Nexperia Philippines Inc.

TEST HANDLER JAM REDUCTION: AN IN-DEPTH ROOT-CAUSE ANALYSIS APPROACH ON UP/DOWN MOTOR ASSEMBLY FAILURE USING RELIABILITY CENTERED MAINTENANCE (RCM) METHODOLOGY

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ABSTRACT

Test Handler ASM FT2026 is a fully automatic and high-speed turret test and finishing system designed to receive singulated packages in the input module, pick and place each unit into the rotary turret, electrically test the units on the test contactors, marking manufacturing code and place the unit into tube. Turret-type are the most widely used handlers in the semiconductor industry. These handlers are used in Electrical Testing of different packages and providing the LASER mark for Bin 1 devices. Untested unit goes into Onload Tube, move into Separator, and pick-up by pickhead assembly. Unit passed through Rotary1, 4P Table, Rotary2, Test Sites, Mark table, 3D Inspection, Rotary3, and Taping Module. Unit in pickhead was transferred from one station to another through turret assembly and being moved down using Up/Down Motor Assembly.

Arm Down error occurs when the unit in pick head assembly fails to reach the defined motor position or if there is misaligned unit placement in package holder of any module along turret assembly. Arm Down Error happens when there is a restrain in motion of the Up/Down motor assembly. As a result, there is a need to include the identified critical mechanical parts of Up/Down motor assembly in Predictive Maintenance. To further validate the defect on mechanism, handler will run in dry cycle mode using recipe file with controlled Up/Down motor parameters as part of handler existing Preventive Maintenance.

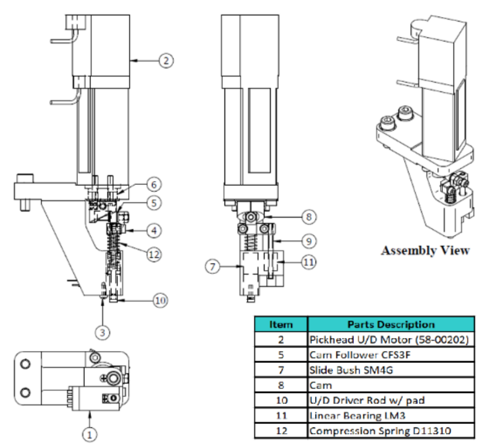
This project provides an in-depth analysis on the Up/Down Motor Assembly failure mechanism. The study aims to resolve the recurring Arm Down Error issue and improve mechanical yield using the Reliability Centered Maintenance (RCM) methodology.

RCM methodology is used to define the appropriate maintenance task/s to be applied with reference to failure type of the Part in consideration. This is to improve the Part reliability and reduce the consequence/s as a result of the Part Failure event. RCM methodology is a highly effective approach in determining the failure mechanism of a tool allowing to further improve parts reliability. Through this, a systematic approach is implemented to determine the current capability of motor assembly and to detect any abnormalities of Up/Down motor sub-assemblies. Rotary2 Arm Down Error was reduced by 50% and eventually zeroed after implementation of identified controls.

1.0 INTRODUCTION

Nexperia is a global semiconductor manufacturer that maintains a good reputation in terms of delivery and product quality of automotive products. Two of its topmost automotive customers are Bosch and Continental.

Various package sizes such as SOT1205, SOT669, SOT1023 and SOT1210 were run on different handlers at back-end final test, mainly composed of ASM FT-2026 handlers which has a common Up/Down motor assembly shown on Fig 1.



Item	Parts Description
2	Pickhead U/D Motor (58-00202)
5	Cam Follower CFS3F
7	Slide Bush SM4G
8	Cam
10	U/D Driver Rod w/ pad
11	Linear Bearing LM3
12	Compression Spring D11310

Fig.1: ASM FT-2026 Up/Down Motor Assembly

Up/Down motor assembly is responsible for the movement of the pickhead that holds and transfers the unit from one module to another. The turret assembly that holds the pickhead moves at great speed and accuracy. Throughout its operation, different handler jams are encountered as the machine continuously moves over time. Without proper maintenance, these handler jams can worsen and become chronic that can later affect the productivity of the machine. During the first quarter of 2023, huge amount of handler downtime was observed. Part of the plan to recover from degrading handler productivity is to identify the main contributors for jams across Final Test handlers. Arm Down Motion Error surfaced as the top handler jam contributing at 70.13% as shown in Fig. 2.

