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Analysis and Optimization of the Maintenance of the Pumping Facilities and Distribution of Potable Water for the Regideso 'N'djili: Impact on the Reliability and Continuity of Service

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ABSTRACT

Reliable drinking-water supply depends largely on the availability and performance of pumping, treatment and distribution facilities. In this context, maintenance of electromechanical and hydraulic equipment is essential to ensure service continuity. This article analyses and suggest ways to optimize the maintenance of drinking-water pumping and distribution facilities of REGIDESO in Ndjili, Kinshasa. Particular attention is given to pumping equipment, electric motors, control systems, pipelines, valves and related components. The study examined the preventive, corrective and condition-based maintenance and their contribution to equipment reliability and availability.

A life-cycle asset management approach based on failure analysis, equipment monitoring and maintenance planning is proposed. The analysis highlights the importance of preventive maintenance schedules, spare-parts availability, maintenance records, staff training and performance indicators. Such measures can help reduce unplanned downtime, improve equipment reliability and contribute to better continuity of drinking-water services.

KEYWORDS: *maintenance, pumping, drinking-water distribution, reliability, availability, REGIDESO, Ndjili, electromechanical equipment, asset management.*

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1. INTRODUCTION

drinking water is an essential service to the public health, hygiene and socio-economic development. The continuity and reliability of supply is dependent on not only the availability of the resource and the capacity of production, but also the proper functioning of the facilities, pumping, treatment, storage, and distribution.

The world Health Organization emphasizes that the safety and reliability of water services require a systematic management of the risks, as well as operation and effective maintenance of the infrastructure. It was also noted that problems of exploitation, management of resources and maintenance can compromise the provision of safe and reliable service. In a production installation, and water distribution, electromechanical equipment, are particularly important. Pumps, electric motors, control cabinets, valves, piping, and protection devices must operate in conditions that are satisfactory to allow the transfer of water between the different points of the system.

The maintenance becomes a strategic element. It is no longer just to repair equipment after a crash, but also to prevent failures, monitor the status of equipment and plan interventions according to their criticality. This article focuses on the pumping facilities and drinking water distribution of REGIDESONdjili. It aims to examine the principles of maintenance applicable to these facilities and to propose an optimization approach that may improve the reliability and continuity of service.

The pumping facilities and distribution are made up of many equipment interdependent. The failure of a single critical element can disrupt the functioning of the whole system. The failures of the pumps or motors may lead to stoppage of production or a reduction in throughput. Electrical problems can cause the stop of pumping equipment. The defects of the valves or pipes, can interfere with the movement of the water. Similarly, the failure of the maintenance operations can accelerate the wear and tear of the equipment.

The main question of this study can therefore be formulated as follows:

How to optimize the maintenance of the pumping facilities and distribution of REGIDESO Ndjili in order to improve the reliability of the equipment and the continuity of service of drinking water ?

Preventive maintenance, properly planned helps to reduce the frequency of failures of the equipment of pumping and distribution. The improvement of the monitoring equipment, the historical failures and the availability of spare parts helps to reduce the duration ofstops. A better organization of the maintenance, and the use of performance indicators can improve the availability and reliability of the facilities.

The general objective is to analyze the practices of maintenance of pumping stations and distribution of REGIDESO Ndjili and to propose strategies to improve the equipment reliability and continuity of service.

- identify the main equipment involved in the maintenance;
- characterize the different types of maintenance to be used;
- analyze the main potential causes of failure;
- identify the critical equipment;
- to propose indicators for monitoring of the maintenance;
- develop strategies for the improvement of maintenance;
- contribute to the reduction of unplanned planned.

2. CONCEPTUAL FRAMEWORK

2.1. Maintenance

Maintenance can be defined as the set of actions of a technical, administrative, and organizational measures designed to maintain or restore equipment in a state to perform the intended function.

It can be organized into several categories.

2.1.1. Corrective Maintenance

It comes after the occurrence of a failure.

It can be**:**

- palliative, when an intervention provisional allows you to temporarily surrender the equipment in operation**;**
- healing, when an intervention is designed to permanently eliminate the cause of the failure. Corrective maintenance is still required, but an over-reliance on this may lead to unexpected shutdowns and additional costs.

