Upgrading a Set of Large Cooling Water Pumps with the Aim to Increase Capacity at Least 13 Percent and Minimize Impeller Cavitation

Frank Visser

Flowserve FSG Pumps

Case Study

27TH International Pump Users Symposium, Houston, Texas, USA
September 12 – 15, 2011

Contents

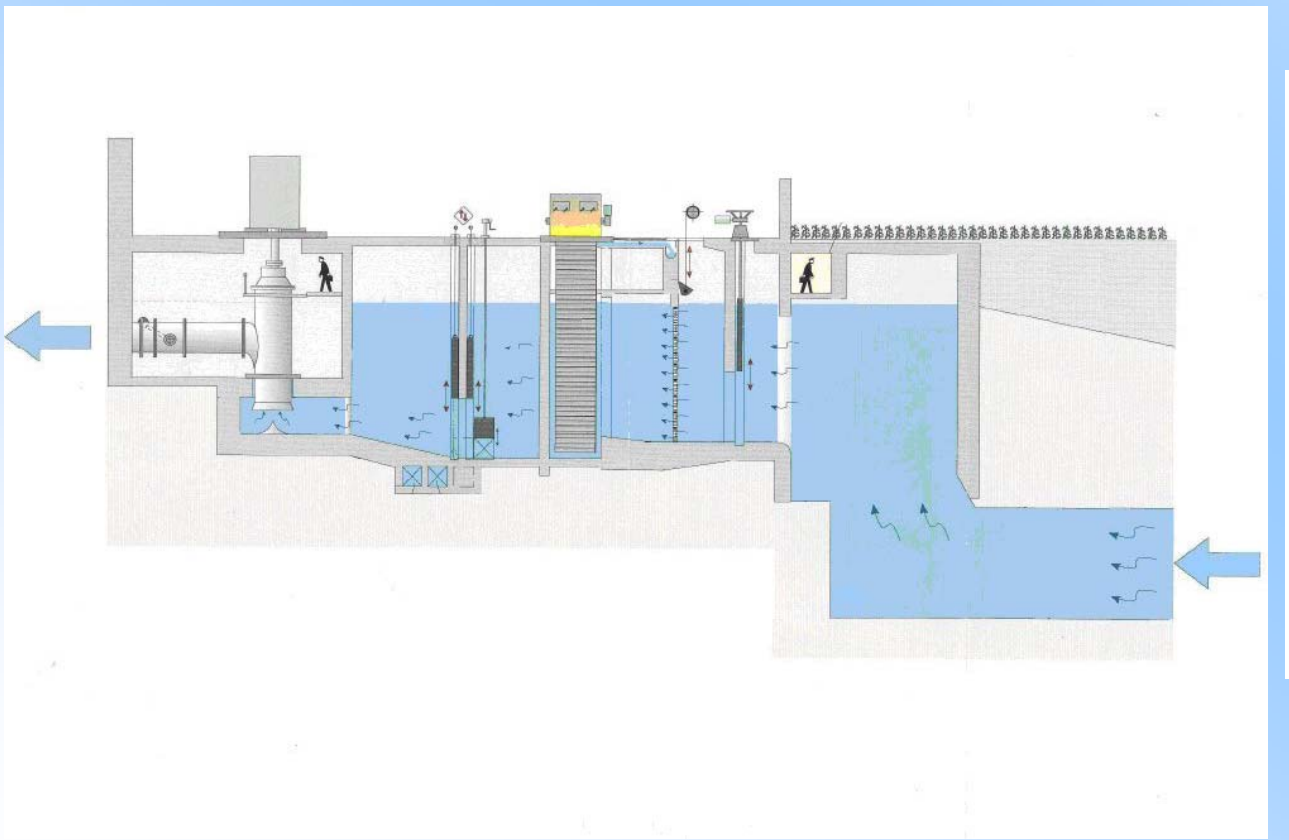
- Background
- In-situ capacity measurement
- Impeller-diffuser CFD study
- Scaled model testing
- Start-up transient
- As built performance

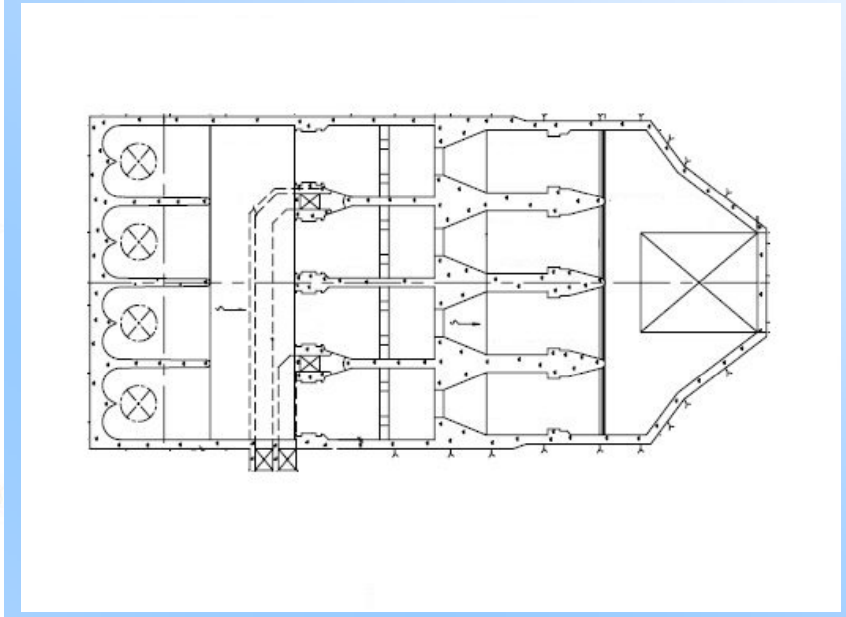
Background

- Up-rate of Nuclear Power Station.
- Increase of electrical output power required increase of cooling water capacity (> 13%).
- Existing cooling water pumps (CWPs) are suffering from cavitation attack.
- CWP retrofit design objective:
  - Cooling water capacity increase of 13%+
  - Minimize impeller cavitation
- CWP E-motor replacement ($P_{CWP}\uparrow$)
  - System start-up transient analysis

Background

Four (4) CWP running in parallel feeding condenser with seawater



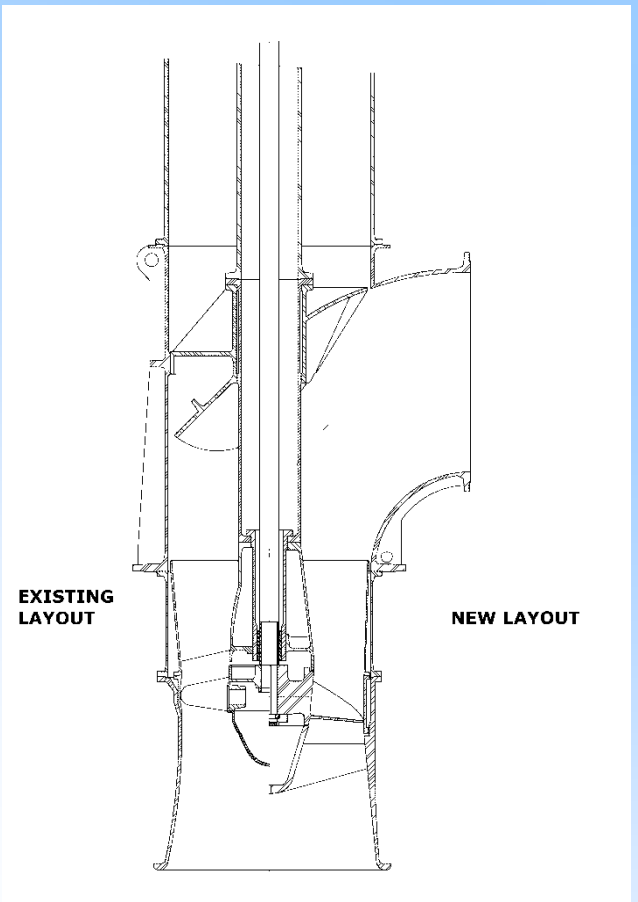


In-Situ Cooling Water Capacity Measurement

- Required to establish pre-upgrade baseline situation
  - Total CWPs flow rate measurement
  - Individual CWP's head measurement
- Flow rate measurement with OTT-mills
  - 6 mills on a horizontal scanning bar
  - 4 throughflow areas scanned (curtain wall)
  - 6x14 scanning window (14 elevations)

