Consultancy Services for the Plant Audit in various Pump Stations and Reservoirs (OP18REFCS03)

Technical Report for Ayala South Vale (ASV) Pump Station

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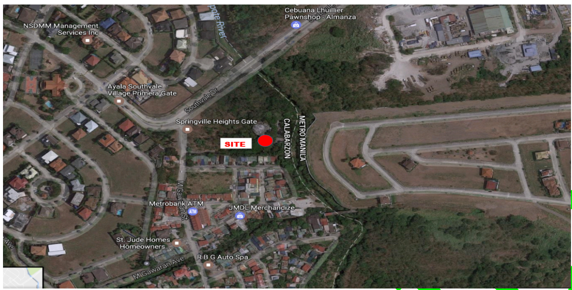
Chapter 1

Introduction

1.1 General introduction

The station is located in Ayala Alabang, Muntinlupa (refer to Figure 1.1 - a and Figure 1.1 - b). The station services two areas namely, Southvale and Sonera. Two 10HP long coupled pumps (Figure 1.2 - a) deliver to Southvale and another two 15HP close coupled pumps (Figure 1.2 - b) deliver water for Sonera area. Built in 1985, this is one of the stations with the smallest average power consumption of only 7,841 kW per month.



a - [$14°23'55.86.74''N, 121°0'5.98''E$]

b - Pump House

Figure 1.1: ASV PSR]

a - Southvale service pumps

b - Sonera service pumps

Figure 1.2: Pump gallery

This PS has been included by the Client in the first cluster of pump stations for systems audit, benchmark establishment and asset management.

The Client has therefore awarded GHD and its sub-consultants (RB Sanchez and APSI) to conduct a plant audit project with an expectation to establish rigorous asset management framework based on reliability study and to determine optimal intervention program for the next five (5) years.

1.2 Objectives

The objectives of this work are as follows

- To evaluate the current operating condition of PS as compared to the original design intent and to provide recommendations for improving the operational efficiency and lowering operating cost;
- To be able to determine an optimal intervention program for the PS in the next 5 years with reference to the recommendations from the assessment and audit based on life cycle cost; and equipment efficiency study whether the equipment is subjected to replacement or repair. These equipment are:
  - Pumps;
  - Motors;
  - Generators;
  - Electrical System and Protective Device;
  - Substation (Transformer, Switchgears);
  - MCC (VFDs, Soft starters, Circuit Breakers, and Protective Devices);
  - Motorize Valves.

1.3 Scope of Work

Scope of Work (SOW) has been defined in the Contract Agreement and be in compliance with the GHD technical and financial proposal and the agreements made during a number of project meetings (refer to minutes of meeting of the project).

It is important to note that the electrical audit and analysis is not part of this report but will be included in the next revision.

1.4 Limitations

Results of the study with analysis, conclusion, and recommendations are only within the scope of work and agreements, and particularly under the following major constraints:

- Operational constraint: It was not possible to shutdown the entire PS for visual inspection of assets, particularly mechanical assets;
- Incomplete historical data: It was a matter of fact that Maynilad has not established an asset management system, thus data regarding historical intervention is limited and incomplete, leading to non-optimal reliability analysis;

1.5 Glossaries

Following glossaries are defined and used in the report:

Level of Services (LOS)

A Level of Services (LOS) is any value or expectation of asset managers and beneficiers regarding the functionality and serviability of an asset of a system of assets.

Intervention

Intervention is a generic and global term used to refer to non-physical and physical activities on assets. It encompasses do-nothing, or do somethings like repair, maintenance, rehabilitation, renewal, investment, and inspection and testing.

Corrective Intervention (CI)

A Corrective Intervention (CI) is an intervention executed without proper and systematic plan. An CI is often incurred by failure/breakdown of assets. In most of cases, it incurs significant negative impacts (e.g. cost to repair, disruption of service, loss in revenue).

Preventive Intervention (PI)

A Preventive Intervention (PI) is an intervention executed with proper and systematic plan. Note that an PI is executed on asset that is still working but not provide adequate level of services.

Intervention Type

An Intervention Type (IT) is a specific and well-defined type of work/task that can be executed on/for an asset (e.g. replacement of a bearing for a pump).

Intervention Strategy (IS)

An Intervention Strategy (IS) is a set/collection of intervention types.

Intervention Program (IP)

An Intervention Program (IP) is a set/collection of intervention strategies for one asset or more than one assets of the same system.

Work Program (WP)

A Work Program (WP) is an execution program consisting of Intervention Program and management program (e.g. project management, procurement) that shall be implemented in order to realize/actualize the Intervention Program.

Chapter 2

Preliminary Assessment and Data Gathering

GHD conducted preliminary assessment on a set of data provided by Maynilad. The data set includes a number of records on daily production and power consumption and intervention reports issued after Maynilad experienced failure/breakdown of assets.

The assessment provided a base for GHD to generate the Inspection Testing Plan (ITP) [6] aiming to gather necessary data for conducting reliability study. The ITP has been reviewed by Maynilad, together with the Work Safety Permit (WSP), prior to execution of visual inspections and testings at the site.

2.1 Maynilad's data

Maynilad provided a set of data as shown in Table 2.1

Table 2.1: Data provided by Client.

No.	Data	Remarks
1	As-built drawings	no CAD drawings, only PDF
2	Monitoring dashboard	Year 2015 to 2017
3	CI records	None
4	Asset registry	Asset registry was incompleted as confirmed by the IAM team of Maynilad.

2.1.1 Intervention records

There are no CI reports for this station. Furthermore, the most important historical data concerning specific failure of components of pumps with elapsed time is missing. Thus, the provided information is not useful for detailed reliability study on frequent failure of assets at component level.

The problem with missing specific failure data was due to a matter of fact that Maynilad still has not come up with preventive maintenance program within the overall asset management framework. The IAM team has recently established with expectation to generate short-term, medium-term, and long-term preventive intervention program. In close discussion with Maynilad, GHD learns that Maynilad has a regular/frequent activities for check-up (e.g. monthly and quarterly), however, recorded data has not been digitalized and the data itself has not aligned well with the asset registry.

Table 2.2 presents highlights on intervention data on pumps.

Table 2.2: Highlight of intervention data on pumps.

Pump	Description of PI/CI	Date/Remarks
All Pumps	Inspection of pump drive coupling, mechanical seal, MCC components. Conducted pump and motor vibration test using vibration meter and monitored bearing condition using thermal scanner. Also check gen-set's engine oil, radiator's coolant, battery solutions and filters.	Regular monthly maintenance activity, may vary at times depending on availability of test equipment
Southvale P2	Replacement of torishima pump	6/15/2015
	Replacement of mechanical seal	7/9/2015
	Pull-out of defective pump unit	7/27/2015
Southvale P1	Replacement of mechanical seal	7/9/2015
Sonera P1	Replacement of Element Coupling (Love joy 110)	N/A
N/A	Installation of Pump 1 - pump and motor alignment	4/9/2016

2.1.2 Interview data

GHD conducted an interview session on 07/12/2018. Results of the interview are summarized in the minutes [4], with the following highlights.

- No further data is available aside from the provided set presented in earlier section;
- There is an existing regular check-up for assets but data is not digitalized and the information is only generic;
- Spare parts are not stocked for most of components, except for bearing. Regarding service delivery, the required discharge pressure remains the top priority in pump operation modulation and sequencing. Critical parts and components for VFD and bearing are usually stacked to have spared in case of emergency repair and replacements. The consumables on the other hand, are not stacked but ordered in advance for use in maintenance activities;
- No visual bank of assets;
- No standard testing regime that follows a regular scheme based on optimality;
- Pumps are operated based on pressure and not manual;
- No existing PI/CI procedure to be followed;
- No expansion plan is forecasted; physically impossible to add another pump in the existing pump room
- There is a problem with the inflow of incoming water, leading to lower level of reservoir chambers that has affected pump operations occasionally;
- no historical data on pump efficiency, which is a simple yet useful value in determining pump performance. The main impediment in the individual pump efficiency is the measurement of flow produced by each pump. The existing configuration of the pump-motor and piping system do not cater to conventional methods of flow determination;
- No intervention records for FDAS. It was revealed that different version on operation and functionality of the FDAS was reported by both guard and site operators.

2.1.3 Asset hierarchy

During the bidding phase, Maynilad did provide the first draft of the Asset Registry (AR) that describes a hierarchy of eight (8) levels. Figure 2.1 visualizes the hierarchy with brief description presented in Table 2.3.

GHD received the latest version of the AR with about 100 assets for this PS. The full list of assets is given in the excel file provided by Maynilad in 2018. GHD has developed a MS Access

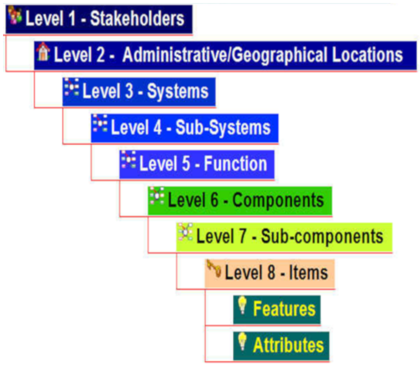


Figure 2.1: Asset Hierarchy

Table 2.3: Condition state definition - Multiple.

Asset hierarchy	Description
Level 1	Stakeholder level. For example, an pump station belongs to MWSI
Level 2	Geographical locations/ or administrative zone (e.g. a pump station belong to Quezon city or Makati)
Level 3	System (e.g. the entire pump stations and reservoir system)
Level 4	Sub-system (e.g. one specific pump station and reservoir such as the Lamesa PSR)
Level 5	Functional system (e.g. booster system or storage system)
Level 6	Component (e.g. Suction line, Reservoir line and Tank)
Level 7	Sub-component (e.g. Suction pipe and fittings, Concrete reservoir, pump)
Level 8	Items (e.g. valve, bearing, motor)

program to convert the data in the excel file to a relational database structure. Per agreement with Maynilad, GHD will only verify level 7 of the AR with the actual site condition for the study [5].

2.2 Preliminary assessment

Assessment on the lastest provided intervention records reveals that the provided pertinent data is incomplete and cannot be used as representative data for a complete reliability study.

It is also confirmed from the provided data that the Client has done regularly check-up on GENSETs to ensure that it provides adequate level of services in case of emergency. To date, no failure records has been observed for the GENSET.

Further evaluations and tests have to be conducted to identify the areas for improvement of preventive measures in mitigating corrective measures and study the ways to strengthen preventive measures to improve operating conditions and life of pump components.

Improving the reliability of the pump stations for the next coming years require evaluation of the existing pump station conditions and maintenance practices, particularly assessment of the pump and its components. With that, areas for improvement of operation and maintenance be addressed through action items that come from the resulting recommendations.

In order to capture a relatively good picture on the reliability of the pump system and its associated assets, a number of tests shall be conducted.

2.3 Summary of the inspection test plan (ITP)

A complete write-up on testing shall be referred to the ITP [6], which has been submitted, reviewed, and approved by the Client. This section only provides highlights to help readers keeping abreast of the flow of the report.

2.3.1 Mechanical Audit

The Mechanical Tests to be conducted are enumerated and discussed hereunder including their background and applications, standards used if applicable, and the equipment to be used. During testing, the following are the assumptions and considerations:

- The operation of the pumps cannot be interrupted (at day time when demand is high).
- The valve settings then cannot be adjusted to produce different flow rates.

2.3.1.1 Structural Inspection for Pump Discharge and Suction Line

This activity measures the current thickness of the existing pipelines at the pump vicinity using ultrasonic thickness gauging. The flow regime especially around the elbow and possibly corrosion and scaling conditions are to be predicted from the measurements of this test.

Following procedures will be executed

Step 1: Locate and mark testing points

At a minimum of two (2) meters away from the pump intake/discharge flange, the test points shall be marked at 3, 6, 9 and 12 o'clock positions and at one (1) meter interval along the pipes, additional test sections with same set points shall be added as long as available beneath the immediate ground level.

Step 2: Prepare test point surfaces

- Wipe the surface free of dirt (no need to remove paint)
- Using a chalkstone (erasable), mark x on the test point

Step 3: Apply sufficient couplant on test point surface

- Use petroleum jelly/Vaseline as couplant

Step 4: Set transducer probe on test point

Step 5: Read and record value as indicated on module display

Step 6: Clean test point after reading

2.3.1.2 Unit Flow Measurement

The activity measures pump capacities. Pump efficiency is then calculated using the measured values.

Step 1: Locate Sensor Position Point Area and mark all points to be taken.

- Observe required offset distance from fittings/pump to consider the fully developed flow. At least 10 times the diameter distance away from the suction/discharge of the pump if applicable, otherwise consider at least 2D distance away from the fittings. This is to ensure the flow will be stable and fully developed for flow measurement accuracy
- Otherwise, test at near turbulent zones and consider normalizing the flow.

In particular, the headers can be chosen as set points for flow measurement. (Figures 2.2 - a to d).

a b c d

Figure 2.2: UFM testing points

Step 2: Pipe Specification Input on the Flow Meter.

- Identify nominal pipe size with equivalent parameters such as schedule designation, equivalent thickness, OD, and etc.
- Input outside diameter.
- Input pipe thickness.
- Input pipe material (carbon steel).
- Input pipe medium (water).

Step 3: Prepare test point surfaces

- Clean the surface of pipe with a sandpaper and steel brush or any suitable abrasive materials, exposing the base metal.

Step 4: Install transducers at set points

- Apply enough couplant that it covers transducers sensors to ensure an acoustically conductive connection to the pipe. Also apply couplant on the test point surface
- Clamp the transducers at the side of pipe using metal chains, straps or mounting rails Observing proper spacing and alignment. Note flow direction and install transducers at either 0 or 45 degrees, whichever would give more stable reading
- Wait for the module to display "System Normal" before reading. Inspect set-up for any fault and properly reinstall if signal is poor/low (no reading)

Step 5: Data gathering

Read and record all necessary data measurement by the equipment, (i.e. flow, fluid velocity, sound velocity, Reynolds number, etc.)

Figure 2.3: UFM Measurement Display

Step 6: Remove transducers and restore paints

Remove the transducers and restore the surface of pipe after measurement.

2.3.1.3 Suction and Discharge Pressure Measurement

The activity measures each pump suction and discharge pressure. The pump efficiency is then calculated using the measured values.

Step 1: Disassembly of existing Pressure Gauge

- Inspect for any leaks or unusual noise before proceeding: If anything is detected, report immediately to the operator;
- Close gate valve located before the pressure gauge and wait for the pressure reading to drop;
- Remove the pressure gauge: (1) Hold the adapter steady with one wrench and the grip the stationary socket of the pressure gauge with another; (2) Loosen the pressure gauge then remove it.

Step 2: Installing the Pressure Gauge

- Prepare the connections: (1) Clean the connections before installing; (2) Put Teflon tape on the pressure connection of the gauge;
- Install the pressure gauge: (1) Mount the pressure gauge on the adapter then hand tighten the arrangement; (2) Further tighten the assembly using a pair of wrenches: hold the adapter steady with one wrench and the grip the stationary socket of the pressure gauge with another; (3) Tighten the assembly;
- Inspect the assembly again.

Step 3: Reading the pressure

- Slowly open the gate valve: Observe any leaks or unusual noise;
- Measurement: (1) Wait until reading is stable; (2) Record the pressure as indicated.

Step 4: Restoring the earlier gauge

- Inspect for any leaks or unusual noise before proceeding: If anything is detected, report immediately to the operator;
- Close gate valve located before the pressure gauge and wait for the pressure reading to drop;
- Remove the pressure gauge: (1) Hold the adapter steady with one wrench and the grip the stationary socket of the pressure gauge with another; (2) Loosen the pressure gauge then remove it;
- Prepare the connections: (1) Clean the connections before installing; (2) Put Teflon tape on the pressure connection of the gauge;
- Install the pressure gauge;
- Mount the pressure gauge on the adapter then hand tighten the arrangement;
- Further tighten the assembly using a pair of wrenches: hold the adapter steady with one wrench and the grip the stationary socket of the pressure gauge with another;
- Tighten the assembly.

2.3.1.4 Parameters

Parameters was recorded using visual inspection form, interview questionnaire, and testing results. Main parameters are listed, but not limited to, in the Table 2.4. Raw data is enclosed in the Appendix.

Table 2.4: Main parameters to be collected.

Parameters	Symbol	Remarks
Pipe thickness Gauge	t	mm
Pump Capacity	Q	Gpm/cmh
Suction Pressure	Ps	mH2O
Discharge Pressure	Pd	mH2O
Vibration Data	-	-
Head	H	mH2O
Efficiency	e	%

2.3.2 Vibration and structural assessment

This activity measures the vibrations of the pump and motor at the drive and non-drive ends. The data will be used to address pump vibration problems such as cavitation, pump flow pulsation, bent pump shaft, pump impeller imbalance, shaft misalignment and bearing problems.

Following procedures will be executed

Step 1: Test location identification

Locate the testing points on drive and non-drive ends of pump and motor

Step 2: Set transducer probe on test point. Observe HIRAC for access to elevated positions

Step 3: Read and record value as indicated on module display (Figure 2.8 - d)

Figure 2.4: a

Figure 2.5: b

Figure 2.6: c

Figure 2.7: d

Figure 2.8: Vibration Analyzer Test

2.3.3 Workplace environment management

GHD/RBSanchez conducted measurements at designated locations (Figure 2.9) to record values of parameters presented in Table 2.5.

Table 2.5: WEM Parameters.

Parameters	Symbol	Units
Dry Bulb Temperature	tdb	oF/oC
Relative Humidity	RH	%
Sound Intensity	-	dB
PM 2.5 Count	PM2.5	ug/m^3
Visible useful light	-	Lux

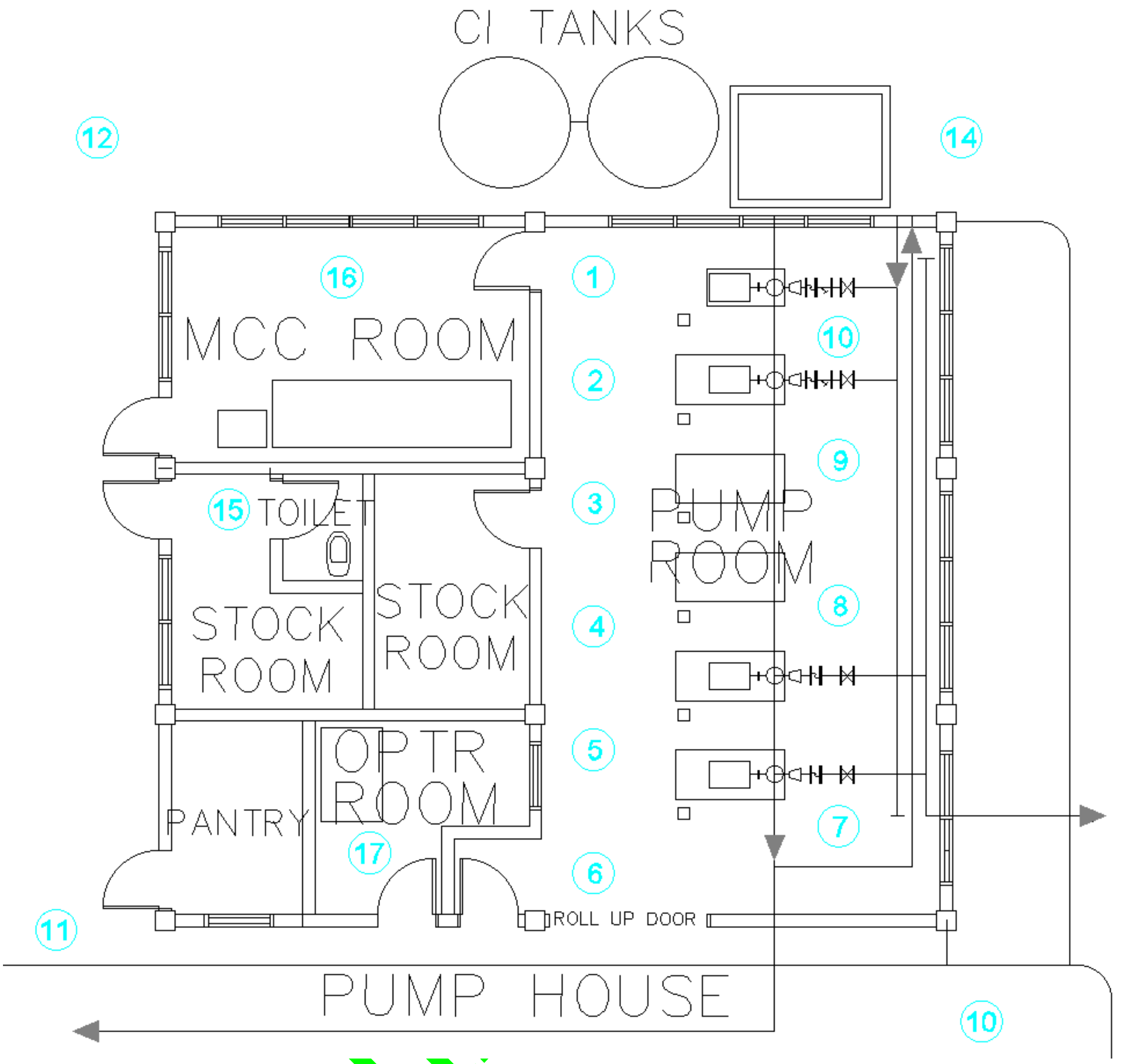


Figure 2.9: Testing locations

2.4 Database

GHD developed an MS Access program that functions as a database used to record data collected from visual inspections and testings. The database has been developed using the concept of Relational Database Management System (RDMS), which is a must to record data systematically. The benefits of using the database are

- Eliminate redundancy and repetition of same data
- Eliminate incorrect data entry that is often found when working with excel files
- Provide linkages among asset hierarchy
- Provide ease for programing (e.g. reliability modeling and life cycle cost analysis)
- Support Maynilad AIM team to learn the benefits of using RDMS in developing an integrated Asset Management System for now and future
- Provide compatibility with any CMMS that is often using other RDMS such as Microsoft SQL Server, Oracle SQL server, or MySQL platform
- Provide ease for compilation of desire tables for further analysis using SQL (Structure Query Language)

- Provide ease for importing/exporting to different extension formats (e.g. flat, csv, xlsx)
- Provide a strong background for Maynilad team to migrate recording practices to Web-based that will be part of GHD's recommendation for future usage.