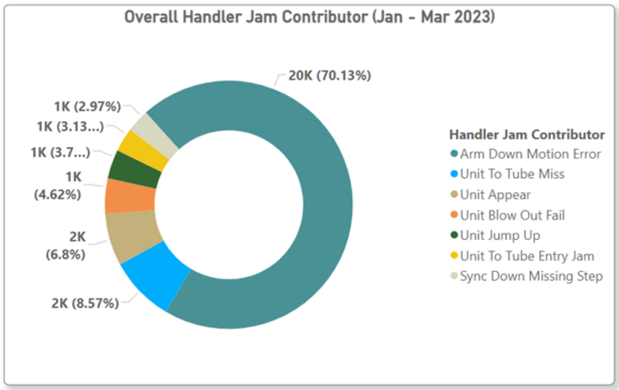


Fig. 2: Top Handler Jam Contributor

Further study also shows Arm Down Motion Error steadily increases for the first quarter of the year. See Fig. 3.

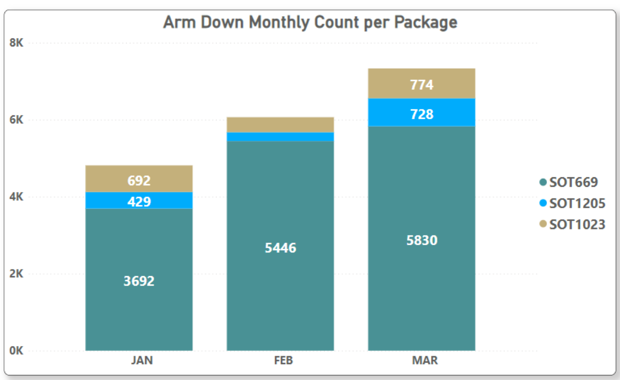


Fig. 3: Increasing Trend of Arm Down Motion Error

During troubleshooting and investigation, Arm Down Motion Error was discovered to be induced by degrading performance of the Up/Down motor assembly. Specific handler and module were listed and became the focus of root cause analysis to resolve the problem.

Arm Down Motion Error directly affects the productivity of the machine due to frequent stoppage. Each error throws away 2 untested units that is placed in the purge bin. Purged units are treated as scrap due to potential quality defects escapee. Using RCM methodology in this study, a more reliable maintenance procedure for Up/Down motor assembly will be identified to resolve the Arm Down Motion Error and improve the productivity of the machine.

2.0 METHODOLOGY

A cross-functional team was created to provide different ideas, expertise, and resolution on the identified problem. The team was composed of Process and Equipment Test Engineer, Operator, Equipment and Preventive Maintenance Technician.

The team selected RCM (Reliability Centered Maintenance) approach for the study of Test equipment. RCM is used to identify all possible causes that can lead to failure in system using cause-and-effect relationships. Prioritization on which part failure will undergo RCM is based on Part failure consequence/s. Maintenance Task/s is applied based on the Part Failure type. These consequence/s were categorized as Hidden Failures, Safety & Environment, Operational and Non-operational consequences. It aims to determine the type of maintenance strategy for different types of failure mechanism such as infant mortality, random failure and age related. After identifying all possible causes, one can determine best maintenance strategy method to eliminate failure. The strategy chosen should be to ensure that equipment and processes should function by ensuring safety and reliability. It basically identifies all failure modes i.e., all possible ways in which equipment or system can fail, different possible ways in which failure can occur for a given piece of equipment.

Failure can have more than one failure mode i.e., more than one way that can lead to similar adverse effects on the system. For overall system, these failures modes can be identified by simply breaking down system into sub-parts or sub-systems. These sub-parts are further breakdown until a failure mode is identified. Benefits of RCM are the following.

a. Managing Environmental, Health and Safety Risks – RCM seeks to understand the implications of every failure mode and takes proactive steps to prevent them. It helps reduce health hazards for employees by effectively preventing, monitoring, and maintaining the equipment and processes.
b. Improved Productivity – By successfully maintaining system and reducing any sudden failures, RCM enhances customer satisfaction and increases reliability.
    - Reduces equipment failures – RCM generally reduces chances of sudden failure of equipment or asset as RCM effectively maintains and minimizes top consequence/s of failure.
    - Reduces occurrence induced product defect – Since RCM reduced the machine failure. The machine will not damage the units produced during in-process.

c. Reduced Maintenance Cost – RCM also reduces maintenance costs by eliminating potential failures before its occurrence as some of failure requires more cost and more resources to be fixed. So, RCM reduces overall maintenance and resource cost.

RCM Major Steps defined are the following:

(1) Determine the Assets Operating Context – covers

a) Team Registration covers Equipment Information, Teams Information and Composition, Pilot Machine and Reason for Selecting the Equipment
b) Machine/Process Function
c) Operating Context

The Operating Context includes the details about the equipment subject to RCM Analysis. It allows the RCM team to get on the same page about the equipment. Details the equipment from a technical perspective including details about the operating environment.

- Where the equipment is used
- How often it's going to be used
- Exactly what is expected from it (Begin here to create a Proactive Maintenance Plan and other Default Strategies.)

