CPQP

TOOLSET
GUIDELINE 8

# Control Plan Guideline

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Construction Innovation Hub

UK Research and Innovation

# Contents

## List of figures



## List of tables

# Use of this Guide

The Control Plan guideline is part of the Construction Product Quality Planning (CPQP) process and should be used in conjunction with the CPQP Guide and its toolset, published by the Construction Innovation Hub.

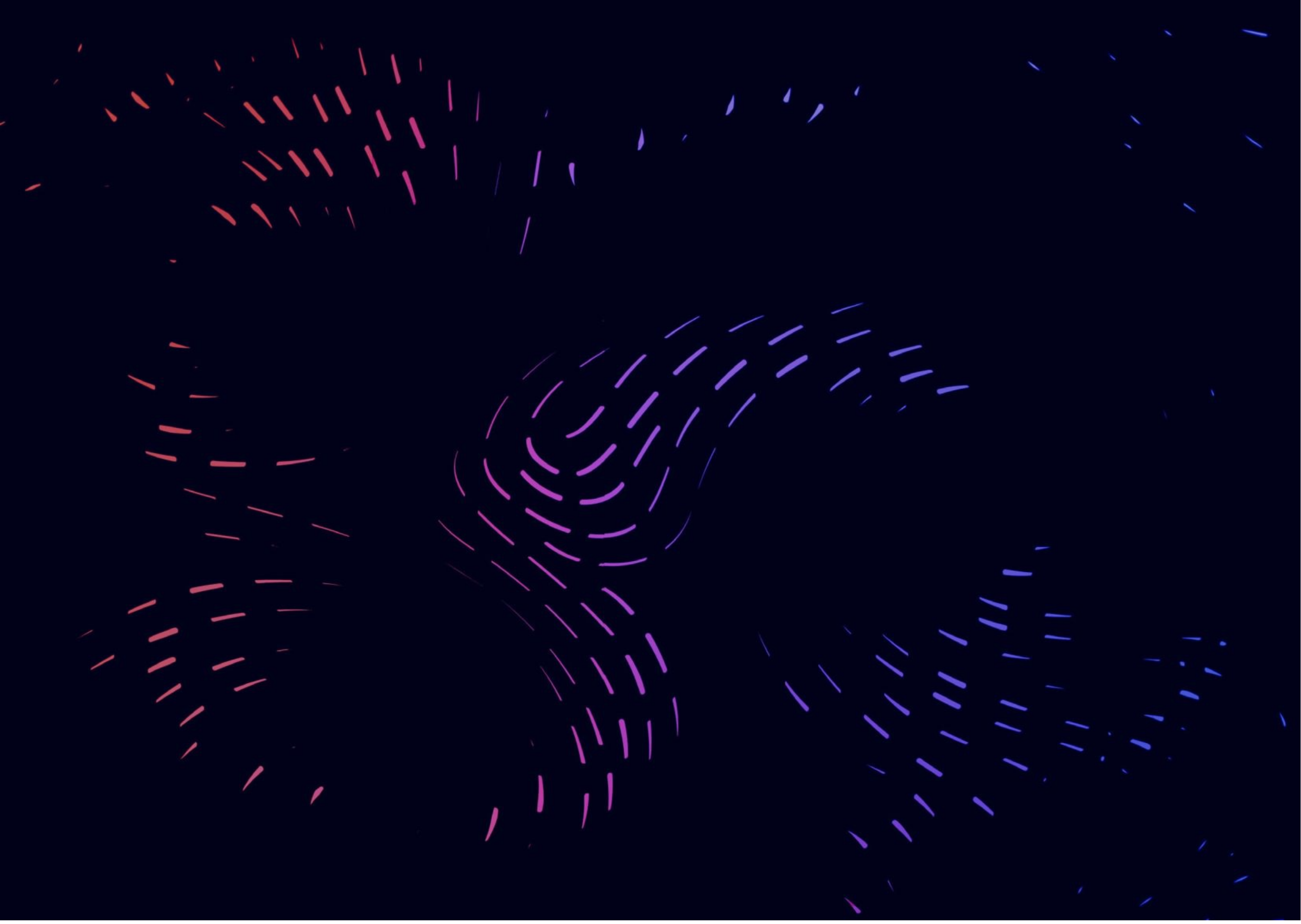
Intended as a guideline to aid the process of creating Control Plans, this document provides the basic principles and a suggested methodology. The templates provided can be changed and modified to suit individual companies.

This guideline is intended for use by companies manufacturing offsite construction products largely using the CPQP process with their customers and suppliers. It aims to provide enough knowledge to enable the CPQP team to complete a Control Plan, particularly where this subject is new to them, as well as to provide ongoing aid. Over time, companies will develop their own expertise, methods and standards through training and practice.

For a list of the acronyms and abbreviations used in this document, refer to Appendix B – List of Abbreviations.

For the various terms used in this document, refer to Appendix C – Glossary of Terms.

For further information about the CPQP Guide and its toolset please contact: cpqp@constructioninnovationhub.org.uk



# Introduction

# Introduction

Control Plans provide a structured approach to define control actions required at each process step to ensure process outputs meet the pre-determined requirements. Control Plans provide the production team with a description of the process control mechanisms (e.g. measurements, inspections, quality checks and monitoring of product and process parameters) to assure that quality requirements and standards are met throughout the production process and the risk of producing defective or non-conforming products are mitigated.

The tool (usually presented as a spreadsheet template) addresses key risks identified in the Process Failure Modes, Effects & Analysis (PFMEA), another tool used by engineers to identify potential failures that could occur in a manufacturing process and for which a guideline is also available as part of the CPQP toolset; Process Failure Modes and Effect Analysis (PFMEA).

Besides defining control methods, the Control Plan also provides the operator with a reaction plan that sets out actions for the operator when non-conformance is detected.

## Background

Control Plans are well established in other industries, such as aerospace, automotive, heavy equipment and many other industries, to ensure product quality standards are met by minimising product and process variation [1].

The adoption of these risk control measures in the automotive, aerospace, and other manufacturing industries has delivered significant improvement with regards to defect prevention, quality control, and cost reduction. Companies that use Control Plans realise that monitoring and controlling the high-risk items identified in the Process Failure Mode and Effects Analysis (PFMEA) enable the team to evaluate process or product for strengths and weaknesses and to prevent problems before they occur. Highlighting these risks and formulating control mechanisms for these processes is imperative before tooling and finalising the manufacturing process, as the costs of revisions at a later stage are significant.

## Purpose

The main purpose of using Control Plans is to monitor and control process quality by providing actionable control methods to reduce the risks highlighted in the PFMEA. This assures that any process improvements are also maintained over the lifecycle of the part.

The Control Plan is a key element of a structured process and contributes to effectively foster a culture of defect prevention. The Control Plan, along with the PFMEA, reduce defects propagating through manufacture, assembly, and construction phases and effectively error-proof the project. Therefore, using the Control Plan acts as an enabler in shifting the focus of the team from quality control and defect checking to quality assurance and defect prevention. The Control Plan ensures ongoing monitoring is carried out by controlling the key sources of variation in the process, which in turn leads to a predictable process and a defect-free product.

