



# Root Cause Map<sup>TM</sup> Documentation

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Houston, TX 77060 USA

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ABS Group  
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# Thank You for Choosing ABS Group' as Your Root Cause Analysis and Incident Investigation Resource

ABS Group personnel have worked on all types of root cause analyses and incident investigations. These range from identifying human errors or component failures that contribute to simple system failures, to discovering the origins of catastrophic incidents by piecing together a complex chain of events through rigorous application of the root cause analysis techniques described in this handbook, to analyzing chronic problems at many facilities. Our techniques have been applied to personnel injuries and fatalities, environmental spills, scheduling issues, reliability problems, quality concerns, and financial issues.

## ABS Group Investigation Assistance

If you need help investigating an accident or problems related to reliability, quality, production, security, or finances, ABS Group can be of assistance. Our investigators can lead a team of your personnel, advise your team, or provide an independent analysis, depending on your specific needs.

## ABS Group Training Services

Based on our experience, we have trained thousands of individuals using the proven techniques outlined in this handbook. Because these training courses emphasize a workshop approach to learning, students gain valuable experience by practicing what they learn on realistic examples. We can even teach a course at your facility using workshops that have been customized to meet the needs of your company or organization. The courses can range from one to seven days in duration. The following are summaries of just a couple of the 75+ public courses that we teach.

**Incident Investigation/Root Cause Analysis** — The focus of this course is on how to gather data, analyze data for causal factors, fill gaps in data, determine root causes, and write effective recommendations using ABS Group's proven RootCause LEADER™ technique. You will learn and apply several systematic methods, such as timelines, cause and effect tree analysis, and causal factor charting to uncover the root causes of system performance problems. You will also participate in several workshops, including one on the use of ABS Group's Root Cause Map™ and another in which you will perform a complete root cause analysis of a realistic problem. You will also learn how to structure an effective incident investigation or root cause analysis program, which includes defining, classifying, and trending data on near misses and other incidents that need to be reported.

**Preventing and Mitigating Human Errors** — In this course you will learn how to examine human errors to identify the conditions and error-likely situations that contributed to mistakes. From this starting point, you will learn to recognize the true causes of most human errors, which are weaknesses in the management systems used to (1) design equipment and processes, (2) develop and use procedures and policies, and (3) select, train, supervise, and communicate with workers.

## ABS Group Web-based Services

In addition to the guidance provided in this handbook and in our courses, ABS Group provides root cause analysis resources on our Web site. Up-to-date clarifications and guidance based on feedback from users of this handbook, as well as other root cause/incident investigation resources, are all available at:

[www.abs-group.com/RCAHandbookResources](http://www.abs-group.com/RCAHandbookResources)

# Contact Us for Information and Assistance

If you would like a copy of our training catalog or more information about how we can assist you, contact ABS Group.

- By phone at 1-800-769-1199
- By fax at 1-281-673-2931
- By e-mail at [knoxtraining@absgroup.com](mailto:knoxtraining@absgroup.com)
- By mail at ABS Group, 16855 Northchase Drive, Houston, TX 77060, USA
- At [www.abs-group.com](http://www.abs-group.com)

## If you need immediate investigation assistance

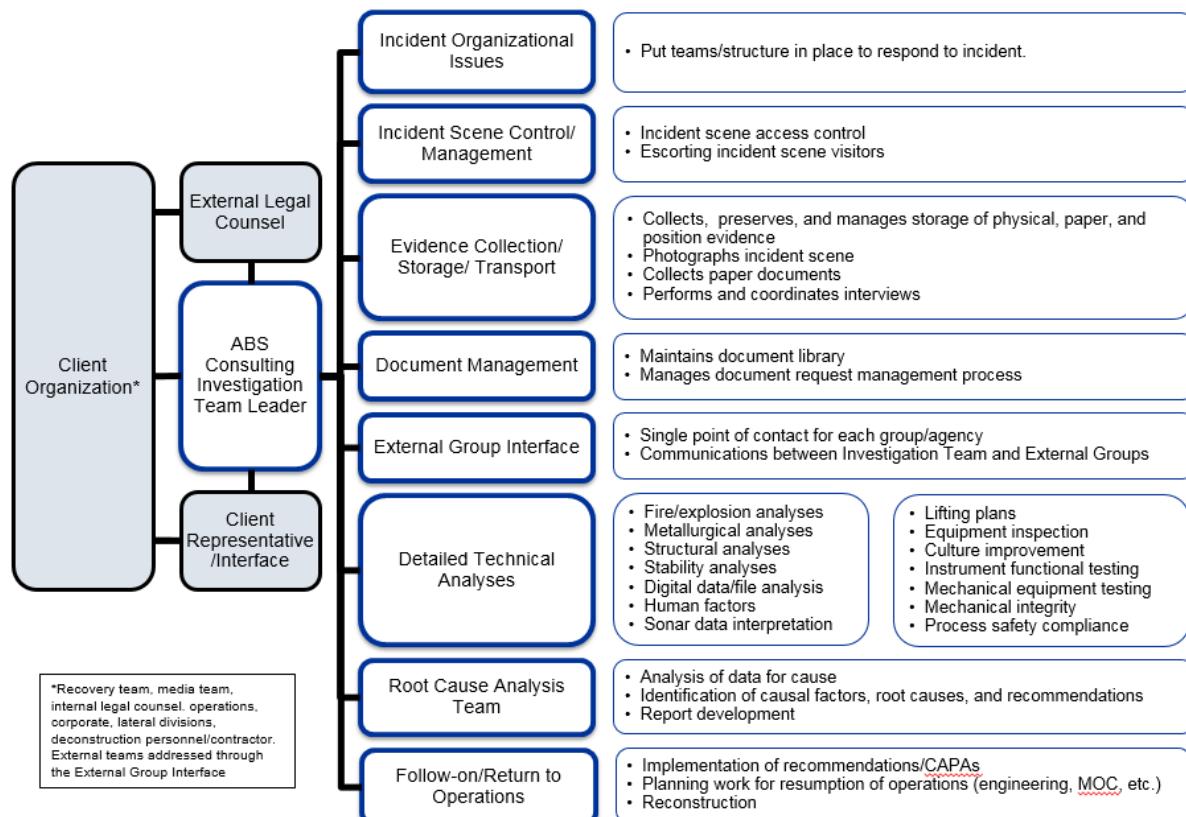
If you need immediate investigation assistance, contact ABS Group on our 24/7 rapid response system number at:

**+1-331-303-2272**

Clients call us for incident investigation/root cause analysis support when they:

- ✓ Have a major accident or incident and need additional investigation expertise, technical expertise, regulatory interface support, and recommendation implementation support,
- ✓ Know they will face issues with regulators, insurance companies, or customers,
- ✓ Know there is the potential for serious litigation.
- ✓ Have a chronic issue that they need assistance with solving, or
- ✓ Want an outsider's view of an incident.

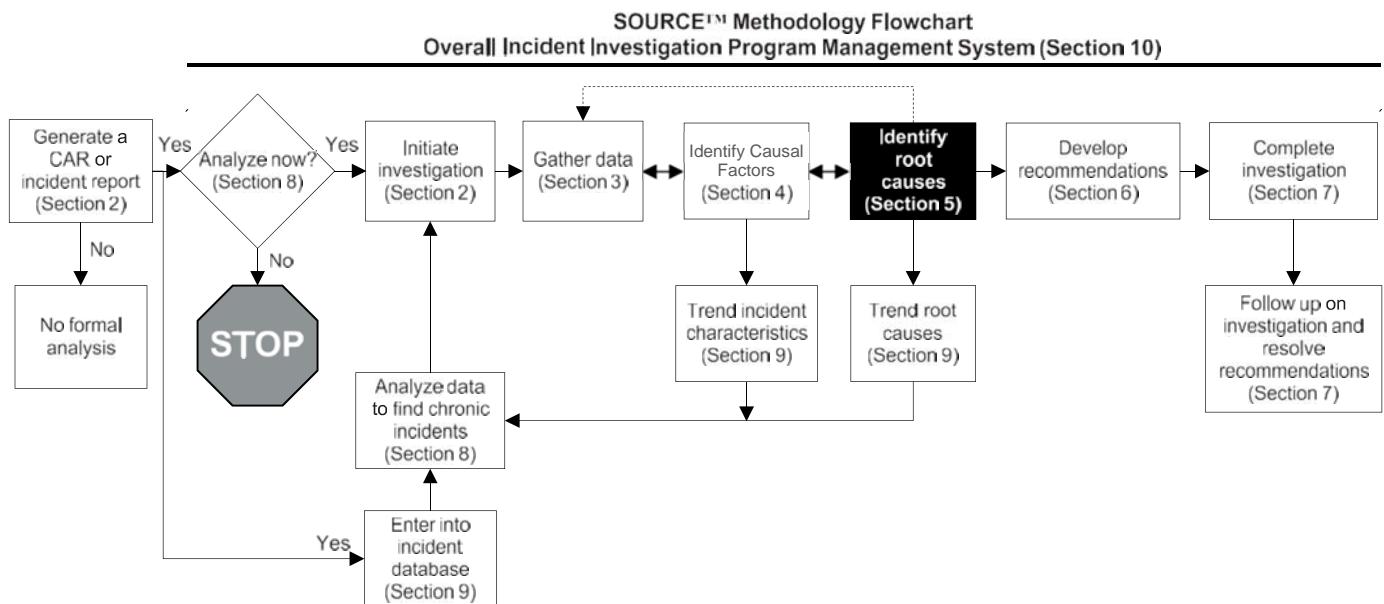
We can provide a comprehensive response to an incident – from simple to complex. The figure below outlines the various roles and activities that ABS Group can provide to support an organization following an incident. **We will tailor our approach and our team to YOUR specific needs.**



# 1 Introduction

This book contains guidance on how to utilize ABS Group's Root Cause Map™. This book is a companion to ABS Group's *Root Cause Analysis Handbook, Third Edition*<sup>1</sup>.

The *Root Cause Analysis Handbook* provides detailed, step-by-step guidance on how to perform an incident investigation as outlined in Figure 1. One step in this process is the identification of root causes. During this step, the Root Cause Map™ is used by root cause analysis (RCA) teams to assist in the identification of root causes.



**Figure 1: Identifying Root Causes Within the Context of the Overall Incident Investigation Process**

## 2 Using the Root Cause Map™

### 2.1 The Five-step Process for Root Cause Identification

As outlined in Section 5.6 of the *Root Cause Analysis Handbook*, the RCA team should use the following five step process for root cause identification.

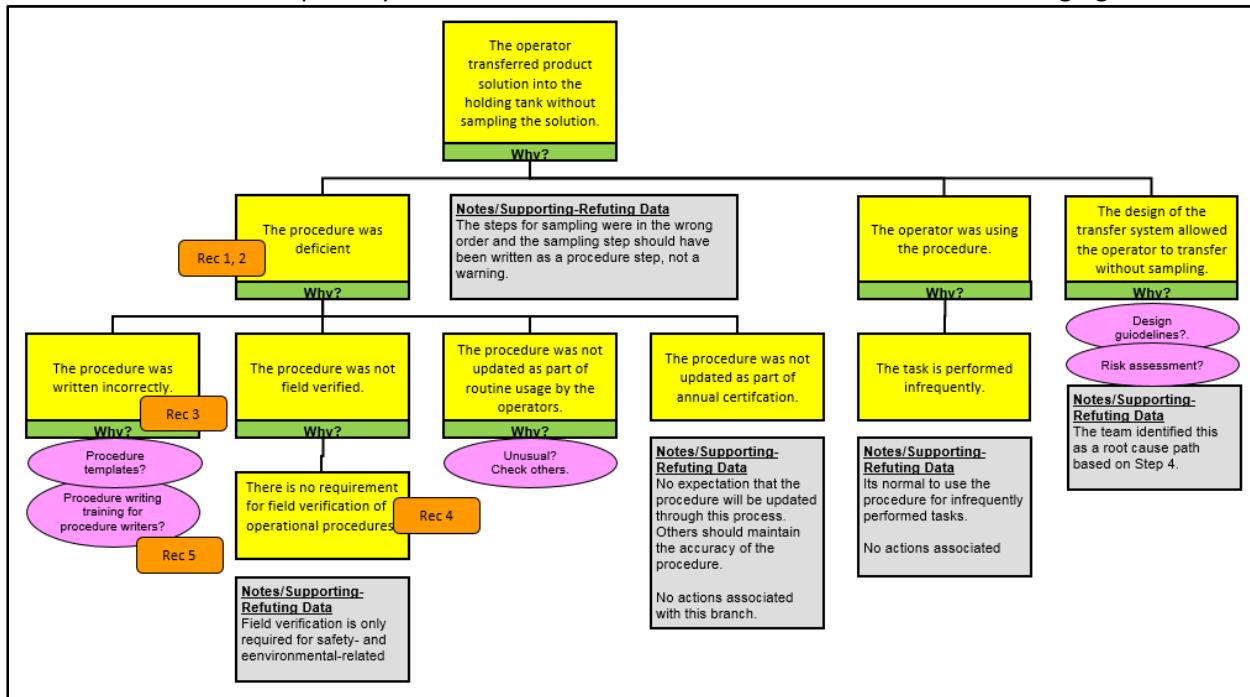
There are five key steps to identifying and coding root causes.

1. Select a causal factor from the timeline, cause and effect tree, and/or causal factor chart.
  - a. Root cause identification should not begin until all of the causal factors are determined. Starting root cause identification before the incident is understood and causal factors are identified may result in:
    - Identifying the wrong root causes
    - Developing the wrong recommendations
    - Developing ineffective recommendations
    - Recurrence of the incident
  - b. Because it is important to identify causal factors before starting root cause identification:
    - Step 1 of this 5-step process is to identify a causal factor.
    - Item 1 on the top of the Root Cause Map™ is entitled "Start here with each

*causal factor.”*

- Reports are laid out with a three-column form where the first column is the causal factor and the second column is for root causes. If causal factor identification is skipped, it should be obvious when looking at the table.

2. Brainstorm to generate a list of underlying management system performance gaps for each causal factor.
  - a. Using a small cause and effect tree or 5-whys type tree can help to structure this connection between causal factors and the underlying root causes. These small cause trees will also prove helpful in the next section when developing recommendations.
  - b. The Root Cause Map™ is NOT needed for this step.
  - c. An example why tree for causal factor-root causes shown in the following figure.



Example of a Why Tree constructed as part of Step 2 of the five-step process for root cause identification.

3. Using the Root Cause Map™, code each issue identified in Step 2.

- a. In this step, the team matches each issue identified in Step 2 to one or more items on the Root Cause Map™. For each causal factor, the team works through the seven levels of the Root Cause Map™. The seven levels are:
  - Causal factor type
  - Problem Category
  - Intermediate Cause Category
  - Intermediate Cause Subcategory
  - Root Cause Type
  - Root Cause
- b. The items on the Root Cause Map™ are referred to as nodes. The numbers on the Root Cause Map™ are referred to as node numbers.
- c. The best way to think about the coding step is to think about the node numbers on the

Map as a foreign language. Your task in this step is to translate each issue from English (or other language) to the numbers on the Map. The best codes to select on the Map are those that do the best job of “translating” the issues to the codes.

Another way to think about this is to pretend that for some reason, you cannot communicate using words and sentences. You can only communicate the root causes using the numbers on the Map. You and the rest of your organization have a copy of the Map so they can translate between the node numbers and the items on the Map. You just need to select nodes on the Map that describe the root cause you identified in Step 2.

- d. For example, say the team identified that there were steps out of order in a procedure used by company personnel. The reason why the procedure had steps out of order was that the standard, policy, or administrative control for generating procedures was not strict enough. To code this issue, the following path would be selected:

- Front-line Personnel Issue (#3): The causal factor was an FLPPG
- Company Personnel Issue (#12): The individual was a company employee
- Procedure Issue (#122): The underlying cause was a procedural issue
- Appropriate Procedure Incorrect/Incomplete (#140): There was an error in the procedure
- Wrong Action Sequence/Ordering (#141): This is the closest match to “steps out of order.”
- Standards, Policies, and Administrative Controls (SPACs) Issue (#225): the underlying cause was a problem with a SPAC
- SPAC Not Strict Enough (#227): The team noted that the SPAC was not strict enough

Going back to our translation analogy, what would someone think of it you told them you had a 3, 12, 122, 140, 141, 225, 227 issue? There was a problem involving a company employee that involved a procedure with the steps out of order that occurred because some policy was not strict enough. Not a perfect or complete translation, but pretty complete for using only seven numbers.

- e. The purpose of coding these paths through the Root Cause Map™ is to facilitate the trending process. Entering the root cause paths into an incident database allows trending analyses to be performed. We want to be able to scan the root cause node codes from numerous incidents and identify recurring types of issues. This would not be possible without this type of numerical coding.
- f. Most causal factors have more than one associated root cause. For example, during an investigation an operator failed to follow a procedure. It was found that operators are taught to always follow procedures. There is even a policy that requires operators to always follow procedures. However, the operators routinely take shortcuts in procedures to get the job done faster, and management often rewards this practice. In other words, the procedure usage policy has not been enforced and, in many cases, personnel are discouraged from complying with the policy. One of the reasons that deviations from procedures are so common and encouraged is that many of the procedures are out of date. As a result, many of the procedures cannot be performed as written because of changes that have occurred since they were written. The procedures are out of date because the organization has not allocated resources to perform this task. Operators routinely identify procedural issues and even document the deficiencies. However, these procedural deficiencies are not resolved.

In this case, there are three root causes. The first root cause is that the SPAC that

requires procedures to be followed is not enforced. The second root cause is that the improper performance of the operators was not corrected. The third root cause is that the organization does not allocate resources for procedural updates. Therefore, three sets of codes would be appropriate (3, 12, 122, 140, 142, 230, 233; 3, 12, 185, 192, 193, 230, 233; and 3, 12, 185, 186, 189, 230, 233). Think again about this coding process as translation. If you provided these codes and the Map to someone, would they generally describe the situation as you did? If so, then the coding is appropriate. If not, alternate or additional coding could be necessary.

4. Use the Root Cause Map as a checklist to stimulate thinking about other potential root causes.
  - a. The purpose of this step is to get the team to think broadly about the underlying causes of the causal factor. By reviewing each of the intermediate cause categories, the team will have considered a broad range of possible causes.
  - b. The best approach to performing this review is to think about potential solutions related to each of the areas. To do this, the team should ask two questions:
    - i. **Question 1:** “Could the frequency or consequences associated with this causal factor be reduced by a more effective \_\_\_\_\_ (design, maintenance strategy, training program, communications, etc.)?”
    - ii. If the answer is no proceed on to the next major root cause category. If the answer to question 1 is yes, then ask Question 2
    - iii. **Question 2:** “Do we want to address this causal factor through an improved \_\_\_\_\_ (design, maintenance strategy, training program, communications, etc.)?”
    - iv. If the answer is no, proceed on to the next major root cause category. If the answer to question 2 is yes, then return to Step 2 to add that issue to the logic tree and use Step 3 to code the issue using the Map.

The first question asks if a potential solution exists related to this cause category (i.e., design, maintenance, training, communications, etc.). The second question asks if it is a performance gap; do we want to say the design, maintenance, etc. is deficient?

- c. For example, when considering design as a potential root cause, ask the question “Could the frequency or consequences associated with this causal factor be reduced by a more effective design?” For almost every causal factor, the answer to this question is yes. Almost any causal factor can be addressed through an improved design. With the answer to the first question yes, then the second question is “Do we want to address this causal factor through an improved design?”

If the investigator answer yes to this second question (believes the design is deficient and should be addressed through recommendations), then return to Step 2 to add that issue to the logic tree and use Step 3 to code the issue using the Map.

If the investigator believes that a better design could be implemented, but that it is not practical, feasible and achievable to do so, then the answer to the second question is no and it is not a performance gap. As a result, no further action is taken.

- d. Likewise, the investigator should consider each of the remaining 10 major root cause categories. For example, for *Material/Parts and Product Issue*, the investigator could ask, “Could better control over the materials, parts, and finished product have prevented or mitigated the consequences associated with this causal factor?” If the

answer is yes, then ask the second question. If the answer to the second question is also yes, then it's a root cause (a performance gap) and you would return to Step 2 to add it to the tree and use Step 3 to code the additional root cause. If the answer to either the first or second question is no, go on to the next category.

- e. For some of the categories, it may be helpful to break the section down into multiple subsections. For example, the *Hazard/Defect Identification and Analysis Issue* section could be broken down into several subsections so several questions are asked associated with that portion of the Map. For example, "Could a more effective MOC program have prevented or mitigated the consequences associated with this causal factor?" or "Could a more effective root cause analysis program have prevented or mitigated the consequences associated with this causal factor?"

5. Document the results of the analysis on the three-column form.

- a. The following table shows an example of the documentation that should be generated for this portion of the analysis.

*Example of a Completed Three-column form (Example 1)*

*See the why tree in Step 2 associated this example.*

Causal Factor	Root Causes and Paths through the Root Cause Map™	Recommendations
<p><b>Causal Factor #1</b></p> <p>The operator transferred product solution into the holding tank without sampling the solution.</p> <p><b>Background</b></p> <p>The operator transferred product solution into the product hold tank before sampling it, violating a company requirement. He used a procedure that had deficiencies. Step 5 of the procedure instructed the operator to transfer the solution to the hold tank. A warning after Step 5 of the procedure said to sample the product before transferring to the hold tank.</p> <p>This procedure was not field verified with the operators. The procedure-writing guidelines only require field verification of safety-significant and environmental-related procedures. This transfer process can only have production impacts.</p> <p>The procedure is implemented about once every six months. Because it is performed infrequently, the operators typically have the procedure in hand while performing the transfer.</p> <p>The procedure is reviewed and certified annually. The last revision of the procedure was approximately 2½ years ago,</p>	<p><b>Root Cause 1-1</b></p> <p>The procedure had steps out of order. The procedure writing guidelines were not strict enough because they did not require field verification of this type of procedure.</p> <ul style="list-style-type: none"> <li>• 3: Front-line Personnel Issue</li> <li>• 12: Company Personnel Issue</li> <li>• 122: Procedure Issue</li> <li>• 140: Appropriate Procedure Incorrect/Incomplete</li> <li>• 141: Wrong Action Sequence/Ordering</li> <li>• 225: Company Standards, Policies and Administrative Controls (SPAC) Issue</li> <li>• 227: SPAC Not Strict Enough</li> </ul> <p><b>Root Cause 1-2</b></p> <p>The procedure did not address how actions to take following receipt of the sampling results. The policy was not strict enough because it did not require field verification of this type of procedure.</p> <ul style="list-style-type: none"> <li>• 3: Front-line Personnel Issue</li> <li>• 12: Company Personnel Issue</li> <li>• 122: Procedure Issue</li> <li>• 140: Appropriate Procedure Incorrect/Incomplete</li> <li>• 144: Missing Steps/Content/Situation Not Covered</li> <li>• 225: Company Standards, Policies and Administrative Controls (SPAC) Issue</li> <li>• 227: SPAC Not Strict Enough</li> </ul> <p><b>Root Cause 1-3</b></p> <p>The procedure warning should have been written in the format of a step. The policy was not strict enough because it did not require field verification of this type of procedure.</p> <ul style="list-style-type: none"> <li>• 3: Front-line Personnel Issue</li> <li>• 12: Company Personnel Issue</li> <li>• 122: Procedure Issue</li> <li>• 131: Correct Procedure Used Incorrectly</li> <li>• 134: More than One Action per Step</li> <li>• 225: Company Standards, Policies and Administrative</li> <li>• Controls (SPAC) Issue</li> <li>• 227: SPAC Not Strict Enough</li> </ul>	<p>1. Revise the transfer procedure as follows:</p> <ul style="list-style-type: none"> <li>• Change the sampling requirement from a warning to a step.</li> <li>• Add procedure steps to provide appropriate response to sample results.</li> <li>• Move the sampling requirements and responses before the transfer step. (Level 2)</li> </ul> <p><b>Implementation responsibility:</b> Chemistry supervisor</p> <p>2. Review a sampling of 5% or more of other operations procedures to determine the extent of similar problems with other procedures. (Level 3)</p> <p><b>Implementation responsibility:</b> Operations manager</p> <p>3. Review the procedure for generating (writing) procedures. Confirm that it provides guidance for when to use cautions and warnings. (Level 4)</p> <p><b>Implementation responsibility:</b> Operations manager</p> <p>4. Revise the procedure-writing guidelines to require field verification of procedures that can have significant operational impact (i.e., cost impacts or customer delivery impacts) in addition to procedures with safety- and environmental related impacts. (Level 4)</p> <p><b>Implementation responsibility:</b> Operations manager</p> <p>5. Consider specific procedure-writing training for the operations personnel responsible for writing procedures. (Level 4)</p> <p><b>Implementation responsibility:</b> Training manager</p>

## **5.6.2 Incorporating Organizational Standards, Policies, and Administrative Controls**

The Root Cause Map™ is set up to allow organizations to capture their organization-specific SPACs in their trending database without modifying the structure of the Root Cause Map™. At the root cause level, the organization-specific SPACs can be included in the root cause coding by including both the node number and the specific policy document at the root cause level. For example, if a path ended at Node 227, SPAC Not Strict Enough, the database coding would include the node number, 227, and the policy document that was not strict enough, such as TPS-11.2. By including both the node number and the SPAC documents in the root cause coding, the organization can identify areas where the specific SPACs, groups, or types of SPACs are dominant contributors to incidents. This allows the organization to focus its efforts on the most significant contributors to losses. As noted before, ABS Group's software is designed to allow you to capture this information in the data structure and perform trending analysis of this data.

## **5.6.3 Using the Root Cause Map™ Guidance during an Investigation**

Using the Root Cause Map™ by itself may be sufficient when the team identifies nodes on the Map that closely match the wording of their issue. However, sometimes it is not obvious which node best "translates" the issue identified by the team. To assist investigators in identifying the more subtle terminology used on the Map, ABS Group has developed detailed guidance for each item (node) on the Map. This detailed guidance can be found on the RCA Handbook Resources web page. For each node on the Root Cause Map™, the guidance on the Web site includes:

- Typical recommendations
- Examples (for selected nodes)
- Notes related to the use of the node
- Notes regarding commonly confused items/nodes

Use of this detailed Map guidance can achieve several goals:

- Increased consistency in identifying root cause codes. This increases the validity of the root cause trending performed by the organization
- Consideration of additional root causes – primarily the result of cross-referencing in the guidance that guides the investigator to consider other related root causes
- Use of consistent terminology in describing root causes

To achieve an even higher level of consistency, the information in the "Root Cause Map™ Guidance" should be customized to make the information and examples specific to the organization. ABS Group's investigation software is specifically structured to allow frequent and routine tailoring of the guidance as the organization develops additional guidance and examples over time. Contact ABS Group to explore customization of the Root Cause Map™ for your organization.

The web-based guidance for using the Root Cause Map™ is always evolving. Updated guidance, based on feedback from ABS Group consultants and customers, can be found on our Web site at [www.abs-group.com/RCAHandbookResources](http://www.abs-group.com/RCAHandbookResources)

## **3 Clarifications and Updated Guidance**

If you need clarification on using the Root Cause Map™, you can go to the ABS Group Web site to:

- Browse the updated guidance and the responses to frequently asked questions (FAQs).
- Submit questions to the handbook authors.

The authors will provide you with updated guidance and clarification on using the Root Cause Map™.

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# Start here with each causal factor – 1

## Definitions/Typical Issues

Start here with each causal factor. Select the appropriate path(s) through the Root Cause Map™ to identify causes at each level of the map.

## Examples

Causal factors are front-line personnel performance gaps and equipment performance gaps.

### **Example 1**

**Desired Performance:** Analyze a sample from each product tank prior to transferring it to a storage tank.

**Actual Performance:** The operator did not take a sample prior to transferring material from a product tank to a storage tank. As a result, the material in the storage tank may no longer meet specifications.

### **Example 2**

**Desired Performance:** Do not have fan bearings fail in service.

**Actual Performance:** The outboard fan bearing on a fan failed.

### **Example 3**

**Desired Performance:** Close the sample valve following maintenance.

**Actual Performance:** The mechanic failed to close the sample valve following maintenance.

### **Example 4**

**Desired Performance:** The reactor feed pump should supply 18 to 22 gallons per minute of catalyst to the reactor.

**Actual Performance:** The reactor feed pump supplied 27 gallons per minute of catalyst to the reactor.

## Typical Recommendations

Recommendations that address causal factors are typically Level 1 recommendations. They fix the specific failure or error that occurred.

### **Example 1**

**Situation:** Operator did not take a sample prior to transferring material from a product tank to a storage tank.

**Level 1 Recommendation:** Take a sample from the storage tank to verify that the product is acceptable.

### **Example 2**

**Situation:** The outboard fan bearing on a fan failed.

**Level 1 Recommendation:** Replace the bearing.

### **Example 3**

**Situation:** The mechanic failed to close the sample valve following maintenance.

**Level 1 Recommendation:** Close the sample valve.

### **Example 4**

**Situation:** The reactor feed pump supplied 27 gallons per minute of catalyst to the reactor.

**Level 1 Recommendation:** Adjust the reactor feed pump so it supplies 27 gallons per minute of catalyst to the reactor.

Levels 2, 3, and 4 recommendations address the lower levels of the Root Cause Map™ (see Section 6 of the Root Cause Analysis Handbook for details on recommendation levels).

## 2 – Equipment/Software Issue

### Definitions/Typical Issues

Was there a difference between the actual and desired performance of the equipment, software, or material/product? Did the equipment, software, or material/product fail to perform as desired?

Was there a variation or change in raw materials that led to the incident? Was there a difference between the anticipated raw materials and those actually used in the process?

This node includes problems with equipment/software design, fabrication, installation, and maintenance. Problems with the equipment/software reliability program are also coded under this node. In addition, issues with materials and products are coded under this node.

If the causal factor was an equipment performance gap, then coding under this node is appropriate.

**Note 1:** Equipment/software failures can also be thought of as performance gaps. The gap is the difference between the desired performance (the equipment/software operates) and the actual performance (the equipment/software failed). Thus, the definition is not failure to perform as designed, but failure to perform as desired. This means that items can perform as designed and still fail, because they fail to perform the desired task. This is shown in Example 4 where an air handling system performs as designed, but not as desired.

### Examples

**Example 1:** A spill to the environment occurred because a valve failed. The valve failed because it was not designed for the environment in which it operated.

**Example 2:** The software control system failed to properly control a machining operation. This resulted in production of out-of-specification parts. The software did not consider an unusual sequence of steps that occurred when machining some parts.

**Example 3:** An air handling system failed to provide adequate cooling to a computer room. When the computer system failed, all of the automatic controls became inoperable. The air-handling unit was designed with an inadequate capacity for the heat load in the room.

**Example 4:** An air handling system failed to provide adequate cooling to a computer room. When the computer system failed, all of the automatic controls became inoperable. The system was undersized due to recent upgrades to the computer systems that rejected more heat to the room. The impact of the increased heat loads on the air handling system was not considered during the computer system modifications.

**Example 5:** The formulation for a lubricant used by the facility was changed by the manufacturer. This led to a number of bearing failures. The facility was unaware of the change and, therefore, did not consider the effect of this change on the process equipment.

**Example 6:** A supplier changed the part number for a specialty wrench. Although the wrench was still available, it appeared that the wrench was no longer stocked. As a result, there were delays in repair of a pump.

### Typical Recommendations

Ensure that equipment is fit for its current use.

Perform hazard assessments of equipment during its design and after the design is complete.

Develop procedures for operation of equipment.

Make the original equipment manufacturer's manuals readily available.

Design equipment with the end use in mind.

## **2 – Equipment/Software Issue (cont.)**

Lay out equipment in the order in which it is used.

Provide appropriate specifications for raw materials.

Verify that stock is current prior to its use.

Establish a process to ensure a first-in/first-out (i.e., the first material placed in storage is the first material used [pulled out of storage]) usage pattern.

## Definitions/Typical Issues

Was there a difference between the desired performance of front-line personnel and their actual performance?

If the causal factor is a front-line personnel performance gap, then coding under this node is appropriate. If the causal factor is an equipment performance that is directly caused by a front-line personnel performance gap, dual coding under this node is appropriate (for example, if a bearing failed (EPG) because it was installed incorrectly (error by front line personnel, then dual coding under nodes 2 and 3 are appropriate).

**Note 1:** Personnel issues include instances where personnel fail to perform as desired, even if they follow the procedure. If an individual follows an incorrect procedure precisely, there is still a performance gap because the individual does not perform the task in the desired manner.

## Examples

**Example 1:** A tank overflowed, resulting in a spill to the environment. The operator filling the tank was using the wrong revision of the procedure. It had an incorrect calibration chart for the tank.

**Example 2:** A mechanic performing maintenance in a confined space was not allowed to take a written procedure with him. As a result, he had to review the procedure and commit it to memory. During performance of the task, he omitted an important step. This resulted in the failure of a key piece of equipment.

**Example 3:** An operator made a mistake performing a calculation. The data used in the calculation came from multiple steps in the procedure. She made a mistake in transferring one of the data points from an earlier step in the procedure to the step at which the calculation was performed.

**Example 4:** A contract employee took a sample from product tank C instead of product tank B. The tanks are arranged from left to right: A C B.

**Example 5:** A company employee made a mistake using a scale to weigh a pallet of material. It was the first time the operator had used the scale. He was told how to use the scale as part of training, but had never actually used it.

## Typical Recommendations

Ensure that third-party personnel do not have access to equipment that they are not qualified to operate.

Ensure that contract employees have sufficient guidance to perform their activities.

Ensure that personnel have sufficient guidance to perform their activities.

Ensure that personnel are trained on all aspects of the job, including unusual and one-of-a-kind equipment.

Develop equipment and procedures with the end-user in mind.

Provide appropriate supervision for personnel.

Ensure that performance standards are understood by personnel.

Reward appropriate behaviors.

## 4 – External Factors

### Definitions/Typical Issues

Did external events contribute to the causal factor?

This node addresses issues that the organization typically has little direct control over, such as:

- Natural phenomena
- External sabotage
- External events
- Weather conditions
- Releases from external sources (adjacent facilities, trucks, etc.)

These issues should also be coded at other locations to address the organization's method of dealing with the external risks.

**Note 1:** Coding under the ***Hazard/Defect Identification and Analysis Issue (#94)*** node may also be appropriate.

### Examples

**Example 1:** Inventory in the warehouse was damaged when the warehouse was flooded following heavy rain.

**Note:** The design and location selection processes should also be addressed to determine why they did not adequately address the potential for flooding.

**Example 2:** A release of chlorine from an adjacent facility affected the operators in your facility.

**Note:** Issues associated with the organization's response to the release should also be addressed to determine whether emergency response planning and implementation should be improved.

**Example 3:** A chlorine tanker accident on a nearby railroad spur required the evacuation of a portion of your facility.

**Note:** Issues associated with the organization's response to the release should also be addressed to determine whether emergency response planning and implementation should be improved.

**Example 4:** A nearby accident on the expressway prevented shipments from leaving your facility for an 8-hour period. As a result, some deliveries were not made on time.

**Note:** Issues associated with the organization's response to traffic issues should also be addressed to determine whether contingency planning and implementation should be improved.

**Example 5:** A key supplier's warehouse was struck by a tornado. As a result, the warehouse was unable to supply your facility with raw materials for two weeks.

**Note:** Issues associated with the organization's supplier selection process should also be addressed to determine whether multiple suppliers should be used.

**Example 6:** The local utility's power plant shut down, resulting in a 5-minute power outage to your facility. It took 2 hours to restart the plant and stabilize the process.

**Note:** Issues associated with the design of backup power supplies for the facility should also be addressed to determine whether emergency power sources should be modified.

**Example 7:** A rabid fox bit a worker who was checking some equipment in a remote location.

**Example 8:** The facility's emergency evaluation plan did not take into account a road construction project that temporarily shut down a bridge that was the primary evacuation route for the facility.

### Typical Recommendations

Coordinate emergency response and planning with nearby facilities.

Develop contingency plans for dealing with external risks.

Develop a written plan or set of written plans that address emergency management.

**Definitions/Typical Issues**

Are the consequences of the causal factor tolerable for the organization given the potential for recurrence and no corrective or preventive actions? Is it acceptable to leave the situation as is?

Is it considered a tolerable risk to continue performing the task as it was performed during the incident? Was the loss associated with the incident considered acceptable?

Did the management systems perform as designed AND as desired?

**Note 1:** Tolerable risk may also be referred to as acceptable risk in some organizations or in some situations. For example, a risk matrix (i.e., a graph of consequences versus frequency) may show a region on it labeled “acceptable risk” or “tolerable risk.”

**Examples**

**Note: The examples here do not indicate ABS Group endorsement of the implied risk tolerance levels. Your organization's level of risk tolerance may be greater than or less than the examples below imply.**

**Example 1:** The organization did not require the investigation of relief valve openings. Although failing to correct the causes of the openings led to an increased risk, the organization believed the risk was tolerable.

**Example 2:** The organization did not require procedures for some operations. It only developed procedures that were required by outside organizations (regulatory bodies and certification organizations). Although development of some additional procedures would have reduced the risk of the operation, the organization believed that the risk was tolerable without them.

**Example 3:** The organization knew that fires could be started because of hot work being performed in the facility. The organization had developed policies and procedures on hot work. The organization ensured that the policies and procedures were followed. A fire occurred when hot work ignited some insulation on the inside of a duct near the work area. The procedure had been reasonably followed by the personnel performing the work. The policy does not require personnel to open up equipment and look inside to identify potential hot work hazards. The organization decided not to change the policies or procedures because they believed that the standards, policies, and administrative controls (SPACs) adequately controlled the risk.

**Example 4:** An employee stumbled and fell. The hallway she was walking down was clear of obstructions and well lit, and the flooring was secure. The employee was not carrying anything and was not distracted. No specific cause of the incident could be identified.

**Typical Recommendations**

Review the organization's risk acceptance criteria to ensure that it is still appropriate.

## 6 – Cause Cannot Be Determined

### Definitions/Typical Issues

This node addresses issues that cannot be coded elsewhere on the map because of insufficient information. Typical issues that are coded under this node include:

- No data exist
- Data are not available to the facility
- The facility doesn't want to pay for the data

### Examples

**Example 1:** A customer complained that the materials sent to him were out of specification. However, when the lab sample was tested, it was acceptable. When the customer retested the material, his test also indicated that the material was acceptable. Product manufactured from this batch was also acceptable.

**Example 2:** A spurious shutdown of a computer in the order-receiving department caused a delay in handling a customer's request. The problem could not be recreated. It could not be determined whether it was equipment failure or human error that led to the shutdown.

**Example 3:** A complex mixing system failed. The manufacturer was called in to repair the equipment. Because the mixing technology is proprietary, the manufacturer will not discuss the details of the failure with your organization. The licensing agreement between the organizations states that the manufacturer does not have to disclose any information about failures to your organization.

### Typical Recommendations

Develop additional data-gathering and recording methods in an effort to obtain sufficient information to determine the causes of subsequent failures.

## 7 – Process/Manufacturing Equipment Issue

### Definitions/Typical Issues

Did variations in the performance of process or manufacturing equipment cause the problem? Was there a performance gap for process or manufacturing equipment? Did process or manufacturing equipment vary from the design intent?

Examples of items coded under this node include:

- Valves (including relief valves)
- Piping
- Pumps
- Reactors
- Tanks
- Vessels
- Agitators
- Controls
- Indicators
- Switches
- Computers (this node only addresses computer hardware; software is addressed by Node #8)
- Displays
- Flares
- Conveyors

**Note 1:** Utilities are coded under the *Utility/Support Equipment Issue (#10)* node.

**Note 2:** Equipment that is not used in the manufacturing process is addressed under the *Other Equipment Issue (#11)* node.

**Note 3:** This node only addresses the hardware portion of the computer system. Computer software issues are addressed under the *Software Issue (#8)* node.

### Examples

**Example 1:** A spill to the environment occurred because a valve in the processing system failed. The valve failed because it was not designed for the environment in which it operated.

**Example 2:** A valve in the processing equipment failed because the designer used obsolete materials requirements. Leakage through the failed valve resulted in a spill to the containment dike.

**Example 3:** A process upset occurred because one of the flow streams was out of specification. The design input did not indicate all of the possible flow rates for the process. The pump was incorrectly sized for the necessary flow requirements.

**Example 4:** A process equipment line ruptured because a gasket failed. The gasket was constructed of the wrong material because the design did not consider all of the possible chemicals that would be in the line during different operating conditions. A chemical that was not considered caused the gasket to fail.

**Example 5:** During the past year, the failure rate for the process feed pumps has doubled. Maintenance records are inadequate to determine why any of the failures occurred. Work records just say that the pumps were repaired.

**Example 6:** A number of processing equipment pump bearings have recently failed. Predictive maintenance was selected as the appropriate type of maintenance for the pump bearings during the maintenance program design. However, no procedure was developed to perform the monitoring of the pump bearings. As a result, the predictive maintenance activity was never implemented.

**Example 7:** A process system line needed to be rerouted during installation to go around existing equipment, but this was not on the layout drawing. The reroute created a low point in the line that allowed contaminants to accumulate. Later, the pipe failed in this low section.

## 7 – Process/Manufacturing Equipment Issue (cont.)

**Example 8:** Field personnel could not determine from the installation package how to connect the power to a new drill press. They decided to connect it in the same way as others in the facility even though this drill press had a different manufacturer than the rest. As a result of the incorrect connection, the drill press control system was damaged.

**Example 9:** To save money, a drill press was purchased to mix chemicals in a lab. The slowest speed on the drill press was still too fast for proper mixing of materials. As a result, technicians were routinely splattered with chemicals while using the drill press.

**Example 10:** The computer for the plant control system failed when a circuit board in the computer failed.

### **Typical Recommendations**

Ensure that equipment is fit for its current use.

Perform hazard assessments of equipment during its design and after the design is completed.

Develop procedures for operation of equipment.

Make original equipment manufacturer's manuals readily available.

Design equipment with the end use in mind.

Lay out equipment in the order in which it is used.

Develop design specifications for computer hardware.

## 8 – Software Issue

### Definitions/Typical Issues

Was there a performance gap with the software? Did the software fail to perform as desired?

Examples of items coded under this node include:

- Access™
- Maximo®
- Operations applications
- Computerized maintenance management system
- Learning management system
- Distributed control system

**Note 1:** This node only addresses software. Computer hardware issues are categorized under the ***Process/Manufacturing Equipment Issue (#7)*** node.

### Examples

**Example 1:** The software control system failed to properly control a machining operation. As a result, a number of parts were improperly machined. The software did not consider an unusual sequence of steps that occurred when machining some parts.

**Example 2:** The software system failed to alert the operator to elevated temperatures on a fired heater (i.e., a heater that uses a flammable gas as the heat source). As a result, the heater was damaged and had to be replaced.

**Example 3:** A defect in a spreadsheet program resulted in a calculation error when computing heating times for a product.

**Example 4:** Some procedure steps were not printed out because of a bug in a word processor program.

### Typical Recommendations

Work with the eventual users of the system to develop a needs specification and a design specification prior to development of the software.

Perform tests of the software prior to implementation.

Review program-user comments prior to purchasing software in order to identify potential problems.

Review release notes and other documentation to identify potential implementation and compatibility problems prior to purchase.

Update commercial software on a routine basis.

## **Definitions/Typical Issues**

Was there a variation or change in raw materials or products that led to the incident? Was there a difference between the anticipated raw materials or products and those actually used or produced in the process?

Examples of items coded under this node include:

- Raw materials
- Chemicals
- Intermediates
- Finished products
- Lubricating oils
- Sealing rings
- Glues/adhesives
- Spare parts

**Note 1:** Processing and manufacturing equipment is addressed under the *Process/Manufacturing Equipment Issue (#7)* node.

## **Examples**

**Example 1:** The formulation for a lubricant used by the facility was changed by the manufacturer. The facility was unaware of the change and, therefore, did not consider the effect of this change on the process equipment.

**Example 2:** A supplier changed the part number for a specialty wrench. Although the wrench was still available, it appeared that the wrench was no longer stocked. As a result, there were delays in repair of a pump.

## **Typical Recommendations**

Provide appropriate specifications for raw materials.

Verify that stock is current prior to its use.

Establish a process to ensure a first-in/first-out (i.e., the first material placed in storage is the first material used [pulled out from storage]) usage pattern.

Ensure that products meet specifications.

## 10 – Utility/Support Equipment Issue

### Definitions/Typical Issues

Was there a performance gap in the performance of utility systems? Did the utility systems fail to perform as desired? Were there variations in the quality or characteristics of the utility systems?

Typical utility systems include compressed air systems, fire protection systems, electrical supply systems, HVAC (heating, ventilation, and air conditioning) systems, and cooling systems. These systems do not directly produce or manufacture the product. Instead, their operation supports the process/manufacturing equipment.

Examples of items coded under this node include:

- Air
- Gas
- Electrical
- Water
- Fire detection systems
- Fire protection systems (deluge, sprinkler)
- Lighting
- HVAC

Purchased utilities, such as electricity, steam, and water, should also be coded here.

### Examples

**Example 1:** An air handling system failed to provide adequate cooling to a computer room. The air-handling unit was designed with an inadequate capacity for the heat load in the room. As a result, the computers housed in that room failed.

**Example 2:** An air handling system failed to provide adequate cooling to a computer room. As a result, the computers housed in that room failed. The system was undersized due to recent upgrades to the computer systems that rejected more heat to the room. The impact of the increased heat loads on the air handling system was not considered during the computer system modifications.

**Example 3:** Power was lost to the manufacturing area when a number of breakers opened following a fault in a single machine. The breakers were incorrectly coordinated and power was lost to the entire area, instead of just to the one machine.

### Typical Recommendations

Ensure that utility systems have adequate capacity for the highest anticipated demand.

Ensure that utility systems meet the applicable specifications for the equipment they supply.

# 11– Other Equipment Issue

## Definitions/Typical Issues

Did performance gaps in the storage equipment, structural components, transportation equipment, or other equipment lead to the problem? Did any of these types of equipment fail to perform as desired? Were there variations in the quality or characteristics of the equipment?

Typical equipment addressed by this node includes:

- Storage equipment
  - » Warehouse areas\*
  - » Warehouse shelving\*
  - » Storage racks\*
  - » Storage containers\*
  - » Drums\*
  - » Container and storage location markings\*
- Material handling equipment\*\*
  - » Cranes (mobile and stationary)
  - » Davits
  - » Forklifts
  - » Manlifts
- Structures
- Process buildings
  - » Control buildings
  - » Office buildings
  - » Portable buildings
  - » Wheelbarrows
  - » Floor elements
  - » Roofs
  - » Walls
  - » Containment dikes
  - » Office cubical elements
- Transportation equipment\*\*
  - » Trucks
  - » Cars
  - » Bicycles/tricycles
  - » Powered scooters
  - » Portable buildings
  - » Other vehicles
  - » Trains
  - » Roads
  - » Shuttles
  - » Elevators
  - » Escalators
- Safety equipment\*\*
  - » Personal protective equipment (PPE), such as hard hats, safety shoes/boots, gloves, fire retardant clothing (FRC), coveralls, safety glasses, safety goggles, respirators, dust masks, and gas monitors, fall protection harnesses, fall protection lanyards
  - » Radios
  - » Fire extinguishers
  - » Respirators
  - » Fire/rescue trucks
  - » Wind socks

\* includes storage for raw materials, intermediate products, and finished products

\*\* includes spare parts for these items

### Examples

**Example 1:** Shelving in a warehouse collapsed when product was loaded onto it.

**Example 2:** Storage containers reacted with the product stored in them. The reaction was not considered during the selection of the containers.

**Example 3:** The storage locations that were painted on the floor could not be read by the forklift operators because they had worn off. As a result, the incorrect product was shipped to customers.

**Example 4:** Storage racks for components awaiting repair were not rated for the loads placed on them. As a result, they bent.

**Example 5:** A walkway collapsed because a field modification of the suspension system resulted in a weakened support system. The walkway collapsed when it was full of people.

**Example 6:** A pipe rack was not strong enough to support the loads placed on it. As a result, the support collapsed and multiple pipes broke.

**Example 7:** A leak on a propane-powered forklift caused a fire in the warehouse.

**Example 8:** A railing on a manlift failed, resulting in an employee falling out of the manlift.

**Example 9:** An elevator power supply failed, resulting in failure of the elevator.

**Example 10:** The pedal on a bike used in the plant failed, resulting in an employee twisting his ankle.

**Example 11:** The drums used to store raw materials had some weld defects. As a result, materials stored in the drums periodically leaked.

**Example 12:** Plastic containers that were used to set up part kits cracked. Some of the small pieces that broke off ended up contaminating the product.

**Example 13:** The portable building that housed the contractors was not designed to withstand explosions. As a result, when a petrochemical release near the trailer exploded, a number of personnel in the trailer were injured when it collapsed.

### Typical Recommendations

Ensure that storage equipment has sufficient capacity for the materials that will be stored there.

Ensure that storage locations are properly marked.

Ensure that storage equipment does not present any personnel safety issues.

Ensure that storage equipment is appropriate for the type of materials stored.

Ensure that structures are capable of supporting the loads placed on them or hung from them.

Ensure that structures have been designed to withstand natural phenomena events.

Ensure that transportation equipment is fit for transporting the load.

Ensure that transportation equipment is properly maintained.

## 12– Company Personnel Issue

### Definitions/Typical Issues

Was a direct-hire company employee involved? Are the employees involved covered by the normal company training programs? Are they covered by the management systems that cover company employees?

Typical personnel addressed by this node include:

- Company operators
- Company mechanics
- Company electricians
- Company instrumentation technicians
- Company delivery personnel

Direct-hire personnel directly involved in the offloading of raw materials and loading of finished products (e.g., tank truck drivers) are typically included in this node. Other vendors (vending machine contractors, freight truck drivers) are usually categorized under the ***Third-party Personnel Issue (#14)*** node.

**Note 1:** Distinguishing between company, contract, and third-party personnel can be important because of the different management systems that influence the behavior of these personnel.

### Examples

**Example 1:** A company employee took a sample from product tank C instead of product tank B. The tanks are arranged from left to right: A C B.

**Example 2:** A company employee made a mistake using a scale to weigh a pallet of material. It was the first time the operator had used the scale. He was told how to use the scale as part of training, but had never actually used it himself.

**Example 3:** A company employee was not wearing her safety goggles while machining parts. As a result, a small piece of metal got in her eye.

### Typical Recommendations

Ensure that company personnel receive adequate training for their positions.

Provide appropriate tools and equipment for personnel to perform their tasks.

Develop procedures for difficult and infrequently performed tasks.

Provide all appropriate information needed by personnel to perform their tasks.

## Definitions/Typical Issues

Was a contract employee involved? Was the person involved covered by the contract-employee training program? Is the person involved directly supervised by someone who does not work for your company? Does this person have to meet different requirements than a “regular” employee?

Typical personnel addressed by this node include:

- Contract operators
- Contract mechanics
- Contract electricians
- Contract sales personnel
- Contract delivery personnel

Contract personnel involved in the delivery of materials that involve direct interaction with the process/manufacturing system are typically addressed by this node. Other vendors (vending machine contractors, truck drivers) are usually categorized under the **Third-party Personnel Issue (#14)** node.

**Note 1:** Distinguishing between company, contract, and third-party personnel can be important because of the different management systems that influence the work performed by these groups.

## Examples

**Example 1:** A contract mechanic installed the wrong type of gasket in a line during a scheduled maintenance activity. As a result, the line failed when the process was restarted. The procedure did not specify the proper material to be used. The in-house mechanics all knew the proper materials and, therefore, it had never been a problem even though it was not specifically covered in the procedure.

**Example 2:** A contract electrician was electrocuted when she started working on a live bus. The bus had multiple power supplies and the electrician failed to isolate one of the supplies.

## Typical Recommendations

Ensure that contract employees have sufficient guidance to perform their activities.

Ensure that work documents used by contract employees have sufficient detail to allow individuals inexperienced with your operations and work methods to adequately perform the job.

Identify appropriate training requirements for contractor personnel.

Provide/confirm awareness training for contractor personnel.

Define roles and responsibilities for corporate or site staff overseeing the contractor programs and personnel.

Train company staff on their role in administering the contractor management program.

Maintain records substantiating decisions to contract/not contract with firms.

Select contractors based upon their functional capabilities, past safety performance, and the soundness of their safety programs.

Provide a controlled waiver policy to address situations where the only available contractors for a particular service do not meet minimum program requirements for safety program and/or performance.

Maintain records of contractor safety performance during the contract (e.g., inspections, audits, injury statistics, incident investigations).

## 14 – Third-party Personnel Issue

### Definitions/Typical Issues

Were third-party personnel involved in the incident?

Third-party personnel typically include:

- Vendors
- Delivery drivers
- Regulators
- Transient contractors
- Visitors
- Members of the public
- Family members of employees

**Note 1:** Distinguishing between company, contract, and third-party personnel can be important because of the different management systems that influence the work performed by these groups.

**Note 2:** It may not be possible to further define intermediate cause or root causes associated with this problem category due to lack of information.

### Examples

**Example 1:** A worker for the local vending company entered the facility to refill the vending machines. The individual was not aware of the requirement to wear a hard hat and safety goggles in the aisle way that led to the lunchroom. As a result, a foreign object got into his eye.

**Example 2:** A government inspector was touring the facility. When he was inspecting an instrument, he accidentally activated a hazardous material detector alarm.

### Typical Recommendations

Ensure that third-party personnel are adequately trained prior to coming on site.

Ensure that third-party personnel do not have access to equipment that they are not trained to operate.

Ensure that third-party personnel adhere to all safety rules in the facility.

Determine what skills the company will attempt to obtain from the external labor pool versus those that will be developed internally.

