51ST TURBOMACHINERY & 38TH PUMP SYMPOSIA
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Installation of a Stall Ring to Mitigate Boiler Feed Water Pump NPSH3 Requirements at Low Flow

Presenter Biography

- **Bobby Souers** graduated from the University of Kentucky in 1980 with a Bachelor's of Science in Mechanical Engineering. He began his career with Ashland Oil in Catlettsburg Ky and has been the owner and Principal Engineer for Equipment Reliability Services since 1998. He is a licensed Professional Engineer in the state of KY.

Abstract

An ubiquitous multistage boiler feed water pump for a SMR Hydrogen Plant in a refinery was specified to meet feed water requirements at plant design hydrogen capacity and at a turndown rate. During testing, it was discovered that the pump could not meet the proposed NPSH3 values at rated or low flow conditions.

The OEM offered two (2) options:

1. A complete redesign of the impeller and a delivery that would not meet the project requirements
2. The installation of a stall ring in the eye of the 1st stage impeller.

Due to project constraints, the stall ring option was chosen: however, multiple test runs and stall rings of varying diameter and entrance chamfers were required to provide a pump that would operate over the specified hydraulic performance envelope.

When the Proposal Curve is Not What You Thought It Was

- NPSHA (Net Positive Suction Head Available) is the absolute total head in feet at the pump centerline or impeller eye minus the liquid vapor pressure in feet at the pumping temperature.
- NPSH3 is the NPSH that results in a 3% loss of head due to cavitation at the 1st stage impeller. NPSH3 is verified by the OEM during performance testing.
- The NPSH margin is the head in feet difference between the NPSH3 and NPSHA. A typical margin requirement provided by specification is 3 feet.
- NPSH3 testing is imperative to ensure reliable operation of pumps operating close to the liquid vapor pressure. Proposal curves based on previous test data do not always reflect the actual test results.

HPBFW Pump Requirements

- Refinery SMR (Steam Methane Reformer) Hydrogen Unit 40 MM SCFD
- Pumps to be rated for 620 GPM at full unit rate and 240 GPM at Unit Turndown
- NPSHA for pump design to be 20.8 feet
- NPSH3 Margin to be a minimum of 3 feet at all operating points including MCSF/Turndown

H2 Unit HPBFW Pump Proposal Conditions

- 5 Stage Horizontal Split
- Rated- 620 GPM @ 1462 TDH
- 3563 RPM, Impeller Trim 8.89”
- 1st Stage Impeller Single Suction w/ Impeller Eye Diameter- 5.5” and Shaft Diameter- 2.25”
- NPSH3- 15.2 feet at Rated Condition
- NPSH3- 11.8 feet at 240 GPM MCSF
- NPSHA- 20.8 feet
- Pumps should have adequate NPSH3 margin based on proposal data

Initial NPSH3 Testing

- The initial NPSH3 testing (unwitnessed) on the 1st pump provided acceptable NPSH3 results of 15.2 feet at the Rated Point and 11.5 feet at MCSF/Turndown.
- The initial NPSH3 testing (unwitnessed) on the 2nd pump provided unacceptable NPSH3 results of 17.89 feet at the Rated Point and 22 feet at MCSF/Turndown
- The 1st pump was retested with more attention to individual data point knee curves and also found to be unacceptable
- Rework (grinding, polishing, profiling) of the impellers was performed with no improvement in NPSH3

