# USER CASE STUDY ABSTRACT
**18th International Pump Users Symposium**

## TITLE:

## *Experience with Vertical-Turbine Pumps Rebowl Upgrade*

## ABSTRACT:

Four 580 HP cooling tower feed pumps were upgraded by retrofitting improved bowl assemblies with enclosed stainless-steel impellers.

Pumps exhibited capacity limitation up to 50% of rated and cavitation damage in original semi-open cast iron impellers, requiring continuous operation of all installed equipment, including the stand-by pump, to cover plant requirements.

Performance of the pumps was optimized by rework of new impellers and stand testing to satisfy guarantee point and improve efficiency to accommodate power limitation of existing drivers.

As a result, rated capacity was recovered, allowing one pump in stand-by, with a significant reliability improvement and considerable savings in maintenance costs, together with a lower capital investment compared to the replacement of the complete units.

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# REBOWL UPGRADE OF VERTICAL-TURBINE PUMPS PROVEN EFFECTIVE

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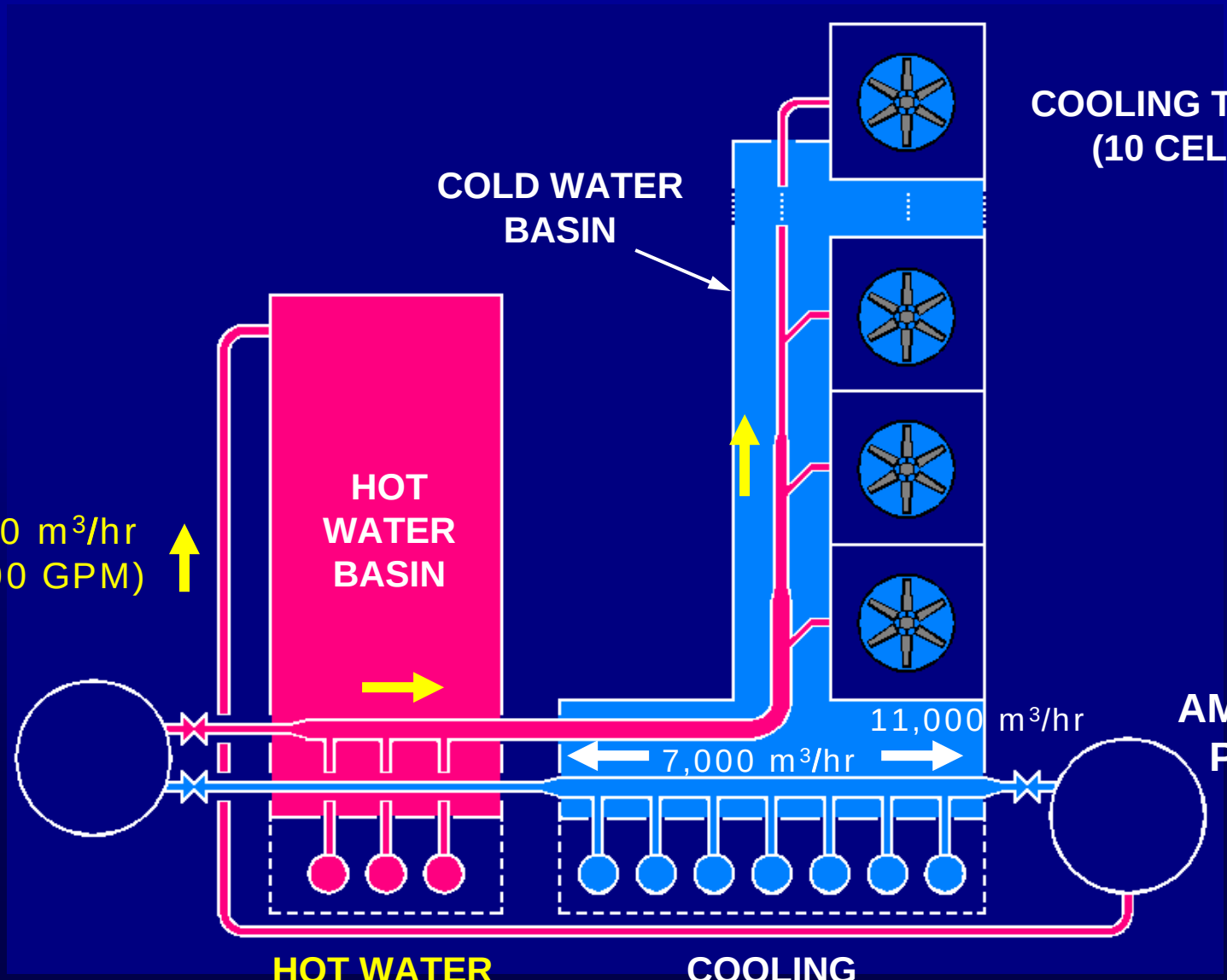
# *SITUATION OVERVIEW*

- **30 year old Cooling Tower servicing a 680 MTD Ammonia Plant and a 750 MTD Urea Plant.**
- **Three 580 HP Cooling Tower Feed Pumps installed (One turbine driven and two motor driven).**
- **An additional pump kept as a spare.**

# *SITUATION OVERVIEW (cont...)*

- **Pumps rated for 22.5 m @ 5,000 $m^3$/hr (75 ft @ 22,000 GPM) each. (66,000 GPM total).**
- **Cooling Water Pumps were uprated 1997 to satisfy larger demand after a revamp of the Ammonia Plant in 1997.**
- **All three pumps required to operate continuously to deliver an average of 11,000 $m^3$/hr (48,400 GPM).**
- **Actual limitation of 73% of rated.**
- **Stand-by pump required in continuous service.**
  - **No operational flexibility.**
  - **High maintenance costs.**

# PROCESS DIAGRAM



# *SITUATION OVERVIEW (Cont...)*

- **Pump efficiency progressively reduced due to cavitation / recirculation damage of impellers.**
- **Yearly overhaul required.**