In-Situ Cooling Water Capacity Measurement

In-Situ Cooling Water Capacity Measurement



	Existing				Up-rate			
Speed	325		r/min		325		r/min	
Capacity	7.8	m^3/s	275	cfs	> 8.81	m^3/s	> 311	cfs
Head	5.7	m	18.7	ft	> 7.3*	m	> 24.0	ft
$N_{s,D}$	12700 4.64		rpm, gpm, ft (-)		11200 4.1		rpm, gpm, ft (-)	
D_{nom}	56”				58” – 59”			

* Per quadratic scaling

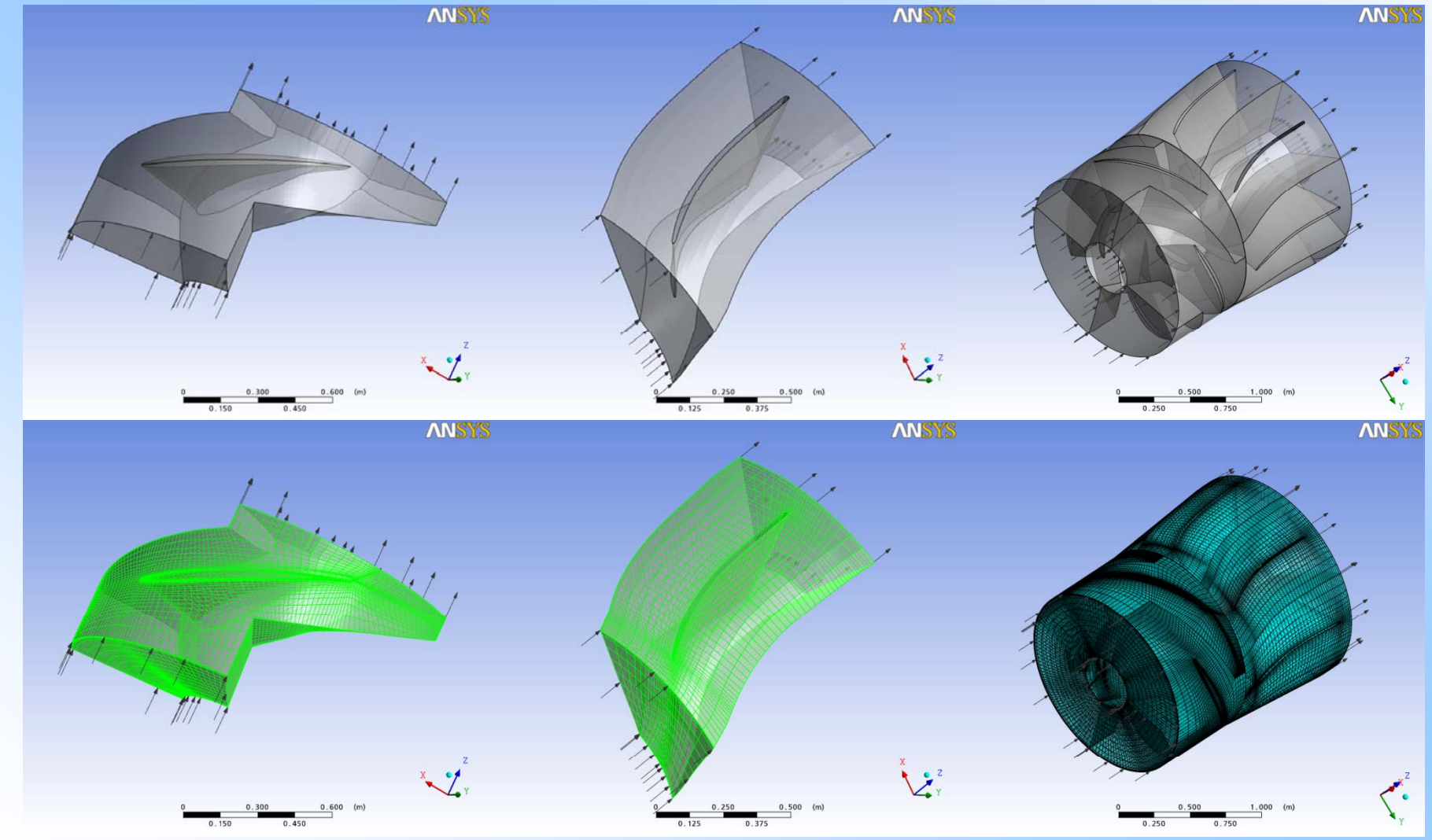
Impeller-Diffuser CFD Study

- Geometries studied:
  - Existing impeller / diffuser combination
  - Retrofit impeller / diffuser combination
- Objective
  - Determination of best cavitation point (BCP) $\rightarrow$ NPSHi
  - Evaluate cavitation development
  - Head comparison

Note: Both the existing and retrofit design have 4 impeller blades / 7 diffuser blades

