RUHRPUMPEN

Specialist for Pumping Technology

The Importance of Using System Curves in Pump Selection and on Successful Pump Operation (2)

Simon Smith October 2023







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.

RUHRPUMPEN

RuhRPumpen Short Courses

Here is a listing of all the previous courses.

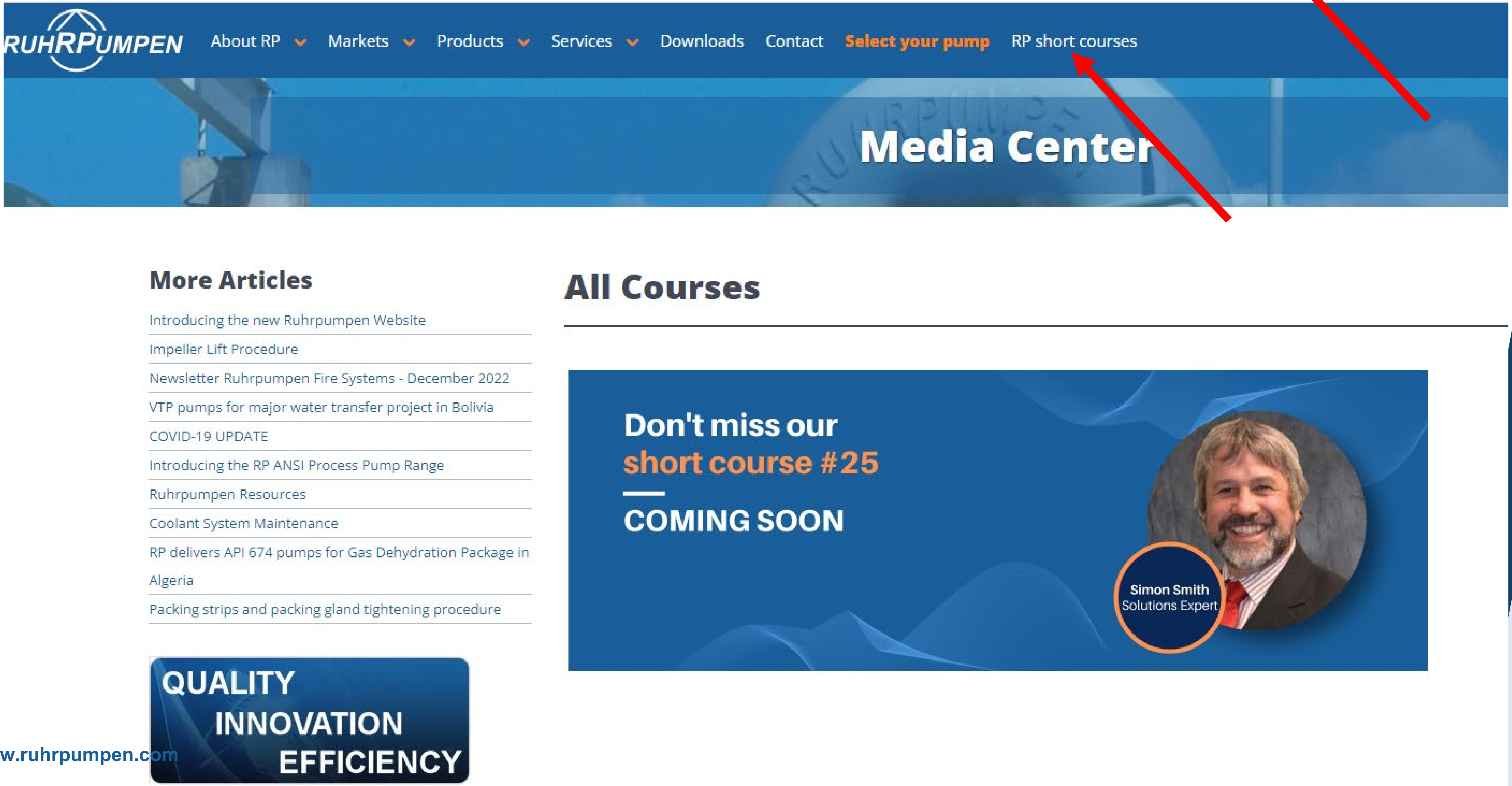
- No 1 – API610 12th v 11th editions
- No 2 - Curve Shape
- No 3 – The Importance of System Curves (1)
- No 4 - Selecting the Right Pump for the Application
- No 5 - NPSH & Nss
- No 6 - Mechanical Seals & Systems (1)
- No 7 - Firepumps
- No 8 - BB5 Barrel Pumps
- No 9 - Pump Instrumentation
- No 10 – 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
- 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)

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

Ruh*RP*umpen Short Courses

www.ruhrpumpen.com



RuhRPumpen Short Courses

https://short-courses.ruhrpumpen.com/

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)

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SHORT COURSE 14

Performance Testing and Inspection of API 610 Pumps

Full session.

