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# Leveraging Data Analysis for Process Optimization and Process Automation Journey in TNPL


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## Abstract:

*Global Paper demand is projected to grow from 417 million tons to 476 million tons by 2032. Despite this growth, Indian Paper manufacturers face challenges including Energy Efficiency, raw material supply and Environmental issues. To stay competitive by focusing on customer-centric strategies, offering quality products at competitive prices through wise capital investments. This involves extending asset lifecycles, improving operational Efficiency and reducing variability with advanced technologies and data-driven decision-making. TNPL aims for a Production capacity of 1 million tons by 2030, emphasizing sustainability and zero-waste manufacturing. Known for eco-friendly practices and cutting-edge technology adoption.*

*As per Peter Drucker's quote 'What gets measured, gets managed'. One such case study utilizing Data driven decision that focuses on the optimization of a Paper Machine's Control Loops performance. By employing Data Analytics, TNPL was able to significantly reduce variability of critical parameters by Optimising the Control Loops to save material cost and increase Productivity. It has paved the way to improve the runnability, shifting the Moisture & Ash Targets. It resulted in huge saving of cost by reducing the variable cost by around 5 to 7%.*

*A key component of TNPL's Manufacturing Excellence initiative involves the Production Process for Copier reams from the A4 Cut Pack line. This Process has been meticulously streamlined and integrated with a Shrink-Packaging Machine using Automation. The data and results of the case studies are discussed in detail.*

***Keywords:*** *Manufacturing Excellence, Optimization, Data Analytics, Tuning.*

## Introduction

In a manufacturing facility, improving system performance and Efficiency can be achieved through two main strategies: Optimization and Capacity Expansion. While both strategies are vital, they have distinct focuses and implementation methods. Optimization focuses on reducing inconsistencies in Process, effective resources utilization, thus enhancing quality and performance without any need for major investments. In contrast, capacity expansion involves increasing Production capabilities, often requiring significant capital outlays for new equipment or infrastructure.

Given the current economic climate, characterized by inflationary pressures and intense global competition, the focus on Optimization is particularly critical. This approach demands less financial investment compared to capacity expansion, making it a practical and cost-effective strategy to remain competitive and profitable.

Optimization can be achieved by Process Variability Reduction and effective utilization of available resources and features. Two of such case studies related to Variability reduction in Paper Machine and automating Ream Bundling operation in Cut Pack Machines are discussed here.

**1. Process Variability Reduction:** In Paper Machine is achieved by optimizing key parameters attributes such as Basis Weight, Moisture, and Ash content. By utilizing statistical analysis and following the technical guidelines set forth by the Technical Association of the Pulp and Paper Industry (TAPPI), manufacturers can systematically reduce variability.

**2. Resource Optimization:** Identifying areas for scope of improvement.

The detailed insight of how Optimization helps in improved Performance, Quality Control and Production optimization are explained in the following two case studies.

### Case Study: 1

**Control Loop Performance Optimization**

Amongst TNPL's three Paper Machines which are operational in Unit-I, this exercise was carried out in Paper Machine#2 which has a standalone Production capacity of 1.4 lakh TPA.

TNPL's strategic approach to utilizing historical data and advanced technological tools to extract valuable insights, emphasizing the importance of data-driven decision-making. Employing Data Analytics and by utilizing Data driven decision that focuses on the optimization of a Paper Machine's Control Loops performance, TNPL was able to significantly reduce variability of critical parameters by Optimising the Control Loop Performance.

**2 Sigma:**

2Sigma generally is used to measure Process Quality. The Lower the Number is the better the Paper. For a Perfectly tuned System Paves way for Target shifts eventually increasing Profit Margins.

**Evaluation:**

In a time where cost savings are more important than ever, there is one low hanging fruit that is being overlooked: Process variability. The impact of this variability is massive. Manufacturing variability is indeed the tip of the iceberg, as lying beneath the surface one will find customer complaints, sheet breaks, excessive consumption of cellulose, water, Energy, and more.

**1. Long Term Reel Report Analysis** : To reduce variability; it needs to be quantified. Historic Reel Report Data of Paper Machine#2 from Data logger was retrieved and statistical study was performed and the inference is as follows;

