gathering, it is the area where most root cause analysis procedures fail. In fact, this step is so important that the next chapter is devoted to increasing this skill. And, no matter what your level of experience, this task will never be complete. There is always more information to learn and store in your data base.

Failed component(s) function – what is it supposed to do?

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____

____

Systems that support the failed component

Components in each system that support the failed component

System: **Components:**

Parameters for input data:

Possible failure causes for each affected component and system:

Considerations:

- First define the component function definition in clear, concise terms for each affected component noted in the previous step.
- Next, define the systems and subsystems that support each component.
- Then define all of the parameters necessary to obtain data for each component and all of its systems and subsystems.

- Be sure to utilize the component condition monitoring lists presented in Chapter 4 when obtaining information.
- Now obtain this information first from DCS and PLC systems if possible before asking questions or using manual logs to assure accuracy. However, pay attention to the information and assure that the sampling rates are sufficient for the trends that you require.
- Once this information is obtained, start to think of the possible failure causes, based on your present knowledge base, and list them for each component and it's systems and sub-systems.
- Do not hesitate to consult reference books, instruction books and to question associates both in your plant, other plants in your company, Internet and Network sources (from past conference, training workshops etc.)

Step 3 – Defining abnormal conditions

Use the data obtained at this point to define abnormal conditions. Do not look for only alarms!! If baseline data (data before the event) was low, a significant change in the parameter value could have occurred without alarm actuation!

Abnormal condition parameters:

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Questions and group to confirm each abnormal condition:

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Considerations:

- Use % change to define abnormal conditions.
- I have used a 50% value as a norm but, it depends on the application and the signature of the specific machine.
- List all abnormal conditions that exceed your defined % value.
- Review the failed component function definitions, systems and sub-systems and prioritize the abnormal conditions ...

- List additional questions for each plant group to confirm that each noted abnormal condition is valid based the history of this machine.

Step 4 – Listing causes

Now, list all possible causes, based on your expanded knowledge base and information gathered to date.

Possible causes:

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Additional questions to confirm causes:

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Considerations:

- Start with the simple causes first.
- Be sure that only causes are listed and not effects.
- Confirm causes by reviewing data an asking additional questions.
- Consult associates in other locations and/or use company network to confirm the validity of the causes.

Step 5 – Eliminating causes

Once the causes are noted, screen each cause based on all the information gathered. Eliminate each cause not totally supported by the facts.

Causes eliminated		**Reason**	
	________		____________
	________		____________
	________		____________
	________		____________

Considerations:

- Carefully screen each listed cause and eliminate those not fully supported by facts.

Step 6 – Determining the root cause

State the root cause.

Root cause(s)

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Considerations:

- Dig deep.
- Most root causes are found in the systems and subsystems that support the failed component(s).
- Root causes frequently involve lack of awareness of personnel.

Step 7 – Constructing an action plan

List the proposed action plans:

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Considerations:

- Justify the action plan to management based on lost profit.
- List the cost of the action required and show savings as a result.
- Make sure the action plan is detailed with responsible persons listed for each task.
- Follow up on all action points to be sure they are implemented.
- If contractor or vendor design meetings are required, prepare a detailed agenda, listing required individual disciplines and be sure to forward it well in advance of the meeting.
- Hold design meetings at the vendor's offices to be sure all required specialists are available.

Answers and comments for the example case history

Answers are arranged in the order of the procedure and include comments for each section of the problem.

1. Facts

The apparent problem – *all journal bearings failed*

Comments:

The apparent problem should always be an effect, not a cause. The tendency is to jump immediately to a cause of the problem. Even if the cause or the root cause is apparent to you, stick with the procedure format. Many a root cause analysis has produced results that are not complete which leads to another root cause analysis after another failure. Note also that the apparent problem has to be precisely stated – all journals bearings failed, not just one of the bearings.

The affected component(s) – *sleeve type journals bearings*

Comments:

Be sure to be precise in listing the failed component. An exact definition is necessary to determine the required parameters to check for causes and root causes. As an example, there are many types of journal bearings and each type has different characteristics, supporting systems and failure causes. Using the incorrect type could lead the analysis in the wrong direction and draw incorrect conclusions. For the present example, noting only a bearing would leave the analysis open to Anti-friction (ball, roller or tapered roller), sleeve, multilobe, tilt pad etc. bearings and their many types of lubrication systems (ring oil, oil mist, pressurized etc.). Be aware that the normal tendency is to think along the lines of your experience. Consult experienced associates, publications and the internet for information concerning the specific affected component.

The facts: failure class number is noted by ( )

- Pressurized lubrication system (1)
- No auxiliary lube oil pump (1)
- Main pump is shaft driven (1)
- The compressor is stopped and started by pressure (volume remaining) in the receiver vessel (1)
- The compressor should not stop and start often based on design values (200 cubic feet receiver capacity and 1 cubic foot per minute flow required) (1)
- There were no problems during the first two weeks of operation (3)

- Condition of all bearings (totally black) showed indication of lack of lubrication and/or excessive load. (1)
- It was confirmed that bearings were correctly installed (2)
- Bearing material was per specification (4)
- Measured vibration and compressor frame bearing housing temperatures using portable instruments were ok (4)

Additional questions (ask additional questions, based on the facts noted and note the discipline required).

