CHAPTER 4

Identifying Potential Failure Causes

IN THE SECOND STEP of the four-step problem-solving process, the failure analysis team should identify all potential failure causes. There are several approaches for doing so:

- Brainstorming
- Mind mapping
- Ishikawa diagrams
- The "five whys" technique
- Flow charting
- Fault-tree analysis

Each of the aforementioned techniques is useful for identifying potential failure causes, but fault-tree analysis is, by far, the most powerful tool for this purpose. The next several chapters address fault-tree analysis, which is a far more rigorous analysis approach than any of the previously mentioned techniques and is preferred in many cases. For simpler problems, however, the techniques outlined in this chapter can be useful.

Brainstorming

Brainstorming is a group discussion designed to elicit as many ideas as possible. An advertising executive named Alex Osborn formalized the technique in the 1940s to help develop ideas for selling new products. In its simplest form, brainstorming involves a group engaging in a free-flow of suggestions to solve a problem. The approach typically includes the following steps:

- *Notification:* The person scheduling the brainstorming sessions notifies the people invited to the session, with a clear problem statement.

This allows those invited to the meeting to start thinking about potential solutions prior to attending the meeting.

- *Introductory comments:* The brainstorming session leader states the problem to be solved and the meeting rules at the beginning of the session.
- *Idea generation:* The brainstorming participants make potential problem-cause suggestions.
- *Idea documentation:* The brainstorming session leader captures all suggestions on paper. It is best to do this on large pads on an easel. The session leader can tape completed sheets to the wall so that they remain visible during the session. Keeping prior ideas visible helps to stimulate new suggestions, and it provides a record for the meeting notes.
- *Meeting notes publication:* After the brainstorming meeting, the session leader makes and circulates copies of the meeting notes.

In many cases, the ideal size for a brainstorming session is five or six people. If the group is much smaller than this, the idea-generation process seems to be tougher to start and sustain. If the group is larger, it becomes difficult to keep up with the ideas and to get everyone to participate. It is recommended that people with different backgrounds be included, because this ensures the emergence of ideas from different perspectives. Including an engineer, a manufacturing person, a quality-assurance specialist, a buyer, and so forth on the failure analysis team (as recommended earlier) ensures a mix of backgrounds.

It is not recommended to include people at different management levels, because lower-level people may be intimated by upper-management people, and this can stifle the free generation of ideas. An exception may be the inclusion of a manufacturing technician (usually an hourly, nonmanagerial type). Manufacturing technicians frequently have an intuitive feel for how the product should work, how it may fail, and other nuances that other failure analysis team members may lack.

The meeting should be kept to one hour or less. People tend to become bored in meetings lasting longer than one hour. The meeting should be held in a quiet room with no interruptions. Meetings over lunch generally do not work well, because people are thinking about eating. Everyone should be asked to turn off their cell phones, because the distractions from phone calls, text messages, and e-mail can interrupt the idea-generation process.

In brainstorming sessions, the flow of ideas is usually slow to start. Then, the ideas start to flow freely (so much so that keeping up with documenting the ideas can be difficult). After a while, the process decelerates, and ideas flow much less freely. The idea-generation process seems to follow the same pattern as making microwave popcorn. At first, not much happens, and the kernels seem to pop very slowly. When they start popping, the popcorn occurs rapidly. After a period of time, the process slows, and kernels pop infrequently.

