MIDDLE EAST TURBOMACHINERY SYMPOSIUM

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# Resolving cavitation problems of high energy water injection pumps


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# Authors (1/2)

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- Engineering Specialist with Saudi Aramco.
- 25 years of experience in rotating equipment.
- Worked in operations engineering for 16 years and currently working with central engineering providing consulting services to Saudi Aramco operating plants and projects and works in the development of Saudi Aramco standards.

**Saad Al-Ali**

- Senior Maintenance and Reliability Engineer working at the reliability unit head at Ras Tanura Producing Department in Saudi Aramco.
- Currently on special assignment with Abu Ali Maintenance Section in the same department.
- Bachelor degree in Mechanical Engineering from KSU with an honor degree.
- Joined Saudi Aramco late in 1997 and assumed different roles and responsibilities in his career and attended two successful commissioning and startup of big projects in Saudi Aramco facilities.
- Has excellent experience in plant maintenance and sound engineering sense.

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**Abdulaziz Al-Qahtani**

- Rotating Equipment Engineer with Saudi Aramco.
- 7 years experience in turbo machinery maintenance, troubleshooting, operation and selection in Aramco Northern Area Oil Operation Plants.

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- Hydraulic Engineer in the Central Project Engineering team with Flowserve.
- 3 years experience in rotating equipment engineering.
- Masters degree in Aerospace Engineering (specialization Aerodynamics) from Delft University of Technology.

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# Introduction – Project objectives

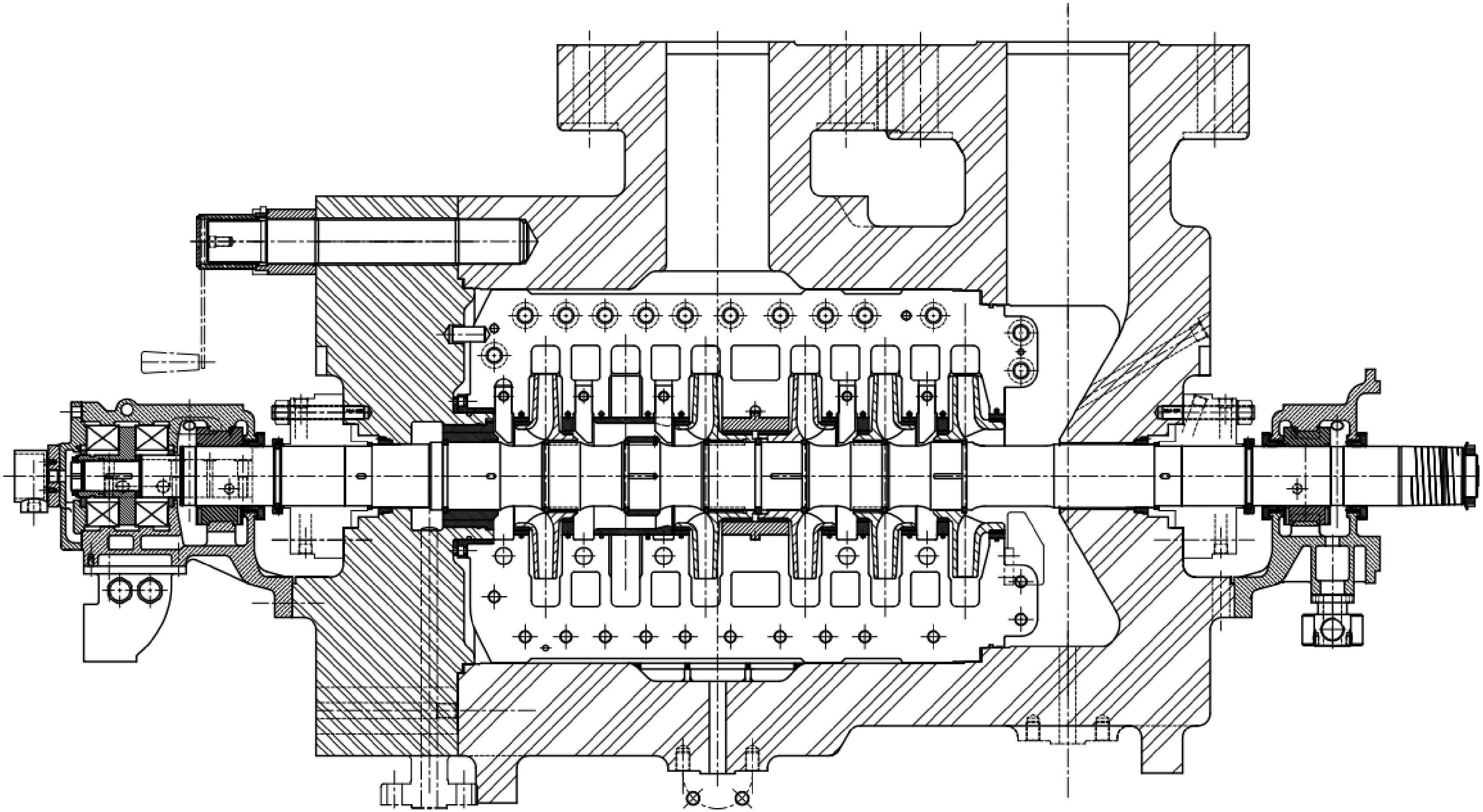
**Design a new first stage impeller using CFD that will minimize cavitation and verify this with a visualization test.**

