2009 Pump Symposium Case Study

Replacing 7 Vane Impellers with 8 Vane Impellers Leads to Electric Motor Overload in 9 Stage Pipeline Pump

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Case Study Abstract

Replacing 7 Vane Impellers with 8 Vane Impellers Leads to Electric Motor Overload in 9 Stage Pipeline Pump

This case study deals with a west Texas pipeline transfer pump with the following design specifications:

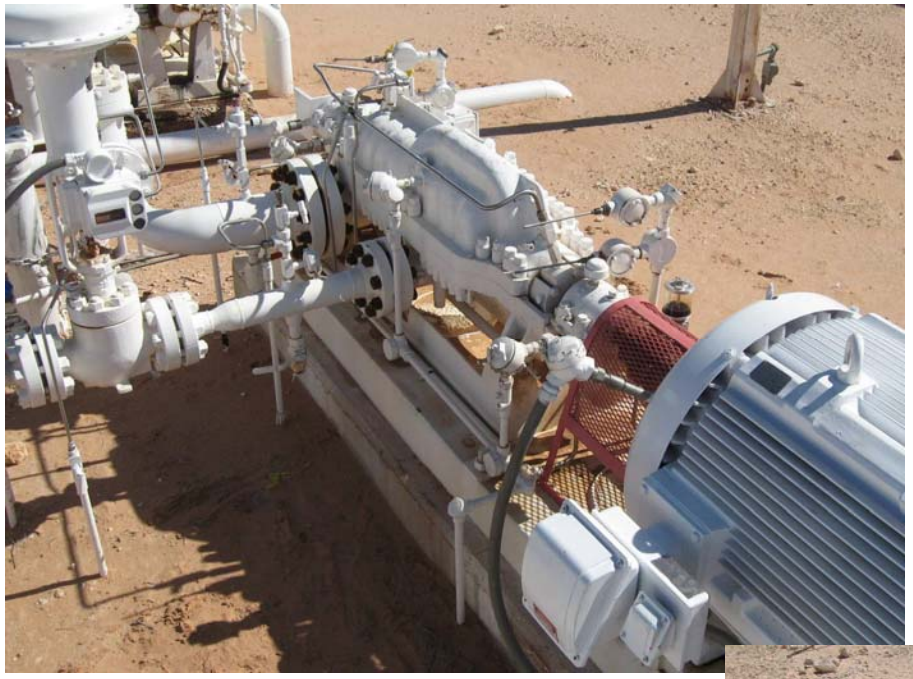
- Byron Jackson 3x6x9E DVMX
- BEP at 650 gpm, 3560 rpm, Ns=1220
- Originally 9 stages, 2 impellers were removed, utilizing remaining 7 stages
- Directly coupled to a 450 HP electric motor driver

After de-bottlenecking the pipeline to obtain more flow, the motor driver for this pump began overloading at the new, higher flowrates. Horsepower calculations suggested that the electric motor driver should have been adequate for the new hydraulic conditions. However, we began to suspect there was an internal pump design problem once it was found that the field performance data did not match the original test data. We discovered that the pump was producing 20% more head than expected at end-of-curve conditions (900 gpm). Upon disassembly, we found that 8 of the 9 impellers had 8 vanes instead of the expected 7 vanes. (The pump OEM provides both 7 and 8 vane impeller designs.) The OEM's 4x6x9D 8 vane design produces more head past the best efficiency point than the corresponding 7 vane design and does not continuously rise to shutoff. To counteract the additional head producing capability of the 8 vane impellers, we decided to remove 2 stages. After de-staging, the motor overload condition was resolved.