Reliability Centered Maintenance (RCM) Process has seven (7) steps. These are the Functions, Functional Failures, Failure Modes, Failure Effects, Failure Consequences, Proactive Maintenance and Intervals, and Default Strategies. See Fig.4

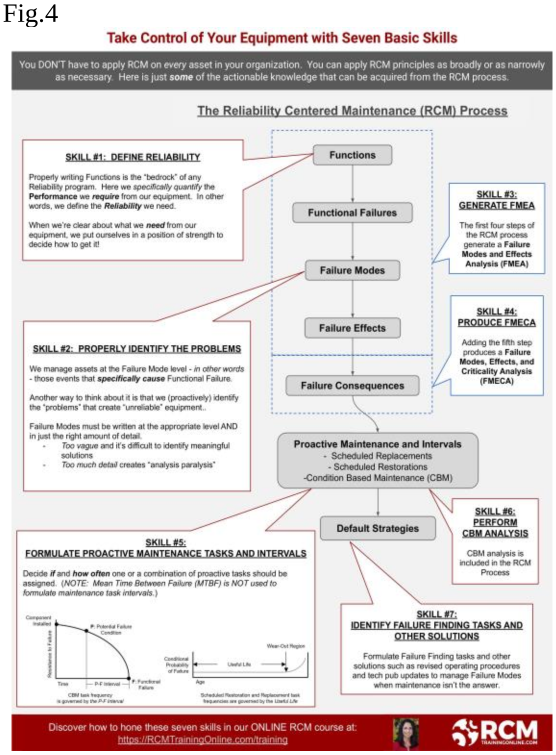


Fig.4: RCM Process (Seven Basic Skills)

(2) Complete the Asset RCM Information Worksheet – covers

a) Functions
- All the primary and secondary functions of the asset/system shall be identified.
- Performance standards incorporated in function statements shall be the level of performance desired by the owner or user of the asset/system in its operational context (as opposed to the design capability).

b) Functional Failure
- All the failed states associated with each function shall be identified.

c) Failure Modes
- shall be identified at a level of causation that makes it possible to identify an appropriate failure management policy. Failure modes should be addressed at the same level of detail that the asset or system will be maintained. Failure modes that can occur within a component of the asset or system that cannot or will not be addressed individually (because the component is the lowest level at which the system will be repaired and maintained) do not need to be enumerated. However, if the component will be disassembled to address specific internal failure modes, then those failure modes do need to be itemized.

d) Failure Effect
- shall describe what would happen assuming the failure mode and corresponding functional failure actually occurs.
- shall include all the information needed to support the evaluation of the consequences of the failure, such as:
  a. What evidence (if any) that the failure has occurred (in the case of hidden functions, what would happen if a multiple failure occurred).
  b. What it does (if anything) to kill or injure someone, or to have an adverse effect on the environment
  c. What it does (if anything) to have an adverse effect on production or operations
  d. What physical damage (if any) is caused by the failure
  e. What (if anything) must be done to restore the function of the system after the failure

e) Failure Consequences
- The consequences of every failure mode shall be formally categorized as follows:
  a. The consequence categorization process shall separate hidden failure modes from evident failure modes.
  b. The consequence categorization process shall clearly distinguish events (failure modes and multiple failures) that have safety and/or environmental consequences from those that only have economic consequences (operational and non-operational consequences)

- The assessment of failure consequences shall be carried out as if no specific task is currently being done to anticipate, prevent, or detect the failure.

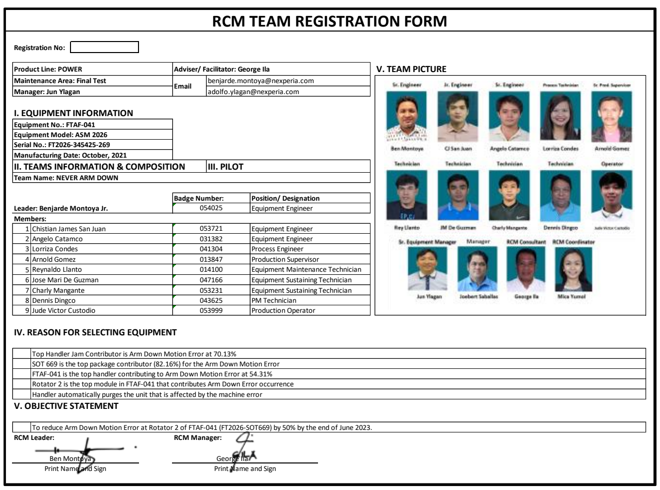
(3) Determine the required Maintenance Task and complete the RCM Tasks Decision Diagram Worksheet – covers
a. Proactive Maintenance and Intervals
- Decide if and how often one or a combination of proactive tasks should be assigned.
b. Default Strategies
- Formulate Failure Finding tasks and other solutions such as revised operating procedures and tech pub updates to manage Failure Modes when maintenance isn't the answer.