# *SITUATION ANALYSIS*

- **Cooling water feed to the Ammonia Plant increased by 50% after revamp.**
  - **Before: 7,400 $m^3$/hr (32,500 GPM)**
  - **After: 11,000 $m^3$/hr (48,200 GPM)**
- **Two pumps in service / one stand-by required.**
- **Flow currently handled is 110% of pump rated.**
- **The upgrade of the Cooling Tower Feed System must include a pump rerate to cover requirements after the revamp.**

# *SUMMARY OF UPGRADE OBJECTIVES*

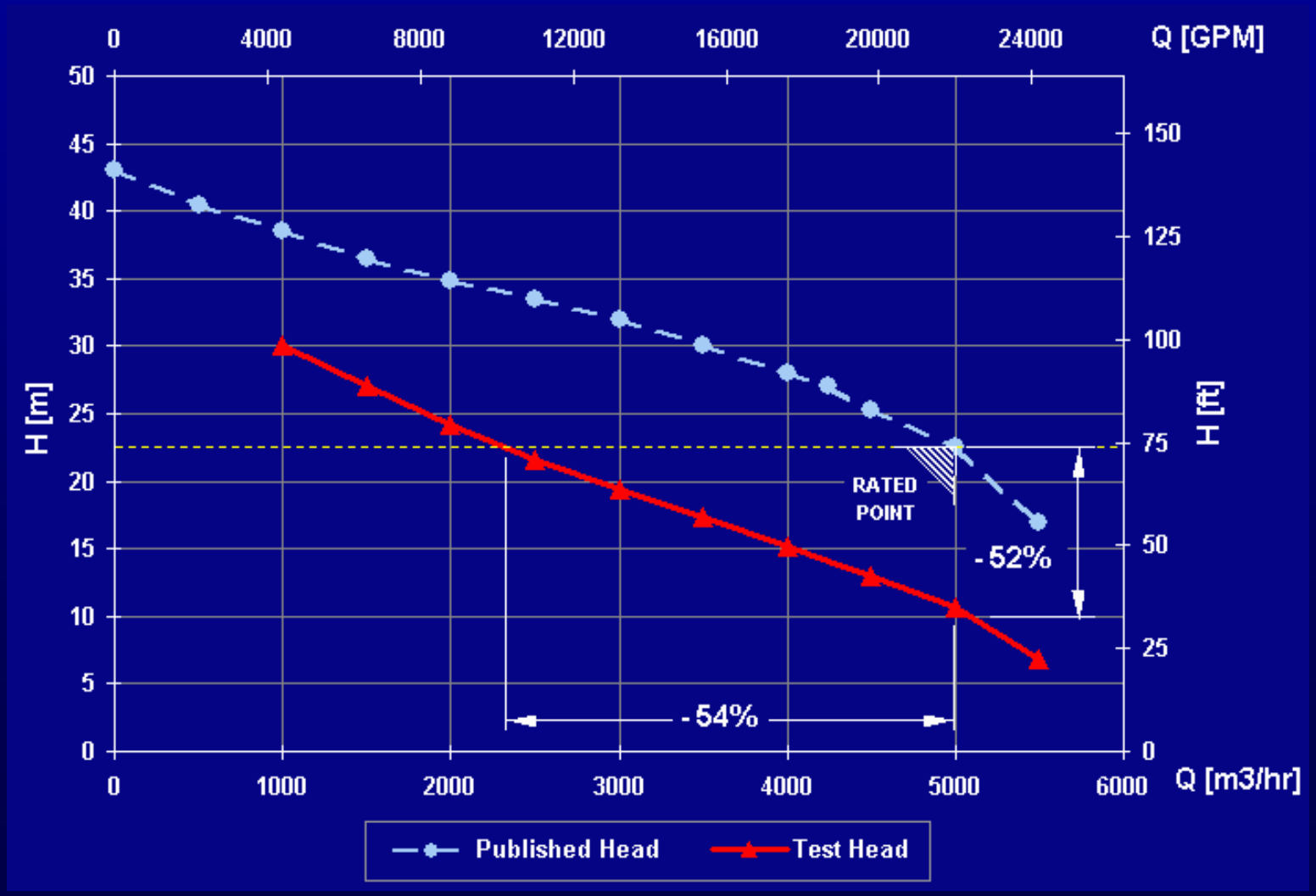
- **Restore design operating conditions (two pumps in service / one stand-by) to achieve:**
  - **Operational flexibility.**
  - **Equipment availability.**
  - **Maintenance cost reduction.**
  - **Operating cost reduction.**
- **Uprate the capacity to 110% of original.**
- **Improve reliability to expect service life extension up to three years in continuous operation.**
- **Cost-effective solution to comply with budgetary constraints:  4-month delivery required.**

# *EVALUATION OF EXISTING PUMP*

- **Qualified supplier with testing capability contracted.**
- **Actual performance of pumps to be assessed.**
- **Test results help determine upgrade workscope.**