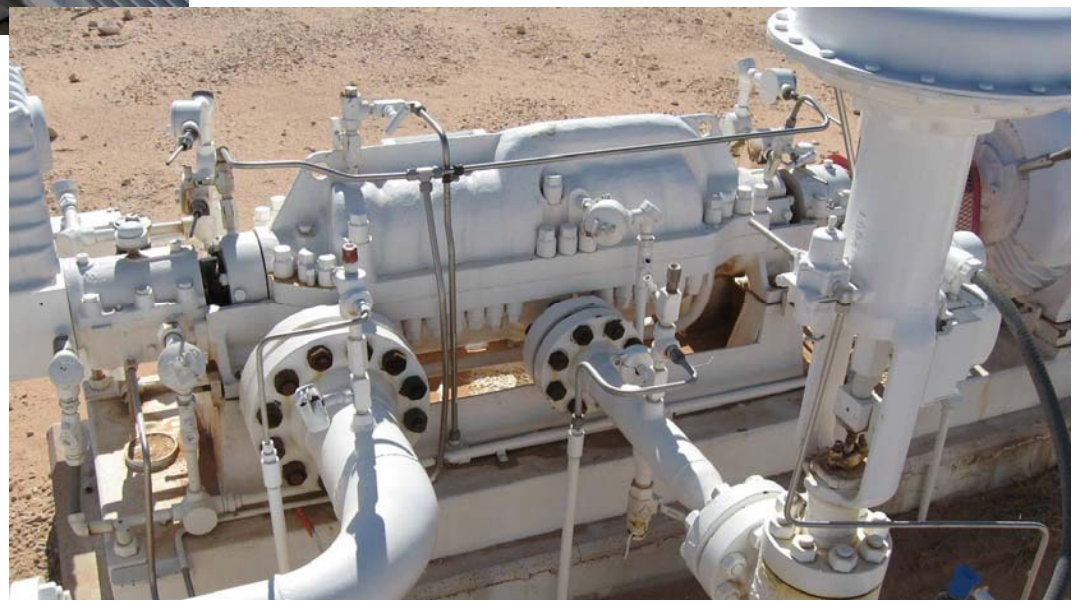
It is assumed that someone replaced the original 7 vane impellers with 8 vane impellers to obtain more head and hence more flow with the same pump. This case study clearly illustrates the danger of changing impeller designs without a thorough hydraulic analysis.

Background

- The west Texas pipeline pump is a Byron Jackson 3x6x9E DVMX driven by a 450 electric motor operating a 3560 rpm. It has a BEP of 650 gpm and a specific speed of (Ns) 1220
- The pump, which was installed in 1995, transfers liquid hydrocarbons approximately 14 miles down a 6” pipeline.
- In 2008, to increase system flow capability, approximately 9 miles of original 4” pipe were upgraded to match the remainder of the 6” pipeline.

