Supervision systems course

Chapter - 01: Principles of Maintenance

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Outline

benefit of maintenance?

- Eliminate unnecessary maintenance. Ensuring continuous machine uptime is the key objective of maintenance. Consequently, when we plan maintenance, we aim to avoid any maintenance activities that are not essential or performed solely for the sake of routine.
- Reduce lost production caused by failures.
- Reduce rework costs.
- Reduce repair parts inventory; When maintenance is scheduled, and I can identify the critical components needed for my inventory, I can maintain a leaner spare parts inventory. This streamlined approach enhances process efficiency and, consequently, has a positive impact on product quality, leading to an overall improvement in product quality.

- Increase process efficiency.
- Extend the operating life of plant systems.
- Improved product quality; For instance, when conducting a machining operation on a surface, a specific tool is employed for the task. If this tool becomes dull due to neglect in monitoring and replacement, it will inevitably impact the resulting surface finish.
- Reduce overall maintenance.
- Increase production capacity.
- Increase overall profit.

In fact, tool condition monitoring is employed precisely to safeguard these qualities from being compromised due to inadequate cutting tool maintenance or failure to replace worn tools. Implementing robust tool condition monitoring systems is instrumental in enhancing product quality. Moreover, this practice would evidently extend the lifespan of plant systems as a whole, encompassing production capacity. By ensuring planned maintenance and eliminating unnecessary maintenance tasks, overall maintenance costs can be significantly reduced, contributing to higher profits. For any company or industry, profitability is a paramount objective, and minimizing production costs, including maintenance-related losses, is a critical factor in achieving this goal.

Bathtub curve.

Bathtub curve

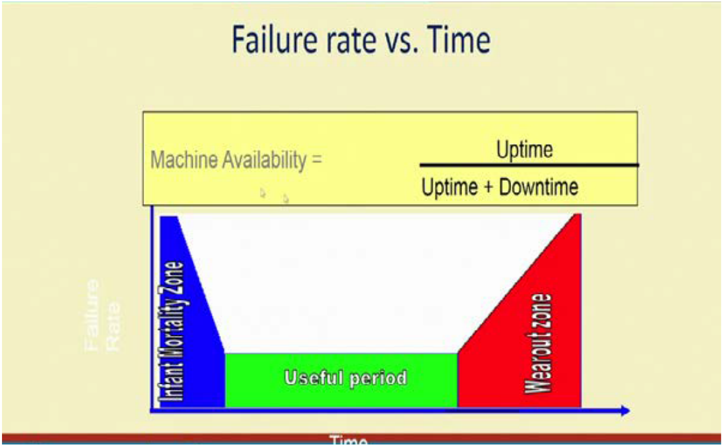
The bathtub curve is a concept often used in reliability engineering and reliability analysis to illustrate the failure rates of products or systems over their lifecycle. It's called the "bathtub curve" because when you plot the failure rate on a graph against time, it roughly resembles the shape of a bathtub. The bathtub curve consists of three distinct phases:

- **Infant Mortality Phase**: This initial phase is characterized by a relatively high and decreasing failure rate. This could occur due to factors such as improper operation, inadequate foundation, a misunderstanding of the machines, or even potential design flaws. Addressing these issues leads to a reduction in failures, resulting in improved reliability. Failures in this phase are often referred to as "infant mortality" failures.

Bathtub curve.

- **Normal Life Phase**: Following the infant mortality phase is a relatively stable period where the failure rate remains low and fairly constant. During this phase, the product is expected to operate without significant issues as long as it is properly maintained and used within its specified parameters.
- **Wear-Out Phase**: In the final phase, the failure rate begins to increase again. This increase is typically gradual at first but accelerates as the product or system ages. Failures in this phase are often the result of wear and tear, aging components, or other factors related to the end of the product's useful life.

Bathtub curve.



Bathtub curve.

The bathtub curve is a useful tool for understanding and managing the reliability of products and systems. It highlights the importance of addressing early failures through quality control and monitoring, maintaining products during their useful life, and eventually planning for replacements or upgrades as they approach the wear-out phase. By doing so, businesses can optimize product reliability and minimize downtime and associated costs.

