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Haiteng Engineering

Balancing Tradition and Technology in the Race for Efficiency

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"*Innovation doesn't mean forgetting our roots; it means building upon them. For us, data science is just another tool to strengthen our legacy.*"

— Zhang Yuelan, CEO, Haiteng Engineering

Introduction

Zhang Yuelan stood by the window of her office, gazing down at the massive factory floor below. The steady hum of machinery, which once symbolized Haiteng Engineering's success, now seemed to echo the company's growing challenges. As the COO of the second-generation family business, Yuelan felt the weight of responsibility - not only to modernize but to preserve the craftsmanship that had been passed down through generations.

Her cousin, Zhang Cheng, the CEO of the company, entered the room with a tablet in hand. His expression was serious. "We need to talk about the bottleneck issues at the pump factory," he said.

Yuelan nodded, turning from the window. "I know. It's time to make a decision."

The Company

For over thirty years, Haiteng Engineering has been a family-run business. Founded in 1988 by Zhang Weimin, a skilled craftsman, the company was built on one core principle: reliability. What began as a small workshop producing high-quality submersible pumps for local boat operators steadily grew. By the late 1990s, Haiteng had established itself as a regional leader in Zhejiang province, recognized for its precision manufacturing and personal approach to customer service (Exhibit 1).

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IESE cases are designed to promote class discussion rather than to illustrate effective or ineffective management of a given situation.

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Haiteng's success was rooted in its meticulous craftsmanship and hands-on quality control. Every pump was carefully crafted and inspected by skilled technicians to uphold the reliability that defined the Haiteng name. These pumps, widely used on fishing boats for crucial tasks such as bilge pumping and seawater circulation, became a trusted solution for local fishermen, ensuring their vessels remained safe and operational in the challenging conditions of the East China Sea. In an industry where failure could mean disaster, Haiteng's commitment to quality made it a preferred choice.

Cheng, 37, the nephew of the founder and now the company's CEO, understood that for Haiteng to thrive in the modern era, it needed to adopt new technologies while preserving the craftsmanship that had built its reputation. Since assuming leadership two years ago, Cheng, with his MBA and strong financial management skills, has been steering the company through these challenges. His cousin, Yuelan, 33, serves as the COO. Having grown up in the family business, she joined full-time after completing her engineering degree. Known for her tireless work ethic and innovative mindset, Yuelan brought deep product knowledge and a passion for advancing the company's manufacturing processes.

As China's maritime industry expanded rapidly and global integration increased, Haiteng faced new pressures. The manual quality control of relying on experienced technicians to manually inspect each pump were no longer sustainable as demand grew. Yet, Cheng and Yuelan knew that abandoning their rigorous hands-on approach to quality would be a complication too. Together, they face the difficult task of modernizing Haiteng while safeguarding the quality and personal touch that had been the cornerstone of their grandfather's legacy.

By 2023, China's marine pump industry had grown to ¥12 billion annually, with Haiteng commanding an 8% market share in the Zhejiang province region. Three larger national competitors - Nanfang Group, East Ocean Marine, and Sino-Pacific Engineering - dominated the broader market with a combined 65% share. These larger players had already implemented automated inspection systems, allowing them to process up to 400 units daily per production line while maintaining acceptable quality levels. While Haiteng's current theoretical capacity of 300 units per day should have allowed it to compete effectively, the inspection bottleneck restricted actual output to just 160 units, severely limiting their market responsiveness.

Haiteng's ¥380M revenue came primarily from impeller production (40%) and complete pump assemblies (45%), with the remainder from services and spare parts. Since impellers were critical components in every pump, the production bottleneck was affecting the entire business. The impact was clear: while competitors delivered in 2-3 weeks, Haiteng's backlog had grown to 12 weeks. Their price premium, once 20% above market average, had dropped to 8% as customers became less willing to wait. While industry growth stood at 11.6% annually, Haiteng's growth had stalled.

The Challenge

With regional demand surging and competition intensifying, Haiteng struggled to meet its production needs. Their manual inspection process became a significant bottleneck, leading to backlogs, deferred revenue, and missed opportunities.