### **Definitions/Typical Issues**

Was the incident a result of a natural phenomenon event? Natural phenomena include:

- Tornadoes
- Hurricanes
- High winds
- Earthquakes
- Lightning
- Floods
- Seiches
- Tidal waves
- Earthquakes
- Forest fires
- Mudslides
- Rain
- Snow
- Other events

**Note 1:** There is no path beyond this node (it is a dead end) because these external events cannot be controlled by the organization through better organizational systems. However, any failures of the organization to address mitigation of these issues through design and management systems should be addressed through other portions of the Root Cause Map™.

### **Examples**

**Example 1:** A process upset occurred in the facility because power was lost as a result of lightning striking a transformer.

**Note:** Issues associated with backup power systems should be addressed to determine whether emergency power systems are adequate.

**Example 2:** The plant site was flooded when the river overtopped the levee designed for a 100-year flood.

**Note:** Issues associated with facility siting should be addressed to determine how the potential flooding was addressed as part of the design process.

**Example 3:** Inventory in the warehouse was damaged when the warehouse was flooded following a heavy rain.

**Note:** The design and location selection process should also be addressed to determine why it did not adequately address the potential for flooding.

**Example 4:** A rabid fox bit a worker who was checking some equipment in a remote location.

### **Typical Recommendations**

Ensure that natural phenomena are considered in the design process.

Ensure that natural phenomena are considered in the development of procedures and training.

Ensure that risk acceptance criteria are properly set and utilized for assessing the risk associated with natural phenomena events.

## 16 – External Events

### Definitions/Typical Issues

Was the incident the result of an external event that cannot be controlled by the organization? Was the incident caused by events that took place outside the facility?

Typical issues coded under this node include:

- Release from outside the facility
- Fire in an adjacent facility
- Supplier problems
- Actions of the public
- Commercial shipping companies external to the organization (e.g., a trucking company not owned by the organization)

**Note 1:** There is no path beyond this node (it is a dead end) because these external events cannot be controlled by the organization through better organizational systems. However, any failures of the organization to address mitigation of these issues through design and management systems should be addressed through other portions of the Root Cause Map™.

### Examples

**Example 1:** A release of chlorine from an adjacent facility affected the operators in your facility.

**Note:** Issues associated with the organization's response to the release should also be addressed to determine whether emergency response planning and implementation should be improved.

**Example 2:** A chlorine tanker accident on a nearby railroad spur required the evacuation of a portion of your facility.

**Note:** Issues associated with the organization's response to the release should also be addressed to determine whether emergency response planning and implementation should be improved.

**Example 3:** A nearby accident on the expressway prevented shipments from leaving your facility for an 8-hour period. As a result, some deliveries were not made on time.

**Note:** Issues associated with the organization's response to the traffic issue should also be addressed to determine whether contingency planning and implementation should be improved.

**Example 4:** A key supplier's warehouse was struck by a tornado. As a result, the warehouse was unable to supply your facility with raw materials for 2 weeks.

**Note:** Issues associated with the organization's supplier selection process should also be addressed to determine whether multiple suppliers should be used.

**Example 5:** The local utility's power plant shut down, resulting in a 5-minute power outage to your facility. It took 2 hours to restart the plant and stabilize the process.

**Note:** Issues associated with the design of backup power supplies for the facility should also be addressed to determine whether emergency power sources should be modified.

**Example 6:** A model airplane club flies its planes near your facility. A stray airplane flew into your facility, striking a worker and injuring a worker at your facility.

**Example 7:** On the 4th of July, some kids were lighting fireworks. One of the fireworks entered your facility and started a small fire.

**Example 8:** Product shipped to a customer via a commercial shipping company was damaged during shipping when the commercial shipping company's truck was involved in an accident. As the truck was crossing a bridge, the bridge collapsed.

**Example 9:** Product shipped to a customer by Good Stuff Inc. via a commercial shipping company (ABC Trucking) did not arrive at the customer's site on schedule. ABC Trucking's driver was provided with an incorrect address by ABC Trucking. The correct shipping address was sent from Good Stuff to ABC Trucking.

### **Typical Recommendations**

Develop emergency response plans to address events that may take place near the facility.

Work with nearby facilities to understand their operations and address any issues in emergency response plans.

Develop contingency plans for supplier issues.

## 17 – External Sabotage and Other Criminal Activity

### Definitions/Typical Issues

Did malicious acts by personnel external to the organization cause or contribute to the causal factor?

Did criminal activity by external personnel contribute to the causal factor?

Typical issues that are coded under this node include:

- Explosions resulting from external sabotage and other criminal activity
- Fires resulting from external sabotage and other criminal activity
- Tampering with product
- Tampering with raw materials

**Note 1:** It may not be possible to further define intermediate causes or root causes associated with this problem category due to limited availability of relevant data.

**Note 2:** Sabotage and criminal activities involving internal personnel are coded under the *Personnel Performance Issue; Individual Issue; Sabotage or Criminal Activity\** (#223) node.

**Note 3:** There is no path beyond this node (it is a dead end) because external sabotage and other criminal activity cannot be controlled by the organization through better organizational systems. However, any failures of the organization to address mitigation of these issues through design and management systems should be addressed through other portions of the Root Cause Map™.

### Examples

**Example 1:** A bomb threat was received by personnel in the control room. Fortunately, it turned out to be a hoax.

**Example 2:** Contaminants were intentionally added to raw materials by an individual at a supplier organization in order to make the final product unusable.

**Example 3:** The spouse of a worker came to work and shot the worker.

### Typical Recommendations

Ensure that security plans and equipment are adequate.

Work with local law enforcement to develop security plans.

Perform a security vulnerability analysis. Implement changes based on the results.

## Definitions/Typical Issues

This intermediate cause category addresses issues related to the design process, including the design input data and the design output.

Was the incident caused by problems related to the design process or problems related to the design and inherent capabilities of the equipment?

Was there a failure to consider all the appropriate design inputs during the design phase? Was the design output, such as drawings and specifications, complete? Were the design input and output inconsistent? Did the design review process fail to detect errors? Was there a failure to perform an independent design review?

**Note 1:** The ***Human Factors Issue (#146)*** node addresses issues that are related to how the output of the design processes addressed the specific needs of the humans that will use the system or equipment. For example, the ***Human Factors Issue (#146)*** node includes issues such as:

- Tools/equipment
- Workplace layout
- Workplace environment
- Physical workload
- Mental workload
- Error mitigation

## Examples

**Example 1:** A valve failed because the designer used obsolete materials requirements. As a result, a small spill occurred.

**Example 2:** A process upset occurred because one of the flow streams was out of specification. The design input did not indicate all the possible flow rates for the process. The pump was incorrectly sized for the necessary flow requirements.

**Example 3:** A line ruptured because a gasket failed. The gasket was constructed of the wrong material because the design did not consider all the possible chemicals that would be in the line during different operating conditions. A chemical that was not considered caused the gasket to fail.

## Typical Recommendations

Develop a preconstruction planning and review process to help ensure that all the specifications agree.

Conduct a feasibility study prior to beginning design to ensure that the criteria can be met.

Develop a tracking system for specification changes and design changes to help ensure that the final design includes all changes.

Eliminate duplicate copies of design information to avoid confusion of which is the “official” version.

Develop standards for symbols and terminology.

Implement methods to control access and changes to design information.

Develop methods for approving changes to design documentation.

Ensure that appropriate personnel are aware of recommended practices contained in recognized and generally accepted good engineering practices (RAGAGEPs) and apply their requirements.

## 19 – Design Input Issue

### Definitions/Typical Issues

Was there a failure to consider all the appropriate design inputs during the design phase? Was the design input inconsistent or incomplete?

### Examples

**Example 1:** A valve failed because equipment conditions during operation, such as corrosivity, were not considered during design. The valve failure resulted in a small steam leak.

**Example 2:** A pump failed to deliver enough cooling water in an emergency because emergency requirements were not considered in the design.

**Example 3:** A pipe failed because the design did not consider the potential for sour gas service. Originally, only sweet gas passed through the piping, but a later switch in suppliers resulted in sour gas in the line. The design inputs should have been modified when the supply was switched. Dual coding with **Change Control Issue (#98)** would be appropriate.

### Typical Recommendations

Conduct a feasibility review prior to beginning design to ensure that the criteria can be met.

Develop a preconstruction planning and review process to help ensure that all specifications agree. ~~are in agreement.~~

Eliminate duplicate copies of design information to avoid confusion of which is the “official” version.

Develop standards for symbols and terminology.

Implement methods to control access and changes to design information.

Develop methods for approving changes to design documentation.

Ensure that appropriate personnel are aware of recommended practices contained in recognized and generally accepted good engineering practices (RAGAGEPs) and apply their requirements.

## **Definitions/Typical Issues**

Did the design scope fail to consider all interactions of the equipment with other processes and equipment in the facility? Did the design scope fail to consider all modes of operation, such as startup, shutdown and part-load operation?

## **Examples**

**Example 1:** An engineer did not account for all types of vehicles that would be required to enter the plant in the design of the guardhouse- and gate. As a result, some of the outside responder's fire trucks can no longer enter the plant's front gate because they are wider than the new entrance.

**Example 2:** An engineer did not account for all of the materials that were to be moved by an overhead crane. As a result, it was undersized for some of the components that were supposed to be lifted by the crane.

## **Typical Recommendations**

Develop a process to define and agree upon the design scope before the detailed design process begins.

Ensure that the needs of end-users are considered during the design process.

## 21 – Design Input Data Issue

### Definitions/Typical Issues

Was there a problem with the input data for the design? Was there a failure to consider all the appropriate design inputs during the design phase? Were the design criteria so stringent that they could not be met? Were some criteria conflicting? Were requirements out of date?

Was there difficulty in accessing the necessary codes and standards? Was a novel design or concept applied for which there was no applicable prescriptive standard? Do applicable standards lack sufficient detail to be easily interpreted? Was the detail provided insufficient to make interpretation of the standard easy? Is there disagreement with the criteria in an existing standard? Does the current standard fail to address a new technology or material? Was the wrong standard, code, or guideline applied? Was the wrong version referenced?

Were there changes in practice or technology not addressed by an industry standard? Was an emerging technology employed by the company for which no standard existed?

Do two applicable standards contain conflicting requirements? Are there conflicting requirements within a standard?

Did a change in the use of the equipment require the application of a different standard?

Was there a failure to incorporate customer requirements into the design? Were the customer requirements confusing? Were there inconsistencies among the customer requirements standards? Were there inconsistencies among the customer requirements that were used and the actual customer requirements? Were the wrong customer standards applied? Were the customer requirements incorrect?

Was the design incompatible with the system performance objectives or design requirements?

Were the required design data not available at the time the design was finalized?

### Examples

**Example 1:** During the design of a control system, the timing for a step was set incorrectly. The vendor-supplied information was modified during word processing from 3-4 minutes to 34 minutes. As a result, the system was installed with the timer set to 34 minutes, resulting in too much catalyst being added to the reactor.

**Example 2:** A valve failed because the designer used obsolete materials requirements. As a result, products did not meet specifications.

**Example 3:** A process upset occurred because one of the flow streams was out of specification. The design input did not indicate all the possible flow rates for the process. The pump was incorrectly sized for the necessary flow requirements.

**Example 4:** A flow controller could not adequately control flow during an infrequent operation. The flow requirements for normal, emergency, and infrequent operation covered too wide a range for a controller to operate properly under all of the conditions. As a result of the flow controller failure, a hose was overpressurized and failed.

**Example 5:** At the time the cooling system was designed, the heat load from the generator had not been determined. As a result, the cooling system capacity was undersized by 10%.

**Example 6:** A pressure vessel was being manufactured out of a new exotic composite material. No standard existed to address the use of this material in a pressure vessel.

**Example 7:** ASME, API, and NACE ~~ANCE~~ standards all addressed the use of certain steels in an underwater application. However, each standard had some requirements that were contradicted by the other two standards.

**Example 8:** A standard required the use of carbon steel in a fire protection system. However, a risk assessment showed that a new fiberglass-reinforced plastic material performed better, but the standard did not allow its use.

**Example 9:** A vessel (i.e., a tank) had been used for processing relatively neutral pH fluids. When operation of the tank shifted to use a more acidic material, the inspection criteria were supposed to change based on the new standards that applied. However, no one identified the need for the change.

**Example 10:** A recent change was made to a NACE standard that required a different material to be used on a drilling rig. However, no one at the manufacturer noticed that the change affected the ~~the~~ rig. As a result, the wrong revision was applied.

### **Typical Recommendations**

Conduct a feasibility study prior to beginning design to ensure that the criteria can be met.

Develop an independent review process to help ensure that appropriate standards are used in the design.

Develop a tracking system to help ensure that current design criteria are used.

Develop comprehensive system design requirements.

Develop a design development schedule to ensure that all information will be available when needed.

Risk analysis should be performed in order to demonstrate equivalency of novel designs with existing standards.

If the requirements of a standard are unclear, contact standards authorities and request clarification to determine the intent or basis of the standard.

When a system changes service, a review of existing regulations and standards should be performed to determine whether additional requirements apply.

If no applicable standard can be identified, request that the appropriate standards organization develop a standard or modify an existing standard to address the situation.

Review conflicting requirements and comply with the most stringent requirement.

Contact standards authorities and request a formal ruling in application of the conflicting requirements.

When the use of equipment changes, review the existing standards to determine whether different requirements apply.

Ensure that the applicable version/revision of a standard or regulation is applied.

File documents in a manner that facilitates easy retrieval.

Eliminate duplicate copies of design information to avoid confusion about which is the “official” version.

Develop standards for symbols and terminology.

Implement methods to control access and changes to design information.

Develop methods for approving changes to design documentation.

Assign customer service personnel to solicit customer requirements.

Identify lessons-learned from each design to be used in future designs.

Define specific methods for customers to communicate with the design group or other company personnel.

Ensure that appropriate personnel are aware of recommended practices contained in recognized and generally accepted good engineering practices (RAGAGEPs) and apply their requirements.

Develop a company- or facility-wide standard that summarizes applicable recognized and generally accepted good engineering practices (RAGAGEPs) related to the design, test, and inspection requirements for each type of equipment.

Actively seek information on new developments in design, test, and inspection requirements.

## 22 – Design Output Issue

### Definitions/Typical Issues

Was the design output, such as drawings and specifications, incomplete? Was there a failure to consider all operating conditions (e.g., normal, startup, shutdown, emergency) in the design? Were the design documents difficult to read or interpret? Did the final design output fail to include all changes? Were there differences among different output documents? Did the design output fail to address all requirements specified in the design input?

### Examples

**Example 1:** A valve failed because the design output specifications were incorrect. The detailed design output did not agree with the design input. The design input stated that the valve must operate in a corrosive environment, but the design output specifications did not indicate this condition. Therefore, the valve was constructed of improper materials.

**Example 2:** A line ruptured because a gasket failed. The gasket was constructed of the wrong material because the gasket was not compatible with all the chemicals that would be in the line during different operating conditions. Although all the chemicals were listed in the design specification, the gasket specified by the designers was incompatible with some of the chemicals in the system.

**Example 3:** A pump did not provide the necessary cooling water during an emergency. The pump was sized incorrectly because the final design specification did not include changes identified in the hazard analysis.

### Typical Recommendations

Include experienced operations and maintenance personnel in design reviews to help ensure that all possible operating conditions are considered in the design.

Include designers in construction and pre-startup reviews to help ensure that design information is properly interpreted.

Conduct an independent technical review of the final design to help ensure consistency among various design documents.

Include satisfaction of design input criteria as a specific review team item during design reviews.

## Definitions/Typical Issues

Were there problems with management practices to track design requirements and relate them to the design outputs? Did the specifications fail to include all of the requirements? Were some criteria left out of the design output?

Were the drawings and other specifications incorrect? Should prototype tests have been conducted but were not? Were compatibility studies and tests performed?

**Note 1:** If the design output was incorrect because the design input was incorrect, that should be coded under the ***Design Input Issue (#19)*** node.

## Examples

**Example 1:** During the initial design review, the company requested that an additional flow indication be added in the cooling water line. The requirement was added to the design requirements document. However, this requirement was never transmitted to the design staff. As a result, the item was not addressed in the design drawings for the system. The system subsequently failed in service.

**Example 2:** The design specification for a fired heater (i.e., a heater that uses a flammable gas as the heat source) did not address all of the applicable design standards noted in the design specification. This resulted in a near miss in that the situation was detected just before the heater failed.

**Example 3:** A display did not show the appropriate range of flow during an emergency. The display did not account for emergency and unusual operation conditions because the design requirement was never addressed. As a result, the operator failed to respond to the emergency properly.

**Example 4:** The design documentation for a new flare tower showed an incorrect line tie-in for a modification. As a result, excessive corrosion of the tower occurred.

## Typical Recommendations

Develop an independent review process to be used during the design process to help ensure that all of the design inputs are addressed in the final output.

Develop a tracking system to help ensure that all design inputs are addressed in the design output.

Develop a tracking system for specification changes and design changes to help ensure that the final design includes all changes.

Develop an independent review process to help ensure that appropriate standards are used in the design.

Develop an independent review process during design to help ensure that calculations and analyses are correct and complete.

## 24 – Design Output Unclear or Inconsistent

### Definitions/Typical Issues

Were there differences among output documents? Did the drawings and other design specifications contain inconsistent requirements? Were the design documents vague, unclear, or ambiguous? Was the design output inconsistent with standard industry practices (e.g., the use of non-standard symbols, abbreviations, terminology)?

### Examples

**Example 1:** The procurement specifications for electrical cable were inconsistent with the requirements on the design drawing. As a result, the installation of the wiring was delayed when the problem was identified.

**Example 2:** The acceptance test requirements for a fire protection pump were inconsistent with the design requirements. As a result, the fire protection pump was placed into operation even though it did not meet its design specifications.

### Typical Recommendations

Develop a database of design requirements to assist in identification of inconsistent requirements.

Develop an independent review process to be used during the design process to help ensure that the output requirements are consistent.

## Definitions/Typical Issues

Was there a problem with the design review/verification process? Was a design review/verification not performed? Did the review/verification process fail to detect a problem in the design?

**Note 1:** This node includes normal design reviews. Hazard reviews, pre-startup safety reviews, change control reviews, and other risk identification methods are addressed by the *Hazard/Defect Identification and Analysis Issue (#94)* node.

## Examples

**Example 1:** The controls for a paper-cutting machine were inconsistent with those of the other machines in the facility. A comparison between the control systems was to be performed as part of the design review, but the design review was never performed. As a result, an operator was killed when another operator incorrectly operated the controls.

**Example 2:** The design review process was supposed to verify that the design outputs were consistent with the design inputs. However, the design review failed to identify multiple discrepancies. As a result, inappropriate equipment was installed.

## Typical Recommendations

Ensure that design personnel present a summary of their design review process to a design review board.

Develop an independent review process to be used during the design process to help ensure that the output requirements are consistent.

Develop an independent review process during design to help ensure that calculations and analyses are correct and complete.

Ensure that the design review process is documented.

Provide qualified individuals to perform design reviews.

## 26 – No Review/Verification

### Definitions/Typical Issues

Was there a failure to perform a design/review verification?

### Examples

**Example 1:** The controls for a paper-cutting machine were inconsistent with those of the other machines in the facility. A comparison between the control systems was to be performed as part of the design review, but the design review was never performed. As a result, an operator was killed when another operator incorrectly operated the controls.

**Example 2:** A new conveyor system design contained three key design errors. No design review was performed, and the errors were carried through to the installed system. The conveyor subsequently failed in service.

### Typical Recommendations

Identify the equipment and processes that require design reviews and verification.

Use the list of equipment and processes that require independent verification and review to develop a schedule for the reviews.

Ensure that design reviews are performed as scheduled.

Ensure that design reviews are documented.

Ensure that design personnel present a summary of their design review process to a design review board.

## **Definitions/Typical Issues**

Was there a problem with the design/review verification process? Did the review/verification process fail to detect a problem in the design?

## **Examples**

**Example 1:** The design review process was supposed to verify that the design outputs were consistent with the design inputs. However, the design review failed to identify multiple discrepancies. As a result, inappropriate equipment was installed.

**Example 2:** A hydraulic press design contained numerous design errors. The design review/verification process did not detect these errors. As a result, expensive modifications had to be implemented.

## **Typical Recommendations**

Ensure that the design review process is documented.

Provide qualified individuals to perform design reviews.

Develop a tracking system to help ensure that design problems and conflicts are resolved prior to startup.

Ensure that design personnel present a summary of their design review process to a design review board.

Develop an independent review process to be used during the design process to help ensure that the output requirements are consistent.

Develop an independent review process during design to help ensure that calculations and analyses are correct and complete.

## 28 – Equipment Reliability Program Issue

### Definitions/Typical Issues

This intermediate cause category addresses issues related to the overall maintenance program, including its design and implementation. It addresses a variety of maintenance types as follows:

- Periodic maintenance
- Event-based maintenance
- Condition-based maintenance
- Fault-finding maintenance and inspection
- Corrective maintenance
- Routine inspection and servicing

Was there a problem related to the design of the maintenance program? Was the wrong type of maintenance specified for the equipment? Are there problems with the analysis process used to determine the appropriate maintenance requirements? Does the repair activity fail to cover the required scope?

Was there a problem related to the implementation of maintenance activities? Was the repair incorrectly performed? Was the troubleshooting less than adequate? Did the monitoring activity fail to detect a failing component? Was there a failure to perform the maintenance activity when it should have been (i.e., following a shutdown, before a startup, when vibration readings reached a trigger point)?

**Note 1:** Some organizations use the reliability-centered maintenance process as the primary driver of their equipment reliability program.

**Note 2:** Problems associated with determining what maintenance to perform should be coded under the ***Equipment Reliability Program Design Issue*** (#29) node. Problems associated with implementation of the maintenance should be coded under the other Intermediate Cause Subcategories under this node (#33, #37, #42, #47, #51, and #54).

**Note 3:** Different terms are sometimes used to refer to the maintenance types specified by the cause types used on the Root Cause Map™. Examples include:

- Periodic maintenance or preventive maintenance
- Event-based maintenance or proactive maintenance
- Condition-based maintenance or predictive maintenance
- Fault-finding maintenance and inspection issues or failure-finding maintenance and inspections
- Corrective maintenance or repair work
- Routine inspection and servicing issue or routine rounds

**Note 4:** For an explanation of the various types of maintenance used on the Root Cause Map™, see Appendix A at the back of this book.

### Examples

**Example 1:** A fan system failure resulted in shutting down three paper machines. The failure was the result of a worn-out bearing. The fan system had not been identified as a critical item because no one realized the consequences of its failure.

**Example 2:** Periodic maintenance procedures require heavy pieces of rotating equipment that are not in operation to be rotated to prevent the shafts from warping. Equipment that is shut down is scheduled to be rotated once per week. However, equipment in the warehouse is not covered by the procedure. As a result, some heavy rotors failed after installation.

**Example 3:** Cranes were supposed to be inspected and lift-tested prior to lifting any item that was greater than 70% of the crane's rated capacity. These inspections and tests were never performed because the crane operators were unaware of this requirement.

**Example 4:** A number of pump bearings have failed recently. Condition-based (predictive) maintenance was selected as the appropriate type of maintenance for the pump bearings. However, there is no procedural requirement for performing monitoring of the pump bearings. As a result, the condition-based maintenance activity was never implemented.

**Example 5:** A standby diesel generator was installed to provide power to vital components during a loss of power. No testing had been performed on the diesel generator since it was installed, even though testing was required every other month. As a result, when there was a loss of power, the diesel generator did not work.

**Example 6:** Mechanics' job performance was judged by how many work requests they completed. As a result, they tried to diagnose the problem as quickly as possible. This led to rework when the original repairs failed to correct the problem.

**Example 7:** Operators are supposed to check for leaks in various portions of the plant. However, they usually only toured the part of the plant that was between the control room and the lunchroom.

### **Typical Recommendations**

Assign additional resources to equipment with a demonstrated history of problems.

Reduce maintenance on equipment that has no significant impact on production or safety and that can be easily repaired or replaced.

Provide maintenance procedures and training appropriate to the experience level of personnel.

Ensure that equipment monitoring for predictive maintenance is appropriate for the component.

Ensure that personnel are provided with sufficient guidance to select appropriate maintenance tasks for different types of equipment.

Review the frequency of periodic maintenance. If the same activity routinely needs to be performed between scheduled intervals, shorten the periodic maintenance interval.

Ensure that triggering events for event-based maintenance are appropriate for the component's potential failure mechanisms.

Provide guidance on the typical parameters that can be monitored to predict failures for different types of components.

Check fault-finding testing procedures to ensure that they test the entire system and not just a portion of it.

Perform post-maintenance testing to ensure that the maintenance is properly performed and corrects the problem.

Ensure that all areas of the plant are covered by periodic rounds.

## 29– Equipment Reliability Program Design Issue

### Definitions/Typical Issues

Was there a problem related to the design of the maintenance program? Was the wrong type of maintenance specified for the equipment? Are there problems with the analysis process used to determine the appropriate maintenance requirements? Does the repair activity fail to cover the required scope (i.e., too broad or too narrow)?

Issues associated with maintenance-related design processes, such as mechanical integrity (MI); reliability-centered maintenance (RCM), risk-based maintenance (RBM); inspection, testing, and preventive maintenance (ITPM), should be coded under this node.

Dual coding under the type of maintenance that was involved (e.g., periodic; event-based; condition-based; faultfinding; corrective; and routine inspection and servicing) is also appropriate.

**Note 1:** Some organizations use the reliability-centered maintenance process as the primary driver of their equipment reliability program.

**Note 2:** This section only addressed the design of the reliability program. Implementation of the reliability program is addressed under the other reliability program Cause Types nodes (#33, #37, #42, #47, #51, and #54).

### Examples

**Example 1:** A fan system failure resulted in shutting down three paper machines. The failure was the result of a worn-out bearing. The fan system had not been identified as a critical item because no one realized the consequence of its failure.

**Example 2:** There was no reliability program for some of the directional drilling tools. As a result, some of the components failed prematurely.

**Example 3:** Corrective maintenance was assigned to an auger that provided raw materials to a food process. This selection was based on a very low expected failure rate and a quick repair time. Actual experience indicates that the failures took much longer to repair than the analysis team estimated. As a result, planned or predictive maintenance would have been more appropriate.

### Typical Recommendations

Assign additional resources to equipment with a demonstrated history of problems.

Review the frequency of periodic maintenance. If the same activity routinely needs to be performed between scheduled intervals, shorten the periodic maintenance interval.

Provide maintenance procedures and training appropriate to the experience level of personnel.

## Definitions/Typical Issues

Was critical equipment (e.g., equipment that should have been included in the maintenance program) not identified? Was no maintenance specified for the equipment because no one realized the risk significance of the equipment?

**Note 1:** This node is appropriate when the organization does not realize the risk-importance of the equipment and does not identify it as a critical piece of equipment. If the organization has identified the equipment as critical, but has not identified any maintenance anyway, then ***No or Inappropriate Maintenance Selected (#31)*** is the appropriate node.

**Note 2:** For an explanation of the various types of maintenance used on the Root Cause Map™, see Appendix A at the back of this book.

## Examples

**Example 1:** A fan system failure resulted in shutting down three paper machines. The failure was the result of a worn-out bearing. The fan system had not been identified as a critical item because no one realized the consequences of its failure.

**Example 2:** Critical equipment was not identified for a drilling equipment line. As a result, maintenance resources were not allocated appropriately to the most risk-significant equipment items.

## Typical Recommendations

Provide appropriate personnel for identifying critical equipment.

Solicit input from a broad spectrum of personnel when determining the critical equipment list.

Use specific criteria to assess the criticality of equipment.

Use the list of equipment in the computerized maintenance management system as a comprehensive list to review as part of identifying critical equipment.

## 31 – No or Inappropriate Maintenance Selected

### Definitions/Typical Issues

Did the organization fail to develop an equipment reliability program for this piece of equipment? Did the organization fail to analyze the maintenance needs for this piece of equipment?

Was an inappropriate maintenance method specified for the equipment? Are there problems with the analysis process that is used to determine the appropriate maintenance requirements?

Was there ~~the~~ a failure to assign resources based on the risk analysis? Are some high-priority maintenance tasks not being specified because other low-priority maintenance tasks are being specified instead?

**Note 1:** If the maintenance needs were analyzed and it was incorrectly determined that no maintenance was appropriate, it is appropriate to code this situation under this node also.

**Note 2:** If the organization did not assign maintenance to the equipment because it did not identify the equipment as critical, then ***Critical Equipment Not Identified (#30)*** is appropriate.

**Note 3:** For an explanation of the various types of maintenance used on the Root Cause Map™, see Appendix A at the back of this book.

### Examples

**Example 1:** Hydraulic hoses on the forklifts in the facility were failing once every 2 months. A review of the maintenance program records indicated that proper maintenance for these hoses had never been determined.

**Example 2:** There was no reliability program for some of the directional drilling tools.

**Example 3:** Corrective maintenance was assigned to an auger that provided raw materials to a food process. This selection was based on a very low expected failure rate and a quick repair time. Actual experience indicates that the failures took much longer to repair than the analysis team estimated. As a result, planned or predictive maintenance would have been more appropriate than corrective maintenance.

**Example 4:** Records indicate that tube failures were occurring in heat exchangers shortly after plant startup. The failures were determined to be caused by hot spots that developed when contaminants collected in portions of the heat exchanger. Event-based maintenance activities implemented to clean out the system prior to startup should be implemented. This would remove the contaminants and prevent the heat exchanger failures.

**Example 5:** Periodic maintenance, performed every 6 months, was put in place for a set of six pumps. However, experience at another plant indicated that most failures could be avoided using condition-based maintenance. Monitoring every month resulted in repair activities being performed every 6 to 18 months based on monitoring pump vibration, reducing parts costs and down time.

**Example 6:** Maintenance activities had been specified for the running components of a wood chipping machine (i.e., bearings, blades) but no maintenance activities had been specified for the safety interlocks associated with the machine. The analysis procedure did not require safety interlocks to be addressed. As a result, an operator's arm was amputated when the emergency stop feature failed.

**Example 7:** Mechanics were always being pulled from scheduled work to work on "emergencies." The percentage of corrective maintenance was 80%. This had not changed since the development of additional planned, predictive, and event-based maintenance activities.

### **Typical Recommendations**

Determine the appropriate level of maintenance for all equipment in the facility that is important to safety, reliability, quality, or security.

Ensure that the analysis process addresses all aspects of equipment operation important to safety, reliability, quality, and security.

Ensure that personnel are provided with sufficient guidance to select appropriate maintenance tasks for different types of equipment.

Ensure that personnel who are responsible for developing the equipment reliability program have the proper training.

Assign additional resources to equipment with a demonstrated history of problems.

Reduce maintenance on equipment that has no significant impact on production, reliability, quality, safety, or security and that can be easily repaired or replaced.

Review the frequency of periodic maintenance. If the same activity routinely needs to be performed between scheduled intervals, shorten the periodic maintenance interval.

For each piece of critical equipment, develop a reliability program plan that is based on recognized and generally accepted good engineering practices (RAGAGEPs), manufacturer's recommendations, equipment history, company standards, and the expected consequence(s) of failure of the specific equipment item.

Ensure that appropriate personnel are aware of recommended practices contained in recognized and generally accepted good engineering practices (RAGAGEPs) and apply their requirements.

Develop a company- or facility-wide standard that summarizes applicable recognized and generally accepted good practices (RAGAGEPs) related to the design, test, and inspection requirements for each type of equipment.

Periodically review the inspection, test, and preventive maintenance (ITPM) plan for each type of equipment (or equipment item) to determine whether there is redundancy or whether the activities could be accomplished more efficiently if they were linked or done in a specific sequence.

## 32 – Risk Acceptance Issue

### Definitions/Typical Issues

Were the wrong or inappropriate risk-acceptance criteria used for analyzing the maintenance needs? Was corrective maintenance assigned as a maintenance strategy (i.e., run to failure and then repair) even though the consequences of failure are very high?

Was an appropriate hierarchy of controls analysis performed? Were lower level controls used (safeguards) when inherently safer design (ISD)/inherently safer measures (ISM) should have been implemented? Were passive, active, and procedural safeguards applied appropriately?

**Note 1:** For an explanation of the various types of maintenance used on the Root Cause Map™, see Appendix A at the back of this book.

### Examples

**Example 1:** Corrective maintenance was assigned to a conveyor that provided raw materials to a food process. Experience indicated that failures took about 16 hours to repair. The risk acceptance criteria did not include downtime as one of the criteria used when assessing the overall risk associated with a failure.

**Example 2:** The analysis team assigned predictive, event-based, and periodic maintenance activities to equipment with failures that resulted in large consequences. They assigned corrective maintenance to equipment with failures that had only low consequences. However, the risk associated with the low-consequence, high-frequency incidents was larger than that associated with some of the high-consequence, infrequent events. The risk acceptance criteria outlined in the analysis procedure incorrectly led them to believe that they were assigning the correct type of maintenance to these different types of risks.

### Typical Recommendations

Ensure that the proper level of risk acceptance is used in determining the level and type of maintenance to perform on equipment.

Provide guidance in the analysis procedure to allow for consistent application of the risk acceptance criteria. Use specific examples.

## Definitions/Typical Issues

Was the frequency of the periodic maintenance incorrect (i.e., too long or too short)? Was the scope of the periodic maintenance activity inappropriate (i.e., too broad or too narrow)? Was the maintenance activity incorrectly performed?

**Note 1:** The *Scope Issue (#34)* node addresses which periodic maintenance activities were supposed to be done. The *Frequency Specification Issue (#35)* node addresses when they were supposed to be done. The *Implementation Issue (#36)* node addresses what was actually performed.

**Note 2:** Periodic maintenance is sometimes referred to as preventive maintenance.

**Note 3:** For an explanation of the various types of maintenance used on the Root Cause Map™, see Appendix A at the back of this book.

## Examples

**Example 1:** Periodic maintenance (a calibration) was being performed on a truck scale every 3 months. However, an investigation by an outside regulatory agency revealed that the scale was routinely out of specification. The company subsequently changed the required calibration frequency to once per month after the company was fined for shipping overloaded trucks.

**Example 2:** Periodic maintenance was being performed on a furnace every week to prevent a buildup of powdered material. However, only the main chamber was being cleaned. Other portions of the furnace were not being cleaned and, as a result, the performance of the furnace degraded over time.

## Typical Recommendations

Ensure that periodic maintenance tasks are being performed as scheduled.

Ensure that periodic maintenance activities address all portions of equipment.

Review maintenance procedures to ensure that they provide adequate guidance based on the experience level of the personnel who will be using the procedures.

Provide training for personnel on periodic maintenance techniques.

## 34 – Scope Issue

### Definitions/Typical Issues

Was the scope of the periodic maintenance activity inappropriate (i.e., too broad or too narrow)?

**Note 1:** For an explanation of the various types of maintenance used on the Root Cause Map™, see Appendix A at the back of this book.

### Examples

**Example 1:** Periodic maintenance was being performed on a furnace every week to prevent a buildup of powdered material. However, only the main chamber was being cleaned. Other portions of the furnace were not being cleaned and, as a result, the performance of the furnace degraded over time.

**Example 2:** Periodic maintenance procedures require heavy pieces of rotating equipment that are not in operation to be rotated to prevent the shafts from warping. Equipment that is shut down is scheduled to be rotated once per week. However, equipment in the warehouse is not covered by the procedures. As a result, some heavy rotors failed after installation.

### Typical Recommendations

Ensure that the scope of periodic maintenance activities covers all portions of the equipment that need repair or service.

Ensure that all of the components requiring periodic maintenance are covered by the procedures.

Identify emergency response equipment, including required inspections and tests, and establish a system to ensure that equipment is properly maintained and tested.

## Definitions/Typical Issues

Was the frequency of the periodic maintenance task incorrectly specified (either too frequently or not often enough)?

**Note 1:** This node addresses how often the periodic maintenance is supposed to be done. **Implementation Issue (#36)** addresses how often the task was actually performed.

**Note 2:** For an explanation of the various types of maintenance used on the Root Cause Map™, see Appendix A at the back of this book.

## Examples

**Example 1:** The periodic monthly maintenance for conveyor #1 took 6 hours and accounted for 50% of the conveyor's unavailability. Conveyor #2 in a similar service in another part of the plant had the same periodic maintenance performed every 6 months. No failures had occurred on either conveyor in the past 3 years. The periodic maintenance interval for conveyor #1 was subsequently changed to once every 6 months.

**Example 2:** An important control system in a nuclear power plant was tested daily to detect hidden failures. The test took about an hour to perform. As a result, the system was inoperable about 5% of the time for scheduled maintenance. After 6 months with no failures, the test frequency was modified so that it was performed once per week.

## Typical Recommendations

Review the frequency of periodic maintenance. If the same activity routinely needs to be performed between scheduled intervals, shorten the periodic maintenance interval.

Review the frequency of periodic maintenance. Consider reducing the frequency of periodic maintenance on components if no adjustments or repairs are required during consecutive periodic maintenance tasks. Monitor equipment performance to determine the effects of a reduced frequency.

Based on the results of tests and inspection activities, make appropriate adjustments to the inspection or test interval.

## 36 – Implementation Issue

### Definitions/Typical Issues

Was the periodic maintenance activity incorrectly performed? Was there a failure to service all required components? Were some items included on the schedule, but the maintenance was never performed?

Was there a failure to perform periodic maintenance at the specified (i.e., scheduled) frequency? Were some periodic maintenance tasks being skipped?

**Note 1:** This node addresses how often the periodic maintenance is actually done. *Frequency Specification Issue* (#35) addresses how often the task was supposed to be performed.

**Note 2:** For an explanation of the various types of maintenance used on the Root Cause Map™, see Appendix A at the back of this book.

### Examples

**Example 1:** An inexperienced mechanic incorrectly installed a pump seal during periodic maintenance, which subsequently leaked. He inserted one of the rubber seals backwards. The procedure provided no guidance other than to “install the rubber seals.”

**Example 2:** Periodic maintenance (a calibration) was being performed on a scale every 3 months. The required calibration frequency had been changed to once per month about 2 years ago after the company was fined for shipping overloaded trucks. However, the instrumentation technicians still performed the calibration only once every 3 months.

**Example 3:** A pump failed soon after installation, far short of the life expectancy of the pump. Investigation revealed that the pump had been stored in the warehouse for a long time. During the storage, no periodic maintenance, such as cleaning and lubrication, had been performed as specified in the manufacturer’s instructions for storage.

**Example 4:** An electrician was performing a maintenance check on a pressure instrument. During performance of the check, a high-pressure signal was simulated in the instrument loop. Because the loop was not properly isolated, it resulted in a pressure relief valve lifting and a release to the environment.

### Typical Recommendations

Review maintenance procedures to ensure that they provide adequate guidance based on the experience level of personnel.

Provide training for personnel on periodic maintenance techniques.

Review the periodic maintenance schedule and completed work requests to ensure that all required activities are being performed.

Perform post-maintenance testing to ensure that the maintenance is properly performed.

Ensure that periodic maintenance tasks are being performed as specified.

Perform maintenance activities in accordance with the equipment reliability program.

Include steps in repair procedures to ensure that equipment is fit for service when it is turned over to the production team.

## Definitions/Typical Issues

Was the scope of the event-based maintenance inappropriate (i.e., too broad or too narrow)? Was there a failure to perform event-based maintenance when it should have been performed (i.e., following a shutdown, before a startup, at the beginning of winter)? Was the work incorrectly performed?

**Note 1:** The *Scope Issue* (#38) node addresses problems with what (the scope) should be done. The *Event Specification Issue* (#39) node addresses selection of the appropriate triggering events. The *Monitoring Issue* (#40) node addresses problems with determining when the triggering events occur. The *Implementation Issue* (#41) node addresses performance of the repair activity.

**Note 2:** Event-based maintenance is sometimes referred to as proactive maintenance.

**Note 3:** For an explanation of the various types of maintenance used on the Root Cause Map™, see Appendix A at the back of this book.

## Examples

**Example 1:** Product barrels were cleaned as they were returned from customers. Dust would accumulate in those barrels that were not used for an extended period. The dust contaminated the product. Cleaning was switched to shortly before use instead of when the barrels were returned from the customers.

**Example 2:** Cranes were supposed to be inspected and lift-tested prior to lifting any item that was greater than 70% of the crane's rated capacity. These inspections and tests were never performed because the crane operators were unaware of this requirement.

**Example 3:** Furnace crucibles (i.e., the containers used to melt and transport molten metals) were to be cleaned whenever the furnace was scheduled to be shut down for more than 8 hours. Operations never told maintenance when the scheduled shutdowns would occur. As a result, the cleaning was not performed as required.

## Typical Recommendations

Ensure that triggering events for event-based maintenance are appropriate for the component.

Ensure that monitoring is performed to determine when triggering events occur.

Review maintenance procedures to ensure that they provide adequate guidance based on the experience level of personnel.

Provide training for personnel on monitoring and maintenance techniques.

Review the event-based maintenance schedule and completed work requests to ensure that all required activities are being performed.

## 38 – Scope Issue

### Definitions/Typical Issues

Was the scope of the event-based maintenance inappropriate? Was the scope too broad or too narrow?

**Note 1:** For an explanation of the various types of maintenance used on the Root Cause Map™, see Appendix A at the back of this book.

### Examples

**Example 1:** At the end of the season, oil in lawn mowers was supposed to be winterized to prevent damage while sitting idle over the winter. However, the event-based maintenance task did not include stabilizing (i.e., winterizing) the gas. As a result, the mowers' fuel lines were gummed up in the spring when the mowers were brought out for use.

**Example 2:** Product barrels that were returned to the plant from customers were cleaned shortly before they were to be used. However, the pallets the barrels sat on were not inspected. The pallets were sometimes damaged prior to returning to the plant. Because the pallets were not inspected, repairs to damaged pallets discovered during use often disrupted production.

### Typical Recommendations

Review the scope of the event-based maintenance procedures to ensure that they are broad enough to address the issue.

Review the scope of the event-based maintenance activities to ensure that they address all aspects of the equipment.

## Definitions/Typical Issues

Was an incorrect triggering event specified for the event-based maintenance? Was no triggering event specified for the event-based maintenance?

**Note 1:** For an explanation of the various types of maintenance used on the Root Cause Map™, see Appendix A at the back of this book.

## Examples

**Example 1:** Product barrels were cleaned as they were returned from customers. However, some product was contaminated when it was placed in the barrels. Dust would accumulate in barrels that were not used for extended periods and contaminate the product. Cleaning was switched to shortly before use instead of when the barrels were returned from the customers.

**Example 2:** Tubes in a heat exchanger were failing prematurely. The tubes were rinsed prior to starting a new batch, but they were not cleaned at the completion of each batch. As a result, the material remaining in the tubes between batches caused the tubes to corrode.

## Typical Recommendations

Ensure that triggering events for event-based maintenance are appropriate for the component.

Review repair records to determine whether the triggering events or triggering levels need to be modified.

## 40 – Monitoring Issue

### Definitions/Typical Issues

Was there a failure to implement an event-based monitoring program to determine when the triggering events occurred? Was there a failure to notify maintenance when these events occurred?

**Note 1:** For an explanation of the various types of maintenance used on the Root Cause Map™, see Appendix A at the back of this book.

### Examples

**Example 1:** Cranes were supposed to be inspected and lift tested by maintenance staff prior to lifting any item that was greater than 70% of the crane's rated capacity. These inspections and tests were never performed. The crane operators were unaware of this requirement and, therefore, did not contact maintenance to trigger the inspections.

**Example 2:** Furnace crucibles (i.e., the containers used to melt and transport molten metals) were to be cleaned whenever the furnace was scheduled to be shut down for more than 8 hours. Operations never told maintenance when scheduled shutdowns would occur. As a result, the cleaning was not performed as required.

### Typical Recommendations

Ensure that monitoring is performed to determine when triggering events occur.

Review the event-based maintenance schedule and completed work requests to ensure that all required activities are being performed when triggering events occur.

## Definitions/Typical Issues

Was there a failure to perform the event-based maintenance as scheduled? Were some parts of the specified task not performed?

**Note 1:** For an explanation of the various types of maintenance used on the Root Cause Map™, see Appendix A at the back of this book.

## Examples

**Example 1:** Trucks used in a northern area were supposed to be cleaned once per week during the winter to clean off road salt that accumulated on the truck. Often the underside of the truck was not cleaned because personnel usually got wet when cleaning the underside of the trucks. As a result, costs to address corrosion of the undersides of the vehicles were high.

**Example 2:** During initial installation of a fan, one of the bearings was installed correctly, but was not lubricated, as it should have been. As a result, it failed shortly after startup.

**Note:** This incident is included under event-based maintenance because the lubrication activity is triggered by an event, the installation of the fan.

## Typical Recommendations

Review the event-based maintenance schedule and completed work requests to ensure that all required activities are being performed.

Perform field inspections to identify event-based maintenance tasks that are not being properly implemented.

Perform maintenance activities in accordance with the equipment reliability program.

Include steps in repair procedures to ensure that equipment is fit for service when it is turned over to the production team.

Review test and inspection reports and either (1) repair deficiencies noted by the inspector or (2) document why repairs are not needed.

Perform post-maintenance testing to ensure that the maintenance is properly performed and corrects the problem.

## 42 – Condition-based Maintenance Issue

### Definitions/Typical Issues

Did the condition monitoring activity fail to detect a failing component? Was there a failure to perform the monitoring activity? Was the correct parameter being monitored to detect failure? Was the predictive maintenance incorrectly performed?

**Note 1:** The **Scope Issue (#43)** node addresses the scope of the condition-based maintenance process. **Detection Method Issue (#44)** node addresses what is supposed to be monitored. The **Monitoring Issue (#45)** node addresses performing the monitoring task. The **Data Interpretation Issue (#46)** node addresses the interpretation of the data that is collected from the field.

**Note 2:** Once the condition-based maintenance activity has detected a problem that needs to be resolved, the issue then proceeds to the **Corrective Maintenance Issue (#51)** cause type. This cause type addresses the subsequent **Troubleshooting/Corrective Action Issue (#52)** and **Repair Implementation Issue (#53)**.

**Note 3:** For an explanation of the various types of maintenance used on the Root Cause Map™, see Appendix A at the back of this book.

### Examples

**Example 1:** A number of pump bearings have failed recently. Condition-based maintenance was selected as the appropriate type of maintenance for the pump bearings. However, monitoring of the pump bearings was never performed even though it was identified as a requirement in the equipment reliability program.

**Example 2:** Turbine bearing temperatures were being monitored to predict impending failures. However, failures occurred even though there was no prediction of failure based on temperature levels. Vibration should have been monitored instead because it was a better predictor of impending failures.

### Typical Recommendations

Provide guidance on the typical parameters that can be monitored to predict failures for different types of components.

Ensure that monitoring equipment used for condition-based maintenance is appropriate for the component.

Ensure that equipment monitoring is being performed.

Ensure that the scope of equipment condition monitoring is adequate.

**Definitions/Typical Issues**

Was the scope of the condition-based maintenance work inappropriate (i.e., too broad or too narrow)?

**Note 1:** For an explanation of the various types of maintenance used on the Root Cause Map™, see Appendix A at the back of this book.

**Examples**

**Example 1:** Each river water pump had four sets of bearings. However, the condition-based monitoring task only specified that two of the four bearings had to be checked for vibration. As a result, by the time the condition-based maintenance monitoring activity detected the impending failure, bearing failure was imminent, and an unscheduled shutdown was required to replace the bearings.

**Example 2:** Infrared inspection of electrical switchgear had been specified for all electrical cubicles 120V AC and higher. The process was very good at predicting failures of 480V AC and 4160V AC switchgear. However, the process was ineffective at predicting failure of the 120V AC equipment.

**Typical Recommendations**

Ensure that the condition-based maintenance activities address all potential failure modes.

Ensure that the condition-based maintenance activities are effective in predicting impending failures.

## 44 – Detection Method Issue

### Definitions/Typical Issues

Was the incorrect parameter being monitored to detect failure? Was there insufficient time to detect an impending failure before the failures actually occurs?

**Note 1:** For an explanation of the various types of maintenance used on the Root Cause Map™, see Appendix A at the back of this book.

### Examples

**Example 1:** Turbine bearing temperatures were being monitored to predict impending failures. However, failures occurred even though there was no prediction of failure based on temperature levels. Vibration should have been monitored instead because it was a better predictor of impending failures.

**Example 2:** Megger testing was being performed yearly on motors in an attempt to predict failures of the windings. However, a number of failures occurred even when megger testing did not predict a failure. Infrared inspections were a better predictor of these types of motor failures.

### Typical Recommendations

Provide guidance on the typical parameters that can be monitored to predict failures for different types of components.

Ensure that monitoring equipment for condition-based maintenance is appropriate for the component.

## **Definitions/Typical Issues**

Was there a failure to perform the monitoring activities? Was some equipment or components not monitored? Did the monitoring fail to detect a failing component? Was there a failure to perform the monitoring frequently enough?

**Note 1:** For an explanation of the various types of maintenance used on the Root Cause Map™, see Appendix A at the back of this book.

## **Examples**

**Example 1:** A number of pump bearings have failed recently. Condition-based maintenance was selected as the appropriate type of maintenance to detect the impending failure of the pump bearings. However, monitoring of the pump bearings was never performed even though it was identified as a requirement in the equipment reliability program.

**Example 2:** The three supply fans for the assembly building were all supposed to be monitored for vibration as part of condition-based maintenance. Only two of the three fans were being monitored. The third fan was difficult to access.

**Example 3:** Pump bearings were being monitored for failure. However, by the time the impending failure could be detected, there was insufficient time to perform the corrective maintenance. Increasing the frequency of the monitoring allowed the impending failures to be detected earlier.

## **Typical Recommendations**

Ensure that equipment condition monitoring is being performed.

Ensure that all pieces of equipment are being monitored.

Ensure that all components (points) are being monitored for each piece of equipment.

Based on the results of tests and inspection activities, make appropriate adjustments to the inspection or test interval.

## 46 – Data Interpretation Issue

### Definitions/Typical Issues

Were the data collected in the field being improperly interpreted? Was there a failure to perform the data analysis?

**Note 1:** For an explanation of the various types of maintenance used on the Root Cause Map™, see Appendix A at the back of this book.

### Examples

**Example 1:** Vibration data were collected from numerous grinders in the facility. However, no data analysis was being performed because the company's only reliability engineer had recently left the company.

**Example 2:** Vibration data were collected from numerous grinders in the facility. However, the data was being interpreted by someone who was not trained in this task. As a result, numerous impending failures were not diagnosed and some repairs were being implemented that were not required.

**Example 3:** High vibration readings generally indicated a bearing problem in the pump. The mechanics replaced the bearing even though it did not look worn or damaged. When the pump was restarted, the high vibration readings were still present. The pump impeller had been damaged and caused the high vibration. This was not considered as a potential cause of the high vibration.

### Typical Recommendations

Provide training for personnel on interpretation of condition-based monitoring data.

Assign interpretation of condition-based monitoring data to a specific individual or group within the facility.

Periodically audit the condition-based monitoring program to ensure that data interpretation is being properly performed.

Perform maintenance activities in accordance with the equipment reliability program.

If equipment is found to be deficient, promptly remove the equipment from service or implement appropriate safeguards to ensure safe operation pending repair or replacement.

Review maintenance records to assess the effectiveness of the condition-based maintenance program.

If the rate of change in equipment condition is faster than anticipated, determine whether there is other equipment that might also be affected by the same conditions that caused the unexpected condition or deficiency and conduct appropriate inspection or test activities to determine whether it is still fit for service.

## Definitions/Typical Issues

Did hidden failures contribute to the loss event? Could these hidden failures have been detected by testing the equipment? Did the faultfinding maintenance and inspection testing failure to include all applicable portions of the system? Was the faultfinding maintenance scheduled to be performed at an incorrect interval (i.e., too frequently or not often enough)? Was the faultfinding maintenance actually being performed at the incorrect interval?

**Note 1:** Fault-finding maintenance and inspection are usually applicable to standby systems or the detection of hidden failures in systems.

**Note 2:** The *Scope Issue (#48)* node addresses the scope of the fault-finding maintenance and inspection process. *Scheduling/Frequency Issue (#49)* node addresses when the maintenance should be performed. The *Implementation Issue (#50)* node addresses performing the fault-finding maintenance or inspection task.

Once the fault-finding maintenance and inspection activity has detected a problem that needs to be resolved, the issue then proceeds to the *Corrective Maintenance Issue (#51)* cause type. This cause type addresses the subsequent *Troubleshooting/Corrective Action Issue (#52)* and the *Repair Implementation Issue (#53)*.

**Note 3:** For an explanation of the various types of maintenance used on the Root Cause Map™, see Appendix A at the back of this book.

## Examples

**Example 1:** A standby diesel generator was installed to provide power to vital components during a loss of power. No testing had been performed on the diesel generator since it was installed, even though testing was required every other month. As a result, when there was a loss of power, the diesel generator did not work.

**Example 2:** A second cooling pump was installed as a spare. It was designed to start when the primary pump fails. The standby pump is smaller than the primary and so is seldom used. The pump is tested when it is periodically placed in service (although it is not done on any schedule). However, the auto start system is never tested. As a result, the standby pump failed to start following an emergency shutdown of the primary pump.

## Typical Recommendations

Ensure that standby systems are periodically tested to determine their operability.

Verify that installed spares are periodically used to ensure that they are ready to operate when the primary components or trains fail.

Check fault-finding testing procedures to ensure that they test the entire system and not just a portion of it.

Ensure that the frequency of testing is correct (not too often, but often enough).

## 48 – Scope Issue

### Definitions/Typical Issues

Did the fault-finding maintenance and inspection issue testing fail to include all applicable portions of the system (i.e., detection system, control systems, actuation systems, and the actual components)? Was the portion of the system that failed not included in the faultfinding maintenance activity? Did an inadvertent actuation of the system occur because failure-finding maintenance was performed on equipment that did not need to be tested?