# TEST RESULTS OF EXISTING PUMP

## PUBLISHED VS TEST PERFORMANCE
## ORIGINAL BOWL ASSEMBLY @ 890 RPM



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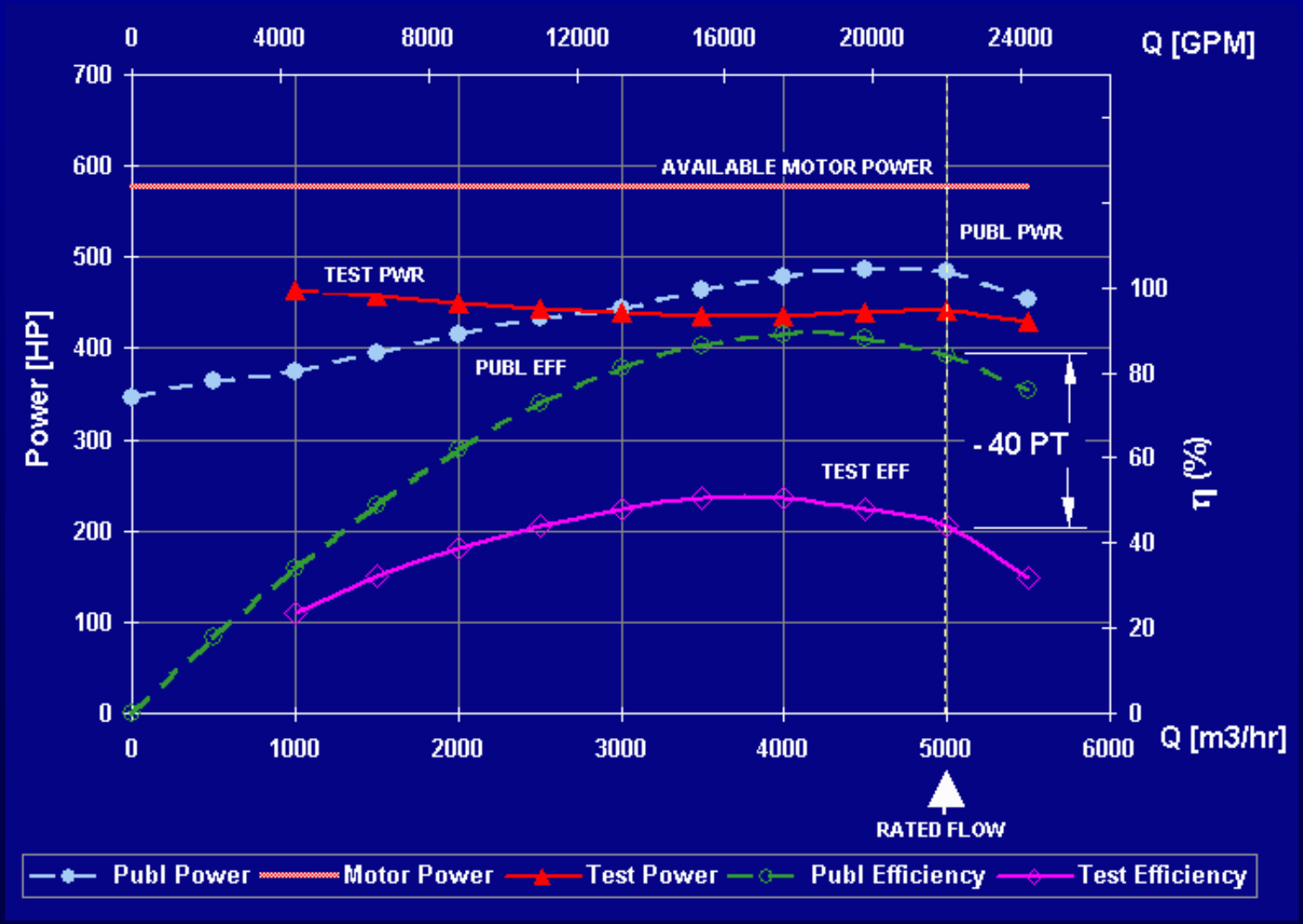
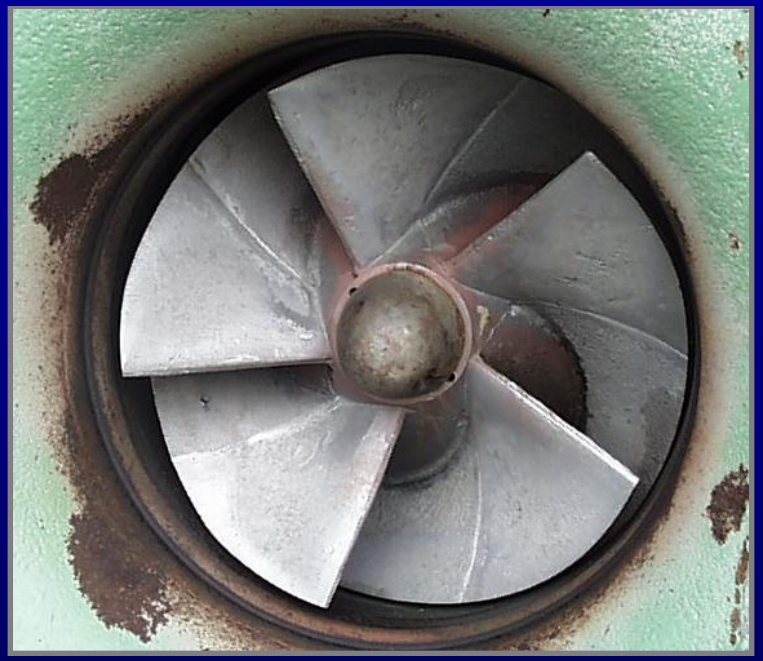