The factory's theoretical production capacity was 300 impellers per day, with a target cycle time of 16 minutes per unit and a takt time of 19.2 minutes to meet customer demand. While the casting line could maintain this pace, the inspection bottleneck reduced actual throughput to just 160 units per day, causing the actual cycle time to balloon to 36 minutes. This 47% capacity loss meant nearly ¥91M in potential annual revenue was being left on the table (based on average unit revenue of ¥3,800). The growing order backlog, which had reached three months' worth of production by 2023, even threatened key customer relationships despite strong guanxi (关系).

Cheng, monitoring the company's financials, noticed disturbing trends: "Our order backlog has nearly doubled from 2020 to 2023, and our inventory levels are dropping. We're turning away business because we can't produce fast enough."

The bottleneck's impact was clear:

1. **Production Inefficiency**: While the casting line maintained capacity, inspection constraints cut output nearly in half.
2. **Inventory Problems**: Work-in-progress inventory of uninspected impellers had more than doubled, while finished goods inventory decreased. The average dwell time for WIP had increased from 12 to 28 days.
3. **Financial Strain**: Overall gross margin declined from 35% to 25% over three years due to rising labor costs and manual process inefficiencies at the pump factory.

Building another factory wasn't viable - the financial strain and time required would only worsen their situation. Faced with these challenges, Cheng and Yuelan agreed that Haiteng needed to dramatically increase production efficiency while maintaining high-quality standards.

Quality Control Challenges in Casting Manufacturing

Casting is one of the most essential manufacturing processes, where liquid material is poured into a mold to form a product once it solidifies. In the marine industry, casting is vital for components like impellers, which must meet strict quality standards due to the harsh conditions they face at sea.

Impellers: The Heart of the Pump

Haiteng's submersible pumps are made up of several key parts, including the engine, control panel, and housing (see Figure 2). At the core of each pump is the impeller, a critical component responsible for moving large volumes of water in commercial and industrial marine vessels. Impellers, due to their central function, require frequent production and are subject to rigorous inspection to ensure they meet stringent quality standards.

Good **Defect**

Figure 1: Example of a good and defect impeller.

Casting Defects

Casting naturally involves challenges, particularly when it comes to defects. Common issues such as blowholes, shrinkage, burrs, and pinholes can affect the structural integrity of cast products. For critical components like marine pump impellers, such defects can result in equipment failure, operational downtime, and significant financial losses.

In this industry, maintaining low defect rates is paramount. Standards typically allow defect rates of 500 ppm for machined parts like pump impellers. The casting process's current process capability index (Cpk) of 1.2 indicated a need for improvement to consistently meet these standards. Total Quality Management (TQM) principles suggested a target Cpk of 1.33 or higher for critical marine components. These standards were not merely internal targets - they reflected the certification requirements of the China Classification Society (CCS; 中国船级社) and international bodies like DNV GL and ABS, which Haiteng needed to maintain for marine equipment supply. Each classification society conducted annual audits, with CCS performing quarterly inspections of quality control processes. Loss of certification would effectively lock Haiteng out of the marine market. While less stringent local certifications existed for non-marine applications, these lower-margin markets made up only 12% of Haiteng's revenue and weren't viewed as a viable strategic alternative to their core marine business.

The financial implications of quality control are significant for Haiteng's operations. Each impeller costs about ¥2,280 to produce, including materials and labor. When defective parts reach customers, the company not only bears the ¥200 shipping cost for returns but must also provide customer compensation of ¥3,000 per incident, as specified in their Service Level Agreements (SLAs).

Manual Quality Control Processes

Historically, Haiteng relied on a two-stage inspection process to ensure quality. At the first stage, six quality control staff (maximum capacity at the inspection stations) performed initial Visual Quality Inspection (VQI) after casting. Each inspector undertook visual and basic dimensional checks, working to reduce defect rates from the initial 49,000 ppm to around 25,000 ppm. Due to space constraints and ergonomic requirements at the inspection stations, this team could process about 170-180 pieces per day across two shifts.

