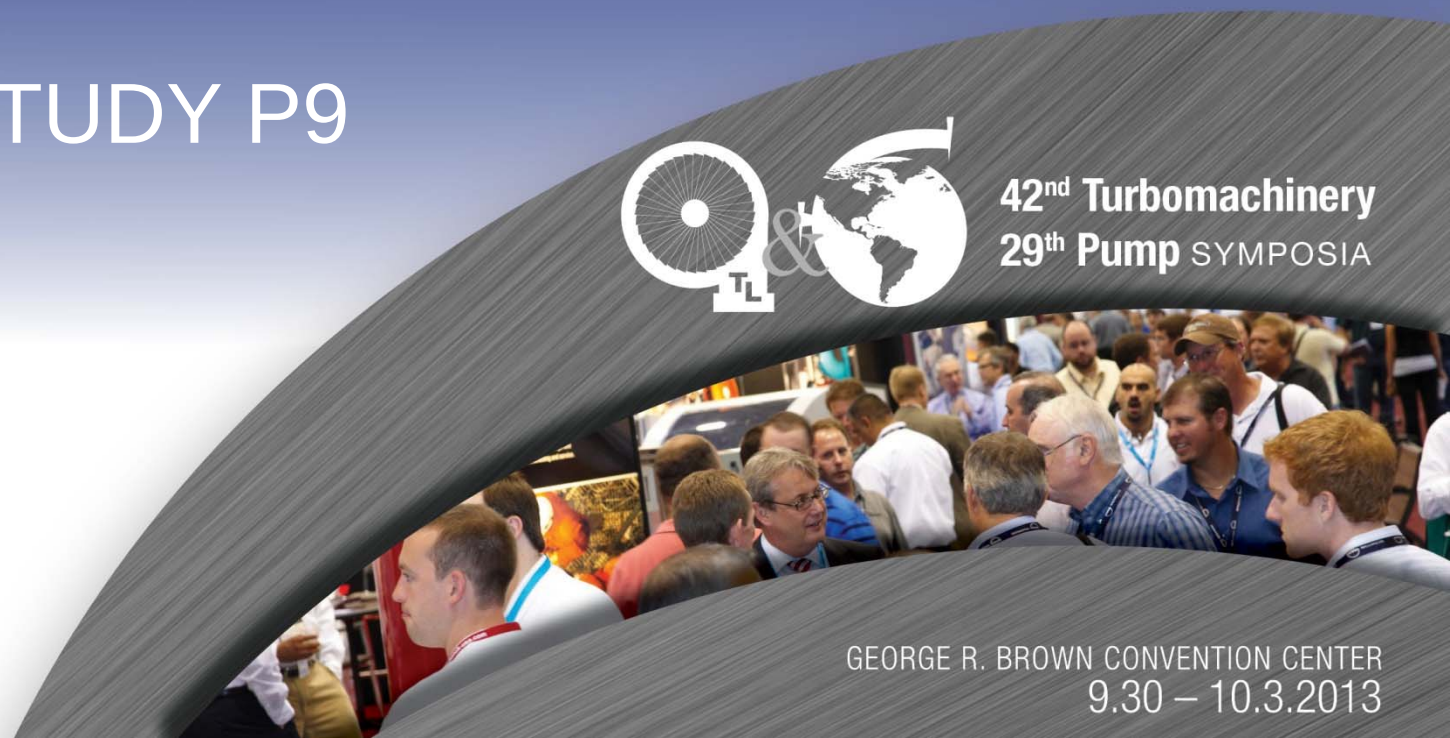
WORLD-CLASS OUTSTANDING INTERNATIONAL

PROGRAM | EXHIBITION | NETWORKING

HYDRAULIC UPGRADE OF HOT WATER CIRCULATION PUMPS IN A DISTRICT HEATING SYSTEM

CASE STUDY P9



FLOWSERVE

TEXAS A&M ENGINEERING TEES TURBOMACHINERY LABORATORY

A&M

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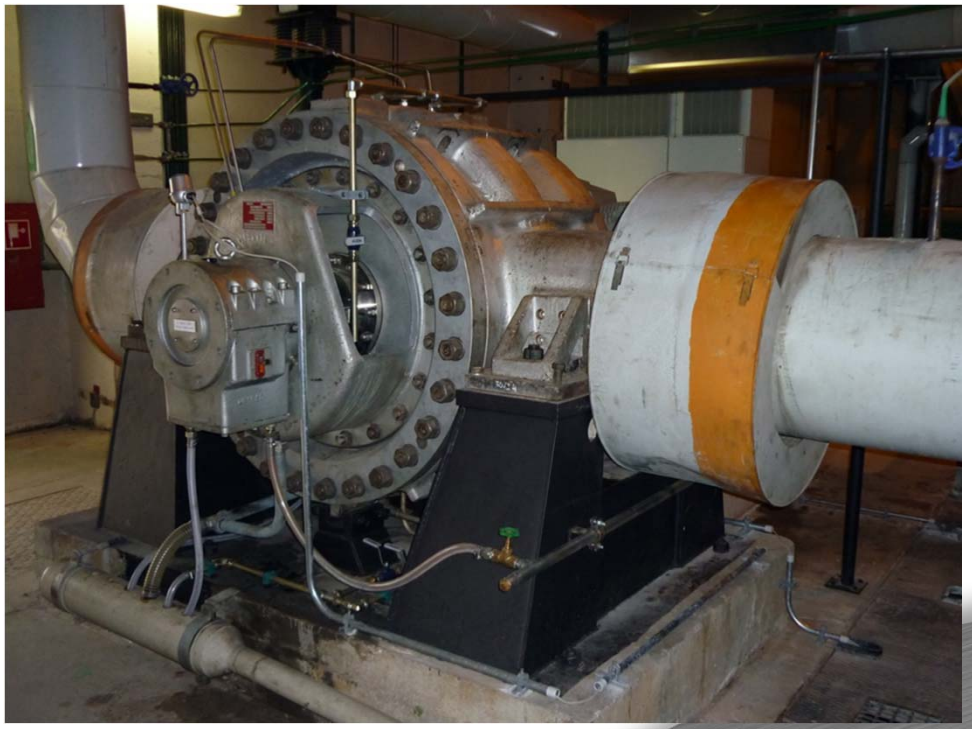
Introduction - Particulars