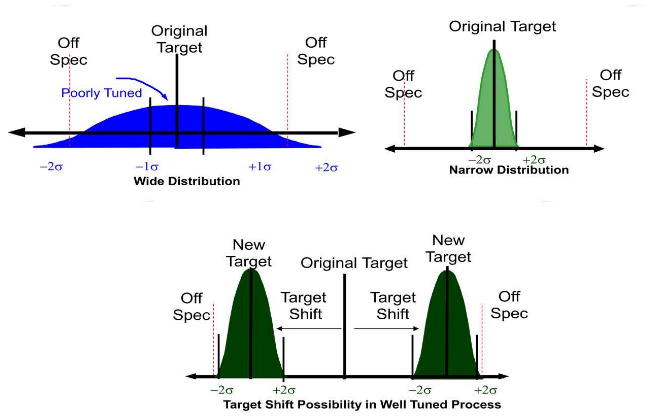



Fig 1. 2 sigma distribution

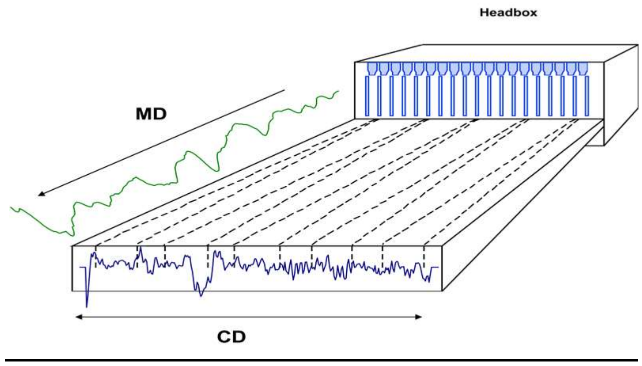



Fig 2. MD and CD representation

| Day / Shift Report | | | | | |
|---|---|---|---|---|---|
| Machine | TNPL PM#2 | | | | |
| Production Summary | | | | | |
| | | Day | Shift 1 | Shift 2 | Shift 3 |
| Production | Tons | 451.95 | 131.47 | 167.87 | 152.62 |
| Throughput | T/Hr | 21.17 | 22.61 | 21.68 | 19.6 |
| Reel Speed | Ft/Min | 783.25 | 743.14 | 790.34 | 806.13 |
| Run Time | Hr:Min | 21:21 | 05:49 | 07:45 | 07:47 |
| Lost Time | Hr:Min | 02:39 | 02:11 | 00:15 | 00:13 |
| Grade Change Time | Hr:Min | 00:00 | 00:00 | 00:00 | 00:00 |
| Manual Grade Changes | | 0 | 0 | 0 | 0 |
| Auto Grade Changes | | 0 | 0 | 0 | 0 |
| Control Summary | | | | | |
| | | Day | Shift 1 | Shift 2 | Shift 3 |
| Basis Weight 1 | Pct | 93.33 | 82.61 | 98.81 | 95.88 |
| Hemi+Moist 1 | Pct | 91.78 | 80.45 | 98.01 | 94.03 |
| Ash 1 | Pct | 89.87 | 80.15 | 93.41 | 93.71 |
| Speed Control | Pct | 0.16 | 0.69 | 0 | 0 |
| Speed Optimization | Pct | 0 | 0 | 0 | 0 |

| Reel Report | | | | | | | |
|---|---|---|---|---|---|---|---|
| Machine | | | | | | | |
| Reel No | | | | | Trim | 650.7CM | |
| Product No | | | | | | | |
| Product | | | | | | | |
| Production Summary | | | | | | | |
| | | | Standard | | Actual | | Efficiency |
| Production | Tons | | 18.99 | | 22.2 | | 116.91 |
| Throughput | T/Hr | | 16.16 | | 18.89 | | 116.91 |
| Reel Speed | Ft/Min | | 680 | | 832.12 | | 122.37 |
| Run Time | Hr:Min | | 01:11 | | 02:24 | | |
| Lost Time | Hr:Min | | 00:00 | | 00:00 | | |
| Quality Analysis | | | | | | | |
| | Actual | Target | Efficiency | MDS | MDL | CD | Total |
| Air Column | -0.23 | 1 | -437.16 | 0.06 | 0.1 | 0.25 | 0.28 |
| Ash | 15.71 | 15.67 | 99.79 | 0.97 | 2.42 | 0.3 | 2.62 |
| Basis Weight | 58.22 | 58.33 | 100.19 | 1.35 | 0.6 | 1.01 | 1.79 |
| Caliper | 83.18 | 75 | 90.16 | 1.33 | 1.1 | 0.33 | 1.76 |
| Conditioned Weight | 54.74 | 54.83 | 100.16 | 1.19 | 0.55 | 0.77 | 1.52 |
| Moisture | 5.96 | 6 | 100.53 | 0.43 | 0.79 | 1.15 | 1.46 |

Fig 3. Sample Reel report.

TABLE 1. REEL REPORT INFERENCE.

| Grade Wise Total 2 Sigma as % of Process | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Parameter | Goal | 48 GSM | 50 GSM | 55 GSM | 60 GSM | 70 GSM | 80 GSM | All |
| Ash | < 4.5 | 8.74 | 8.09 | 7.44 | 6.89 | 6.34 | 5.76 | 7.21 |
| Caliper | < 1 | 4.26 | 3.96 | 3.61 | 3.92 | 3.09 | 2.78 | 3.6 |
| Cond. Weight | < 1.5 | 3.29 | 3.11 | 3.03 | 2.94 | 2.75 | 2.57 | 2.94 |
| Moisture | < 10 | 24.92 | 25.24 | 28.62 | 29.11 | 31.13 | 31.65 | 28.5 |
| Weight | <1.7 | 3.69 | 3.53 | 3.52 | 3.43 | 3.41 | 3.39 | 3.5 |
| Reel Count | | 3254 | 5702 | 6827 | 3996 | 2760 | 1270 | 23809 |
| | | 11% | 18% | 22% | 13% | 9% | 4% | 77% |

TABLE 2. 2 - DISTRIBUTION FOR REEL REPORT

| 2σ Distribution as % of Process Value | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Goal** | **Ash_B** | **Ash_A** | **CA_B** | **CA_A** | **CW_B** | **CW_A** | **MT_B** | **MT_A** | **WT_B** | **WT_A** |
| MDS | <70 | 70.38 | 82.1 | 15.27 | 41.07 | 56.99 | 66.1 | 21.88 | 11.22 | 47.43 | 60.71 |
| MDL | <10 | 18.37 | 10.5 | 82.12 | 55.1 | 15.43 | 8.88 | 24.44 | 15.8 | 21.59 | 10.5 |
| CD | <20 | 11.25 | 7.3 | 2.61 | 3.4 | 27.58 | 24 | 53.68 | 79.3 | 30.98 | 28.7 |

**Labels:**

MDS: Related to noise - Time to make 2 Data boxes to 2 scans

MDL: Related to scan average trend - Time to make 2 Scans to Full Reel Build Up

CD: Related to average profile - Width of 2 Data boxes to Width of reel

**TOT: MDL+MDS+CD →2 Data Boxes to Full Reel**

CA- Caliper / CW-Conditioned Weight / MT-Moisture / WT-Basis Weight

*_A-Grade A *_B-Grade B

The total Variability plot using reel report data collected for Moisture, Ash, Caliper and Conditioned weight are as shown below.