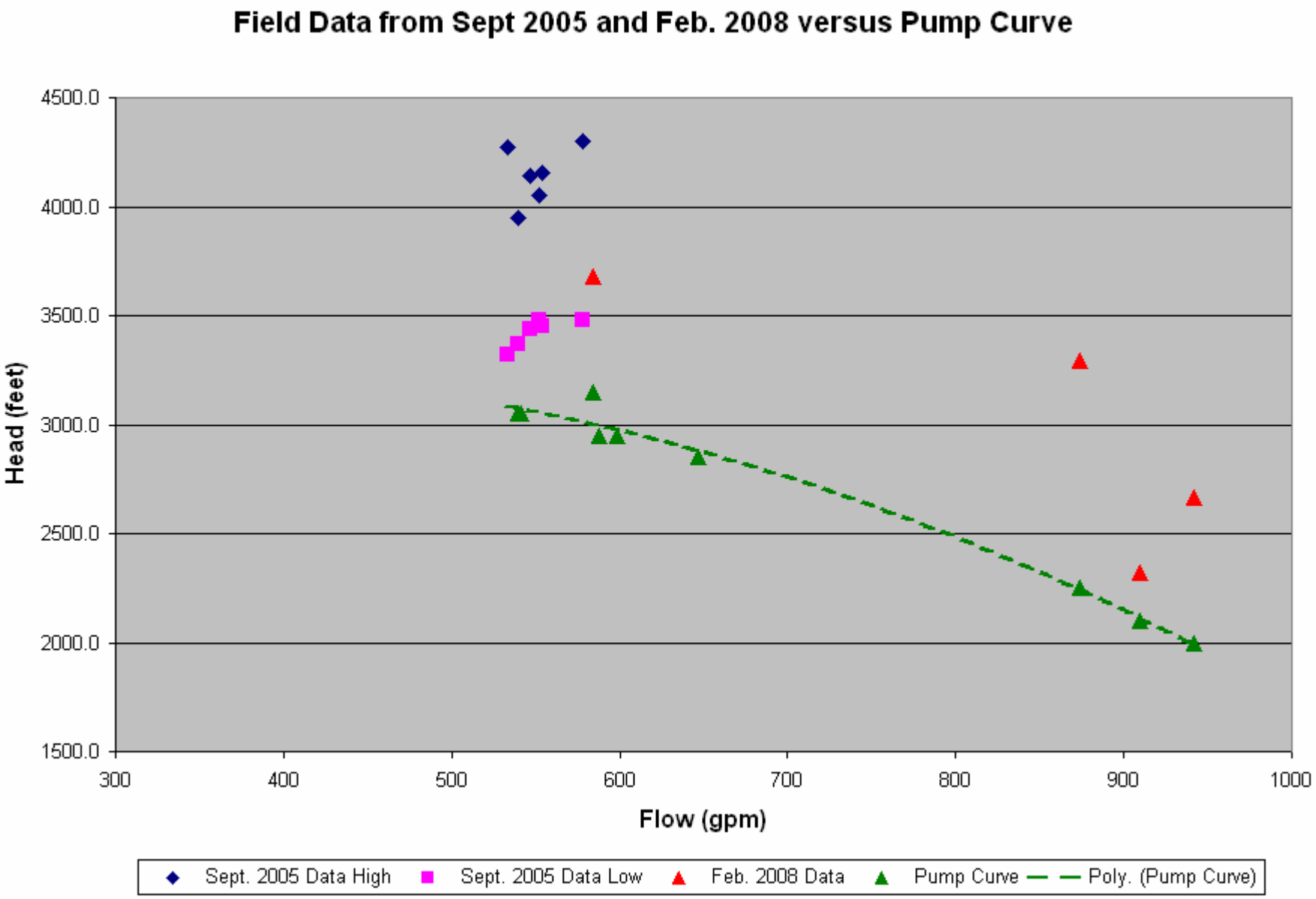


Photos of the west Texas pipeline pump installation

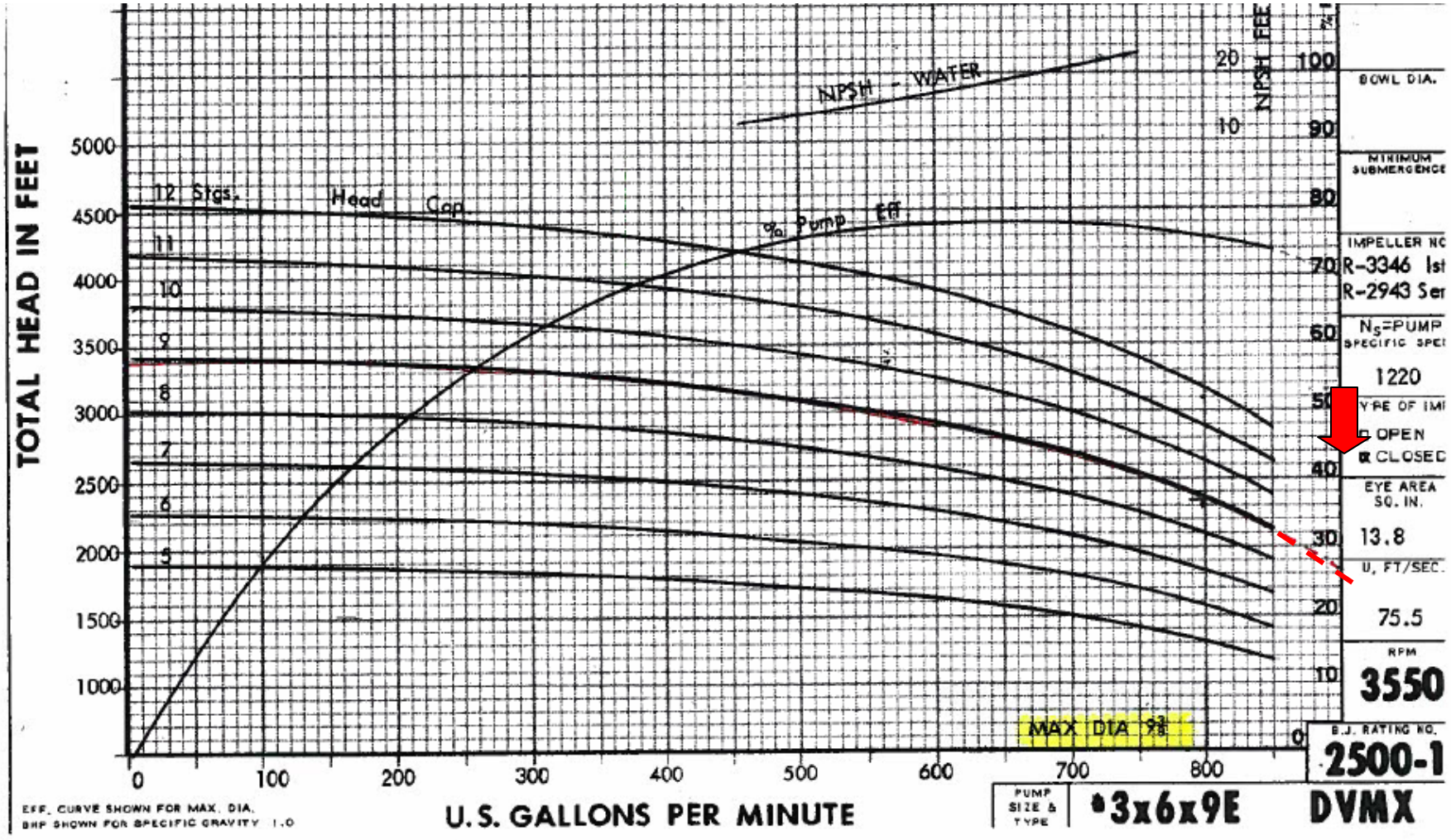


Problem

- West Texas pipeline pump driver is rated for 450 hp. Calculations show there should be enough horsepower for all flows on pump curve.
- However, the motor began tripping on high amps after the pipeline size was increased.
- A field performance test 2/11/08 showed that the pump was generating significantly more pressure head and drawing more horsepower than expected.


Field Data from Sept 2005 and Feb. 2008 versus Pump Curve
Head (feet)
4500.0
4000.0
3500.0
3000.0
2500.0
2000.0
1500.0
300
400
500
600
700
800
900
1000
Flow (gpm)
Sept. 2005 Data High
Sept. 2005 Data Low
Feb. 2008 Data
Pump Curve
Poly. (Pump Curve)

Comparison with OEM Pump Curve with Field Data Point



Horsepower Analysis

Flow (gpm)	**HP_{curve}**	**HP_{elec}**	HP ratio	Head ratio	**Diff.due to eff., pf, etc.**
910	**464.9**	**627**	**1.35**	**1.2**	**15%**
910	**464.9**	**610**	**1.31**	**1.2**	**11%**
941.5	**471.4**	**625**	**1.33**	**1.2**	**13%**
889	**465.0**	**561**	**1.20**	**1.2**	**0**
873.6	**454.8**	**555**	**1.22**	**1.2**	**2%**

Our Thinking After Field Testing

- The excessive power draw observed is due to either:
  - 20% higher than expected head. This may be due to different impeller geometry (rare 8-vane) than originally purchased
  - Internal pump wear. More than likely, wear at the impeller wear rings.
  - Unknown motor factors such as the actual power factor and efficiency.

Findings After Field Testing

- Upon disassembly of the pump, we discovered that 8 of 9 impellers had 8 vanes instead of the expected 7 vanes. (The pump OEM provides both 7 and 8 vane impeller designs.)
- The existing 2” flow control valve and 2” and 3” piping on the pump discharge represents a large percentage (55%) of the total head losses in the yard.