2.1.2. Preventive Maintenance

The preventive maintenance is to intervene before the failure, to reduce the likelihood of failure.

It may include:

- the inspections;
- the cleaning**;**
- the lubrication;
- the clamping connections;
- the vibration control;
- the temperature control;
- the replacement planned for some parts;
- the periodic testing of protection devices.

The WHO emphasizes the importance of programs, operating, and maintenance of solid to support the sustainability and security of water supply systems.

2.1.3. Condition-based Maintenance

Condition-based maintenance is based on the monitoring of the actual state of the equipment.

For an engine or a pump, we can monitor**:**

- the temperature;
- the vibration;
- the absorbed current;
- the voltage;
- the pressure;
- the flow rate;
- the noises;
- the leaks.

A defective development of these parameters may allow to detect degradation before failure complete.

The evolution of the life time of the equipment can be traced according to a curve called a curve in the bath (figure 2.1). According to the equipment, whether mechanical or electronic, the allure of the failure rate are different.

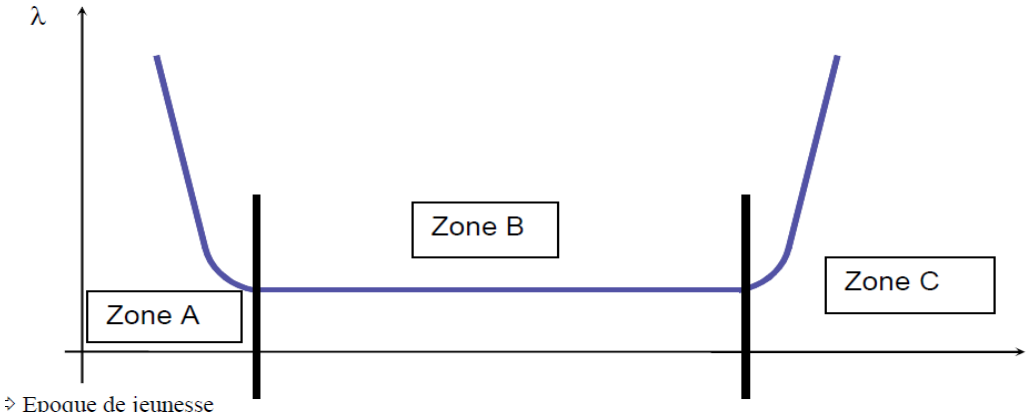


Figure 2.1: The curve in the bath.

- **Zone A**: Time of youth
- **Area B**: Time of maturity, normal operation, failure random time-independent.
- **Zone C**: Time of obsolescence, wear-out failures or malfunctions of old age.

2.1.4. The law of Weibull

It is the most popular of the laws, used in many fields (electronic, mechanical, etc). It allows to model many situations wear and tear of equipment.

It characterizes the behaviour of the system in the three phases of life: the period of youth, period of useful life and a period of wear and tear or aging. In its most general form, the distribution of Weibull depends on the following three parameters: **β, η** and **γ.** The probability density of a law of Weibull has the expression:

$$f_{(t)} = \frac{\beta}{\eta}\left(\frac{t-\gamma}{\eta}\right)^{\beta-1} e^{-\left(\frac{t-\gamma}{\eta}\right)^{\beta}}, t \geq \gamma \qquad (2.1)$$

Where:

- β: is the shape parameter **(β >0)**
- **η**: is the scale parameter **(η >0)**
- **γ**: is the position parameter **(γ ≥ 0)**

Service reliability is written:

$$R_{(t)} = e^{-\left(\frac{t-\gamma}{\eta}\right)^{\beta}} \qquad (2.2)$$

The failure rate is given by:

$$\lambda_{(t)} = \frac{\beta}{\eta}\left(\frac{t-\gamma}{\eta}\right)^{\beta-1} \qquad (2.3)$$

According to the values of β, the rate of failure is either decreasing **(β< 1)** is a constant **(β=1),** or increasing **(β > 1).** The distribution of Weibull can therefore represent the three periods of the life of a device described by the curve in the bath. (figure 2.1)

The case **γ > 0** corresponds to devices of which the probability of failure is zero up to a certain age **γ**

- **Area of use:**

The act of "Weibull" three parameters is very " soft ", which allows him to adjust to a large number of samples collected along the life of the equipment. It covers the case of the failure rates of the variables, decreasing (the period of youth) or increasing (the period of old age). This law is widely used in reliability, especially in the mechanical field. Its operations provides:

- An estimate of the "**MTBF**" of the population.
- The equations of **R(t)** and **λ(t),** as well as their changes in a graphical form.
- The shape parameter **β**, which may guide diagnosis, its value is characteristic of certain failure modes.

