RUHRPUMPEN

*Specialist for Pumping Technology*

# Session 29 –

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

*Simon Smith January 2024*

# Presenter Profile – Simon Smith

Simon graduated with an honours degree in Chemical Engineering from the University of Surrey in 1978 and began a long career in the engineered pump industry spanning 40 years (so far!) with Peerless Pump, BW/IP International / Flowserve, SPP Pumps, Ruhrpumpen and Ebara Cryodynamics.

Over his long career he has filled various roles as Applications Engineer / Manager, Project Manager, Key Account Specialist, Vertical Pump Product Specialist, International Sales Engineer / Manager / Director and he has considerable experience in Training & Mentoring young engineers.

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# RuhR*P*umpen Short Courses

**Here is a listing of all the previous courses.**

- No 1 – API610 12th v 11th editions
- No 2 - Curve Shape (1)
- No 3 – The Importance of System Curves (1)
- No 4 - Selecting the Right Pump for the Application
- No 5 - NPSH & Nss
- No 6 - Mechanical Seals & Systems (1)
- No 7 - Firepumps
- No 8 - BB5 Barrel Pumps
- No 9 - Pump Instrumentation
- No 10 – Non-Destructive Examination
- No 11 - Vertical Pumps (Part 1) Type VS1, VS2, VS3
- No 12 – Vertical Pumps (Part 2) Type VS4, VS5, VS6 & VS7
- No 13 – Performance Testing of Centrifugal Pumps; the What, the Why & the How
- No 14 – Testing & Inspection of API 610 Pumps
- No 15 – Start-Up, Commissioning & Troubleshooting Centrifugal Pumps
- No 16 – Introduction to Positive Displacement (Plunger) Pumps
- No 17 – Refresher Session
- No 18 – Overhung Process Pumps OH1 & OH2

**Continued next slide**

Any you have missed you can get from our website using this link https://short-courses.ruhrpumpen.com/

Or from www.ruhrpumpen.com and follow the link to RP Short Courses

# RuhRPumpen Short Courses

**Here is a listing of all the previous courses.  Contd**

- No 19 – Vertical Overhung Process Pumps OH3-OH6
- No 20 – New Developments in the VS6 Market
- No 21 – BB4 Multistage Pumps for the Power Industry
- No 22 – Coking Process and Hydraulic Decoking Equipment
- No 23 – Pumps for the Desalination Market
- No 24 – Cryogenic Pumps
- No 25 – Magnetic Drive Pumps
- No 26 – Mechanical Seals & Systems (2)
- No 27 – The Importance of System Curves (2)
- No 28 – NPSH & Nss Made Simple (2)

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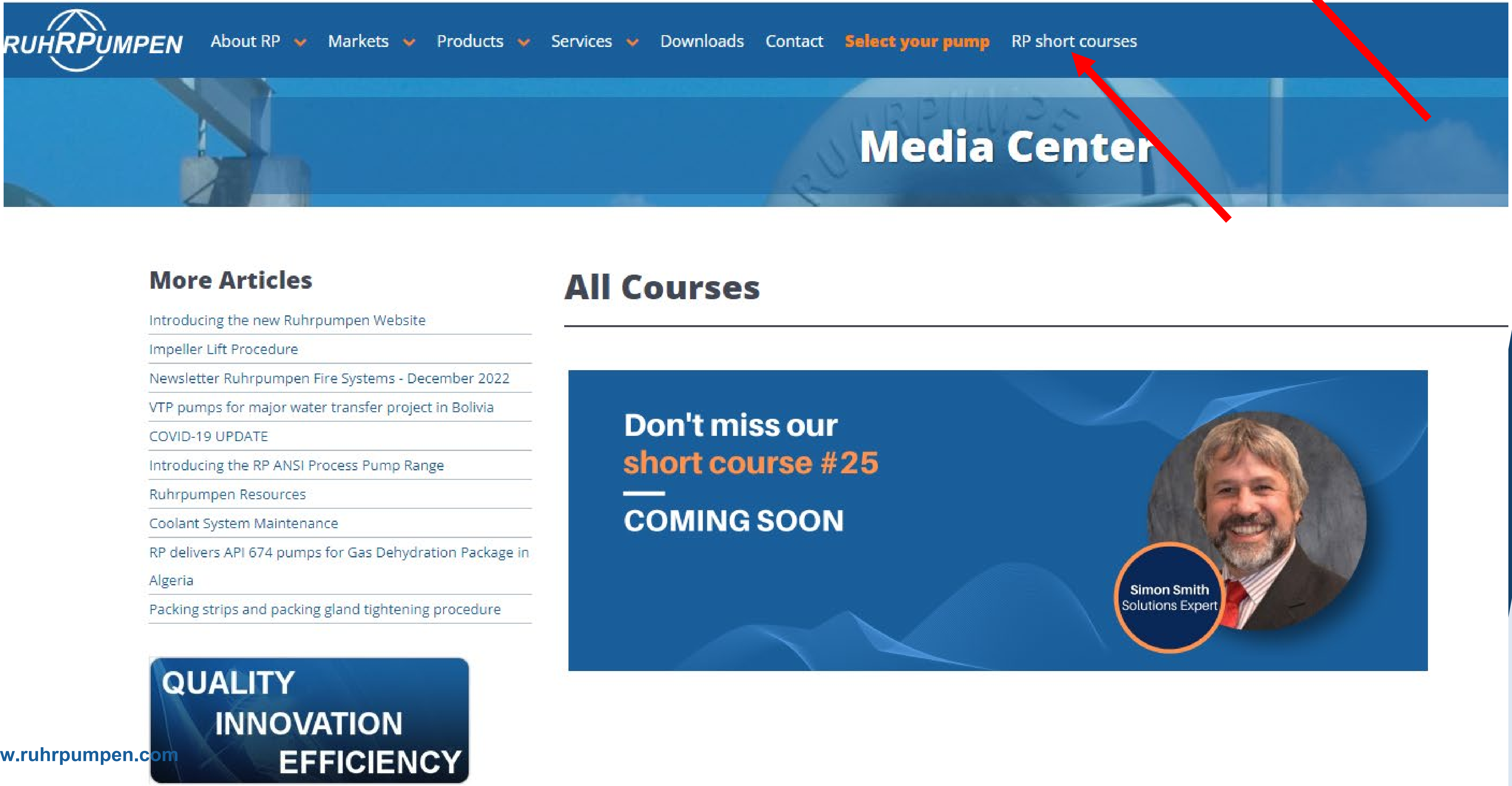
# RuhRPumpen Short Courses

www.ruhrpumpen.com



# RuhRPumpen Short Courses

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SHORT COURSE 12

## Vertical Pumps (VS4/5, VS6, VS7)

Full session.

Downloads. (14.73 MB)

SHORT COURSE 13

## Performance Testing and Inspection of API 610 Pumps

Full session.

Downloads. (4.58 MB)

SHORT COURSE 14

## Performance Testing and Inspection of API 610 Pumps

Full session.

Downloads. (7.30 MB)

# RuhRPumpen Short Courses

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SHORT COURSE 14

## Performance Testing and Inspection of API 610 Pumps

Full session.

Downloads. (7.30 MB)

SHORT COURSE 15

## Start-Up, Commissioning & Troubleshooting Centrifugal Pumps

Full session.

Downloads. (6.14 MB)

SHORT COURSE 16

## Introduction to Positive Displacement (Plunger) Pumps

Session part 1.

Session Part 2.

Downloads. (10.50 MB)

# Session 29 –
# The Impact of Curve Shape, Head-Rise to Shutoff and “Zero Tolerances” on Equipment Selection, Reliability, & Pricing and on Downstream Equipment

*Aimed at Process and Mechanical Engineers and Consultant Engineers specifying pumping equipment. The (wrong) assumption that pumps should all have a 10-15% head rise to shutoff can lead to the oversizing of pump and motor equipment, and subsequent poor performance in the field. This presentation will help engineers to specify the right pump for the application.*