These visually inspected parts then moved to final quality control, where twelve skilled inspectors working across two shifts performed detailed examinations. These final inspectors, each with an average of 8 years' experience, spent 8-9 minutes per impeller conducting comprehensive measurements and critical surface quality checks to detect 99% of the defects in this stage. This effectively achieves results better than the required 500 ppm quality standard (1% x 25,000 ppm=250ppm). The complete inspection process, including necessary material handling and transport between stations (2-3 minutes per unit), meant each piece required 12-15 minutes of total processing time.

As demand for Haiteng pumps surged, this traditional inspection system started showing serious strain. Simply adding more visual quality inspectors wasn't possible due to the physical constraints of the inspection stations, and the manual nature of the process made it difficult to maintain consistent quality across shifts. The growing backlog of uninspected products began to pile up, leading to increased costs and missed opportunities to fulfill orders.

Discovery of the Bottleneck

After conducting a process optimization study, Yuelan discovered that the Visual Quality Inspection (VQI) of impellers had become the primary bottleneck in their production line (see Appendix 3). This stage, which required detailed manual visual inspection of all incoming impellers, was too slow to meet the growing demand. The study showed that while the casting process itself could sustain 300 units per day, the manual inspection was the critical constraint, operating at just over half that rate. This massive efficiency gap was creating an accelerating backlog that threatened both current operations and future growth opportunities.

Detailed time studies revealed that when accounting for setup time between shifts, employee breaks, equipment maintenance, and quality calibration checks, the Overall Equipment Effectiveness (OEE) of the inspection process had dropped to 62%, well below the industry standard of 85%. While the casting equipment maintained an OEE of 85% (allowing for production of 255 units daily), the inspection process bottleneck meant a maximum daily inspection capacity of just

160 units across two shifts. During peak periods, this gap created a daily buildup of 95 uninspected units, which quickly accumulated into significant backlogs and a worse quality (Appendix 6).

Yuelan remarked, "Our manual inspection process just can't keep up with demand. We're seeing more defects slip through, and our inventory is piling up because we can't inspect fast enough. We need a solution that maintains our quality standards while dramatically increasing our inspection speed."

Financial Impact of Quality Control

The financial implications of the quality control challenges were becoming increasingly severe for Haiteng's operations. Labor expenses had risen dramatically, with the inspection team of 18 staff now costing ¥3.36M annually when including benefits and growing overtime requirements - representing a 40% increase from 2020 levels. The quality-related costs were equally concerning, with each customer return incident requiring ¥3,000 in compensation plus ¥200 in shipping costs. Every scrapped unit represented ¥2,280 in wasted materials and labor, while the growing work-in-progress inventory incurred storage costs averaging ¥15 per unit per day.

Faced with these costs, Cheng and Yuelan established clear performance requirements for any potential solution. Their targets included increasing daily throughput from 160 to at least 240 units, reducing inspection cycle time to 8 minutes per unit, and cutting WIP inventory by 50%. Additionally, any new system would need to reduce customer returns by 60% and decrease scrap rates by 40%, all while maintaining or improving current quality standards. These ambitious but necessary goals would guide their evaluation of potential automation solutions.

The Solutions

Process Automation Integration

Recognizing the critical nature of this bottleneck and how far ahead the competition already was, Yuelan and her team decided to explore automation as a solution. Their Production Planning and Control (PPC) analysis indicated that implementing an Integrated Quality Management System (IQMS) using computer vision could reduce non-value-added inspection time by greatly.

In this new system, an Automated Optical Inspection (AOI) would serve as the first line of defense, scanning impellers for defects with high speed and accuracy. Impellers that passed this AOI would proceed to the final inspection to ensure final quality standards were met, while those flagged as defect would be discarded (Final inspection in Exhibit 3).

This approach would strike a balance between the efficiency of automation and the precision of human oversight, reducing inspection time without sacrificing the quality that Haiteng had built its reputation on. By adopting a more data-driven approach, Haiteng could enhance both consistency and speed, ensuring each impeller met their strict standards while addressing the bottleneck that was slowing down production.

With the bottleneck and solution identified, Haiteng's leadership now had two potential implementation projects presented by different departments.