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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.

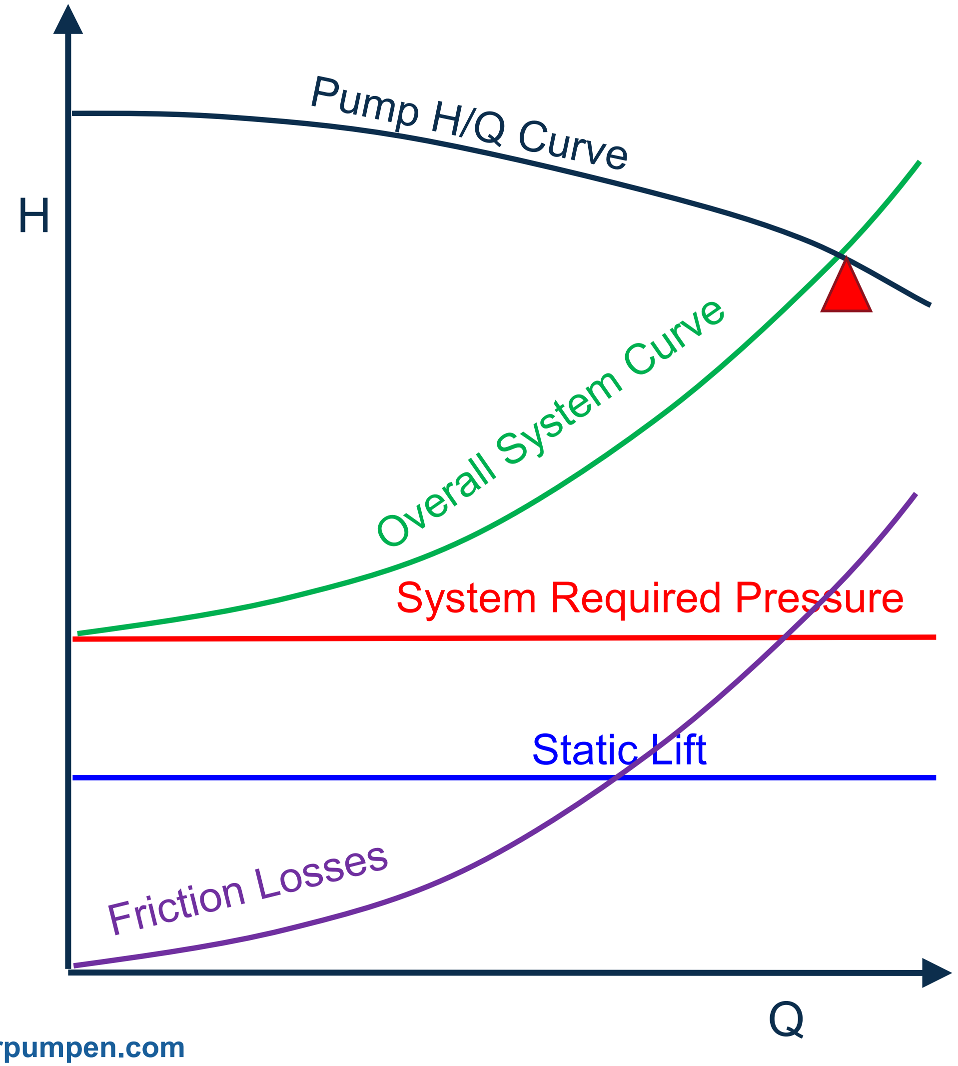
Downloads. (10.50 MB)

“The Importance of Using System Curves in Pump Selection and on Successful Pump Operation”

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

1- System Curves

System Head Curve



Calculating Pipeline Friction Losses

The **Hazen-Williams** head loss equation is as follows:

$$H = \frac{10.583 * L * Q^{1.85}}{C^{1.85} * d^{4.87}}$$ (for metric units)

or

$$H = \frac{4.72 * L * Q^{1.85}}{C^{1.85} * d^{4.87}}$$ (for imperial units)

H = head loss (m or ft) in pipe
L = length of pipe (m or ft)
d = diameter of pipe (m or ft)
Q = flow rate in the pipe (m3/s or cfs)
C = Hazen-Williams roughness coefficient

The Hazen-Williams coefficient C varies from about 150 for smooth pipes, to about 70 for very rough pipes

Works for water. Unreliable for hydrocarbons.

Calculating Pipeline Friction Losses

Darcy Weisbach Formula

The Darcy formula or the Darcy-Weisbach equation as it tends to be referred to, is now accepted as the most accurate pipe friction loss formula, and although more difficult to calculate and use than other friction loss formula, with the introduction of computers, it has now become the standard equation for hydraulic engineers. Weisbach first proposed the relationship that we now know as the Darcy-Weisbach equation or the Darcy-Weisbach formula, for calculating friction loss in a pipe.