# 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).

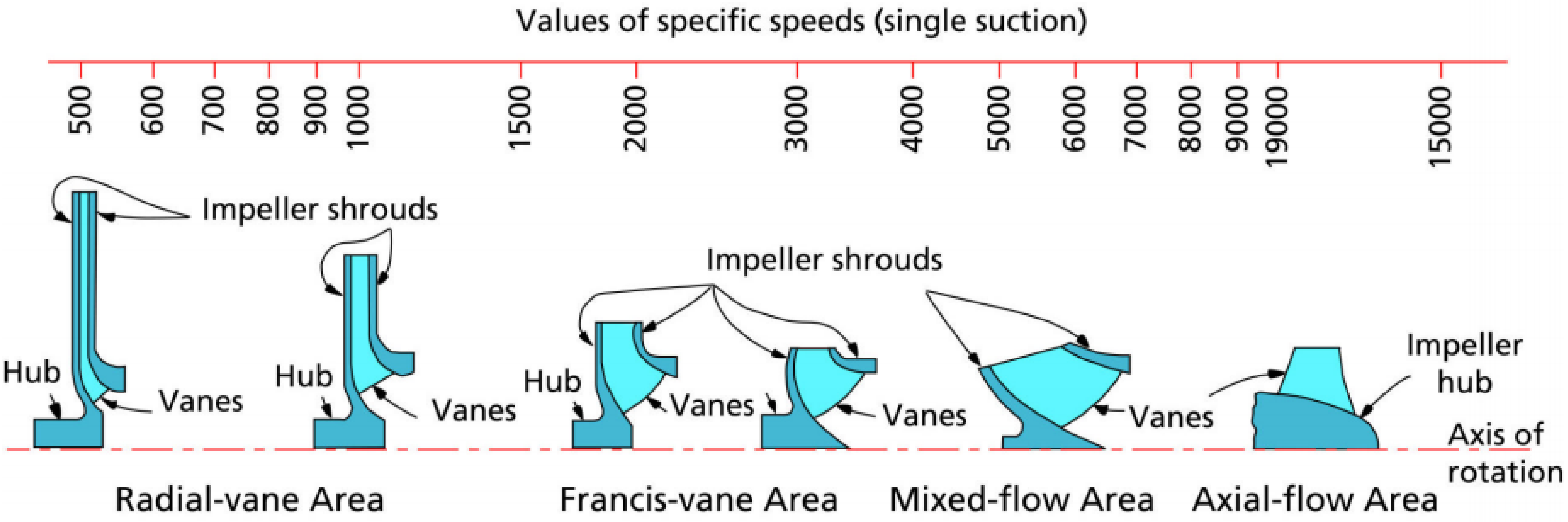
# Zero Negative Tolerance

- 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 (2” & 3” discharge)
- 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%

# Pump Curve Shape vs Specific Speed

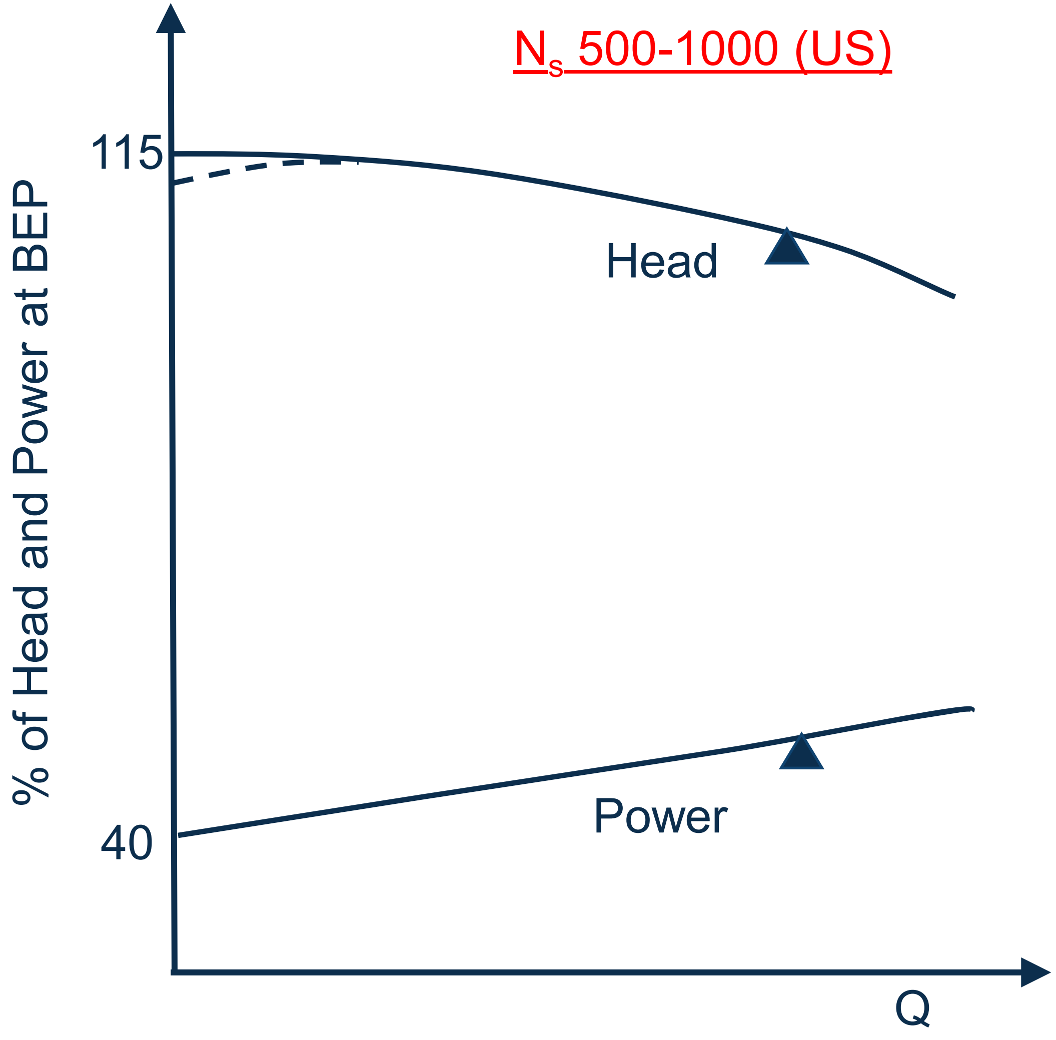


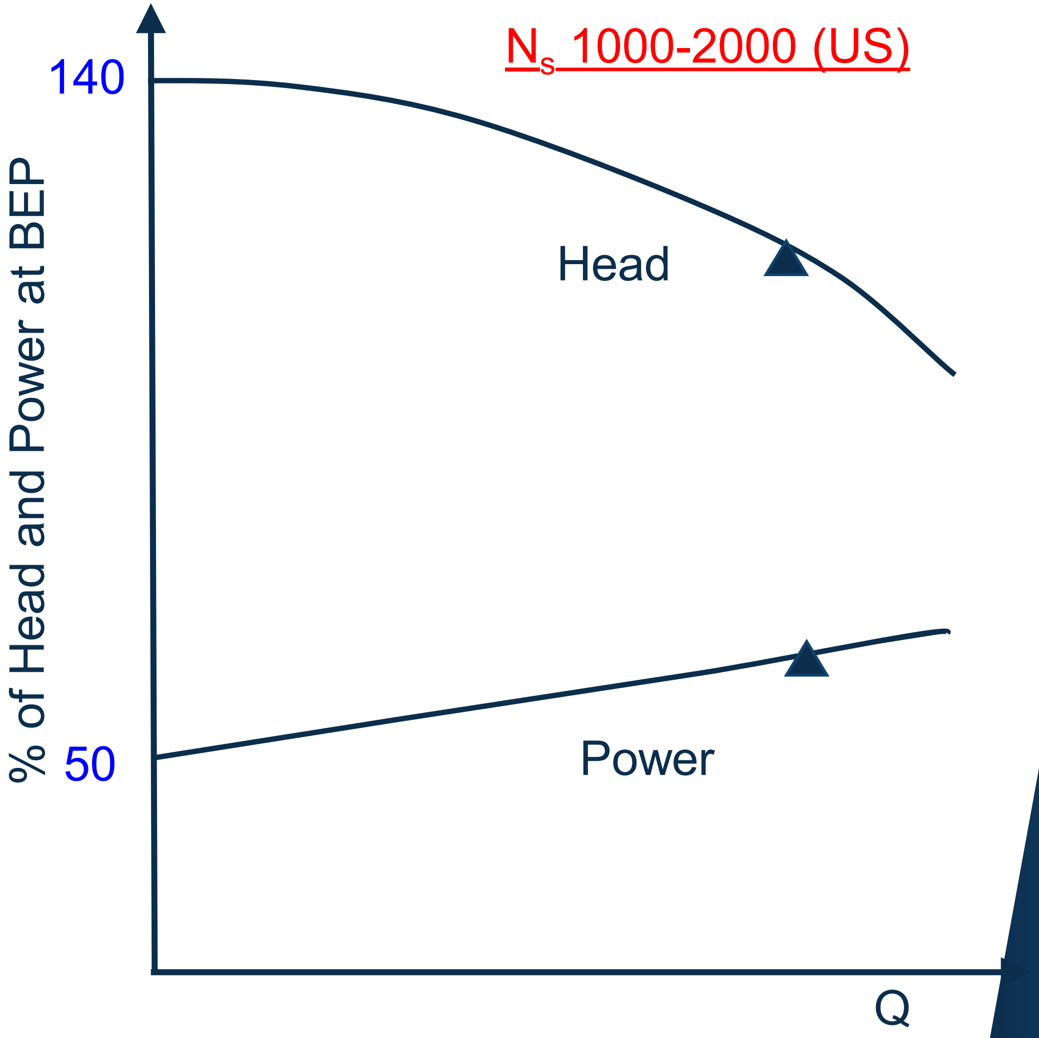

$N_S = N_{(RPM)}\, Q_{(BEP\ Full\ Dia)}^{\ 0.5} / H_{(BEP\ Full\ Dia)}^{\ 0.75}$

$N_{S(Metric)} = N_{S(US)} \times 1.16$ (m³/hr, m, rpm)

