Session 2

The Impact of Curve Shape, Head-Rise to Shutoff and "Zero Tolerances" on Equipment Selection, Reliability, & Pricing and on Downstream Equipment

The Problems

1. An increasing number of pump or project specifications are assuming (or even **specifying**) a head rise to shutoff of as little as10 to 15%.

   This (wrong) assumption can lead to the oversizing of pump and motor equipment and subsequent poor performance in the field.

2. Many specifications especially those for Transfer or Loading services are specifying "zero negative tolerance on TDH". (The concern being meeting the contractual guaranteed output flow at the negative tolerance TDH condition).

These two requirements can seriously impact the design and price of not only the pumps but also of downstream equipment.

This presentation will help engineers to specify the right pump for the application.

What Does API 610 Say?

Pressure Rating of Pump Casings

- 6.3.1 "The maximum discharge pressure shall be the maximum suction pressure plus the maximum differential pressure that the pump is able to develop when operating with the furnished impeller at the rated speed and specified normal relative density (specific gravity)" –i.e. shutoff head rated impeller

- 6.3.2 Options for a) max SG, b) max dia impeller, c) trip speed

- 6.3.5 "…the MAWP shall be at least the maximum discharge pressure (see 6.3.1 & 6.3.2)   plus 10% of the maximum differential pressure…"

- Note 3   The 10% differential pressure margin is intended to accommodate head increases (6.1.4) (i.e. 5%), higher speed in variable speed pumps (6.1.5) and head (testing) tolerance (see 8.3.3.3b)

What Does API 610 Say?

- 8.3.3.3b Table 16

Table 16 — Performance tolerances

Condition	Rated point %	Shutoff %
Rated differential head:		
0 m to 75 m (0 ft to 250 ft)	± 3	± 10[a]
> 75 m to 300 m (> 250 ft to 1 000 ft)	± 3	± 8[a]
> 300 m (1 000 ft)	± 3	± 5[a]
Rated power	4[b]	—
Efficiency	c	
Rated NPSH	0	—

[a]   If a rising head flow curve is specified (see 6.1.11), the negative tolerance specified here shall be allowed only if the test curve still shows a rising characteristic.

[b]   With test results corrected to rated conditions [see 8.3.3.3 b)] for flow, speed, density (specific gravity) and viscosity, it is necessary that the power not exceed 104 % of the rated value, from all causes (cumulative tolerances are not acceptable).

[c]   The uncertainty of test efficiency by the test code specified is ± 2,5 %; therefore, efficiency is not included in the pump's rated performance. In those applications where efficiency is of prime importance to the purchaser, a specific value and related tolerance should be negotiated at the time of the order (see 8.3.3.4).

Zero Negative Tolerance

- API 610 allows tolerances on rated head, shutoff head and rated power. It does this for a very good reason.

- BECAUSE THAT IS THE REALITY OF MANUFACTURING

- Semi-Engineered Pumps are not built from investment castings and some variations between batches of castings is inevitable

- It is impossible to accurately measure shutoff head

- Imposing "zero negative head" will result in us quoting a tolerance of -0%/+6% instead of +/-3% with a corresponding increase in shutoff head tolerance (e.g -2%/+8% instead of +/-5%)

- This will impact MAWP and Rated Power

- Imposing "zero positive power" will result in us quoting 4% higher guaranteed power

How Much is the Head-rise to Shutoff Head of a Pump?

- DO NOT ASSUME 10% - this is seldom achievable except on very small process pumps

- For typical process pumps (flow rates of 500 to 1000m3/hr) head rise will be in the range of 115% to 130%

- Many vertical pumps (VS1 & VS6) will have a head rise of 140% to 150%

- For parallel operation a head rise of at least 15% is recommended. The steeper the curve the more controllable the pump operation.