1° distribution Function (γ=0, η=1)

These graphs show the polymorphism of the law of "Weibull " under the influence of the shape parameter **(β)**.

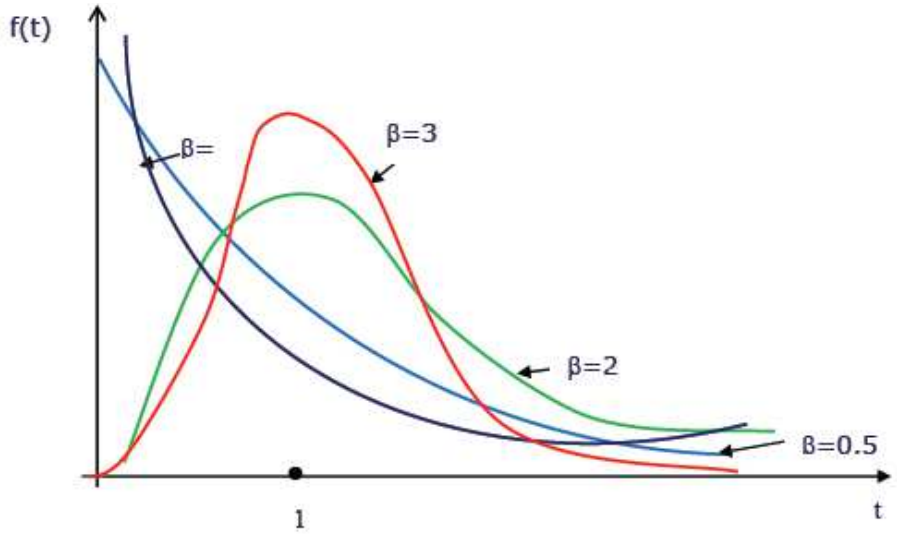


Fig. 2.2: Influence of the shape factor β on the curve of the density probability

2° Curves representative of R(t), λ(t) (γ=0, η=1)

The reliability R(t) for an act of "Weibull" is represented by different curves depending on the value of shape factor **β**. (figures 2.3 and 2.4)