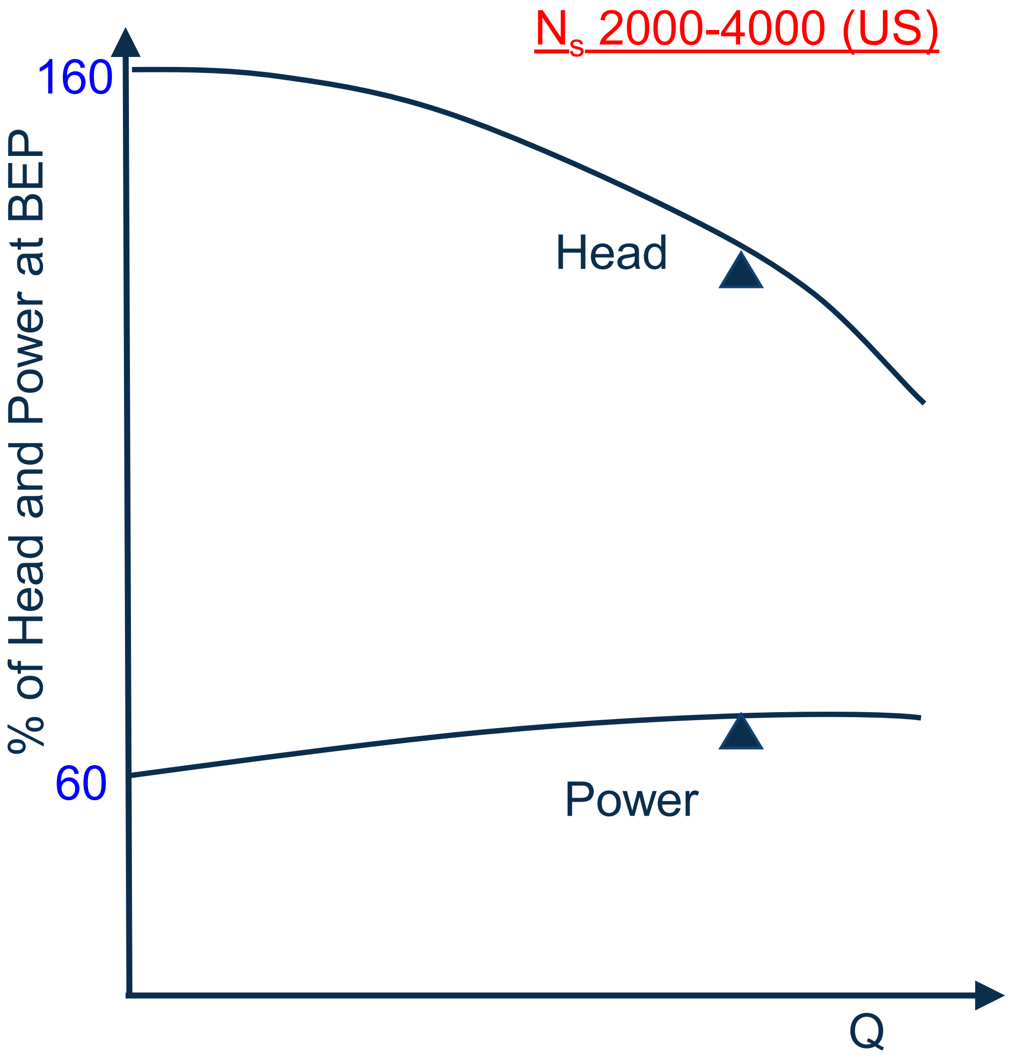
$N_{S(Metric)} = N_{S(US)} \times 0.02$ (m³/s, m, rpm)

# Pump Curve Shape vs Specific Speed



# Pump Curve Shape vs Specific Speed

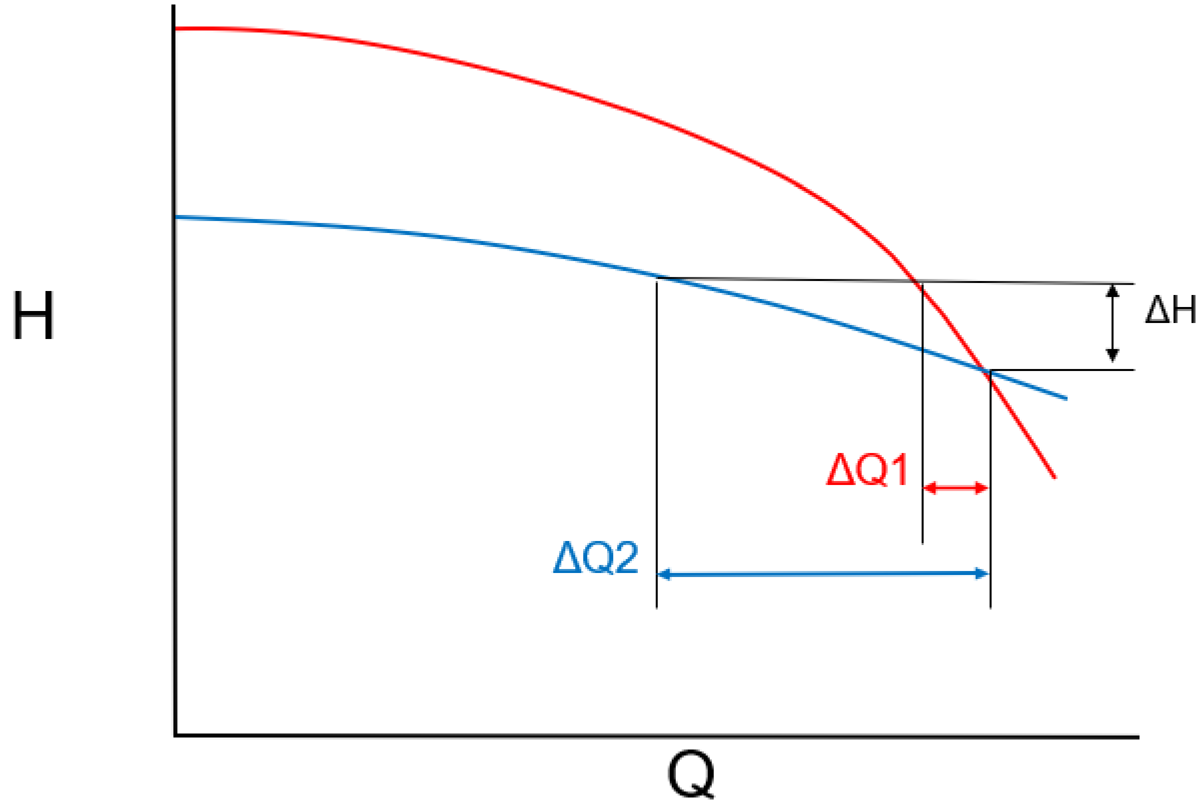


# How Much is the Head-rise to Shutoff Head of a Pump?

- 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

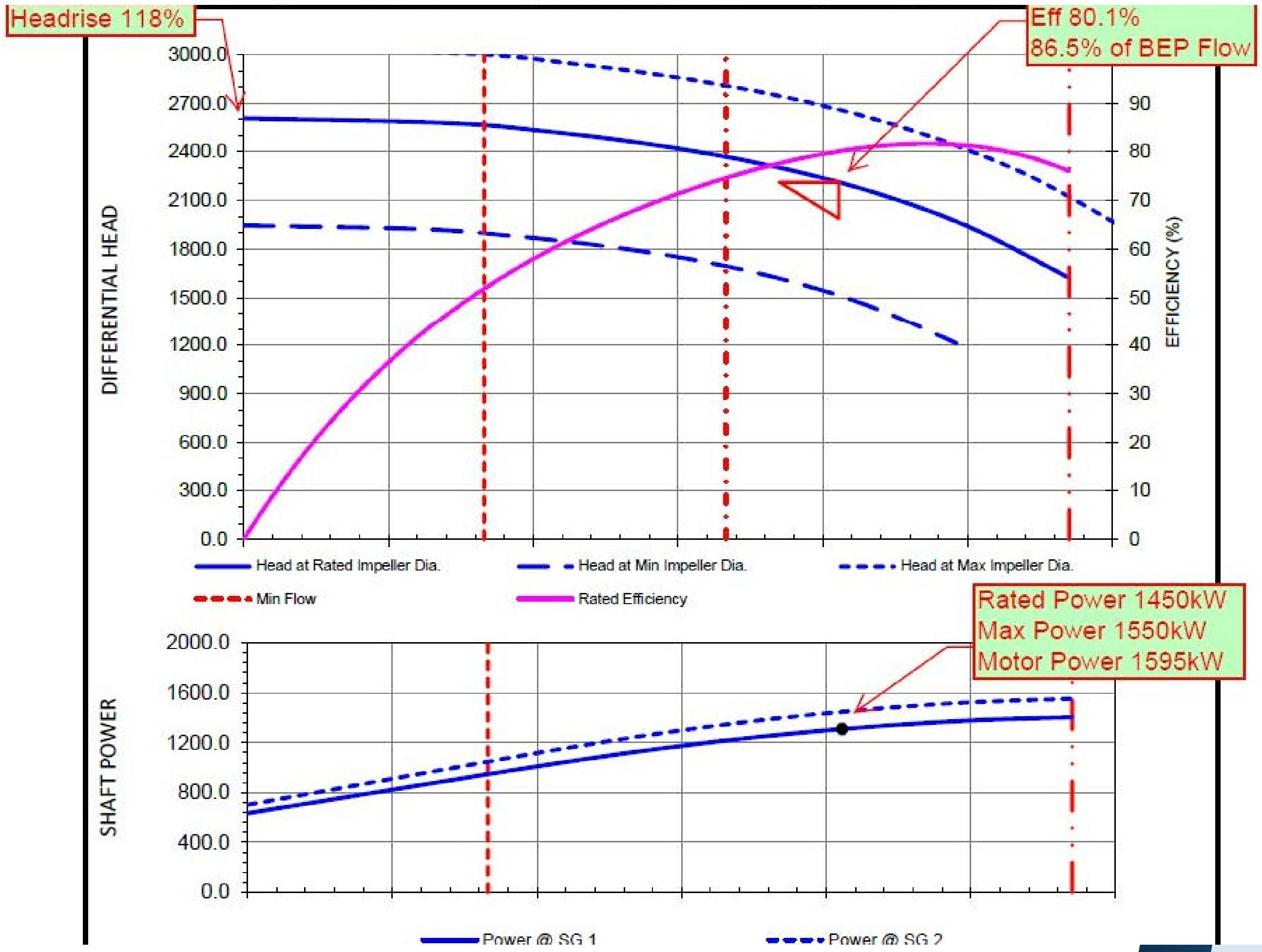
  * (Based on A216WCB Steel castings or A105 forged plate at 150 deg C)