## Benefits

The Control Plan benefits have been documented in various industries. The expenditure within businesses is ever increasing with the rising costs of raw material and labour and the need for advanced equipment. The majority of manufacturing companies today are looking for ways to reduce cost by eliminating waste within processes, while ensuring that the parts produced conform to customer requirements every time.

Some of the benefits associated with the Control Plan include:

- Process defect prevention:
  Actionable tasks make it possible to monitor, control, and remove or reduce variation within a process. This contributes to the overall process efficiency and eventually to the reduction in the number of non-conforming parts;

- Efficient use of resources:
  Clear and actionable process control methods contribute to improving product quality, reducing waste, and eliminating costly rework;

- Cost savings:
  Proactive plans to mitigate issues early within production processes contribute to significant savings relative to implementing a solution once production is already underway;

- Increased customer satisfaction:
  Key product and process instructions, actions, and control methods documented in the Control Plan contribute to delivering a product with a high level of customer perceived quality;

- Effective communication:
  Successful implementation of a control method for a process risk requires ongoing communication This level of involvement to deliver a solution improves communication within the relevant team, across the organisation and, importantly, with the team on the shop floor. The documented control methods and actions should provide operators with clear instructions to ensure processes and products meet the pre-defined requirements; and

- Team Engagement:
  A cross-functional team develops and manages the Control Plan to ensure that the high-risk features or characteristics identified in the PFMEA are either mitigated or prevented.

## How does the Control Plan fit in with Construction Product Quality Planning?

The Construction Product Quality Planning (CPQP) process supports the development of new products for manufacturing-led construction approaches. The process covers the entire product development cycle, from concept design through to product launch. The Construction Product Quality Planning (CPQP) process has been broken down into five phases as shown in Figure 1. Similar to the Process Failure Mode and Effect Analysis (PFMEA) document, the Control Plan is developed during phase 3 (Process Design & Development) of the CPQP process. Therefore, the PFMEA and Control Plan are paired together within the CPQP process to enable the delivery of products to ensure customer satisfaction.

## Team Approach

The advanced planning approach in the CPQP is built upon a team-based approach. Similarly, the effective use of the Control Plan tool requires the engagement and participation of a cross-functional team. The team composition will vary by organisation and the needs of the process improvement. However, the team should include members from a variety of disciplines with relevant knowledge and experience (i.e. design, process, manufacturing and quality departments) to ensure that the Control Plan is actionable and facilitates the work of the team on the shop floor.

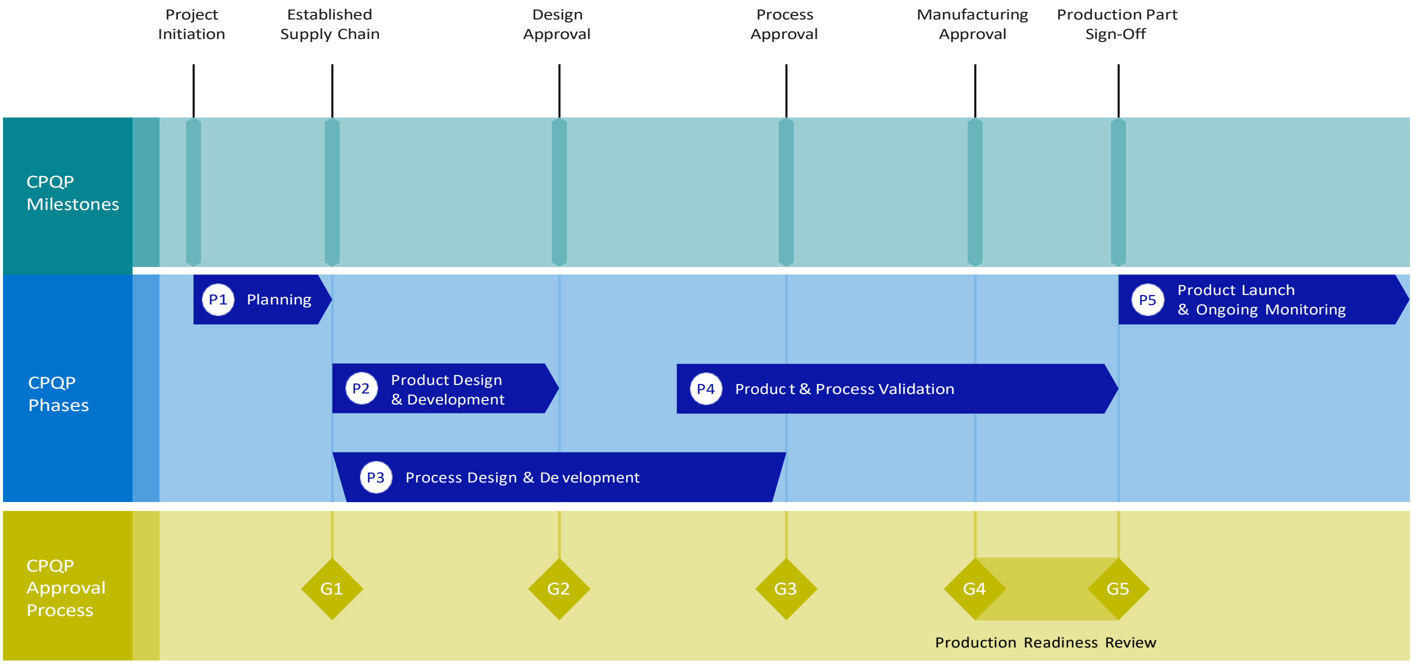
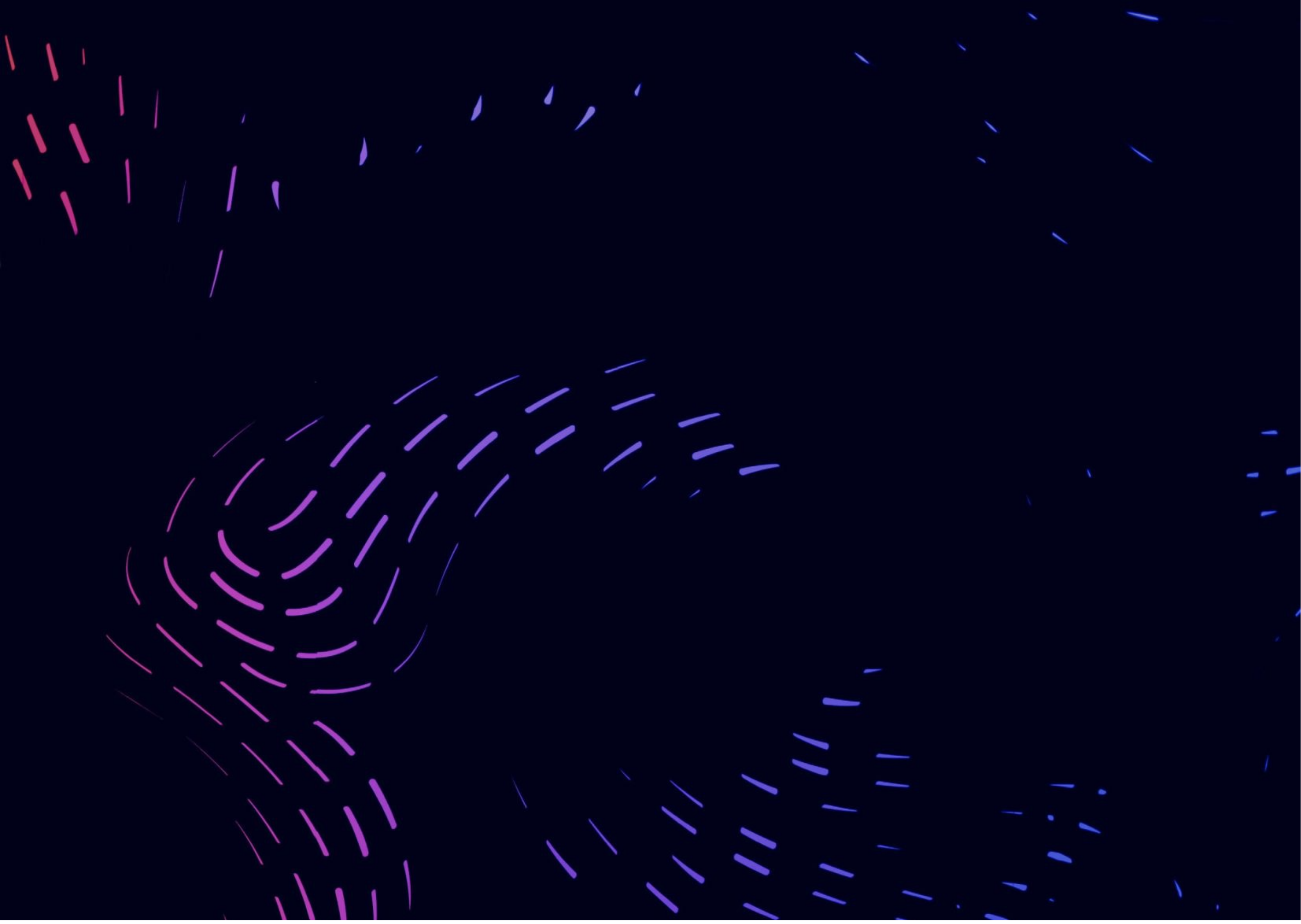