Impact of Curve Shape on Controllability

- A small change in Head (H) will have far less impact on the Flow Rate (Q) with a steep curve (red) than with a shallow curve (blue) -so negative head tolerance is not such a problem.
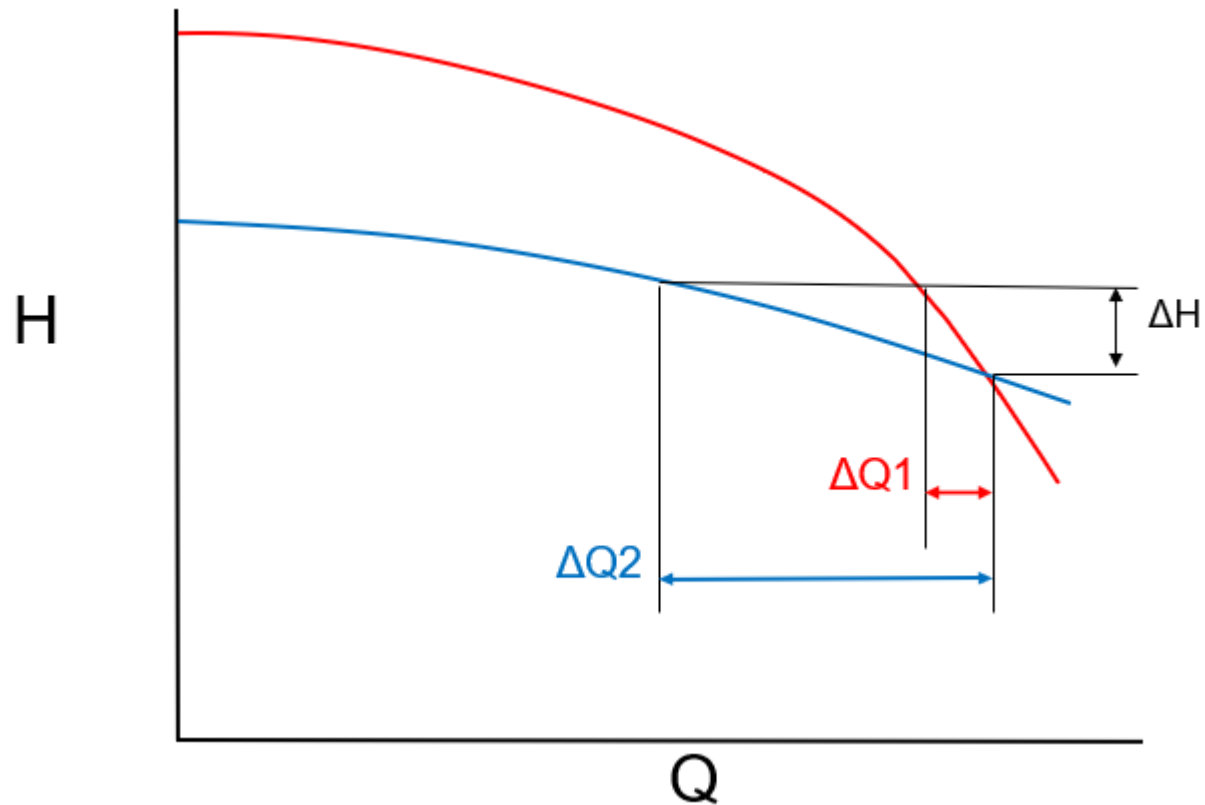
What MAWP should I assume for Downstream Equipment?

- Start with Rated Differential Pressure (with max SG)

- Assume 30% head rise (50% for VS1 or VS6)

- Add 10% per API610 Para 6.3.5

- Add max possible suction pressure (Note **NOT** the suction side ***design pressure***)

- If this brings the calculated MAWP close to:-

  - 15 Barg (150# flange rating) * or

  - 45 Barg (300# flange rating) * or

  - 90 Barg (600# flange rating) * or

  - 135 Barg (900# flange rating) *

  then consult pump vendors to get more accurate SOH predictions

- Don't specify "zero tolerances" or if you have no choice, discuss the implications and possible options with the pump vendors

  * (Based on A216WCB Steel castings or A105 forged plate at 150 deg C)

Real World Example

How to get it wrong!

- Here is a pump on LNG sendout duty 411m3/hr @ 2212m, 1450kW

- With this pump and API tolerances pump MAWP was 150.4 Barg

- This selection was used for FEED, EPC Selection, and Purchase Stages.