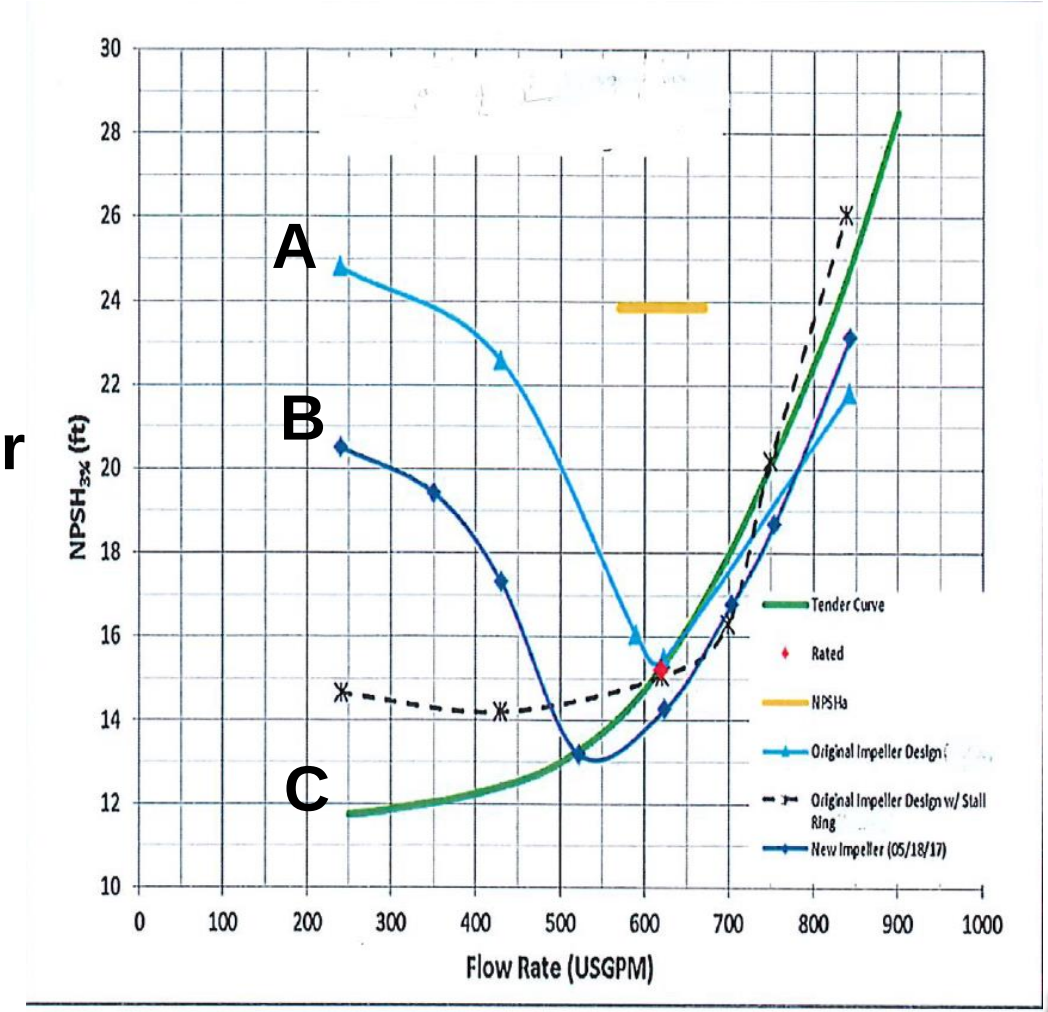
Options Proposed by the Pump OEM

- The original impellers were sand cast and there was a concern with dimensional non-conformances, vane profile, and surface finish. The first option was to provide a new investment cast 1st stage impeller and retest for NPSH3.
- The second option was to install a choke/stall ring into the eye of the 1st stage impeller. The stall ring inside diameter would be determined by iterative testing to optimize the NPSH3 from the rated point down to the MCSF.
- The new investment cast impeller was to use the same pattern dimensions as the sand cast with no changes in blade angle or profile.
- Third option would be a new impeller design with CFD modeling.

