# Chapter 23: Failure Root Cause Prevention

Highly reliable organizations proactively focus on preventing problems from entering their operation and removing those that remain. They set control mechanisms, standards, and checkpoints to spot and stop the defects that turn into future failures. They look for what can go wrong before it does and prevent its causes from happening. Instead of having problems and then investigating their causes, they imagine their problems and proactively act to eliminate their possibility. If your operation is suffering equipment and production problems, don't try to discover why they happen and figure out how to solve them. First, look at your processes. Most of your production problems are caused by bad business process design. Fix your process weaknesses and do the new training, then put the answers to use. The problems disappear because they no longer can exist in your company.

Solving the real problem means finding its true causes. The technique used to investigate plant and equipment failures is known as Root Cause Failure Analysis (RCFA). RCFA is manpower and time intensive, and so it is only applied after a serious incident justifies it use.[1] Reserving RCFA for investigating major failures ensures that major failures will continue to occur. You might find and remove some contributing causes, but thousands of defects in your business will stay behind to create more future catastrophes. Failures are the result of multiple failed processes. There is never just one cause of equipment failure. There are at least four, and usually more, contributing factors to a machine failure event. Using Root Cause Failure Analysis will not discover all the contributing factors because many of them are hidden in the distant past, while others started in other places far from your operation. In the Plant Wellness Way, the first thing you do after a failure is review the processes for the causes that contributed to the event. Figure

23.1 shows how this root cause removal strategy works to prevent the many defects at the bottom of the failure pyramid from becoming big troubles that you later must fix one at a time with RCFA.

