ITT

Modification of BB1 pump vibration characteristics to meet ISO 13709 2nd edition (API 610 11th) limits

Simon Bradshaw, Director of API Product Development & Technology

ITT Goulds Pumps

Seneca Falls, NY

Engineered for life

Simon Bradshaw is the Global API Product Development Manager for ITT Goulds Pumps, in Seneca Falls NY.

His responsibilities include the design and development of new products and processes for the oil and gas industry. Prior to joining ITT Goulds, he worked for both Sulzer Pumps and Weir Pumps, where he held various positions of engineering and contractual responsibility. Additionally he has supported the Hydraulic Institute in the development of pump standards and best practice guides.

Mr. Bradshaw has accumulated 24 years in the pump industry. He attributes this to having never exhausted the fun inherent in moving fluid between two improbable locations.

He holds a BEng (Hons) degree (Mechanical Engineering) from Heriot Watt University, is a registered Chartered Engineer in the UK and a member of the Institute of Engineering Designers.

Summary of the pump in question #1

API 610 designation BB1

Pump Service	**Cooling water circulation (through cooling towers)**
Ruling Specification	**API 610 8th edition**
Impeller diameter D2	**1073mm (42.25”) rated, 1219mm (48”) maximum**
Running speed	**514 RPM**
Flow	**8400 m3/hr (36985 USGPM) rated**
Design Head	**40m (131.2 ft)**
Specific Speed	**50 Metric (2600 US)**
Suction Specific Speed	**166 Metric (8550 US)**
Casing Arrangement	**Double volute, 180° opposed volute lips**
Impeller Arrangement	**6 vane double entry impeller, non staggered vanes**
Bearing arrangement	**Sleeve radial with dual oil rings, flooded tilting pad thrust bearing with shaft drive circulation system**

Summary of the pump in question #2

Supplied by a different division of ITT

Factory tested September 2007

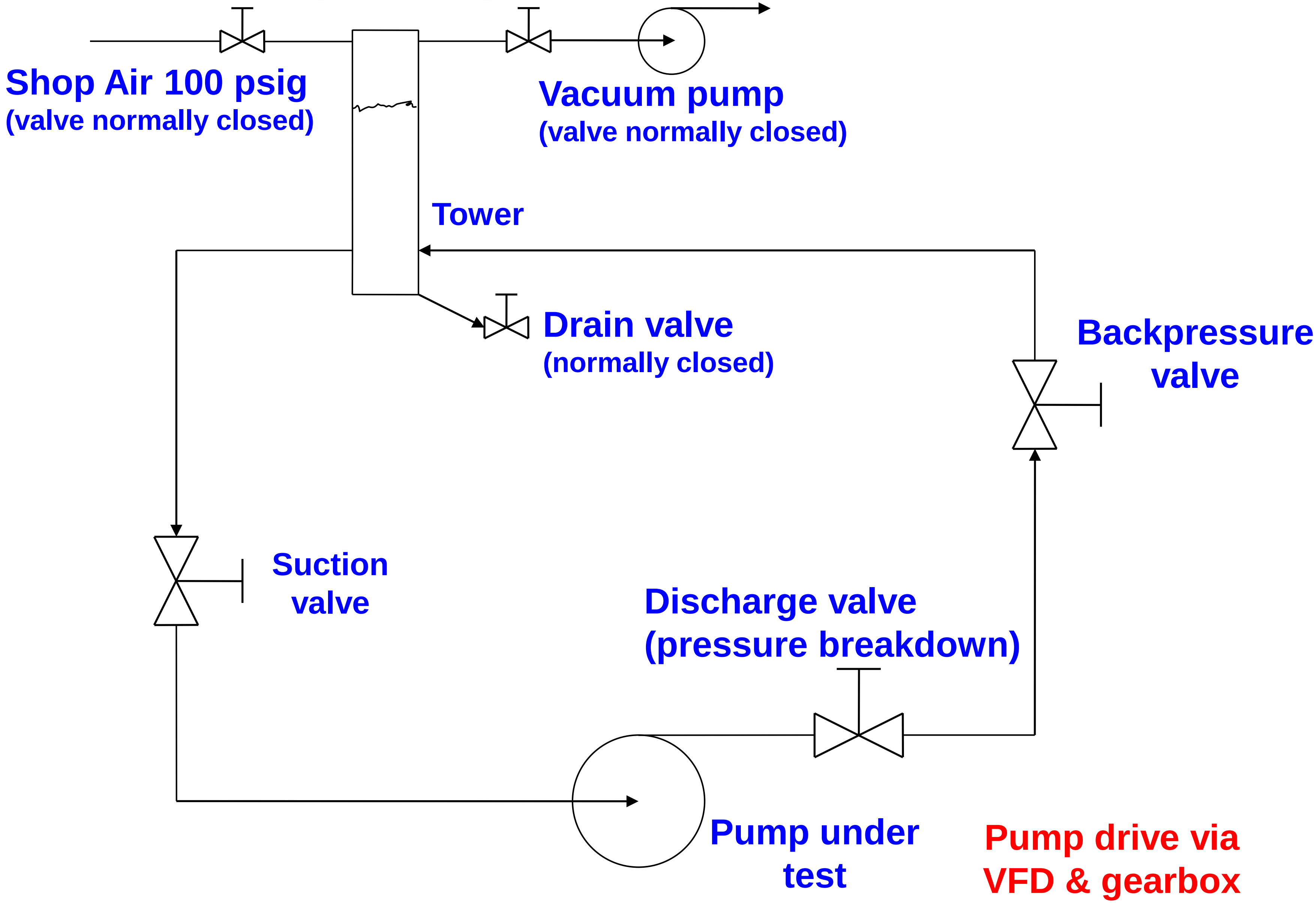
Commissioned ≈ 2008

Vibration problems seen at low flow (50 to 75% of rated) that were not seen during factory testing