(4) Implement the defined Maintenance Task and Interval

RCM Methodology Application

The following section describes the application of the RCM Methodology to the Arm Down problem.

<u>2.1 Determine the Assets Operating Context</u>
Cross functional team were identified based on their individual contribution in the project. The machine was identified based on the lots processed history and based on Fish bone diagram. See Fig.5.



RCM TEAM REGISTRATION FORM

Registration No:

Product Line: POWER	Adviser/ Facilitator: George Ila		
Maintenance Area: Final Test	Email	benjarde.montoya@nexperia.com	
Manager: Jun Ylagan		adolfo.ylagan@nexperia.com	

I. EQUIPMENT INFORMATION

Equipment No.: FTAF-041
Equipment Model: ASM 2026
Serial No.: FT2026-345425-269
Manufacturing Date: October, 2021

II. TEAMS INFORMATION & COMPOSITION | **III. PILOT**

Team Name: NEVER ARM DOWN

		Badge Number:	Position/ Designation
Leader: Benjarde Montoya Jr.		054025	Equipment Engineer
Members:			
1	Chistian James San Juan	053721	Equipment Engineer
2	Angelo Catamco	031382	Equipment Engineer
3	Lorriza Condes	041304	Process Engineer
4	Arnold Gomez	013847	Production Supervisor
5	Reynaldo Llanto	014100	Equipment Maintenance Technician
6	Jose Mari De Guzman	047166	Equipment Sustaining Technician
7	Charly Mangante	053231	Equipment Sustaining Technician
8	Dennis Dingco	043625	PM Technician
9	Jude Victor Custodio	053999	Production Operator

V. TEAM PICTURE

IV. REASON FOR SELECTING EQUIPMENT

	Top Handler Jam Contributor is Arm Down Motion Error at 70.13%
	SOT 669 is the top package contributor (82.16%) for the Arm Down Motion Error
	FTAF-041 is the top handler contributing to Arm Down Motion Error at 54.31%
	Rotator 2 is the top module in FTAF-041 that contributes Arm Down Error occurrence
	Handler automatically purges the unit that is affected by the machine error

V. OBJECTIVE STATEMENT

	To reduce Arm Down Motion Error at Rotator 2 of FTAF-041 (FT2026-SOT669) by 50% by the end of June 2023.

RCM Leader: Ben Montoya — Print Name and Sign
RCM Manager: George Ila — Print Name and Sign

Fig.5: Team Registration

Fig.6 shows ASM FT-2026 machine diagram and location of all functional modules. Arm Down Error occurs in package guided assemblies where pick head places the unit onto it. The error is caused by the inability of the Up/Down Motor assembly to move the unit to its desired height.

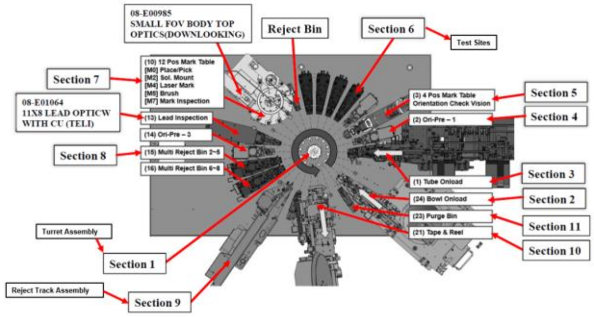


Fig.6: ASM FT2026 Machine Diagram

The Ishikawa diagram/Fish-bone diagram was used to analyze the mechanism of the Up/Down Motor Assembly and the cause of the Arm Down Error. All the potential causes were listed by the team through thorough analysis and eventually validated. See Fig.7.

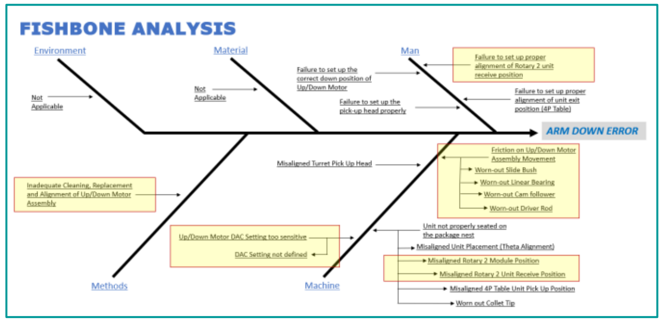


Fig.7: Fishbone Analysis for Arm Down Error

Based on the validation results, the probable root causes for the Arm Down Error occurrence were pertaining to Rotary 2 and on the Up/Down Motor assembly shown on Fig.8.

