



أرامكو السعودية  
Saudi Aramco



# Exploring Alternative Designs to Integrally Geared High Speed Pumps - Case Study

Abdulmajeed Al-Shaye : Saudi Aramco

Yousuf Al-Shuhail : Saudi Aramco



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- Failure Analysis
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- Summary

# Introduction

Caustic Transfer



Wash Water



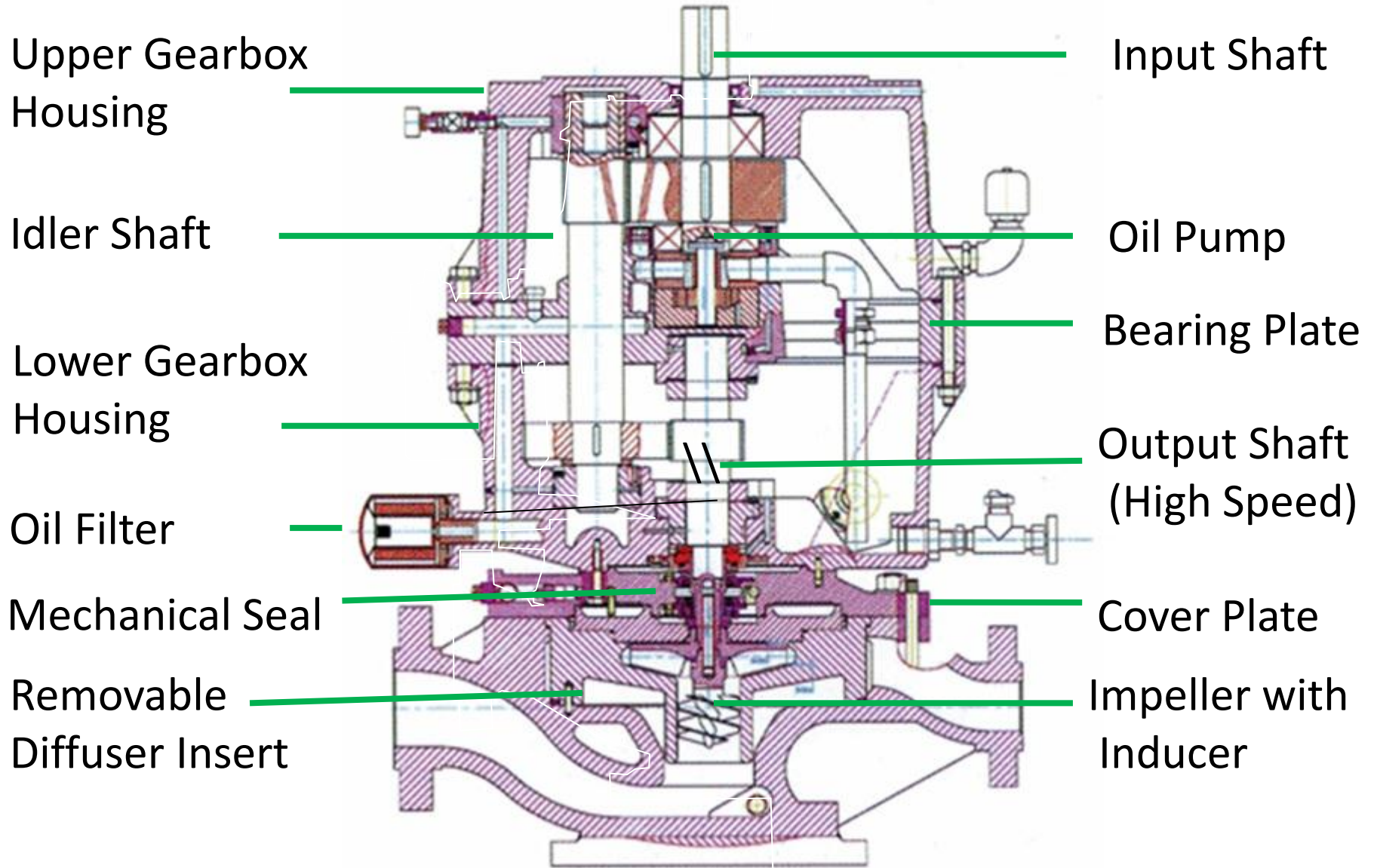
# Introduction - Integrally Geared

- API 610 OH6
- Low specific speed Impeller
- Partial emission diffuser
- 1<sup>st</sup> Choice for engineering contractors
- Inducer provides adequate NPSH to impeller
- Vertical or Horizontal orientations