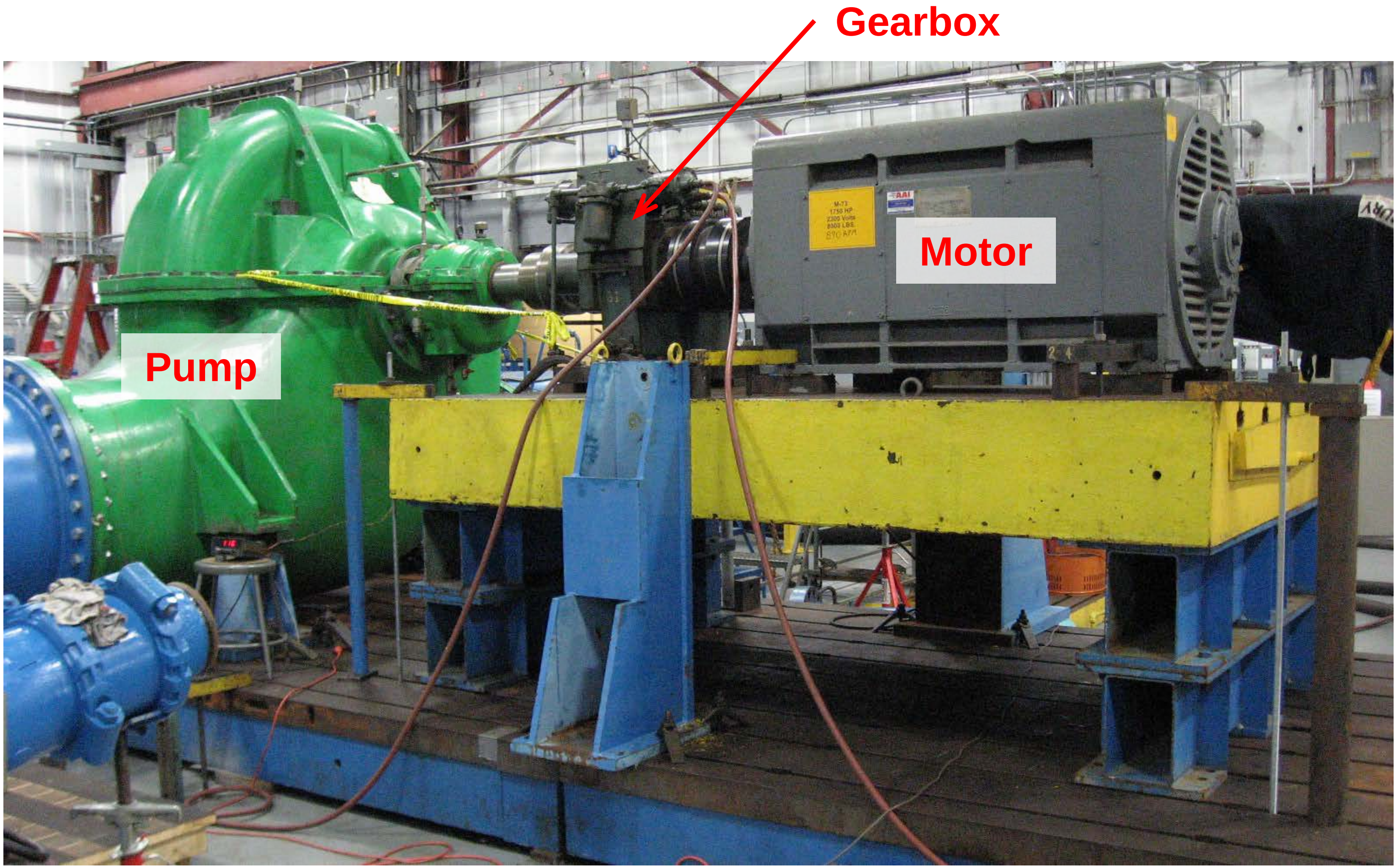
Site vibration values exceeded API 610 allowable levels