Maintenance Techniques

Maintenance techniques are a set of strategies and practices used to ensure the optimal functioning, reliability, and longevity of equipment, machinery, systems, and infrastructure. These techniques are employed across various industries to minimize downtime, prevent breakdowns, and extend the useful life of assets. Here are some common maintenance techniques:

- Preventive Maintenance (PM): preventive maintenance is also known as periodic maintenance it involves scheduled, routine. PM is performed without implementing any sensors on the machine, and we continuously do service or maintenance on the machine. e.g. lubrication, cleaning, and parts replacement, oil change in vehicles, field gun.
- Predictive maintenance (Condition Based): predictive maintenance relies on data and monitoring to predict when equipment is likely to fail.

Maintenance Techniques

It uses technologies such as sensors, data analysis, and condition monitoring to identify issues and trigger maintenance tasks only when needed, reducing unnecessary downtime. Analyze the signal and then try to find out from a signal analysis, what is the machine's conditions. Now, this is what is done in CBM known as condition-based maintenance.

- Breakdown maintenance (Reactive): In certain cases, it may be more cost-effective to run equipment until it fails, especially for non-critical components or equipment with low replacement costs. e.g: Ballpoint Pen(refill is exhausted; we replace the refill)

Selecting the most appropriate maintenance technique(s) depends on factors such as equipment criticality, cost considerations, available resources, and industry-specific requirements. Many organizations use a combination of these techniques to create a comprehensive maintenance strategy tailored to their needs.

Benefits of Predictive Maintenance

Predictive maintenance offers several benefits across various industries, helping organizations optimize their maintenance practices and improve overall operational efficiency. Some of the key benefits of predictive maintenance include:

- **Reduced Downtime**: By identifying and addressing potential issues before they cause equipment failures, predictive maintenance minimizes unplanned downtime. This leads to increased production uptime and reduced disruptions to operations.
- **Cost Savings**: Predictive maintenance helps organizations optimize their maintenance spending. It reduces the need for unnecessary preventive maintenance tasks and prevents costly breakdowns, ultimately lowering maintenance costs.

Benefits of Predictive Maintenance

- **Enhanced Safety**: Maintaining equipment in good working condition reduces the risk of accidents and safety incidents associated with equipment failures.
- **Efficient Resource Allocation**: Resources, including labor and spare parts, can be allocated more efficiently. Maintenance teams can focus their efforts on equipment that needs attention, rather than conducting routine maintenance on all assets.
- **Optimized Inventory Management**: Predictive maintenance reduces the need for large spare parts inventories since parts can be ordered just in time when a failure is predicted. This minimizes carrying costs and the risk of obsolete parts.
- **Improved Product Quality**: Unplanned equipment failures can lead to defects in products. Predictive maintenance helps maintain consistent process conditions, leading to improved product quality.

Benefits of Predictive Maintenance

- **Energy Efficiency**: Maintaining equipment in optimal condition often leads to improved energy efficiency, as well-maintained equipment tends to operate more efficiently.
- **Data-Driven Insights**: Predictive maintenance generates valuable data and insights about equipment performance. This data can be used for continuous improvement, process optimization, and better decision-making.
- **Extended Equipment Life**: By addressing issues early and proactively, predictive maintenance can extend the operational life of equipment and assets.

Benefits of Predictive Maintenance

- **Environmental Benefits**: Fewer equipment breakdowns and failures can reduce the environmental impact associated with the disposal and replacement of equipment.
- **Competitive Advantage**: Organizations that implement predictive maintenance can gain a competitive edge by offering more reliable and efficient services, which can lead to increased customer satisfaction.
- **Improved Equipment Reliability**: Continuous monitoring and early detection of equipment issues enhance equipment reliability and extend its useful life. This results in less frequent equipment replacement and capital expenditure.

Benefits of Predictive Maintenance

These types of effects can be managed by continuously monitoring the machine's health. By 'continuously,' it doesn't necessarily mean monitoring every moment but rather at a frequency determined by the criticality of the machine. For instance, a patient in the ICU is monitored around the clock, 24/7, whereas a patient in a regular bed may be checked by a doctor two or four times a day. Similarly, the monitoring frequency for a machine can be adjusted based on its criticality.

Overall, predictive maintenance is a valuable strategy for organizations looking to maximize the availability, reliability, and cost-effectiveness of their equipment and assets while minimizing disruptions and unnecessary maintenance activities.

Techniques for Predictive Maintenance

Predictive maintenance and condition-based maintenance rely on various techniques and technologies to monitor equipment and predict potential failures. Here are some of the different techniques and methods available today:

- Vibration Analysis: Vibration sensors are used to monitor the vibrations of rotating machinery. Changes in vibration patterns can indicate issues with components such as bearings, shafts, or gears.
- Infrared Thermography: Infrared cameras are used to detect abnormal temperature patterns in equipment. Elevated temperatures can signal problems like overheating or electrical faults.
- Ultrasound Testing: Ultrasound sensors pick up high-frequency sound waves emitted by equipment. Changes in ultrasound patterns can indicate issues with bearings, valves, and other components.