Figure 1. Construction Product Quality Planning (CPQP) Process



# Methodology

# Methodology

The Control Plan details the controls required at each step of the production and assembly processes. It includes checking product characteristics (e.g. dimensions, surface finishes, evidence of damages) as well as process characteristics (e.g. pressures, temperatures, step duration).

The results of the PFMEA usually feed into the Control Plan. It is during the PFMEA that the team identifies the high-risk items and key process characteristics that need to be monitored and controlled. The PFMEA also identifies the prevention and detection controls that need to be in place to mitigate the identified risk. Mitigation of these risks forms part of the Control Plan, which details the control method for these key characteristics of the process to deliver the product.

In general, Control Plans provide details of the in-process checks that need to be completed during the manufacturing of a specific product. Some other controls are specific to the general process rather than to specific product manufacturing processes. This is the case for instance of maintenance and equipment inspections which are then covered in the maintenance plan.

Figure 2 illustrates how the Control Plan fits in the documentation breakdown structure for the outputs of the PFMEA. For information on PFMEA and a copy of the template, refer to the Process Failure Modes and Effect Analysis (PFMEA) guideline, which forms part of the CPQP toolsets.

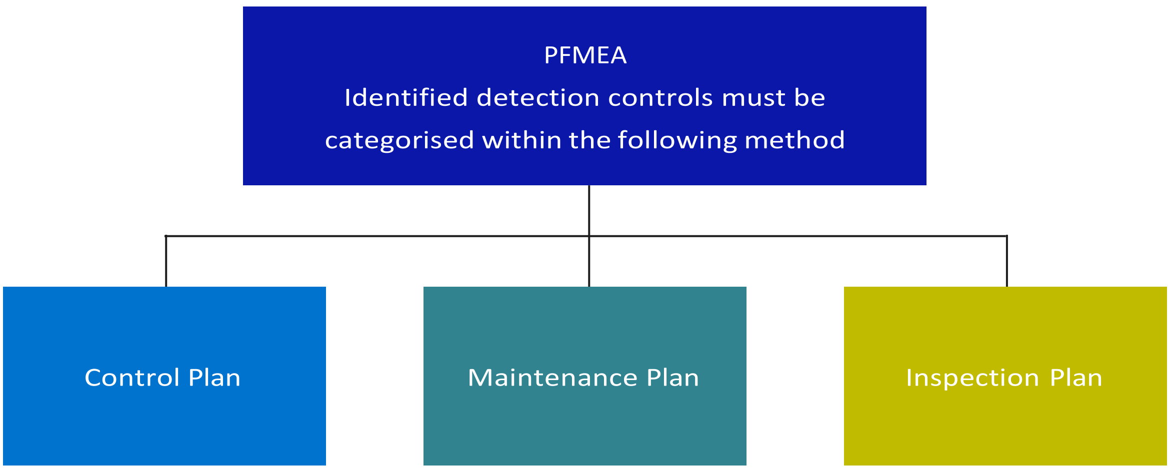



Figure 2. Prevention and Detection Control Documentation

The development of the Control Plan requires a cross-functional team with the expertise to define the process control mechanisms that can prevent the root causes for failures. The control method selected within the Control Plan ensures that the design intent for the product is protected from end to end and that the process parameters are monitored to ensure consistent product quality [2]. Figure 3 illustrates the key inputs used to develop the Control Plan.