Pump was shipped to our R&D facility for further evaluation

Test loop setup #1



Test loop setup #2

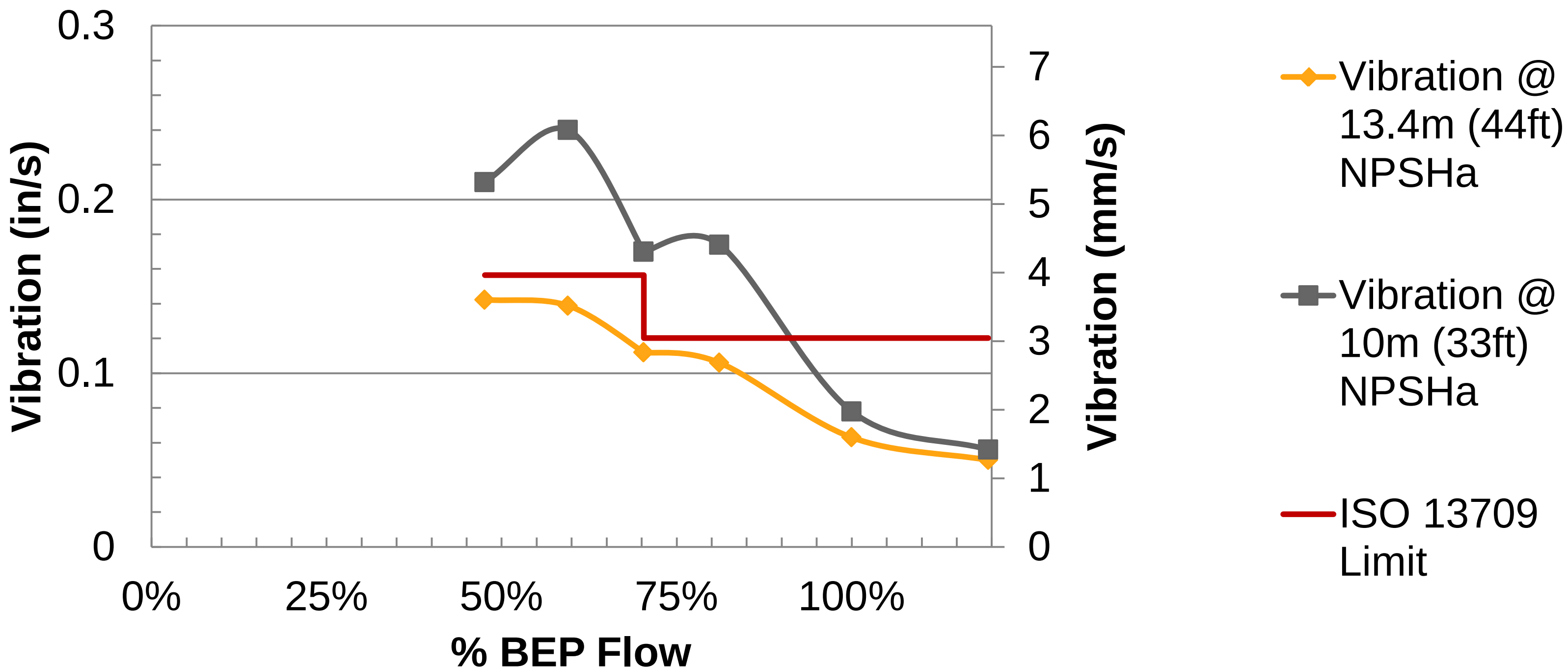


Initial testing results #1

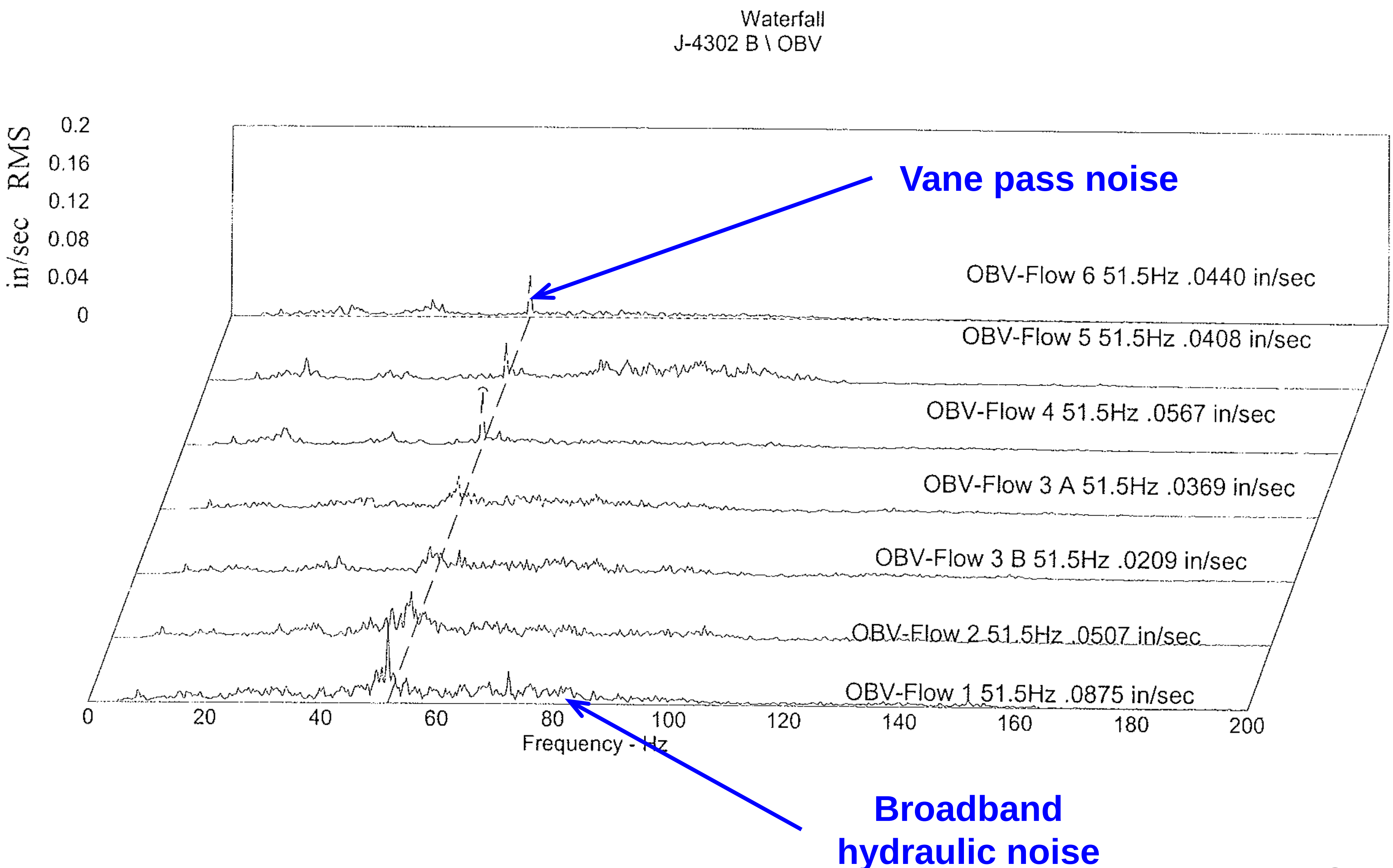
Tested with "expected" site NPSHa of 13.4m (44ft), the pump met IS0 13709 (API 610) vibration criteria of 3.0 mm/s (0.12 in/s) in the preferred region (70 to 120% of rated) and 3.9 mm/s (0.156 in/s) elsewhere

The customer requested testing to ISO 13709 2nd edition (API 610 11th) section 8.3.3.6, which requires testing at no more than 110% of rated NPSHa.

The pump was retested at the rated NPSHa of 10m (33 ft) and vibration levels significantly exceeded the allowable vibration criteria



Initial testing results #2



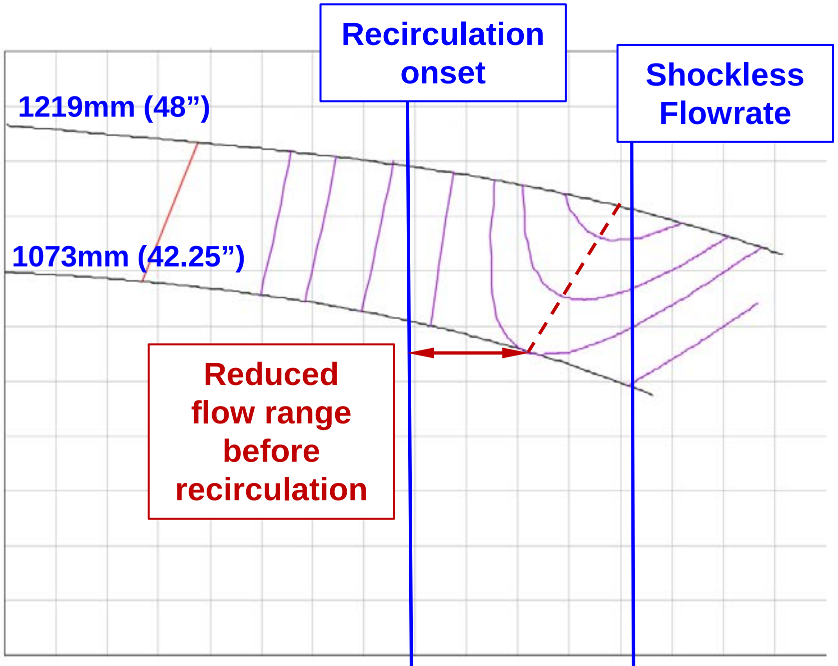
Analysis of contributors

1. **Pump design circa 1970 intended for municipal water service (although successful used in ISO 13709 service on prior occasions)**

   - **6 vane design, less than ideal with a 180° volute**
   - **Unstaggered vane design**
   - **Impeller eye larger than optimum by modern design rules**
   - **Suction casing area progression not optimum by modern design rules**