# Introduction – Pump info

**2005: Commissioning of high speed Water Injection Pumps (WIP) at Saudi Aramco QATIF GOSP-2.**

- Three identical pumps
- Five stages
- Single suction
- Between bearing
- Radial split barrel (API 610 BB5)
- Top-top nozzles
- High speed (5000 [RPM])
- Fluid: raw water; TDS 11000 ppm

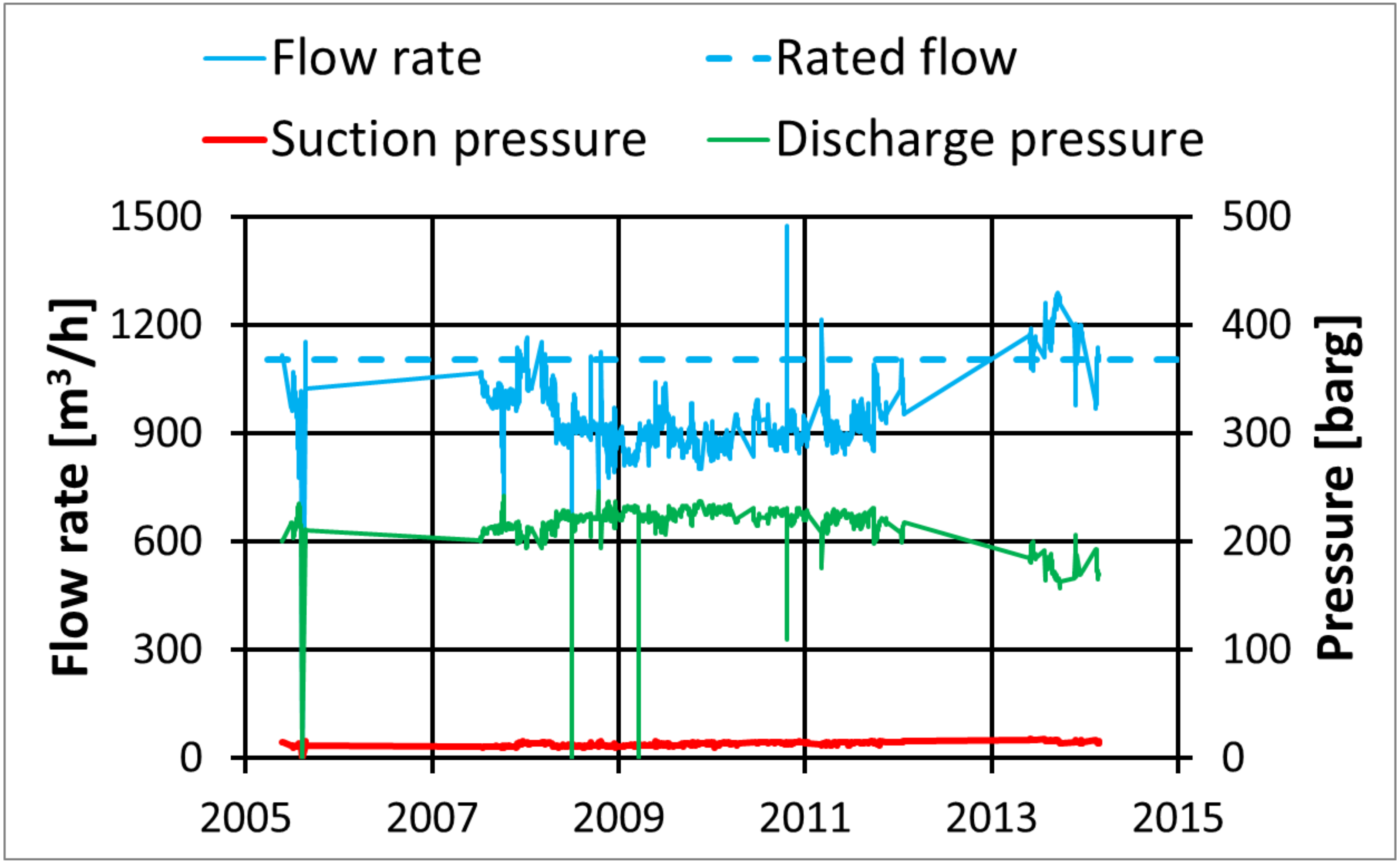
# Introduction – Pump info



# Introduction – Pump info

| | Design | Operating range | | |
|---|---|---|---|---|
| Flow | 1104 | 820 | 1000 | [$m^3$/h] |
| Head | 1966 | 2303 | 2060 | [m] |
| Temperature | 74 | 79 | 79 | [°C] |
| Power | 8203 | 6711 | 7084 | [kW] |
| Speed | 4964 | 4964 | 4964 | [RPM] |
| $U_{eye}$ | 54.5 | 54.5 | 54.5 | [m/s] |