Techniques for Predictive Maintenance

- Oil Analysis: Regular oil samples are analyzed to detect contaminants, wear particles, and chemical changes in lubricating oils, providing insights into the condition of the equipment.
- Acoustic Emission (AE): AE sensors detect stress waves generated by equipment under load. This technique is useful for detecting fatigue cracks and other structural issues.
- Motor Current Analysis: Monitoring the current draw of electric motors can reveal anomalies related to issues like imbalance, misalignment, or winding faults.
- IoT Sensors: Internet of Things (IoT) sensors are used to collect real-time data from equipment and send it to centralized systems for analysis.

Techniques for Predictive Maintenance

- Visual Inspection: Regular visual inspections of equipment can identify wear and damage that may not be apparent through other techniques.
- Corrosion Monitoring: Sensors and probes are used to monitor corrosion rates on metal structures and equipment.
- Lubrication Analysis: Analyzing the condition and properties of lubricants can help detect issues with gears, bearings, and other lubricated components.
- Pressure and Temperature Monitoring: Monitoring pressure and temperature parameters in systems can reveal abnormalities and performance issues.

Techniques for Predictive Maintenance

- Machine Learning and AI: Advanced data analytics, machine learning, and artificial intelligence are increasingly used to analyze vast amounts of data from multiple sources to predict equipment failures and provide early warnings.
- Remote Monitoring: Equipment can be monitored remotely using connected technologies, allowing maintenance teams to assess equipment health from a distance.
- vibration Signature Analysis: Analyzing the unique vibration patterns, or signatures, of equipment can help detect specific faults and abnormalities.

The choice of technique depends on factors such as the type of equipment, its criticality, the nature of potential failure modes, and the resources available. Many organizations use a combination of these techniques to create a comprehensive predictive maintenance program tailored to their specific needs.

Transducer for Monitoring in condition-based maintenance (CBM)

Transducers play a crucial role in condition-based maintenance by converting physical parameters or signals from machinery and equipment into electrical signals that can be monitored and analyzed. The choice of transducer depends on the specific parameter you need to monitor. Here are some common transducers used in condition-based maintenance:

- Vibration Transducers: These sensors detect mechanical vibrations in machinery and convert them into electrical signals. Types of vibration transducers include accelerometers, velocity sensors, and displacement sensors.
- Pressure Transducers: Pressure transducers measure fluid or gas pressure within the equipment. They are used to monitor pressure variations that may indicate problems.

Transducer for Monitoring in condition-based maintenance (CBM)

- Flow Transducers: Flow transducers measure the rate of fluid flow within pipes and systems. Changes in flow rates can indicate issues like blockages or leaks.
- Electrical Signature Analysis Sensors: These sensors capture electrical signals from motors and generators, which can be analyzed to detect anomalies. (Hall effect sensor)
- Acoustic Emission Sensors: These sensors detect stress waves or acoustic emissions generated by equipment under load, helping identify defects and structural issues.(Particle count meter)

Transducer for Monitoring in condition-based maintenance (CBM)

- Infrared (IR) Thermocouples: IR thermocouples measure temperature by capturing the infrared radiation emitted by an object. They are used for non-contact temperature monitoring. (IR detector)
- Acoustic Emission Sensors: These sensors detect stress waves or acoustic emissions generated by equipment under load, helping identify defects and structural issues.

The selection of the appropriate transducer depends on the specific monitoring needs and the parameters critical to the equipment's health and performance.

Predictive Maintenance System

A predictive maintenance system comprises several key components. It begins with the essential hardware, which primarily consists of transducers. Alongside the hardware, there is an automated data acquisition system responsible for collecting signals from these sensors. Furthermore, the system is complemented by specialized software. In order to be effective, the entire system must possess the qualities of flexibility, reliability, and precision.

- User-friendly with hardware and software
- Automated data acquisition
- Automated data management and trending
- Accuracy
- Reliability
- Flexibility

Predictive Maintenance Management

Predictive maintenance management is a philosophy that leverages the real-time operational status of plant equipment and systems to enhance overall plant performance. It is a condition-based preventive maintenance program designed to optimize plant operations.