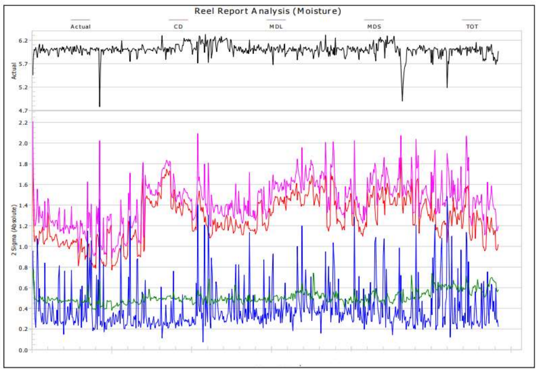



*Fig 4. Conditioned Weight TOT Variability Chart*

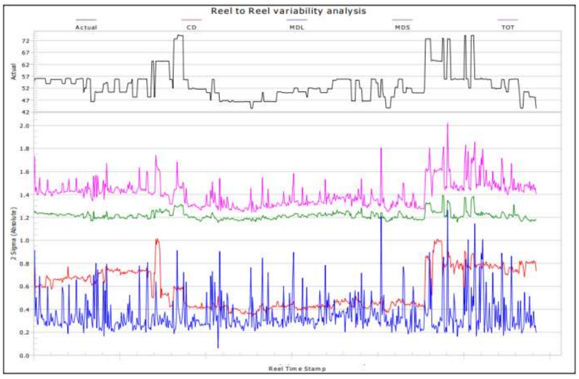



*Fig 5. Moisture TOT Variability Chart*

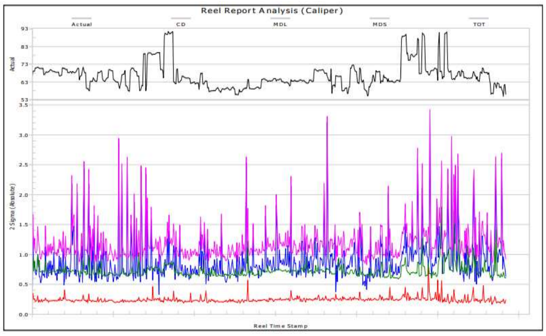



*Fig 6. Ash TOT Variability Chart*

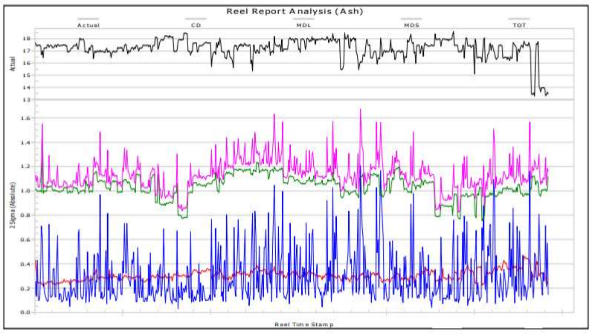



*Fig 7. Caliper TOT Variability Chart*

**Inference:** It is evident from the data that the variability is way above our Goal for Conditioned Weight, Moisture, Ash and Weight whereas Caliper seems to be under control. Long term data signifies that the Variability needs to be curtailed.

**2. Reel Data Analysis (Over Night 8 hours)** : Reel Data containing Basis Weight, Moisture, Ash is collected for a period of 8 hours with 5 Seconds Sampling rate and Statistical analysis was carried out and tabulated below.

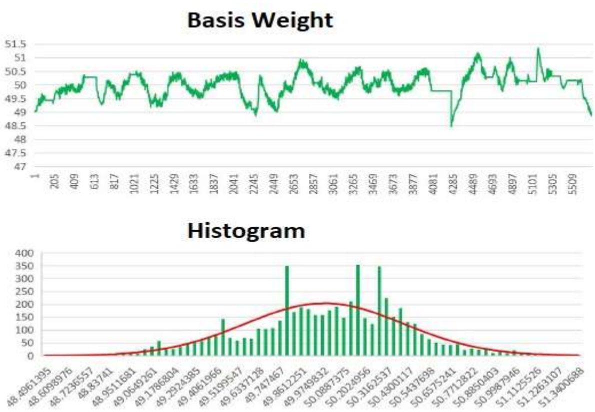



*Fig 8. Basis weight and BW Histogram*

**Table 3. BW Statistics**

| | | |
|---|---|---|
| No of Points | 5710 | Global Benchmark 2 Sigma: 0.2 |
| No of Hrs | 8 | |
| Sample Time | 5Sec | |
| Max Value | 51.4 | |
| Min Value | 48.45 | |
| 2σ Absolute | 0.56 | |
| Average | 49.77 | |
| Skewness | -0.21 | |
| Kurtosis | 0.129 | |
| Peak to Peak | 2.9 | |

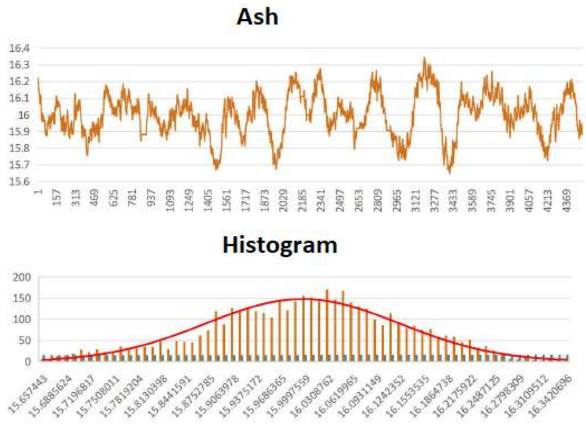



*Fig 9. Ash and Ash Histogram*

**Table 4. Ash Statistics**

| | | |
|---|---|---|
| No of Points | 5710 | Global Benchmark 2 Sigma: 0.2 |
| No of Hrs | 8 | |
| Sample Time | 5Sec | |
| Max Value | 16.34 | |
| Min Value | 14.64 | |
| 2σ Absolute | 0.826 | |
| Average | 15.99 | |
| Skewness | -0.21 | |
| Kurtosis | 0.24 | |
| Peak to Peak | 1.7 | |

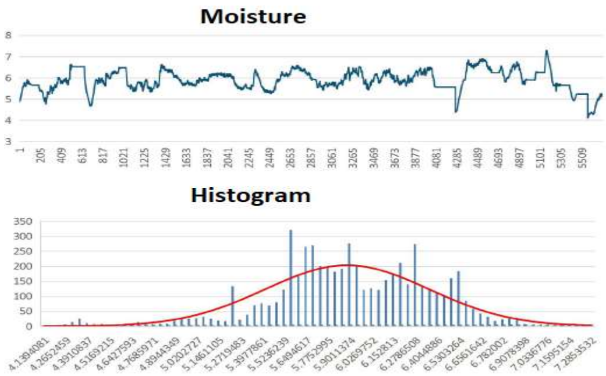



*Fig 10. Moisture and Moisture Histogram*

**Table 5. Moisture Statistics**

| | | |
|---|---|---|
| No of Points | 5710 | Global Benchmark 2 Sigma: 0.16 |
| No of Hrs | 8 | |
| Sample Time | 5Sec | |
| Max Value | 7.28 | |
| Min Value | 4.09 | |
| 2σ Absolute | 0.624 | |
| Average | 5.88 | |
| Skewness | -0.49 | |
| Kurtosis | 0.85 | |
| Peak to Peak | 3 | |

**Inference:** In absolute terms 2 Sigma variations is more than Benchmark Figure.

**3. Time to Frequency Domain Analysis :** Data collected in the time domain is translated to Frequency Amplitude domain to identify occurrence rates.