| $NPSH_a$ | 98.8 | 106.7 | 121.9 | [m] |
| $NPSH_{3\%}$ | 33.5 | 15.2 | 22.7 | [m] |
| $NPSH_{40000\ [h]}$ | 45.7 | - | - | [m] |

# Introduction – Field data



# Introduction – History

**2003 (FAT):**
Vane leading edge reworked to meet $NPSH_{3\%}$.

**2008 (28000 [h] operation):**
316 Stainless steel impeller (cavitation) damaged.
Upgrade to Nitronic 50.

# Introduction – History

**2012 (13000 [h] operation):**
Nitronic 50 - impeller faces same damage pattern

↓

**Required to re-design first stage impeller**

# Analysis method – CFD

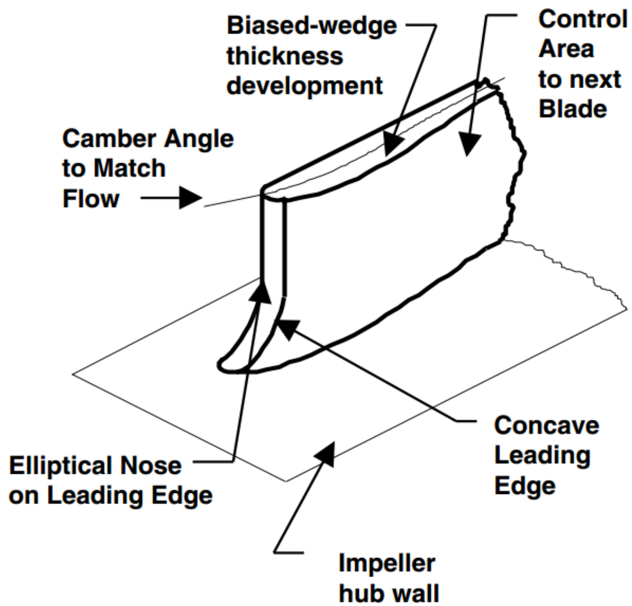
CFD simulations performed to determine $\mathbf{NPSH_i}$ characteristic of:

- Original impeller
- Optimized impeller (new design)

# Analysis method – CFD

**Principle:**

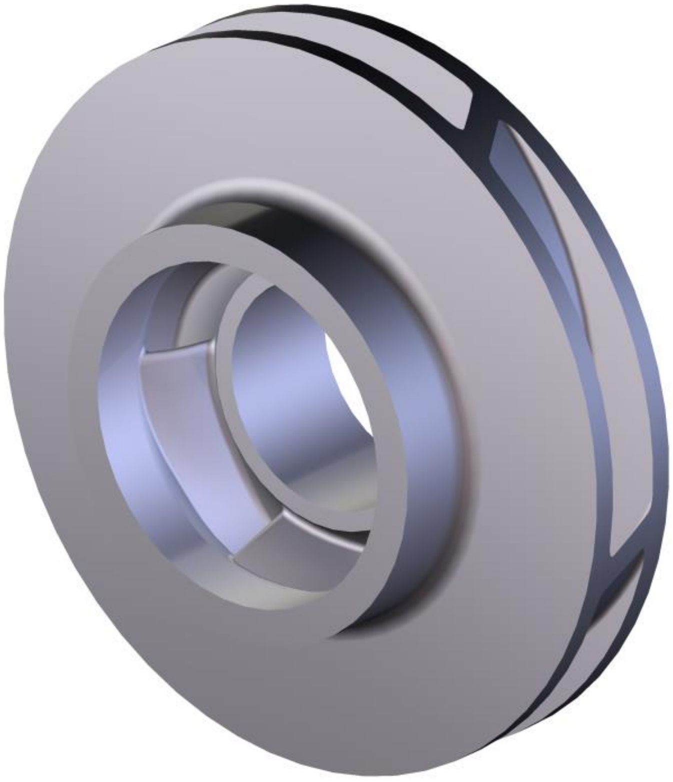
Shape the blade leading edge airfoil-style in order to have minimum pressure drop at the leading edge. This is referred to as a biased wedge leading edge design.