- What changed after 2 weeks of operation? (Operations, maintenance instrumentation, process engineers) – the only change was the amount of flow required by the catalyst feeder. It was 1 cubic foot per minute but was changed to 10 cubic feet per minute by the process design company
- What was the design stop and start time of the compressor? – Approximately 6 times a day
- What was the actual stop and start time observed? – Approximately one every 5 minutes
- Have other plants using the same technology had the same problem to date? – No
- Has the compressor vendor experienced this type of problem in the past? – No

Comments:

Use the failure classification in recording the facts:

1. The effect of the process and associated systems.
2. Improper assembly/disassembly.
3. Improper operating procedures.
4. Design and manufacturing deficiencies.
5. Component wear out.

It has been my experience that the majority of root causes are found in failure classification 1. This is also the most difficult failure classification to define since it requires detailed knowledge of the process and associated systems.

Do not limit the input information to what you obtain, involve all required disciplines in the plant.

Refer to the fact list in Chapter 5 and be sure to ask these important questions. Especially, has it always been a problem and what changed?

Be sure to inspect all damaged components very carefully.

Be specific regarding the question what has changed and be sure to ask regarding each component in the supporting systems for the failed component.

2. Failed component function

A sleeve journal bearing supports the load with an oil film of the correct thickness and the proper viscosity to reduce friction.

Components present in the system that supports the failed component.

- Oil sump in the base of the compressor.
- Oil strainer in the line to the main pump.
- Main pump.
- Coupling between the pump and the shaft.
- Oil filter (no oil cooler required based on the specified stop and start time).
- Pressure control valve.

Parameters for input data.

- Oil sample analysis, including particle analysis.
- Measured bearing housing temperatures.
- Measured vibration on bearing housing.

Possible failure causes for each affected component and system:

- Lack of lubrication.
- Insufficient bearing clearance.
- Excessive bearing clearance.
- Excessive bearing load.
- Internal misalignment between bearings.
- Improper bearing Babbitt material specification.

Questions:

- Was the proper oil used? – Yes
- Was the oil type changed after the first 2 weeks? – No
- Was there any wear on the oil system components? – No
- Was there any blockage of the suction strainer or the filter? – No

Comments:

- Note the answers above carefully and compare to the facts stated in section 1 of the procedure.
- Knowledge of not only the failed component and its systems is necessary but also knowledge of the design characteristics of the failed machine. In this case, a positive displacement compressor has the characteristic of constant volume flow for a given speed.

3. Abnormal conditions

- The number of stops and starts per unit time.
- The lack of the ability to remove heat and lubricate all journal bearings.

Comments:

- Abnormal conditions are usually defined using trends of instruments. However, on small machines such as this, little if any data is trended and the team must rely on either observed facts (the best source) or information from other sources. The number of stops and starts was observed during operation after the failures had begun.

4. List the possible causes based on facts and abnormal conditions

- Poor lube system design – no auxiliary pump.
- Poor control system design – compressor is stopped and started.
- Change of the required flow – increase of 10 times.
- Rapid stops and starts – every 5 minutes therefore not providing proper lubrication to the bearings.

Comments:

- Be sure to look for the simplest causes first.
- Screen listed cause to be sure that they are not effects.
- If there are possible effects listed, it may be a cause but not a root cause.

5. Eliminate causes

Causes eliminated (causes eliminated with reasons for)

- Poor lubrication system design – proven vendor experience and no problems experienced during the first two weeks of operation
- Poor control system design – this system was used in all other plants of the same design with no reported problems to date.

Comments:

- The action taken above required detailed discussion with the compressor vendor, process designer and users in other plants.
- It is important to network with other plants in your company or user groups in your geographical area.
- Attending industry conferences and recommended training sessions by associates is also a source of increased knowledge base that can optimize your effectiveness.

6. State the root causes remaining

- Change of process conditions – required flow increase by 10 times.
- Rapid stops and starts of the compressor.

Root cause – change of process conditions

Comments:

- Since the type of compressor in this case is positive displacement, it is important to know that the volume flow rate of 20 cubic feet per minute is constant for a given speed. Note that this application is a fixed speed belt driven compressor.
- Rapid stops and starts are related to change of the required flow. Since the flow produced by the compressor is constant, the increased flow now required by the process will reduce the pressure in the receiver vessel more rapidly and result in more frequent stops and starts.
- Therefore, the change of the required flow was the root cause.
- It could be argued that the root cause was the process designer's lack of awareness of the effect on a positive displacement compressor, on stop/start control, when required system flow is significantly increased.
- The final task is to define a simple, cost effective action plan that can be rapidly implemented.

7. Action plan

- Confirm that the requirement for a 10 fold increase of flow is a real requirement.
- Eliminate the stops and starts on the compressor by disconnecting the pressure switches from the motor starter and operate the compressor continuously.
- Install a bypass control valve from the receiver to recycle back to the suction of the compressor to maintain a constant receiver pressure of 350 psig.

- Switch over the compressors for diaphragm inspection (initially every 4 months based on experience) and extend the inspection time based on observed findings.

Comments:

- A meeting was held with the process design company to confirm that the requirement for the increased flow was justified and resulted in increased process unit reliability and revenue. This fact was confirmed in the meeting.
- Present the action plan to management based on the loss of revenue if the problem is not corrected. Be sure to include the cost and time required for the modification. The final action plan should be a proven, cost effective approach with the shortest implementation time.
- Note that in this case, a blank flange for the bypass connection existed on the receiver vessel. The required valve was immediately available and the compressor intercooler capacity was checked and confirmed to be acceptable for the revised case.
- The option to increase the compressor capacity to minimize the number of starts, was not implemented due to the required modifications to the pulley system (to increase the speed and therefore capacity), the need to install a new motor and the lack of compressor experience at the increased speed.