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Effectiveness Analysis of Centrifugal Pump Maintenance System for Performance Optimization at PT. Sumber Air Abadi

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ABSTRACT

This paper analyzes the centrifugal pump maintenance system and its impact on the effectiveness of pump performance at company PT. Sumber Air Abadi. The study identifies current maintenance practices, evaluates their effectiveness in preventing failures and optimizing pump operation, and proposes improvements for better system reliability and efficiency. Data were collected from maintenance records, pump performance, and personnel interviews. The findings indicate key areas for improvement in preventive maintenance scheduling, spare parts management, and personnel training. Implementation of these recommendations is expected to improve pump performance, reduce downtime, and contribute to the company's overall operational efficiency. The main focus is on the transition to a proactive maintenance culture through technology adoption and continuous skills development.

KEYWORDS : *Pump Maintenance, Centrifugal Pump, Performance Effectiveness, Water Company, Predictive Maintenance, Vibration Analysis, Asset Management, Reliability.*

NOMENCLATURE

API	American Petroleum Institute
ΔT	Inlet and Outlet Temperature Difference
A	Thermal Expansion
LA	Anchor Length
ΔL	Expansion
FP	Pressure Force
Ff	Friction Force
ϵc	Design Compressive Strain
ϵcrit	Critical Strain
MTBF	Mean Time Between Failures
MTTR	Mean Time to Repair
OEE	Overall Equipment Effectiveness
Vf	Volume of water lost due to inefficiency
Vnf	Nominal water volume
η	Pump efficiency

1.0 INTRODUCTION

Centrifugal pumps are crucial assets in the water distribution infrastructure at the Abadi Water Resources Company, playing a vital role in the sustainability of supply and operational efficiency [1].

Optimal pump performance not only ensures service to customers, but also directly reduces financial losses due to energy inefficiency and unexpected breakdowns. As demands for system reliability increase, industrial maintenance practices have evolved significantly, shifting from a reactive approach (fixing after failure) to a proactive approach that utilizes monitoring technology for early detection of potential failures [2].

Although preventive maintenance is commonly practiced, a systematic evaluation of its effectiveness in this case study company has never been conducted in depth, especially in

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linking maintenance practices to quantitative performance degradation data. This study aims to fill this gap by comprehensively analyzing the centrifugal pump maintenance system implemented in PT. Sumber Air Abadi. The objectives are to document the existing maintenance practices, analyze their effectiveness in maintaining pump performance through metrics such as efficiency, MTBF (Mean Time Between Failure), MTTR (Mean Time To Repair), and energy consumption, identify root causes (such as technological limitations, spare parts management, and human resource competencies), and finally provide actionable strategic recommendations for improving pump performance and overall system reliability.

2.0 METHODOLOGY

This study adopts a mixed-methods approach, which combines quantitative and qualitative data analysis to gain a comprehensive understanding of the pump maintenance system. The research design used is a descriptive-evaluative case study at the PT. Sumber Air Abadi Company.

The research sample includes 5 critical centrifugal pump units that have a vital role in the main distribution network, as well as maintenance personnel directly involved in the maintenance cycle. Interviews were conducted with 1 maintenance manager, 2 supervisors, and 5 technicians to obtain perspectives from various levels.

Data collection is done in three main ways:

1. Direct Observation: Observation at the pump operational location and in the maintenance workshop.
2. Interviews: Structured and semi-structured interviews with care personnel.
3. Document Analysis: Study of maintenance history records, failure reports, pump performance data (pressure, flow, power consumption), maintenance SOPs, and spare parts inventory data.

Quantitative data on pump efficiency (η), Mean Time Between Failures (MTBF), and Mean Time To Repair (MTTR) were analyzed statistically. Qualitative data from interviews and observations were analyzed descriptively and using the Root Cause Analysis (RCA) method to identify the root causes of failure. Quantitative data on MTBF and efficiency degradation were used to validate qualitative findings from interviews on the limitations of condition monitoring.

3.0 RESULTS

The centrifugal pump maintenance system at the Abadi Water Resources Company is currently dominated by a time-based preventive maintenance approach.

3.1 Implementation of Preventive Maintenance

The company has a structured preventive maintenance schedule, as summarized in Table 1.