The MySQL database is then migrated into MySQL server, which is powerful database system that is used also to migrate, compile, and store all production and power consumption data into a single table. Main reasons behind the development of the MySQL server are for statistical computing with R and for faster compilation of queries.

GHD will provide these two sets of database as part of our deliverable and will provide training for Maynilad team to learn how to use the database in an efficient approach.

Chapter 3

Methodology

3.1 The Integrated Asset Management Approach (IAM)

We proposes an Integrated Asset Management (IAM) approach with its framework shown in Figure 3.1 for executing this project. The IAM approach will eventually be beneficial to Clients as it will lay a foundation to build up a systematic asset management plan for the future.

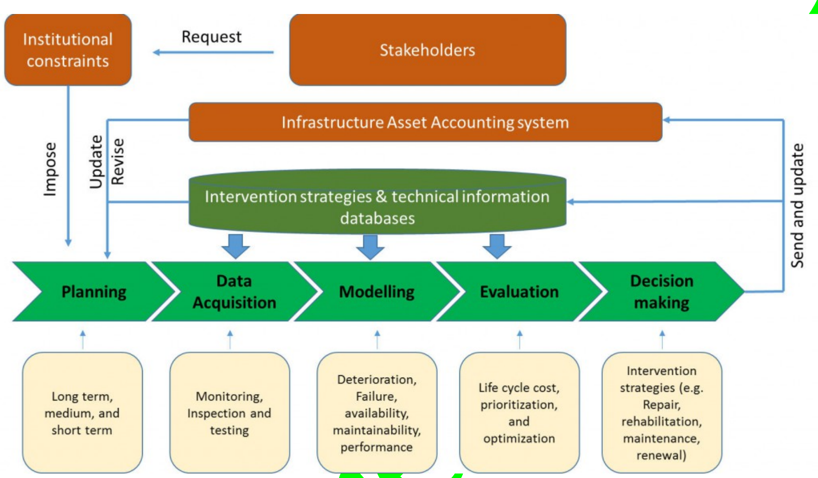


Figure 3.1: Integrated asset management approach (adopted from POM+ http://www.pomplus.vn)

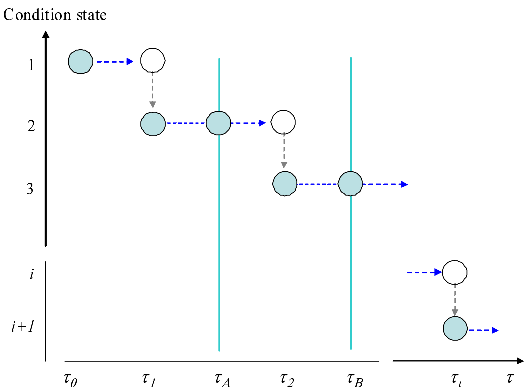
As can be seen in Figure 3.1, we sees the overall picture of works that should be executed in close connection to each other in order to make a full cycle of asset management effectively.

Works associated with auditing equipment and facilities of pump stations and reservoirs, coming up with a preventive maintenance program, tendering, and detailed design can be described explicitly using the framework in Figure 3.1. For example, various type of data concerning physical and operational condition and performance of equipment and facilities will be collected, filtered, and analyzed (Data Acquisition); the data will be further used for modeling purposes (e.g. prediction of failure rate, draw deterioration curve, reliability and efficiency); life cycle cost analysis will be then performed for each equipment and for its system. In this process, either prioritization or optimization technique can be used; finally a set of preventive maintenance intervention strategies will be generated for decision making purposes.

3.2 Deterioration process and rating index

In order to analyze and forecast the deterioration of assets, it is necessary to accumulate time series data on the CS of the assets. The historical deterioration process of an asset is described in Figure 3.2. This figure shows the deterioration progress of a component that has not been repaired. In reality, there exists uncertainty in the deterioration progress of the asset, and moreover, the CS at each point in the time axis is restricted by the time, at which, visual inspection is carried out.

In this figure, τ represents real calendar time (the expression "time" will be used instead throughout this paper). The deterioration of the asset starts immediately after it begins to operate at time τ_0. The CS of an asset is expressed by a rank J representing a state variable i $(i = 1, \cdots, J)$. For a component in the good or new situation, its condition state is given as $i = 1$, and increasing of CS i describes progressing deterioration. A value of $i = J$ indicates that an asset has reached its service limit. In Figure 3.2, for each discrete time τ_i $(i = 1, \cdots, J-1)$ on the time-axis, the corresponding CS has increased from i to $i+1$. Hereinafter τ_i is referred to the time a transition from a CS i to $i+1$ occurs.



Note) In this example, the deterioration process of a infrastructure component if expressed in terms of calendar time $\tau_1, \tau_2, ..., \tau_i$, and condition state of the section is increased in unitary units.

Figure 3.2: Transition Time of Condition State (adopted from [13]).

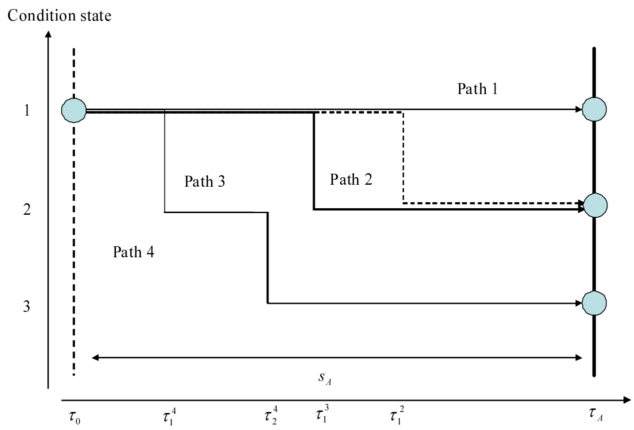
Information regarding the deterioration process of an asset can be acquired through periodical visual inspections. However, information on the CS based on continuous visual inspection is difficult to obtain. In this case, the initial inspections is carried out at times τ_A on the time-axis. It is supposed that at time τ_A the CS observed by inspection is i $(i = 1, \cdots, J-1)$. The deterioration progress in future times is uncertain. Among the infinite set of possible scenarios describing the deterioration process only one path is finally realized.

Figure 3.3 shows four possible sample paths. Path 1 shows no transition in the CS 1 from initial time τ_0 to first inspection time τ_A. In paths 2 and 3, CS has advanced to one upper CS at the calendar times τ_1^2 and τ_1^3 respectively. The CS of these two paths observed at time τ_A become 2. In a periodical inspection scheme, the point times τ_1^2 and τ_1^3 in which the CS has changed from 1 to 2 are not determined. In addition, path 4 shows transitions in the CS at times τ_i^4 and τ_{i+1}^4 during the inspection interval. The CS observed at time τ_A becomes 3. That is, in spite of the transitions in the CS are observable at the time of periodical inspection, it is not possible to obtain information about the times in which those transitions occur.

Figure 3.4 further describes the deterioration process inferring the inspection approach and how the CS is assumed. In this figure, it is assumed that the CS at the calendar time τ_{i-1} has changed from $i-1$ to i. The calendar time τ_{i-1} is assumed to be equivalent to $y_i = 0$. The time represented by the sample time-axis is referred from now on as a "time point", and differs from "time" on the calendar time axis. The times τ_A and τ_B correspond to the time points y_A and y_B on the sample axis. It can be seen that $y_A = \tau_A - \tau_{i-1}$, $y_B = \tau_B - \tau_{i-1}$.

Information on the CS i at the beginning of the calendar time τ_{i-1} cannot be obtained in a periodical inspection scheme. Therefore, time points y_A and y_B on the sample time-axis cannot be correctly obtained either. For convenience of description, it is assumed that the information at the time a point is known in order to develop the model, despite this assumption is not necessarily essential. The following paragraph discusses that even without information at time points y_A and y_B an exponential hazard model can be estimated.

In the case the CS of an asset at time τ_i (time point y_C) is assumed to change from i to $i+1$, the period length in which the CS has remained at i (referred as the life expectancy of a CS i) is represented by $\zeta_i = \tau_i - \tau_{i-1} = y_C$. The life expectancy of a CS i is assumed to be a stochastic

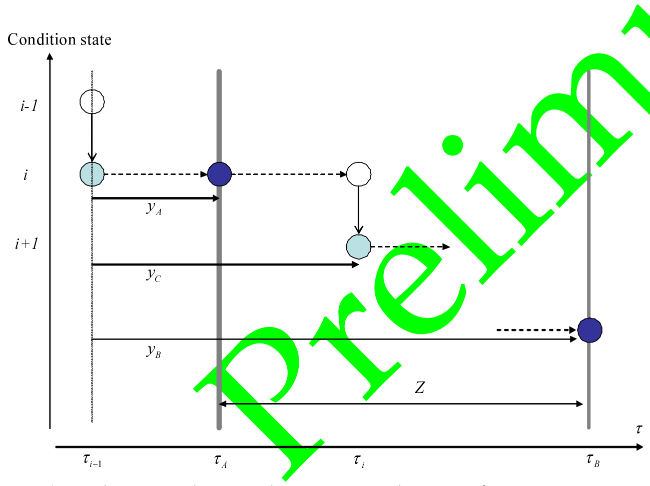


Note) In this example, the deterioration process of an asset is expressed in terms of four different sample paths. In paths 2 and 3 the CS has advanced to one upper CS at the calendar times τ_1^2 and τ_1^3 respectively. In path 4, the CS has increased one state at each time τ_1^4 and τ_2^4. However, in the case of a periodical inspection carried out at times τ_A the CS at any point in time between inspections cannot be observed.

Figure 3.3: Transition Pattern of Condition State.

variable ζ_i with probability density function $f_i(\zeta_i)$ and distribution function $F_i(\zeta_i)$. Random variable ζ_i is defined in the domain $[0, \infty]$. The distribution function is defined as

$$F_i(y_i) = \int_0^{y_i} f_i(\zeta_i) d\zeta_i. \tag{3.1}$$



Note) In the case the condition state changes from $i-1$ to i at the calendar time τ_{i-1} the inspections carried out at times τ_A and τ_B will also correspond to the points in time y_A and y_B when using τ_{i-1} as the time origin. The figure shows a sample deterioration path in which the condition state has advanced in one unit to y_c in the interval time $\tau_{i-1} - y_C$. However, observations at time τ_{i-1} are not possible in a periodical inspection scheme, so there is no way to obtain observation at y_A, y_B and y_C. Nevertheless, it is possible to use the information contained in $z = y_C - y_A \in [0, Z]$.

Figure 3.4: Model of Deterioration Process.

The distribution function $F_i(y_i)$ represents the cumulative probability of the transition in the CS from i to $i+1$. CS i is assumed to be observed at initial time $y_i = 0$(time τ_A). The time interval measured along the sample time-axis until the time point y_i is $\tau_{i-1} + y_i$. Therefore, using the cumulative probability $F_i(y_i)$, the probability $\tilde{F}_i(y_i)$ of a transition in the CS i during the time points interval $y_i = 0$ to $y_i \in [0, \infty]$ is defined by $\tilde{F}_i(y_i)$:

$$\text{Prob}\{\zeta_i \geq y_i\} = \tilde{F}_i(y_i) = 1 - F_i(y_i). \tag{3.2}$$

The conditional probability that the CS of an asset at time y_i advances from i to $i+1$ during the time interval $[y_i, y_i + \Delta y_i]$ is defined as

$$\lambda_i(y_i)\Delta y_i = \frac{f_i(y_i)\Delta y_i}{\tilde{F}_i(y_i)}, \tag{3.3}$$

where the probability density $\lambda_i(y_i)$ is referred as the hazard function.

3.3 Condition State (CS) definition

Condition of an asset can be described either by a range of discrete condition state (CS) or by continuous values of one or more than one parameters such as cracking, thickness, and corrosion. In asset management practice, discrete range of CS is often for the following reasons:

- It can be converted/mapped from continuous value of monitoring data;
- It is convenient for non-technical persons and managers;
- It is suitable for determination of intervention strategy and thus for life cycle cost modeling.

Assets in pump stations are different in category and functionality, thus it is not easy to define a universal range of CSs. However, it is possible that a generic range of CSs can be used to map appropriately different type of assets. In this project, following definitions are used for multiple CSs (Table 3.1) and binary state (Table 3.2) systems.

Table 3.1: Condition state definition - Multiple.

CS i	Definition	Require Intervention	Remarks
1	New/likely new and provide adequate LOS	No	Good (None/Insignificant)
2	Install <=5 years, provide adequate LOS	No	Acceptable (Minor)
3	Moderate aging, not provide adequate LOS, observed moderate breakdown	Yes	Damaged (Significant)
4	Moderate aging, not provide adequate LOS, require frequent CI and PI	Yes	Poor (Extensive)
5	Aging and not provide adequate LOS	Yes	Safety is endangered

Table 3.2: Condition state definition - Binary.

CS i	Definition	Require Intervention	Remarks
0	Not provide adequate LOS	No	
1	Provide adequate LOS	Yes	

3.4 Technical efficiency

Technical efficiency is a coefficient measured as the ratio of actual parameter value and expected/design parameter value. In case of PSs, TE is often discussed around the value of pump efficiency (η), which is a factor that accounts for the kinetic energy lost during the operation [7]. The PE is a product of the followings:

- Hydraulic efficiency (primarily, disk friction against the liquid with impeller shrouds). This efficiency is contributed by the speed and impeller geometry. Shock losses during rapid changes in direction along the impeller and volute can also resulted in additional shock losses;
- Volumetric efficiency (recirculation losses at wear rings, interstage bushes and other);
- Mechanical efficiency (friction at seals or gland packing and bearings)

Hydraulic efficiency and volumetric efficiency are used at the design stage of PS when there is a need to determine suitable pump or group of pumps that satisfies the designed LOS. Whilst, mechanical efficiency is used to determine operational efficiency once pumps are in used.

The mechanical efficiency (η_m) is estimated based on the equation 3.4

$$\eta_p = \frac{P_W}{P_B} \tag{3.4}$$

Where P_W and P_B are water power and brake power, respectively.

Following equations are used to calculated the P_W and P_B:

$$P_{W(kW)} = \gamma \times H \times Q \tag{3.5}$$

$$P_{B(kW)} = P_E \times e_m \tag{3.6}$$

where

P_W	*Water power (kW);*
P_B	*Brake power (kW);*
P_E	*Electric power (kW);*
Q	*Water flow rate (m^3/s);*
H	*Head produced by pump (m_{H_2O});*
η_e	*Motor efficiency (%);*
γ	*specific weight of fluid (water) (kN/m^3).*

3.5 Reliability

3.5.1 Qualitative and Operational Analysis

3.5.1.1 Failure Mode and Effects Analysis (FMEA)

An FMEA is often the first step of a system reliability study. It involves reviewing as many components, assemblies, and subsystems as possible to identify failure modes, and their causes and effects. FMEA is an inductive reasoning (forward logic) single point of failure analysis and is a core task in reliability engineering, safety engineering and quality engineering.

A successful FMEA activity helps identify potential failure modes based on experience with similar products and processes—or based on common physics of failure logic. It is widely used in development and manufacturing industries in various phases of the product life cycle.

Functional analyses are needed as an input to determine correct failure modes, at all system levels. The FMEA is in principle a full inductive (forward logic) analysis, however the failure probability can only be estimated or reduced by understanding the failure mechanism. Hence, FMEA may include information on causes of failure (deductive analysis) to reduce the possibility of occurrence by eliminating identified (root) causes.

3.5.1.2 Reliability Centered Maintenance (RCM)

Reliability-centered maintenance (RCM) is a process to ensure that systems continue to do what their user require in their present operating context. It is generally used to achieve improvements in fields such as the establishment of safe minimum levels of maintenance. Successful implementation of RCM will lead to increase in cost effectiveness, reliability, machine uptime, and a greater understanding of the level of risk that the organization is managing. It is defined by the technical standard SAE JA1011, Evaluation Criteria for RCM Processes.

Reliability centered maintenance is an engineering framework that enables the definition of a complete maintenance regimen. It regards maintenance as the means to maintain the functions a user may require of machinery in a defined operating context. As a discipline it enables machinery stakeholders to monitor, assess, predict and generally understand the working of their physical assets. This is embodied in the initial part of the RCM process which is to identify the operating context of the machinery, and write a Failure Mode Effects Analysis (FMEA). The second part of the analysis is to apply the "RCM logic", which helps determine the appropriate maintenance tasks for the identified failure modes in the FMEA. Once the logic is complete for all elements in the FMEA, the resulting list of maintenance is "packaged", so that the periodicities of the tasks are rationalised to be called up in work packages; it is important not to destroy the applicability of maintenance in this phase. Lastly, RCM is kept live throughout the "in-service" life of machinery, where the effectiveness of the maintenance is kept under constant review and adjusted in light of the experience gained.

RCM can be used to create a cost-effective maintenance strategy to address dominant causes of equipment failure. It is a systematic approach to defining a routine maintenance program composed of cost-effective tasks that preserve important functions.

3.5.2 Weibull model

In hazard analysis, the deterioration of element is subjected to follow a stochastic process [12]. For binary state system, two condition level $0, 1$ are often used. When receiving a PI or CI, the CS from 1 must be changed into 0. In reliability study, this process is often regarded as renewal process. The renewal is carried out at alternative time t_k $(k = 0, 1, 2, ...)$. In this way, the next renewal time is denoted as $t = t_0 + \tau$, where τ indicating the elapsed time. The life span of an asset is expressed by a random variable ζ. The probability distribution and probability density function of the failure occurrence are $F(\zeta)$ and $f(\zeta)$ respectively. The domain of the random variable ζ is $[0, \infty]$. The living probability (hereafter named as survival probability) expressed by survival function $\tilde{F}(\tau)$ can be defined according to the value of failure probability $F(\tau)$ in the following equation:

$$\tilde{F}(\tau) = 1 - F(\tau). \tag{3.7}$$

The probability, at which the asset performs in good shape until time τ and break down for the first time during an interval of $\tau + \Delta\tau$ can be regarded as hazard rate and expressed in the following equation:

$$\lambda_i(\tau)\Delta\tau = \frac{f(\tau)\Delta\tau}{\tilde{F}(\tau)}, \tag{3.8}$$

where $\lambda(\tau)$ is the hazard function of the asset. In reality, the breakdown probability depends largely on the elapsed time of the asset since its beginning of operation. Thus, the hazard function should take into account the working duration of the asset (time-dependent). In another word, the memory of the system should be inherited. Weibull hazard function is satisfied in addressing the deterioration process [2, 11]:

$$\lambda(\tau) = \frac{1}{\eta}\beta\tau^{\beta-1}, \tag{3.9}$$

where η is the scale parameter expressing the arrival density of the asset, and β is the acceleration or shape parameter. The probability density function $f(\tau)$ and survival function $\tilde{F}(\tau)$ in the form of Weibull hazard function can be further expressed in equation (3.10) and (3.11):

$$f(\tau) = \frac{1}{\eta}\beta\tau^{\beta-1}\exp(-\alpha\tau)^{\beta}, \tag{3.10}$$

$$\tilde{F}(\tau) = \exp(-\frac{1}{\eta}\tau)^{\beta}. \tag{3.11}$$

Estimation for Weibull's parameter is often with Maximum Likelihood Estimation (MLE) approach on historical data. Thus, the model's parameter is sensitive to how data behaves. We recommend to use this model only when there is sufficient data to be used.