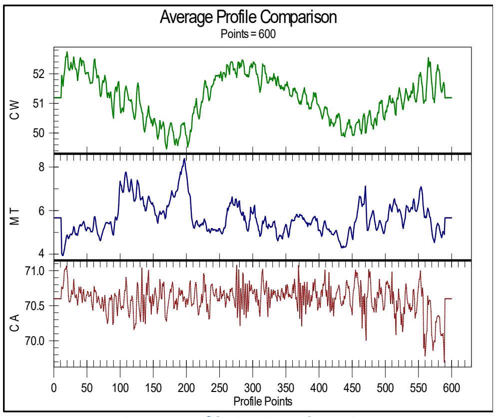



*Fig 11. Profile in time domain*

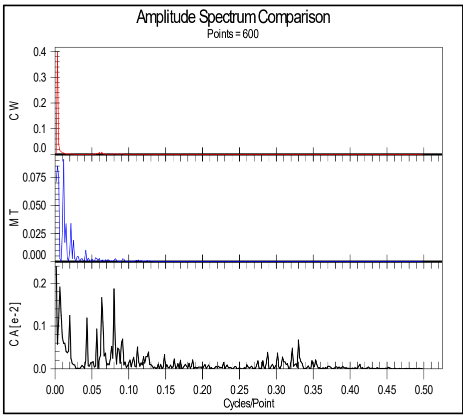



*Fig 12. Rate of Occurrence in Frequency domain*

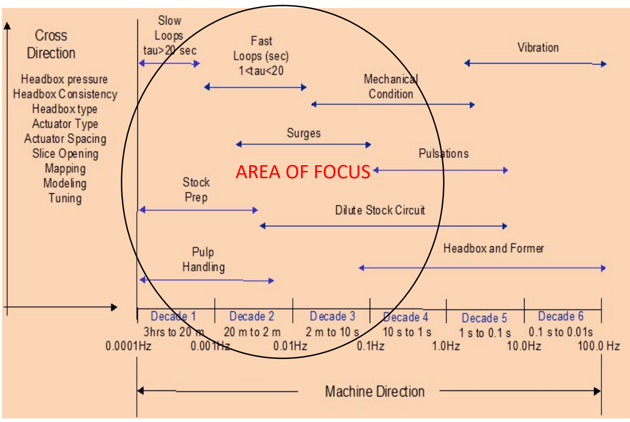



*Fig 13. TAPPI Spectrum Guidelines*

Decade#1 &2: Areas that require attention to prevent Low Frequency Variations. Generally, Level#2 loops are related to QCS and nevertheless Level#1 Loop performance has significant impact in reducing Decade#1 variations.

Decade#3&4: Areas that require attention to avert medium range Frequency Variations; Generally, Level#1 loops related to DCS Controls

Decade#5&6: Areas that require attention to reduce High frequency Variations.

**Inference:** Based on the inference and the Spectral guidelines, it was decided to evaluate and optimize control Loops performance as Low and medium frequency amplitudes are a significant contributor to variability.

**4. Stock Stability Evaluation:** Stock Stability Index and numerical figure which is used for the comparison with global benchmark indexes for improvement.

$$\text{Index } I = 100\frac{\sqrt{\frac{\sum_{i=1}^{N}(0-e_i)^2}{N}}}{\text{Range}} \qquad \text{Total Index} = \sqrt{\sum {I_i}^2}$$

No. of Sample =N
Error (e) =Set Point – Process Variable
Range of Process Variable

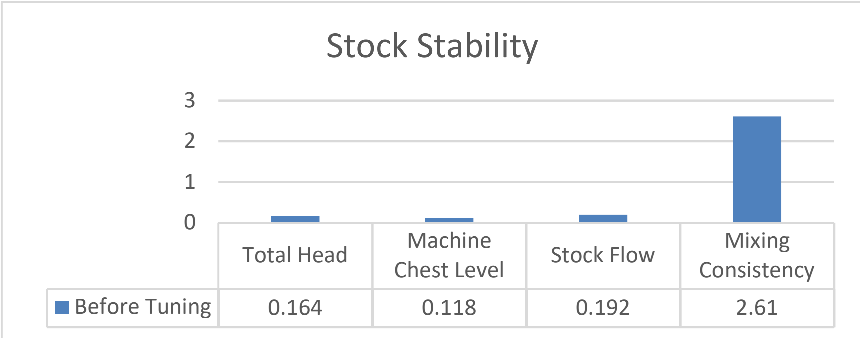



*Fig 14. Stock Stability*

Inference: Mixing Consistency Loop Index needs attention and performance to be fine-tuned and optimized.

**Setting Up Goal:**

- Reduction of variability on Basis weight by 30%
- Reduction of variability on Moisture by 30%
- Reduction of variability on Ash by 30%