When the flow of ideas slows, the failure analysis team leader can use any of several techniques to reenergize the process. These include:

- *Seeking similar problems and solutions:* The failure analysis team leader can ask the brainstorming participants to consider other similar problems and their solutions.
- *Getting wild:* The failure analysis team leader can ask the team participants to think "outside the box" and develop solutions that appear to be completely outrageous. Sometimes, such thinking evokes solutions that would not have otherwise been considered.
- *Considering other perspectives:* The failure analysis team leader can ask the brainstorming participants to consider looking for solutions from other perspectives.
- *Using a reporter's approach:* The failure analysis team leader can ask the team to consider the problem from a journalist's perspective and ask the questions a reporter would ask (who, what, when, where, why, and how).
- *Mental imaging:* The failure analysis team leader can ask the team to imagine themselves physically in the system and ask (from this new perspective) what may be causing the problem. For example, if a light bulb fails to illuminate, the brainstorming session members can mentally picture themselves in the light bulb interior and ask what could cause the illumination failure.
- *Considering more (or less) is better:* The failure analysis team leader can ask the team to consider previous suggestions from the perspective of adding more (or less) of the suggestion.
- *Seeking synonyms:* The failure analysis team leader can ask the team to identify synonyms for each previously suggested potential cause.
- *Expanding previous ideas:* The failure analysis team leader can ask the team to consider previous suggestions that emerged during the brainstorming session and expand on them.
- *Rereading ideas:* The failure analysis team leader can reread all of the previous suggestions aloud.

Brainstorming sessions should be freewheeling, "think-outside-the-box" types of meetings. There are only a few rules. One is to never criticize or allow criticism of any ideas, because this can stifle the team's willingness to express ideas. The other is to focus on the quantity (and not the quality) of the ideas. The intent is to get people to open up and to generate as many potential causes as possible.

Mind Mapping

Mind mapping, developed by Tony Buzan in the early 1970s, is essentially a graphical outlining technique. What sets it apart from other outlining

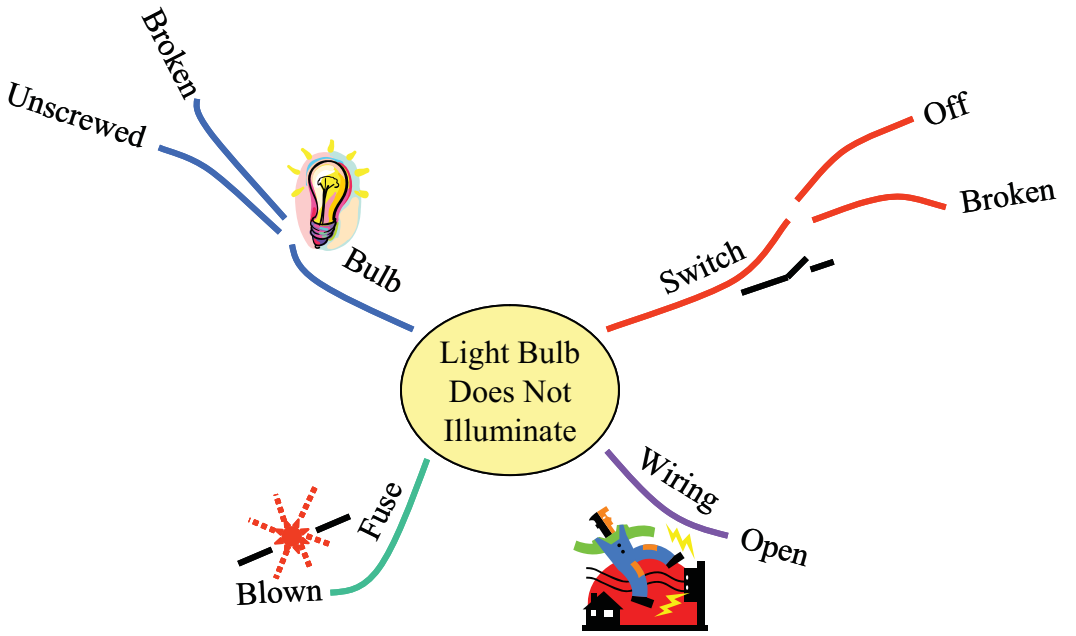

Fig. 4.1 Mind map for a light bulb failing to illuminate. Compare this image with Fig. 4.2 and with the fault-tree analysis prepared for the same failure in Fig. 5.4

techniques is that it is said to foster creativity through the use of images, curved lines, and colors. Mind-mapping images are free-flowing with an idea in the center, supporting concepts arranged around it, and lines connecting the supporting concepts to the center concept. In a problem-solving scenario, the central idea is the problem, with the outwardly radiating curves defining families of potential causes. Figure 4.1 shows a typical mind map applied to a light bulb failing to illuminate.

