FMEA
Failure Mode and Effects Analysis

Adapted from presentation by Dr. Stamper

Outline

- Failure Mode and Effects Analysis
  - What is it?
  - Motivation
  - FMEA Methods
  - Example
- FMEA in-class exercise

What is an FMEA?

Description:

- A procedure that examines each item in a system, considers how that item can fail and then determines how that failure will affect (or cascade through) the system

Acronyms

- FMEA: Failure Modes and Effects Analysis
- FMECA: Failure Modes and Effects and Criticality Analysis

Motivation for Conducting a FMEA

- Improves design by discovering unanticipated failures
- Highlights the impact of the failures
- Potentially helpful during legal actions
- Provides a method to characterize product safety
- Often required (e.g. FDA and DOD procurement)

Method to Conduct an FMEA

(taken from ASM Handbook Vol. 11)

- Identify all components or systems at given level of the design hierarchy.
- List the function of each identified component or system.
- Identify failure modes for each component/system. Typically there will be several ways in which a component can fail.
- Determine the effect (both locally and globally) on the system.

Method to Conduct an FMEA

(taken from ASM Handbook Vol. 11)

- Classify the failure by its effects on the system operation.
- Determine the failure's probability of occurrence.
- Identify how the failure mode can be detected (may point out what needs to be inspected on a regular basis).
- Identify any compensating provisions or design changes to mitigate the failure effects.

Other Variations of the Method

- Mil-STD-1629A, Fig 101.3

http://www.fmea-fmeca.com/milstd1629.pdf

- SAE J1739

http://www.fmea-fmeca.com/fmea-examples.html

DESIGN FMEA (DFMEA)

- The Design FMEA is used to analyze products before they are released to production.
- It focuses on potential failure modes of products caused by design deficiencies.
- Design FMEAs are normally done at three levels – system, subsystem, and component levels.
- This type of FMEA is used to analyze hardware, functions or a combination.

PROCESS FMEA (PFMEA)

- The Process FMEA is normally used to analyze manufacturing and assembly processes at the system, subsystem or component levels.

- This type of FMEA focuses on potential failure modes of the process that are caused by manufacturing or assembly process deficiencies.

FMEA Template for AIAG and Six Sigma

MEADinfo Product

Prepared By:												FMEA No/Rev: 0000/01						
Date: 00/00/00												Process/Component:						
												Action Results						
Item	Function	Potential Failure Mode	Potential Effects or Failure	Svrty	Potential Causes of Failure	Ocrnc	Current Controls for Prevention/ Detection	Dtctn	RPN	Recommended Action	Responsibility and Target Completion Date	Action Taken	Svrty	Ocrnc	Dtctn	RPN		
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http://www.meadinfo.org/2009/11/download-fmea-template-aiag-six-sigma.html

POTENTIAL
FAILURE MODE AND EFFECTS ANALYSIS
Front Door L.H.

System: 1 - Automobile

___ Subsystem: 2 - Body Closures

X Component: 3 - Front Door L.H.

Model Year(s)/Program(s): 199X/Lion 4dr/Wagon

Core Team: T. Fender - Car Product Dev., C. Childers - Manufacturing, J. Ford - Assy Ops (Dalton, Fraser, Henley Assembly Plants)

Design Responsibility: Body Engineering

Key Date: 3/3/2003

FMEA Number: 1234

Prepared By: A. Tate - X6412 - Body Engr

FMEA Date (Orig.): 2/28/2003 (Rev): 3/3/2003

Item / Function	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Class	Potential Cause(s)/Mechanism(s) of Failure	Occur	Current Design Controls	Detec	RPN	Recommended Action(s)	Responsibility & Target Completion Date	Action Results: Actions Taken	Sev	Occ	Det	RPN
3 - Front Door L.H.																
- Ingress to and egress from vehicle. - Occupant protection from weather, noise, and side impact. - Support anchorage for door hardware including mirror, hinges, latch and window regulator. - Provide proper surface for appearance items - paint and soft trim.	Corroded interior lower door panels	Deteriorated life of door leading to: - Unsatisfactory appearance due to rust through paint over time. - Impaired function of interior door hardware.	7		Upper edge of protective wax application specified for inner door panels is too low.	6	Vehicle general durability test veh. T-118 T-109 T-301	7	294	Add laboratory accelerated corrosion testing.	A. Tate Body Engrg - 2/25/2003	Based on test results (Test No. 1481) upper edge spec raised 125 mm.	7	2	2	28
					Insufficient wax thickness specified.	4	Vehicle general durability testing - as above. - Detection	7	196	Add laboratory accelerated corrosion testing.	A. Tate Body Engrg - 3/28/2003	Test results (Test No. 1481) show specified thickness is adequate.	7	2	2	28
										Conduct Design of Experiments (DOE) on wax thickness.	A. Tate Body Engrg - 3/28/2003	DOE shows 25% variation in specified thickness is acceptable.				
					Inappropriate wax formulation specified.	2	Physical and Chem Lab test - Report No. 1265. - Detection	2	28				7	2	2	28
					Entrapped air prevents wax from entering corner/edge access.	5	Design aid investigation with nonfunctioning spray head. - Detection	8	280	Add team evaluation using production spray equipment and specified wax.	Body Engrg & Assy Ops - 3/28/2003	Based on test, addition vent holes will be provided in affected areas.	7	1	3	21
					Wax application plugs door drain holes.	3	Laboratory test using "worst case" wax application and hole size. - Detection	1	21				7	3	1	21
					Insufficient room between panels for spray head access.	4	Drawing evaluation of spray head access. - Detection	4	112	Add team evaluation using design aid buck and spray head.	Body Engrg & Assy Ops - 3/28/2003	Evaluation showed adequate access.	7	1	1	7