**Optimization:**

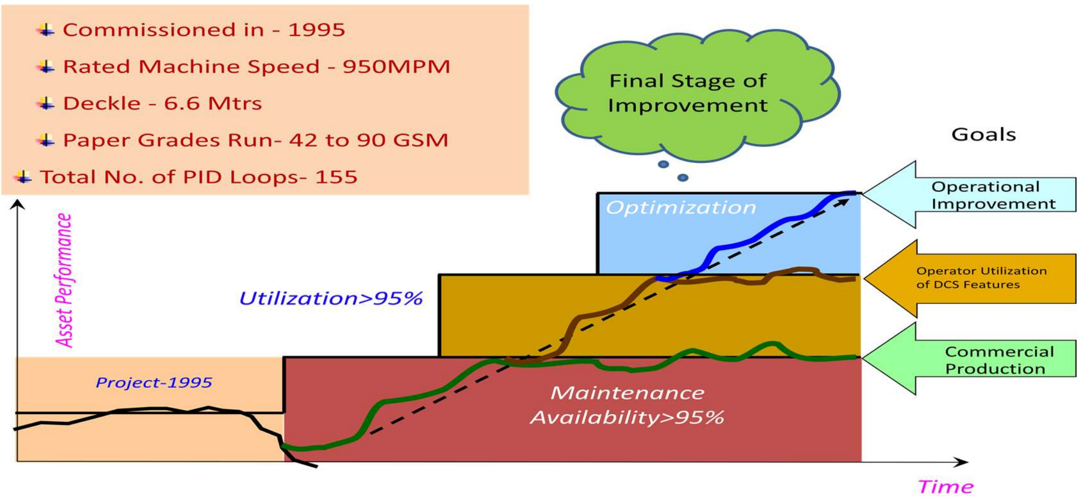



*Fig 15. Road Plan of Optimization*

This is a graph of Machine performance. Often, a project is assumed to be finished when the performance guarantees have been met. Once the project phase is completed and operational phase starts Preventive, Predictive and Reactive maintenance phase emerges to provide Machine availability. Once the availability is ensured, comes the Utilization portion where the operators get to know the system and utilize the features provided in the system.

Optimizing Machine performance in alignment with mechanical constraints will ultimately result in improvement of yield.

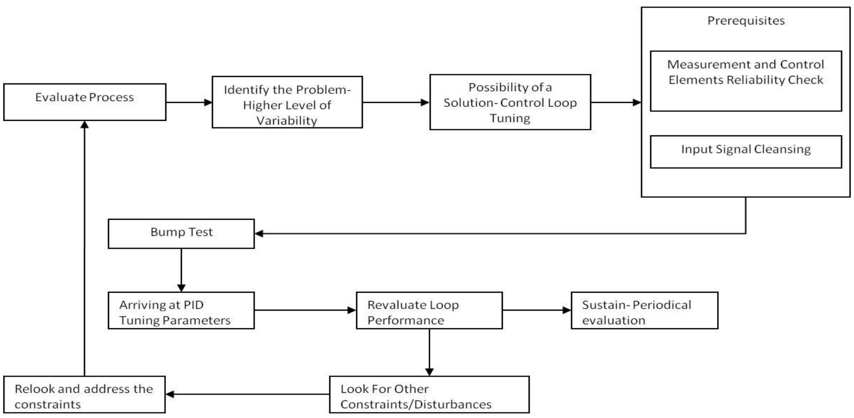



*Fig 16. Bump test and Evaluation*

The bump cycle method is a practical and effective approach for tuning PID controllers, especially in systems where precise control is critical. By leveraging the system's actual response to disturbances, it enables more accurate and reliable PID parameter settings.

The types of Bump Test are Step Test, Pulse Test, Doublet Test, and pseudo-random binary sequence (PRBS) test.

• **Step Test:** A single step change is introduced into the system. The behavior of the system is observed in one direction.

• **Pulse Test:** It is a 2-step test. The first change is step is introduced and as soon as Process variable settles down, the change introduced is revert to original state. It is limited as it doesn't reveal complete Process dynamics.

• **Doublet Test:** A doublet test is essentially two (2) pulse tests. Each pulse test is performed in rapid succession and in opposite directions. The second pulse is implemented as soon as the Process has shown a clear response to the first pulse. The doublet is highly effective as it fully reveals the dynamics associated with a control loop.

• **Pseudo-Random Binary Sequence (PRBS) test:** It can provide the most insight it is the least used in industry due largely to its complexity. A sequence of pulses, those are uniform in amplitude, alternating in direction and of random duration.


*Fig 17. CNT1 Consistency Pulse Test*

**Calculating Process gain (Kp):**

Process Gain (Kp) is defined as **how far the measured Process Variable (PV) moves to a change in Controller Output (CO).**

$$\text{Process Gain } (K_p) = \frac{\textit{Change in Output (Measured Variable)}}{\textit{Change in Input (Final Control ELement)}}$$

Change given to Final Control Element (dilution valve opening) is from 38% to 44%

Change observed in Measured Value (Consistency) is from 5.3% to 4.6%

$$K_p = \frac{5.3 - 4.6}{44 - 38} = 0.11$$

Table 6: Tuning Parameter for $K_p$ and $T_I$

| $\tau_{Ratio}$ | Controller Gain | Integral Time |
|---|---|---|
| 1 | $K_c = \frac{1}{K_p}$ | $T_I = \tau_P$ |
| 2 | $K_c = \frac{1}{K_p * 2}$ | $T_I = \tau_P$ |
| 3 | $K_c = \frac{1}{K_p * 3}$ | $T_I = \tau_P$ |
| 4 | $K_c = \frac{1}{K_p * 4}$ | $T_I = \tau_P$ |

Where,

Time constant (τ_P) is defined as the time the Process takes to reach 63.2 % of the final steady state value.

$\tau_{Ratio}$ is closed loop time constant divided by open loop time constant.

$K_c$ Controller Gain represents the proportional control action for any given error in the Process. If the controller gain is set too high the control loop will begin oscillating and become unstable. If the controller gain is set too low, it will not respond adequately to disturbances or set point changes.

$$\text{Controller Gain, } K_c = \frac{1}{K_p * \tau_{Ratio}} * \frac{MV\ Range}{Output\ Range} = \frac{1}{0.11*2} * \frac{3}{100} = 0.13$$

$$\text{Integral Gain, } T_I = \tau_P = 20 \text{ sec.}$$

TABLE 7: PID SETTINGS FOR COMMON CONTROL LOOPS

| Loop type | PB % | Integral min/rep | Integral rep/min | Derivative min | Valve type |
|---|---|---|---|---|---|
| Flow | 50 to 500 | 0.005 to 0.05 | 20 to 200 | none | Linear or modified percentage |
| Liquid pressure | 50 to 500 | 0.005 to 0.05 | 20 to 200 | none | Linear or modified percentage |
| Gas pressure | 1 to 50 | 0.1 to 50 | 0.02 to 10 | 0.02 to 0.1 | Linear |
| Liquid level | 1 to 50 | 1 to 100 | 0.1 to 1 | 0.01 to 0.05 | Linear or modified percentage |
| Temperature | 2 to 100 | 0.2 to 50 | 0.02 to 5 | 0.1 to 20 | Equal percentage |
| Chromatograph | 100 to 2000 | 10 to 120 | 0.008 to 0.1 | 0.1 to 20 | Linear |