Investment Cast Impeller

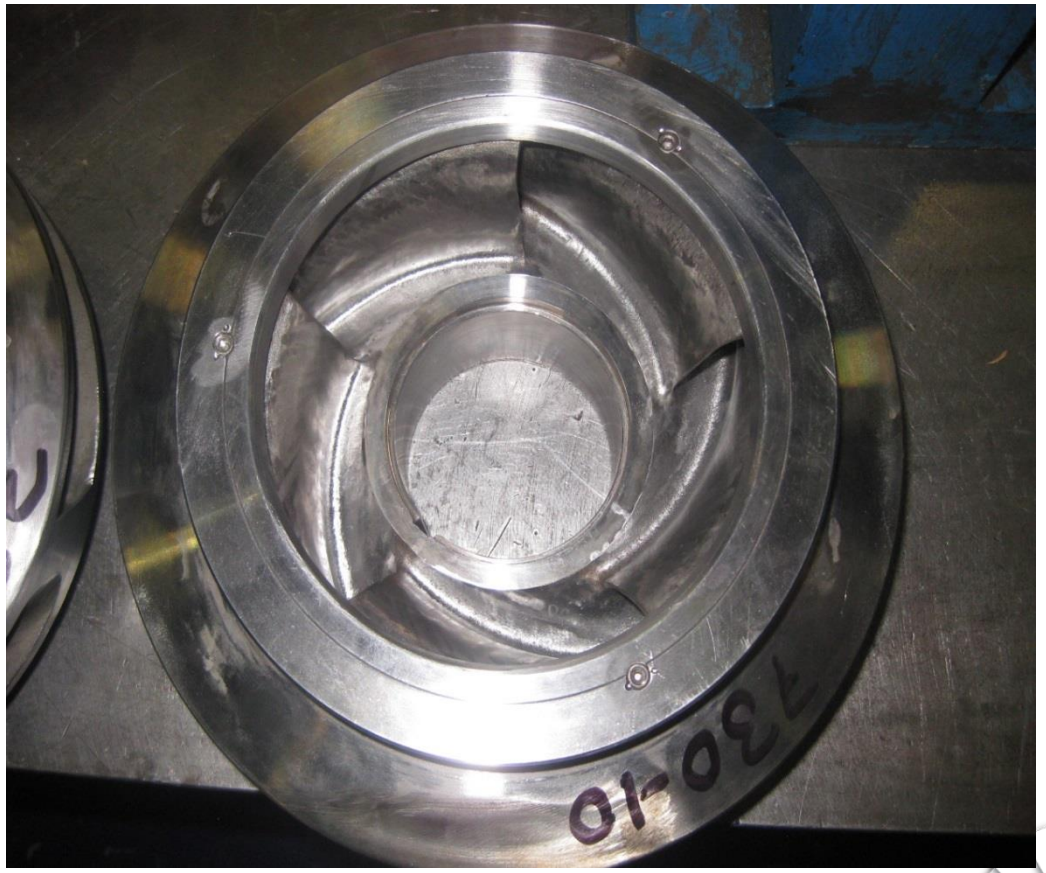
New Impeller NPSH Testing Results

- **A- Original Sand Cast Impeller NPSH3 Curve**
  - Does not meet NPSH3 at MCSF/Turndown Spec
- **B- New Investment Cast Impeller NPSH3 Curve**
  - Meets NPSH3 requirements at rated point with 6 feet margin
  - Better at Turndown, but still does not meet NPSH3 margin.
- **C-Proposal NPSH Curve**



