Failure Mode & Effects Analysis

Handbook Supplement for Machinery

Ford Production System

TABLE OF CONTENTS

FOREWORD

The Ford Motor Company continues to drive towards continuous improvement in the Quality of our products that we supply to our Customers Worldwide. A key to this improvement is the use of manufacturing facilities that have a high degree of safety for our personnel, reliability and dependability in our manufacturing operations, while at the same time having low maintainability costs. To this end, we believe that the use of Machinery FMEAs will provide a disciplined approach to preventing problems early in the design phase of the machinery where action steps can be more readily taken to produce robust machinery designs.

The Machinery Failure Modes and Effects Analysis (MFMEA) has been developed by the Ford Motor Company to supplement the information contained in the FMEA Handbook for System, Design and Processes presently in use. Its use is intended where Ford Motor Company specifically requires a Machinery FMEA to be done as part of contractual specifications or for those applications where the machinery designer and manufacturer find it more suitable to their use than the other FMEA applications.

The principles followed in this handbook are analogous to the principles used in the System, Design and Process FMEA Handbook referenced above. In some cases the designer may want to use one or all of these tools during the analysis of the design. Selection of the right tool for the specific application will ensure a robust design and improve the total reliability and maintainability of the machinery. Guidelines for selecting these tools are shown in the following pages.

The contents of this handbook are intended to standardize the formats and tables used by all Ford Motor Company machinery suppliers, and to be consistent with the FMEA Handbook based on SAE Standard J1739. It is hoped that the material will help ensure improved quality in Ford Motor Company Products Worldwide.

GUIDELINES FOR FMEA USE

Concept FMEA – is used to analyze concepts for systems and subsystems in the early stages.

- Focuses on potential failure modes associated with the functions of a concept proposal caused by design decisions that introduce deficiencies.
- Includes the interaction of multiple systems, and interactions between the elements of a system at concept stages.
- Would apply to all new machinery concepts that have never been done before, all new plant machinery layout, new architecture for machinery, etc.)

Design FMEA – is used to analyze products, high volume tools or standard machines, machine components, standard production tooling, etc., before they are released to production.

- Focuses on potential failure modes of products caused by design deficiencies.
- Focuses on parts that can be prototyped and tested or modeled before high volume production of the product is launched.

Machinery FMEA – is used to analyze low-volume specialty machinery (equipment and tools), that allows for customized selection of component parts, machine structure, tooling, bearings, coolants, etc.

- Focuses on designs that improve the reliability and maintainability of the machinery for long-term plant usage.
- Considers preventive maintenance as a control to ensure reliability.
- Considers limited volume, customized machinery where large scale testing of a number of machines is impractical prior to production and manufacture of the machine.
- Considers parts that can be selected for use in the machine, where reliability data is available or can be obtained before production use.

Process FMEA – is used to analyze manufacturing and assembly processes.

- Focuses on potential product failure modes caused by manufacturing or assembly process deficiencies.
- Useful in analyzing process steps that can influence the design of machinery, including selection of appropriate tooling and machinery component parts.

WHAT CAN I READ TO OBTAIN MORE BACKGROUND ON FMEAs?

Ford	Potential Failure Mode and Effects Analysis Handbook No. 1696A
Ford/GM/Chrysler	Advance Product Quality Planning and Control Plan Reference
Ford/GM/Chrysler	Quality System-9000
SAE Handbook AE-9	SAE Electronics Reliability Handbook

WHO DO I CONTACT TO FIND OUT ABOUT . . . ?

Item:	Contact:	Telephone:
Receiving Future FMEA Handbook Updates	Environmental and Safety Engineering Strategic Standardization Organization (ESE-SSO)	1-(313) 24-84550
Ordering FMEAPLUS® Software: Ford Activities	SNAPP	1-(313) 845-7755
FMEA Training: Ford Employees	NAAO/ACG: Fairlane Training Development Center	1-(313) 248-2100
	EAO: Training	1-44(1277) 253852
FMEA Training: Suppliers	U.S.A.: Dearborn, Michigan	1-(313) 248-2100
	England: West Horndon Brentwood	1-44(1277) 253842
FMEAPLUS® Software Training	Fairlane Training Development Center	1-(313) 248-2100
Help with FMEAPLUS® Questions	FMEAPLUS® Hotline	(313) 33-71616 or FMEAHELP
Help with FMEA Handbook Questions	ESE-SSO	(313) 24-84550 or FMEAHELP
FMEA Consulting	ESE-SSO	(313) 24-84550

MACHINERY FMEA

What is a Machinery FMEA?

A Machinery Failure Mode and Effects Analysis is a standardized technique for evaluating equipment and tooling during its design phase to improve the operator safety, reliability and robustness of the machinery.

What are the Purposes of a Machinery FMEA?

- To identify potential failure modes
- To identify effects of the failure mode
- To rate the severity of each effect
- To determine the potential causes of the failure starting with the highest severity rating
- To identify robust designs or controls that will prevent the failure from occurring
- To identify corrective actions required to prevent, mitigate, or improve the likelihood of detecting failures early
- To establish a priority for design improvement actions

What are the Benefits of a Machinery FMEA?

- Improves the safety, reliability, and robustness of equipment and tooling
- Allows design changes to be incorporated early to minimize machinery cost and delivery delays
- Minimizes the risk of delaying product programs
- Reduces overall life cycle costs

When is a Machinery FMEA Started?

A Machinery FMEA must be started early in the design phase when:

- The equipment and tooling being specified is able to take advantage of revisions in order to derive the desired benefits.
- When GDT information on component parts are available and Critical/Special Characteristics are identified.

Normally, Design FMEAs on the products that are being manufactured and Process FMEAs on the steps used during the manufacture will be available.