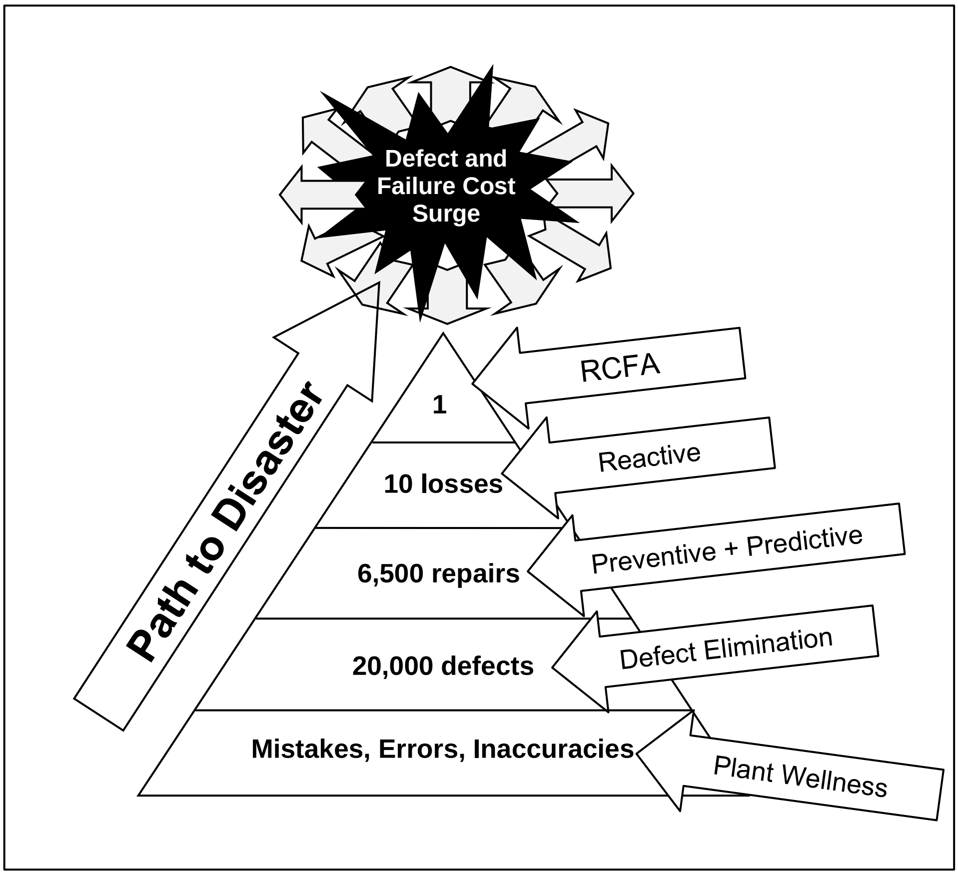


Figure 23.1—Stop the Causes of Defects at the Bottom of the Failure Pyramid

**Improve the Process Design**

World-class operations recognize the interconnectivity of their processes and work hard to ensure the right results at every stage in every process. Figure 23.2 shows a failure in product assembly. The root cause traces back to its manufacture, where it leaves the process and enters another, then a second and a third. The defective item started its life elsewhere and ended up causing problems during assembly. There are innumerable opportunities for errors and defects to occur in all processes. Process after process connects with others, causing a tangled web of interaction. Errors, mistakes, and defects can come from everywhere. Any process that goes wrong has an impact on numerous others downstream. Much time, money, and resources will be wasted. If you want an operation in which good results are natural and excellence abounds, ensure that your processes permit no defects.

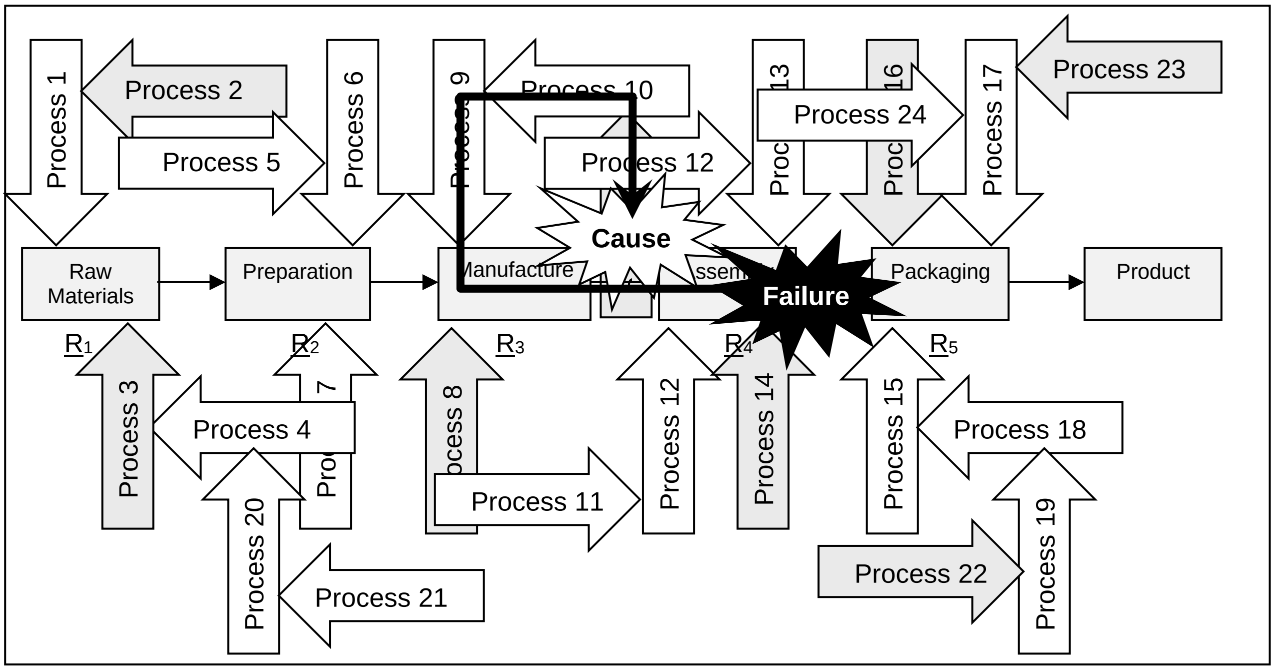


Figure 23.2—Failures Occur throughout the Process Chain

There is an insightful story told of the late Sir Ernest Shackleton, one of the great early South Pole explorers. On board his ship bound for Antarctica, he watched a man tie a knot in a rope that was holding down vital supplies. Shackleton saw that it was the wrong knot for the job. In wild seas, it would come loose, and all the goods and supplies would be lost. Shackleton went to the man and asked him about his experience at sea. He learned that the man was new to seafaring. With patience and thoroughness, Shackleton taught him how to tie the correct knot, one that would be secure in all weather and sea conditions. His comment to the new seafarer is insightful for all of us who want successful outcomes: "There is always only one knot that is right for the situation."