The Vendor-Provided Solution: A Low-Cost, High-Risk Option

The Finance Department, driven by immediate cost control, proposed a vendor-provided automated optical inspection system. At ¥1,200,000, this system was attractive due to its moderate cost and potential for rapid deployment. Additionally, the vendor offered a yearly service fee of ¥125,000, covering software updates, maintenance, and support. This service fee would be waived for the first year, making the initial investment more appealing, but installation/training was estimated at ¥200,000.

However, initial tests raised concerns by engineers about the system's performance in detecting subtle casting defects, such as internal pinholes or slight warping. The test conducted on 5,040 impellers generated the following confusion matrix:

	Predicted: No Defect	**Predicted: Defect**
Actual: No Defect	3,603	1,152
Actual: Defect	87	198

This matrix revealed that while the system caught some defects, it missed a couple of defective impellers (false negatives) and incorrectly identified over 22% good parts as defective (false positives). Even so, the Finance Department was convinced that the vendor's solution would reduce manual labor and costs while maintaining operational standards that were on par with the status quo.

The In-House Custom Solution: A Tailored Approach

Meanwhile, the Engineering and Operations Department, led by Yuelan, advocated for developing a custom in-house system specifically tailored to detect the subtle defects that could cause impeller failures in harsh marine conditions. While this approach came with a higher initial cost of ¥2.2M and a three-month development timeline, it promised higher accuracy and longer-term efficiency gains.

The financial considerations included:

- **Development cost**: ¥2,200,000 for cameras, sensors, analytics development, and employee retraining.

- **Ongoing Maintenance**: ¥250,000 annually for software updates and part-time personnel
- **Expected Benefit**: Significant reduction in defect-related costs and material waste.

Before moving forward, Cheng asked the team to define the minimum acceptable performance metrics for the custom system. What should the confusion matrix look like for this system to be worth the investment over the vendor solution?

The Decision

Cheng and Yuelan now face a critical decision: should Haiteng move forward with the vendor-provided system or invest in building a custom in-house solution? To make the decision, you will need to:

For the vendor solution, they need to analyze its performance based on initial testing. The confusion matrix from 5,040 test impellers shows mixed results - it catches many defects but also generates false alarms. Each missed defect that reaches customers costs ¥3,200 (¥3,000 compensation plus ¥200 shipping), while each false positive means scrapping a good ¥2,280 impeller. With annual production of 50,000 units, they need to carefully evaluate both the accuracy metrics and financial implications of these error rates.

The custom solution requires a different analysis. While they know the ¥2.2M investment and ¥250,000 annual maintenance costs, they need to determine what performance levels would justify this higher investment. The engineering team has developed a prototype computer vision system that can be tuned by adjusting its detection threshold - a lower threshold catches more defects but increases false positives, while a higher threshold reduces false positives but risks missing defects. Through careful threshold tuning and performance analysis, they need to determine if this system can achieve the accuracy and cost savings needed for a one-year payback period.

To make the decision, you will need to:

1. **Evaluate the vendor-provided solution**: analyze its confusion matrix performance and project the annual financial impact, considering both defect costs and operational savings.
2. **Determine the minimum required performance**: determine what confusion matrix performance their system needs to achieve, analyze how different detection thresholds affect performance, and find the optimal operating point that balances defect detection with false positives.