FAILURE MODE AND EFFECTS ANALYSIS
MACHINERY FMEA

FMEA Number ______(1)______ Prepared By ______(4)______ Page ______ of ______

Machinery Name ______(2)______ Model ______(5)______ FMEA Date ______(7)______

Design Responsibility ______(3)______ Review Date ______(6)______ Core Team ______(8)______

Subsystem Name 9(a) / 9(b) Function & Performance Requirements	Potential Failure Mode(s) (10)	Potential Effect(s) of Failure (11)	Severity (12)	Class (13)	Potential Causes of Failure (14)	Occurrence (15)	Current Design Controls and Machinery Controls (16)	Detection (17)	RPN (18)	Recommended Action(s) (19)	Responsibility & Target Completion Date (20)	Action Results: Actions Taken (21)	Action Results: Severity	Action Results: Occurrence	Action Results: Detection (22)	Action Results: RPN

What are the Key Differences Between a Product Design FMEA and a Machinery FMEA?

- Product Design FMEAs are intended for high production systems/subsystems and components. Prototype or surrogate part testing is used to verify design intent.
- Machinery FMEAs are used for relatively low volume designs, where statistical failure data on prototypes is not practical to be obtained by the manufacturer.
- Machinery FMEAs are targeted for long-term, repetitive cycles, where wear out is a prime consideration. For example, machinery running at two 10-hour shifts per day, 50 weeks per year, will accumulate 120,000 hours of operation in twenty years. This would be equivalent to a vehicle being driven 600,000 miles at an average speed of 50 mph.
- The severity, occurrence, and detection tables used are tailored to meet the needs of the machinery design engineer in order to maintain a standard interpretation across a wide variety of machinery designs.

What are the Similarities Between a Product Design FMEA and a Machinery FMEA?

- Both emphasize operator/passenger safety as the first consideration of the design.
- Both emphasize robustness in designs to prevent problems before they occur.
- Both use 1-10 ranking scales for calculating Risk Priority Numbers.
- Both emphasize taking corrective actions based first on severity and then on overall RPN .
- Both use a standardized form to document the FMEA analysis.

NOTE: This handbook is intended to supplement the Potential Failure Mode and Effects Analysis Concept – Design – Process© available from the Ford Motor Company. All users of this handbook are encouraged to obtain a copy of this for reference.

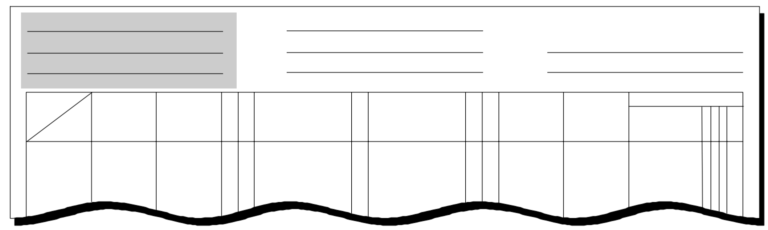
FAILURE MODE AND EFFECTS ANALYSIS
MACHINERY FMEA

FMEA Number 1451 (1)
Machinery Name ABC Boring Machine (2)
Design Responsibility ABC Machine Tool Company, Machinery Group (3)

Prepared By Max Temple, (313) 594-4555 (4)
Model 1234 (5)
Review Date 96 08 01 (6)

Page 10 of 35
FMEA Date 96 08 20 (7)
Core Team T. Fender - Mfg. Eng., C. Childers - ABC Machine; J. Ford - Transmission Division (8)

Subsystem Name 9(a) / Function & Performance Requirements 9(b)	Potential Failure Mode (10)	Potential Effect(s) of Failure (11)	Severity (12)	Class (13)	Potential Causes of Failure (14)	Occurrence (15)	Current Design Controls and Machinery Controls (16)	Detection (17)	RPN (18)	Recommended Action(s) (19)	Responsibility & Target Completion Date (20)	Action Results: Actions Taken (21)	Action Results: Severity (22)	Action Results: Occurrence (22)	Action Results: Detection (22)	Action Results: RPN (22)
Precision Boring Spindle Function: Bore the ID and machine retaining ring groove on the E4OD Aluminum Transmission Case Performance Requirements: • Maintain 1200 RPM Cutting Speed for 23 seconds • Maintain 120 JPH • Availability: MTBF 24 mo.	Reduced Cutting Speed	Undersized Bore; Rough Finish; Incomplete Groove	7		Worn, loose or broken belt. Present design uses "Classical" V-belts per ANSI/ RMA-IP-20.	7	Inspect and adjust belt tension every 200 hours.	3	147	Upgrade belt design to "Narrow" multiple V-belts as defined in RMA-IP-22 (1983) Cross sections (3V). Inspect and adjust belts every 500 hours. Replace belts every 2500 hours.	C. Childers/ T. Fender	Update machinery specification and Maintenance Schedule	7	6	3	126
			7		Loose pulley or sheared key.	6	Remove pulley, inspect and replace key every 500 hours.	3	126	Ensure motor shaft meets Ford Mfg. Spec. EM-1, Para. 6.3 for ANSI-U-frame motors – Class II. Visually inspect every 500 hours, concurrent with belt inspection.	C. Childers/ T. Fender	Update machinery specification and Maintenance Schedule	7	5	3	105
			7		Worn or seized spindle bearing.	6	Lube every 300 hours. Check spindle speed (min. 1200 RPM) and run vibration analysis every 600 hours.	2	84	Replace spindle bearing every 24 months. Lube every 100 hours.	J. Ford	Update Maintenance Schedule	7	2	2	28
			7		Motor field windings overheated or shorted Motor bearings worn or seized.	6	Check motor temperature and current draw every 600 hours. Run vibration analysis on motor shaft every 600 hours.	2	84	Replace motor every 24 months. Original and replacement must meet Ford Mfg. Std. EM-1.	J. Ford	Update Maintenance/ Replacement Schedule	7	2	2	28
			7		Worn or broken cutting tool – Carbide insert VC67.	8	Replace cutting tool every 10 hours or 1200 jobs.	5	280	Specify polycrystalline diamond C1500 with minimum life of 500 hours or 60,000 jobs.	T. Fender/ J. Ford	Update cutting tool specification and Maintenance Schedule	7	6	5	210



1 FMEA NUMBER

Enter the FMEA document number, which may be used for tracking.