Darcy-Weisbach equation:

hf = f (L/D) x (v^2/2g)

where:

hf = head loss (m)
f = friction factor
L = length of pipe work (m)
d = inner diameter of pipe work (m)
v = velocity of fluid (m/s)
g = acceleration due to gravity (m/s²)

or:

hf = head loss (ft)
f = friction factor
L = length of pipe work (ft)
d = inner diameter of pipe work (ft)
v = velocity of fluid (ft/s)
g = acceleration due to gravity (ft/s²)

Calculating Pipeline Friction Losses

On-Line Resources

For water-

There is no shortage of website calculation tools that will calculate the friction loss in a ***straight length of pipe.***

But so far, I have found only ONE that will also calculate the losses in the bends, elbows, valves, tees and fittings that are in every piping system.

Here is the link to that site

https://allpumps.com.au/friction-loss-calculator/

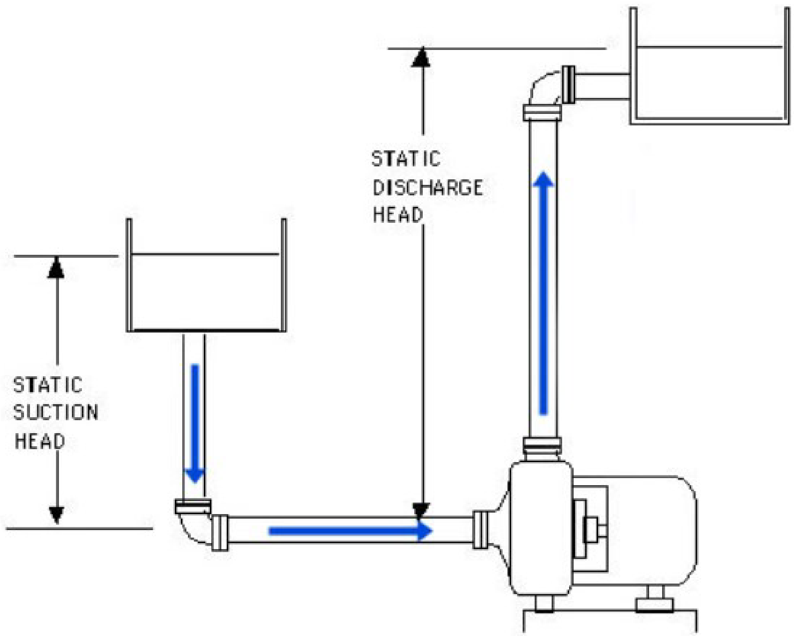
Calculating Pipeline Friction Losses

On-Line Resources

ALL-PUMPS APPLICATIONS PRODUCTS MAINTENANCE CAPABILITIES RESOURCES ABOUT

FRICTION LOSS CALCULATOR

All-Pumps » Friction Loss Calculator



Friction loss is the loss of energy or “head” that occurs in pipe flow due to viscous effects generated by the surface of the pipe. Friction Loss is considered as a “major loss”.

“Head” is a very convenient term in the pumping business. Pressure is not as convenient a term because the amount of pressure that the pump will deliver is dependent upon the weight (specific gravity) of the liquid being pumped and as you know, the specific gravity changes with the fluid temperature and concentration.

Each litre of liquid has weight so we can easily calculate the kilograms per minute being pumped. Head or height is measure in meters so if we multiply these two together we get kilogram meters per minute which converts directly to work at the rate of 610 kgM/min = 1 kilowatt.

Please note that we always measure from the center-line of the pump impeller to the highest liquid level.

Calculating Pipeline Friction Losses

On-Line Resources

ALL-PUMPS

APPLICATIONS · PRODUCTS · MAINTENANCE CAPABILITIES · RESOURCES · ABOUT

FLOW RATE (Q) - cu.m/hr	Converted cu.m/s
200	0.05555556
Kinematic Viscosity (v) - cst	**Converted sq.m./s**
5	0.00000500
Pipe Diameter (D) - mm	**Converted m**
100	0.10000000
Pipe Length (L) - m	**SELECT PIPE MATERIAL**
200	Carbon Steel (New)

Specific Roughness (ε) - m	AVE. VELOCITY (V) - m/s	REYNOLDS NUMBER (Re)	DARCY FRICTION FACTOR (f)
0.00002	7.07355359	141471.07180000	0.02066988

Angle Valve	Elbow 45 deg
0	3
0	3.060254458140789
Foot Valve	**Pipe Entrance, sharp edge**
0	2
0	2.550212048450657
Ball Valve, Full Port	**Elbow 90 Deg Long Radius**
0	4
0	6.120508916281577