ASM FT2026 ANALYSIS TABLE

Why's	Problem	Probable Cause	Analysis	Remarks
Man	Failure to set-up proper alignment of Rotary2 unit receive position	YES	Rotary 2 smoothly receives the unit from the pick-up head	Unit is placed properly on the package nest
	Failure to set-up proper alignment of unit exit position (4P Table)	No	Rotary 2 smoothly receives the unit from the pick-up head	Unit is properly picked up from the 4P Table
	Failure to set-up the correct down position of Up/Down Motor	No	Unit smoothly goes into the package nest and properly seated	Down Position was set using 0.15mm filler gauge
	Failure to set-up the pick-up head properly	No	Pick head properly set up using alignment Jig	All turret pick head are properly aligned
Method	Inadequate Cleaning, Replacement and alignment of Up/Down motor assembly	YES	Observed worn-out slide bush, linear bearing, cam follower and driver rod	
Machine	Misaligned Turret Pickup Head	No	Pick-Up Head properly aligned using calibration jig	Not probable cause.
	Friction on Up/Down Motor Assembly Movement	YES	Identified Worn-out Critical parts • Worn-out Slide Bush • Worn-out Linear Bear • Worn-out Cam Follower • Worn-out Driver Rod	Root Cause
	Unit not properly seated in the package nest - Misaligned unit placement (Theta Alignment) - Misaligned Rotary 2 Module Position - Misaligned Rotary 2 unit receive position - Misaligned 4P Table unit pickup position - Worn-out collet tip	YES	No misalignment during unit placement in Rotary 2 nest	Not Probable Cause
	Up/Down Motor DAC setting too sensitive	YES	Parameter below defined setting will prompt an error at any given case	The lower the value of the DAC Range the more sensitive the motor is

Fig.8: Validation table of Possible Causes

Observed worn-out parts of the Up/Down motor sub-assemblies. Accumulation of dirt, corrosion, and deformation of sub-assemblies were noted as shown on Fig.9.

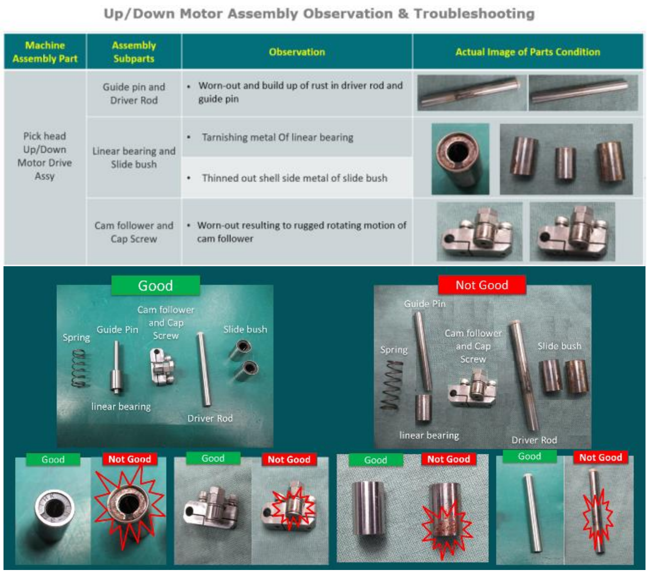


Fig.9: Pickhead Up/Down Motor Drive assembly

The worn-out and corroded parts in the assembly restrict the motor movement shown on Fig.10. This phenomenon is not the desirable function of the assembly as it should move the pickup head down smoothly, placing the unit on the module's package guide for proper orientation.

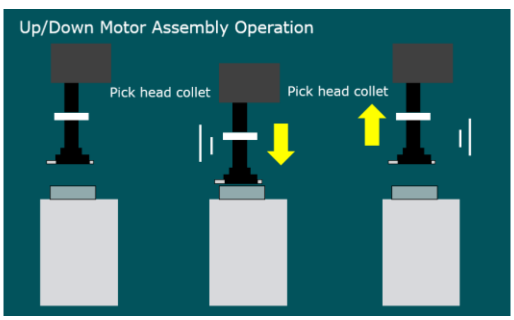


Fig. 10: Up/Down Motor Assembly Operation (w/ worn-out parts)

From this, objective to reduce 50% of Arm Down Error Occurrence in Rotary 2 of FTAF-041 FT-2026 Handler by end of June 2023 was defined.

To further understand which of the machine modules encounter frequent Arm Down Error, the team started to identify and check each module and process steps involved. Highlighted on yellow shows the process step where arm down error mostly occurred. See Fig.11.

