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SOLVING CENTRIFUGAL PUMP INSTALLATION AND HIGH VIBRATION ISSUE DUE TO IMPELLER DIAMETER UPGRADE (CASE STUDY)

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23 years of experience in Oil and Gas Industry covering maintenance, engineering and project management, specializing in Rotating Equipment. Had an opportunity under Development Program to be attached at various Departments in Gas Processing Plant, later assigned as an Executive responsible for Compressor Station in ensuring integrity and reliability of all static and rotating equipment at Transmission Operation Division in PGB. Had spent most of the time within the first 20 years in the maintenance department at plant, with medium term exposure to engineering and project execution both in domestic and international. Currently a Principal in Rotating, Technical Authority Level 1 responsible for PETRONAS Upstream.

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22 years of experience in Oil and Gas Industry covering engineering, inspection and maintenance of Rotating Equipment. Had spent most of the time in the engineering and maintenance department in oil refinery as well as assuming roles as Business Technical Authority [BTA] for plant change and revamp project. He also provide technical coaching and responsible for the technical talent development for Rotating Equipment engineers. Currently a Principal in Rotating Equipment for oil Refinery in Melaka.

ABSTRACT

- There are various ways to execute modification to the Centrifugal Pump Performance (Head vs Flow) to suit to the new operating condition. In this case study, impeller diameter increase was opted.

- This case study will discuss on various challenges faced during implementation of the modification of the pump during project execution and commissioning of the pump.

- The key lesson learnt from the case study are as follows;
  - Data or information shown in the pump datasheet or performance curve may not tell the maximum size of impeller that can be upgraded.
  - A minimum radial clearance or cut water information shall be considered for all cases which is not specified in the API 610. Clarification with Manufacturer is necessary.

- This presentation also covers other consideration for any pump modification for technical sharing purposes.

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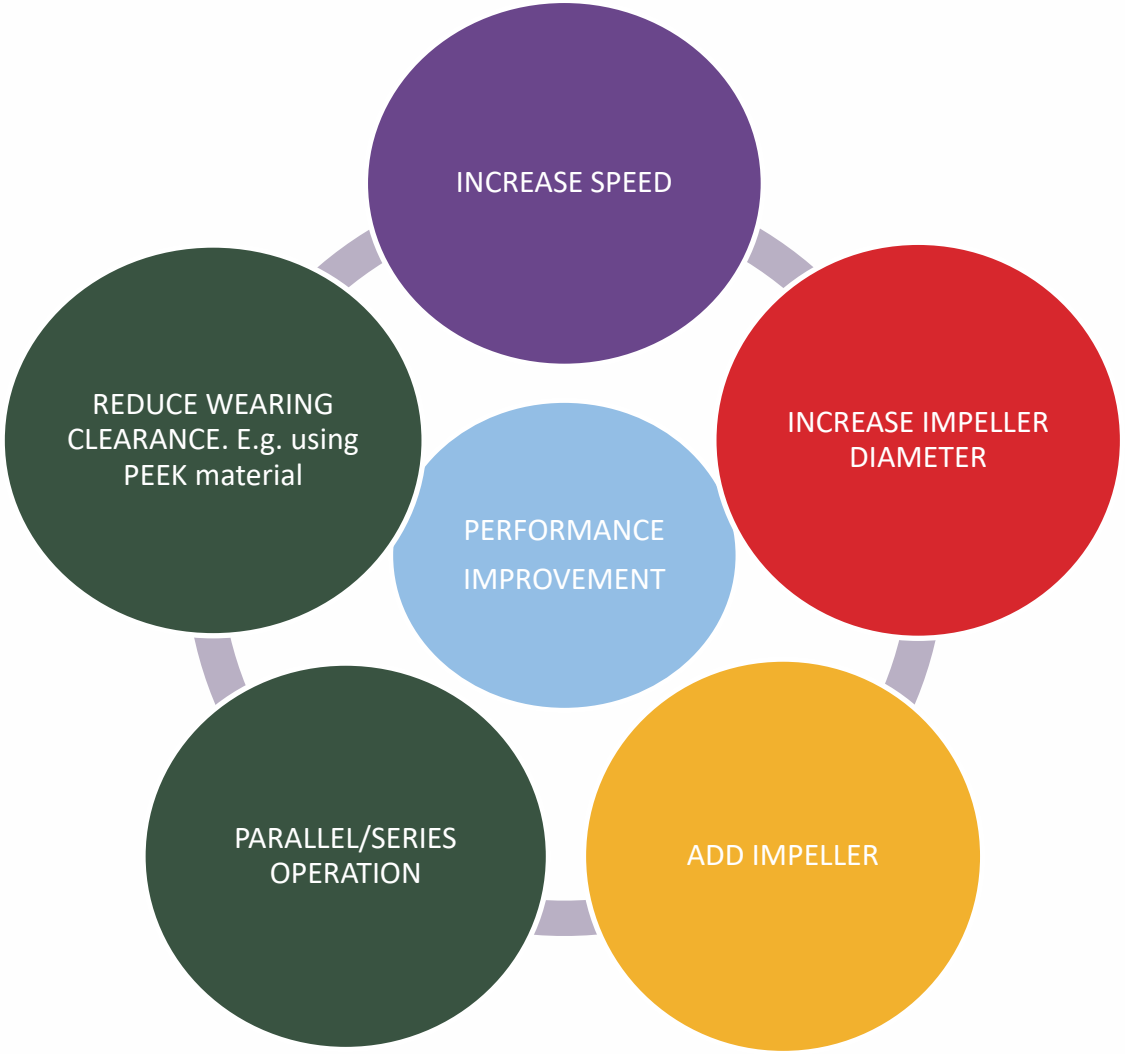
Introduction

Example of Centrifugal Pump

As operating condition changes, the pump has to be assessed for the new operating condition and modification may deem required for pump reliable operation.

Various Method for Improving Centrifugal Pump Performance (Head vs Flow Performance Curve)