District heating circulation pumps (2 blocks):

- Single stage
- Double suction
- Between bearing
- Radial split casing

  (API 610 BB2)
- Side-side nozzles
- Variable speed

  (1000 – 1500 r/min)



Introduction - Particulars

Conditions of service:

- Pre-upgrade: 500 – 1500 m^3/h @ 60 m
- Requested for upgrade: 720 – 2400 m^3/h @ 80 m

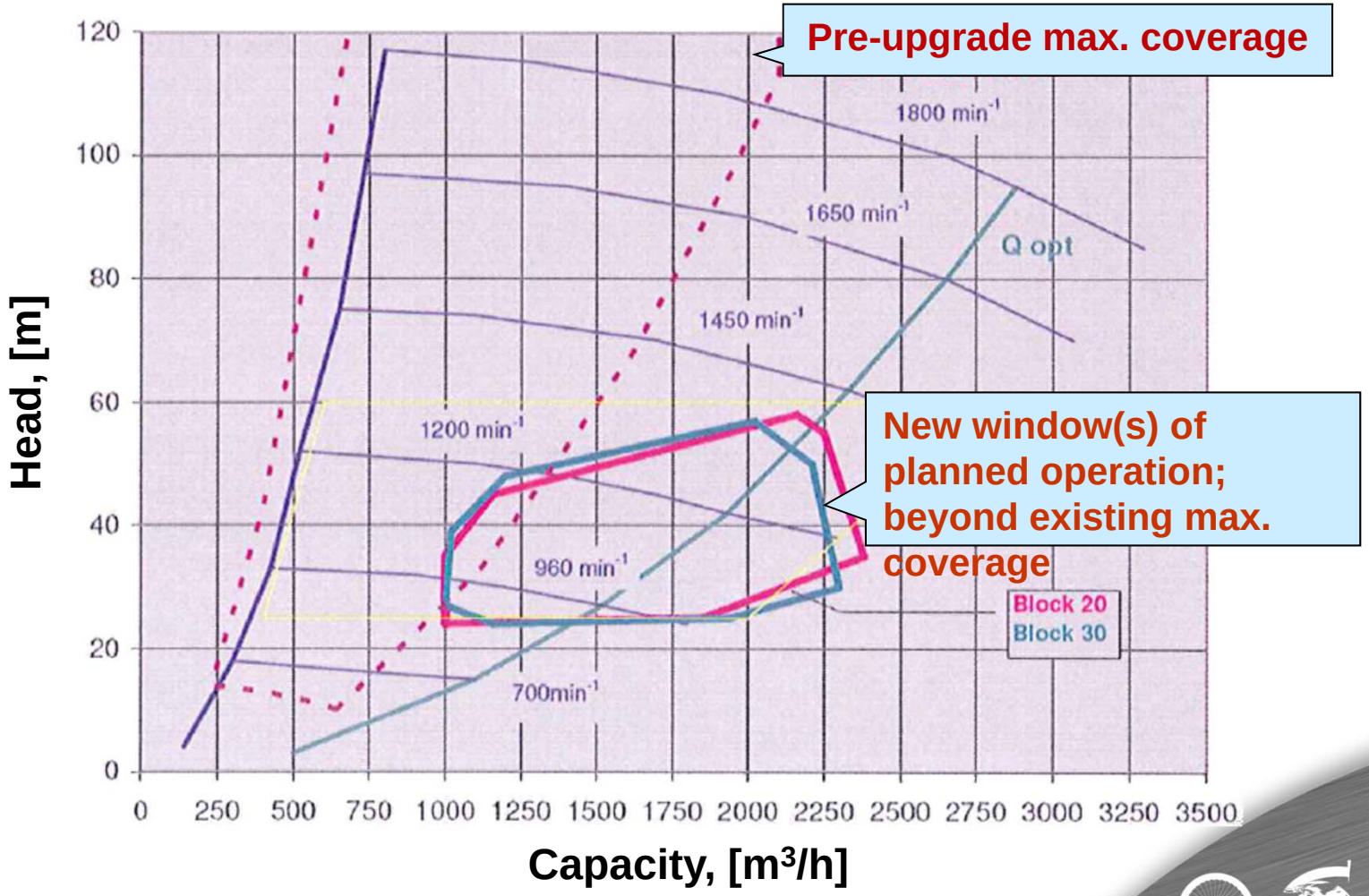
↓

Normal duty: 1750 m^3/h @ 35 m (1000 r/min)

Max. (design) duty: 2400 m^3/h @ 80 m (1490 r/min)

- Fluid: Hot pressurized water (70 – 140 °C)
- Suction pressure: 6.9 – 11 bar

Introduction - Particulars



Introduction - Objective

Objective / Scope of supply:

1. Re-rate existing pumps with new hydraulic end, keeping existing shaft.
2. Replace existing DC speed controlled motors with VFD driven asynchronous motors
3. Replace existing conventional packing with mechanical seal

Hydraulic Options:

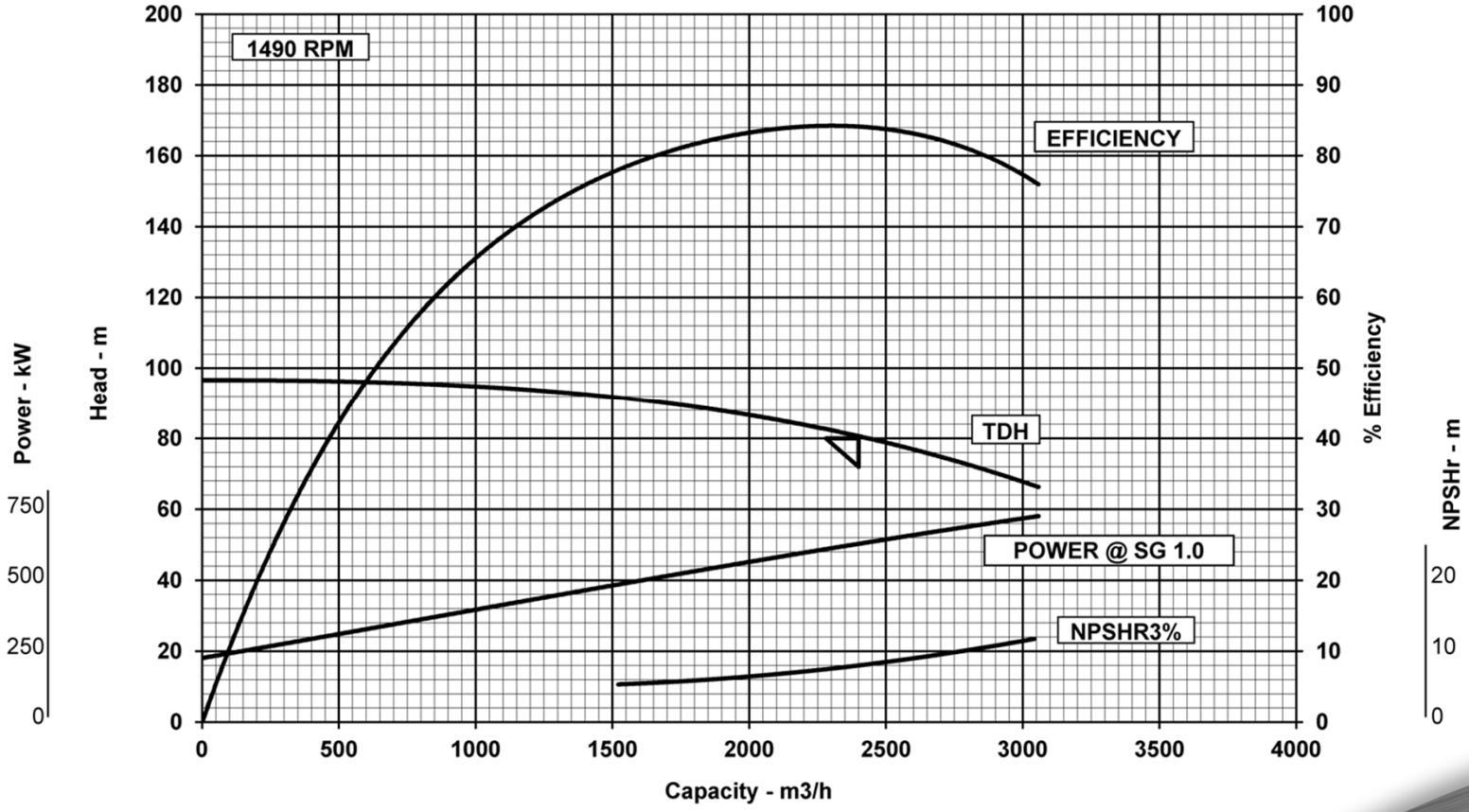
- New impeller and new **diffuser** (→ First design iteration)

vs.

- New impeller and **volute insert**

(→ Second design iteration)

Introduction - Objective



Proposal curve for the hydraulic upgrade

(@ max. duty ➔ $N_{s,design}$ =2350)