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

# Real World Example

## How to get it wrong!

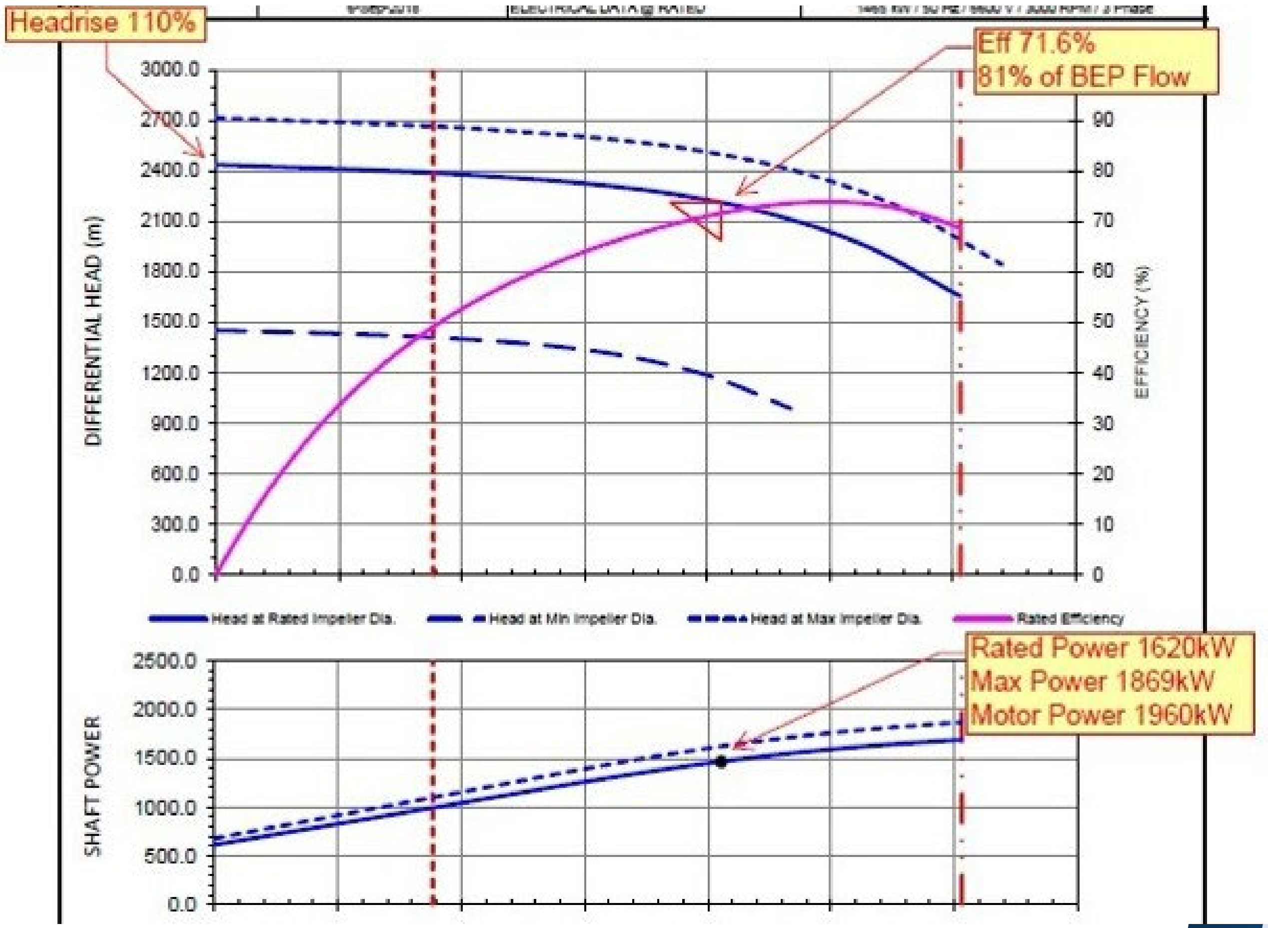
- Here is a pump on LNG sendout duty 411m3/hr @ 2212m, 1450kW
- With this pump and API tolerances pump MAWP was 150.4 Barg
- This selection was used for FEED, EPC Selection, and Purchase Stages.
- Only at the final pre-award meeting was it realised that …
- PMC had assumed 10% headrise to shutoff with 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

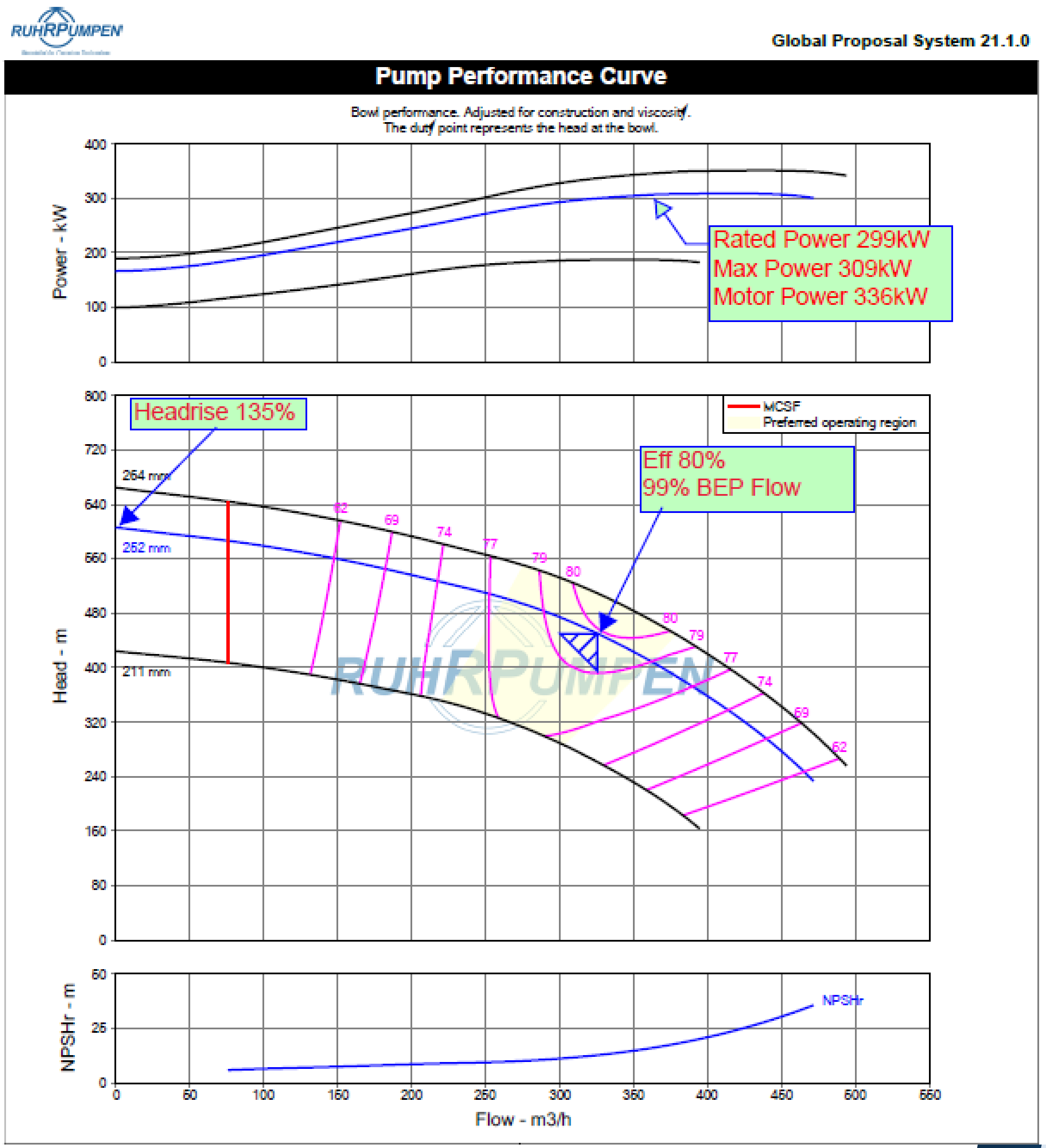
## How to get it wrong (2)!