What to Do

- Function comes from Functional Analysis, Functional Decomposition
- Potential Failure Mode comes from things that have gone wrong in the past, concerns of designers, and brainstorming. Possible considerations are partial function, intermittent function, excess function.
- Potential Effects are consequences to the design, the user, and the environment. Safety and regulation noncompliance are critical issues.

IN-CLASS PROBLEM 1

Most cars have a fuel filter between the fuel tank and the engine. Consider the consequences of

a) Anti-function (opposite of filtering)

b) Partial function

c) Intermittent function

d) Excess function

What to Do

- Potential Causes of failure should be engineering related such as incorrect material, corrosion, wear and human related such as inexperience, misuse, etc.
- Current Design Controls are things like inspections, testing, poke yoke, and other design checks that are intended to prevent the problem.

What to Do

- Assign values to Severity, Occurrence, and Detection using the tables on the next three pages.
- Determine the Risk Priority Number (Severity* Occurrence * Detection)
- Develop an action plan
- Implement an action plan

AIAG Compelled Rating			
Rating	Severity of Effect	Likelihood of Occurrence	Ability to Detect
10	Hazardous without Warning	Very high; Failure is almost inevitable	Can not detect
9	Hazardous with Warning	Very high; Failure is almost inevitable	Very remote chances of detection
8	Lose of primary function	High; Repeated failures	Remote chances of detection
7	Reduced primary function performance	High; Repeated failures	Very low chances of detection
6	Lose of secondary function	Moderate; Occasional failures	Low chances of detection
5	Reduced secondary function performance	Moderate; Occasional failures	Moderate chances of detection
4	Minor defect noticed by most customers	Moderate; Occasional failures	Moderate high chances of detection
3	Minor defect noticed by some customers	Low; Relatively low failures	High chances of detection
2	Minor defect noticed by discriminating customers	Low; Relatively low failures	Very high chances of detection
1	No effect unlikely	Remote; Failure is unlikely	Almost certain

http://www.meadinfo.org/2009/11/download-fmea-template-aiag-six-sigma.html

Severity Guidelines

Effect	Rank	Criteria
None	1	No effect
Very Slight	2	Negligible effect on Performance. Some users may notice.
Slight	3	Slight effect on performance. Non vital faults will be noticed by many users
Minor	4	Minor effect on performance. User is slightly dissatisfied.
Moderate	5	Reduced performance with gradual performance degradation. User dissatisfied.
Severe	6	Degraded performance, but safe and usable. User dissatisfied.
High Severity	7	Very poor performance. Very dissatisfied user.
Very High Severity	8	Inoperable but safe.
Extreme Severity	9	Probable failure with hazardous effects. Compliance with regulation is unlikely.
Maximum Severity	10	Unpredictable failure with hazardous effects almost certain. Non-compliant with regulations.

Occurrence Ranking (one interpretation)

Occurrence	Rank	Criteria
Extremely Unlikely	1	Less than 0.01 per thousand
Remote Likelihood	2	≈0.1 per thousand rate of occurrence
Very Low Likelihood	3	≈0.5 per thousand rate of occurrence
Low Likelihood	4	≈1 per thousand rate of occurrence
Moderately Low Likelihood	5	≈2 per thousand rate of occurrence
Medium Likelihood	6	≈5 per thousand rate of occurrence
Moderately High Likelihood	7	≈10 per thousand rate of occurrence
Very High Severity	8	≈20 per thousand rate of occurrence
Extreme Severity	9	≈50 per thousand rate of occurrence
Maximum Severity	10	≈100 per thousand rate of occurrence

Occurrence Ranking (another Interpretation)