Shackleton's method of failure prevention is the technique used in the Plant Wellness Way: do what stops the causes of failures from starting. First, put the right practices into your processes and make sure they are done right every time. In the Plant Wellness Way, when things fail, the first question you should ask is, what is wrong with the process? You can skip the RCFA, but you cannot skip finding and fixing the design faults and missing quality controls in your processes.

Prevent the Chance of Failure Starting

The necessities for high equipment reliability cannot be left to luck. If Shackleton had left it to the new seafarer to realize that he was using the wrong knot for the job, the expedition would have failed. Like Shackleton, you must find and remove the risks in your processes before they destroy your operation. Do the same for your business that Shackleton did for the Antarctic Expedition: look for where troubles will start in your processes, then introduce, teach and use the right practices so that risks will never arise.

Identify Where Your Equipment Problems Begin

An important asset management indicator to collect and present is where failures arose during the equipment life cycle. Today's failures started in the past when their causes were initiated in previous processes. Tracing the parts replaced on corrective and breakdown work orders back through the processes they traveled lets you observe their life cycle. Where you find problem causes, you stop them so that they cannot arise in the future. If a part's failure was started by an error at an external repair shop, it will happen again if you don't get the shop to fix the causes. A stress-induced failure from shaft misalignment indicates that your equipment installation process is weak. You seek to understand whether your reliability troubles are in fact attributable to manufacturing defects, subcontractor mistakes, production process causes, material selection causes, equipment installation troubles, operating errors, vendor-produced causes, procurement errors, warehouse management failure, poor workmanship, and so on.

The failed item or part is used to start the review of its life. The failure is the last event in a long chain of causes and effects. The failure mode site on the part contains evidence of the causes of its failure. The causes that came together to fail the part passed through your processes undetected until they combined to initiate the failure. It is necessary find the culprit processes and fix them. This is not a root cause analysis investigation to find the actual cause of failure. It is an investigation of process design weakness to identify the presence of failure-causing steps. Typically, an experienced discipline maintenance engineer or design engineer, or a career maintenance supervisor, or maintenance planner would identify all of the processes associated with the replaced parts.

A process is weak if it does not prevent all of the Physics of Failure Factors that damage or destroy the part. Finding answers to the eight life-cycle questions (see Chapter 11) is a good place to start an investigation. Using evidence from the failure, process maps of all of the processes used during the failed part's life cycle are reviewed for risks that could have allowed defects and causes of the failure to arise and remain active. When a weakness is found, the process is reengineered to remove the opportunity for out-of-control variation. The process redesign is trialed, and the successful solution is documented and implemented. The people inside and outside the organization affected by the change are trained in the proper use of the new process.

A few examples of life-cycle process monitoring measures used to find weakness in processes by observing their effects on the operation are listed below. The indicators are simply a count of the processes used during the life of failed and replaced parts. A pie chart or bar chart of the number of maintenance corrective work orders and breakdown work orders per category for a period shows the regularity that these indicators of process design weakness arise in an operation. The measures are selected with the intention of finding the weak life-cycle processes that are making your machines fail in order to identify what more to do to make a process more robust, anti-fragile and successful.

When failed equipment parts were serviced by external vendors

- Whether repaired equipment had service duty specifications
- Who did the previous repairs or replacements?
- Whether repaired equipment had be run using ACE 3T operating procedures
- Count of the number of events when the equipment was run overloaded
- The equipment repairs in which parts were drawn from our store
- The equipment repairs in which parts were purchased direct
- Whether equipment repairs were done to ACE 3T procedures

These measures let you target your process redesign to build more successful maintenance and operating processes. The lists used in the Plant Wellness Index Audit explained in Chapter 25 contain other useful criteria to use as indicators of weak processes to be add to the above list of process issues. As time goes by and data accumulate, you can develop additional subcategories within the measures to focus on finding the specific process step that starts the defects causing the repairs and breakdowns.