- 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)



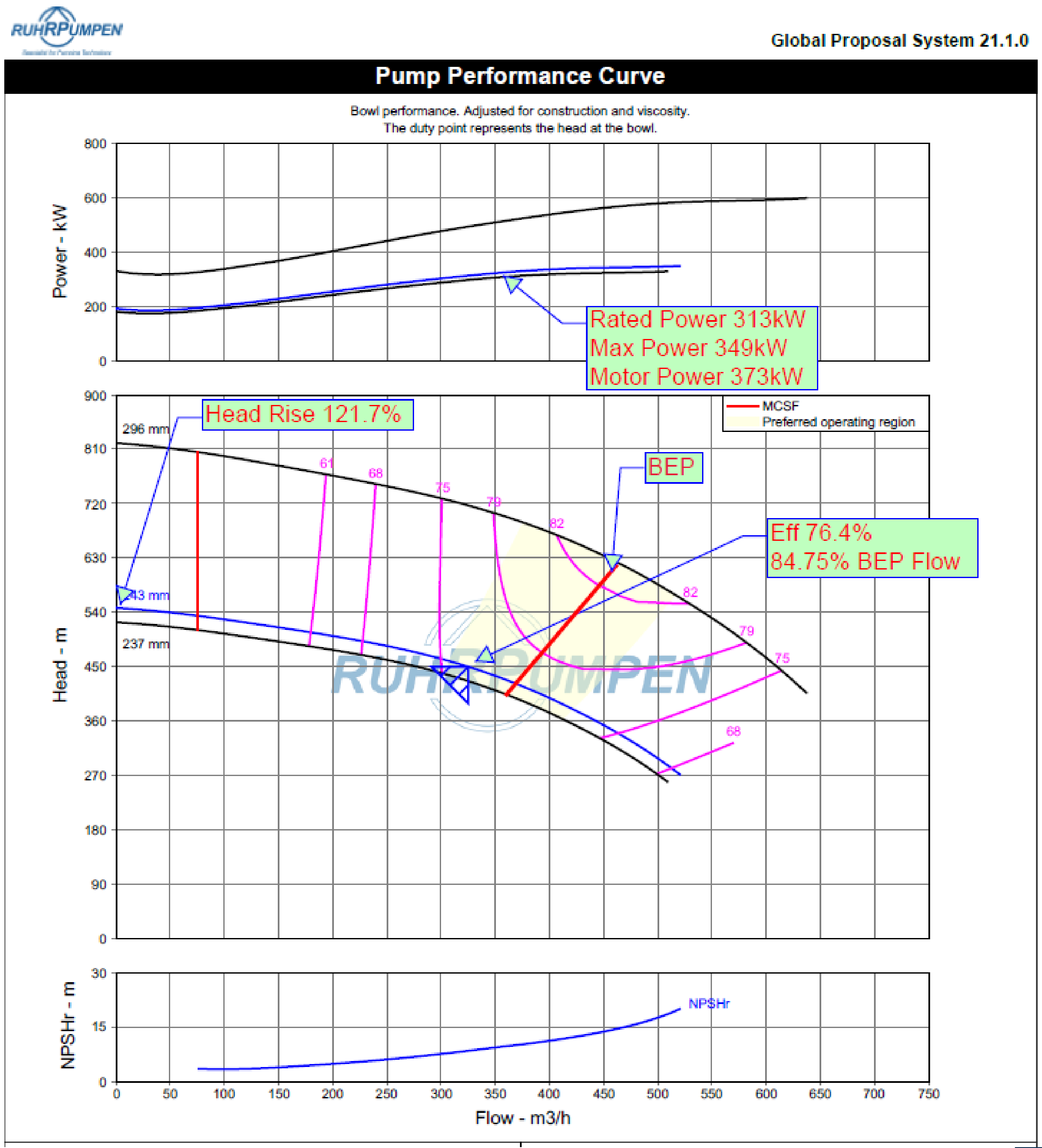
# How to Get it Wrong 2

- 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

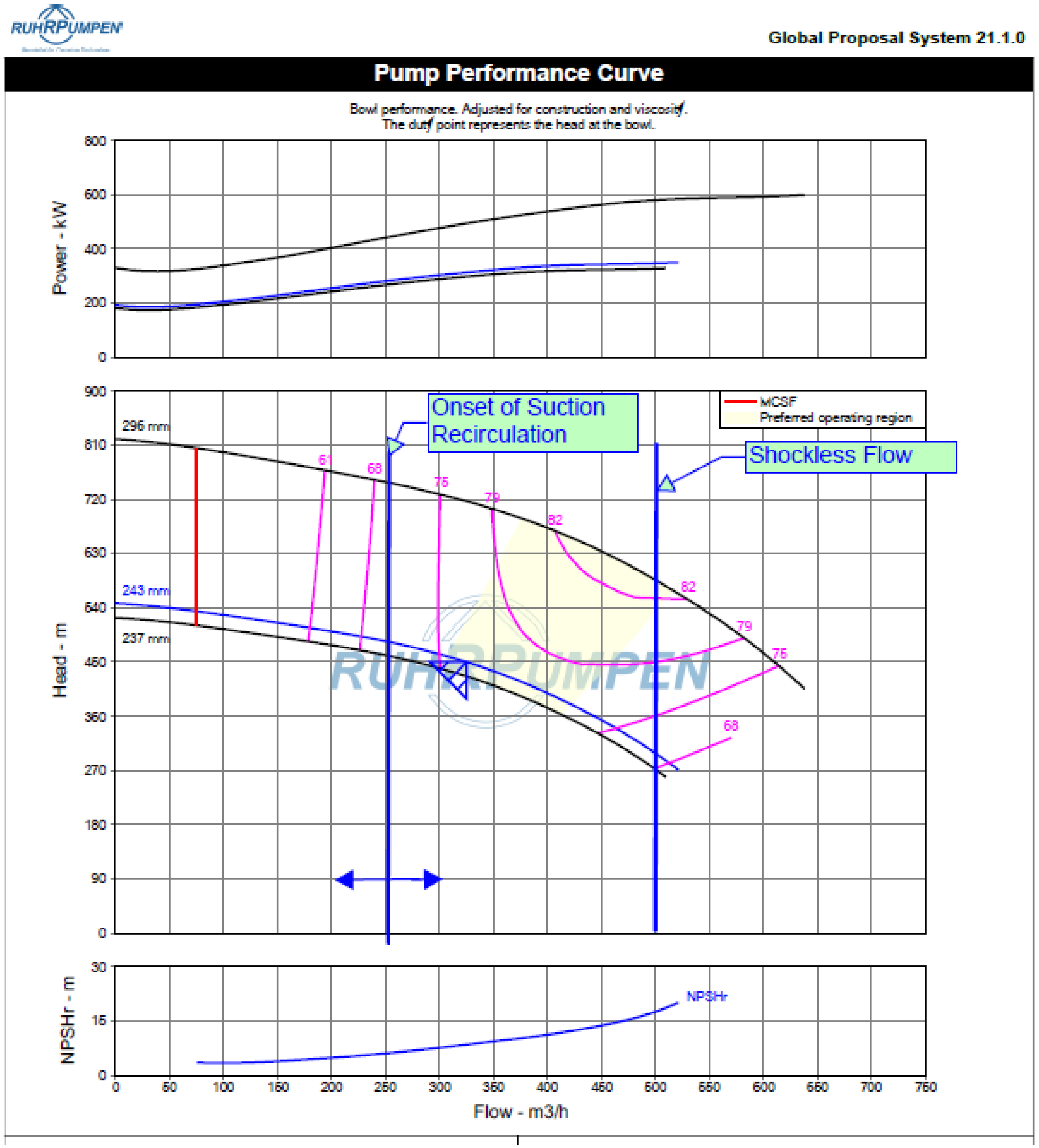
- Compromise selection
  - Next Frame Size up Pump
  - Rated Point 84.75% of BEP Flow (just within the “Preferred Operating Range”) instead of 99% BEP Flow
  - Efficiency 3.5 points lower
  - Power 27 kW higher
  - Motor rating 37 kW higher
  - Headrise 122% (still OK for parallel operation)
- An inexperienced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