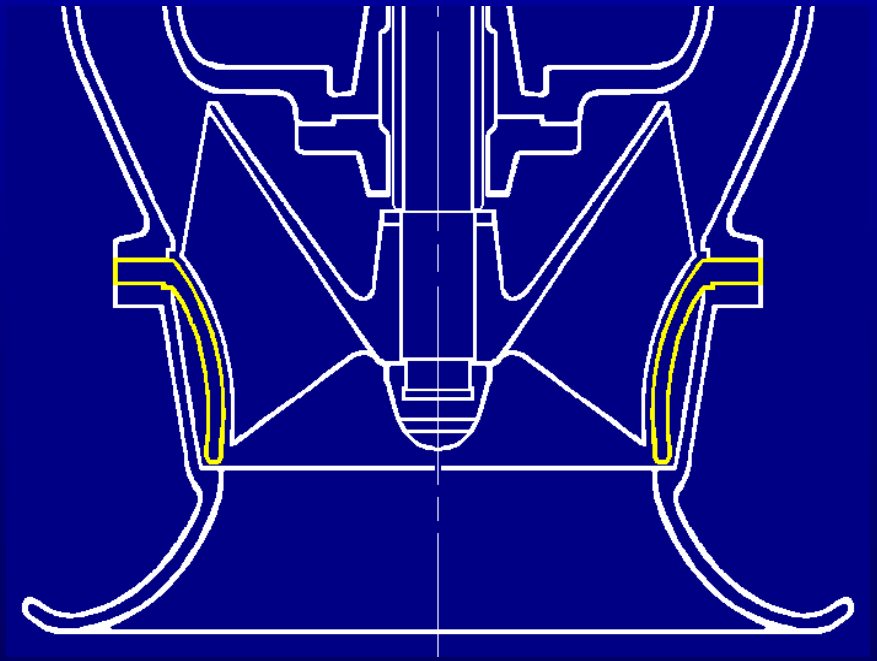
# *TEST CONCLUSIONS*

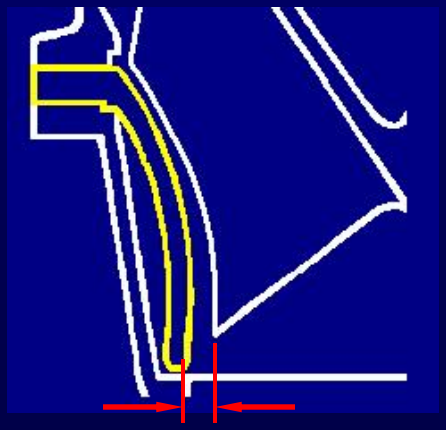
- **Considerable performance impairment found.**
- **Excessive radial clearance between impeller and suction liner is a primary cause for efficiency loss.**
- **Manufacturing deficiencies cause mismatching between impeller and liner profile.**
- **Proper adjustment of uniform clearance is difficult and time consuming.**
- **It is unlikely to reach new operating requirements even if the bowl assembly is fully restored.**

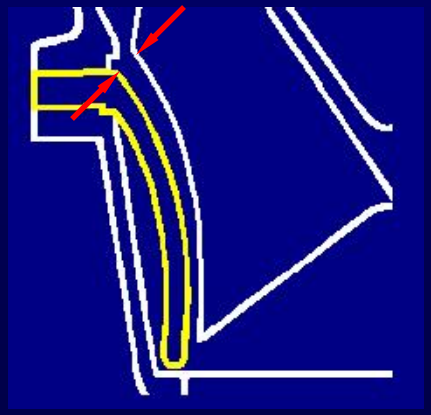
# EXISTING BOWL DEFICIENCIES

## LARGE RADIAL CLEARANCE / IMPELLER-LINER PROFILE MISMATCH







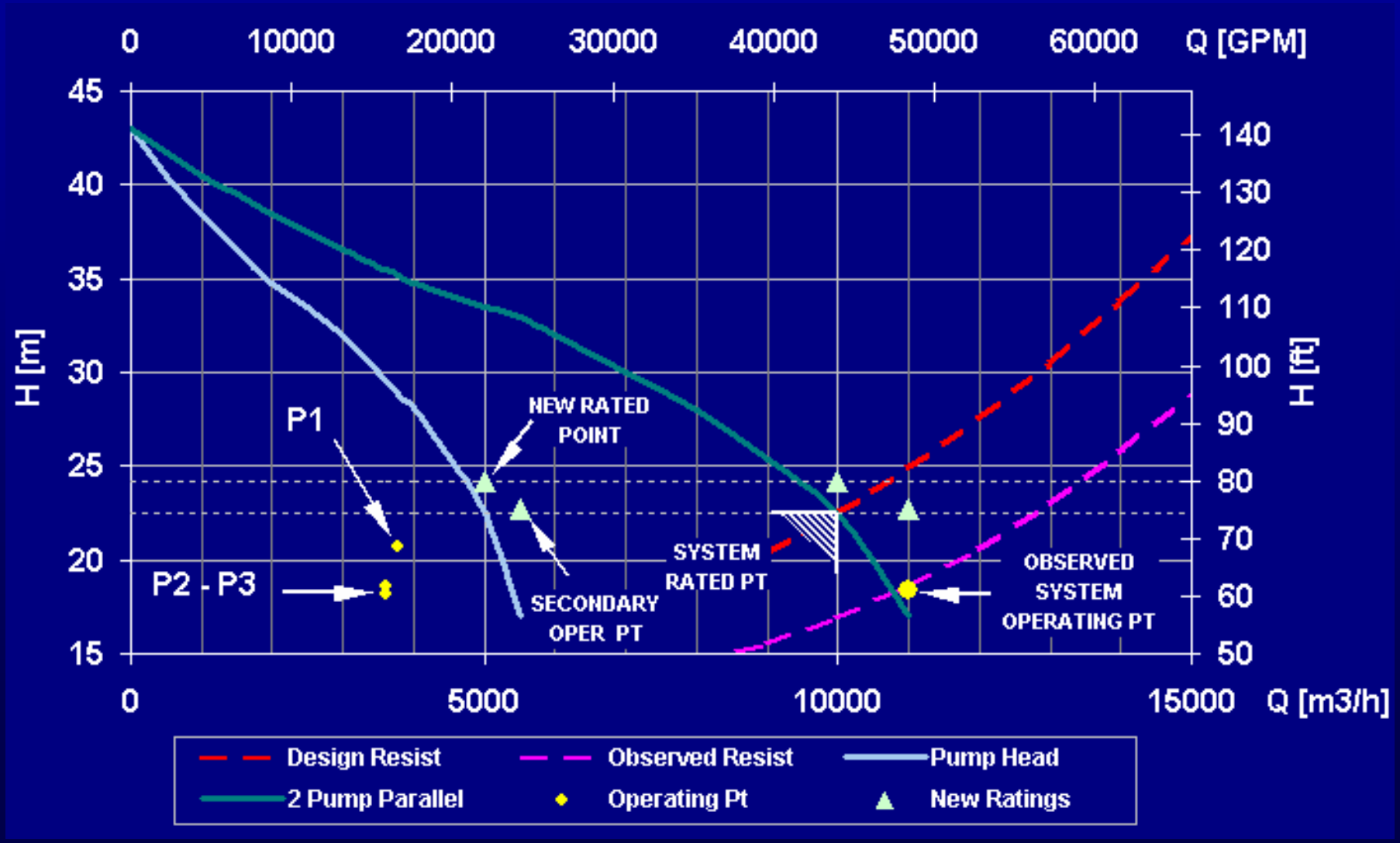


# PUMP UPGRADE CHOICES

| | PROS - CONS | COST & LEAD TIME |
|---|---|---|
| *PUMP REPLACEMENT* | • Field work required<br>• Larger cost & lead time | • 4 PUMPS $400 K<br>• 3 MOTORS $230 K<br>• 2 YR SPARE PARTS $70 K<br>• FOUND & PIPING $200 K<br>**TOTAL: $ 900 K**<br>**7 MONTH DELIVERY** |
| *PUMP REBOWL* | • No field work required<br>• Less cost & lead time | • 4 BOWL ASSY'S $ 220 K<br>• 2 YR SPARE PARTS $ 60 K<br>• INSTALL & TEST $ 140 K<br>**TOTAL: $ 420 K**<br>**4 MONTH DELIVERY** |

