Are we making any progress?

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Flowserve Corporation
Pump Division
Vernon, California

ASME FEDSM
May 31, 2001
“LARGEST PUMP”

• HIGHEST HORSEPOWER
  – American Electric Power John E. Amos plant
  – Boiler Feed Pump - Multistage, Barrel
  – 21,800 GPM
  – 11,300 ft TDH
  – 4160 RPM
  – 63,200 HP
  – 1973
“LARGEST PUMP”

- HIGHEST CAPACITY
  - South Florida - Mill Creek
  - Flood Control
  - 695,000 GPM
  - 180 RPM
  - 24 ft TDH
  - 5000 HP
  - 1985
“LARGEST PUMP”

• LARGEST SIZE
  – Grand Coulee Dam on the Columbia River
  – Single Stage Vertical Volute Pump
  – 605,000 GPM, 330 ft TDH, 200 RPM
  – 55,200 HP
  – Volute “Diameter” ~ 21 ft
  – 1951
POWER PLANT DEVELOPMENT

PLANT OUTPUT (MW)

FOSSIL PLANT OUTPUT (MW)

H. Ohashi: ASME FED SM 1997
POWER PLANT DEVELOPMENT

- Nuclear Plant Output (MW)
- Fossil Plant Output (MW)
- Pump Power (MW)

H. Ohashi: ASME FED SM 1997
CUSTOMER REQUIREMENTS

- RELIABILITY
- EFFICIENCY
- EMISSION FREE
- PRICE
- NOISE EMISSION
- CONTROL RANGE
- SUCTION ABILITY
- RECYCLING ABILITY
- PRESSURE SURGE
- SUPERSYNCHRONOUS RPM

P. Hergt: ASME FED SM 1997
ECONOMICS OF RELIABILITY

• The cost of maintaining a pump significantly exceeds the first cost.
COST OF RELIABILITY

- PRICE: 9%
- REPAIR COST (NPV): 27%
- ENERGY (NPV): 64%

ANSI PUMP
ECONOMICS OF RELIABILITY

• The cost of maintaining a pump significantly exceeds the first cost.

• The imperative on the manufacturer is to increase MTBR.
CHARGE PUMP FAILURE DATA

- AUX. SYSTEMS: 31%
- SEAL: 43%
- SHAFT: 13%
- BEARINGS: 13%

Source: NERI Smart NPP report Task 1
June 2000
RELIABILITY IMPROVEMENT
INITIATIVES

• ROBUST MECHANICAL DESIGN
  – Minimizing Vibrations
    • Reduction of Forces
    • Elimination of resonances
  – Improving cavitation resistance
RELIABILITY IMPROVEMENT

API VIBRATION LIMITS

VIBRATION VELOCITY (MM/SEC)

OVERALL
FILTERED

YEAR

RELIABILITY IMPROVEMENT

DSHF
RELIABILITY IMPROVEMENT

- Increase foot thickness
- Decrease bearing span
- Robust bearing adaptors
EXISTING DSHF BEARING ADAPTER DESIGN

NEW DSHF BEARING ADAPTER DESIGN
INCREASE OF GAP “B”
IMPELLER VANE
STAGGER
DSHF Pump Vibration Data

MAXIMUM BEARING HOUSING VIBRATION VERSUS FLOW RATE

- Curve Fit
- New 360 degree Bracket
- Staggered Impeller
- Thicker Pump Feet
- Flex in/out

RMS in/sec

Q/Qbep (ratio)

New API LIMIT

1.30 x
RELIABILITY IMPROVEMENT


12 month rolling MTBR

NPSH REQUIRED

FLOW (m^3/sec) vs NPSH (m)

- INCEPTION
- 3 % HEAD DROP
- DAMAGE FREE
REDUCTION OF CAVITATION DAMAGE
REDUCTION OF CAVITATION DAMAGE

![Graph showing reduction of cavitation damage for different materials: Cast Iron, CA 15, Cast Carbon Steel, CA6NM, 17-4 PH (H1150), X Cavalloy. The Y-axis represents MPDR, and the X-axis lists the materials.]
REDUCTION OF CAVITATION DAMAGE
REDUCTION OF CAVITATION DAMAGE

• We still need a way to assess damage potential at factory testing stage.
ECONOMICS OF EFFICIENCY

API PUMP

ENERGY (NPV) 83%
PRICE 9%
REPAIR COST (NPV) 8%

ANSI PUMP

ENERGY (NPV) 64%
PRICE 9%
REPAIR COST (NPV) 27%
ENERGY COST CALCULATION MODEL

\[ C_e = \sum_{j=1}^{Z} \left\{ n \cdot \frac{E_0}{[1+r]^n} \cdot \int_{t_0}^{t_1} \frac{Q(t) \cdot H(t)}{?p \cdot ?m} \, dt \right\} \]

1. Power in one annual cycle
2. Cost of energy
3. No. of years
4. Net present value

ECONOMICS OF EFFICIENCY

• A project funded by the European Commission (SAVE) has concluded:
  – Pump efficiencies can be improved with present technology by 3 points.
  – If all EU pumps are upgraded, a total of 1.1 TWhr of energy can be saved. At 5 c/kWhr, this amounts to about 50 million $ saving per year.
  – Basic infrastructure issues are the impediment to this upgrade.
THEORETICAL EFFICIENCY

European Association of Pump Manufacturers No. 2 (1999): Attainable Efficiencies of Volute Casing Pumps

FLOW = 800 GPM
BASELINING WITH CFD

H. Goto: ASME FED SM 1997
CRYOGENIC EXPANDER
## EFFICIENCY IMPROVEMENT

### CALCULATED EFFICIENCES (%)

<table>
<thead>
<tr>
<th></th>
<th>SINGLE STAGE</th>
<th>MULTI-STAGE</th>
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<tr>
<td></td>
<td>Hydraulic</td>
<td>Net</td>
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<td>8 RH - Final</td>
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HIGH PERFORMANCE
EXPANDER

Flow (l/sec)

Efficiency
Total Turbine Output
Head

Net Head (meters)
Total Turbine Output (kW)

1800 RPM

Efficiency
Total Turbine Output
Head

Flow (l/sec)
ASSEMBLY OF SCAMP

Motor stator embedded and sealed into rear casing cover

Pump Casing

Rotor Assembly with Shaft
CONCLUSIONS

• Pump Technology is driven by customer requirements
  – Reliability: Significant improvements in MTBR
  – Efficiency: CFD techniques are producing good results
  – Emission: Novel mechanical designs are being introduced