Probability of Failure	Possible Failure Rates	Ranking
Very High: Failure is almost inevitable	≥ 1 in 10 or ≥ 10%	10
	≥ 1 in 20 < 1 in 10 or ≥ 5% < 10%	9
High: Repeated failures	≥ 1 in 40 < 1 in 20 or ≥ 2.5% < 5%	8
	≥ 1 in 100 < 1 in 40 or ≥ 1% < 2.5%	7
Moderate: Occasional failures	≥ 1 in 200 < 1 in 100 or ≥ 0.5% < 1%	6
	≥ 1 in 1000 < 1 in 200 or ≥ 0.1% < 0.5%	5
	≥ 250 PPM < 1000 PPM or ≥ 0.025% < 0.1%	4
Low: Relatively few failures	≥ 50 PPM < 250 PPM or ≥ 0.005% < 0.025%	3
	≥ 1 PPM < 50 PPM	2
Remote: Failure is unlikely	< 1 PPM	1

http://rmcpharmanews.blogspot.com/2010/06/informing-fmea.html

Detection Ranking

Detection	Rank	Criteria
Extremely Likely	1	Can be corrected prior to prototype/ Controls will almost certainly detect
Very High Likelihood	2	Can be corrected prior to design release/Very High probability of detection
High Likelihood	3	Likely to be corrected/High probability of detection
Moderately High Likelihood	4	Design controls are moderately effective
Medium Likelihood	5	Design controls have an even chance of working
Moderately Low Likelihood	6	Design controls may miss the problem
Low Likelihood	7	Design controls are likely to miss the problem
Very Low Likelihood	8	Design controls have a poor chance of detection
Remote Likelihood	9	Unproven, unreliable design/poor chance for detection
Extremely Unlikely	10	No design technique available/Controls will not detect

IN-CLASS PROBLEM 2

Suppose you are designing an accelerator pedal assembly for an automobile. After the publicity of accelerator sticking issues and the multiple recalls, you are concerned about the function "Returns to original position after release."

Estimate the numbers for Severity, Occurrence, and Detection.