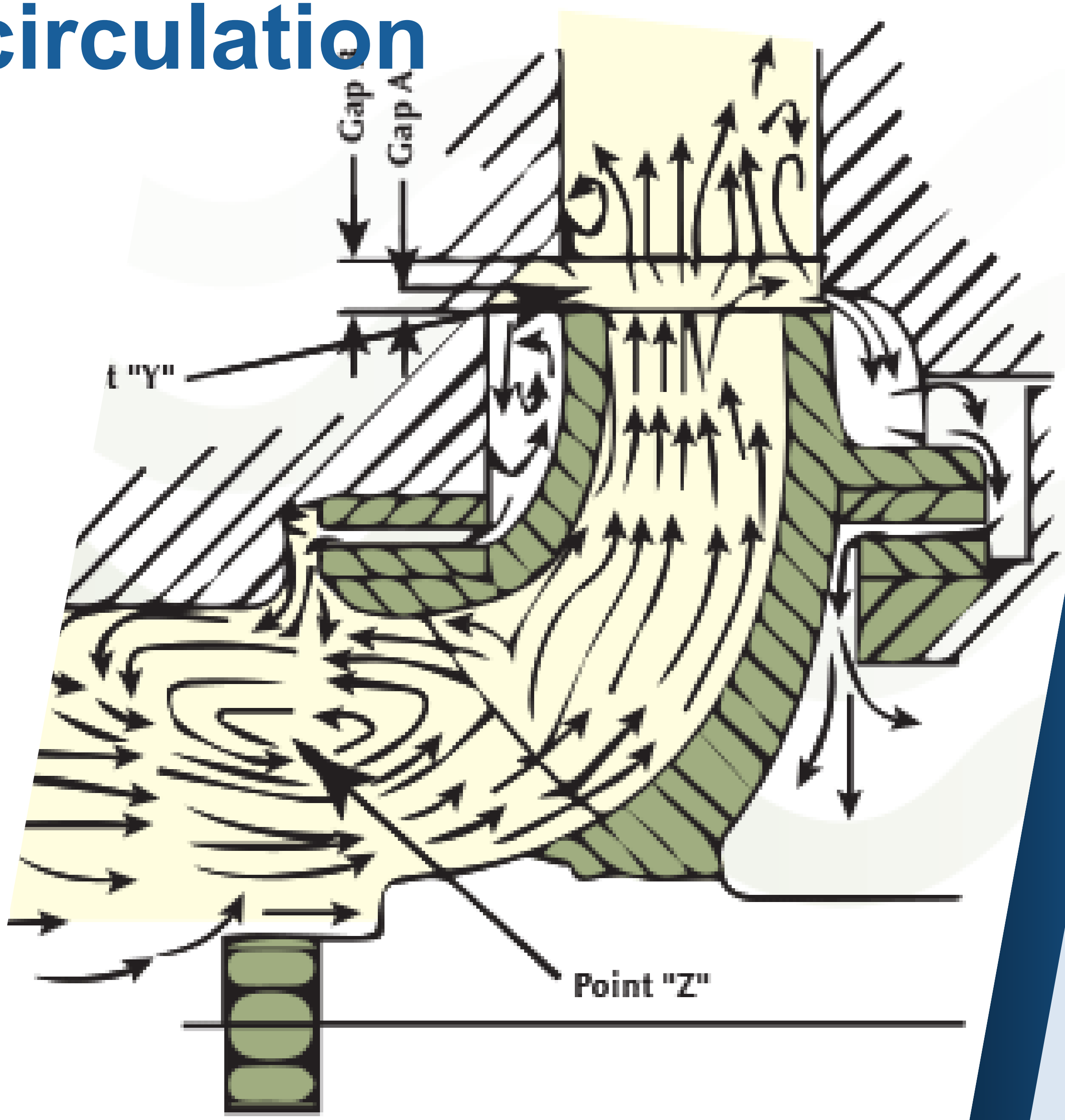


# Suction & Discharge Recirculation

## A Different kind of Cavitation

Occurs when pumps operate back on the curve from BEP

- When two flow paths within a fluid are moving in opposing directions and in close proximity to each other, vortices form.
- These vortices result in low pressure areas (where bubbles form) and high pressure areas (where they collapse).

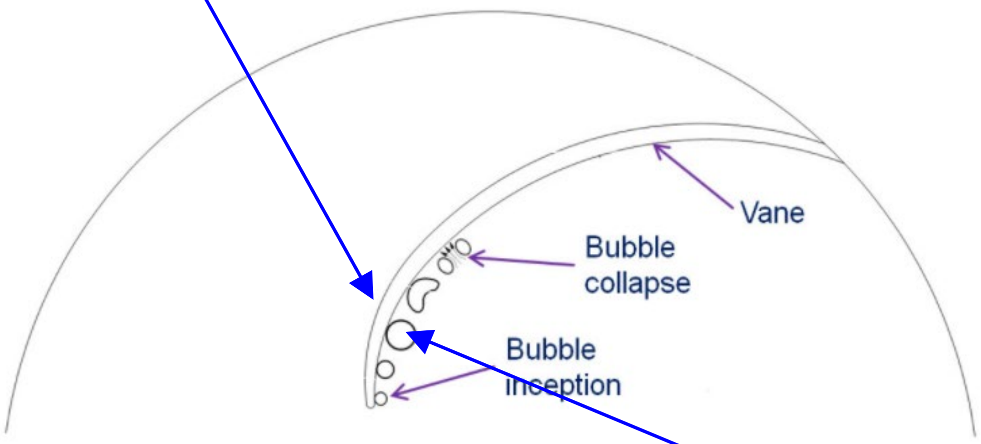



*Recirculation vortices at impeller suction eye and at vane tips (sourc*
*Handbook, Igor J. Karassik and Joseph P. Messina; ISBN-10 007033*

# Suction Recirculation

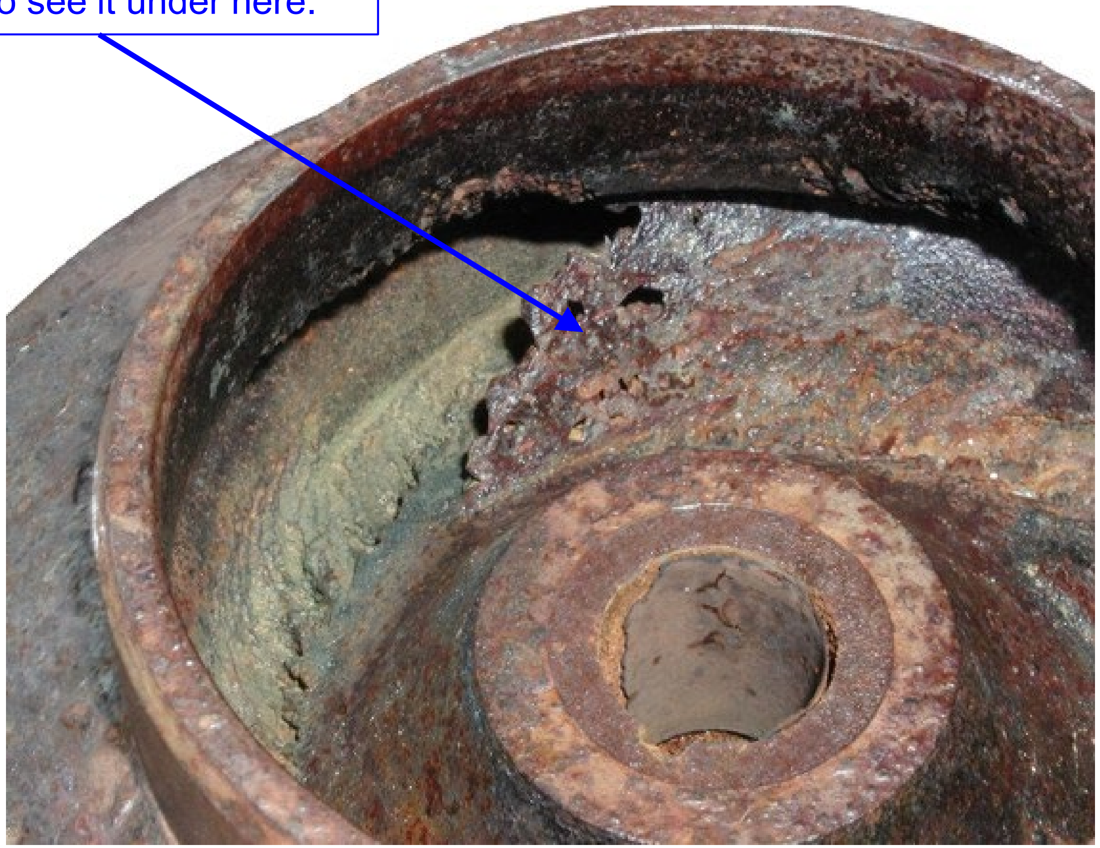
## A Different kind of Cavitation

Suction Recirculation Cavitation Damage appears on back side (pressure side) of vane