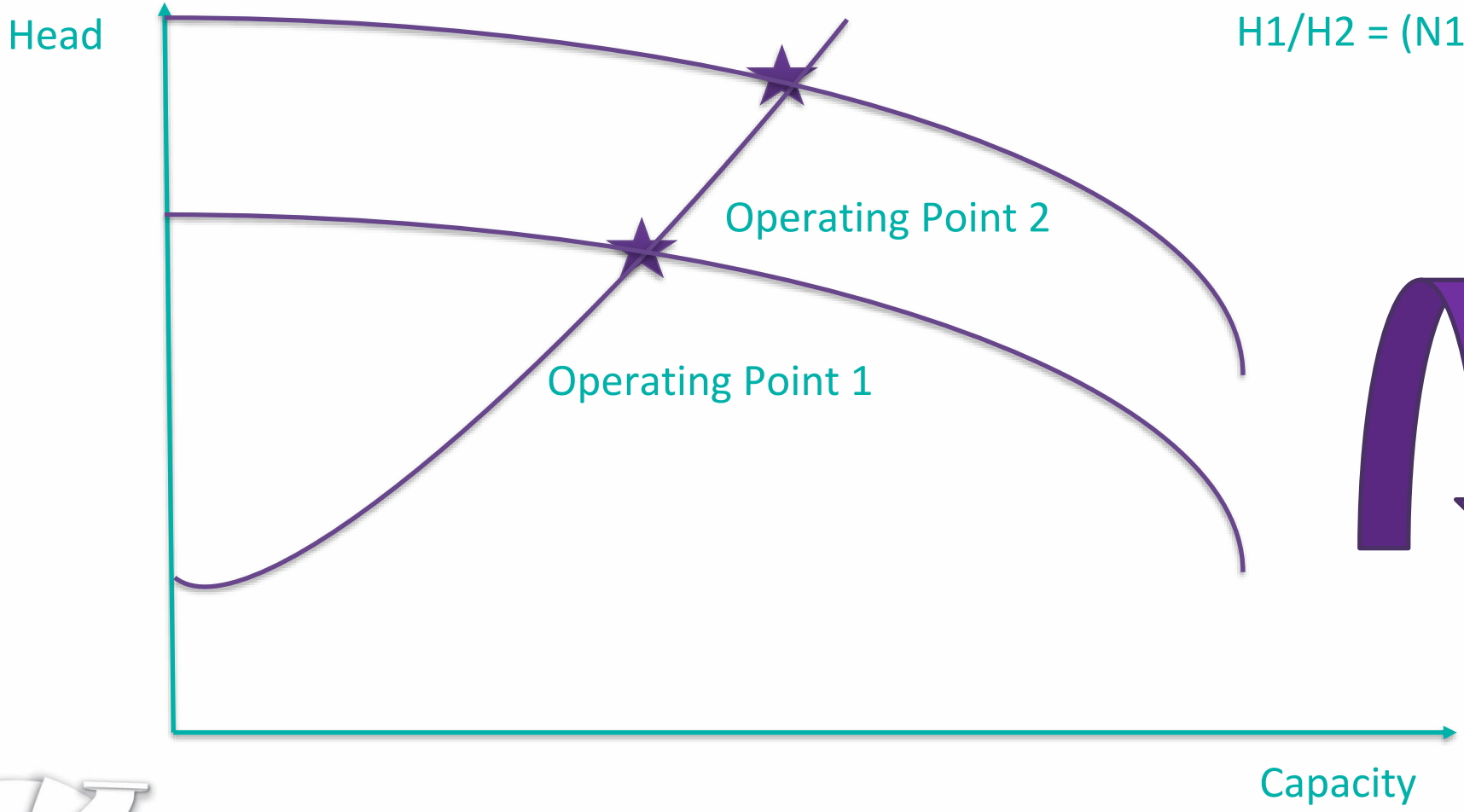


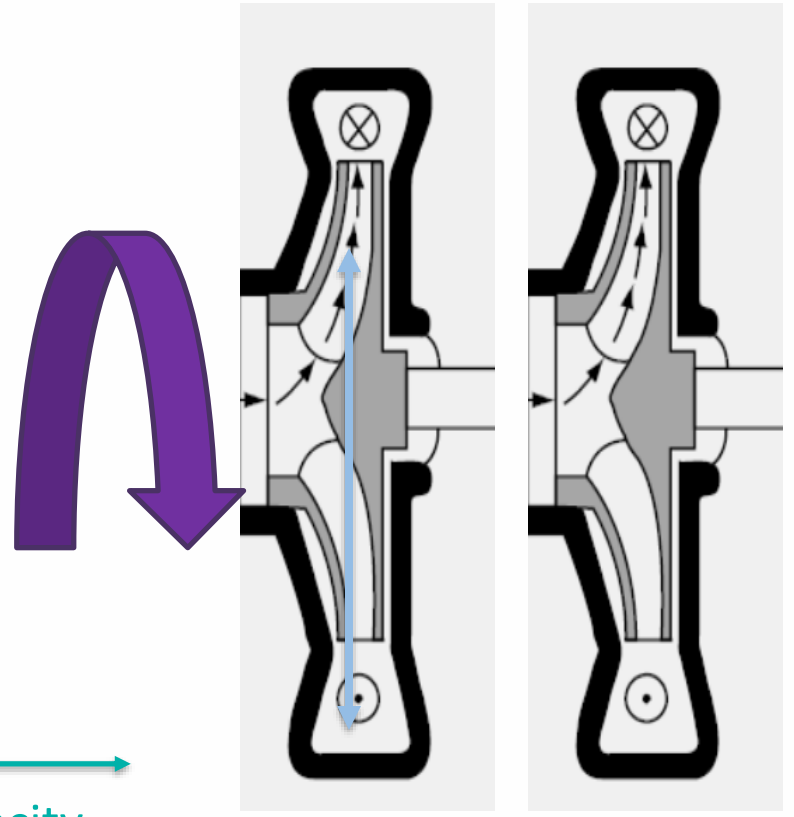
Increasing Speed/Impeller Size/Adding Impeller