Calculating Pipeline Friction Losses

On-Line Resources

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Gate Valve	2	1.020084819380263	Pipe Exit	Qty	0
Butterfly Valve	Qty	0	Elbow 90 Deg, Standard	2	4.590381687211183
Globe Valve	Qty	0	Tee, Standard, Flow Through Branch	2	9.180763374422366
Check Valve, Swing	2	11.730975422873023	Flow Meter, Turbine Type	1	17.8514843391546
Pipe Entrance, Inward projected pipe	1	2.550212048450657	Tee, Standard, Flow Through Run	Qty	0

TOTAL VELOCITY HEAD LOSS IN ALL FITTINGS - m

58.65487711

TOTAL VELOCITY HEAD LOSS IN ALL STRAIGHT PIPE - m

105.42515403

TOTAL HEAD LOSS IN PIPELINE - m

164.08003114

On-Line Resources

Calculating Pipeline Friction Losses

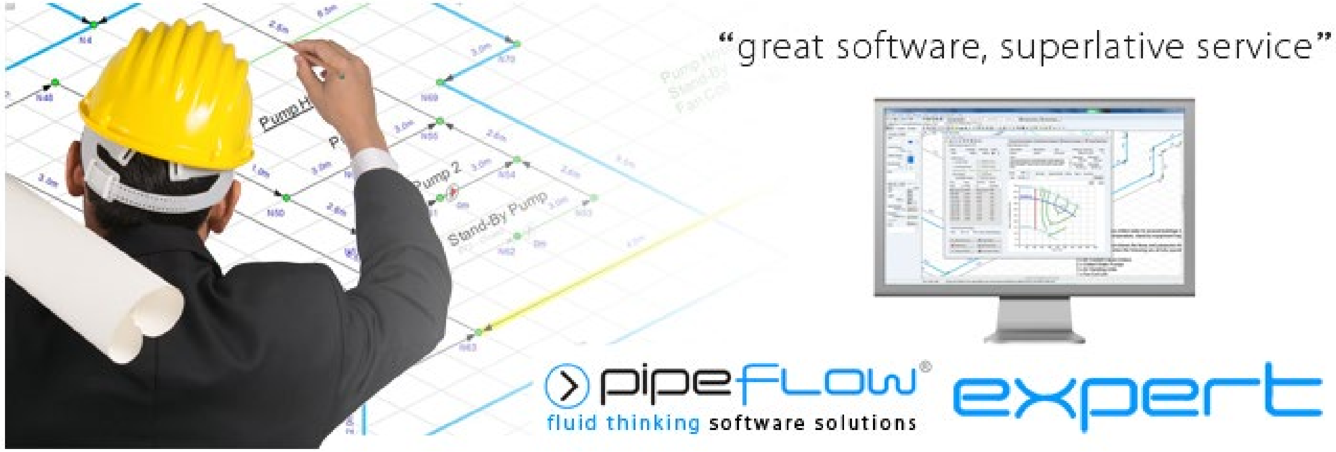
For Hydrocarbons-

This page is worth a look

https://www.pipeflow.com/pipe-pressure-drop-calculations/pipe-friction-loss

You can download a trial copy of the software package to evaluate

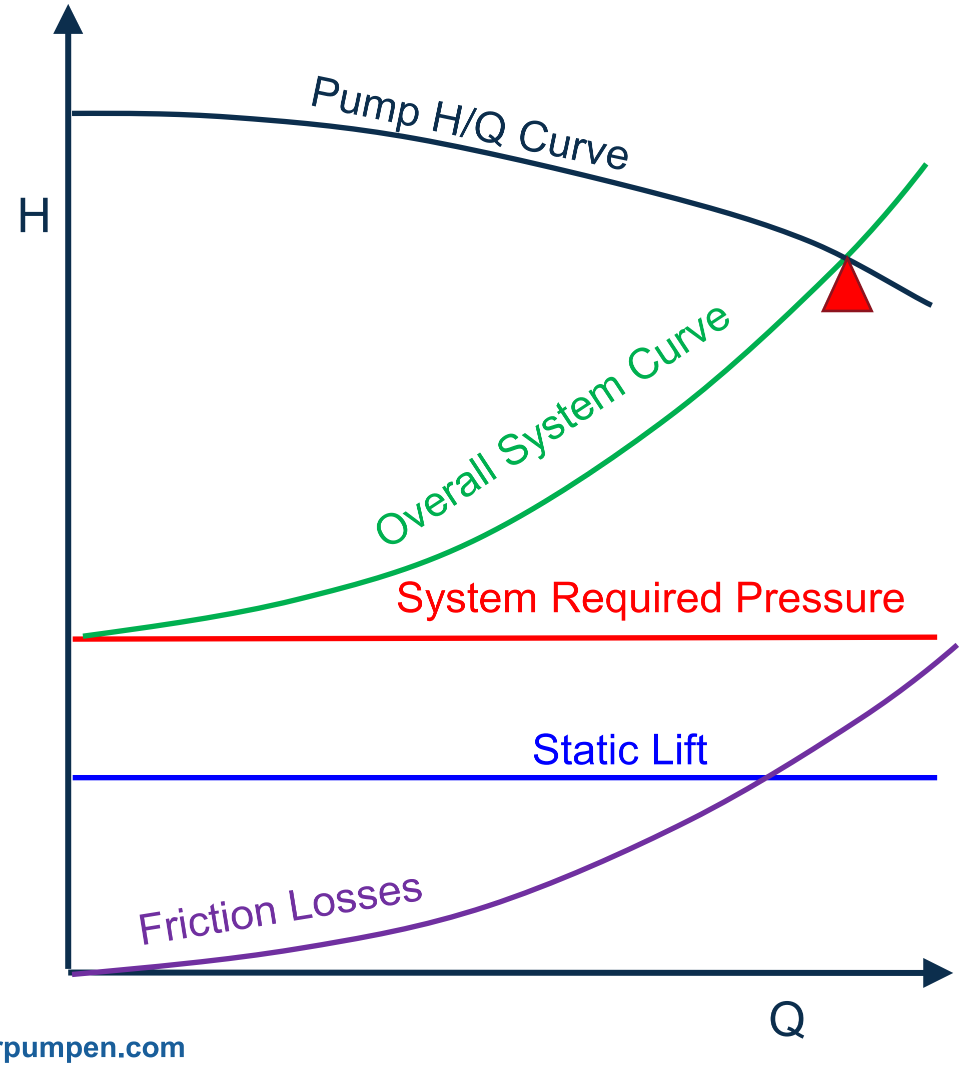
Pipe Flow Software: System Flow Rate & Pipe Pressure Drop Calculators