The results after tuning all the Control Loops yielded reduction in variability and good results. Few of them are shared below;


Fig 18. Tertiary Cleaner Reject


Fig 19. PIC4173 Heating Section 1

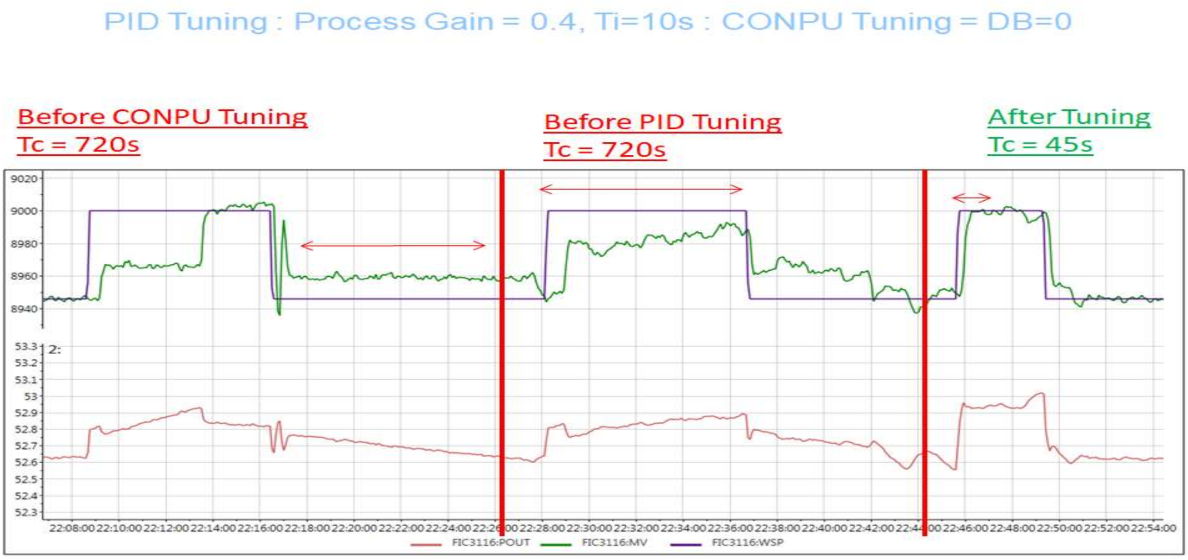



Fig 20. Stock Flow

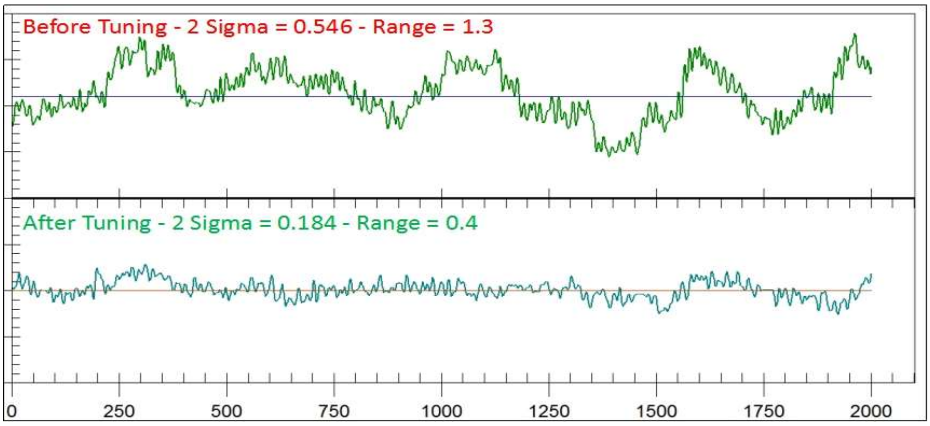



*Fig 21. Weight Before and After Tuning*

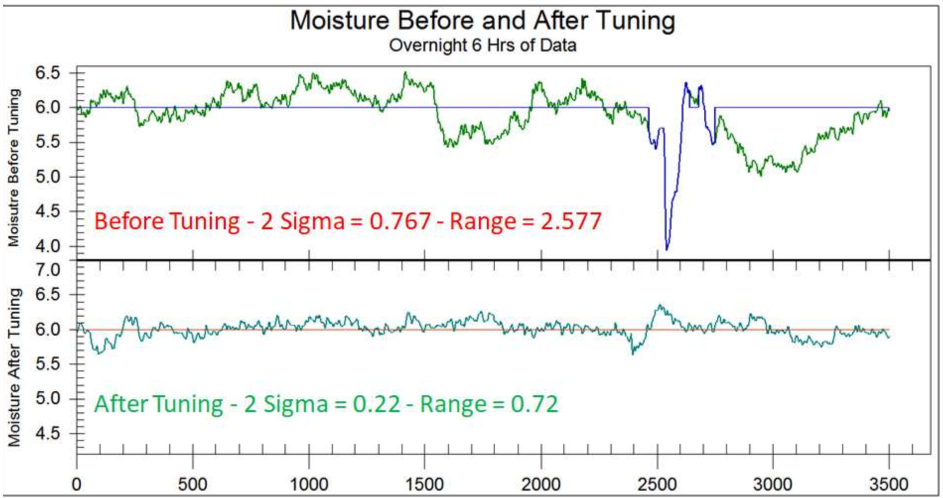



*Fig 22. Moisture before and after tuning*

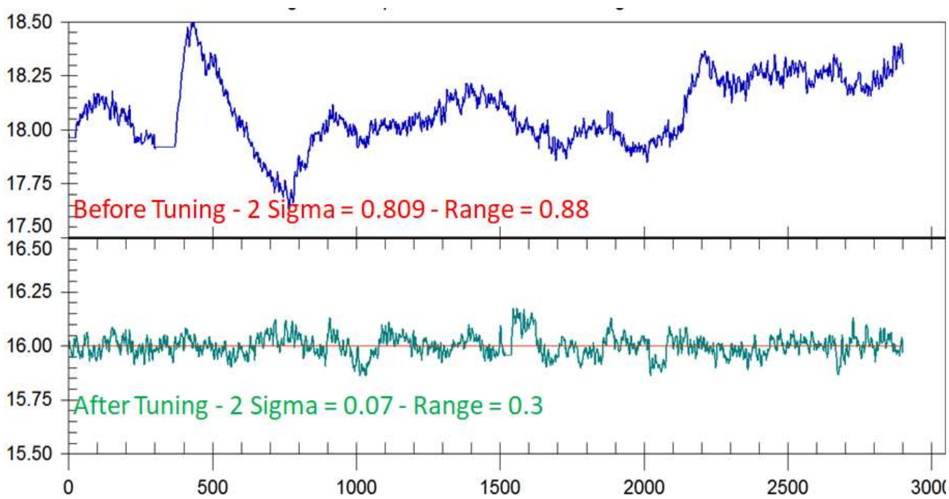



*Fig 23. Ash Before and After Tuning*

TABLE 8: FINAL OBSERVATION BEFORE AND AFTER TUNING

| Parameter | Before - Tuning | After -Tuning | % Improvement |
|---|---|---|---|
| 2 Sigma reduction in MDL Basis Weight | 0.799 | 0.24 | 70% |
| 2 Sigma reduction in MDL Moisture | 0.604 | 0.18 | 71% |
| 2 Sigma reduction in MDL Ash | 0.826 | 0.10 | 87% |

**Benefits:**

This reduction in variability will allow the Organization to optimize Process by taking target shifts. Target shifts provide economic benefits in the areas of fiber savings, Energy savings, as well as a Production increase. Roughly, 1% increase in final moisture will result in 2 - 2.5% Energy savings and a 3 - 3.5 % speed increase and similarly for Weight and Ash target Shifts will contribute even more in reducing the Production cost of Paper. The tangible benefits visible from the day of optimizing Loop performance are;

Reductions in Process variability flagged the following improvements;

- Improved quality / Uniformity of Product.
- Improved Productivity by establishing good Machine runnability and reduced Sheet Breaks.
- Faster Grade Change Time.
- Reduction in Rejection due to Quality issues.
- Reduction in Cost by shifting the Moisture & Ash Targets

**Case Study 2: Resource Optimization**

As part of Management initiative towards implementation of Manufacturing Excellence Concept, Automation of Ream Handling from Copier Cut Pack lines was taken up for improvement.

**1. Integration of Shrink Packing Machine with Copier Cut Pack Lines:**

**Preamble:**

Bielomatik#2 and ECH Will Cutters are an Automated A4 Cutter and Packaging Machine with a combined capacity of 320 TPD.

Pre-stacker Unit in ECH WILL Cutter & Bielomatik#2 Copier Cut pack lines were equipped with stacking reams as bundles when they are to be packed in cartons. However, for orders demanding Shrink Packed Bundles reams are transported in a different route without entering Pre-stacker Machine through a diverter which demands manual intervention in collecting and storing in pallets. The stored reams are manually stacked as bundles (Containing 5 reams each) and fed to Shrink Bundling Machine for packing.