Table 1: Centrifugal Pump Preventive Maintenance Schedule.

Activity	Daily	Weekly	Monthly	Yearly	Description
Visual & Sound Inspection	✔				Checking for leaks, vibration, abnormal noise, temperature.
Parameter Recording	✔				Suction/discharge pressure, motor current, operating hours.
Lubrication		✔			Inspection and replenishment of oil/grease levels.
Strainer Cleaning		✔			Manual cleaning of suction strainer.
Valve Function Check			✔		Operational testing of check valve and gate valve.
Seal/Packing Inspection			✔		Detailed inspection of mechanical seal or gland packing condition.

3.2 Pump Performance Effectiveness

Analysis of performance data shows that the effectiveness of current care systems varies:

1. Pump Efficiency Trend: After the overhaul process, the pump efficiency is at the optimum level. However, data shows a 5-10% decrease in efficiency in the first 6-12 months of operation. This decrease pattern is often not detected early through basic daily inspections as shown at Figure 1.

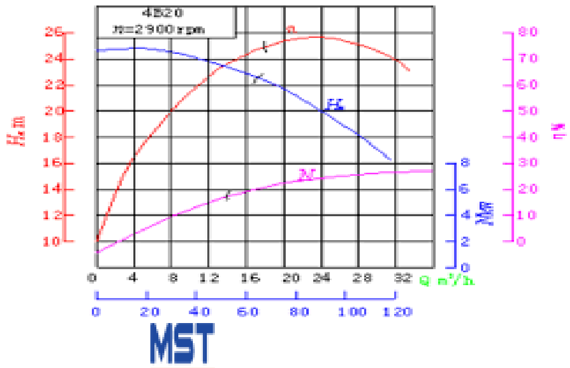

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Figure 1: Pump Efficiency Decrease Pattern After Overhaul

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2. Failure Rate (MTBF & MTTR): Unplanned failures are still an issue. The most common failure types are mechanical seal failures (40%) and bearing failures (30%). MTBF for critical pumps is in the range of 8-12 months, with an average MTTR of 12-24 hours. The high failure rate of these internal components indicates that the existing preventive maintenance schedule is not effective enough to detect wear before failure occurs.
3. Energy Consumption: Decreased pump efficiency directly correlates to increased energy consumption, which gradually increases operational costs without being noticed.

4.0 DISCUSSION

Although a preventive maintenance system is in place, Abadi Water Resources Company faces challenges in condition monitoring, spare parts management, and personnel competency that affect the effectiveness of pump performance.

4.1 Problem Analysis and Recommendations

In the operation of centrifugal pumps and other rotating equipment, maintenance plays a pivotal role in ensuring reliability, efficiency, and cost-effectiveness. Traditional maintenance practices in many industries are still dominated by time-based schedules, where inspections, servicing, or replacements are conducted at predetermined intervals. While this approach can provide a sense of regularity, it often fails to capture the true condition of the asset. As a result, some components may be replaced prematurely while others may deteriorate unnoticed until a serious failure occurs. Such "blind" maintenance strategies not only increase operational costs but also expose critical systems to unexpected breakdowns that can disrupt production, compromise safety, and reduce overall equipment effectiveness (OEE).

To address these challenges, it is essential to transition from conventional maintenance to a more data-driven and condition-based approach. By leveraging modern diagnostic tools and predictive technologies, maintenance activities can be targeted precisely when and where they are needed, thus minimizing waste, preventing downtime, and maximizing asset lifecycle. The following analysis outlines the problems with the current practice and provides recommendations for implementing a Predictive Maintenance (PdM) strategy, supported by advanced condition monitoring methods such as vibration analysis, infrared thermography, and oil analysis, as well as an economic justification through Return on Investment (ROI) evaluation.

4.1.1 Maintenance Management

Given this context, the following section highlights the main problem identified in the current maintenance approach and presents a set of targeted recommendations. These recommendations are structured to introduce practical strategies and technologies that can transform maintenance practices from time-based routines into predictive, condition-based interventions.

