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Feature Report

Getting to the Root of Chronic Failures

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The right combination of management support, an ideal analysis team and proper application of root-cause analysis improves the bottom line

The objective of root-cause analysis (RCA) is to eliminate the recurrence of an undesirable event, or failure. This is somewhat different from the objectives of predictive and preventive maintenance, which focus on sharpening our response to undesirable events. Although the latter is necessary in today's environment, we should be focusing more on why the event occcurs in the first place.

In the future, understanding of this concept will be imperative as global competition becomes fiercer and margins tighten. Reactive, or "firefighting," cultures will no longer be acceptable. Accepting the cost-of-doing-business events that comprise every maintenance budget will become taboo. Every undesirable outcome will be questioned as to why it occured, rather than how can we better respond to it. RCA will be expected rather than being seen as a luxury.

Unfortunately, RCA has become another industry buzzword. The problem with labeling such well-intended efforts is that they become stereotyped as "programs," and therefore have a finite beginning and end. We fail to realize such efforts as "processes" that evolve over time and eventually become the way to do business.

When we discuss how to conduct a true RCA, it involves a common vocabulary, full documentation of how the logic was derived, utilization of multidisciplined teams, and availability and accessibility of the conclusions to all in the organization so that learning can take place across the corporation on an international scale. These are the issues addressed in this article.

Agree on the definitions

All organizations claim they do RCA, and they are absolutely correct because their RCA method would conform to their definition. This is where the problem lies. Everyone has a different definition of RCA. Many would consider their predictive maintenance efforts as a form of RCA. Others would say that RCA must involve the use of advanced techniques such as finite element modeling, rotor dynamics, and electron microscopy. Probably the most common paradigm regarding RCA holds that it is only done on "incidents" and must involve either someone being injured or catastrophic mechanical damage.

We troubleshoot every day of our lives. Some are better than others at performing the task. Why is there such a disparity in the methods used to solve problems and their results? The answer lies in lack of uniformity of purpose. Everyone is performing his or her own method of problem solving. When this occurs, since the approaches are different, the conclusions will be inconsistent with each other as well. The result is a lack of communication among people within a department, a site and a corporation. Much of this miscommunication is due to a lack of a common vocabulary.

Failure classification

As with the introduction of any major initiative in an organization, in order for it to be effective, words must have the same meaning to the people that are hearing them. Consider the term, "failure." A mechanical person would likely define failure in terms of a piece of equipment or component that fails to perform its intended function. A process person would see failure as the inability of a process to produce target rates. The quality person may say a failure is the production of materials that do not meet customer specifications or product that must be reworked. The safety people would likely define a failure as a near miss, injury or fatality. Different people perceive the same words from completely different perspectives. The result is miscommunication.

Consider other terms, such as a chronic event versus a sporadic event. A sporadic event is typically a one-time occurrence; for example, a fire or explosion. However, if a failure occurs on the same piece of equipment for the same reason more than once, it should be labeled a chronic event, even if the occurrences are five years apart.

What events require RCA, the chronic or the sporadic? Which type of event promises the greater return? In our experience, the greater yields to be gained from true RCA efforts are going to be from the chronic or repetitive type of events.

By their nature, sporadic events are always going to be investigated, and they will likely involve members of the legal and insurance professions, or the plant safety department. On the other hand, who is charged, on a routine basis, to investigate chronic events? Likely few people, if any.

Chronic events are those that have been deemed as a "cost of doing business." They literally are just that, and are often budgeted for in the maintenance budgets, usually residing under a heading of "routine" with no detailed description. The budgeted amount is usually based on historical information from the past year, with a cost-of-living increase tacked on. In other words, we are saying that in spite of these events, we will produce our target productions. We have simply rele-

TABLE 1. LINE ITEM FOR SPORADIC EVENT						
Event	Mode	Frequency	Manhours	Materials	Lost production	Total annual loss
Process shutdown	Explosion	1/20 years	$5,000	$500,000	$1,000,000	$75,250/yr
LINE ITEM FOR CHRONIC EVENT						
Pump failure	Bearing failure	6/year	$1,000	$200	$40,000	$247,200/yr

gated ourselves to accepting these chronic events as a cost of doing business. This is where the money really is. This is the low-hanging fruit.