2. **Never previously required to meet ISO 13709 section 8.3.3.6 test**

3. **Large impeller trim**



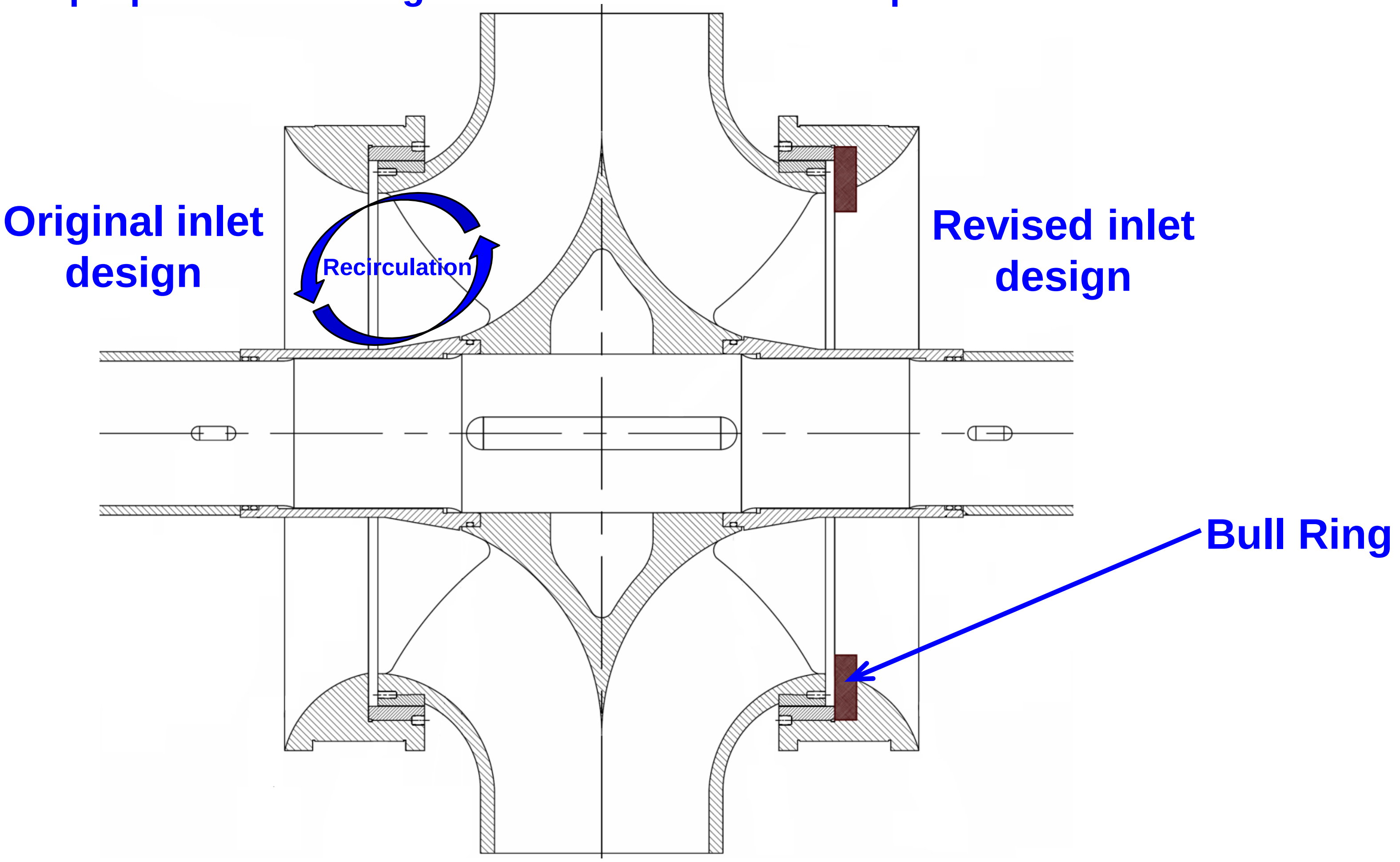
Analysis of fixes

Fix	Positives	Negatives	Vane pass vibration	Suct. side recirc.	Disch. side recirc	Used
Bull ring in the impeller ring eye	Will suppress suction side recirculation	Increases NPSHr at high flows	0	++	0	Yes
Profile ring with artificial “A” gap and bull ring incorporated	Will suppress suction side and discharge side recirculation	Long lead time	0	++	+++	
Cutback top half casing volute lip to 168°	Will reduce vane pass vibration	Will increase radial thrust.	++	0	0	Yes
V cut both casing volute lips	Will reduce vane pass vibration	Reduction effect will not be as much as the 168° cutback	+	0	0	Yes
Alter the position of the suction casing stop piece	Can improve the uniformity of flow into impeller and suppress instability	Requires a CFD analysis for correct location. Only a small improvement expected	0	+	0	
Cast and machine and impeller with full diameter shrouds and trimmed vanes	Will suppress discharge side recirculation	Long lead time Cost	0	0	++	
Design and manufacture a new 5/7 vane impeller with closer to full diameter	Improves all symptoms	Long lead time Cost	+++	++	++	

Application of chosen Fixes #1

A suction side restriction ring (commonly known as a "Bull Ring"), was added to the casing.