**Note 1:** Fault-finding maintenance and inspection are usually applicable to standby systems or the detection of hidden failures in systems.

**Note 2:** For an explanation of the various types of maintenance used on the Root Cause Map™, see Appendix A at the back of this book.

### Examples

**Example 1:** A second cooling pump was installed as a spare. It was designed to start when the primary pump fails. The standby pump is smaller than the primary and so it is seldom used. The pump is tested when it is periodically placed in service (although this is not done on any schedule). However, the auto start system is never tested. As a result, the standby pump failed to start following an emergency shutdown of the primary pump.

**Example 2:** Testing of an emergency diesel generator backup system only involved starting and synchronizing the generator to the grid. However, the test did not involve loading the generator.

### Typical Recommendations

Check fault-finding testing procedures to ensure that they test the entire system and not just a portion of it. Check to see that the following portions of the system are included:

- Detection systems (i.e., systems that detect low voltage to start an emergency generator)
- Actuation systems (i.e., the parts of the system that tell the standby component to start)
- The component itself (i.e., the diesel generator)

Identify emergency response equipment, including required inspections and tests, and establish a system to ensure that equipment is properly maintained and tested.

Identify emergency evacuation equipment, including required inspections, tests, and other preventive maintenance or replacement activities, and establish a system to ensure that equipment is properly maintained and tested.

## Definitions/Typical Issues

Was the fault-finding maintenance scheduled to be performed at an incorrect interval? Was the maintenance scheduled to be performed too frequently (too many inadvertent actuations or wearing out the equipment from excessive testing)? Was it not scheduled to be performed often enough?

**Note 1:** Fault-finding maintenance and inspection are usually applicable to standby systems or the detection of hidden failures in systems.

**Note 2:** This node addresses how often the maintenance should be performed. If scheduled tests are not actually being performed, this is addressed by the ***Implementation Issue (#50)*** node.

**Note 3:** For an explanation of the various types of maintenance used on the Root Cause Map™, see Appendix A at the back of this book.

## Examples

**Example 1:** A standby diesel generator was scheduled to be tested twice per month. The diesel engine was worn out by the testing.

**Example 2:** No testing was being performed for an emergency cooler. As a result, the cooler failed to start when the primary cooler failed.

## Typical Recommendations

Ensure that standby systems are scheduled to be tested periodically to determine their operability.

Ensure that the frequency of specified testing is correct (not too often, but often enough).

Assess the impact of fault-finding maintenance on the system and adjust the frequency accordingly.

Based on the results of tests and inspection activities, make appropriate adjustments to the inspection or test interval.

## 50 – Implementation Issue

### Definitions/Typical Issues

Was the fault-finding maintenance actually being performed at the incorrect interval? Was the maintenance actually performed too frequently? Was it not being performed often enough? Was the maintenance performed incorrectly?

**Note 1:** Fault-finding maintenance and inspection are usually applicable to standby systems or the detection of hidden failures in systems.

**Note 2:** This node addresses how often the maintenance is actually performed. If tests are not scheduled to be performed, this is addressed by the *Scheduling/Frequency Issue (#49)* node.

**Note 3:** For an explanation of the various types of maintenance used on the Root Cause Map™, see Appendix A at the back of this book.

### Examples

**Example 1:** No testing was being performed for an emergency cooler even though testing was scheduled for six times per year. As a result, the cooler failed when the primary cooler failed.

**Example 2:** An emergency communications system was supposed to be tested once per quarter. However, the testing was never performed. As a result, the system did not operate properly during an emergency.

**Example 3:** An emergency alarm was supposed to be tested Monday mornings when all the manufacturing equipment was in operation. However, the test was often performed on Sunday night when the plant was largely idle. As a result, the testing did not identify that there were areas where the alarm could not be heard over the noise of the operating equipment during an actual emergency.

**Example 4:** A standby diesel generator (DG) was installed to provide power to vital components during a loss of power. To perform testing of the DG, the maintenance technician takes the DG offline. After testing, maintenance failed to return the DG to an online condition. As a result, when there was a loss of power, the DG did not work.

### Typical Recommendations

Ensure that fault-finding maintenance is being performed as scheduled.

Ensure the fault-finding maintenance is being performed in the manner specified by the procedure.

Perform maintenance activities in accordance with the equipment reliability program.

Review test and inspection reports and either (1) repair deficiencies noted by the inspector or (2) document why repairs are not needed.

If equipment is found to be deficient, promptly remove the equipment from service or implement appropriate safeguards to ensure safe operation pending repair or replacement.

Review maintenance records to assess the effectiveness of the fault-finding maintenance program.

## Definitions/Typical Issues

Was the problem misdiagnosed? Was the corrective maintenance repair performed incorrectly?

**Note 1:** Corrective maintenance deals with failures that have already occurred and impending failures that have been identified by other maintenance types. When the other maintenance tasks identify the need for corrective maintenance to repair or restore a component to service, the corrective maintenance activity is addressed by the ***Corrective Maintenance Issue (#51, #52, and #53)*** nodes.

**Note 2:** The ***Troubleshooting/Corrective Action Issue (#52)*** node addresses problems with determining what repair/restoration activities need to be performed. The ***Repair Implementation Issue (#53)*** node addresses problems with performing the repair.

**Note 3:** For an explanation of the various types of maintenance used on the Root Cause Map™, see Appendix A at the back of this book.

## Examples

**Example 1:** Mechanics' job performance was judged by how many work requests they completed. As a result, they tried to diagnose the problem as quickly as possible. This led to rework when the original repairs failed to correct the problem.

**Example 2:** An inexperienced mechanic incorrectly repaired a pump seal, which subsequently leaked. He inserted one of the rubber seals backwards. The procedure provided no guidance other than to "install the rubber seals."

## Typical Recommendations

Provide troubleshooting guides based on equipment failure analyses for diagnosis of failed components.

Review maintenance procedures to ensure that they provide adequate guidance based on the experience level of personnel.

Provide training for personnel on troubleshooting processes.

Provide training for personnel on repair techniques.

Perform post-maintenance testing to ensure that the maintenance is properly performed and corrects the problem.

## 52 – Troubleshooting/Corrective Action Issue

### Definitions/Typical Issues

Was the problem misdiagnosed? Was the wrong problem corrected because the troubleshooting was insufficient?

**Note 1:** Corrective maintenance deals with failures that have already occurred and impending failures that have been identified by other maintenance types. When the other maintenance tasks identify the need for corrective maintenance to repair or restore a component to service, the corrective maintenance activity is addressed by the **Corrective Maintenance Issue (#51, #52, and #53)** nodes.

**Note 3:** For an explanation of the various types of maintenance used on the Root Cause Map™, see Appendix A at the back of this book.

### Examples

**Example 1:** Mechanics' job performance was judged by how many work requests they completed. As a result, they tried to diagnose the problem as quickly as possible. This led to rework when the original repairs failed to correct the problem.

**Example 2:** The electricians were attempting to locate a short in a feeder circuit. They thought they had isolated the problem to a portion of the circuit, but they were mistaken. They had misread the electrical diagrams and misinterpreted their instrument readings.

### Typical Recommendations

Provide troubleshooting guides based on equipment failure analyses for diagnosis of failed components.

Provide guidance for resolving typical failures that occur.

Provide training for personnel on troubleshooting processes.

Perform post-maintenance testing to ensure that the maintenance is properly performed and corrects the problem.

## Definitions/Typical Issues

Was the corrective maintenance repair performed incorrectly?

**Note 1:** For an explanation of the various types of maintenance used on the Root Cause Map™, see Appendix A at the back of this book.

## Examples

**Example 1:** An inexperienced mechanic incorrectly repaired a pump seal, which subsequently leaked. He inserted one of the rubber seals backwards. The procedure provided no guidance other than to “install the rubber seals.”

**Example 2:** During corrective maintenance, mechanics identified a problem with a seal on a pressure transmitter. To correct the problem, a new rubber gasket should have been installed. However, the mechanic would have had to go to the warehouse to get a new gasket and it was close to quitting time. Instead, the operator applied a sealant to the gasket. This caused problems during subsequent repairs when the old seal could not be removed.

**Example 3:** Condition-based monitoring of a pump indicated an upcoming failure (e.g., from condition-based maintenance monitoring). Corrective maintenance was initiated to repair the pump. The pump was repaired incorrectly.

## Typical Recommendations

Review maintenance procedures to ensure that they provide adequate guidance based on the experience level of personnel.

Provide training for personnel on repair techniques.

Perform field inspections to identify troubleshooting/corrective action maintenance tasks that are not being properly implemented.

Review maintenance records to assess the effectiveness of the troubleshooting/corrective action maintenance program.

## 54 – Routine Inspection and Servicing Issue

### Definitions/Typical Issues

Was there a failure to perform routine inspections of equipment? Are personnel unaware of the types of problems they should look for? Was there a problem with the performance of the routine servicing activities? Was there a problem with the documentation of the problem in the maintenance system?

**Note 1:** Routine inspection and servicing maintenance is separated from the other types of maintenance because it is normally performed by operators instead of maintenance personnel. As a result, different management systems usually influence performance of these tasks.

**Note 2:** The *Scope Issue* (#55) node addresses what is supposed to be performed. The *Scheduling/Frequency Issue* (#56) node addresses how often and when the activities should be performed. The *Troubleshooting/Corrective Action Issue* (#57) node addresses problems with the performance of the repair activities.

**Note 3:** For an explanation of the various types of maintenance used on the Root Cause Map™, see Appendix A at the back of this book.

### Examples

**Example 1:** Operators are supposed to inspect the line for problems at the beginning of each shift. Often the operators skip the rounds because they have too much paperwork to complete.

**Example 2:** During routine rounds, the operators found leaking valves. They were supposed to attempt corrective maintenance immediately. However, operators did not always attempt repairs until the leaks were more severe.

### Typical Recommendations

Develop guidance for operator and maintenance rounds.

Ensure that personnel are aware of the process for initiating corrective maintenance.

Make the process of reporting problems as simple as possible to encourage reporting problems.

**Definitions/Typical Issues**

Was the scope of the specified routine servicing and inspection (rounds) inappropriate (i.e., too broad or too narrow)? Are some portions of the plant not covered by routine rounds?

**Note 1:** This node addresses issues with the specified scope of the routine servicing and inspection activity. If the scope was appropriately specified, but not executed properly, the ***Troubleshooting/Corrective Action Issue (#57)*** node should be used.

**Note 2:** For an explanation of the various types of maintenance used on the Root Cause Map<sup>TM</sup>, see Appendix A at the back of this book.

**Examples**

**Example 1:** Operators were told to perform rounds in the steam plant but were not told what activities they were to perform. As a result, the operators poked their head in the door of the building and glanced around, but did nothing else.

**Example 2:** A plant was recently upgraded to a fully automated control system. The operators rarely had to leave the control room to operate the plant. The operators only toured the area right around the control room. As a result, no one routinely toured the entire plant.

**Example 3:** Equipment rounds were supposed to be performed in all areas of the tank farm. However, some were quite distant from the control room. As a result, the areas furthest from the control room were rarely covered on rounds.

**Typical Recommendations**

Ensure that all areas of the plant are covered by periodic rounds.

Provide guidance on the activities that are to be performed during routine rounds.

Develop specific inspection logs for operator rounds.

Develop a list of tests and testing procedures that operators should exercise when the opportunity arises.

Encourage workers to notice and report abnormalities in processes and equipment.

## 56 – Scheduling/Frequency Issue

### Definitions/Typical Issues

Was the specified frequency of the routine servicing and inspection (rounds) incorrect (i.e., too often or not often enough)?

**Note 1:** This node addresses issues with the specified frequency of the routine servicing and inspection activity. If the appropriate frequency was specified, but the task was not performed on the proper schedule, the **Troubleshooting/Corrective Action Issue (#57)** node should be used.

**Note 2:** For an explanation of the various types of maintenance on the Root Cause Map™, see Appendix A at the back of this book.

### Examples

**Example 1:** Operators performed equipment rounds in some areas of the plant only once a day. Frequently, significant valve packing leaks were found by the operators. More frequent rounds resulted in detections of leaks while they were still very small.

**Example 2:** Some damage occurred to a portion of a walkway above a machine. Normally operators used the walkway to perform periodic inspection of a portion of the equipment. With the walkway off limits, the routine inspections of that portion of the equipment were deleted from the round sheets.

### Typical Recommendations

Review the frequency of the rounds to determine whether they are performed at the required frequency.

Ensure that all areas are accessible for personnel to perform their routine rounds.

Check local equipment conditions frequently.

## Definitions/Typical Issues

Were the routine servicing and inspection (rounds) being performed at the wrong frequency? Do the routine servicing and inspection (rounds) fail to cover all areas that are specified?

**Note 1:** This node addresses issues with the execution of the troubleshooting/corrective action issue. If the specified scope of the routine servicing and inspection activity was incorrect, use the *Scope Issue (#55)* node. If the specified frequency of the routine servicing and inspection activity was incorrect, the *Scheduling/Frequency Issue (#56)* node should be used.

**Note 2:** For an explanation of the various types of maintenance used on the Root Cause Map™, see Appendix A at the back of this book.

## Examples

**Example 1:** During routine rounds, the operators found leaking valves. They were supposed to attempt corrective maintenance immediately. However, operators did not always attempt repairs until leaks were more severe.

**Example 2:** As part of routine rounds, operators are supposed to blow down the receivers for all of the air compressors to remove condensate. However, the operators did not always blow the compressors down completely.

## Typical Recommendations

Ensure that rounds are performed as required.

Ensure that all equipment is covered on rounds as required.

Include steps in repair procedures to ensure that equipment is fit for service when it is turned over to the production team.

Provide training for personnel on repair techniques.

Perform field inspections to identify routine inspection and servicing tasks that are not being properly implemented.

Review maintenance records to assess the effectiveness of the routine inspection and servicing program.

## 58 – Documentation and Records Issue

### Definitions/Typical Issues

This intermediate cause category addresses issues related to most documentation. It includes:

- Equipment records and manuals
- Operational and maintenance history
- Risk assessment records
- Personnel records
- Other documents and records

It does NOT include procedures (see **Procedures** [#122]) or standards, or policies (see #224).

Does an equipment records program exist for the equipment or component? Is it inadequate or out of date? Does it contain incorrect information? Does it fail to contain all the information necessary to ensure equipment and process reliability?

Are operational and maintenance records maintained? Are they inaccurate? Are they out of date? Are risk assessment records maintained? Are they inaccurate? Are they out of date?

Are personnel records maintained? Are they inaccurate? Are they out of date? Are other records maintained? Are they inaccurate? Are they out of date?

### Examples

**Example 1:** During the past year, the failure rate for feed pumps has doubled. Maintenance records are inadequate to determine why any of the failures occurred. Work records just say, “Pump repaired.”

**Example 2:** A tank overflowed because of faulty liquid level instrumentation. The records indicated that a calibration was called for and performed 3 months prior, but did not indicate how much adjustment was made during calibration. A large adjustment might have indicated pending failure.

**Example 3:** A pressure vessel was not properly tested after a modification. The design information for the salvaged vessel had been lost.

**Example 4:** During an audit, it was discovered that the training records of personnel were inadequate to determine whether they met all of the qualification requirements for their current position.

**Example 5:** Suppliers are qualified by passing a detailed assessment performed by facility personnel. However, records of the assessments were not updated on a timely basis. As a result, it was difficult to determine the current list of qualified suppliers.

### Typical Recommendations

Improve equipment operational and maintenance records to enable the selection of the proper type of maintenance.

Ensure that design information is retained on equipment and accessible to personnel responsible for operation, maintenance, and modification of the equipment.

Establish a plan for distributing original equipment manufacturers' manuals to the areas that require the information in order for personnel to plan and execute their work.

Assess the adequacy of maintenance tasks that collect information on the status of equipment.

Ensure that information collected on rounds is documented in a manner that allows identification of abnormal conditions.

Establish access controls for personnel records.

Establish a process to update documents and records.

Periodically audit documents and records to identify missing documents.

## 59 – Equipment Records and Manuals Issue

### Definitions/Typical Issues

Have problems with design records caused problems with the operation, maintenance, or modification of equipment?

Was there an error, omission, or other problem with the manuals provided by the manufacturer? Did the facility personnel not have access to the manufacturers' manuals?

Did a missing, deficient, or poorly maintained manufacturer's manual or drawing contribute to a problem? Were manufacturers' manuals containing important design information missing? Were the manufacturers' manuals or drawings deficient in providing useful and necessary design information? Had drawings or manufacturers' manuals been poorly maintained? Were the manuals inaccessible or difficult to access by the personnel who needed them?

Was an "unofficial" copy of a record or drawing used?

Was the error caused by improper control of as-built documents?

Examples of documents that are addressed by this node include:

- Original equipment manufacturers' manuals
- Material requirements
- Bill of materials
- Drawings

**Note 1:** Problems with procedures are covered under the ***Procedure Issue (#122)*** node, and problems with policies are addressed under the ***Standards, Policies, and Administrative Controls (SPAC) Issue (#225)*** and ***Standards, Policies, and Administrative Controls (SPAC) Not Used (#230)*** nodes.

**Note 2:** This node addresses a portion of the process safety information (PSI) that is required to perform some of the proactive analyses addressed under ***Proactive Risk/Safety/Reliability/Quality/Security Analysis Issue (#104)***. PSI is also addressed by ***Operational and Maintenance Records Issue (#63)*** and ***Risk Assessment Records Issue (#67)***.

### Examples

**Example 1:** As part of a capacity upgrade, engineers attempted to determine the design throughput of a blender. No equipment records could be located to determine the design capacity of the equipment. As a result, a significant amount of time was required to recreate the information.

**Example 2:** Maintenance procedures were being developed for a new freezer. Lack of design information required extensive field verification of equipment configuration to develop the procedure.

**Example 3:** The facility had only one copy of the oil cooler manual. It was in poor condition with some torn and missing pages, indicating that it had been well used. The section regarding maintenance was missing several pages, so the maintenance on the oil cooler was not performed according to the manufacturer's recommendations. As a result, operators had great difficulty in operating the oil cooler.

**Example 4:** The facility frequently purchased equipment that had been used at other facilities. As a result, personnel often did not have original equipment manufacturers' manuals for the equipment.

**Example 5:** Drawings of the new pulverizer were not submitted to the drawing control system. As a result, field walkdowns were needed to design a modification to the system.

**Example 6:** A settling tank was moved 4 feet from its original location to allow for proper forklift access to other equipment. This field change was not indicated in the final design documentation. As a result, a skid-mounted demineralizer installation had to be field modified because the settling tank took up part of the floor to be used for installation of the demineralizer skid.

### **Typical Recommendations**

Ensure that design information is retained on equipment and accessible to personnel responsible for operation, maintenance, and modification of the equipment.

Establish a plan for inventory and maintenance of manufacturers' manuals. Contact manufacturers regarding missing information.

Establish a plan for distributing original equipment manufacturers' manuals to the areas that require the information in order for personnel to plan and execute their work.

Develop a system to control plant drawings, including timely updates and in-process modifications.

## 60 – Documentation Content Inaccurate or Incomplete

### Definitions/Typical Issues

Were there errors or omissions in the content of the documents? Did the documents contain confusing or contradictory information?

Examples of documents that are addressed by this node include:

- Original equipment manufacturers' manuals
- Material requirements
- Bill of materials
- Drawings

### Examples

**Example 1:** The facility had only one copy of the oil cooler manual. It was in poor condition with some torn and missing pages, indicating that it had been well used. The section regarding maintenance was missing several pages, so the maintenance on the oil cooler was not performed according to the manufacturer's recommendations. As a result, operators had great difficulty in operating the oil cooler.

**Example 2:** A settling tank was moved 4 feet from its original location to allow for proper forklift access to other equipment. This field change was not indicated in the final design documentation. As a result, a skid-mounted demineralizer installation had to be field modified because the settling tank took up part of the floor to be used for installation of the demineralizer skid.

### Typical Recommendations

Field changes should be reviewed and approved prior to incorporation into documentation.

Create a technology manual that documents the history of the process system and knowledge that is critical to maintaining process safety competency.

Control changes to the technology manual.

Develop methods for controlling access and changes to documents.

Develop methods for approving changes to documents.

Develop a company- or facility-wide standard that summarizes applicable recognized and generally accepted good engineering practices (RAGAGEPs) related to the design, test, and inspection requirements for each type of equipment.

## **Definitions/Typical Issues**

Were the documents not available, missing, or difficult to obtain? Examples of documents that are addressed by this node include:

- Original equipment manufacturers' manuals
- Material requirements
- Bill of materials
- Drawings

## **Examples**

**Example 1:** As part of a capacity upgrade, engineers attempted to determine the design throughput of a blender. No equipment records could be located to determine the design capacity of the equipment.

**Example 2:** Following an incident related to the flare, drawings of the flare internals could not be located.

**Example 3:** Maintenance procedures were being developed for a new freezer. Lack of design information required extensive field verification of equipment configuration to develop the procedure.

**Example 4:** The facility frequently purchased equipment that had been used at other facilities. As a result, personnel often did not have original equipment manufacturers' manuals for the equipment.

**Example 5:** Drawings of a new conveyor control system were only available at headquarters. Plant personnel had to ask for specific drawings to be sent out to them. As a result, they often did the work without them.

## **Typical Recommendations**

Ensure that drawings are available to all personnel who are required to use them.

Provide read-only access to drawings for all personnel.

Provide backup power to computers and printers to allow printing of drawings during power outages.

Establish an administrative procedure that requires a work permit (or sign-in/sign-out) to be issued and authorized by the controlling work group before another work group may perform job tasks in the controlling work group's area.

Document what information is available in a manner that facilitates searches.

Maintain a protected archive of documents at a remote location.

Ensure that original equipment manufacturers' manuals are stored in a retrievable manner.

## 62 – Out-of-date Documents Used

### Definitions/Typical Issues

Were the documents out of date? Did documents fail to reflect the current status of the system? Was there a failure to update drawings and documents when changes were made?

Was there a problem with the system for controlling documents? Did the system fail to provide appropriate methods for keeping documents up to date? Was there a failure to keep all official copies of the document updated? Were unofficial copies or outdated copies used in the field?

Examples of documents that are addressed by this node include:

- Original equipment manufacturers' manuals
- Material requirements
- Bill of materials
- Drawings

### Examples

**Example 1:** An operator was using an out-of-date process drawing in the field because it contained all of his markups. The markups were required to correct errors on the drawing and to add information the drawing did not contain. As a result, equipment was improperly isolated for maintenance.

**Example 2:** Drawings of the new pulverizer were not submitted to the drawing control system. As a result, field walkdowns were needed to design a modification to the system.

**Example 3:** Two system modifications were being implemented concurrently; however, the design engineers did not know this. The drawings did not indicate that changes were pending from these two modifications. As a result, changes implemented by the first modification were undone by implementation of the second modification.

**Example 4:** An acid spill occurred during the opening of a line break. Lockouts had been made based on current drawings. The drawings were not up to date and did not show an acid stream that had been tied into the line 3 months earlier. The system that existed for controlling documents was not adequate. The organization was 6 months behind on updating marked-up drawings and distributing new copies to all official document holders.

### Typical Recommendations

Develop a system to control plant drawings, including timely updates and in-process modifications.

Make current documents readily available to personnel.

In addition to controlling changes, update information when it becomes obsolete or is impacted by a change to the process or process equipment.

Periodically audit to verify that all official copies are updated.

## Definitions/Typical Issues

Was the equipment history incomplete? Would more complete knowledge of the equipment history have prevented the incident or lessened its severity? Was the information difficult to obtain or analyze?

Were logs, work requests, work orders, or other formal documentation not complete or up to date?

Did an error in a work request or work order cause the incident?

Do logs, work requests, work orders, and other work history documents contain insufficient detail?

Are personnel unaware of threats and hazards to operations? Were personnel unaware of the relevant aspects of the immediate situation and operational expectations for the near future? Was there a failure to have all the required information at hand to form a realistic assessment of the risks of the current situation?

Examples of documents that are addressed by this node include:

- Operator logs
- Computer logs
- Batch sheets
- Work requests
- Work orders

**Note 1:** Work requests and work orders serve a dual purpose; they document what was to be done (line a procedure) and document what was actually done (a historical record). As a result, work requests and work orders are addressed on two parts of the Map. The portion of the documents that describe the work to be done is addressed by the Procedures (#122) portion of the Map. The documentation of what was performed (the historical record of what was done) is covered here.

**Note 2:** This node addresses a portion of the process safety information (PSI) that is required to perform some of the proactive analyses addressed under *Proactive Risk/Safety/Reliability/Quality/Security Analysis Issue (#104)*. PSI is also addressed by *Equipment Records and Manuals Issue (#59)* and *Risk Assessment Records Issue (#67)*.

## Examples

**Example 1:** A tank overflowed because of a faulty liquid level instrument. A nonroutine mode of operation caused the device to fail. Previous problems had occurred with the instrumentation under these conditions. Current personnel were unaware of the problem because no equipment history was available.

**Example 2:** A flow meter in a product line failed, resulting in the wrong amount of material being sent to a customer. Records indicated that calibration of the flow sensor had been performed three times in the last month, but did not indicate how much of an adjustment was made during calibration. A large adjustment, or larger adjustments each time the maintenance was performed, might have indicated an impending failure.

**Example 3:** Operators routinely performed rounds twice each shift. However, there were no guidelines provided regarding what to look for or what data to document. Following a number of pump failures, the equipment logs were reviewed to determine what was causing the failures, but nothing could be identified. Although the operators had looked at the pumps each shift, they had not collected any operating history on them.

**Example 4:** Although the plant had undergone several mode changes and a number of other significant operations, most of these were not reflected in the operations logs. This violated company requirements.

## Typical Recommendations

Improve equipment operational and maintenance records to enable selection of the proper type of maintenance. Collect available information from other sources (e.g., vendors) to help complete existing equipment histories. Improve the system for tracking equipment histories to help ensure that all pertinent information is retained.

Assign responsibility for maintaining and analyzing equipment repair and maintenance records. Periodically audit

the equipment history files to help ensure that the records system is being followed. Assess adequacy of operator rounds and the information collected on rounds.

Assess the adequacy of maintenance tasks that collect information on the status of equipment.

Ensure that information collected on rounds is analyzed to determine whether problems exist with equipment.

Develop a system for tracking equipment histories.

## 64 – Documentation Content Inaccurate or Incomplete

### Definitions/Typical Issues

Were there errors or omissions in the content of the documents?

Were there errors or omissions in the documents? Do documents used in the field have markups to make them useful?

Were logs, work requests, work orders, or other formal documentation incomplete?

Do logs, work requests, work orders, and other work control documents contain insufficient detail? Examples of documents that are addressed by this node include:

- Operator logs
- Computer logs
- Batch sheets
- Work requests
- Work orders

**Note 1:** Work requests and work orders serve a dual purpose; they document what was to be done (line a procedure) and document what was actually done (a historical record). As a result, work requests and work orders are addressed on two parts of the Map. The portion of the documents that describe the work to be done is addressed by the Procedures (#122) portion of the Map. The documentation of what was performed (the historical record of what was done) is covered here.

### Examples

**Example 1:** A flow meter in a product line failed, resulting in the wrong amount of material being sent to a customer. Records indicated that calibration of the flow sensor had been performed three times in the last month, but did not indicate how much of an adjustment was made during calibration. A large adjustment, or larger adjustments each time the maintenance was performed, might have indicated an impending failure.

**Example 2:** During the past year, the failure rate for the feed pumps has doubled. Maintenance records are insufficient to determine why any of the failures occurred. Work records just say, “Pump repaired.”

### Typical Recommendations

Develop a system to control and track operator logs, computer logs, work requests, batch sheets, and other operational and maintenance history records.

Periodically audit operator and maintenance logs for completeness.

Develop methods for controlling access and changes to documents.

Develop methods for approving changes to documents.

Ensure that ongoing work is well communicated to unit operators and other potentially affected employees.

Establish work requests in the computerized maintenance management system based on the reliability program.

Review completed logs and reports and, based on the results of the review, take steps to improve their accuracy and completeness.

## **Definitions/Typical Issues**

Were documents not available, missing, or inconvenient to obtain?

Were documents not available because they did not exist or were difficult to locate? Examples of documents that are addressed by this node include:

- Operator logs
- Computer logs
- Batch sheets
- Work requests
- Work orders

**Note 1:** Work requests and work orders serve a dual purpose; they document what was to be done (line a procedure) and document what was actually done (a historical record). As a result, work requests and work orders are addressed on two parts of the Map. The portion of the documents that describe the work to be done is addressed by the Procedures (#122) portion of the Map. The documentation of what was performed (the historical record of what was done) is covered here.

## **Examples**

**Example 1:** Operators were trying to determine whether the maintenance had been completed on a feed pump. However, they had difficulty locating the work requests associated with the pump. As a result, there was a delay in the startup of the system.

**Example 2:** A tank overflowed because of a faulty liquid level instrument. A nonroutine mode of operation caused the device to fail. Previous problems had occurred with the instrumentation under these conditions. Current personnel were unaware of the problem because no equipment history was available.

## **Typical Recommendations**

Ensure that documents are readily available for personnel.

Provide information at the point of use to direct personnel to the appropriate location of documents.

Provide ready access to documents stored in computer systems.

Document what information is available in a manner that facilitates searches.

Provide a means to quickly locate technical information, facilitate maintenance of existing information, and file new information in a logical manner.

Maintain a protected archive of documents at a remote location.

Provide backup power to computers and printers to allow printing of logs, work requests, and batch sheets during power outages.

## 66 – Out-of-date Documents Used

### Definitions/Typical Issues

Was there a problem with updating documents when changes were made?

Was the system for controlling documents insufficient or inappropriate? Did the system fail to provide appropriate methods for keeping documents up to date? Was there a failure to keep all official copies of the document updated? Were unofficial copies or outdated copies used in the field?

Examples of documents that are addressed by this node include:

- Operator logs
- Computer logs
- Batch sheets
- Work requests
- Work orders

**Note 1:** Work requests and work orders serve a dual purpose; they document what was to be done (line a procedure) and document what was actually done (a historical record). As a result, work requests and work orders are addressed on two parts of the Map. The portion of the documents that describe the work to be done is addressed by the Procedures (#122) portion of the Map. The documentation of what was performed (the historical record of what was done) is covered here.

### Examples

**Example 1:** The warehouse inventory list was supposed to be updated whenever items were withdrawn from the warehouse. However, in many cases the inventory was only updated once a month. As a result, items were sometimes out of stock.

**Example 2:** Maintenance personnel often completed the maintenance work in the field but did not update the work request status promptly. As a result, it was often difficult to determine the current status of equipment.

### Typical Recommendations

Include the task of updating batch sheets in the document change tracking system.

Solicit input from document users on required changes.

Involve the document users in periodic reviews and updates of the documents.

Search for and destroy unofficial copies of documents.

Periodically conduct an audit to ensure that all official copies are updated.

## Definitions/Typical Issues

Were risk assessment records inaccurate or incomplete? Were risk assessment records not available or missing? Were risk assessment records out of date?

Examples of documents that are addressed by this node include:

- HAZOP (hazard and operability) analysis
- PHA (process hazard analysis)
- RCA (root cause analysis)
- FMEA (failure modes and effects analysis)
- Reliability program analysis
- Inspection analysis
- Management of change
- Readiness reviews

**Note 1:** Job safety analyses/task safety analyses are job specific and provide specific activities to perform the task safely, like a procedure. As a result, these documents are addressed by the **Procedures (#122)** section of the Map.

**Note 2:** This node addresses the historical records (documents) produced by these risk analysis activities. If the activities themselves were performed incorrectly, this should be addressed by the **Hazard/Defect Identification and Analysis Issue (#94)** portion of the Map.

**Note 3:** This node addresses a portion of the process safety information (PSI) that is required to perform some of the proactive analyses addressed under **Proactive Risk/Safety/Reliability/Quality/Security Analysis Issue (#104)**. PSI is also addressed by **Equipment Records and Manuals Issue (#59)** and **Operational and Maintenance Records Issue (#63)**.

## Examples

**Example 1:** Recently, a number of changes had been made in the facility. However, the reliability analyses had not been updated to reflect the new equipment.

**Example 2:** The RCA documentation contained a number of factual errors. As a result, the recommendations that were implemented did not solve the problems and wasted resources.

**Example 3:** When performing an FMEA, a number of components were left off the equipment list. As a result, some equipment that was not analyzed had low availability.

**Example 4:** Although an FMEA had been performed on the conveyor system, it could not be located. As a result, the development of the reliability program was hindered by not having the analysis available.

**Example 5:** A PHA needed to be updated. However, the prior PHA could not be located. As a result, the analysis had to be completely redone.

## Typical Recommendations

Ensure that risk assessment records are retained and accessible to personnel.

Establish a plan for maintenance of risk assessment records.

Use software to update and maintain risk assessment records.

## 68 – Documentation Content Inaccurate or Incomplete

### Definitions/Typical Issues

Were there errors or omissions in the content of the documents?

Do documents fail to contain all of the required information? Do documents used by personnel have markups to make them useful?

Did the risk assessment documents contain confusing or contradictory information? Examples of documents that are addressed by this node include:

- HAZOP (hazard and operability) analysis
- PHA (process hazard analysis)
- RCA (root cause analysis)
- FMEA (failure modes and effects analysis)
- Reliability program analysis
- Inspection analysis
- Management of change
- Readiness reviews

**Note 1:** Job safety analyses/task safety analyses are job specific and provide specific activities to perform the task safely, like a procedure. As a result, these documents are addressed by the **Procedures (#122)** section of the Map.

**Note 2:** This node addresses the historical records (documents) produced by these risk analysis activities. If the activities themselves were performed incorrectly, this should be addressed by the **Hazard/Defect Identification and Analysis Issue (#94)** portion of the Map.

### Examples

**Example 1:** When performing an FMEA, a number of components were left off the equipment list. As a result, some equipment that was not analyzed had low availability.

**Example 2:** The RCA documentation contained a number of factual errors. As a result, the recommendations that were implemented did not solve the problems and wasted resources.

**Example 3:** An FMEA of a conveyor had been performed. However, the only documentation produced by the analysis was the recommendations. The facility had difficulty prioritizing implementation of the recommendations because it did not have any of the backup information.

**Example 4:** A HAZOP analysis included cross-references between causes and consequences of different deviations. However, when additional deviations were added, the cross-references were not updated.

**Example 5:** An investigation team was attempting to determine whether a previous incident investigation team had performed tests on a level sensor. The documentation of the previous incident investigation did not indicate whether testing was performed, and no backup data could be located.

### Typical Recommendations

Provide a review process to ensure that risk assessment records are accurate and complete.

Establish a plan for maintenance of risk assessment records.

Use software to update and maintain risk assessment records.

Develop criteria for the thoroughness of change assessment documentation.

Provide examples of appropriate change assessment documentation for different types of changes.

Develop methods for controlling access and changes to documents.

Develop methods for approving changes to documents.

Compile hazard information, process technology information, and process equipment information.

Keep a running summary log of all management of change (MOC) reviews to aid in day-to-day management of the MOC process.

MOC review packages should be prepared and retained, and they should contain materials and information used by reviewers and authorizers to perform the review.

Prepare readiness review documentation that contains the review completion form and the readiness rationale.

## Definitions/Typical Issues

Were the documents not available, missing, or inconvenient to obtain?

Were documents not available because they did not exist or were difficult to locate? Examples of documents that are addressed by this node include:

- HAZOP (hazard and operability) analysis
- PHA (process hazard analysis)
- RCA (root cause analysis)
- FMEA (failure modes and effects analysis)
- Reliability program analysis
- Inspection analysis
- Management of change
- Readiness reviews

**Note 1:** Job safety analyses/task safety analyses are job specific and provide specific activities to perform the task safely, like a procedure. As a result, these documents are addressed by the **Procedures (#122)** section of the Map.

**Note 2:** This node addresses the historical records (documents) produced by these risk analysis activities. If the activities themselves were performed incorrectly, this should be addressed by the **Hazard/Defect Identification and Analysis Issue (#94)** portion of the Map.

## Examples

**Example 1:** Although an FMEA had been performed on the conveyor system, it could not be located. As a result, the development of the reliability program was hindered by not having the analysis available.

**Example 2:** A PHA needed to be updated. However, the prior PHA could not be located. As a result, the analysis had to be completely redone.

## Typical Recommendations

Ensure that documents are available to all personnel who are required to use them.

Provide read-only access to documents for all personnel.

Provide a controlled storage location for analysis documentation.

Ensure that risk assessment records are retained and accessible to personnel.

Establish a plan for maintenance of risk assessment records.

Use software to update and maintain risk assessment records.

Establish a filing structure to ensure that risk assessment records can be readily located.

Document what information is available in a manner that facilitates searches.

Provide a means to quickly locate technical information, facilitate maintenance of existing information, and file new information in a logical manner.

Maintain a protected archive of documents at a remote location.

## 70 – Out-of-date Documents Used

### Definitions/Typical Issues

Was the system for controlling documents inadequate or inappropriate? Did the system fail to provide methods for keeping documents up to date? Was there a failure to keep all official copies of each document updated? Were unofficial copies or outdated copies used in the field?

Were documents updated when changes were made?

Examples of documents that are addressed by this node include:

- HAZOP (hazard and operability) analysis
- PHA (process hazard analysis)
- RCA (root cause analysis)
- FMEA (failure modes and effects analysis)
- Reliability program analysis
- Inspection analysis
- Management of change
- Readiness reviews

**Note 1:** Job safety analyses/task safety analyses are job specific and provide specific activities to perform the task safely, like a procedure. As a result, these documents are addressed by the **Procedures (#122)** section of the Map.

**Note 2:** This node addresses the historical records (documents) produced by these risk analysis activities. If the activities themselves were performed incorrectly, this should be addressed by the **Hazard/Defect Identification and Analysis Issue (#94)** portion of the Map.

### Examples

**Example 1:** The PHA for a reactor was supposed to be updated every 5 years. However, it had not been updated as required. As a result, a significant hazard had not been identified.

**Example 2:** Recently, a number of changes had been made in the facility. However, the reliability analyses had not been updated to reflect the new equipment.

**Example 3:** A modification was performed to install a fired heater to replace one that was damaged during an incident. The change assessment indicated “No issues,” even though the modification involved significant changes to the control system and alarm setpoints.

### Typical Recommendations

Establish a plan for maintenance of risk assessment records.

Use software to update and maintain risk assessment records.

Update risk assessment documents as part of modifications to the facility.

Include the task of updating of risk assessment records in the document change tracking system.

Solicit input from document users on required changes.

Involve the document users in periodic reviews and updates of the documents.

Search for and destroy unofficial copies of documents.

Periodically conduct an audit to ensure that all official copies are updated.

## **Definitions/Typical Issues**

Personnel Records Issue addresses any records specific to an individual such as training, qualification, work records (hours worked), and human resource-related records.

Was the training record system incomplete or not up to date? Did it fail to accurately reflect the employee's training? Was there a failure to use the records to determine worker selection and assignments to tasks?

Did the records show training that the individual had not received? Did the records incorrectly indicate the individual's qualifications?

Did the training records fail to show the individual's current status for job qualification? Did the qualification expire and was this not reflected in the training records?

Examples of documents that are addressed by this node include:

- Hiring records
- Training records
- Qualification records
- Work hour records
- Records of commendations, disciplinary issues or other human resources activities

## **Examples**

**Example 1:** A tank overflowed because the operator had not received training on how to calculate liquid levels. The training records were not routinely updated; therefore, the worker who was assigned to the job was assumed to be qualified.

**Example 2:** An operator overflowed a solvent tank. He had been given the assignment to fill the tank because his records indicated that he had been trained on calculating liquid levels of solutions with specific gravities less than water. The operator had not received this training.

**Example 3:** An operator overflowed a solvent tank because he had not received training on calculating liquid levels for solvent solutions. He had been qualified before this training was made part of the qualifications. The training records still showed him as qualified because they did not reflect the new requirements.

## **Typical Recommendations**

Document the training that an individual is required to receive prior to qualification and to maintain qualification status.

Document the required training that an employee is required to complete annually.

Document all in-house, on-the-job, and outside training that an employee completes. Include dates of completion, test scores, instructor comments, certifications, and a description of how competency is assessed.

Establish a training records management system that assigns specific individuals the responsibility for:

- Scheduling employees and instructors for specific training modules
- Alerting employees and supervisors of upcoming training requirements
- Recording training completion dates
- Notifying records management personnel of employee training completion dates
- Forwarding materials that verify employee understanding of the training to records management personnel

## 72 – Documentation Content Inaccurate or Incomplete

### Definitions/Typical Issues

Were there errors or omissions in the content of the documents?

Did the documents fail to reflect the current status? Do documents fail to contain all of the required information? Do documents used by personnel have markups to make them useful?

Examples of documents that are addressed by this node include:

- Hiring records
- Training records
- Qualification records
- Work hour records
- Records of commendations, disciplinary issues or other human resources activities

### Examples

**Example 1:** An operator overflowed a solvent tank. He had been given the assignment to fill the tank because his records indicated that he had been trained on calculating liquid levels of solutions with specific gravities less than water. The operator had not received this training.

**Example 2:** Training records were completed based on the personnel scheduled to attend the training. As a result, personnel who did not attend the training as scheduled were marked as having completed the training when they did not.

### Typical Recommendations

Document the training that an individual is required to receive prior to qualification and to maintain qualification status.

Ensure that personnel are assigned responsibilities for maintenance of training records.

Document the training that personnel are required to complete annually.

Document all in-house, on-the-job, and outside training that an employee completes. Include dates of completion, test scores, instructor comments, certifications, and a description of how competency is assessed.

Develop methods for controlling access and changes to documents.

Develop methods for approving changes to personnel documents.

Establish a training records management system that assigns specific individuals the responsibility for:

- Scheduling employees and instructors for specific training modules
- Alerting employees and supervisors of upcoming training requirements
- Recording training completion dates
- Notifying records management personnel of employee training completion dates
- Forwarding materials that verify employee understanding of the training to records management personnel

## Definitions/Typical Issues

Was the document not available, missing, or inconvenient to obtain?

Were documents not available because they did not exist or were difficult to locate? Examples of documents that are addressed by this node include:

- Hiring records
- Training records
- Qualification records
- Work hour records
- Records of commendations, disciplinary issues or other human resources activities

## Examples

**Example 1:** An operator was transferred to a new facility. Before she could begin work at the new facility, her training records had to be transferred to the new facility. The training records had been stored at an offsite storage facility and were not available for 2 weeks. This delay caused a loss of productivity for the new plant.

**Example 2:** The operator's certification could not be located. As a result, a lengthy process was needed to replace the document.

## Typical Recommendations

Ensure that personnel records are readily available to appropriate personnel.

Develop a filing structure to ensure that personnel records are easily retrievable.

Ensure that documents are available to all personnel who are required to use them.

Document what information is available in a manner that facilitates searches.

Provide a means to quickly locate technical information, facilitate maintenance of existing information, and file new information in a logical manner.

Maintain a protected archive of documents at a remote location.

## 74 – Out-of-date Documents Used

### Definitions/Typical Issues

Was there a failure to update documents when changes were made?

Did an inadequate or inappropriate system exist for controlling documents? Did the system fail to provide methods for keeping documents up to date? Was there a failure to keep all official copies of the document updated? Were unofficial copies or outdated copies used?

Examples of documents that are addressed by this node include:

- Hiring records
- Training records
- Qualification records
- Work hour records
- Records of commendations, disciplinary issues or other human resources activities

### Examples

**Example 1:** A tank overflowed because the operator had not received training on how to calculate liquid levels. The training records were not routinely updated; therefore, the worker who was assigned to the job was assumed to understand this task.

**Example 2:** A resume submitted to the company from a prospective employee was not current. It showed that the individual was currently employed. However, the prospective employee had been terminated from his last job about 2 months before.

### Typical Recommendations

Include the task of updating documents in the document change tracking system.

Solicit input from document users on required changes.

Involve the document users in periodic reviews and updates of the documents.

Search for and destroy unofficial copies of documents.

Maintain a library of current, approved training materials.

Periodically conduct an audit to ensure that all official copies are updated.

Update personnel records annually.

Provide a structured process for updating training and qualification records.

Perform performance appraisals annually.

## 75 – Other Documents and Records Issue

### Definitions/Typical Issues

Were documents inaccurate or incomplete? Were documents not available or missing? Were documents out of date?

Was there a failure to incorporate customer requirements into documentation processes?

Was there an issue with the documentation that was developed as a result of an inspection? Did the document contain errors or omissions? Were the records not created?

Examples of documents that are addressed by this node include:

- Inspection records
- Purchasing records
- Regulatory compliance
- Financial records
- Marketing materials
- Bills/invoices
- Contracts
- Inventory records
- Pre-startup safety review (PSSR) records
- Management of change (MOC) records
- Management of organizational change (MOOC) records
- Any records in the above list submitted by a contractor to the contracting organization

Examples of records that are NOT addressed by this node include:

- *Equipment Records and Manuals Issue (#59)*
- *Operational and Maintenance History Issue (#63)*
- *Risk Assessment Records Issue (#67)*
- *Personnel Records Issue (#71)*

### Examples

**Example 1:** The organization's copy of the Securities and Exchange Commission (SEC) regulations was out of date. As a result, the organization's SEC filing contained numerous noncompliances.

**Example 2:** The marketing materials for the polymers division were out of date. They did not reflect the current capabilities of the organization.

**Example 3:** There were no marketing materials available for the construction services offered by the organization. As a result, sales for the construction services sector were down 20% from the previous year.

**Example 4:** The expenditure records for personal credit cards issued to employees were incomplete. As a result, the company could not account for approximately \$50,000 of the payouts it had made to employees.

**Example 5:** There were a number of errors in the bills supplied to customers. As a result, a number of customers took their future business elsewhere.

**Example 6:** A contract to hire subcontractors did not specify who was responsible for paying for hazardous material handling training for contract personnel. As a result, the company had to pay for the training and for the time that the contractor's personnel had to spend in the training.

**Typical Recommendations**

Ensure that billing records are reviewed by knowledgeable personnel prior to being sent to customers.

Ensure that purchasing records are stored in a readily accessible manner.

Ensure that financial records are maintained in accordance with appropriate regulations.

Develop purchase specifications for contract services with input from the technical contacts, procurement specialists, attorneys, and others in your company to ensure that all contractual requirements are addressed.

## 76– Documentation Content Inaccurate or Incomplete

### Definitions/Typical Issues

Were there errors or omissions in the content of the documents?

Do documents fail to contain all of the required information? Do documents used by personnel have markups to make them useful?

Examples of documents that are addressed by this node include:

- Inspection records
- Purchasing records
- Regulatory compliance
- Financial records
- Marketing materials
- Bills/invoices
- Contracts
- Inventory records
- Pre-startup safety review (PSSR) records
- Management of change (MOC) records
- Management of organizational change (MOOC) records
- Any records in the above list submitted by a contractor to the contracting organization

Do contracts address the following?

- Safety requirements
- Training
- Experience
- Liability
- Scheduling
- Management

### Examples

**Example 1:** There were a number of errors in the bills supplied to customers. As a result, a number of customers took their future business elsewhere.

**Example 2:** The expenditure records for personal credit cards issued to employees were incomplete. As a result, the company could not account for approximately \$50,000 of the payouts it had made to employees.

**Example 3:** The documentation associated with a quality assurance inspection only required documentation of out-of-specification measurements. As a result, the facility could not identify an adverse trend of acceptable, but progressively more deviant, measurements.

**Example 4:** Inspection of pressure rings at a machine shop was performed. However, there was no documentation of the dimensions. Only a yes/no inspection resulted. Therefore, inspection details were not available during a root cause analysis.

**Example 5:** Documentation for an inspection of respirators was supposed to show the results of each inspection. Instead, the results only had a list of respirators that were inspected and passed all six tests. As a result, the review of the results could not identify unacceptable results.

**Example 6:** A review of completed respirator fit test dates revealed that some of the test dates were in the future.

**Typical Recommendations**

- Solicit input from document users on required changes.
- Involve the document users in periodic reviews and updates of the documents.
- Ensure that billing records are reviewed by knowledgeable personnel prior to being sent to customers.
- Ensure that financial records are maintained in accordance with appropriate regulations.
- Review inspection documents for completeness and accuracy.
- Simplify documentation requirements as much as possible.
- Periodically audit records for completeness and accuracy.
- Establish a program to solicit input from customers.
- Define the documentation that must be available at each stage of the equipment/process life cycle.
- Develop methods for controlling access and changes to documents.
- Develop methods for approving changes to documents.
- Include company safety expectations in the request-for-bid package sent to candidates.

## 77– Documents Not Available or Missing

### Definitions/Typical Issues

Was the document not available, missing, or inconvenient to obtain?

Were documents not available because they did not exist or were difficult to locate?

Examples of documents that are addressed by this node include:

- Inspection records
- Purchasing records
- Regulatory compliance
- Financial records
- Marketing materials
- Bills/invoices
- Contracts
- Inventory records
- Pre-startup safety review (PSSR) records
- Management of change (MOC) records
- Management of organizational change (MOOC) records
- Any records in the above list submitted by a contractor to the contracting organization

### Examples

**Example 1:** There were no marketing materials available for the construction services offered by the organization. As a result, sales for the construction services sector were down 20% from the previous year.

**Example 2:** Bills/invoices were never sent for work performed by personnel in the bolting services group during February. As a result, the organization lost \$86,000.

### Typical Recommendations

Ensure that purchasing records are stored in a manner such that they are readily accessible.

Provide password-controlled access to financial records for appropriate personnel.

Provide applicable documents to management, regulatory agencies, and industry groups.

Document what information is available in a manner that facilitates searches.

Provide a means to quickly locate technical information, facilitate maintenance of existing information, and file new information in a logical manner.

Maintain a protected archive of documents at a remote location.

Save inspection data in a manner so that it can be easily searched (e.g., file data and reports by equipment item rather than by the year the inspection was performed or the contractor who performed the inspection).

## Definitions/Typical Issues

Was there a failure to update documents when changes were made?

Did an inadequate or inappropriate system exist for controlling documents? Did the system fail to provide methods for keeping documents up to date? Was there a failure to keep all official copies of the document updated? Were unofficial copies or outdated copies used?

Examples of documents that are addressed by this node include:

- Inspection records
- Purchasing records
- Regulatory compliance
- Financial records
- Marketing materials
- Bills/invoices
- Contracts
- Inventory records
- Pre-startup safety review (PSSR) records
- Management of change (MOC) records
- Management of organizational change (MOOC) records
- Any records in the above list submitted by a contractor to the contracting organization

## Examples

**Example 1:** The organization's copy of the Securities and Exchange Commission (SEC) regulations was out of date. As a result, the organization's SEC filing contained numerous noncompliances.

**Example 2:** The marketing materials for the polymers division were out of date. They did not reflect the current capabilities of the organization.

## Typical Recommendations

Periodically conduct audits to ensure that all official copies are updated.  
Assign the task of updating records to specific personnel.

Solicit input from document users on required changes.

Involve the document users in periodic reviews and updates of the documents.  
Search for and destroy unofficial copies of documents.

Periodically conduct an audit to ensure that all official copies are updated.

## 79 – Material/Parts and Product Issue

### Definitions/Typical Issues

This intermediate cause category addresses issues related to raw materials, intermediate products, and finished products.

Was the problem the result of inadequate control of changes to procurement specifications or purchase orders? Did product acceptance requirements fail to match design requirements or were they otherwise unacceptable?

Was there a problem with products and materials manufactured by the facility, including intermediate and final products? Did manufactured goods fail to meet acceptance criteria? Were products manufactured, handled, stored, packaged, or shipped incorrectly? Was the shelf life for the product exceeded?

**Note 1:** The *Material/Parts Issue (#80-86)* section only applies to raw materials and parts, whereas the *Product Control and Acceptance Issue (#87-93)* section applies to manufactured/finished products.

### Examples

**Example 1:** A large tank was fabricated using an incorrect grade of stainless steel because the buyer was offered a better price on the lower grade of steel, and the personnel who signed off on the order did not detect the change. As a result, the tank failed prematurely.

**Example 2:** A contract to purchase logs from a supplier did not include late delivery penalties. As a result, the supplier was routinely a week or two behind schedule.

**Example 3:** Acceptance criteria specified that a moisture test should be performed on a sample of each shipment of powder. The warehouse was not told who was supposed to do the test. As a result, the material was shipped to a customer without the test being performed.

**Example 4:** Because of a snowstorm, product could not be shipped on schedule. The warehouse was full of finished product, so it was temporarily stored in narrow aisles in the process area. Some of the product was damaged when an operator ran into the skids with a forklift.

### Typical Recommendations

Procurement specifications should not be changed without review and approval by knowledgeable personnel.

Ensure that acceptance requirements are documented and match the design requirements.

Provide proper environmental conditions for raw materials to ensure quality.

Ensure that appropriate maintenance is performed on equipment and parts in storage.

Eliminate stock for parts/materials that are no longer used in the plant.

Provide personnel with the capability to implement the inspection requirements.

Provide directions for unpacking items so that they are not damaged by the customer.

Provide proper packaging of products to avoid damage during shipping.

## Definitions/Typical Issues

Was the error the result of inadequate control of changes to procurement specifications or purchase orders for raw materials or parts? Did product acceptance requirements fail to match design requirements or were they otherwise unacceptable?

Was material improperly packaged? Was equipment exposed to adverse conditions because of the packaging?

Was there difficulty in understanding or implementing the acceptance criteria for raw materials and parts? Were the acceptance criteria ambiguous or unclear? Was there a failure to perform tests to implement the acceptance criteria? Were the tests inconsistent with the acceptance criteria? Did the tests fail to address all acceptance criteria?

Was the problem caused by inadequate material/part handling? Were materials/parts stored improperly? Were they damaged in storage? Were they weather damaged?

Was there a problem with inventory levels, such as not enough inventory, too much inventory, poorly organized inventory, or inventory that is not available at the time it is needed?

