Failure Modes, Effects & Criticality Analysis
PRODUCT EXCELLENCE USING SIX SIGMA

Failure Modes, Effects & Criticality Analysis

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Introduction

This section will describe the technique Failure Modes Effects and Criticality Analysis (FMECA), often referred to as FMEA. Simply stated, FMECA is a disciplined method of product or process analysis that is conducted to identify potential failures that could affect the customer's expectations of product quality or process performance. It is by no means a new technique; it started to come into prominence in the early 1950s in the aerospace industries as flight control systems became more complex.

Figure 1. Analysis of system failures.
Although the technique is inherently simple, its application has been misunderstood and consequently many organisations have failed to gain the enormous benefit that can result if it is applied properly. Figure 1 shows the percentage of failures that have occurred over a 5-year period in each of the 65 systems that comprise a particular type of motor vehicle. Figure 2 shows that the 3 most unreliable systems account for about 40% of in-service failures; the top 5 systems about 50% and so on.

![Figure 2. Cumulative failure plot.](image)

If we were able to obtain such data during the concept and design phases of a product's life cycle we could do much to prevent future failures occurring. FMECA provides us with the opportunity of acquiring such knowledge; it is one of the simplest yet most powerful predictive tools available to us.

When questioned, many groups express poor experiences of using this technique. Examples of frequently held opinions include *it takes too long; it is boring; it is done too late* and *nothing is done with the results*. Some organisations apply the technique because its customer requires it to do so; often such organisations will delegate the job to some hapless engineer who conducts the analysis in miserable isolation from those who understand the product or process being studied. The aim of these notes is to offer a counter view to the poor experiences and provide some guidelines upon which a successful analysis may be conducted.
FMECA applications

While it is true that the conduct of FMECA requires an investment of time, the analysis can be used to resolve many issues that are often studied separately. Its key application is to:

- Identify failures that have undesirable or significant effects; to determine the failure modes that may seriously affect the expected or required quality.

However, because we are attempting to understand how a product or process may fail to achieve the requirements placed upon it and which to categorise the failure causes for their severity, the analysis will enable us to

- Identify safety hazard and liability problem areas, or non-compliance with regulations.

If we are able to understand the areas of technical risk associated with a product or process, then provided we have that understanding early enough in the life cycle we will be able to

- Focus development testing on areas of greatest need.

instead of using the "scatter gun" approach to testing which occurs when we do not have sufficient understanding of how a product or process may fail. Many organisations apply standard tests to successive generations of product. This is a strategy that is doomed to failure unless every generation of product has to meet identical requirements and operate in an identical environment. If this is the case, it begs the question why we should wish to continue testing the product.

The application of built-in test and diagnostic routines is becoming ever more common. If the diagnostic part of the system is treated as a "bolt on" it can often cause more problems than the system it is supposed to diagnose. If we use FMECA to gain an appreciation of how the system can fail it follows that the analysis will assist

- The design of Built-in-Test and failure indications.
- Preparation of diagnostic flowcharts or faultfinding tables.
- Maintenance planning.

The application of FMECA to processes will help us to

- Identify key areas in which to control the process and, where appropriate, place inspection and manufacturing controls.
• Provide a systematic and rigorous study of the process and its environment that will almost always improve our understanding of how the process might fail.

• Support the need for a standby or alternative process or improvements to current processes.

• Identify deficiencies in operator and supervisor training and practices.

Benefits of FMECA

Four key benefits arise from the use of FMECA:

• It assists communication between:

  Main contractor and suppliers who work more closely during the concept and design stages of a product or process life cycle.

  Production, design, development, maintenance, purchasing, conformance personnel and other groups involved in the development of the product or process.

  Management and producers.

• It improves knowledge and understanding of the behaviour of the process or equipment being studied. There may be some occasions in which the FMECA owner may not gain knowledge, but the FMECA process will have formalised and recorded the understanding to provide corporate memory.

• If conducted rigorously and used to drive the programme, it will reduce the total time required to design and develop a product/process and help to ensure that requirements are met at first entry to service. Realising this benefit will mean that the cost of development will be reduced from current levels because of the emphasis placed on maximizing change early in the programme.