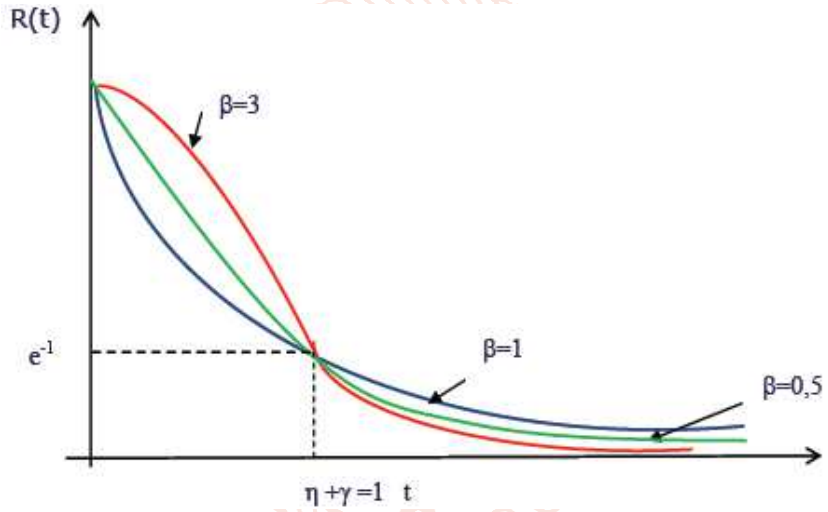


Fig. 2.3: the Influence of the shape factor β on the curve of reliability

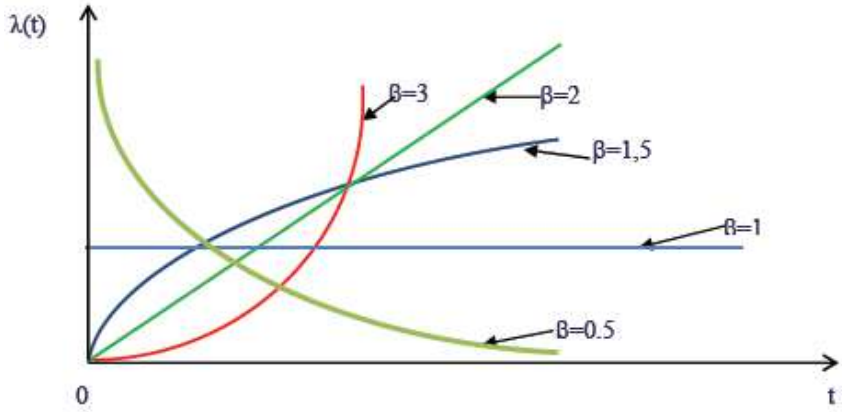


Fig. 2.4: Influence of the shape factor β on the curve of the failure rate

3° Meaning of the parameters of reliability of the "Weibull"

- **β:** called shape parameter (β>0), it is often equal to, less than or greater than 1.The act of "Weibull" corresponds to a failure rate instant, constant, decreasing or increasing.
- **η:** is called a scale parameter (η>0) sometimes called a "characteristic of life" it is a simple parameter of time.
- **γ:** is called a positional parameter (-∞<γ<+∞) it defines a change of origin in the time scale.

For example, ($\gamma > 0$) ; there is a survival total (not to failure between 0 and γ). (figure 2.5)

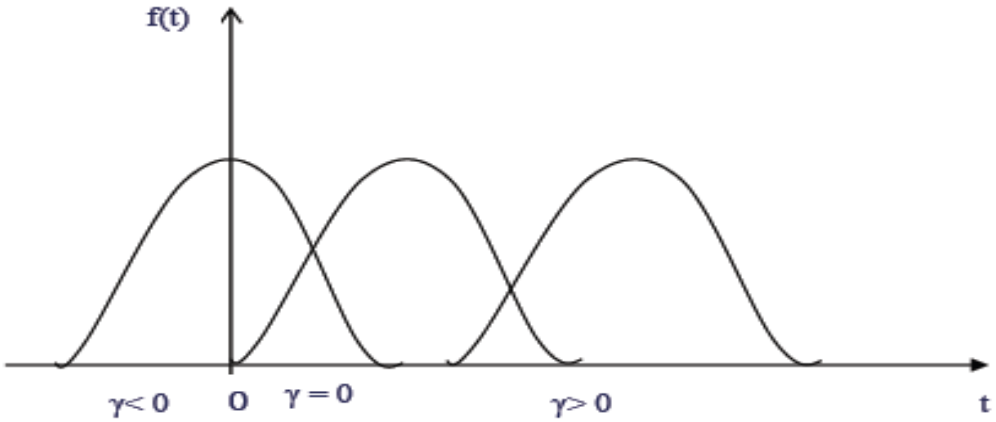


Fig. 2.5 : graph of the density function of the position parameter (γ)

2.2. Pumping facilities and distribution

An installation of water supply usually has several functions : to capture or raw-water supply, treatment when necessary, pumping, storage and distribution. In the framework of this study, the attention is focused primarily on the following equipment :

2.2.1. Pumps

Centrifugal pumps (figure 2.6) are operating according to the principle of rotation of the fluid to be pumped in a wheel rotating at high speed. They have an area of application of pressures of 0.6 to 20 bar and flow rates up to 50 000 m^3/h.



Figure 2.6: centrifugal Pump.

The main potential failures may concern :

- the bearings;
- the mechanical seals;
- the trees;
- the wheels or turbines;
- the imbalances;
- the vibration;
- the phenomena hydraulic abnormal.