**Note 1:** This section (nodes #80-86) only applies to raw materials and parts received from outside the facility or organization, whereas the ***Product Control and Acceptance Issue (#87-#93)*** section applies to products and materials manufactured within the facility or organization.

## Examples

**Example 1:** A large tank was fabricated using an incorrect grade of stainless steel because the buyer made an unauthorized change to the purchase order and the personnel who signed off on the order did not detect the change.

**Example 2:** A contract to purchase logs from a supplier did not include late delivery penalties. As a result, the supplier was routinely a week or two behind schedule.

## Typical Recommendations

Procurement specifications should not be changed without review and approval by knowledgeable personnel.

Ensure that acceptance requirements are documented and match the design requirements.

Ensure that tests address all acceptance criteria.

For products with a shelf life, develop a system to document the product's date of manufacture and date of distribution.

Monitor inventory levels and restock in a timely manner.

## 81 – Purchasing Specification Issue

### Definitions/Typical Issues

Did the purchase specifications for raw materials/parts fail to include:

- A schedule for delivery of the materials
- Material packaging and shipping requirements
- Safety requirements
- Reliability requirements
- Quality requirements
- Liability clauses
- Payment schedules

Were changes made to purchase orders or procurement specifications without the proper reviews and approvals?

Did the changes result in purchase of the wrong materials or parts? Did changes in contract language cause safety, reliability, quality, or legal problems?

Were incorrect materials substituted? Were material or part specifications substituted without authorization? Did the requirements fail to specify “no substitution”?

Did the purchase order/purchase specification/contract fail to address contingencies for failure to meet a contract requirement?

**Note 1:** This node applies to what was **specified**, not what was **actually received**. See *Acceptance Criteria Issue* (#83) for problems with what was actually received by the facility.

### Examples

**Example 1:** A contract to purchase logs from a supplier did not include late delivery penalties. As a result, the supplier was routinely a week or two behind schedule.

**Example 2:** A pump was ordered for use in a hypochlorite liquid plant. Purchasing went out for bids on a Hastelloy pump (and did not specify Hastelloy C as required). A Hastelloy B pump was received, and it failed after only 40 days of service because of chemical attack.

**Example 3:** A batch of product was ruined because of improper mixing of the components. Purchasing had switched suppliers to reduce costs. The feed material was now purchased at twice the concentration as before. The management of change system did not identify it as a change because the same material was purchased from both suppliers.

**Example 4:** Glass lenses that were shipped to your facility arrived broken. Purchasing specifications did not include requirements for packaging of the lenses. As a result, the supplier sent them in some loose paper packing. However, that was insufficient to prevent breakage.

### Typical Recommendations

Develop purchase specifications with input from the technical contacts, procurement specialists, attorneys, and others in your company to ensure that all contractual requirements are addressed.

Include procurement control procedures in the management of change program.

Implement a management of change program.

Train employees to use the management of change system.

Ensure that field/warehouse personnel understand the management of change system’s importance to them.

Assess the impact of material substitutions on the quality of the product produced.

Ensure that materials are properly labeled to prevent inadvertent substitution.

Attempt to design the manufacturing and product so that only the correct item will fit.

Develop specifications for critical repair parts and maintenance materials.

## **Definitions/Typical Issues**

Was material improperly packaged? Was it damaged because of improper packaging? Was equipment exposed to adverse conditions because the packaging had been damaged? Was the material transported improperly? Was it damaged during shipping?

## **Examples**

**Example 1:** An electronic part incurred water damage because it was not packaged in waterproof packaging by the supplier. The purchasing specification specifically included appropriate packaging requirements.

**Example 2:** An electronic device used for chemical analysis provided incorrect analysis results. As a result, 10,000 gallons of product were later found to be unacceptable. Investigation revealed that the electronic device had been dropped off a forklift during handling at the supplier's facility. Because there was no obvious physical damage, the manufacturer shipped the device.

**Example 3:** A water-based coating material was peeling off within several days of being applied. This shipment of the coating material had frozen during transport by truck from the supplier. Freezing changed the adhesiveness of the coating material.

**Example 4:** Glass lenses that were shipped to your facility arrived broken. Although the purchasing specifications included specific requirements for packing the lenses, the lenses broke when the box was crushed during transport.

## **Typical Recommendations**

Ensure that packaging specifications for raw materials and spare parts are documented, communicated, and clearly understood by the suppliers.

Ensure that proper packaging methods are used for raw materials and parts.

## 83 – Acceptance Criteria Issue

### Definitions/Typical Issues

Was there difficulty in understanding or implementing the acceptance criteria for raw materials and parts? Were the acceptance criteria ambiguous or unclear?

**Note 1:** This node only applies to raw materials and parts ~~and materials~~ procured from outside your facility. Acceptance criteria for manufactured items (fabricated within your facility) are specified as part of the ***Product Control and Acceptance Issue (#87-93)*** section.

### Examples

**Example 1:** Acceptance criteria specified that the bolts should have a Rockwell-C hardness of 30. Warehouse personnel did not know what this meant or how to determine whether the bolts met this specification. As a result, some bolts failed in service.

**Example 2:** Acceptance criteria specified that the powder should not contain excessive moisture. Warehouse personnel did not know exactly what this meant. As a result, they accepted material that was unusable.

**Example 3:** Acceptance criteria had not been developed for rubber gaskets used in a process. The gaskets deteriorate rapidly if they are not individually sealed in plastic. Without any acceptance criteria, the warehouse accepted a shipment of gaskets that were not individually wrapped and sealed.

### Typical Recommendations

Have the warehouse personnel assist in the development of the acceptance criteria to ensure that the criteria are clearly understood by those who will use them.

Develop specifications for critical repair parts and maintenance materials.

Ensure that vendors supply parts and materials that conform to specifications.

## Definitions/Typical Issues

Was there a failure to perform tests to implement the acceptance criteria? Were the tests inconsistent with the acceptance criteria? Did the tests fail to address all acceptance criteria?

**Note 1:** This node only addresses inspections performed by warehouse or operations personnel (including the chemistry or analytical group). Inspections performed by quality assurance personnel should be addressed under the ***Inspection/Audit/Measurement Issue (#116)*** node or one of its subnodes.

## Examples

**Example 1:** The acceptance criteria for a raw material specified that a lengthy test be performed before the material would be transferred from the tanker to the supply tanks. Another, less rigorous test was often substituted to save time. Sometimes, this resulted in use of raw materials that did not meet specifications.

**Example 2:** Although acceptance testing was specified for electronic components, the tests were often skipped. As a result, many failed during final product testing.

## Typical Recommendations

Ensure that acceptance testing is implemented.

Ensure that appropriate tools and testing equipment are available for acceptance testing.

Ensure that tests address all acceptance criteria.

Inspect materials for damage upon arrival at the facility.

Provide receipt inspection that compares the materials supplied against the original plant request.

## 85 – Handling and Storage Issue

### Definitions/Typical Issues

Was the problem caused by inadequate material/part handling? Were materials/parts stored improperly? Were they damaged in storage? Were they weather damaged? Were the materials/parts stored in an environment (heat, cold, acid, fumes, etc.) that damaged them? Were material/equipment/parts issued after their shelf life was exceeded or used after their shelf life was exceeded? Were spare parts/materials and equipment stored improperly? Was inadequate preventive maintenance (cleaning, lubrications, etc.) performed on spares? Were spare parts and materials improperly labeled? **Note:** for labeling issues, consider dual coding with **Poor/Illegible/Labeling of Control/Display/Alarm or Equipment (#155)**.

Did unauthorized access to the spare parts storage area result in problems locating or retrieving spare parts? Was the control of access insufficient?

**Note 1:** This node applies regardless of where the items are stored (warehouse/stores, storage yard, field location, temporary location, etc.).

### Examples

**Example 1:** As a result of improper labeling, grease was placed into inventory on the wrong shelf in the supply room. Subsequently, a pump failed when this grease was used instead of the one specified for that pump.

**Example 2:** An absorption column installed to remove contaminants from solvent did not operate as designed. Investigation revealed that the absorbent material used to pack the column had been stored outside and uncovered. The damaged material reduced the efficiency of the column.

**Example 3:** A pump failed shortly after installation, which was much earlier than anticipated given the life expectancy of the pump. Investigation revealed that the pump had been stored in the warehouse for a long time. During the storage, no periodic maintenance, such as cleaning and lubrication, had been performed as specified in the manufacturer's instructions for storage.

### Typical Recommendations

Ensure that materials are stored in a proper environment.

Provide proper environmental conditions for raw materials to ensure quality.

Ensure that appropriate maintenance is performed on equipment and parts in storage.

Promptly correct problems affecting storage in controlled environments (failures of heating/cooling systems, humidity control systems, etc.).

For products with a shelf life, develop a system to document the product's date of manufacture and date of distribution.

Ensure that the storeroom for maintenance parts and materials is well organized and controlled.

## **Definitions/Typical Issues**

Was there a problem with inventory levels, such as not enough inventory, too much inventory, poorly organized inventory, or inventory that is not available at the time it is needed?

## **Examples**

**Example 1:** An oil filtering system failed when the filters became clogged. The filters are usually replaced on a monthly basis, but they were not replaced during the previous month, as there were no other filters in stock.

**Example 2:** Warehouse staff was having difficulty keeping spare parts organized because they ran out of room in the warehouse. Much of the warehouse was taken up by parts for equipment that was no longer installed in the plant.

## **Typical Recommendations**

Develop methods to determine appropriate inventory levels.

Monitor inventory levels and restock in a timely manner.

Eliminate stock for parts/materials that are no longer used in the plant.

## 87 – Product Control and Acceptance Issue

### Definitions/Typical Issues

Was there a problem with products and materials manufactured by the facility, including intermediate and final products? Did manufactured goods fail to meet acceptance criteria? Were products manufactured, handled, stored, packaged, or shipped incorrectly? Was the shelf life for the product exceeded?

**Note 1:** This node applies to materials produced within the facility, including intermediate and finished products. Problems related to purchased materials and parts produced outside the facility or organization are addressed by the *Material/Parts Issue (#80)* section.

### Examples

**Example 1:** An electronic device used for chemical analysis provided incorrect analysis results. As a result, 10,000 gallons of product were later found to be unacceptable at a customer's site. Investigation revealed that the electronic device had been dropped off a forklift at your facility. Because there was no obvious physical damage, the device was shipped anyway.

**Example 2:** Acceptance criteria specified that a moisture test should be performed on a sample of each shipment of powder out of your facility. The warehouse was not told who was supposed to do the test. As a result, the material was shipped to one of your customers without the test being performed.

**Example 3:** Because of a snowstorm, product could not be shipped on schedule. The warehouse was full of finished product, so it was temporarily stored in narrow aisles in the process area. Some of the product was damaged when an operator ran into the skids with a forklift.

### Typical Recommendations

Develop acceptance criteria for manufactured items that include all relevant parameters.

Ensure that proper packaging methods are used for the final product.

Provide proper packaging of finished products to avoid damage during shipping.

Develop methods to determine appropriate inventory levels.

## **Definitions/Typical Issues**

Was there a failure to include all performance requirements in product specification requirements?

Were some customer requirements not addressed in the product specifications? Were inappropriate or out-of-date codes and standards used in the product specifications?

## **Examples**

**Example 1:** Recent changes to an American Society of Mechanical Engineers bolting standard were not addressed in the product specification for a new piece of workout equipment that your organization was going to manufacture. As a result, the product had to be recalled when a few failures occurred while the equipment was in use.

**Example 2:** The customer (ABC Inc.) wanted a training program customized to address its specific methods for work request processing. However, the company (Great Trainers Inc.) delivered a generic course instead. As a result, ABC Inc. refused to pay Great Trainers Inc. for the training.

## **Typical Recommendations**

Track product performance requirements to ensure that they are addressed in the final product, its packaging, and delivery to the customer.

Assign to personnel the responsibility for monitoring changes in industry standards.

Develop a system for incorporating changes in industry standards into product design.

Assign customer service personnel to solicit customer requirements.

## 89 – Product Acceptance Criteria Issue

### Definitions/Typical Issues

Were acceptance criteria for manufactured items inadequate? Was it difficult to determine whether the manufactured material or item was acceptable?

### Examples

**Example 1:** Inspection of toilet paper rolls included checks of the dimensions of the roll, the adequacy of the paper rolling process, and the fragrance added to the roll. Acceptance criteria were specified for the roll dimensions and the adequacy of the rolling process. No acceptance criteria existed for the adequacy of the fragrance level. As a result, some batches were shipped without the required fragrance.

### Typical Recommendations

Develop acceptance criteria for manufactured items that include all relevant parameters.

Ensure that product acceptance criteria can be reasonably implemented through tests.

**Definitions/Typical Issues**

Were inspections of the finished products inconsistent with the acceptance requirements? Did a lack of inspection lead to safety, reliability, or quality problems? Was there a problem with the inspection of manufactured parts, materials, and final products prior to shipment? Are inspection requirements unreasonable to implement? Do intellectual products (i.e., reports, analyses, and data) fail to meet requirements?

**Note 1:** This node only applies to materials and work products produced within your facility. Inspections of all materials and work products received from outside the facility are addressed as part of the procurement process under *Material/Parts Issue (#80)*.

**Examples**

**Example 1:** Acceptance criteria specified that a moisture test should be performed on a sample of each shipment of powder. The warehouse was not told who was supposed to do the test. As a result, the material was shipped to a customer without the test being performed.

**Example 2:** Product inspection requirements specified that 10% of all items be inspected before shipment. When one of the quality assurance inspectors was gone (e.g., sick, in training), only 5% could be inspected without holding up shipments. As a result, a number of bad lots of material were shipped.

**Typical Recommendations**

Ensure that material/product inspections are performed in accordance with requirements.

Provide clear inspection specifications and methods for product testing.

Provide personnel with the capability to implement the inspection requirements.

# 91 – Packaging, Handling, Transportation Issue

## Definitions/Typical Issues

Was material improperly packaged? Was it damaged because of improper packaging? Was equipment exposed to adverse conditions because the packaging had been damaged? Was the material transported improperly? Was it damaged during shipping? Was the problem caused by inadequate material handling?

**Note 1:** If the damage to the item occurs after the item leaves your control, then code this issue under *External Factors (#4)*. This is appropriate only if the company performing the shipping is not controlled by your organization.

## Examples

**Example 1:** An electronic system incurred water damage because it was not packaged in waterproof packaging as specified in the packaging requirements.

**Example 2:** An electronic device used for chemical analysis provided incorrect analysis results. As a result, 10,000 gallons of product were later found to be unacceptable at a customer's site. Investigation revealed that the electronic device had been dropped off a forklift at your facility. Because there was no obvious physical damage, the device was shipped anyway.

**Example 3:** A water-based coating material was peeling off within several days of being applied to a customer's product. This shipment of the coating material had frozen during transport by truck from your plant to the customer's facility. Freezing changed the adhesiveness of the coating material.

**Example 4:** Motorcycle windshields were packaged in cardboard boxes that were held shut with large metal staples. If the staples were not completely pulled out of the box, they would scratch the plastic windshield when it was removed from the package, making the windshield unusable. Your organization had to replace numerous windshields that were scratched by the staples.

## Typical Recommendations

Ensure that packaging specifications are documented, communicated, and clearly understood.

Ensure that proper packaging methods are used for the final product.

Provide directions for unpacking items so they are not damaged by the customer.

**Definitions/Typical Issues**

Was material stored improperly? Was it damaged in storage? Did it have weather damage? Was it stored in an environment (heat, cold, acid, fumes, etc.) that damaged it? Was product improperly stored? Were products shipped after the shelf life was exceeded? Was inadequate preventive maintenance (cleaning, lubrications, etc.) performed on finished product in storage?

**Examples**

**Example 1:** Because of a snowstorm, product could not be shipped on schedule. The warehouse was full of finished product, so it was temporarily stored in narrow aisles in the process area. Some of the product was damaged when an operator ran into the skids with a forklift.

**Example 2:** The air conditioning system in the finished product storage area at a glue factory was inoperable for about a week during the summer. The warehouse reached temperatures of more than 120°F. Some of the glues were damaged from the excessive heat.

**Note:** Additional coding under *Design Issue (#18)* or *Equipment Reliability Program Issue (#28)* may be appropriate.

**Example 3:** Rubber tubing used in the cooling system of portable generators cracked and failed. The shelf life of the rubber tubing installed had been exceeded and the tubing had become brittle.

**Typical Recommendations**

Ensure that products are stored in a proper environment.

Provide proper packaging of products to avoid damage during shipping.

Before stacking products in a warehouse, ensure that the contents and the packaging are compatible with this storage configuration and will not be damaged.

Promptly correct problems affecting storage in controlled environments (failures of heating/cooling systems, humidity control systems, etc.).

For products with a shelf life, develop a system to document the product's shelf life, date of manufacture, and date of distribution.

## 93 – Inventory Level Issue

### Definitions/Typical Issues

Was there a problem with inventory, such as not enough inventory, too much inventory, poorly organized inventory, or inventory that is not available at the time it is needed?

### Examples

**Example 1:** Customer orders for shampoo additives could not be satisfied due to low inventory.

**Example 2:** The finished product area was filled with lettuce that could not be removed from the warehouse fast enough to accommodate production levels.

**Example 3:** Customer orders could not be fulfilled in time because the requested products could not be located in the warehouse.

### Typical Recommendations

Develop methods to determine appropriate inventory levels.

Monitor inventory levels and restock in a timely manner.

Monitor customer orders and adjust production levels accordingly.

## 94: Hazard/Defect Identification and Analysis Issue

### Definitions/Typical Issues

This intermediate cause category addresses issues related to methods used to identify and analyze hazards and defects. It includes:

- Readiness reviews (including pre-startup safety reviews)
- Change control
- Proactive risk/safety/reliability/quality/security analyses, including job safety analyses/task safety analyses
- Reactive risk/safety/reliability/quality/security analyses
- Inspections that are not part of normal maintenance activities
- Audits
- Measurement programs and metrics

Was there a problem with the readiness review performed prior to starting the equipment? Did the readiness review fail to address all appropriate portions of the system?

Was there a problem with the management of change program? Were changes improperly assessed or were responses to changes improperly implemented?

Were inappropriate or insufficient proactive analyses (safety, reliability, quality, and security analyses) performed? Were process hazard analyses, reliability-centered maintenance analyses, vulnerability analyses, and potential defect analyses not performed when appropriate? Did the analyses fail to address all the appropriate issues? Were inappropriate recommendations generated? Were the recommendations not implemented in a timely manner?

Were reactive analyses, such as root cause analyses, not performed when appropriate? Were inappropriate recommendations generated? Were the recommendations not implemented in a timely manner?

Were audits and inspections not performed when appropriate? Did they have inappropriate scope? Were inappropriate recommendations generated? Were the recommendations not implemented in a timely manner?

Were inappropriate measurements and metrics specified, measured, or analyzed? Were inappropriate recommendations generated? Were the recommendations not implemented in a timely manner?

Were inappropriate risk acceptance criteria used during the analyses? Were the criteria improperly applied?

### Examples

**Example 1:** A new supplier was selected to supply product barrels to the facility. Barrels from the new supplier were cheaper but only came in one color (black). This caused shipment problems because different-colored barrels had been used previously to easily identify the barrel contents. Purchasing did not realize the importance of the color coding. No management of change had been performed.

**Example 2:** A control valve failed to the wrong position upon loss of instrument air. A pre-startup safety review was not performed because the valve was inappropriately installed as part of a replacement-in-kind.

**Example 3:** A new air compressor was installed. A pre-startup review of the installation was performed to ensure that it was installed correctly. However, no operational tests of the compressor were performed. As a result, the compressor failed soon after startup because of an insufficient cooling water supply.

**Example 4:** No analysis had been performed to determine the operational risks associated with a new conveyor system.

**Example 5:** SO<sub>2</sub> (a toxic gas) was released because a stiffer gasket was installed in an SO<sub>2</sub> line. The gasket installed could last longer in this chemical service, but would not seal properly using previous torque settings. The management of change system defined “replacement-in-kind” as use of “similar or better” materials. Because the maintenance department considered the new gasket material superior, a change review was not performed.

**Example 6:** As a result of a facility risk/reliability analysis, recommendations were made to have a final inspection performed of unusual and partial shipments to ensure that they are correct. This recommendation had not been implemented yet. As a result, a partial shipment was sent to a customer that was incorrect.

**Example 7:** An engineer noted oil dripping from a pump seal. The process for reporting and documenting the problem required many forms to be completed. The engineer did not want to take the time to complete the forms. As a result, he did not report the problem and the pump subsequently failed.

### **Typical Recommendations**

Train all employees to understand the difference between a change and a replacement-in-kind.

**Note:** A replacement-in-kind is a replacement item that is functionally the same as the part or item it replaces. If the item is not functionally the same, then a change assessment should be performed.

Develop examples of situations that do and do not require a change assessment.

Provide a list of issues that should be considered during a change assessment.

Enforce requirements to have change assessments completed prior to performing the modification.

Assess field changes and new installations to ensure proper operation of the equipment following startup.

Require authorization signatures for all design/field changes.

Track and document the final resolution for all recommendations.

Provide a safety/hazard/risk review procedure that complies with all applicable orders, regulations, and guides.

Track implementation of recommendations to ensure timely completion.

Measure the effectiveness of selected recommendations.

Refer design/development of recommendations to specialists when teams have difficulty identifying practical solutions.

Reward personnel for completing recommendations.

## 95 – Readiness Review Issue

### Definitions/Typical Issues

Was there failure to verify that new equipment and installations conform to specifications prior to startup? Was there a failure to functionally test new or modified components prior to startup?

This node addresses issues with pre-startup safety reviews (PSSR) elements of process safety management (PSM) programs.

**Note 1:** Readiness reviews are performed to verify that all appropriate equipment is ready for operation and procedures, documents and assessments are updated, and training is completed. Readiness reviews are performed for (1) new processes, (2) processes that have been shut down for modification, and (3) processes that have been administratively shut down for other reasons. Readiness reviews only involve verification of the condition of the equipment, documents, and processes. Installation of equipment, training workers to operate the equipment, updating drawings, etc., are not part of readiness review activities.

### Examples

**Example 1:** A control valve failed to the wrong position upon loss of instrument air. A pre-startup safety review was not performed because the valve was installed as part of a replacement-in-kind.

**Example 2:** A new air compressor was installed. A pre-startup review of the installation was performed to ensure that it was installed correctly. However, no operational tests of the compressor were performed. As a result, the compressor failed soon after startup because of an insufficient cooling water supply.

**Example 3:** During restart, operators discovered a blind that was still installed. The blind should have been removed as part of startup preparations, and the readiness review should have identified it as still being in place.

### Typical Recommendations

Conduct a readiness review for new or modified facilities, and ensure that all requirements of the review have been met before starting the process.

Assess field changes and new installations to ensure proper operation of the equipment following startup.

Establish and implement procedures to perform readiness reviews.

Assign someone as the “owner” of the readiness review system.

Define the readiness review system roles and responsibilities for various types of company/facility personnel.

**Definitions/Typical Issues**

Was there a failure to perform a readiness review? Was a readiness review designated but not performed?

This node addresses issues with pre-startup safety reviews (PSSR) elements of process safety management (PSM) programs.

**Examples**

**Example 1:** A control valve failed to the wrong position upon loss of instrument air. A pre-startup safety review was not performed because the valve was installed as part of a replacement-in-kind.

**Example 2:** A mechanic failed to install an audio alarm in the waste treatment area. No readiness review was performed and the error was not detected.

**Typical Recommendations**

Conduct a readiness review for new or modified facilities, and ensure that all requirements of the review have been met before starting the process.

Determine the types of readiness reviews that are needed and a schedule for conducting them.

Determine the areas of the facility where the readiness review procedure applies. Identify areas/situations where it does not apply.

Define the readiness review roles and responsibilities of various types of company/facility personnel.

Provide training on the readiness review system to employees and contractors.

Provide detailed training to personnel who are assigned specific roles within the readiness review system.

## 97 – Implementation Issue

### Definitions/Typical Issues

Was the readiness review poorly performed? Was there a failure to consider all significant risks during the readiness review?

This node addresses issues with pre-startup safety reviews (PSSR) elements of process safety management (PSM) programs.

### Examples

**Example 1:** A new air compressor was installed. A readiness review of the installation was performed to ensure that it was installed correctly. However, no operational tests of the compressor were performed. As a result, the compressor failed soon after startup because of an insufficient cooling water supply.

**Example 2:** A readiness review of the new processing line was about halfway done when the operations manager decided to start up the system without completing the remaining items. As a result, some instrumentation was not restored to operability.

**Example 3:** During restart, operators discovered a blind that was still installed. The blind should have been removed as part of startup preparations, and the readiness review should have identified it as still being in place.

### Typical Recommendations

Assess field changes and new installations to ensure proper operation of the equipment following startup.

Determine the content/issues to be addressed for each type of startup situation.

Create a list of the necessary information that should be provided to participants of readiness reviews.

Provide personnel for each readiness review.

Have readiness reviews confirm that preparations have been completed prior to the introduction of hazardous substances into a process or restart of an existing process.

Perform a readiness review for facilities that are being started.

Use tools, including checklists, to conduct and document the basis for the readiness review.

If issues are discovered that require action, determine actions to be completed.

Each readiness review should be authorized by approved individual(s)/department(s)/function(s) as specified in the written program.

## **Definitions/Typical Issues**

Was a change assessment performed? Was there a delay in performing the change assessment? Was the change assessment improperly or inappropriately performed? Was control of design/field changes inadequate?

**Note 1:** Change control issues address the process safety management (PSM) management of change (MOC) and management of organizational change (MOOC) elements.

## **Examples**

**Example 1:** A modification to a flare system needed to be performed because of an instrumentation failure. Although maintenance identified the change, no change assessment was performed prior to the modification being installed. As a result, the flare instrumentation was rendered inoperable for 11 hours, contrary to environmental regulations.

**Example 2:** A new oil cooler was installed. The management of change assessment did not consider the impact on the overall cooling system. Because many coolers had been installed without considering the impact on the overall cooling system, it was overloaded on the first hot day.

**Example 3:** The management of change policy requires safety reviews of all process changes, but during an overnight emergency, a failed gate valve was replaced with a ball valve. No change assessment was performed to save time. The valve subsequently ruptured when peroxide that was trapped in the ball decomposed.

## **Typical Recommendations**

Train all employees to understand the difference between a change and a replacement-in-kind.

Develop examples of situations that do and do not require a change assessment to be performed.

Provide a list of issues that should be considered during a change assessment.

Enforce requirements to have change assessments completed prior to performing the modification.

Establish and implement procedures to manage changes.

Assign someone as the “owner” of the management of change system to routinely monitor its effectiveness.

Create a system to address management of change action items and to document their completion.

## 99 – Change Identification Issue

### Definitions/Typical Issues

Was there a failure to identify the change to the system? Was the definition of change less than adequate? Did personnel fail to understand the definition of “change” versus “replacement-in-kind”?

**Note 1:** Change control issues address the process safety management (PSM) management of change (MOC) and management of organizational change (MOOC) elements.

### Examples

**Example 1:** SO<sub>2</sub> (a toxic gas) was released because a stiffer gasket was installed in an SO<sub>2</sub> line. The gasket installed could last longer in this chemical service, but would not seal properly using previous torque settings. The management of change system defined “replacement-in-kind” as use of “similar or better” materials. Because the maintenance department considered the new gasket material superior, a change review was not performed.

**Example 2:** A field modification to an instrument air line had to be made to route the line around a water line that was not on the drawings used by the designer. This reroute created a low point in the air line where contaminants collected. The field modification was not identified as a change that required a review.

**Example 3:** A batch of product was ruined because of improper mixing of the components. Purchasing had switched suppliers to reduce costs. The feed material was now purchased at twice the concentration as before. The management of change system did not identify it as a change because the same material was purchased from both suppliers.

### Typical Recommendations

Ensure that authorization signatures are obtained from key personnel before design/field changes can be implemented.

Train employees on how to initiate a request for change.

Provide specific examples of what is and is not a change requiring review.

Train all employees to understand the difference between a change and a replacement-in-kind.

Ensure that all newly installed and/or modified equipment is included in a hazard review prior to startup.

Involve design personnel in field reviews of the fabrication and installation of equipment.

Allow field fabrication and installation personnel to have access to design personnel to resolve problems encountered in the fabrication and installation process.

Empower personnel with the ability to initiate change assessments.

Define the technical scope of the management of change system so that types of changes to be managed are certain and sources of changes are monitored.

Define the management of change roles and responsibilities of various types of company/facility personnel.

Develop specific examples of changes and replacements-in-kind for each category of change to be evaluated, and use these in employee awareness training in order to minimize the chance that the management of change system is inadvertently bypassed.

## Definitions/Typical Issues

Did personnel fail to perform a change assessment when it was required? Did personnel fail to realize that a change assessment was required?

**Note 1:** Change control issues address the process safety management (PSM) management of change (MOC) and management of organizational change (MOOC) elements.

## Examples

**Example 1:** A mechanic had to tie in a caustic line to a different location than indicated in the modification package. The mechanic identified that a change assessment was needed and requested one. The mechanic was told that the assessment was completed when in actuality it had not been performed. As a result, the line was tied in at an inappropriate location.

**Example 2:** The management of change policy requires safety reviews of all process changes, but during an overnight emergency, a failed gate valve was replaced with a ball valve. No change assessment was performed to save time. The valve subsequently ruptured when peroxide that was trapped in the ball decomposed.

**Example 3:** A new supplier was selected to supply product barrels to the facility. Barrels from the new supplier were cheaper but only came in one color (black). This caused shipment problems because different-colored barrels had been used previously to make it easier to identify the barrel contents. Purchasing did not realize the importance of the color coding. No management of change assessment had been performed.

## Typical Recommendations

Develop criteria for when a change assessment is required.

Develop examples of situations that do and do not require a change assessment.

Audit the change assessment process to identify situations that need additional clarification regarding the need to perform a change assessment.

Provide awareness training and refresher training on the change control system.

# 101 – Change Assessment Issue

## Definitions/Typical Issues

Was the change assessment improperly scoped? Did the change assessment scope fail to include all appropriate items and considerations? Did the change assessment fail to dig deep enough to identify relevant hazards and risks? Was the review abbreviated due to time requirements (e.g., an emergency change)?

**Note 1:** Change control issues address the process safety management (PSM) management of change (MOC) and management of organizational change (MOOC) elements.

## Examples

**Example 1:** A modification was made to install a new treater. A management of change assessment was completed but failed to consider the impacts on the sewage treatment system.

**Example 2:** A new oil cooler was installed. The management of change assessment did not consider the impact of the new cooler on the overall cooling system. Because many coolers had been installed without considering the impact on the overall cooling system, it was overloaded on the first hot day.

## Typical Recommendations

Provide a list of issues that should be considered during a change assessment.

Develop examples of change assessments to provide guidance on the depth of analysis required during the analysis.

Provide detailed training to people who are assigned specific roles within the management of change (MOC) system.

If emergency changes are allowed, the MOC review procedure should address the definition of emergency change and the process for evaluating and authorizing the emergency change.

Provide descriptions of the necessary disciplines (i.e., the appropriate skills and knowledge) that should be represented for an MOC review for each type of change. Each review should include someone qualified in hazard analysis.

The MOC procedure should address the issue of providing back-up personnel when designated authorizers are not available.

Each MOC should be authorized. Sometimes the “MOC approver” function is satisfied by the MOC reviewers; sometimes the approver is different from the MOC reviewers.

Develop a list of responsibilities for MOC authorizers.

Create a system to address MOC review action items and to document their completion.

Confirm that temporary changes are removed from service and that conditions are properly restored to normal operations.

If emergency changes are permitted, the MOC review procedure should define (1) what constitutes an emergency change and (2) the process for evaluating and authorizing the emergency change.

## Definitions/Typical Issues

Was there a failure to perform the change assessment in a timely manner? Was there a failure to implement corrective actions identified in the change review?

**Note 1:** Change control issues address the process safety management (PSM) management of change (MOC) and management of organizational change (MOOC) elements.

## Examples

**Example 1:** A management of change assessment of a flare modification was performed, but not until after the modification had been performed and used. This violated company policy, but did not result in a failure.

**Note:** This incident is a near miss.

**Example 2:** During a turnaround (or outage), some of the change assessments could not be processed before the plant was ready for startup. As a result, the plant startup was performed without completing all of the change assessments. Plant startup had to be delayed because some of the modifications were not properly implemented.

## Typical Recommendations

Enforce requirements to have change assessments completed prior to performing the modification.

Ensure that personnel are notified of upcoming changes in a timely manner.

## 103 – Risk Acceptance Issue

### Definitions/Typical Issues

Were the risk acceptance criteria used during the change assessment set inappropriately? Were the risk acceptance criteria improperly applied? Were risks deemed acceptable that should have been reduced? Was an appropriate hierarchy of controls analysis performed? Were lower level controls used (safeguards) when inherently safer design (ISD)/inherently safer measures (ISM) should have been implemented? Were passive, active, and procedural safeguards applied appropriately?

**Note 1:** Change control issues address the process safety management (PSM) management of change (MOC) and management of organizational change (MOOC) elements.

### Examples

**Example 1:** During a change assessment, the team used the incorrect risk matrix. As a result, they deemed some risks acceptable that should have been addressed with corrective or mitigative actions.

**Example 2:** During a change assessment for a new instrumentation system, the personnel performing the assessment did not use the organization's standard risk matrix. Instead, they just reviewed the change and made a decision based on what they felt should be done. As a result, two recommendations were implemented for risks the company deemed acceptable (based on application of the risk matrix).

### Typical Recommendations

Ensure that a diverse team (able to reasonably assess the appropriate risks) is involved in the change assessment.

Develop criteria that are more objective for judging risk levels (e.g., a simplified risk scoring scheme or listing requiring safeguards for specific situations).

Provide guidance to team members to help ensure that the analyses are conducted properly.

Develop the appropriate risk tolerance criteria or guidance for use in risk-based decision-making situations.

# 104—Proactive Risk/Safety/Reliability/Quality/Security Analysis Issue

## Definitions/Typical Issues

Was the problem caused by an inadequate hazard review of the system? Was there a failure to perform a risk assessment of the system? Was there a failure to identify the safety, reliability, quality, and security hazards?

Typical analyses addressed by this node include:

- Process hazard analyses (PHA)
- Hazard and operability analyses (HAZOP)
- Reliability analyses
- Security vulnerability analyses (SVA)
- Failure modes and effects analyses (FMEA)
- Reliability-centered maintenance analyses (RCM)
- Enterprise risk management analyses (ERM)
- Project risk management analyses
- Fault tree analyses (FTA)
- Event tree analyses (ETA)
- Probabilistic risk assessments (PRA)
- Job safety analyses/task safety analyses (JSA/JTA)
- Damage mechanism review (DMR)
- Safeguard protection analyses (SPA)
- Hierarchy of controls analysis (HCA)
- Process safety culture assessment (PSCA)
- Human factors assessment (HFA)

**Note 1:** Proactive analyses are performed before a failure occurs. Reactive analyses are performed after a failure occurs. Reactive analyses are addressed under nodes **#110-115**.

**Note 2:** This node addresses general proactive analyses. Analyses performed specifically as part of a change assessment are addressed under the **Change Control Issue (#98)** node.

Note 3: Normally, pre-job briefings are addressed under the Job Plan/Instructions to Workers Issue (#187) node. However, if the pre-job briefing includes the performance of a job safety analysis (JSA) and the causal factor occurred as a result of failure to properly perform the JSA, it is appropriate to code under this node.

**Note 4:** Issues associated with the design of the reliability program, such as mechanical integrity (MI); reliability-centered maintenance (RCM), risk-based maintenance (RBM); inspection, testing, and preventive maintenance (ITPM), should be coded under Node 29 – Equipment Reliability Program Design Issue.

**Note 5:** Safe work permits, such as hot work permits, confined space entry permits, line-breaking permits, and excavation permits, are addressed under **Procedures (#122)**. Although they have some safety analysis aspects to them, they are more appropriately covered under the procedures section as these permits provide detailed guidance for performing the task safely.

## Examples

**Example 1:** During a process hazard analysis of a new system, the review team recommended the installation of a larger overflow line to handle the largest possible flow into the tank. The results of the review were not incorporated into the installation package. The system was started up without a larger overflow line installed. As a result, the wastewater tank was overpressurized and failed.

**Example 2:** A scenario for rapid overpressurization of an atmospheric decanter system was not considered prior to startup of a process because the hazard review did not address procedural deviations during an allowable startup mode. As a result, no safeguards were put in place to mitigate these errors.

**Example 3:** No job safety analysis was performed prior to disassembly of a pump involved in an incident. Acid had entered the pump during the incident, and the workers were exposed to it during the disassembly process. No job safety analysis had been performed because the disassembly used a standard procedure.

**Example 4:** Linemen were assigned the task of moving a 30-foot utility pole as part of a road-widening project. The linemen performed a pre-job brief that included a job safety analysis (JSA) of this particular situation because the generic JSA needed to be tailored to the specific conditions of this job site. A cable television cable, that the personnel failed to identify during the JSA, was damaged during the work.

### **Typical Recommendations**

Ensure that all newly installed and/or significantly modified equipment is included in a hazard review prior to startup.

Track and document the final resolution for all recommendations.

Ensure that personnel, equipment, and environmental losses are all addressed in the review.

# 105 – Analysis Not Performed

## Definitions/Typical Issues

Was there a failure to perform a safety/hazard/risk review? Typical analyses addressed by this node include:

- Process hazard analyses (PHA)
- Hazard and operability analyses (HAZOP)
- Reliability analyses
- Security vulnerability analyses (SVA)
- Failure modes and effects analyses (FMEA)
- Reliability-centered maintenance analyses (RCM)
- Enterprise risk management analyses (ERM)
- Project risk management analyses
- Fault tree analyses (FTA)
- Event tree analyses (ETA)
- Probabilistic risk assessments (PRA)
- Job safety analyses/task safety analyses (JSA/JTA)
- Damage mechanism review (DMR)
- Safeguard protection analyses (SPA)
- Hierarchy of controls analysis (HCA)
- Process safety culture assessment (PSCA)
- Human factors assessment (HFA)

## Examples

**Example 1:** An explosion occurred in a waste tank after a new stream had been tied into the tank. No safety review had been performed prior to tying in the stream to determine whether incompatible materials would be in the waste tank after the tie in.

**Example 2:** No analysis had been performed to determine the operational risks associated with a new conveyor system. As a result, the line had to be redesigned after several failures.

**Example 3:** No job safety analysis was performed prior to disassembly of a pump involved in an incident. Acid had entered the pump during the incident, and the workers were exposed to it during the disassembly process. No job safety analysis had been performed because the disassembly used a standard procedure.

**Example 4:** A new composite material for which no applicable standard existed was employed as part of a ship hull structure. A risk assessment was not performed from which to determine the best means of integrating the material with otherwise conventional vessel structure.

**Example 5:** The process hazard analysis for a reactor was supposed to be updated every 5 years. However, it had not been updated as required. As a result, a significant hazard had not been identified.

**Example 6:** No security analysis for the facility had been performed, even though regulations and company policy required the analysis to be performed.

## **Typical Recommendations**

Provide a safety/hazard/risk review procedure that complies with all applicable orders, regulations, and guides.

Ensure that the hazard review procedure is readily available to personnel who will conduct the review.

Periodically audit hazard review meetings and reports.

Establish minimum training criteria for hazard review leaders.

Review hazardous operations to ensure that hazard assessments have been performed.

Develop a list of equipment and the corresponding job safety analyses (JSAs). Develop JSAs for any equipment that needs one.

Perform field audits of personnel activities to determine which activities require JSAs.

Determine when risk analyses should be performed:

- Laboratory-scale development
- Pilot-scale or semiworks operations
- Conceptual design
- Before selecting a plant site
- Before ordering long-lead equipment
- Detailed design
- Before construction
- Before startup
- During operation
- Before shutdown
- Before demolition

Develop a schedule for performing proactive risk assessments.

Specify when proactive analyses need to be revalidated.

Assign the task of performing proactive analyses to specific personnel.

Develop a list of units and activities that must have proactive analyses performed.

Train workers on how to recognize hazards and how to recognize when unknown hazards may be present.

# 106 – Analysis Issue

## Definitions/Typical Issues

Was the safety/hazard/risk review procedure inappropriate? Does it provide insufficient guidance for the scope of the review? Are the resources needed to perform the review not available? Are personnel inadequately trained in use of the procedure?

Did the analysis fail to consider all modes of operation/maintenance or other required hazard review issues? Did the review fail to address the requirements of all applicable orders, regulations, and guides?

Typical analyses addressed by this node include:

- Process hazard analyses (PHA)
- Hazard and operability analyses (HAZOP)
- Reliability analyses
- Security vulnerability analyses (SVA)
- Failure modes and effects analyses (FMEA)
- Reliability-centered maintenance analyses (RCM)
- Enterprise risk management analyses (ERM)
- Project risk management analyses
- Fault tree analyses (FTA)
- Event tree analyses (ETA)
- Probabilistic risk assessments (PRA)
- Job safety analyses/task safety analyses (JSA/JTA)
- Damage mechanism review (DMR)
- Safeguard protection analyses (SPA)
- Hierarchy of controls analysis (HCA)
- Process safety culture assessment (PSCA)
- Human factors assessment (HFA)

**Note 1:** This node addresses situations where the analysis identified the wrong hazards, causes, or consequences. Situations where the correct hazards, causes, and consequences were identified but incorrect or ineffective recommendations are specified are addressed by the ***Recommendation Identification Issue (#107)*** node.

## Examples

**Example 1:** An explosion occurred in a waste tank because incompatible materials were mixed. The process hazard review had been performed, but it failed to consider all the possible sources of material that could be added to the tank.

**Example 2:** A complex shutdown system failed to mitigate a process upset, resulting in a release of a hazardous material. The review procedure for the plant specified that a hazard and operability (HAZOP) analysis be performed for all new/modified systems; however, the HAZOP system was not well suited for analyzing this type of system (the failure modes and effects analysis technique would have been a better choice of technique).

**Example 3:** A major spill violating an environmental permit occurred at a process that had recently undergone a hazard review. This type of spill, which had no safety consequences, was not addressed in the study because the review procedure did not require evaluation of environmental hazards.

**Example 4:** A risk assessment was recently performed on a packaging operation. The risk assessment did not address supply problems because the review procedure did not require that issue to be considered. Later, a fire at a key supplier's facility led to a 4-week shutdown.

**Example 5:** The facility's control system was modified to allow wireless control of systems from throughout the facility. There was no existing standard to assess the wireless control system against. Interactions with other radio signal devices in the facility caused spurious actuations of equipment.

## **Typical Recommendations**

Ensure that the hazard review technique is appropriate for the complexity of the process.

Ensure that the hazard review technique is appropriate for the process being analyzed.

Ensure that hazard reviews comply with all applicable orders, regulations, and guides (e.g., some include specific checklists for the safety/hazard review).

Ensure that the review procedure addresses the scope of analyses and the training required for hazard analysis team leaders.

Determine the types and severity of consequences to be addressed in the program, for example:

- Worker injuries exceeding a threshold
- Public injuries exceeding a threshold
- Environmental damage exceeding a threshold
- Property damage exceeding a threshold
- Business interruption losses exceeding a threshold
- Company reputation damage exceeding a threshold

Provide detailed training to all employees and contractors who are assigned specific roles in performing proactive analyses.

Use checklists to prompt personnel to consider a broad spectrum of hazards.

List accident scenarios that represent the range of consequences identified in previous hazard identification and risk assessment work activities.

Expand the list of accident scenarios to those that are identified based on expert opinion.

For emergency response planning analyses, critically review the accident scenario list and (1) remove scenarios that are not credible or very unlikely to be severe enough to warrant emergency response, (2) consolidate scenarios that appear to be very similar in effects and tactics that might be used for response, and (3) ensure that it includes both worst credible case scenarios and more likely, less severe scenarios.

Assess the range of accident scenarios in terms of types of consequences (fire, explosion, toxic release, etc.) and the “footprint” of these consequences.

Model the expected impacts from the planning scenarios to determine the geographical area that might be affected by each scenario.

# 107 – Recommendation Identification Issue

## Definitions/Typical Issues

Were actions unsuccessful in controlling risk? Should other actions have been identified? Did the actions fail to address the causes and consequences identified in the analysis?

Typical analyses addressed by this node include:

- Process hazard analyses (PHA)
- Hazard and operability analyses (HAZOP)
- Reliability analyses
- Security vulnerability analyses (SVA)
- Failure modes and effects analyses (FMEA)
- Reliability-centered maintenance analyses (RCM)
- Enterprise risk management analyses (ERM)
- Project risk management analyses
- Fault tree analyses (FTA)
- Event tree analyses (ETA)
- Probabilistic risk assessments (PRA)
- Job safety analyses/task safety analyses (JSA/JTA)
- Damage mechanism review (DMR)
- Safeguard protection analyses (SPA)
- Hierarchy of controls analysis (HCA)
- Process safety culture assessment (PSCA)
- Human factors assessment (HFA)

**Note 1:** This node addresses situations where the analysis identified the correct hazards, causes, and consequences, but incorrect or ineffective recommendations are specified. Situations where the incorrect hazards, causes, and consequences have been identified are addressed by the *Analysis Issue (#106)* node.

## Examples

**Example 1:** As part of a process hazard analysis of a chlorine unloading system, the team recommended installation of multiple check valves to prevent back flow of liquid chlorine into the air compression system. However, the check valves were not very reliable, and a large release of chlorine occurred when a relief valve in the air compressor system lifted.

**Example 2:** During a reliability-centered maintenance analysis, the team recommended performing condition-based maintenance on a pump. This maintenance strategy was relatively ineffective because the pump was a standby pump that ran infrequently. Fault-finding maintenance would have been more effective in identifying the types of issues that caused the pump to be unreliable.

## Typical Recommendations

Involve a multidisciplinary team in identifying actions to ensure that the issue is appropriately addressed.

Refer design/development of actions to specialists when teams have difficulty identifying practical solutions.

Develop measures to determine the effectiveness of actions.

Define a list of preferred risk controls.

Document the residual risk left after implementation of recommendations.

## Definitions/Typical Issues

Was there a failure to implement the recommendations from the safety/hazard/risk/reliability/quality/security review? Was there a problem in implementing the recommendations from the safety/hazard/risk/reliability/quality/security review? Was there a failure to assign the recommendation to a specific individual? Did management fail to monitor the implementation of recommendations?

Typical analyses addressed by this node include:

- Process hazard analyses (PHA)
- Hazard and operability analyses (HAZOP)
- Reliability analyses
- Security vulnerability analyses (SVA)
- Failure modes and effects analyses (FMEA)
- Reliability-centered maintenance analyses (RCM)
- Enterprise risk management analyses (ERM)
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- Damage mechanism review (DMR)
- Safeguard protection analyses (SPA)
- Hierarchy of controls analysis (HCA)
- Process safety culture assessment (PSCA)
- Human factors assessment (HFA)

## Examples

**Example 1:** A release of hazardous material through a rupture disk was discharged to the diked area of the process. The hazard review had recommended installing a catch tank, with a rain hood/cover, to receive any discharged material. The catch tank had not been installed because of scheduling conflicts with other construction in the area. The released material reacted violently with rainwater in the diked area, producing a large quantity of toxic gas.

**Example 2:** Because of a facility risk/reliability analysis, recommendations were made to have a final inspection performed of unusual and partial shipments to ensure that they are correct. This recommendation had not been implemented yet. As a result, a partial shipment was sent to a customer that was incorrect.

## Typical Recommendations

Update the tracking system daily, weekly, or monthly, as appropriate, by adding new action items and/or documenting the current status of all action items.

Conduct periodic, unannounced audits to verify that those action items documented as “complete” are actually complete.

Prioritize action items and assign realistic dates for completion.

Ensure that all hazard review recommendations are documented and reviewed by management personnel.

Management should address all hazard review recommendations and document the manner in which the recommendation will be resolved (i.e., assign a responsible party for completion or reject the recommendation with documented reason for doing so).

Communicate hazard review recommendations to all affected parties.

Document the final resolution or implementation of each recommendation.

Publish periodic reports of resolution status for management.

Ensure that implementation of the recommendations is assigned to a specific group or individual.

# 109 – Risk Acceptance Issue

## Definitions/Typical Issues

Were inappropriate risk acceptance criteria used during the safety/hazard/risk/reliability/quality/security review? Were the risk acceptance criteria improperly applied? Were risks deemed acceptable that should have been reduced? Was an appropriate hierarchy of controls analysis performed? Were lower level controls used (safeguards) when inherently safer design (ISD)/inherently safer measures (ISM) should have been implemented? Were passive, active, and procedural safeguards applied appropriately?

Typical analyses addressed by this node include:

- Process hazard analyses (PHA)
- Hazard and operability analyses (HAZOP)
- Reliability analyses
- Security vulnerability analyses (SVA)
- Failure modes and effects analyses (FMEA)
- Reliability-centered maintenance analyses (RCM)
- Enterprise risk management analyses (ERM)
- Project risk management analyses
- Fault tree analyses (FTA)
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- Probabilistic risk assessments (PRA)
- Job safety analyses/task safety analyses (JSA/JTA)
- Damage mechanism review (DMR)
- Safeguard protection analyses (SPA)
- Hierarchy of controls analysis (HCA)
- Process safety culture assessment (PSCA)
- Human factors assessment (HFA)

## Examples

**Example 1:** An explosion occurred when the incorrect material was fed into the reactor. The supplier had mislabeled the material. The hazard review had identified this as a risk factor but concluded that the risks associated with not analyzing the incoming materials were acceptable.

**Example 2:** A team performing a security assessment had not been given clear guidance on what risks were and were not acceptable. As a result, several scenarios were inappropriately dispositioned.

**Example 3:** Company criteria for multiple layers of safeguards allowed a large risk reduction credit for relief valves in systems. As a result, insufficient attention was given to reducing the frequency of relief valve actuations.

**Example 4:** During a process hazard assessment, the team used an inappropriate risk matrix. As a result, they judged risks as acceptable with no action required. They should have developed recommendations to address some of these risks.

## Typical Recommendations

Ensure that a diverse team (able to reasonably assess the appropriate risks) is involved in the hazard review.

Develop criteria that are more objective for judging risk levels (e.g., a simplified risk scoring scheme or listing requiring safeguards for specific situations).

Provide guidance to team members to help ensure that the reviews are conducted properly.

Develop the appropriate risk tolerance criteria or guidance for use in risk-based decision-making situations.

## Definitions/Typical Issues

Was an incident caused by failure to provide recommendations for known deficiencies or failure to implement recommendations before known deficiencies recur? Had the problem occurred before and never been reported? Did an investigation fail to identify the issue? Did the recommendations that were implemented fail to correct the problem?

Typical analyses addressed by this node include:

- Incident investigations
- Root cause analyses (RCA)
- Accident investigations
- Near-miss investigations

**Note 1:** Reactive analyses are triggered whenever a deficiency is identified regardless of whether a loss or accident occurs. Reactive analyses also address incident investigations and root cause analyses (RCAs).

**Note 2:** If the problem/deficiency could/should have been identified as part of a proactive analysis or was identified in a proactive safety/hazard/risk/reliability/quality/security review, then code the incident in that portion of the Root Cause Map™ (**nodes #104-109**) and not here.

## Examples

**Example 1:** A gear tooth failure destroyed the gear train of a printing press. Only those gears with visibly damaged teeth were replaced because no recommendations were made to examine the adjacent gears. The press failed again about 6 months later when another gear tooth, overstressed but not visibly deformed by the first incident, failed.

**Example 2:** A tank collapsed under vacuum. An earlier root cause analysis (completed due to a near miss) recommended vacuum breakers for this tank, but these devices had not yet been installed.

**Example 3:** A tank had overflowed when the operator started the wrong pump. None of the pump control switches were labeled. A recommendation from this incident was to install labels on the pump switches. After installation of the labels, another pump was damaged when the operator started the wrong pump. The switches for these pumps were not labeled either.

## Typical Recommendations

Track implementation of recommendations to ensure timely completion.

Consider implementing the same recommendations for similar situations at this and other facilities.

Measure the effectiveness of recommendations.

Periodically compare the results of audits with incidents that occur in the facility to ensure that audits are effective in identifying problems.

Establish and implement written procedures to report on, collect data related to, investigate, and learn from incidents.

Assign a job function as the champion of the incident investigation process.

# 111 – Problem/Incident Reporting/Identification Issue

## Definitions/Typical Issues

Are personnel failing to report incidents that have significant impacts on health, safety, reliability, quality, or security? Are personnel unaware of the types of incidents that should be reported? Are personnel not familiar with the methods for incident reporting? Are employees punished for reporting problems?

Was there a failure to identify chronic problems? Was there a failure to use a database to analyze the historical data to identify recurring problems? Were the historical data misinterpreted?

Was there a failure to identify a similar past incident?

Typical analyses addressed by this node include:

- Incident investigations
- Root cause analyses (RCA)
- Accident investigations
- Near-miss investigations

**Note 1:** Coding under the ***Rewards/Incentives Issue (#211)*** node may also be appropriate.

## Examples

**Example 1:** An engineer noted oil dripping from a pump seal. The process for reporting and documenting the problem required many forms to be completed. The engineer did not want to take the time to complete the forms. As a result, he did not report the problem and the pump subsequently failed.

**Example 2:** A manager noted a problem with one of the facility's security systems. However, when the manager reported the problem to the security supervisor, he was told that it was not important and the security supervisor did not record the issue. As a result, a significant security vulnerability was not addressed.

**Example 3:** An operator reported a problem with the drying oven he was using. The temperature control system had malfunctioned and a batch of product had been damaged. Company policy required individuals who reported problems to help personnel correct the situation. As a result, the operator was required to work overtime to assist with the repairs, and he missed the football championship game on television. The next time the operator discovered a problem near the end of his shift, he did not report it because he did not want to stay over past his shift.

