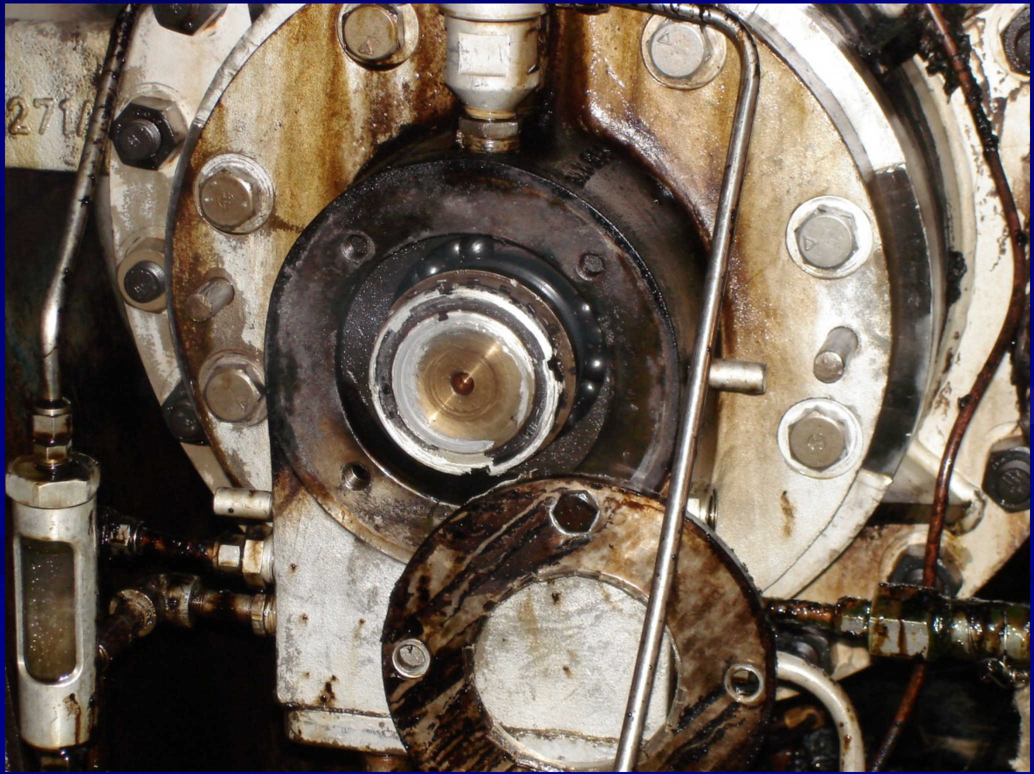
Effects of High Suction Energy in a Vacuum Tower Bottoms Pump Design



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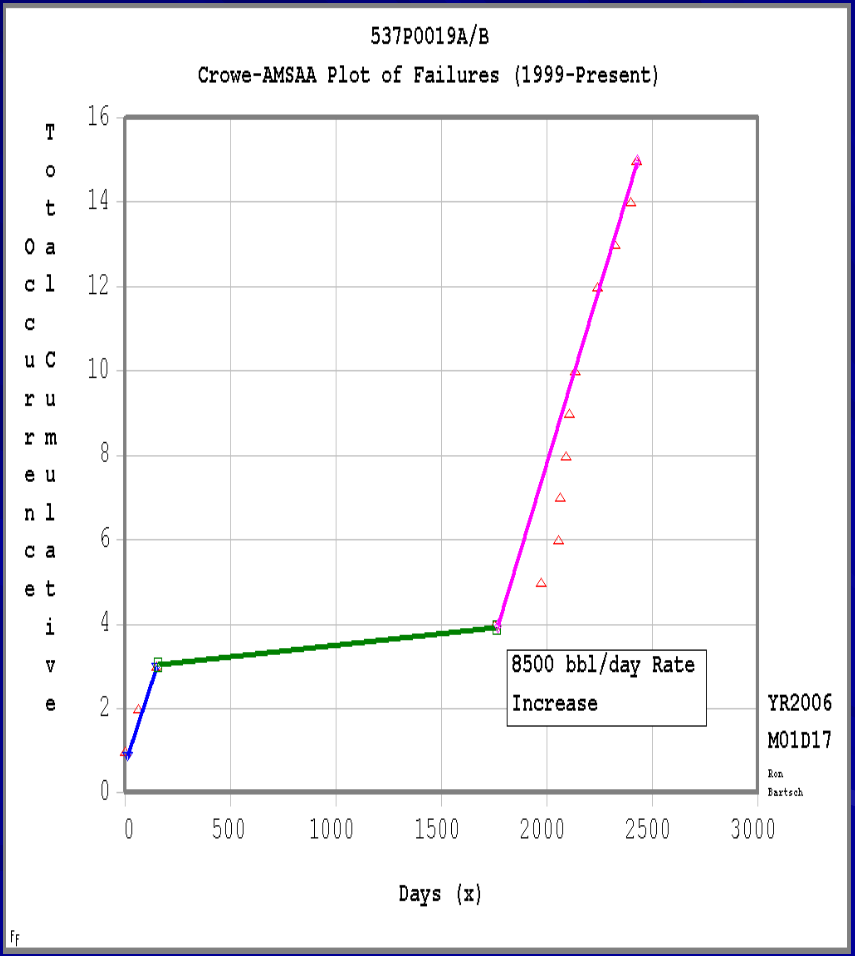
Abstract