Documentation is important

The best analysts are usually the ones that are the experts in the nature of the undesired event. Most experts have predetermined conclusions about why something occurred and what the solution will be. Rarely have we seen a logic process mapped out on paper of how "experts" derived their conclusions. It usually remains in their heads. In some cases this is a form of job security, because they know that they are the one to be called in the "clutch" and will be viewed as necessary to the organization for that reason. But in the big picture, this does not serve in the organization's best interest.

Examples of this can be seen when a company decides to re-engineer. When this happens, usually the most talented individuals decide to take the early retirement packages because they know that they can get another job while getting severance from the current employer. We have seen many of the experts leave corporations for this reason.

Typically a huge void of knowledge is left behind and when certain undesirable events occur, everyone is at a loss of how to resolve them because the talent left through the door with the answers in his or her head. This is a real problem today, and illustrates the importance of documentation.

Creating the right environment

People must be properly trained for performing RCA. Yet, a common fallacy with corporate views of training is the tendency to believe that "if we hold training, it will be successful." In some organizations, it has become almost therapeutic for management to provide training to its personnel. Results are rarely forthcoming when training is held in this capacity.

The first step to creating the environment for RCA to succeed is to set the expectation, to the trainers and to the students, that management expects a certain percentage return-on-investment (ROI) for its money. When such expectations are set forth prior to a training class, the class tends to be more attentive. Tying the expected returns to impact-performance evaluations provides the individual incentive to produce results.

We rarely see a corporation that holds its training departments to providing a certain ROI for the training. Why not? Engineering projects must justify the cost/benefit of a project to meet certain corporate ROI standards. Why do we not measure the effectiveness of training?

Get management involved

Management must also support the RCA activities in the field. Students leave training classes motivated, only to return to their responsibilities in the field and go back to the same old "firefighting." Managements must realize that performing RCA on chronic type events is a proactive activity. It is proactive because unless these trained analysts look at the chronic events that are hidden in the maintenance budget, no one else will. Performing a proactive task in a reactive environment is nearly impossible without the support of management.

Most of the tasks necessary to create the successful environment are common sense. For instance, people trained in how to conduct RCA's must be given the time in their job responsibilities to practice. If RCA is dumped on someone's lap in addition to his or her current backlog, then RCA will be viewed as a burden. If some items are instead removed from their job description, we set the expectation that we have provided the time, now we are anticipating the results.

If analysts are to draw accurate conclusions, they will also need various technical resources to confirm their hypotheses. This may mean that if we implement such an initiative, we must budget some engineering resources to support the effort. This could be as simple as a mechanic being able to ask an engineer a question. Or, we may need to send a bearing to a metallurgist.

Another common-sense item commonly overlooked is as follows: When the analysis is finished and the recommendations are approved, what happens to them? They typically go into the work order system with a very low priority. Recommendations from an RCA are considered improvement work, which is proactive. Where does a proactive recommendation stand in a reactive work order system? It truly becomes a low-priority item unless the system changes.

Management must make the planners and schedulers aware that such recommendations will be coming through, and that a certain percentage of resources should be set aside for handling them in a prompt manner. An RCA is a waste of time if the recommendations are never implemented. Worse yet, if the analyst spends all that time performing the RCA and the recommendations are ignored, they are likely not to try again.

These are only a few of the support roles that management must play for an RCA effort to be successful. It should be emphasized that having trained and experienced analyst's alone does not guarantee success.

Which events to analyze?

One of the most difficult tasks in RCA for most organizations is determining when to utilize a formalized approach. No corporation has the resources to formally analyze every single event that occurs within the organization. Therefore, criteria are needed for when it is appropriate to utilize a structured RCA approach.