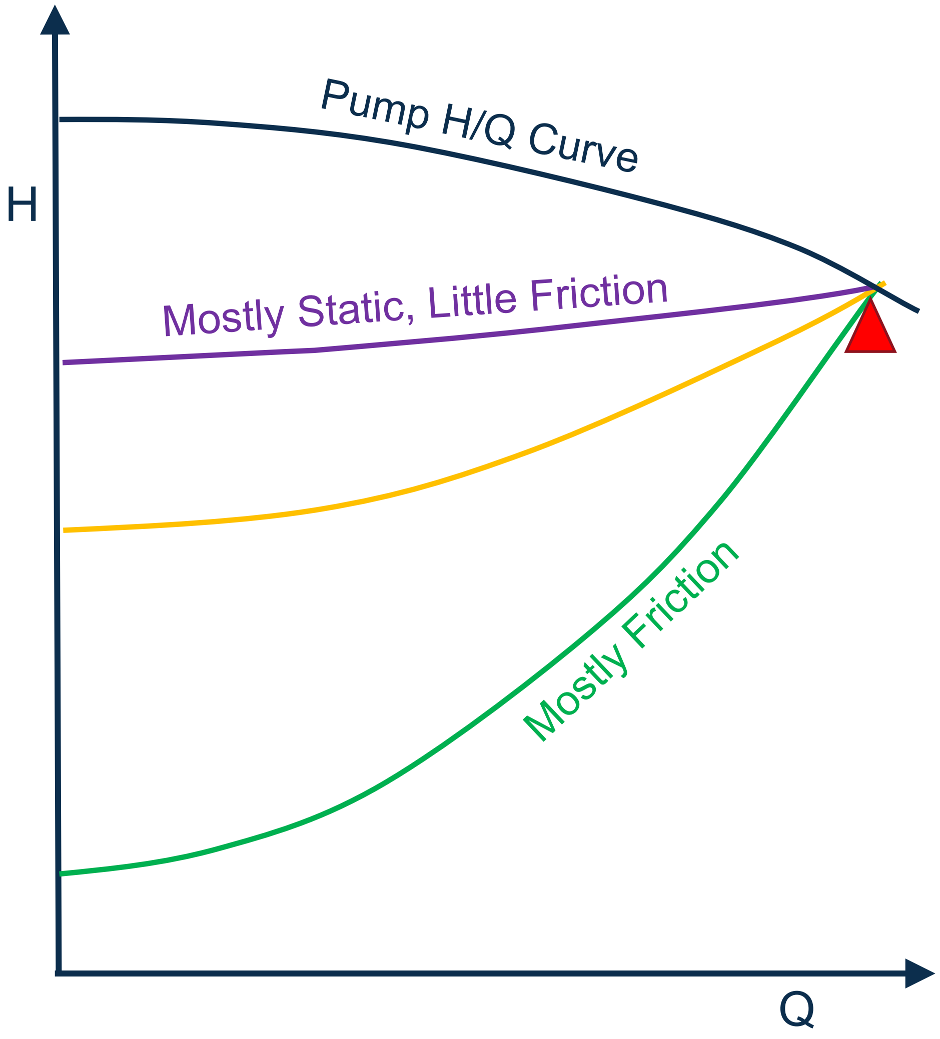


Pipe Flow Expert Software is used by pipe system designers & hydraulic engineers in over 100 countries worldwide. The software calculates flow rates, pipe pressure drops, and pump performance. It can model pipe systems with multiple supply points, discharge tanks, components, valves, & multiple pumps in series or in parallel.