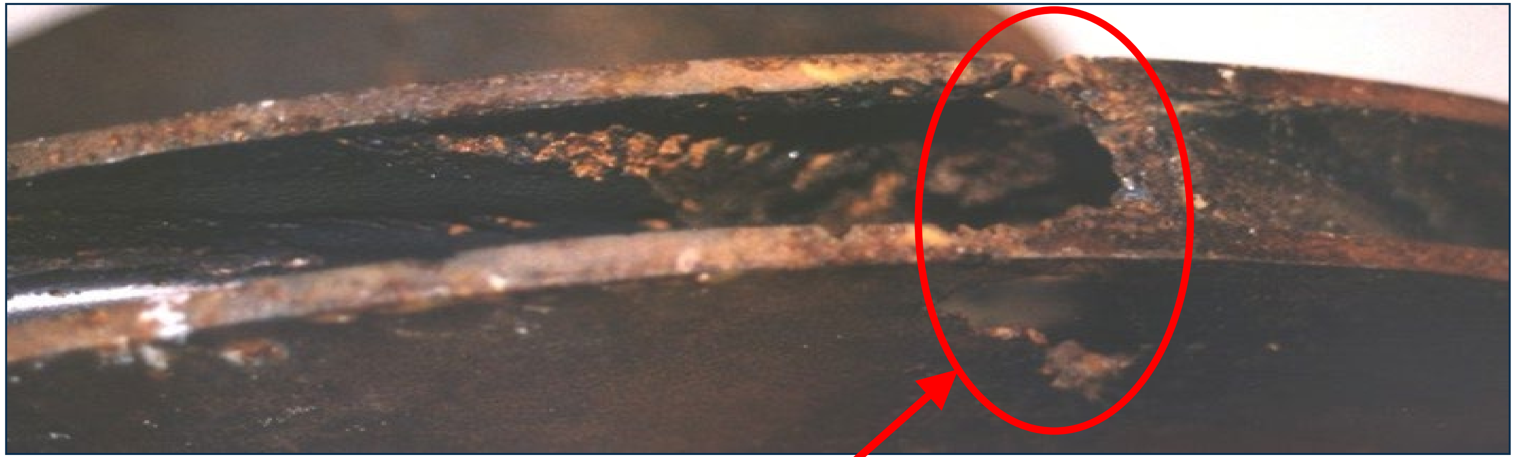

NPSH Cavitation Damage appears on front side (suction side) of vane

Suction Recirculation Cavitation Damage appears on back side (pressure side) of vane. You need a dentist's mirror to see it under here.



# Discharge Recirculation

## A Different kind of Cavitation



The central core of the Discharge Recirculation Vortex, is such a low pressure that the liquid starts to vapourise & as the bubbles move to the outer area of the vortex, where the pressure is much higher, they Cavitate (implode) against the Impeller Shrouds, and cause the hole damage shown.

# Summary

If you are a Process Engineer calculating the required pressure rating of equipment downstream of a pump – Then……

1. Start with the pump 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
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

   * (Based on A216WCB Steel castings or A105 forged plate at 150 deg C)
6. Don't specify "zero tolerances" or if you have no choice, discuss the implications and possible options with the pump vendors

# Coming Attractions ☺

## “Selecting the Right Pump for the Application”

Thurs 8th February – 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 & Sales Engineers selecting and quoting them. Develop an understanding as to which type of pump is appropriate for different applications.*

*Will cover such topics as when to transition from an OH2 to a BB2, when to consider VS6 pumps, Barrel vs Horizontal Split Case multi-stage pumps*

Future subjects in preparation include:

- API 610 12th Edition

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# Q & A

# RUHRPUMPEN AT A GLANCE

**VERTICAL INTEGRATION**

**SALES OFFICES** IN +35 COUNTRIES

MANUFACTURING **FACILITIES** IN 10 COUNTRIES

**+70 YEARS** OF EXPERIENCE

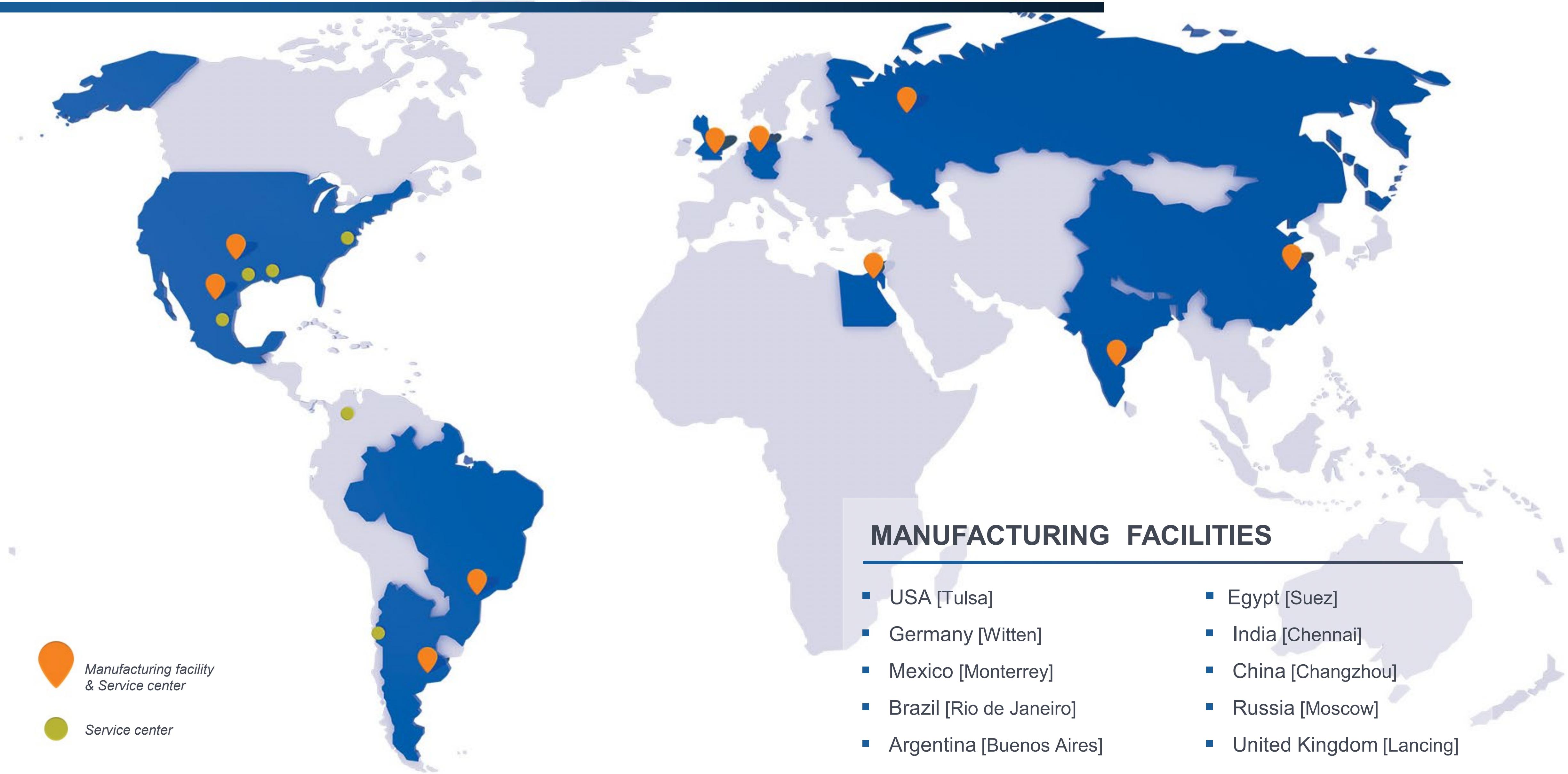
**+2,000** EMPLOYEES

15 **SERVICE CENTERS**

**+70,000** PUMPING SOLUTIONS INSTALLED WORLDWIDE

# A GLOBAL COMPANY

RUHRPUMPEN

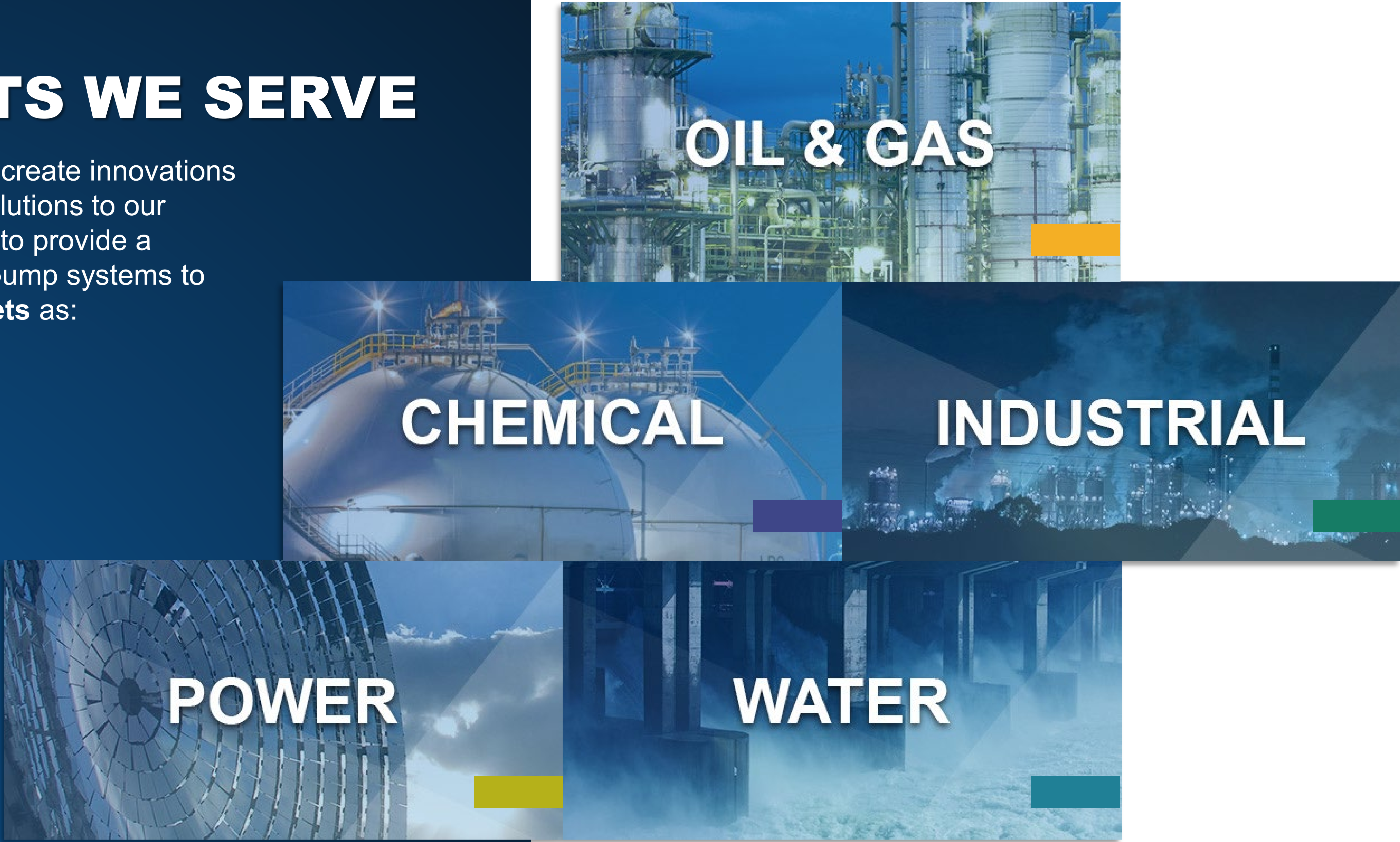



## MANUFACTURING FACILITIES

- USA [Tulsa]
- Germany [Witten]
- Mexico [Monterrey]
- Brazil [Rio de Janeiro]
- Argentina [Buenos Aires]
- Egypt [Suez]
- India [Chennai]
- China [Changzhou]
- Russia [Moscow]
- United Kingdom [Lancing]

# MARKETS WE SERVE

Our commitment to create innovations that offer reliable solutions to our customers allow us to provide a complete range of pump systems to support **core markets** as:




RUHRPUMPEN

# OUR PUMP LINES

**Ruhrpumpen offers a broad range of highly engineered and standard pumping products that meet and exceed the requirements of the most demanding quality specifications and industry standards.**

Our pumps can handle head requirements as high as 13,000 ft (4,000 m) and capacities up to 300,000 gpm (68,000 $m^3$/hr). Moreover, our pump designs cover temperatures from cryogenic temperatures of -310 °F (-196 °C) up to 752 °F (400 °C).

**Products include:**

- Single Stage Overhung Pumps
- Between Bearings Pumps
- Horizontal Multi-Stage Pumps
- Vertical Multi-Stage Pumps
- Vertical Mixed Flow & Axial Flow Pumps
- Positive Displacement Pumps
- Full Range of Industrial Pumps
- Submersible Pumps
- Magnetic Drive Pumps
- Decoking Systems
- Packaged Systems
- Fire Systems

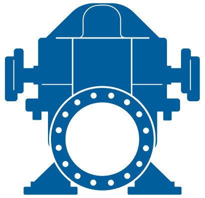
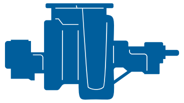
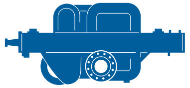
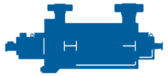
# OVERHUNG PUMPS

| CATEGORY | RP MODEL | DESIGN STANDARD |
|---|---|---|
| Sealless Magnetic Drive Pumps | **CRP-M / CRP-M-CC** | ISO 2858 & 15783<br>HI design (OH11) |
| | **SCE-M** | API 685 |
| Foot Mounted OH1 and General End Suction Pumps | **IPP** | HI design (OH1) |
| | **CPP / CPP-L** | HI design (OH1)<br>ANSI B73.1 |
| | **CPO / CPO-L** | HI design (OH1)<br>ANSI B73.1 |
| | **CRP** | HI design (OH1)<br>ISO 2858 & 5199 |
| | **GSD** | HI design (OH0) |
| | **SHD / ESK / SK / SKO SKV / ST / STV** | HI design (OH1) |
| | **SWP** | HI design (OH3A) |
| Centerline Mounted | **SCE** | API 610 (OH2) |
| Vertical In-Line Pumps | **SPI** | API 610 (OH3) |
| | **IVP / IVP-CC** | HI design (OH4 / OH5) |
| | **IIL** | HI design (OH5)<br>Dimensionally compliant with ANSI B73.2 |
| | **SPN** | API 610 (OH5) |




OUR PUMPS

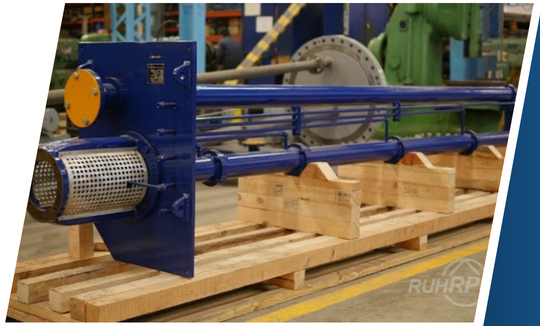
# BETWEEN BEARING PUMPS

| CATEGORY | | RP MODEL | DESIGN STANDARD | |
|---|---|---|---|---|
| 1 and 2 stage | Axially split | **HSC / HSD / HSL HSR / ZW** | HI design (BB1) |  |
| | | **HSM** | HI design (BB3) | |
| | | **ZM / ZMS ZLM / ZME** | API design (BB1) | |
| | Radially split | **HVN / J** | API design (BB2) |  |
| | | **RON / RON-D** | API design (BB2) | |
| Multi-stage | Axially split | **SM / SM-I** | API design (BB3) |  |
| | | **JTN** | API design (BB3) | |
| | Radially split *single casing* | **GP** | API design (BB4) |  |
| | Radially split *double casing* | **A LINE** | API design (BB5) |  |

OUR PUMPS

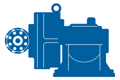
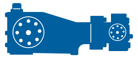
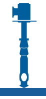
# VERTICAL PUMPS

| CATEGORY | | RP MODEL | DESIGN STANDARD |
|---|---|---|---|
| Single casing | Diffuser | **VTP** | HI & API 610 (VS1) |
| | | **VCT** | HI & API 610 (VS1) |
| | | **HQ** | HI & API 610 (VS1) |
| | | **VLT** | HI & API 610 (VS1) |
| | Volute | **DSV / DX** | HI & API 610 (VS2) |
| | Discharge through column – Axial flow | **VAF** | HI & API 610 (VS3) |
| | Separate discharge line | **VSP / VSP-Chem** | HI & API 610 (VS4) |
| Double casing | Diffuser | **VLT / VMT** | HI & API 610 (VS6) |
| | Volute | **DSV / DX** | HI & API 610 (VS7) |
| Submersible pumps | | **SMF** | HI design (OH8A) |
| | | **VLT-Sub / VTP-Sub** | HI design (VS0) |



OUR PUMPS

# SPECIAL SERVICE PUMPS

| CATEGORY | RP MODEL | DESIGN STANDARD | |
|---|---|---|---|
| Pitot tube pumps | **COMBITUBE** | HI design |  |
| Reciprocating pumps | **RDP** | API 674<br>ISO 13710 |  |
| Vertical turbine generator | **VTG** | HI design (VS6) |  |
| Barge | **LS BARGE** | HI design |  |
| Floating dock pumps | **ZVZ** | HI design |  |
| | **LVZ** | HI design |  |
| Cryogenic pumps | **SVNV** | - | |
| | **VTG Cryogenic** | - |  |
| | **VLT Cryogenic VLTV** | - | |
| Pre-packaged fire pump systems | Fire systems incorporate pumps, drivers, control systems and pipework in a single container. They can be skid mounted, with or without enclosure and supplied with electric motor or diesel engine. | **NFPA-20-850**<br>UL and FM approved components |  |