- The reliability of a pair of vacuum tower bottoms pumps declined in correlation to a rate increase in 2004.
- While pumps were noisy and vibration levels marginal, reliability had been tolerable prior to this increase.
- $NPSH_a$ to $NPSH_r$ margins should be sufficient to fully suppress cavitation, but are not.
- Pump has experienced axial shuttling, leading to catastrophic bearing failure.

Maintenance History

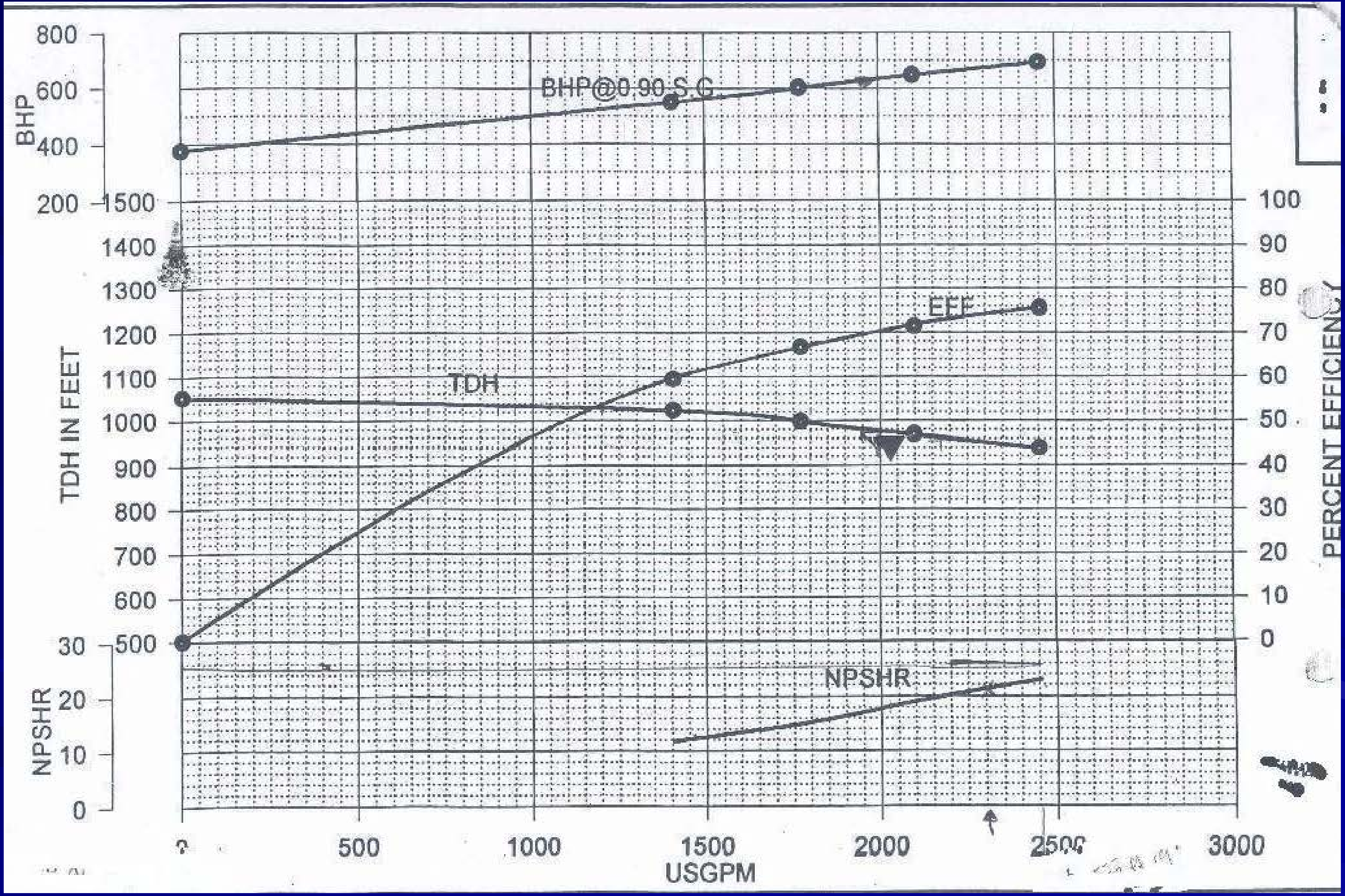
- MTBF about 4 months months in the years 2004 and 2005.
- Total Maintenance Expenditures of $750,000 in the same period.