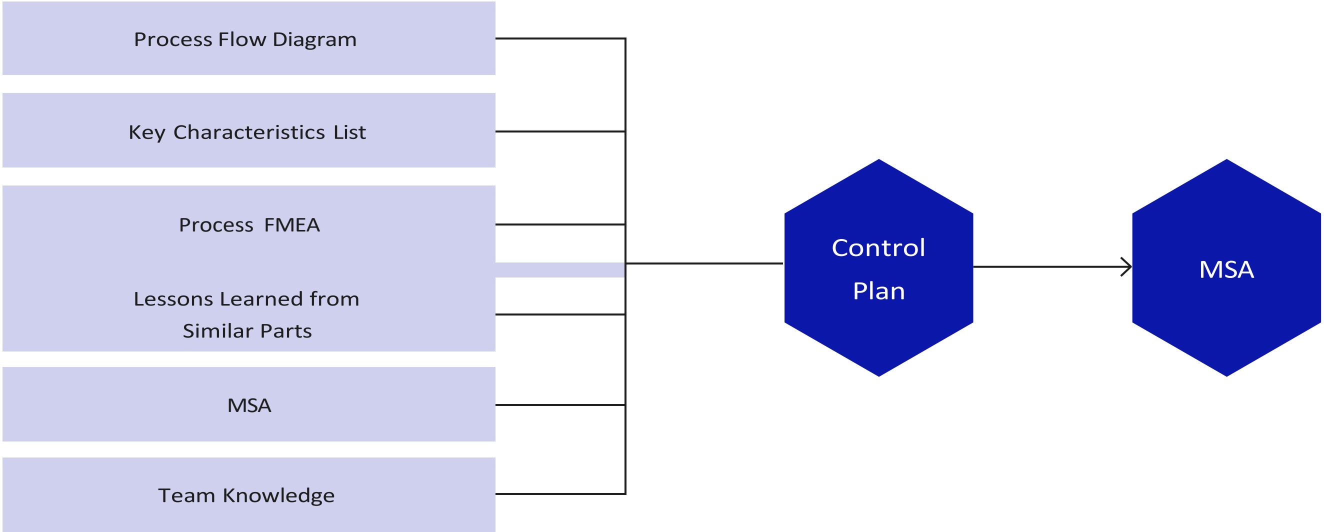


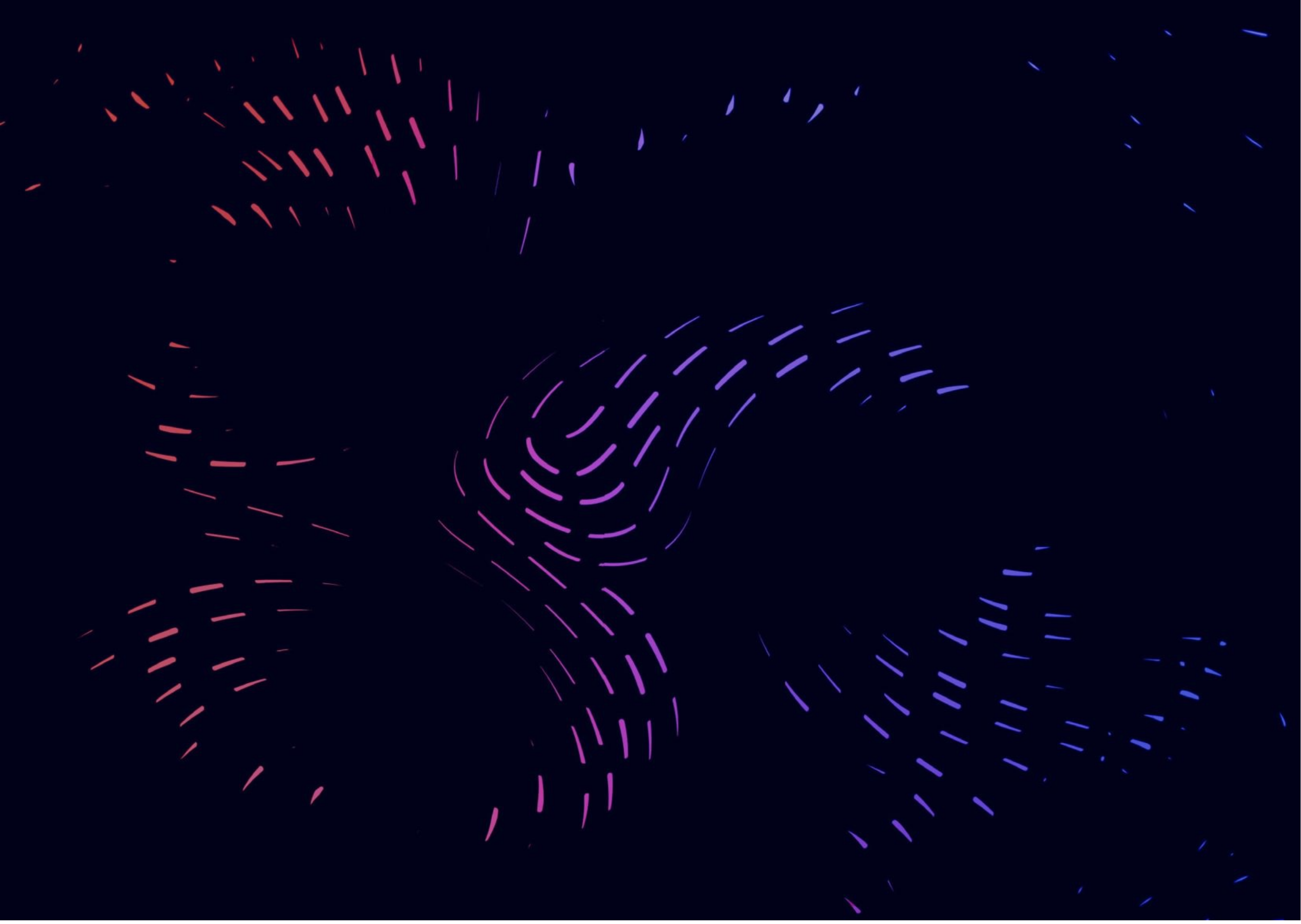

Figure 3: Control Plan Inputs

It is important to ensure that the Control Plan is updated at regular intervals and reflects the current manufacturing process.

Along with the process control mechanisms, the Control Plan specifies a separate reaction plan for each high-risk item. The reaction plan comes into use in the event of a failure of the control method itself, for example, instances where an error-proofing fixture might break.

The effectiveness of the actions and controls described in the Control Plans depends on its deployment and the adoption on the shop floor. Some of the more common issues that teams can face during the implementation of the Control Plan are:

- Accessibility: The correct Control Plan should be easy to locate and identify. The document needs to be easily accessible by the team in the shop floor so they can refer to it to carry out the required check when during the process;
- Document size: The Control Plan should present the information clearly and concisely. Overcrowded plans can make it difficult for operators to quickly identify actions required for control measures; and
- Updated document: Control Plans are linked to the PFMEA. Updates to the PFMEA need to be translated into the Control Plan. Both the PFMEA and the Control Plan are live documents; they need to be updated regularly following any changes in the processes.



# Guideline

# Guideline

The following steps describe the process to create a Control Plan. These steps provide high-level information on the requirements. Detailed steps are provided in the Worked Example section.

## Step 1: Assign Control Plan Team

Assign a cross-functional team to carry out the actions agreed upon in the PFMEA.

## Step 2: Collect Outputs from PFMEA

Capture the outputs from the PFMEA and other sources, making sure that all aspects shown in Figure 2 have been considered.

## Step 3: Prioritise Process Risk

Prioritise failure modes based on the highest process risk to lowest for each operation. If a failure mode in the PFMEA is common and has been mentioned for several other operations, then due diligence is required to confirm if repetition can be avoided.

## Step 4: Population of Control Plan

Begin populating the document based on the PFMEA template. Essential data required for the Control Plan includes:

- Description of failure mode;
- Feature or Part Number;
- Part description;
- Component features;
- Summary of operation;
- Risk Classification;
- Failure Modes;
- Measurement methods; and
- Control Methods.

## Step 5: Control Plan Action

The required control method will be carried out for each stage by the relevant operator. The actions should be described in the Control Plan.