Requirements of a successful Maintenance Program

A successful maintenance program requires careful planning, resources, and commitment to ensure equipment reliability, minimize downtime, and optimize overall operations. Here are some key requirements for a successful maintenance program:

- Clear Objectives: Define clear and specific maintenance objectives aligned with overall business goals. Understand what you want to achieve with your maintenance program, such as reducing downtime, improving equipment lifespan, or enhancing safety.

- Management Support: Gain support and commitment from senior management to allocate resources, budget, and personnel to the maintenance program. Leadership endorsement is critical for program success.

Requirements of a successful Maintenance Program

- Skilled Workforce: Employ and train skilled maintenance personnel with expertise in various maintenance techniques and technologies. Having a well-trained team is essential for effective maintenance.
- Equipment Knowledge: Develop a deep understanding of your equipment and machinery, including their critical components, maintenance requirements, and failure modes.
- Asset Management: Implement an asset management system to track and document equipment, maintenance history, and performance data.

Requirements of a successful Maintenance Program

- Reliable Data Collection: Use sensors, data loggers, and monitoring systems to collect accurate and relevant data on equipment condition. Ensure data accuracy and integrity.
- Maintenance Planning and Scheduling: Create a structured maintenance plan that includes routine preventive maintenance tasks, inspections, and schedules. Prioritize maintenance tasks based on criticality.
- Predictive Maintenance Tools: Utilize predictive maintenance technologies, such as sensors and data analytics, to monitor equipment health and predict failures before they occur.
- Inventory Management: Maintain an organized spare parts inventory to ensure quick access to critical components when needed. Implement an efficient inventory management system to avoid overstocking or stockouts.

Requirements of a successful Maintenance Program

- Safety Protocols:Develop and enforce safety protocols and procedures for maintenance activities to protect employees and equipment.
- Root Cause Analysis: Implement a process for investigating the root causes of equipment failures to prevent recurring issues.
- Documentation and Records: Maintain accurate records of maintenance activities, including work orders, inspections, and repairs. Document lessons learned and share knowledge among the maintenance team.
- Performance Metrics: Establish key performance indicators (KPIs) to measure the effectiveness of the maintenance program. Monitor and analyze data to identify areas for improvement.

Requirements of a successful Maintenance Program

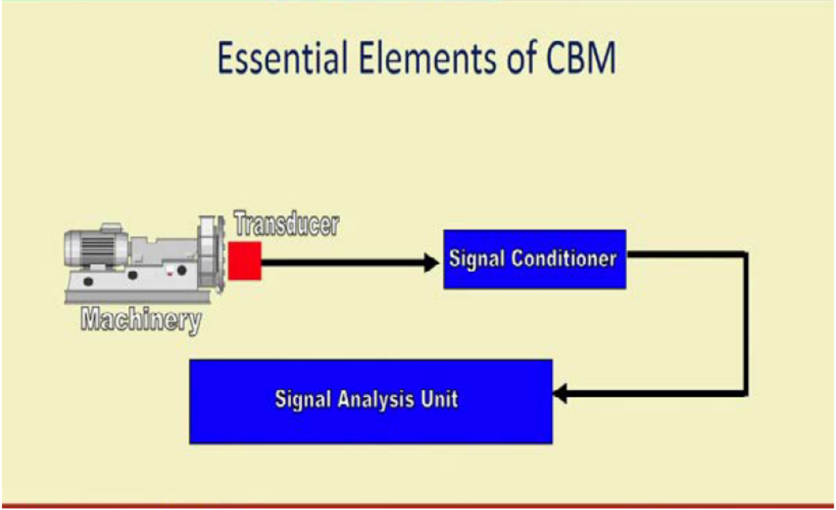
- Continuous Improvement: Continuously review and refine the maintenance program based on data and feedback. Seek opportunities for process optimization and cost reduction.
- Budgeting and Resource Allocation: Allocate sufficient budget and resources to meet maintenance requirements. Balance cost-effectiveness with the need for quality maintenance.
- Training and Development: Provide ongoing training and development opportunities for maintenance staff to keep them updated on industry best practices and new technologies.
- Communication: Foster open communication and collaboration between maintenance teams, operations, and other relevant departments to ensure everyone is aligned with maintenance goals.

Requirements of a successful Maintenance Program

- Compliance: Ensure compliance with regulatory requirements, safety standards, and industry best practices.
- Asset Replacement Planning: Develop a strategy for asset replacement or upgrades when equipment reaches the end of its useful life or becomes obsolete.
- Emergency Response Plan: Have a well-defined plan in place to respond to emergency maintenance situations and minimize unplanned downtime.