1. Problem: Time-based maintenance is often "blind" to the real condition of the asset. Repairs are made based on a schedule, not based on the actual condition of the machine, so that gradually developing problems go undetected.
2. Recommendation: Implement a Predictive Maintenance (PdM) strategy by utilizing Condition Monitoring technology.
   a. Vibration Analysis: Installation of vibration sensors to detect problems such as unbalance, misalignment, or bearing damage long before they become catastrophic failures [3].
   b. Infrared Thermography: Use of a thermal camera to detect overheating in motors, bearings, or electrical connections.
   c. Oil Analysis: Periodic testing of oil samples to detect lubricant contamination or degradation that indicates internal wear.
   d. Economic Aspect: Investment in PdM technology can be justified through Return on Investment (ROI) analysis, by comparing investment costs with potential.
   savings from reducing unplanned downtime, emergency repair costs, and losses due to energy inefficiencies. Volume losses due to inefficiencies can be quantified using the formula:

$$V_f = V_{nf} \times (1 - \eta) \quad (1)$$

Where V_ *f* is the volume of water lost due to inefficiency, V_ *nf* is the nominal volume, and eta is the pump efficiency. This data can be used by managers to understand financial losses.

4.1.2 Spare Parts Management: Inventory Optimization

Effective spare parts management is a critical factor in ensuring the reliability and availability of industrial equipment. In many cases, equipment downtime is not only caused by technical failures but also by delays in procuring essential components. Poorly managed inventories—either due to understocking or overstocking—can lead to significant inefficiencies, such as extended repair times, increased operational costs, and reduced overall productivity. To overcome these challenges, a structured and strategic approach to spare parts management is required.

Given these considerations, the following section identifies the key problem in current spare parts practices and outlines recommendations for optimizing inventory through systematic analysis and control mechanisms.

1. Problem: Limited availability of critical spare parts often results in extended time to repair (MTTR) and high emergency procurement costs.
2. Recommendation: Implement a strategic inventory management system [4].
   a. Analysis: Classify parts to determine control priorities.
   b. Stock Optimization: Determine Re-Order Point (ROP) and Safety Stock based on historical data to minimize the risk of stockouts without piling up capital in excessive inventory.

4 .1.3 Personnel Training: Competency Improvement HR

Human resources represent one of the most decisive factors in the success of a modern maintenance system. Even with advanced technologies and optimized processes, the absence of adequately skilled personnel can limit the effectiveness of maintenance strategies. In many organizations, workforce competencies remain heavily oriented toward conventional mechanical repairs, which makes it difficult to adapt to new approaches such as predictive and reliability-centered maintenance. This gap in knowledge and skills underscores the need for a more systematic effort in developing maintenance personnel competencies.

In line with this, the following section outlines the key problem in the current human resource capabilities and provides recommendations for structured training programs aimed at equipping personnel with the competencies required for the modern maintenance era.

1. Problem: Current personnel skills are more focused on conventional mechanical repairs and are not adequate to adopt modern diagnostic technologies.
2. Recommendation: Structured HR competency improvement program.
    a. PdM Technology Training: Intensive training on the basics of vibration analysis, thermography, and how to interpret data for decision making.
    b. Maintenance Philosophy Training: Introducing the concept of Reliability-Centered Maintenance (RCM) to change the mindset from "fixing" to "maintaining reliability" [5].

5.0 CONCLUSION

The analysis shows that the preventive maintenance system at PT. Sumber Air Abadi has succeeded in reducing catastrophic failures, but has not been optimal in maximizing pump efficiency and reliability. Limitations in condition monitoring, spare parts management, and HR competency are the main obstacles.

Transitioning from time-based preventive maintenance to condition-based predictive maintenance (PdM) is a recommended strategic move. Implementation of technologies such as vibration analysis and thermography, supported by optimized inventory management and comprehensive personnel training programs, will enable early detection of anomalies, smarter repair scheduling, and failure prevention. These steps are projected to improve energy efficiency, reduce *downtime* , extend asset life, and ultimately drive sustainable operational excellence.

5.1 Suggestions and Further Research

It is recommended to conduct a detailed feasibility study and cost-benefit analysis (CBA) for PdM technology investment. Further research can focus on developing *machine learning models* to predict *the Remaining Useful Life* (RUL) of pumps based on historical data and *real-time sensor data* [7].

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