# Analysis method – CFD

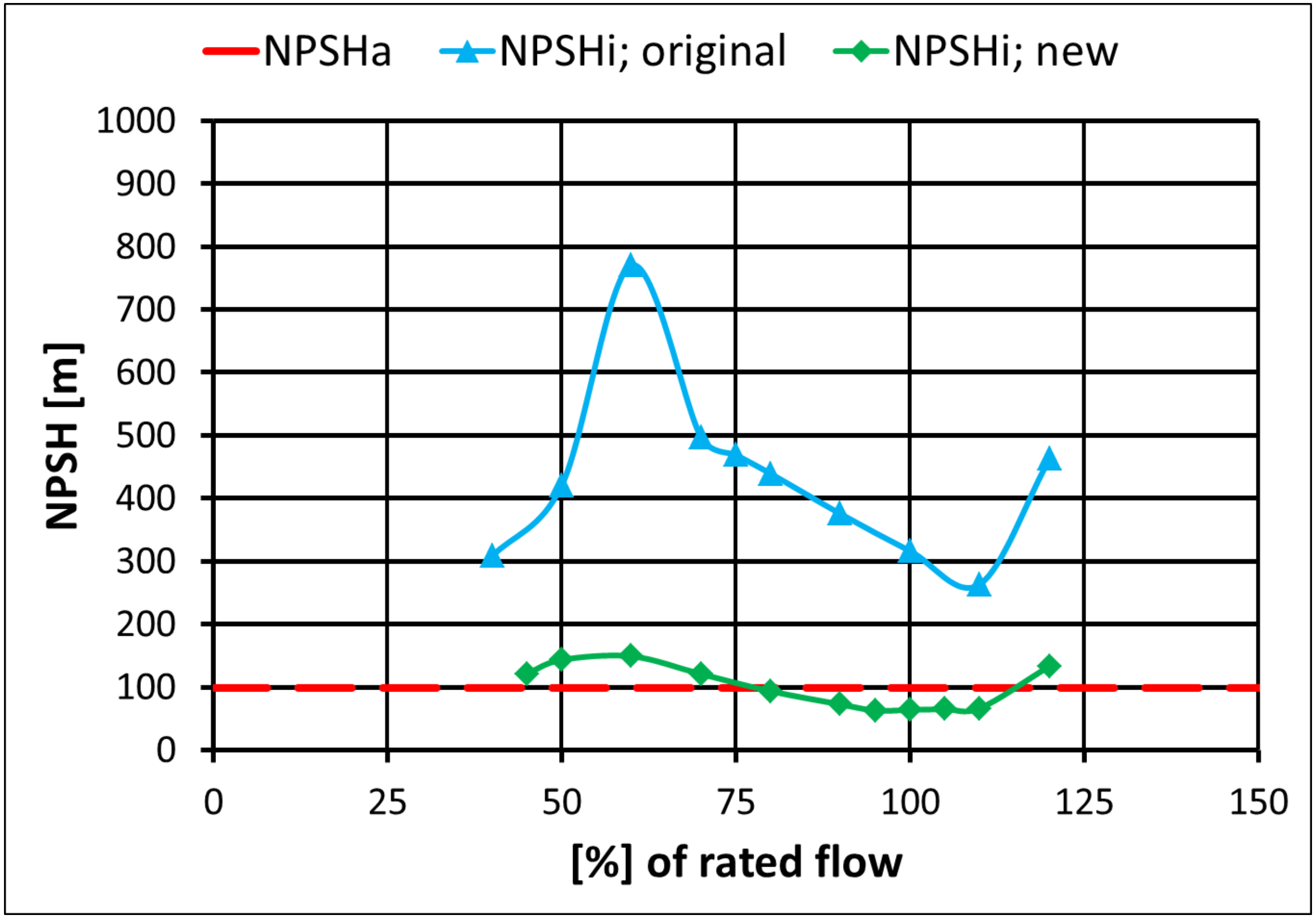
**New design:**

- Based on same parent impeller hydraulic as original
- Five design iterations performed on **$NPSH_i$** simulations
- Design decisions:
  - Best Cavitation Point (BCP) near rated flow
  - 3% head drop criteria met at maximum operating flow
- By rapid prototyping, a full scale physical model was created