1451

2 MACHINERY NAME

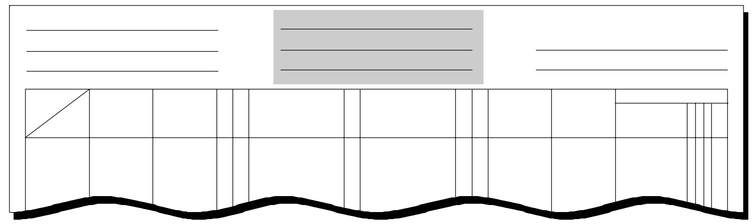
Indicate the appropriate machinery name.

ABC Boring Machine

3 DESIGN RESPONSIBILITY

Enter the OEM, department, and group.

ABC Machine Tool Company, Machining Group



4 PREPARED BY

Enter the name, telephone number, and company of the engineer responsible for preparing the FMEA.

Max Temple, (313) 594-4555

5 MODEL

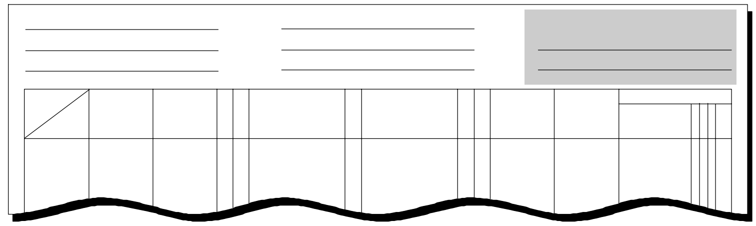
Enter the model number of the machinery.

Model 1234

6 REVIEW DATE

Enter the initial FMEA review date. The date should fall within the design and development phase of the machinery life cycle process.

96-08-01 (year-month-day)



7 FMEA DATE

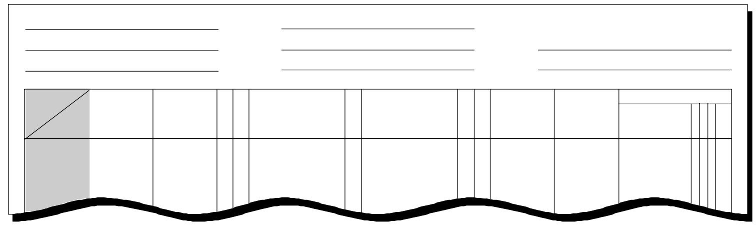
Enter the date the original FMEA was compiled, and the latest revision date.

96-08-20 (year-month-day)

8 CORE TEAM

List the names of the responsible individuals and departments which have the authority to identify and/or perform tasks. (It is recommended that all team members' names, departments, telephone numbers, addresses, etc., be included on a distribution list.)

Core Team T. Fender-Mfg. Eng., C. Childers-ABC Machine, J. Ford-Assy. Opns.



9a SUBSYSTEM NAME

Enter the description of the subsystem name being analyzed.

Automatic Loader, Spindle, Hydraulic, Electrical, Station-5-Left

Terminology Equipment Hierarchy	Example
Machine	transfer line
System	machine stations
Subsystem	station 7 left
Component	spindle
Part (lowest serviceable level)	bearing

9b FUNCTION & PERFORMANCE REQUIREMENTS

Enter, as concisely as possible, the function of the subsystem being analyzed to meet the design intent. Include information regarding the environment in which this subsystem operates (e.g., define environmental conditions, machine performance specification). If the subsystem has more than one function with different potential modes of failure, list all the functions separately.

Start by listing the wants, needs or requirements of the system. Function analysis should be used to insure requirments are defined in terms that can be measured.

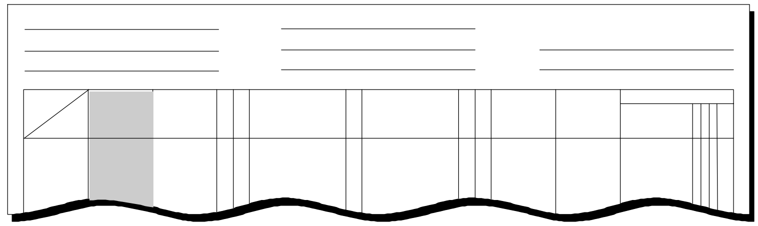
Describe the function in terms that can be measured. A description of the function should answer the question: “What is this subsystem supposed to do?” It is helpful to describe the function using a verb-noun phrase. However, avoid the use of verbs like “provide, facilitate, allow,” which are too general.

When a subsystem must function under certain conditions, it is helpful to describe the conditions. Conditions may include environmental parameters, engineering requirements, and/or machine performance specifications (i.e., operating temperature, capability, cycle time, mean-time-between-failure (MTBF), mean-time-to-repair (MTTR) or other measurable engineering attributes).

The function(s), conditions and requirements of the subsystem being analyzed. When the subsystem has many functions with different potential failure modes for each function, list each function separately.

Examples:

Function	Condition Requirement
load part	120 JPH
index head	MTBF > 300 hrs.
control flow-hydraulic	cubic centiliters/second
position subsystem	angle of rotation
drill hole	1st run % – 99.9%



10 POTENTIAL FAILURE MODE(S)

Potential Failure Mode is defined as the manner in which machinery could potentially fail to meet its intended function. The potential failure mode may also be the cause of a potential failure mode in a system, subsystem, or component. Machinery failure is an event when machinery is not available to produce parts at specified conditions when scheduled or is not capable of producing parts or performing scheduled operations to specification. For every potential failure, an action is required to bring the machinery back to its intended production capability. Machinery failure mode can occur three ways:

(1) A type of machinery component defect contributing to a failure (hard failures; i.e., bearing seized, shaft broke).

(2) The manner by which machinery system failure is observed or the way the failure occurs (degraded performance; i.e., slow cycle time, excessive process variation).

(3) The abnormality of performance that constitutes the machinery system to be classified as failed (quality defects; i.e., high micro due to vibration, concentricity due to worn shaft bearing diameter).