**Example 4:** A valve failed, resulting in a process upset. Shift employees had noticed problems with the valve prior to the incident and had expressed concern to the first-line supervisors, but the problem had not been recognized by management and corrected.

**Example 5:** A reliability engineer noted some repeat failures in a particular component. He wanted to communicate this to the engineering design group so that the problem could be eliminated in a redesign of the component. However, he was unsure how to communicate this issue to the design group. Note: This organization used the root cause analysis program to report and formally track actions from the analysis of reliability and operational data.

## Typical Recommendations

Develop incident-reporting guidelines.

Provide training to personnel on the types of incidents that should be reported.

Provide process-specific examples of incidents that should be reported.

Ensure that the incident-reporting process is as simple as possible.

Define the technical scope of the incident investigation program by specifying the risk and consequence threshold that trigger different levels of investigations.

Identify and eliminate barriers for reporting of incidents.

Assess incidents and incident recommendations from other facilities for their impact on your facility.

Use an incident database to trend incident characteristics and track recommendations.

Perform a periodic analysis of the incident database to identify adverse trends.

Perform an analysis of historical incident data during each incident investigation to identify any prior similar instances.

## 112– Investigation Issue

### Definitions/Typical Issues

Was the problem misdiagnosed? Was there a failure to involve knowledgeable personnel in the problem analysis/root cause analysis? Was insufficient emphasis placed on problem diagnosis? Was there a failure to identify the underlying causes?

Was the information needed to perform the incident investigation unavailable? Were personnel unavailable for interviews?

Was there a failure to perform an investigation or analysis of the incident or problem? Was a near miss reported but not investigated?

Typical analyses addressed by this node include:

- Incident investigations
- Root cause analyses (RCA)
- Accident investigations
- Near-miss investigations

**Note 1:** This node addresses situations where the analysis identified the wrong causes of the problem. Situations where the correct causes were identified but incorrect or ineffective recommendations were specified are addressed by the ***Recommendation Identification Issue (#113)*** node.

### Examples

**Example 1:** An accident occurred in a reactor vessel. The incident investigation team guessed that the explosion was caused by a lack of grounding on the tank. After a second event, it was determined that the wrong materials were being fed into the tank and that this had triggered both explosions.

**Example 2:** A root cause analysis team determined that spurious shutdowns of a mixing line were caused by operator errors. Subsequent shutdowns indicated that electronic spikes were causing pressure spikes that caused a safety system to actuate and shut down the line. The operator errors were not the cause of the shutdowns after all.

**Example 3:** Following a “root cause analysis,” an operator was fired for poor performance. The operator had produced a number of bad batches. An experienced operator was moved into this position and that operator also produced a number of bad batches. When a more formalized root cause analysis was performed, it was determined that the control system was poorly designed and could not be easily controlled.

**Example 4:** During the investigation of a performance problem, detailed documentation on the design of the electrical distribution system was not available on the back shift. As a result, personnel could not easily identify the source of the problem and extensive troubleshooting was needed to restore power to one of the facility’s computer systems.

**Example 5:** Operators reported that large temperature excursions were occurring in some batch reactors processing reactive chemicals. No investigations of the causes were performed. A few months later, a vessel ruptured when a runaway reaction occurred in one of the reactors.

### **Typical Recommendations**

Develop generic methods for problem analysis, such as the cause and effect tree technique and/or causal factor charting.

Train all personnel to some level of troubleshooting.

Provide appropriate experts to assist analysis teams.

Have the results of the analysis reviewed by someone outside the organization where the incident occurred.

Review contractor incident and near-miss investigation practices and reports.

Provide root cause analysis and forensics training to incident investigation leaders, focusing on the skills needed to lead an investigation team and the use of root cause analysis techniques.

Establish a formal investigation review process for teams to use at the conclusion of each investigation.

Develop a list of information, data, interviews, and records that incident investigators typically consider collecting during investigations.

Use consistent and effective methods (i.e., interviewing techniques and physical data analysis plans) to collect data.

Provide data-collection guidance and methods to perform incident investigations to facilitate rigorous analysis of the data collected.

Analyze each incident in accordance with the analysis levels (i.e., apparent cause analysis versus root cause analysis) defined in the investigation program.

Ensure that the investigation team approaches the investigation with an open mind and considers all evidence.

Assign personnel who have expertise in investigation methodologies to perform investigations.

Review near-miss reports and verify that they have been investigated.

Set a goal of performing 10 near-miss investigations for each accident investigation.

# 113: Recommendation Identification Issue

## Definitions/Typical Issues

Were recommendations unsuccessful in preventing recurrence? Should other recommendations have been identified? Did the actions fail to address the causes and consequences identified in the analysis?

Typical analyses addressed by this node include:

- Incident investigations
- Root cause analyses (RCA)
- Accident investigations
- Near-miss investigations

**Note 1:** This node addresses situations where the root cause analysis/incident investigation identified the correct causes of the problem but incorrect or ineffective recommendations were specified. Situations where the incorrect causes have been identified are addressed by the ***Investigation Issue (#112)*** node.

## Examples

**Example 1:** A problem with operators bypassing alarms had been identified. The recommendation from the root cause analysis was to administratively control alarm bypasses. After a couple of years, the administrative control requirements were being ignored. Physical changes to equipment may have been a more successful approach for preventing the bypassing of alarms.

**Example 2:** During a root cause analysis, personnel developed 15 recommendations. Some of the recommendations addressed issues that were tolerable to the organization. In addition, no recommendations were developed to address some other unacceptable risks. As a result, resources were dedicated to addressing some risks that were already acceptable, and some unacceptable risks were not addressed.

**Example 3:** A gear tooth failure destroyed the gear train of a printing press. Only those gears with visibly damaged teeth were replaced because no recommendations were generated to examine the adjacent gears. The press failed again about 6 months later when another gear tooth, overstressed but not visibly deformed by the first incident, failed.

## Typical Recommendations

Involve a multidisciplinary team in identifying recommendations to ensure that the problem has been fully analyzed.

Refer design/development of recommendations to specialists when teams have difficulty identifying practical solutions.

Develop measures to determine the effectiveness of recommendations.

Trend incident causes and root causes to determine whether recommendations are effective in preventing recurrence.

Provide training to incident investigation team leaders and team members.

Provide a suggestion box in the facility.

Review contractor incident and near-miss investigation practices and reports.

Develop appropriate recommendations for each cause.

Require the investigation team to specifically show the relationship between the incident, the causes, and the recommendations identified.

## 114 – Recommendation Implementation Issue

### Definitions/Typical Issues

Was a recommendation for a known deficiency not implemented (because of delays in funding, delays in project design, normal length of implementation cycle, tracking deficiencies, etc.) before recurrence of the deficiency?

Typical analyses addressed by this node include:

- Incident investigations
- Root cause analyses (RCA)
- Accident investigations
- Near-miss investigations

### Examples

**Example 1:** A tank collapsed under vacuum. An earlier root cause analysis of a near miss recommended vacuum breakers for this tank, but these devices had not yet been installed.

**Example 2:** A root cause analysis of a quality problem recommended that special orders be packaged in different-colored barrels to highlight the need for special handling. Since this recommendation was made, 16 more instances of mistakes with special orders occurred. The recommendation had never been implemented.

**Example 3:** An incident investigation recommended that small drain holes be drilled in the discharge line of all fire monitors to prevent accumulation of water that could freeze and plug the monitor. This recommendation had not been implemented before another fire occurred, and two of the three monitors failed because they were plugged with ice.

**Example 4:** An audit recommended shape coding of certain controls on the control panel to avoid selection errors. This recommendation had not been implemented when another batch of product was ruined as a result of an operator switch selection error.

**Example 5:** A number of action items had been generated from root cause analyses and process hazard analyses. The facility tracked the open items using a simple document table. Only one person had access to the table. As a result, it was difficult for managers to identify which actions were assigned to them.

**Note:** This example should also be coded under Recommendation Implementation Issue (#108) because it also addresses implementation of recommendations from PHAs (proactive analyses).

**Example 6:** The procedure development process was modified, based on an investigation, to ensure that precautions and warnings were placed in procedures where appropriate. However, an audit of procedures performed a year later identified hundreds of procedures that did not have the proper precautions and warnings.

**Example 7:** An investigation team recommended a modification to a part inspection process to allow different types of defects to be identified. However, the recommendations were never implemented. As a result, unacceptable products were shipped to customers.

### **Typical Recommendations**

If a system is deficient and requires recommendations that cannot be implemented immediately, interim measures should be taken (implementing a temporary operating procedure, process parameter changes, shutting equipment down, etc.).

The cost of implementing recommendations with significant impacts on reliability and quality should be balanced against the anticipated savings from implementation.

Ensure that management periodically reviews the status of recommendations.

Reward personnel for completing recommendations.

Communicate the results of incident investigations to appropriate personnel.

Implement recommendations to address contractor safety performance problems, as required.

Establish a system to promptly address and resolve the incident report recommendations. Resolutions and recommendations are documented and tracked. A database is usually required to track the status of each recommendation.

Review the status of each action item on a periodic basis; including review and approval of changes to the implementation plan/schedule (reasons for slips in the implementation schedule or significant changes to the scope of actions should be valid and well documented).

Review the status of action items and conformance to the plan/schedule on a periodic basis with upper management.

## 115 – Risk Acceptance Issue

### Definitions/Typical Issues

Were the risk acceptance criteria used during the reactive analysis (root cause analysis/incident investigation) set inappropriately? Were the risk acceptance criteria improperly applied? Were risks deemed acceptable that should have been reduced? Was an appropriate hierarchy of controls analysis performed? Were lower level controls used (safeguards) when inherently safer design (ISD)/inherently safer measures (ISM) should have been implemented? Were passive, active, and procedural safeguards applied appropriately?

Typical analyses addressed by this node include:

- Incident investigations
- Root cause analyses (RCA)
- Accident investigations
- Near-miss investigations

### Examples

**Example 1:** A root cause analysis team identified four recommendations to address a root cause of an incident. According to the risk acceptance criteria the organization used, no action was required. As a result, resources were inappropriately diverted to implement the team's four recommendations.

**Example 2:** A root cause analysis team presented its recommendations to the senior management review board. However, the board rejected the team's recommendations and they were not implemented. When a subsequent error occurred and unacceptable product was shipped to the same customer, and the customer discovered that no recommendations were implemented following the incident because senior management rejected them, the customer took its business elsewhere.

### Typical Recommendations

Ensure that a diverse team (able to reasonably assess the appropriate risks) is involved in the reactive analysis.

Develop criteria that are more objective for judging risk levels (e.g., a simplified risk scoring scheme or listing required safeguards for specific situations).

Provide guidance to team members to help ensure that the analyses are conducted properly.

Develop the appropriate risk tolerance criteria or guidance for use in risk-based decision-making situations.

## Definitions/Typical Issues

Was there a failure to perform an inspection? Was there a failure to perform inspections at regular intervals? Do inspections fail to find problems before they cause safety, reliability, or quality problems? Was there a failure to act upon the results?

Was there a failure to perform audits? Did an audit fail to find problems before they caused safety, reliability, or quality problems? Was there a failure to perform audits at regular intervals? Was there a failure to act upon the results?

Was there a failure to appropriately identify system (hardware, software, and organizational) measurements and metrics? Was there a failure to collect measurement and metric data? Was there a failure to identify appropriate key performance indicators (KPIs)? Was there a failure to analyze the data? Was there a failure to act upon the results?

Was there a failure in the safety observation program or other observation program? Was there a failure implement the program? Was there a failure to act on the data or the recommendations developed?

**Note 1:** Compliance audits (CA) performed to comply with the requirements of various process safety management (PSM) regulations are addressed by this node and the sub-nodes #117-121.

**Note 2:** Inspections performed by maintenance personnel as part of normal maintenance activities should be addressed under the *Equipment Reliability Program Issue (#28)* node.

**Note 3:** Inspections performed by warehouse personnel as part of receipt inspection should be addressed under the *Acceptance Testing Implementation Issue (#84)* node.

## Examples

Example 1: An audit had been developed to ensure that personal protective equipment (hard hats, safety goggles, etc.) was being worn by plant personnel. The audit was supposed to be performed annually. However, the audit was only conducted once.

**Example 2:** No audits had been developed to determine whether quality assurance inspections of final products were being implemented effectively.

## Typical Recommendations

Ensure that periodic audits of systems important to safety, reliability, and quality are developed.

Ensure that audits are periodically implemented.

Use audits to perform field inspections and measure performance improvement over time.

Develop an auditing program that addresses issues such as:

- Scope of application
- Scheduling
- Team staffing
- Recommendation resolution
- Documentation of audits

Establish an auditing system owner.

Define roles and responsibilities for the auditing system.

## 117 – Requirements Not Identified

### Definitions/Typical Issues

Was there a problem in developing the requirements of the quality assurance program?

Was there a problem in developing a metrics and key performance indicators (KPIs) program to assist in evaluating equipment and organizational performance?

Were requirements for inspections not identified? Was the scope of the inspections too narrow or too broad?

Was there a failure to identify the requirements for the safety observation program or other observation program?

### Examples

**Example 1:** No audits had been developed to determine whether quality assurance inspections of final products were being implemented effectively.

**Example 2:** No quality acceptance criteria were in place for machined parts that were used in a drilling operation.

### Typical Recommendations

Develop methods to translate functional requirements into quality assurance requirements.

Develop methods to translate customer requirements into quality assurance requirements.

Define safety, reliability, quality, and security program goals.

Define and track a diverse set of metrics that encompass a balanced mix of both leading and lagging indicators.

Develop an auditing schedule.

Implement the auditing schedule.

Perform internal audits prior to performing external audits.

Conduct unannounced field inspections of contractor work activities.

Periodically audit contractor records.

Identify measures by which training program effectiveness will be judged.

Establish and collect data on performance indicators and efficiency indicators.

Establish metrics data on the readiness review process.

Provide input to internal audits of readiness review practices based upon learnings from the performance indicators.

Perform management reviews of management systems, such as the incident investigation process.

Define the roles of personnel in monitoring and analyzing metrics.

Develop appropriate metrics for each management system.

**Definitions/Typical Issues**

Was there an issue with the implementation of the audit/inspection process? Was there a failure to perform the audits/inspections at the frequency specified? Was there a failure to perform the audits/inspections in accordance with the specification? Were the inspection tools inappropriate? Were the inspection tools improperly calibrated?

Was there a failure to monitor or collect data for equipment and organizational metrics or key performance indicators (KPIs)?

Was there a failure to implement the safety observation program or other observation program?

**Examples**

**Example 1:** An audit had been developed to ensure that personal protective equipment (hard hats, safety goggles, etc.) was being worn by plant personnel. The audit was supposed to be performed annually. However, the audit was only conducted once.

**Example 2:** A requirement for quality assurance inspection of final products had been developed and it included specific acceptance criteria. However, the procedure did not detail how the measurements were to be performed.

**Example 3:** Quality acceptance criteria and procedures were developed for machined parts used in a drilling operation. However, the inspection tools used had not been calibrated in more than 2 years.

**Example 4:** An audit of the reliability program failed to identify that several surveillance activities had not been performed.

**Typical Recommendations**

Review inspection methods to ensure that implementation is feasible to implement.

Improve the reliability of inspection equipment.

Improve availability of (access to) inspection equipment.

Make personnel available for interviews.

Ensure that personnel are aware of the goals and metrics for the organization and their department or group.

Use third-party auditors.

Collect data on management of change performance indicators and efficiency indicators.

Provide input to internal audits of management of change practices based upon learnings from the management of change performance indicators.

Collect appropriate data to assess each metric.

Review audit protocols.

Select team members, assign management system elements to the respective team members, and confirm their availability.

Assign audit responsibilities to audit team members based on expertise, experience, and interest.

Gather audit data through records sampling and reviews, observations, and interviews.

Assess management system implementation strengths, weaknesses, and gaps relative to established requirements.

Prepare a draft report for review and forward it to the appropriate facility personnel for review.

Issue the final report and forward it to the appropriate facility personnel.

## 119 – Recommendation Identification Issue

### Definitions/Typical Issues

Were recommendations unsuccessful in preventing recurrence of the issues? Should other recommendations have been identified? Did recommendations fail to correct the causes of the problem?

Were recommendations identified for adverse metric trends or key performance indicators (KPIs)? Was there a failure to analyze the data from the safety observation program or other observation program or develop appropriate recommendations?

### Examples

**Example 1:** A process safety management program audit was performed and numerous findings were issued. However, no recommendations were included in the report. As a result, plant staff did not do anything to resolve the findings. They were waiting for recommendations to be assigned to them.

**Example 2:** Inspections of metal grid straps were performed on all incoming parts. About 10% of the grid straps were rejected as not meeting acceptance criteria. As a result, a recommendation was implemented to provide a second inspection of the parts, because the reject rate was so high. A more effective strategy would have been to work with the supplier to reduce the reject rate. It turned out that many of the straps were bending during shipment to the facility. A simple change in packaging would have prevented the parts from being deformed.

### Typical Recommendations

Involve a multidisciplinary team in identifying recommendations to ensure that the problem has been fully analyzed.

Refer design/development of recommendations to specialists when the team has difficulty identifying practical solutions.

Develop measures to determine the effectiveness of recommendations.

Trend problem characteristics and problem causes to determine whether recommendations are effective in preventing recurrence.

## **Definitions/Typical Issues**

Was there a problem in tracking quality issues?

Was there a problem in tracking the implementation of recommendations related to metrics or key performance indicators (KPIs)? Did the organization fail to assign the recommendations to a specific individual?

Was there a failure to track the issues and recommendations from the safety observation program or other observation program?

## **Examples**

**Example 1:** Quality issues were tracked by each quality control specialist. There was no centralized list of issues. As a result, issues were not appropriately prioritized for resolution.

**Example 2:** A number of action items had been generated from quality audits. The facility tracked the open items by using a simple document table. Only one person had access to the table. As a result, it was difficult for managers to identify which actions were assigned to them.

## **Typical Recommendations**

Develop a database to track the status of action items.

Periodically review the action items in the database.

Assign all action items to personnel.

Ensure that personnel are aware of the action items assigned to them.

Communicate progress toward goals.

## 121 – Risk Acceptance Issue

### Definitions/Typical Issues

Were the risk acceptance criteria used during the audits and inspections set inappropriately? Were the risk acceptance criteria used for the metrics program set inappropriately? Were the risk acceptance criteria improperly applied? Were risks deemed acceptable that should have been reduced? Was an appropriate hierarchy of controls analysis performed? Were lower level controls used (safeguards) when inherently safer design (ISD)/inherently safer measures (ISM) should have been implemented? Were passive, active, and procedural safeguards applied appropriately?

### Examples

**Example 1:** Inspection of metal grid straps resulted in a rejection rate of about 5%. Although this was an unacceptably high rate, the quality assurance personnel did not identify this as a condition adverse to quality.

**Example 2:** During an audit, it was found that several isolation valves were closed upstream of vessel relief valves. Operators opened the valves as soon as the situation was identified. Because the corrective action was taken promptly, no further actions were identified by the auditor. Because of the serious nature of the situation, a report of a Condition Adverse to Quality should have been generated and an incident investigation initiated. During a subsequent incident, a vessel violently ruptured when it was overpressurized and its relief was isolated because of a closed upstream isolation valve.

### Typical Recommendations

Ensure that a diverse team (able to reasonably assess the appropriate risks) is involved in setting audit and inspection review criteria.

Develop more objective criteria for judging risk levels (e.g., a simplified risk-scoring scheme or listing required safeguards for specific situations).

Provide guidance to team members to help ensure that the reviews are conducted properly.

Develop the appropriate risk tolerance criteria or guidance for use in risk-based decision-making situations.

### **Definitions/Typical Issues**

This intermediate cause category addresses issues related to all aspects of procedures, including:

- Failure to use the correct procedure
- Failure to use the correct procedure correctly
- Errors and omissions in the procedures

This portion of the Map also addresses safe work permit documents (which are treated as procedures when using the Root Cause Map), such as:

- Hot work permits
- Confined space entry permits
- Excavation permits
- Line breaking permits

Did personnel fail to use a procedure for the task? Was the procedure incorrect or incomplete? Was no procedure developed for the job, even though a procedure was required to perform the job?

**Note 1:** Procedures provide detailed step-by-step directions on how to accomplish a task. Guidance documents that provide general guidance and principles should be addressed under the ***Company Standards, Policies and Administrative Controls (SPAC) Issue (#225)*** or ***Standards, Policies and Administrative Controls (SPAC) Not Used (#230)*** nodes.

**Note 2:** Job safety analyses/job task analyses are covered in the ***Proactive Risk/Safety/Reliability/Quality/Security Analysis Issue (#104)*** portion of the Map.

### **Examples**

**Example 1:** An operator failed to complete a critical step in an operation because the procedure he obtained from the procedure files was not the most recent revision.

**Example 2:** A new operator failed to complete a critical step because the procedure was not detailed enough; it was written as a guideline/reminder for experienced operators.

### **Typical Recommendations**

Ensure that copies of procedures are available for worker use at all times.

Ensure that procedures are in a standard, easy-to-read format.

Perform a walkthrough of new and revised procedures.

Use look-up tables instead of requiring calculations to be performed.

Develop a written policy describing the management system for the procedures management system that describes the process for creating, updating, and maintaining operating procedures.

Address specific roles and responsibilities in the written policy describing the management system for the procedures management system.

## 123 – Correct Procedure Not Used

### Definitions/Typical Issues

Was there a procedure for the task that was not used? Was the wrong procedure used to perform the job? Was a copy of the procedure not available to the worker? Was it difficult to obtain the procedure? Did the procedure system require that the procedure be used as a task reference or was it just for training? Were personnel required to take copies of the procedures to the field? Should the use of the procedure be required even though it was not in the past? Was the procedure written in a language that was familiar to the worker? Was the use of the procedure discouraged?

**Note:** This node would also cover the situation where a safe work permit (e.g., hot work permit, confined space entry permit, excavation permits, line-breaking permit) should have been used for a task, but none was used.

### Examples

**Example 1:** An operator made a valving error. He performed the task without using the controlled procedure because he would have had to make a copy of the master.

**Example 2:** A mechanic incorrectly performed a repair job on an important pump without using the procedure. Mechanics were not required to use the procedure in the field because it was for training purposes only. However, using the procedure in the field would probably have prevented the error made by the mechanic.

### Typical Recommendations

Ensure that copies of procedures are available for worker use at all times.

Develop procedures with sufficient detail for the least experienced, but qualified worker.

Supplement training and reference materials with easy-to-carry checklists.

## Definitions/Typical Issues

Was there no procedure for the task?

**Note:** This node would also cover the situation where a safe work permit (e.g., hot work permit, confined space entry permit, excavation permits, line-breaking permit) should have been used for a task, but none was written/developed.

## Examples

**Example 1:** A mechanic made a mistake during repair of a security system camera. There was no procedure for the repair process, even though one was supposed to have been developed.

**Example 2:** No procedure was developed for a particular quality assurance inspection. Acceptance requirements existed and were well known. However, each quality assurance technician performed the inspection somewhat differently, resulting in acceptance of components that were outside the specified requirements.

**Example 3:** The facility shipped limited quantities of acids and caustics between two adjacent facilities. No contingency plan had been developed to deal with a potential spill of the materials.

## Typical Recommendations

Review task analyses to identify tasks that require procedures.

Ask new workers about instances where procedures could assist in learning new tasks or in preventing errors.

Ensure that all modes of operation (e.g., temporary shutdown, shutdown for annual maintenance, emergency shutdown, startup after each type of shutdown, initial startup, and temporary operations), all maintenance activities, and all special activities have written procedures.

Develop contingency procedures for anticipated emergency operations.

Develop special procedures to address hazards for units that process extremely toxic or otherwise hazardous chemicals.

For all maintenance tasks and critical repair activities, develop job plans that list:

- The procedures to be applied (typically in the order they are to be used)
- Repair parts and maintenance materials that are needed
- Special tools that will be required
- Special calibration requirements (e.g., note if an instrument used for calibration must be traceable to a national or international standard)
- Certification requirements for personnel involved in doing the work

Develop a written emergency action plan that specifies actions to protect and account for employees, contractors, and visitors.

Establish pre-plans that address the range of accident scenarios that have been identified in the emergency plan.

Develop a written plan or suite of written plans that address emergency management.

## 125 – Procedure Difficult to Obtain

### Definitions/Typical Issues

Was the procedure difficult to access? Were no copies of the procedure available in the designated file, shelf, or rack? Was the “master copy” of the procedure not available for reproduction? Were the copies of the procedures located remotely from where the work is performed? Was procedure use inconvenient because of working conditions (e.g., tight quarters, weather, protective clothing)?

**Note:** This node would also cover the situation where a safe work permit (e.g., hot work permit, confined space entry permit, excavation permits, line-breaking permit) was difficult to obtain.

### Examples

**Example 1:** An operator made a valving error that resulted in an overflow. He did not use the controlled procedure because it would have required him to make a copy of the master. Instead, he used the procedure copy he had at his workstation. This procedure was out of date.

**Example 2:** An electrician was troubleshooting a large breaker. After determining what the problem was, she should have obtained a copy of the procedure for replacement of the charging springs. However, that would have required her to return to the maintenance shop. So she replaced the spring based on memory. As a result, a plant startup was delayed when the breaker failed to close.

### Typical Recommendations

Place copies of operations and maintenance procedures in the appropriate work areas so that the procedures are always available for personnel to use.

Maintain master copies of all procedures and control access to these masters.

Make procedures available to operators at all times.

Provide backup power supplies to computers and printers so that procedures can be printed during power outages.

## **Definitions/Typical Issues**

Was the procedure classified for “training” or “reference”? Based upon the significance or difficulty of the job, should the procedure have been classified as a “use every time” or “must be in hand” procedure?

Was the use of safe work permits discouraged?

## **Examples**

**Example 1:** An operator made a valving error, resulting in a tank overflow. He did not take a copy of the procedure with him because it was for reference only, and he thought he knew how to perform the valving operation.

**Example 2:** A mechanic incorrectly performed a repair job on a key pump without using the procedure. Mechanics were not required to use the procedure in the field because it was for training purposes only. Mechanics were discouraged from using procedures in the field. However, using the procedure in the field would probably have prevented the error made by the mechanic.

## **Typical Recommendations**

Procedures classified as “reference” procedures should contain very few steps. If the number of steps is too overwhelming for short-term memory, it should be classified as a “use every time” procedure.

Training and reference materials may need to be supplemented by:

- Easy-to-carry checklists that parallel the procedure
- More detailed step-by-step procedures for “use every time” if the training and reference manuals are too cumbersome

Have supervisors enforce appropriate use of procedures in the field.

## 127 – Procedure Difficult to Use

### Definitions/Typical Issues

Considering the training and experience of the user, was the procedure too difficult to understand or follow? Did the procedure fail to address the needs of the “less practiced” user?

**Note 1:** Dual coding under *Correct Procedure Used Incorrectly (#131)* may also be appropriate.

### Examples

**Example 1:** An inexperienced mechanic made a mistake installing a piece of equipment. The mechanic did not take a copy of the procedure with him because it was long, it used terminology that he did not understand, and he felt he understood the task well enough.

**Example 2:** The operator did not use the procedure because of its numerous cross-references to other procedures. To carry all of them would have required a large notebook.

### Typical Recommendations

Develop procedures such that the content provides the least experienced employee with adequate direction to successfully complete required tasks.

Choose a procedure format that is easy to read and follow.

Choose a procedure format that is appropriate to the level of complexity of the task.

If certain job aspects require an employee to be in an awkward position or to wear uncomfortable personal protective equipment, make procedure use as convenient as possible by posting applicable procedures at eye level in an easy-to-read format in these specific locations.

If tasks require users to reference a procedure in the field, ensure that employees are provided with a concise yet complete (with no references to other procedures) procedure (or checklist) that is easy to carry and use in the field (like a one- or two-page printout of the pertinent procedure).

**Definitions/Typical Issues**

Was there an issue with the languages used in the facility? Did the front-line workers use a different language than the written procedures?

**Examples**

**Example 1:** An assembly line malfunction procedure was written in English. However, most workers only spoke Spanish. As a result, most assembly line workers did not use the procedure.

**Example 2:** Platform workers primarily spoke Urdu. However, because most supervisors spoke English, most procedures were written in English.

**Typical Recommendations**

Survey workers to determine the predominant languages spoken and read in the facility.

Screen workers for reading/writing capabilities prior to hire.

Provide training on the languages used in procedures and verbal communications.

## 129 – Procedure Difficult to Identify

### Definitions/Typical Issues

Is it difficult to identify the correct procedure to use? Do many procedures have similar names? Was there a failure to clearly distinguish procedures for different units from one another?

### Examples

**Example 1:** An operator used the wrong procedure to start up compressor 3B. Originally, there was one compressor installed, designated as Compressor 3. During modifications to the plant, Compressor 3 was replaced with two compressors of a different type, designated as Compressor 3A and Compressor 3B. However, the procedure for Compressor 3 was still available even though that particular compressor had been removed years earlier. When the operator needed to start up Compressor 3B, he saw the procedure labeled “Compressor 3 Startup” and assumed that it applied to 3A and 3B. The correct procedure, “Startup of Compressors 3A and 3B,” was much farther down the alphabetical list of procedures.

**Example 2:** A mechanic incorrectly calibrated a pressure transmitter. A page from a similar procedure was inadvertently substituted into his calibration procedure. Individual procedure pages did not contain procedure titles or procedure numbers, so the substituted page was difficult to distinguish from the others.

### Typical Recommendations

Include a header at the top of each procedure page that includes the procedure number, page number, procedure revision, and unit number.

Use different-colored paper for each unit’s procedures (i.e., blue for Unit 1, pink for Unit 2).

Provide clear, descriptive names for each procedure.

## Definitions/Typical Issues

Was an older version of the procedure used? Did the procedure user perform the action as described in the previous revision specified rather than the current revision?

## Examples

**Example 1:** An operator liked to use his marked-up version of the procedure because it contained the system operating limits, which were contained in a different document. The operator always checked his personal version for updates, but he missed adding a recent change. As a result, he shut down the process when he performed the procedure incorrectly.

**Example 2:** Revision 6 of a procedure was used instead of the current Revision 7. The operator had printed out the procedure when she was about to begin the work 2 weeks ago. When the task was delayed, she set the procedure aside. When the task came up on the schedule again, she just grabbed the old procedure from 2 weeks earlier.

**Example 3:** Maintenance personnel often made printouts of procedures that they kept at their workstations. That way they did not need to get a new copy of the procedure each time. However, they did not check for updates each time before use. As a result, some procedure steps were missed.

**Example 4:** The facility used a software system to manage their procedures. When the operator obtained the procedure for repair of the pressure transmitter, the search results included the wrong revision of the procedure.

## Typical Recommendations

Ensure that only current copies of procedures are available.

Seek out and destroy old versions of procedures.

Consider incorporating information added by operators to their “personal” copies of procedures.

Provide a means to ensure that previous versions of procedures are not available or used.

Conduct a “tool box” audit to ensure that personal copies of outdated, marked-up copies of procedures are not used by workers in the field.

# 131– Error While Using Correct Procedure

## Definitions/Typical Issues

Was an incident caused by an error made while following or trying to follow a procedure? Was the procedure laid out in the wrong format? Was the procedure misleading or confusing? Was there more than one action per step? Were the procedure graphics inappropriate? Were there language or wording issues that made the procedure difficult to use? Was the procedure too detailed? Was the procedure not detailed enough?

**Note 1:** This node addresses errors that occur while using the appropriate procedure. Use of the wrong procedure is addressed under the ***Correct Procedure Not Used (#123)*** node.

**Note 2:** This node and nodes #132–#139 would also cover the situation where errors were made while using a safe work permit (e.g., hot work permit, confined space entry permit, excavation permits, line-breaking permit).

## Examples

**Example 1:** An operator incorrectly completed a step of a procedure requiring him to open six valves. He skipped one of the valves.

**Example 2:** An operator was calculating the catalyst required for a batch of material. He used the chart incorrectly and added the wrong amount of catalyst.

## Typical Recommendations

Ensure that procedures are in a standard, easy-to-read format.

Ensure that procedures use the appropriate level of detail for the complexity and frequency of a task.

Use look-up tables instead of requiring calculations to be performed.

Use specific component identifiers.

Monitor incident reports for evidence of deviation from established procedures.

## 132– Format Inappropriate

### Definitions/Typical Issues

Did the layout of the procedure make it difficult to follow? Did the format differ from that which the user was accustomed to using? Were the steps of the procedure illogically grouped?

Is the procedure format inappropriate for the task? Is a flowchart used when a checklist is more appropriate? Is a checklist used when a T-bar format is more appropriate?

Are warnings or cautions presented in an inconsistent manner?

Was the procedure user required to carry out actions different from those he was accustomed to doing? Did the procedure fail to identify that the step for the action had been revised?

Were data recorded incorrectly because of poor formatting of the procedure?

Were revised steps difficult to identify?

### Examples

**Example 1:** An operator made a mistake while performing a startup procedure. The procedure was confusing because it required the operator to complete part of section A, then B, back to A, then to C, back to A, then to D and E. The operator failed to go back to A after completing C.

**Example 2:** Each step in the procedure was numbered. Subsequent levels of substeps were numbered by adding a decimal point and another set of numbers. The procedure used too many levels on substeps (i.e., a step was numbered 2.3.6.5.1.1.1.1.5). As a result, the operator skipped a step in the procedure.

**Example 3:** A troubleshooting guide was developed using a checklist format. The mechanics did not understand how to move through the procedure; they just completed the items they thought were appropriate.

**Example 4:** A procedure was developed by an engineer in a paragraph format. About half of the information in the procedure was design information that the operators did not need.

**Example 5:** An operator incorrectly completed a step of a procedure. The operator was experienced and performed the action as he always had. The new procedure (which had been correctly updated) was not marked to indicate that the step had recently been revised, and the operator did not realize that a change had been made.

### **Typical Recommendations**

Ensure that procedures are in an easy-to-read format.

Avoid using the narrative or paragraph format; personnel tend to get lost in a sea of print. The T-bar, flowchart, or checklist formats are highly effective.

Choose one or two effective formats and use these same formats consistently throughout the facility. The format for a troubleshooting guide may be inappropriate for a step-by-step startup procedure.

List procedure steps in a logical, sequential order. Also, be sure that any special precautions are listed at the beginning of the procedure.

Review procedures to ensure that warnings and cautions are presented in a consistent format in all procedures.

Involve procedure users in the procedure development process.

Have an inexperienced user review the procedure to ensure that sufficient detail is provided.

Use checklists for verification processes and initial alignments of systems.

Use flowcharts when decisions affect which part of the procedure is implemented (e.g., a troubleshooting guide, or an emergency procedure that requires diagnosis of the problem).

Clearly identify (such as with a sidebar) which steps/information have changed, and ensure that all employees are trained on or informed of changes.

Identify via a list or description the acceptable formats/structure for all procedures.

Format procedures in a consistent manner and select the best type of procedure for each task.

## 133 – Confusing/Complex/Difficult to Use

### Definitions/Typical Issues

Were data recorded incorrectly because the procedure was confusing/complex or otherwise difficult to use?

Were the instructions in the procedure unclear? Could they be interpreted in more than one way? Was the grammar unclear/complex?

Were the instructions in the procedure unclear? Could they be interpreted in more than one way? Was the language or grammar unclear/complex?

Were data recorded incorrectly because the procedure was ambiguous or confusing?

### Examples

**Example 1:** An instruction called for cutting XYZ rods into 10-foot-long pieces. The intent was to have pieces 10 feet long. The person cutting the pieces cut 10 pieces, each a foot long.

**Example 2:** A step in the root cause analysis procedure stated, “Use the RCM to assist in determining the management system deficiencies that contributed to the event.” The supervisor assumed it meant to use reliability-centered maintenance not the Root Cause Map™.

### Typical Recommendations

Have procedures validated by a team of subject matter experts (workers) and by walkthroughs in the field.

To find difficult steps, have the newest employee walk through the procedure without coaching.

Avoid procedures that require employees to make calculations. Instead, provide employees with precalculated tables or worksheets with easy-to-fill-in blanks and with thorough training in their use. Alternatively, automate calculations within the system.

Allow technical editors to review procedures to ensure that ambiguous terms have been avoided.

Perform a hazard review of critical procedures to determine other accident scenarios related to errors in procedures and to determine whether sufficient safeguards are provided to ensure that employees follow the written procedures.

Ensure that procedures clearly state what to do and, for critical steps or tasks, how to determine whether the step or task was completed correctly.

Develop a procedure numbering or index system that is logical to the end user.

## Definitions/Typical Issues

Did any steps in the procedure have more than one action or direction to perform? Did some steps in the procedure state one action, which, in practice, actually required several steps to perform?

Do warnings or cautions contain information that should be contained in procedure steps? Are important warnings and cautions embedded in procedure steps?

## Examples

**Example 1:** An operator failed to close a valve, resulting in a tank overflow. The instruction to close the valve was one of six actions required in one step of the procedure. She completed the other five actions but overlooked closing the valve, which was the fourth action in the step.

**Example 2:** Most of the computer reset procedure was written in a bulleted format with an action and a check-off box. However, Step 17 was a paragraph description with three embedded actions.

## Typical Recommendations

Avoid broad procedure steps such as “Charge the reactor.” Instead, use this as a subheading and include all the steps associated with charging the reactor below the heading.

Do not assume that an employee will remember all the steps associated with an action item. Clearly communicate all the required steps associated with an action item so that the least experienced employee can successfully perform the required job tasks.

## 135 – Inadequate Checklist

### Definitions/Typical Issues

If a checklist was necessary, was it confusing? Was insufficient room provided for the response? Did each instruction (regardless of format) fail to clearly indicate what was required? Was a detailed checklist required for a task that was not very important? Was an error made because each separate action in a step did not have a check-off space provided (for procedures that are complex and critical enough to require check-offs)?

Were incomplete or incorrect data recorded because numerous items were included in a single step?

### Examples

**Example 1:** An operator failed to complete a step of a procedure. The procedure required a check at the completion of each step. Because it did not require unique responses for the steps, the operator completed the procedure and then checked off all the steps at one time.

**Example 2:** A checklist was designed so that the desirable answer to most questions (23 out of 26) was yes. As a result, the three remaining questions were often answered incorrectly. An operator failed to open a valve.

**Example 3:** The procedure required an operator to open seven valves. He missed one, opening the other six. A separate check-off space for each valve manipulation was not provided in the procedure.

### Typical Recommendations

Develop a checklist for all safety-critical tasks to provide a quick reference for inexperienced and experienced users.

Require that checklists be turned in if necessary for quality assurance.

Avoid using checklists instead of supervision to ensure that tasks are performed correctly because checklists can easily be filled out before or after the task. If supervision is required, then provide a supervisor.

Include the unique system response to be expected when an employee completes each step of a checklist.

Provide enough white space on the checklist so that the employee may record both expected as well as unexpected responses.

Ensure that checklists are only developed for critical tasks. Overuse of checklists will reduce their effectiveness on critical tasks.

For actions that require multiple steps, ensure that all the steps are specifically defined. When appropriate, include a check-off space for each of these individual steps so that the employee can be certain that he/she has performed this step.

When the sequence of operations is important, or when it is important that certain steps be complete prior to moving to the next phase of operation, include a checklist in the procedure that the operator can use to mark that each step is complete.

## Definitions/Typical Issues

Was an error made because graphics or drawings were of poor quality? Were the graphics or drawings unclear, confusing, or misleading? Were graphics, including data sheets, illegible? Would a graphic (diagram, picture, chart, etc.) have significantly reduced the likelihood of this error?

## Examples

**Example 1:** A mechanic replaced the wrong seal on a large piece of equipment. The pump subsequently failed prematurely. The seal that he was to remove was shaded on the drawing, but he could not determine which seal was shaded because the copy was of poor quality.

**Example 2:** An electrician incorrectly terminated a wire. This resulted in problems restarting the system. The wire terminations were shown on the installation diagram. The procedure copy he was using was not legible because it was made from a copy of a copy of the original.

**Example 3:** An operator opened two valves in the wrong sequence during a complex procedure to backwash an enclosed rotary filter containing highly reactive peroxides. A diagram of the filter (showing equipment labels) and proper labeling of the filter valving would have greatly clarified the procedure.

**Example 4:** An operator made an error in determining whether the reactor's temperature and pressure were acceptable. The acceptable temperature was dependent on the pressure. The operator had a long set of look-up tables that listed the acceptable temperature for each pressure. A pressure-temperature graph indicating acceptable and unacceptable regions would have reduced errors.

## Typical Recommendations

For hard-copy graphics that have been reproduced, ensure that the copy is easy to read (e.g., not too dark, too light, or splotchy).

Include color-coding on graphics when possible for easy use.

Ensure that the graphics accurately depict actual process operations and/or equipment configuration.

Do not overwhelm the user with too many graphics on one screen or one sheet of paper. Information should not appear crowded.

The text should support the graphics.

Flowcharts should be used to support decision-making and branching processes.

Include pictures and diagrams where appropriate.

## 137 – Language/Wording Issue

### Definitions/Typical Issues

Did personnel have difficulty using the procedure because of the language used in the procedure? Did the front-line workers speak a different language than the written procedures?

### Examples

**Example 1:** An assembly line malfunction procedure was written in English. However, most workers only spoke Mandarin. As a result, most assembly line workers did not understand the procedure. Supervisors were needed to work with every crew to verbally explain what was in the procedure.

**Example 2:** Platform workers primarily spoke Spanish. However, because most supervisors spoke English, most procedures were written in English. As a result, some of the workers could not understand the details of the maintenance procedures.

**Example 3:** An inexperienced Spanish-speaking worker was injecting too much grease into bearings during maintenance rounds. The procedures said to inject grease into each bearing “once.” “Once” in Spanish means “11.” As a result, he was injecting 11 times as much grease into the bearing as he should have been.

### Typical Recommendations

Survey workers to determine the predominant languages spoken and read in the facility.

Screen workers for reading/writing capabilities prior to hire.

Provide training on the languages used in procedures and verbal communications.

## Definitions/Typical Issues

Did the procedure refer to an excessive number of additional procedures? Did the procedure contain numerous steps of the type “Calculate limits per procedure XYZ”? Was the procedure difficult to follow because of excessive branching to other procedures? Did the procedure contain numerous steps of the type “If X, then go to procedure ABC. If Y, then go to procedure EFG”? Did the procedure contain numerous references to other parts of the procedure?

Did it contain steps of the type, “If the material is acceptable, go to Step 13.3. If the material is unacceptable, go to Step 12.4. If the test cannot be run, redo Step 4 and contact your supervisor”?

## Examples

**Example 1:** An operator exceeded an operating limit. The primary procedure did not contain the limits but referred to four other procedures to find the limits. When checking his results against the limits, he looked at the wrong limit in one of the referenced procedures.

**Example 2:** An operating procedure indicates that personnel should verify the proper operation of the relays in accordance with the original equipment manufacturer’s manual without indicating the document number. However, because the facility used many relays from this same manufacturer, it was difficult to determine which manual was required.

**Example 3:** The operator did not use the procedure because of its numerous cross-references to other procedures. To carry all of them would have required a large notebook.

## Typical Recommendations

List all information that an employee must have in order to perform a specific task in the procedure designated for this task. If the same information is required to perform different tasks, repeat the information in each procedure.

Do not branch to (reference) more than one other procedure (module) from a procedure.

Procedures intended for step-by-step use in the plant/field need to contain all required tasks; an employee is unlikely to return to the file/manual to get any referenced procedure.

Use a flowchart to determine the correct procedure steps to be implemented. Avoid too many jumps within a procedure.

When procedures are interrelated, provide clear, distinct, but not excessive references.

## 139 – Too Much/Too Little Detail

### Definitions/Typical Issues

Do the procedures provide too little detail to ensure proper performance of the task by the most inexperienced operator? Do the procedures have too much detail, such as design details?

### Examples

**Example 1:** The instructions for a computer software program just stated, “Change the loading preferences to user-defined values.” No further directions were provided on how this could be done.

**Example 2:** An engineer developed a procedure in paragraph format. About half of the information in the procedure was design information that the operators did not need.

**Example 3:** An operations procedure for the shutdown of the cooling water system included specific steps on how to close manually operated valves. This information was not needed in the procedure because it was a common operator skill that did not require any task-specific knowledge.

**Example 4:** An inexperienced mechanic made a mistake installing a piece of equipment. The procedure stated only to remove the old item and replace it with a similar unit. This was not detailed enough for the inexperienced mechanic.

### Typical Recommendations

Consider using an outline format with high-level steps for experienced users and detailed steps for inexperienced users.

Provide guidance on content, including what should not be included in procedures. Also, include guidance on what information should be included in related documents such as training or technology manuals.

Refrain from embedding operational steps within a long descriptive narrative that explains the unit or theoretical basis for how the unit operates.

## Definitions/Typical Issues

Was the procedure incorrect? Did the procedure fail to address a situation that occurred during performance of the task? Is the procedure inconsistent with the installed equipment?

**Note 1:** This node and nodes #141-#145 would also cover the situation where errors were made when a safe work permit (e.g., hot work permit, confined space entry permit, excavation permits, line breaking permit) was incorrect or incomplete.

## Examples

**Example 1:** A mechanic made a mistake calibrating a level alarm because the procedure specified the wrong limits. As a result, the alarm failed to annunciate during an emergency.

**Example 2:** An operator ruined a batch of product when he incorrectly operated the computer control system. New software had been installed, but the procedure had not been updated to be consistent with the new software.

## Typical Recommendations

Ensure that procedures are technically reviewed.

Perform a walkthrough of procedures.

Instill a practice of identifying errors in procedures; correct errors in a timely manner.

# 141 – Wrong Action Sequence/Ordering

## Definitions/Typical Issues

Were the instructions/steps in the procedure out of sequence? Were the steps out of order?

## Examples

**Example 1:** An operator made a mistake because the steps were out of sequence in a procedure. Step 5 directed the operator to transfer material from Tank A to Tank B. Step 7 directed the operator to sample the contents of Tank A before transferring.

**Example 2:** To isolate a sludge tank, a drain line was supposed to be closed before opening a flush line. However, the procedure had the operator open the flush line first. As a result, a small amount of sludge was sent down the drain line every time the procedure was implemented.

## Typical Recommendations

Have procedures validated by a team of subject matter experts (workers) and by walkthroughs in the field.

Perform a guideword analysis of procedures to identify out-of-sequence action steps.

Validate new procedures to ensure that they reflect intended practice.

Instill a practice of identifying errors in procedures; correct errors in a timely manner.

## Definitions/Typical Issues

Was specific information in the procedure incorrect? Did the procedure contain out-of-date requirements? Did the procedure fail to reflect the current status of equipment? Were calculations performed incorrectly in the procedure?

Was a typographical error in the procedure responsible for the event?

Was there a failure to incorporate customer requirements into the procedure?

**Note 1:** Errors in graphics are addressed under the *Graphics/Drawing Issue (#136)* node.

**Note 2:** This node addresses the situation where the current procedure content that is out of date or not consistent with the current status of the facility. If the procedure has been revised and the wrong procedure revision was used, use *Wrong Revision Used (#130)*.

## Examples

**Example 1:** A mechanic made a mistake calibrating a level alarm because the procedure specified the wrong limits. As a result, the alarm failed to annunciate during an emergency.

**Example 2:** An operator ruined a batch of product when he incorrectly operated the computer control system. New software had been installed, but the procedure had not been updated to be consistent with the new software.

**Example 3:** A safety limit was violated because the procedure did not contain the current limits. The limits had been changed, but the master procedure had not been revised.

**Example 4:** An operator made a mistake because the procedure contained the wrong limit. The maximum temperature was supposed to be 38°C, but the procedure said 48°C. The mistake was made during typing the procedure and not caught by the procedure validation process.

**Example 5:** An operator overfilled a tank because of a procedure error. The procedure should have stated “Hold the valve open for 3-4 seconds.” The typist inadvertently removed the hyphen (when the spell-checker in the word processing software flagged this potential misspelling) and the procedure then read, “Hold the valve open for 34 seconds.”

## Typical Recommendations

Have procedures validated by a team of subject matter experts (workers) and by walkthroughs in the field.

Perform a hazard review of critical procedures to identify errors in procedures.

Use a word processor to electronically spell-check the procedure immediately after it has been typed.

Allow a technical editor to review procedures for typographical errors.

Allow employees to review procedures for accuracy. Solicit feedback from employees.

Validate new procedures to ensure that they reflect intended practice.

Instill a practice of identifying errors in procedures; correct errors in a timely manner.

Provide a method to quickly make clarifications, correct typographical or grammatical errors, or make other adjustments that improve the procedures.

## 143 – Inconsistent Procedural Requirements

### Definitions/Typical Issues

Did different procedures related to the same task contain different requirements? Were there conflicting or inconsistent requirements stated in different steps of the same procedure? Were requirements stated in different units (i.e., gallons versus liters, meters versus feet)?

### Examples

**Example 1:** An operator exceeded the environmental discharge limits. A caution in the procedure stated the flow rate limit in pounds per hour of material. The procedure step stated the limit in gallons per minute. The operator set the flow rate based on the gallons per minute limit, which was less restrictive in this case.

**Example 2:** The procedure said to send the completed form to the PSM Coordinator, but the form itself had a note on the bottom that said to send it to the operations manager. As a result, the form was misrouted.

**Example 3:** A caution on the cover of a detector stated: “The cover of this detector should not be opened until power is disconnected. However, Step 9 of the procedure said, “After removing the cover, disconnect power to the detector and push the red button to discharge the capacitor.” As a result, the technician received an electrical shock.

### Typical Recommendations

Have procedures validated by a team of subject matter experts (workers) and by walkthroughs in the field.

Develop a system for personnel to report procedure issues.

Validate new procedures to ensure that they reflect intended practice.

Instill a practice of identifying errors in procedures; correct errors in a timely manner.

## Definitions/Typical Issues

Were details of the procedure incomplete? Was insufficient detail presented? Did the procedure fail to address all situations likely to occur during the completion of the procedure? Was a critical step missing?

**Note 1:** This node addresses specific issues that are not included in a procedure. If procedures in general do not have a sufficient level of detail, consider coding under the *Too Much/Too Little Detail* (#139) node.

## Examples

**Example 1:** A mechanic did not correctly replace a pump. The instruction stated to “replace the pump.” Numerous actions were required to replace the pump, including an electrical lockout, which was incorrectly performed.

**Example 2:** A severe decomposition and release of chlorine occurred when the operator failed to check the strength of caustic in the neutralizer. The procedure did not include an instruction for this step, although most experienced operators did perform this check.

## Typical Recommendations

Ensure that all modes of operation, all maintenance activities, and all special activities have written procedures.

Perform a hazard review of critical procedures to identify missing content in procedures.

Establish safe operating limits for each process parameter where deviation from the limit is credible and could lead to an unsafe condition. Also, for each safe operating limit, state the potential consequence of exceeding the limits and the steps to avoid deviation or return the process to a safe condition if there is an excursion outside of the safe operating limits.

Clearly state limiting conditions for each mode of operation (e.g., whether or not to stop processing if certain safety systems are not in service).

Validate new procedures to ensure that they reflect intended practice.

Instill a practice of identifying errors in procedures; correct errors in a timely manner.

## 145 – Overlap or Gaps Between Procedures

### Definitions/Typical Issues

Do multiple procedures cover the same task? Are there gaps between procedures that are used in sequence?

### Examples

**Example 1:** An operator started up the plant air system using the normal procedure. He then discovered a separate procedure specifically for starting up the system. The two procedures had different startup steps. The startup steps in the normal procedure were incorrect. As a result, the plant compressor was damaged.

**Example 2:** The operator started the cooling water system using CW-N-01, Normal Cooling Water System Startup. He then began the startup of three feed pumps using procedure FP-N-01, Startup of the Feed System. Gaps existed between these two procedures. Key steps were missing that were supposed to be performed after startup of the cooling water system and before startup of the feed system. As a result, one of the feed pumps was damaged.

**Example 3:** A booster pump on a pipeline was not included in the maintenance or operations procedures. The divisions upstream and downstream of the pump each thought the pump was the responsibility of the other division. As a result, the pump failed due to lack of maintenance.

### Typical Recommendations

Develop a procedure development plan to allocate tasks between procedures.

Review procedures to determine overlaps between them.

Perform a walkthrough of the procedures to identify overlap or gaps between them.

Validate new procedures to ensure that they reflect intended practice.

Instill a practice of identifying errors in procedures; correct errors in a timely manner.

### **Definitions/Typical Issues**

This intermediate cause category addresses issues related to the design of equipment, systems, and administrative processes. This includes:

- Tools and equipment
- Workplace layout
- Work environment
- Physical workload
- Mental workload
- Error mitigation

Was there a failure to consider the capabilities and limitations of humans in the design, development, production, and control of systems? Is the layout of the workplace inadequate? Is the work environment excessively noisy, hot, or cold? Does the task impose an excessive physical or mental workload? Is it difficult for personnel to detect and correct errors?

Note 1: Issues with the human factors analysis (HFA) program and its implementation should be addressed by ***Proactive Risk/Safety/Reliability/Security Analysis Issue (#104)***.

### **Examples**

**Example 1:** An operator assigned the responsibility of monitoring a computer screen for an entire 8-hour shift failed to detect high level in a tank. As a result, product was unacceptable.

**Example 2:** An operator failed to control the flow rate in a process because the flow rate meter could not be seen from the location where the flow was controlled. As a result, the material produced did not meet specifications.

**Example 3:** An operator inadvertently switched on the wrong pump because all three pump switches looked the same and were not labeled. As a result, the pump was damaged.

**Example 4:** An operator was supposed to open cartons of materials. It was difficult to obtain utility knives from the warehouse (they never seemed to have them in stock), so the operator often used a screwdriver to open the packages. As a result, some of the items were scratched by the tip of the screwdriver.