An example of source code for education purpose is given in Github site of Nam Le [1]. The complete program is a copyright of Nam Le.

3.5.3 Markov model

The transition process among the condition states of an infrastructure component is uncertain. Therefore, future condition states cannot be forecasted deterministically. In this situation, Markov transition probability is employed to represent the uncertain transition pattern of the condition states during two time points. Markov transition probabilities can be defined for arbitrary time intervals.

For simplification, Markov transition probabilities can be defined and used to forecast the deterioration of a infrastructure component based on the information from periodical inspection scheme shown in Figure 3.4. The observed condition state of the component at time τ_A is expressed by using the state variable $h(\tau_A)$. If the condition state observed at time τ_A is i, then the state variable $h(\tau_A) = i$. A Markov transition probability, given a condition state $h(\tau_A) = i$ observed at time τ_A, defines the probability that the condition state at a future time (τ_B for example) will change to $h(\tau_B) = j$:

$$\text{Prob}[h(\tau_B) = j | h(\tau_A) = i] = \pi_{ij}. \tag{3.12}$$

The Markov transition probability matrix can be defined and rearranged by using the transition probabilities between each pair of condition states (i, j) as

$$\mathbf{\Pi} = \begin{pmatrix} \pi_{11} & \cdots & \pi_{1J} \\ \vdots & \ddots & \vdots \\ 0 & \cdots & \pi_{JJ} \end{pmatrix}. \tag{3.13}$$

The Markov transition probability (3.12) shows the transition probability between the condition states at two given times τ_A and τ_B, therefore, it is straightforward that the values of a transition probability will differ for different time intervals. Since deterioration continues as long as no repair is carried out $\pi_{ij} = 0$ $(i > j)$. From the definition of transition probability $\sum_{j=1}^{J} \pi_{ij} = 1$. Following conditions must be satisfied:

$$\left.\begin{array}{l} \pi_{ij} \geq 0 \\ \pi_{ij} = 0 \ \ (\text{when } \ i > j) \\ \sum_{j=1}^{J} \pi_{ij} = 1 \end{array}\right\}. \tag{3.14}$$

The worse level of deterioration is expressed by the condition state J, which remains as an absorbing state in the Markov chain as long as no repair is carried out. In this case $\pi_{JJ} = 1$.

Markov transition probabilities are defined independently from the deterioration history. As shown in Figure 3.4, the condition state at the inspection time τ_A is i, however, the time, at which, condition state changed from $i - 1$ to i is unobservable. In a Markov chain model, it is assumed that the transition probability between the inspection times τ_A and τ_B is only dependent on the condition state at time τ_A.

The Markov chain model is operative and widely applied in management of infrastructure system. Particularly, at management of network level, Markov chain model is used to define the average transition probability of the entire system, or a group of infrastructure components given two periodical inspection data.

Estimation for the Markov transition probability can be done by the MLE approach [12, 13] or Bayesian Estimation approach [8, 10] based on historical data. One advance of using the Markov model is that one time monitoring data can be used. A generic formula to estimate the transition probability is given in following Equations:

[1] https://github.com/namkyodai/Models

$$\pi_{ii} = \exp(-\theta_i Z), \tag{3.15-a}$$

$$\pi_{ii+1} = \frac{\theta_i}{\theta_i - \theta_{i+1}} \{-\exp(-\theta_i Z) + \exp(-\theta_{i+1} Z)\}, \tag{3.15-b}$$

$$\pi_{ij} = \sum_{k=i}^{j} \prod_{m=i}^{k-1} \frac{\theta_m}{\theta_m - \theta_k} \prod_{m=k}^{j-1} \frac{\theta_m}{\theta_{m+1} - \theta_k} \exp(-\theta_k Z), \tag{3.15-c}$$

$$\pi_{iJ} = 1 - \sum_{j=i}^{J-1} \pi_{ij}, \tag{3.15-d}$$

$$(i = 1, \cdots, J-1) \quad (j = i, \cdots, J).$$

An example of source code for education purpose is given in Github site of Nam Le [2]. The complete program is a copyright of Nam Le.

3.6 Intervention Strategy (IS)

Intervention Strategy (IS) is at asset level (level 7). It is a collection of intervention type for component level (level 8). A collection of ISs will form an Intervention Program for (IP) the station. A collection of IPs will form a Work Program (WP) for network level intervention (e.g. a bid awarded for a designer/contractor can be a WP that consists of intervention program for one or more than one pump stations). Following generic IS is defined to guide the selection of IPs that will be details in the later part of the report.

Table 3.3: Generic intervention strategy (IS).

IS	Definition	Remarks
1	Do Nothing	
2	Minor repair	Require minimal effort and can be done only for certain asset type
3	Major repair	Require extensive efforts to return the asset to likely new condition
4	Replacement/Renewal	Replacing assets or components of asset with identical one or with new model

For each type of asset, IS will be selected based on reliability study and consideration of cost. Further more, Employers inputs and requirements are also taken into account.

3.7 Determination of optimal intervention strategy

Following subsections briefly describe the model that can be used to determine optimal intervention strategy.

3.7.1 Block Replacement Model

It is assumed that a PI is executed after a pre-defined time $n \cdot T$ ($n = 0, 1, 2, \cdots, N$). Once the PI is executed, the functionality and serviceability of the asset could be the same or different from that of the asset before the intervention. In between the time Δt ($[0 \leq \Delta t \leq T]$), hazards could occur and cause the asset in worse CSs (hereafter denoted as i ($i = 1, \cdots, I$)), in which the asset is no longer providing an adequate level of services (LOS). In both cases, when the PI or CI is executed, there are impacts incurred by stakeholders s (e.g. the owner, the users, the public).

Following notations are used to describe the formulation of the model.

[2] https://github.com/namkyodai/Models

$\theta(\Delta t|t)$ Conditional failure rate i ($i = 1, \cdots, I$) when the asset has been in service in an interval t after the PI

$\Psi(\cdot|t)$ Any conditional function Ψ given that a PI is executed by a unit of age t, where t is a random variable

$F(t)$ Cumulative distribution function (cdf) of age t of a unit for a PI at execution time

$w_p^s(t)$ Impacts incurred by stakeholder s due to the execution of PI

$w_c^s(t)$ Impacts incurred by stakeholder s due to the execution of CI

$w_o^s(\Delta t|t)$ Conditional impacts incurred by stakeholder s when the structure is remains in normal operation (*i.e.* providing an adequate LOS) during time interval Δt after a PI has been carried out and the asset has not entered failure state

ρ discount factor

$p_l^k(t)$ probability of failure at time t of the affecting other assets k

$C_c^{s,k}$ Impacts incurred by stakeholder s due to the execution of an CI on other assets k

T interval between the PIs

$T^\star$ Optimal interval time between PIs, which is the variable of the model

$\Omega_p(T,t)$ minimum expected total discounted impact for an infinite time span when the asset has been in service during an interval t after the execution of the PI and the asset has not entered failure state

$\Omega_c(T,t)$ minimum expected total discounted impact for an infinite time span when a CI has been executed, of the asset that has been in service during a time interval t after the execution of the PI and the asset has entered failure state

In the model, it is assumed that at each damage level i, there exists a corresponding well defined CI. Within an increment of time Δt, after the asset has been under the PI after time t, the total expected impacts due to the execution of CIs are:

$$v_c(\Delta t|t) = \sum_{s=1}^{S} \left[w_c^s(\Delta t) + \sum_{k=1}^{K} p_l^k \cdot C_c^{s,k} \right] \cdot \theta(\Delta t|t). \tag{3.16}$$

The total impacts due to the execution of PIs and the total impacts incurred by stakeholders during the service time of the asset are defined in Eq. (3.17) and Eq. (3.18), respectively.

$$v_p(t) = \sum_{s=1}^{S} w_p^s(t). \tag{3.17}$$

$$v_o(t) = \sum_{s=1}^{S} w_o^s(t). \tag{3.18}$$

According to the principle of optimality, which is described in [1, p. 15], the minimum expected total discounted impact $\Omega_c(T,t)$ for infinite time is formulated in following equation.

$$\Omega_c(T,t) = \int_0^\infty \left[v_c(\Delta t|t) + \Omega_p(T, \Delta t|t) \right] dF(t). \tag{3.19}$$

The minimum expected total discounted impact $\Omega_p(T, \Delta t|t)$, which appears inside Eq. (3.16), is obtained as follows

$$\Omega_p(T, \Delta t) = min\Gamma(\Delta t). \tag{3.20}$$

where $\Gamma(\Delta t)$ is defined as

$$\begin{aligned}\Gamma(\Delta t) = \int_0^\infty \Big[v_o \int_0^{dt} exp(-\rho\tau)d\tau + \{1 - \theta(\Delta t|t)dt\} \cdot \Omega_p(T, \Delta t + dt|t) exp(-\rho dt) \\ + \theta(\Delta t|t)dt \cdot \Omega_c(T, \Delta t + dt|t) exp(-\rho dt) \Big] dF(t).\end{aligned} \tag{3.21}$$

According to [9], Eq. (3.21) is rewritten in following form

$$\begin{aligned}\Gamma(\Delta t) = \Omega_p(T, \Delta t) + \left[-\rho\Omega_p(T, \Delta t) + d\Omega_p(T, \Delta t)/dt \right] dt \\ + \int_0^\infty \left[v_o + v_c(\Delta t|t) \right] dF(t) dt.\end{aligned} \tag{3.22}$$

Thus, from $\Omega_p(T,\Delta t) = \Gamma(\Delta t)$ (Eq. (3.20)), the following equation can be derived:

$$\Omega_p(T,\Delta t) = exp(\rho\Delta t)\left[\Omega_p(T,0) - \int_0^\infty \int_0^t exp(-\rho\tau)\left\{v_o + v_c(\tau|t)\right\}\right] d\tau dF(t). \tag{3.23}$$

where,

$$\begin{aligned}\Omega_p(T,0) = \{1 - exp(-\rho T)\}^{-1} \int_0^\infty \Bigg[& exp(-\rho T)\left\{v_p(T,t)\right\} \\ & + \int_0^T exp(-\rho\Delta t)\left\{v_o(\Delta t|t) + v_c(\Delta t|t)\right\} dt \Bigg] dF(t).\end{aligned} \tag{3.24}$$

when T tends to infinity $T \to \infty$, Eq. (3.24) becomes

$$\Omega_p(\infty,0) = \int_0^\infty \int_0^\infty exp(-\rho t)\left[v_o + v_c(\Delta t|t)\right] dtdF(t). \tag{3.25}$$

Eqs. (3.24) and (3.25) are the explicit forms of the expected total discounted impact in infinite time horizon. This is the classical optimization problem. By differentiating the expected total discounted impact $\Omega_p(T,0)$ and $\Omega_p(\infty,0)$ and setting it equal to zero, the optimal time $T^\star$ can be obtained. The optimal time $T^\star$ for PI is the solution of the following system of equations:

$$\begin{cases} T^\star = \arg \min\limits_{T^\star \in [0,T]} \Theta_p(T,0) \\ T^\star = \arg \min\limits_{T^\star \in [0,\infty]} \Theta_p(\infty,0) \end{cases} \tag{3.26}$$

in which the differentiates of $\Theta_p(T,0)$ and $\Theta_p(\infty,0)$ are respectively:

$$\begin{aligned}\Theta_p(T,0) &= \frac{\delta(\Omega_p(T,0))}{\delta T} \\ &= [1 - exp(-\rho T)] \int_0^\infty \Bigg[-\rho v_p(T,t) \\ &\quad + d(v_p(T,t))/dT + v_o(T,t) + v_p(T,t) \Bigg] dF(t) \\ &\quad -\rho \int_0^\infty \Bigg[exp(-\rho T)\left\{v_p(T,t)\right\} \\ &\quad + \int_0^T exp(-\rho\Delta t)\left\{v_o(\Delta t|t) + v_c(\Delta t|t)\right\} dt \Bigg] dF(t).\end{aligned} \tag{3.27}$$

and

$$\begin{aligned}\Theta_p(\infty,0) &= \frac{\delta(\Omega_p(\infty,0))}{\delta T} \\ &= \int_0^\infty \Bigg[-\rho \left\{ v_p(\infty|t) + \int_0^\infty exp(-\rho t)\left\{v_o(\Delta t|t) + v_p(\Delta t|t)\right\}\right\} \\ &\quad + \lim_{T\to\infty} d(v_p(T,t))/dT + v_o(\infty|t) + v_p(\infty|t) \Bigg] dF(t)\end{aligned} \tag{3.28}$$

3.7.2 Time-dependent replacement model

Time-dependent replacement model (or Age replacement model) are the ones where the following conditions apply:

- the asset starts operating at $t = 0$, i.e. it is newly built or newly restored to a like new condition following an intervention;
- the probability of failure is described with $f(t)$ and $F(t)$, i.e. the lifetime density and the lifetime;
- if the asset fails on the interval $(0,T]$ a CI is executed;

- if the object does not fail on the interval $(0, T]$ the object is replaced at T, i.e. the PI replacement is executed, regardless if the object has failed and been restored in the time interval $(0, T]$;
- the execution of a PI restores the object to a like new condition;
- the execution of a CI restores the object to a like new condition.

3.7.2.1 Minimize impact

If an age replacement IS is followed the time to the first intervention, Z, is the minimum amount of the time to failure of the length of the renewal period:

$$Z = min(\tau, T) \tag{3.29}$$

The expected, or mean, time to the first intervention is then determined by

$$E[Z = \int_0^T (1 - F(x))dx] \tag{3.30}$$

The mean impact in one renewal period then equals the probability of failure on T multiplied by the impacts associated with the CI plus the probability that no failure occurs on T multiplied by the impacts associated with the PI:

$$F(T) \times I^{CI} + (1 - F(T)) \times I^{PI} \tag{3.31}$$

The mean impacts per unit time, therefore, equal the mean cost in one renewal period divided by the length of the renewal period, i.e. the time to the first intervention.

$$\eta_{AC} = \frac{F(T) \times I^{CI} + (1 - F(T)) \times I^{PI}}{\int_0^T (1 - F(x))dx]} \tag{3.32}$$

3.7.2.2 Maximize availability

If it is desired to determine the age replacement IS that maximizes availability the following is often assumed, additionally that:

- the PI replacement takes t^{PI};
- the PI takes t^{CI};

If the asset fails before T then the length of the renewal period will, therefore, be $X = t + t^{CI}$, which has the probability $f(t)dt$ of occurring, and if the object does not fail before T then the length of the renewal period will be $X = t + t^{PI}$, which has the probability $1 - F(T)$ of occurring.

In this case, the expected, or mean, renewal period length is:

$$E[X] = \int_0^T (1 - F(x))dx + t^{CI}F(T) + t^{PI}(1 - F(T)) \tag{3.33}$$

As the asset is operational on average $\int_0^T (1 - F(x))dx$ then the availability is given by:

$$\eta_{AA} = \frac{\int_0^T (1 - F(x))dx}{\int_0^T (1 - F(x))dx + t^{CI}F(T) + t^{PI}(1 - F(T))} \tag{3.34}$$

Chapter 4

Data and Analysis

4.1 Qualitative and Operational Analysis

4.1.1 Facts and Data

Summary of facts and data concerning operational and overall plan reliability is presented in this subsection.

4.1.1.1 Operation Scenario

- Pump station is already 17 years in operation
- 2 pumps (10hp) for Southvale but only 1 in operation at any one time. Pumps switch every 24 hours.
- 2 pumps (15hp) for Sonera but only 1 pump in operation at any one time.
  - P1 operates from 6PM to 6AM.
  - P2 operates from 6AM to 6PM.
  - P1 is used during low demand period because it cannot maintain pressure during high demand period.
- Maintain 50psi 24 hours for all distribution lines.

4.1.1.2 Spares Policy

- Since only 1 pump is used, the other acts as spare.

4.1.1.3 Emergency Situation (loss of electrical power from Meralco)

- Auto-start of pumps

4.1.1.4 Maintenance

- For operational problems, operator will call Control Center to report problem.
- Control Center to send contractor within 1 to 2 hours.
- Maintenance contractors conduct a weekly visit to do some maintenance activities.

4.1.1.5 Current (Reliability) Problems

- None.

4.1.2 Way forward/Recommendations

In order to ensure the PS to provide adequate level of services around the clock, it is important to establish a good operational scheme that allows optimization of use of pumps to reduce breakdown and to conserve energy. A summary of the observations and their corresponding recommendations to be considered are:

- There is enough flexibility in the system to allow for the smaller pumps to fail. The larger spare 15hp pump can supply the requirements. However, if P2 of the 15hp pumps fails, the system cannot maintain the 50psi requirements and there will be a loss of water to some customers. First, overhaul Sonera Service Pump1 to upgrade its performance equal to its pair Pump2. Then, consider an additional storage pump3 (15hp) to increase the reliability of the whole system (including the Sonera system).
- Consider a dedicated duty and a dedicated spare set-up for the pumps. If this is not acceptable, then consider doing a much longer switch of the storage pumps. Currently, it is being switched daily. This allows for almost an equal rate of deterioration between the two pumps and if one pump fails due to age-related component failure, the other one is close to a similar failure which may occur before the first pump is fully repaired. It is suggested that the switch happen once a month or even every 3 months.
- In place of the longer switching cycle (e.g. every 3 months), there should be a corresponding maintenance program for the standby pump for both booster and storage.
- Know what maintenance activities are done weekly and how the contractors/Maynilad use the information gathered to predict equipment failures.
- Develop a more structured discipline in applying routine maintenance work process to ensure that maintenance tasks are given the proper priority in terms of mitigation measures and avoid unplanned shutdown of critical pumps in operation.

Aside from the above recommendations, we also generate a list of recommendations based on the RCM methodology. This is presented at at the end of the document (refer to Appendix)A). The list shall be considered as a living program, which requires continuously improvement as part of the total quality management system (refer to Deming cycle presented in GHD's technical proposal).

4.2 Pump discharge and suction pipe - thickness

4.2.1 Data and measurement

Thickness data on discharge and suction pipes of pumps is presented in Table 4.1 and the positions and the distances for the Ultrasonic Thickness Gauging (UTG) are referred to Figure 4.1 and Figure 4.2.

4.2.2 Analysis

This section provides analysis/discussion on estimation of minimum allowable thickness of pipes and statistics around the measured data collected during inspection and testings.

<u>Sonera BP1</u>

- Suction Piping System-Suction side thickness is not critical when compared to the discharge side of the pump.
- Discharge Piping System- The discharge pipe side of the pump is not so critical, however, this sonera pump has lower thickness when compared to the other sonera pump by around 92 - 97 percent which might be associated to the health condition of the pump - which as per vibration analysis is not acceptable.

Table 4.1: Thickness data - Booster Pumps (mm).