USER TESTIMONIALS | FREE TRIAL | BUY NOW | RENEW LICENSE

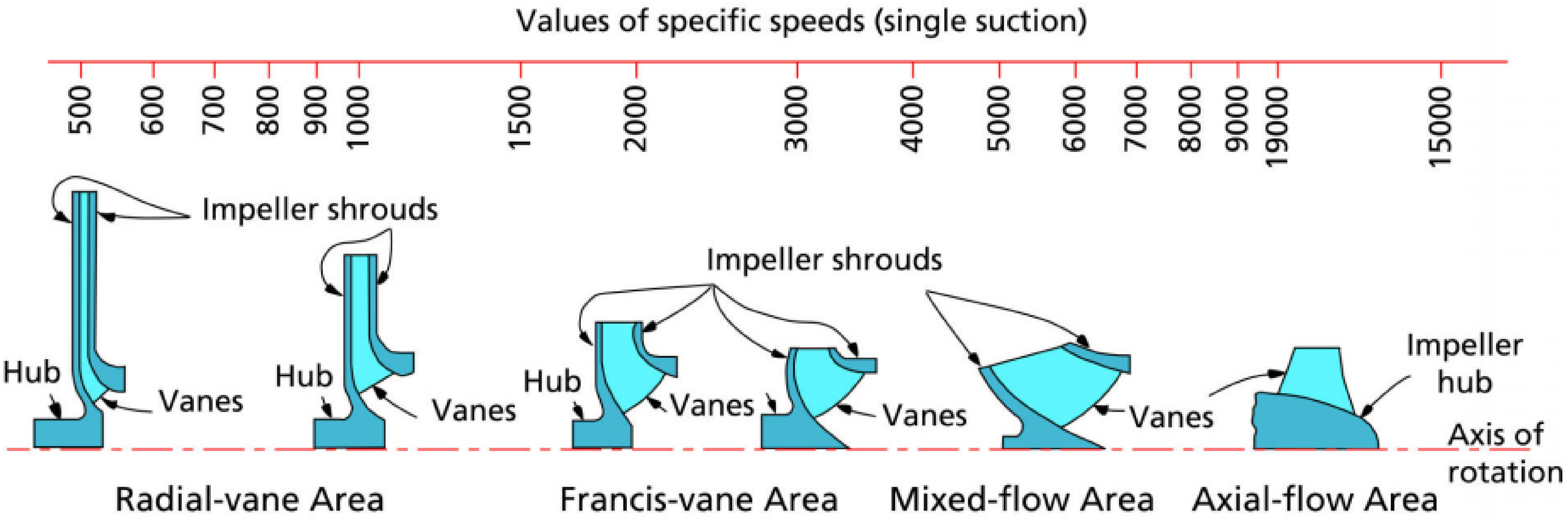
System Head Curve





2- Pump Curve Shapes

Pump Curve Shape vs Specific Speed