First Design

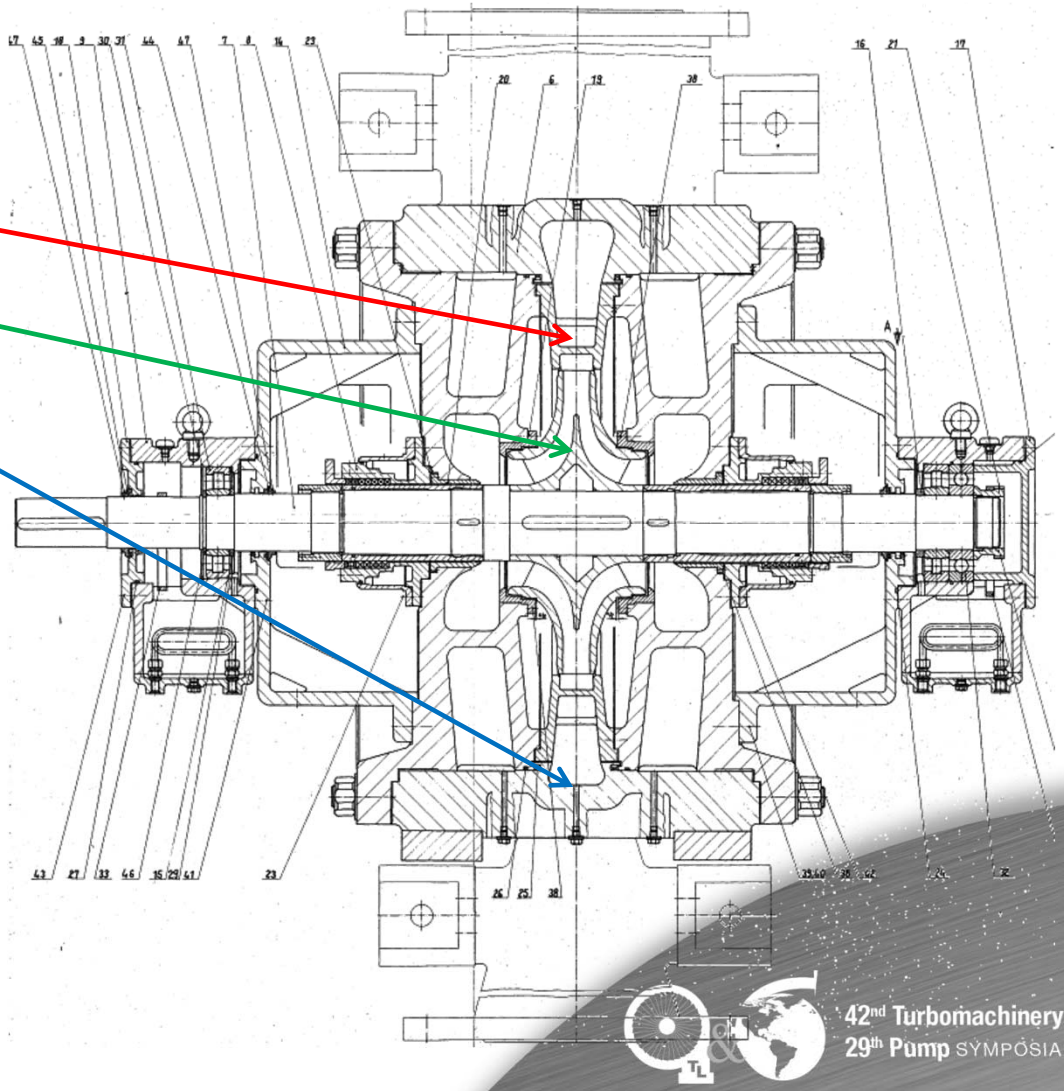
Existing pump

Impeller/diffuser

in

single volute casing

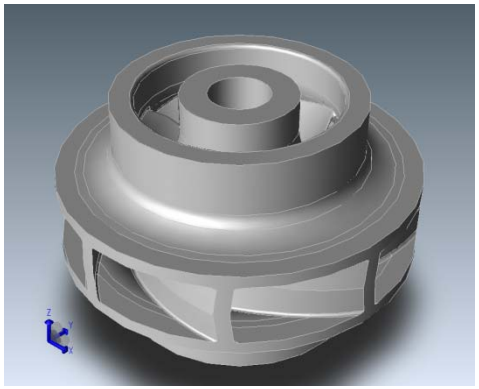
Existing diffuser (4 vanes)

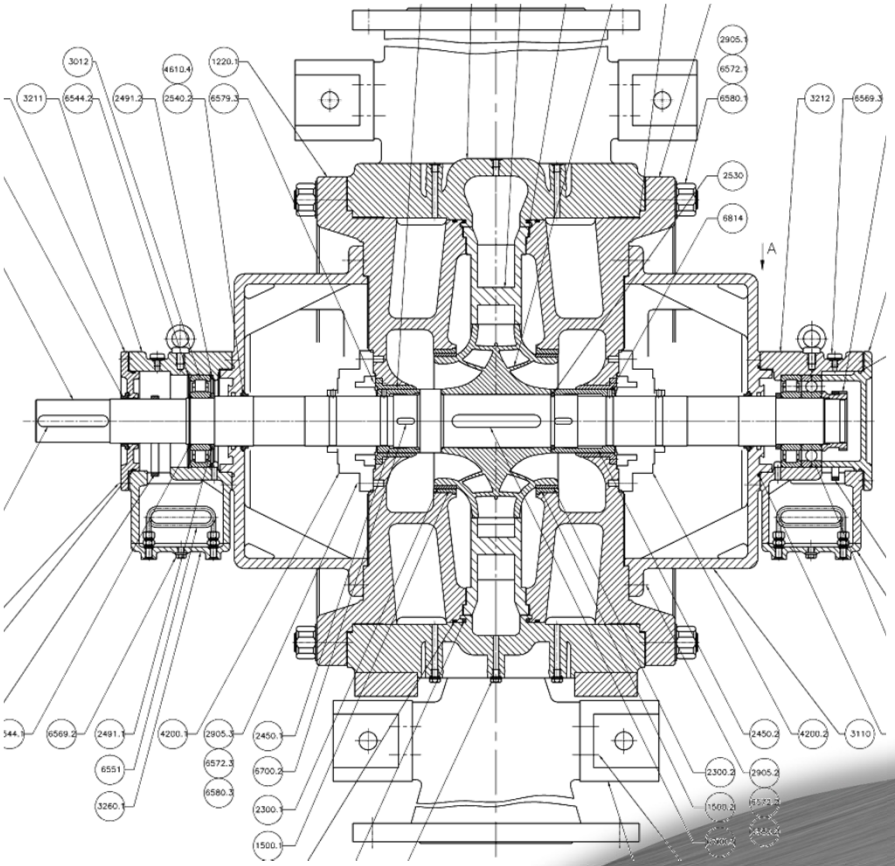


First Design

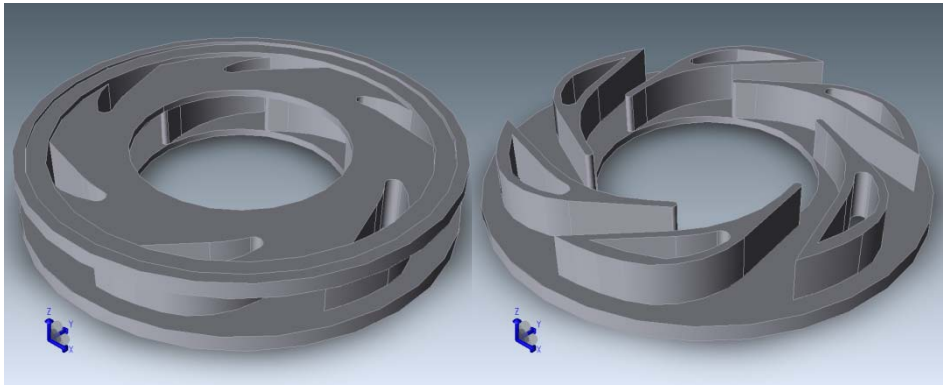
- **New high capacity impeller**
  - ❑ **8 vanes**
  - ❑ **$D_{2,max}$ 21½”**

  (546.1 mm)