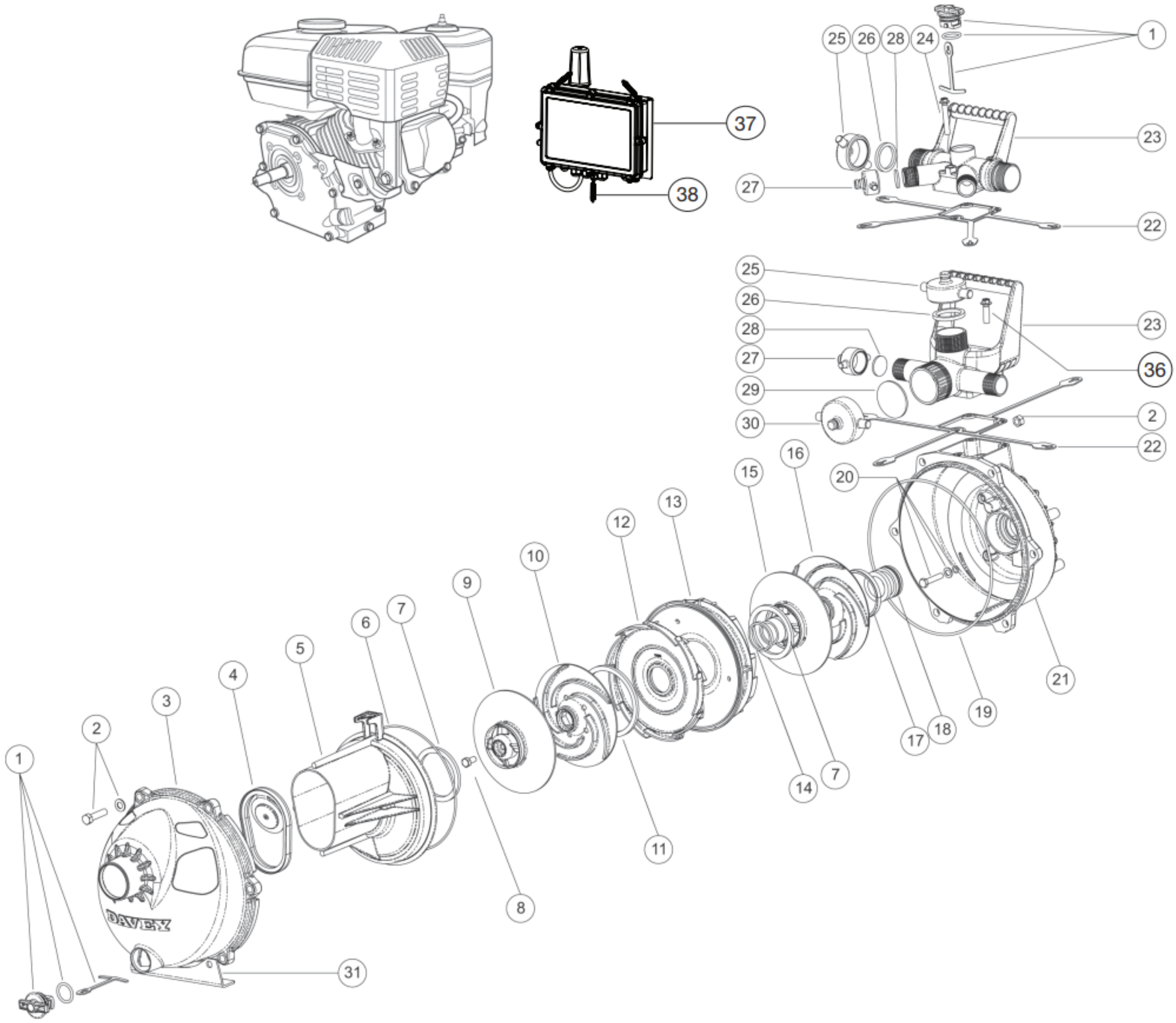
In making your decision, consider not only the financial impacts but also the long-term effects on quality control, operational efficiency, brand value, and customer satisfaction.