# RERATE ESTIMATE

## PUMP OPERATING CONDITIONS



# RERATE ESTIMATE

- Available motor power : 580 HP
- Max BHP limited to 95% of available : 550 HP
- Maximum head attainable:

$$Ns = \frac{n\sqrt{Q}}{H^{3/4}}$$

$$H = \frac{P\eta}{Q\rho g}$$

$Q = 5{,}000\ m^3/hr\ ;\ H = 22{,}5\ m\ ;\ n = 890\ rpm$

$Ns \approx 5{,}000$ (US) – 100 (SI)

$\eta_{bowl} \approx 87\ \%$ (typical)

$\eta_{pump} \approx 82\ \%$ (- 5 pt losses)

$H_{max} = 24{,}7\ m$ (81 ft)

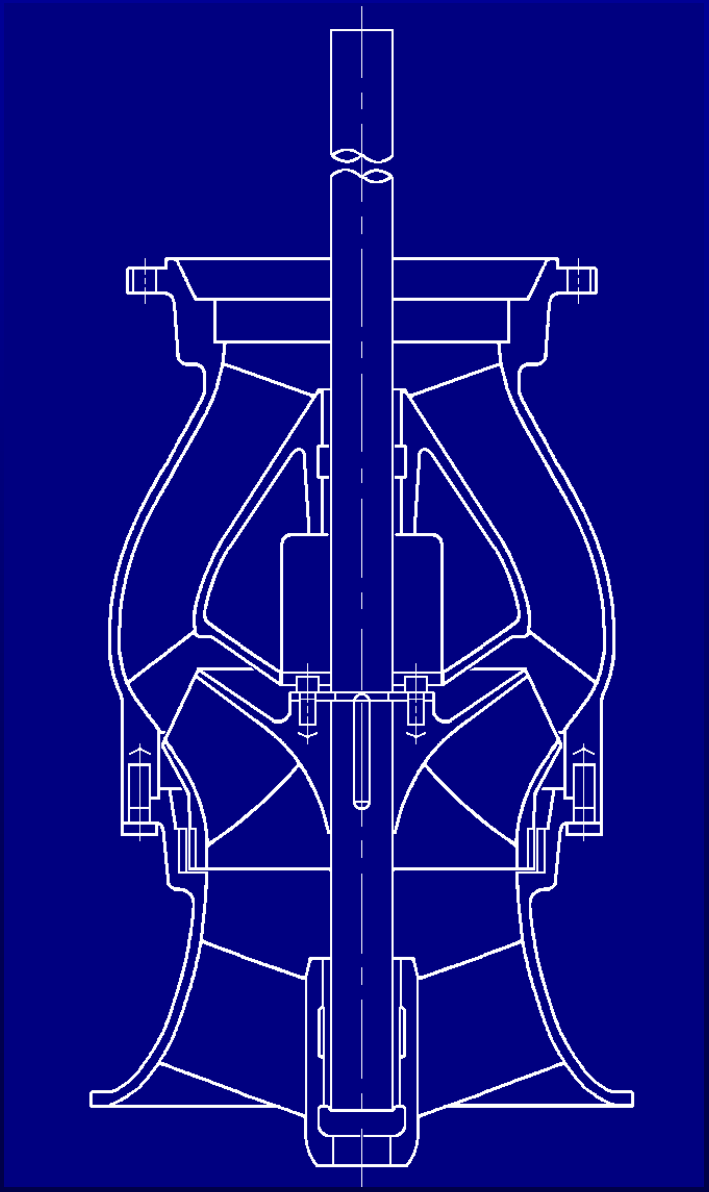
***New Rated Point:***

*24 m @ 5,000 m³/hr (80 ft @ 22,000 GPM)*

***Secondary Operating Point:***

*22,5 m @ 5,500 m³/hr (75 ft @ 24,200 GPM)*

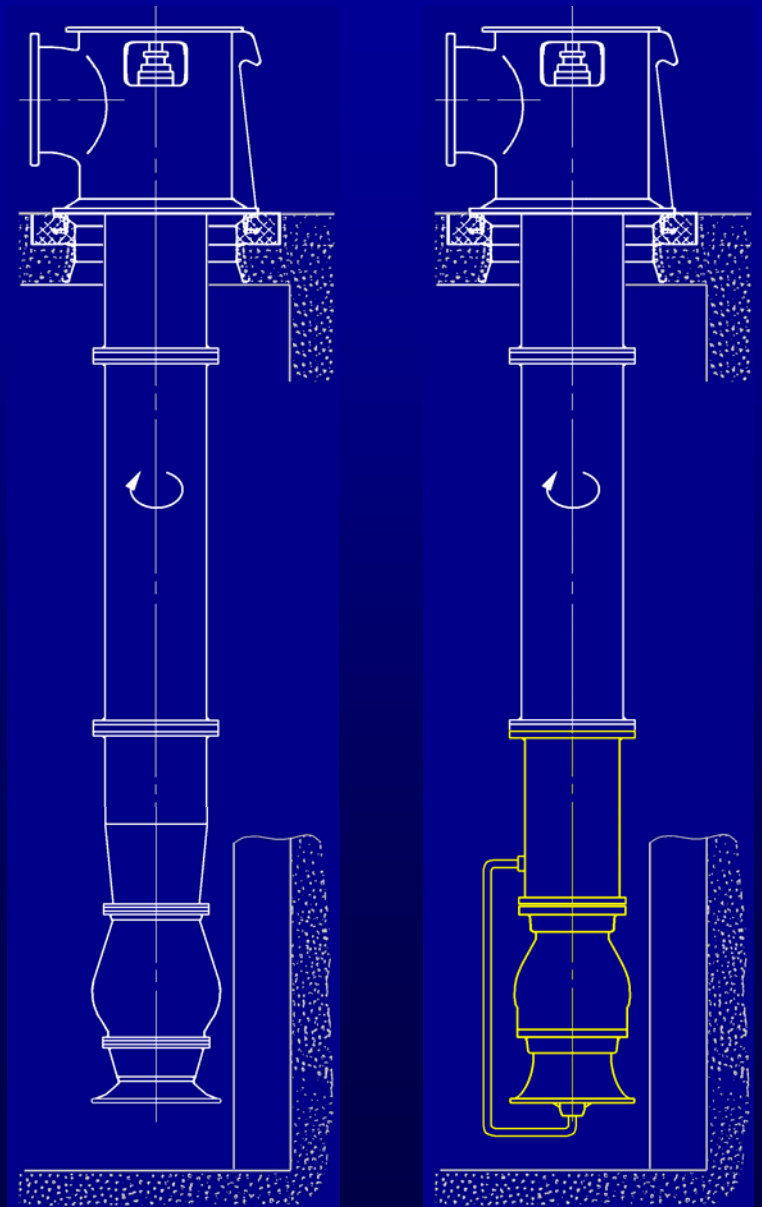
# NEW BOWL ASSEMBLY



## FEATURES:

- **PERFORMANCE:**
  - **Q : 5,000 $m^3$/hr (22,000 GPM)**
  - **H : 24,4 m (80 ft)**
  - **$\eta$ : 87% Bowl / 80% Pump**
  - **P : 555 HP (580 HP Motor)**
- **Enclosed impeller.**
- **Dual wear rings.**
- **Impeller in SS ASTM A743 Gr. CF105MnN (Nitronic 60).**
- **Hard faced shaft at bearings (Chrome Oxide on 416 SS).**
- **Special reverse rotation (CW)**

# NEW BOWL ASSEMBLY INSTALLATION



## WORKSCOPE:

- Keep existing pump length.
  - New Lower Column Pipe.
  - Adjust shaft length & machine coupling end for new bowl
- Install lube line for suction bell bearing.
- Hard face all shaft sleeves.
- Test pump for performance guarantee.
- Ensure 550 BHP as a maximum.
- Complete refurbishment.