The foremost considerations should obviously be the cost of the event and the anticipated return as a result of conducting the RCA. But these can be misleading if the focus is on single occurrences.

Consider a major fire at a facility. This, hopefully, does not happen often, which would class it as a sporadic event. The cost associated with the event includes man-hours, materials, lost production and possibly even fines. This line item may look like the top row of Table 1. While the event cost a total of $1,505,000, when spread out over a 20 year period, it averages out to $75,250 per year.

Now consider a chronic event, such as a pump failure, and see how its impor-

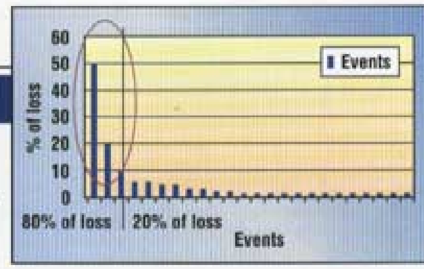


FIGURE 1. Typically, only 20% of the events account for 80% of the losses encountered. These select few should be the targets for formal root-cause analysis

tance can be overlooked (bottom row, Table 1). A single bearing failure is a $200 loss of material. Often we do not add the associated costs of the man-hours necessary to repair the equipment or the production hours lost due to the downtime. When these considerations are included and multiplied by the frequency of occurrence per year, we get a more revealing cost of the event. The total annual loss of this chronic event far outweighs that of the sporadic event.

Utilizing this type of approach for individual processes creates a list of events that prevent us from reaching our production goals and maintenance objectives. When the spreadsheet is completed, the total annual loss column is sorted from highest to lowest. The most fruitful events to analyze are then selected by taking a "Pareto split," or utilizing the 80–20 rule (Figure 1).

The 80–20 rule applies very well for selecting events for formal RCA. Typically 20%, or less, of the events experienced account for 80%, or more, of the losses encountered. Once this type of analysis is completed, we can focus our resources on those specific events that will provide the greatest returns. In the absence of such an analysis, we often find that our clients are chasing the "political failures of the day" on the right side of the divider in the graph (Figure 1).

Armed with this factual information, we can no longer necessarily justify allocating RCA resources to the events that will provide the greatest payback in the shortest amount of time. This analysis, in effect, becomes the justification tool for requesting resources to conduct RCAs.

Theoretically, once we have utilized a structured approach to identify our significant few — the 20% of the events causing 80% of the loss — then we can move on to the task of determining the causes of the event. Once a qualified candidate for RCA has been selected and approved, it must be subjected to a formal investigative process. We utilize one called Proact, an acronym for:

- PReserving event data
- Ordering the analysis team
- Analyzing the data
- Communicating findings and recommendations
- Tracking for results.

Preserving event data

The first step in any analysis is the collection of data. A useful analogy to use is that of a detective at a crime scene. The area is roped off, all the evidence preserved and interviews are conducted. This is standard practice for investigative agencies. Yet, the only time we see this discipline in manufacturing is likely to be for sporadic events because they are usually classed as incidents by some regulatory agency. But this contradicts the argument that the more-costly events are chronic ones.

The chronic events are particularly neglected in data collection terms. Chronic events happen so often that they are no longer seen as failures; they have become a part of the job. They happen so often that success is usually defined as decreasing the mean time to restore (MTTR). Whenever mechanics become very good at fixing something, we should ask ourselves, "Why are they getting so much practice?" The focus should not be on MTTR; it should be on why the event is occurring in the first place.

Chronic events are hidden gold. They are hidden because even the most elaborate computerized maintenance-management systems (CMMS) cannot possibly record every event accurately. If true chronic events do make it into a CMMS, they are usually masked under a blanket work order. We often see event entries such as "pump broke" and the repair being "fixed." This is not a wealth of data for an analysis.