## Step 6: Reaction Plan

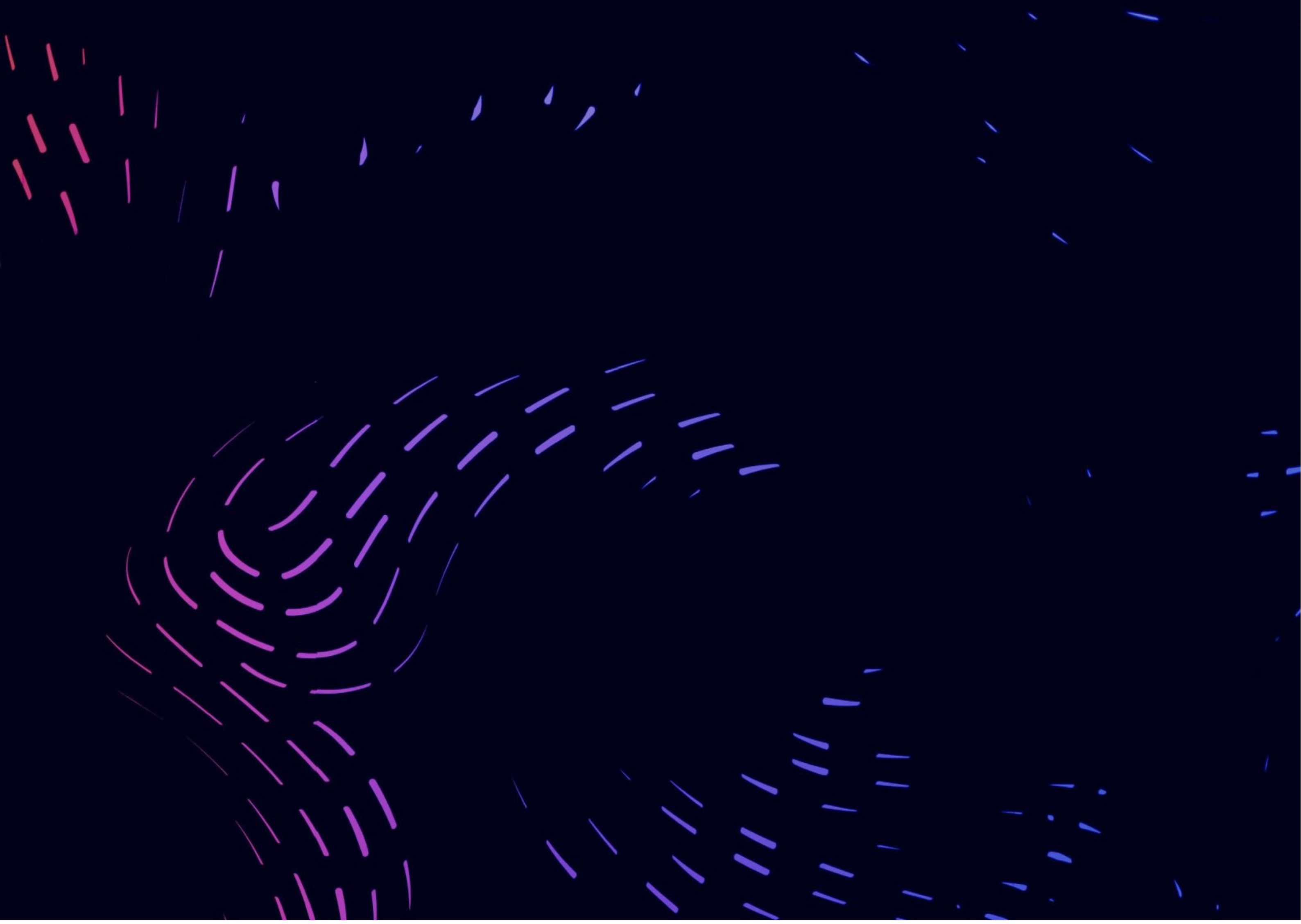
If a planned control method fails, the Control Plan also provides the operator with a reaction plan, for example, machine stoppage. A good practice on a manufacturing shop floor is to have some key reaction plans in the form of laminated numbered documents (e.g. reaction plan 1, reaction plan 2 and so on), which can be quickly implemented during uncertain situations.

## Step 7: Process Validation

Process validation should be signed-off on by the quality manager after ensuring that the Control Plan has been completed with no outstanding issues and all actions have been closed.

## Step 8: Handover

Hand over each process template to the relevant operators, who are responsible for completing the template and have full working knowledge of the operation, product characteristics, and product/process specifications. These actions should ensure that risks are mitigated and prevented wherever possible. Only in instances where it may not be possible to mitigate certain risks, the team should ensure that high-fidelity detection mechanisms are put in place.



# Worked Example

# Worked example

Based on the methodology discussed in the previous section, the implementation of the Control Plan is outlined using a worked example. This step-by-step worked example should lead to a fully populated Control Plan. This can be found at the end of this section in Table 1. The example should not be regarded as a complete and comprehensive case study; it aims only to illustrate the implementation of the Control Plan in a simple manner.

The worked example considers the off-site manufacturing of an insulated wall system. The wall system comprises a sandwich structure composed of a gypsum fibreboard and an insulation board joined before being shipped to the site for building assembly. The Control Plan is a continuation of the PFMEA worked example from the PFMEA Guideline released from the Construction Innovation Hub. The failure modes with the highest Risk Priority Number (RPN) are taken forward to the Control Plan. This worked example considers the two highest risk items: loading the panel face down and loading a panel with the wrong colour, with RPNs of 70 and 56, respectively.

## Step 1: Assign Control Plan Team

The initial step is to select a team to carry out the actions agreed upon in the PFMEA. This can be the same team that completed the PFMEA, or another team determined internally. Details of the selected team are recorded in the template (Figure 4).

| Name | Position | Email |
|---|---|---|
| Luke Harrington | Manufacturing Engineer | L.Harrington@example.co.uk |
| Amelie Hamilton | Design Engineer | A.Hamilton@example.co.uk |
| Lauren Cannon | Quality Engineer | L.Cannon@example.co.uk |
| Dylan Reese | Production Manager | D.Reese@example.co.uk |
| Alyssa Finley | Manufacturing Team Leader | A.Finley@example.co.uk |

Figure 4. Control Plan Team Selection

# Step 2: Collect Outputs from PFMEA

All relevant information needs to be added in the template to allow quick and easy referencing of the operations in the Control Plan heading section (Figure 5). This includes details of operations, actions and parts within the plan.