By addressing these requirements, organizations can establish a robust and effective maintenance program that contributes to improved equipment reliability, reduced costs, and enhanced overall operational performance.

Essential Elements of CBM



Condition Based Maintenance

And today CBM is used almost everywhere.

FMECA

Failure Modes, Effects, and Criticality Analysis.

FMECA

In this section, we delve into the world of FMECA, which stands for "Failure Modes Effects and Criticality Analysis." As you've come to understand, we've explored three maintenance techniques: periodic maintenance (or preventive maintenance), predictive maintenance (also known as condition-based maintenance), and reactive maintenance (or breakdown maintenance). While predictive maintenance is often the more cost-effective choice in the long run, managing maintenance for extensive operations like steel plants, cement plants, or shipyards presents a unique challenge. Determining which equipment should take precedence for maintenance can be a complex task. FMECA serves as a powerful tool in this regard by helping identify and prioritize critical equipment that demands heightened maintenance attention. We will delve into the process of conducting FMECA and explore how it aids in making informed decisions about maintenance strategies for complex industrial systems.

FMECA

FMECA

Failure Modes Effects and Criticality Analysis.

What is FMECA?

FMECA is a methodology to identify and analyze

- All potential failure modes of the various parts of the system.
- The effects these failures may have on the system
- How to avoid the failures and mitigate the effects of the failures on the system.

E.g. where we see FMECA

- steel plant
- cement plant
- shipyard

FMECA in a Steel Plant

In a steel manufacturing facility, the production process involves various critical components and systems, including blast furnaces, converters, ladle furnaces, rolling mills, and material handling equipment. Implementing FMECA in this context can help identify and prioritize maintenance efforts for optimal operational efficiency and safety.

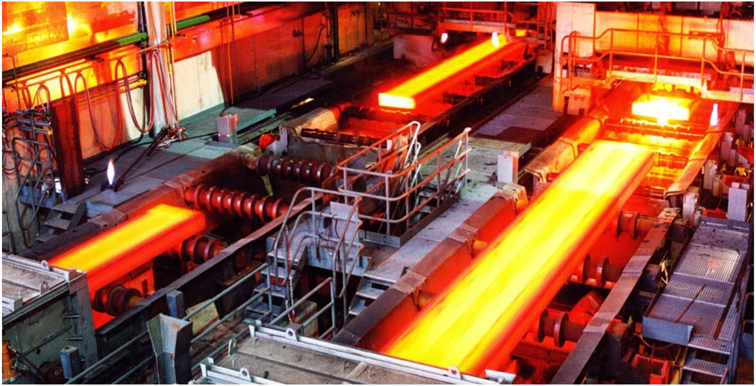
- Blast Furnace
- Rolling Mills:
- Material Handling

Blast Furnace

Blast Furnace

- Failure Modes: FMECA would assess potential failure modes of the blast furnace, such as refractory lining wear, temperature control system malfunctions, or gas leakage.
- Criticality Assessment: These failure modes are ranked by their criticality based on their impact on production, safety, and environmental factors. For example, a refractory lining failure can lead to a costly shutdown and pose safety risks.
- Preventive Measures: FMECA guides the establishment of a proactive maintenance plan. Regular refractory inspections, temperature sensor calibration, and gas leak detection systems are implemented to address identified failure modes.

Rolling Mills



Rolling Mills

- Failure Modes: FMECA examines rolling mill components, including rollers, motors, and cooling systems. Failure modes might include roller wear, motor breakdowns, and coolant system failures.
- Criticality Assessment: These failure modes are assessed based on their potential to disrupt production and product quality. Roller wear may result in defective steel sheets.
- Preventive Measures: FMECA informs a maintenance strategy that includes routine roller inspections, motor maintenance, and coolant system monitoring to mitigate identified failure modes.

Material Handling

Material Handling

- Failure Modes: Material handling equipment, such as cranes and conveyors, can experience breakdowns, electrical faults, or structural issues.
- Criticality Assessment: FMECA evaluates these failure modes in terms of their impact on material flow, production downtime, and safety.
- Preventive Measures: Maintenance plans are developed based on FMECA findings, incorporating regular inspections, lubrication, and structural integrity checks to minimize material handling disruptions.

Through FMECA, the steel plant can systematically identify and prioritize critical equipment and failure modes. This enables the plant to implement targeted preventive and predictive maintenance measures, ensuring smoother operations, enhanced safety, reduced downtime, and cost-effective maintenance practices. FMECA ultimately contributes to the overall efficiency and competitiveness of the steel manufacturing process.