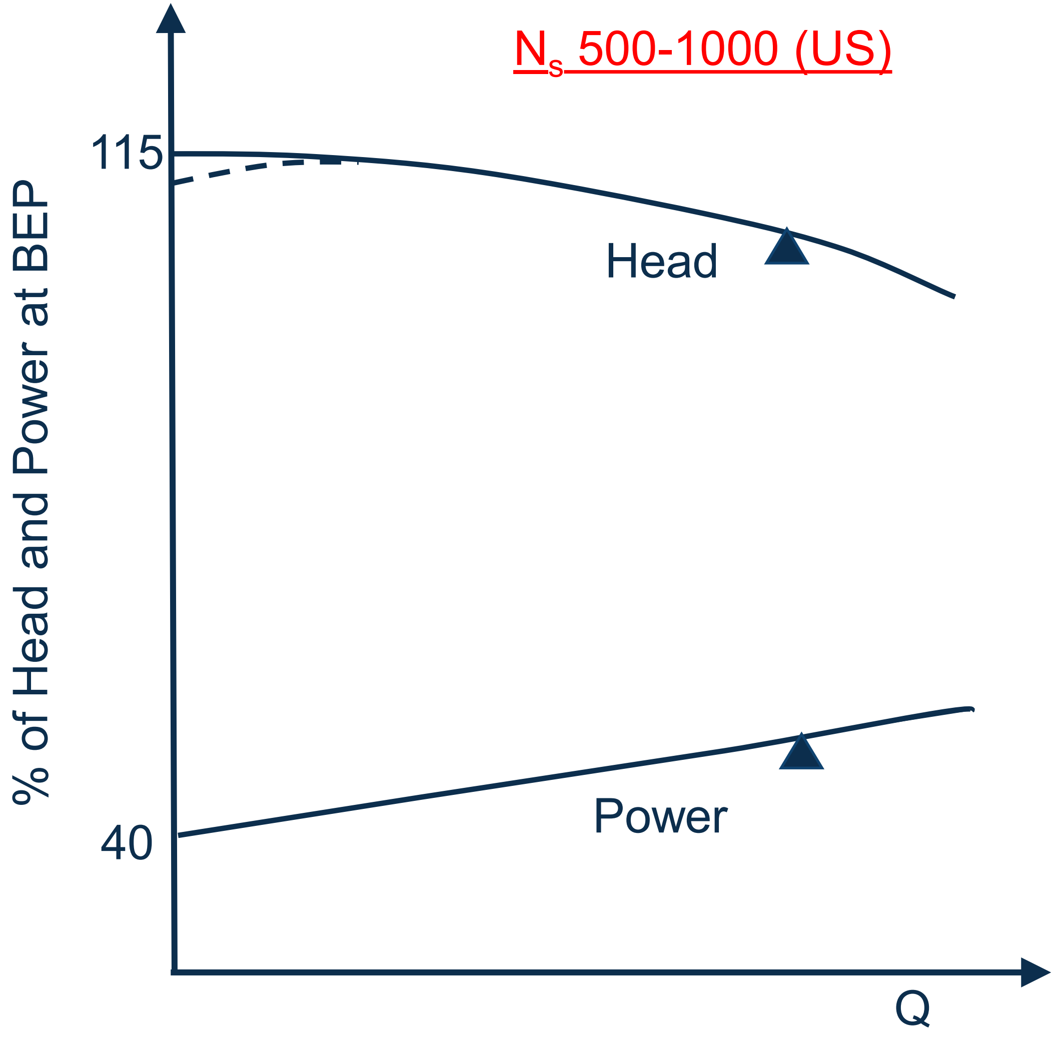


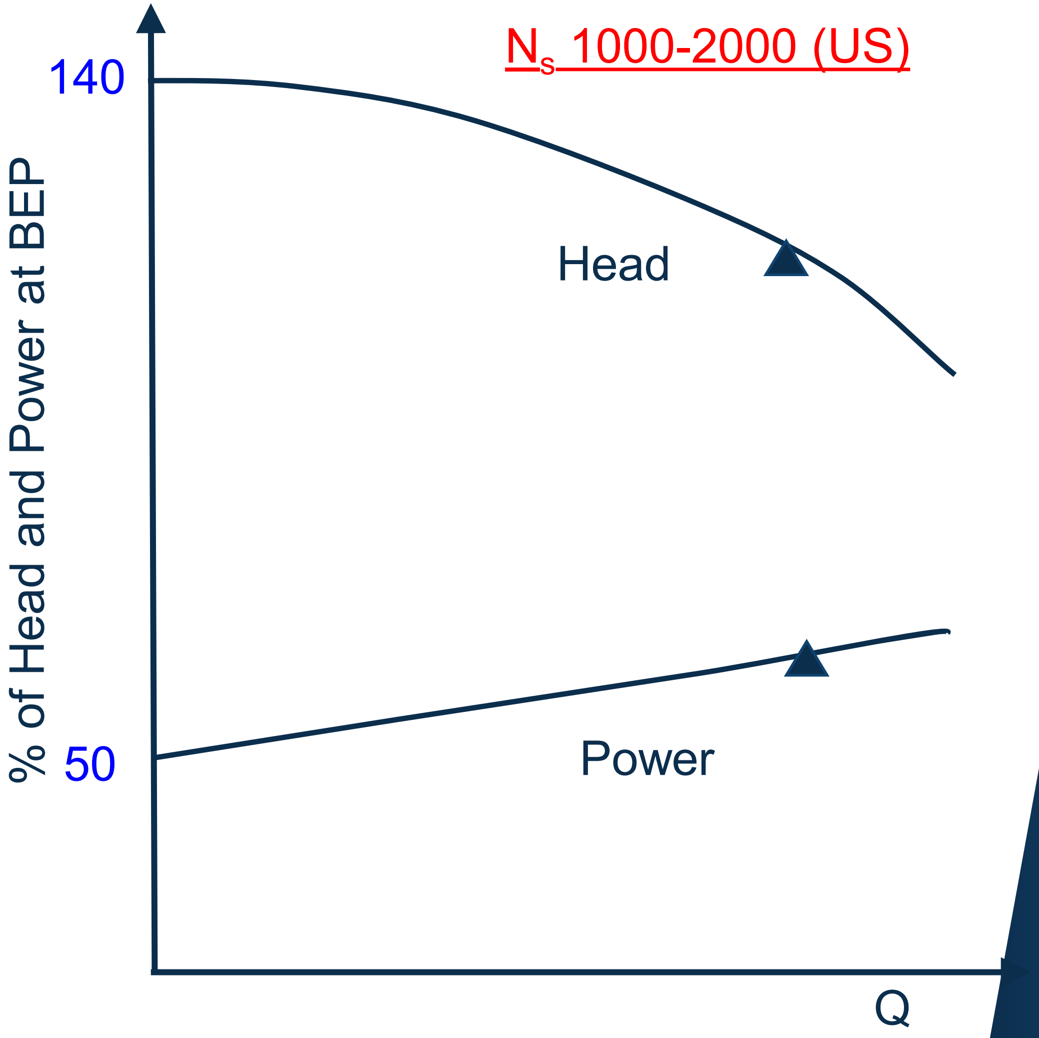
$N_S = N_{(RPM)}\, Q_{(BEP\ Full\ Dia)}^{\ 0.5} / H_{(BEP\ Full\ Dia)}^{\ 0.75}$