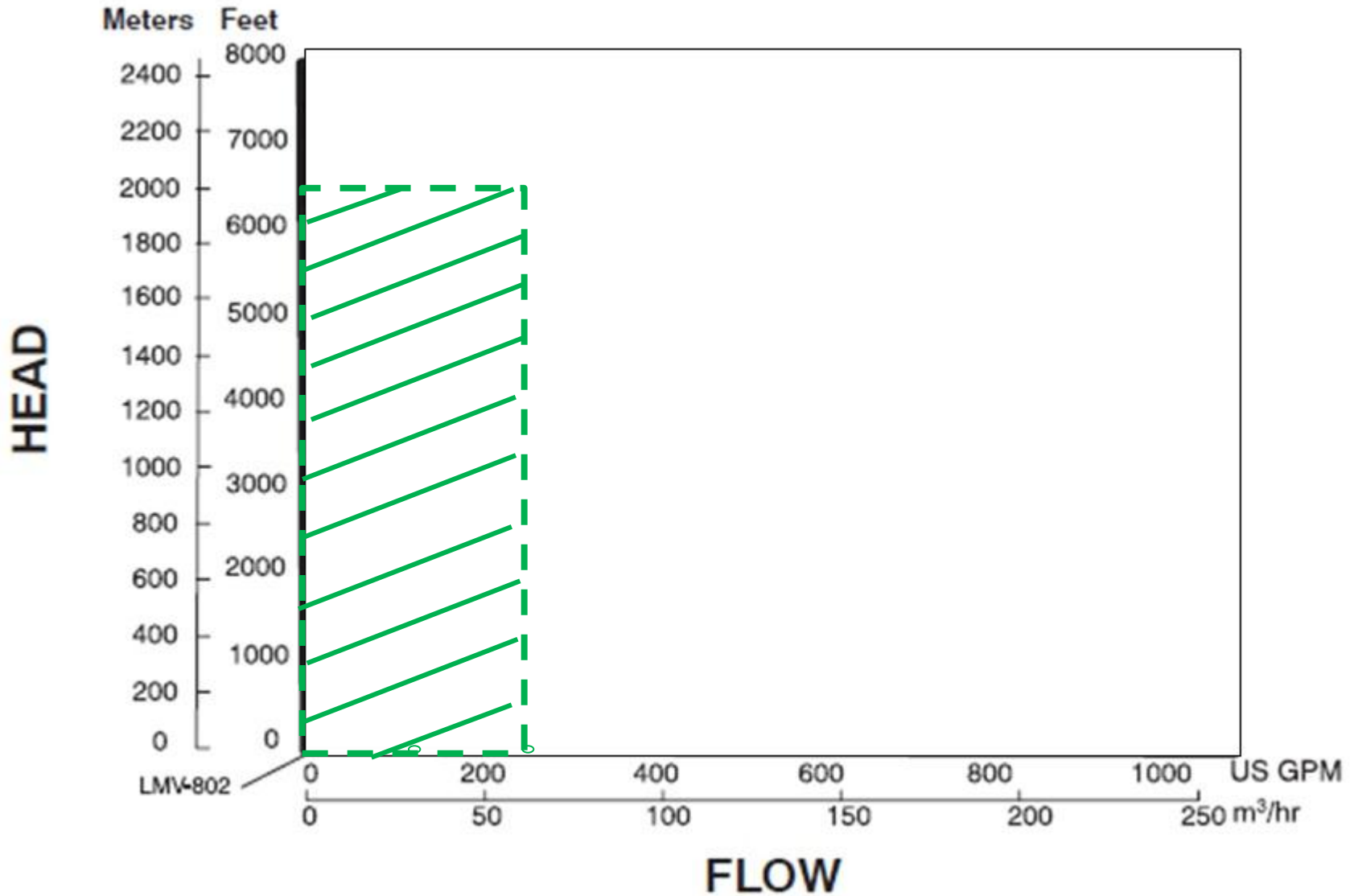
# Introduction - Integrally Geared Cross Section