Pump Affinity Law

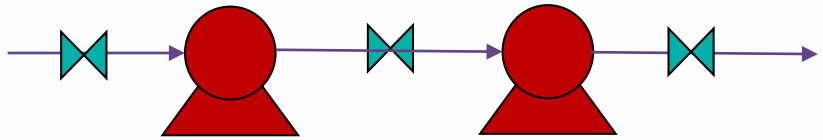
$Q1/Q2 = N1/N2 = D1/D2$

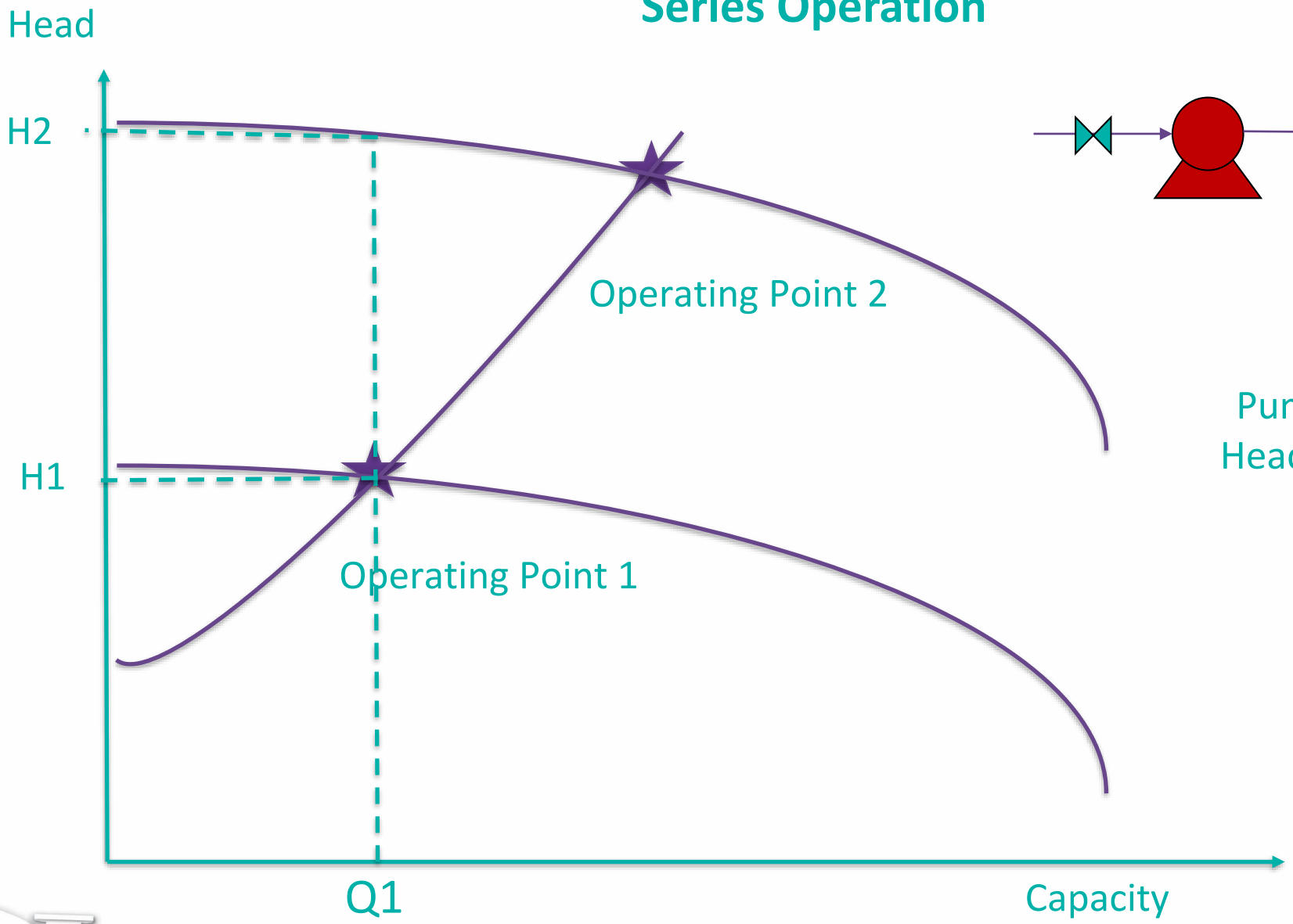
$H1/H2 = (N1/N2)^2 = (D1/D2)^2$





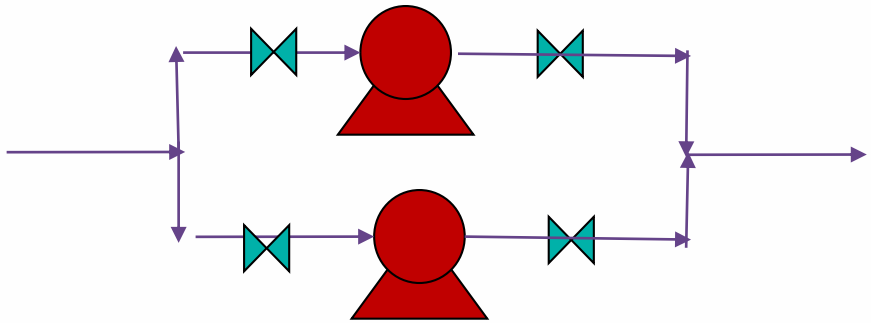
Series Operation





Pump Affinity Law
Head 2 = Head 1 X 2

Parallel Operation



Reducing clearances

- Table 6 of API 610 provides the minimum diametrical clearances for wear ring based on the diameter of rotating member at clearance.
- However, API 610 also mentioned the use of non metallic wear ring materials with very low or no galling affects.
- Published data showed wear ring clearance can be reduced up to about 50% if this material is being employed.
- The material that can be used are specified in Table H.3 in the API 610.
- The use of this material and reduced clearances will improve the pump performance. The improvement will vary depending on pump type, size and specific speed of the hydraulic.