	SOT669 FINAL TEST
1	**TUBE ONLOADER**
	Tube Cassette guides the tube with untested devices while in Onloader
	Load single tube with Full or Partial devices from tube stacker to buffer track
	Air blows to move the untested unit out from tube to buffer track
	Buffer track air moves the unit while in buffer track to unit stopper and separator package holder
2	**SEPARATOR**
	Move to onload position, move up unit stpper and receive the 1st unit in buffer track
	Holds the unit while in package holder, move to offload position and releases vacuum pressure to pick head
3	**Rotary 1**
	Up-Down motor moves the pickhead with unit into Rotary 1 nest
	Rotary 1 nest receive and guide unit and rotates -90˚ prior 4P table nest
4	**4 POS MARK TABLE ORIENTATION CHECK VISION**
	Up-Down motor moves pickhead with unit into the 4P table nest
	4P table nest receive the unit from pick head and rotates 90° until it reach orientation check vision
	Mark+Top check the presence of assembly defect (X-Mark)
	4P table moves the inspected unit back to pick head
5	**ROTARY 2**
	Up-Down motor moves the pickhead with unit into Rotary 2 nest
	Rotary 2 nest receive and guide unit prior FT1 test module
6	**TEST SITE**
	Pickhead moves down the unit in FT1 test module contact finger and moves up after testing proper
	Pickhead moves down the unit in RUGG test module contact finger and moves up after testing proper
	Pickhead moves down the unit in RGCG test module contact finger and moves up after testing proper
	Pickhead moves down the unit in FT2 test module contact finger and moves up after testing proper
7	**MARK TABLE**
	Pickhead moves down the unit in mark table nest
	Mark table moves until reaching laser marking station
	Mark table moves until reaching Top Mark and 2D Leads inspection station
	Mark table moves until reaching pick head to move back the unit in pick head
8	**LEAD INSPECTION**
	Pickhead moves down the unit until the unit reach the lead inspection
9	**ROTARY 3 (Orientator-Precisor)**
	Pickhead moves down the unit in Rotary 3 nest
	Rotary 3 nest Receive and guide unit prior Reject Bucket Bin
10	**REJECT BUCKET BIN**
	Pickhead moves down and blows the unit in Reject bucket Bin
11	**REJECT TRACK**
	Pickhead moves down the unit in Reject track
	Reject tube motor moves and ready the tube based on reject unit category to be sorted
12	**TAPING**
	Pickhead moves down and release the unit in carrier Tape
	Taping indexes until unit reached In-pocket inspection
	In-pocket performs automatic optical inspection
	Sealing assembly pearforms sealing process to attach the cover tape in carrier tape
	Post Seal inspection checks the sealing quality
13	**PURGE BIN**
	Pickhead moves down and blows the unit in Purge bucket Bin
14	**TURRET ASSEMBLY**
	Holds all pickhead assembly and moves in succedding station

Fig.11: Machine/Process Function of Test handler FT2026

Rotary 2 module Up/Down Motor sub assembly is classified as critical part that may lead to inconsistent up/down movement of the assembly. The breakdown of sub assembly individual parts is identified and the possible failure that contributes to machine breakdown. See Fig.12.

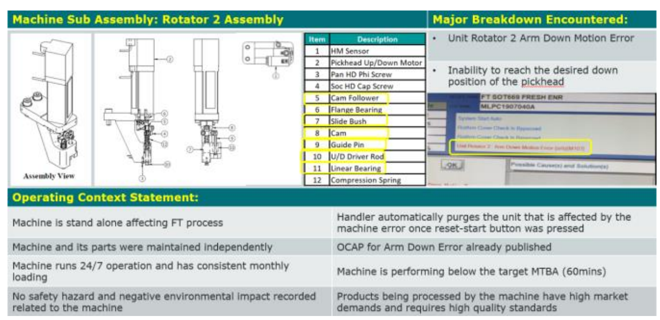


Fig.12: RCM Equipment's Operating Context

2.2 Complete the Asset RCM Information Worksheet

Up/Down Motor assembly which has contribution to arm down error and it's stated the Function, Functional failure, Failure mode and Failure effect. See Fig. 13.