Asset	Position	Distance					
		Suction	Discharge				
		1.0 m	0.7 m	1.2 m			
Sonera BP1	12	13.82	6.92	-	-	-	-
	3	14.25	6.71	-	-	-	-
	6	14.21	6.91	-	-	-	-
	9	-	6.67	-	-	-	-
Sonera BP2	12	13.02	7.19	6.12	-	-	-
	3	13.62	7.07	6.21	-	-	-
	6	14.22	7.12	6.14	-	-	-
	9	-	7.21	6.38	-	-	-
		-	A	B	C	D	E
Sonera Main Line	12	-	5.68	6.07	6.16	6.08	6.09
	3	-	5.71	6.16	6.14	5.78	6.18
	6	-	5.98	6.12	6.36	5.75	5.92
	9	-	5.44	6.13	6.08	5.62	6.03
Spare 1	12	13.31	-	-	-	-	-
	3	13.22	-	-	-	-	-
	6	14.38	-	-	-	-	-
	9	-	-	-	-	-	-
Spare 2	12	13.35	-	-	-	-	-
	3	12.82	-	-	-	-	-
	6	14.04	-	-	-	-	-
	9	-	-	-	-	-	-
		-	0.7 m	1.0 m	1.3 m	1.6 m	2.5 m
Southvale BP1	12	14.55	6.56	6.38	5.41	6.23	8.08
	3	13.43	6.73	6.39	5.36	6.22	8.32
	6	13.21	6.55	6.67	5.83	6.19	8.15
	9	-	6.83	6.31	5.93	6.19	-
Southvale BP2	12	14.83	6.88	6.25	5.32	6.27	8.11
	3	14.15	6.68	6.24	5.83	6.21	8.4
	6	13.21	6.54	6.32	5.88	6.5	8.02
	9	-	6.82	6.24	5.42	6.28	-

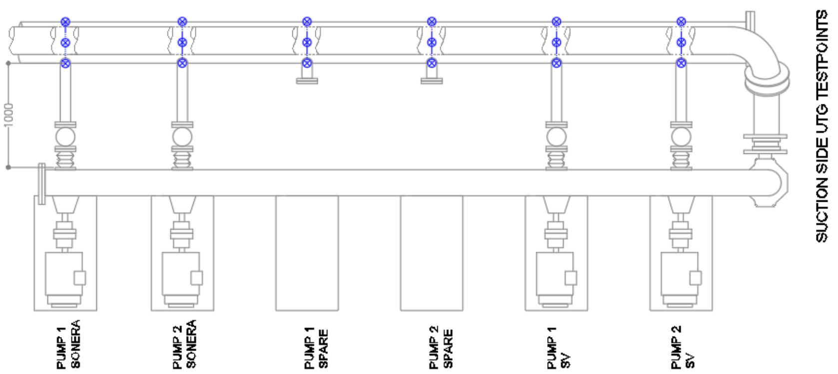


Figure 4.1: Positions and distances of UTG - Booster Pump Suction Side

<u>Sonera BP2</u>

- Suction Piping System- In comparison to the thickness at the discharge side, suction side is thinner by a great number, almost a factor of two thus this side is relatively not critical compared to the discharge side.

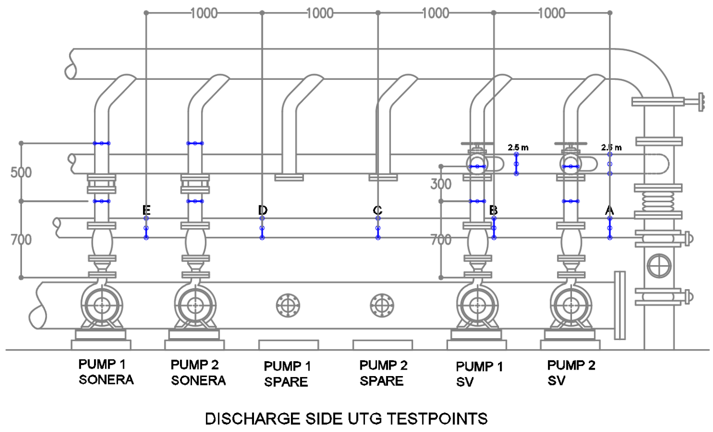


Figure 4.2: Positions and distances of UTG - Booster Pump Discharge Side

- Discharge Piping System- This pump is observed to have a thinner section at 1.2 m compared to that of in 0.7 m from the pump flange. It has a 2.14 mm per m of length of pipe but, the thickness of the 0.7 m of Sonera Pump 2 is thicker than of Pump 1, and thus might be projected that Pump 1 might have thinner 1.2 m section that of Pump 2. Such factor might be associated to its pump performance over time and possible system operations reconfigurtion that need to be analyzed further to have a concrete comparison of Sonera BP1 and BP2.

<u>Southvale BP1</u>

- Suction Piping System- Suction side is not critical when compared to the discharge side of the pump. The distance between pumps is 1 meter. When the suction header is to be analysed, it can be observed that the flow of water from Sonera BP1 1 up to Southvale BP2 has a thinning pattern, that might corresponds to its flow pattern. It can be seen that the flow from the start of the header (referenced to Pump 1) flows in the top of the piping, continued and swirls slowly clockwise (referenced by facing the reservoir) to the 3 o'clock position for 2 meters and then flows at the bottom in a span of 2 meters again. This might means that the flow of water in the suction header does not flow erratically as the other pump suction sides.

- Discharge Piping System- The 1.3 m section of the discharge side is the thinnest part of the section with thickness of 5.36 mm to 5.93 mm, minimum and maximum , respectively. This is apparent to that section, which is the turning area of an elbow. This might means that it receives most of the shearing energy of the water flow due to the change in direction and momentum. It is also evident that the both 1.0 m and 1.6 m section of the discharge line has the next thinnest section, because these sections are the entering and exiting part of the bend.

<u>Southvale BP2</u>

- Suction Piping System- Thi side is not critical when compared to the discharge side of the pump, similar with the other pumps where the thickness is twice greater than of the discharge side.

- Discharge Piping System- The 1.3 m section of this pump is the thinnest section of the discharge side as it might receives the shearing effect of the change in direction of the water flowing in it. It is also evident that the pre- and pro-elbow sections have thickness difference when compared to the 0.7 m section of the pump. .

4.2.2.1 Assumptions

Following assumptions are used in calculating the required thickness of pipe

- Maximum Working Head – based on the design drawings and pump nameplate;
- Pipe Material – assume pipe material is ASTM A570 Grade 33 (market available material for spiral welded pipe);
- Design Guide – basis used for the simulated calculation is AWWA Manual M11 – Steel Pipe, A Guide for Design and Installation, 4th Edition. Statement for corrosion allowance is located at Chapter 4, which states *"At one time, it was a general practice to add a fixed, rule-of-thumb thickness to the pipe wall as a corrosion allowance. This was not an applicable solution in the water work field, where standard for coating and lining materials and procedures exists. The design shall be made for the required wall-thickness pipe as determined by the loads imposed, then linings, coatings, and cathodic protection selected to provide the necessary corrosion protection"*;
- Thickness calculation will be based on the internal pressure. External pressure will not be considered because much of the discharge line is not buried.
- Surge Pressure was not considered since there are surge protection along the line.
- This document will only consider the calculation of the minimum thickness along the discharge line since this is the part of the system where maximum pressure is experience.

4.2.2.2 Limitations

As confirmed by Maynilad, there is no available data regarding the design report. Design assumptions herein may be different from what was used by the designer/contractor of this station.

This document will not be able to provide the corrosion/degradation factor of the pipe since there is no available historical data on the thickness of the pipe.

4.2.2.3 Parameter values for thickness estimation

In order to estimate the minimum allowance thickness for pipes in straight line considering material handling (t_{mh}) and maximum internal pressure based on AWWA M11 (t_{sph}), following equations are used, respectively:

$$t_{mh} = \frac{\Phi}{\delta} \tag{4.1}$$

$$t_{sp} = \frac{\epsilon \times P_{max} \times \Phi}{2 \times S_e} \tag{4.2}$$

where P_{max} is maximum internal pressure

$$P_{max} = \frac{\rho_{H_2O} \times g \times H_{max}}{1000} \quad (4.3)$$

In order to estimate the minimum allowance thickness for pipes at elbows (Miter Bend), only maximum internal pressure is considered:

$$t_{mb} = \frac{P_{max} \times \Phi}{2 \times S_e} \times \left[1 + \frac{\Phi}{(3 \times R) - (1.5 \times \Phi_d)}\right] \times \epsilon \quad (4.4)$$

Paramater values used for computation are given in Table 4.2

Table 4.2: Parameter values for thickness estimation.

Parameters	Symbol	Unit	Pumps	Remarks
			Booster	
Discharge diameter	Φ_d	mm	150	
Max flow rate	Q_max	m^3/s	0.0094	nameplate data
Max pump head	H_max	m	46	nameplate data
Yield strength of material	S_y	MPa	227.5	ASTM A570 Grade 33, spiral welded pipe based on AWWA C200
Allowable stress	S_e	MPa	113.75	
Density of water	ρ_{H_2O}	kg/m^3	1000	
Gravity constant	g	m/s^2	9.81	
Safety factor	ϵ		1.5	
Bulk modulus of compressibility of liquid	k	Pa	2.1E+09	
Young's modulus of elasticity of pipe wall	E	Pa	2.1E+11	
Radius of Elbow	R	mm	225	
Emprical constant	δ		288	

4.2.2.4 Required thickness

Results of computation for minimum allowable thickness for booster pumps and storage pumps are given in Table 4.3.

Table 4.3: Minimum thickness allowance.

Pumps	Internal pressure (Mpa)	Minimum allowable thickness (mm)		
	P_{max}	t_{mh}	t_{sp}	t_{mb}
Booster	0.451	0.521	0.595	0.793

4.2.2.5 Recommendations

Given the current thickness of pipe the lack of design information, it is advisable to

- Not perform any major intervention on the pipes;
- Keep regular testing on exact locations using the same type of UTG device. It is important for Maynilad to establish a testing regime for obtaining thickness at exact same location over time (e.g. every year). Information obtained from testing will be then used to compute deterioration rate based on thickness value;
- Establish an approach to inspect/test the thickness of underground pipe, which is considered to be more vulnerable to leakage and corrosion on external wall;

- The elbows in the suction and the discharge piping systems must be monitored regularly;

- It is recommended to have a profiling of the piping systems above and below the ground in order to have a baseline in the analysis of the Maynilad Piping System. In order to have a profiling of pipe thickness at differential time T, additional measurement at similar locations shall be conducted periodically, behavior can then be monitored;

- Perform coating regularly of the pipe to prevent possible corrosion/errosion and damage that cause by external factors and surrounding condition;

4.3 Visual Inspection on Pipe, valves, fittings, supports, expansions, and appurtenances

4.3.1 Highlights

Visual inspection data on pipes, valves, fittings, supports, expansions, and appurtenances is highlighted in Table 4.4.

Table 4.4: Highlights of visual inspection

No.	Items	Remarks
1	Existing suction pipe and fittings	Suction line too short and is jam packed with fittings. Does not promote good flow development. Intake water will be turbulent and is not desired
2	Discharge piping and fittings	Pressure gauge near pump discharge is prefered for measuring head of indivual pump
2	Pump vibration isolation	Does not appropriately serve its function to isolate vibration from building and reduce noise
3	As built difference	Actual system contain many differences from provided copy of old as-built including valve positions and pipe design
4	Pump foundation block	Unitary block with multiple slots and may
5	Space	Modifications for improvement are possible because of available space inside pump room
6	Instrumentation and monitoring	Pump instrumentation do not include PLC and other important parameters typically displayed by PLC not monitored

Visual inspections are supported with the photos taken at particular locations/positions in question.

The pump station is situated in Ayala Southvale subdivision where the available space is quite ample relative to the other stations. As earlier mentioned, the station services two areas namely, Southvale and Sonera. Two 10HP long coupled pumps (Figure 1.1 - a) deliver to Southvale and another two 15HP close coupled pumps (Figure 1.1 - b) deliver water for Sonera area. In contrast to other pumping stations, the pumps and motors installed have relatively smaller capacity.

Machine support

The four booster pump units in this station are bolted onto spring-mounted baseplates (Figure 4.3) typical of small Goulds pumps installations. Designed to allow displacement under applied loads associated with thermal expansion of piping, such as those employed in small chilled water or hot water systems, said spring-mounted baseplates typically sit or slide on a smooth floor. However, the station designers choose to bolt the spring mounts onto concrete blocks, which defeats the purpose of the spring-mount design. (Refer to Goulds Pumps Installation, Operation and Maintenance Instructions.)

If possible, it is best to inquire the station designers to re-examine the assumptions or reasons behind this unusual mounting design.

a - Southvale service pump baseplate

b - Sonera service pump baseplate

c - Deflection Spring Mounting Assembly

Figure 4.3: Spring Mounted Baseplates

On another point of view, assemblies on the pump mounting such as spring isolators are for isolating or reducing the damaging structure vibration and annoying vibration induced noise produced by the mechanical equipment. This is designed for modern buildings with which vibration and noise can become the major source of occupant complaint. Also, installation of vibration isolators is for the purpose of protecting the building from micro-vibrations which could potentially lead to structural failures.

Special spring isolators are important and appropriate for industries that have sensitive process machining, where more damping is required and less motion can be tolerated due to certain special requirements, precision for example. Special cases such as wind loads will require isolators for pumps or fans of cooling towers and condensers. None of the conditions stated above do not fit the situation for the pump station. Vibration isolators are not necessary for the pump system. Furthermore, springs might have deteriorated with time and might need to be removed and the equipment foundation and mounting be refurbished.

Pipe design and flow profile Fittings neary the pump intake will cause flow disturbances and turbulence (Figure 4.4)

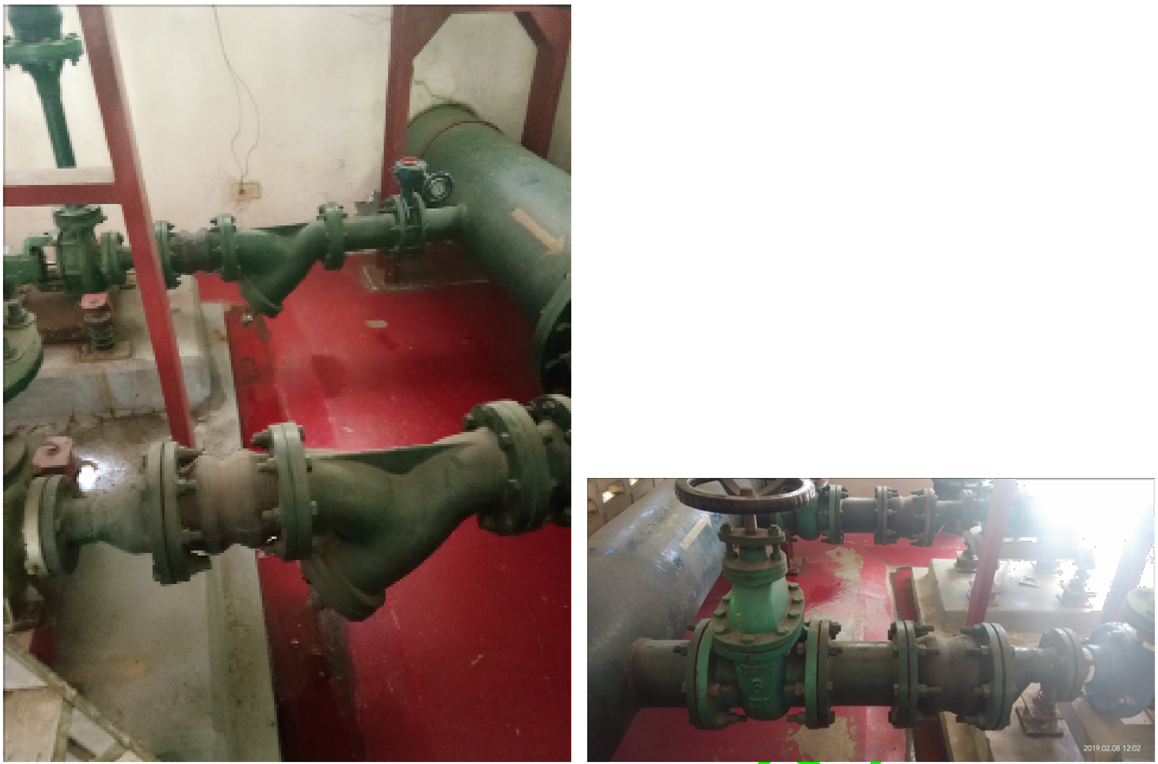
It is important to observe good flow development for water as it enters the pump. As is always noted, a developed water inflow helps in the reducing vibration, cavitation, noise and many other problems that will occur in long term operation of the pump. In this regard, it is best to reinstall the pump and lengthen the suction pipe and reposition them. Follow recommended straight pipe provisions, resize the existing pipe diameters and refurbish the machine mounting and foundation to improve pump performance. on the other end the foundation blocks instead. Since in actual, the jockey pumps are not really needed, the foundation block for pump 1 might as well be refurbished. Even then, these changes are only quick fixes and do not really involve massive overhaul or redesign of the whole system but will definitely help improve the operating conditions. These are made more expedient with the results of the vibration analyzer tests presented in Section 4.4.

Parameter monitoring opportunities. The longer suction run will also allow use of flow meters for individual pumps. Current spots for tapping flow meter probes are not very convenient for both device accuracy and technician access.

(Note that these recommendations are not oriented towards total plant redesign but only for addressing existing plant problems and providing possible solution as the consultant see fit. If total plant redesign is desired, it will have to be done in a separate contract and will likely disregard the most if not all of the current problems stated.)

Other pertinent observations include the following:

- The motors lack frame ground wires (Figure 4.5). The motor frames should



a -Southvale service pump suction

b - Sonera service pump suction

Figure 4.4: Suction side

be bonded to the station grounding bus. If there are any, the grounding design/policies for this station should be reviewed.

- Defective valves – valves have already locked up either due to age and/or corrosion (Figure 4.6).
- Valve not easily accessible - located above head level and require ladder to access (Figure 4.7)
- Clogged tapping point - during testing, clogged pressure tapping points and pressure gauges on the same line were found.
- Inconveniently placed gauges (Figure 4.8)
- Cluttered Electric wires (Figure 4.12)
- Minor Deteriorations (Figure 4.9)
- Exhaust fan not easily accessible for cleaning or repair (Figure 4.10)
- Inconvenient blank nameplate (Figure 4.11)

It is acknowledged that the station is already old and will suffer from issues typical to deterioration with time. However, it is necessary to do refurbishments to meet desired level of performance of the station.

As built discrepancy

Differences in as-builts are observed for the machine foundation. Initially, there was only one discharge header where all pumps would deliver water (Figure 4.13 - a). However, there are two headers, one to Southvale and the other to Sonera. Old as-built

Figure 4.5: no frame ground wires

Figure 4.6: defective valve

Figure 4.7: over-head valve location

a

b

Figure 4.8: Different gauges tapped at header

show that there are 7 slots with 2 outer jockey pumps and the rest in between the main storage pumps (Figure 4.13 - b). However, there are only 5 slots for main storage pumps and 1 slot for the jockey pump. Installed on the jockey pump slot is Southvale service pump1. Pumps 2 to 4 are installed on the main storage pump slots. Corresponding piping adjustments then follows.

4.4 Vibration and structural assessment

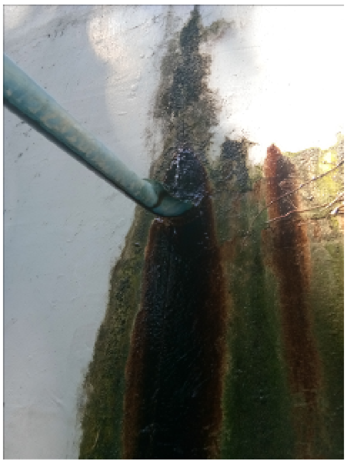
4.4.1 Measurement and spectrum reading

Rotating equipment generate vibration waveforms that are mathematical functions of machine dynamics, such as speed, alignment, and rotor balance, among others. Vibration analysis entails measurement and analysis of the amplitude of vibration at certain frequencies to gather useful information relating to the accuracy of shaft alignment and balance, the physical condition of bearings, and the possible effects of structural issues; in the case of Maynilad, the problem of impeller possible cavitation is an added and serious concern.

Three main parameters are measured to determine the severity or amplitude of vibration; namely: displacement, velocity and acceleration. Along with temperature, the vibration level is a primary indicator of the physical condition of a machine. As a generally rule, higher vibration levels indicate greater defects.