Sample of Impeller wear ring

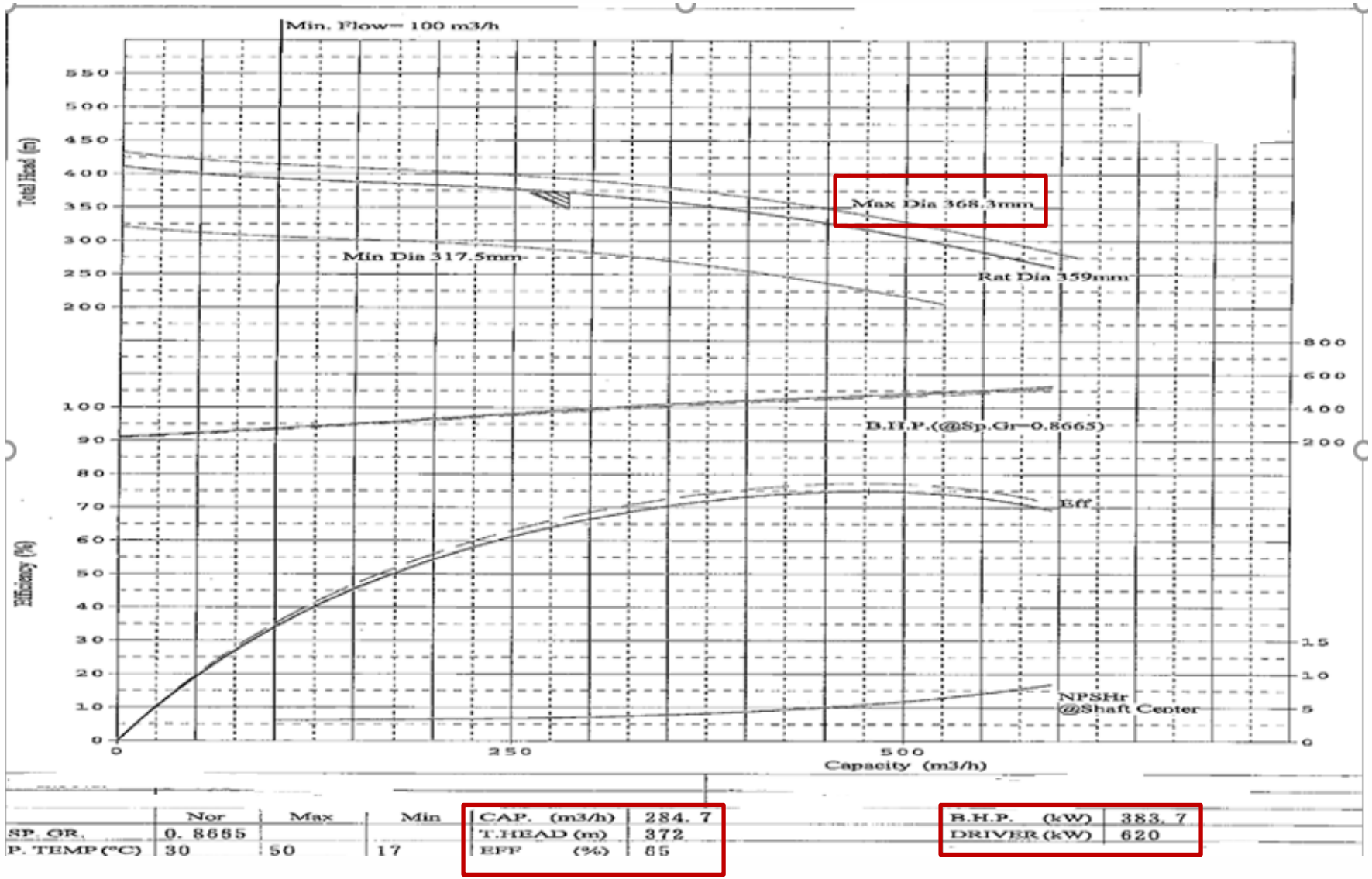
Example of Impeller wear ring

Case Study for Impeller Diameter Increase

Background

- Due to future operating condition, a BB1 designed centrifugal pump at one of the plant, require higher head and flow.
- During engineering phase, it was decided that the impeller diameter required to be increased. This option was selected as this was the most cost effective, quick and easiest modification to be pursued at site.
- The impeller size has been increased by about 3.1 % from 348 mm to 359 mm.
- The maximum impeller size given in the performance curve and datasheet is about 368 mm, about 5.7% above original impeller diameter.

Scope of Work



	Nor	Max	Min
SP. GR.	0. 8665		
P. TEMP (°C)	30	50	17

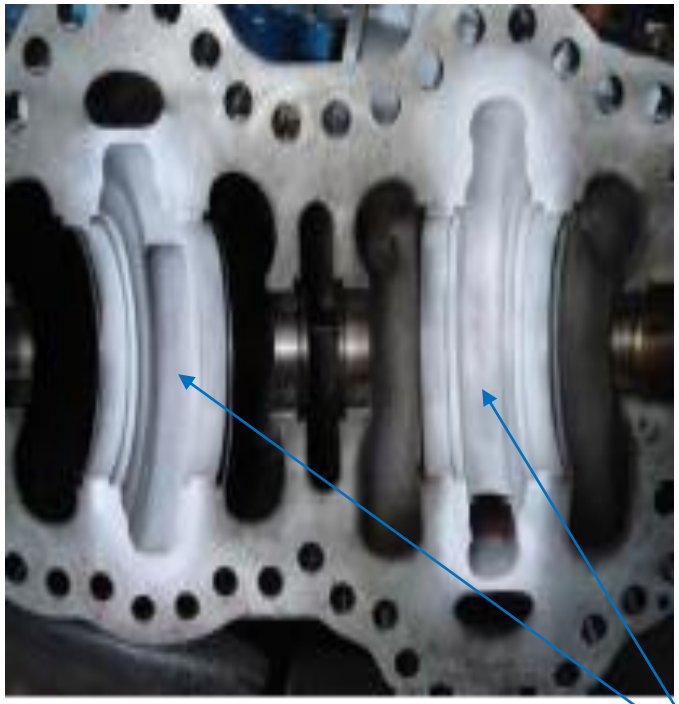
CAP. (m3/h)	284. 7
T.HEAD (m)	372
EFF (%)	65

B.H.P. (kW)	383. 7
DRIVER (kW)	620

Head is about 186 m/ stage

Power is about 191.85 kW per stage

Issues

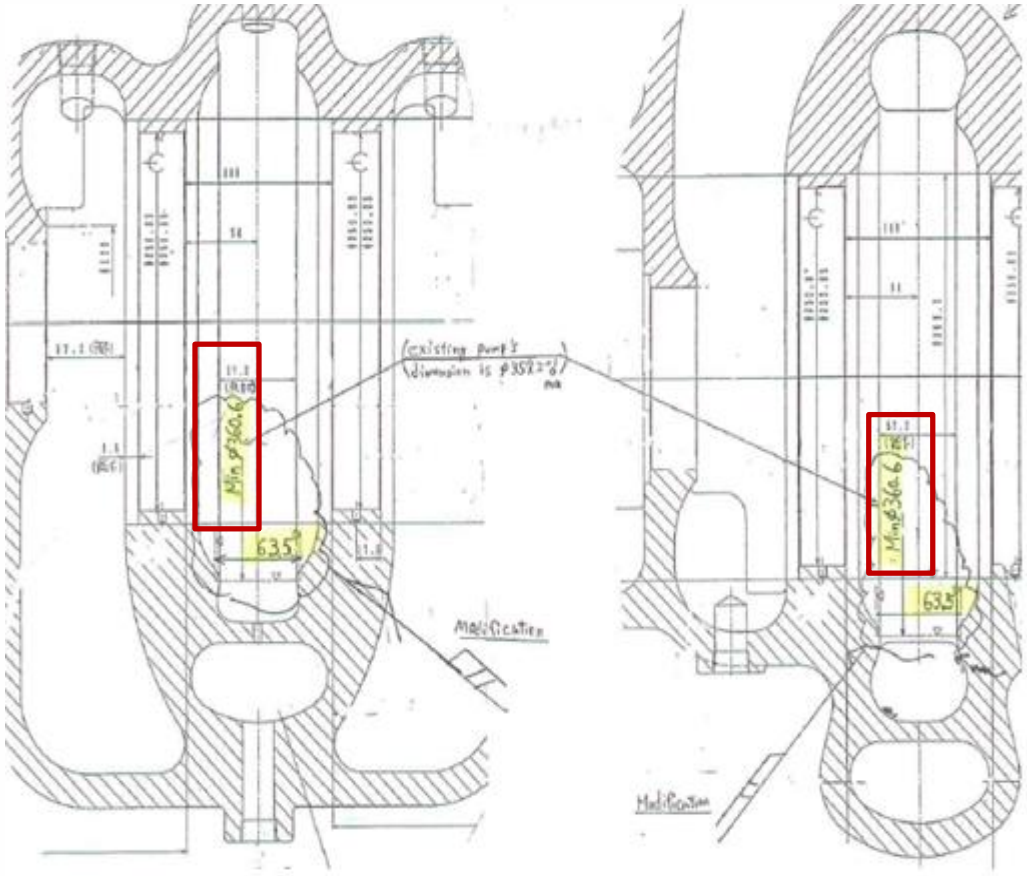


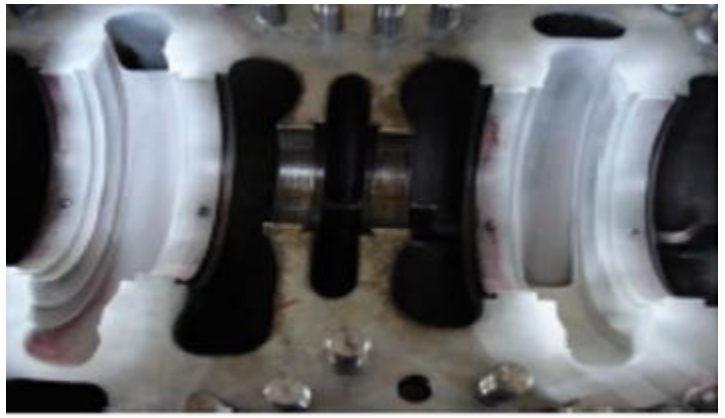
- During the installation of the new rotor, it could not fit into the casing as the volute size is smaller than the impeller diameter. The volute size is just about 2.61% higher than the original impeller size – about 357.1 mm .
- As remedial action, the volute diameter size is bored further to obtained the inside diameter of clearance 3.4% than the original impeller size (0.3% of the new impeller size) – about 360.6 mm.