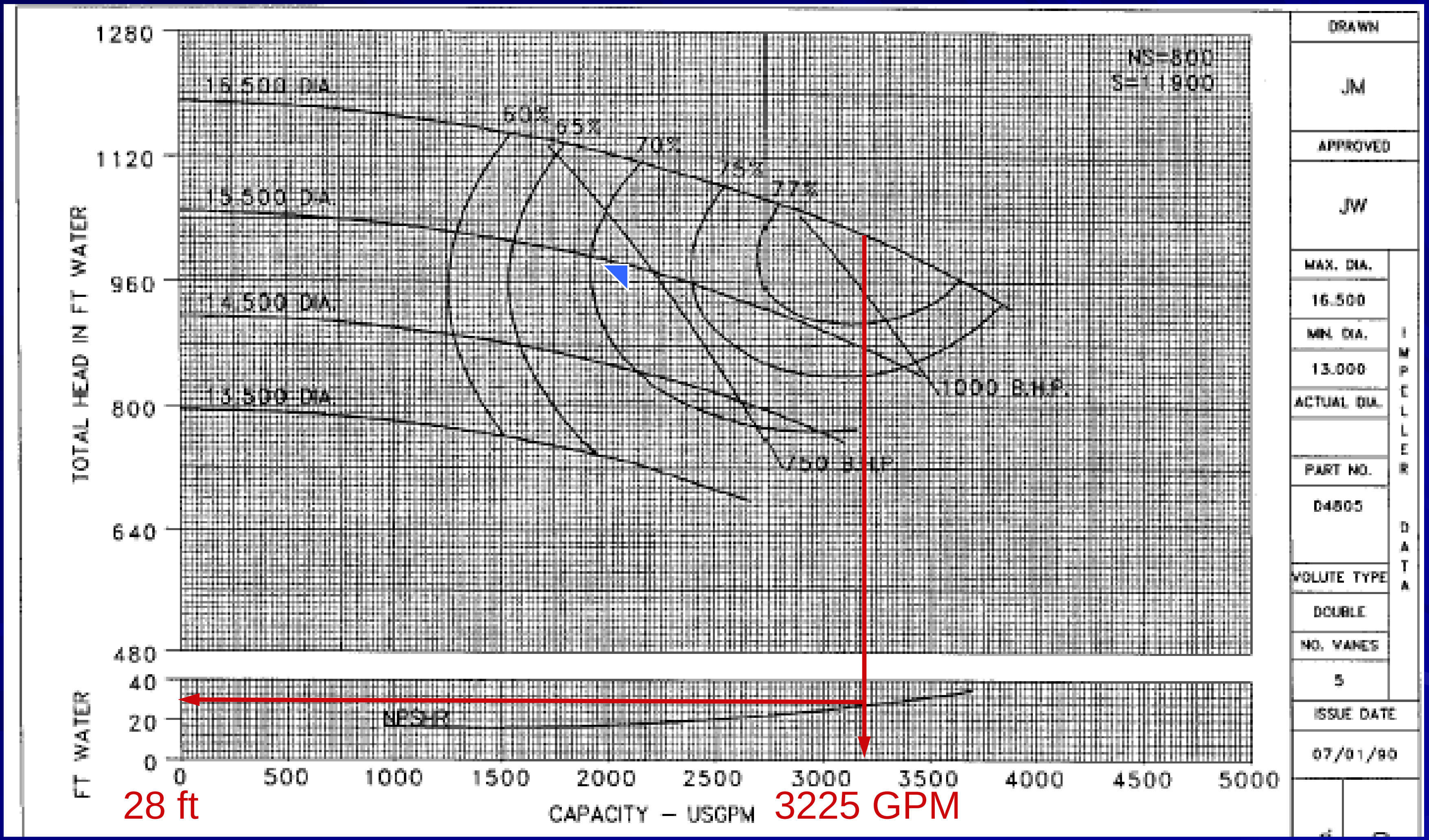
Pump Design

- 8x10x16 Double Suction Pump
- Impeller has 5 vanes per side in a staggered pattern.
- Eye Diameter, D_{eye}= 7.5 inches.
- Peripheral Velocity, U_{eye}= 117 ft/s

Supplied Pump Curve



Book Curve



TOTAL HEAD IN FT WATER
1280
1120
960
800
640
480
16.500 DIA.
15.500 DIA.
14.500 DIA.
13.500 DIA.
60%
65%
70%
75%
77%
NS=800
S=11900
1000 B.H.P.
750 B.H.P.
FT WATER
40
20
0
NPSHR
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
CAPACITY – USGPM
DRAWN
JM
APPROVED
JW
MAX. DIA.
16.500
MIN. DIA.
13.000
ACTUAL DIA.
PART NO.
04805
VOLUTE TYPE
DOUBLE
NO. VANES
5
ISSUE DATE
07/01/90
IMPELLER DATA
28 ft
3225 GPM

Suction Specific Speed

$$N_{ss} = \frac{N\sqrt{Q}}{NPSH_r^{\ 3/4}}$$

- Statement of energy level and stability of pump.
- Values over 10,000 suggests that pump will be unreliable when operated away from BEP.

Suction Specific Speed

$$N_{ss} = \frac{N\sqrt{Q}}{NPSH_r^{3/4}}$$

$$N_{ss} = \frac{3580\ RPM\sqrt{(3225\ GPM)/2}}{28\ ft^{3/4}}$$

$$N_{ss} = 11{,}810$$

Suction Energy

$$SuctionEnergy = D_{eye} \times N \times Nss \times SG$$

- Tip velocity of the suction blade multiplied by the Nss.
- Very high energy levels are considered $180X10^6$.
- High levels mean that more NPSH margin is needed to suppress cavitation. Budris and Bloch predict margins may need to be as great as 20 to 1.

Source: Budris and Bloch, "Pump Users Handbook Life Extension", 2004 Fairmont Press, pgs 93-98

Suction Energy

$$SuctionEnergy = D_{eye} \times N \times Nss \times SG$$

$$SuctionEnergy = 7.5\,in \times 3580\ RPM \times 11{,}810 \times 0.89$$

$$SuctionEnergy = 282x10^{6}$$

Symptoms

- Pump audibly cavitates.
- Pump seems to operate in regions where a lower energy pump would have enough NPSH margin to suppress cavitation.
- At higher rates, pump is prone to violent axial shuttling, destroying the thrust bearings.
- Older impellers show evidence of recirculation cavitation while newer ones do not. 316 ss masks this damage.
- Primary failure modes are bearings and seals.