Rotating speeds below 600 rpm (10 Hz) generate minimal acceleration, moderate velocity, but relatively high displacement. Hence, shaft displacement is a critical parameter for slow speed rotors, such as steam turbines. Between 600 – 60000 rpm (10 - 1000 Hz) velocity and acceleration levels provide useful indications of the severity of defects. While velocity as a parameter may indicate the presence or relative magnitude

a



b

Figure 4.9: Other deterioration

Figure 4.10: exhaust fan

Figure 4.11: blank nameplate

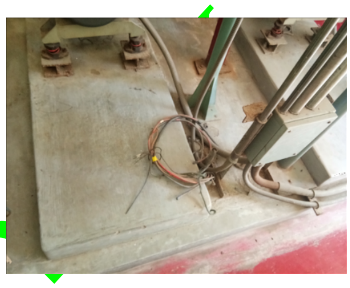
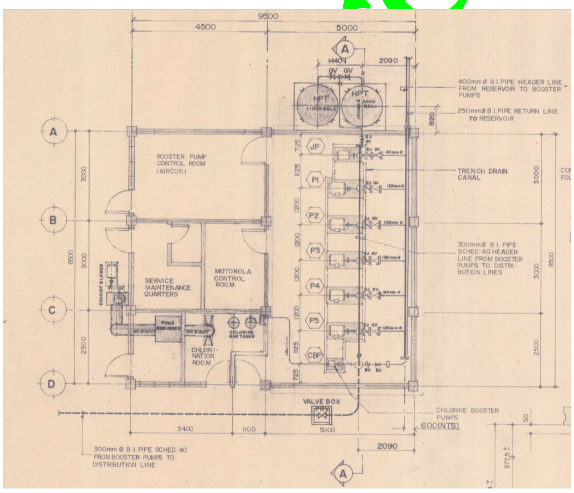
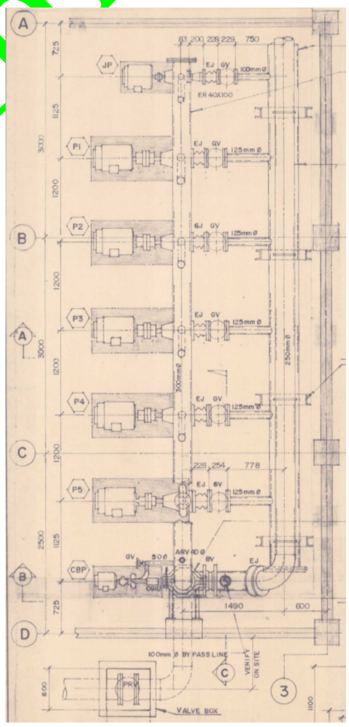


Figure 4.12: wire clutters



a - Pumps and pipings



b - Pump slots

Figure 4.13: Old as-built plan

of a problem, it makes no distinction as to the source or cause. This is where an FFT vibration analyzer comes in. A fast Fourier transform algorithm converts acceleration waveforms into functions of frequency in a way suitable-trained humans can distinguish the component sources or causes of the vibration.

By means of a OneProd Falcon high-resolution FFT analyzer equipped with tri-axial accelerometer with a linear frequency range of 2Hz-30kHz, vibration spectral readings were taken from four bearing locations in each motor-pump unit. Analysis and results are summarized as follows:

4.4.2 Data and analysis

Raw data of vibration measurement is provided in separately digital format. The raw data of each pump is used to generate a set of graphs provided in Appendix B. Analytical results on vibration are also included.

A summary of grading for each pump is given in Table 4.5.

Table 4.5: Pump vibration condition state.

Assets	Operational issues detected	Condition	
		Motor	Pump
Pump 1	Health is not acceptable for a long time service. Rubbing (Metal to metal) at Motor NDE (Rubbing at 21 Hz peak)	3	
Pump 2	Health is not acceptable for a long time service. Motor NDE Bearing Inner Race Fault Motor NDE Bearing Inner Race Fault - Stage 2 out of 4 Motor NDE Bearing noise with Ringing rate at shaft rate	3	
Pump 3	Misalignment, Unbalance, Rotating Loosen Overall state NOT acceptable for both pump and motor Highest vibrations measured at Motor NDE Axial with Overall velocity of 14.4 and dominant peak at 1x,2x,3x caused by Misalignment and Unbalance Fault Severe Rotating Looseness at Pump	4	4
Pump 4	Rotating Looseness and Misalignment Highest vibration measured at Pump IB Bearing Vertical with Overall Velocity of 6.07mm/s, with Defect Factor of 5.18 due to 1x Rate Repetitive 1x Harmonics caused by Rotating Looseness High 2x peak caused by Misalignment Impact caused by Rotating Looseness at Pump Bearings, Rubbing and Misalignment	4	4

Note that the unusual installation of the spring-mounted baseplates as mentioned earlier can lead to unusual operating behaviour and/or vibration characteristics.

It is noted that the CS 2, and 3 shown in Table 4.5 infers good and fair, respectively [1].

4.4.3 Recommendations

Recommendations are shown in Table 4.6

[1] The CS is slightly different from that defines in Table 3.1

Table 4.6: Corresponding recommendations from Vibration Analysis

Assets	Condition		Recommendations	IT
	Motor	Pump		
Pump 1	3		Check rubbing noise at Motor NDE	3
Pump 2	3		Continue monitor and trend Motor NDE Brg.	3
Pump 3	4	4	Schedule Reconditioning of Motor and Pump to include Shop Balancing of Motor Rotor, Pump impeller assembly balancing Resleeving or restoration of shaft and housing bearing clearances.	3
Pump 4	4	4	Schedule reconditioning of Pump Bearings. Check Pump bearings fit for shaft wear or Pump housing wear. Rectify those first prior bearing replacement. Realign shaft/coupling using precision laser alignment tool upon installation of pump onsite.	3

4.5 Workplace environment management

4.5.1 Temperature and relative humidity

4.5.1.1 Data

Air temperatures and relative humidity measured are presented in Table 4.7. Data was measured at targeted points shown in Figure 2.9. Raw data is with the site inspection reports, which will be provided to the Client separately. Persuant to ASHRAE standard, the recommended ranges for temperature and humidity are [72 - 80 $^\circ F$] and [45 - 60 %], respectively.

4.5.1.2 Data and Analysis

The pump station is situated near dense forestry and is connected to the subdivision roads via an access road. There are no significant sources of pollution and almost no passersby. As an old pump station building, there is no mechanical air conditioning. The pump room relies on natural ventilation via the access door and room windows. The MCC room beside the pump room is also naturally ventilated and has windows installed. Air properties are similar for all the areas in the station. From the table, the temperatures inside the pump house at every measurement points are significant higher than the maximum value of the recommended range (80 F). The average value is around 87 F. High values of temperature compared to the range have also been observed for points outside the pump house. The same is observed for the values of RH.

Solar load on the operators room is high during the day until noon (Figure 4.16 - a) and is low for the afternoon. To avoid consistent exposure to heat, the operator can stay on the shaded areas for cooling where the guard's booth is also positioned. Thus, comfort is sought of by the operator by feel and by shading himself when especially when the sun is up.

In terms of operatorship, there is not much significance deviation of the readings from recommended range since the operator spends small amount of time intermittently to record information or to start or stop the pumps during his shift.

Table 4.7: Temperature and Relative Humidity

Point	Description of the Point Location	Temperature Reading (F)		Humidity Reading	
		Actual	Range	Actual	Range
	A.				
1	Pump room point 1	83.5	72-80	63.4	45-60
2	Pump room point 2	83.3	72-80	62.9	45-60
3	Pump room point 3	83.8	72-80	63.6	45-60
4	Pump room point 4	84.0	72-80	61.7	45-60
5	Pump room point 5	84.2	72-80	62.5	45-60
6	Pump room point 6	84.4	72-80	61.9	45-60
7	Pump room point 7	84.4	72-80	61.5	45-60
8	Pump room point 8	84.7	72-80	61.1	45-60
9	Pump room point 9	84.6	72-80	62	45-60
10	Pump room point 10	85.6	72-80	60	45-60
	Average	84.3		62.1	
	B.				
11	Pump house corner 1	92.3	72-80	52.2	45-60
12	Pump house corner 2	87.8	72-80	57.9	45-60
13	Pump house corner 3	89.78	72-80	53.9	45-60
14	Pump house corner 4	88.7	72-80	56.2	45-60
	Average	89.6		55.1	
	C.				
15	Comfort Room	97.7	72-80	58.4	45-60
16	MCC room	87.8	72-80	57.3	45-60
17	Operator room	86.7	72-80	60.6	45-60

Nonetheless, temperature and humidity are correlated and as per ASHRAE standard 55 under summer comfort zone, the recommended combination of temperature and humidity shall be within the comfortable zone as shown in Figure 4.14.

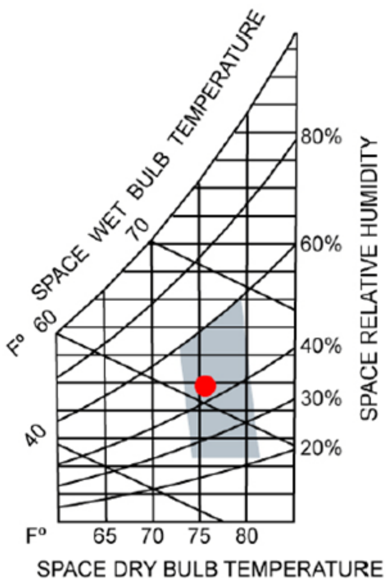


Figure 4.14: ASHRAE standard 55 : Summer Comfort Zone

Table 4.8: Air Quality - PM2.5

Point	Description of the Point Location	PM2.5
	A.	
1	Pump room point 1	6
2	Pump room point 2	6
3	Pump room point 3	6
4	Pump room point 4	7
5	Pump room point 5	6
6	Pump room point 6	6
7	Pump room point 7	6
8	Pump room point 8	6
9	Pump room point 9	6
10	Pump room point 10	6
	Average	6
	B.	
11	Pump house corner 1	5
12	Pump house corner 2	4
13	Pump house corner 3	4
14	Pump house corner 4	4
	Average	4
	C.	
15	Comfort Room	5
16	MCC room	5
17	Operator room	6

4.5.1.3 Recommendations

In order to reduce the negative impacts from high temperature, particularly inside the pump house, the Client shall consider

- Establishing a good daily monitoring, exercise, and management considering ergonomic and health and occupational activities (e.g. appropriate time window for break in designated resting area);.
- Transfer operators room or refurbish existing room to negate heat especially during day.
- Install AC equipment at least for the MCC room where cool air is desired to help MCC function efficiently and safely.

4.5.2 Air quality

4.5.2.1 Data and analysis

Air particulate matter concentrations are presented in Table 4.8. Data was measured at targeted points shown in 2.9. Raw data is with the site inspection reports, which will be provided to the Client separately. Pursuant to currently applied standard, excellent air quality range for PM2.5 is in [0-35].

The air quality for the pump station in terms of particulate matter is excellent. This is simply because there are no nearby significant sources of pollution such as emissions from vehicles for pump stations situated near heavy traffic roads.

4.5.2.2 Recommendations

Follow strictly safety and environmental regulation. For example, all employees and staff to wear appropriate dust-proofed masks when working with activities that potentially incurs dusts or other harmful particles.

Table 4.9: Illumination

Point	Description of the Point Location	Sound
	A.	
1	Pump room point 1	87.3
2	Pump room point 2	86.1
3	Pump room point 3	86.2
4	Pump room point 4	88.3
5	Pump room point 5	86.4
6	Pump room point 6	86.7
7	Pump room point 7	87.1
8	Pump room point 8	86
9	Pump room point 9	87.7
10	Pump room point 10	85.5
	Average	86.7
	B.	
11	Pump house corner 1	69.5
12	Pump house corner 2	70.4
13	Pump house corner 3	66.3
14	Pump house corner 4	64.8
	Average	67.8
	C.	
15	Comfort Room	67.4
16	MCC room	79.3
17	Operator room	65.4

4.5.3 Illumination

4.5.3.1 Data and analysis

Illumination within various areas of the pump station are presented in Table 4.9 with the LUX value. Data was measured at targeted points shown in Figure 2.9. Raw data is with the site inspection reports, which will be provided to the Client separately. Persuant to RULE 1075.4 of DOLE-OSH standard [3], the recommended minimum for LUX is in 100.

Illumination levels measured are above recommended minimum. The pump station is mostly solar lit during the day thru door and windows (Figure 4.15). Lightings can provide necessary illumination if brighter working area is needed, especially during afternoon and evenings. Concern is raised for evening or graveyard shifts where the operator needs to inspect around the reservoir area. Ample lighting is desired to help operator safely roam and inspect the area.

4.5.3.2 Recommendations

- Install necessary lighting along path to reservoir and vicinity

4.5.4 Industrial ventilation

4.5.4.1 Data and analysis

The pump room relies on natural ventilation via the access door and room windows. The MCC room beside the pump room is also naturally ventilated and has windows installed. The open access doors and windows serve double purpose to both promote air change in the rooms and also provide natural lighting inside (Figure 4.15)

4.5.4.2 Recommendations

- No action needed.

a b c d

Figure 4.15: Pump house openings

Table 4.10: Housekeeping.

Description	Status	CS	IT	Remarks
- Sufficient waste segregation assets	yes	1	1	
- waste segregation policy	yes	1	1	
- Signage	yes	1	1	
- Genset emission control	yes		1	

4.5.5 Housekeeping

4.5.5.1 Documentation

Following problems are the facts:

- Current documentation practice is heavily dominated with paper based system, which follows the current practice in Maynilad. There is a large amount/collection of papers that recorded past activities but is of no use and beneficial if data cannot be transformed into digital format for time series analysis, which is an essential part of asset management practice;

- No proper filing/library system with standardized coding rule that will provide convenience for operators/users to timely find appropriate documents;

- Daily operation data is crucial information for future analysis but it is recorded in excel based file without relational tables, which makes it from hard to impossible for data compilation, filtering, and mining. Many past data has been recorded with outliers and incorrect data types.

4.5.5.2 Waste management and environmental control

There is no issue with regard to waste management and environmental control as confirmed by the checklist shown in Table 4.10

4.5.5.3 Office arrangement and ergonomic

Table 4.11 shows the data concerning parameters associated with office arrangement and ergonomic considerations.

4.5.5.4 Recommendations

Followings are recommendations

Table 4.11: Ergonomics.

Parameters	Sub-parameters	Status	Remarks
Posture	Head	1	Ceiling height is high enough to cause head injury while sitting or when standing.
	Neck	1	Neck posture is in good ergonomic condition. Consider having an interval for fit-break to avoid neck muscles stiffening.
	Back	1	Back posture while sitting is in good posture. Consider standing and doing fit-break exercises to relax spine.
	Hands/Wrist	0	Proper hand positioning in the keyboard is not observed. Wrist bending is seldom.
	Feet	1	Feet position is in good posture. Good clearance below worktables.
	Eyes	0	The computer monitor is on eyelevel in a certain operator only. Consider adjusting the monitor level comfortable to every operator. Look away into distance in order to rest the eyes for every 10 minutes or so.
Equipment / Tool			
	Computer display	0	Not adjusted and the operator get used to its current setting. Display brightness must be adjustable in the comfort of the operator-in-charge. Consider the use of anti-glare and blue light to reduce the possibility of eyestrain.
	Keyboard	1	Keyboard position causes poor hand posture that can lead to injury at long exposure.
	Mouse	1	Mouse usage is average due to monitoring. Prolong usage may cause reduced blood flow leading to muscular injury.
	Chair	0	Consider using ergonomic chair that is capable of back support, height, armrest adjustments.
	Table	0	Consider use of ergonomic tables to adjust the height of the table in desired position easily without exerting much effort to adjust manually.
	Files	1	Hard copy file system and location is well observed. Too high or too low file location may require a person to bend his body or force his hand to grip a file in an awkward posture. Frequent situation may lead to MSD.
Operations / Maintenance	Illumination	0	According to the maintenance team, the motion-activated light is not bright enough to complete their task efficiently at night. Moreover, the light has short on-off delay operation that means that the team must move more often to avoid the light to dim. Consider having a manual switch option to by-pass the motion sensors and le the light on while doing maintenance.
	Noise Exposure	1	Noise emitted by the machines in the pump station is high. Consider the use of proper ear protections to reduce the sound intensity. In offices, the sound intensity is acceptable.
	Temperature	1	Temperature in the pump station is not acceptable at long exposure. Consider cooling down the body temperature at the designated area (i.e. outside, office).
Facility / General Workplace	Layout	1	Layout of the pump station is well observed. Distance between pumps is acceptable for well maintenance movement.
	Height clearances	1	Height clearances from ceiling to head is high. Chance of getting head injury is very low.

- Development of a web-based database management system, with appropriate set of relational data tables to record operational data, power consumption data, and

Table 4.12: Sound Levels.

Point	Description of the Point Location	Sound
	A.	
1	Pump room point 1	104
2	Pump room point 2	104
3	Pump room point 3	74
4	Pump room point 4	115
5	Pump room point 5	91
6	Pump room point 6	172
7	Pump room point 7	93
8	Pump room point 8	184
9	Pump room point 9	622
10	Pump room point 10	666
	Average	222
	B.	
11	Pump house corner 1	13980
12	Pump house corner 2	4880
13	Pump house corner 3	4470
14	Pump house corner 4	2190
	Average	6380
	C.	
15	Comfort Room	57
16	MCC room	44
17	Operator room	731

intervention data;

- Development of documentation code and naming for appropriate filing and library/referencing;
- Refurbish operator's office (Figure 4.16 - b) and include necessary organizing items such as file cabinet

a - High solar load during the day

b - Operator's desk

Figure 4.16: Operator's room

4.5.6 Noise

4.5.6.1 Data and analysis

Sound level measurements are presented in Table 4.12. Data was measured at targeted points shown in Figure 2.9. Raw data is with the site inspection reports, which will be provided to the Client separately.

Regular operation was considered during the sound level measurement and so the reading closely represents the normal daily noise generated by the pump system inside the plant. The average sound level inside the Pump room is around 86 dBa which means the operator; maintenance team can inspect or repair inside the room for considerably long without hearing impairment.

Sound levels are recorded around the vicinity of the pump room have an average of dBa. This means that sound levels within these areas are considered safe even for prolonged stay. Safe lower values are also recorded for the operator room and mcc room.

4.5.6.2 Recommendations

- Continue to use protective hearing equipment when working inside the Pump House to further bring down sound level during repair or maintenance.