List each potential failure mode for the particular subsystem function. The assumption is made the failure could occur, but may not necessarily occur. A recommended starting point is a review of maintenance logs, downtime reports, field service reports, warranty documents, scrap reports and group “brainstorming.”

The task of identifying subsystem failure modes can take either of two approaches:

- **Functional approach:** involves listing each subsystem, its functions, and the failure modes leading to the loss of each function. The functional approach is used most often in the preliminary design stages when machinery design detail is not complete. When taking a functional approach, it may be necessary to list the cause(s) in column 14 before listing the effect(s) first in column 11. This could assist in selecting the appropriate severity rating.
- **Hardware approach:** involves listing each part, and its probable failure modes. The hardware approach is used most often when detailed part design information is available.

Ford Motor Company prefers to use the Functional Approach for all Machinery FMEAs.

Review historical and surrogate Machinery FMEAs, test reports, warranty data, field maintenance logs, field service reports, and other applicable documents listed in Appendix II. Identify known design failure modes.

Brainstorm potential failure modes by asking:

- In what way can this subsystem fail to perform its intended function?
- What can go wrong although the subsystem is manufactured/assembled to print?
- If the subsystem function were tested, how would its failure mode be recognized?
- How will the environment contribute to or cause a failure?
- In the application of the subsystem, how will it interact with other subsystems?

Fault Tree Analysis (FTA) can be used to help determine component failure modes. Assume the top level event of the Fault Tree is how a component may fail to meet its intended function. Then the next level down will identify the causes as part failure modes.

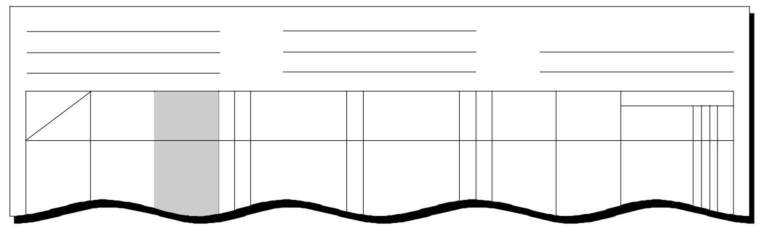
Enter the potential failure mode(s) for each function listed in Column 9. Potential failure modes should be described in "physical" or technical terms, not as a symptom noticeable by the operator. (To track the failure modes, it may be beneficial to assign them a number.) Do not enter trivial failure modes, i.e., failure modes that will not, or cannot, occur.

General types of failure modes for the functional approach include:

- Failure to operate at the prescribed time
- Failure to stop operating at the prescribed time
- Intermittent operation
- Wear out

General types of failure modes for the hardware approach include:

- Fractured
- Corroded
- Sticking
- Short circuit
- Warped
- Loose
- Cracked
- Leaking



11 POTENTIAL EFFECT(S) OF FAILURE

Potential Effects of Failure are defined as the consequence(s) of the failure mode on the subsystem, described in terms of **Safety** and the “7 Big Losses.” The “7 Big Losses” are as follows:

- Breakdowns
- Setup and Adjustment
- Idling and Minor Stoppages
- Reduced Cycle
- Start-up Losses
- Defective Parts
- Tooling

Note: If a functional approach is used, it may be necessary to list the cause(s) in column 14 before listing the effect(s) first in column 11.

Review historical and surrogate FMEAs, warranty data, concern reports, field reports, and other applicable documents. Identify historical failure mode effects.

Definitions of Losses:

Breakdowns – Losses that are a result of a functional loss (mechanical, chemical, or electrical) or function reduction (e.g., one spindle not operating on a multi-spindle drill) on a piece of equipment requiring maintenance intervention.

Setup and Adjustment – Losses that are a result of setup procedures such as retooling, changeover, die/mold change, etc. Adjustments include the amount of time production is stopped to adjust process or machinery to avoid defect and yield losses, requiring operator or jobsetter intervention.

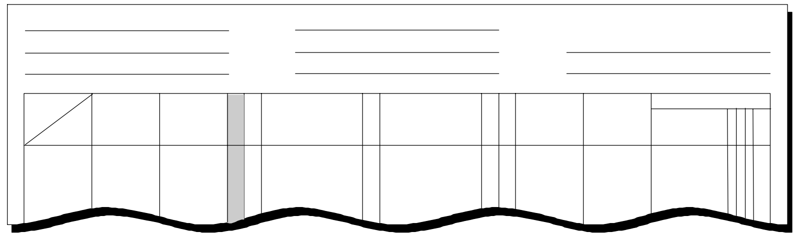
Idling and Minor Stoppage – Losses that are a result of minor interruptions in the process flow, such as a process part jammed in a chute or a limit switch sticking, etc., requiring only operator or jobsetter intervention. Idling is a result of process flow blockage (downstream of the focus operation) or starvation (upstream of the focus operation). Idling can only be resolved by looking at the entire line/system.

Reduced Cycle – Losses that are a result of differences between the ideal cycle time of a piece of machinery and its actual cycle time. Ideal cycle time is determined by: a) Original design speed; b) Optimal conditions: and c) Highest cycle time achieved on similar machinery.

Start-up Losses – Losses that occur during the early stages of production after extended shutdowns (weekends, holidays, or between shifts), resulting in decreased yield or increased scrap and rejects. (This may also include non-value activities required prior to production, such as bringing process to temperature.)

Defective Parts – Losses that are a result of process part quality defects resulting in rework, repair, and/or non-useable parts.

Tooling – Losses that are a result of tooling failures/breakage or deterioration/wear (e.g., cutting tools, fixtures, welding tips, punches, etc.).



12 SEVERITY

Severity is a rating corresponding to the seriousness of the effect(s) of a potential equipment failure mode in accordance with Table 1. Severity is comprised of three components: safety considerations to equipment operator or downstream customer, equipment downtime, and defective parts. *A reduction in Severity Rating index can be effected only through a design change.*

Assess the seriousness of each effect listed in Column 11. **Safety of the personnel is the primary criteria in determining the rating.**

Note: If a functional approach was used, it may be necessary to list the cause(s) in column 14 before listing the effect(s) first in column 11. This could assist in selecting the appropriate severity rating.