**Control Plan**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Project | Future Cell Wall System | Manufacturer (FMEA Owner) | Fireboard Solutions Limited | Location | Processes/ Operations Covered | PFMEA Number | PFMEA FC.20 |
| | | | | Watford Factory | Insulated Wall Panel Sub Assembly | | |
| Project Description | Offsite manufacture of new wall system for Prisons. Wall sections will comprise of an Insulated Wall Panel and an Uninsulated wall panel of standard sizes. Complete the wall system before shipping to site for building assembly. | Customer | ABC Main Contractor | Location | Process Flow Chart References | Date | 03-Nov-20 |
| | | | | Birmingham (site) | Op20 - Insulated Wall Panel Sub Assembly | | |
| | | Team | | | | Revision | B |

| Part Name | Part Number | Rev | Name | Position | Email | Summary: | Revision notes: |
|---|---|---|---|---|---|---|---|
| Insulated Wall Panel | FSL213 | 2 | Luke Harrington | Manufacturing Engineer | L.Harrington@example.co.uk | This process flow covers the sub assembly of the Insulated Wall Panel ready for assembly with the uninsulated Wall Panel to complete the Wall System. Made on Panel Sub Assembly Line 1. | Updated after PFMEA RPN reduction actions were implemented. |
| | | | Amelie Hamilton | Design Engineer | A.Hamilton@example.co.uk | | |
| | | | Lauren Cannon | Quality Engineer | L.Cannon@example.co.uk | | |
| | | | Dylan Reese | Production Manager | D.Reese@example.co.uk | | |
| | | | Alyssa Finley | Manufacturing Team Leader | A.Finley@example.co.uk | | |

Figure 5. Control Plan Heading Section

The Control Plan Number (CP Number) for the document is added. This is related to the PFMEA Number. In this example, the Control Plan Number is CP FC.20 and the PFMEA Number is PFMEA FC.20. The CP number is found in the top-right-hand corner (Figure 6).

| | |
|---|---|
| Control Plan Number | CP FC. 20 |

Figure 6. Control Plan Number

The project name, description, and summary are populated based on the PFMEA template (Figure 7). This can be copied from the PFMEA document if needed. The overall project is the final product that is compiled of the sub-parts. These populated cells show what the aim of this process is and provide guidance on what the plan is trying to achieve. In this example, the aim is to manufacture a new system of prison walls comprised of insulated and uninsulated wall panels.

| | |
|---|---|
| Project | Future Cell Wall System |
| Project Description | Offsite manufacture of new wall system for Prisons. Wall sections will comprise of an Insulated Wall Panel and an Uninsulated wall panel of standard sizes. Complete the wall system before shipping to site for building assembly. |

Summary:

This process flow covers the sub assembly of the Insulated Wall Panel ready for assembly with the uninsulated Wall Panel to complete the Wall System. Made on Panel Sub Assembly Line 1.

Figure 7. Control Plan Project Description & Summary

A record of the two primary parties involved is populated (Figure 8). The manufacturer and the customer information, including their location, is populated.

| | | |
|---|---|---|
| Manufacturer (FMEA Owner) | Fireboard Solutions Limited | Location<br>Watford Factory |
| Customer | ABC Main Contractor | Location<br>Birmingham (site) |

Figure 8. Control Plan Primary Parties

Parts and sub-parts assembled within this process flow are recorded (Figure 9). The part name, number, and revision/iteration are the key inputs required. The revision/iteration is important due to the differing risks that are applicable to different designs or materials. This example considers the insulated wall panel process risk.

| Part Name | Part Number | Rev |
|---|---|---|
| Insulated Wall Panel | FSL213 | 2 |

Figure 9. Control Plan Part Description

A link to the PFMEA document number is recorded on the Control Plan. Alongside this information, the process/operation covered and process flow chart reference are also entered. This data is important with regards to providing a link between the PFMEA and Control Plan (Figure 10).

| Processes/Operations Covered | PFMEA Number | PFMEA FC.20 |
|---|---|---|
| Insulated Wall Panel | | |
| **Process Flow Chart References** | Date | 03-Nov-20 |
| Op20 - Insulated Wall Panel Sub Assembly | Revision | B |

Figure 10. Control Plan and PFMEA Link Information

A record of updates to the Control Plan is documented (Figure 11). It is imperative to include revision, date of revision and the description of the details of the last revision to ensure the end user can track changes.

| Date | 03-Nov-20 |
|---|---|
| Revision | B |
| Revision notes:<br><br>Updated after PFMEA RPN reduction actions were implemented. | |

Figure 11. Control Plan Revision Control

## Step 3: Prioritise Based on RPN Score

This section of the Control Plan is based on the PFMEA failure modes (Figure 12). The order is based on RPN from highest to lowest for each operation. Each section is further detailed below.

| Process/ Op Number | Process/ Opperation Description | Process Revision | Key Characteristic | Failure Mode | Tool/Machine Used | Control Method | Tolerance | Evaluation Technique | Reaction Plan |
|---|---|---|---|---|---|---|---|---|---|
| 20.1 | Place large external Gypsum Fibreboard panel (base part no. 234768) of the right external colour finish onto roller bed in the correct orientation | B | CC | Panel loaded face down on conveyor | Colour Sensor | Use sensor to detect if 'light' internal or 'darker' external side is facing up. Machine will no cycle until orientation is detected. | N/A | Colour scanner will identify the part, which the system will determine if it is the correct part or not. Staff will act on results. | Remove Gypsum Fibreboard Panel from conveyer belt. Return to starting position, with panel loaded face down. |
| | | | SC | Wrong colour panel loaded - different external finish spec | Bar Code Scanner | Scan barcode of panel into the system so machine knows correct part loaded and cycle will not start until correct board present. | N/A | Bar code scanner will identify the part, which the system will determine if it is the correct part or not. Staff will act on results. | Remove Gypsum Fibreboard Panel from conveyer belt. Notify line manager. |

Figure 12. Control Plan Failure Mode Population

## Step 4: Population of the Control Plan

The first three columns are populated with the Process/Operation number, its description, and the revision of the operation to keep track of the number of times the controls have been changed due to quality escapes or other problems (Figure 13). In this example, the PFMEA highlights that the highest risk is the potential of the wrong component being used, which can lead to two potential failures. These failures are recorded on the lower section of the Control Plan highlighting the operational description. This description gives a more detailed account of how to successfully accomplish this process.

| Process/ Op Number | Process/ Opperation Description | Process Revision | Key Characteristic |
|---|---|---|---|
| 20.1 | Place large external Gypsum Fibreboard panel (base part no. 234768) of the right external colour finish onto roller bed in the correct orientation | B | CC |
| | | | SC |

Figure 13. Control Plan Process Description

The characteristic level of the operation is taken from the corresponding PFMEA (Figure 14). This can be classed as either a Critical (CC), Significant (SC), or Unclassified Characteristic (UC).

The Failure Modes are obtained from the PFMEA. The two highest RPN scored failure modes are shown in Figure 15. In this instance, two possible failure modes relate to the assembly process: the orientation of the board required to build the wall panel and the wrong panel colour loaded.

| Key Characteristic |
|---|
| CC |
| SC |

Figure 14. Control Plan Key Classification

| Failure Mode |
|---|
| Panel loaded face down on conveyor |
| Wrong colour panel loaded - different external finish spec |

Figure 15. Control Plan Potential Failure Modes

## Step 5: Control Plan Action

The next two columns are populated with information highlighting the control method and the associated tools (Figure 16). In this instance, the use of a sensor or scanner allows the control method to be adhered to. The two control methods use a sensor to detect which side of the gypsum fibreboard panel is on the conveyor using a light sensor and scanning the barcode of the panel to ensure the correct panel is loaded onto the conveyer. In both instances, the control states the conveyer belt will not cycle forward to the workstation until the correct board is present and facing the correct side.