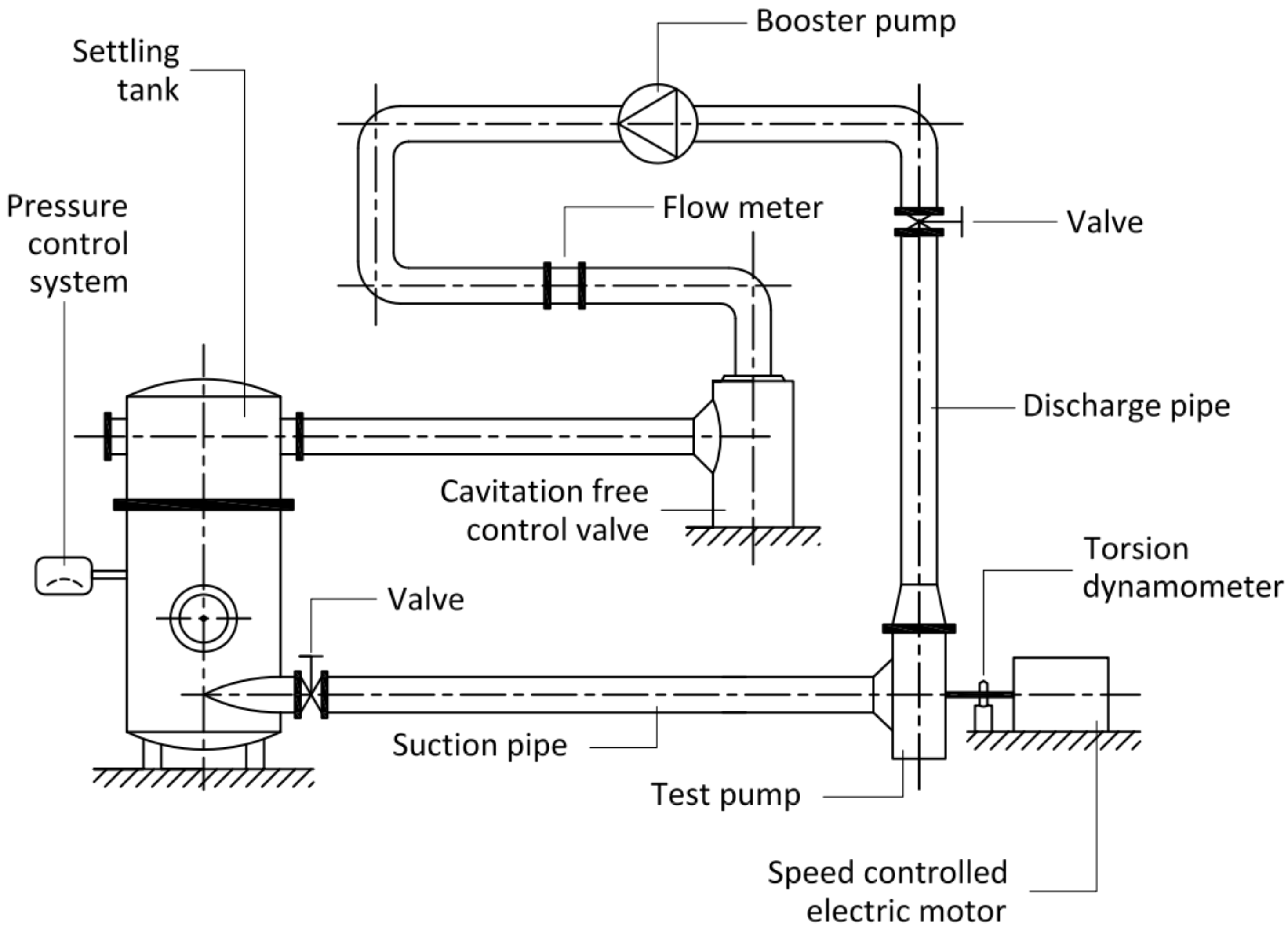


# Analysis method – CFD

**Results:**



# Analysis method – Visualization test



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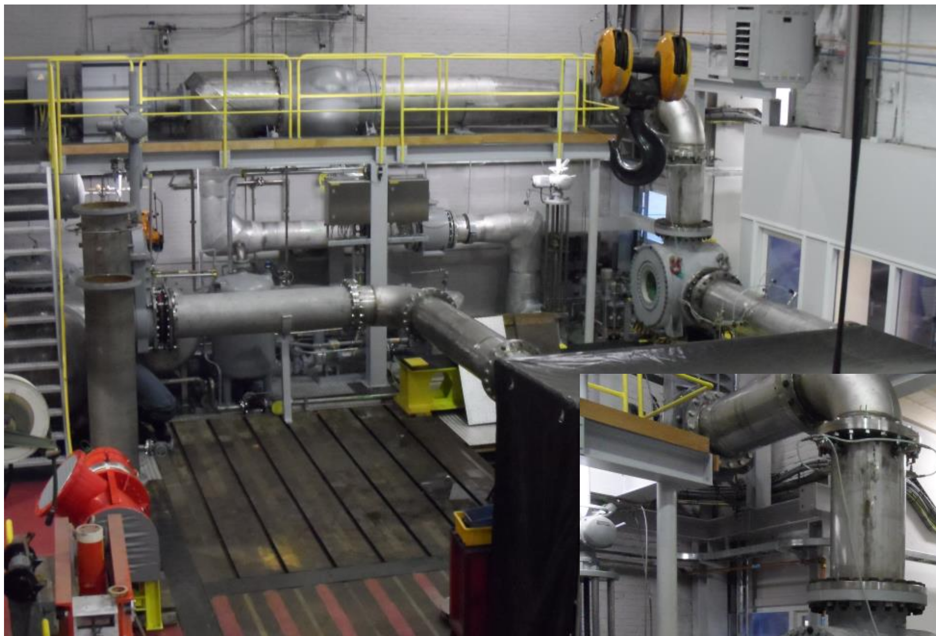