Often, chronic events never make it to a recording device because the repair may take less time than the entry into CMMS. Therefore, the only way to find out that they are occurring is to ask the people that do the work. When such events are so routine and not viewed as a failure anymore, then data collection is almost nonexistent. The PROACT approach uses the 5-P's for gathering data: parts, position, people, paper, and paradigms.

Any necessary data from an event falls into one of these categories. This is simply a tool to assist in data collection. It helps to manage the information and organize documentation efforts. Mainly, it obtains the data in a formalized manner and makes it available for the analysis. Without the preservation of data, we are like a detective trying to solve a crime with no evidence and no lead.

Ordering the analysis team

When an event occurs, what is the typical make-up of the task team that will be aggregated for the analysis? Usually the technical experts with a background in the nature of that event are chosen. They will have likely been successful on past such occurrences and be considered the "stars" to solve the problem. What is wrong with this scenario?

We like to use the analogy that if we put four metallurgists on a task team to review a boiler-tube rupture, the answer will surely be metallurgical. The danger with this approach is that the narrow focus of the group's collective expertise can limit the exploration of other possibilities. In the above example, if the cause were other than metallurgical, such as contamination of some sort in the environment, then it would be overlooked. So who should lead a RCA team?

The role of a RCA team leader is to facilitate, not participate, in the RCA methodology. The expertise on the team will provide the talent to look at various hypotheses. By not being an expert in the nature of the event being analyzed, the RCA leader can ask any question he or she likes because he or she is not expected to know the answer. Experts leading teams are not afforded this luxury. They are expected to know and therefore must act as if they know all, even if they do not. It has been our experience that when such "experts" lead RCA teams, they tend to know their conclusions before they start with the team, and subsequently will drive the team to their conclusions. Such an expert also tends to intimidate the team members because of his or her perceived expertise even if this effect is not intended.

Needless to say, the make up of the core team members should include the true experts. However, the team members should represent a diversity of backgrounds. Operations, maintenance and technical people should be

CASE STUDY OF A SUCCESSFUL ROOT-CAUSE ANALYSIS

Five similar customer complaints were received at Eastman Chemical Co. (Kingsport, TN) concerning green pellets mixed with clear pellets of a polymer product. Complaints were received from more than one customer, but not all railcars of product received a complaint.

The silos and conveying systems were checked prior to their initial use for the clear product. They were also cleaned and inspected after each customer complaint. Each time, one or more potential sources of green contamination was found and corrected. After the fifth complaint, a team was put together to discover and eliminate the root cause of the contamination. The line item for this problem is given in the box below the tree. The RCA process and results are outlined as follows:

Identified root causes:

Physical roots

- One of the silo blend tubes was damaged, causing green pellets to be held in place and released intermittently.

Human roots

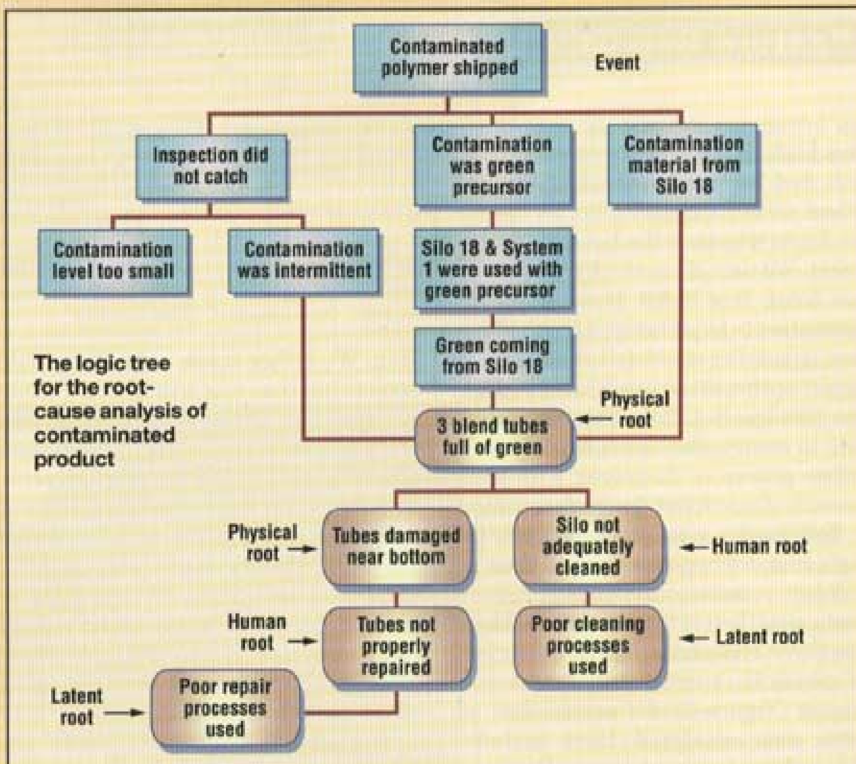
- Poor repair process used in the past to patch the broken blend tube.
- Inadequate cleaning
- Inadequate inspection of silo