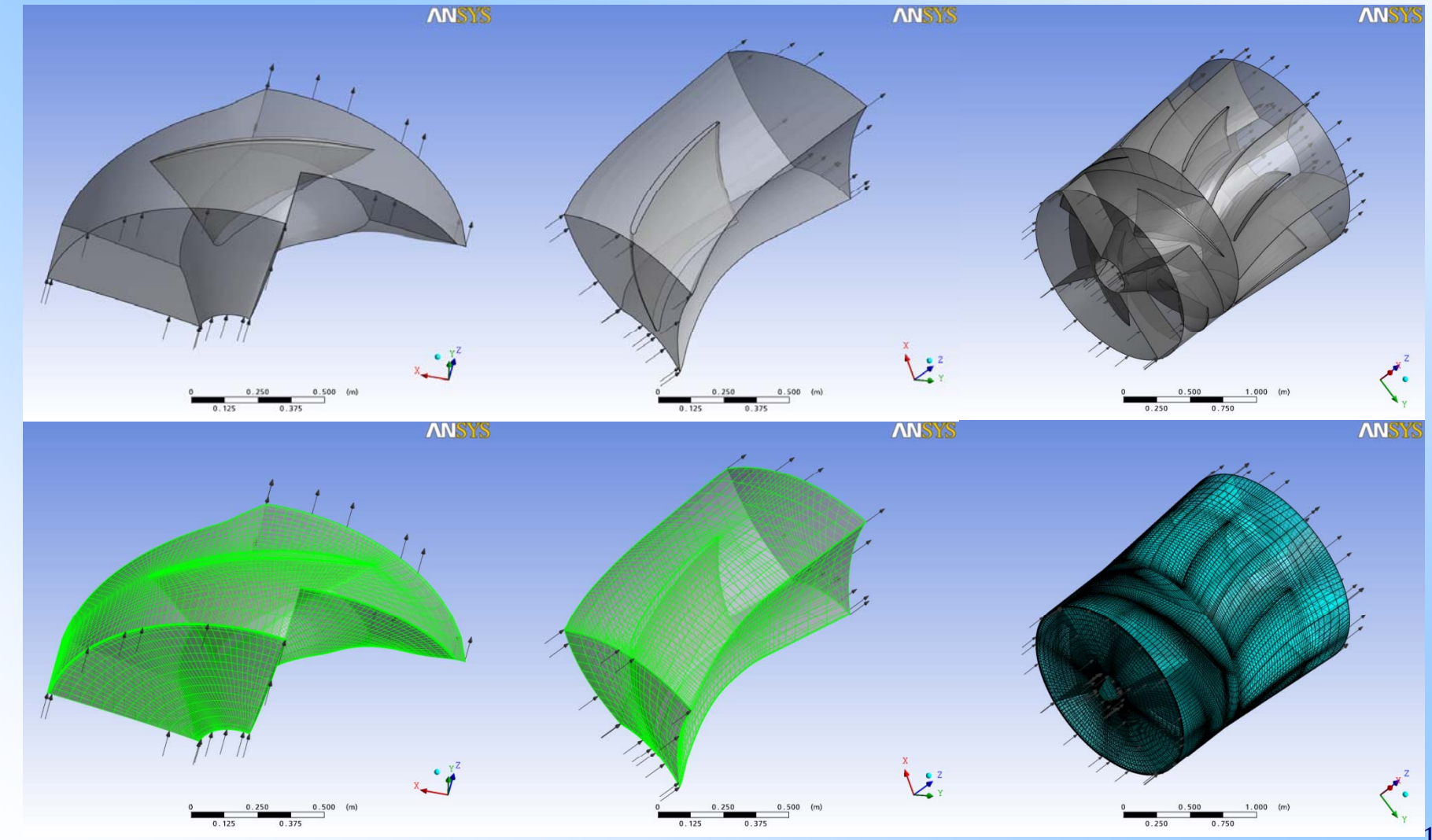
Impeller-Diffuser CFD Study

Existing Design

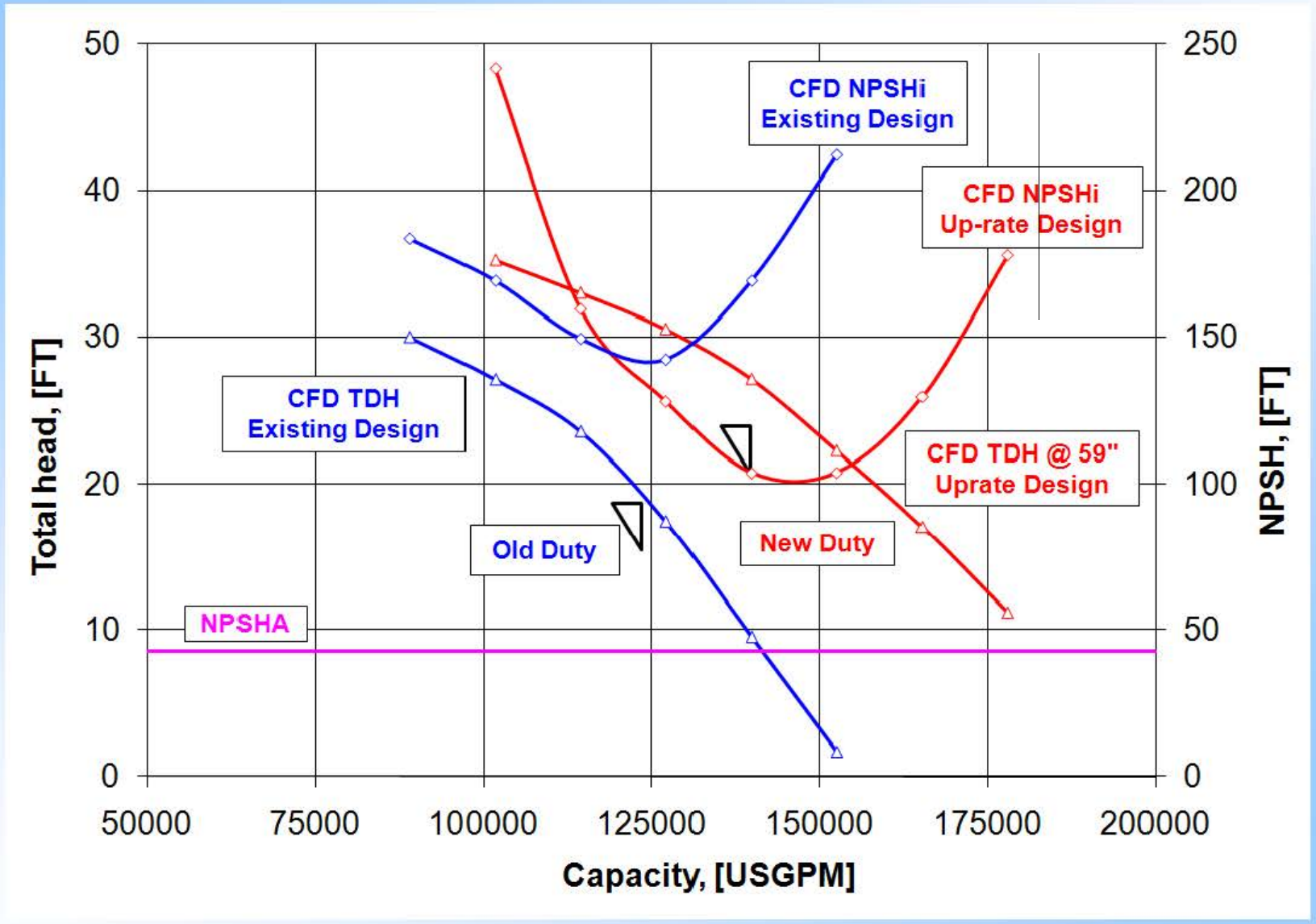


Impeller-Diffuser CFD Study

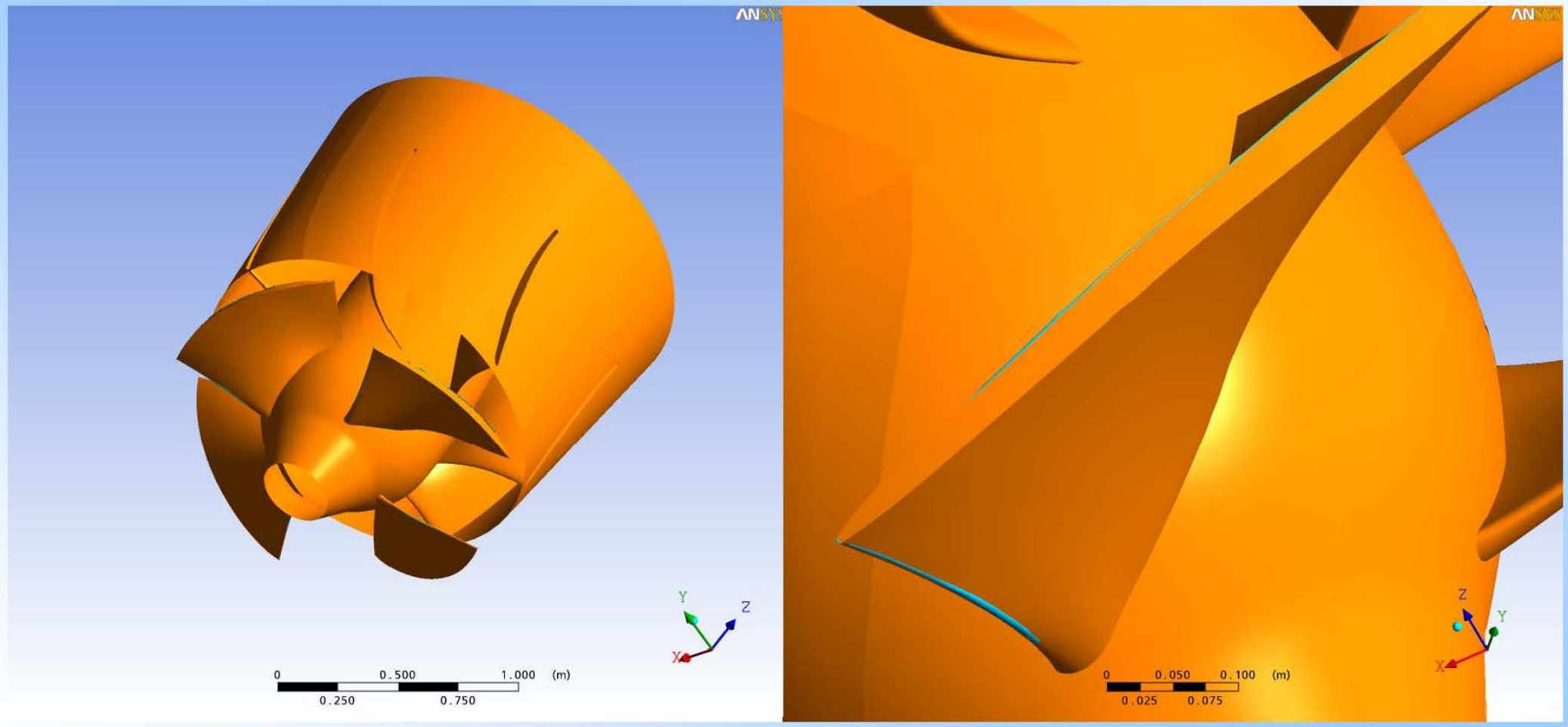
New Design for Upgrade



Impeller-Diffuser CFD Study

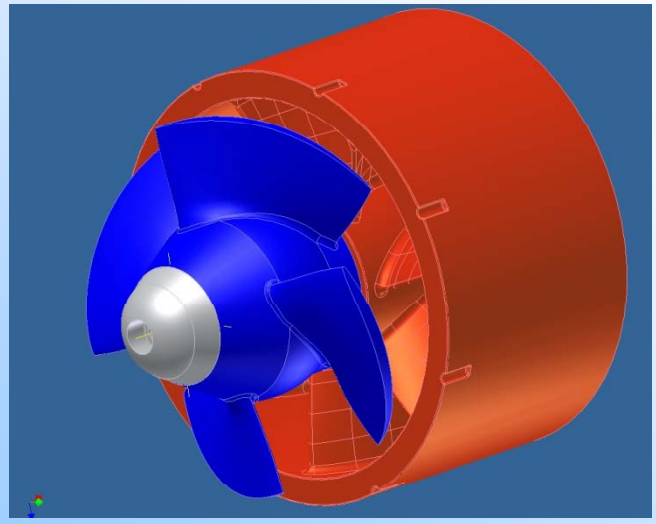


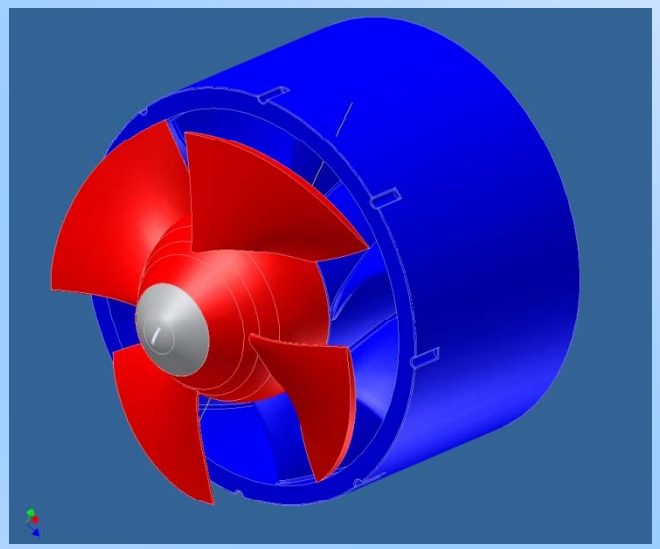
Impeller-Diffuser CFD Study



Scaled Model Testing

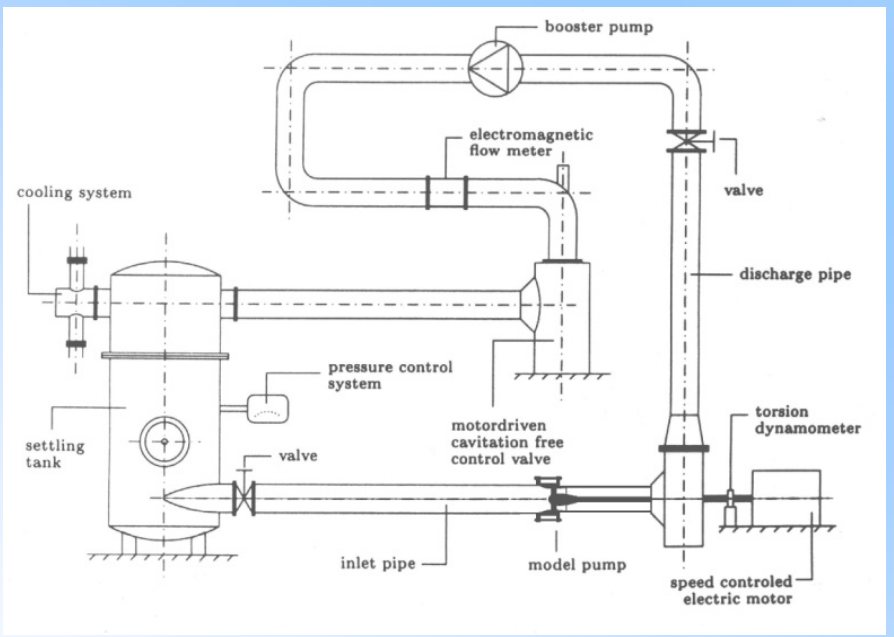
- Objective
  - Verify hydraulic performance