- Only at the final pre-award meeting was it realised that …

- PMC had assumed 10% headrise to shutoff with zero positive tolerance on SOH and set a downstream pressure rating of only 130 Barg

- To ensure parallel operation PMC specified zero negative tolerance on SOH too!
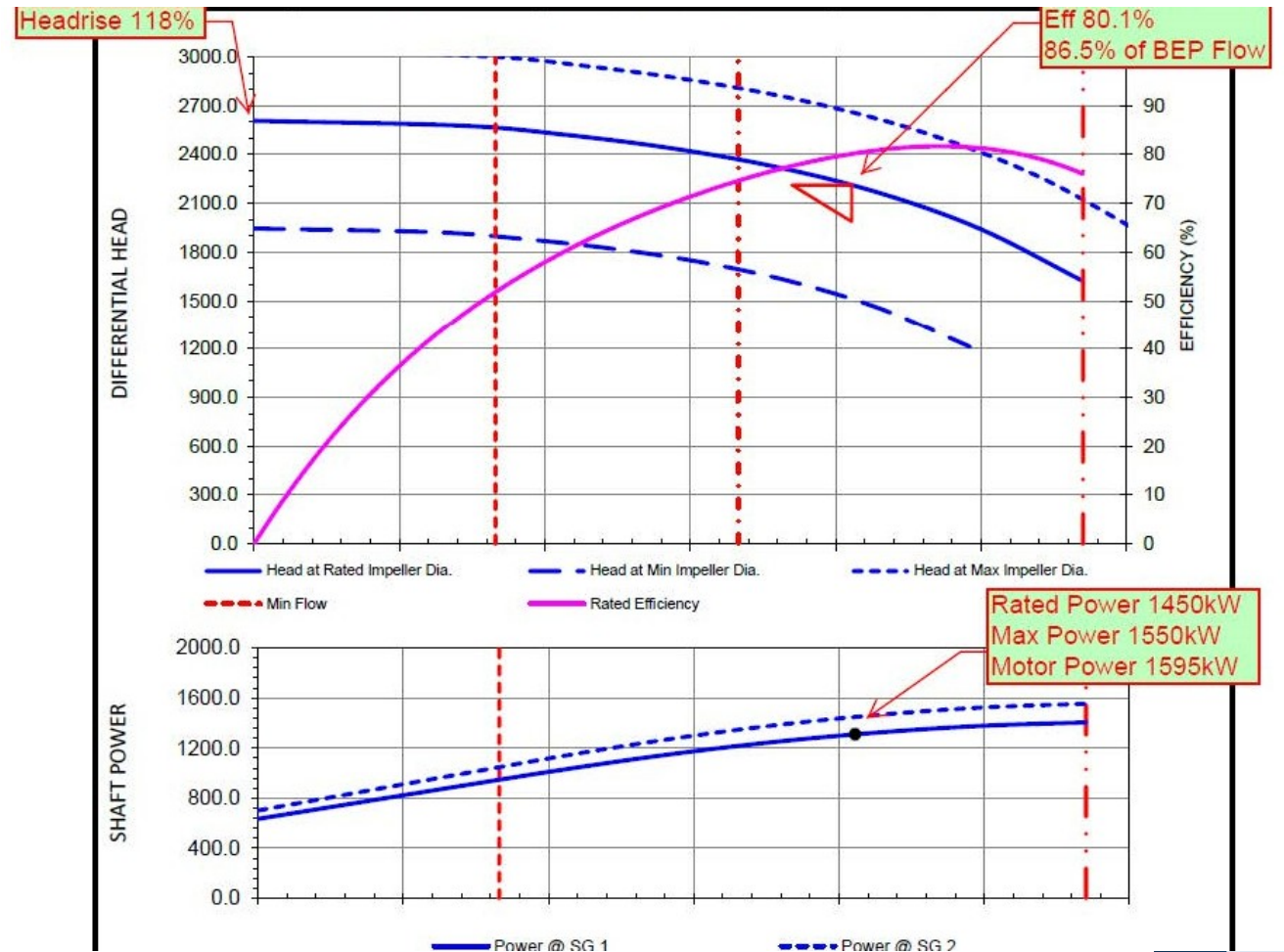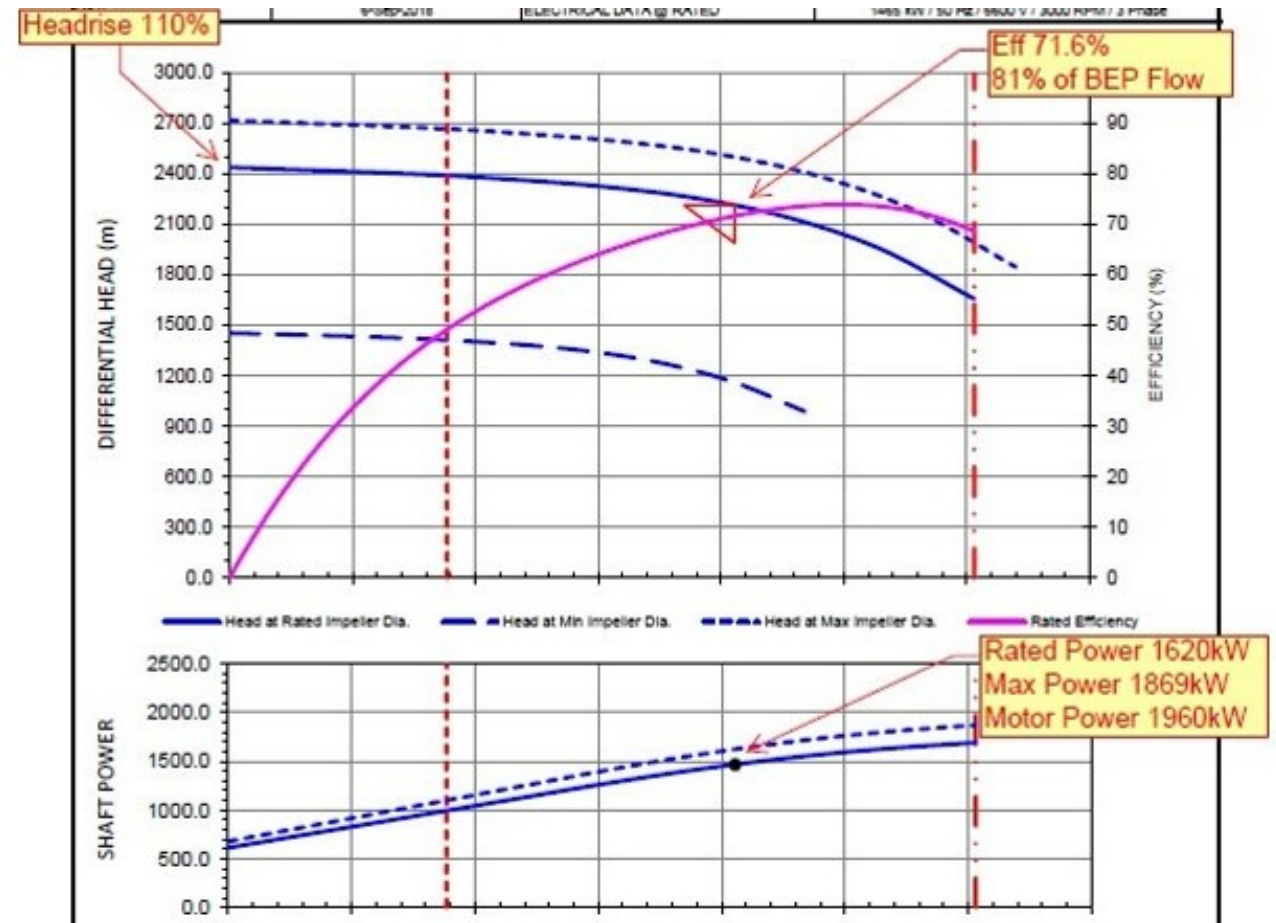
# Real World Example