• It provides proof of the extent of care that has been taken to ensure that the product will meet the needs and expectations of the customer in service. Provided that the company has acted upon the analysis and taken corrective action where appropriate, few documents could be more helpful during litigation. This analysis may require that company policy on document retention be reviewed; there appears to be little merit in having say, a two year document retention policy.
when the FMECA contains full knowledge of how the product/process may fail.

**FMECA terminology**

Like most techniques, FMECA has its own terminology. Clearly, it is important to fully understand the terms before embarking upon the analysis.

**Function**
The purpose of the product or process under consideration. "What is this product or process supposed to do?"

**Potential Failure Mode**
In order to identify the potential failure modes the question "What could possibly go wrong with this equipment/part or part of the process?" has to be asked. It is important to identify all of the things that could possibly go wrong; a simple list of known warranty or other known problems is not necessarily sufficient. Some of the worst problems to afflict an organisation are ones that have not occurred before. Do not be influenced by the likelihood of the failure mode occurring, as this consideration will be made later.

**Potential Effects of Failure**
To determine the potential effects of failure we have to answer the question "What will happen if the failure mode occurs?"

**Level of Effect**

**Product**
For a complex system, it may be useful to record the effect of failure at the same level of analysis, the next higher level and the final system level.

**Process**
For a process, a failure mode may have a relatively low consequential cost if found early in the process; it is almost inevitable that this cost will be greater the further from the point of occurrence it is discovered. By final audit large teardown costs could result, and if the final customer identifies the failure, the costs could be immense.

**Potential Causes of Failure**
It is essential that all the possible causes of each failure mode are identified. We must ask the question, "What could happen to the product/process which could result in the potential failure mode?" If our list of potential causes is not exhaustive, we will find that potential failure modes that we had intended to eradicate will recur as other causes trigger the failures.
Current Controls
The current controls are those process controls which are intended to prevent the causes of failure occurring, or detect the causes of failure or the resulting failure mode before the effect can take place.

Occurrence
The Occurrence Rating is the numerical probability or likelihood of a particular cause occurring, thereby resulting in the failure mode observed. Score occurrence on a scale of 1 to 10 where 1 indicates that it is unlikely to occur and 10 indicates that it is almost certain to occur. Note that it is better to use a relative scale rather than an absolute figure such as is available from databases of failure data. If an absolute figure is used, there is a danger that the figure is believed absolutely. For example, a failure rate probability of $1 \times 10^{-8}$ is so remote that one can be tempted to say "That will never happen", and ignore the failure under consideration. Unfortunately, a one in a hundred million chance can occur on first use of the product, and occur again very soon after. If the effects of failure are very severe, it is of little comfort to know that on average, it is unlikely to occur for another 100 million/1 billion operations.

Severity
The Severity Rating is a numerical estimate of the severity of effect of the failure to the customer, where the customer may be an end user or the next person in the process. Again, a sliding scale of 1 to 10 is used where 1 is not significant and 10 is very serious/dangerous/catastrophic. Note that many organisations have a policy in which any failure mode whose effect scores 9 or 10 is the subject of mandatory consideration for corrective action regardless of the other ratings.

Detection
The Detection Rating is the numerical estimate of the probability of detecting a failure mode arising from a particular cause such that the effect of failure is prevented. A sliding scale of 1 to 10 is used in which 1 indicates that detection is highly likely and 10 almost impossible. Note that most failure modes are detectable and could be rated as 1. It is important, therefore, to relate detectability to the occurrence of the failure effect. For instance, it is easy to detect brake failure if it occurs when driving down a long steep hill at the bottom of which is a 90-degree bend. However, if the vehicle doesn't have a dual brake system and a brake warning light, it is unlikely that you will be able to prevent the end effect from taking place.

