Process Failure Modes and Effects Analysis

PFMEA for Suppliers
Process Failure Modes and Effects Analysis

A structured approach that ensures potential process failure modes and their associated causes have been considered and addressed in the design of the process

– What can go wrong?
– Where will the variation come from?
– How can we prevent or control?
Overview of the PFMEA Process

- People knowledgeable about the process analyze situations where critical customer requirements might not be met
- A ranking system is used to estimate three factors:
  - how severe the failure would be
  - how frequently the failure would occur,
  - how difficult it would be to detect, and
- The S/O/D factors are multiplied; the resulting value is called the Risk Priority Number (RPN)
- The RPN is used to prioritize the failure modes so that corrective actions can be taken to reduce the frequency, severity and/or improve the detectability of the failure mode
- PFMEA output is the starting point for the
  - Process redesign/leaning
  - Control Plan
  - Out-of-Control Action Plan (OCAP)
PFMEA Benefits

- Disciplined approach for identifying the ways a process design can fail before impacting the customer or the product function
  - Identifies potential manufacturing and/or assembly process failures
  - Identifies the significant process variables to control to reduce occurrence and improve detection of failure conditions
- Rational prioritization of potential failures for corrective/preventive action and/or redesign
- Helps to identify critical process parameters
- Provides critical input for the process control plan
- Opportunity to collaborate with and influence Raytheon designers to eliminate problems before they occur in your production line
- Smoother production ramps
- Reduced development, production and warranty cost
- Higher customer satisfaction
PFMEA Prerequisites

- Select proper team and organize members effectively
- Select teams for each process
- Create/agree on a ranking system
- Agree on format for the PFMEA matrix
- Define the customer and customer needs/expectations
- Define the process requirements
- Map the baseline process with a flow chart
PFMEA Flow

1. Assemble the team
2. Map the process
3. Assign S/O/D ratings
   Calculate RPN
4. Create action plan to reduce RPN
5. Drive actions to resolution
6. Implement controls
7. Re-baseline RPNs

FAILURE MODE: How a product can fail to meet design specifications or functional intent
CAUSE: A deficiency that results in a failure mode ➔ e.g. sources of variation
EFFECT: Impact on customer if the failure mode is not prevented or corrected
Typical PFMEA Team Members

- Process Engineer - Generally the Team Leader
- Production Operators
- Industrial Engineer
- Design Engineer
- Quality Engineer
- Reliability Engineer
- Tooling Engineer
- Maintenance Engineer
- Project Manager
- Others including Sales, QA/QC, Operations
Creating the Process Map

- Identify the process to map
- Ask the people most familiar with the process to help construct the map
- Agree on the start and end points; defining the scope of the process to be mapped is important, otherwise the task can become unwieldy
- Agree on the level of detail to use; it’s better to start out with less detail, increasing detail only as needed to accomplish your purpose
- Identify the sequence and the steps taken to carry out the process; walk the line if necessary
- Construct the process map either from left to right or from top to bottom, using standard flow chart symbols and connecting the steps with arrows
- Identify key process characteristics as potential sources of failure
  - Is the process standardized, or are the people doing the work in different ways?
  - Are steps repeated or out of sequence?
  - Are there steps where errors occur frequently?
  - Are there rework loops?
- Analyze the results and document potential failure modes at each process step
HV Capacitor: High Level Process Map

Winding → Curing → Swage & Assemble → Solder to Covers → Weld cover → Impregnation

WO issue & kitting → Weld cans, blanks & covers → Braze terminals → Weld back plates & can → Clean can & cover

Note: Test points are at winding, curing, assembly, weld, impregnation and seal
Organizing Information Using the PFMEA Template

- List each process step from the process map
- Describe the potential failure modes for each process step
- Identify the impact of each potential failure mode on downstream processes, product functionality or the customer experience
- Identify likely causes in the process for these failure modes
- Describe the current process controls—if they exist—that are in place to contain the causes
- Assign appropriate values to Severity/Occurrence/Detectability to obtain RPN (note: scale descriptions are included in PFMEA template)
  - Severity: Scale 1-10, 1=no impact, 10=catastrophic impact/hazardous
  - Occurrence: Scale 1-10, 1=predicted <3 defects/million, 10=>500K defects/million
  - Detectability: Scale 1-10, 1=always detected by current control plan, 10=unable to detect
- Sort process steps by RPN number high-to-low to prioritize the action plan for maximum impact
PFMEA Template