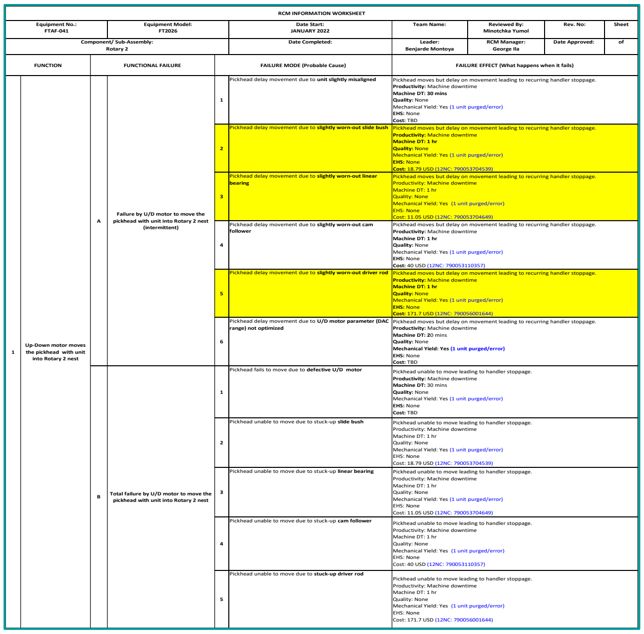


Fig.13: RCM Information Worksheet

The team conducted Design of Experiment (DOE) focusing on Digital Analog Converter (DAC) Range Parameter to determine the sensitivity for up/down motor movement as shown in Fig 14.

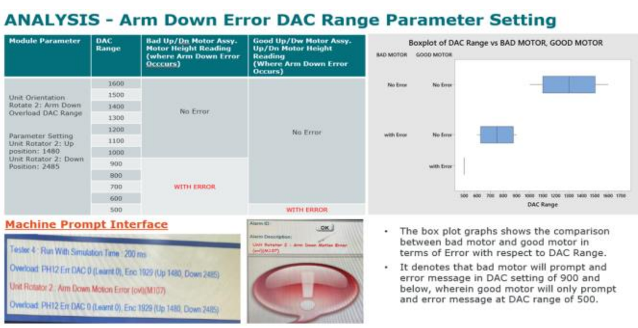


Fig.14: DOE – DAC Range Parameter Simulation

After the DOE and RCM Information Worksheet were defined. Each Failure mode was assessed and scrutinized using RCM Decision Diagram Tree as shown on Fig.15.

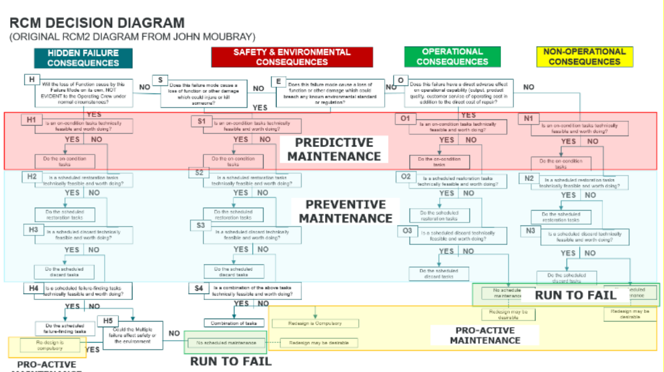


Fig.15: RCM Decision Diagram Tree

2.3 Generate Maintenance Task and complete the RCM Tasks Decision Diagram Worksheet

All failure modes will have a procedural maintenance task activity to alleviate the problem. Each was classified through RCM Decision Diagram Tree. See Fig.16

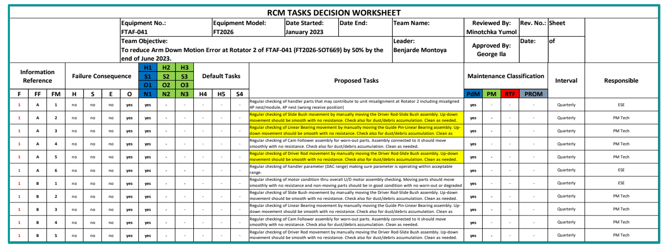


Fig.16: RCM Task Decision Diagram Worksheet

2.4 Implement the defined Maintenance Task and Interval

Identified machine module achieved good quality response and formulated score of solution that reach beyond maintenance by using this RCM methodology. As shown on Fig.17, we highlight the top 6 big contributors of proposed maintenance task activity that change the result of rotary 2 (up/down motor mechanism).

Fig.17: Top 6 Proposed Maintenance task

Additional control defined on DAC Range Parameter setting will be used as the assembly's health check for Up/Down Motor Assembly as shown in Fig.18.

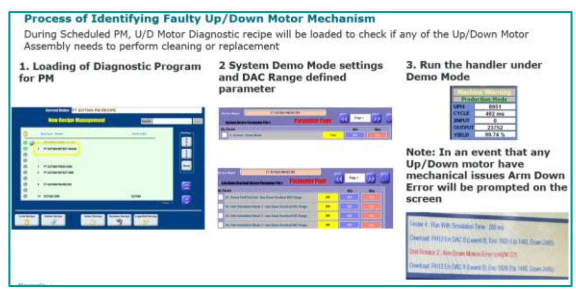


Fig.18: DAC Optimum Parameter (Defined after DOE)

All relevant documents/specifications were updated to ensure that the changes on the ASM FT2026 will be properly deployed.