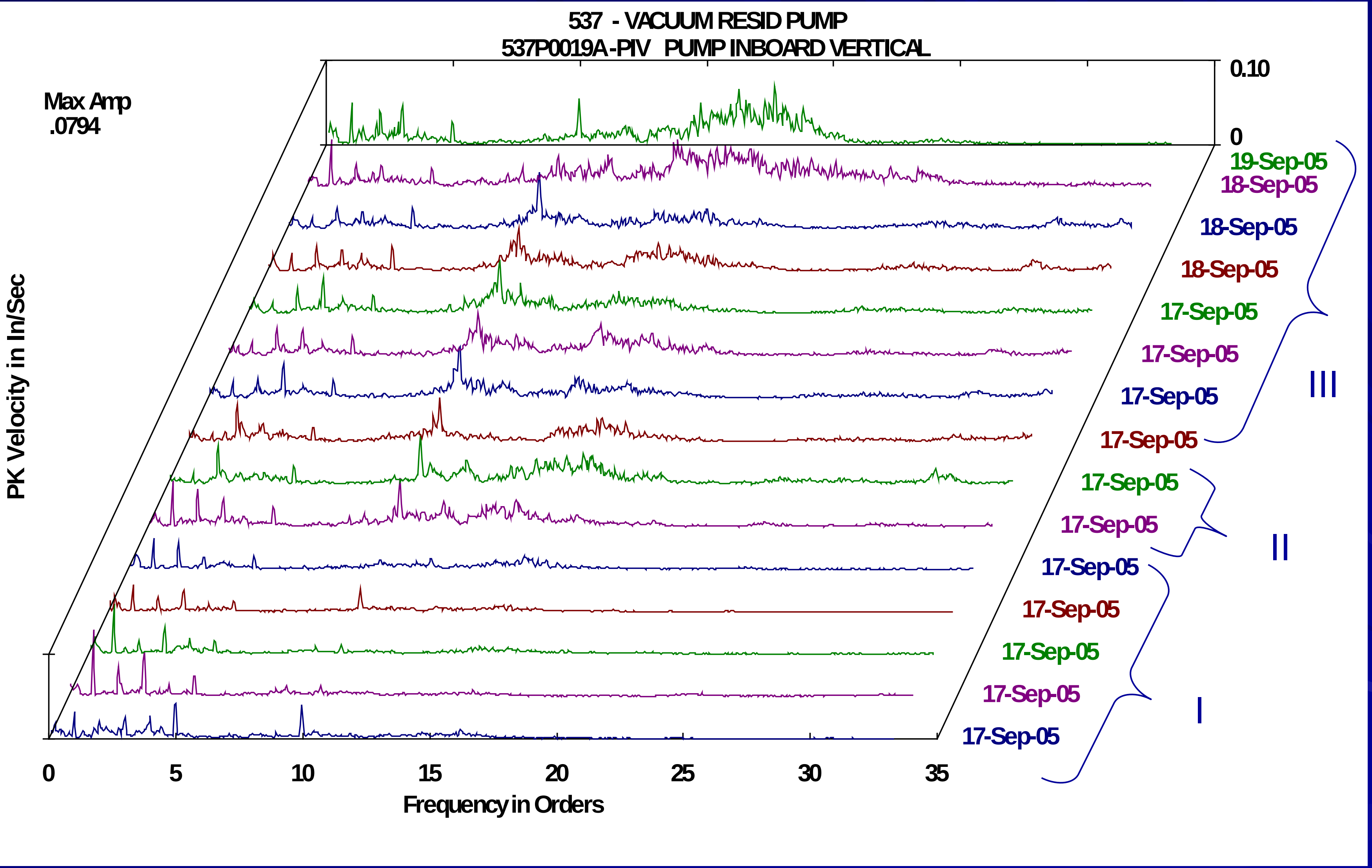
Explanation of Failure

- Pump has an Nss of 11,810.
- Pump sized and selected to the left of BEP. Pump will experience classic cavitation before approaching BEP.
- Pump experiences recirculation cavitation at lower flows.
- Pump suction energy level is $282x10^6$. This is 57% over the very high threshold level.
- Rate has increased ~40% since commissioning of the unit.