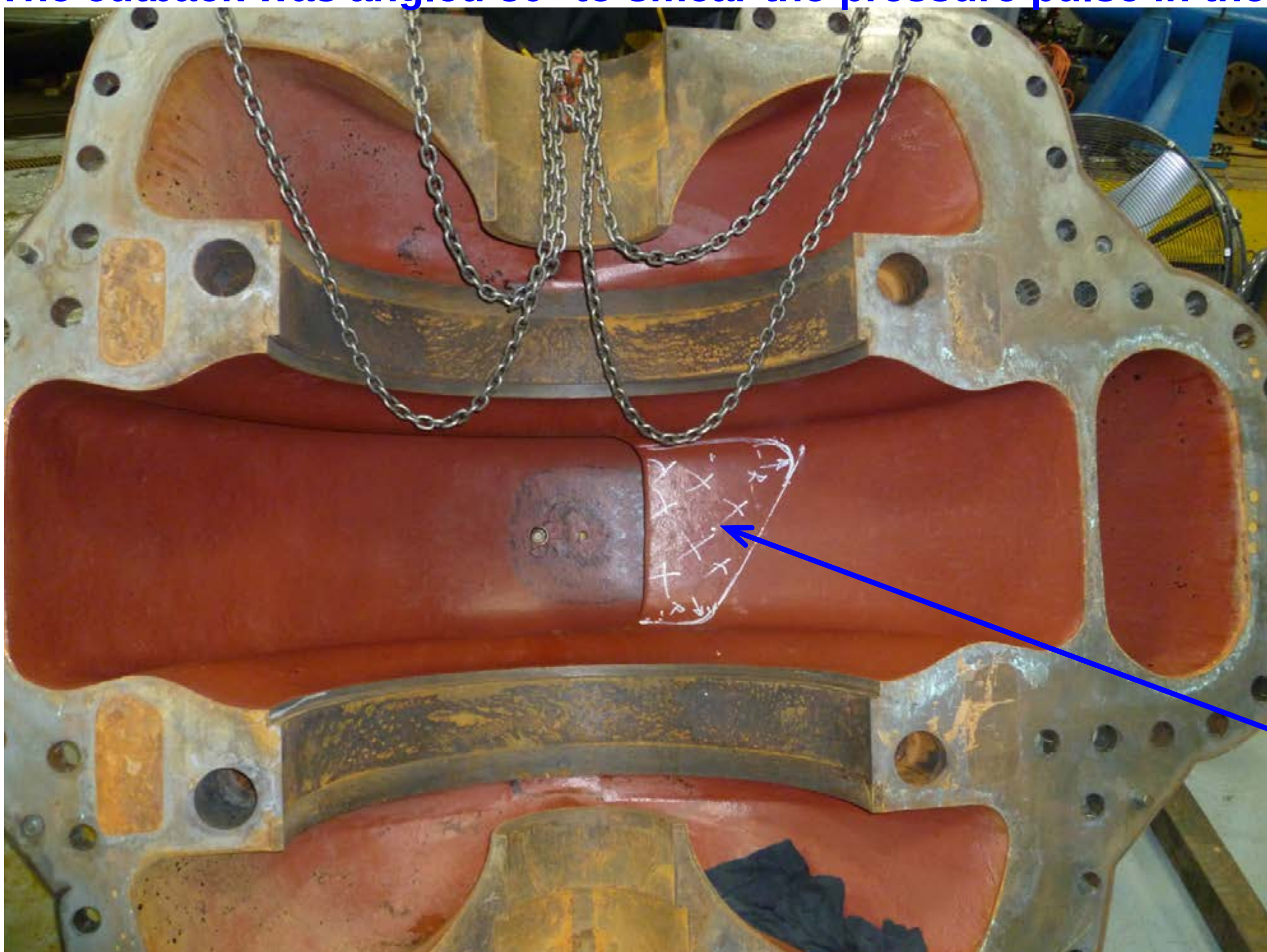
The purpose of this ring is to limit suction side impeller recirculation



Application of chosen Fixes #2

The top half casing volute lip was cutback to create an angle of 168° relative to the lower half volute lip.

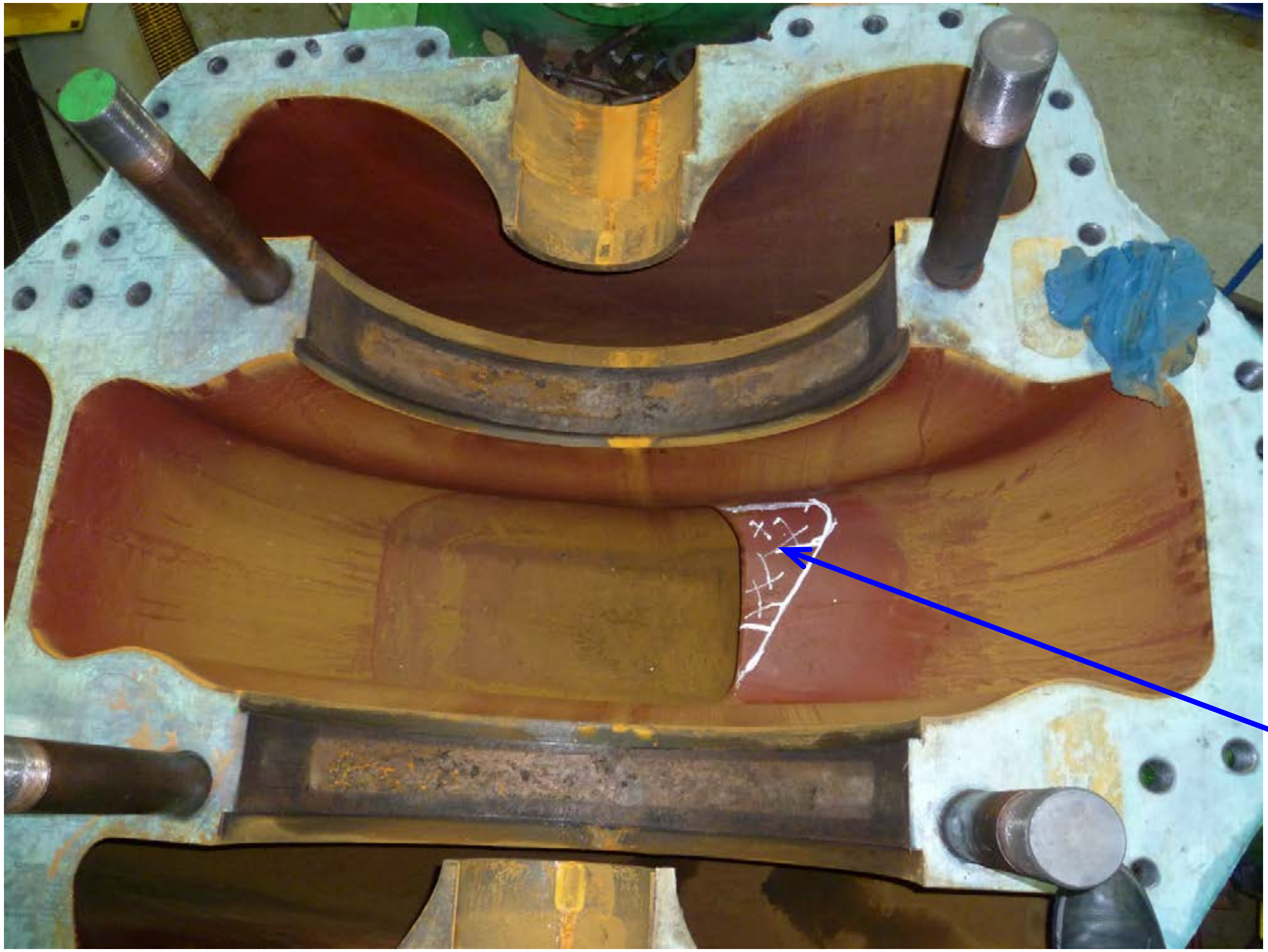
The cutback was angled 30° to smear the pressure pulse in the time domain



White marks indicate material removed

Application of chosen Fixes #3

The bottom half casing volute lip was angled 30° to smear the pressure pulse in the time domain