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Appendix A

Recommended Maintenance Program

Maintenance Program

Code	Name	Station ID	Asset Description	Component	Failure Mode	Criticality	Failure Pattern	Task	Frequency	Done by	Comments
For dedicated spare pumps & motors only	**Pump**	**AYA**	**Horizontal pump between bearings**	**Bearings**	**bearing failure caused by false brinelling**	**High**	**Age-related**	**Rotate pump shaft 2-1/4 times**	**Every shift**	**Operator**	**Ensure that pump is isolated from power source**
For dedicated spare pumps & motors only	**Pump**	**AYA**	**Horizontal pump between bearings**	**Bearings**	**Bearing failure caused by contaminated oil**	**High**	**Random**	**Inspect oil for water contamination Regrease as necessary**	**Weekly**	**Maintenance contractor**	
For dedicated spare pumps & motors only	**Motor**	**AYA**	**Horizontal pump between bearings**	**Starter; Auto start system**	**Fail to start**	**High**	**Random**	**Start pump and run for at least 2 hours. Check all functionalities.**	**Monthly**	**Operator**	**Do this during visit by maintenance contractor.**
WSO-AYAPR-0031	Discharge Valve SP4	AYA	Valve	Valve disc & seat	Valve passing (leaks)	Medium	Age-related	Test valve integrity	Annually	Maintenance contractor	Use qualified maintenance contractor. Failure of this valve may cause problems during maintenance of pump/motor.
WSO-AYAPR-0009	Air Valve SP1	AYA	Air Valve	Actuator	Fail Open/Fail Close	Medium	Random	Overhaul pneumatic actuaor & clean internals	Annually	Maintenance contractor	Assign task to OEM contractor.
WSO-AYAPR-0016	Air Valve SP2	AYA	Air Valve	Actuator	Fail Open/Fail Close	Medium	Random	Overhaul pneumatic actuaor & clean internals	Annually	Maintenance contractor	Assign task to OEM contractor.
WSO-AYAPR-0023	Air Valve SP3	AYA	Air Valve	Actuator	Fail Open/Fail Close	Medium	Random	Overhaul pneumatic actuaor & clean internals	Annually	Maintenance contractor	Assign task to OEM contractor.
WSO-AYAPR-0030	Air Valve SP4	AYA	Air Valve	Actuator	Fail Open/Fail Close	Medium	Random	Overhaul pneumatic actuaor & clean internals	Annually	Maintenance contractor	Assign task to OEM contractor.
WSO-AYAPR-0008	Check Valve SP1	AYA	Check Valve	Valve disc & seat	Valve passing (leaks)	Medium	Age-related	Test valve integrity	Annually	Maintenance contractor	Use qualified maintenance contractor. Failure of this valve may cause problems during maintenance of pump/motor.
WSO-AYAPR-0015	Check Valve SP2	AYA	Check Valve	Valve disc & seat	Valve passing (leaks)	Medium	Age-related	Test valve integrity	Annually	Maintenance contractor	Use qualified maintenance contractor. Failure of this valve may cause problems during maintenance of pump/motor.
WSO-AYAPR-0022	Check Valve SP3	AYA	Check Valve	Valve disc & seat	Valve passing (leaks)	Medium	Age-related	Test valve integrity	Annually	Maintenance contractor	Use qualified maintenance contractor. Failure of this valve may cause problems during maintenance of pump/motor.
WSO-AYAPR-0029	Check Valve SP4	AYA	Check Valve	Valve disc & seat	Valve passing (leaks)	Medium	Age-related	Test valve integrity	Annually	Maintenance contractor	Use qualified maintenance contractor. Failure of this valve may cause problems during maintenance of pump/motor.
WSO-AYAPR-0034	Discharge Butterfly Valve 1	AYA	Valve	Valve disc & seat	Valve passing (leaks)	Medium	Age-related	Test valve integrity	Annually	Maintenance contractor	Use qualified maintenance contractor. Failure of this valve may cause problems during maintenance of pump/motor.
WSO-AYAPR-0033	Discharge Pipe and Fittings	AYA	Piping	Flange	Leaks due to loose bolts and/or gasket failure	Medium	Age-related	Re-tighten bolts using specified torque values	Annually	Maintenance contractor	Use proper bolt tightening methods (e.g. manual, hydraulic, pneumatic, tensioning, etc.) Apply required bolt torque values.
WSO-AYAPR-0044	Fuel Storage	AYA	Tank	Tank wall & bottom	Leaks due to corrosion	High	Age-related	Inspect tank for leaks	Daily	Operator	Anytime during day shift.
WSO-AYAPR-0044	Fuel Storage	AYA	Tank	Tank wall & bottom	Leaks due to corrosion	High	Age-related	Clean tank & inspect bottom plates for corrosion	Every 2 years	Maintenance contractor	Use qualified maintenance contractor.
WSO-AYAPR-0010	Motorized Discharge Valve SP1	AYA	Motor Valve	Motor winding	Motor burns due to failure of winding insulation	Low	Age-related	Inspect motor winding insulation	Annually	Maintenance contractor	Use qualified maintenance contractor.

WSO-AYAPR-0017	Motorized Discharge Valve SP2	AYA	Motor Valve	Motor winding	Motor burns due to failure of winding insulation	Low	Age-related	Inspect motor winding insulation	Annually	Maintenance contractor	Use qualified maintenance contractor.
WSO-AYAPR-0024	Motorized Discharge Valve SP3	AYA	Motor Valve	Motor winding	Motor burns due to failure of winding insulation	Low	Age-related	Inspect motor winding insulation	Annually	Maintenance contractor	Use qualified maintenance contractor.
WSO-AYAPR-0045	Overhead Travelling Crane	AYA	Lifting	Chain & gear mechanism	Failure of manual chain hoist due to wear & tear	High	Age-related	Inspect manual chain hoist for wear	Annually	Maintenance contractor	Use qualified maintenance contractor.
WSO-AYAPR-0045	Overhead Travelling Crane	AYA	Lifting	Motor drive	Motor burns due to failure of winding insulation	High	Random	Inspect motor winding insulation	Annually	Maintenance contractor	Use qualified maintenance contractor.
WSO-AYAPR-0005	Pipes and Fittings SP1	AYA	Piping	Flange	Leaks due to loose bolts and/or gasket failure	Medium	Age-related	Re-tighten bolts using specified torque values	Annually	Maintenance contractor	Use proper bolt tightening methods (e.g. manual, hydraulic, pneumatic, tensioning, etc.) Apply required bolt torque values.
WSO-AYAPR-0012	Pipes and Fittings SP2	AYA	Piping	Flange	Leaks due to loose bolts and/or gasket failure	Medium	Age-related	Re-tighten bolts using specified torque values	Annually	Maintenance contractor	Use proper bolt tightening methods (e.g. manual, hydraulic, pneumatic, tensioning, etc.) Apply required bolt torque values.
WSO-AYAPR-0019	Pipes and Fittings SP3	AYA	Piping	Flange	Leaks due to loose bolts and/or gasket failure	Medium	Age-related	Re-tighten bolts using specified torque values	Annually	Maintenance contractor	Use proper bolt tightening methods (e.g. manual, hydraulic, pneumatic, tensioning, etc.) Apply required bolt torque values.
WSO-AYAPR-0026	Pipes and Fittings SP4	AYA	Piping	Flange	Leaks due to loose bolts and/or gasket failure	Medium	Age-related	Re-tighten bolts using specified torque values	Annually	Maintenance contractor	Use proper bolt tightening methods (e.g. manual, hydraulic, pneumatic, tensioning, etc.) Apply required bolt torque values.
WSO-AYAPR-0004	Reservoir Blow-off Butterfly Valve	AYA	Valve	Valve disc & seat	Valve passing (leaks)	Medium	Age-related	Test valve integrity	Annually	Maintenance contractor	Use qualified maintenance contractor. Failure of this valve may cause problems during maintenance of pump/motor.
WSO-AYAPR-0003	Reservoir Inlet Butterfly Valve 1	AYA	Valve	Valve disc & seat	Valve passing (leaks)	Medium	Age-related	Test valve integrity	Annually	Maintenance contractor	Use qualified maintenance contractor. Failure of this valve may cause problems during maintenance of pump/motor.
WSO-AYAPR-0007	Storage Pump 1	AYA	Storage pump	Bearings	Loss of lubrication	High	Age-related	Scheduled greasing	Weekly	Maintenance contractor	Avoid overgreasing. Use correct grease as stipulated by bearing manufacturer.
WSO-AYAPR-0007	Storage Pump 1	AYA	Storage pump	Bearings	High vibration due to cavitation	High	Random	Monitor suction pressure not go below **xx** head.	Every hour	Operator	Refer to pump specifications on minimum NPSH requirements. Follow company policy in dealing with cavitation issues (e.g. call MCC to increase suction pressure and/or shutdown pumps)
WSO-AYAPR-0007	Storage Pump 1	AYA	Storage pump	Bearings	High vibration due to bearing failure (e.g. foreign materials in lubrication)	High	Random	Vibration monitoring	2-weekly (every 2 weeks)	Maintenance contractor	Use trained contractor for the appropriate vibration monitoring device. Report findings every month.
WSO-AYAPR-0007	Storage Pump 1	AYA	Storage pump	Packing	Excessive leaks	Medium	Age-related	Tighten packing bolts	2-weekly (every 2 weeks)	Maintenance contractor	Avoid overtightening of packing bolts.
WSO-AYAPR-0007	Storage Pump 1	AYA	Storage pump	Flange	Leaks due to loose bolts and/or gasket failure	Medium	Age-related	Re-tighten bolts using specified torque values	Annually	Maintenance contractor	Use proper bolt tightening methods (e.g. manual, hydraulic, pneumatic, tensioning, etc.) Apply required bolt torque values.

WSO-AYAPR-0007	Storage Pump 1	AYA	Storage pump	Vibration dampers	Leaks due to deteriorated materials caused by fatigue	Medium	Age-related	Replace vibration dampers based on recommended life	Every 10 years	Maintenance contractor	Refer to recommended life of dampers by manufacturer. Otherwise, purchase spare damper before its recommended life to ensure availability when needed.
WSO-AYAPR-0007	Storage Pump 1	AYA	Storage pump	System	General system leaks	Low	Random	Inspect system for leaks	Shift	Operator	Report excessive leaks for scheduled repairs.
WSO-AYAPR-0007	Storage Pump 1	AYA	Storage pump	Impeller	Impeller wear	Low	Age-related	-Replace impeller -Inspect and measure clearances	-10 years -Annually	Maintenance contractor	Inspect during annual overhauls.
WSO-AYAPR-0007	Storage Pump 1	AYA	Storage pump	Suction strainer	Blockage	Medium	Age-related	Clean strainer	Annually	Maintenance contractor	During annual overhauls.
WSO-AYAPR-0014	Storage Pump 2	AYA	Storage pump	Bearings	Loss of lubrication	High	Age-related	Scheduled greasing	Weekly	Maintenance contractor	Avoid overgreasing. Use correct grease as stipulated by bearing manufacturer.
WSO-AYAPR-0014	Storage Pump 2	AYA	Storage pump	Bearings	High vibration due to cavitation	High	Random	Monitor suction pressure not to go below <u>**xx**</u> head.	Every hour	Operator	Refer to pump specifications on minimum NPSH requirements. Follow company policy in dealing with cavitation issues (e.g. call MCC to increase suction pressure and/or shutdown pumps)
WSO-AYAPR-0014	Storage Pump 2	AYA	Storage pump	Bearings	High vibration due to bearing failure (e.g. foreign materials in lubrication)	High	Random	Vibration monitoring	2-weekly (every 2 weeks)	Maintenance contractor	Use trained contractor for the appropriate vibration monitoring device. Report findings every month.
WSO-AYAPR-0014	Storage Pump 2	AYA	Storage pump	Packing	Excessive leaks	Medium	Age-related	Tighten packing bolts	2-weekly (every 2 weeks)	Maintenance contractor	Avoid overtightening of packing bolts.
WSO-AYAPR-0014	Storage Pump 2	AYA	Storage pump	Flange	Leaks due to loose bolts and/or gasket failure	Medium	Age-related	Re-tighten bolts using specified torque values	Annually	Maintenance contractor	Use proper bolt tightening methods (e.g. manual, hydraulic, pneumatic, tensioning, etc.) Apply required bolt torque values.
WSO-AYAPR-0014	Storage Pump 2	AYA	Storage pump	Vibration dampers	Leaks due to deteriorated materials caused by fatigue	Medium	Age-related	Replace vibration dampers based on recommended life	Every 10 years	Maintenance contractor	Refer to recommended life of dampers by manufacturer. Otherwise, purchase spare damper before its recommended life to ensure availability when needed.
WSO-AYAPR-0014	Storage Pump 2	AYA	Storage pump	System	General system leaks	Low	Random	Inspect system for leaks	Shift	Operator	Report excessive leaks for scheduled repairs.
WSO-AYAPR-0014	Storage Pump 2	AYA	Storage pump	Impeller	Impeller wear	Low	Age-related	-Replace impeller -Inspect and measure clearances	-10 years -Annually	Maintenance contractor	Inspect during annual overhauls.
WSO-AYAPR-0014	Storage Pump 2	AYA	Storage pump	Suction strainer	Blockage	Medium	Age-related	Clean strainer	Annually	Maintenance contractor	During annual overhauls.
WSO-AYAPR-0021	Storage Pump 3	AYA	Storage pump	Bearings	Loss of lubrication	High	Age-related	Scheduled greasing	Weekly	Maintenance contractor	Avoid overgreasing. Use correct grease as stipulated by bearing manufacturer.
WSO-AYAPR-0021	Storage Pump 3	AYA	Storage pump	Bearings	High vibration due to cavitation	High	Random	Monitor suction pressure not to go below <u>**xx**</u> head.	Every hour	Operator	Refer to pump specifications on minimum NPSH requirements. Follow company policy in dealing with cavitation issues (e.g. call MCC to increase suction pressure and/or shutdown pumps)
WSO-AYAPR-0021	Storage Pump 3	AYA	Storage pump	Bearings	High vibration due to bearing failure (e.g. foreign materials in lubrication)	High	Random	Vibration monitoring	2-weekly (every 2 weeks)	Maintenance contractor	Use trained contractor for the appropriate vibration monitoring device. Report findings every month.

WSO-AYAPR-0021	Storage Pump 3	AYA	Storage pump	Packing	Excessive leaks	Medium	Age-related	Tighten packing bolts	2-weekly (every 2 weeks)	Maintenance contractor	Avoid overtightening of packing bolts.
WSO-AYAPR-0021	Storage Pump 3	AYA	Storage pump	Flange	Leaks due to loose bolts and/or gasket failure	Medium	Age-related	Re-tighten bolts using specified torque values	Annually	Maintenance contractor	Use proper bolt tightening methods (e.g. manual, hydraulic, pneumatic, tensioning, etc.) Apply required bolt torque values.
WSO-AYAPR-0021	Storage Pump 3	AYA	Storage pump	Vibration dampers	Leaks due to deteriorated materials caused by fatigue	Medium	Age-related	Replace vibration dampers based on recommended life	Every 10 years	Maintenance contractor	Refer to recommended life of dampers by manufacturer. Otherwise, purchase spare damper before its recommended life to ensure availability when needed.
WSO-AYAPR-0021	Storage Pump 3	AYA	Storage pump	System	General system leaks	Low	Random	Inspect system for leaks	Shift	Operator	Report excessive leaks for scheduled repairs.
WSO-AYAPR-0021	Storage Pump 3	AYA	Storage pump	Impeller	Impeller wear	Low	Age-related	-Replace impeller -Inspect and measure clearances	-10 years -Annually	Maintenance contractor	Inspect during annual overhauls.
WSO-AYAPR-0021	Storage Pump 3	AYA	Storage pump	Suction strainer	Blockage	Medium	Age-related	Clean strainer	Annually	Maintenance contractor	During annual overhauls.
WSO-AYAPR-0028	Storage Pump 4	AYA	Storage pump	Bearings	Loss of lubrication	High	Age-related	Scheduled greasing	Weekly	Maintenance contractor	Avoid overgreasing. Use correct grease as stipulated by bearing manufacturer.
WSO-AYAPR-0028	Storage Pump 4	AYA	Storage pump	Bearings	High vibration due to cavitation	High	Random	Monitor suction pressure not to go below **xx** head.	Every hour	Operator	Refer to pump specifications on minimum NPSH requirements. Follow company policy in dealing with cavitation issues (e.g. call MCC to increase suction pressure and/or shutdown pumps)
WSO-AYAPR-0028	Storage Pump 4	AYA	Storage pump	Bearings	High vibration due to bearing failure (e.g. foreign materials in lubrication)	High	Random	Vibration monitoring	2-weekly (every 2 weeks)	Maintenance contractor	Use trained contractor for the appropriate vibration monitoring device. Report findings every month.
WSO-AYAPR-0028	Storage Pump 4	AYA	Storage pump	Packing	Excessive leaks	Medium	Age-related	Tighten packing bolts	2-weekly (every 2 weeks)	Maintenance contractor	Avoid overtightening of packing bolts.
WSO-AYAPR-0028	Storage Pump 4	AYA	Storage pump	Flange	Leaks due to loose bolts and/or gasket failure	Medium	Age-related	Re-tighten bolts using specified torque values	Annually	Maintenance contractor	Use proper bolt tightening methods (e.g. manual, hydraulic, pneumatic, tensioning, etc.) Apply required bolt torque values.
WSO-AYAPR-0028	Storage Pump 4	AYA	Storage pump	Vibration dampers	Leaks due to deteriorated materials caused by fatigue	Medium	Age-related	Replace vibration dampers based on recommended life	Every 10 years	Maintenance contractor	Refer to recommended life of dampers by manufacturer. Otherwise, purchase spare damper before its recommended life to ensure availability when needed.
WSO-AYAPR-0028	Storage Pump 4	AYA	Storage pump	System	General system leaks	Low	Random	Inspect system for leaks	Shift	Operator	Report excessive leaks for scheduled repairs.
WSO-AYAPR-0028	Storage Pump 4	AYA	Storage pump	Impeller	Impeller wear	Low	Age-related	-Replace impeller -Inspect and measure clearances	-10 years -Annually	Maintenance contractor	Inspect during annual overhauls.
WSO-AYAPR-0028	Storage Pump 4	AYA	Storage pump	Suction strainer	Blockage	Medium	Age-related	Clean strainer	Annually	Maintenance contractor	During annual overhauls.
WSO-AYAPR-0011	Storage Pump Motor 1	AYA	Motor	Motor winding	Motor trip due to overloading	High	Random	Motor (skin) temperature measurement	Every hour	Operator	Refer to motor specifications on maximum allowable surface temperature.
WSO-AYAPR-0011	Storage Pump Motor 1	AYA	Motor	Motor winding	Motor burns due to failure of winding insulation	Low	Age-related	Inspect motor winding insulation	Annually	Maintenance contractor	Use qualified maintenance contractor.

WSO-AYAPR-0018	Storage Pump Motor 2	AYA	Motor	Motor winding	Motor trip due to overloading	High	Random	Motor (skin) temperature measurement	Every hour	Operator	Refer to motor specifications on maximum allowable surface temperature.
WSO-AYAPR-0018	Storage Pump Motor 2	AYA	Motor	Motor winding	Motor burns due to failure of winding insulation	Low	Age-related	Inspect motor winding insulation	Annually	Maintenance contractor	Use qualified maintenance contractor.
WSO-AYAPR-0025	Storage Pump Motor 3	AYA	Motor	Motor winding	Motor trip due to overloading	High	Random	Motor (skin) temperature measurement	Every hour	Operator	Refer to motor specifications on maximum allowable surface temperature.
WSO-AYAPR-0025	Storage Pump Motor 3	AYA	Motor	Motor winding	Motor burns due to failure of winding insulation	Low	Age-related	Inspect motor winding insulation	Annually	Maintenance contractor	Use qualified maintenance contractor.
WSO-AYAPR-0032	Storage Pump Motor 4	AYA	Motor	Motor winding	Motor trip due to overloading	High	Random	Motor (skin) temperature measurement	Every hour	Operator	Refer to motor specifications on maximum allowable surface temperature.
WSO-AYAPR-0032	Storage Pump Motor 4	AYA	Motor	Motor winding	Motor burns due to failure of winding insulation	Low	Age-related	Inspect motor winding insulation	Annually	Maintenance contractor	Use qualified maintenance contractor.
WSO-AYAPR-0006	Suction Butterfly Valve SP1	AYA	Valve	Valve disc & seat	Valve passing (leaks)	Medium	Age-related	Test valve integrity	Annually	Maintenance contractor	Use qualified maintenance contractor. Failure of this valve may cause problems during maintenance of pump/motor.
WSO-AYAPR-0013	Suction Butterfly Valve SP2	AYA	Valve	Valve disc & seat	Valve passing (leaks)	Medium	Age-related	Test valve integrity	Annually	Maintenance contractor	Use qualified maintenance contractor. Failure of this valve may cause problems during maintenance of pump/motor.
WSO-AYAPR-0020	Suction Butterfly Valve SP3	AYA	Valve	Valve disc & seat	Valve passing (leaks)	Medium	Age-related	Test valve integrity	Annually	Maintenance contractor	Use qualified maintenance contractor. Failure of this valve may cause problems during maintenance of pump/motor.
WSO-AYAPR-0027	Suction Butterfly Valve SP4	AYA	Valve	Valve disc & seat	Valve passing (leaks)	Medium	Age-related	Test valve integrity	Annually	Maintenance contractor	Use qualified maintenance contractor. Failure of this valve may cause problems during maintenance of pump/motor.
WSO-AYAPR-0001	Suction Pipes and Fittings	AYA	Piping	Flange	Leaks due to loose bolts and/or gasket failure	Medium	Age-related	Re-tighten bolts using specified torque values	Annually	Maintenance contractor	Use proper bolt tightening methods (e.g. manual, hydraulic, pneumatic, tensioning, etc.) Apply required bolt torque values.