### **Typical Recommendations**

Locate related controls and indications together.

Provide employees with adequate personal protective equipment such as hearing protection, gloves, and safety glasses. Ensure that the equipment is available in different sizes to ensure a comfortable fit.

Reduce the complexity of control systems.

Provide feedback to operators so that they can tell if actions are performed correctly.

## 147 – Tools/Equipment Issue

### Definitions/Typical Issues

Were the wrong or inappropriate tools supplied for the job? Were the tools in poor condition?

### Examples

**Example 1:** A maintenance helper was assigned the task of checking batteries in smoke alarms in the office areas of the plant. She was not allowed to use a voltmeter to check the condition of the 9-volt batteries (only electricians could use voltmeters). So, she stuck the batteries on her tongue to see if they were still good. As a result, some of the batteries that were thought to be good were not.

**Example 2:** A carpenter was using a hammer with a worn handle. When he was pulling out a nail, the handle broke and the carpenter injured his elbow.

### Typical Recommendations

Provide the proper tools to do the job correctly.

Ensure that worn tools are repaired or replaced.

## Definitions/Typical Issues

Were the proper tools to do the job difficult to access? Were wrong or inappropriate tools used to perform the job?

Were improper tools supplied to do the job? Were the tools in poor condition?

## Examples

**Example 1:** A maintenance helper was assigned the task of checking batteries in smoke alarms in the office areas of the plant. She was not allowed to use a voltmeter to check the condition of the 9-volt batteries (only electricians could use voltmeters). So she stuck the batteries on her tongue to see if they were still good. As a result, some of the batteries that were thought to be good were not.

**Example 2:** A special five-sided sprocket tool was supposed to be used to close a fire hydrant. One was not readily available, so the fire brigade team member used large pliers to close it instead, resulting in damage to the hydrant.

## Typical Recommendations

Provide the right tools for the job.

Ensure that tools are readily available.

Ensure that personnel are aware of how to properly use tools and equipment.

Provide adequate equipment (radios, meters, computers, vehicles, etc.).

Store emergency response equipment in a manner that is easily retrievable.

# 149 – Tools/Equipment Not Functioning Properly

## Definitions/Typical Issues

Were the tools in poor condition? Was there a failure to properly calibrate the tools and instruments?

## Examples

**Example 1:** A technician was calibrating level indicators using a voltmeter. However, the voltmeter was out of calibration because the calibration checks had not been performed on schedule.

**Example 2:** A carpenter was using a hammer with a worn handle. When he was pulling out a nail, the handle broke and the carpenter injured his elbow.

## Typical Recommendations

Ensure that worn tools are repaired or replaced.

Ensure that tools and equipment are properly calibrated before use.

Develop a program for ensuring that instruments and tools are kept in good working order.

## Definitions/Typical Issues

Did inadequate controls or displays contribute to the error? Was poor integration of controls and displays a factor? Did differences in equipment between different processes or areas contribute to the problem? Did poor arrangement or placement of equipment contribute to the incident? Was there a failure to appropriately and clearly label all controls, displays, and other equipment?

## Examples

**Example 1:** In one processing plant, two units performed the same function. Each unit had a separate control room. The control rooms were identical except that they were mirror images of one another. An operator, normally assigned to the first unit, caused a serious process upset when he was assigned to work in the second unit.

**Example 2:** The controller for an automatic valve was located on the front side of a vertical panel. The flow indication for the line was on the back side of the panel. A mirror was installed so that the operator could see the flow indication while adjusting the valve position. However, the reversed image in the mirror caused problems in setting the correct valve position.

## Typical Recommendations

Ensure that operators are provided with sufficient information to control the process.

Locate related controls and indications together.

Follow expected norms in labeling and arranging of controls and indications (e.g., left-to-right, top-to-bottom progression, consistent color codes).

# 151 – Individual Control/Display/Alarm Issue

## Definitions/Typical Issues

Did inadequate equipment controls or control systems (e.g., push buttons, rotary controls, J-handles, key-operated controls, thumbwheels, switches, joy sticks) contribute to the occurrence? Did the control fail to provide an adequate range of control for the function it performs? Was the control inadequately protected from accidental activation? Did one switch control a number of parameters or have different functions under different conditions?

Did inadequate displays or display systems (e.g., gauges, meters, light indicators, graphic recorders, counters, and video display terminals) contribute to the occurrence? Did the display fail to provide all information about system status and parameter values needed to meet task requirements? Did the configuration of the display make information difficult to see or to interpret? Was it necessary for the user to convert information presented by the display prior to using it? Did unnecessary or redundant information contribute to the error?

Was there a failure to develop alarms for critical device failures? Are alarms difficult to hear? Are alarm tiles or computer displays difficult to read? Are alarms poorly arranged or formatted to support situation assessment? Was there a failure to prioritize alarms in terms of criticality to safety and immediacy of required crew response? Are there inadequate controls for alarms, including acknowledgment and reset? For computer-displayed alarms, was there a failure to present alarms in the order in which the initiating condition occurred? Is there alarm overload in the workplace?

**Note 1:** Arrangement of controls is addressed by the *Control/Display/Alarm Integration/Arrangement Issue (#152)* node. The location of controls is addressed by the *Awkward/Inconvenient/Inaccessible Location of Control/Display/Alarm (#153)* node.

## Examples

**Example 1:** The operator of a remotely driven crane inadvertently struck a machine with the load being moved. The keys on the keypad he was using to operate the crane were very small and close together. The operator's fingers, even though they were average size, were too large to accurately press one button without inadvertently pressing the surrounding keys.

**Example 2:** During an emergency, an operator made the incident worse by increasing flow instead of stopping flow. All flow controllers in the plant were moved counterclockwise to reduce flow except for the one involved in this incident. It was moved clockwise to reduce flow. This violated the standard practice at this plant.

**Example 3:** An operator made an error in reading a meter because of the unusual scale progression. Instead of a scale with major markings divided by units of five (i.e., 5, 10, 15, 20), the scale was divided into units of six (i.e., 6, 12, 18, 24).

**Example 4:** A digital display was used to monitor the flow rate of a system. The system responded slowly to control changes. This required the operator to write down values at various times to create a time log. A chart recorder would have been a more appropriate type of display.

**Example 5:** Alarms cannot be heard in the cogeneration unit above the noise when it is in operation. No visible indicator is provided. Therefore, alarms are not communicated to personnel working in the cogeneration unit when the unit is in operation.

**Example 6:** An operator set the flow rate improperly. The procedure specified the flow rate in gallons per minute. The display indicated pounds per hour.

**Example 7:** Operators did not know that a regeneration was taking place in a treater. No indication of the regeneration status was displayed on the computer screen. They just thought that one of the valves had been left open. Closing the valve interrupted the regeneration process. As a result, the treater failed during subsequent use.

### **Typical Recommendations**

Configure controls such that it would be difficult to accidentally activate them.

Ensure that the device/display allows the necessary range of control (e.g., 0-100 GPM control dial would be inappropriate if the flow sometimes required settings as high as 110 GPM).

Ensure that sensitivity of controls allows an operator to quickly and accurately make process changes.

Ensure that displays provide enough information about the process so that the operators can adequately control it.

Configure displays so that they are easy to read and interpret.

Provide direct display of the necessary parameters so that operators do not have to convert the information for it to be usable.

Display only the information that is necessary/helpful to safely and efficiently control the process.

Avoid the use of dual-purpose controls. Provide one control for each parameter being controlled.

Equipment or systems that are critical to safe operation should be equipped with failure alarms.

Make alarms for critical systems and equipment audible, visible, and easy to read to allow personnel to easily assess the situation.

Alarm recording systems should record alarms in order of occurrence.

Place flashing lights in locations where an audible alarm cannot be heard over the surrounding noise.

## 152 – Control/Display/Alarm Integration/Arrangement Issue

### Definitions/Typical Issues

Was there a failure to arrange related controls and displays close to each other? Was a display arranged so that it was obscured during manipulation of the related control? Were control/display relationships unclear to the user? Was the response of a display to control movements inconsistent, unpredictable, or incompatible with populational stereotypes or with the user's expectations? Was there difficulty with multiple displays being affected by a single control? Was there a failure to develop a clear relationship between the controls and the displays? Was there a failure to locate controls near the displays they affected? Is it difficult for the operator to read the display while adjusting the control? Are control/display arrangements inconsistent with populational stereotypes?

Did differences in controls, displays, or alarms between different processes or areas contribute to the event? Were similar controls indistinguishable from one another?

### Examples

**Example 1:** The temperature control had numbers on the dial that ranged from 0 to 100. The temperature indication ranged from 0 to 100°C. However, setting the dial to 75 did not result in a temperature of 75°C.

**Example 2:** The operator incorrectly started pump D instead of pump B. The pump controls are all identical and arranged in reverse alphabetical order from left to right like this: E D C B A. This violates an expectation that controls will be in alphabetical order from left to right.

**Example 3:** The controls for three pumps were arranged differently than the pumps themselves. As a result, the wrong pump was often started.

**Example 4:** There were three sections of lights in the room (front, middle, and back). However, the light switches were not in the same arrangement. The light switch for the lights in the back of the room was located closest to the front of the room.

**Example 5:** Two computer systems, located side-by-side in the facility, were programmed using different color schemes. On the first system, the color red indicated an open valve and green indicated a closed valve. On the second system, green indicated normal and red indicated an abnormal condition. Because of the inconsistency in color-coding between the two systems, an operator who normally worked on the first system allowed a tank to overflow when he was temporarily assigned to the second system. His mindset was that green indicated lack of flow.

**Example 6:** An operator inadvertently started the wrong pump. The cooling water pumps are arranged alphabetically (A-D) from left to right. However, the control panel has the controls arranged as follows:

A C

B D

**Example 7:** In one processing plant, two units performed the same function. Each unit had a separate control room. The control rooms were identical except that they were mirror images of one another. An operator, normally assigned to the first unit, caused a serious process upset when he was assigned to work in the second unit.

### **Typical Recommendations**

Configure the control panel so that it is easy to locate related controls and displays.

Locate displays so that the related control can be manipulated while watching the display.

Ensure that the control and its displays are directly related to one another (i.e., if pressure is displayed, the corresponding control should directly affect pressure as opposed to another parameter, like temperature).

Ensure that each display responds consistently with populational stereotypes when the control is manipulated (e.g., the display shows a quantitative increase when a control is turned clockwise).

Ensure that one display is provided for every control.

Ensure that there is clear mapping between the controls and displays.

Ensure that color codes consistently have the same meaning on all control boards in the facility.

Ensure that identical units have identical control configurations.

Label components in sequential order: ABC not ACB.

Ensure that similar controls have distinguishable features.

## 153 – Awkward/Inconvenient/Inaccessible Location of Control/Display/Alarm

### Definitions/Typical Issues

Were there problems related to the location of controls or displays? Were the controls or displays out of the normal work area? Were the controls/displays difficult or awkward to access? Did the locations of controls make them prone to inadvertent actuation?

### Examples

**Example 1:** A large control handle on a control panel stuck out beyond the edge of the panel when the pump was running. Someone walking past the panel accidentally bumped the switch and shut down the pump. This resulted in a process upset.

**Example 2:** The speed control for a pump was located three floors below the normal operating area. As a result, operators ignored an out-of-tolerance condition because they did not want to go up and down the three flights of stairs.

**Example 3:** The only open space on a control panel was near the floor. As a result, a new chart recorder was installed 6 inches above the floor. To read the display, the operators had to get down on their hands and knees. Sometimes the operators just looked at the display while standing and guessed at the readings.

### Typical Recommendations

Locate controls in convenient locations to encourage their proper use.

Locate displays in convenient locations to encourage their use.

Locate displays so that they can be read by the average person.

Locate controls so that they can be easily operated by the average person.

Locate controls so that they are not accidentally bumped.

## Definitions/Typical Issues

Is equipment (tools, work surfaces, supplies) that personnel need to perform their jobs inconveniently located? Is equipment difficult for workers to access when needed?

## Examples

**Example 1:** An operator needed to make a copy of a procedure to use in the startup of a system. Her printer was out of paper. The paper supply was locked in the supply room and she could not find a key. As a result, she spent 45 minutes locating enough paper by taking it from other printers.

**Example 2:** All tools were returned to a central tool crib each night. As a result, mechanics spent 30 minutes at the beginning of each day obtaining the tools they needed for the day and 20 minutes returning them at the end of the day.

**Example 3:** All batch recipes were supposed to be shredded after use in the field. However, the only shredder was on the other side of the plant. So, many operators just threw them in the wastebasket. As a result, competitors were able to acquire their product recipes.

**Example 4:** A worker operating an automatic lift inside a glove box was required to operate two sets of hand controls simultaneously. These controls were located on the exterior of the glove box. One set of buttons, located on the left of the glove box, controlled the up/down motion of the lift. The other set, located on the right side, controlled side-to-side motion. While operating the left-side controls, it was necessary for the operator to have one hand in a gloveport to balance the load. The load on the lift fell when the operator momentarily removed his hand from the gloveport to operate the controls.

**Example 5:** A worker was injured during assembly operations. The work surface was too low for the worker to maintain proper posture while performing the task.

## Typical Recommendations

Ask workers about problems they have encountered in locating needed tools or equipment.

Locate tools and supplies so that workers will have access to them when needed. Consider back shift and weekend access.

Review workstations to ensure that proper ergonomics are being implemented.

# 155 – Poor/Illegible Labeling of Control/Display/Alarm or Equipment

## Definitions/Typical Issues

Was there a failure to appropriately and clearly label all controls, displays, or other equipment items that had to be located, identified, or manipulated by the user while performing a task? Did labeling fail to clearly identify equipment? Did labeling incorrectly identify equipment? Were labels hard to read, incorrect, or misleading? Were labels in a language that is unfamiliar to the user? Were parts, raw materials, or finished products not labeled or mislabeled?

## Examples

**Example 1:** An operator selected the wrong valve from a configuration of 20 valves because more than half of the valves in the group were unlabeled. The adhesive used to attach labels to the valves was not reliable in the acidic environment in which the valves were located; therefore, many of the labels had fallen to the floor. The operator tried to determine which was the correct valve using the labels that remained attached.

**Example 2:** An operator opened the wrong valve, causing a transfer error. The label was positioned between two valves, forcing the operator to choose between them.

**Example 3:** A row of bins in the warehouse contained different types of bolts. The labels for the bins had part numbers on them, but no equipment descriptions. As a result, some items were incorrectly restocked after being returned to the warehouse.

**Example 4:** As a result of improper labeling, a type of grease was placed into inventory on the wrong shelf in the supply room. Subsequently, a pump failed when this grease was used instead of the one specified for that pump.

**Example 5:** A new supplier was selected to supply product barrels to the facility. Barrels from the new supplier were cheaper but only came in one color (black). This caused shipment problems because different-colored barrels had been used previously to easily identify the barrel contents. Purchasing did not realize the importance of the color-coding.

## Typical Recommendations

Ensure that all controls and displays are labeled correctly.

Ensure that labels are made using an easy-to-read font and are color-coded if necessary.

Locate all labels close to the related control/display.

Maintain labels as necessary (clean, ensure reliable adhesive, etc.).

Ensure that equipment locations and locations of materials are properly labeled.

Ensure that equipment bins in the warehouse are properly labeled.

Ensure that the relative position of controls and their labels is consistent.

Develop standards for labeling, color-coding, and posting operator aids.

Apply consistent labeling and color-coding to all equipment.

Apply special labeling and color-coding to all safety-critical equipment.

Ensure that color codes consistently have the same meaning on all equipment in the facility.

## Definitions/Typical Issues

Did poor housekeeping contribute to the problem? Did excessive vibration or excessive noise contribute to the error? Was the problem caused by difficulties associated with protective clothing? Were there other stressors present in the work area that may have contributed to the problem (e.g., movement constriction, high jeopardy, or risk)?

## Examples

**Example 1:** An operator received a cut to her head when she bumped into an overhead pipe. The lighting in the area was not sufficient to detect overhead obstacles.

**Example 2:** A step was skipped during performance of a job. The operator hurried through the job because it required him to wear a respirator and work in a confined space. None of the available respirators fit comfortably.

## Typical Recommendations

Remove unused equipment and piping.

Provide employees with adequate personal protective equipment such as hearing protection, gloves, and safety glasses. Ensure that the equipment is available in different sizes to ensure a comfortable fit.

Reduce work environment stresses such as noise, vibration, excessive temperatures, and poor lighting.

## 157 – Housekeeping Issue

### Definitions/Typical Issues

Did poor housekeeping conditions contribute to the incident? Was the error caused by a cluttered work environment? Was an unsafe situation created by a sloppy workplace?

### Examples

**Example 1:** A mechanic received a puncture wound to his hand when he reached into a toolbox and came into contact with an open penknife. The toolbox was full of old rags and crumpled paper; therefore, the mechanic was unable to detect the hazard.

**Example 2:** An operator needed to check the operating records from a couple of months ago. The records were stored on CDs. The CDs were labeled but were just thrown in a drawer. As a result, it took the operator 25 minutes to locate the correct disc.

### Typical Recommendations

Ensure that work areas are maintained in a clean, organized manner.

Remove (demolish) unused equipment and piping.

Provide storage locations for all equipment, supplies, and tools.

Use 5S principles to help organize the workplace.

State housekeeping expectations and enforce them.

## 158 – Ambient Conditions Issue

### Definitions/Typical Issues

Was the incident caused by excessive exposure of personnel to a hot or cold environment? Was poor ventilation (i.e., poor air quality or inadequate air velocity) a contributor to the incident? Was the effect of rain, snow, etc., a factor?

Was the incident caused because illumination levels were not sufficient for task performance? Did the level of illumination vary greatly over a given workstation? Was the error caused by failure to provide supplemental lighting for personnel performing specialized visual tasks in areas in which fixed illumination was not adequate? Was there shadowing of labels, instructions, or other written information? Was there a problem with glare or reflection? If the event occurred during an emergency, such as loss of power, was emergency lighting inadequate?

Was the incident caused by diminished human performance caused by excessive noise? Were personnel unable to hear auditory signals or alarms because of excessive background noise? Did auditory distraction, irritation, or fatigue of personnel result from excessive noise?

### Examples

**Example 1:** During an extreme cold spell, a mechanic damaged an expensive piece of equipment by dropping a tool into its moving parts. Even though the mechanic was wearing gloves, his hands were so cold that he was unable to get a firm grip on the tool.

**Example 2:** A serious incident occurred when glare caused by improper overhead lighting prevented an operator from detecting that an important alarm was illuminated.

**Example 3:** During a loss of power event, an operator was injured while attempting to troubleshoot the emergency generator. Lighting levels from the control room to the generator were insufficient, and he tripped on the forks of a forklift on his way to the generator.

**Example 4:** A computer operator failed to respond to a system alarm because background noise from the computer's cooling fans masked the auditory alarm signal.

**Example 5:** A jackhammer operator was injured when he dropped his jackhammer on his foot. He had been using the tool for several hours without relief, and the constant vibration caused his hands to "fall asleep." This weakened his grip and caused him to lose control of the jackhammer.

**Example 6:** Working in a confined space contributed to an incident because personnel rushed through the job to get out of the high-risk environment.

### **Typical Recommendations**

Ensure that indoor work areas are adequately ventilated and heated/cooled.

Allow personnel to take frequent breaks if they are required to work in an uncontrolled, uncomfortable climate for extended periods.

Consider the need for roofing or walls over work areas for which protection from wind and precipitation reduces the hazards of operation and maintenance.

Solicit comments from employees regarding workstation lighting. Appropriately address any comments received.

Provide glare-free screens for computer monitors.

Conduct an emergency drill at night and use emergency lighting. Solicit employee feedback to determine whether the lighting is adequate for emergency operations/evacuation.

Install additional equipment to diminish workplace noise when possible (e.g., mufflers, sound enclosures).

Post danger signs in areas in which noise is in excess of 85 dB to alert employees to wear hearing protection in those areas.

Ensure that emergency alarms and the emergency public address system can be heard throughout the process area.

When possible, reduce certain physiological and psychological stresses such as:

- Pain or discomfort caused by seating, etc.
- Hunger or thirst
- Vibration
- Movement constriction
- Disruption of circadian rhythm
- Perceived threat (e.g., of failure or job loss)
- Monotonous, degrading, or meaningless work

# 159 – Protective Clothing/Equipment Issue

## Definitions/Typical Issues

Did protective clothing or equipment (e.g., plastic suit, gloves, respirator) contribute to the difficulty? Did protective clothing or equipment significantly diminish any of the senses (i.e., sight, touch, smell, hearing, or taste) necessary to perform the task? Were personnel required to wear protective clothing or equipment for an excessive length of time? Were personnel required to dress in and out of protective clothing an excessive number of times?

Was there a problem with protective equipment, such as safety glasses/safety goggles, fall protection harnesses, personal gas monitors/gas monitoring equipment, radiation monitors/radiation badges, respirators (supplied air [self-contained breathing apparatus - SCBA] or filtered-air respirators), welding helmets/welding goggles, etc. Did the equipment malfunction? Was the equipment insufficient or inappropriate for the task? Was the equipment not used?

## Examples

**Example 1:** An operator wearing a full-face respirator was injured when he walked into the path of a forklift. The respirator reduced his peripheral vision; therefore, he did not see the forklift coming from his left side.

**Example 2:** An operator using an overhead crane allowed the load to collide with operating equipment. The protective gloves he was wearing prevented him from accurately manipulating the crane's controls.

**Example 3:** An operator splashed some alkaline catalyst onto his hands, causing a severe chemical burn, while manually loading the catalyst into a vessel. The operator was wearing gloves, but the gloves were not chemically resistant.

## Typical Recommendations

Install engineering controls to eliminate or reduce the need for protective clothing or equipment.

Ensure that protective clothing is available in different sizes so that all employees can be properly fitted.

If several consecutive tasks require that protective clothing be worn for a long time, investigate the possibilities of using more comfortable protective clothing (e.g., looser or tighter fit) or protective clothing made with more comfortable material (e.g., "breathable" fabric, ventilated suits).

If protective clothing diminishes senses required to complete the task, investigate altering the clothing, if possible, so that personnel can perform their duties more effectively.

## Definitions/Typical Issues

Were the physical demands of the task beyond the capabilities of the personnel? Did the tasks require an excessive amount of strength or did the task cause repetitive stress injuries?

Was the worker rushed to get the job done? Was there pressure to get the job done to allow the system to be restarted? Did he/she perceive that he/she was at risk?

**Note 1:** Dual coding under the *Supervision Issue (#185)* node may also be appropriate.

**Note 2:** Consider dual coding under the *Awkward/Inconvenient/Inaccessible Location of Control/Display/Alarm (#153)* and/or *Awkward/Inconvenient/Inaccessible Equipment Location (#154)* nodes.

## Examples

**Example 1:** Personnel in the warehouse stacked 30-pound boxes of finished product onto pallets. They were assigned to work 8-hour shifts with three breaks. Worker stress injuries were frequently occurring just prior to the break periods.

**Example 2:** During a startup, an operator had to climb several towers in quick succession to take readings and check valve alignments. While descending one of the personnel access ladders, he became fatigued. His foot slipped off one of the ladder rungs and he fell a few feet to the grating below.

## Typical Recommendations

Make the system more stable to reduce the number of control adjustments required.

Increase the frequency and/or length of break periods.

Provide a remote means of actuating the component or performing the task. For example, provide a control for a heater in the control room in addition to the local control.

Automate the task to reduce the physical burden placed on personnel.

Modify the system to provide mechanical assistance in performing the task (e.g., cranes, lifts, carts).

# 161 – Sustained High Workload/Fatigue

## Definitions/Typical Issues

Were personnel fatigued (i.e., worn out) by extended periods of high physical workload? Was the person fatigued due to chronic physical workload?

## Examples

**Example 1:** The thickness of a sheet material needed constant monitoring and adjustment by the operator (15 to 20 times an hour). The adjustment required a great deal of force to be applied to the adjustment wheel. As a result, operators sometimes did not make the required adjustments.

**Example 2:** Personnel in the warehouse stacked 30-pound boxes of finished product onto pallets. They were assigned to work 8-hour shifts with three breaks. Worker stress injuries were frequently occurring just prior to the break periods.

## Typical Recommendations

Automate the system so that an employee is not required to constantly manipulate controls.

Make the system more stable to reduce the number of control adjustments required.

Increase the frequency and/or length of break periods.

Have personnel perform stretching and warm-up exercises prior to starting work.

Rotate workers assigned to tasks to vary the physical work.

Consider methods to allocate tasks to a machine instead of a human.

Automate the task to reduce the physical burden placed on personnel.

Modify the system to provide mechanical assistance in performing the task (e.g., cranes, lifts, carts).

## Definitions/Typical Issues

Were personnel fatigued (i.e., worn out) by a short-term high level of physical work?

## Examples

**Example 1:** A 20" feed line in a tank farm had to be manually isolated. This involved closing two remotely controlled valves and one manual isolation valve. While closing the manual isolation valve, the mechanic had to stand on the line itself. He closed the valve as quickly as he could so he could get to lunch on time. During the last couple of turns to close the valve, he became fatigued, lost his balance, and fell to the ground.

**Example 2:** During a startup, an operator had to climb several ladders in quick succession to take readings and check valve alignments. While descending one of the personnel access ladders, he became fatigued. His foot slipped off one of the ladder rungs and he fell a few feet to the grating below.

## Typical Recommendations

Implement methods to provide equipment to assist workers in performing the task.

Implement methods to allow equipment to perform the task instead of a human.

Modify the system to eliminate the need to perform the task.

## 163 – Mental Workload Issue

### Definitions/Typical Issues

Was the error caused by a complex situation or system? Were system controls so complex that they contributed to user error? Did the system impose unrealistic monitoring or mental processing requirements? Did a successful outcome depend upon a novel decision?

### Examples

**Example 1:** Eight maintenance tasks were in progress at the same time. The control room operator had to perform some steps for each of these tasks. He was to transfer the contents of tank A to tank B to support one of the maintenance tasks. While he was involved with another task, he lost track of the tank level and tank B overflowed.

**Example 2:** The audible alarm on the toxic gas detector was inoperable. An operator was assigned to watch the toxic gas meters for an entire 8-hour shift to detect a toxic gas release. The operator failed to notice a release when it occurred.

**Example 3:** A line had to be flushed to clear out some contaminants. This process was only performed a few times a year. No procedure was developed for this process because it was performed so infrequently. The operator used his best judgment in performing the lineup but failed to close one valve. The backflow through this line resulted in an exothermic reaction in one of the supply tanks.

**Example 4:** During an upset condition, the operators misdiagnosed the situation. As a result, they implemented procedure ABN-001 instead of ABN-002.

### Typical Recommendations

Provide tools to make decision making easier and to reduce the chances of human error.

Reduce the complexity of control systems.

Do not place workers in situations requiring extended, uneventful vigilance.

### Definitions/Typical Issues

Was the error caused by a complex situation or system? Could better system design eliminate the error? Do personnel have to recall infrequently used information to adequately perform the task? Did the task require that personnel commit extensive amounts of information to memory? Should information have been provided on the equipment or in a procedure?

Was the error due to the need for excessive mental processing by personnel? Were personnel required to work through complicated logic sequences or other written instructions? Were personnel required to carry out mental arithmetic? Did a successful outcome depend upon a novel decision?

Were the system or equipment controls excessively complex? Could the system have been designed with simpler controls so that the chance of error was reduced?

Note 1: The use of skill-based, rule-based, and knowledge-based behaviors refers to terms used in the S-R-K human performance model. See ABS Group's [Human Error Prevention](#) course for more information on this terminology.

### Examples

**Example 1:** During an emergency, more than 80% of the annunciator tiles in the control room illuminated at once. The operators on duty were used to responding to a single alarm at a time using very specific procedures. In this situation, they did not have enough specific knowledge of how the various systems interacted; therefore, they were at a loss in determining the appropriate response to the situation. As a result, the operators responded to a few alarms in the wrong priority, worsening the situation. In this case, knowledge of the overall system was required.

**Example 2:** The clock on a data-recording unit needed to be advanced 1 hour for the switch to daylight savings time. The process for doing this was not obvious as there were no time-set buttons on the device. No procedure or directions were available for this task either. As a result, the operator tried a number of different ways before succeeding.

**Example 3:** A line had to be flushed to clear out some contaminants. This process was only performed a few times a year. No procedure was developed for this process because it was performed so infrequently. The operator used his best judgment in performing the lineup but failed to close one valve. The backflow through this line resulted in an exothermic reaction in one of the supply tanks.

**Example 4:** In order to determine the amount of acid to add to a particular mixture, an operator was required to take readings from three meters and perform a mental calculation. The operator made a mental error in performing the arithmetic and added the wrong amount of acid to the tank. As a result, the product was out of specification.

**Example 5:** An operator was attempting to determine whether the present plant condition was acceptable. To do this, the operator had to determine the pressure and temperature of a vessel, then use a 20-page table to determine whether the vessel had adequate subcooling by determining the saturation temperature for the pressure of the vessel. Then he compared the vessel temperature to the saturation temperature. This task could have been simplified by using a graph, a job aid, or letting the plant process computer perform the task. This task had been performed incorrectly several times in recent months.

### **Typical Recommendations**

Modify system design to eliminate knowledge-based decision making.

Ensure that enough time is provided to complete the knowledge-based decision.

Provide tools (such as decision trees or flowcharts) to make decision making easier and to reduce chances of human error.

Provide adequate staffing to assist in making a knowledge-based decision.

Reduce the complexity of the control system demands on the operator.

Provide workers with the information they need (e.g., procedures, calculated tables) instead of relying heavily on their mental capabilities (e.g., memory, mental calculations).

Provide the information that workers need in the simplest form possible.

Provide information in the most direct form possible. Examples include the following:

- Provide a flow rate instead of the output of a square root instrument and conversion table
- Provide a mass flow rate instead of a load cell output for a tank and stopwatch
- Provide tank level indication instead of flow rate into the tank, flow rate out of the tank, and a watch
- Provide acceptable parameter ranges (i.e., 75-85 psig) instead of error allowances (i.e., 70 psig  $\pm$  5 psig)
- Provide subcooling values rather than temperature, pressure, and subcooling look-up tables

Anticipate the types of conditions workers may encounter and provide the information they will need under each of these conditions.

Seek out expertise when making critical decisions.

Appoint a technology steward for each type of process operated by the company.

Appoint a technology steward for broader technology areas that are critical to the company, such as corrosion, inspection of fixed equipment, predictive maintenance methods, etc.

Establish organizational processes to create, acquire, interpret, transfer, and retain knowledge.

Ensure that those authorizing deviations from standard procedures are well aware of the hazards and have a sense of vulnerability.

Ensure that persons authorized to approve abnormal operations have the (1) training and experience to understand a wide range of hazards and (2) knowledge of well-established methods to manage risk associated with the hazards.

## 165 – Rule-based Behavior Issue

### Definitions/Typical Issues

Was the issue caused by blind application of a rule or procedure? Was the issue caused by the inappropriate application of a rule or procedure?

Note 1: The use of skill-based, rule-based, and knowledge-based behaviors refers to terms used in the S-R-K human performance model. See ABS Group's [Human Error Prevention](#) course for more information on this terminology.

### Examples

**Example 1:** The alarm limits for cooling water flow were set very close to the normal values. The alarm went off frequently. The operators learned to ignore the alarm because it was part of normal operations. As a result, when cooling water flow stopped because of a failed pump, the operators did not respond.

**Example 2:** The procedure for shutting down lines A and B were slightly different. Line B was shut down frequently. Line A was rarely shut down. As a result, when operators shut down line A, they used the procedure for line B. This resulted in dumping 1,000 pounds of product on the floor.

**Example 3:** A supervisor did not contact the contracts administrator, as he was supposed to, when purchasing some spare parts. Normally, he did not have to work through the contracts administrator to purchase parts. As a result of omitting the step, some mandatory inspection requirements were not included in the contract.

**Example 4:** Operators did not perform a lockout/tagout for a simple valve repair. The repair was only going to take about 10 minutes and they had performed this same task numerous times before.

### Typical Recommendations

Avoid situations that appear similar but require different actions to be taken.

Provide error-proofing to alert operators that their actions are incorrect.

Ensure that procedures for similar tasks are distinctive.

Provide information at the point of use that provides the directions/procedure for the task.

## Definitions/Typical Issues

Was the issue caused by the automatic (skill-based) response of a worker to a situation?

Note 1: The use of skill-based, rule-based, and knowledge-based behaviors refers to terms used in the S-R-K human performance model. See ABS Group's Human Error Prevention course for more information on this terminology.

## Examples

**Example 1:** An operator was distracted during a startup process when a mechanic came by to discuss last week's football game. As a result, he performed the steps for shutting down the equipment instead of starting up the equipment.

**Example 2:** Although the parts were not the same color, as they should be, assembly line personnel continued to assemble vegetable cutters. As a result, they assembled 227 half-red/half-blue vegetable cutters.

**Example 3:** When acknowledging an alarm, an operator read the alarm as High Outlet Temperature T303, when the alarm actually said, High Outlet Temperature T803. T303 had been alarming frequently over the last few days and required no action. When T803 alarms, numerous local actions are required. As a result of the operator doing nothing in response to the alarm, a fired heater (i.e., a heater that uses a flammable gas as the heat source) was damaged.

## Typical Recommendations

Avoid situations that appear similar but require different actions to be taken.

Provide error-proofing to alert operators that their actions are incorrect.

Provide a means to automate the task.

Provide clear, unambiguous feedback.

## 167 – Unrealistic Monitoring Requirement

### Definitions/Typical Issues

Were personnel required to monitor multiple variables at once, causing overload or failure to notice important information? Could the error be attributed to loss of alertness because of the excessive length of a monitoring task?

### Examples

**Example 1:** An operator given the responsibility for temporarily monitoring the alarms for another unit allowed a tank to overflow. He acknowledged the audible level alarm for the tank, which resulted in muting of the horn. He meant to return to the problem; however, an alarm from one of the other systems sounded, and his immediate attention was required there. The tank associated with the first alarm overflowed before he was able to take appropriate action.

**Example 2:** A radar operator was given the responsibility of monitoring a screen for planes during an entire 8-hour shift. During a normal shift, no planes enter his radar space. As a result of a decrease in vigilance, the operator failed to identify an intruder into his air space late in his shift.

**Example 3:** Because of reductions in staffing levels, an operator was given the added responsibility of monitoring the operation of the flare system that serves several units, including his own. The operator can easily perform these duties during normal operations; however, during nonroutine modes of operation (e.g., startup), the operator is unable to monitor the flare system because of increasing responsibilities in his own unit. Inattention to the flare system caused the flare system to fail to function properly, allowing a release of unburned process material to the atmosphere.

**Example 4:** Eight maintenance tasks were in progress at the same time. The control room operator had to perform some steps for each of these tasks. He was to transfer the contents of tank A to tank B to support one of the maintenance tasks. While he was involved with another task, he lost track of the tank level and tank B overflowed.

**Example 5:** The audible alarm on the toxic gas detector was inoperable. An operator was assigned to watch the toxic gas meters for an entire 8-hour shift to detect a toxic gas release. The operator failed to notice a release when it occurred.

### Typical Recommendations

Automate the system so that personnel are not required to monitor several variables simultaneously. However, provide enough employee interaction with the system to keep personnel alert.

Do not place workers in situations requiring extended, uneventful vigilance.

Ensure that staffing levels are adequate for normal, abnormal, and emergency operations.

## Definitions/Typical Issues

Were personnel unable to detect errors (by way of alarms or instrument readings) during or after the occurrence? Was the system designed such that personnel were unable to recover from errors before a failure occurred?

## Examples

**Example 1:** An operator was simultaneously filling two large vessels with gasoline. While attending to one of the vessels, he allowed the other one to overflow because no level alarms or indicators were provided to let him know that the vessel was reaching its capacity.

**Example 2:** An operator thought he closed a valve on the feed line to a tank. However, the valve stem was binding and the valve was half-open. No position indicator was provided for the valve, and no flow indication was provided for the line.

## Typical Recommendations

Ensure that important safety- and quality-related equipment is adequately equipped with error-detection systems.

Provide feedback to the operator so that he/she can tell whether procedure steps are performed correctly.

Design tasks and equipment to allow time to detect and correct errors for safety- and quality-critical tasks and equipment.

## 169 – Errors Not Detectable

### Definitions/Typical Issues

Were personnel unable to detect errors (by way of alarms or instrument readings) during or after the occurrence? Did a serious error go unnoticed because no means were provided to monitor system status?

Should multiple or redundant sources of critical information have been provided? Is there an inadequate update rate for sensed information (e.g., flow rates, tank levels)? Should methods or procedures have been provided to test and verify information? Should alternate means to acquire and verify information have been provided? Are components and devices needed to verify information not available in the area where the situation assessment is performed?

**Note 1:** Consider dual coding with the *Workplace Layout Issue (#150)* node.

### Examples

**Example 1:** An operator intending to stop flow to a tank accidentally closed the wrong valves. No level alarm was provided on the tank to indicate that overflow was imminent (indicating the operator closed the wrong valve); therefore, the tank overflowed.

**Example 2:** A warehouse stock person obtained the wrong bolts for a job. The bolts were in bins that were only labeled with the part numbers; no part descriptions were included. Small parts like these were not labeled with part numbers. As a result, the stock person could not verify that the materials in the bin were the ones that were supposed to be there.

**Example 3:** An operator attempted to open a block valve underneath a relief valve. The gate separated from the stem, so even though the valve appeared open (based on stem position), the gate was still closed and obstructing the pressure relief valve inlet. No other means was available to determine the position of the valve.

**Example 4:** A temperature indicator was indicating a low outlet temperature for a cooling system. However, the temperature indicator had failed low. There was no ready means for the operator to determine that the indication was wrong. As a result, the operator did not put the backup cooler into operation as required.

### Typical Recommendations

Ensure that important safety-related equipment is adequately equipped with error-detection systems.

Ensure that systems important to reliability and quality are equipped with error-detection systems.

## Definitions/Typical Issues

Was the system designed such that personnel were unable to recover from errors before a failure occurred?  
Was there insufficient time to respond (i.e., take action) to address or correct the situation?

## Examples

**Example 1:** A computer operator started an automatic operating sequence controlled by a distributed control system before the valving lineups in the process area had been completed. Even though operators in the field called in to tell the operator to stop the operation, the computer was not programmed to allow interruption of the sequence once it started. As a result, process flow was routed to waste.

**Example 2:** During startup, the operator failed to check the tank level prior to starting the pump. Shortly after starting the pump, a low tank alarm occurred, indicating insufficient level for the pump drawing suction from the tank. By the time the operator was able to stop the pump, the pump was already damaged.

**Example 3:** Samples were drawn from each batch prior to shipment. However, the batches were often sent out before the analysis of the samples was complete. As a result, when a sample indicated an unacceptable batch, the delivery could not be stopped before it reached the customer. The customer had to be called and asked to ship the batch back.

**Example 4:** A high-level alarm sounded in the control room. To prevent an overflow, the operator had to locally shut down a pump. By the time the operator was able to get to the location of the pump, the tank had already started to overflow.

**Example 5:** A low temperature alarm on a heater activated. The operator immediately began to increase fuel gas flow to the heater to bring temperature back up. However, before the temperature could be stabilized, the heater tripped out on low temperature.

## Typical Recommendations

Design safety- and quality-related equipment so that the detected errors can be corrected before system failure occurs.

Design tasks and related procedures to allow employees time to detect and correct errors for safety- and quality-critical tasks.

Modify equipment to go to a safe state or mode when problems are detected.

Design equipment to recover from abnormal conditions with no or limited human intervention.

Develop means to alert personnel to situations requiring attention sooner in order to allow additional response time.

Modify the system to reduce the time required to travel to the location where the task needs to be performed. For example, use a valve handle extender to allow a valve on the third level to be operated from the first floor.

Provide a remote means of actuating the component or performing the task. For example, provide a control for a heater in the control room in addition to the local control.

Modify the system to allow additional response time. For example, reduce fill rates to allow additional response time following a high-level alarm.

# 171 – Training/Personnel Qualification Issue

## Definitions/Typical Issues

This intermediate cause category addresses issues related to the training and qualification of personnel, including all training that is the responsibility of the company to provide to company personnel, contractors, and third-party personnel.

Was there a failure to provide training on the task? Was the training insufficient to perform the task? Did the training fail to correspond to the actual work environment?

## Examples

**Example 1:** A solvent tank overflowed because the operator had not been trained on how to calculate liquid levels of tanks. Training was not required because it was assumed to be a “skill of the trade.” However, the operators were not experienced with solvents and solutions with specific gravities less than water.

**Example 2:** Management decided to only train one mechanic to repair a special digital processor used in the lab. However, while this mechanic was on vacation, the digital processor broke and another mechanic had to fix it. The untrained mechanic broke several other parts of the processor during her “repair” work.

## Typical Recommendations

Provide training in the hazards of the process and job tasks.

Provide refresher training on appropriate tasks.

Solicit comments from the trainees after they have been on the job for 3 months to identify “holes” in the training program.

Ensure that instructors are properly qualified.

Provide training on tasks critical to safety, reliability, and quality.

Develop a formal training policy.

Develop a written procedure for managing the training management system that describes the process for creating, updating, and maintaining training materials.

Include specific roles and responsibilities in the management system procedure governing training.

Review incident investigation results and correct any root causes related to training program deficiencies.

Establish and promote an environment that encourages workers to develop a thorough understanding of their process.

**Definitions/Typical Issues**

Was there a failure to develop training on the task? Was there a failure to conduct the training? Did the individual(s) involved in the incident fail to receive training? Was there a failure to identify the training requirements? Was a decision made to not train on the task?

**Examples**

**Example 1:** A solvent tank overflowed because the operator had not been trained on how to calculate liquid levels of tanks. Training was not required on this task because it was assumed to be a “skill of the trade.” However, the operators were not experienced with solvents and solutions with specific gravities less than water.

**Example 2:** An operator made a mistake in weighing materials. A new computerized scale had been installed a month before. Training was not provided in the use of the new scale even though it was significantly different from the mechanical type that had been used in the past.

**Typical Recommendations**

Provide training in the hazards of the process and job tasks.

Provide refresher training in appropriate areas.

Provide a written description of the training requirements associated with a specific job title.

Provide training on tasks critical to reliability, safety, and quality.

Hold periodic technical seminars on subjects related to process safety, reliability, quality, safety, security, and other organizational programs.

## 173 – Decision Not to Train

### Definitions/Typical Issues

Was the decision made to not provide specific training on a task? Were some employees not required to receive training? Was experience inappropriately considered to be a substitute for training?

### Examples

**Example 1:** A solvent tank overflowed because the operator did not know how to calculate the liquid level. The operator was not required to receive training because he had years of experience working in a similar facility. However, the previous facility did not use solvent, and the operator did not have experience with solutions with specific gravities less than water.

**Example 2:** A solvent tank overflowed because the operator had not been trained on how to calculate liquid levels of tanks. Training was not required on this task because it was assumed to be a “skill of the trade.” However, the operators were not experienced with solvents and solutions with specific gravities less than water.

**Example 3:** Management decided to only train one mechanic to repair a special digital processor used in the lab. However, while this mechanic was on vacation, the digital processor broke and another mechanic had to fix it. The untrained mechanic broke several other parts of the processor during her “repair” work.

### Typical Recommendations

Provide training in the hazards of the process and job tasks associated with normal operations, nonroutine operations, and emergency operations.

Provide training for maintenance tasks such as inspection, testing, calibration, preventive maintenance, repair, replacement, and installation.

Provide annual refresher training for all employees in their assigned duties.

If experience is used as a substitute for training, consider (1) performance testing and (2) reviewing prior experience to ensure that it matches current job requirements.

## **Definitions/Typical Issues**

Was there a failure to identify training on the task as part of the employee's training requirements? Was there a failure to define the necessary training for the job?

Did the organization fail to perform a job/task analysis? Did it incorrectly identify the knowledge and skills necessary to complete the task? Did it fail to identify all the steps required to successfully complete the task?

Was training on the issue overlooked?

## **Examples**

**Example 1:** A technician made an error when analyzing a sample of material. The job/task analysis did not identify the need to dry the sample as part of the sample preparation. As a result, no training was provided on this task.

**Example 2:** An operator overflowed a solvent tank because he did not know how to calculate liquid levels. The operator had transferred from a similar facility, and the training required for his present assignment had not been defined. Since the other facility did not use solvent, the operator did not have experience working with solutions with specific gravities less than water.

**Example 3:** Although reliability was a key issue for the organization, there were no requirements for personnel to have reliability training. No training needs assessment for reliability training had been performed.

## **Typical Recommendations**

Identify all of the specific duties associated with each job title. Include pertinent topics associated with these duties within the corresponding training module.

Perform a job/task analysis to identify all knowledge, skills, and abilities (KSA) required to perform the job. For each KSA, determine appropriate training requirements.

Provide a written description of the training requirements associated with a job title, including relevant safety, reliability, quality, security, and other program requirements.

Identify required certifications for unique qualifications such as for welders, heavy equipment operators, nondestructive testing technicians, etc., and ensure that required documentation of such certifications is maintained.

Ensure that similarly situated contractor personnel receive training comparable to that given to their company employee counterparts.

Include the contract workforce in any relevant emergency response drills.

# 175 – Training Requirements Not Completed

## Definitions/Typical Issues

Was there a failure to provide the required training? Did failure to complete all required training contribute to the incident?

## Examples

**Example 1:** The company established an organized program of safety training to be carried out in a 4-month cycle. The training included the viewing of videos followed by an actual drill or walkthrough to familiarize personnel with the facility's actual equipment and arrangements. The supervisor often ended the training with the video and did not follow through with the drill or walkthrough. When a fire broke out in the cogeneration unit, personnel were not familiar with the operation of the ventilation dampers and their locations and the operation of the CO<sub>2</sub> fire extinguishing system. As a result, a couple of dampers were left open. After the cogeneration unit was evacuated and CO<sub>2</sub> was subsequently released into the space, the fire was reignited by the natural air draft flowing through the open dampers.

**Example 2:** Personnel were supposed to complete monthly training on lessons learned from recent incidents. However, the supervisor decided not to allocate time during crew meetings to this task.

**Example 3:** A contractor was supposed to complete orientation training for six new welders so they would be ready to go when the equipment was removed from service. This request was never communicated to the contractor, so the six new welders were not trained and not on site when the equipment was removed from service.

## Typical Recommendations

Review training records of new personnel against requirements to determine what training/retraining needs exist and plan training to fulfill those needs.

Require that each employee complete the training and qualification associated with his/her job title before performing specific job tasks unsupervised.

Establish an organized program of training, including drills, to address likely emergencies and ensure that training is provided to personnel on a schedule that ensures that an adequate number of personnel are prepared to respond at any time to a variety of emergencies.

Include the contract workforce in any relevant emergency response drills.

## **Definitions/Typical Issues**

Were job/task analyses inadequate? Were the program design and objectives incomplete? Did the training organization have inadequate instructors or facilities? Is refresher training performed properly? Does testing inadequately measure the trainee's ability to perform the task? Does training fail to include normal and abnormal/emergency tasks?

## **Examples**

**Example 1:** A solvent tank overflowed because the operator did not know how to calculate the liquid level of solutions with specific gravities less than water. The training included instruction in how to calculate the liquid level but did not include testing to determine whether the operator could perform the calculations.

**Example 2:** An operator made a mistake in weighing material because he used the scale incorrectly. The scale he used in training was the previous model and it had key differences from the one used on the job.

**Example 3:** A mechanic made a mistake when repairing a pressure transmitter. Some transmitters had special seals so they would work in high-humidity environments. The job/task analysis did identify that training would be needed for these different types of transmitters.

## **Typical Recommendations**

Perform job/task analyses for routine jobs/tasks.

Solicit comments from the trainees after they have been on the job for 3 months to identify “holes” in the training program.

Ensure that training is provided in all required settings (i.e., classroom, computer-based training, on-the-job training, simulator).

Ensure that on-the-job training consists of “doing” rather than just “watching.”

Provide refresher training for nonroutine tasks.

# 177 – Training Program Design/Development Issue

## Definitions/Typical Issues

Did the training program fail to equip the trainees to perform the task? Did it contain improper amounts of classroom and on-the-job instruction?

Did the training objectives fail to satisfy the needs identified in the task analysis? Did the objectives fail to cover all the requirements necessary to successfully complete the task? Were the objectives written at incorrect cognitive levels?

Did the lesson content fail to address all the training objectives? Did the lessons fail to contain all of the information necessary to perform the job? Was the lesson material inconsistent with the current system configuration and procedures?

**Note 1:** This node addresses the design and development of the training program, including:

- Translating the job task analysis into training documents
- Developing learning objectives
- Developing lesson plans
- Determining the appropriate settings (i.e., classroom, laboratory, simulator, on-the-job) for training

Implementation of the training in these various settings is addressed by nodes #176-184.

## Examples

**Example 1:** An operator made a mistake in weighing material to be added to a solution. The operator had received classroom training on the task but had not received laboratory or on-the-job training on how to use the scale because the training program design did not indicate that training was required in these settings.

**Example 2:** An operator opened the wrong valve during an emergency. In training, the operator had read the procedure but had never performed the procedure in the plant or on a simulator; nor had he performed a walkthrough. None of these were required by the training program.

**Example 3:** An operator made a mistake weighing material because he used the scale incorrectly. The task analysis identified that training was required on the use of the scale, but the training objectives did not include it; therefore, training did not stress this skill.

**Example 4:** An operator overfilled a tank. The training objectives for this system required the operator to list the components in the system but did not include an objective to explain the function and operation of the control system.

**Example 5:** An operator made a mistake weighing material because of incorrect use of the scale. The lesson plan did not address training on the scale, although it was in the lesson plan objectives.

**Example 6:** An operator made an error in determining the amount of material to add to a batch. The scale he used was installed 6 months before. The training he received on the system the previous month had not incorporated the new scale into the lesson content.

**Example 7:** Classroom training was developed based on the original equipment manual. However, the configuration of the installed equipment was significantly different. As a result, the classroom training was incorrect.

**Example 8:** Laboratory training was developed for the use of electrical testing equipment. However, the training used an older version of the equipment. As a result, it did not cover a key calibration step.

## **Typical Recommendations**

Consider conducting a job/task analysis for some jobs/tasks that may seem trivial or routine.

Include all pertinent information in the job/task analysis, including job skills required to perform the task, the sequence of task steps, and hazards of performing each task.

Conduct a walkthrough of the job/task while performing the analysis in order to trigger thoughts concerning the skills required to complete the task and the correct sequence of completing the steps.

For skill-related tasks, provide employees with classroom and on-the-job training. After completion of the training, have the trainee physically demonstrate all tasks (without receiving direction) to ensure that the trainee can adequately perform the task.

After completion of a training module, have trainees evaluate the program design. Solicit comments to improve the program design.

Establish an overall training management system that assigns certain individuals the responsibility for:

- Analyzing training needs for each job title
- Establishing training criteria for each job title
- Designing curricula to meet training needs
- Continually assessing and improving the training program

Using the job/task analysis, define and document training objectives so that employees will be equipped with sufficient skills to perform their assignments successfully.

Ensure that trainees understand training objectives at the start of each new training module.

Ensure that objectives are written at the correct cognitive level. For example, the objective should be written as “Use the laboratory scale to weigh a sample” rather than “Explain how a sample is weighed.” The technician’s job is to perform the task, not merely to explain how to do it. Knowing and doing are on two different cognitive levels.

Ensure that the lesson content for each training module addresses learning objectives to ensure complete understanding of the required tasks.

Periodically evaluate work practices in the field to verify that they are consistent with training.

Provide a means to ensure that training materials are updated to reflect changes in the process.

Identify jobs and tasks that are performed by each worker (or logical group of workers).

Identify the knowledge, skills, and abilities required to successfully perform each job and task.

Perform gap analyses between job candidates’ skills and required skills.

Perform gap analyses between job incumbents’ skills and required skills.

Categorize training requirements for knowledge-based, rule-based, and skill-based tasks consistent with the written operating and maintenance procedures.

Organize training modules into logical courses of study.

Identify how each training module can be presented (e.g., live, videotape/DVD, interactive computer) and where the training should take place (e.g., classroom, shop/lab, simulator, operating unit, off site).

Prepare/acquire course plans, presentations, and exercise materials.

Review the quality of course plans, presentations, and exercise materials.

Identify what training must be completed before a worker or visitor can enter the facility.

Identify what training must be completed before a worker can begin on-the-job training.

## 178 – Classroom Training Issue

### Definitions/Typical Issues

Was there a failure to conduct classroom training in accordance with the training program design? Were unskilled personnel used to perform the instruction? Was the training inconsistent with desired practice? Did the training fail to reflect the current practice? Was there insufficient classroom training?

### Examples

**Example 1:** Classroom training on the new computerized maintenance management system was about 20 minutes long. It did not cover key aspects regarding work request closeout that were included in the lesson plan.

**Example 2:** The instructor who taught the facility-siting course was not familiar with the topic. She simply read the slides during the course. As a result, many of the trainees performed the facility siting calculations incorrectly.

### Typical Recommendations

Ensure that training is conducted by qualified instructors.

Ensure that classroom training addresses all of the learning objectives.

Ensure that classroom training is consistent with the desired practice.

Ensure that classroom training is current.

## **Definitions/Typical Issues**

Was there a failure to conduct laboratory/practical training in accordance with the training program design? Were unskilled personnel used to perform the instruction? Was the training inconsistent with desired practice? Did the training fail to reflect the current practice? Was there insufficient laboratory/practical training?

## **Examples**

**Example 1:** Practical training on the use of the new computerized maintenance management system was about 15 minutes long. It did not cover key aspects regarding work request closeout that were included in the learning objectives.

**Example 2:** The instructor who taught the work request processing system in the computer lab was not familiar with the process used to document as-found conditions during calibration tasks. As a result, the students did not cover this during their training.