- Scaled model testing
  - 1:4 model scale (approx. 14” test impeller)
  - 4:1 speed ratio (approx. 1300 r/min)
  - Existing impeller-diffuser
  - Up-rate impeller-diffuser
- Existing parts reproduced on scale from 3D Faro-arm scan
- Up-rate hydraulic parts modeled directly in 3D CAD

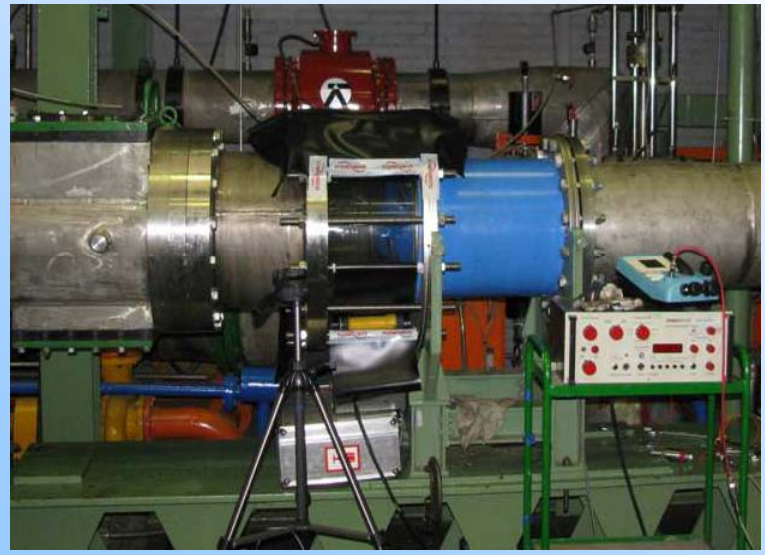


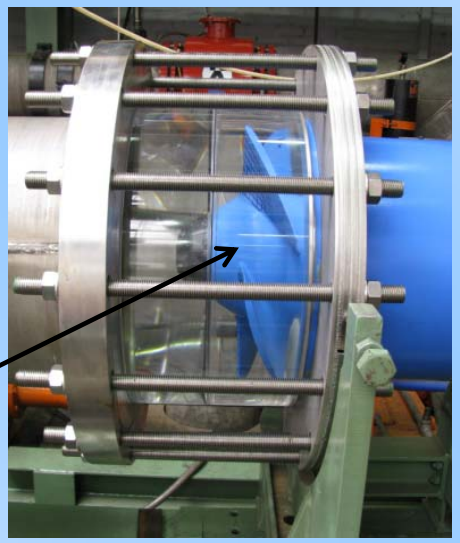


Scaled Model Testing

- Test Loop & Test Set-up
  - Q, H, η performance testing
  - Cavitation visualization