**Problems Faced are as follows:**

1. Reams produced from Bielomatik#2 and ECH Will Cutter were collected, stacked and fed to Shrink Wrapping Machines manually.

2. Manual hanlding of reams from high speed Copier Cut pack lines were tedious and tiresome activity.

3. Continuous manual supervision towards handling & stacking reams was required in order to ascertain Machine Production target.

**Execution:**

The idea was to utilize the Pre-Stacker unit to stack reams as bundles containing five reams. By utilizing old roller conveyors ream transport path were laid from Pre-Stacker unit of respective copier cut pack lines to the shrink-wrapping Machines separately. Interlocking and logic modification was done to cater stacked bundles to the wrapping Machines in a controlled manner. By doing so, Machine runnability is ensured.

*Fig 24. Before Integration- Single Reams getting discharged*

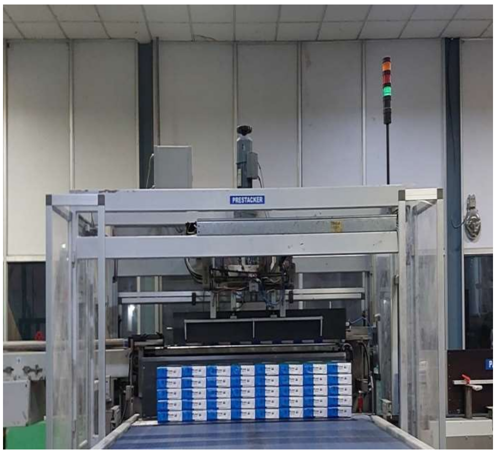



*Fig 25. After Integration through Pre-stacker*


*Fig 27. Packed Bundles*


*Fig 26. After Integration Real transport Route*

**Benefits:**

1. Manual stacking of reams and transportation for Shrink wrapping were eliminated.
2. Elimination of delay in handling reams led to higher Production rate.
3. Reduction in waste generation during ream transportation and mishandling.
4. Cost reduction by eliminating the Manual Labour Cost.

**2. Core End Waste reduction in Reel Processing at Cut Pack Machine:**

**Preamble:**

Decurlers are used to remove the Curl of the sheets drawn from the child reels to the Machine for trouble free operation. However, the operation was manual erst while.

There are in total 5 Nos. of Decurler units in service for 5 Nos. of Unwind stands in ECH WILL Cut pack Machine used for conversion of reels to A4 sized Copier Reams. Decurler control was in manual and required time to time operator intervention in adjusting Decurlers position depending on the reel Diameter and web properties.

**Problems Faced are as follows:**

1. During Machine run at core End, adjusting decurlers manually led to sheet breaks and Machine was stopped at 122-125mm (Core Dia 110mm) and the 12mm Dia of web wound goes waste for repulping.
2. Planned to minimize the core end wastages as minimum as possible. So, there was a need to automate the Decurler operation.