<table>
<thead>
<tr>
<th>Process Step</th>
<th>Potential Failure Mode(s)</th>
<th>Potential Effect(s) of Failure</th>
<th>P-M</th>
<th>Potential Cause(s)/ Mechanism(s) of Failure</th>
<th>R-C</th>
<th>Current Process Controls</th>
<th>S</th>
<th>P</th>
<th>R</th>
<th>Recommended Action(s)</th>
<th>Owner</th>
<th>Completion Date</th>
<th>Actions Taken</th>
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</tbody>
</table>
### PFMEA Example

**PFMEA Objective, scope and goal:** Review capacitor assembly/test process for potential failure modes and control risk mitigation strategy

<table>
<thead>
<tr>
<th>Process ID</th>
<th>Process Description</th>
<th>Potential Failure Mode(s)</th>
<th>Potential Effect(s) of Failure</th>
<th>Potential Cause(s)/Mechanism(s) of Failure</th>
<th>Current Process Controls</th>
<th>Recommended Action(s)</th>
<th>Owner</th>
<th>Completion Date</th>
<th>Action Results</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
<tr>
<td>Terminal brazing (cover and cap)</td>
<td>leaks, dimensions</td>
<td>scrap</td>
<td>9 time and temperature</td>
<td>10 humidity leak test, ATP seat test, internal shock</td>
<td>3.5 115 DOE to optimize parameter settings for robustness</td>
<td>PE/GE</td>
<td>Complete</td>
<td>9 1 2 18</td>
<td></td>
</tr>
<tr>
<td>Swaging</td>
<td>hpot, corona, DF, IR</td>
<td>scrap</td>
<td>9 operator error, material</td>
<td>4 can size</td>
<td>5 116 review operator certification requirements, material requirements</td>
<td>PE/GE/Line Supy</td>
<td>Complete</td>
<td>9 2 1 16</td>
<td></td>
</tr>
<tr>
<td>Welding</td>
<td>leaks, dimensions, hpot, corona</td>
<td>scrap</td>
<td>9 fixture, operator skill</td>
<td>8 PM, low temp, electrical test</td>
<td>2 116 process capability analysis, review operator certification requirements</td>
<td>PE/GE/Line Supy</td>
<td>Complete</td>
<td>9 1 2 16</td>
<td></td>
</tr>
<tr>
<td>Impregnation</td>
<td>corona</td>
<td>var</td>
<td>20 process capability analysis</td>
<td>20 operation, P/F, dimension</td>
<td>PE/GE/Line Supy</td>
<td>Complete</td>
<td>9 1 2 16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impregnation</td>
<td>DF, low capacitance</td>
<td>scrap</td>
<td>8 machine (time, temp, oil quality), operator</td>
<td>8</td>
<td>PE/GE</td>
<td>Complete</td>
<td>9 1 2 16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Welding</td>
<td>leaks, dimensions, hpot failure, corona</td>
<td>var</td>
<td>3 fixture, operator skill, specification</td>
<td>3 operator error, operator skill, specification, material type, contamination</td>
<td>PE/GE</td>
<td>Complete</td>
<td>3 1 2 18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cutting</td>
<td>dimensions, soft, cap variation, DF</td>
<td>scrap or rework</td>
<td>3 variable component time, variable pressure, temperature, contamination</td>
<td>3</td>
<td>PE/GE</td>
<td>Complete</td>
<td>3 1 2 16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Welding</td>
<td>capacitance, dimension</td>
<td>scrap</td>
<td>2 operator error, welding machine, material (thickness, elongation, damaged, curl)</td>
<td>2</td>
<td>PE/GE</td>
<td>Complete</td>
<td>2 3 2 17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Testing Pads</td>
<td>damage to pad</td>
<td>scrap</td>
<td>2 operator error, shorting, test error</td>
<td>2</td>
<td>None</td>
<td>--</td>
<td>2 3 2 17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Testing</td>
<td>false failure</td>
<td>of test</td>
<td>2 operator error, test fixture error</td>
<td>2</td>
<td>None</td>
<td>--</td>
<td>2 3 2 17</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Raytheon**  
*Customer Success Is Our Mission*
## Potential Process Failure Causes

<table>
<thead>
<tr>
<th>Causes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Omitted processing</td>
</tr>
<tr>
<td>Processing errors</td>
</tr>
<tr>
<td>Errors setting up work pieces</td>
</tr>
<tr>
<td>Missing parts</td>
</tr>
<tr>
<td>Wrong parts</td>
</tr>
<tr>
<td>Processing wrong work piece</td>
</tr>
<tr>
<td>Mis-operation</td>
</tr>
<tr>
<td>Adjustment error</td>
</tr>
<tr>
<td>Equipment not set up properly</td>
</tr>
<tr>
<td>Tools and/or fixtures improperly prepared</td>
</tr>
<tr>
<td>Poor control procedures</td>
</tr>
<tr>
<td>Improper equipment maintenance</td>
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<tr>
<td>Bad recipe</td>
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<tr>
<td>Fatigue</td>
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<tr>
<td>Lack of Safety</td>
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<tr>
<td>Hardware failure</td>
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<tr>
<td>Failure to enforce controls</td>
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<tr>
<td>Environment</td>
</tr>
<tr>
<td>Stress connections</td>
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<tr>
<td>Poor FMEA(s)</td>
</tr>
</tbody>
</table>
# PFMEA S/O/D Ratings