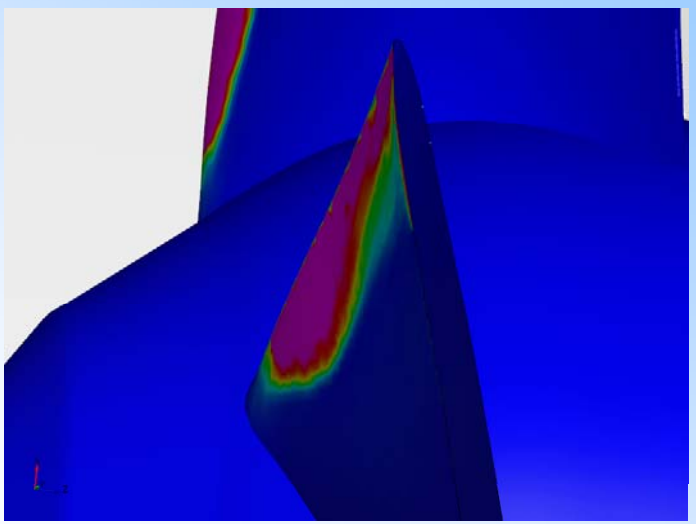
Flow visualization window

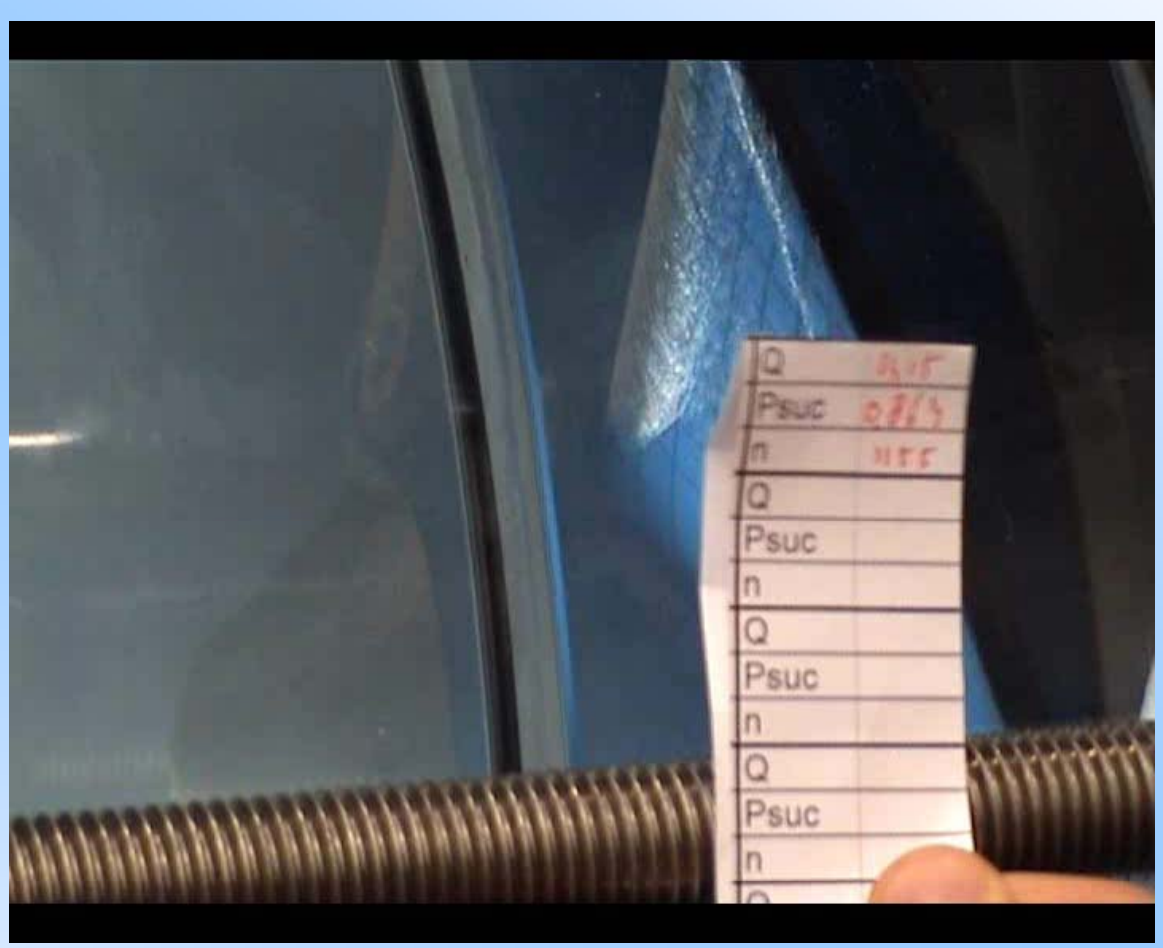
with impeller mounted

Scaled Model Testing

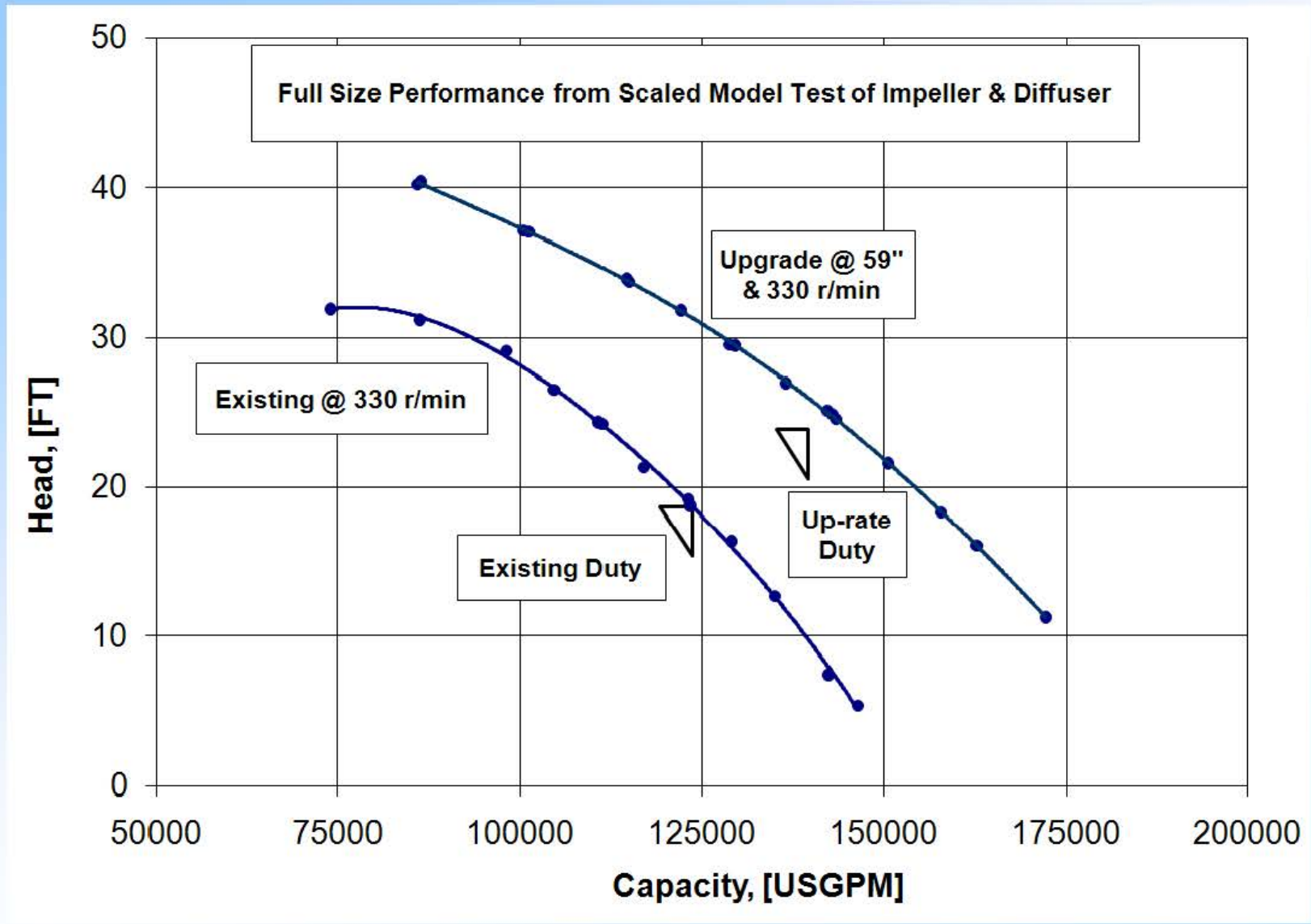
Cavitation @ 90% duty capacity:

- Experiment
- CFD



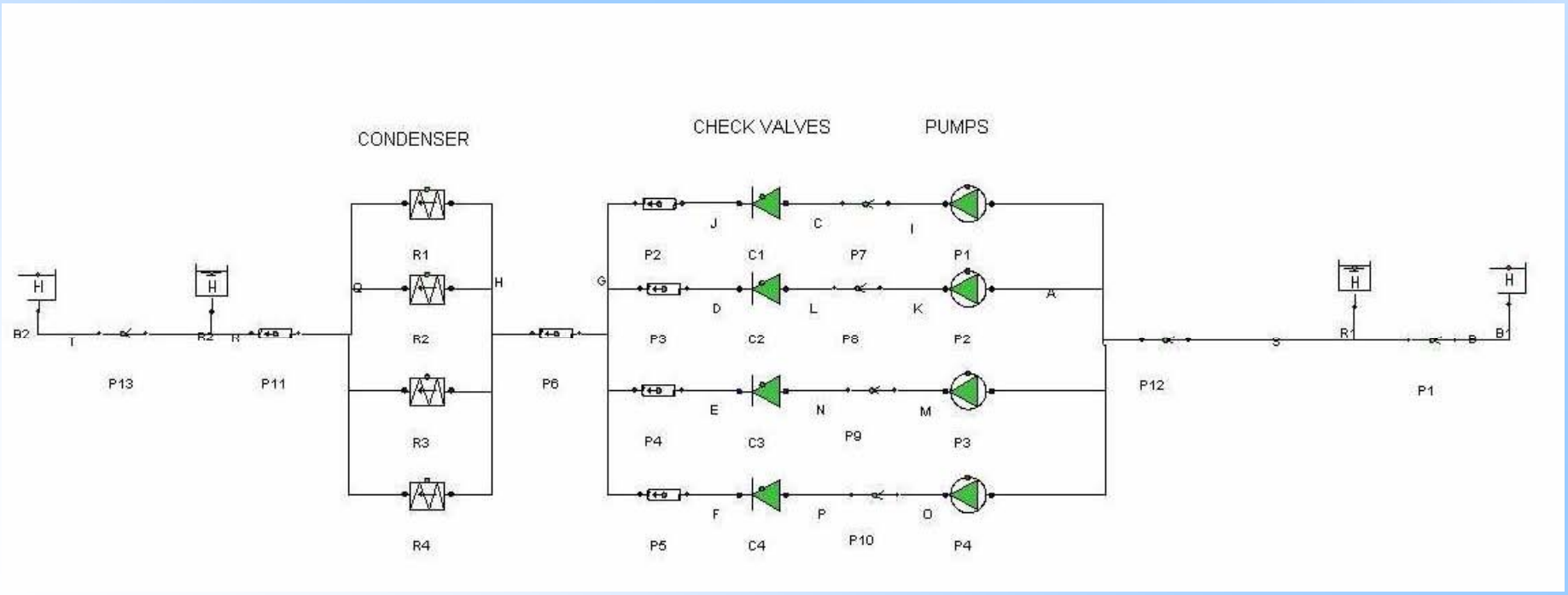


Scaled Model Testing



Start-Up Transient

- Objective:
  - Check motor capability (torque) to start the pumps
  - Determine start-up time(s)
- Entire cooling water system is modeled

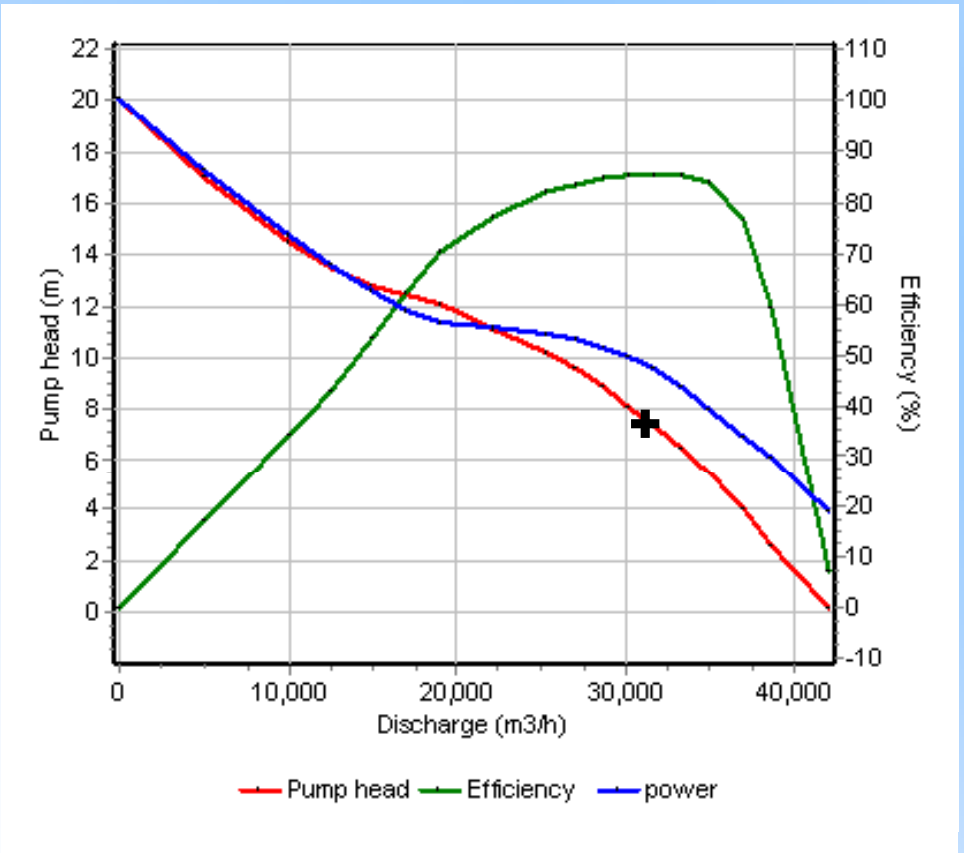


Start-Up Transient

- Start-up requirement E-motor:
  - 80% Voltage
  - -15% Torque (tolerance per IEC 60034-1)
- Start-up scenario:
  - P1 thru P4 are started at 60 sec intervals
- Initially selected motor showed problem when starting 4th pump
  - P4 could not be accelerated to full speed due to insufficient motor torque
  - P4 ended up running against closed (check) valve at intermediate speed