The next step is to populate the tolerance of the failure mode characteristic. This column is used to state a customer requirement.

| Tool/Machine Used | Control Method |
|---|---|
| Colour Sensor | Use sensor to detect if 'light' internal or 'darker' external side is facing up. Machine will no cycle until orientation is detected. |
| Bar Code Scanner | Scan barcode of panel into the system so machine knows correct part loaded and cycle will not start until correct board present. |

Figure 16. Control Plan Tools / Machine Used & Control Method

## Step 6: Reaction Plan

The final two columns of this example deal with the technique to control the process and creation of a reaction plan (Figure 17). The evaluation technique is pivotal in providing greater detail on how to execute the control method. To ensure the panel is facing the correct side and the correct panel is loaded, the two scanners are integrated as part of an automated detection system. Both techniques ensure that the staff play no role in determining the correct panel and its orientation. At this point, the operator has a control method and how to execute it – which removes both process risks. Finally, the reaction plan informs the operator of the necessary steps to take in the event of an unexpected failure. In this instance, a staff member must manually remove the panel from the line and either place it in its correct orientation at the starting point or inform a manager that the incorrect part has been loaded.

| Evaluation Technique | Reaction Plan |
|---|---|
| Colour scanner will identify the part, which the system will determine if it is the correct part or not. Staff will act on results. | Remove Gypsum Fibreboard Panel from conveyer belt. Return to starting position, with panel loaded face down. |
| Bar code scanner will identify the part, which the system will determine if it is the correct part or not. Staff will act on results. | Remove Gypsum Fibreboard Panel from conveyer belt. Notify line manager. |

Figure 17. Control Plan Evaluation & Reaction Plan

## Step 7 & 8: Process Validation & Handover

Process validation is signed-off on by the quality manager, who ensures that the Control Plan is complete with no outstanding issues and all the actions are closed.

The team then hands over each process's template to the relevant operators who are responsible for completing the template and have full working knowledge of the operation, product characteristics, and product/process specifications. These actions ensure that the risks are mitigated and prevented wherever possible.

| Control Plan | Control Plan Number | CP FC. 20 |
|---|---|---|

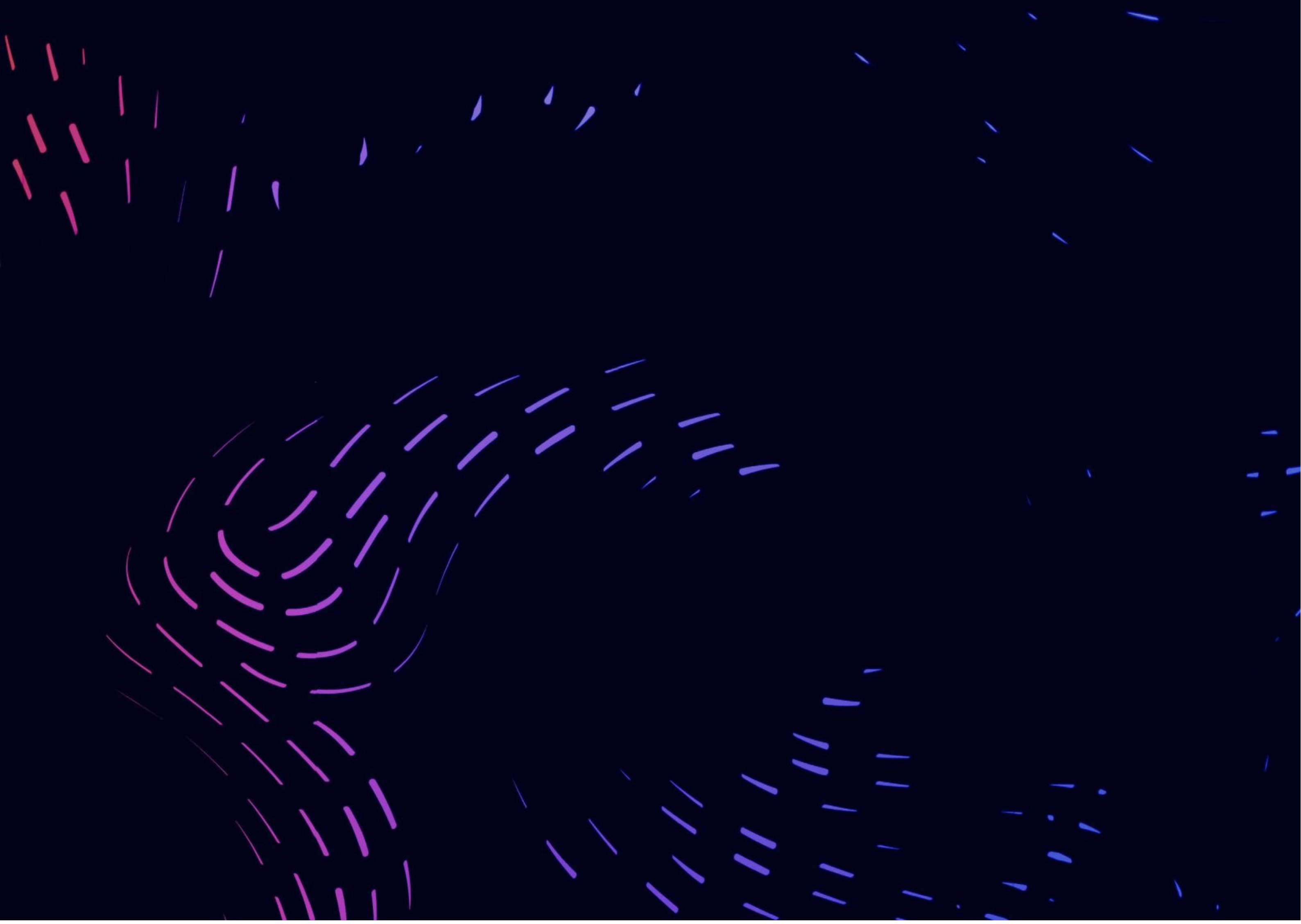
| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Project | Future Cell Wall System | Manufacturer (FMEA Owner) | Fireboard Solutions Limited | Location | Processes/Operations Covered | PFMEA Number | PFMEA FC.20 | Page 1 of 1 |
| | | | | Watford Factory | Insulated Wall Panel Sub Assembly | | | |
| Project Description | Offsite manufacture of new wall system for Prisons. Wall sections will comprise of an Insulated Wall Panel and an Uninsulated wall panel of standard sizes. Complete the wall system before shipping to site for building assembly. | Customer | ABC Main Contractor | Location | Process Flow Chart References | Date | 03-Nov-20 | CONSTRUCTION INNOVATION HUB |
| | | | | Birmingham (site) | Op20 - Insulated Wall Panel Sub Assembly | | | |
| | | Team | | | | Revision | B | |