Execution:

Logic was developed and decurlers operation was automated through Interpolation. Decurler operation is verified via the Feedback Potentiometer. Logic is developed using the below formula with minimum prerequisite parameters to be fed by the operator during every reel change such as Reel Diameter, Min and Maximum Decurling Range.

$$\textbf{Decurler Output} = \left[\left(\frac{\text{Max Reel Diamter} - \text{Current Reel Diameter}}{\text{Max Reel Diameter}}\right) * \text{Max Decurling Limit} + \text{Offset}\right]$$

$**$ **Ouput** Limited to Minimum and Maximum Decurling Range

Fig 28. Decurler Screw Shaft

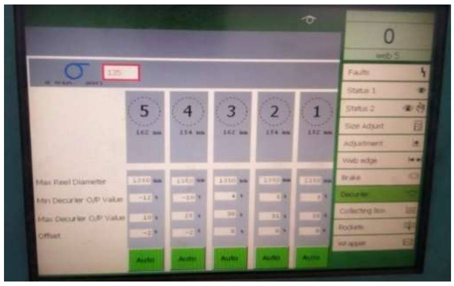
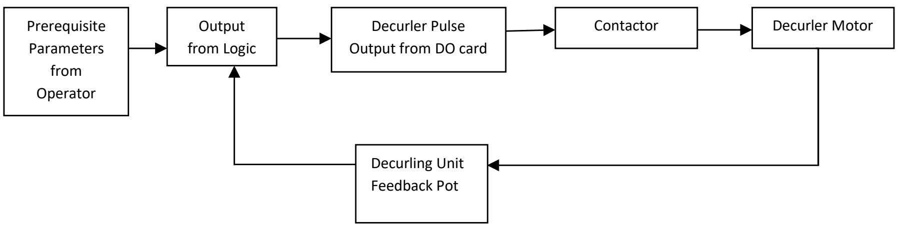


Fig 29. HMI Display Modification

Based on the above formula, output of the decurler is calculated using interpolation with the Operator entered ranges. An Induction Motor operates a screw shaft which is coupled with the Decurler for Decurling operation. A feedback Potentiometer is available to obtain the current Decurling position of each Unit. With all the available hardwares already in place automation of decurlers was carried out only with developing PLC logic as follows;



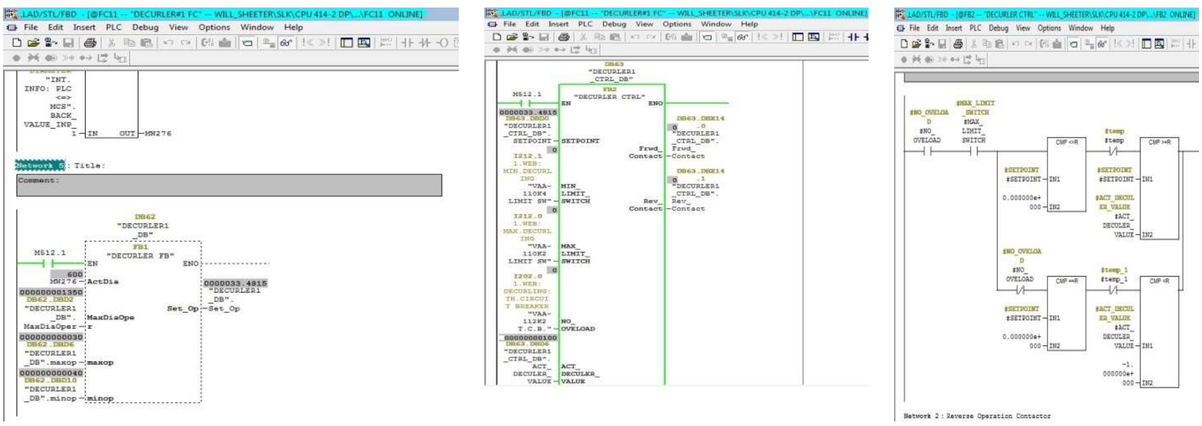



Fig 30. PLC Coding Snapshot

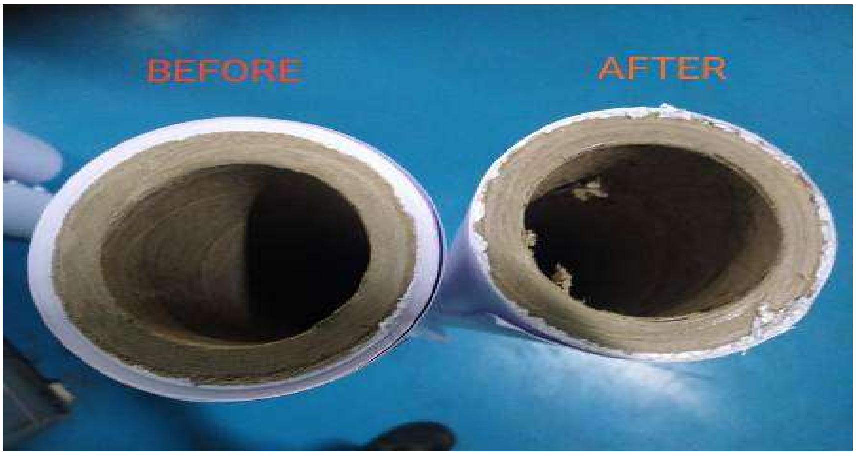



*Fig 31. Utilization of Reels till Core End after Modification*

**Benefits:**

- 12 mm of unprocessed Paper Web wound/ Reel sent for re-pulping was eliminated
- Approximate calculation: 12mm Paper Dia (1205mm Width & 70GSM) accounts for 8Kg\Reel by weight.
- No of reels Processed per day=40 Reels. Total Finishing loss saved = 0.32 MT/day
- Conversion cost (Re-Pulp)/MT: Rs.10,000/-
- Cost savings: 0.32MT x 300 days (Average running days) x Rs.10000 conversion cost =Rs. 9.6 Lakhs / year

## Conclusion:

TNPL's strategic implementation of data-driven decision-making and advanced technological tools has significantly enhanced their manufacturing Processes. By optimizing the performance of Paper Machines through Data Analytics, streamlining the Copier Reams Production with Automation and increasing the reel diameter in the cutter area, TNPL has achieved substantial improvements in Efficiency and waste reduction. These initiatives, part of their Manufacturing Excellence framework, underscore TNPL's commitment to continuous improvement, operational Efficiency and Sustainability. The success of these measures highlights the importance of integrating historical data and Automation in modern manufacturing practices.

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