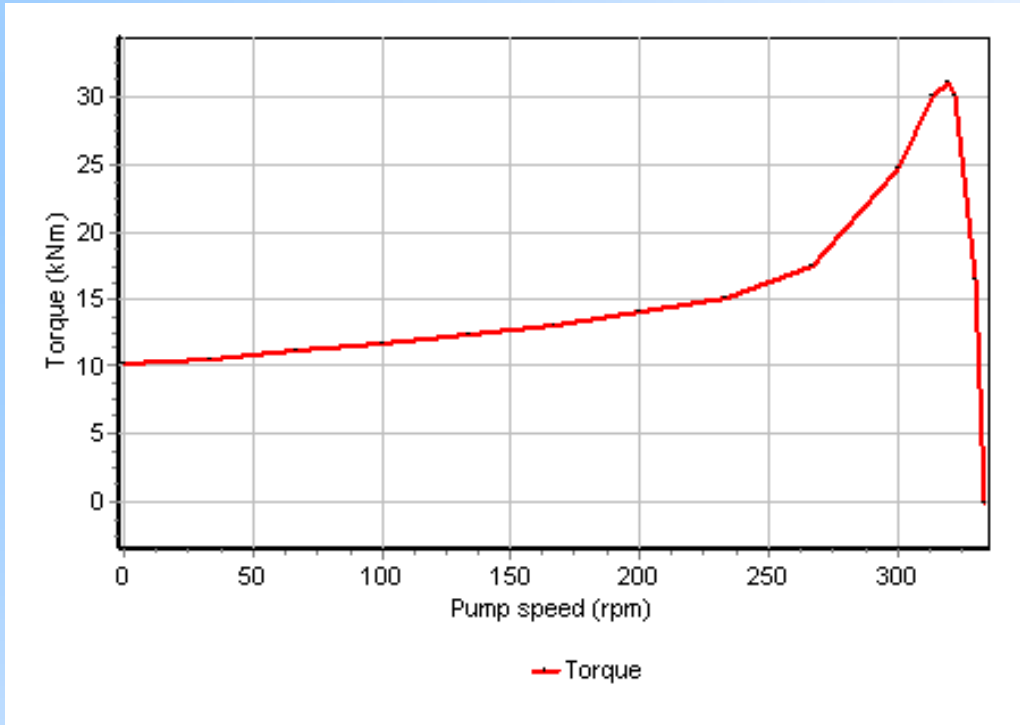
Start-Up Transient

Pump curve

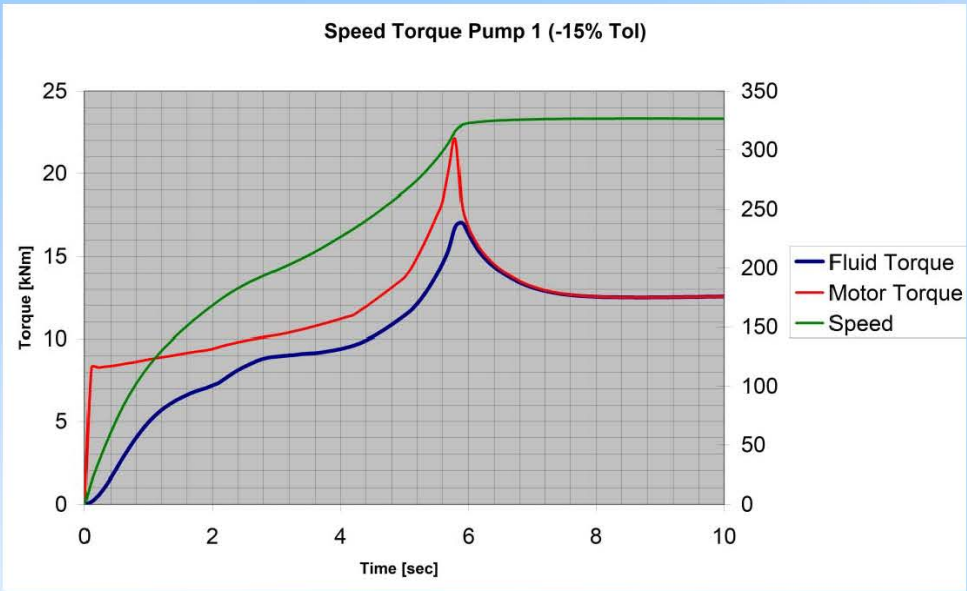


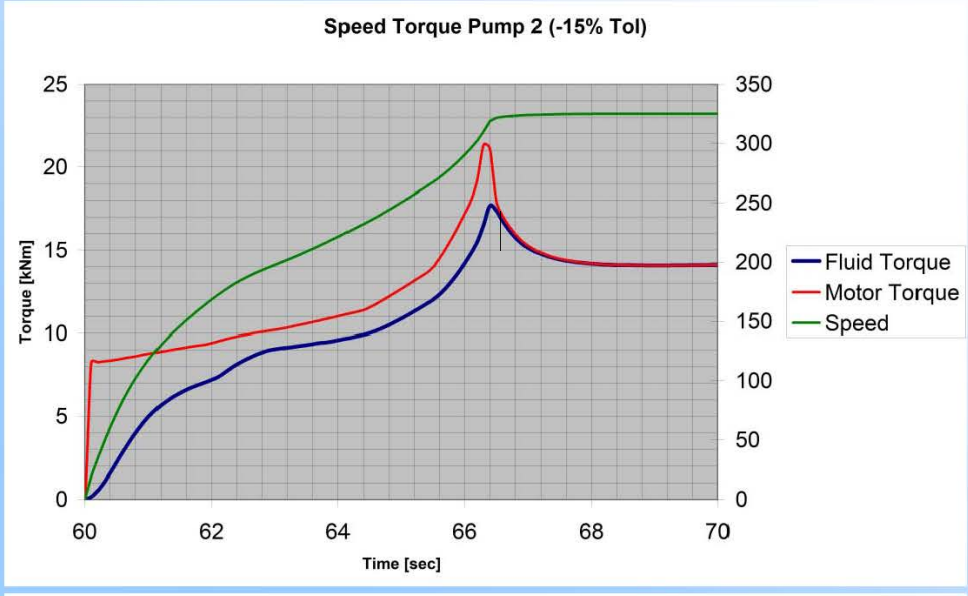
Motor speed-torque curve

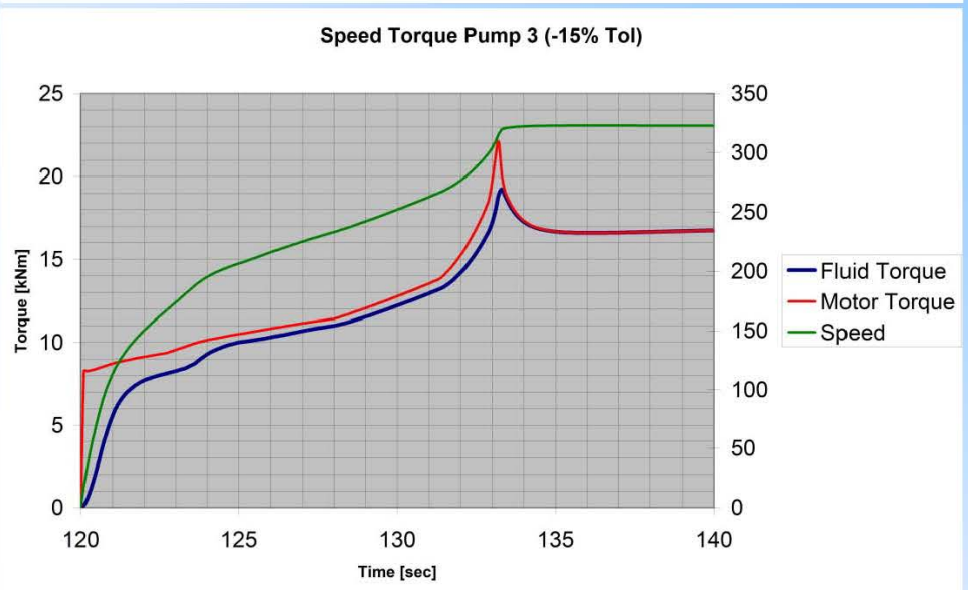
(80% Voltage; -15% Torque)