Appendix B

Vibration Data

DOCUMENT TITLE

SOUTHVALE MOTOR & PUMP UNITS
VA STATUS REPORT
AS OF 15 FEB 2019

COMMENT

SOUTHVALE PUMP STATION

VISA

Written by	Approved by	State	Date
ENGR.JAY DIMALIBOT	ENGR. PETER VASQUEZ	PHI	25/03/2019 08:52:27

Table of contents

Synthesis Report

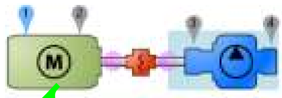
Filter: Equipment name (+) \ Tree order (+)

Location	Equipment	Diagnosis: Previous Date	Diagnosis: Current Date	Recommendations
SOUTHVALE PUMP\	BOOSTER PUMP UNIT 1	 Oper.	FAIR 15/02/2019 15:08:12 Oper. DfCnd	Check rubbing noise at Motor NDE
		Rubbing (Metal to metal) at Motor NDE		
SOUTHVALE PUMP\	BOOSTER PUMP UNIT 2	 Oper.	FAIR 15/02/2019 14:59:51 Oper. DfCnd	Continue monitor and trend Motor NDE Brg
		Motor NDE Bearing Inner Race Fault		
SOUTHVALE PUMP\	BOOSTER PUMP UNIT 3	 Oper.	CRITICAL 15/02/2019 15:[illegible]5:27 Oper. DfCnd	Schedule Reconditioning of Motor & Pump
		Misalignment, Unbalance, Rotating Loose[illegible]		
SOUTHVALE PUMP\	BOOSTER PUMP UNIT 4	 Oper.	CRITICAL 15/02/2019 1[illegible]:[illegible]8:55 Oper. DfCnd	Schedule Reconditioning of Pump
		Rotating Looseness and Misalignment		

Expertise Report

Filter: Equipment name (+) \ Tree order (+)

Location	SOUTHVALE PUMP\	Fixed speed
Designation	SOUTHVALE PUMP STATION	
Equipment	BOOSTER PUMP UNIT 1	
Designation		
Abbreviation	BP#1	
Serial No		
Model		
Periodicity (d)	*Normal* 60 *Alarm* 15	



Previous Advice	*Condition*	*Rotation Speed*

Date 15/02/2019 15:08:12	FAIR *Health is not acceptable for a long time service.*	*Speed*	56.1 Hz / 3368 rpm
Condition DfCnd		*Author*	u1
		System - Serial	FALCON - 11407
		Sensor	
		Connector	

Diagnosis & Recommendation

Parameters sheet

Diagnosis

Rubbing (Metal to metal) at Motor NDE

Fair state for the component 'Electric motor'.

Rubbing or Metal to metal contact at below 1x peak of at 21 Hz

Recommendations

Check rubbing noise at Motor NDE

Check rubbing noise at Motor NDE

6908f2.jpg

Rubbing at 21 Hz peak

Location	SOUTHVALE PUMP\	Fixed speed
Designation	SOUTHVALE PUMP STATION	
Equipment	BOOSTER PUMP UNIT 2	
Designation		
Abbreviation	BP#2	
Serial No		
Model		
Periodicity (d)	*Normal* 60 *Alarm* 15	

Previous Advice	*Condition*	*Rotation Speed*

Date 15/02/2019 14:59:51	FAIR *Health is not acceptable for a long time service.*	*Speed* 29.2 Hz / 1750 rpm
Condition DfCnd		*Author* u1 *System - Serial* FALCON - 11407 *Sensor* *Connector*

Diagnosis & Recommendation

Parameters sheet

Diagnosis

Motor NDE Bearing Inner Race Fault

Fair state for component 'Electric motor'.

Motor NDE Bearing Inner Race Fault - Stage 2 out of 4

Recommendations

Continue monitor and trend Motor NDE Brg

Continue monitor and trend Motor NDE Brg.

IP1.jpg

corrosion

390896.jpg

Motor NDE Bearing noise with Ringing rate at shaft rate

Location	SOUTHVALE PUMP\	Fixed speed
Designation	SOUTHVALE PUMP STATION	
Equipment	BOOSTER PUMP UNIT 3	
Designation		
Abbreviation	BP#3	
Serial No		
Model		
Periodicity (d)	*Normal* 60 *Alarm* 15	

Previous Advice	*Condition*	*Rotation Speed*
Date 15/02/2019 15:05:27 *Condition* DfCnd	CRITICAL ***Measurement observed shows that vibration levels could generate damages!***	*Speed* 58.7 Hz / 3520 rpm *Author* u1 *System - Serial* FALCON - 11407 *Sensor* *Connector*

Diagnosis & Recommendation

Parameters sheet

Diagnosis

Misalignment, Unbalance, Rotating Loosen

Overall state NOT acceptable for the component 'Electric motor'.
Highest vibrations measured at Motor NDE Axial with Overall velocity of 14.4 and dominant peak at 1x,2x,3x caused by Misalignment & Unbalance Fault

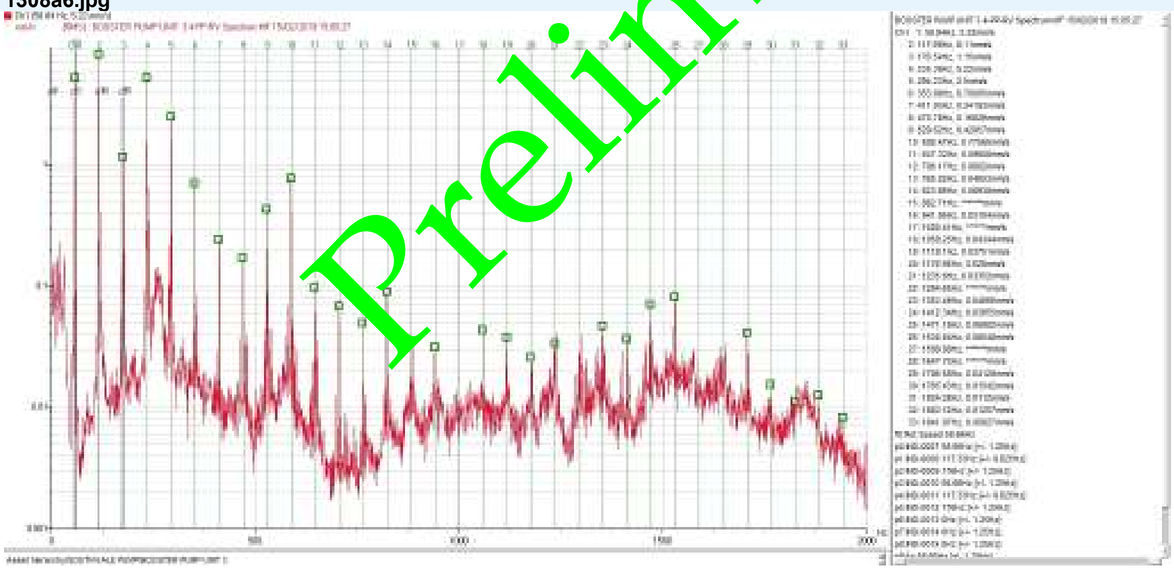
Overall state NOT acceptable for the component 'Pump'.
Rotating Looseness

Recommendations

Schedule Reconditioning of Motor & Pump

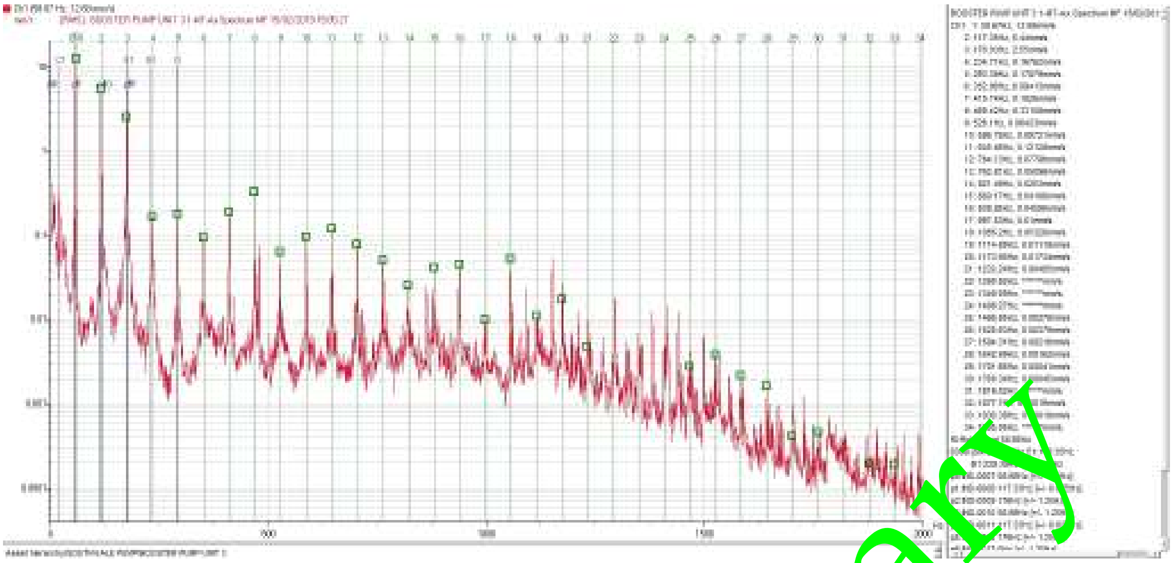
Schedule Reconditioning of Motor & Pump to include Shop Balancing of Motor Rotor, Pump impeller assy balancing, Resleeving or restoration of shaft and housing bearing clearances.

1308a6.jpg



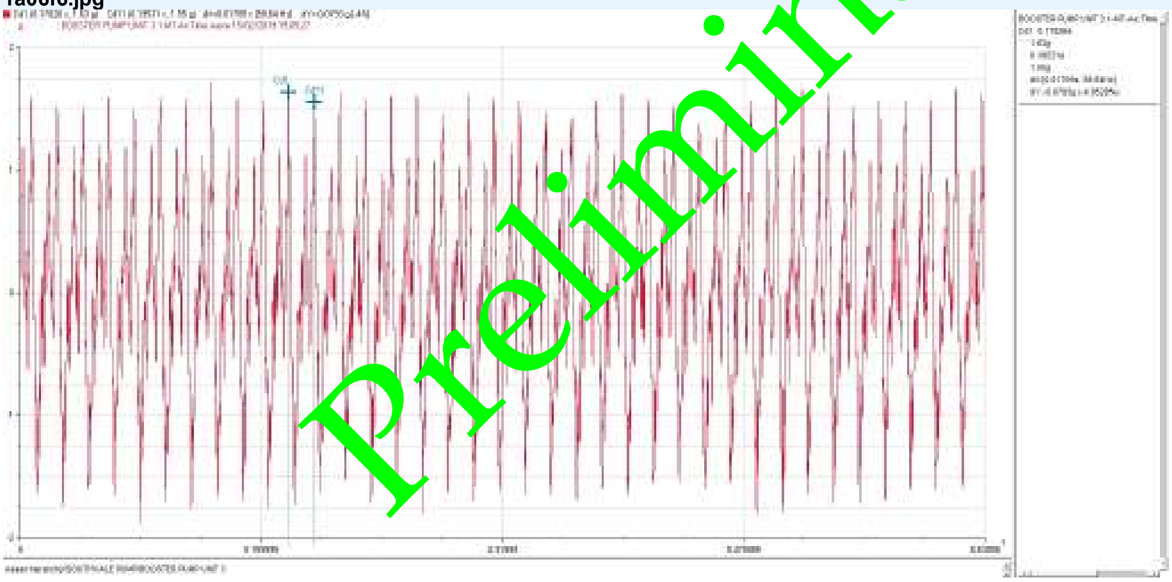
Severe Rotating Looseness at Pump

5e06cc.jpg



Misalignment and Unbalance at 1x,2x,3x peaks

1a06f6.jpg



Misalignment fault pattern in Time Signal

Location	SOUTHVALE PUMP\	Fixed speed
Designation	SOUTHVALE PUMP STATION	
Equipment	BOOSTER PUMP UNIT 4	
Designation		
Abbreviation	BP#4	
Serial No		
Model		
Periodicity (d)	*Normal* 60 *Alarm* 15	

Previous Advice	*Condition*	*Rotation Speed*

Date 15/02/2019 15:18:55 *Condition* DfCnd	CRITICAL ***Measurement observed shows that vibration levels could generate damages!***	*Speed* [illegible] Hz / 3545 rpm *Author* u1 *System - Serial* FALCON - 11407 *Sensor* *Connector*

Diagnosis & Recommendation

Parameters sheet

Diagnosis

Rotating Looseness and Misalignment

Overall state still acceptable for the component 'Electric motor'.
Overall state NOT acceptable for the component 'Pump'.
Highest vibration measured at Pump IB Bearing Vertical with Overall Velocity of 6.07mm/s, with Defect Factor of 5.18 due to 1x Rate Repetitive Impact caused by Rotating Looseness at Pump Bearings, Rubbing and Misalignment

Recommendations

Schedule Reconditioning of Pump

Schedule reconditioning of Pump Bearings. Check Pump bearings fit for shaft wear or Pump housing wear. Rectify those first prior bearing replacement. Realign shaft/coupling using precision laser alignment tool upon installation of pump onsite.

IP2.jpg

corrosion
220896.jpg

1x Harmonics caused by Rotating Looseness
c08ca.jpg

High 2x peak caused by Misalignment

Analysis Report

Filter: Equipment name (+) \ Tree order (+) Alarm type: Danger \ Alarm \ Pre-Alarm \ Error \ Ok \ Undefined \ Inhibited

SOUTHVALE PUMP\

BOOSTER PUMP UNIT 1

Selected Date	15/02/2019 15:08:12	Speed	56.1 Hz / 3368 rpm
Author	u1	Connector	
System - Serial No	FALCON - 11407	Sensor	

Operating param.	1	H/S	Last Date	Value	Unit	T-1	Ref.	Avg
Ovrl:Rotation speed	Rot Spd	Hard	15/02/2019 15:08:12	3368	rpm		3368	

1-MT-Ax	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:08:12	3.32	mm/s		3.32		DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 15:08:12	0.504	g		0.504		DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:08:12	2.54	DEF		2.54		DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 15:08:12	0.374	mm/s		0.374		DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 15:08:12	1.10	mm/s		1.10		DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 15:08:12	0.0239	mm/s		0.0239		DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 15:08:12	0.103	g		0.103		DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 15:08:12	0.471	g		0.471		DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 15:08:12	0.164	g		0.164		DfCnd	High	0	0	0	0	2	4	0
1-MT-RH	**9**	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:08:12	4.00	mm/s		4.00		DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 15:08:12	0.408	g		0.408		DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:08:12	2.55	DEF		2.55		DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 15:08:12	1.84	mm/s		1.84		DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 15:08:12	0.916	mm/s		0.916		DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 15:08:12	0.0288	mm/s		0.0288		DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 15:08:12	0.117	g		0.117		DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 15:08:12	0.282	g		0.282		DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 15:08:12	0.255	g		0.255		DfCnd	High	0	0	0	0	2	4	0
1-MT-RV	**9**	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:08:12	5.45	mm/s		5.45		DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 15:08:12	0.454	g		0.454		DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:08:12	2.55	DEF		2.55		DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 15:08:12	0.760	mm/s		0.760		DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 15:08:12	0.408	mm/s		0.408		DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 15:08:12	0.0284	mm/s		0.0284		DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 15:08:12	0.0867	g		0.0867		DfCnd	High	0	0	0	0	.15	.3	0

SOUTHVALE PUMP\

BOOSTER PUMP UNIT 1

Selected Date	15/02/2019 15:08:12	Speed	56.1 Hz / 3368 rpm
Author	u1	Connector	
System - Serial No	FALCON - 11407	Sensor	

En-MF	En-MF	Soft	15/02/2019 15:08:12	0.417	g		0.417		DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 15:08:12	0.158	g		0.158		DfCnd	High	0	0	0	0	2	4	0
2-MT-Ax	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:08:12	2.82	mm/s		2.82		DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 15:08:12	0.229	g		0.229		DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:08:12	2.47	DEF		2.47		DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 15:08:12	0.538	mm/s		0.538		DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 15:08:12	1.17	mm/s		1.17		DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 15:08:12	0.0655	mm/s		0.0655		DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 15:08:12	0.153	g		0.153		DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 15:08:12	0.156	g		0.156		DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 15:08:12	0.0627	g		0.0627		DfCnd	High	0	0	0	0	2	4	0
2-MT-RH	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:08:12	1.69	mm/s		1.69		DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 15:08:12	0.324	g		0.324		DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:08:12	2.52	DEF		2.52		DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 15:08:12	0.988	mm/s		0.988		DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 15:08:12	0.448	mm/s		0.448		DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 15:08:12	0.0303	mm/s		0.0303		DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 15:08:12	0.0640	g		0.0640		DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 15:08:12	0.310	g		0.310		DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 15:08:12	0.0604	g		0.0604		DfCnd	High	0	0	0	0	2	4	0
2-MT-RV	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:08:12	2.14	mm/s		2.14		DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 15:08:12	0.210	g		0.210		DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:08:12	2.38	DEF		2.38		DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 15:08:12	0.975	mm/s		0.975		DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 15:08:12	0.391	mm/s		0.391		DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 15:08:12	0.0391	mm/s		0.0391		DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 15:08:12	0.0584	g		0.0584		DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 15:08:12	0.195	g		0.195		DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 15:08:12	0.0479	g		0.0479		DfCnd	High	0	0	0	0	2	4	0

SOUTHVALE PUMP\

BOOSTER PUMP UNIT 1

Selected Date	15/02/2019 15:08:12	Speed	56.1 Hz / 3368 rpm
Author	u1	Connector	
System - Serial No	FALCON - 11407	Sensor	

		H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
3-PP-Ax	9																
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:08:12						DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 15:08:12						DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:08:12						DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	2	4	0
3-PP-RH	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:08:12						DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 15:08:12						DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:08:12						DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	2	4	0
3-PP-RV	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:08:12						DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 15:08:12						DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:08:12						DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	2	4	0
4-PP-Ax	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:08:12						DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 15:08:12						DfCnd	None							

SOUTHVALE PUMP\
BOOSTER PUMP UNIT 1

Selected Date	15/02/2019 15:08:12	Speed	56.1 Hz / 3368 rpm
Author	u1	Connector	
System - Serial No	FALCON - 11407	Sensor	

Defect factor	IND-0003	Hard	15/02/2019 15:08:12						DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	2	4	0
4-PP-RH	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:08:12						DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 15:08:12						DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:08:12						DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	2	4	0
4-PP-RV	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:08:12						DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 15:08:12						DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:08:12						DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	2	4	0

SOUTHVALE PUMP\
BOOSTER PUMP UNIT 2

Selected Date	15/02/2019 14:59:51	Speed	29.2 Hz / 1750 rpm
Author	u1	Connector	
System - Serial No	FALCON - 11407	Sensor	

SOUTHVALE PUMP\ BOOSTER PUMP UNIT 2

Selected Date	15/02/2019 14:59:51	Speed	29.2 Hz / 1750 rpm
Author	u1	Connector	
System - Serial No	FALCON - 11407	Sensor	

Operating param.	1	H/S	Last Date	Value	Unit	T-1	Ref.	Avg
Ovrl:Rotation speed	Rot Spd	Hard	15/02/2019 14:59:51	1750	rpm		1750	

1-MT-Ax	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 14:59:51	3.33	mm/s		3.33		DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 14:59:51	0.680	g		0.680		DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 14:59:51	2.76	DEF		2.76		DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 14:59:51	0.0220	mm/s		0.0220		DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 14:59:51	0.265	mm/s		0.265		DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 14:59:51	0.0046	mm/s		0.0046		DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 14:59:51	0.0496	g		0.0496		DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 14:59:51	0.575	g		0.575		DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 14:59:51	0.353	g		0.353		DfCnd	High	0	0	0	0	2	4	0

1-MT-RH	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 14:59:51	1.42	mm/s		1.42		DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 14:59:51	1.10	g		1.10		DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 14:59:51	3.03	DEF		3.03		DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 14:59:51	0.0244	mm/s		0.0244		DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 14:59:51	0.242	mm/s		0.242		DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 14:59:51	0.0037	mm/s		0.0037		DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 14:59:51	0.0534	g		0.0534		DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 14:59:51	1.06	g		1.06		DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 14:59:51	0.230	g		0.230		DfCnd	High	0	0	0	0	2	4	0

1-MT-RV	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 14:59:51	2.00	mm/s		2.00		DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 14:59:51	0.414	g		0.414		DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 14:59:51	2.91	DEF		2.91		DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 14:59:51	0.0717	mm/s		0.0717		DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 14:59:51	0.0850	mm/s		0.0850		DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 14:59:51						DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 14:59:51	0.0449	g		0.0449		DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 14:59:51	0.159	g		0.159		DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 14:59:51	0.365	g		0.365		DfCnd	High	0	0	0	0	2	4	0

