Issues Affecting Water Distribution Systems

V.D. Shibnauth, and B.Y.R. Surnam

***Abstract*—** Mauritius receives enough rainfall (over 2000 mm/year) to cater for the national demand. However, Mauritians face problems of water stress, especially during periods of low rainfall. This study investigates the technical problems in the water distribution system and discusses on the means to solve these problems and improve the system.

Three main water distribution plants were considered. Information leading to the breakdown of the pumps, increase in power consumption and problems in the water pipeline were gathered at the plants for investigation.

It was observed that failures in the pumps were mainly due to components such as bushings, bearings, wear rings and mechanical seals. Energy consumption of some pumps was also a problem since they were not being used at their Best Efficiency Point. Cavitation was another problem which affected the pumps. Problems related to the pipelines were found to be less significant.

Hence, to solve these problems, it was recommended that alignment of the pumps and motor should be performed accurately. Also, preventive or predictive maintenance should be performed on the pumps, especially in relation to the bearings and the bushings. Adjustable Speed Drives could be used on the pumps which were not used efficiently. For the cavitation problems, use of impellers made of materials resistant to cavitation could be envisaged.

***Keywords*—** Pumps, pipes, water distribution

I. Introduction

FRESHWATER makes up a very small fraction of all water on the planet. Though around 70 percent of the world is covered by water, only 2.5 percent of it is fresh. The rest is saline and ocean-based. Out of the 2.5% freshwater, only 1% is easily accessible, with much of it trapped in glaciers and snowfields. In essence, only 0.007 percent of the planet's water is available to fuel and feed its 6.8 billion people. In many of the developing countries, clean water is either hard to come by or a commodity that requires laborious work or significant currency to obtain[1].

Mauritius also faces some problems of water stress during the periods of low rainfall. Hence, much investment is being done in the water distribution system in Mauritius. Proper functioning of water distribution systems is essential for any population. Presently, only 23% of the rainwater can be mobilised as surface and ground water [2].

It is seen that Mauritius receives enough rainfall (over 2000 mm/year) to cater for the national demand. The demand for potable and industrial use has gone up by an average of 2% a year while the trend in rainfall is down by approximately the same percentage. Therefore, the need to plan for capturing more rainfall through strategically placed surface reservoirs has been highly advocated [2]. On and above these measures that need to be taken, the water distribution system should also be improved to make it more efficient.

Hence, this study investigates on the problems faced in the water distribution system in Mauritius and discusses about the means to solve these problems and improve the system.

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II. Methodology

Three main water distribution plants and their related pipeline circuit in Mauritius were studied in order to identify the main problems. The main components of the water distribution systems which were considered are the pumps in the distribution plants and pipeline circuits. One of the plants considered for investigation is shown in fig. 1.

Fig. 1- One of the plants considered for investigation

Information leading to the breakdown of the pumps, increase in power consumption and problems in the water pipeline were gathered at the plants for investigation. Logistics and other management aspects of the distribution system were not considered.

Eventually, causes of the problems and their solutions were discussed.

III. Results and discussion

A. Failures in pumps

The failures in each of the pumps were considered. Breakdowns due to the following parts were observed:

- Bearing

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- Wear Ring
- Mechanical Seal
- Bushings
- Non-Return Valve
- Burnt out Motor (or Failed Stator)
- Shaft
- Gear Coupling
- Impeller

Table 1 shows the results obtained for one of the pumps with the highest amount of failures in the last 12 years.

TABLE I
FAILURES IN ONE OF THE PUMPS

Failed Components	No. of components failed between 2002 and 2013
Bearing	9
Wear Ring	7
Mechanical Seal	8
Bushings	24
Non-Return Valve	1
Burnt out Motor (or Failed Stator)	2
Shaft	2
Gear Coupling	3
Impeller	2
Total	58

Figures 2 to 4 show some of the common problems encountered with the pumps.