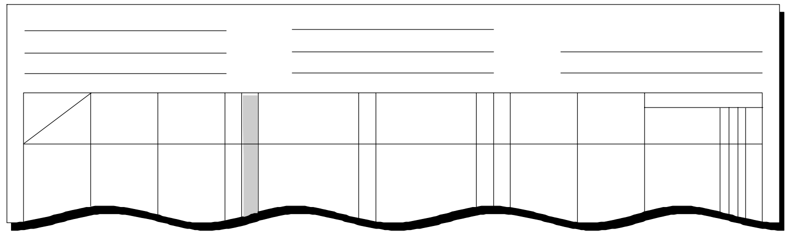
Subsystem functions can be prioritized by rating the severity of the effect that will result from loss of the subsystem function. Estimate the Severity of failure of the subsystem function and enter the rating in the subsystem function worksheet. Rank the functions in descending order. Begin the analysis with the highest ranked functions. Generally, these will be the functions that affect safe equipment operation, government regulations, and customer specification (downtime, defective parts).

The FMEA Team should consent on Severity ratings for each effect listed. The effects on downtime and defective parts are independent events, and the team should select the highest rating that meets the individual criteria (i.e., downtime of 4 hours or defective part loss of 2 to 4 hours of production, select rating of 7; downtime of 40 minutes, or loss of 40 minutes of production, select 5).

Enter the rating for the **most serious** (highest) effect.

TABLE 1 — SEVERITY EVALUATION CRITERIA

Effect on	Criteria: Severity of Effect	Rating
Hazardous – without warning	Very high severity ranking – Affects operator, plant, or maintenance personnel, safety and/or affects non-compliance with government regulations	10
Hazardous – with warning	High severity ranking – Affects operator, plant, or maintenance personnel, safety and/or affects non-compliance with government regulations	9
Very High Downtime or Defective Parts	Downtime of more than 8 hours or defective parts loss more than 4 hours of production	8
High Downtime or Defective Parts	Downtime of 4 to 7 hours or defective parts loss of 2 to 4 hours of production	7
Moderate Downtime or Defective Parts	Downtime of 1 to 3 hours or defective parts loss of 1 to 2 hours of production	6
Low Downtime or Defective Parts	Downtime of 30 minutes to 1 hour or defective parts loss of up to 1 hour of production	5
Very Low Downtime – No Defective Parts	Downtime up to 30 minutes – no defective parts	4
Minor Effect	Process parameter variability exceeds Upper/Lower Control limits. Adjustment or other process controls need to be taken – no defective parts	3
Very Minor Effect	Process parameter variability within Upper/Lower Control limits. Adjustment or other process controls need to be taken – no defective parts	2
No Effect	Process parameter variability within Upper/Lower Control limits, adjustment or other process controls not needed or can be taken between shifts or at normal maintenance – no defective parts	1

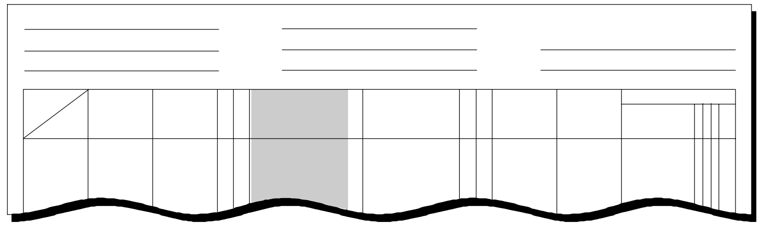


13 CLASSIFICATION

This column is used to highlight those failure modes with a Severity rating of 9 or 10 (column 12).

These failure modes affect the safety of the workers and will require design action to be taken.

Highlight the failure mode by placing the letters “OS” in column 13.



14 POTENTIAL CAUSE(S)/MECHANISM(S) OF FAILURE

The cause of a failure mode is:

1) a design deficiency, or

2) machinery process variation that can be described in terms of something that can be corrected or can be controlled.

Identification of causes should start with those failure modes with the highest severity rating.

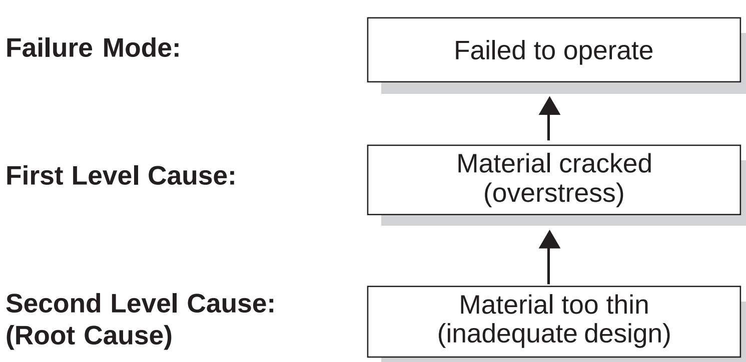
Review historical test reports, warranty data, concern reports, recalls, field reports, and other applicable documents listed in Appendix II. Also review surrogate FMEAs. List the known causal factors of the failure modes listed in Column 14.

Brainstorm potential cause(s) of each failure mode by asking questions, such as:

- What could cause the subsystem to fail in this manner?
- What circumstance(s) could cause the subsystem to fail to perform its function?
- What can cause the subsystem to fail to deliver it intended function?

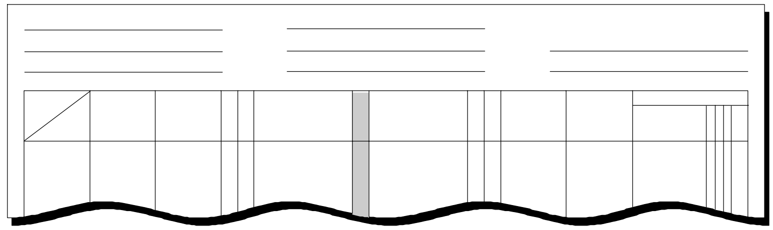
Identify all first level causes. A first level cause is the immediate cause of the failure mode. It will directly make the failure mode occur. In a Cause and Effect Diagram, it will be an item on the major "fishbone" of the diagram. In a Fault Tree Analysis (FTA), it will be the first cause identified below the failure mode.