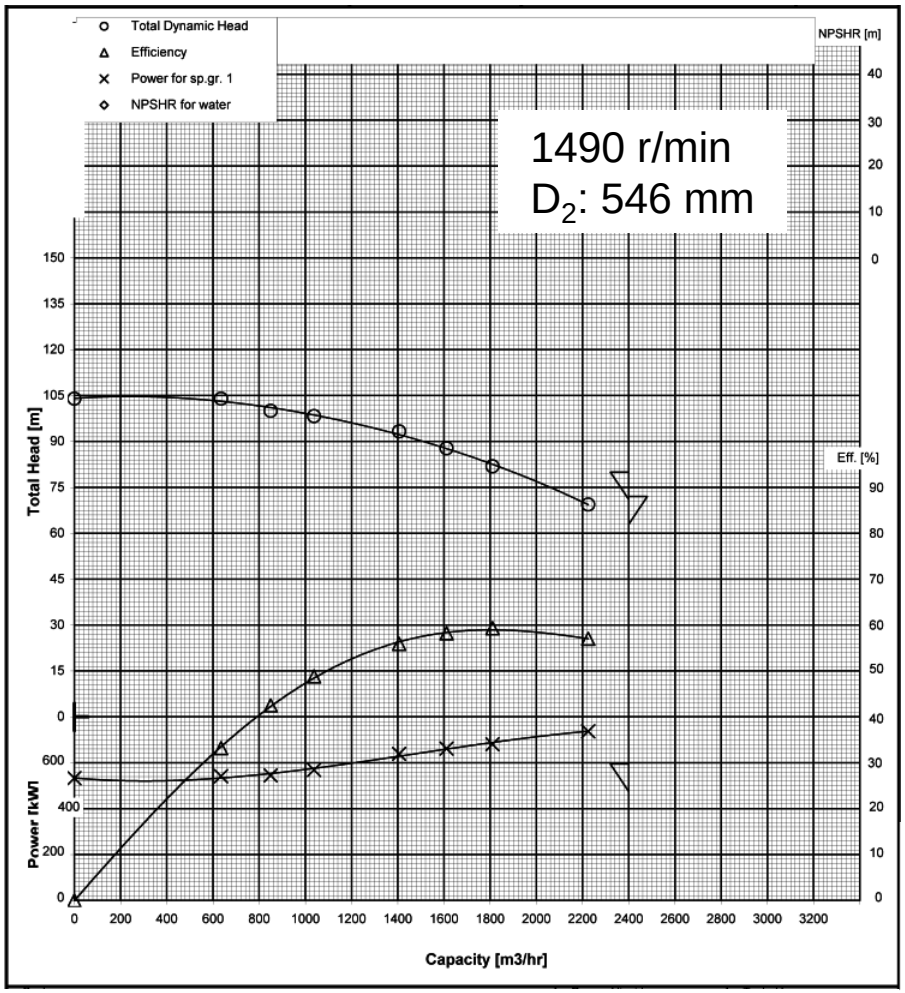




- **New diffuser (6 vanes)**



First Design

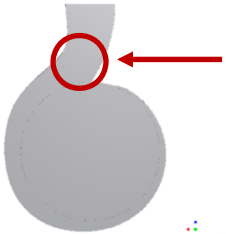


First Test Result:

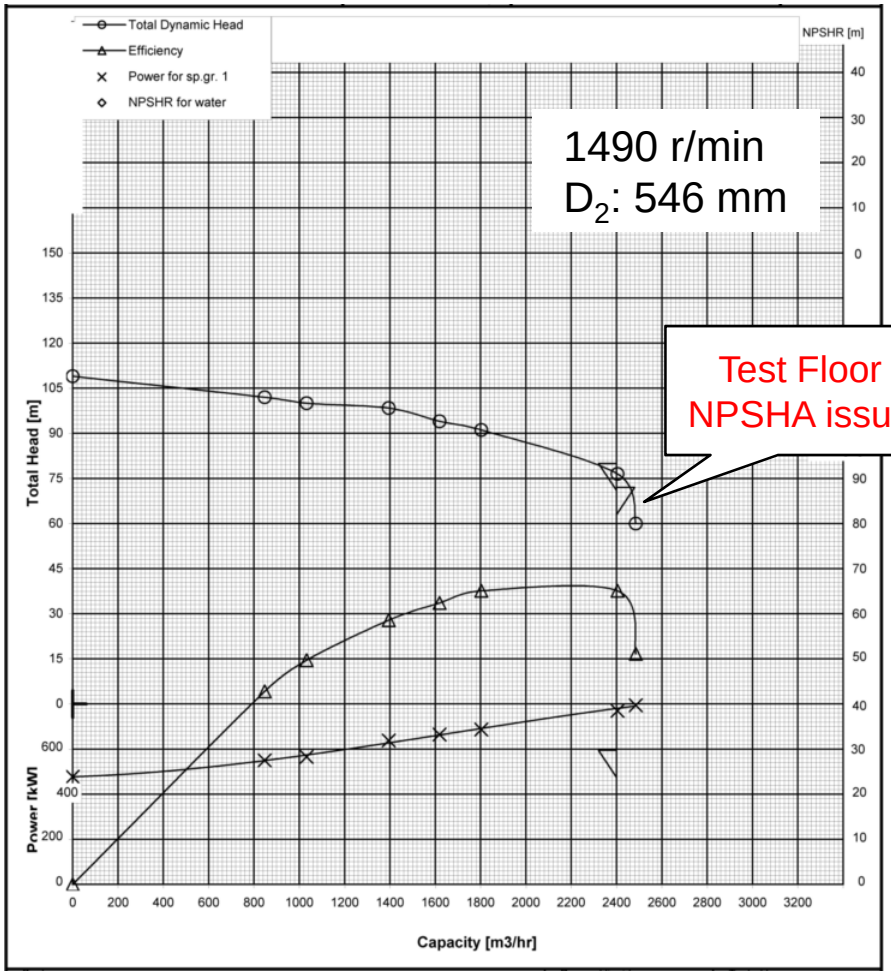
- Failed to make the head
- Efficiency too low
- Power too high
- BEP at too low capacity

Suspected Cause:

- Choking flow at casing outlet (narrowing throat passage)



First Design



Second Test Result:

(After opening up casing area)

- Head picked-up
- Efficiency improved
- BEP shifted to higher capacity

BUT, pump still not making expected performance

Suspicion:

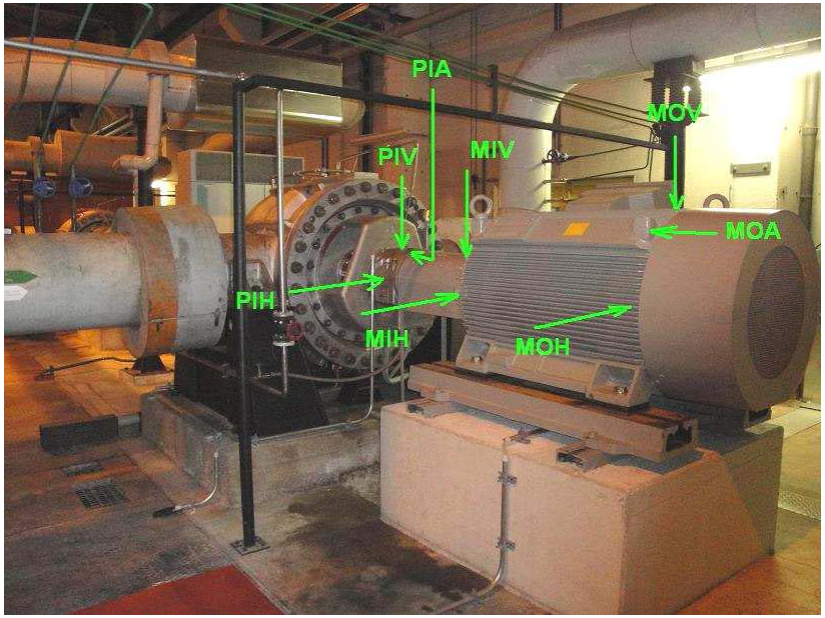
- Incorrect diffuser design?!?