Latent roots

- Blend tube and support design allowing fatigue failure
- Cleaning and inspection process inadequate and poorly documented

Implemented corrective actions:

- Damaged blend tube thoroughly cleaned
- Cleaning and inspection procedures developed and documented
- Blend tube repair procedure developed and documented
- Communicate new procedures to operations and maintenance personnel
- Conveying system-silo product changeover check sheet developed and deployed
- An improved blend tube design used in new silos



The logic tree for the root-cause analysis of contaminated product

Sub-system	Event	Mode	Frequency	Impact/occurrence*	Total annual loss
Customer service	Customer complaints	Green pellets mixed with clear pellets	5 railcars in 7 months (190,000#/railcar)	$17,000	$85,500

Effect on bottom line:

Tracking metrics: The number of customer complaints concerning green pellets

Results:

- Have experienced zero customer complaints since root cause was found and countermeasures implemented.
- Conservative estimates report the damaged blend tube held enough green pellets to contaminate five more railcars of clear product.

Corrective-action timeframes:

- From first complaint to correction was seven months
- RCA team found and corrected root causes in seven days

RCA Team statistics:

- Start date: July 14, 1998
- End date: July 21, 1998
- Estimated cost to conduct RCA: $2,700
- Estimated returns from RCA: $85,500
- Return on investment: ~3,200%

represented, as well as others based on the nature of the event. It is vital to have an unbiased RCA team leader and a diversity of backgrounds amongst the team members.

Analyzing the data

At this point we have collected our initial data and have organized a specific team to analyze the event. The items of data at this point are like the pieces of a puzzle. To make sense of the puzzle, a logic tree is constructed. A logic tree is a graphical representation of a cause-and-effect sequence. No matter the nature of an event, there is always a sequence of "chain links" that led to the event. It is the RCA team's responsibility to determine the sequence of events leading to an undesirable outcome and to base the findings on solid facts.

To construct a logic tree, we must start off with facts. This is in contrast to a fault tree that starts off with the probability that something will occur. At this point, we are dealing with what has occurred, not what might occur. This first step in the logic-tree development is called the "top box," usually involving the first two levels of the tree (Figure 2). The top block describes the event and can be characterized as the reason we care. It is the last effect in the cause-effect chain.

For example, suppose a bearing has failed. Why do you care that the bearing failed? If the failed bearing were not causing a pump to fail, hence causing a loss of product, we probably would not care. In this scenario, we will say that we care because the pump has failed and cut production. This becomes the true event.

The level beneath the event is called the mode. This often consists of the symptoms or indicators that the event did occur. Keep in mind, these first two levels are facts. If the pump failing is the event, what are the modes? The modes are the symptoms that the pump did fail. Possible answers are bearing failure, motor failure, seal failure and coupling failure.