A Root Cause(s) may be below the first level cause. For example, consider the following illustration:



For failure modes whose effects have a severity rating of 9 or 10, identify the Root Cause(s) of the failure mode. Root Causes are sometimes below the first level cause, and there may be more than one lower level root cause. Techniques such as TOPS (8D), Cause and Effect Diagram, or Fault Tree Analysis (FTA) can be used to help determine Root Causes.

Design Deficiency	Equipment Process Variation
Switch rocker cracked	Inadequate or no lubrication
Incorrect algorithm	Part mislocated
Material fatigued	



15 OCCURRENCE

Occurrence is a rating in accordance with Table 2, corresponding to the likelihood that a particular failure mode will occur within a specific time period.

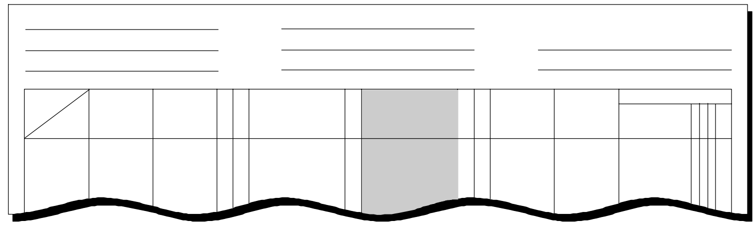
Note: Controls can be used to prevent or minimize the likelihood that failure cause(s) will occur. **In this event, the presence or application of the control should be considered when estimating the Occurrence rating.**

For each cause listed in Column 14, estimate the possible failure rates and/or mean time between failure.

The occurrence of failure can be based upon historical data, including the service history, warranty data, and maintenance experience with similar or surrogate parts. Review applicable historical documents from those listed in Appendix II.

TABLE 2 — OCCURRENCE EVALUATION CRITERIA

Likelihood of Occurrence	Criteria: Possible Failure Rates/ Mean Time Between Failure (MTBF)	Rating
Very High	Intermittent operation resulting in 1 failure in 10, or MTBF of less than 1 hour	10
Very High	Intermittent operation resulting in 1 failure in 100 production pieces or MTBF of 2 to 10 hours	9
High	Intermittent operation resulting in 1 failure in 1000 production pieces or MTBF of 11 to 100 hours	8
High	Intermittent operation resulting in 1 failure in 10,000 production pieces or MTBF of 101 to 400 hours	7
Moderate	MTBF of 401 to 1000 hours	6
Moderate	MTBF of 1001 to 2000 hours	5
Moderate	MTBF of 2001 to 3000 hours	4
Low	MTBF of 3001 to 6000 hours	3
Low	MTBF of 6001 to 10,000 hours	2
Remote	MTBF greater than 10,000 hours	1



16 CURRENT DESIGN/MACHINERY CONTROLS

Design/Machinery Controls are methods, techniques, devices, or tests used to:

1) Prevent the Cause/mechanism or Failure Mode from occurring, or reduce rate of occurrence.

2) Detect the Cause/mechanism and lead to corrective design actions, and

3) Detect the Failure mode.

Identification of Design/Machinery Controls should begin with those failure mode combinations that have the highest Severity and Occurrence ratings.

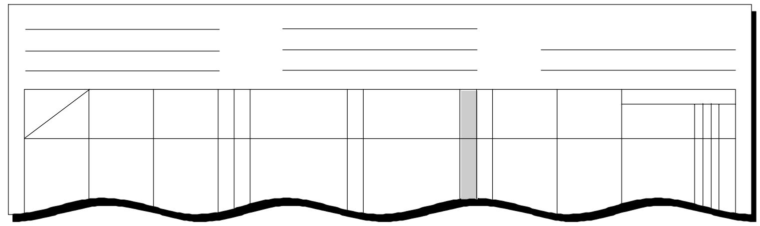
Design/Machinery Controls used to prevent the cause/mechanism or failure mode/effect from occurring, or reduce their rate of occurrence may affect the Occurrence rating. If this is the case, these Controls should be taken into account when estimating the Occurrence rating (Column 15). Only Controls that are used before engineering release are to be considered when estimating the Detection rating.

Examples of:

Design Controls	Machinery Controls
Worst Case Analyses	Proximity Sensors
Derating	Temperature Sensors
Tolerance Studies	Oil Pressure Light
Simulations Studies	Timing Sensors
Design Reviews	Proactive Maintenance*
Safety Margins	Vibration Sensor

* **Proactive Maintenance** actions are key preventive, predictive, and visual management tools to control the reliability of machinery. Preventive maintenance schedules, procedures, and in-plant resources are valid design controls to reduce the occurrence ratings of the machinery FMEA, only if they have been developed as part of the design process, and are included in the machinery user's manual.

> **Note:** The Machinery Design Engineer's goal is to make the design robust so that machinery controls are not required. The Machinery Design Engineer must not rely on machinery controls or control plans to overcome potential design weaknesses.



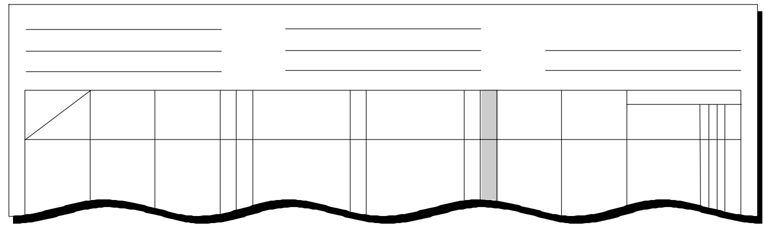
17 DETECTION

Detection is an assessment, in accordance with Table 3, of the ability of the Design/ Machinery Controls to detect a potential cause/mechanism or to detect the potential failure mode.