The intent of mind mapping is to defeat linear thinking. Linear thinking refers to thinking about things in a sequential, one-at-a-time manner. For example, these words are read sequentially, one at a time. Words are written one letter at a time; sentences are created one word at a time; and so on. Some believe that this linear, sequential, one-step-at-a-time approach inhibits creativity. The mind-mapping technique attempts to break out of this linear thinking by relying on images, curved lines, colors, and a graphical structure.

To implement the mind-mapping approach, the failure analysis team should use the following steps:

- Start in the center of the page. The approach involves taking a clean sheet of paper, preferably one that is unlined, and creating an image in the center of the page showing the problem to be solved. Due to the graphical nature of this approach, it is best to draw the mind map by hand (rather than using a computer). The earlier example is shown with a computer only for the sake of clarity.

- Draw curved lines, in different colors, radiating outward from the central image (i.e., the image depicting the problem). These curved, outward-radiating lines should show potential problem causes. The theory behind using curved lines is that straight lines may induce linear, restricted, creativity-inhibiting thinking. Curved lines are thought to foster creativity. The different colors are intended to further foster creativity.
- On each line, and for the central image, add single-word descriptions stating the problem and its potential causes. The concept behind using a single word is that it is less restrictive, allowing for greater creativity.
- On each line, add an image associated with the single word. The theory here is that people are used to thinking in images, and adding an image promotes greater creativity.
- Continue to develop the curved lines, showing subsets (or causes) of each hypothesized cause. As described earlier, use colors, curved lines, and single-word descriptions. Continue developing these subbranches until all possible failure causes are identified.

Ishikawa Diagrams

The Ishikawa diagram is another graphical technique used to identify potential failure causes. Kaoru Ishikawa, a quality manager at Kawasaki shipyards in the 1960s, developed the technique that bears his name. An Ishikawa diagram loosely resembles a fish skeleton (Fig. 4.2), and for this reason, Ishikawa diagrams are frequently referred to as fishbone diagrams. Sometimes, these graphical analyses are also called cause-effect diagrams.

As was the case with the mind-mapping technique, it is best to start the Ishikawa diagram with a large sheet of unlined paper.* The problem is expressed on the right side of the paper, with a horizontal line drawn across the page (Fig. 4.2). The failure analysis team can then add ribs (diagonal lines) to the chart to show failure-cause categories. For each of these categories, the failure analysis team can then add branches that show the underlying causes. It is a good idea to have failure analysis team members present as the Ishikawa diagram is created, because the team will have ideas to add bones to the fish's skeleton.

Some suggest using the four "M," "P," and "S" categories to assist in brainstorming Ishikawa diagram potential failure causes:

- *The four "M's":* These include methods, machines, materials, and manpower.
- *The four "P's":* These include place, procedure, people, and policies.

*Although Fig. 4.2 was computer generated, trying to use a computer during the brainstorming process can stifle creativity. When the failure analysis team has created the chart, it can be converted to a computer image using any of several software programs.