**Behaviors of High-Reliability Organizations**

The U.S. nuclear aircraft carrier fleet and nuclear submarine fleet are renowned worldwide as high-reliability organizations. Starting with vision and leadership, it took a lot of consistent, persistent effort, and some tragic failures to get there.

The nuclear submarine USS *Thresher* sank with 129 people on board on April 10, 1963. Although the vessel was not recovered from its resting place 2.5 kilometers deep, the naval investigation review board used photographic and retrieved evidence, along with laboratory tests, to identify failed brazed pipe joints as the most likely cause of the incident. The loss triggered a complete review of naval nuclear vessel design and operating procedures. Even though the fleet's equipment was built and maintained to high quality standards, and its personnel had specialist technical training, the quality control requirements became more demanding. Designs were simplified to remove complexity and to behave in known ways. Quality control in manufacture was improved. Operating practices became more stringent to remove the chance of variation. All crew members had to reach expert status in their discipline and equipment if they were to remain on the ship or submarine.

The organizational structure on U.S. nuclear fleet vessels is unusual. The crew members are the experts in running the ship and keeping it safe; the officers are there to support the crew in their efforts and to address issues that might reduce the crew's effectiveness.[2] That structure makes the operating crew more important to the ship's survival than the officers—a true inverted organization with managers at the bottom working for the producers at the top.

Central to the success of high-reliability organizations is the realization that everything can go wrong. The only sure protection is to know exactly what is happening with the equipment throughout the plant all the time. The equipment must be set up perfectly at the start and then monitored to ensure that it behaves exactly as it should when it is used. What you don't understand, you don't do yourself—instead, you get help from those who do know until you are trained and expert enough to do the task. Human error is acknowledged and addressed through teamwork, in which people help each other constantly and documented checks, counterchecks, and double-checks are a way of life.

High-reliability organizations proactively control every process and every step in those processes. Nothing is unimportant because consequential effects mean that the smallest risk can be the start of the biggest catastrophe. This requires a dedication to diligence beyond what people in commercial industry expect and are paid to do. High reliability cannot be bought with money—it lives in the hearts and minds of people who want to be the best at what they do and are respected by their peers and managers for that expertise because it is so valuable to the success of the organization.

The U.S. nuclear fleet's equipment is designed for simplicity, high reliability, and maintainability. The business systems in use demand proof of compliance with best practices. Its crews are educated to be a technical knowledge repository on their plant. Its people are trained to act skillfully in a highly reliable manner. The organization is structured to put knowledgeable experts immediately at the situation of risk and danger and bring the power of teamwork into play. Those are key reasons why the U.S. nuclear fleet is a high-reliability organization.

**Limitations of Our Materials of Construction**

We live in a probabilistic universe in which its physics produces divergence and sudden change in the way matter behaves when it reaches critical points.[3] Unless the physics of a situation is controlled, you can get sudden changes in the behavior of your materials of construction. The failure of equipment parts and the resulting poor reliability and safety are direct results of exceeding the physical and chemical boundaries of the materials of construction. Poor reliability and poor safety are to be expected in organizations in which people do not know the limits of their machinery and do not understand what is happening to the parts inside them.

People create high reliability when they know the engineering of their plant and process and expertly keep their equipment parts well within the capability of the materials of construction. The experience of high-reliability organizations is that equipment failure starts with poor business system process control. The necessary systems and controls that produce high reliability are not present and followed. Equipment failures then result from out-of-control variation. The organization’s quality management system fails first, and then the equipment is failed by the system. To fix management system failures, it is necessary to understand how business processes can fail. By understanding how each process step can fail, you build in the correct risk controls needed to achieve high reliability at each step.

You cause your own equipment reliability through the quality management systems that you use and enforce. To get high reliability, the experience of high-reliability organizations tells us, we must put into the business the processes, the specialist technical knowledge, and the right activities done correctly that cause high reliability. Don’t begrudge drawing a process flow diagram for each of your processes, and for each step in a process, to identify the hundreds of ways the processes could fail. Risks can live anywhere, and you need to see all of the places where your problems can start. Figure 23.3 traces a machine component manufacturing process step down to the fundamental tasks and actions. The workflow details expose opportunity for failure everywhere. Once you go into the details of your own processes, you’ll see an enormous number of risks you were not even aware of. The presence of those risks means that things can go wrong, and they will with a frequency dependent on the designs of the processes used during the life cycle and whether they were constructed to stop and prevent each risk from arising.