What can FMECA use for?

- Assist in the selection of design alternatives with high reliability
- Ensure that all conceivable failure modes and their effects on the operational success of the system have been considered
- How to avoid the failures and mitigate the effects of the failures on the system.
- List potential failures and identify the severity of their effects
- Develop early criteria for test planning and test equipment requirement
- Provide historical documentation for future reference
- Provide a basis for maintenance planning
- Provide a basis for quantitative reliability and availability analysis

When do we perform FMECA?

When do we perform FMECA?

The FMECA should be initiated early in the design process, where we can have the greatest impact on the equipment reliability.

Types of FMECA

- Design FMECA is carried out to eliminate failures during equipment design, taking into account all types of failures during the whole lifespan of the equipment.
- Process FMECA is focused on problems stemming from how the equipment is manufactured, maintained, or operated.
- System FMECA looks for potential problems and bottlenecks in larger processes, such as entire production lines.

Types of FMECA

For instance, when designing a shaft, one can approach it in several ways—designing based solely on a constant torque, considering only dynamic torque, or factoring in a comprehensive range of loads, including bending, axial, and torsional dynamic loads.
Likewise, in the context of design FMECA (Failure Modes Effects and Criticality Analysis), engineers consider a multitude of failure-related factors while designing equipment. This meticulous analysis enables them to determine the robustness of the design and its ability to withstand potential challenges.
Similarly, in the realm of manufacturing, consider an assembly line for automobiles. This complex process involves critical junctures such as engine installation, body shell integration, suspension system assembly, and more. A flaw at any of these points can significantly impact the final product's quality and performance. System FMECA is instrumental in identifying potential issues and bottlenecks within large-scale processes, including entire production lines.

FMECA prerequisites

- Define the system to be analyzed.
- Collect available information that describes the system to be analyzed; including drawings, specifications, schematics, component lists, interface information, functional descriptions, and so on.
- Collect information about previous and similar designs from internal and external sources, interviews with design personnel, operations, and maintenance personnel, and component suppliers.

System structure analysis

- Divide the system into manageable units, typically functional elements.
- Sometimes it may be beneficial to illustrate the system by a functional block diagram.
- The analysis should be carried out on as high a level in the system hierarchy as possible.

Risk ranking and team review

Risk ranking and team review are important aspects of risk assessment and management in various fields, including engineering, project management, and safety management.
Risk ranking, often referred to as risk prioritization or risk assessment, is a process used to evaluate and prioritize risks based on their significance, potential impact, and likelihood of occurrence. The goal is to identify and focus on the most critical risks that require attention and mitigation efforts.

Risk ranking and team review

The risk related to the various failure modes often presented either by a

- Risk Matrix.
- Risk priority number (RPN).

The most important number in FMECA is known as the risk priority number. So, from FMECA we find out what is known as a risk priority number.

Risk priority number

RPN is defined by this quantity OSD

- O: The rank of occurrence of a failure mode (how or what is the frequency of occurrence of this failure mode).
- S: The rank of the severity of the failure mode (means if a failure has occurred, how is it going to affect the process).
- D: The rank of the likelihood that the failure will be detected before the system reaches the end-user or the customer).
- Each one of these is given a rank, from 1 to 10.
- Risk Priority Number $=$ O $\times$ S $\times$ D
- The smaller RPN the better - and - large the worse.

RPN has no clear meaning

- How the ranks O, S, and D are defined depends on the application and FMECA standard that is used.
- RPN can have different meanings for each FMECA.
- sharing numbers between companies and groups is very very difficult.

Review objectives

How do we do the review of the FMECA? The review team studies the FMECA worksheets and the risk matrices and/or the risk priority number. The main objectives are

- To decide whether or not the system is acceptable.
- To identify the feasible improvement of the system to reduce the risk. this may be achieved by:
  - Reducing the likelihood of occurrence of failure.
  - Reduce the effects of failure.
  - Increase the likelihood that the failure is detected before the system reaches the end-user.

Actions for reduction of risks

- Design changes.
- Engineered safety features.
- Safety devices.
- Warning device.
- Procedure/training.

Application of FMECA

- Design Engineering: The FMECA worksheets are used to identify and correct potential design-related problems.
- Manufacturing: The FMECA worksheets may be used as input to optimize production, and acceptance testing.
- Maintenance planning: The FMECA worksheet is used as an important input to maintenance planning.

Thank You!