Partial Example

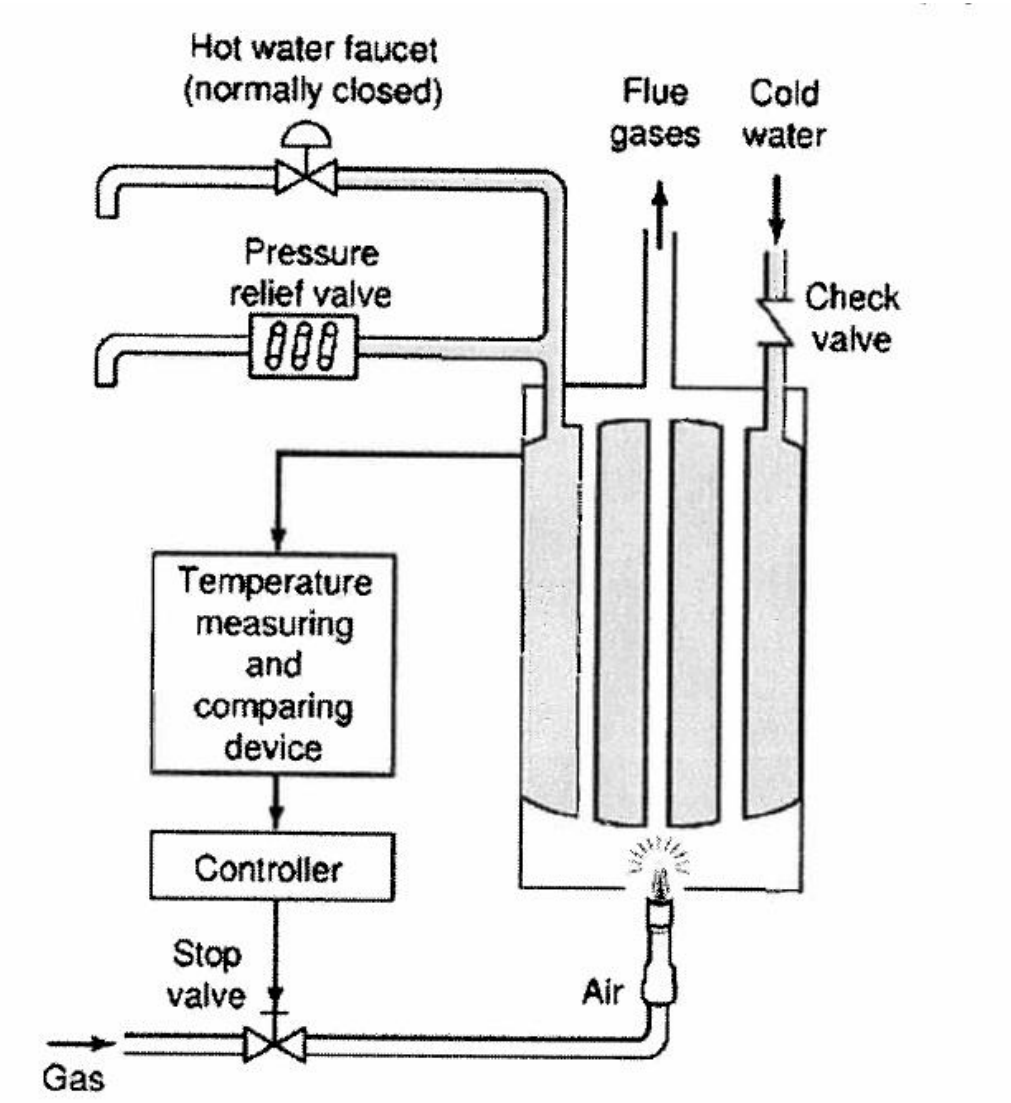


Fig. 1 Schematic for a gas hot water heater (Ref 25)

Partial Example (Cont.)

Table 1 FMEA analysis of the stop valve for a hot water heater

Failure mode	Effect	
	Local	System
1. Fails closed	Burner off	No hot water
2. Fails open	Burner will not shut off	Overheats, release valve releases pressure, may get scalded
3. Does not open fully	Burner not fully on	Water heats slowly or does not reach desired temperature
4. Does not respond to controller—stays open	(Same as 2)	(Same as 2)
5. Does not respond to controller—stays closed	(Same as 1)	(Same as 1)
6. Gas leaks through valve	Burner will not shut off; burns at low level	Water overheats (possibly)
7. Gas leaks around valve	Gas leaks into room	Possible explosion, fire, or gas asphyxiation

IN-CLASS PROBLEM 3

We wish to generate an FMEA for an aerosol can (assume spray paint)

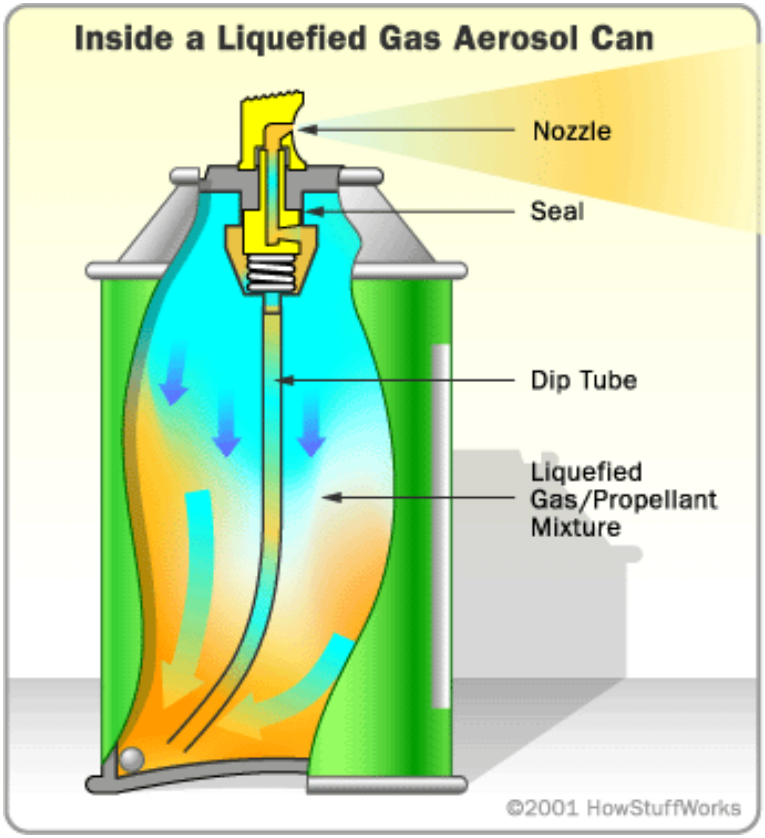
a) Discuss the functions and list the three most significant

b) For the function selected by the instructor, name PotentialFailure Modes

c) For each Potential Failure Mode, name Potential Effects

d) For each Potential Failure Mode, name Potential Causes

e) For each Potential Failure Mode, assign Severity, Occurrence, and Detection values



To Learn More

- A collection of information including links to examples, guides, standards, etc. http://www.fmeainfocentre.com/index.htm
- A training company with good overview material http://www.qualitytrainingportal.com/resources/fmea/index.htm
- Another company http://www.fmea-fmeca.com/index.html