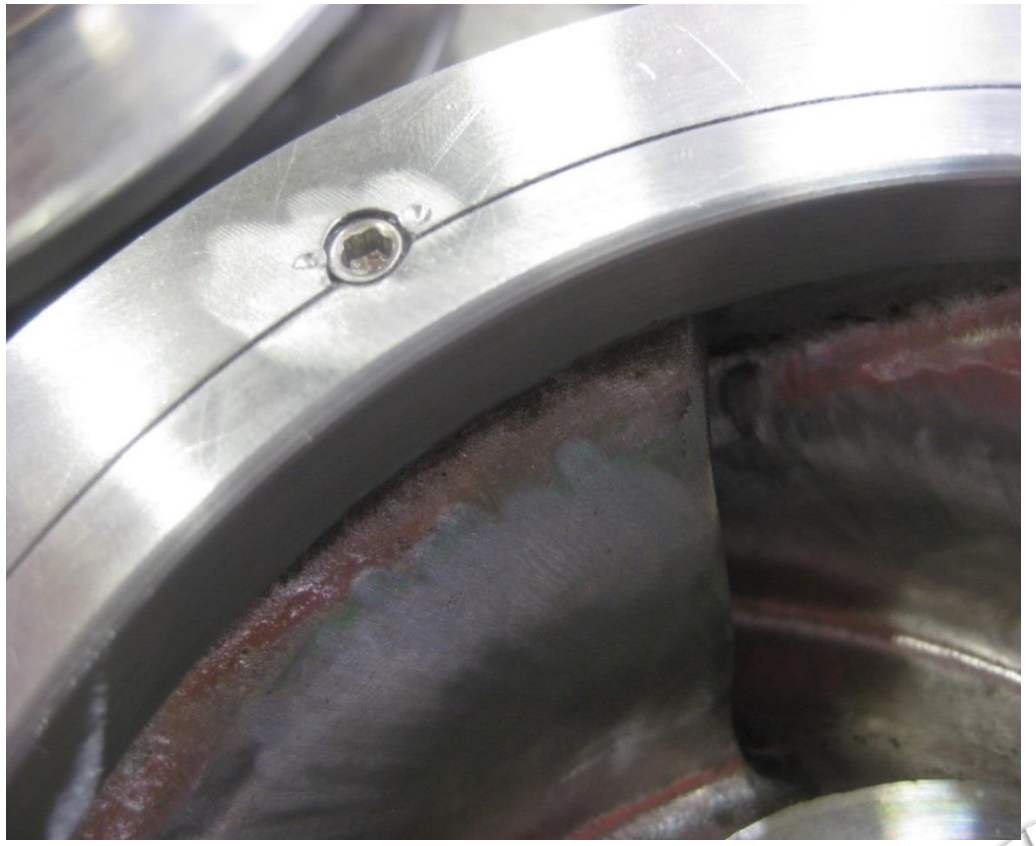
Installation of a Stall Ring in the 1st Stage Impeller Eye

- As the new investment cast impeller did not provide acceptable results and a new design impeller did not fit the project schedule, the installation of a stall ring was the only viable option.
- The stall ring was installed in the impeller to help reduce suction recirculation at reduced flow
- Rings of 5”, 4 7/8”, and 4 3/4” inside diameter were tested.



Stall Ring Chamfer and Radius

- The stall ring was installed into the impeller eye 0.001”/0.002” interference and secured for anti-rotation with three (3) set screws.
- The leading/entrance edge of the ring was provided with a minimum 1/8” chamfer and all machined edges radiused.