At this point in the tree, we must re-

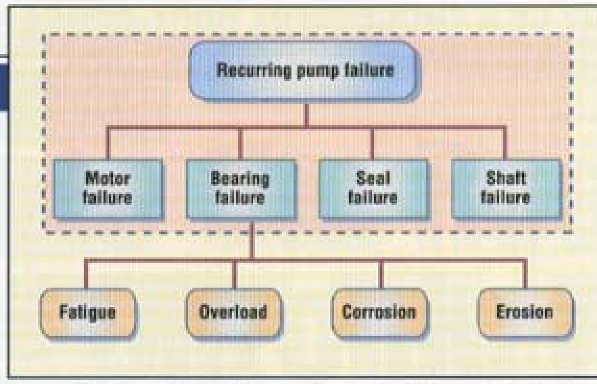


FIGURE 2. An example of the "top box" and physical roots for a chronic pump failure

vert back to the fault-tree concept and become hypothetical. When we were at the scene, all we knew was that the bearing failed. We do not know why we just know that it did. Now we must start to hypothesize about how a bearing could fail. The team of experts provide the hypotheses to fill in the blanks. But it is the facilitator's role to ensure that each hypothesis is either proven or disproven with some essence of science or direct observation.

Reiterating this process down the logic tree, we hypothesize and then we validate continuously until various root-cause levels are reached. There are three root-cause levels, comprised of physical, human and latent root causes (Figure 3). All events that we have ever analyzed have included these three levels of cause. However, we cannot say the same for some of the analyses we have seen from our clients. Let us explain.

The physical root is usually where most organizations that claim to do RCA stop. This is the tangible or component level. For example, if it is found that there is excessive vibration on a bearing, we may stop the analysis there and just replace the bearing. Have the root causes of the event been resolved? Not likely, since we have merely replaced the part and not considered how we could have developed excessive vibration. The physical root is the easiest level to stop at for most analysts. The corrective action usually involves the allocation of money to purchase equipment or components. Management is more apt to stop at this level because it can spend money and receive an investment that it can see. This is unlike the issue with human and latent roots.

The human root(s) are generally one level below the physical roots. A human root is actually a decision error by an individual or a group. These are either errors of omission or errors of commission. We either made a decision to do something that was wrong or we made a decision to not do something that we should have. An error of omission might be a missed inspection. An error of commission might be misalignment by a mechanic; the mechanic intended to align correctly, but it did not work out that way. This is a sensitive level and one that is often perceived as "witch hunting" if handled incorrectly. This is also not the level to stop at when performing a RCA.

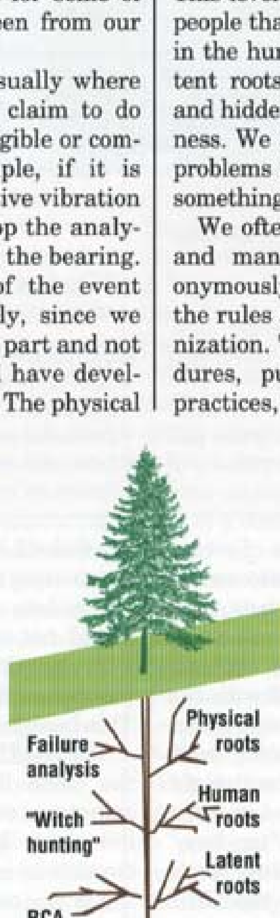


FIGURE 3. The true root cause of an event lies below the physical and human root causes

The latent root cause, below the human root, is the true root-cause level. This level delves into the minds of the people that made decision errors above in the human root. They are called latent roots because they are dormant and hidden in the daily routine of business. We all know that we have these problems and we accept the fact until something fails to perform as desired.

We often use the terms, latent root and management-system root, synonymously. Management systems are the rules and regulations of any organization. They are the policies, procedures, purchasing practices, stores practices, and so on, which are put in place to help us make better decisions. However, sometimes we modify our operations and do not modify the support systems along with it.