3.0 RESULTS AND DISCUSSION

After the project completion, Arm Down Error occurrence in Rotary2 Module significantly reduced by 99%. Purged units generated from Rotary2 also reduced by 99.91% from the last 4 months after implementation of improvement activities. Projected savings is $45k from parts usage and replacement. SPC chart was implemented to ensure the on-conditioned monitoring of the part is properly monitored and maintained as stated in Fig.19 – Fig21.

3.1 Arm Down Error Occurrence Trend Chart

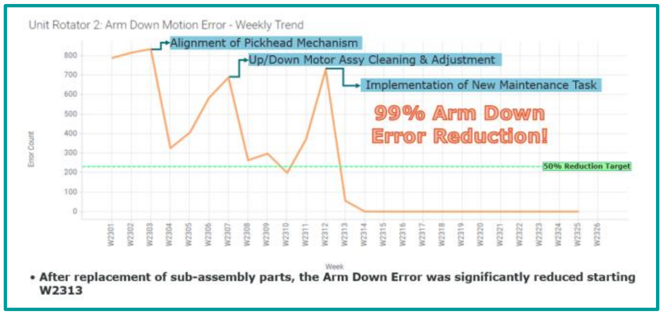


Fig.19: Arm Down Error Reduction Trend Chart

3.2 Reduction of Purged units

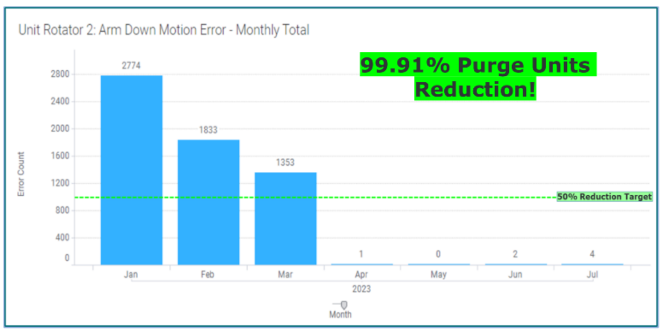


Fig.20: Purged units Reduction Chart

3.3 SPC Implementation

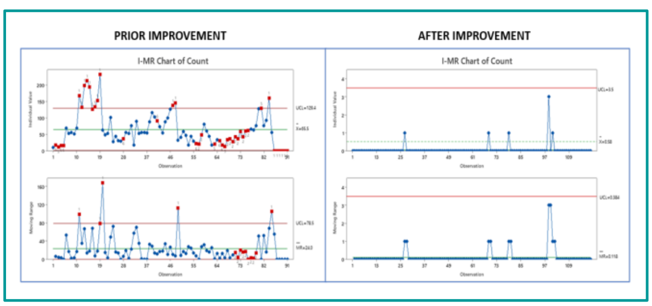


Fig.21: SPC Chart

4.0 CONCLUSION

Abnormalities in handler operation such as excessive Arm Down Motion Error is an indicator that the machine is running out of the ideal condition. Inability to resolve it can cause productivity loss and wastage due to purged units.

Using RCM methodology, parts that are not included in the existing maintenance task are now considered as critical items to be monitored and maintained during maintenance activity.

The overall machine performance improved by applying the appropriate maintenance task for the Up/Down Motor Assembly and its critical sub-assembly.

5.0 RECOMMENDATIONS

The authors highly recommend the same methodology (Reliability Centered Maintenance "RCM") in solving any machine related problems as it guides authors with its technical process and analysis.

6.0 ACKNOWLEDGEMENT

The authors would like to acknowledge the Project Team who worked together to complete the project. These include the Engineers, Equipment and PM Technicians, and Operations Management. Special thanks to Jun Ylagan, George Ila, Debbie Alcala, and Gareth Hughes for their support, to the authors' family and lastly to Almighty God.

7.0 REFERENCES

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4. JOV-2H0-040/3112 – Work Instructions of ASM FT2026 Maintenance Task Procedure

8.0 ABOUT THE AUTHORS

BENJARDE G. MONTOYA JR. is a graduate **of** B.S. Electronics and Communication Engineering from Rogationist College – Silang, Cavite. Hired at Nexperia Philippines as Senior Test Engineer and assigned at Power Clip-bonded Backend Final Test Equipment Sustaining.

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MINOTCHKA O. YUMOL is a Sr. Project Engineer at Nexperia Philippines Inc for Maintenance Systems. She holds a bachelor's degree in Mechanical Engineering from Polytechnic University of the Philippines – Taguig Campus and a certified RCM LEVEL 1 and Six Sigma Blackbelt holder. She has 10 years experience in Backgrind and Die preparation process and development and 3 years experience in Reliability Centered Maintenance.