Risk Priority Rating (RPN)
The RPN is simply the multiplication of the occurrence, severity and detection ratings and its magnitude indicates the priority for corrective action. If the policy of mandatory consideration of corrective action is applied to severity scores of 9 and 10, the remaining causes will have ratings from 1 to 800 at worst. In general, we should concentrate our corrective action efforts on the high scoring causes. However, there may be occasions in which corrective actions for some low scoring causes could be applied easily and inexpensively. Every opportunity to make more robust the product or process should be taken. The RPN is quite simply a guide for corrective action; there is no score below which corrective action should not be taken. Scarce resources for corrective action should be applied to maximum effect.
and product or process improvement should continue for as long as time and resources permit.

**FMECA worksheets**

Examples of various FMECA worksheets are shown in Annex A. The differences between them show that there is no definitive standard, nor is there any reason to have a standard layout, providing that an organisation adopts a style that suits and applies that style consistently. It is important to complete the header information on each sheet because this uniquely identifies the sheet. It is worth noting at this point that no-one can check the completeness or validity of a completed FMECA beyond ensuring that details have been entered clearly. The reason for this is that the analysis is the result of a team exercise and to check the analysis would effectively mean conducting the same analysis with a new team. What a study of a completed worksheet will show is the extent to which corrective action has been taken. It should be obvious that to conduct the analysis but take no corrective action as a result is a singular waste of time and effort. Nevertheless, the author is aware of many projects in which the analysis was undertaken to satisfy the customer - no use was made of the analysis to make the product more robust to failure.

Note that the SMMT worksheet is easily adaptable for both design and process and it has columns for *Recommended Corrective Action, Action By* and *Action Taken*. The Rover Group worksheet goes a stage further in terms of management by having columns for *Action Date* and *Revised Control System*. It can be seen that there is sufficient opportunity here to identify all of the potential things that can go wrong with the product or process and record decisions made to overcome these problems. Clearly, this document could and should drive the design and development of the product/process, thereby maintaining the focus on the key problem areas.

**To which products/processes should FMECA be applied?**

Should an organisation that has not previously used this technique, or other analytical design techniques, immediately try to study all products and processes? The author believes that to do so would be to expose the organisation to a requirement to provide resources for such analyses on an unprecedented scale. Few organisations could cope with such a requirement and temptation to take short cuts would be great. FMECA would probably be conducted improperly and the resulting low payoff would serve to treat the technique as another initiative that has failed.
For new product programmes FMECA should be applied to **Reliability Critical Items (RCI)** the criteria for which are:

- Poor service history
- Unproven service history
- Novel use of existing equipment/technology
- Safety critical
- Failure would cause expensive maintenance
- Failure would occur without prior warning i.e. no graceful degradation
- Items which operate above derated levels
- Item has stringent tolerances for manufacturing or performance
- Item has a life limitation which adversely affects cost of ownership/availability
- Items which have long procurement lead times

Similarly, it would be impossible to study all of the processes in a company and a complementary list of **Reliability Critical Process (RCP)** criteria should be applied:

- Poor Right First Time record
- Unknown Right First Time record
- Involves technology unproven in company
- Involves novel use of existing equipment/technology
- Poor maintenance history
- Breakdown immediately stops production
- Difficult/expensive to identify/rectify problems
- Difficult/expensive to rectify problems if found in subsequent processes
- Process involves reliability critical items (RCI)
Failure of the process could jeopardize safety (includes human failure)

At first sight it might appear that all items on a new product programme could be rated as reliability critical, but experience has shown that the application of RCI criteria greatly reduces the number of items that must be subject to FMECA because of the risk they bring to the programme.

The purpose of managing a reliability critical item list is to focus project management or process management on risk. At any stage as a result of new information items or processes may be added to the list, but the aim must be to remove items from the list through corrective action.

The FMECA team

It is essential to realise that FMECA is a team-based analysis, and as such has to be conducted in a concurrent or simultaneous engineering environment. Too many examples exist in which some unfortunate engineer (often tagged with a reliability label) is tasked to conduct the FMECA for a system. Even if the engineer is diligent and attempts to tap into the knowledge of the design team, his efforts are bound to be inferior to a properly managed team-based analysis.