How to get it wrong (2)!

- This reselection met the 110% rise to shutoff but with API tolerances +/- 5%

- MAWP was thus 136 Barg

- Selection is
  - away from BEP (81% vs 86%),
  - has lower efficiency (71.6% vs 80.1%)
  - rated and max power are significantly higher (1620 & 1869kW vs 1450 & 1550kW)
  - Motor rating is significantly higher (1960kW vs 1595kW)
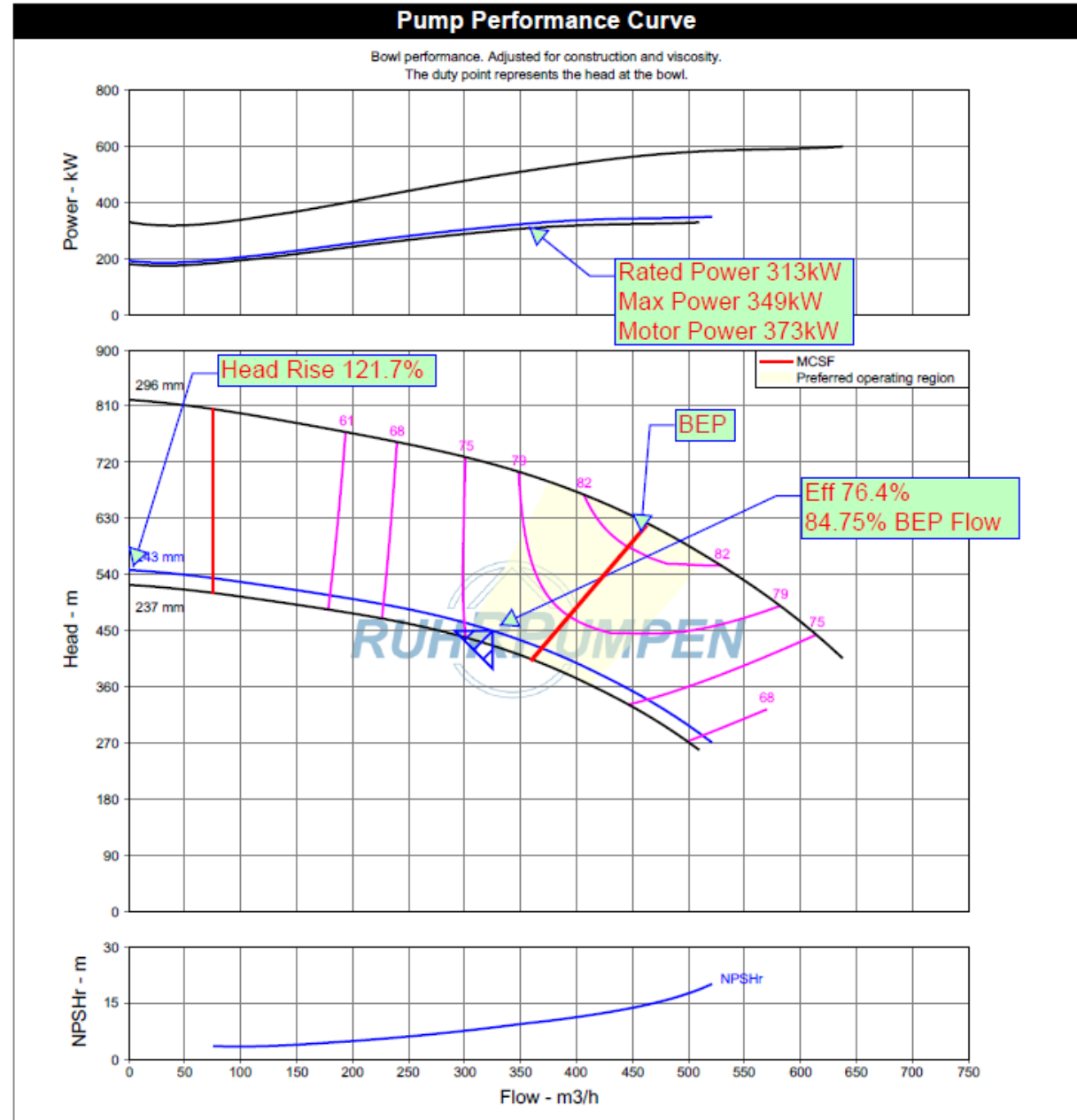
How to Get it Wrong 2