Exhibit 1

Zhejiang province, China

Exhibit 2

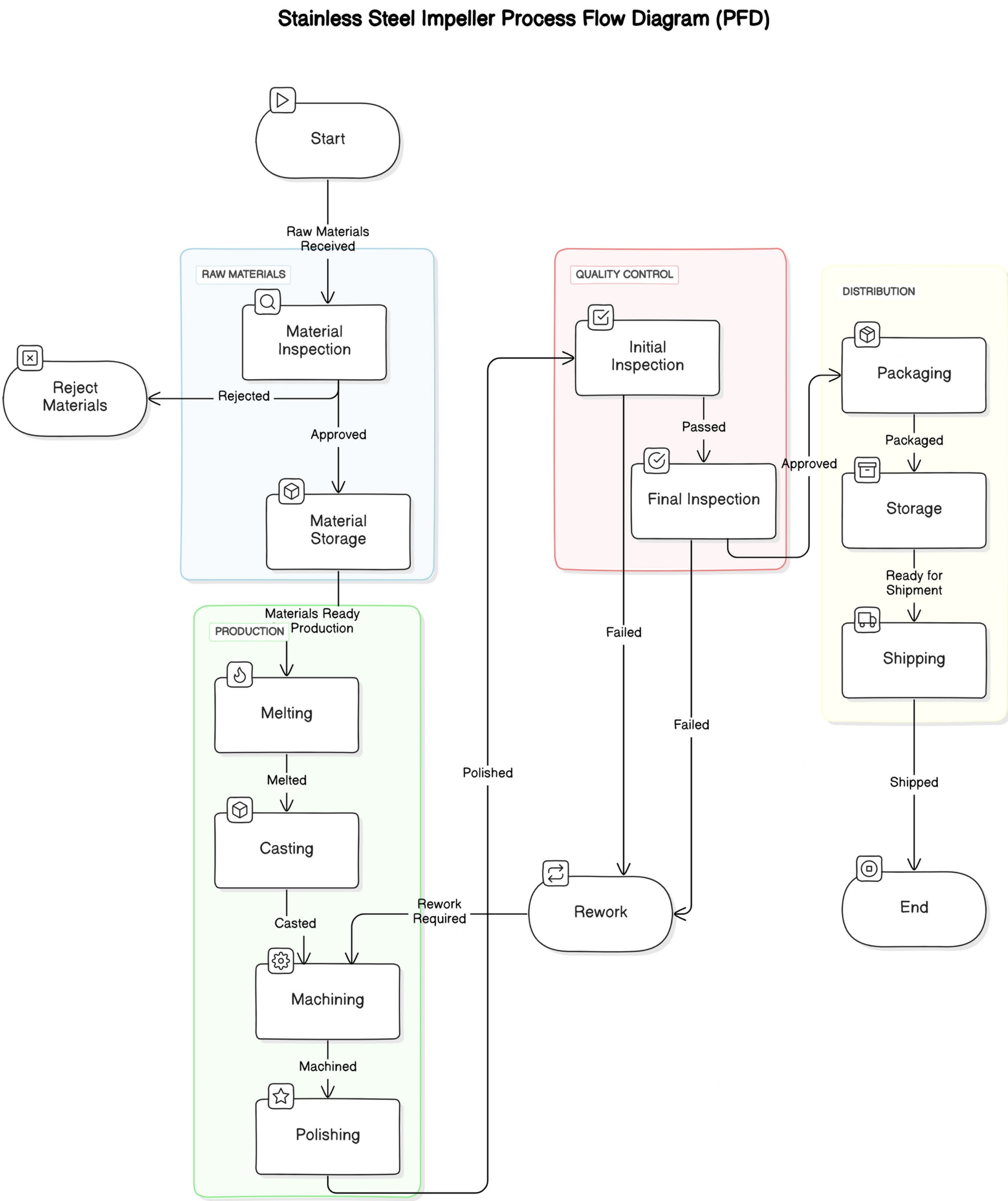
Example of a submersible pump with a single impeller used for firefighting (number 8)



Source: Davey Firefighting manual

Exhibit 3

Stainless Steel Impeller Process Flow Diagram.



Source: prepared by the author.