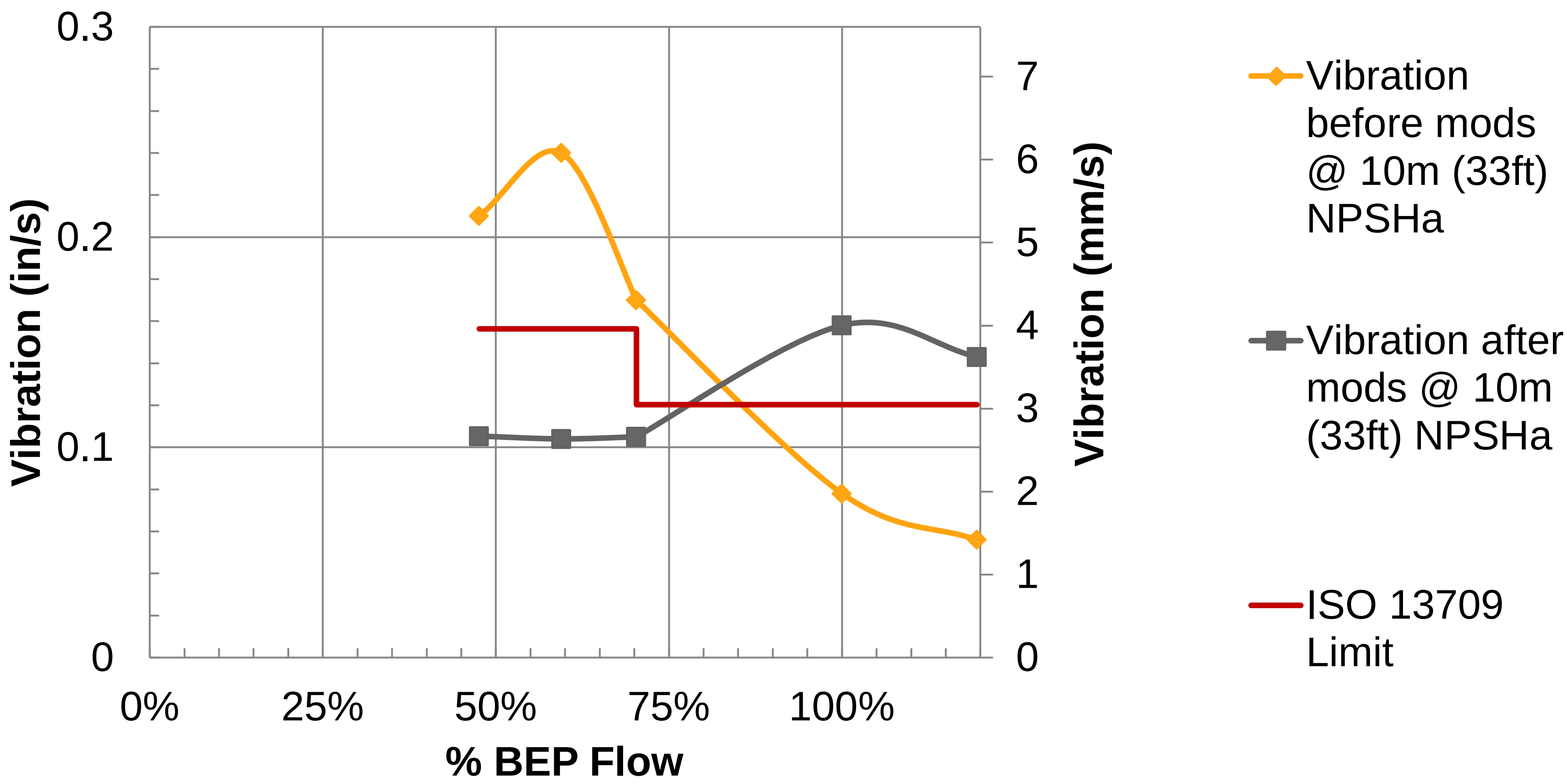


White marks indicate material removed

Testing results after modifications #1

Testing confirmed the effectiveness of the modifications at suppressing low flow vibration behavior, but created a problem at higher flows.

So what went wrong ?