Scope of Work

1st Stage

2nd Stage





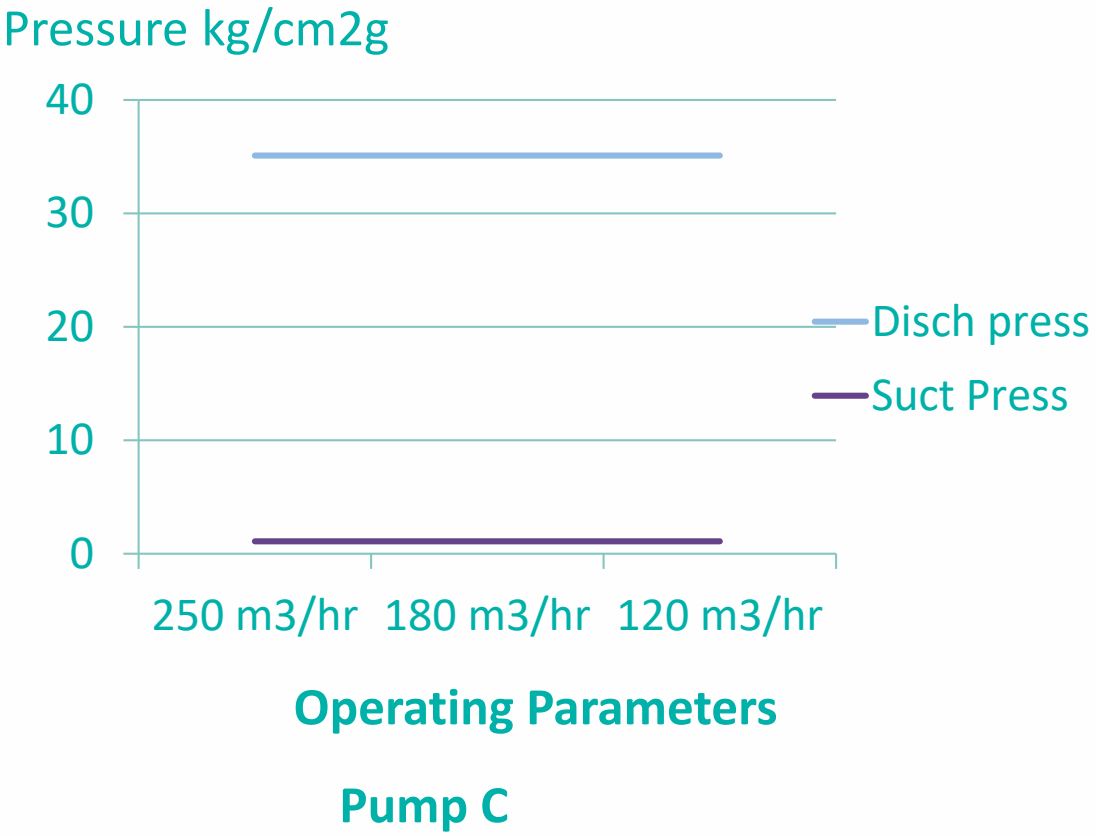
Bottom Half of the Pump

Top Half of the Pump

Testing and Commissioning

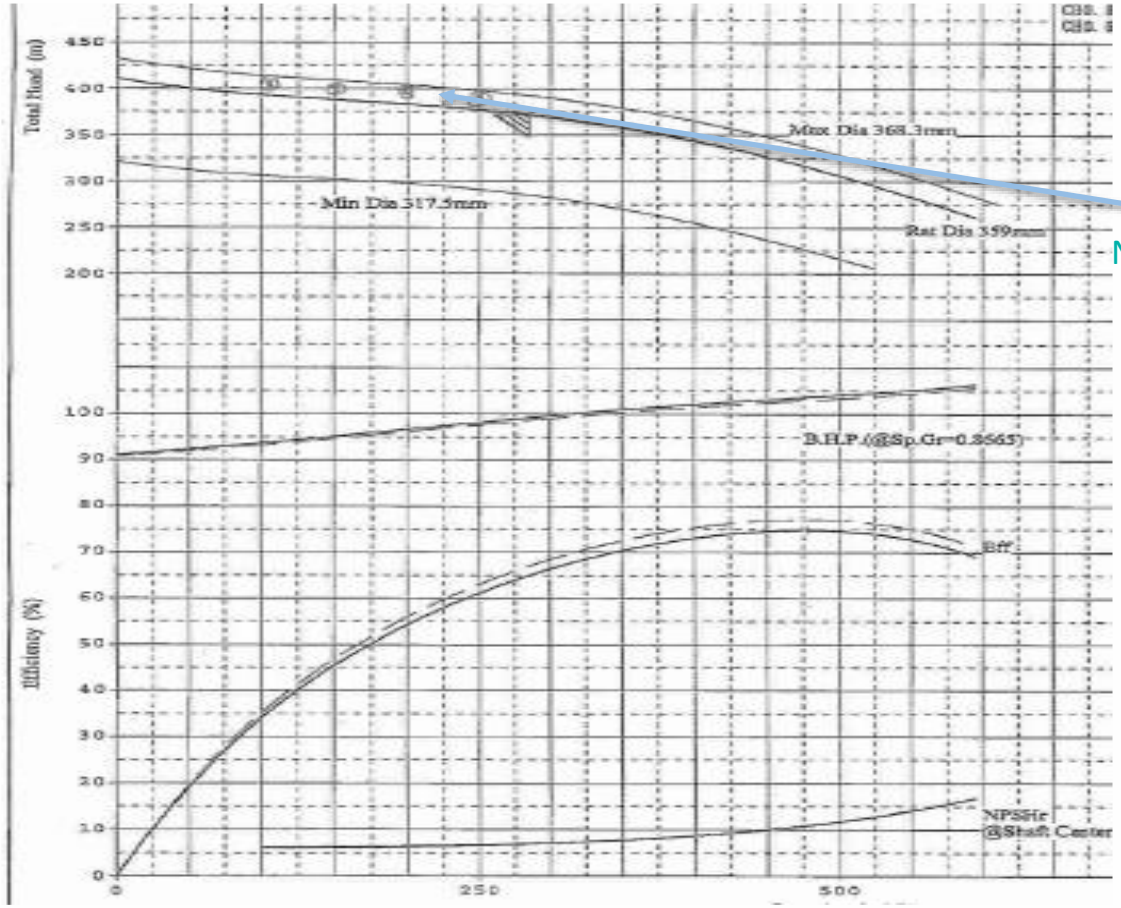
- Vibration was found higher than previous readings.
- Abnormal noise also heard during low flow operation.
- No performance issue.
- The impeller to volute radial gap is now only about 0.3% [(360.6-359 mm)/360.6 mm X 100) as compared to about 2.6 % original.