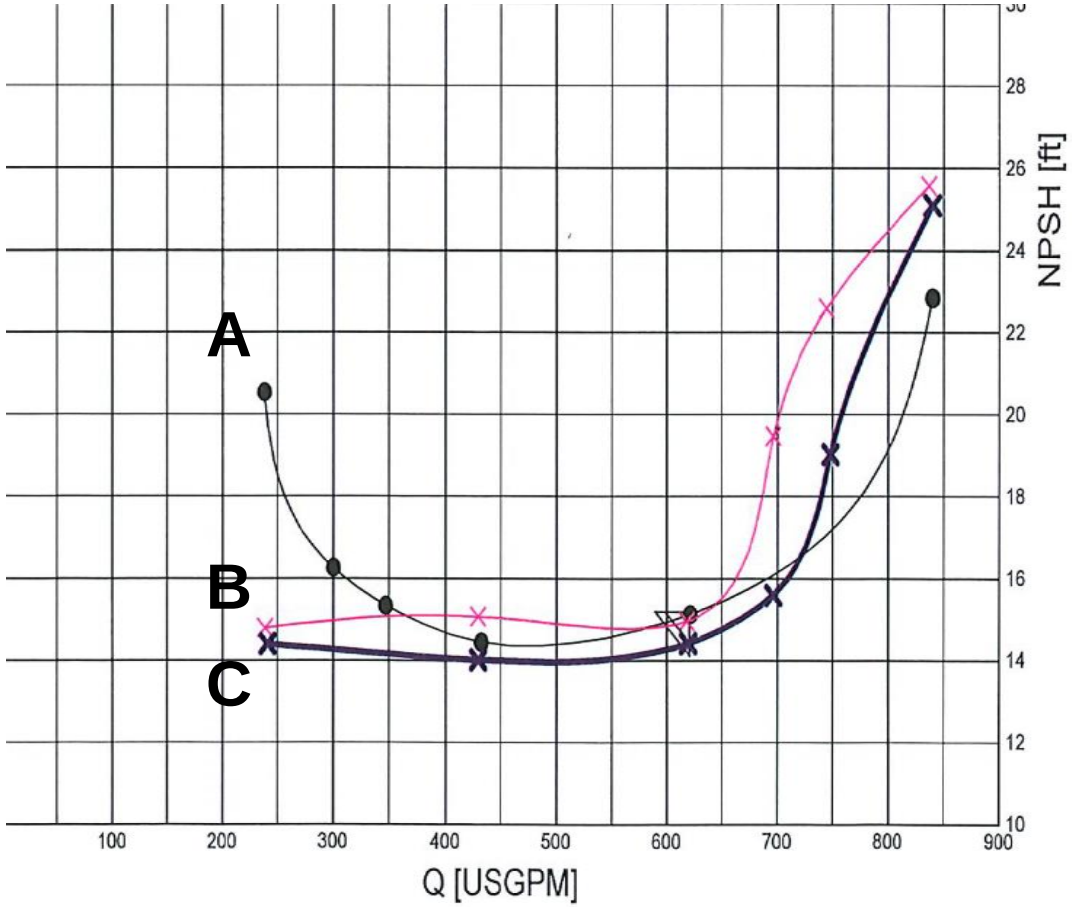


View of Stall Ring Installed in Impeller and Pump

- Pump Suction Chamber with rotor installed

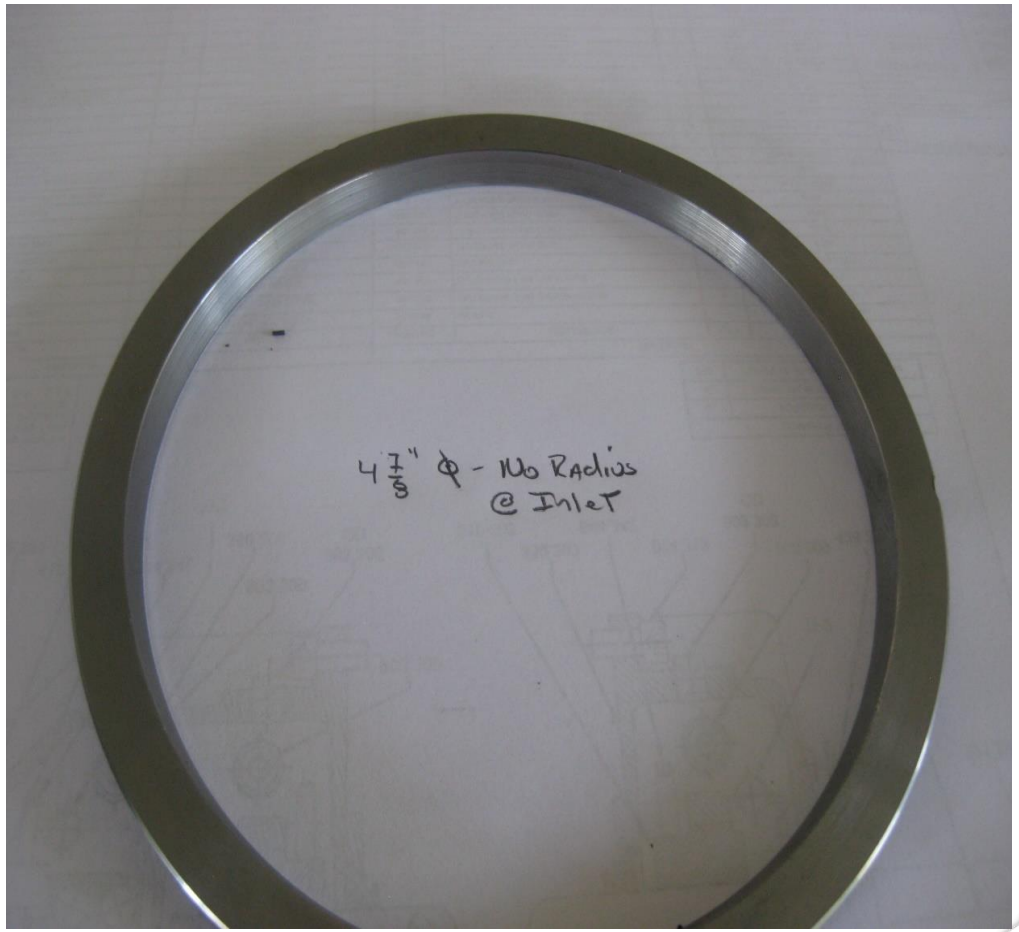
Stall Ring Test Data

- “A” Line is 5” Stall Ring
  - Margin not acceptable at Low Flow
- “B” Line is 4 ¾”
  - Acceptable at Low Flow
- “C” Line is 4 7/8”
  - Acceptable and best results
  - NPSH3 14.2’ at Rated and MCSF/Turndown
  - The process is limited above 700 GPM, but turndown to 240 GPM is required.