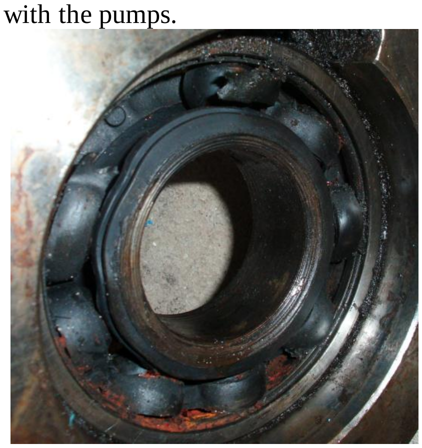

Fig. 2- Corroded and damaged bearing

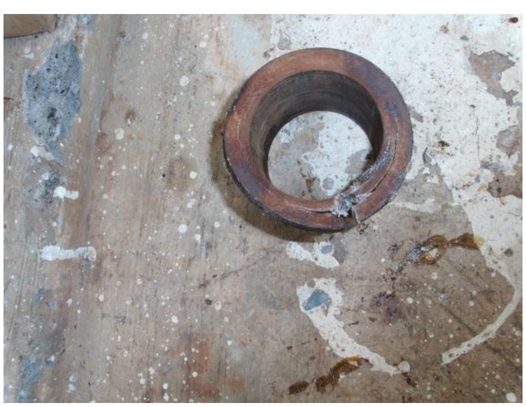

Fig. 3- Worn out bushing

Fig. 4- Failed shaft

For each pump considered a Pareto chart was used to determine the most dominant components to failure. A typical Pareto chart is shown in Fig. 5.

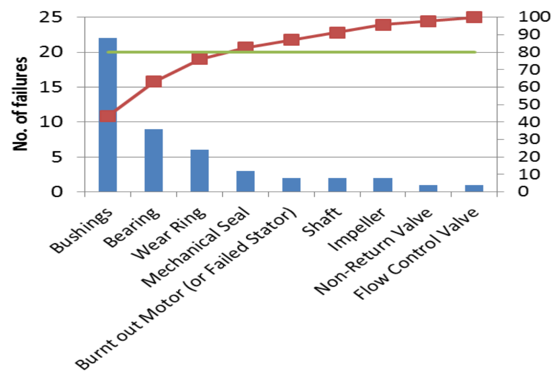

Fig. 5- Pareto chart of the failures occuring in one of the pumps considered

The components most frequently representing 80% of the failures are:

- Bushings
- Bearings
- Wear Rings
- Mechanical Seals

Bushings and wear rings are expected to wear out and thus protect other components. Bearings and mechanical seals, on the other hand, can lead to serious problems, especially to more critical components such as the shaft and the motor. In fact, the actual lifetime of the bearings were found to be a third of their expected lifetime.

Many of the pumps considered are submersible ones. For these pumps a run-to failure strategy was normally adopted and it has been found better to continue with this practice because the pumps are found at a certain depth below the surface ground. Hence, maintenance could prove to be uneconomical. Besides removal and installation of such a pump requires between 8 to 24 hours, depending on the depth and size of the pump. There would hence be a significant downtime on the system.

Moreover, it has also been observed that there is a gradual increase in the failure rate as pumps as they get older. Fig. 6 shows the failure distribution of one of the pumps which is 15 years old.

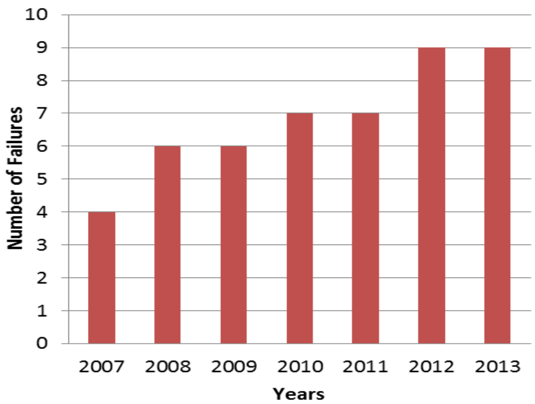

Fig. 6- Failure distribution of a 15 years old pump

The mean time between failures for the components were calculated. All the components have an expected lifetime. However, many of them fail unexpectedly before their lifetime. This incurs additional cost

B. Energy consumption of pumps

It was observed that some pumps were not operating at their Best Efficiency Point. Though many of them were used optimally, a few were throttled to be able to operate at the required discharge rate.

The problem of energy consumption of the pumps can be solved through:

(i)The use of Adjustable Speed Drive (ASD) – which varies the rotational speeds of pumps and controls the flow rate more efficiently. A small decrease in speed would represent a significant decrease in energy usage as the pump power is said to be proportional to the cube of the rotational speed. ASDs are best suited high power pumps, a minimum operating pumping hours of 2000 per year, low static head, and pumps with variable torque necessities. Payback for an ASD is achieved within more or less a year [3]. However the use of ASD is only worthwhile in the range of 85-100% of maximum speed of the pump and also its improper use could lead to undesired conditions such as lack of head, or pressure [4].

(ii) In case of oversized or throttled pumps, it is possible to improve their efficiency by replacing the impeller with a smaller one, given they satisfy the same geometric and kinematic similarity conditions [5]. Otherwise it is also possible to trim the impeller to the required diameter if the impeller diameter reduction lies within the manufacturer's recommended limits [4,5]. Upon trimming, the geometric and kinematic characteristics of the impeller are partly altered [5].