# Introduction – Integrally Geared Advantages and Disadvantages

Advantages	Disadvantages
<ul style="list-style-type: none"><li>• Low initial cost</li><li>• Single-stage</li><li>• Open impeller design (no wear rings)</li><li>• Compact size and in-line mounting minimizes foundation requirements</li></ul>	<ul style="list-style-type: none"><li>• Requires special sealing design</li><li>• May require inducer</li><li>• High spare parts and repair cost. Repair in specialized service centers</li><li>• Gearbox requires lube oil system</li><li>• Narrow operating window</li><li>• More vulnerable to catastrophic failures</li><li>• Limited vendors</li></ul>

# Introduction – Low Flow High Head Operating Range



# Case Study - Operating Conditions

Service	Caustic transfer	Wash water
Flow (GPM)	40	106
Head (Feet)	730	1600
Speed (RPM)	11,000	14,838



# Failure Analysis

Caustic Transfer



# Failure Analysis – Caustic Transfer

- Batch operation to varying header pressures
- Pump has narrow operating window and operates away from BEP without proper control
- Pump experiences high vibration
- Pump experiences frequent seal leaks
- Gearbox experiences abnormal noise

# Failure Analysis – Caustic Transfer Maintenance Record

Caustic transfer pump 801-P-3 A		
Failure Date	Failure Mode	Cost (\$)
Dec 2001	Seal failure	6,000
Nov 2002	Gearbox failure	18,000
Feb 2003	Seal failure	14,000
Jun 2004	Gearbox failure	11,000
Jul 2005	Gearbox failure, oil leak and low performance	20,000
Apr 2006	Seal failure	9,000
Oct 2008	Seal failure	17,000
Sep 2009	Gearbox failure and oil leak	40,000
Total		135,000

# Failure Analysis – Caustic Transfer Maintenance Record (cont.)

Caustic transfer pump 801-P-3 B		
Failure Date	Failure Mode	Cost (\$)
Nov 2002	Gearbox failure	15,000
Oct 2004	Seal failure	11,000
Aug 2005	Seal failure	7,000
May 2007	Seal failure	16,000
Jan 2009	Gearbox failure	40,000
May 2009	Gearbox failure	13,000
Jan 2010	Seal failure	10,000
Sep 2010	Seal failure	26,000
Total		138,000

# Failure Analysis

Wash Water





# Failure Analysis – Wash Water

- Two pumps experienced catastrophic failures

# Failure Analysis – Wash Water Maintenance Record

WASH WATER PUMP Z97-G-002 A		
Failure Date	Failure Mode	Cost (\$)
2006	Catastrophic failure	Repaired Under Warranty
Oct 2008	High vibration	12,000

WASH WATER PUMP Z97-G-002 B		
Failure Date	Failure Mode	Cost (\$)
Mar 2008	Catastrophic failure	162,000
May 2011	High vibration	31,000
Total		193,000

# Root Causes

- **Caustic pump**

Incorrect selection of pump type since integrally geared pump has narrow operating window for this varying operating range

- **Wash Water**

Both pumps experienced catastrophic failures to the point the root cause of failure could not be identified.

# Alternative Pump Designs

- Horizontal Axially Split BB3
- Horizontal Radial Ring-Section BB4
- Double-Casing Diffuser Vertically Suspended VS6
- Sealless Multistage Canned Motor
- Overhung low  $N_s$  Impeller OH2
- Between Bearing low  $N_s$  Impeller BB2
- Surface mounted Electric Submersible Pump
- Vertical in-line with High Speed Motor OH4
- Positive Displacement Reciprocating
- Pitot Tube