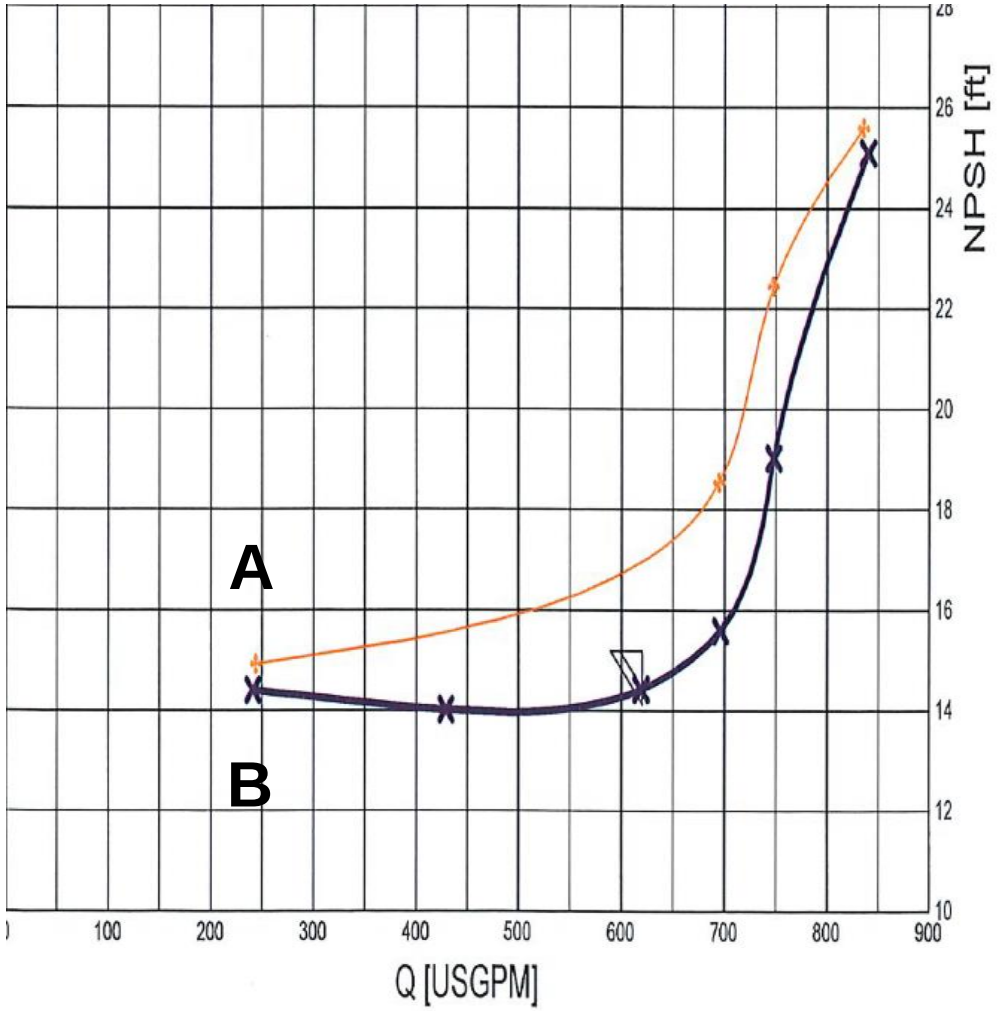
Stall Ring without Inlet Chamfer

- During installation of the 4 7/8” ring, the inlet chamfer was inadvertently not machined
- The error was discovered on disassembly and a new ring with the correct chamfer was installed and the pump retested



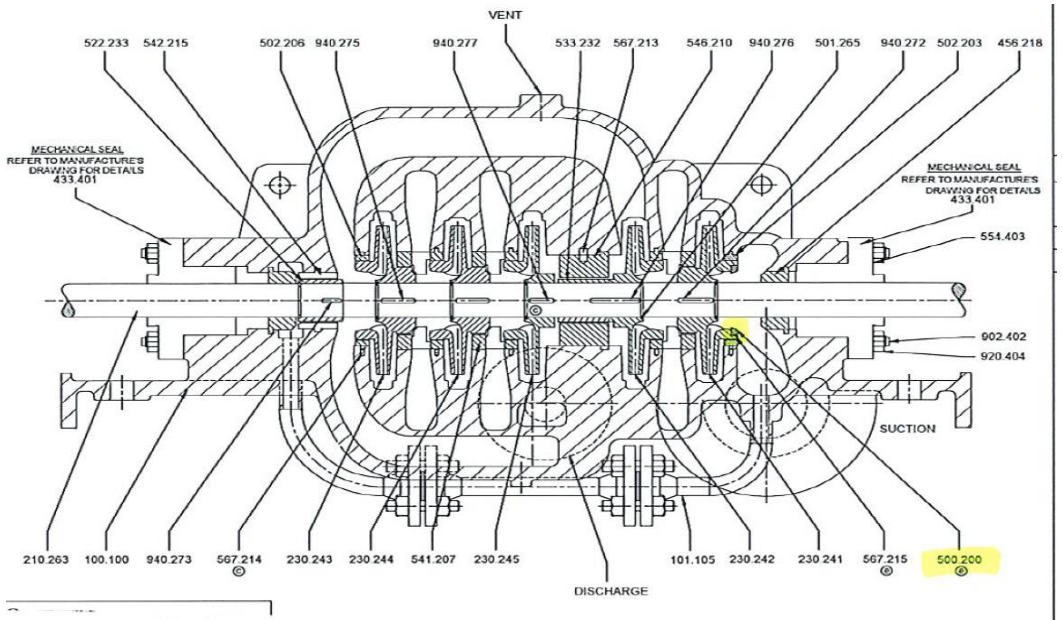
Stall Ring without Inlet Chamfer

- “A” 4 7/8” Stall Ring Without inlet Chamfer
- “B” 4 7/8” Stall Ring With inlet Chamfer
- Minimal effect at low flow
- Fairly significant increase at Rated Condition



Spare Parts Management

- Concern for losing history of the stall ring installation during future repairs
- Stall ring clearly identified on the Pump Cross Section and BOM
- Spare 1st stage impeller purchased with the stall ring installed