The FMECA team should comprise, where appropriate:

<table>
<thead>
<tr>
<th>Role</th>
<th>Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design Engineer</td>
<td>Cell Manager/Team Leader/Operator</td>
</tr>
<tr>
<td>Process Engineer</td>
<td>Purchase Technical Support Engineer</td>
</tr>
<tr>
<td>Materials Engineer</td>
<td>Development Test Engineer</td>
</tr>
<tr>
<td>Staff Engineer</td>
<td>Maintenance Engineer</td>
</tr>
<tr>
<td>Facilities Engineer</td>
<td>Logistics</td>
</tr>
<tr>
<td>Suppliers' Engineers</td>
<td>Commercial</td>
</tr>
<tr>
<td>Conformance Engineer</td>
<td>Customer</td>
</tr>
<tr>
<td>Service Engineer</td>
<td>Wildcard (non-technical person)</td>
</tr>
</tbody>
</table>

The leader of the FMECA team should be the person responsible for the product or process (usually the design or process engineer involved); the owner of the FMECA is responsible for the administration for convening analysis meetings and for producing the analysis in worksheet format.
Creating a FMECA

The conduct of FMECA is a step-wise iterative process which is described in the following sections. A procedure for product analysis will be described and later special considerations for process analysis will be described.

Learn about the design
Although the people who make up the FMECA team will be selected for their knowledge, it is unlikely that all have a full understanding of the product under consideration. It is important to avoid the temptation to rush into analysis before a common understanding of the key characteristics is achieved. The FMECA leader should use this initial phase to introduce team members to each other if necessary, and set the objectives of the analysis.

Set the level of the analysis
FMECA is usually applied as a bottom up technique in which a study is made of how components can fail; the causes of failure and the effects are subsequently identified. This knowledge is then used to study the next higher level of integration and so on until a full understanding is gained of every potential mode of failure throughout the product. Frequently, the application of FMECA is delayed because there is insufficient design information available upon which to base an analysis. While this may be true at the most detailed level of the product, there are compelling reasons to commence study at higher levels of product. Simply stated, an understanding of how a product can fail at system level can guide the designer in the detailed design of assemblies and components and enable him to better understand how the system may fail from the end users' point of view. Consider the following schematic of a motor vehicle. The vehicle depicted comprises 12 major systems. At the early stages of design some of the components that are used in the systems may be carried over from the previous generation of design. Many more, however, will be dependent on the design features at system level.

Figure 3. A vehicle's systems.
The schematic shown in Figure 3 can be expanded in the general form shown in Figure 4. If the analysis is set at the system level it is likely that failure modes will be expressed in the language of the customer. The immediate causes of failure will be found at sub-system level and thus, if initial analysis found that the majority of serious problems occurred in one of the sub-systems, priority could be placed on that sub-system for further analysis. Similarly, the causes of sub-system failures lie at assembly level where again, if one of the assemblies is a major contributor, emphasis for further analysis would be placed on that assembly and so on until completion of analysis. By taking this “lightning strike” approach to FMECA, coverage of all dominant failure modes may be achieved with considerable efficiency.

It is good practice to draw a diagram of the product being studied in a manner similar to Figure 4. By having a simple picture of the product and how it relates to other parts of its parent system, or if it is a top-level system itself, how it breaks down into lower levels of assembly, it is easier to retain the analysis at the level set. For the process, it is equally important to set the level of the analysis. The mechanism by which this is done is the flowchart; all processes can be represented by a flowchart that represents the activities undertaken. A high-level flowchart is often used for management purposes and an analysis at this level will identify the major issues that require corrective action. If further detail is required, the high-level flowchart can be broken down into individual charts of increasing levels of detail until, finally, a flowchart could be drawn which represents every part of an operation in minute detail.

Describe the desired functions
Before considering how the product can fail, it is important to understand its functions. Indeed, it would be very difficult, if not impossible to be sure that all failure modes had been identified without first considering the functions or purpose of the product.
An examination of the functions is achieved through brainstorming, and although brainstorming is a common technique, the author believes that it is important to recognize certain guidelines that are particularly applicable to this situation. The first meetings of a FMECA team may bring together people from different functional groups who do not regularly meet and operate as a team. Therefore, the dynamics of the group are uncertain in the initial stages of analysis. Failure to motivate the team will inevitably lead to reduced effectiveness of analysis with consequential problems later in development or in service as a result.