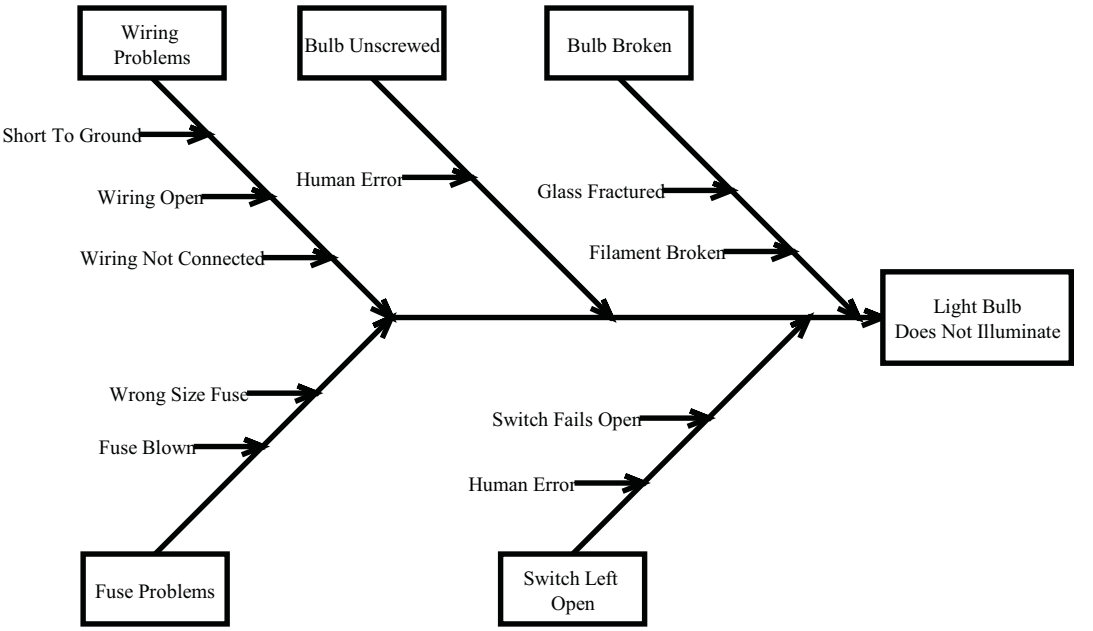

Fig. 4.2 Ishikawa diagram showing potential failure causes for a light bulb not illuminating. Ishikawa diagrams may help the failure analysis team identify more potential causes of failure than the mind-mapping technique.

- *The four "S's":* These include surroundings, suppliers, systems, and skills.

The aforementioned categories should be viewed as suggestions only. They can be helpful, but they should not constrain the failure analysis team members from examining other areas.

The "Five Whys" Technique

The "five whys" technique is another approach that some find useful for unearthing potential failure causes. Sakachi Toyoda originally developed the technique at Toyota Motor Company, and it became part of the famous Toyota Production System. It is also part of the Six Sigma approach to quality management.

The "five whys" approach is quite simple (some say trivially so). It is usually and perhaps best used to support brainstorming and Ishikawa diagram preparation. The following steps are involved in its use:

- State the problem.
- Ask why the problem occurred, and note the answer.
- Determine if the aforementioned answer defines the root cause of the problem.

- If the aforementioned answer does not identify the root cause of the problem, examine the answer and ask why it (i.e., the answer to the preceding "Why?") occurred.
- Continue to iterate the previous process until the group agrees that the root cause has emerged.

There is nothing magical about asking "Why?" five times. If the root cause is identified in fewer than five "Why's?", the analysis can be concluded. If the root cause has not emerged with five "Why's?", the process can be continued until the root cause has been identified.

The "five whys" approach has been criticized as being too superficial to be effective. Critics feel it can stop too early without unearthing the root cause of a failure, it does not lend itself to identifying all potential root causes, and it tends to focus on symptoms rather than underlying problems. Its principle value is that it can force the failure analysis team to go beyond simple answers and to dig deeper for underlying causes.

Flow Charting

Flow charting involves preparing a block diagram showing how the product or process works. (Figure 4.3 shows a flow chart for the light bulb used in the earlier examples). The failure analysis team starts with the action or activity that initiates the process or the product functioning and then shows succeeding blocks for each subsequent, sequential step. At each block in the flow chart, the failure analysis team should show required inputs and outputs. The steps involved in preparing a flow chart help the failure analysis team identify how the product or process works. If the team asks (at each block in the flow chart) if anything can happen to induce the failure, the flow chart becomes a useful tool for unearthing additional potential failure causes.