2.2.2. Electric motors

The motors ensure the drive of the pumps. They require monitoring:

- of the bearings**;**
- of temperature**;**
- of the input current**;**
- of the state of isolation**;**
- the electrical connections**;**
- of alignment with the pump**;**
- of vibration.

2.2.3. Cabinets and control systems

The electrical equipment and control allow you to control the operation of motors and pumps. Maintenance must include the protections, connections, contactors, relays, control devices and monitoring systems.

2.2.4. Valves and pipes

The valve is used to control or isolate the different parts of the network. The pipes carry the water. The inspections must, in particular, to search for leaks, corrosion, damage to mechanical and operational anomalies.

2.2.5. Approach to the management of assets

The maintenance modern can be integrated into an approach to asset management.

ISO55000: 2024provides a reference framework for the management of assets throughout their life cycle,

and puts particular emphasis on a proactive approach and the alignment between the management of the assets and goals of the organization.

For installation of pumping, this means that it is not necessary to consider a pump only as a piece of equipment to be repaired when it breaks down. It is also necessary to take into account**:**

- his age**;**
- his state;
- his history of failure;
- its importance in the process;
- the cost of downtime;
- the availability of spare parts;
- the consequences of a failure;
- the possibilities of replacement or modernization.

This approach allows you to prioritize interventions according to the criticality of the equipment.

3. RESEARCH AND METHODOLOGICAL JUSTIFICATION

To carry out a field study on the maintenance of the facilities of Ndjili, a mixed approach can be used.

3.1. Direct Observation

The observation allows us to collect information safe:

- the state of the equipment;
- the organization of work stations;
- the maintenance operations;
- the operating conditions;
- the availability of safety equipment;
- the practices of cleaning and lubrication.

3.2. Interviews

Interviews can be carried out with:

- the maintenance managers;
- the technicians électromécaniciens;
- the operators;
- the operations manager;
- the officers in charge of inventory management.

3.3. Literature review

The consultation documents can include**:**

- the sheets of maintenance**;**
- the reports of intervention**;**
- the historical fault**;**
- the maintenance programs**;**
- the technical data sheets of the equipment**;**
- the registers of operation**;**
- the reports of energy consumption**;**
- the inventories of spare parts.

3.4. Analysis of the indicators

The main indicators that can be calculated are given in sub-points below.

3.4.1. MTBF (Mean Time Between Failures),

The MTBF is the average time between two failures from time to time. According to Dhillon (2002), this indicator is used to measure the operational reliability of equipment.

It is calculated by:

$$MTBF = \frac{Time\ of\ correct\ operation\ (TBF)}{number\ of\ failures} \qquad (3.1)$$

An increase in the MTBF translates to an improvement of the reliability.

3.4.2. MTTR (Mean TimeTo Repair)

It represents the average time required to replace the equipment in a state after a failure. According to Kelly (2006), this indicator assesses the effectiveness of interventions for maintenance.

3.4.3. Availability

An approximation of the current availability intrinsic can be expressed by:

Availability = MTBF / (MTBF + MTTR), (3.2)

These indicators were used to assess the evolution of the reliability and maintainability of equipment. Availability is one of the most widely used indicators in industrial maintenance. According to Ebeling (2010), a high level of availability translates to a better performance of the maintenance system

3.5. Analysis of the causes of failure

The failure analysis has to search for the causes of a technical and organizational.

The causes can be grouped into several categories:

3.5.1. Material

- wear and tear**;**
- corrosion;
- aging;
- default alignment;
- failure electric;
- deterioration of the bearings.

3.5.2. Methods

- absence or insufficient planning;
- procedures of maintenance incomplete;
- interventions are not standardized.

3.5.3. Workforce

- inadequate training**;**
- lack of effective specialized**;**
- errors of manipulation.

3.5.4. Materials and spare parts

- parts unavailable**;**
- parts unsuitable**;**
- quality insufficient components.

3.5.5. Mid

- humidity**;**
- dust;
- temperature;
- conditions difficult operating.

The use of tools like the Ishikawa diagram or the analysis of failure modes can contribute to identifying priority causes.