C. Cavitation

This problem occurs quite frequently in Mauitius. This can lead to the damage of impeller of the pump, as shown in fig. 7 (a) and (b).

Fig. 7(a) – Damaged impeller due to cavitation

Fig. 7(b)- Damaged impeller due to cavitation

It was observed that pumps which were frequently damaged by cavitation had the available Net Positive Suction Head less than the required Net Positive Suction Head for much of their operating time.

To solve this problem of cavitation, the supply tank would either have to be raised or the pump level would have to be decreased so as to eliminate cavitation. In both cases it would be practically impossible. Hence, the solution to this problem would be to use impellers which are more resistant to cavitation. Materials such as 316 stainless steels or 6082 Al Alloys would resist cavitation better than contemporary impeller material like bronze and cast iron [6,7]. Nitriding of low alloy steel impellers have also demonstrated significant resistance to cavitation [8,9]. Use of ceramic coatings are also considered as a solution to protect the impeller against cavitation and increase the hydraulic efficiency of the pump as well [10]. It should be noted that this solution was implemented to reduce the problem of cavitation. However, it was not effective.

D. Piping

The pipes for water distribution used by the Central Water Authority are listed below:

- Cement-Mortar lined Ductile Iron pipes
- HDPE pipes
- Galvanized Mild Steel pipes
- Steel 316 Austenitic pipes for submersible pumps

Cement-Mortar lined Ductile Iron and more recently

HDPE pipes are used for the entire water distribution network though an insignificant part of mild steel pipes might also be used in certain regions. Mild steel pipes are also used in the light connections from pumps to the main pipes. Those are better suited because of their lower cost and do not need regular maintenance. Stainless steel 316 pipes are used inside boreholes only and once the fluid pumped is at ground level HDPE pipes are normally used for the distribution.

E. Head loss in the pipes

The pipes supplying water to the consumers from the different plants were investigated. In fact, some of the pipes in the system were of 25 to 26 years old. Two types of pipes are used- the mortar cement ductile iron pipe and the HDPE pipe. The average roughness (Ra) value of the mortar cement ductile iron pipes, after 25 years of service were found to be 35µm. The new ones were found to have an Ra value of 30µm. HDPE pipes on the other side had lower surface roughness with Ra for the new ones being 15 µm. The ones used over 12 years period were found to be 15.2 µm. Many old pipes are now being replaced by HDPE ones. The lower surface roughness of the HDPE pipes would lead to lesser pumping cost in the long term. However, not much is obtained as saving. Over 6000 m, for example, only 10 m in savings in head loss were estimated.

F. Pipe Leakage

Water lost in distribution systems due to probable leakages or other causes is estimated to be about 20-25% per year by the authorities involved in water distribution. This high percentage has its repercussion socially as leaks can act as a source of contaminant in the water and economically, leakages mean loss of water whether it is raw or treated, extra cost for digging foundations to reach the pipes beneath, repair of old pipe or investment in new ones.

Some causes of pipe leakage include bursting of old pipes depending on the velocity and the pressure of the water and old or defective valves, pipe connecting fittings such as gaskets and saddles [17]. As already mentioned, old pipes are gradually being replaced by new HDPE ones and leakage problems are expected to decrease gradually.

G. Pipe Corrosion

For Cement-Mortar lined Ductile Iron and HDPE pipes, corrosion is not a major problems. For the Ductile Iron pipes, their inside cements and outside mortar linings protect the pipes from corrosion. Moreover, the soil in Mauritius is not considered to be corrosive. Ductile Iron pipes generally have a lifetime of about 100 years and are suitable for repeated use at a pH varying from 4 to 12 [12]. HDPE pipes are highly resistant to corrosion, especially to microbiologically induced corrosion and to pH and have a lifespan in excess of 50 years [13]. The stainless steel 316 pipes having excellent corrosion are also not a major concern.

Mild steel is the only pipe more susceptible to corrosion. They are, however, being replaced gradually.

IV. CONCLUSION

The problems encountered in the system are two main types: those related to pumps and those related to the piping system.

Though much effort is being done to reduce or eliminate the problems occurring in the plants and the distribution system, there are a lot of improvements that can be brought.

Since bearings and bushings are a major problem in the pumps, alignment of the pumps and motor should be performed accurately. It should be noted that presently this is performed very rapidly using rulers, as shown in fig. 8.

Fig. 8- Alignment of pump and motor

Also, preventive or predictive maintenance should be performed on the pumps, especially in relation to the bearings and the bushings. Predictive maintenance could involve vibration analysis. Preventive maintenance could involve routine checks, quarterly and annual checks. Adjustable Speed Drives could be used on the pumps which were not used efficiently. For the cavitation problems, since ceramic coating of the impellers have not proved effective, other methods should be envisaged.

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