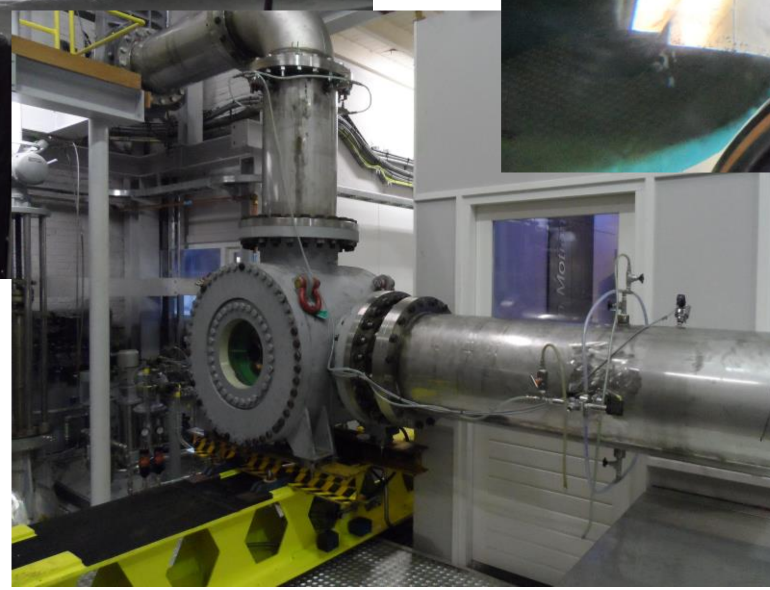

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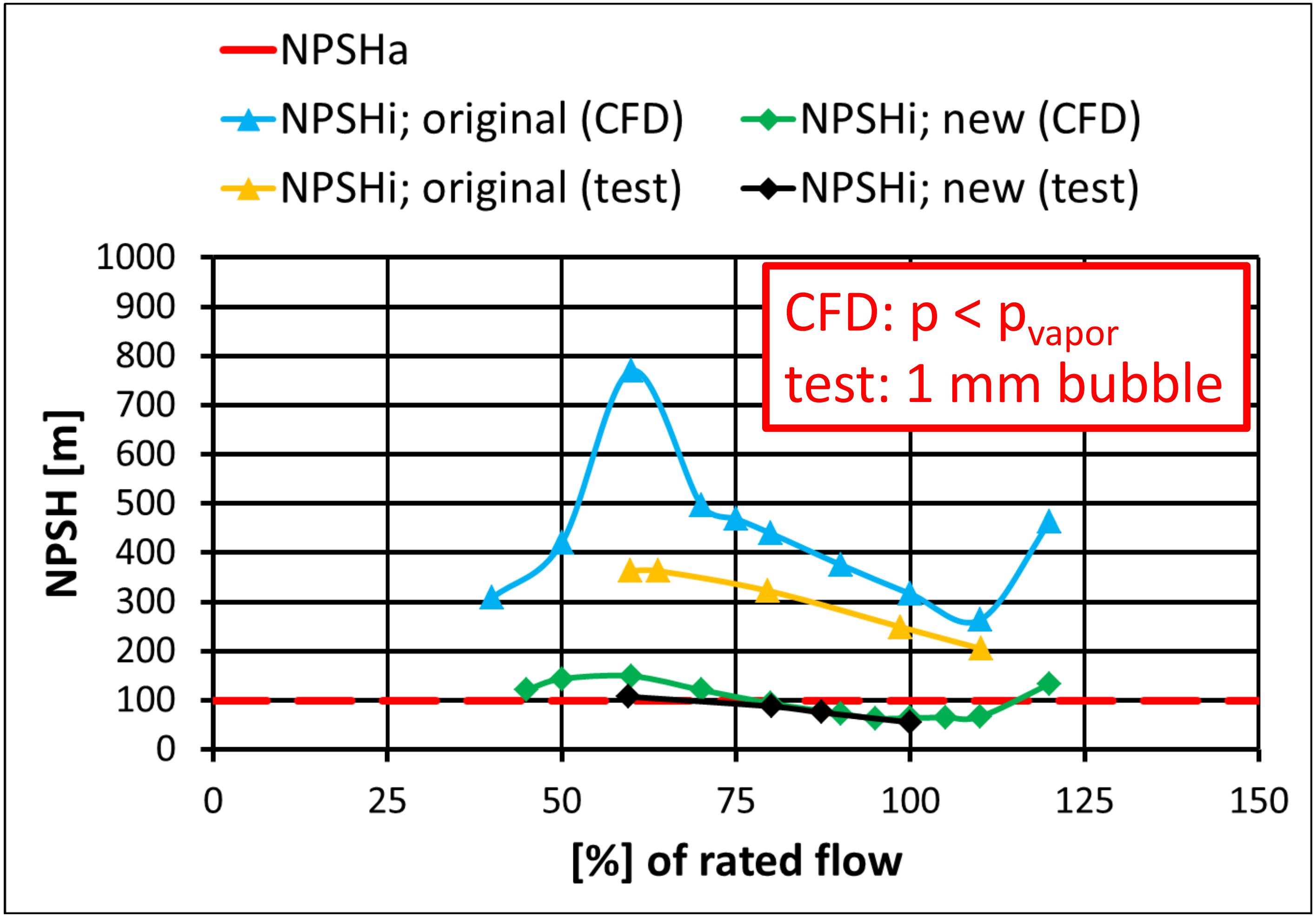
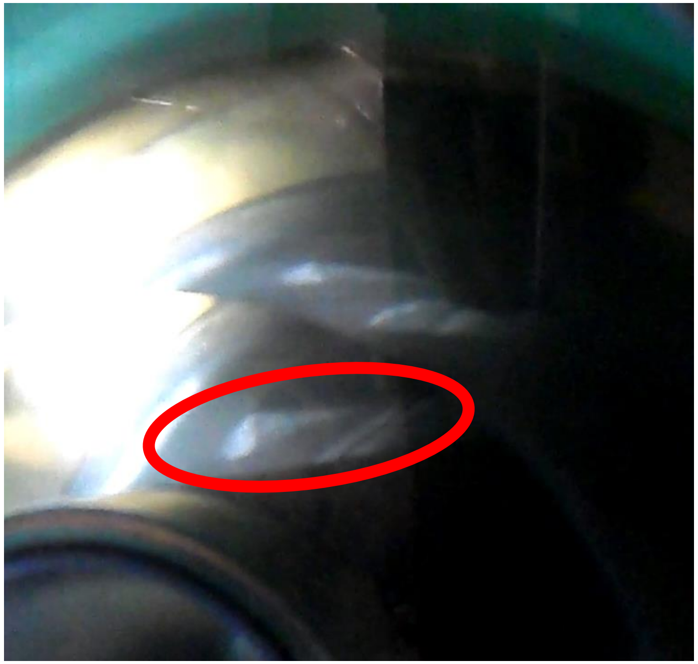


# Analysis method – Visualization test

## Results @ rated flow and $NPSH_a$

Original



New

# Project results

- Impeller leading edge has been optimized using CFD and the improvement has been verified with a visualization test
- Biased wedge design decreased the cavity lengths significantly:
    - No cavitation at 100% and 80% of rated flow @ $NPSH_a$
    - 40.000 hours lifetime will be met

# Lessons learned

- A biased wedge design can improve cavitation characteristics significantly for a wide range of flow rates

- The 3% head drop is an inappropriate criterion for high energy pumps having high eye peripheral speed

# Lessons learned: revised standard

| Pump type | $NPSH_{3\%}$ curve | 40000 [h] curve | Visualization test | Acceptance criteria |
|---|---|---|---|---|
| All pumps | ✔ | ✘ | ✘ | Margin MCSF[1]-120 % > 1 [m] |
| High energy water injection pumps | ✔ | ✔ | ✘ | Depth of penetration < 75% of vane thickness |
| Water injection pumps eye peripheral velocity > 47 [m/s] | ✔ | ✔ | ✔ | Depth of penetration < 75% of vane thickness |

✔ Required

✘ Not required

[1] Minimum Continuous Stable Flow

# Thank you for your attention.

# Questions?