# NEW BOWL ASSEMBLY INSTALLATION

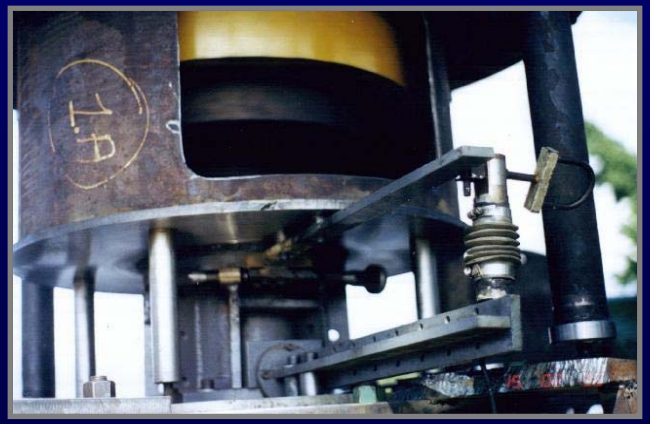
OLD BOWL ASSEMBLY

NEW BOWL

WORN SHAFT SLEEVE

NEW HARD FACED SHAFT

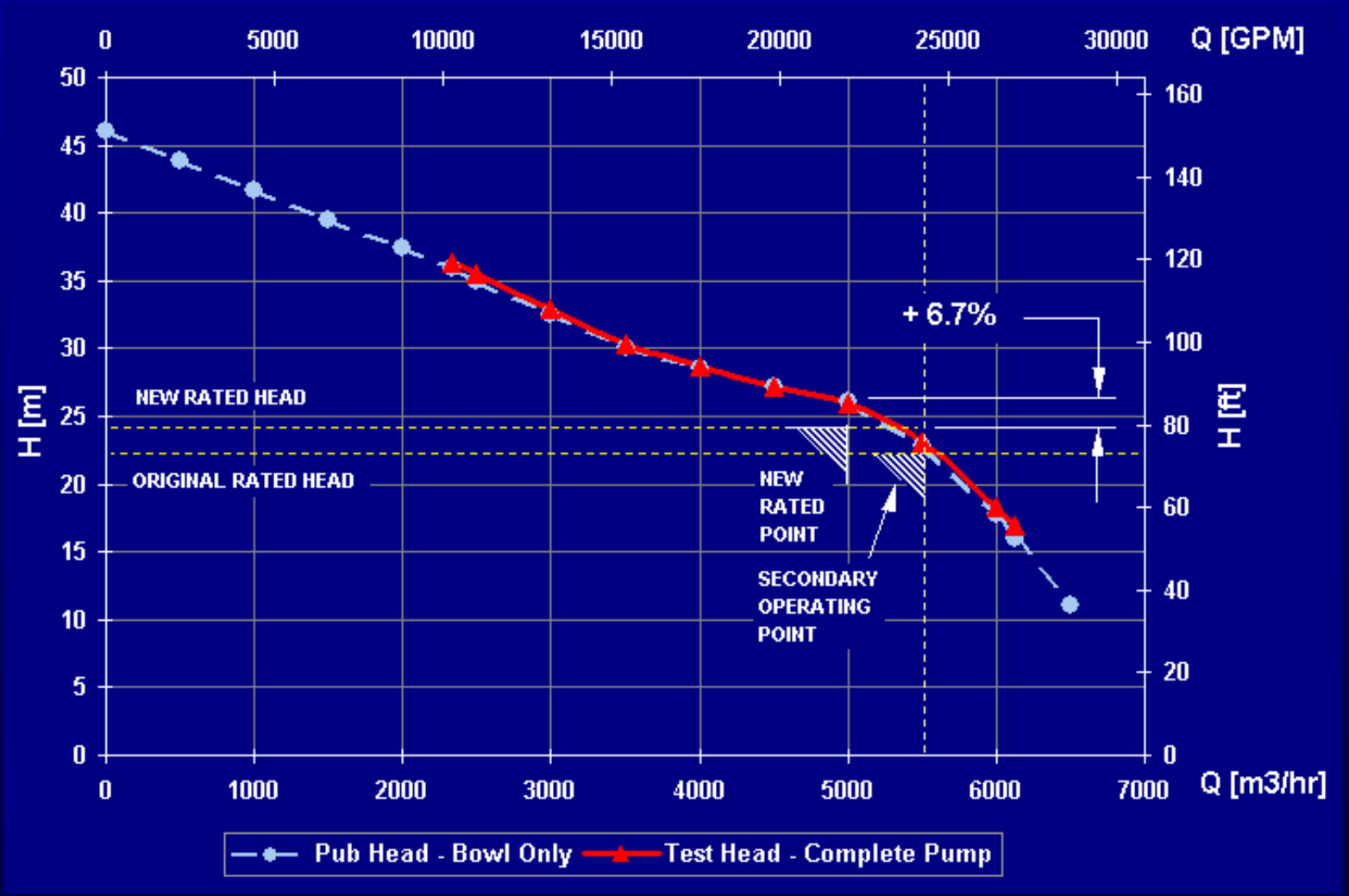
# REBOWLED PUMP TESTING




PERFORMANCE TEST WITH TORQUEMETER

# REBOWLED PUMP TESTING

## PUBLISHED VS TEST PERFORMANCE
## IMPELLER Ø 21.25” @ 890 RPM