Exhibit 4

Projected timeline of the custom implementation

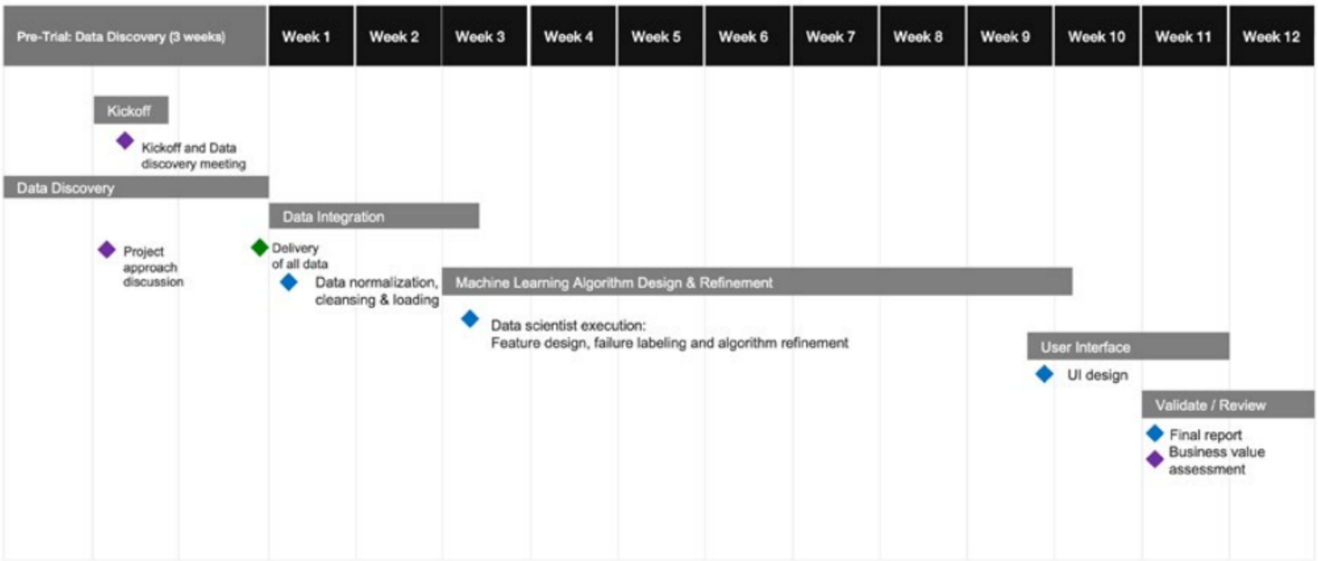
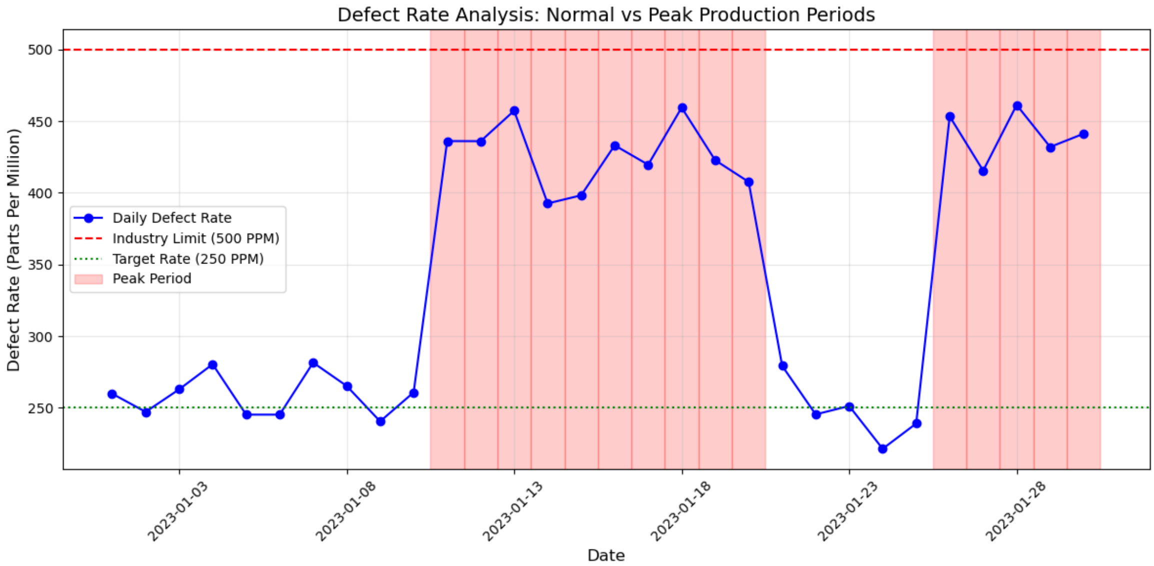


Exhibit 5

Impact of Production Pressure on Quality Control



Daily defect rates measured in parts per million (PPM) over a representative 30-day period in Q4 2023. Red shaded areas indicate peak production periods when the quality control team attempted to increase throughput to address backlogs. While normal operations maintained defect rates around 250 PPM, pressure to increase inspection speed during peak periods caused defect rates to approach the industry maximum allowable limit of 500 PPM, highlighting the trade-off between speed and quality in the manual inspection process.