How the number of vanes affects pump performance

(Source: Centrifugal Pumps, Design and Application by Lobanoff and Ross, page 30)

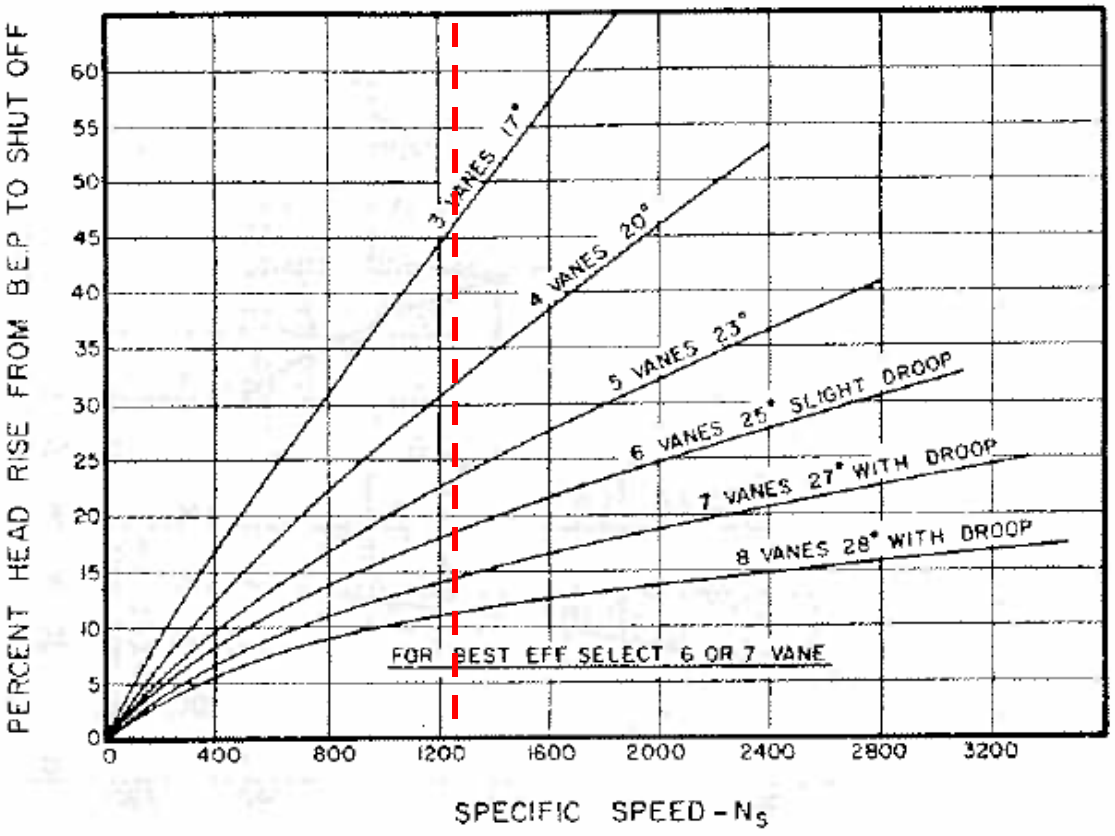
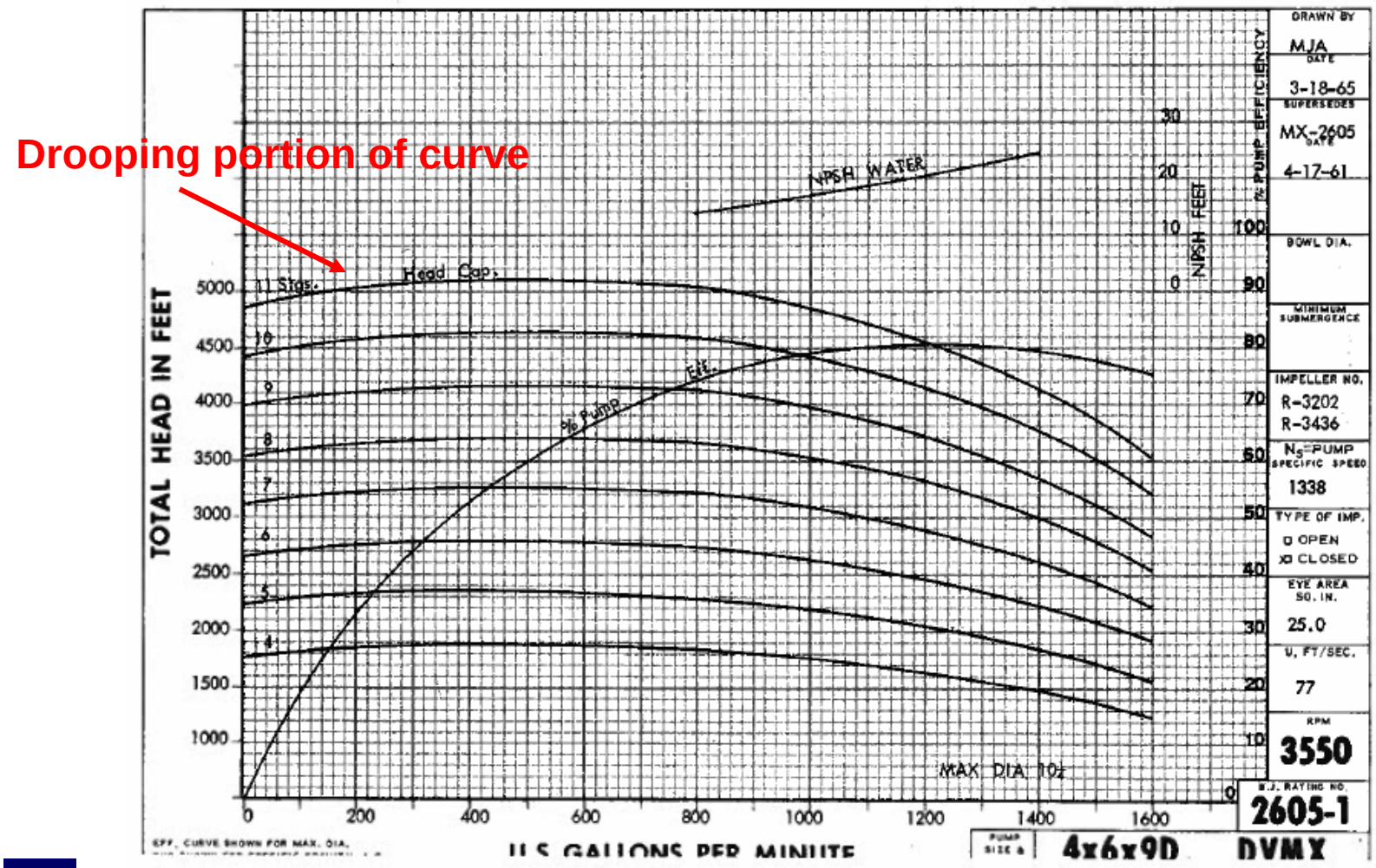