Testing and Commissioning



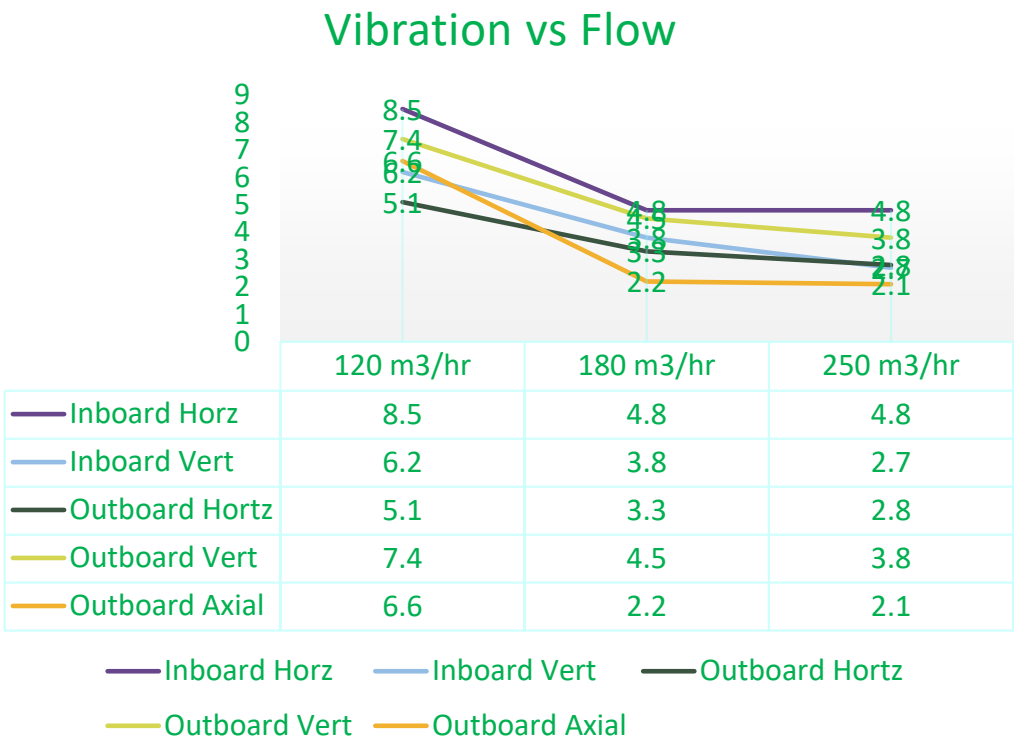
Operating Parameters

Pump C

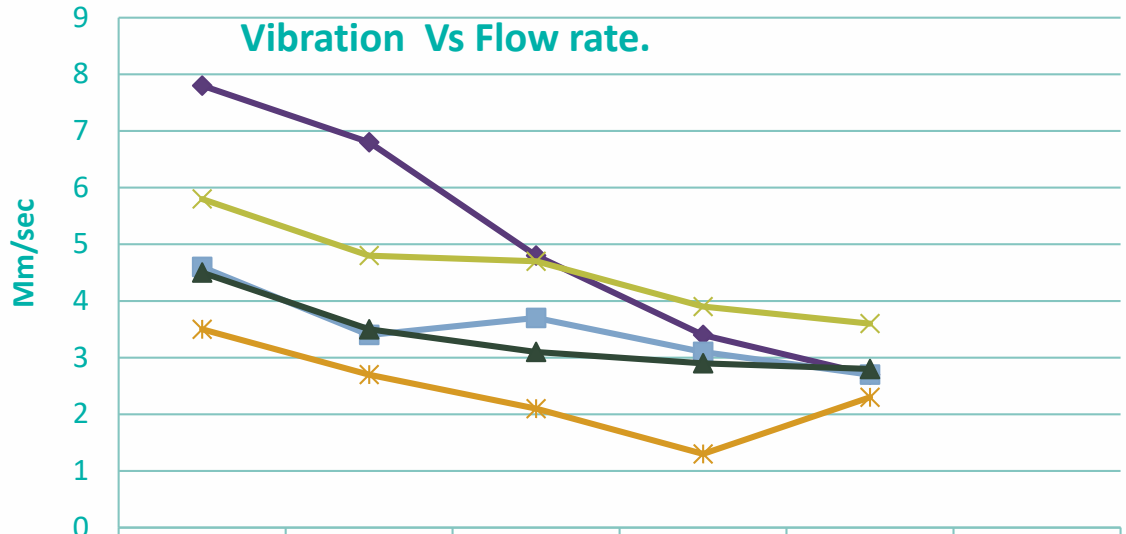


No performance issue

Testing and Commissioning Result

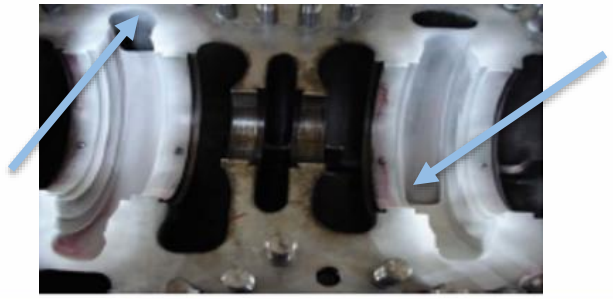


	120 m3/hr	180 m3/hr	250 m3/hr
Inboard Horz	8.5	4.8	4.8
Inboard Vert	6.2	3.8	2.7
Outboard Hortz	5.1	3.3	2.8
Outboard Vert	7.4	4.5	3.8
Outboard Axial	6.6	2.2	2.1



	105 m³/hr	120 m³/hr	150 m³/hr	200 m³/hr	250 m³/hr	
In board Horz.	7.8	6.8	4.8	3.4	2.7	
In board Vert.	4.6	3.4	3.7	3.1	2.7	
Out board Horz.	4.5	3.5	3.1	2.9	2.8	
Out board Vert.	5.8	4.8	4.7	3.9	3.6	
Out board Axial.	3.5	2.7	2.1	1.3	2.3	