Estimate the effectiveness of each Design/Machinery Control listed in Column 16 to detect the cause/mechanism or the failure mode. Assume the failure mode has occurred. When several Controls are listed, estimate a Detection rating for each Control and then select the best (lowest) rating to enter into column 17.

TABLE 3 — DETECTION EVALUATION CRITERIA

Detection	**Criteria: Likelihood of Detection by Design or Machinery Controls**	**Rating**
Absolute Uncertainty	Machinery Controls CANNOT detect a potential cause and subsequent failure, or there is no Design or Machinery Control	10
Very Remote	Very remote chance a Design/Machinery Control will detect a potential cause and subsequent failure mode	9
Remote	Remote chance a Design/Machinery Control will detect a potential cause and subsequent failure mode, and Machinery Control will provide indicator of imminent failure	8
Very Low	Very low chance a Design/Machinery Control will detect a potential cause and subsequent failure mode, and Machinery Control will prevent an imminent failure (e.g., stop machine)	7
Low	Low chance a Design/Machinery Control will detect a potential cause and subsequent failure mode, and Machinery Control will prevent an imminent failure (e.g., stop machine)	6
Moderate	Moderate chance a Design/Machinery Control will detect a potential cause and subsequent failure mode, and Machinery Control will prevent an imminent failure (e.g., stop machine) and isolate the cause	5
Moderately High	Moderately high chance a Design/Machinery Control will detect a potential cause and subsequent failure mode, and Machinery Control will prevent an imminent failure (e.g., stop machine) and isolate the cause. Machinery Control MAY be required	4
High	High chance a Design/Machinery Control will detect a potential cause and subsequent failure mode, and Machinery Control will prevent an imminent failure (e.g., stop machine) and isolate the cause. Machinery Control MAY be required	3
Very High	Very high chance a Design Control will detect a potential cause and subsequent failure mode. Machinery Controls NOT required	2
Almost Certain	Design Controls will almost certainly detect a potential cause and subsequent failure mode. Machinery Controls NOT required	1



18 RISK PRIORITY NUMBER (RPN)

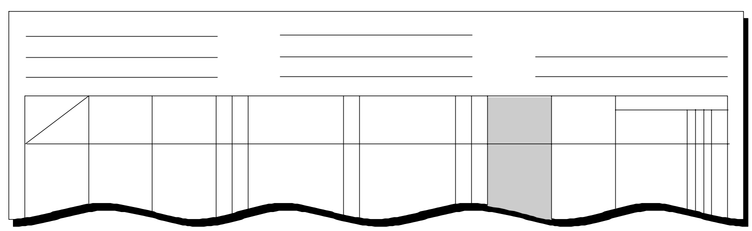
The Risk Priority Number is the product of the Severity (S), Occurrence (O), and Detection (D) ratings.

FORMULA: RPN = (S) x (O) x (D)

The Risk Priority Number (RPN) is obtained by multiplying the Severity, Occurrence and Detection ratings.

Remember, ratings and RPN numbers, in themselves, have no value or meaning. Ratings and RPN numbers should be used only to prioritize the potential design weaknesses (root causes) for consideration of possible design actions to reduce criticality and/or to make the design more robust (less sensitive to manufacturing variation).

The product of the Severity, Occurrence and Detection ratings.



19 RECOMMENDED ACTION(S)

Design actions taken to reduce the Severity, Occurrence, and/or Detection ratings.

Remedial design actions should be considered in the following order:

- A Failure Mode has an effect with a Severity rating of 9 or 10.
- A Failure Mode/Cause combination has a high Severity and Occurrence rating (based on Team consensus).
- A Failure Mode/Cause/Design Control and Machinery Control combination has a high RPN rating (based on Team consensus).

The intent of design actions is to reduce the Severity, Occurrence and Detection ratings, in that order. The following types of actions should be considered:

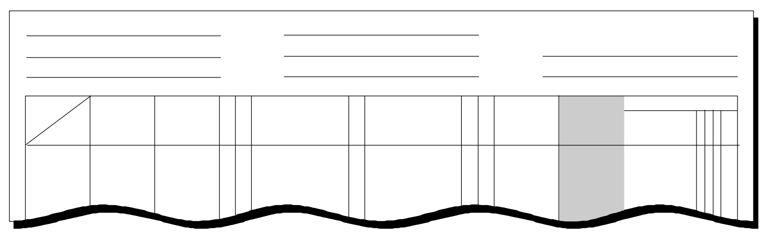
Whenever failure mode/cause combinations have Severity ratings of 9 or 10, design actions must be considered before engineering release to eliminate a safety concern. For these ratings, the goal is to reduce criticality below conditions that could adversely affect the safety of the operator.

Note: The Machinery Design engineer's goal is to make the design robust so that equipment controls are not required. Remember, the Equipment Design engineer CANNOT rely on machinery controls or control plans to overcome potential weaknesses.

Emphasis should be placed upon design actions aimed at preventing or reducing the severity of the efforts of failure modes, or preventing or reducing the occurrence of causes. Detection does not decrease criticality.

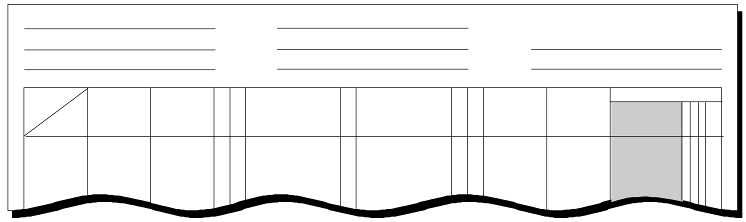
In order to track and follow up design actions, it may be helpful to assign a number to them. If no actions are recommended, it is desirable to enter "No action at this time" in the column. This prevents someone interpreting a blank space as an oversight or an incomplete resolution.

List the actions that can be taken to prevent or reduce the occurrence of the causes of a failure mode, or to detect the failure mode. Enter a design action. If no actions are recommended, then enter "No action at this time."



20 AREA/INDIVIDUAL RESPONSIBLE AND TARGET COMPLETION DATE

The organizational department or activity, the engineer responsible for the recommended action, and the target completion date for the action.