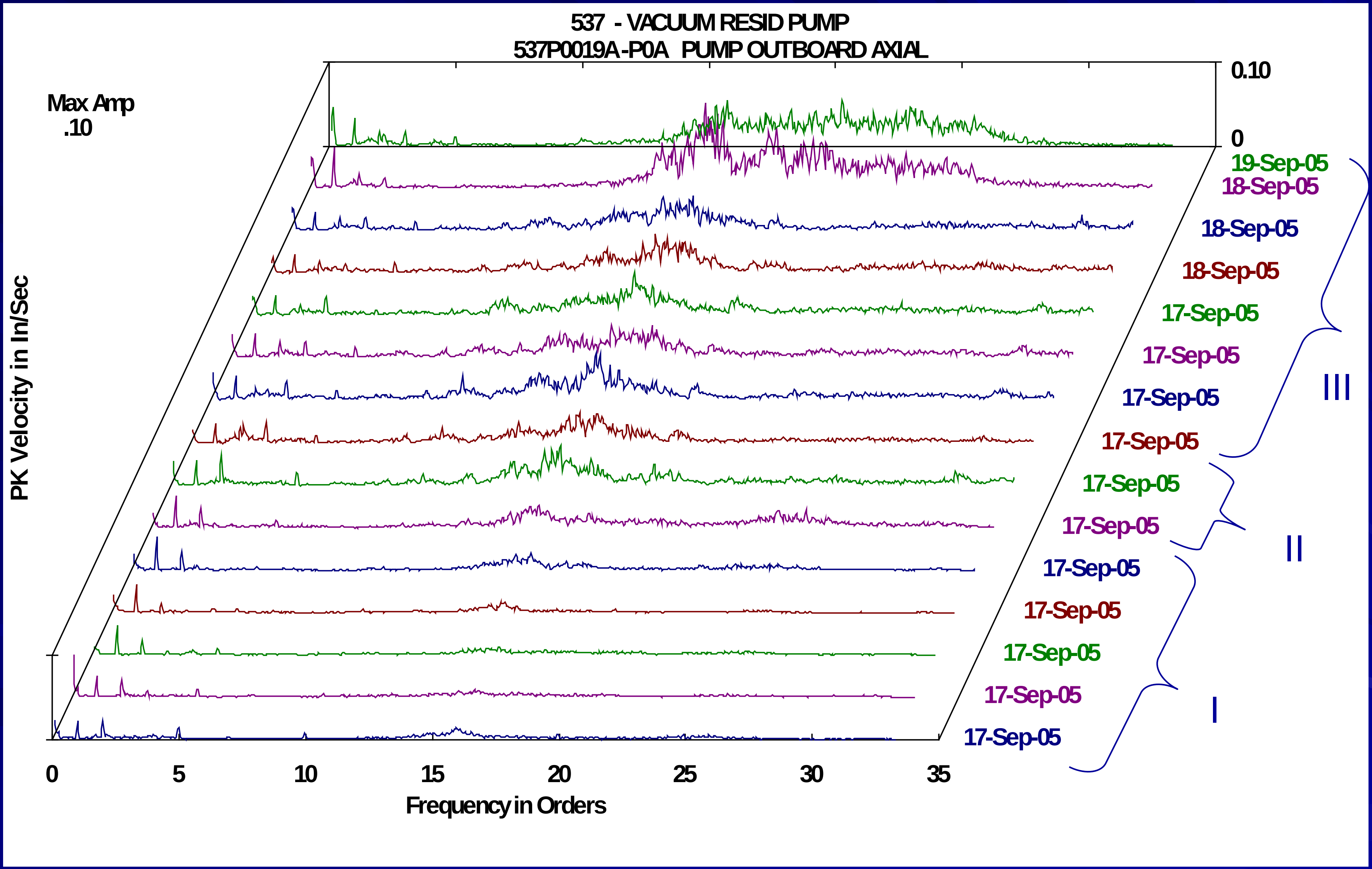
Vibration Data Explanation

- Waterfall plots of data taken during unit startup. The first plot is axial data and the second plot is taken on the inboard bearing in the vertical direction.
- Vacuum side is started by circulating and heating HGO to dry the tower. The HGO is sub-cooled and vacuum is not present in the tower. At around 600 degrees F, vacuum is pulled on the tower and atmospheric reduced crude is introduced.
- Points in Region I have estimated NPSH margins of 3 or greater.
- Points in Region II have margins that are estimated to be around 2. The tower is circulating under vacuum, but the bottom is sub-cooled.
- Points in Region III have margins between 1.8 and 2. The unit is operating at steady state.