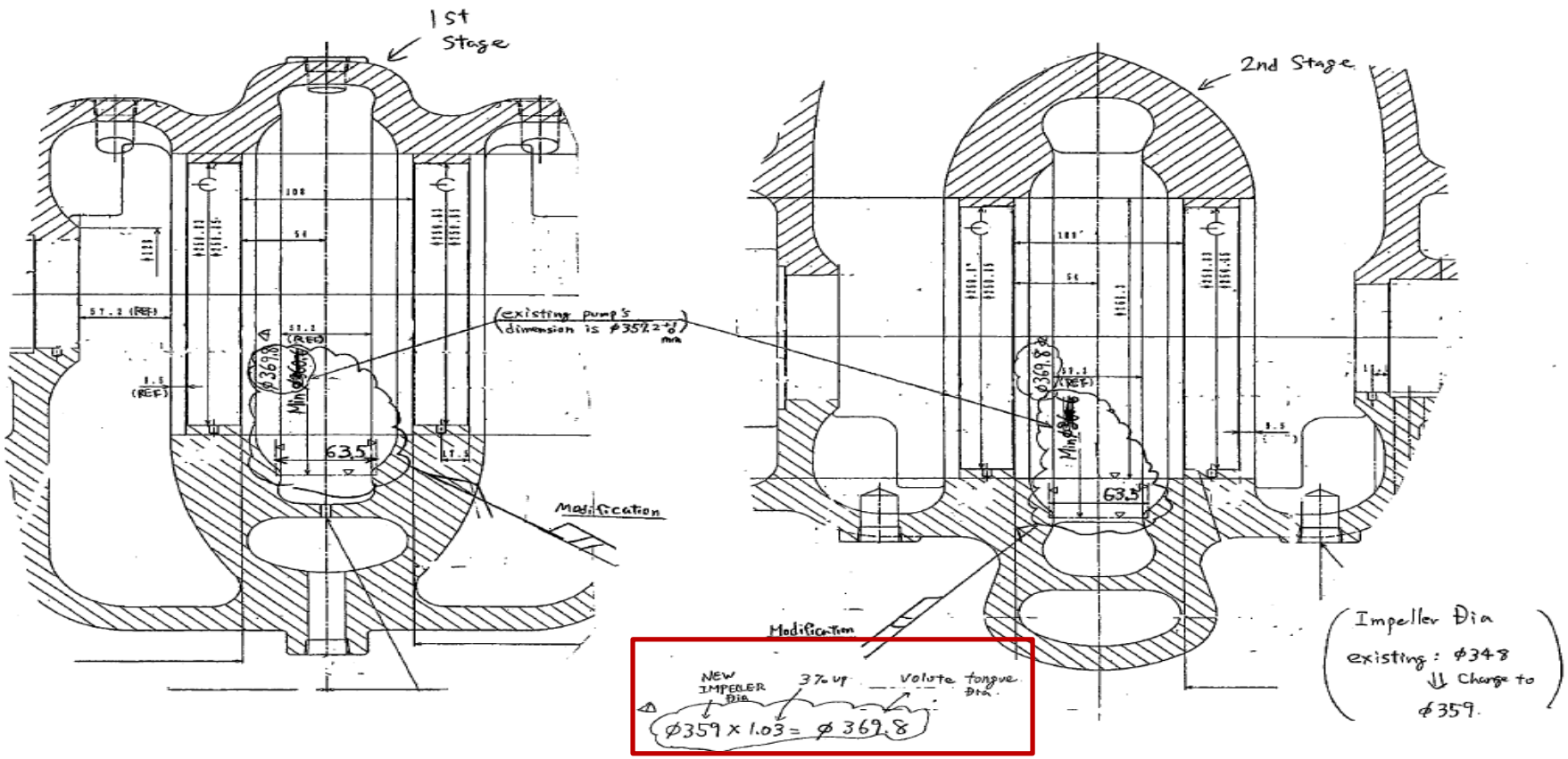
Note : The value mentioned above are an approximate value



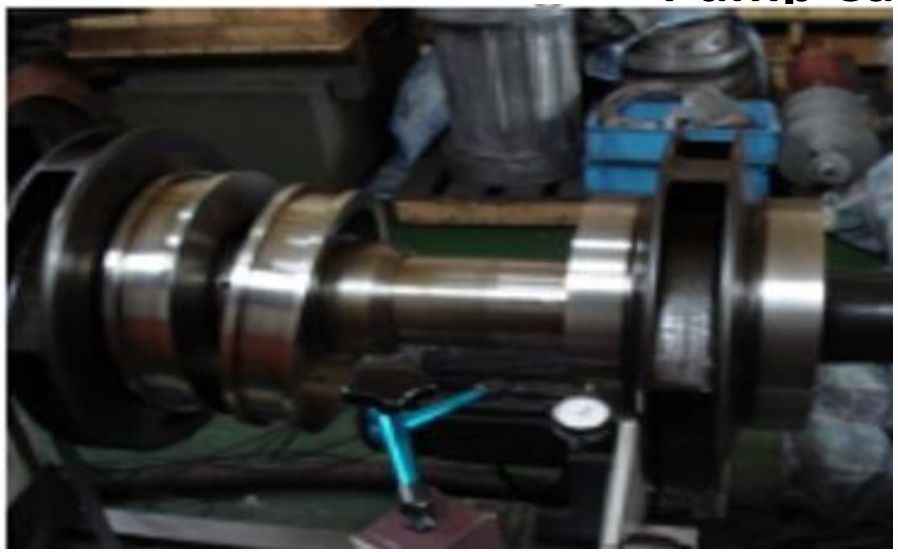
Volute start point location contributes to the Vibration at Inboard Horizontal and Outboard Vertical

Remedial Action

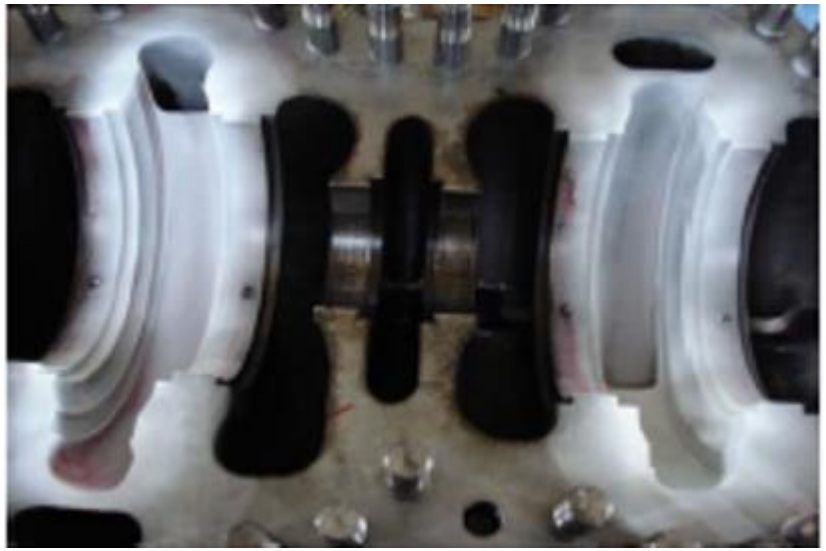
- Action taken to increase further the volute diameter gap size to about 3% of the new impeller size- about 369.8 mm.