# Alternative Pump Designs

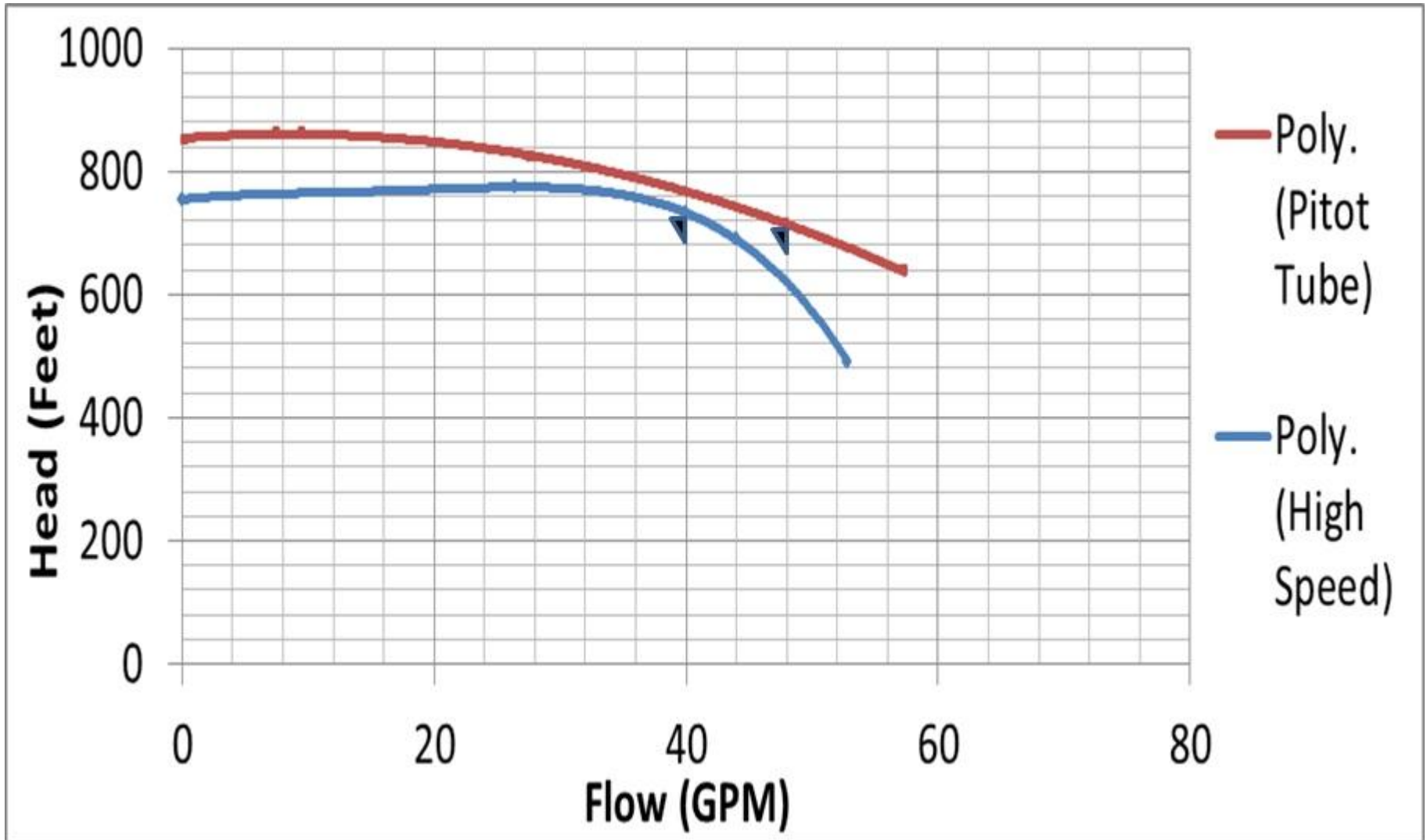
After evaluation of all advantages and disadvantages and experiences with the different pump designs, Pitot Tube pump type was selected for trial installation



# Alternative Pump Designs - Considerations

- Life cycle cost
- Space limitation
- Available local service center
- Efficiency difference to account for electrical system modifications
- Requirement for control system
- Suspended particles
- NPSHr vs. NPSHa
- Curve shape to match varying flow