4. OPTIMIZATION AND PRESENTATION AND DISCUSSION OF RESULTS

4.1. Strategies for the optimization of the maintenance

4.1.1. Development of a preventive maintenance program

Each device should have a program specifying:

- the operations to be performed;
- the frequency;
- the officials;
- the tools needed;
- the spare parts;
- the acceptance criteria.

4.1.2. Introduction of a history of the equipment

Each critical equipment should have a sheet, comprising:

- identification;
- brand and model**;**
- features techniques;
- date placed in service;
- transactions are performed;
- failures recorded;
- parts replaced;
- time to stop.

This documentation facilitates the diagnosis and planning of interventions.

4.1.3. Spare parts management

A stock-out can greatly extend a failure.

It is therefore necessary to determine the critical parts and set minimum levels of stock depending on the criticality and time of supply.

4.1.4. Development of condition-based maintenance

Vibration monitoring, temperature, pressure, flow and electrical parameters can help to detect some potential issues before they lead to a major breakdown.

4.1.5. Staff training

The competence of the technicians and operators is an important factor of reliability. The training may include**:**

- the rotating machines**;**
- electricity industrial**;**
- hydraulics**;**
- instrumentation**;**
- the fault diagnosis**;**
- the security**;**
- the modern methods of maintenance.

4.2. Safety and water quality

The maintenance should not only be the availability of the equipment. It should also contribute to maintaining the safety of the water. The WHO stresses that the degradation of the water quality in the distribution networks can be associated with such an operation, maintenance and control of the quality to be inadequate.

The maintenance interventions must therefore be arranged in such a way as to avoid the introduction of contaminants into the facilities. The health monitoring and risk management must be integrated into the operating and maintenance. The security plans of the water are, in this respect, an approach based on the identification and control of risks throughout the supply chain.

4.3. Discussion

The maintenance of the pumping facilities and distribution should be considered as a strategic function and not only as a repair activity. An organization primarily reactive, can lead to unexpected shutdowns, increased repair costs and downtime, extended equipment. Conversely, a policy of preventive and conditional allows us to anticipate some of the failures and to better organize the resources.

However, the optimization does not necessarily increase the maintenance operations. Maintenance in excess can also lead to costs and unnecessary interventions. Rather, the objective is to adapt the strategy to the criticality, the state and the mode of failure of each device.

The management of the assets proposed by the ISO55000:2024precisely allows to register the decisions of maintenance in a perspective of life-cycle and value creation for the organization. For REGIDESO Ndjili, an empirical study should therefore measure the actual performance of the equipment from the available data**:** the number of failures, duration of stops, average repair time, frequency of interventions, availability of parts and equipment availability.

These data would allow to objectively determine which equipment is the most critical, and adapt to the maintenance plans.

4.4. Recommendations

From the proposed analysis, the following recommendations can be made**:**

a) Set up or update a preventative maintenance plan for critical equipment**;**

b) Be a history of electronic failures and interventions**;**

c) Regularly calculate the indicators MTBF, MTTR and availability**;**

d) Identify the equipment according to their level of criticality;

e) Enhance the availability of spare parts critical;

f) Gradually developing condition-based maintenance;

g) Train regularly technicians and operators;

h) Improve the technical documentation of the facility;

i) Periodically check the electric parameters, mechanical, and hydraulic

j) Integrate the requirements of health and safety of the water in the maintenance procedures.

k) Put in place a monitoring system to analyze the recurring causes of failure;

l) Consider an approach to the management of assets based on the cycle of life.

5. CONCLUSION

The maintenance of the pumping facilities and distribution is an important determinant of the reliability of systems of drinking water supply. In an installation such as that studied at N'djili airport, electromechanical equipment and hydraulic systems must be monitored, and a maintenance suitable to their criticality.

The evolution of a maintenance essentially corrective to a strategy combining preventive maintenance, and conditional asset management can help to reduce unplanned stoppages and improve equipment availability.

The implementation of such a strategy, however, requires reliable data on the failures, the interventions, the stopping time and the condition of the equipment. It should also be accompanied by a proper management of spare parts, personnel training and regular monitoring of performance indicators.

Finally, the maintenance should be considered a component of the overall service quality of drinking water. The principles of the WHO show that the operation, maintenance and risk management must be integrated to support the safety and reliability of the water supply.

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