Pump Casing Modification



Rotor Run Out Measurement using Dial Gauge

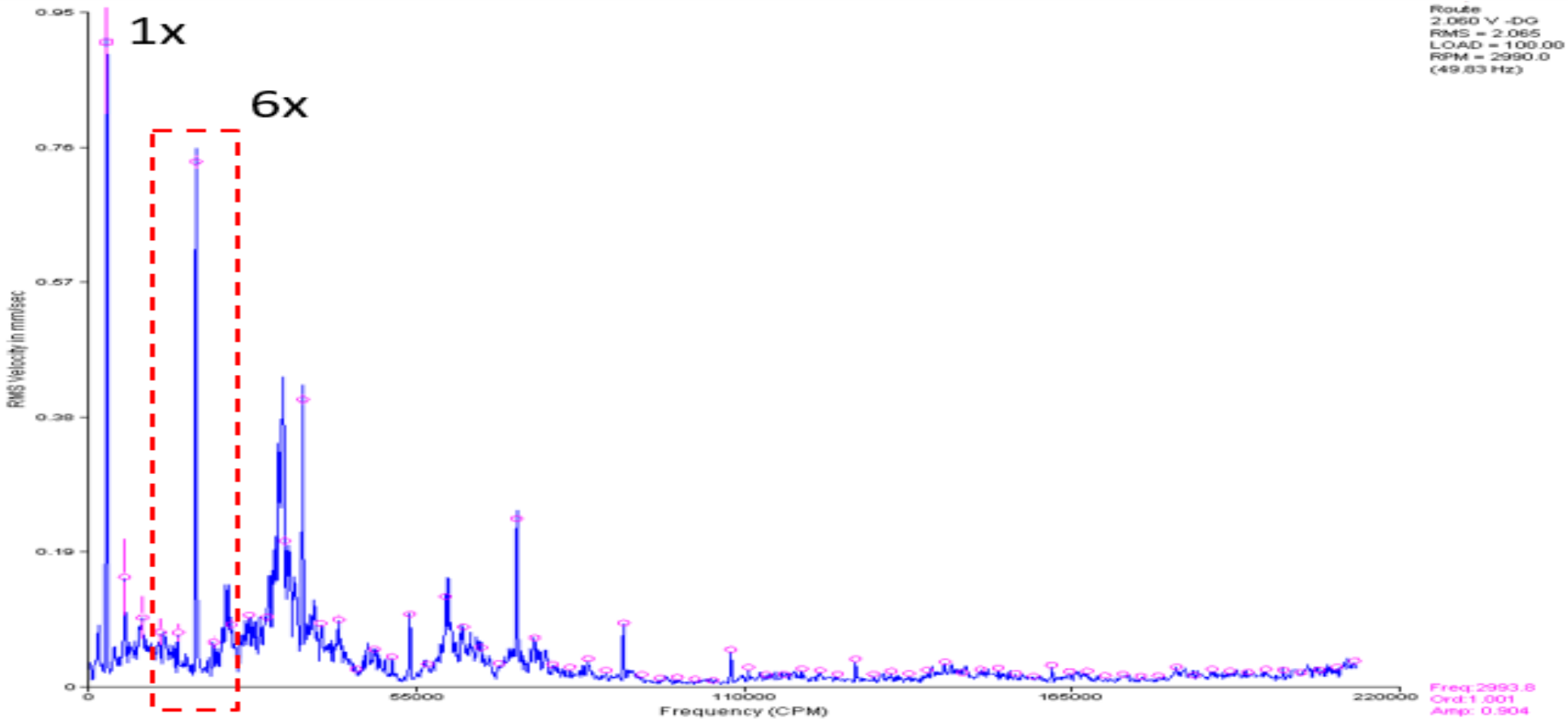


The volute was bored using boring machine and Die Penetration Tested - Result Acceptable

Hydrotested at 1.5 x MAWP

Testing and Commissioning Result

Vibration amplitude at 6th order [Vane Pass frequency] and overall vibration reduces to about 2 mm/s at pump flowrate of 200 m^3/hr



Lesson Learnt

- The impeller increase in size is not only depending on the information from datasheet or performance curve, but it is also the volute size or inside diameter which determined the limits.
- It is recommended to consider the radial gap clearance requirement in engineering as power stage or head per stage are within 10% of the mentioned value in clause 6.1.15 of API 610 11th Edition. .
- Irrespective of the head and power, it is required to maintain a minimum radial gap clearance. As rule of thumb, it is recommended to keep a minimum radial gap of 3 % for other condition. This minimum radial gap for other condition is not specified in the API 610 design requirement.
- The conformance to requirement 6.1.12 of API 610 for design of Rated Flow to Best Efficiency Point (BEP) and preferred Operating Region shall be followed.

Other Technical Consideration

- When, the pump head – curve requires improvement for new operating condition, the following consideration shall be verified ;
-
  - **Driver Power Margin** : Motor, engines, steam turbine etc.
  - **Coupling Rating : ** Coupling Power Rating shall be checked
  - **Driver Speed :** margin availability
  - **Mechanical Seal :** Stuffing Box Pressure, speed and etc.
  - **Axial Thrust :** Pressure Reducing Bush sizing and etc.
  - **Speed Torque Curve :** 10% margin shall be maintained during start up condition.
  - **Pump Critical Speed :** New operating speed shall be 10% away from pump critical speed.
  - **Best Efficiency Point(BEP)/Minimum Stable Flow :** normal operation against BEP.

APPENDIX : Reference from API 610

Requirements of 6.1.15 of API 610 11th Edition

6.1.15 Pumps with heads greater than 200 m (650 ft) per stage and with more than 225 kW (300 hp) per stage shall be deemed high-energy pumps and can require special provisions to reduce vane passing-frequency vibration and low-frequency vibration at reduced flowrates. For these pumps, the radial clearance between the diffuser vane or volute tongue (cutwater) and the periphery of the impeller blade shall be at least 3 % of the maximum impeller blade-tip radius for diffuser designs and at least 6 % of the maximum blade-tip radius for volute designs. The maximum impeller blade-tip radius is the radius of the largest impeller that can be used within the pump casing (see 6.1.4). The clearance, P, expressed as a percentage, is calculated as given in Equation (1):

$$P = 100\ R_2 - R_1\ / R_1 \qquad (1)$$

where

R_2 is the radius of volute or diffuser inlet tip;

R_1 is the maximum impeller blade tip radius.

It is common practice for the impellers of pumps covered by this clause to be modified after initial test to correct hydraulic performance by underfiling, overfiling or "V"-cutting; see 8.3.3.7 c). Any such modifications shall be documented in accordance with 10.3.4.1.

Requirements of 6.1.12 of API 610 11th Edition

6.1.12 Pumps shall have a preferred operating region of 70 % to 120 % of best efficiency flowrate of the pump as furnished. Rated flow shall be within the region of 80 % to 110 % of best efficiency flowrate of the pump as furnished.