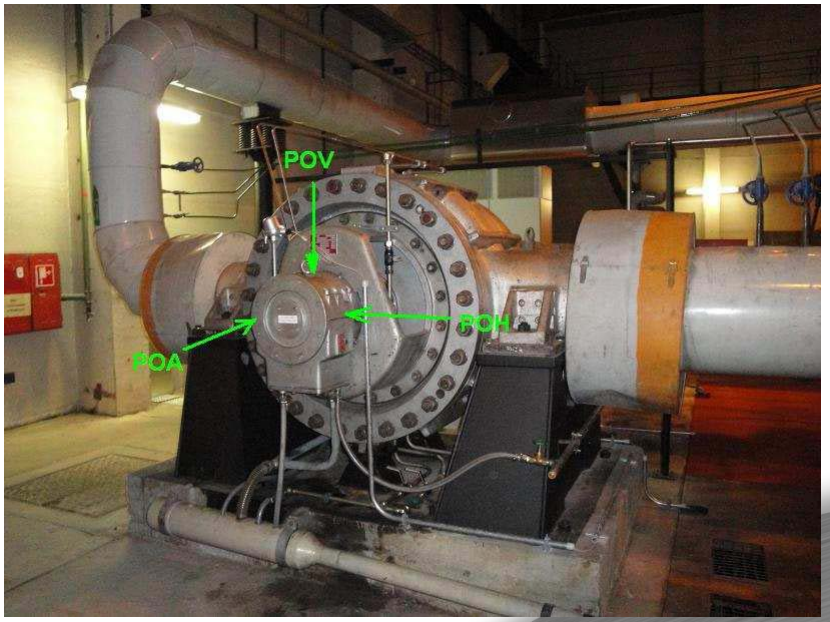
Diffuser throat area laid out too small

➔ **Second Hydraulic Option: Volute insert**

First Design

- While developing volute insert and manufacturing parts pump was shipped to site.
- At site an **8X vane pass vibration** issue @ PIH emerged when running **around 1200 r/min***.



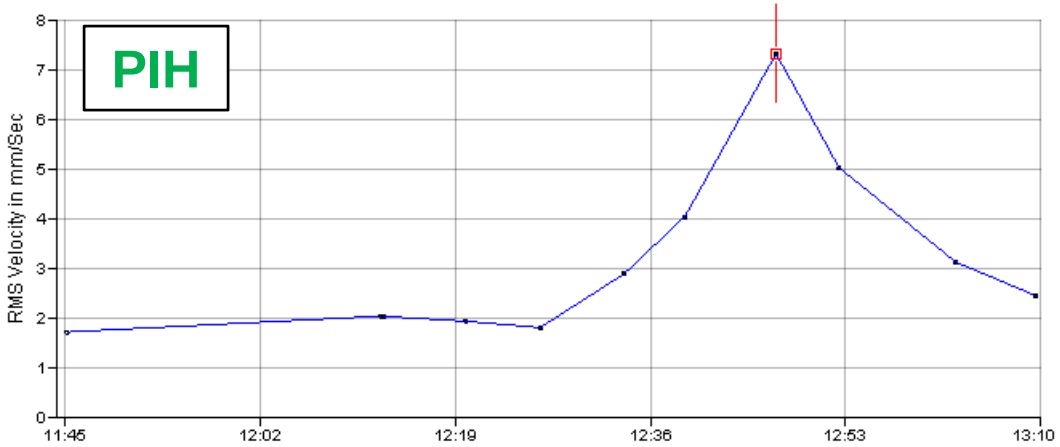


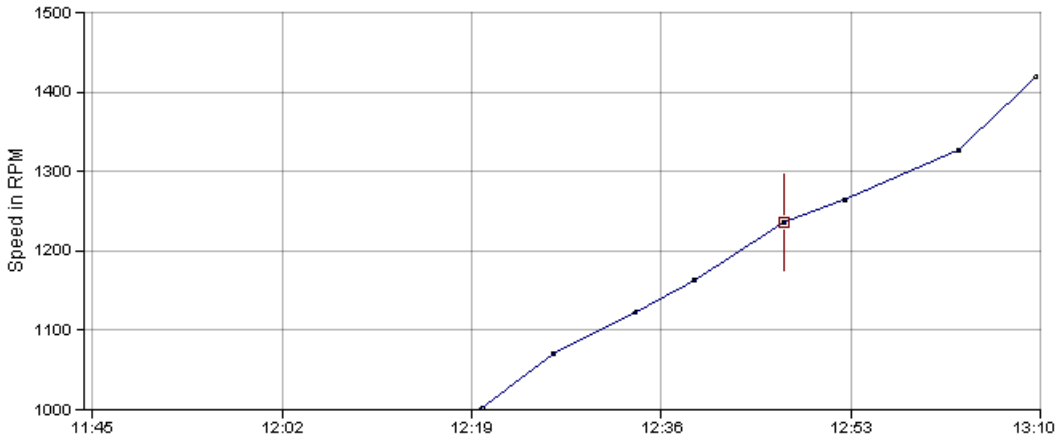
Vibration measurement locations

* Shop tests were @ 1500 r/min.

First Design

Onsite vibration measurement





Order Tracking

1000 – 1420 r/min

- **PIH: 7.3 mm/s** @1236 r/min (8X, or 165 Hz)

Bump Test:

- 169 Hz resonance frequency (Hor.)