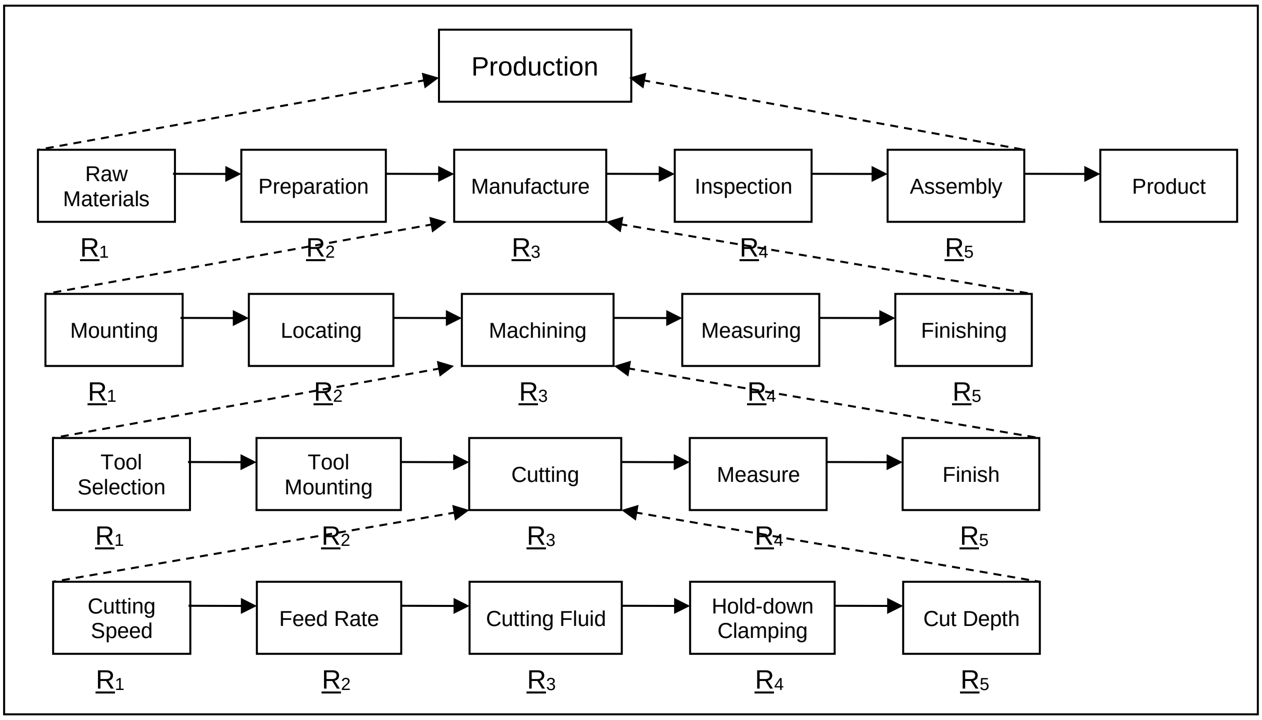


Figure 23.3—Dig into Your Processes and Their Step Activities to Spot Risks

In an organization using a Plant Wellness Way system of reliability, the problems and troubles caused by your processes are uncovered using Chance of Success Mapping to identify the risks. At each step, you list what has gone wrong in the past and what could go wrong in the future. For each risk, you develop mitigations to proactively prevent them from happening. You compile a list of the changes needed to maximize each step's chance of success, and that is your plan to create a far more successful process. In this way, you design and build highly successful operations and equipment without roots of failure inside them.

FOOTNOTES

1. Robert C. Nelms, “The Latent Causes of Industrial Failure . . . How to Identify Them, and What to Do about Them,” Failsafe Network, Inc., Montebello, VA.

2. Charles R. Jones, nuclear safety consultant, American Nuclear Society, Nuclear Safety Culture Panel Discussion Presentation, June 2, 2003.

3. Philip Ball, *Critical Mass: How One Thing Leads to Another* (New York: Farrar, Straus and Giroux, 2004).