2-MT-Ax	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err

SOUTHVALE PUMP\

BOOSTER PUMP UNIT 2

Selected Date	15/02/2019 14:59:51	Speed	29.2 Hz / 1750 rpm
Author	u1	Connector	
System - Serial No	FALCON - 11407	Sensor	

Overall Vib Vel	IND-0001	Hard	15/02/2019 14:59:51	2.05	mm/s		2.05		DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 14:59:51	0.773	g		0.773		DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 14:59:51	3.05	DEF		3.05		DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 14:59:51	0.0471	mm/s		0.0471		DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 14:59:51	0.495	mm/s		0.495		DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 14:59:51	0.0489	mm/s		0.0489		DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 14:59:51	0.105	g		0.105		DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 14:59:51	0.296	g		0.296		DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 14:59:51	0.691	g		0.691		DfCnd	High	0	0	0	0	2	4	0
2-MT-RH	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 14:59:51	1.18	mm/s		1.18		DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 14:59:51	0.918	g		0.918		DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 14:59:51	3.32	DEF		3.32		DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 14:59:51	0.0218	mm/s		0.0218		DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 14:59:51	0.243	mm/s		0.243		DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 14:59:51	0.0260	mm/s		0.0260		DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 14:59:51	0.0589	g		0.0589		DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 14:59:51	0.401	g		0.401		DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 14:59:51	0.806	g		0.806		DfCnd	High	0	0	0	0	2	4	0
2-MT-RV	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 14:59:51	1.40	mm/s		1.40		DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 14:59:51	0.848	g		0.848		DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 14:59:51	3.21	DEF		3.21		DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 14:59:51	0.0699	mm/s		0.0699		DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 14:59:51	0.466	mm/s		0.466		DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 14:59:51	0.0100	mm/s		0.0100		DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 14:59:51	0.0334	g		0.0334		DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 14:59:51	0.346	g		0.346		DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 14:59:51	0.770	g		0.770		DfCnd	High	0	0	0	0	2	4	0
3-PP-Ax	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 14:59:51						DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 14:59:51						DfCnd	None							

SOUTHVALE PUMP\

BOOSTER PUMP UNIT 2

Selected Date	15/02/2019 14:59:51	Speed	29.2 Hz / 1750 rpm
Author	u1	Connector	
System - Serial No	FALCON - 11407	Sensor	

Defect factor	IND-0003	Hard	15/02/2019 14:59:51						DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 14:59:51						DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 14:59:51						DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 14:59:51						DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 14:59:51						DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 14:59:51						DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 14:59:51						DfCnd	High	0	0	0	0	2	4	0
3-PP-RH	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 14:59:51						DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 14:59:51						DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 14:59:51						DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 14:59:51						DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 14:59:51						DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 14:59:51						DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 14:59:51						DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 14:59:51						DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 14:59:51						DfCnd	High	0	0	0	0	2	4	0
3-PP-RV	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 14:59:51						DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 14:59:51						DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 14:59:51						DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 14:59:51						DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 14:59:51						DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 14:59:51						DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 14:59:51						DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 14:59:51						DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 14:59:51						DfCnd	High	0	0	0	0	2	4	0
4-PP-Ax	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 14:59:51						DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 14:59:51						DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 14:59:51						DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 14:59:51						DfCnd	High	0	0	0	0	3	6	0

SOUTHVALE PUMP\ BOOSTER PUMP UNIT 2

Selected Date	15/02/2019 14:59:51	Speed	29.2 Hz / 1750 rpm
Author	u1	Connector	
System - Serial No	FALCON - 11407	Sensor	

		H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
2x	2x	Soft	15/02/2019 14:59:51						DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 14:59:51						DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 14:59:51						DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 14:59:51						DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 14:59:51						DfCnd	High	0	0	0	0	2	4	0
4-PP-RH	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 14:59:51						DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 14:59:51						DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 14:59:51						DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 14:59:51						DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 14:59:51						DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 14:59:51						DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 14:59:51						DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 14:59:51						DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 14:59:51						DfCnd	High	0	0	0	0	2	4	0
4-PP-RV	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 14:59:51						DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 14:59:51						DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 14:59:51						DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 14:59:51						DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 14:59:51						DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 14:59:51						DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 14:59:51						DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 14:59:51						DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 14:59:51						DfCnd	High	0	0	0	0	2	4	0

SOUTHVALE PUMP\ BOOSTER PUMP UNIT 3

Selected Date	15/02/2019 15:05:27	Speed	58.7 Hz / 3520 rpm
Author	u1	Connector	
System - Serial No	FALCON - 11407	Sensor	

		H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Operating param.	1	H/S	Last Date	Value	Unit	T-1	Ref.	Avg									
Ovrl:Rotation speed	Rot Spd	Hard	15/02/2019 15:05:27	3520	rpm		3520										
1-MT-Ax	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:05:27	14.4	mm/s		14.4		DfCnd	High	0	0	0	2	3.5	6	0

SOUTHVALE PUMP\
BOOSTER PUMP UNIT 3

Selected Date	15/02/2019 15:05:27	Speed	58.7 Hz / 3520 rpm
Author	u1	Connector	
System - Serial No	FALCON - 11407	Sensor	

Overall Acc	IND-0002	Hard	15/02/2019 15:05:27	0.739	g		0.739		DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:05:27	2.47	DEF		2.47		DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 15:05:27	12.2	mm/s		12.2		DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 15:05:27	4.93	mm/s		4.93		DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 15:05:27	2.62	mm/s		2.62		DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 15:05:27	0.718	g		0.718		DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 15:05:27	0.194	g		0.194		DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 15:05:27	0.0344	g		0.0344		DfCnd	High	0	0	0	0	2	4	0
1-MT-RH	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:05:27	10.8	mm/s		10.8		DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 15:05:27	0.535	g		0.535		DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:05:27	2.40	DEF		2.40		DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 15:05:27	10.2	mm/s		10.2		DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 15:05:27	0.747	mm/s		0.747		DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 15:05:27	0.305	mm/s		0.305		DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 15:05:27	0.412	g		0.412		DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 15:05:27	0.338	g		0.338		DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 15:05:27	0.0361	g		0.0361		DfCnd	High	0	0	0	0	2	4	0
1-MT-RV	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:05:27	11.5	mm/s		11.5		DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 15:05:27	0.474	g		0.474		DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:05:27	2.39	DEF		2.39		DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 15:05:27	10.8	mm/s		10.8		DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 15:05:27	0.0774	mm/s		0.0774		DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 15:05:27	0.557	mm/s		0.557		DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 15:05:27	0.433	g		0.433		DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 15:05:27	0.191	g		0.191		DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 15:05:27	0.0470	g		0.0470		DfCnd	High	0	0	0	0	2	4	0
2-MT-Ax	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:05:27	9.16	mm/s		9.16		DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 15:05:27	0.791	g		0.791		DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:05:27	2.53	DEF		2.53		DfCnd	High	0	0	0	4	6	9	0

SOUTHVALE PUMP\
BOOSTER PUMP UNIT 3

Selected Date	15/02/2019 15:05:27	Speed	58.7 Hz / 3520 rpm
Author	u1	Connector	
System - Serial No	FALCON - 11407	Sensor	

1x	1x	Soft	15/02/2019 15:05:27	5.92	mm/s		5.92		DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 15:05:27	4.36	mm/s		4.36		DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 15:05:27	1.41	mm/s		1.41		DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 15:05:27	0.474	g		0.474		DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 15:05:27	0.629	g		0.629		DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 15:05:27	0.0878	g		0.0878		DfCnd	High	0	0	0	0	2	4	0
2-MT-RH	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:05:27	10.9	mm/s		10.9		DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 15:05:27	0.605	g		0.605		DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:05:27	2.61	DEF		2.61		DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 15:05:27	10.1	mm/s		10.1		DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 15:05:27	1.05	mm/s		1.05		DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 15:05:27	0.0924	mm/s		0.0924		DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 15:05:27	0.412	g		0.412		DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 15:05:27	0.431	g		0.431		DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 15:05:27	0.102	g		0.102		DfCnd	High	0	0	0	0	2	4	0
2-MT-RV	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:05:27	9.17	mm/s		9.17		DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 15:05:27	0.631	g		0.631		DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:05:27	2.56	DEF		2.56		DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 15:05:27	6.22	mm/s		6.22		DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 15:05:27	4.98	mm/s		4.98		DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 15:05:27	0.903	mm/s		0.903		DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 15:05:27	0.506	g		0.506		DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 15:05:27	0.363	g		0.363		DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 15:05:27	0.103	g		0.103		DfCnd	High	0	0	0	0	2	4	0
3-PP-Ax	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:05:27	6.68	mm/s		6.68		DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 15:05:27	0.965	g		0.965		DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:05:27	2.67	DEF		2.67		DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 15:05:27	2.51	mm/s		2.51		DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 15:05:27	1.73	mm/s		1.73		DfCnd	High	0	0	0	0	1.5	3	0

SOUTHVALE PUMP\
BOOSTER PUMP UNIT 3

	Selected Date	15/02/2019 15:05:27	Speed	58.7 Hz / 3520 rpm
	Author	u1	Connector	
	System - Serial No	FALCON - 11407	Sensor	

3x	3x	Soft	15/02/2019 15:05:27	1.97	mm/s		1.97		DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 15:05:27	0.292	g		0.292		DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 15:05:27	0.899	g		0.899		DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 15:05:27	0.191	g		0.191		DfCnd	High	0	0	0	0	2	4	0
3-PP-RH	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:05:27	7.29	mm/s		7.29		DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 15:05:27	1.09	g		1.09		DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:05:27	2.81	DEF		2.81		DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 15:05:27	4.99	mm/s		4.99		DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 15:05:27	1.90	mm/s		1.90		DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 15:05:27	0.802	mm/s		0.802		DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 15:05:27	0.275	g		0.275		DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 15:05:27	1.02	g		1.02		DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 15:05:27	0.243	g		0.243		DfCnd	High	0	0	0	0	2	4	0
3-PP-RV	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:05:27	12.1	mm/s		12.1		DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 15:05:27	0.952	g		0.952		DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:05:27	2.64	DEF		2.64		DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 15:05:27	9.41	mm/s		9.41		DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 15:05:27	4.64	mm/s		4.64		DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 15:05:27	0.826	mm/s		0.826		DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 15:05:27	0.544	g		0.544		DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 15:05:27	0.757	g		0.757		DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 15:05:27	0.175	g		0.175		DfCnd	High	0	0	0	0	2	4	0
4-PP-Ax	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:05:27	2.85	mm/s		2.85		DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 15:05:27	0.575	g		0.575		DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:05:27	2.58	DEF		2.58		DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 15:05:27	0.965	mm/s		0.965		DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 15:05:27	1.50	mm/s		1.50		DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 15:05:27	0.993	mm/s		0.993		DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 15:05:27	0.170	g		0.170		DfCnd	High	0	0	0	0	.15	.3	0

SOUTHVALE PUMP\
BOOSTER PUMP UNIT 3

Selected Date	15/02/2019 15:05:27	Speed	58.7 Hz / 3520 rpm
Author	u1	Connector	
System - Serial No	FALCON - 11407	Sensor	

En-MF	En-MF	Soft	15/02/2019 15:05:27	0.527	g		0.527		DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 15:05:27	0.142	g		0.142		DfCnd	High	0	0	0	0	2	4	0

4-PP-RH	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:05:27	5.20	mm/s		5.20		DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 15:05:27	0.707	g		0.707		DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:05:27	2.73	DEF		2.73		DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 15:05:27	4.13	mm/s		4.13		DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 15:05:27	0.481	mm/s		0.481		DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 15:05:27	0.876	mm/s		0.876		DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 15:05:27	0.206	g		0.206		DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 15:05:27	0.642	g		0.642		DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 15:05:27	0.165	g		0.165		DfCnd	High	0	0	0	0	2	4	0

4-PP-RV	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:05:27	12.3	mm/s		12.3		DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 15:05:27	1.36	g		1.36		DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:05:27	2.69	DEF		2.69		DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 15:05:27	4.76	mm/s		4.76		DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 15:05:27	8.53	mm/s		8.53		DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 15:05:27	1.30	mm/s		1.30		DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 15:05:27	0.704	g		0.704		DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 15:05:27	1.15	g		1.15		DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 15:05:27	0.147	g		0.147		DfCnd	High	0	0	0	0	2	4	0

SOUTHVALE PUMP\
BOOSTER PUMP UNIT 4

Selected Date	15/02/2019 15:18:55	Speed	59.1 Hz / 3545 rpm
Author	u1	Connector	
System - Serial No	FALCON - 11407	Sensor	

Operating param.	1	H/S	Last Date	Value	Unit	T-1	Ref.	Avg
Ovrl:Rotation speed	Rot Spd	Hard	15/02/2019 15:18:55	3545	rpm		3545	

1-MT-Ax	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:18:55	4.43	mm/s		4.43		DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 15:18:55	0.414	g		0.414		DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:18:55	2.71	DEF		2.71		DfCnd	High	0	0	0	4	6	9	0

SOUTHVALE PUMP\
BOOSTER PUMP UNIT 4

Selected Date	15/02/2019 15:18:55	Speed	59.1 Hz / 3545 rpm
Author	u1	Connector	
System - Serial No	FALCON - 11407	Sensor	

1x	1x	Soft	15/02/2019 15:18:55	3.75	mm/s		3.75		DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 15:18:55	1.09	mm/s		1.09		DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 15:18:55	0.748	mm/s		0.748		DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 15:18:55	0.196	g		0.196		DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 15:18:55	0.355	g		0.355		DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 15:18:55	0.0867	g		0.0867		DfCnd	High	0	0	0	0	2	4	0
1-MT-RH	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:18:55	3.88	mm/s		3.88		DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 15:18:55	0.520	g		0.520		DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:18:55	2.35	DEF		2.35		DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 15:18:55	3.55	mm/s		3.55		DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 15:18:55	0.520	mm/s		0.520		DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 15:18:55	0.442	mm/s		0.442		DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 15:18:55	0.152	g		0.152		DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 15:18:55	0.495	g		0.495		DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 15:18:55	0.0632	g		0.0632		DfCnd	High	0	0	0	0	2	4	0
1-MT-RV	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:18:55	9.90	mm/s		9.90		DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 15:18:55	0.522	g		0.522		DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:18:55	2.49	DEF		2.49		DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 15:18:55	9.42	mm/s		9.42		DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 15:18:55	1.95	mm/s		1.95		DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 15:18:55	0.724	mm/s		0.724		DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 15:18:55	0.400	g		0.400		DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 15:18:55	0.328	g		0.328		DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 15:18:55	0.0813	g		0.0813		DfCnd	High	0	0	0	0	2	4	0
2-MT-Ax	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:18:55	5.27	mm/s		5.27		DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 15:18:55	0.454	g		0.454		DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:18:55	3.02	DEF		3.02		DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 15:18:55	4.07	mm/s		4.07		DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 15:18:55	1.93	mm/s		1.93		DfCnd	High	0	0	0	0	1.5	3	0

SOUTHVALE PUMP\

BOOSTER PUMP UNIT 4

Selected Date	15/02/2019 15:18:55	Speed	59.1 Hz / 3545 rpm
Author	u1	Connector	
System - Serial No	FALCON - 11407	Sensor	

		H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
3x	3x	Soft	15/02/2019 15:18:55	0.308	mm/s		0.308		DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 15:18:55	0.251	g		0.251		DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 15:18:55	0.349	g		0.349		DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 15:18:55	0.176	g		0.176		DfCnd	High	0	0	0	0	2	4	0
2-MT-RH	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:18:55	4.42	mm/s		4.42		DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 15:18:55	0.540	g		0.540		DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:18:55	3.46	DEF		3.46		DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 15:18:55	3.66	mm/s		3.66		DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 15:18:55	1.15	mm/s		1.15		DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 15:18:55	0.346	mm/s		0.346		DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 15:18:55	0.183	g		0.183		DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 15:18:55	0.484	g		0.484		DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 15:18:55	0.195	g		0.195		DfCnd	High	0	0	0	0	2	4	0
2-MT-RV	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:18:55	5.21	mm/s		5.21		DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 15:18:55	0.382	g		0.382		DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:18:55	3.15	DEF		3.15		DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 15:18:55	3.66	mm/s		3.66		DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 15:18:55	2.29	mm/s		2.29		DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 15:18:55	0.391	mm/s		0.391		DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 15:18:55	0.273	g		0.273		DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 15:18:55	0.205	g		0.205		DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 15:18:55	0.210	g		0.210		DfCnd	High	0	0	0	0	2	4	0
3-PP-Ax	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:18:55	3.53	mm/s		3.53		DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 15:18:55	0.982	g		0.982		DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:18:55	4.15	DEF		4.15		DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 15:18:55	1.83	mm/s		1.83		DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 15:18:55	0.840	mm/s		0.840		DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 15:18:55	0.405	mm/s		0.405		DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 15:18:55	0.174	g		0.174		DfCnd	High	0	0	0	0	.15	.3	0

SOUTHVALE PUMP\
BOOSTER PUMP UNIT 4

Selected Date	15/02/2019 15:18:55	Speed	59.1 Hz / 3545 rpm
Author	u1	Connector	
System - Serial No	FALCON - 11407	Sensor	

En-MF	En-MF	Soft	15/02/2019 15:18:55	0.744	g		0.744		DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 15:18:55	0.601	g		0.601		DfCnd	High	0	0	0	0	2	4	0
3-PP-RH	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:18:55	4.20	mm/s		4.20		DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 15:18:55	1.47	g		1.47		DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:18:55	5.18	DEF		5.18		DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 15:18:55	1.11	mm/s		1.11		DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 15:18:55	1.98	mm/s		1.98		DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 15:18:55	0.240	mm/s		0.240		DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 15:18:55	0.189	g		0.189		DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 15:18:55	1.29	g		1.29		DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 15:18:55	0.683	g		0.683		DfCnd	High	0	0	0	0	2	4	0
3-PP-RV	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:18:55	6.07	mm/s		6.07		DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 15:18:55	1.09	g		1.09		DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:18:55	3.78	DEF		3.78		DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 15:18:55	2.74	mm/s		2.74		DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 15:18:55	3.91	mm/s		3.91		DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 15:18:55	0.464	mm/s		0.464		DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 15:18:55	0.389	g		0.389		DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 15:18:55	0.885	g		0.885		DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 15:18:55	0.490	g		0.490		DfCnd	High	0	0	0	0	2	4	0
4-PP-Ax	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:18:55	4.58	mm/s		4.58		DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 15:18:55	0.856	g		0.856		DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:18:55	3.44	DEF		3.44		DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 15:18:55	2.09	mm/s		2.09		DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 15:18:55	1.52	mm/s		1.52		DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 15:18:55	0.594	mm/s		0.594		DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 15:18:55	0.214	g		0.214		DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 15:18:55	0.783	g		0.783		DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 15:18:55	0.222	g		0.222		DfCnd	High	0	0	0	0	2	4	0

SOUTHVALE PUMP\

BOOSTER PUMP UNIT 4

Selected Date	15/02/2019 15:18:55	Speed	59.1 Hz / 3545 rpm
Author	u1	Connector	
System - Serial No	FALCON - 11407	Sensor	

4-PP-RH	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:18:55	3.77	mm/s		3.77		DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 15:18:55	1.10	g		1.10		DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:18:55	3.28	DEF		3.28		DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 15:18:55	1.03	mm/s		1.03		DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 15:18:55	2.11	mm/s		2.11		DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 15:18:55	0.183	mm/s		0.183		DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 15:18:55	0.200	g		0.200		DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 15:18:55	1.04	g		1.04		DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 15:18:55	0.250	g		0.250		DfCnd	High	0	0	0	0	2	4	0

4-PP-RV	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:18:55	4.81	mm/s		4.81		DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 15:18:55	0.935	g		0.935		DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:18:55	3.11	DEF		3.11		DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 15:18:55	1.72	mm/s		1.72		DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 15:18:55	2.61	mm/s		2.61		DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 15:18:55	0.411	mm/s		0.411		DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 15:18:55	0.265	g		0.265		DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 15:18:55	0.868	g		0.868		DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 15:18:55	0.205	g		0.205		DfCnd	High	0	0	0	0	2	4	0