First Design

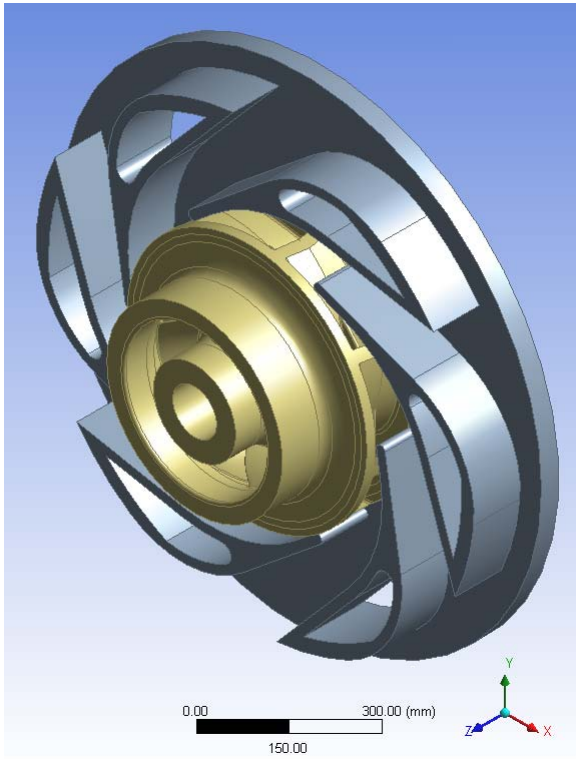
Elevated vibration levels due to:

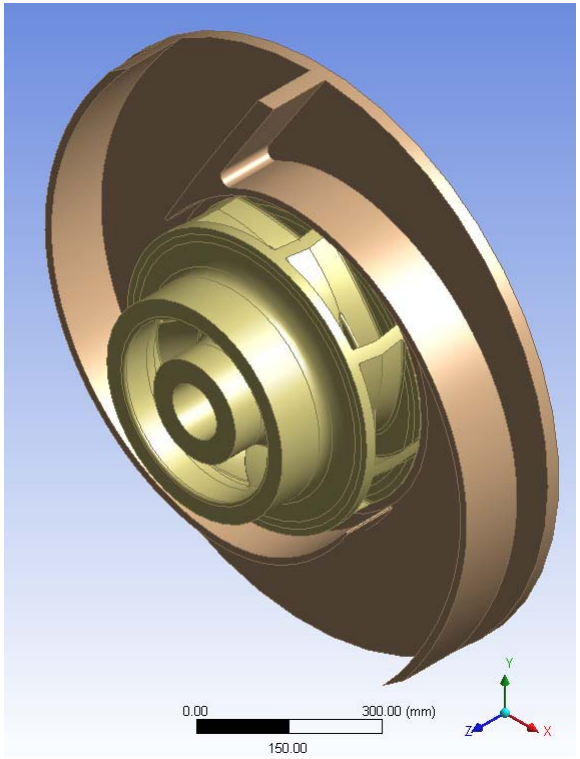
- 8X vane passing excitation forces @**165 Hz**
- Natural (resonance) frequency in horizontal plane @**169 Hz**.
- **Very small impeller tip ("Gap B") clearance**, causing **strong vane passing excitation forces**

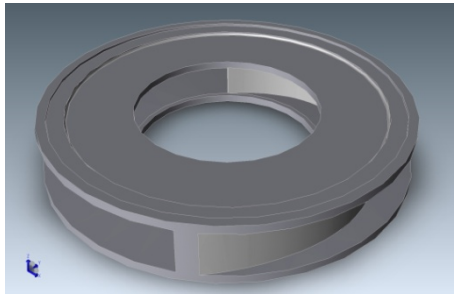
$$(D_3 - D_2) / D_2 = 553 - 546 / 546$$

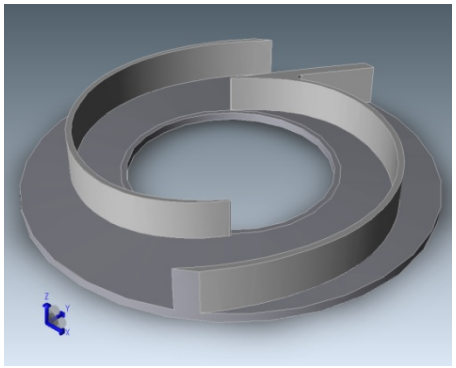
$$= 0.013 \text{ or } \mathbf{1.3\%} \text{ (!)}$$