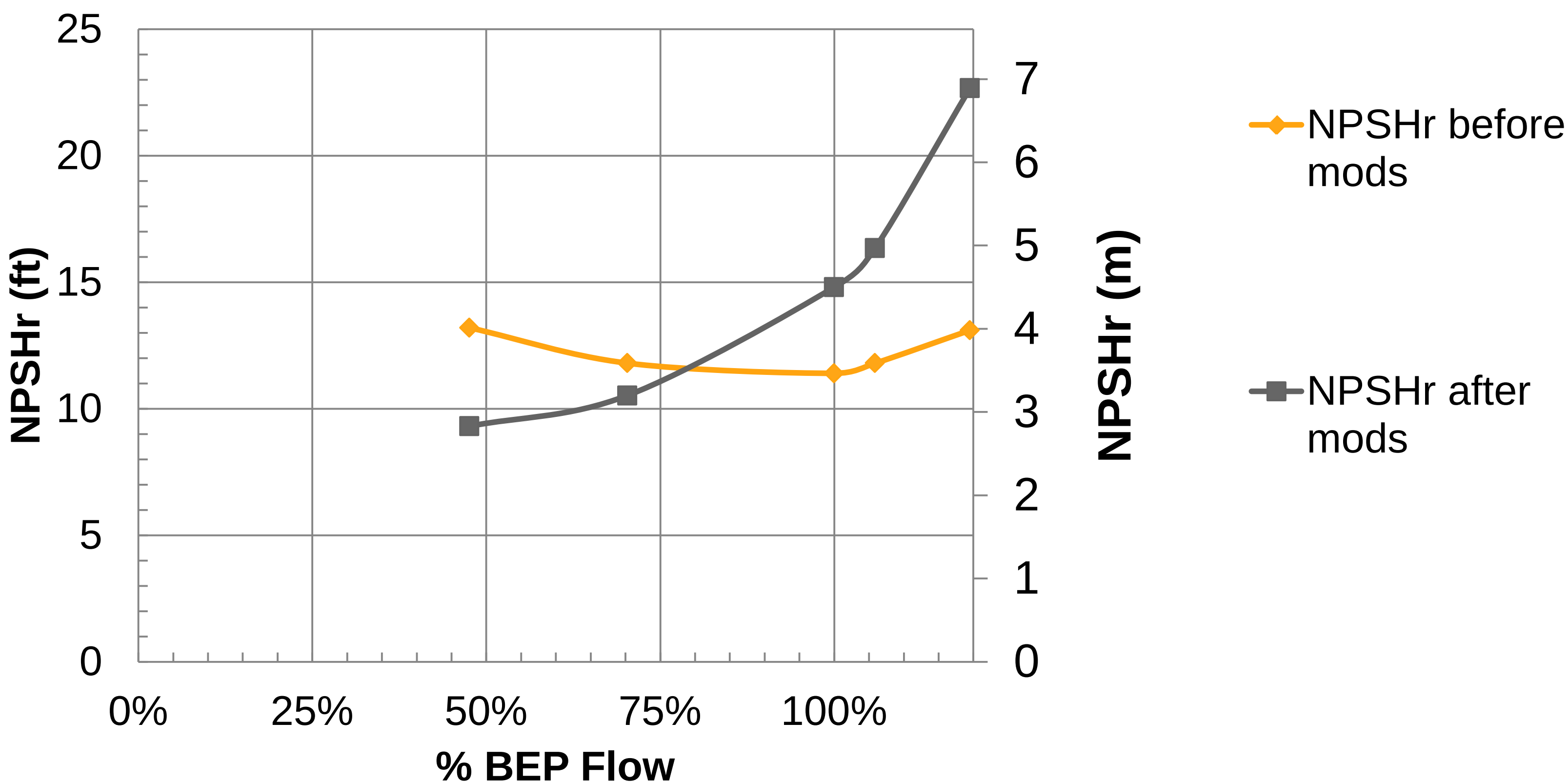


Testing results after modifications #2

A review of the NPSHr results gave a clue

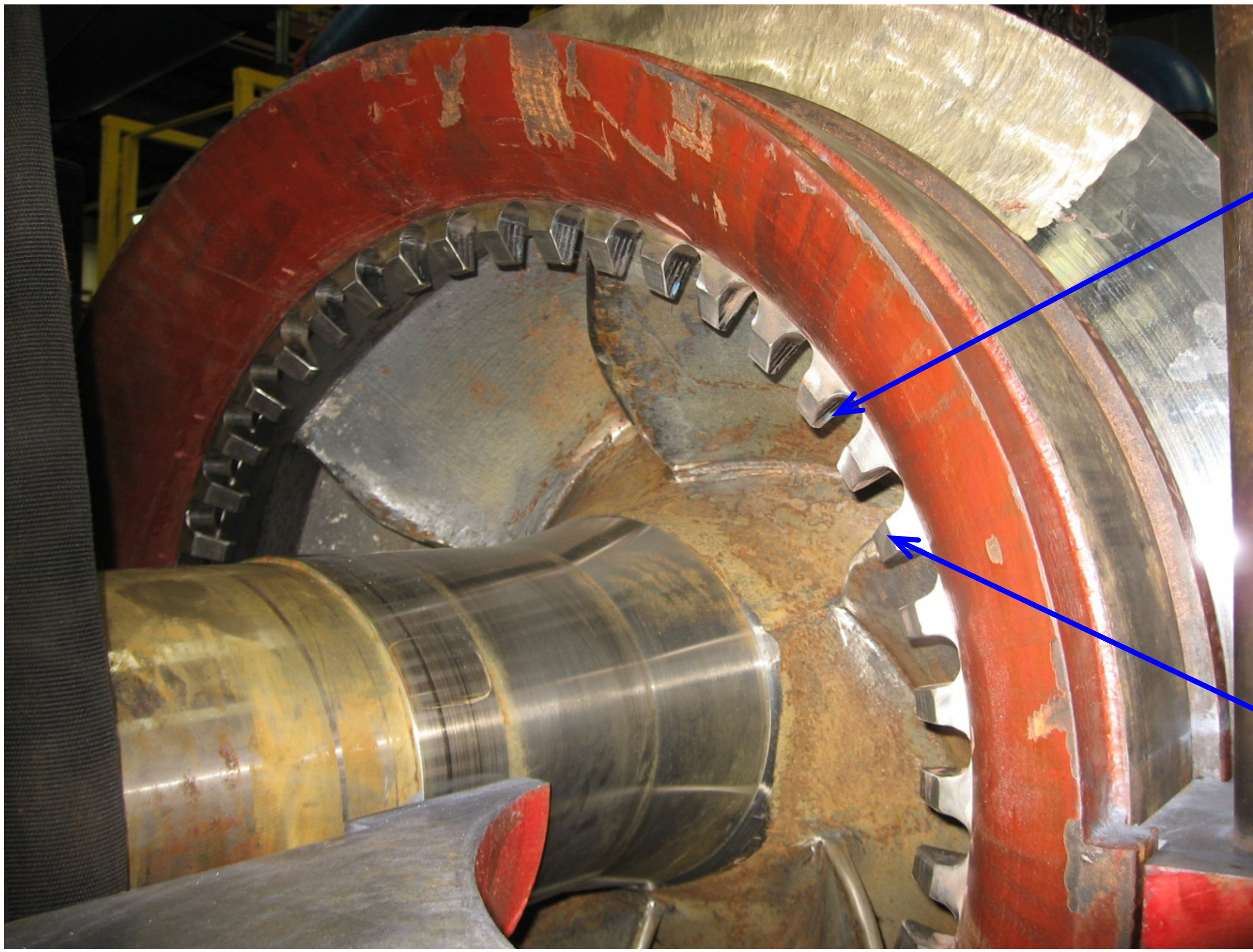
The bull ring was causing significant head loss at higher flows:

- **Head loss = Broadband hydraulic noise = Extra vibration**



How to fix a Bull Ring #1

We applied a little used variant of the bull ring, which we call the Sabini Ring



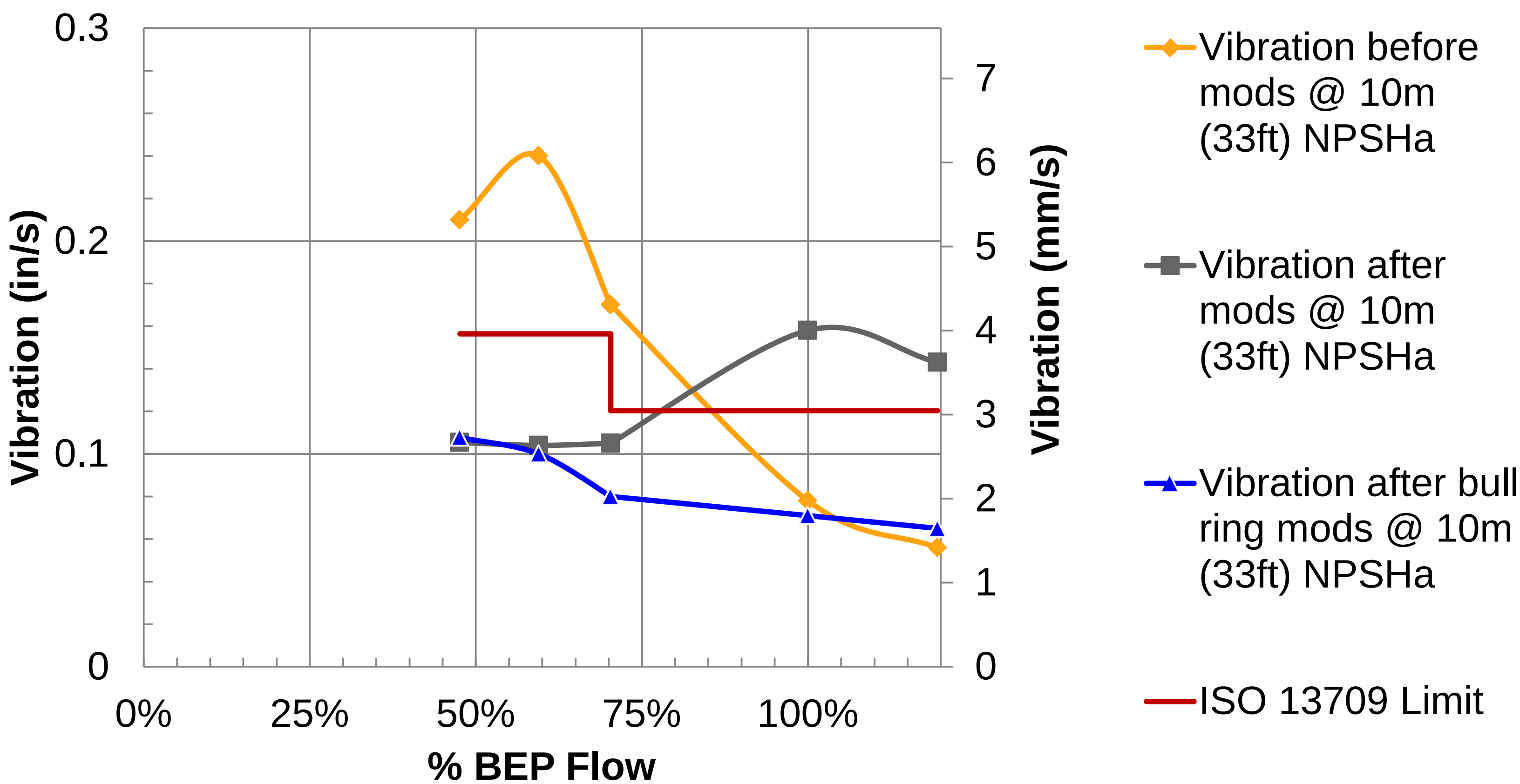
Existing bull ring slotted to achieve approximately 47% open area

Leading edge chamfered to reduce losses

Testing results after bull ring changes #1

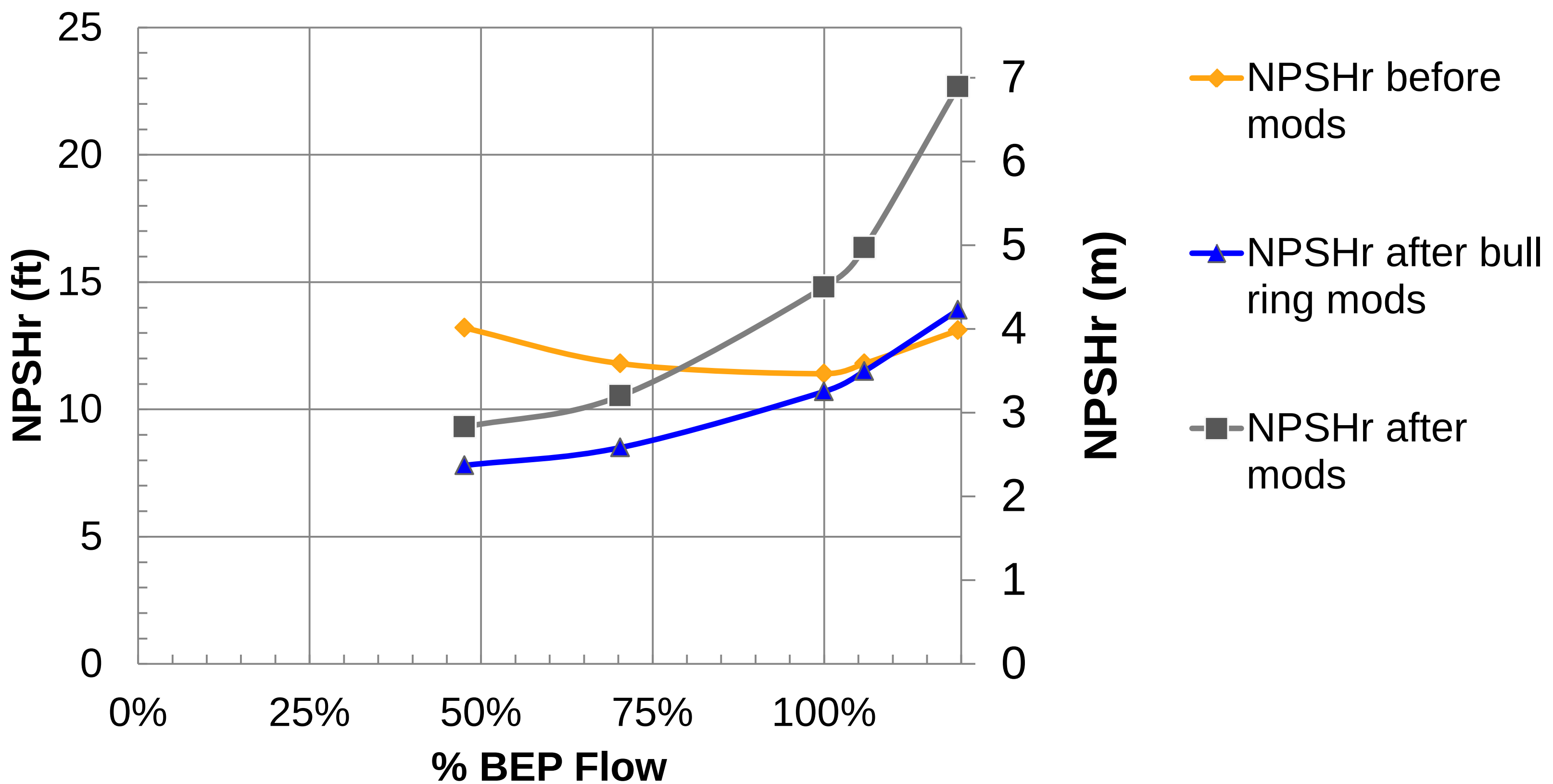
Testing confirmed the effectiveness of the changes to the bull ring

Vibration was now well controlled over the whole flow range



Testing results after modifications #2

The NPSHr results also indicate the success of the final bull ring design



Conclusions

1. ISO 13709 section 8.3.3.6 testing can cause problems in older pump designs

2. Modern designs with the following are preferred:
   - 5 or 7 vane impellers with 180° volutes
   - 6 vane impellers with 168° volutes
   - Impeller eye diameter minimized in relation the target Nss value

3. Avoid large impeller trims as these promote recirculation and give a false indication of the true BEP (shockless) flow

4. Slotted bull rings offer a superior balance of recirculation suppression vs. NPSHr increase compared to plain rings.

Thanks for your attention