Conduct the brainstorming in strict rotation rather than allowing anyone to interject ideas at any time. The reason for this guideline is that some members of the FMECA team will be quieter by nature than others whose natural dominance may overshadow the potential contribution of their more reserved colleagues. After a number of unsuccessful attempts to make their ideas heard the quieter members are likely to give up trying, thereby denying the analysis the value of their knowledge.

There are compelling reasons for adhering to this rule under all situations. Firstly, the person who is laughed at for his or her idea is unlikely to contribute further to the analysis and may even leave the meeting if feelings are sufficiently hurt. Secondly, an idea that is apparently silly or of little value may, when examined in depth be "pure gold". The author experienced one such situation in which his seemingly daft idea subsequently saved his employer over £200,000. Thirdly, an idea of little intrinsic merit in itself may spark through some strange word association, an idea in another team member that may otherwise have lain dormant. This typifies the power of brainstorming - the end result is greater than the sum of individual contributions.

There will be many occasions in which a team member may have several ideas ready for his/her next contribution, only to see them expressed by others before having the opportunity to do so him/herself. Unless the "Five Second Rule" discipline is used there will be great temptation to think of an idea - any idea, rather than pass, particularly if this is the first pass situation. Under pressure for a good idea, ideas will be thought of and abandoned and consequently the brainstorming session will stagnate - much like a team of board game players deliberating at length each move. Successful brainstorming is dependent on spontaneity, and behaviour that slows down the session is likely to make it less efficient and boring. This will potentially have adverse effects on the current session and future sessions may be less well supported because of poor previous performance. It is important, therefore, to establish the rule that a pass is required if the contribution is not available in a five second "turn".

It is vital that the person recording the ideas writes down verbatim the idea and does not paraphrase its meaning. Attendant to this rule is that ideas should be expressed accurately and not reduced to a single word. In the author's
experience as facilitator to FMECA sessions, there have been many occasions in which teams could not remember the context in which a single word represented a complete idea that had been expressed only minutes before. Since an individual or a sub-group may study the outcome of a brainstorming session at a later session, it is essential that the ideas generated be recorded accurately.

Resist the temptation to discuss ideas as they are generated. Such behaviour severely reduces the effectiveness of brainstorming; people become too focused on a single idea, discussions may turn to argument and the spontaneity of the session is lost.

For a detailed study of a process, brainstorming functions may be unnecessary because the sub-process under examination may have a singular function.

**Review and rationalise the functions**

On completion of brainstorming the functions of the product, it may be worth spending a short time to rationalise the brainstorm. This is an opportunity to review the outcome of the brainstorm to remove obvious duplications and ensure that the ideas expressed are functions not features. The differentiation between a function and a feature often causes problems to FMECA teams. Perhaps the clearest way of stating the difference is that a function employs the active verb and a feature the passive. That is "to cool the engine" is a function, whereas, "to be lightweight" is a feature. If the team has difficulty in fully reaching agreement, the review process should be postponed in favour of commencing the next stage.

**List all potential failure modes**

Using brainstorming, list all the potential failure modes. There are two major options available here. First, and more common in situations in which all potential failure modes are to be identified, failure modes for all functions can be considered in any order. Second, when particular functions are of interest for detailed analysis, the failure modes may be brainstormed for each function separately. The method should be selected to suit the team preference. It is worth noting that the inverse of the functions are the easiest of the failure modes to identify, but perhaps rather than focus on these, it is better to brainstorm and check that the inverse of the functions are included in the list of potential failure modes during the rationalisation that follows.

**Review and rationalise failure modes against functions**

It is unlikely that the FMECA team will identify only potential failure modes at the declared level of the analysis; along with failure modes will be effects of failure and causes - sometimes even causes of causes. It is a natural outcome and should not be considered undesirable. The extra information generated is valuable and should not be discarded, but put to one side for later use. At this stage it will become clear if there are functions for which there are no identified failure modes and vice versa, and so the iterative process begins. New functions and/or failure modes may be identified as a result of this review. On completion, it should be possible to list the
functions and their associated failure modes so that the next stage of the process may begin.