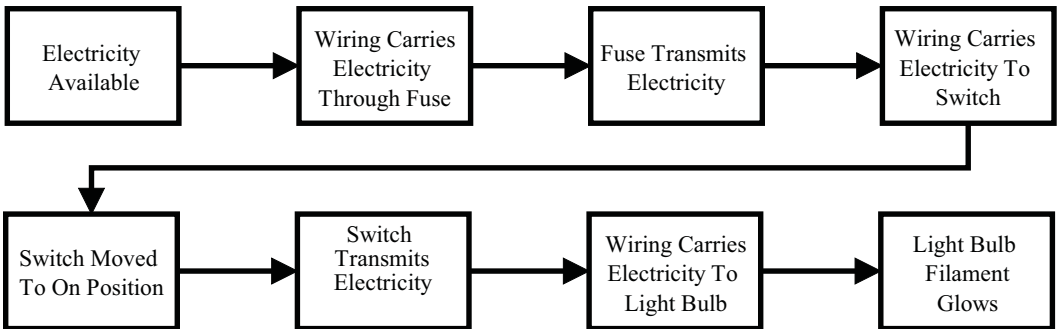

Fig. 4.3 Light bulb flow chart showing the sequence of steps required for the light bulb to illuminate

Summary

This chapter discussed five techniques for identifying potential failure causes:

- Brainstorming involves a group free-flow of ideas in which the ideas are not evaluated as they are generated. The failure analysis team should be encouraged to "think outside the box" in listing potential failure causes. In brainstorming, idea quantity is valued over idea quality. The ideas will be evaluated later.
- Mind mapping is a graphical technique emphasizing images, colors, curved lines, and single-word descriptions. The concept is to foster idea-generation creativity.
- Ishikawa (or fishbone) diagrams are another graphical technique. Ishikawa diagrams identify potential failure causes. Brainstorming, "five whys," and flow-charting techniques can be used to support Ishikawa diagram generation.
- The "five whys" technique states the problem, asks why it occurred, and then asks why the answer occurred. The theory is that repeatedly asking "Why?" for each succeeding answer will bring the failure analysis team to the root cause of the problem.
- Flow charting defines in a graphical manner how products and processes operate. Flow charting can help the failure analysis team better understand how the system operates.

While each of the aforementioned analysis techniques may be useful, none of them develop potential failure causes as rigorously as fault-tree analysis. The discussion of fault-tree analysis begins with Chapter 5.

Example for Group Discussion. The Sargent-Fletcher Company manufactured wing-mounted fuel tanks for various fighter jets using a bulge-forming process. The wing tanks had a sleek, curved forward profile called the ogive. The ogive-forming process included several steps:

- Aluminum sheet was cut into a pattern and then rolled into a cone.
- The cone longitudinal seam was welded.
- The aluminum cone was inserted into a bulge-forming die. (The die had the forward ogive shape of the tank.)
- Compressed air entered the aluminum cone and forced it outward, such that it took the shape of the bulge-forming die.

During a 20-year production run, the aluminum cones frequently burst while being bulge formed. Sargent-Fletcher assigned a failure analysis team to find the cause of this failure. The failure analysis team found that the bulge-forming process stretched the aluminum material beyond its yield point. Sargent-Fletcher solved the problem by partially bulge forming the aluminum cone (so it did not exceed the yield point), annealing

the aluminum, and then bulge forming the partially formed cone to its final shape. After modifying the process in this manner, the ruptures disappeared.

Which of the failure-cause identification techniques discussed in this chapter would have been best for finding the cause of this problem?

If the cause of the ruptures had been a combination of factors, would any of the techniques discussed in this chapter have identified the cause?

Could Sargent-Fletcher have used any of the techniques discussed in this chapter before starting production to identify and control potential failure causes?

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