21 ACTIONS TAKEN

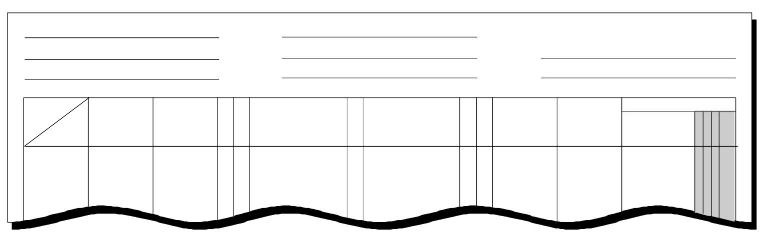
After an action has been implemented, enter a brief description of the actual action and effective date.

FOLLOW UP: The need for taking actions with quantified benefits, and following up all recommended actions cannot be overemphasized. A thorough Machinery FMEA will be of limited value without positive and effective actions to eliminate machine downtime or prevent part defects.

The vendor is responsible for updating the Machinery FMEA. The Machinery FMEA is a living document. It should reflect the latest design level and latest design actions.

In addition, any machinery design changes need to be communicated to the Ford responsible Machinery FMEA Team member so that Process FMEAs, Control Plans and Process sheets can be updated.

After an action has been taken, enter a brief description of the action, and its effective or actual completion date.



22 RESULTING RPN

After design actions are taken, the ratings for Severity, Occurrence, and/or Detection are revised by the FMEA Team. Calculate and rate the revised RPNs. The Machinery FMEA Team Engineer will review the revised RPNs and determine if further design actions are necessary. If so, then Columns 19-22 should be repeated.

After design actions are taken, reestimate and enter the ratings for Severity, Occurrence, and Detection. Calculate and enter the resultant RPN. If no actions are listed, leave these columns blank.

MACHINERY FMEA

Use the checklist below to help assure the Machinery FMEA is complete. All answers to the following questions should be YES:

Preliminaries	☐	Was a Machinery FMEA Team formed?
Performance Specification	☐	Were Machinery performance specifications specified?
Header Information	☐	Are all the applicable entries in the header completed?
Subsystem/ Function	☐	Does the function meet the design intent? Are environmental conditions and machine performance specifications listed?
Failure Modes	☐	Do the failure modes relate to the subsystem function?
Failure Effects	☐	Are effects on the machinery, the part produced, the operator, the downstream operation, the customer and safety or government regulation considered?
Failure Causes/ Mechanisms	☐	Are design deficiencies or process variation considered? Are the Root Causes identified?
Design and Equipment Controls	☐	Can Design Controls detect the cause(s) of a failure or detect a failure mode? Can Machinery Controls prevent or minimize the likelihood of occurrence or recognize or detect an unspecified failure mode?
Severity Rating	☐	Are the ratings based upon the most serious effect (safety, downtime, scrap) of the failure mode?
Occurrence Rating	☐	Are the ratings based on the Occurrence of the first level cause? Do the ratings consider the Current Design and Machinery Controls to reduce the likelihood of failure?
Detection Rating	☐	Are the ratings based on the ability of the Design Machinery Controls to detect a potential cause or to detect the potential failure mode?
Classification	☐	Have all potential failure modes with Severity rating of 9 or 10 been assigned the letters “OS” for a classification code?
RPN	☐	Are the Risk Priority Numbers (RPN) ranked from high to low?
Recommended Actions	☐	Do actions address failure modes with Severity Rankings of 9 or 10? Are actions aimed at making the machinery design more robust?
Follow-Up	☐	Are the Risk Priority Numbers ranked from high to low? Have the machinery design changes been communicated to the Process FMEA Team?

INFORMATION SOURCES USEFUL WHEN PREPARING THE MACHINERY FMEA

Some information sources useful when conducting an FMEA are listed below:

Engineering Drawings/Diagrams:
- Part/Component
- Subassembly
- Higher Level Assembly
- System

Design Requirements/Specifications
- System Design Specification
- Engineering Specification
- Manufacturing/Process Specifications
- Equipment Performance Specification

Control Plans
- Dimensional Control Plans
- DCP-Plus
- RQP

Previous or Similar Data
- Warranty Data
- Reliability Data
- Recall Data
- Field Service Data

Other Studies
- Quality Function Deployment (QFD)
- Competitive New Vehicle Quality (CNVQ)
- National New Car Buyer's Study (NNCB)
- Durability Tracking Study (DTS)
- EAO Quality Audit Survey (QAS)
- EAO Quality Telephone Study (QTS)
- EAO Van Quality Panels

Reports
- Service Investigation Reports (SIRs)
- Dealer Problem Reports
- Field Service Reports
- Laboratory Test Reports
- Durability Test Reports
- Extended Service Plan (ESP) Reports
- Teardown Reports

Other FMEAs
- Previous/Similar Design FMEAs
- Previous/Similar Process FMEAs
- Upstream/Downstream Processes
- Higher Level Designs
- Supplier FMEAs
- Generic FMEAs

Miscellaneous Information
- Rebuilders Surveys
- Dealer Service Bulletins

TERMS FOR GLOSSARY MACHINERY FMEA

Derating

The practice of limiting the stresses on components/subsystems to levels well within their specified or proven capabilities in an effort to improve reliability.

Machinery Failure

An event when machinery is not available to produce parts at specified conditions when scheduled or is not capable of producing parts or performing scheduled operations to specification. For every failure, an action is required to bring the machinery back to its intended production capability.

Mean Time Between Failures (MTBF)

The average time between failure occurrences. The sum of the operating time of a machine divided by the total number of failures.

Mean Time-To-Repair

The average time to restore machinery to specified conditions.

Proactive Maintenance [Preventive and Predictive]

Preventive maintenance are all actions performed in an attempt to retain a machine in specified condition by providing systematic inspection, detection, and prevention of incipient failures.

Predictive maintenance are techniques used to detect potential failures so that action can be taken to avoid the consequences which could occur if they degenerate into functional failures.