# Alternative Pump Designs – Comparison of Curves Caustic Pump



# Alternative Pump Designs - Caustic Transfer Replaced With Pitot Tube



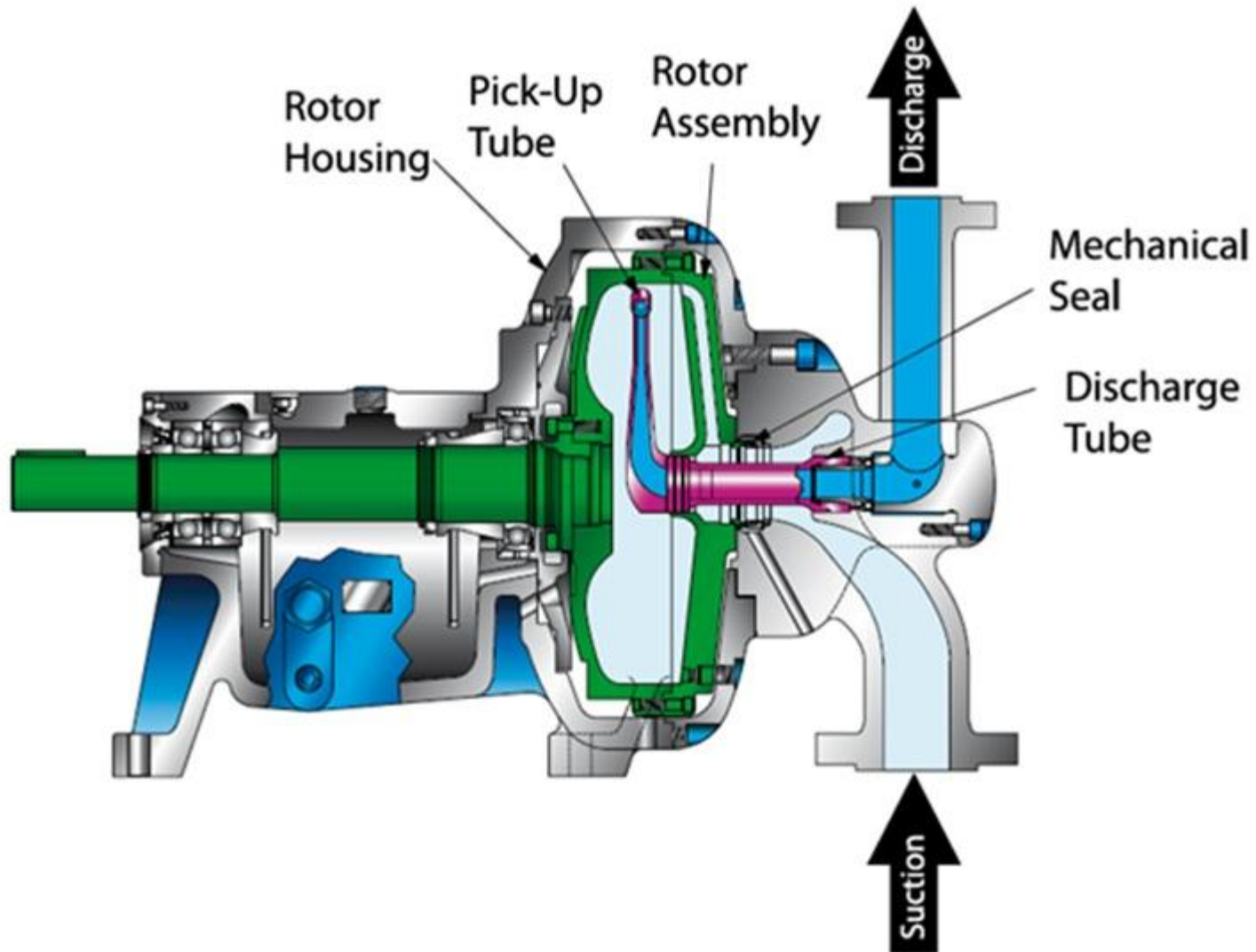


# Alternative Pump Designs – Wash Water Replaced With Pitot Tube



# Alternative Pump Designs

## – Pitot Tube Pump





# Alternative Pump Designs – Limitations of Pitot Tube Pump



# Alternative Pump Designs - Pitot Tube Pump

Advantages	Disadvantages
<ul style="list-style-type: none"><li>• Requires standard speed 3600 RPM (higher speed requires gearbox)</li><li>• Low initial cost</li><li>• Very low thrust load</li></ul>	<ul style="list-style-type: none"><li>• Pitot tube sensitive to erosion from products with suspended hard particles (requires fine mesh strainer)</li><li>• More sensitive to unbalance due to large rotating mass</li></ul>

# Summary

Consider the following main points for alternative designs:

- Life cycle cost
- Space limitation
- Efficiency to account for electrical system modifications
- Suspended particles
- Operating conditions

**Thank you**