## **Typical Recommendations**

Ensure that training is conducted by qualified instructors.

Ensure that laboratory/practical training addresses all of the learning objectives.

Ensure that laboratory/practical training is consistent with the desired practice.

Ensure that laboratory/practical training is current.

Practice the emergency action plans.

Train incident commanders and all emergency response team members on all of the skills needed to effectively and safely mount an emergency response or rescue effort.

Periodically conduct tabletop exercises or other actions to train managers and other personnel who would help manage the crisis but are not directly involved in the tactical emergency response activities.

Periodically conduct drills to assess the (1) effectiveness of the plan and (2) state of readiness of the emergency response team.

Conduct a formal critique using independent, experienced observers.

## 180 – On-the-job Training Issue

### Definitions/Typical Issues

Did the on-the-job training (OJT) fail to provide opportunities to learn the skills necessary to perform the job? Was OJT insufficient? Did OJT fail to cover unique and unusual situations or equipment to avoid surprising the operator later on? Were OJT trainers not qualified to perform the training?

### Examples

**Example 1:** An operator made a mistake weighing material because of incorrect use of the scale. He had received classroom instruction but no on-the-job experience in using the scale even though OJT was required for the task.

**Example 2:** Four furnaces were installed in a boiler house. They had each been installed at different times as the plant expanded. The control systems were similar but had significant differences. During OJT, the operator only operated two of the four furnaces even though a walkthrough was required to be performed on all four. As a result, the operator accidentally shut down one of the furnaces shortly after he was “qualified.”

**Example 3:** A clerk incorrectly entered a customized order into the computer. During OJT, the instructor had shown her the wrong way to perform the task.

### Typical Recommendations

Ensure that OJT consists of actually “doing” rather than only “watching.”

Match trainees with experienced personnel who can explain not only how to perform certain tasks, but also why certain tasks are performed.

Ensure that OJT covers unique and unusual situations or equipment.

Ensure that OJT addresses emergency operations.

Instill a practice of challenging workers randomly with “what-if” scenarios and having them walk through their response.

## **Definitions/Typical Issues**

Was there a failure to conduct self-study and computer-based training in accordance with the training program design? Was the training inconsistent with desired practice? Did the training fail to reflect the current practice? Were the training materials unavailable? Was there insufficient self-study/computer-based training?

## **Examples**

**Example 1:** A generic computer-based training program was purchased to perform hazardous materials training. However, the training did not address some specific hazards at the facility.

**Example 2:** A self-study course was purchased from the valve manufacturer to complete training on valve maintenance. However, the training materials were too general and not detailed enough to address the needs of the maintenance personnel.

**Example 3:** A computer-based training program was purchased to address pressure transmitter calibration training needs. The training contained a number of errors. As a result, personnel were unable to calibrate certain transmitters.

## **Typical Recommendations**

Ensure that training is conducted by qualified instructors.

Ensure that self-study and computer-based training address all of the learning objectives.

Ensure that self-study and computer-based training are consistent with the desired practice.

## 182 – Continuing Training Issue

### Definitions/Typical Issues

Was there a failure to perform continuing training to keep employees up to date on performing nonroutine tasks? Was the frequency of continuing training inadequate or inappropriate?

Was there a failure to provide training when the work methods for a task were changed? Was there a failure to provide training on changes to procedures for the task? Was there a failure to provide training on new equipment used to perform the task?

### Examples

**Example 1:** An operator made a mistake weighing material because he used a scale incorrectly. The scale on which he was trained had been replaced with a newer model, and no training had been provided on the new model.

**Example 2:** A mechanic had trouble reading a graph with a logarithmic scale. The graph had been recently added to the procedure. The training department had not been notified of the change and did not identify the need to provide training on this topic.

**Example 3:** A member of the fire team had trouble getting the foam system actuated. He received training on the system when he was hired 5 years before but had not received any refresher training since then.

### Typical Recommendations

Provide all personnel with refresher training for routine and nonroutine tasks associated with their job assignments (for operations, this would include training on startup, shutdown, troubleshooting, emergency shutdown, and safe work practices).

Consult employees regarding the frequency of training. Should the training be conducted more often? Less often? Should the content of refresher training be revised?

Provide additional training for new procedures, procedure modifications, and process modifications involving new equipment.

Ensure that training on new work methods includes instructions that relate to nonroutine tasks (changes to startup, shutdown, emergency operations, etc.).

Verify understanding of continuing training to the same degree that is required for initial training (classroom exams, physical demonstration, etc.).

Perform emergency drills and exercises.

Periodically evaluate whether workers are retaining the necessary knowledge, skills, and abilities to perform their jobs.

Identify when refresher training must be performed (both to retain skills and to meet any regulatory requirements).

## **Definitions/Typical Issues**

Was the training equipment inadequate? Was there a failure to use simulators or demonstration components? Was there a failure to use equipment in training that was the same as that used on the job? Were the instructors and other personnel providing the training inadequate? Do the instructor qualifications fail to require the instructor to be able to perform the task? Was the instructor who performed the training unqualified on this task?

## **Examples**

**Example 1:** An operator made a mistake weighing material because he used a scale incorrectly. The scale he had used in training was different from the one he used on the job.

**Example 2:** A mechanic had trouble repairing a transmitter. The repair required the operator to wear gloves and a respirator. When he had practiced during training, he did not wear any protective clothing because the training department did not have any of the required protective clothing.

## **Typical Recommendations**

Use simulators when possible to provide personnel with hands-on experience.

If simulators are not a viable option, use models (perhaps computer models) instead. Ensure that the models are similar enough to the real equipment to avoid confusion (e.g., if a control button is actually red on the control panel, make sure it appears red on the cardboard model).

When possible, use the same equipment in training that will be used on the job. Personal protective equipment is a good example.

Ensure that proper facilities and training equipment/supplies are available for training and conducive to learning:

- Video equipment
- Overhead projectors
- Interactive workstations
- Distraction-free classrooms

Provide guidance for determining instructor qualifications.

Review current instructor qualifications for adequacy. Address any deficiencies that are found. Ensure that instructors are properly qualified.

Define the qualifications for a trainer.

### Definitions/Typical Issues

Do personnel filling positions that require a certification or qualification fail to have the current and valid certification or qualification? Is the certification or qualification expired? Is it a forgery?

Did the testing fail to cover all of the knowledge and skills necessary to do the job? Did the testing fail to adequately reflect the trainee's ability to perform the job? Was on-the-job demonstration not part of qualification or was the demonstration not thorough enough?

Has the worker's certificate, endorsement, or license expired or is it otherwise invalid?

### Examples

**Example 1:** A load was damaged during a lift. The operator was supposed to have a certificate to operate the crane. However, the operator's certificate had expired.

**Example 2:** The master of a vessel was supposed to have a certificate for the class of vessel he was operating. However, he only had a certificate for smaller vessels.

### Typical Recommendations

Review the qualifications of personnel prior to hire.

Periodically review certificates/qualifications of personnel to ensure that they are current.

Verify that the trainee fully understood the training in some tangible manner (such as a classroom exam, physical demonstration without direction, oral exam, working with an experienced employee who is able to evaluate the trainee's performance).

Ensure that understanding of all areas of the lesson content is verified (including both complex task skills and rudimentary skills).

Develop methods for testing job applicant qualifications.

Develop methods for testing trainee progress toward and achievement of minimum acceptable performance standards.

Identify remedial training requirements for those who fail or lose their initial qualification.

Identify skills and abilities that require periodic testing to assure performance.

Identify methods for testing qualified/experienced workers.

Develop a database or matrix of qualification requirements and periodically update it.

**Definitions/Typical Issues**

This intermediate cause category addresses issues related to supervision of personnel, including job preparation and supervision during the performance of the work.

Did immediate supervision fail to provide adequate preparation, job plans, or walkthroughs for a job? Was there a failure to identify potential problems identified before the work began? Were inappropriate personnel selected and scheduled for the task? Did immediate supervision fail to provide adequate support, coverage, or oversight during job performance? Did supervisors fail to correct improper performance? Did personnel fail to work together as a coordinated team?

**Examples**

**Example 1:** An operator failed to respond properly to an alarm because he was covering for two unit operators simultaneously. This was required because his immediate supervisor did not schedule enough control room operators to cover the shift operations.

**Example 2:** Operators were supposed to perform plant rounds at least once per shift and generate work requests for any equipment that was inoperable or needed repairs. Often the operators skipped the rounds when it was cold or raining even though the rounds were still required. Supervisors knew what was occurring and did nothing to correct the situation.

**Typical Recommendations**

Adopt a standard job plan format.

Distribute duties equally among similarly skilled/trained personnel.

For nonroutine jobs or jobs that require specific safety precautions, encourage supervisors to oversee the job and provide job support as necessary.

Encourage supervisors to provide more supervision to less experienced workers.

Ensure that supervisors correct improper performance.

### Definitions/Typical Issues

Did immediate supervision fail to provide adequate preparation, job plans, pre-job briefing, or walkthroughs for a job? Was there a failure to identify potential interruptions or special circumstances before the work began? Were inappropriate personnel selected and scheduled for the task? Was responsibility for the different portions of the job task not clearly assigned?

### Examples

**Example 1:** Late in the shift, a first-line supervisor instructed a mechanic to repair a valve in a confined space. However, his supervisor failed to schedule anyone else to assist with the entry. To get the job done before the end of the shift, the mechanic entered the confined space alone.

**Example 2:** A job required the coordinated effort of the operators, mechanics, and electricians. The electricians were the lead group on the project. The electrical supervisor failed to arrange for support from the other two groups. As a result, the job took six additional hours to complete.

### Typical Recommendations

Ensure that supervisors understand their role in providing a job plan for subordinates.

Adopt a standard job plan format.

Distribute duties equally among similarly skilled/trained personnel.

Verify that personnel have the credentials to complete the task before assignment.

## Definitions/Typical Issues

Did immediate supervision fail to provide proper preparation (e.g., instructions, job plan, pre-job briefing, walkthrough) for the task performed? Did immediate supervision provide an incorrect, incomplete, or otherwise inadequate job plan for performance of the work?

Did immediate supervision provide incorrect, incomplete, or otherwise inadequate job instructions before the beginning of work?

**Note 1:** This node addresses the overall directions (written and verbal) to workers. The *Ineffective Walkthrough (#188)* node addresses showing personnel how to perform the task in the field.

Note 2: This node addresses the overall directions (written and verbal) to workers. Problems with procedures, including safe work permits, are addressed by the **Procedures (#122)** section of the Map.

## Examples

**Example 1:** An immediate supervisor sent her crew out to paint stripes in a parking lot. No instructions were given for the job. As a result, the crew used the wrong color paint to stripe the lot. In addition, the resulting parking spaces were not of adequate size to accommodate anything bigger than compact cars.

**Example 2:** A new unit was undergoing its first turnaround. During the turnaround, maintenance personnel contaminated the replacement catalyst because of handling/loading errors. The new catalyst required special handling precautions that the crew was not aware of. The turnaround plans were the same as for the old unit that was replaced and did not provide for special handling of the new catalyst.

**Example 3:** An electrician was instructed to check the potential transformer on the main generator. His supervisor meant to tell him to check the potential transformer on an emergency generator. When the electrician opened the access panel on the main generator, the plant shut down.

## Typical Recommendations

Ensure that supervisors understand that it is their responsibility to provide subordinates with instructions and/or a job plan and to conduct walkthroughs when appropriate (to show workers the location of equipment, discuss the proper sequence of steps, etc.).

Provide supervisors with written job descriptions so that responsibilities are clearly communicated and documented.

Provide coaching to supervisors whose job preparation skills need improvement.

Establish an administrative procedure that requires all supervisors (including contract supervisors) to provide their subordinates with a job plan that includes instructions necessary for completing nonroutine job tasks.

Establish a facility-wide job plan format to ensure that all necessary information is included in the job plan. Train supervisors on how to give instructions and how to verify that instructions are understood.

Provide periodic leadership training for supervisors.

## 188 – Ineffective Walkthrough

### Definitions/Typical Issues

Did immediate supervision fail to perform an adequate walkthrough (show workers the location of equipment, discuss operation of the equipment and the proper sequence of steps, etc.) with the workers before they started their job?

**Note 1:** This node addresses showing personnel how to perform the task in the field. The ***Job Plan/Instructions to Workers Issue (#187)*** node addresses the overall directions (written and verbal) provided to workers.

### Examples

**Example 1:** A team of expert mechanics was assembled to install a special piece of equipment in a new facility. Although these were experienced mechanics, they were unfamiliar with both the facility and the specific piece of equipment. The immediate supervisor assumed that, because these mechanics were experts in their field, they did not need to be “stepped through” the job. However, the job required some special precautions, and the mechanics damaged the equipment because they were not shown the specific problem areas before starting the job.

### Typical Recommendations

Encourage supervisors to show workers the location of equipment involved in the job task.

Encourage supervisors to discuss operation of the equipment and the sequence of steps involved in nonroutine job tasks.

## Definitions/Typical Issues

Was the work scheduling system inadequate? Was there a failure to use the work schedule for implementing work? Was there a failure to consider the impact of safety and reliability on the work scheduled?

**Note 1:** This node addresses the scheduling of work activities only, not the scheduling of personnel to accomplish the work. Problems with scheduling of personnel are addressed under the *Personnel Selection/Assignment/Scheduling Issue (#190)* node.

## Examples

**Example 1:** A scheduling system was developed by the maintenance planner; however, because there were too many panic repairs, the schedule was never followed. No one actually used the scheduling system to determine the priorities of the work that was performed.

**Example 2:** A tank overflowed during filling because the automatic shutoff valve failed to close. An earlier inspection found that the level switch for the valve was defective, but the equipment deficiency had never been entered into the work scheduling system.

**Example 3:** A job required the coordinated effort of the operators, mechanics, and electricians. The electricians were the lead group on the project. The electrical supervisor failed to arrange for support from the other two groups. As a result, the job was delayed for 4 hours.

## Typical Recommendations

Develop and utilize a job tracking system.

Provide access to the scheduling system for all personnel who need the information to make good decisions.

Limit access to the work tracking/scheduling system to authorized personnel (e.g., use a password for an electronic system, lock system documentation in a filing cabinet and distribute keys only to authorized personnel).

Provide controls and limits in the work scheduling system to avoid overscheduling of work.

Plan repair and maintenance activities so that they will be executed in a timely manner with adequate technical and logistical support.

# 190 – Personnel Selection/Assignment/Scheduling Issue

## Definitions/Typical Issues

Did immediate supervision fail to select capable workers to perform the job? Did workers assigned to the task have inadequate credentials? Were insufficient numbers of trained or inexperienced workers assigned to the task?

Were too many concurrent tasks assigned to workers? Were duties not well distributed among personnel? Were personnel fatigued because they were assigned too many tasks (work was not well distributed among an adequately sized staff)? Were individuals required or allowed to work an excessive number of hours or overtime?

**Note 1:** This node addresses the assignment of personnel to work tasks only, not the scheduling of work activities. Problems with scheduling of work activities are addressed under the *Job Scheduling Issue (#189)* node.

**Note 2:** This node addresses the assignment of existing or qualified workers to job tasks. For example, the selection of a laborer from a preapproved pool of individuals would be covered by this node. It does NOT address the hiring or preselection processes. Employee hiring is addressed by the *Personnel Hiring Issue (#209)* node.

## Examples

**Example 1:** Three technicians were assigned to a shift. Normally, at least one senior technician was assigned as the lead technician on each shift to plan and help coordinate the work. On the back shift, an older but inexperienced technician was assigned as lead technician even though he was not qualified.

**Example 2:** As a result of inadequate planning by a first-line supervisor, a control room was staffed by one trained operator and five trainees. Because the trained operator was continuously stopped by the trainees to answer questions, he missed an important step in his own procedure. This caused a significant period of downtime in the facility.

**Example 3:** Four mechanics and three electricians were assigned to install a new compressor. There was only enough work to keep two of the mechanics and one electrician busy. The remaining four workers just sat around and watched the others work.

## Typical Recommendations

Before assigning any employee to a task, verify that the employee has the credentials to successfully complete the task.

Ensure that the individual assigned to a task matches the experience level required to effectively and safely perform the task.

Provide supervisors with the means to quickly determine whether workers are qualified for a task.

Provide supervisors with an adequate number of employees to effectively and safely complete the tasks assigned for the shift.

Distribute duties equally among similarly skilled/trained personnel.

Consider the amount of time and concentration required to perform each task.

Assign individuals fewer responsibilities for tasks that require more time and concentration.

## **Definitions/Typical Issues**

Did the lack of definition of responsibility and authority contribute to the incident? Was responsibility for the operation unclear? Was the incident the result of conflicting authority? Could responsibility or authority for the operation be understood in more than one way? Was a lack of specificity in responsibility and authority a contributing factor to the incident or its mitigation? Did confusion exist over who was responsible for the activity? Did an activity exist for which no one took responsibility? Did the lack of documented responsibility and authority contribute to the incident?

## **Examples**

**Example 1:** A technical limit for the length of time allowed between air flow checks on a stack exhaust system was violated. The operations department considered the checks to be maintenance items. The maintenance department considered the checks to be an operations item. Responsibility for the checks was not defined.

**Example 2:** The responsibility and authority of some shore management personnel were not documented within the company's management system. As a result, new shipboard officers only became familiar with who was responsible for what by word of mouth. This sometimes resulted in confusion about who to contact concerning various shipboard issues.

## **Typical Recommendations**

Review operations where responsibility and authority are assigned to more than one person, and ensure that the descriptions are specific enough to eliminate confusion.

Provide sufficient detail within descriptions of responsibility and authority to fully clarify what is encompassed.

Develop a means of quickly resolving responsibility and authority conflicts if they arise.

Establish responsibilities and reinforce accountabilities for safety, reliability, quality, security, and other program roles.

Give personnel the necessary authority and support commensurate with their responsibilities.

## 192 – Supervision During Work Issue

### Definitions/Typical Issues

Did immediate supervision fail to provide adequate support, coverage, oversight, or supervision during job performance?

Was there a lack of coordination between workers? Were there overlaps or gaps in the work that was assigned to different groups or team members?

**Note 1:** The investigator must judge what level of supervision was appropriate based on the importance of the job in relation to safety and production. It is not possible or practical to provide continuous supervision on every job.

### Examples

**Example 1:** A first-line supervisor was in her office performing audits of completed procedures. She told the operator in the control room to contact her if problems arose. The operator, a newly qualified person on the job, did not want the supervisor to think that he did not know what he was doing, so he “took his best guess” when he was unsure. By the time the supervisor came to the control room to check on the operator’s progress, a significant amount of product had already been lost to the waste stream.

### Typical Recommendations

For nonroutine jobs or jobs that require specific safety precautions, encourage supervisors to oversee the job and provide job support as necessary.

Encourage supervisors to provide more supervision to less experienced workers.

## Definitions/Typical Issues

Do supervisors fail to correct improper performance when they observe it or know about it? Did they let improper performance slip “just this once”? Are there insufficient methods for supervisors to detect improper performance?

## Examples

**Example 1:** A supervisor noticed an operator in the process area who was not wearing a hard hat or safety goggles. The supervisor was just passing through the area and did not say anything to the operator.

**Example 2:** Operators were supposed to perform plant rounds at least once per shift and generate work requests for any equipment that was inoperable or needed repairs. Often the operators skipped the rounds when it was cold or raining even though the rounds were still required. Supervisors knew what was occurring and did nothing to correct the situation.

## Typical Recommendations

Correct the behavior when improper performance is observed or is known by supervision. If supervision knows a task is being performed incorrectly and does not correct it, workers will continue to perform the task incorrectly.

Enforce existing rules and requirements. If the rule is important enough to exist, it should be enforced. If it's not important enough to enforce, eliminate the requirement.

Establish and enforce high standards of performance.

Establish a system to routinely inspect work areas to determine whether (1) safe work permits are being followed, (2) permit conditions appear to be appropriate, and (3) permit conditions are being followed. Correct deviations from practices/procedures whenever they are noticed.

## 194 – Teamwork/Coordination Issue

### Definitions/Typical Issues

Was there a lack of coordination between workers? Were there overlaps or gaps in the work that was assigned to different groups or team members?

**Note 1:** This node addresses teamwork issues for the personnel assigned to perform the task. If the wrong personnel were assigned to perform the task, code under the *Personnel Selection/Assignment/Scheduling Issue (#190)* node.

### Examples

**Example 1:** Work was being performed on two different portions of a pipeline. The work performed at one booster station affected the work being performed at the receiving station. Because the work of the two groups was not coordinated, a small release of material from the pipeline occurred.

**Example 2:** Operators were supposed to take a pump out of service so that maintenance personnel could perform work on it. However, when maintenance personnel went to get authorization to start work on the work request, they discovered that operations had not done anything to the pump. As a result, the maintenance work was delayed until the next day.

### Typical Recommendations

On tasks that require coordination of work, ensure that tasks are assigned to team members and that an adequate means of communication is provided between workers.

For work that requires coordination of multiple work groups (i.e., operations, maintenance, and chemists), ensure that there are clear methods and means for exchanging information between work groups.

Coordinate tasks between different work groups. Develop a work plan prior to beginning the work. Foster a sense of mutual trust between workers.

Encourage teamwork.

## Definitions/Typical Issues

Did immediate supervision provide inadequate support, coverage, or oversight during performance of the job? Was an inadequate level of supervision provided at the job site? Was contact with workers too infrequent? Did direct supervision's involvement in the task interfere with the supervisory overview role?

**Note 1:** The investigator must judge what level of supervision was appropriate based on the importance of the job in relation to safety and production. It is not possible or practical to provide continuous supervision on every job.

## Examples

**Example 1:** A mechanic was told by his immediate supervisor to “fix the leak” in a tank containing a hazardous chemical. The supervisor gave him no instructions on how to perform the task and did not provide any oversight of the work activities. Because of the mechanic’s lack of understanding about the hazards associated with this job, he allowed the chemical to come into contact with his skin. This caused severe burns.

**Example 2:** During the installation of a new computer system, the immediate supervisor of the responsible crew became so interested in installing the central control unit that he picked up a screwdriver and became involved in the work. As a result, he ignored those members of the crew who were installing the auxiliary unit. Some important checks were missed on the auxiliary unit; therefore, it failed upon startup.

## Typical Recommendations

For nonroutine job tasks or for tasks that require specific safety precautions, encourage supervisors to remain at the job site to provide coverage for the entire job, or at least visit the job site frequently to provide direction as necessary.

Encourage supervisors to give their supervisory role priority over assisting others in actually performing the job task.

Ensure that supervisors understand their responsibilities to provide more supervision to less experienced workers. Make supervisors available to subordinates so that they can ask questions about job tasks.

# 196 – Verbal and Informal Written Communication Issue

## Definitions/Typical Issues

This intermediate cause category addresses issues related to verbal and informal written communications. It includes communications using the following methods:

- Face-to-face
- Telephone
- Radio
- Short written messages
- E-mails
- Signs/labels
- Hand signals

It does not address more formal methods of communications like procedures, logs, and design specifications.

Was the problem caused by a failure to communicate? Did a method or system exist for communicating between the groups or individuals? Was an error caused by misunderstood communication between personnel? Was there incorrect, incomplete, or otherwise inadequate communication between workers during a shift or between workers during a shift change? Was there a problem communicating with contractors or customers?

**Note 1:** Communications is defined as the act of exchanging information. This node addresses many informal modes of communication (e.g., face-to-face, telephone, radio, short written messages, e-mails, signs, and hand signals). It does not address the more formal methods of communication involving written procedures, logs, specifications, etc. These more formal methods of communicating information are addressed under the ***Procedure Issue (#122)*** and ***Documentation and Records Issue (#58)*** nodes.

## Examples

**Example 1:** An operator opened the wrong valve, resulting in a process upset. He misunderstood the verbal instructions from a coworker. No repeat-back or other verification method was used.

**Example 2:** A tank transfer was in progress during shift change. During shift change, the shift going off duty did not tell the one coming on duty that the transfer was in progress. The tank overflowed.

## Typical Recommendations

Provide a backup means of communication for times when the primary system is inoperable.  
Establish standard terminology for equipment and operations.

Use the repeat-back method of communication.

Encourage a culture that is feedback oriented (i.e., repeating instructions back to ensure understanding).

Conduct shift-change meetings to alert oncoming shifts of special job tasks, safety issues, or problems that occurred during the previous shift.

## Definitions/Typical Issues

Was the problem caused by a failure to communicate? Did a lack of a method or system for communicating between the groups or individuals contribute to the problem? Did the communication take place too late? Did obstacles hinder or delay communication? Was a sign/label that should have been present, missing?

**Note 1:** Each individual involved in the occurrence should be questioned regarding messages he or she feels should have been received or transmitted. Determine what means of communication were used (i.e., the techniques). Persons on all sides of a communication link should be questioned regarding known or suspected problems. Often the message that was sent and the message that was received are different. That is why it is important to gather data on all sides of a conversation.

## Examples

**Example 1:** An operator failed to close a valve when needed, resulting in a process upset. He should have received an instruction from control room personnel to close the valve. The instruction was not given to the operator in time because the two-way radios did not work in the area in which the operator was located.

**Example 2:** A tank transfer was in progress during shift change. During the turnover, the shift going off duty did not tell the one coming on duty that the transfer was in progress. The tank overflowed.

**Example 3:** Operations were supposed to shift production from one mixture to another. However, the first shift never communicated this to the second shift. As a result, the mixture was not changed.

**Example 4:** There was no CONFINED SPACE warning sign at the entrance to the skirt under a tank.

## Typical Recommendations

Provide a backup means of communication when the primary system is inoperable.

Establish formal means of verbal communications when required.

Conduct meetings between shift workers and management.

Encourage employees to alert others on their shift of changes in job tasks that may affect others (tell others when you plan to take a break, tell others when you move from one job location to another, etc.).

## 198 – Method Unavailable or Inadequate

### Definitions/Typical Issues

Was there a method or system for communicating the necessary message or information? Was the communication system out of service or otherwise unavailable at the time of the incident?

### Examples

**Example 1:** An automatic valve was stuck open. The control room operator attempted to contact the building operator using the public address system to instruct him to manually close the valve. The public address system was not functioning properly, and the building operator could not be contacted, resulting in overflow of a vessel.

**Example 2:** An operator failed to close a valve when needed, resulting in a process upset. He should have received an instruction from control room personnel to close the valve. The instruction was not given to the operator in time because the two-way radios did not work in the area in which the operator was located.

### Typical Recommendations

Ensure that some method of communication is functional at all times.

When the primary method of communication is unavailable, provide some temporary means of communication (e.g., two-way radios).

Provide contact information in the company phone book by function.

Use logbooks to communicate between shifts.

Provide guidance on the content of shift turnovers.

Conduct shift meetings that involve members of management during various shifts.

Provide policy and procedure updates to contractors.

Set up a Web page with password protection to allow communications between your organization and your contractors.

## Definitions/Typical Issues

Did the communication take place too early or too late? Did obstacles hinder or delay communication?

## Examples

**Example 1:** Operations was supposed to shift production from one mixture to another. However, the first shift never communicated this to the second shift. As a result, the mixture was not changed.

**Example 2:** Late in the day, a customer service representative (CSR) received a call from a customer asking to change their delivery scheduled for the next day. The CSR got involved in another matter. By the time they called the dispatch desk with the change in the customer's order, the trucks were already loaded for the next day. **Note:** This node is appropriate in this situation because the change in the customer order is communicated via a phone call. If a formal program (software or paper-based) is used, then this node should not be used to code this communication issue. If a formal procedure should have been used and was not, see the *Procedures (#122)* section of the Map.

**Example 3:** A customer called with a question on installation of your product. The customer was told that an installation technician would return the call in an hour. The customer called again the next day after having not been called back. **Note:** This assumes that the organization uses an informal method of communication between the CSR and the technicians. If a formal program (software or paper-based) is used, then this node should not be used to code this communication issue. If a formal procedure should have been used and was not, see the *Procedures (#122)* section of the Map.

**Example 4:** A chemistry technician used handwritten directions to enter data into the computer system. The handwritten note was supposed to provide a means to work around an existing computer problem. The computer problem had been resolved a few days earlier and the handwritten process no longer applied. However, no one had notified the chemistry technicians.

**Example 5:** During discussions with ABC Inc., the customer service representative determined that ABC Inc. wanted product delivered by March 1. However, this requirement was not communicated to the manufacturing facility. As a result, the delivery to ABC Inc. was not made until April 1. **Note:** This node is appropriate in this situation because the change in the customer order is communicated via a phone call. If a formal program (software or paper-based) is used, then this node should not be used to code this communication issue. If a formal procedure should have been used and was not, see the *Procedures (#122)* section of the Map.

## Typical Recommendations

Provide a backup means of communication when the primary system is inoperable.

Establish formal means of communication when required.

Conduct periodic meetings between shift workers and management.

Emphasize the importance of prompt communications.

Ensure that adequate and relevant information is provided in a timely manner to the user as a basis for decision making.

Provide information in a timely manner that ensures its relevance.

Stress the importance of timely communications in training and tailgate sessions.

Provide a means to alert all personnel of the emergency.

## 200 – Communication Misunderstood/Incorrect

### Definitions/Typical Issues

Was an error caused by misunderstood communications between personnel? Was there an error in verbal communication? Did someone misunderstand a hand signal? Was a sign/label misunderstood? Were oral instructions given when written instructions should have been provided?

### Examples

**Example 1:** An operator located in a noisy part of the plant was given an instruction by “walkie-talkie” (radio) to open Valve B-2. He thought the verbal instruction was to open Valve D-2. No repeat-back or other type of verification was used. He opened D-2, resulting in a process upset.

**Example 2:** Two mechanics were working together to perform maintenance on a tank agitator. During one step, the mechanics had to work together to remove the motor from the shaft. Because of a miscommunication between the two mechanics, the motor was damaged.

### Typical Recommendations

Establish standard terminology for equipment and operations.

Use the repeat-back method of communication.

Provide written instructions when necessary.

Minimize interference from noise.

Solicit feedback to ensure that the communication was understood.

## Definitions/Typical Issues

Was nonstandard or unacceptable terminology used? Could the communication/sign/label be interpreted more than one way? Did one piece of equipment have two or more commonly used names? Could the terminology have applied to more than one item?

## Examples

**Example 1:** An operator was told to verify that a solution was clear before adding it to a process. The operator thought that “clear” meant “not cloudy.” What was actually meant was “no color” since color was an indication of contaminants in the solution. The solution was clear (translucent), but had a slightly pink tint. As a result, an out-of-specification solution was used.

**Example 2:** A helper was told to cut 10 foot-long pieces. He wasn’t sure whether he was supposed to cut 10 pieces, each 1-foot long, or one piece that was 10-feet long. Normally, the staff had a practice of specifying 10 pieces, each 1-foot long.

## Typical Recommendations

Establish standard terminology for equipment, process operations, and maintenance operations. Encourage all employees to stop using nonstandard terminology.

Avoid ambiguous terms and phrases in procedures, work instructions, logbooks, etc.

Solicit feedback to ensure that the communication was understood.

## 202 – Language/Translation Issue

### Definitions/Typical Issues

Was there a miscommunication because of the languages used by the sender and receiver of the communication? Was there a problem with the translation of a statement from one language to another? Was the sign/label in a language that the reader could not understand?

### Examples

**Example 1:** Front-line personnel predominantly speak Spanish. However, most engineering personnel speak English. As a result, the operators have difficulty discussing issues with the engineering staff.

**Example 2:** A U.S.-based company purchased a plant in Brazil. All of the staff spoke Portuguese. None of the corporate quality staff could understand Portuguese.

### Typical Recommendations

Provide methods for translating between languages.

Provide multilingual speakers in the workforce to assist with translation.

Use verification/repeat-back to ensure that communications are understood.

Solicit feedback to ensure that the communication was understood.

## Definitions/Typical Issues

Was a communication error caused by failure to repeat a message back to the sender for the purpose of verifying that the message was heard and understood correctly?

## Examples

**Example 1:** An operator located in a noisy part of the plant was given an instruction by “walkie-talkie” (radio) to open Valve B-2. The operator understood D-2. No repeat-back or other type of verification was used. When he opened Valve D-2, a process upset occurred.

**Example 2:** During a test, a field operator was working with a control room operator on a valve test. When the control room operator asked the field operator how it was going, the operator said, “Everything is fine.” However, the control room operator thought he heard “one more time.” So, he cycled the valve again. As a result, a small spill occurred.

**Example 3:** A tank transfer was in progress when Operator A went on break. He mentioned to Operator B that the transfer was taking place, but Operator B did not realize that he needed to stop the transfer. As a result, the tank overflowed.

**Example 4:** A tank overflowed because maintenance had taken the liquid level instrumentation out of service for calibration. A misunderstanding with production occurred over which equipment was out of service. Believing that it was another instrument that was being calibrated, they started a transfer into the tank, resulting in an overflow.

## Typical Recommendations

Encourage employees and personnel at all levels to use the repeat-back communication method to ensure thorough understanding of related job tasks.

If employees/workers forget to use the repeat-back method, instruct supervisors and work-team leaders to request that the employee repeat-back.

Solicit feedback to ensure that the communication was understood.

Develop and use verbal communication protocols.

## 204 – Long Message

### Definitions/Typical Issues

Was a message or instruction misunderstood because it was too long? Should the message have been written instead of spoken? Could the message have been shortened or broken up?

### Examples

**Example 1:** An operator was verbally instructed to open Valves A-7, B-4, B-5, C-6, D-6, D-7, D-8, and F-1. He failed to open D-6, resulting in a process upset. No written instructions were given.

**Example 2:** A senior chemist told a junior chemist how to draw a sample and analyze it during a radio conversation. The chemist missed some key steps in the process.

### Typical Recommendations

Keep oral instructions short and rehearsed (especially if communicating in noisy areas).

If several lengthy details must be conveyed, consider providing them as written instructions rather than as oral instructions (i.e., generate a written procedure).

## Definitions/Typical Issues

Did someone misunderstand a hand signal? Was a sign misunderstood? Was another method of communicating misunderstood?

## Examples

**Example 1:** A crane operator misunderstood a hand signal. As a result, the load struck a process line.

**Example 2:** A sign that showed the directions for correcting a problem with a sandblaster was misunderstood by personnel attempting to fix it. As a result, a part of the sandblaster was broken.

**Example 3:** A contractor was assigned the task of digging a ditch to install an underground tank. An engineer used flags to mark areas that should be avoided so as not to disturb underground utilities. The contractor thought the flags marked the spot to dig. As a result, a natural gas line feeding the plant was struck and broken.

## Typical Recommendations

Use standard hand signals for crane operations.

Have end users review the content of signs before installing them.

Use unambiguous communications methods.

Solicit feedback to ensure that the communication was understood.

Provide a means to alert all personnel of the emergency.

Ensure that all personnel at the facility, including contractors, can recognize emergency alarms and know what actions to take for each type of alarm.

## 206 – Wrong Instructions

### Definitions/Typical Issues

Was the information contained in the message or on the sign/label errant, inaccurate, or wrong?

### Examples

**Example 1:** A supervisor told an operator to open Valve 101 instead of Valve 201. As a result, the system startup was delayed.

**Example 2:** A chemistry technician was told to run a sample on Tank 78 when he should have been directed to take a sample on Tank 87. As a result, no sample was drawn on Tank 87.

**Example 3:** A truck driver made a late delivery. The map he was given was out of date and didn't show some changes in expressway exits.

**Example 4:** The sign for non-potable water was missing the word “NOT”. It read, “Non-Potable Water, Do Use for Drinking, Washing, or Cooking.”

### Typical Recommendations

Use feedback to ensure that proper instructions are provided.

Have end users review the content of signs before using them.

Ensure that sources of information are reliable and accurate.

## Definitions/Typical Issues

This intermediate cause category addresses two major sections: **Company Issue (#208)** and **Individual Issue (#213)**. The majority of the nodes on the map address organizational management systems (including nodes #208-#212). However, the **Individual Issue (#213-223)** nodes specifically address issues related to individuals.

### Typical Company Issue Issues (#208-#212)

Were inappropriate personnel hired to perform the work? Were insufficient personnel available to perform the task?

Were personnel rewarded for undesirable behavior? Were personnel punished for desirable behavior?

Was there a failure to promptly detect an individual performance problem?

### Typical Individual Issue Issues

Did the worker's physical or mental well-being, attitude, mental capacity, attention span, off-the-job sleeping patterns, substance abuse, etc., adversely affect the performance of the task? Was the problem the result of the individual not being capable of performing the task or not wanting to do his or her job? Was there a delay in taking corrective action?

**Note 1:** The 10 asterisked nodes (#214-223) are included to provide the investigator with an understanding of the types of problems that might be categorized as **Personnel Performance Issue; Individual Issue (#213)**. However, the investigator should not include these in the investigation report. Also, there should be management systems in place to detect and correct most (if not all) individual personnel performance issues (for example, see **Detection of Individual Performance Problem Issue [#212]**) before a loss event occurs. Therefore, the failure or absence of the management systems should be coded as well.

## Examples

**Example 1:** The workload for the document control group recently increased by a factor of three. However, the resources assigned to complete the task were not changed. As a result, many drawing and procedure changes were not processed in a timely manner.

**Example 2:** An operator failed to close a valve after completing a transfer. The operator was not paying attention to the level of the tank into which the material was being transferred. The operator had a history of not paying attention to his work. He had been involved in several other incidents during which he had left his job location or was not performing his job requirements. Other operators performed these same job tasks with no problems.

**Example 3:** An individual came to work drunk. The operator was stumbling while walking to his workstation. However, no one did anything to stop him from going to work.

**Example 4:** Six months ago, an engine mechanic was hired who could not read. The supervisor and human resources group had not detected the problem, even though this mechanic had trouble with all of his nonroutine tasks (those that required him to use a procedure).

## Typical Recommendations

Ensure that personnel meet the job requirements at the time of hiring.

Ensure that plant staffing levels are appropriate.

Provide supervisors with training on the detection of personal problems.

Provide supervisors with training on the detection of drug and alcohol abuse.

Give supervisors the authority to remove workers from hazardous assignments when personal problems are detected.

Encourage coworkers to help identify individual personnel performance problems.

Develop rewards that are consistent with company goals and objectives.

Ensure that metrics and other measurements for performance are consistent with facility goals and objectives.

Ensure that there is a process in place to detect personal performance problems.

Provide a means for personnel to self-report problems.

## 208 – Company Issue

### Definitions/Typical Issues

Were inappropriate personnel hired to perform the work? Were insufficient numbers of personnel available to perform the task?

Were personnel rewarded for undesirable behavior or improper performance? Were personnel punished for desirable behavior?

Should the individual personnel performance issues have been detected prior to the incident?

**Note 1:** Consider dual coding under *Supervision During Work Issue (#192)*.

### Examples

**Example 1:** The workload for the document control group recently increased by a factor of three. However, the resources assigned to complete the task were not changed. As a result, many drawing and procedure changes were not processed in a timely manner.

**Example 2:** Supervisors that increased output were typically given large raises. As a result, many supervisors bypassed safe work practices to increase production whenever they could.

**Example 3:** A mechanic came to work drunk. He was having trouble walking and talking. When talking to his supervisor, he had trouble speaking and understanding the work directions he was being given. The supervisor didn't notice that he was drunk. While going to get a part from the warehouse, the mechanic fell down some steps and injured himself and another worker.

**Example 4:** Six months ago, an engine mechanic was hired who could not read. The supervisor and human resources group had not detected the problem, even though this mechanic had trouble with all of his nonroutine tasks (those that required him to use a procedure).

### Typical Recommendations

Ensure that personnel meet the job requirements at the time of hiring.

Ensure that plant staffing levels are appropriate.

Provide supervisors with training on the detection of personal problems.

Provide supervisors with training on detection of drug and alcohol abuse.

Give supervisors the authority to remove workers from hazardous assignments when personal problems are detected.

Encourage coworkers to help identify individual personnel performance problems.

Develop rewards that are consistent with company goals and objectives.

Ensure that metrics and other measurements for performance are consistent with facility goals and objectives.

## Definitions/Typical Issues

Was the employee screening program ineffective? Did it fail to correctly identify requirements for particular jobs? Did it fail to screen employees against those requirements?

**Note 1:** This node addresses the hiring of personnel into new positions. This includes hiring from outside the current organization or reassignment of personnel to new positions within the organization. Assignment of existing or qualified workers to job tasks (i.e., selection of a laborer from a preapproved pool of individuals) is covered by the *Personnel Selection/Assignment/Scheduling Issue (#190)* node.

## Examples

**Example 1:** An operator made a mistake operating a process on a color-coded distributed control system because he was colorblind. As a result, raw materials were wasted and production was delayed. Although a screening program existed for the job, it did not specify the ability to differentiate colors as a requirement.

**Example 2:** A maintenance technician made an error in repairing a mill. The technician could not read the procedure that he was supposed to use. As a result, the startup of the machine was delayed. No one knew the operator could not read.

**Example 3:** Six months ago, an engine mechanic was hired who could not read. The supervisor and human resources group had not detected the problem at the time the mechanic was hired, even though reading was an important job skill.

## Typical Recommendations

Ensure that personnel meet the job requirements at the time of hiring.

Ensure that plant staffing levels are appropriate.

Provide supervisors with training on the detection of personal problems.

Provide supervisors with training on detection of drug and alcohol abuse.

Give supervisors the authority to remove workers from hazardous assignments when personal problems are detected.

Encourage coworkers to help identify individual personnel performance problems.

Develop rewards that are consistent with company goals and objectives.

Ensure that metrics and other measurements for performance are consistent with facility goals and objectives.

## 210 – Resource/Staffing Issue

### Definitions/Typical Issues

Were there insufficient personnel resources to perform the tasks that were scheduled? Does the organization have an inappropriate mix of personnel to perform the work?

### Examples

**Example 1:** Condition-based maintenance tasks were not performed because there were insufficient numbers of personnel to perform all of the work. As a result, some equipment failed prematurely.

**Example 2:** A new paper machine was supposed to be installed to replace an aging machine. However, due to limited engineering resources, the installation was delayed for about 4 months.

**Example 3:** The workload for the document control group recently increased by a factor of three. However, the resources assigned to complete the task were not changed. As a result, many drawing and procedure changes were not processed in a timely manner.

### Typical Recommendations

Assess resources as work tasks are revised.

Assess resource levels when fundamental changes are made in the allocation of work, such as implementing a reliability-centered maintenance program or lean manufacturing, or introducing new equipment.

Assess staffing levels at least annually.

Provide sufficient levels of staffing to support organizational safety, reliability, quality, security, and other goals.

Provide the proper mix and amount of expertise for operating and managing the facility.

## **Definitions/Typical Issues**

Were workers rewarded for improper performance? Were incentives inconsistent with the goals of the company and facility? Did the reward system encourage workers to take shortcuts or waste resources?

## **Examples**

**Example 1:** Performance of customer service representatives was measured by the number of calls they handled each day. As a result, they tried to diagnose the problem as quickly as possible and provide a recommended solution. Because the representatives were trying to diagnose the problem quickly, they often misdiagnosed the problem. About 40% of the phone calls handled by the center were repeat calls from customers whose problems were misdiagnosed the first time.

**Example 2:** One of the metrics for the maintenance organization was the percentage of utilization for a certain lathe. This was measured by the percentage of time the lathe was operating. As a result, the operators turned on the lathe in the morning when they came in and let it run until they went home. They never used the lathe for work because it would decrease the amount of time the machine ran.

**Example 3:** Supervisors that increased output were typically given large raises. As a result, many supervisors bypassed safe work practices to increase production whenever they could.

## **Typical Recommendations**

Develop rewards that are consistent with company goals and objectives.

Ensure that metrics and other measurements for performance are consistent with facility goals and objectives.

Ensure that rewards systems do not encourage undesirable behaviors.

Hold workers accountable for their performance. Reward workers for good performance.

## 212 – Detection of Individual Performance Problem Issue

### Definitions/Typical Issues

Did personnel performance issues contribute to the incident? Should the individual performance issues have been detected prior to the incident?

**Note 1:** Consider dual coding under *Supervision During Work Issue (#192)*.

### Examples

**Example 1:** A worker came to work drunk. When talking to his supervisor, he had trouble speaking and understanding the work directions he was being given. He was also having trouble walking and talking. The supervisor didn't notice that he was drunk. While going to get a part from the warehouse, the worker fell down some steps and injured himself and another worker.

**Example 2:** Six months ago, a maintenance technician was hired who could not read. His supervisor had not detected the problem, even though this technician had trouble with all of his nonroutine tasks (those that required him to use a procedure).

**Example 3:** A company stopped random testing for substance abuse. An impaired worker caused a crane accident one Monday morning.

**Example 4:** Six months ago, an engine mechanic was hired who could not read. The supervisor had not detected the problem, even though this mechanic had trouble with all of his nonroutine tasks (those that required him to read a procedure).

### Typical Recommendations

Provide supervisors with training on the detection of personal problems.

Provide supervisors with training on the detection of drug and alcohol abuse.

Give supervisors the authority to remove workers from hazardous assignments when personal problems are detected.

Encourage coworkers to help identify personnel performance problems.

Ensure that there is a process in place to detect personnel performance problems.

Provide a means for personnel to self-report problems.

Ensure that workers are both physically and mentally fit to perform their required duties.

## Definitions/Typical Issues

The majority of the nodes on the map address organizational management systems. However, the ***Individual Issue (#213-223)*** nodes specifically address issues related to individuals.

Did the worker's physical or mental well-being, attitude, mental capacity, attention span, off-the-job sleeping practices, substance abuse, etc., adversely affect the performance of the task? Was the problem the result of the individual not being capable of performing the task or not wanting to do his or her job?

**Note 1:** The ***Personnel Performance Issue; Individual Issue (#213)*** node should only be used when the problem is isolated to one individual. If other personnel have difficulty performing the same task under similar circumstances, then other portions of the Root Cause Map™ should be used to code the issue.

**Note 2:** There should be management systems in place to detect and correct most (if not all) individual performance issues BEFORE an incident occurs (for example, see ***Detection of Individual Performance Problem Issue (#212)***). Therefore, the failure or absence of the management systems should be coded as well.

**Note 3:** Consider coding under the ***Personnel Hiring Issue (#209)*** node because there should be management controls to ensure that employees possess the required job capabilities prior to being hired. Also consider coding under the ***Supervision During Work Issue (#192)*** or ***Detection of Individual Performance Issue (#212)*** nodes because supervision should detect this problem.

**Note 4:** Code as ***Personnel Performance Issue; Individual Issue (#213)*** only. The 10 nodes beneath ***Individual Issue (#213)*** are included to provide the investigator with an understanding of the types of problems that might be categorized as ***Personnel Performance Issue; Individual Issue (#213)***. However, the investigator should NOT include these cause nodes in the investigation report.

## Examples

**Example 1:** An operator failed to close a valve after completing a transfer. The operator was not paying attention to the level of the tank into which the oil was being transferred. The operator had a history of not paying attention to his work. He had been involved in several other incidents during which he had left his job or was not performing his job requirements. Other operators performed these same job tasks with no problems.

**Example 2:** A mechanic came to work drunk. He did not look visibly impaired, so no one did anything to stop him from going to work. Later, while operating a crane, he dropped the load, damaging production equipment.

**Example 3:** A middle-aged worker's vision had deteriorated but she would not wear her prescription glasses at work. As a result, she misread the DCS screen values and improperly operated the equipment.

## Typical Recommendations

Ensure that job requirements are complete, including required physical/perceptual capabilities.

Provide reasonable accommodations for coworkers with sensory/perceptual limits.

Review employee screening and hiring processes to ensure that the individuals who are hired have the required reasoning capabilities.

Inform and encourage workers to take advantage of employee assistance programs.

Disciplinary policies should be used to reinforce compliance with company rules and policies:

- Discipline needs to be fair, impartial, communicated in advance, sure, and swift
- Enforcement needs to be consistent

## 214 – Sensory/Perceptual Abilities Issue

### Definitions/Typical Issues

Was the problem a result of less than adequate vision (e.g., poor visual acuity, color blindness, tunnel vision)? Was the problem a result of some limitation in hearing (e.g., hearing loss, tone deafness)? Was the problem a result of some sensory limitation (e.g., poor sense of touch or smell)?

**Note 1:** The ***Personnel Performance Issue; Individual Issue (#213)*** node should only be used when the problem is isolated to one individual. If other personnel have difficulty performing the same task under similar circumstances, then other portions of the Root Cause Map™ should be used to code the issue.

**Note 2:** There should be management systems in place to detect and correct most (if not all) individual performance issues BEFORE an incident occurs (for example, see ***Detection of Individual Performance Problem Issue (#212)***). Therefore, the failure or absence of the management systems should be coded as well.

**Note 3:** Consider coding under the ***Personnel Hiring Issue (#209)*** node because there should be management controls to ensure that employees possess the required job capabilities prior to being hired. Also consider coding under the ***Supervision During Work Issue (#192)*** or ***Detection of Individual Performance Issue (#212)*** nodes because supervision should detect this problem.

**Note 4:** Code as ***Personnel Performance Issue; Individual Issue (#213)*** only. The 10 nodes beneath ***Individual Issue (#213)*** are included to provide the investigator with an understanding of the types of problems that might be categorized as ***Personnel Performance Issue; Individual Issue (#213)***. However, the investigator should NOT include these cause nodes in the investigation report.

### Examples

**Example 1:** An operator read the wrong temperature on a chart that recorded temperatures for several tanks. The chart was color-coded. The operator was partially colorblind and confused the readings. He recorded a temperature that was in range when the actual temperature was out of range.

**Example 2:** An operator failed to hear an evacuation alarm. The operator's hearing was poor, and the alarm was not loud enough for the operator to hear.

**Example 3:** An older operator needed to wear reading glasses to read the computer display. However, he refused to wear his glasses because it made him look "old." As a result, he misread the computer display and prematurely stopped a batch.

### Typical Recommendations

Ensure that job requirements are complete, including required physical/perceptual capabilities. Provide reasonable accommodations for coworkers with sensory/perceptual limits.

**Note 1:** A review of the human factors engineering for the process (see ***Human Factors (#146)***) is also appropriate to accommodate a wider spectrum of perceptual capabilities. For example:

- Can the displays be redesigned so that lights that indicate "closed" conditions of valves are always in the same relative location on the panel?
- Can more chart recorders be installed with fewer points per chart to eliminate the need for color-coding?
- Can visual indicators (strobe lights) be used in addition to the audio alarms?

## Definitions/Typical Issues

Was the problem caused by inadequate intellectual capacity? Does the person frequently make wrong decisions? In general, does the person have difficulty processing information? Is the difficulty isolated to this one worker?

Was the problem caused by lack of attention? Does the individual involved in this occurrence frequently “daydream”? Is the person distracted easily? Is the person’s ability to maintain vigilance frequently below minimum standards? Is the difficulty isolated to this one worker?

**Note 1:** The ***Personnel Performance Issue; Individual Issue (#213)*** node should only be used when the problem is isolated to one individual. If other personnel have difficulty performing the same task under similar circumstances, then other portions of the Root Cause Map™ should be used to code the issue.

**Note 2:** There should be management systems in place to detect and correct most (if not all) individual performance issues BEFORE an incident occurs (for example, see ***Detection of Individual Performance Problem Issue (#212)***). Therefore, the failure or absence of the management systems should be coded as well.

**Note 3:** Consider coding under the ***Personnel Hiring Issue (#209)*** node because there should be management controls to ensure that employees possess the required job capabilities prior to being hired. Also consider coding under the ***Supervision During Work Issue (#192)*** or ***Detection of Individual Performance Issue (#212)*** nodes because supervision should detect this problem.

**Note 4:** Code as ***Personnel Performance Issue; Individual Issue (#213)*** only. The 10 nodes beneath ***Individual Issue (#213)*** are included to provide the investigator with an understanding of the types of problems that might be categorized as ***Personnel Performance Issue; Individual Issue (#213)***. However, the investigator should NOT include these cause nodes in the investigation report.

## Examples

**Example 1:** An operator made a mistake in a calculation and added too much material to the mixer. The operator had frequently made errors with calculations and appeared to have problems with numbers. Other operators did not have difficulty performing these tasks.

**Example 2:** An operator missed several steps in a procedure. The operator was unable to clearly understand the procedures because they were written at a sixth-grade level and he could only read at a second-grade level.

**Example 3:** An operator failed to stop a transfer, resulting in a tank overflow. The operator had a history of being distracted easily and losing track of the next step in the process.

**Example 4:** A technician in the field ran out of a water-based cleaner. Someone nearby was using gas to run a lawn mower. Instead of going back to the truck to get the water-based cleaner, the technician put some gas on a rag and used it. The operator’s hair was burned when the rag contacted a hot bearing, starting a fire.

## Typical Recommendations

Review employee screening and hiring processes to ensure that the individuals who are hired have the required reasoning capabilities.

**Note 1:** A review of the human factors engineering for the process (see ***Human Factors (#146)***) is also appropriate to accommodate a wider spectrum of mental capabilities. For example:

- Can the displays be redesigned to reduce the need to perform calculations?
- Can procedures and supervisor resources be provided to assist workers in performing the task?

## 216 – Physical Capabilities Issue

### Definitions/Typical Issues

Can the problem be attributed to trouble with inadequate physical coordination or inadequate strength? Was the problem a result of inadequate size or stature of the individual involved? Did other physical limitations (e.g., shaking, poor reaction time) contribute to the problem?

**Note 1:** The ***Personnel Performance Issue; Individual Issue (#213)*** node should only be used when the problem is isolated to one individual. If other personnel have difficulty performing the same task under similar circumstances, then other portions of the Root Cause Map™ should be used to code the issue.

**Note 2:** There should be management systems in place to detect and correct most (if not all) individual performance issues BEFORE an incident occurs (for example, see ***Detection of Individual Performance Problem Issue (#212)***). Therefore, the failure or absence of the management systems should be coded as well.