**Describe the potential effects of each failure**
For each potential failure mode, describe the potential effects, remembering that it might be appropriate to consider the effects at the same level of assembly, the next higher level and end system level.

**Describe the potential causes of each failure**
The potential causes of each failure should be identified at a brainstorming session. Failure to identify all potential causes of failure modes may result in that failure mode occurring at some time in the population of products or operation of the process.

**Describe the current controls**
Describe the controls that currently exist which will prevent or at least detect the causes of failure. It is essential that the controls described are current and not an expectation of what may be in place at some time in the future.

**Assess criticality**
Using guidelines that are suitable for the organisation (see Annex B) score the occurrence, severity and detection ratings and multiply these together to give the Risk Priority Number. From the RPN scores a pareto plot of the causes of failure may be drawn which will show the priority for corrective action.

**Take corrective action**
The value from FMECA arises from the corrective action that results from knowledge gained of how the product/process may fail. The columns in the worksheet allocated for corrective action should describe the agreed corrective action, the responsibility for taking that action and the date when the action was completed. As completion details are entered for corrective actions the RPN should be rescored to reflect the improvements made.

**Standardise the actions taken**
As part of the corrective action it is important to assess how the information gained on the particular product/process could be applied elsewhere in the organisation. The cost/benefit of any analysis is greatly increased if multiple applications result. The FMECA is a living document for the subject product/process; the document without the criticality rating can also be used as a generic analysis for the type of product/process and can thus be used to assist the analysis of the next generation of product/process.

**FMECA cascade**
As mentioned earlier, the brainstorming process will frequently generate ideas that are effects or causes rather than failure modes at a particular level of analysis. Failure to recognize that some the "failure modes" are causes or effects can result in a very cumbersome analysis and considerable despondency among the team members as the enormity of the analysis becomes apparent. If a
FMECA team finds itself involved in increasing detail and generally finds the analysis difficult, it would be well worth reviewing the ideas to see how they fit in the FMECA cascade shown below.

**Figure 5. The general form of FMECA cascade.**

It is perhaps useful to remember that people like to solve problems and, therefore, our natural behaviour tends to drive us towards identifying solutions before we have fully understood the causes of problems. In this way we engage our minds on levels of detail too great for us to have a full comprehension, and hence, solutions abound that tackle the symptoms rather than root causes. The purpose of FMECA is to encourage discipline in the analytical process so that we are more likely to generate solutions to problems that take into account all potential causes of failure, or at least, recognition that a particular solution does **not** resolve root causes that we have consciously chosen to ignore.

**Figure 6. Cascade example for a flip chart stand.**
The best use of resource

If FMECA is to be adopted by an organisation as one of the standard methods of product and process analysis, it is important that consideration is given to the most effective use of resources. Stated simply, there are some activities that can only be or are best undertaken by a group of people and some that are better performed by an individual as suggested in the table below:

<table>
<thead>
<tr>
<th>GROUP</th>
<th>INDIVIDUAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brainstorm</td>
<td>Definition</td>
</tr>
<tr>
<td>Review</td>
<td>Rationalise Brainstorm</td>
</tr>
<tr>
<td>Approve</td>
<td>Set Current Controls</td>
</tr>
<tr>
<td></td>
<td>Propose Initial Scores</td>
</tr>
<tr>
<td></td>
<td>Propose Corrective Actions</td>
</tr>
<tr>
<td></td>
<td>Generate Forms</td>
</tr>
</tbody>
</table>

It is usual for the FMECA owner to assume the role of the individual, thereby acting as chairperson at FMECA meetings and ensuring that the analysis process is completed in the required timescale. By effectively conducting the individual activities, meetings can be kept as short as possible by circulating the information to be discussed beforehand. In this way the FMECA process will become dynamic and people will look forward to becoming a member of a FMECA group.

The use of FMECA software

There are a number of FMECA software packages available and all share the characteristic that they do not think! The author believes that FMECA software should only be used by those competent in the analysis; it may then be used to good effect to reduce the mundane aspects of form generation and update.