# REBOWLED PUMP TESTING

## PUBLISHED VS TEST PERFORMANCE
## IMPELLER Ø 21.25” @ 890 RPM

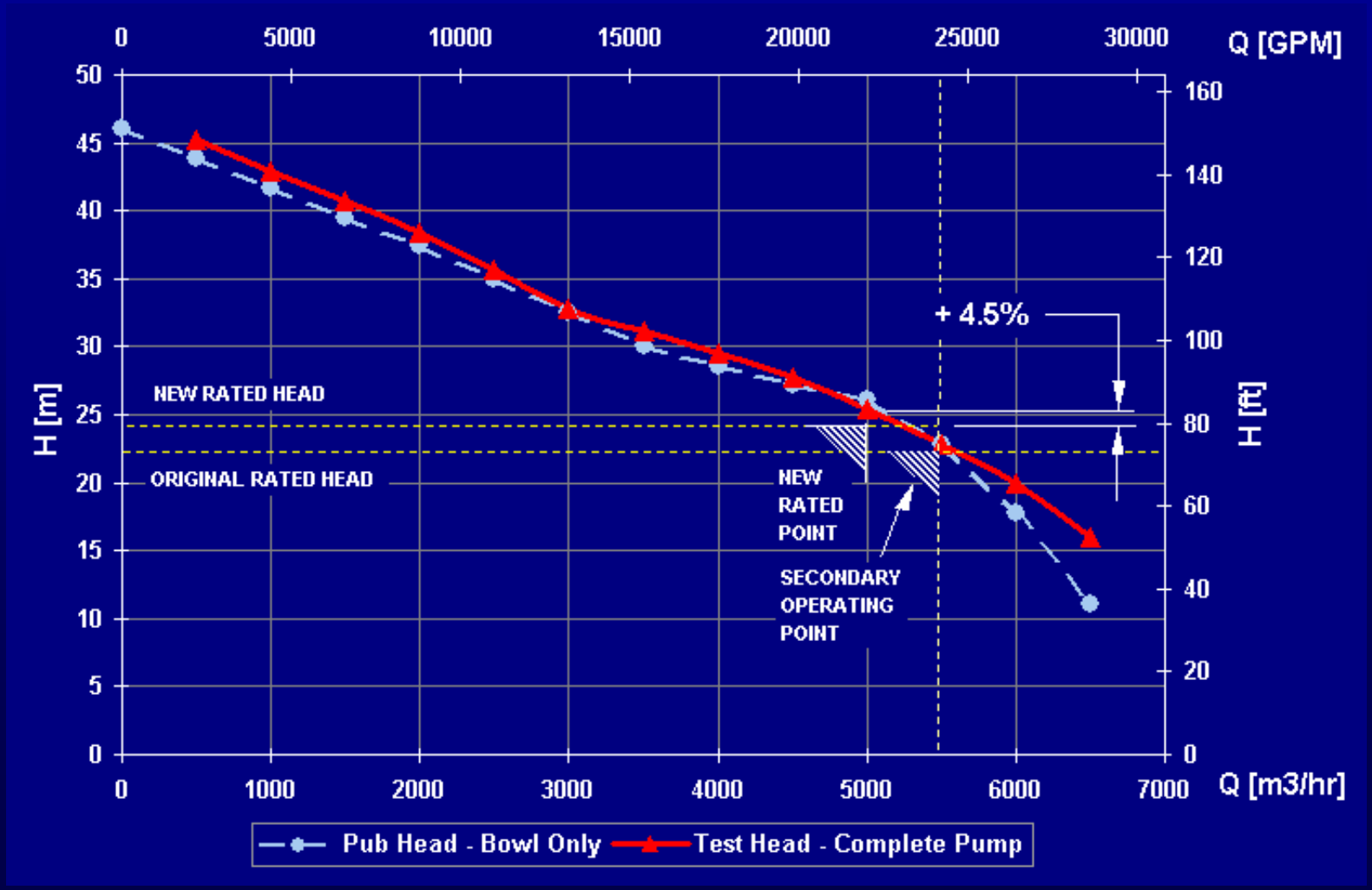
# *REBOWLED PUMP TESTING RESULTS*

- Satisfactory head-flow performance.
- Complete pump BHP larger than expected:
  - Bowl published: + 16%
  - Motor rating: + 10%
- Impeller rework required to adjust performance.