**Note 3:** Consider coding under the ***Personnel Hiring Issue (#209)*** node because there should be management controls to ensure that employees possess the required job capabilities prior to being hired. Also consider coding under the ***Supervision During Work Issue (#192)*** or ***Detection of Individual Performance Issue (#212)*** nodes because supervision should detect this problem.

**Note 4:** Code as ***Personnel Performance Issue; Individual Issue (#213)*** only. The 10 nodes beneath ***Individual Issue (#213)*** are included to provide the investigator with an understanding of the types of problems that might be categorized as ***Personnel Performance Issue; Individual Issue (#213)***. However, the investigator should NOT include these cause nodes in the investigation report.

### Examples

**Example 1:** A tank overflowed because the operator could not close the valve. The valve was large and difficult to close. The operator did not have the strength to close the valve. By the time he obtained help in closing it, the tank had overflowed.

**Example 2:** An operator was too short to be able to accurately read a gauge.

### Typical Recommendations

Ensure that job requirements are complete, including required physical/perceptual capabilities.

Provide reasonable accommodations for workers with physical limitations.

**Note 1:** A review of the human factors engineering (see ***Human Factors Issue (#146)***) for the process is also appropriate.

- Is it reasonable for an “average” individual to perform this task?
- Can the individual be provided with a tool to assist in the task?
- Can the task be redesigned to reduce the physical requirements?

### **Definitions/Typical Issues**

Was the individual involved in the incident experiencing a significant personal problem that may have temporarily affected his or her ability to perform the task? Examples include:

- Close relative just died
- Spouse undergoing cancer treatment
- Going through divorce proceedings
- Parent moving into nursing home

**Note 1:** The ***Personnel Performance Issue; Individual Issue (#213)*** node should only be used when the problem is isolated to one individual. If other personnel have difficulty performing the same task under similar circumstances, then other portions of the Root Cause Map™ should be used to code the issue.

**Note 2:** There should be management systems in place to detect and correct most (if not all) individual performance issues BEFORE an incident occurs (for example, see ***Detection of Individual Performance Problem Issue [#212]***). Therefore, the failure or absence of the management systems should be coded as well.

**Note 3:** Consider coding under the ***Personnel Hiring Issue (#209)*** node because there should be management controls to ensure that employees possess the required job capabilities prior to being hired. Also consider coding under the ***Supervision During Work Issue (#192)*** or ***Detection of Individual Performance Issue (#212)*** nodes because supervision should detect this problem.

**Note 4:** Code as ***Personnel Performance Issue; Individual Issue (#213)*** only. The 10 nodes beneath ***Individual Issue (#213)*** are included to provide the investigator with an understanding of the types of problems that might be categorized as ***Personnel Performance Issue; Individual Issue (#213)***. However, the investigator should NOT include these cause nodes in the investigation report.

### **Examples**

**Example 1:** An operator's wife was recently in a car accident. She was in the intensive care unit in critical condition. He spent most evenings at the hospital visiting her and had been very fatigued at work. Some of his log entries were found to be incorrect.

**Example 2:** A technician incorrectly calibrated a level sensor. The previous night he had attended funerals for both his mother and father. They had been shot and killed during a robbery at a grocery store.

### **Typical Recommendations**

Establish an employee assistance program and encourage workers to take advantage of it.

## 218 – Prescribed Drug Interaction Issue

### Definitions/Typical Issues

Was the individual taking prescribed medications that affected his or her job performance?

**Note 1:** This node addresses inadvertent prescription drug interactions. Drug and alcohol abuse are addressed by the *Drug/Alcohol Abuse* (#222) node.

**Note 2:** The *Personnel Performance Issue; Individual Issue* (#213) node should only be used when the problem is isolated to one individual. If other personnel have difficulty performing the same task under similar circumstances, then other portions of the Root Cause Map™ should be used to code the issue.

**Note 3:** There should be management systems in place to detect and correct most (if not all) individual performance issues BEFORE an incident occurs (for example, see *Detection of Individual Performance Problem Issue* [#212]). Therefore, the failure or absence of the management systems should be coded as well.

**Note 4:** Consider coding under the *Personnel Hiring Issue* (#209) node because there should be management controls to ensure that employees possess the required job capabilities prior to being hired. Also consider coding under the *Supervision During Work Issue* (#192) or *Detection of Individual Performance Issue* (#212) nodes because supervision should detect this problem.

**Note 5:** Code as *Personnel Performance Issue; Individual Issue* (#213) only. The 10 nodes beneath *Individual Issue* (#213) are included to provide the investigator with an understanding of the types of problems that might be categorized as *Personnel Performance Issue; Individual Issue* (#213). However, the investigator should NOT include these cause nodes in the investigation report.

### Examples

**Example 1:** An operator was prescribed a medication that caused drowsiness. During a tank transfer, he lost track of time and the tank overflowed.

**Example 2:** A quality assurance technician was prescribed a drug that interacted with another medication he was taking. It caused him to become dizzy. As a result, he fell down while going up some stairs.

### Typical Recommendations

Encourage personnel to report personnel performance problems that they observe.

## Definitions/Typical Issues

Was the incident the result of horseplay or other nonwork-related activities?

**Note 1:** The ***Personnel Performance Issue; Individual Issue (#213)*** node should only be used when the problem is isolated to one individual. If other personnel have difficulty performing the same task under similar circumstances, then other portions of the Root Cause Map™ should be used to code the issue.

**Note 2:** There should be management systems in place to detect and correct most (if not all) individual performance issues BEFORE an incident occurs (for example, see ***Detection of Individual Performance Problem Issue (#212)***). Therefore, the failure or absence of the management systems should be coded as well.

**Note 3:** Consider coding under the ***Personnel Hiring Issue (#209)*** node because there should be management controls to ensure that employees possess the required job capabilities prior to being hired. Also consider coding under the ***Supervision During Work Issue (#192)*** or ***Detection of Individual Performance Issue (#212)*** nodes because supervision should detect this problem.

**Note 4:** Code as ***Personnel Performance Issue; Individual Issue (#213)*** only. The 10 nodes beneath ***Individual Issue (#213)*** are included to provide the investigator with an understanding of the types of problems that might be categorized as ***Personnel Performance Issue; Individual Issue (#213)***. However, the investigator should NOT include these cause nodes in the investigation report.

## Examples

**Example 1:** As a practical joke, operators sent a junior operator to check out the electrical zerts (there are no such things) on the generator. As a result of trying to find the electrical zerts, the junior operator accidentally shut down the generator.

**Example 2:** During a slow time, operators were throwing a ball around the control room. When the operator failed to catch the ball, it hit a control panel, shutting down a feed pump.

## Typical Recommendations

Ensure that inappropriate behavior, such as horseplay, is addressed and corrected by management and supervision.

## 220 – Off-the-job Rest/Sleep (Fatigue) Issue

### Definitions/Typical Issues

Was the worker involved in the incident asleep while on duty? Was the person too tired to perform the job? Was the issue caused by rest and sleep practices outside of the workplace?

**Note 1:** This node addresses problems associated with an individual's rest and sleep practices outside of the workplace. Problems with workers who are forced to work unreasonable amounts of overtime should be coded using the *Supervision; Personnel Selection/Assignment/Scheduling Issue (#190)* node.

**Note 2:** Physical fatigue caused by high workloads is addressed under the *Sustained High Workload/Fatigue (#161)* and *High Transient Workload (#162)* nodes.

**Note 3:** The *Personnel Performance Issue; Individual Issue (#213)* node should only be used when the problem is isolated to one individual. If other personnel have difficulty performing the same task under similar circumstances, then other portions of the Root Cause Map™ should be used to code the issue.

**Note 4:** There should be management systems in place to detect and correct most (if not all) individual performance issues BEFORE an incident occurs (for example, see *Detection of Individual Performance Problem Issue (#212)*). Therefore, the failure or absence of the management systems should be coded as well.

**Note 5:** Consider coding under the *Personnel Hiring Issue (#209)* node because there should be management controls to ensure that employees possess the required job capabilities prior to being hired. Also consider coding under the *Supervision During Work Issue (#192)* or *Detection of Individual Performance Issue (#212)* nodes because supervision should detect this problem.

**Note 6:** Code as *Personnel Performance Issue; Individual Issue (#213)* only. The 10 nodes beneath *Individual Issue (#213)* are included to provide the investigator with an understanding of the types of problems that might be categorized as *Personnel Performance Issue; Individual Issue (#213)*. However, the investigator should NOT include these cause nodes in the investigation report.

### Examples

**Example 1:** A mechanic was found asleep while he was supposed to be calibrating equipment. The mechanic had another job away from the site and routinely appeared to be extremely tired.

**Example 2:** A chemistry technician was found asleep in a back office. The technician liked to watch the rugby channel all night. As a result, he often slept at work.

### Typical Recommendations

Disciplinary policies should be used to reinforce compliance with company rules and policies:

- Discipline should be fair, impartial, communicated in advance, sure, and swift
- Enforcement needs to be consistent

## Definitions/Typical Issues

Was the problem the result of a poor attitude on the part of an individual? Did the individual deliberately ignore the rules, even though he or she understood the consequences?

Typical characteristics of personnel with a disregard for company policy include the following:

- Engages in horseplay
- Is not at the work location
- Does not perform the expected work
- Exhibits maliciousness
- Exhibits insubordination
- Exhibits the inability to work well or communicate with other people
- Ignores safety rules

**Note 1:** The ***Personnel Performance Issue; Individual Issue (#213)*** node should only be used when the problem is isolated to one individual. If other personnel have difficulty performing the same task under similar circumstances, then other portions of the Root Cause Map™ should be used to code the issue.

**Note 2:** There should be management systems in place to detect and correct most (if not all) individual performance issues BEFORE an incident occurs (for example, see ***Detection of Individual Performance Problem Issue (#212)***). Therefore, the failure or absence of the management systems should be coded as well.

**Note 3:** Consider coding under the ***Personnel Hiring Issue (#209)*** node because there should be management controls to ensure that employees possess the required job capabilities prior to being hired. Also consider coding under the ***Supervision During Work Issue (#192)*** or ***Detection of Individual Performance Issue (#212)*** nodes because supervision should detect this problem.

**Note 4:** Code as ***Personnel Performance Issue; Individual Issue (#213)*** only. The 10 nodes beneath ***Individual Issue (#213)*** are included to provide the investigator with an understanding of the types of problems that might be categorized as ***Personnel Performance Issue; Individual Issue (#213)***. However, the investigator should NOT include these cause nodes in the investigation report.

## Examples

**Example 1:** An operator failed to close a valve while filling a tank, resulting in an overflow from the tank and a process upset. The operator was often away from his assigned work location for personal reasons, such as making personal phone calls.

**Example 2:** A procurement clerk was running a Web site on his computer at work. He was selling spare parts for vintage motorcycles over the Web site and used the warehouse shipping system to send the parts to his customers.

**Example 3:** Personnel failed to obtain a hot work permit because they were only going to perform a minor repair involving a very small weld. Normal practice included getting a hot work permit.

## Typical Recommendations

Disciplinary policies should be used to reinforce compliance with company rules and policies:

- Discipline should be fair, impartial, communicated in advance, sure, and swift
- Enforcement needs to be consistent

Establish and enforce a zero-tolerance policy for willful violation of company policies.

### Definitions/Typical Issues

Is the individual abusing drugs or alcohol? Typical symptoms include:

- Chronic inattention
- Acute inattention
- Frequent daydreaming
- Easily distracted
- Poor vigilance
- Frequent illness
- Poor psychological health

**Note 1:** The ***Personnel Performance Issue; Individual Issue (#213)*** node should only be used when the problem is isolated to one individual. If other personnel have difficulty performing the same task under similar circumstances, then other portions of the Root Cause Map™ should be used to code the issue.

**Note 2:** There should be management systems in place to detect and correct most (if not all) individual performance issues BEFORE an incident occurs (for example, see ***Detection of Individual Performance Problem Issue (#212)***). Therefore, the failure or absence of the management systems should be coded as well.

**Note 3:** Consider coding under the ***Personnel Hiring Issue (#209)*** node because there should be management controls to ensure that employees possess the required job capabilities prior to being hired. Also consider coding under the ***Supervision During Work Issue (#192)*** or ***Detection of Individual Performance Issue (#212)*** nodes because supervision should detect this problem.

**Note 4:** Code as ***Personnel Performance Issue; Individual Issue (#213)*** only. The 10 nodes beneath ***Individual Issue (#213)*** are included to provide the investigator with an understanding of the types of problems that might be categorized as ***Personnel Performance Issue; Individual Issue (#213)***. However, the investigator should NOT include these cause nodes in the investigation report.

### Examples

**Example 1:** A mechanic came to work drunk. The mechanic was stumbling while walking to the change house. Later, while operating a crane, he dropped the load, damaging production equipment.

### Typical Recommendations

Establish an employee assistance program and encourage workers to take advantage of it. Disciplinary policies should be used to reinforce compliance with company rules and policies:

- Discipline should be fair, impartial, communicated in advance, sure, and swift
- Enforcement needs to be consistent

## Definitions/Typical Issues

Was the problem caused by sabotage or criminal activity performed by facility (company or contractor) personnel?

**Note 1:** *External Sabotage and Other Criminal Activity (#17)* addresses these issues when external personnel are involved.

**Note 2:** The *Personnel Performance Issue; Individual Issue (#213)* node should only be used when the problem is isolated to one individual. If other personnel have difficulty performing the same task under similar circumstances, then other portions of the Root Cause Map™ should be used to code the issue.

**Note 3:** There should be management systems in place to detect and correct most (if not all) individual performance issues BEFORE an incident occurs (for example, see *Detection of Individual Performance Problem Issue [#212]*). Therefore, the failure or absence of the management systems should be coded as well.

**Note 4:** Consider coding under the *Personnel Hiring Issue (#209)* node because there should be management controls to ensure that employees possess the required job capabilities prior to being hired. Also consider coding under the *Supervision During Work Issue (#192)* or *Detection of Individual Performance Issue (#212)* nodes because supervision should detect this problem.

**Note 5:** Code as *Personnel Performance Issue; Individual Issue (#213)* only. The 10 nodes beneath *Individual Issue (#213)* are included to provide the investigator with an understanding of the types of problems that might be categorized as *Personnel Performance Issue; Individual Issue (#213)*. However, the investigator should NOT include these cause nodes in the investigation report.

## Examples

**Example 1:** A mechanic intentionally damaged a lathe. He was disgruntled about being placed into a new assignment.

**Note:** Issues with problem detection should also be addressed to determine whether the organization could have prevented or mitigated the damage.

**Example 2:** Two workers were arguing about a football game when they started fighting. Both workers were injured and had to be transported to the hospital.

**Example 3:** A chemistry technician was making illegal drugs with some of the materials found in the lab. He was selling them to other personnel in the plant.

## Typical Recommendations

Criminal activity should be referred to law enforcement personnel.

Disciplinary policies should be used to reinforce compliance with company rules and policies:

- Discipline should be fair, impartial, communicated in advance, sure, and swift
- Enforcement needs to be consistent

## 224 – Enter here with each intermediate cause

### Definitions/Typical Issues

Continue here with each Intermediate Cause (hexagon shape) from the first portion of the Root Cause Map™. The **Personnel Performance Issue; Individual Issue (#214-223)** nodes are NOT intermediate nodes, and coding should NOT continue to this section for those nodes.

## Definitions/Typical Issues

Was there a failure to develop standards, policies, or administrative controls (SPACs) that apply to the task? Are they inadequate or inadequately implemented? Were the SPACs inaccurate, confusing, incomplete, unclear, ambiguous, not strict enough, or otherwise inadequate?

**Note 1:** SPACs provide guidance on how an activity should be accomplished, whereas procedures provide a detailed, step-by-step method for performing a specific task. For example, there are SPACs that describe the policies governing scheduling of workers. There is also a procedure that provides a detailed, step-by-step process for performing the task, including the forms to complete and data to enter into the software.

**Note 2:** Selecting Nodes 225-229 should result in changes to the SPACs (the SPACs need to be modified). Selecting Nodes 230-233 should NOT result in any modifications to the SPACs (the SPACs are correct, they just need to be appropriately implemented).

**Note 3:** In addition to the node number, the company- or facility-specific SPAC may also be coded in the trending database to aid in trending of causes. For example:

- If the root cause is the No SPAC or Issue Not Addressed in SPAC (#226) node; and
- The issue is that the facility's procedure guidelines (for example: plant policy AD-01.7) only requires field validation of safety-related procedures, but not quality-related procedures; and
- As a result of a procedure error that could have been corrected during field validation, unacceptable product was sent to a customer.

In addition to coding the root cause of ***No SPAC or Issue Not Addressed in SPAC (#226)***, AD-01.7 should also be entered into the trending database. This will allow the facility to specifically identify the SPAC that is associated with each root cause.

## Examples

**Example 1:** A mechanic installing a cable tray drilled into a live wire within a wall because the facility drawings he was using were not up to date. A management system for control of electrical drawings may have prevented this occurrence by ensuring that the mechanic had up-to-date documentation. A management policy/procedure would also be required to ensure that such drawings are obtained/reviewed as part of the work permit system for penetrations into any wall.

**Example 2:** An operator was unable to read at the level needed to understand facility procedures because employee screening policies did not include a requirement for performance testing (including having the prospective employee read and explain a portion of a procedure). As a result, he made a serious mistake in operating a key piece of equipment.

## Typical Recommendations

Provide written documentation of SPACs.

Ensure that all levels of affected employees are aware of SPAC changes.

When errors are found, modify SPACs accordingly.

Ensure that policies regarding production, material control, procurement, security, etc., do not contradict safety policies.

## 226 – No SPAC or Issue Not Addressed in SPAC

### Definitions/Typical Issues

Was there a failure to develop a SPAC to control the particular type of work or situation involved in the incident? Was the work or situation significant or complex enough to warrant some type of SPAC to ensure adequate job quality and work control, but none was developed? Did the SPACs fail to consider all possible scenarios or conditions?

**Note 1:** In addition to the node number, the company- or facility-specific SPAC may also be coded in the trending database to aid in trending of causes. For example:

- If the root cause is the No SPAC or Issue Not Addressed in SPAC (#226) node; and
- The issue is that the facility's procedure guidelines (for example: plant policy AD-01.7) only requires field validation of safety-related procedures, but not quality-related procedures; and
- As a result of a procedure error that could have been corrected during field validation, unacceptable product was sent to a customer.

In addition to coding the root cause of ***No SPAC or Issue Not Addressed in SPAC (#226)***, AD-01.7 should also be entered into the trending database. This will allow the facility to specifically identify the SPAC that is associated with each root cause.

### Examples

**Example 1:** A maintenance worker was exposed to a pressurized release of a process material. The line from which the material was released had not been depressurized and cleared before maintenance work began. The plant did not have a general safe work practice/permit process for opening process equipment (i.e., “line breaking”).

**Example 2:** An operating procedure was not field verified. Company policy did not require field verification of procedures. As a result of the procedure error, unacceptable products were shipped to multiple customers.

### Typical Recommendations

Compile a list of SPACs mandated by regulatory requirements (OSHA, EPA, etc.) and compare it to a current list of existing SPACs. Develop any missing SPACs.

Provide written documentation of SPACs.

Define, document, and communicate missing SPACs.

Define core organizational values in SPACs.

Develop a comprehensive list of applicable codes, standards, and guidelines that the facility must comply with.

Establish owners of each of the SPAC documents.

### **Definitions/Typical Issues**

Were the existing SPACs not strict enough to provide adequate job quality or work control? Were the requirements of the policy correct, but they should be applied to additional conditions or situations? Were the requirements of the policy generally correct, but additional thoroughness, precision, and/or rigor should be specified?

**Note 1:** This node assumes the SPAC is correct and needs to be applied to additional situations/conditions or needs more rigor. If the SPAC contains errors, code under SPAC Incorrect.

**Note2:** In addition to the node number, the company- or facility-specific SPAC may also be coded in the trending database to aid in trending of causes. For example:

- If the root cause is the No SPAC or Issue Not Addressed in SPAC (#226) node; and
- The issue is that the facility's procedure guidelines (say it's plant policy AD-01.7) only requires field validation of safety-related procedures, but not quality-related procedures; and
- As a result of a procedure error that could have been corrected during field validation, unacceptable product was sent to a customer.

In addition to coding the root cause of ***No SPAC or Issue Not Addressed in SPAC (#226)***, AD-01.7 should also be entered into the trending database. This will allow the facility to specifically identify the SPAC that is associated with each root cause.

### **Examples**

**Example 1:** A safety limit was violated during operation of a process because an alarm indicating a high temperature was bypassed. The first-line supervisor thought the alarm was false and bypassed it. The SPACs were not strict enough because they allowed the supervisor to bypass an alarm without getting any management of change review or approvals from management and technical support.

**Example 2:** The manufacturer specified that vibration readings and temperatures should be documented for several pumps while they are operating. However, the operators just performed a visual check of the pumps. The SPACs did not specify the level of detail required in procedures and how manufacturer's recommendations should be addressed in procedures.

**Example 3:** An operating procedure was not field verified. Company policy only required field verification of safety-related procedures. This procedure only had an impact on product quality. However, as a result of the procedural error, unacceptable products were shipped to multiple customers.

### **Typical Recommendations**

Improve the level of detail of SPACs.

Improve the description of accountabilities in SPACs (for resolving ambiguities).

Define core organizational values in SPACs.

Establish owners of each of the SPAC documents.

## 228 – SPAC Confusing or Contradictory

### Definitions/Typical Issues

Were the SPACs correct but confusing, hard to understand or interpret, or ambiguous? Did contradictory requirements exist? Were some requirements violated or disregarded in order to follow others? Was a SPAC not followed because no practical way of implementing the SPAC existed?

**Note 1:** This node assumes the SPAC is correct and is just confusing or that one SPAC is correct and another is contradictory (incorrect). If the SPAC contains errors, code under SPAC Incorrect.

**Note 2:** In addition to the node number, the company- or facility-specific SPAC may also be coded in the trending database to aid in trending of causes. For example:

- If the root cause is the No SPAC or Issue Not Addressed in SPAC (#226) node; and
- The issue is that the facility's procedure guidelines (say it's plant policy AD-01.7) only requires field validation of safety-related procedures, but not quality-related procedures; and
- As a result of a procedure error that could have been corrected during field validation, unacceptable product was sent to a customer.

In addition to coding the root cause of ***No SPAC or Issue Not Addressed in SPAC (#226)***, AD-01.7 should also be entered into the trending database. This will allow the facility to specifically identify the SPAC that is associated with each root cause.

### Examples

**Example 1:** A plant policy indicated that all “fatigue-related failures” be reported to the Equipment Reliability group. However, the maintenance organization had no guidance on what sort of failures were “fatigue-related.” In addition, a recent reorganization resulted in the elimination of the Equipment Reliability group, and their previous functions were split among four other groups. So, it was unclear whom the failures should be reported to.

**Example 2:** A release of a flammable liquid was larger than expected, overflowing the tank’s dike. Administrative controls on the maximum intended inventories for the tanks in the dike were violated because of an anticipated shortage of the material from the supplier. Production had a policy of “stocking up” on materials whenever supplier issues were encountered, even if these higher inventories exceeded the administrative inventory levels. As a result, the policy that requires “stocking up” contradicts the inventory limits.

### Typical Recommendations

Solicit comments and recommendations from operations, maintenance, and other personnel regarding ambiguous or unclear language in the SPACs. Resolve comments.

Ensure that policies regarding production, material control, procurement, security, safety, etc., do not contradict each other.

Provide the proper balance among safety, production, quality, reliability, and security.

Communicate to personnel that safety should be given top priority.

Ensure that SPACs reflect management’s decision to make safety a top priority.

SPACs that require specific authorization signatures should state alternate sources of authorization in the event that the primary authorizers are not available.

Provide the necessary tools/equipment features to allow/encourage personnel to follow the SPACs.

Establish owners of each of the SPAC documents.

## Definitions/Typical Issues

Did technical errors or incorrect facts exist in the SPACs?

**Note 1:** If the policy is generally correct, but needs clarification on its application, consider coding under ***SPAC Not Strict Enough (#227)***. If the policy is correct, but just confusing, code under ***SPAC Confusing or Contradictory (#228)***. If one policy is correct and another is contradictory, code under ***SPAC Confusing or Contradictory (#228)***.

**Note 2:** In addition to the node number, the company- or facility-specific SPAC may also be coded in the trending database to aid in trending of causes. For example:

- If the root cause is the No SPAC or Issue Not Addressed in SPAC (#226) node; and
- The issue is that the facility's procedure guidelines (say it's plant policy AD-01.7) only requires field validation of safety-related procedures, but not quality-related procedures; and
- As a result of a procedure error that could have been corrected during field validation, unacceptable product was sent to a customer.

In addition to coding the root cause of ***No SPAC or Issue Not Addressed in SPAC (#226)***, AD-01.7 should also be entered into the trending database. This will allow the facility to specifically identify the SPAC that is associated with each root cause.

## Examples

**Example 1:** A fire occurred when grinding near a process unit ignited vapors leaking from a nearby flange. The hot work policy for the plant erroneously indicated that a hot work permit was not necessary for grinding. Grinding was inadvertently deleted from the list of activities requiring a hot work permit during the previous revision of the policy.

**Example 2:** The organization did not require any analysis of the parts handling practices for potential hazards. As a result, parts were being routinely damaged during handling operations within the facility. When the parts were stacked on tables, the weight would sometimes cause damage of delicate tabs on the parts.

## Typical Recommendations

Include SPACs in the scope/charter of hazard review teams.

When errors are found, modify SPACs accordingly.

Establish owners of each of the SPAC documents.

## 230 – Company Standards, Policies, and Administrative Controls (SPAC) Not Used

### Definitions/Typical Issues

Were SPACs or directives correct, but not used, not adhered to, or not followed? Was communication or enforcement of existing, correct SPACs inadequate? Were the SPACs recently revised or difficult to implement? Was there a failure to enforce the existing SPACs?

**Note 1:** SPACs provide guidance on how an activity should be accomplished, whereas procedures provide a detailed, step-by-step method for performing a specific task. For example, there are SPACs that describe the policies governing scheduling of workers. There is also a procedure that provides a detailed, step-by-step process for performing the task, including the forms to complete and data to enter into the computer system.

**Note 2:** Selecting Nodes 225-229 should result in changes to the SPACs (the SPACs need to be modified). Selecting Nodes 230-233 should NOT result in any modifications to the SPACs (the SPACs are correct, they just need to be appropriately implemented).

**Note 3:** In addition to the node number, the company- or facility-specific SPAC may also be coded in the trending database to aid in trending of causes. For example:

- If the root cause is the No SPAC or Issue Not Addressed in SPAC (#226) node; and
- The issue is that the facility's procedure guidelines (say it's plant policy AD-01.7) only requires field validation of safety-related procedures, but not quality-related procedures; and
- As a result of a procedure error that could have been corrected during field validation, unacceptable product was sent to a customer.

In addition to coding the root cause of ***No SPAC or Issue Not Addressed in SPAC (#226)***, AD-01.7 should also be entered into the trending database. This will allow the facility to specifically identify the SPAC that is associated with each root cause.

### Examples

**Example 1:** A mechanic bypassed an important step in calibrating a key safety instrument because he did not take a printout of the procedure with him, as required by plant policy. This was found to be common practice in the facility.

**Example 2:** A requirement was in place to have the operators check instruments in the field once per shift. The operators never performed the checks. Supervision was aware of the situation and never enforced the requirement.

**Example 3:** The surveillance testing for the fire protection system had not been conducted for the past 2 years. The requirements for performing surveillance tests were not enforced.

**Example 4:** A corporate HSE standard addressed how materials were charged to reactors. However, the standard practices were not implemented at some facilities. As a result, an explosion occurred during a charging operation.

### Typical Recommendations

Ensure that all levels of affected employees are aware of SPACs changes.

Take appropriate actions concerning those employees who choose not to use the SPACs.

### **Definitions/Typical Issues**

Were standards, directives, or policies not communicated from management down through the organization?

**Note 1:** If personnel are unaware of the SPAC because of a recent change, code under ***SPAC Recently Changed*** (#232). If personnel are aware of the SPAC requirements but do not comply with the requirements, code under ***SPAC Enforcement Issue*** (#233).

**Note 2:** In addition to the node number, the company- or facility-specific SPAC may also be coded in the trending database to aid in trending of causes. For example:

- If the root cause is the No SPAC or Issue Not Addressed in SPAC (#226) node; and
- The issue is that the facility's procedure guidelines (say it's plant policy AD-01.7) only requires field validation of safety-related procedures, but not quality-related procedures; and
- As a result of a procedure error that could have been corrected during field validation, unacceptable product was sent to a customer.

In addition to coding the root cause of ***No SPAC or Issue Not Addressed in SPAC*** (#226), AD-01.7 should also be entered into the trending database. This will allow the facility to specifically identify the SPAC that is associated with each root cause.

### **Examples**

**Example 1:** During an extended facility outage, routine surveillances of process alarm panels were not performed. As a result, a chemical leak went undetected for 2 days. Facility management had not communicated to first-line supervisors that normal surveillance procedures remained in effect during the outage.

**Example 2:** The corporate reliability group set up a database to capture field problems. However, facility personnel were not made aware of the new system. As a result, the database was not populated.

**Example 3:** A standard was in place that addressed the use of storage racks. The standard was not applied because personnel were unaware it existed. As a result, the storage racks were undersized.

### **Typical Recommendations**

Review the contents of relevant SPACs during initial and refresher training; assess employees' understanding. Periodically stress the importance of using SPACs during shift-change meetings, safety meetings, etc.

Ensure that SPAC documentation is readily available to all affected employees at all times.

## 232 – SPAC Recently Changed

### Definitions/Typical Issues

Had standards or directives been recently changed? Did information concerning changes fail to reach all levels of the organization? Had some confusion been created by the changes?

**Note 1:** If there has been adequate time to communicate the changes to the SPACs, but personnel are still unaware of the requirements, code under ***Unaware of SPAC (#231)***.

**Note 2:** In addition to the node number, the company- or facility-specific SPAC may also be coded in the trending database to aid in trending of causes. For example:

- If the root cause is the No SPAC or Issue Not Addressed in SPAC (#226) node; and
- The issue is that the facility's procedure guidelines (say it's plant policy AD-01.7) only requires field validation of safety-related procedures, but not quality-related procedures; and
- As a result of a procedure error that could have been corrected during field validation, unacceptable product was sent to a customer.

In addition to coding the root cause of ***No SPAC or Issue Not Addressed in SPAC (#226)***, AD-01.7 should also be entered into the trending database. This will allow the facility to specifically identify the SPAC that is associated with each root cause.

### Examples

**Example 1:** The policy on calibration of flow indicators was recently changed. All of the maintenance department supervisors were briefed about the change, but the mechanics were not told of the change. As a result, the policy was not implemented as required.

**Example 2:** A new policy was put in place to require personnel to enter the time charged against each work order into a computer system. No one was told of the requirement or taught how to enter the information in the computer. As a result, the requirement was not implemented.

### Typical Recommendations

Ensure that all levels of affected employees are aware of SPAC changes.

Verify that employees fully understand recent changes before expecting them to implement the changes.

Ensure that there is a process for communicating SPAC changes to the individuals who need to know about the changes.

### **Definitions/Typical Issues**

In the past, has enforcement of the SPAC been lax? Have failures to follow the SPAC in the past gone uncorrected or unpunished? Has noncompliance been accepted by management and supervision?

**Note 1:** Coding under the ***Rewards/Incentives Issue (#211)*** or ***Improper Performance Not Corrected (#193)*** nodes may be appropriate.

**Note 2:** In addition to the node number, the company- or facility-specific SPAC may also be coded in the trending database to aid in trending of causes. For example:

- If the root cause is the No SPAC or Issue Not Addressed in SPAC (#226) node; and
- The issue is that the facility's procedure guidelines (say it's plant policy AD-01.7) only requires field validation of safety-related procedures, but not quality-related procedures; and
- As a result of a procedure error that could have been corrected during field validation, unacceptable product was sent to a customer.

In addition to coding the root cause of ***No SPAC or Issue Not Addressed in SPAC (#226)***, AD-01.7 should also be entered into the trending database. This will allow the facility to specifically identify the SPAC that is associated with each root cause.

### **Examples**

**Example 1:** A mechanic made a mistake installing a piece of equipment. He did not refer to a procedure when performing the test. Although the policy is to always refer to the procedure, the policy had not been enforced. Mechanics often did not take procedures to the work site, and their supervisors were aware of this.

**Example 2:** Operators were supposed to log local tank levels every 2 hours. However, they would typically take the reading only at the beginning of the shift. They used these readings to fill in the readings for the remainder of the shift. No one ever took issue with this practice until after an accident occurred.

### **Typical Recommendations**

Management should set an example by always following the intent of the SPACs. Employees who choose not to use the SPACs should be corrected and/or punished:

- Discipline should be fair, impartial, communicated in advance, sure, and swift
- Enforcement needs to be consistent

Define core organizational values in SPACs.

## APPENDIX A

# Maintenance Strategies used on the Root Cause Map™

## 1. Types of Maintenance Tasks

There are various philosophies about how to most effectively preserve system function while controlling maintenance costs. The Root Cause Map™ structure is based on seven different types of maintenance tasks as shown in Figure 1. Each type of maintenance task has strengths and limitations. Because each approach can be effective in different situations, the key is to apply the proper appropriate method to each situation. Although there are many ways to view the maintenance function, there are two types of maintenance tasks: **Planned Tasks** and **Unplanned Tasks**.

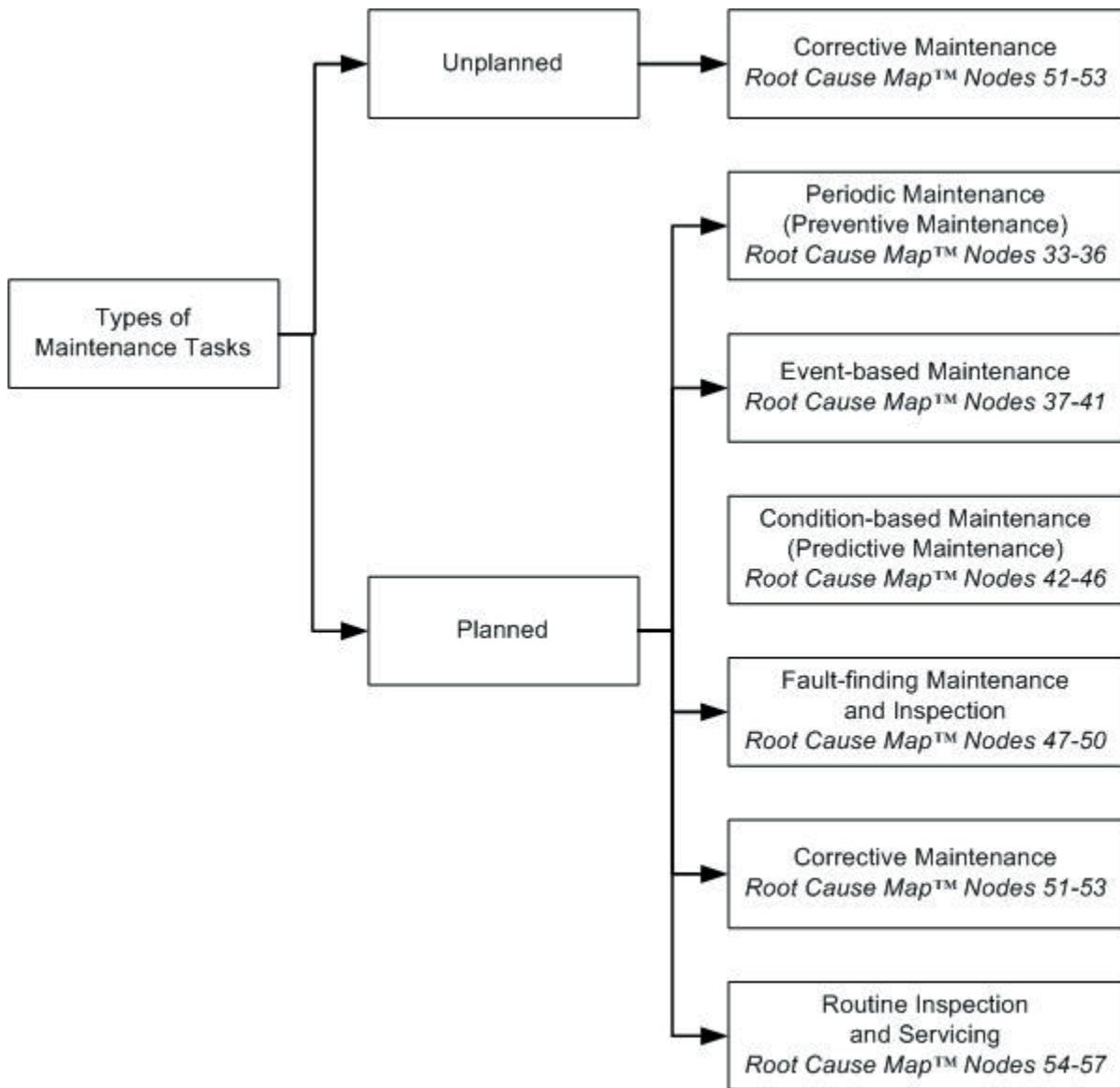


Figure 1: Relationship of Maintenance Strategies Used on the Root Cause Map™

## 1.1 Planned Tasks

These tasks consist of various activities to prevent failures, identify failures, or detect the onset of failures. The following are the six types of planned maintenance tasks:

1. **Periodic Maintenance** – (Root Cause Map™ Nodes 33-36)
2. **Event-based Maintenance** – (Root Cause Map™ Nodes 33-36)
3. **Condition-based Maintenance** – (Root Cause Map™ Nodes 33-36)
4. **Fault-finding Maintenance and Inspection** – (Root Cause Map™ Nodes 33-36)
5. **Corrective Maintenance** – (Root Cause Map™ Nodes 33-36)
6. **Routine Inspection and Servicing** – (Root Cause Map™ Nodes 33-36)

## 1.2 Unplanned Tasks

These tasks consist of unanticipated repairs of equipment or components that have failed. Although it may be unrealistic to attempt to eliminate unplanned tasks, the maintenance function should work to control the number of unplanned tasks. There is only one type of unplanned maintenance task: **Corrective Maintenance**.

## 2. Periodic Maintenance (Preventive Maintenance) – Root Cause Map™ Nodes 33-36

These tasks are performed on an interval (e.g., months, days, hours, startups, shutdowns, revolutions, cycles) with the objective of preventing a failure. Preventive maintenance includes a range of tasks from minor servicing of equipment (e.g., lubrication, cleaning) to completely restoring (e.g., overhauling and rebuilding) complex machinery. This type of task is most effective when good age-to-failure data are available (i.e., if the probability of failure is known to increase with time, cycles, etc.). The objective of periodic maintenance is to perform the task just prior to the increase in the probability of failure (see Figure 2).

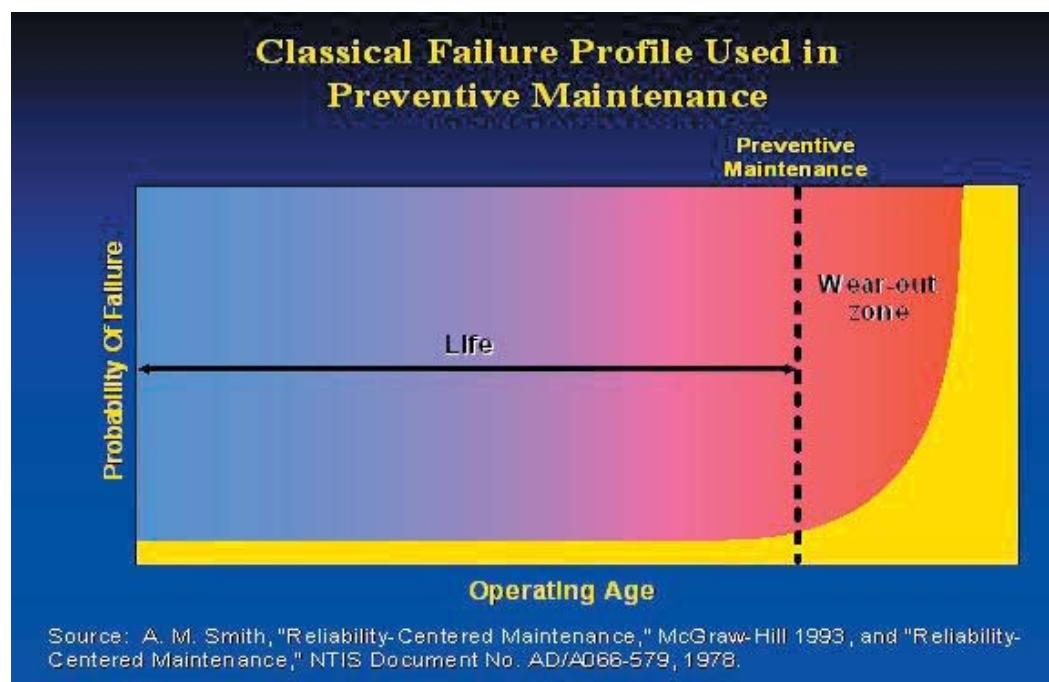


Figure 2: Classical Failure Profile Used in Preventive Maintenance

Performing effective periodic maintenance tasks presumes that:

- Accurate failure data are available
- The failure rate is steady until it rapidly increases (i.e., a relatively low standard deviation) at a consistent age,

where age can be calendar days, run time, cycles, etc.).

However, many equipment failures are not consistent with the bathtub curve, good failure data are uncommon, and many equipment failures have large standard deviations.

Too much maintenance can reduce system reliability from maintenance-induced failures. For highly reliable systems, the most likely failure can be human intervention under the pretense of preventive maintenance. An Air Force study on this subject found that 40% of the work required to restore a sample of F-4 Phantom jets to operational condition was the direct result of failures induced by previous maintenance.

Prevention-directed tasks may be applicable to situations where:

- other types of tasks (e.g., condition-based) are not applicable or too expensive (poor cost/benefit),
- Original equipment manufacturers require these activities, especially for warranty protection;
- Instrumentation needs periodic calibration; or
- Regulations (e.g., OSHA, PSM, EPA, RMP) and/or industry-standards require the performance of the task.

### **3. Event-based Maintenance – Root Cause Map™ Nodes 37-41**

These maintenance tasks are typically associated with activities (events) such as purchasing, fabricating, constructing, installing, and starting up/shutting down equipment. As a result, these tasks (more than others) require effective teamwork among the engineering, purchasing, and storeroom functions. Event-based maintenance involves fundamentally sound reliability practices aimed at preventing the underlying mechanisms of equipment failures. Many of these tasks are commonly understood to be quality assurance (QA) types of activities. Below are example applications of proactive maintenance activities:

- Precision alignment
- Precision balancing
- Installation specifications and procedures
- Commissioning specifications and procedures
- Oil analysis of lubricant inventories
- Preparing equipment for hotter or colder weather
- Startup of equipment

### **4. Condition-based Maintenance (Predictive Maintenance) – Root Cause Map™ Nodes 42-46**

These tasks are directed at monitoring the condition of a piece of equipment to detect the onset of a failure or a failure symptom. This type of strategy is based on the fact that many failures don't occur instantaneously, but rather develop over time and do not happen at a consistent age (i.e., calendar days, run time, cycles). Predictive maintenance is performed by periodically measuring (normally while the equipment is in service) a parameter that correlates with the incipient failure mode. The objective is to detect the onset of failure so that a corrective maintenance task can be scheduled just prior to the impending failure to prevent the failure or mitigate the consequences of the failure. Figure 3 illustrates the process of predictive maintenance. This graph represents the condition of a piece of equipment and its degradation over time. Point P is the point at which we can detect the onset of failure, and point F is the time at which functional failure has occurred. The P-F interval is the time between when the onset of failure is detected and the point at which functional failure occurs.

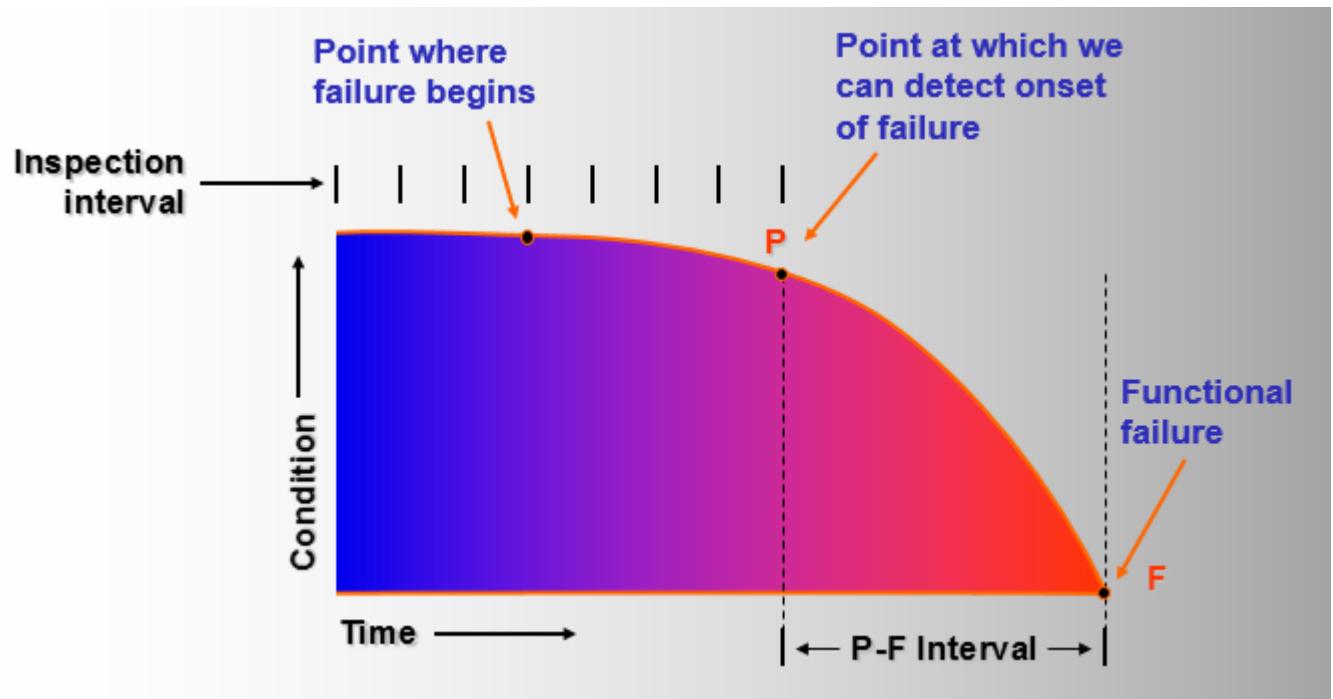


Figure 3 P-F Interval

Other key aspects of predictive maintenance and the P-F curve are as follows:

- The time interval between condition-based tasks must be less than the P-F interval if the failure is to be prevented or the failure consequence mitigated (setting task intervals at half the P-F interval is normally sufficient). This means that if the P-F interval is 4 months, every 2 months we perform a predictive maintenance task to determine if we have reached point P on the diagram.
- If the time interval between condition-based tasks is much shorter than the P-F interval, valuable resources will be wasted (i.e., we are performing the predictive maintenance task too often and the onset of failure could be detected with fewer inspections). As an extreme example, if the P-F interval is 4 months and the predictive maintenance task is performed every day, which would not be appropriate.
- The net P-F interval must be long enough to (1) organize and implement a corrective maintenance task (repair/replace the equipment) to prevent the failure or (2) develop a contingency plan to mitigate the consequences of the failure.

In general, condition-based tasks are applicable if:

- The task is cost-effective (i.e., the cost of performing the condition-based task is less than the cost of repairing the failure),
- A potential failure condition can be determined clearly (in other words, there is some parameter [vibration, temperature, composition, electric current flow, etc.] that is a clear and effective indicator of impending failure that can be reliably detected),
- The P-F interval is generally consistent or predictable,
- The condition-based task frequency is less than the P-F interval, and/or
- The net P-F interval allows enough time to take appropriate preventive or mitigative action.

Predictive maintenance is beneficial because it:

- Avoids consequences of failures,
- Avoids unnecessary reactive and preventive maintenance,
- Optimizes turnaround/outage efficiency,
- Facilitates teamwork with operations/engineering, and
- Promotes understanding of failure mechanisms (e.g., vibration analysis: unbalance = 1 time rotation speed; misalignment = 2 times rotation speed).

## 5. Fault-finding Maintenance and Inspection – Root Cause Map™ Nodes 47-50

A fault-finding task is aimed at checking to see whether equipment has failed. A fault-finding task is applicable to those failures that are hidden (i.e., in the normal course of operation, no one would know that the item failed) and to failures for which an effective and applicable periodic maintenance task or condition-based maintenance task is not suitable (which is normally the case for standby equipment). Fault-finding tasks are normally performed on backup systems, emergency systems, and infrequently used equipment. Hidden failures in those equipment items are generally critical because the design intent of the equipment is to perform some function (alarm, shut down, provide backup electrical power, etc.) as a result of some other unpredictable upset condition. These types of tasks are usually performed to prevent or mitigate some undesirable consequence (e.g., system shutdown, equipment damage, overpressure). Examples of fault-finding maintenance tasks are:

- Checking the pressure in your spare tire before leaving on a big family vacation,
- Checking your home smoke alarm (unless your model alarms when failed!),
- Periodically starting a standby diesel generator,
- Testing high-high level alarms on a reactor vessel,
- Periodically starting a spare pump in a critical process line,
- Checking that all the lights in a control panel are operational,

- Testing fire protection systems, and
- Testing evacuation alarms.

## 6. Corrective Maintenance – Root Cause Map™ Nodes 51-53

There are two types of corrective maintenance: **Unplanned** and **Planned**.

### 6.1 Unplanned Corrective Maintenance

These tasks are performed “on demand” when equipment fails. The maintenance organization should quickly respond to these failures and fix the problem as efficiently as possible. This strategy of maintenance is based on the assumption that all equipment is going to fail. In fact, this way of thinking may seem logical because equipment failures are so common. Maintenance personnel stay “covered up” with equipment repairs, day in, and day out. Generally, the maintenance organization is staffed to accommodate immediate repair, which often means substantial resources on night shifts.

#### 6.1.1 Costs and Safety Risks Associated with Unplanned Corrective Maintenance

**Ancillary Damage.** Component failures often have a domino effect on other components within that specific piece of equipment or on other pieces of equipment. This ancillary damage is often more costly than the repair cost for the initial failure.

**Overtime.** Equipment failures often occur when maintenance staffing is lowest (i.e., other than day shifts). Even when failures occur when staffing levels are highest, the repairs can exceed normal shift hours, thereby requiring overtime by supervisors and craftsmen.

**Spare Parts.** Because the ability to quickly repair equipment failures could be jeopardized, reactive maintenance often necessitates a larger variety of spare parts and higher stocking quantities. Larger inventories are costly because they represent capital that is not generating a return.

**Downtime/Output.** Obviously, failed equipment can no longer provide its intended function and, depending on the failure, can represent an enormous financial loss.

**Errors in Repair.** When equipment fails, the pressure is on to do whatever it takes to get the system back up and running as fast as possible. Time is money. In the rush to make the repairs, errors are often made that eventually cause subsequent failures – hours, days, weeks, or months later. In addition, because these failures demand so much attention, there is little time to examine their root causes. Therefore, craftsmen will likely make similar repairs in the future until the root causes are identified and resolved.

**Increased Personnel Exposure.** With increased equipment repairs comes a higher probability that maintenance craftsmen or even operators will be injured (due to upsets during equipment shutdown, impacts from tools or equipment, releases of hazardous process materials, etc.).

**Catastrophic Failures/Releases.** Allowing equipment to run to failure can result in equipment damage that can result in injury or loss of life. For example, failure of a high-speed axial compressor under operating conditions can literally cause an explosion. A failure of this sort could send shrapnel flying hundreds of feet, possibly causing injury to personnel and considerable damage to ancillary equipment. Failure of a reactor containing highly hazardous chemicals could result in fires/explosions and/or toxic vapor clouds with catastrophic consequences.

## **6.2 Planned Corrective Maintenance**

Although these tasks are also performed on demand (as in the case of unplanned corrective maintenance tasks), the difference here is that the maintenance organization has made a conscious decision to allow the equipment to run to failure. Opting to use a corrective maintenance strategy is more the exception than the rule, but there are cases where this makes sense. Here are three reasons why a run- to-failure decision may be prudent:

1. There is no safety impact as a result of failure, and it costs less to repair the failure than to perform other preventive tasks.
2. No other task (e.g., periodic/condition-based) can be found that will help prevent or detect the failure, regardless of how much money is spent.
3. Based on existing budget/labor constraints, the failure is too low on the priority list to warrant attention.

When a failure is expected (at some point in time), there are activities that can be performed in advance to help mitigate the consequences of the failure. For example, one could ensure that a replacement for the failed part is available from either the plant storeroom or local vendor stock, or within reasonable delivery time from the manufacturer/distributor. Procedures and instructions can be developed to help ensure efficient repair/replacement. In addition, if ancillary damage could occur, guarding or protection could be provided for the at-risk equipment (assuming that this is cost-effective).

## **7. Routine Inspection and Servicing – Root Cause Map™ Nodes 54-57**

Routine inspection and servicing maintenance is separated from the other types of maintenance because it is normally performed by operators instead of maintenance personnel. As a result, different management systems usually influence performance. Routine inspection and servicing typically includes the following:

- Inspections performed by operations personnel as part of normal tours through the facility
- Routine servicing of equipment by operations personnel, such as minor adjustments to operating equipment
- Routine cleaning activities performed by operations personnel, such as cleaning minor spills of materials
- Recording operational parameters as part of routine rounds (e.g., completing a routine rounds data collection form)