Waterfall Plot - PIV



Waterfall Plot - POA

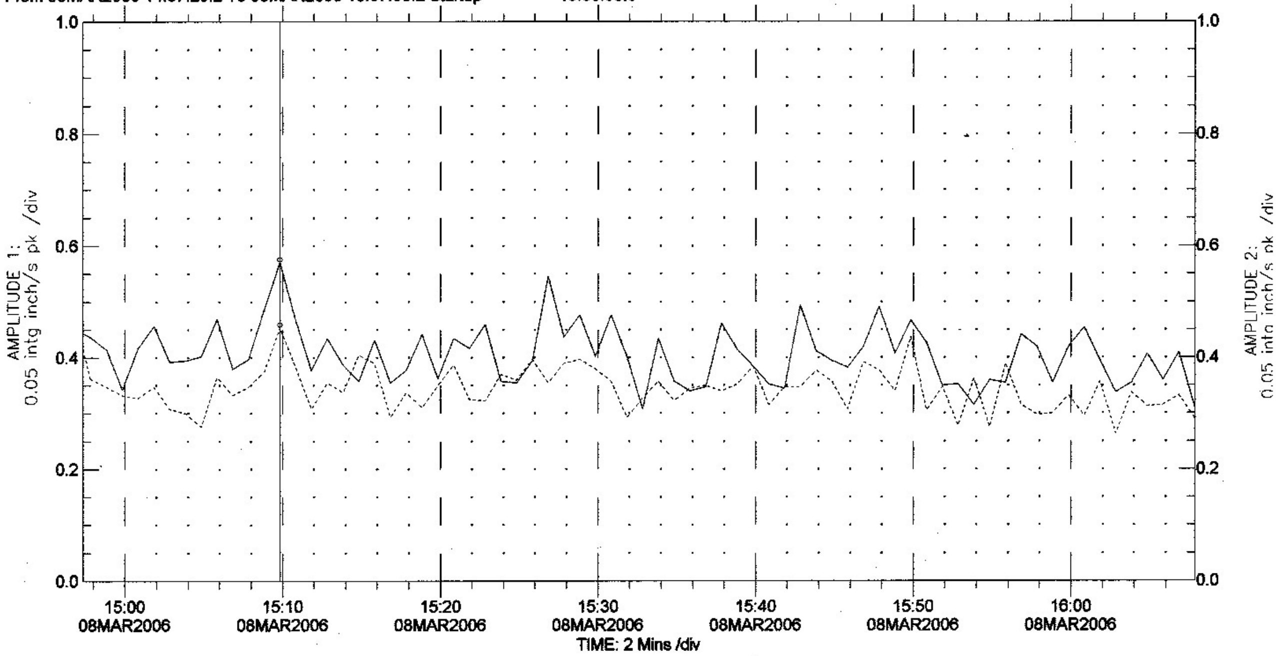


Steady State Trend Showing Hydraulic Instability

TREND PLOT
COMPANY: LCR
MACHINE TRAIN: Vacuum Tower Bottom

PLOT NO.______
PLANT: LCR
JOB REFERENCE: 537P0019A/B

POINT: OB Vertical	45° Left	——	DIRECT	0.570 intg inch/s pk
POINT: OB Horizontal	45° Right	------	DIRECT	0.454 intg inch/s pk
MACHINE: Pump				08MAR2006
From 08MAR2006 14:57:20.2 To 08MAR2006 16:07:50.2 Startup				15:09:50.0



COMMENTS

This is a trend of overall vibration levels for the P19A taken on March 8, 2006 for one hour.
One line shows the horizontal and the other shows the vertical positions.

Notice the erratic nature of the vibration. Levels regularly double. This vibration is entirely fluid induced.

BENTLY NEVADA

Evidence of Recirculation

Evidence of Recirculation

View of
Underside of
Impeller

Resolution and Lessons Learned

- Rate on Unit Capped.
- Shutdown on axial position being added to pump.
- Never accept a curve that has been truncated.
- Always ensure a low energy vacuum tower bottoms pump by providing the following:
  - Low speed – 1800 RPM rather than 3600 RPM
  - Low Nss
  - Low Suction Energy
- Alternate Selections:
  - Two stage 1800 RPM pump.
  - Primary/Booster Arrangement with the bottoms pump operating at 1800 RPM.