Summary

FMECA is a potentially powerful analytical technique that can improve the quality of the design process. To be successful, teams must be formed that capture the corporate knowledge on a particular product or process, and the analysis must be conducted as early as possible in the product/process life cycle. While it is not possible to assess the accuracy of a FMECA, the analysis should be used as a management tool to drive the development process by ensuring that the high-risk areas are improved by appropriate corrective action.
ANNEX A

FMECA example worksheets
### FMECA WORKSHEETS

**PART OR ASSEMBLY NAME**: Bottom Bracket (Engine Mtg)  
**SUPPLIERS**: Proform (Raw Matl.)  
**FMEA COMMITTEE**: Design, Development, Manufacturing & Quality Engineering  
**FMEA NUMBER**: F.175  
**SHEET**: 1 OF 12  
**DATE**:  
**NAME**  
**SIGNATURE**

<table>
<thead>
<tr>
<th>ITEM</th>
<th>PART NO. ISSUE</th>
<th>FUNCTION OR PROCESS</th>
<th>FAILURE MODE</th>
<th>EFFECT OF FAILURE</th>
<th>CAUSE OF FAILURE</th>
<th>CURRENT CONTROLS</th>
<th>CURRENT STATUS</th>
<th>RECOMMENDED CORRECTIVE ACTION</th>
<th>ACTION BY</th>
<th>ACTION TAKEN</th>
<th>REVISED STATUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>ASYM BOTTOM BRACKET ISSUE A</td>
<td>TO PROVIDE ENGINE FRONT SUPPORT</td>
<td>BUCKLING FAILURE OF BRACKET VERTICAL WALLS</td>
<td>ENGINE DROP (INSULATING FOAMS FOU LS RADIATOR)</td>
<td>INCORRECTLY SPECIFIED MATERIAL THICKNESS</td>
<td>STRESS REPORT SA 100</td>
<td>TEST TO TS 109</td>
<td>TESTS TO BE CARDED OUT TO TEST ASSEMBLY STRENGTH</td>
<td>TEST / DAVT</td>
<td>TEST / DAVT</td>
<td>2 4 3 10</td>
</tr>
<tr>
<td>12</td>
<td>&quot; &quot;</td>
<td>&quot; &quot;</td>
<td>&quot; &quot;</td>
<td>&quot; &quot;</td>
<td>&quot; &quot;</td>
<td>&quot; &quot;</td>
<td>&quot; &quot;</td>
<td>VERIFICATION BY LOAD TESTS; DESIGNED LOADS ARE SATISFACTORY</td>
<td>TEST / DAVT</td>
<td>TEST / DAVT</td>
<td>2 4 3 10</td>
</tr>
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<td>INSTALLATION TO BE REVISED AFTER ROAD &amp; LABORATORY TESTS</td>
<td>VEHICLE PROVING</td>
<td>LABORATORY &amp; ROAD TESTS</td>
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<td>VERIFY BY SPECIFIED BIG TEST</td>
<td>TEST / DAVT</td>
<td>TEST / DAVT</td>
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<td>ITEM</td>
<td>PART NUMBER</td>
<td>FUNCTION OR PROCESS</td>
<td>FAILURE MODE</td>
<td>EFFECT OF FAILURE</td>
<td>CAUSE OF FAILURE</td>
<td>CURRENT CONTROLS</td>
<td>CURRENT STATUS</td>
<td>RECOMMENDED CORRECTIVE ACTION</td>
<td>ACTION BY</td>
<td>ACTION TAKEN</td>
<td>REVIEWED STATUS</td>
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<td>11</td>
<td>SHEET 100</td>
<td>DRILL HOLES</td>
<td>HOLES OUT OF POSITION</td>
<td>DIFFICULT ASSEMBLY</td>
<td>UNCORRECT LOCATION IN DRILL</td>
<td>OPERATOR &amp; INSPECTION</td>
<td>5 7 8 220</td>
<td>POSITIVE LOCATION OF FIXTURE &amp; FINAL ACCEPTANCE GAUGE</td>
<td>PROD ENG  &amp; QUALITY CONTROL</td>
<td>Fixture location modified &amp; acceptance gauge implemented</td>
<td>2 7 6 12</td>
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<td>DRILL HOLES</td>
<td>HOLES UNDERSIZE</td>
<td>DISABLED TO ASSEMBLE TO ENGINE</td>
<td>UNCORRECT DRILL SIZE</td>
<td>OPERATOR &amp; INSPECTION CHECK WITH PLUG GAUGE</td>
<td>3 6 1 12</td>
<td>FIRST OFF CHECK &amp; USE OF ACCEPTANCE GAUGE</td>
<td>PROD ENG &amp; QUALITY CONTROL</td>
<td>Recommended actions implemented</td>
<td>2 6 1 12</td>
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<td>13</td>
<td>FORM BRACKET</td>
<td>UNCORRECT GRADE OF MATERIAL USED</td>
<td>STRUCTURAL FAILURE</td>
<td>POOR RAW MATE IDENTIFICATION &amp; STORAGE</td>
<td>OPERATOR LOCAL KNOWLEDGE</td>
<td>4 6 9 420</td>
<td>IDENTIFY RAW MATE LOCATION &amp; COLOR CODING</td>
<td>PROCESS ENG &amp; RAW MATE SUPPLIER</td>
<td>Recommended actions implemented</td>
<td>2 8 9 12</td>
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**ADDITIONAL ACTIONS REQUIRED TO FURTHER REDUCE RPM**