- ## Perfect Pump!
  - Good headrise for parallel operation
  - Rated flow v close to BEP
- EPC Specified Max headrise to shutoff 120%
- EPC also specified zero negative tolerance on rated head.
- This resulted in us quoting a tolerance of -0%/+6% instead of +/-3% with a corresponding increase in shutoff head tolerance (i.e.-2%/+8% instead of +/-5%) increasing the MAWP proportionately (from 39.2 to 40.4 Bar)
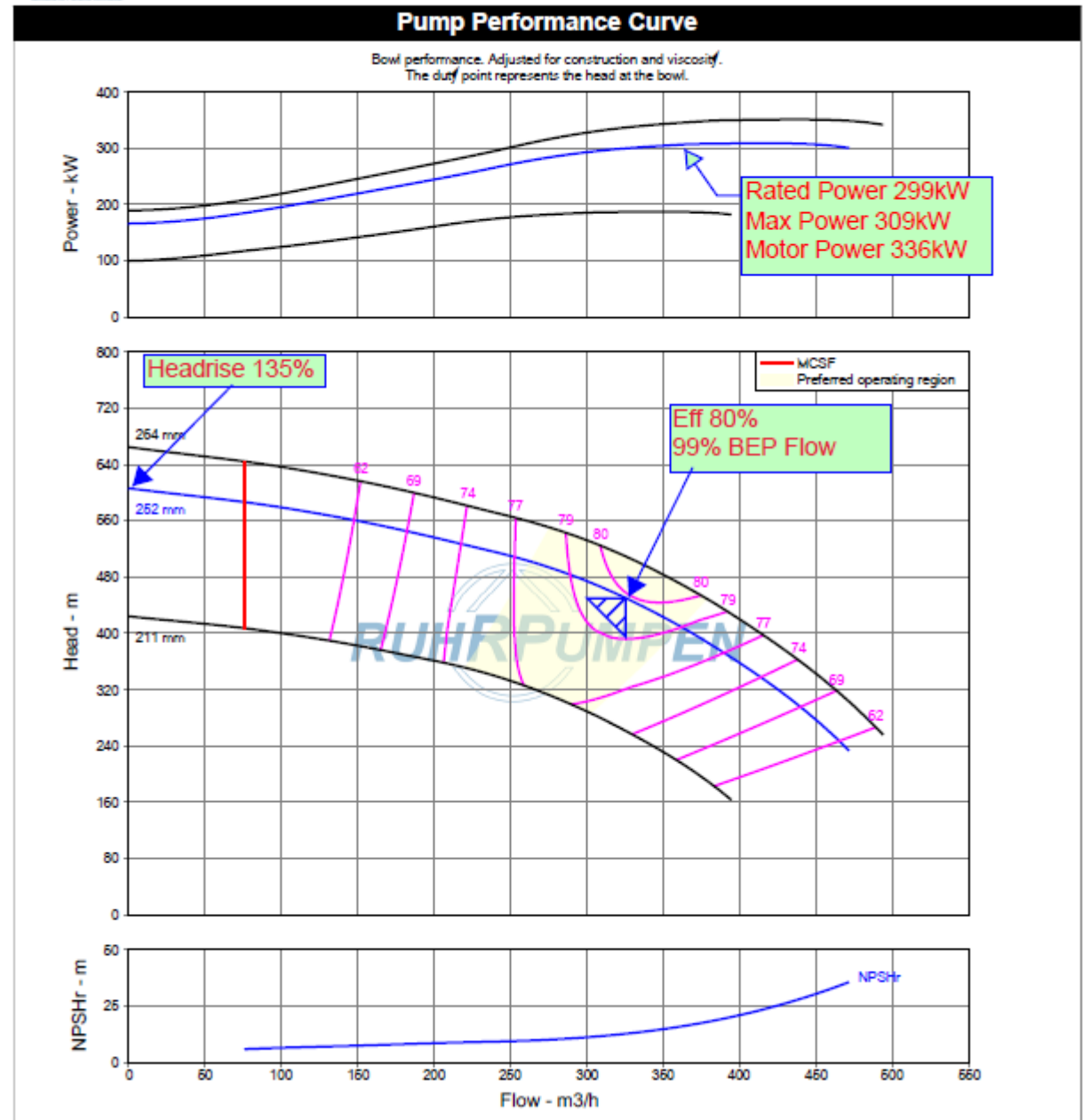
How to get it Wrong 2

- Compromise selection
    - Next Frame Size up Pump
    - Rated Point 84.75% of BEP Flow (just within the "Preferred Operating Range") instead of 99% BEP Flow
    - Efficiency 3.5 points lower
    - Power 27 kW higher
    - Motor rating 37 kW higher
    - Headrise 122% (still OK for parallel operation)

- An inexperienced engineer would be tempted to say "That's an acceptable compliant selection"

- **BUT HE/SHE WOULD BE WRONG**

How to Get it Wrong 2

- ## Shockless Flow

  - This is the flow rate at which the flow into the impeller impinges on the inlet vanes at the optimum angle. It is normally close to the BEP Flow of the full diameter impeller.