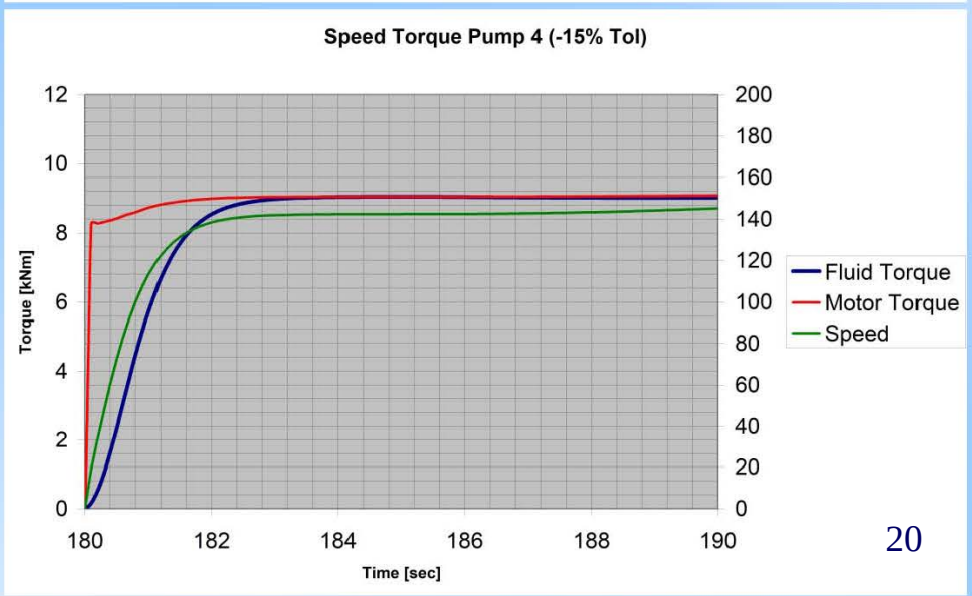


Start-Up Transient



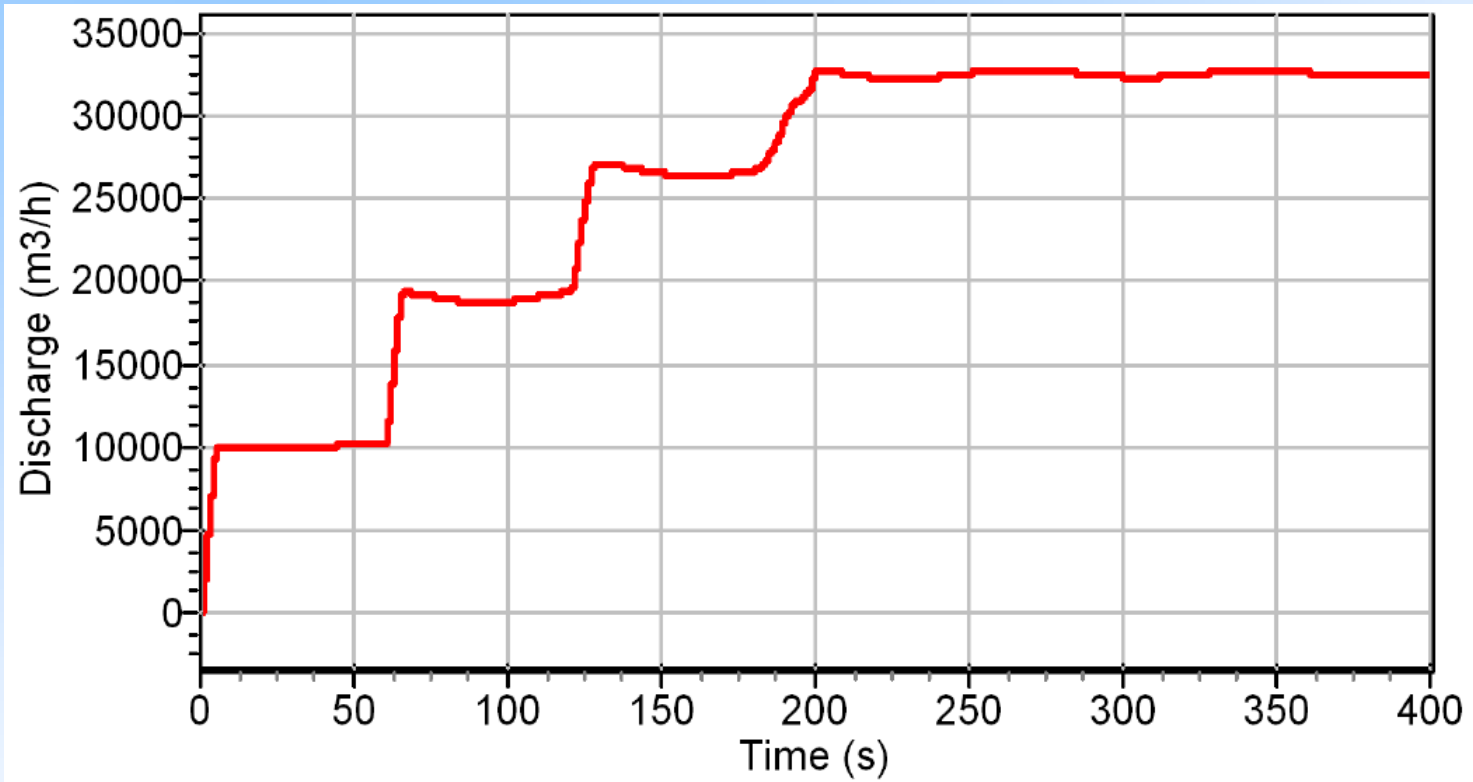






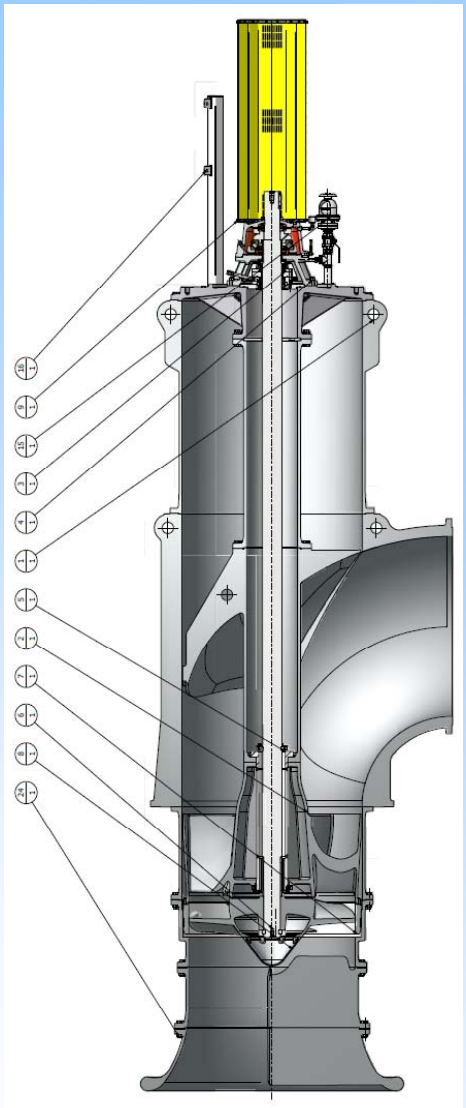
Start-Up Transient

- Issue solved by new motor with better speed-torque



Cooling water flow through condenser at start-up

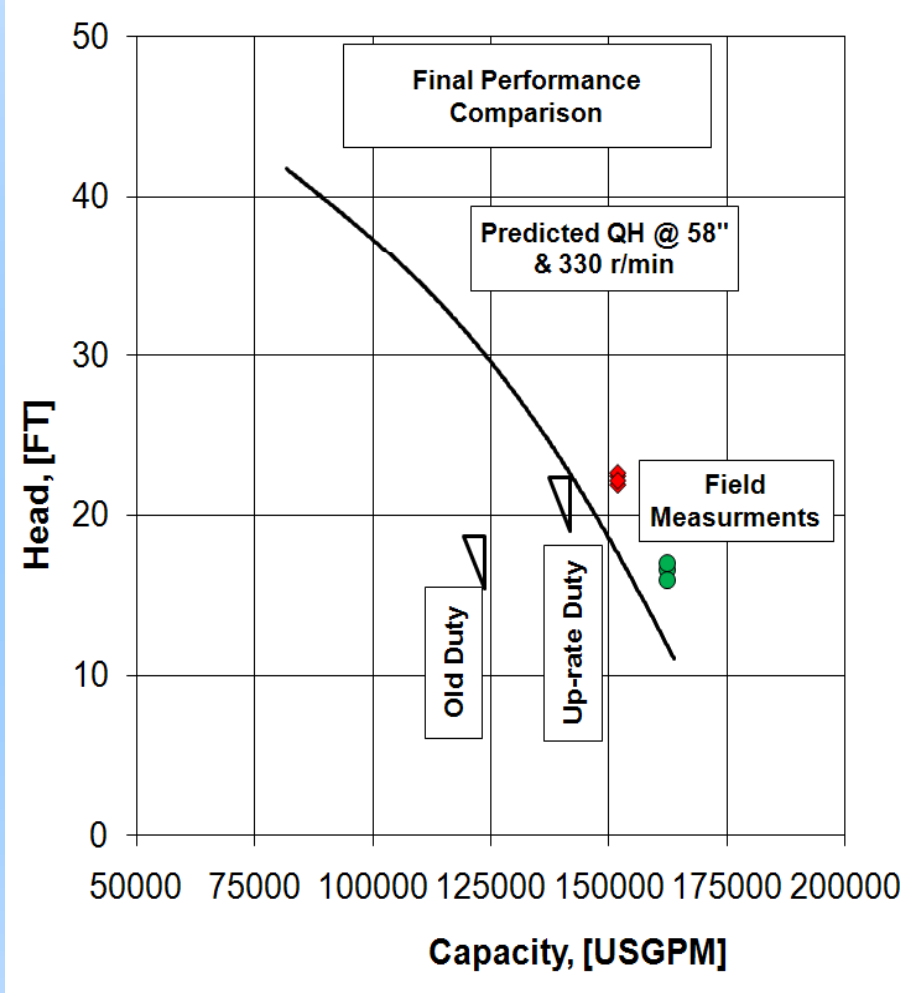
As Built Performance



- Final design built @ 58 1/16”
- Taking into account:
  - Performance pick-up due to up-scaling
  - Intake & discharge losses not being accounted for in impeller/diffuser CFD study and scaled model testing
  - System resistance line was lowered due to installing power pack (actuator) on check values → less steep characteristic
  - Contractually required capacity increase of 113%, with +3% tolerance.

As Built Performance

- In-situ field performance check
  - Four pumps running
  - Three pumps running
- Pumps are over-performing (Q-H)
  - Pump Q-H above predicted curve
  - System resistance curve lowered more than expected
  - Higher condenser cooling capacity
  - Higher driver power, but motors are not overloaded
- At the end: Everybody Happy!



Thank you for your attention