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<th>ITEM</th>
<th>FAILURE MODE</th>
<th>EFFECT OF FAILURE</th>
<th>CAUSE OF FAILURE</th>
<th>CURRENT CONTROLS</th>
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## FMECA WORKSHEETS

### FAILURE MODE & EFFECTS ANALYSIS FOR DESIGN

**ISSUED BY**

**FMEA ANALYSIS AUTHORISED BY**

**ISSUE DATE**

**NAME**

**CIRCULATION**

**POSITION**

**DATE**

**TEAM MEMBERS**

### NOTES ON SCORING

| OCCURRENCE | LOW No. | UNLIKELY |
| SEVERITY | HIGH No. | HIGH SEVERITY |
| DETECTION | LOW No. | LOW SEVERITY |

**RECOMMENDED CORRECTIVE ACTION**

**RESPONSIBILITY**

**ACTION TAKEN**

### DESIGN SECTION

**PART NUMBER**

**DRAWING ISSUE**

**MODEL(S)**

**OUTSIDE SUPPLIER**

**DESCRIPTION**

### SHEET OF

**ITEM**

**PART NO.**

**NAME (SUP) LEVEL**

**FUNCTION (S)**

| POTENTIAL | INITIAL SCORE OCC | SEV | DET | RPn |
| CONTROL SYSTEM | |

| RECOMMENDED CORRECTIVE ACTION |
| RESPONSIBILITY |

| ACTION DATE |
| NEW CONTROL SYSTEM OCC | SEV | DET | RPn |
Annex B

Criticality scoring guidelines
FMECA criticality ratings for a product

**OCCURRENCE**

1. Extremely unlikely
2. Unlikely/low probability
3. Likely
4. Highly likely/high probability
5. Extremely likely/almost certain

**SEVERITY**

1. No effect on customer
2. Slight customer annoyance/minor effect on product
3. Moderate customer annoyance/significant effect on product
4. High degree of customer annoyance/expensive repair/secondary damage
5. Total loss of function/potential effect on safety
6. Catastrophic - safety related failure

**DETECTION**

1. Extremely likely
2. Highly likely
3. Likely
4. Unlikely
5. Extremely unlikely
FMECA criticality ratings for a process

OCCURRENCE

1 Extremely unlikely
2 Unlikely/low probability
3 Likely
4 Highly likely/high probability
5 Extremely likely/almost certain

SEVERITY

1 No effect on customer or process
2 Slight customer annoyance/operator inconvenience
3 Moderate customer annoyance/minor in-house cost
4 High degree of customer annoyance/major in-house cost
5 Failure to provide the service/loss of production capability
6 Catastrophic - safety/health implications

DETECTION

1 Extremely likely
2 Highly likely
3 Likely
4 Unlikely
5 Extremely unlikely
(Intentionally blank)