  - Trimming the impeller has no impact on the shockless flow rate.

  - Onset of Suction Recirculation is generally around 40-60% of the Shockless Flow rate

  - So the Rated Duty Point might be 85% of BEP Flow for the trimmed impeller but it is at 65% of the Shockless Flow

- This selection is a train wreck waiting to happen
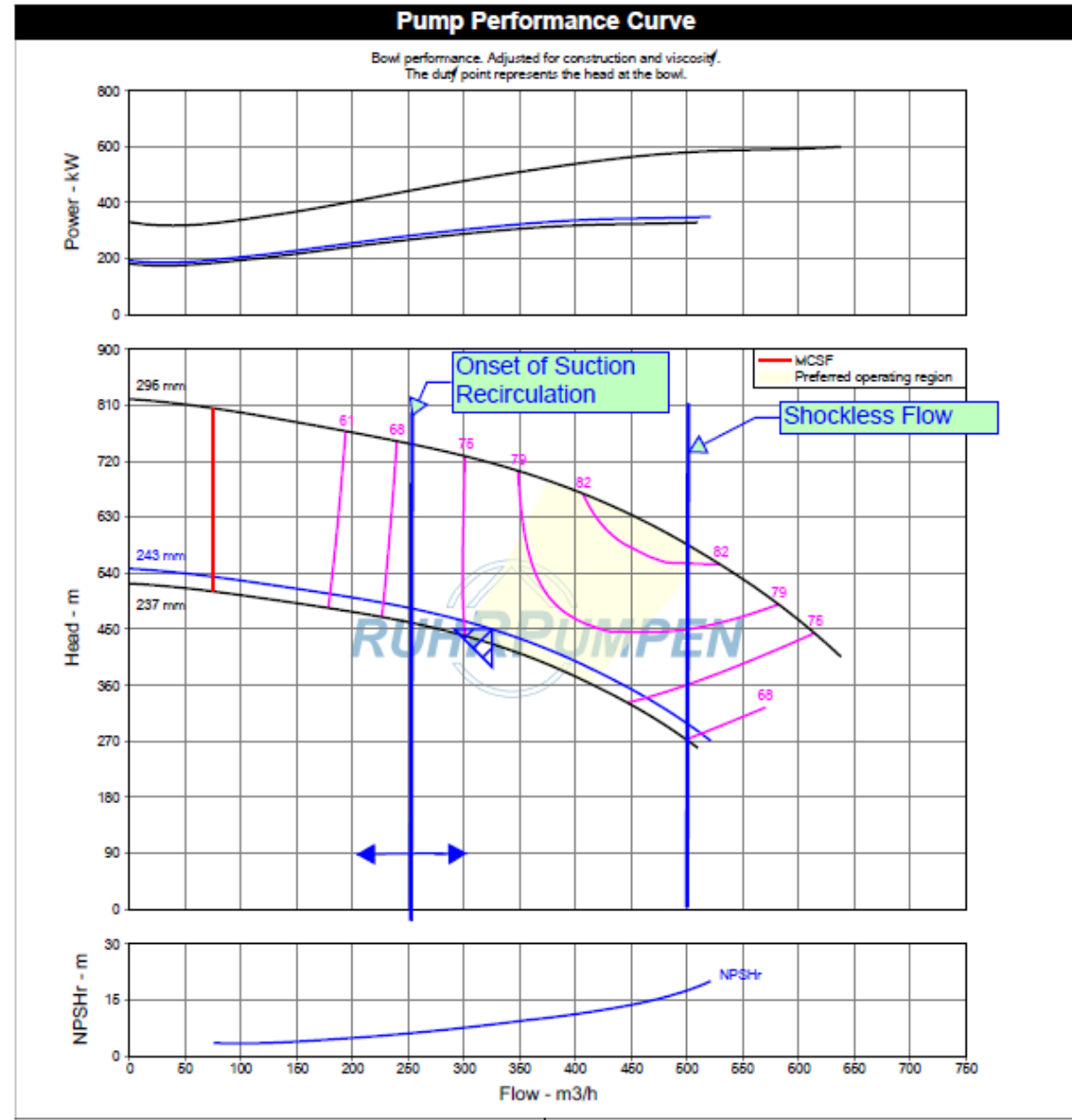
Suction Recirculation