Continuing with the failed-pump example, we have a mechanic who aligned a pump improperly and it resulted in excessive vibration of a bearing. Now we must explore why the mechanic would align improperly. The mechanic presumably does not awake in the morning and proclaim, "Today will be the day that I misalign all the rotating equipment." Instead, it may be that the mechanic does not possess the correct tools or was not properly trained, or there was no procedure in place requiring alignment. These are examples of latent roots. The root cause of the logic tree for this example is shown in Figure 4.

Making the findings available

After identifying all of the root causes, deciding what's to be done about them is often a frustrating point in the analysis for the RCA team. Now it must "sell" its recommendations to management in order to obtain funding for the corrective actions. The situation is similar to a detective having his day in court. Our situation is similar with the exception that our judges will be our management review team. They are the one we must sell in order to implement our recommendations.

This is pure salesmanship at this point. The development of the report and the final presentation are vital to the success of the overall RCA. The managers should be afforded the same respect as a judge. They are entitled to hearing a solid case before making their judgement. Realizing the importance of this meeting, we should be totally prepared.

A technical presentation should never be given to a group of managers with a financial background. Instead, the presentation should be customized to their world and present the benefits of implementing the recommendations in units they understand: dollars.

Tracking for bottom-line results

What is the true definition of a successful RCA? Is it determining accurate causes? Is it developing plausible recommendations? Is it gaining approval of the recommendations? Is it implementing recommendations? The answer to all of the above should be no.

The true definition of a successful RCA is that some bottom-line performance measurement has improved as a result of recommendations implemented from the RCA. The simplest way to determine the appropriate measure is to look back at how you know you had a problem in the first place. What indicators alerted you that a problem existed? Was it excessive maintenance costs? Was it inadequate number of tons produced? Was the mean time between failure (MTBF) unacceptable? Was the mean time to restore (MMTR) taking too long? These are usually the best means to see if the bottom-line performance is positively impacted. A true RCA is not successful unless we have improved the bottom-line performance.

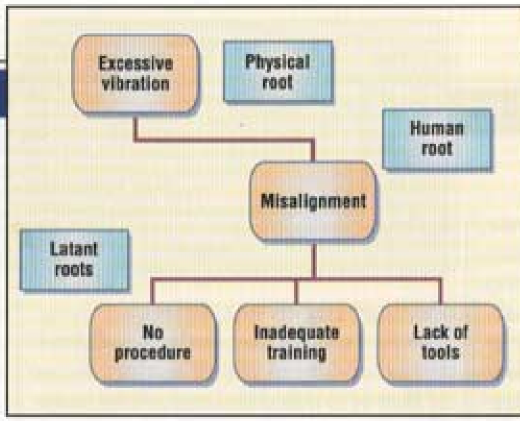


FIGURE 4. An example of the root cause logic tree for a chronic pump failure

The case study outlined on page 4 is a good example of how RCA can improve the bottom-line performance. This and other actual studies give ROIs for eliminating actual cronic events ranging from 3,100 to 17,900%. The time frames to complete the RCAs range from seven days to eight months.

Automating RCA

The PROACT method described above has been performed manually for decades. With recent advances in technology and the availability of computers in the workplace, automation has proven to be a sound alternative.

However, automation does not mean that we use computer software to do the thinking for us. Automation should be introduced when humans must perform repetitive tasks. By automating such tasks, the risk of human error is reduced.

In conducting a RCA, the repetitive tasks are the multiple handling of data. When a RCA is performed manually, we often must first write on an easel, a marking board, drafting paper, or other surface. This requires someone to transcribe what was on the paper to a software program. Once this is done, the information is then disseminated to the remaining team members. This process usually involves a lapse of a day or two before all the team members have the same information.

We have found that administrative burden of conducting a RCA extends its cycle time about 100%. By automating the RCA process, we have reduced our cycle times by 50%. ■

Edited by Gerald Ondrey

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