PARTS LIST

PART NO.	DESCRIPTION	QTY	MATERIAL
100.100	CASE ASSEMBLY	1	A487 CA6NM CL. A
101.105	BALANCE LINE	1	A312 GR. F316L
210.263	SHAFT	1	A582 TYPE 416 COND. T
230.241	IMPELLER W/ INTEGRAL RINGS (STG. 1)	1	A743 / A487 GR. CA6NM / CL. A
230.242	IMPELLER W/ INTEGRAL RINGS (STG. 2)	1	A743 / A487 GR. CA6NM / CL. A
230.243	IMPELLER W/ INTEGRAL RINGS (STG. 3)	1	A743 / A487 GR. CA6NM / CL. A
230.244	IMPELLER W/ INTEGRAL RINGS (STG. 4)	1	A743 / A487 GR. CA6NM / CL. A
230.245	IMPELLER W/ INTEGRAL RINGS (STG. 5)	1	A743 / A487 GR. CA6NM / CL. A
400.123	GASKET (CASE)(NOT SHOWN)	1	KLINGER C-4430
433.401	MECHANICAL SEAL	2	BY JOHN CRANE
456.218	THROAT BUSHING	2	VESPEL CR-6100
500.200	STALL RING (e)	1	A487 GR CA6NM CL A
501.265	SPLIT RING	6	12% CHROME STAINLESS
502.203	STATIONARY RING (STG 1)	1	VESPEL CR-6100
502.206	STATIONARY RING (SERIES)	1	VESPEL CR-6100
522.233	THROTTLE SLEEVE	1	12%-17% CHR. STAINLESS / HF
533.232	CENTER SLEEVE	1	12%-17% CHR. STAINLESS / HF
541.207	BRIDGED STAGE PIECE D	3	VESPEL CR-6100

PARTS LIST

PART NO.	DESCRIPTION	QTY	MATERIAL
542.215	THROTTLE BUSHING	1	VESPEL CR-6100
546.210	CENTER BUSHING	1	VESPEL CR-6100
554.118	WASHER (CASE)(NOT SHOWN)	36	AISI 316
554.403	WASHER SEAL GLAND	8	AISI 316
567.213	SPRING PIN (BUSHING)	2	AISI 304
567.214	SPRING PIN (RING)	7	AISI 304
567.215	SPRING PIN (STALL RING) (e)	3	AISI 304
763.116	CAPNUT (CASE)(NOT SHOWN)	36	A194 GR. 2H (b)
902.112	STUD (CASE)(NOT SHOWN)	34	A193 GR. B7
902.113	STUD (CASE)(NOT SHOWN)	2	A193 GR. B7
902.402	STUD (SEAL / GLAND)	8	A193 GR. B7 (b)
			(b)
920.404	NUT (SEAL / GLAND)	8	A194 GR. 2H
940.272	KEY (IMPELLER 1STG.)	1	12 - 17% CHROME STAINLESS
940.273	KEY (THROTTLE SLEEVE)	1	12 - 17% CHROME STAINLESS
940.275	KEY (IMPELLER - SERIES)	2	12 - 17% CHROME STAINLESS
940.276	KEY (CENTER - SLEEVE)	1	12 - 17% CHROME STAINLESS
940.277	KEY (IMPELLER - FINAL)	1	12 - 17% CHROME STAINLESS

Conclusions

- The Installation of a stall ring proved to be a viable solution to meeting the required NPSH3 at reduced flow
- NPSH3 test results require rigorous evaluation to ensure compliance
- Purchaser should require all test data and individual test point Knee Curves
- Witness inspection of NPSH testing is invaluable for pumps in critical service
- NPSH3 testing acceptance criteria must be clearly defined on the Data Sheet and purchase documents
- Legend: **A**-Sand Cast Impeller, **B**-Investment Cast Impeller, **C**- Impeller with 4 7/8” Stall Ring, **D**- Proposal NPSH3 Curve