Figure 1
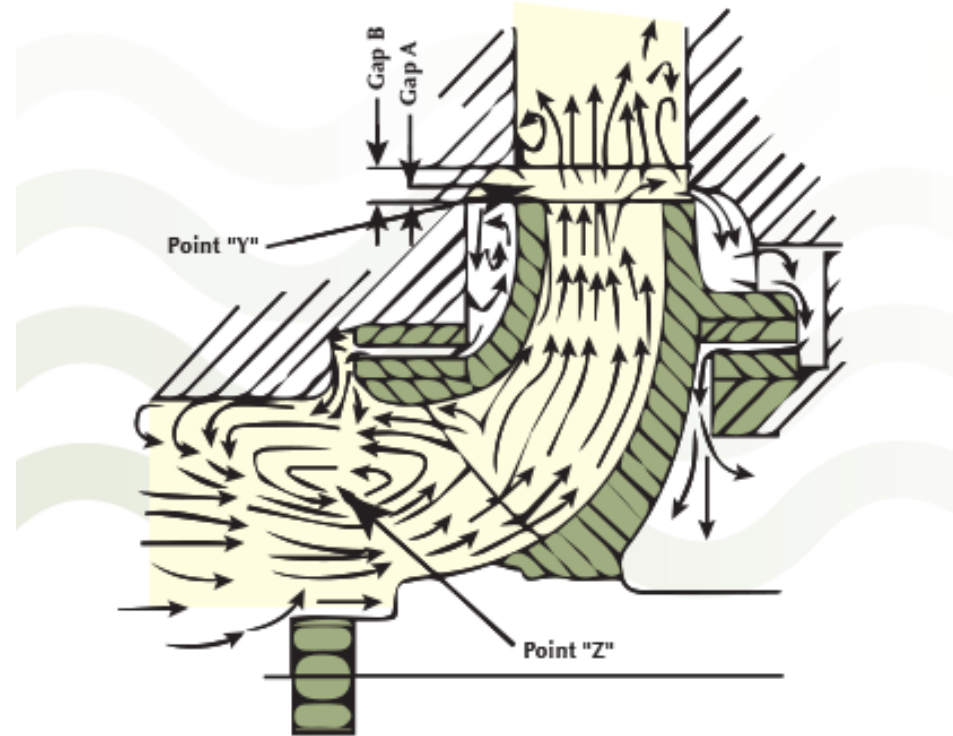
Recirculation vortices at impeller suction eye and at vane tips (source: Pump Handbook, Igor J. Karassik and Joseph P. Messina; ISBN-10 0070333025).

Summary

1. Start with Rated Differential Pressure (with max SG)

2. Assume 30% head rise (50% for VS1 or VS6)

3. Add 10% per API610 Para 6.3.5

4. Add max possible suction pressure (Note **NOT** the suction side ***design pressure***)

5. If this brings the calculated MAWP close to:-

    - 15 Barg (150# flange rating) * or

    - 45 Barg (300# flange rating) * or

    - 90 Barg (600# flange rating) * or

    - 135 Barg (900# flange rating) *

    then consult pump vendors to get more accurate SOH predictions

6. Don't specify "zero tolerances" or if you have no choice, discuss the implications and possible options with the pump vendors

    * (Based on A216WCB Steel castings or A105 forged plate at 150 deg C)

Coming Attractions ☺

"The Importance of Using System Curves in Pump Selection and Successful Pump Operation"

Thurs 3rd June – ==08.00 (UK BST)== (Eastern Hemisphere) & ==17.00 (UK BST)== (Western Hemisphere)

> *Aimed at Process and Mechanical Engineers and Consultant Engineers specifying pumping equipment as well as Applications Engineers selecting and quoting them. Develop an understanding of how the System Curve works with the Pump H/Q Curve to determine how a pump will operate in the field.*

> *Will cover such topics as parallel operation, steep vs shallow curves, and "hooked" curves*

Future subjects in preparation include:

- "Selecting the right pump for the application"

   (when to transition from an OH2 to a BB2 , when to consider VS6 etc etc)

- "NPSH made simple (or "simpler" anyway!)"