## AIAG Compiled Ratings

<table>
<thead>
<tr>
<th>Rating</th>
<th>Severity of effect</th>
<th>Likelihood of Occurrence</th>
<th>Ability to Detect</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Hazardous and without warning</td>
<td>Very high; failure is almost inevitable</td>
<td>Cannot detect</td>
</tr>
<tr>
<td>9</td>
<td>Hazardous and with warning</td>
<td></td>
<td>Very remote chance of detection</td>
</tr>
<tr>
<td>8</td>
<td>Loss of primary function</td>
<td>High, repeated failures</td>
<td>Remote chance of detection</td>
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<tr>
<td>7</td>
<td>Reduced primary function performance</td>
<td></td>
<td>Very low chance of detection</td>
</tr>
<tr>
<td>6</td>
<td>Loss of secondary function</td>
<td>Moderate; occasional failures</td>
<td>Low chance of detection</td>
</tr>
<tr>
<td>5</td>
<td>Reduced secondary function performance</td>
<td></td>
<td>Moderate chance of detection</td>
</tr>
<tr>
<td>4</td>
<td>Minor defect noticed by most customers</td>
<td></td>
<td>Moderately high chance of detection</td>
</tr>
<tr>
<td>3</td>
<td>Minor defect noticed by some customers</td>
<td></td>
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<tr>
<td>2</td>
<td>Minor defect noticed by discriminating customers</td>
<td></td>
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<tr>
<td>1</td>
<td>No effect</td>
<td>Remote: failure is unlikely</td>
<td>Almost certain detection</td>
</tr>
</tbody>
</table>

## Severity  Occurrence  Detectability

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Defining the Action Plan

- If the control plan for the process step is adequate, no further action required (typically if RPN value is <20)
- If the control plan for the process step is inadequate:
  - Identify differences between the current and the desired situation
  - Determine how the failure can be better contained and/or eliminated
    - Consider implementation of new or more effective process controls
    - Assess if process steps that don’t add value to the output can be eliminated
    - Determine if design modification is effective at eliminating or reducing occurrence or detectability of the failure mode, and if it can be accommodated
- Document plan and reassess S/O/D and RPN values; is it enough?
- Separate between
  - Supplier actions
  - Raytheon actions
  - Joint actions
- Publish result and include in quote/feedback to Raytheon Engineering and Procurement teams
- **Manage to the plan**
Potential Process Controls

- Standardized work instructions/procedures
- Fixtures and jigs
- Mistake-proofing tooling and/or product design
- Mechanical interference interfaces
- Mechanical counters
- Mechanical sensors
- Electrical/Electronic sensors
- Job sheets or Process packages
- Bar coding with software integration and control

- Marking
- Training and related educational safeguards
- Visual checks
- Post process inspection/testing
- Gage/MSA studies
- Statistical Process Control
- Design of experiments on the process/Robust process design
- Preventive maintenance
- Automation & Real Time Control
PFMEA as Part of ISO9001

Process Failure Mode and Effect Analysis
Measurement System Analysis
Advanced Product Quality Planning & Control Plan
Statistical Process Control
Quality System Analysis
Production Part Approval Process
Tooling and Equipment Supplement

ISO-9001 QS-9000
Linkage to Raytheon

- PFMEA is a team effort
- Promotes actionable input to the design phase
  - Designs can and do impact ability to execute processes, and vice versa
- Enables suppliers to add value and influence designs by highlighting functional concerns earlier in the design/development process
- The risk of some failure modes will be associated with:
  - Supplier process capabilities
  - Non value-added steps
  - Material or finish selection
  - Design requirements
  - Material flows
  - Rework flows
  - Test and/or detection strategies and capabilities
- Mitigation action plans could include:
  - Supplier actions
  - Joint Raytheon/supplier actions
Resources

Textbooks:

- **Failure Mode and Effect Analysis: FMEA from Theory to Execution**; **Author:** D.H. Stamatis
- **The Basics of FMEA**; **Authors:** Robin E. McDermott, Raymond J. Mikulak, Michael R. Beauregard

On the Web:

  - [http://www.fmeainfocentre.com/examples.htm](http://www.fmeainfocentre.com/examples.htm)