Second Design



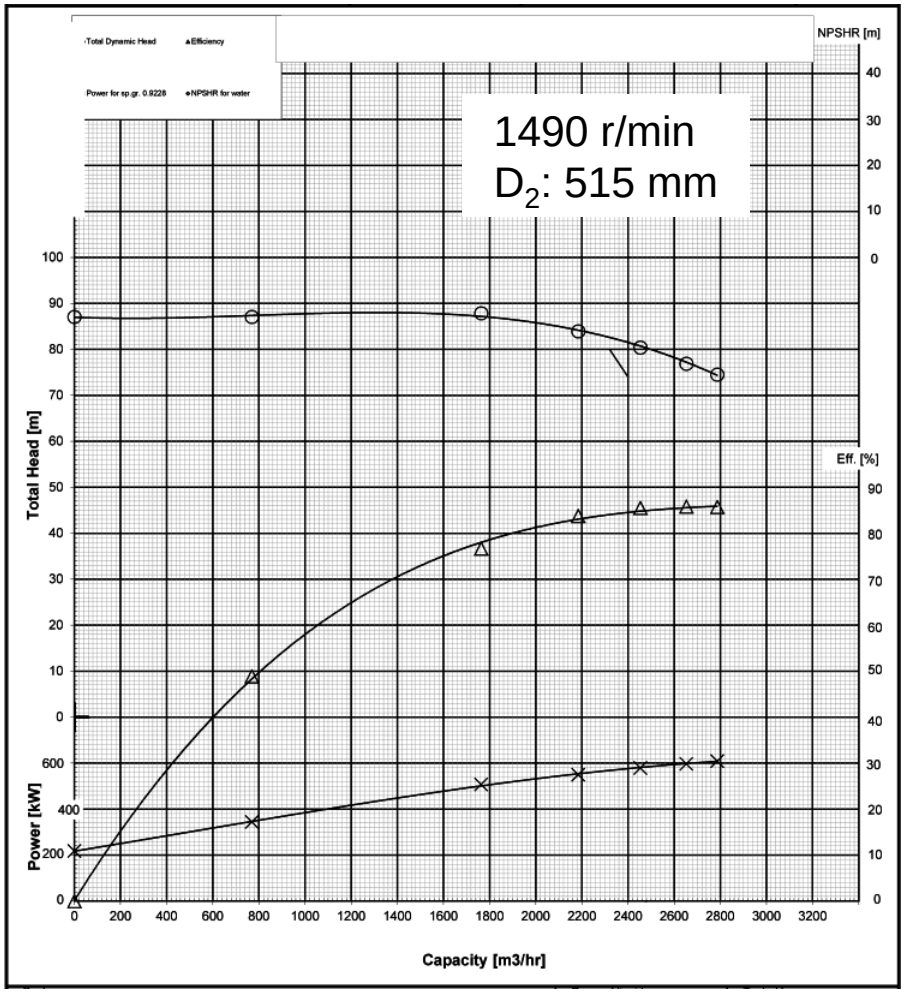


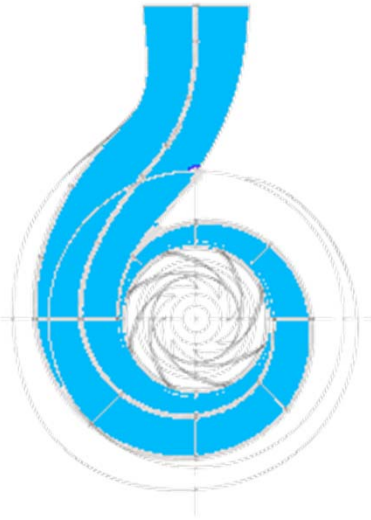




- Keep new high capacity impeller
- Replace diffuser with (dual) **volute insert**
- Increase impeller tip clearance

Second Design





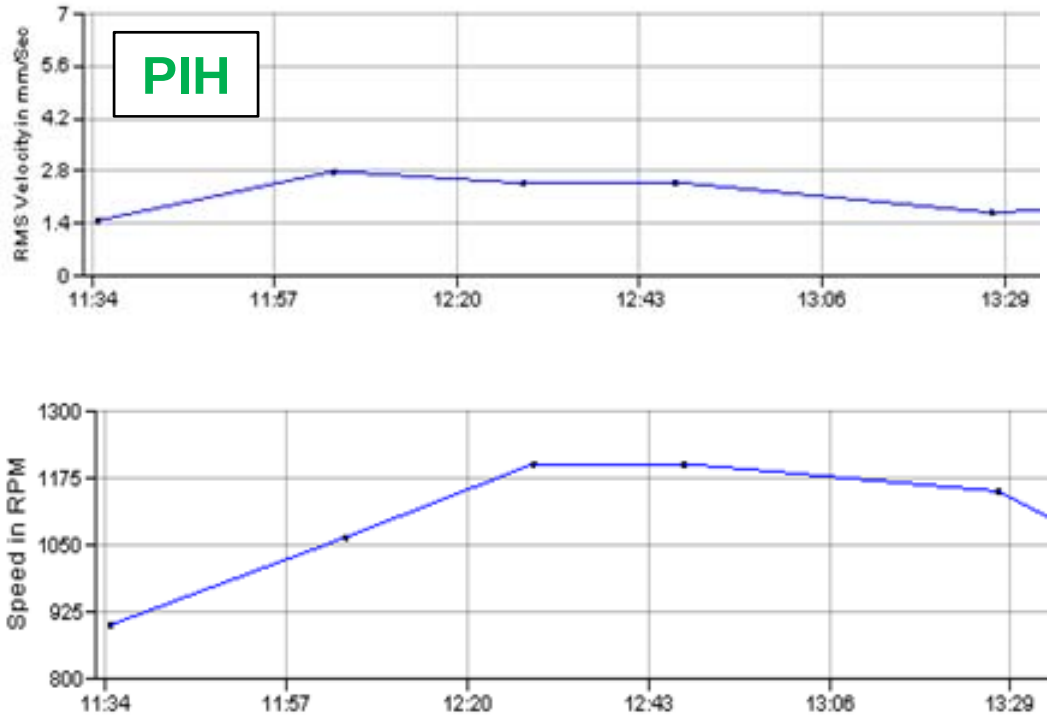
Final test result:

- ✓ Head okay
- ✓ Efficiency okay
- ✓ Power okay
- ✓ Tip clearance (Gap B) okay:

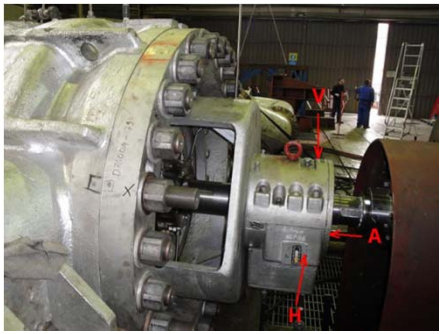
$$(D_3 - D_2) / D_2 =$$
$$578.2 - 515 / 515 =$$
$$0.123 \text{ or } \mathbf{12.3\%}$$

- ✓ 8X vane pass vibration issue resolved (next slide)

Second Design



Shop test with VFD demonstrated strong reduction in vibration response.



- 8X Vibration response not peaking up anymore
- Overall vibration level below 3 mm/s (RMS)

Concluding Remarks

- Pumps have been upgraded with new hydraulic internals for **60% increase in design capacity**.
- **First design iteration** with new impeller and new diffuser was **not successful**:
  - **Hydraulic performance failure**
  - **Vibration issue** (at intermediate running speed)
- **Second design iteration** with same new impeller and volute insert **proved to be successful.**

Concluding Remarks

- First design iteration was unsuccessful because of:
  - **Diffuser throat area was designed too small**
  - **Impeller tip clearance (Gap B) was much too small**
- Particulars of second design iteration:
  - **Sufficient volute (cutwater) throat area**
  - **Ample impeller tip clearance (Gap B) solved the PIH vibration response without having to introduce structural modifications.**
- Pumps with new impeller and volute insert have been installed at site, and are in operation for more than 2 years now.

Thank you for your attention

Questions?