| Part Name | Part Number | Rev | Name | Position | Email |
|---|---|---|---|---|---|
| Insulated Wall Panel | FSL213 | 2 | Luke Harrington | Manufacturing Engineer | L.Harrington@example.co.uk |
| | | | Amelie Hamilton | Design Engineer | A.Hamilton@example.co.uk |
| | | | Lauren Cannon | Quality Engineer | L.Cannon@example.co.uk |
| | | | Dylan Reese | Production Manager | D.Reese@example.co.uk |
| | | | Alyssa Finley | Manufacturing Team Leader | A.Finley@example.co.uk |

| Summary: | Revision notes: |
|---|---|
| This process flow covers the sub assembly of the Insulated Wall Panel ready for assembly with the uninsulated Wall Panel to complete the Wall System. Made on Panel Sub Assembly Line 1. | Updated after PFMEA RPN reduction actions were implemented. |

| Process/ Op Number | Process/ Opperation Description | Process Revision | Key Characteristic | Failure Mode | Tool/Machine Used | Control Method | Tolerance | Evaluation Technique | Reaction Plan |
|---|---|---|---|---|---|---|---|---|---|
| 20.1 | Place large external Gypsum Fibreboard panel (base part no. 234768) of the right external colour finish onto roller bed in the correct orientation | B | CC | Panel loaded face down on conveyor | Colour Sensor | Use sensor to detect if 'light' internal or 'darker' external side is facing up. Machine will no cycle until orientation is detected. | N/A | Colour scanner will identify the part, which the system will determine if it is the correct part or not. Staff will act on results. | Remove Gypsum Fibreboard Panel from conveyer belt. Return to starting position, with panel loaded face down. |
| | | | SC | Wrong colour panel loaded - different external finish spec | Bar Code Scanner | Scan barcode of panel into the system so machine knows correct part loaded and cycle will not start until correct board present. | N/A | Bar code scanner will identify the part, which the system will determine if it is the correct part or not. Staff will act on results. | Remove Gypsum Fibreboard Panel from conveyer belt. Notify line manager. |

Table 1. Control Plan Template, 2D Prefabricated Panel Installation



# References and Appendices

# References

[1] Quality One International. Quality-One International. Retrieved December 2nd, 2020, from https://quality-one.com/control-plan/

[2] British Standards Institution. (2011). Aerospace series. Paints and varnishes. Test method for determination of chromate leaching. BS EN 4195. Retrieved from: https://shop.bsigroup.com/ProductDetail?pid=000000000030247578.

[3] British Standards Institution. (2018). Aerospace series. Requirements for advanced product quality planning and production part approval process. British Standards Institution, BS EN 9145. UK: British Standards Institution.

# Appendices

## Appendix A – Tool Templates

Templates to be used within the context of this guideline are available, please contact: cpqp@constructioninnovationhub.org.uk

Table 2 and Table 3 show a standard Control Plan template and a PFMEA template, respectively.

| Control Plan | Control Plan Number | |
|---|---|---|

| Project | | Manufacturer (FMEA Owner) | | Location | Processes/Operations Covered | PFMEA Number | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| Project Description | | Customer | | Location | Process Flow Chart References | Date | | |
| | | | | | | | | |
| | | Team | | | | Revision | | |

| Part Name | Part Number | Rev | Name | Position | Email | Summary: | Revision Notes: |
|---|---|---|---|---|---|---|---|
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| Process/ Op Number | Process/ Opperation Description | Process Revision | Key Characteristic | Failure Mode | Tool/Machine Used | Control Method | Tolerance | Evaluation Technique | Reaction Plan |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |
| | | | | | | | | | |

Table 2. Control Plan Template

# Process Failure Mode Effects Analysis (PFMEA)

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Project | | Manufacturer (FMEA Owner) | | Location | Processes/Operations | PFMEA Number | | Page 1 of |
| Project Description | | Customer | | Location | Process Flow Chart | Date | | |
| | | Team | | | | Revision | | |

| Part Name | Part Number | Rev | Name | Position | Email | Summary: | Revision Notes: |
|---|---|---|---|---|---|---|---|
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| | | | | | | | |
| | | | | | | | |

| | | | | | | | | | Current Process Controls | | | | Recommendations | | | | Action Results | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Op. No. | Operation/Process Step | Requirements/Expected Outcome | Potential Failure Mode | Potential Failure Mode Effect | SEV | Classification | Potential Failure Mode Cause | OCC | Prevention of Potential Failure Mode Cause | Detection of Potential Failure Mode Occurrence | DET | RPN | Recommended Improvements/Corrective Actions | Action Owner | Target Completion Date | Responsible Business/ Department | Actual Improvement/ Corrective Actions Implemented | Actual Completion Date | SEV | OCC | DET | RPN | Additional Notes and Considerations |
| | | | | | | | | | | | | | | | | | | | | | | | |

Table 2. PFMEA Template

## Appendix B – List of Abbreviations

The following is a list of initialisations and acronyms used in this guideline.

| | | |
|---|---|---|
| C | CC | Critical Characteristic |
| | CP | Control Plan |
| | CPQP | Construction Product Quality Planning |
| D | DFMEA | Design Failure Mode and Effects Analysis |
| F | FMEA | Failure Mode and Effects Analysis |
| P | PFMEA | Process Failure Mode and Effects Analysis |
| R | RPN | Risk Priority Number |
| S | SC | Significant Characteristic |
| U | UC | Unclassified Characteristic |

## Appendix C – Glossary of Terms

The following is a list of commonly utilised quality, manufacturing and construction specific terms and their definitions within this context used within this guideline.

C

Control Plan (control plan)

BS EN 9145 [3]: "Documented description linking manufacturing process steps to key inspection and control activities. The intent of a control plan is to control the design characteristics and the process variables to ensure product quality."

Construction Product Quality Planning (CPQP)

An adaptation of Advanced Product Quality Planning (APQP) that is aimed at those enterprises that will feed construction with new componentry for offsite builds.

Critical Characteristic (CC)

An attribute or feature whose non-conformance would result in loss of primary function of the product resulting in catastrophic or hazardous failures without any warning. These are failures that would potentially lead to loss of life and/or irreparable damage.

D

Detection Control

Measures put in place to detect the failure mode after the failure has occurred but before the product is released to the downstream process.

Design Failure Mode Effects Analysis (DFMEA)

An application of Failure Mode Effects Analysis (FMEA) for product design.

K

Key Characteristic (KC)

BS EN 9145: "An attribute or feature whose variation has a significant influence on product fit, performance, service life or producibility; that requires specific action for the purpose of controlling variation."

P

Process Failure Mode Effects Analysis (PFMEA)

An application of Failure Mode Effects Analysis (FMEA) for process design and implementation.

Prevention Control

Measures put in place to stop or reduce the likelihood of the failure mode from occurring.

R

Reaction Plan

A Reaction Plan is a plan that introduces the required actions to prevent producing an unconventional product and non-verified operations. It also demonstrates the containment plans for detected non-conforming process.

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