Figure 3-2. Percent head rise.

How the number of vanes affects pump performance

- The fewer the vane number the greater the difference between the BEP head and the shutoff head
- The greater the number of vanes the smaller the difference between the BEP head and the shutoff head.
- As the number of vanes increase beyond 6, curve droop becomes more pronounced.

Example of drooping 8 vane impeller

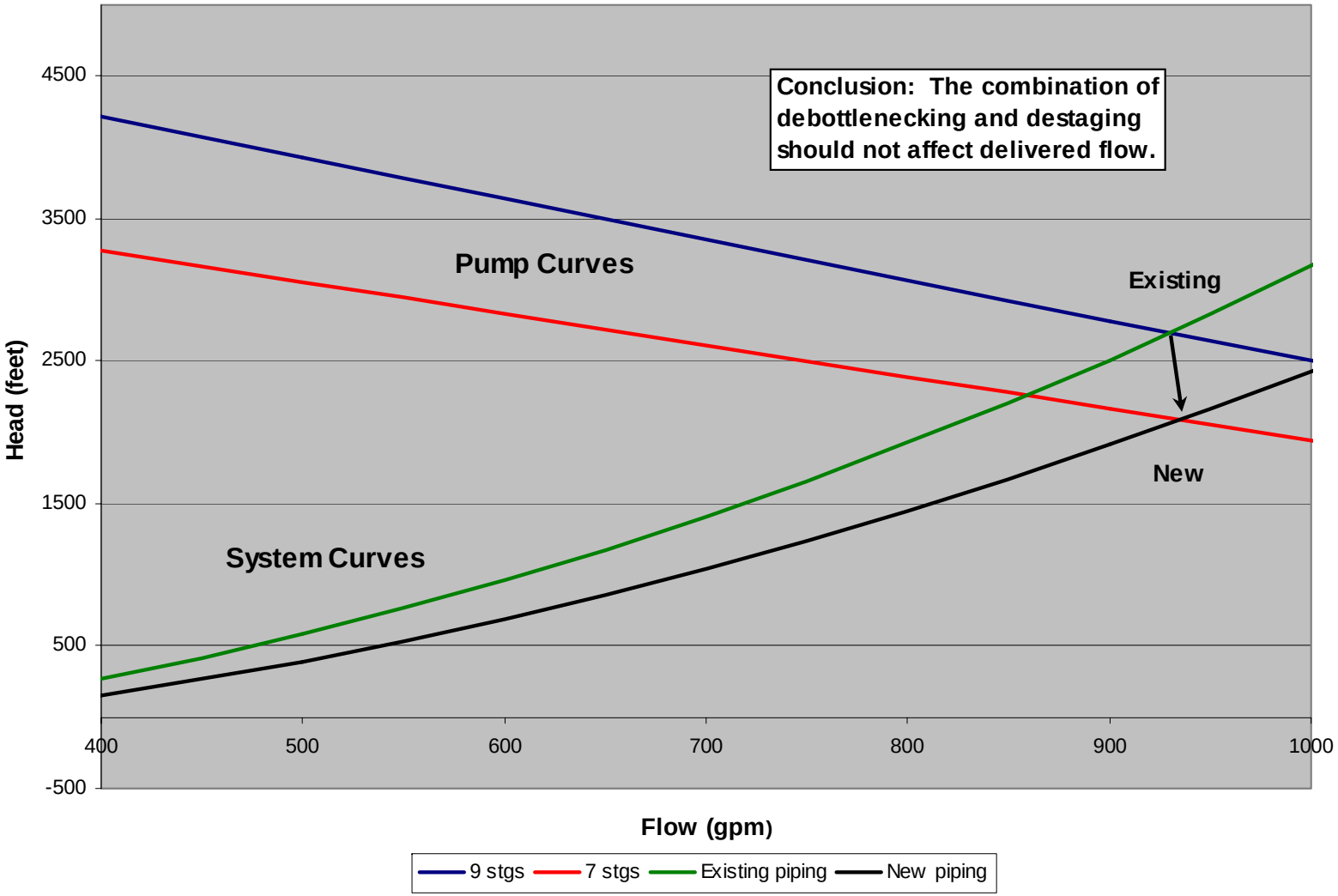


Path Forward

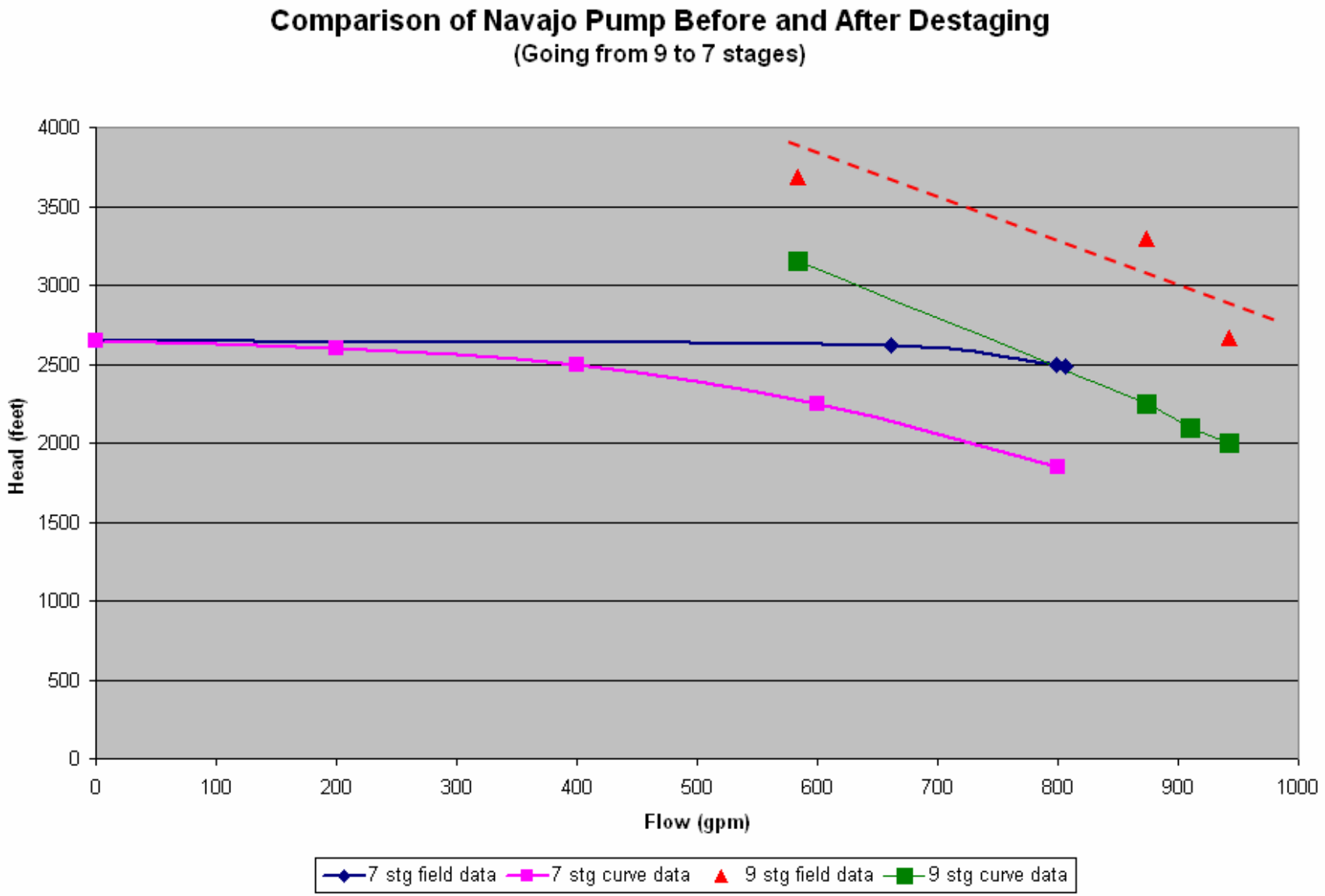
- Debottleneck existing 2” control valve and 2” and 3” piping on the pump’s discharge.
- Remove two pump stages to reduce horsepower requirements at required flows.

Navajo Pump Derate Analysis

Expected system effects from removing 2 stages and debottlenecking yard piping



Results


Comparison of Navajo Pump Before and After Destaging
(Going from 9 to 7 stages)
Head (feet)
4000
3500
3000
2500
2000
1500
1000
500
0
0
100
200
300
400
500
600
700
800
900
1000
Flow (gpm)
7 stg field data
7 stg curve data
9 stg field data
9 stg curve data

Lessons Learned

- It is assumed that someone replaced the original 7 vane impellers with 8 vane impellers to obtain more head and hence more flow with the same pump.
- This case study clearly illustrates the danger of changing impeller designs without a thorough hydraulic analysis.
- These effects are more pronounced beyond BEP.