SURFACE FINISH IMPROVEMENT – UNDERFILE DETAILS

# REWORKED IMPELLER TESTING RESULTS

## PUBLISHED VS TEST PERFORMANCE
## IMPELLER Ø 20.75” @ 890 RPM



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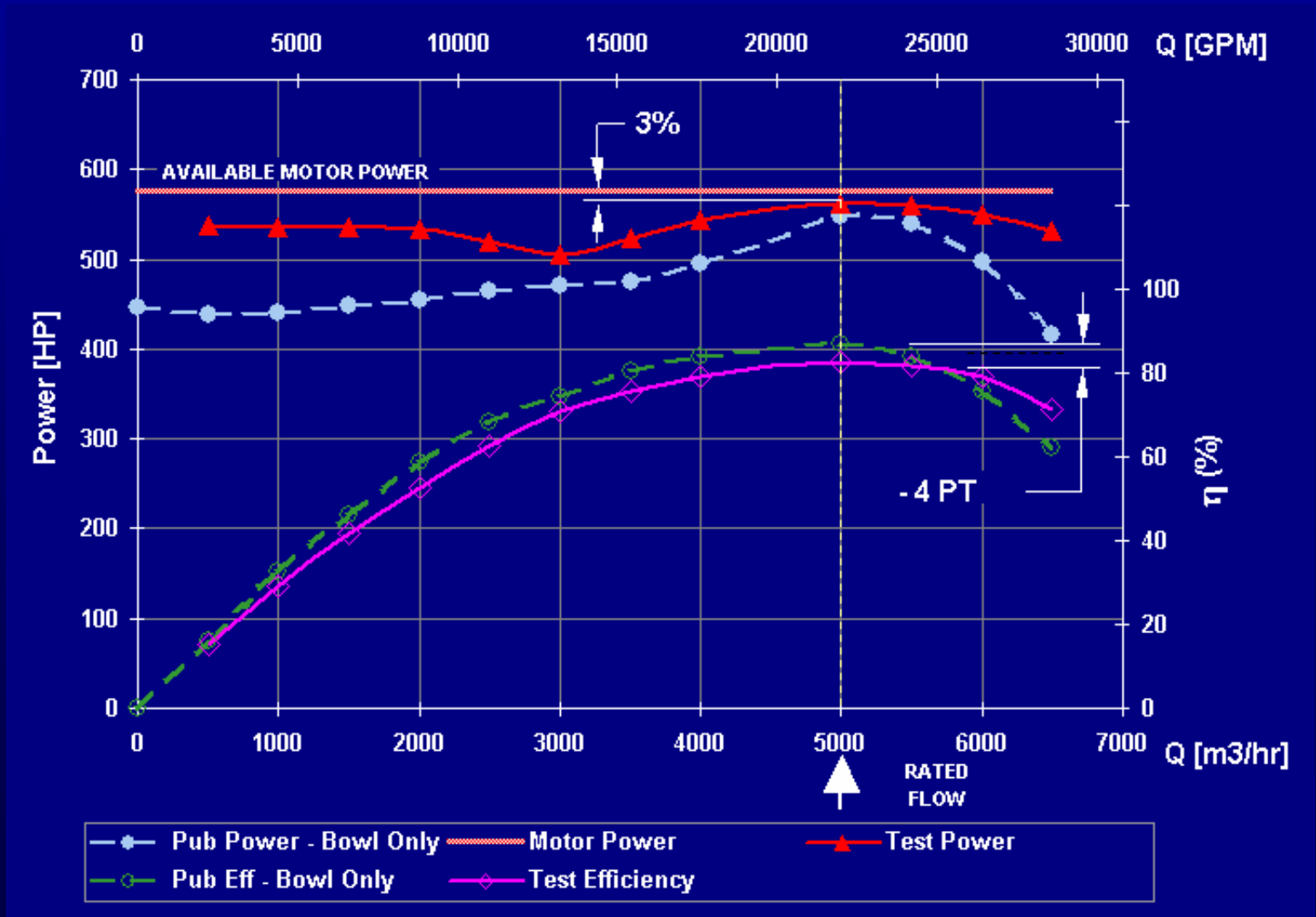

# *FINAL TEST RESULTS*

- **Specified operating points successfully reached.**

  **Rated: 80 ft + 5% @ 22,000 GPM**

  **Secondary: 75 ft + 1% @ 24,200 GPM**

  **BEP: Coincident with rated point**

- **Shaft horsepower adjusted to limitations.**

  **BHP: 95 – 97% of motor rated**

- **Efficiency improved by impeller rework.**

  **Final: 83% @ BEP**

  **Before rework: 75% @ BEP**

# *OVERALL RESULTS*

- **Upgrade objectives were achieved.**
- **Optimized operation:**
  - **Successful capacity uprate to 110%.**
  - **2 pump running / 1 stand-by.**
  - **Energy savings of 3 MW-hr/year.**
  - **Increased operational flexibility.**
- **Increased reliability:**
  - **Performance sustained after two years in service.**
  - **No maintenance performed since the upgrade.**
- **Rebowl upgrade completed at 50% of the cost of pump replacement (savings of $ 480K).**

# *CONCLUSIONS*

- **Pump upgrade objectives were successfully achieved.**
- **Rebowl of existing pumps was the best choice for a cost-effective & time-saving solution.**
- **Extended service life achieved by component improvement.**
- **Stand-testing is an invaluable tool to optimize equipment operation and guarantee trouble-free operation of upgraded equipment.**

# *LESSONS LEARNED*

- **Consider to improve existing equipment for lower investment and time savings.**
- **Testing of modified equipment is mandatory for reliability guarantee.**
- **Close cooperation between manufacturers, service suppliers and users is a key for success.**

***THANK YOU !***