$N_{S(Metric)} = N_{S(US)} \times 1.16$ (m^3/hr, m, rpm)

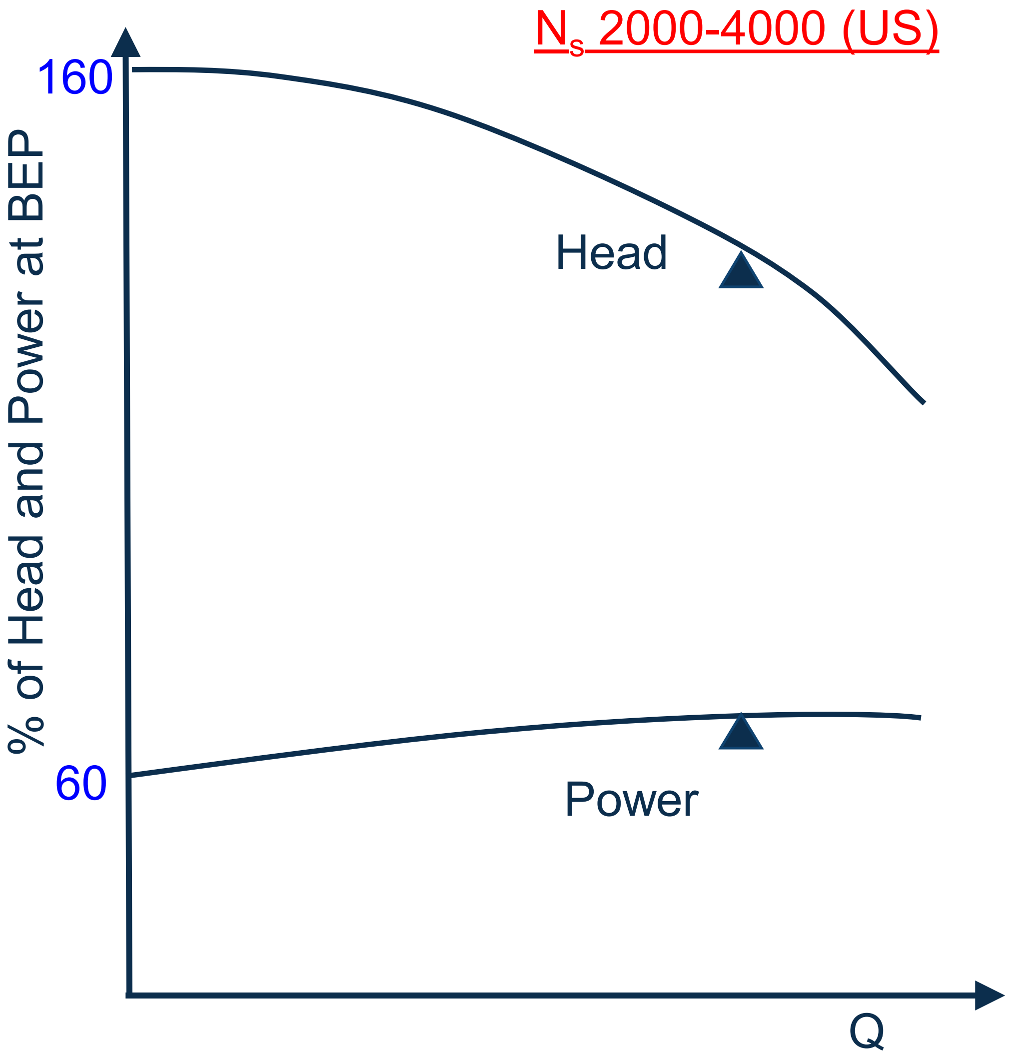
$N_{S(Metric)} = N_{S(US)} \times 0.02$ (m^3/s, m, rpm)

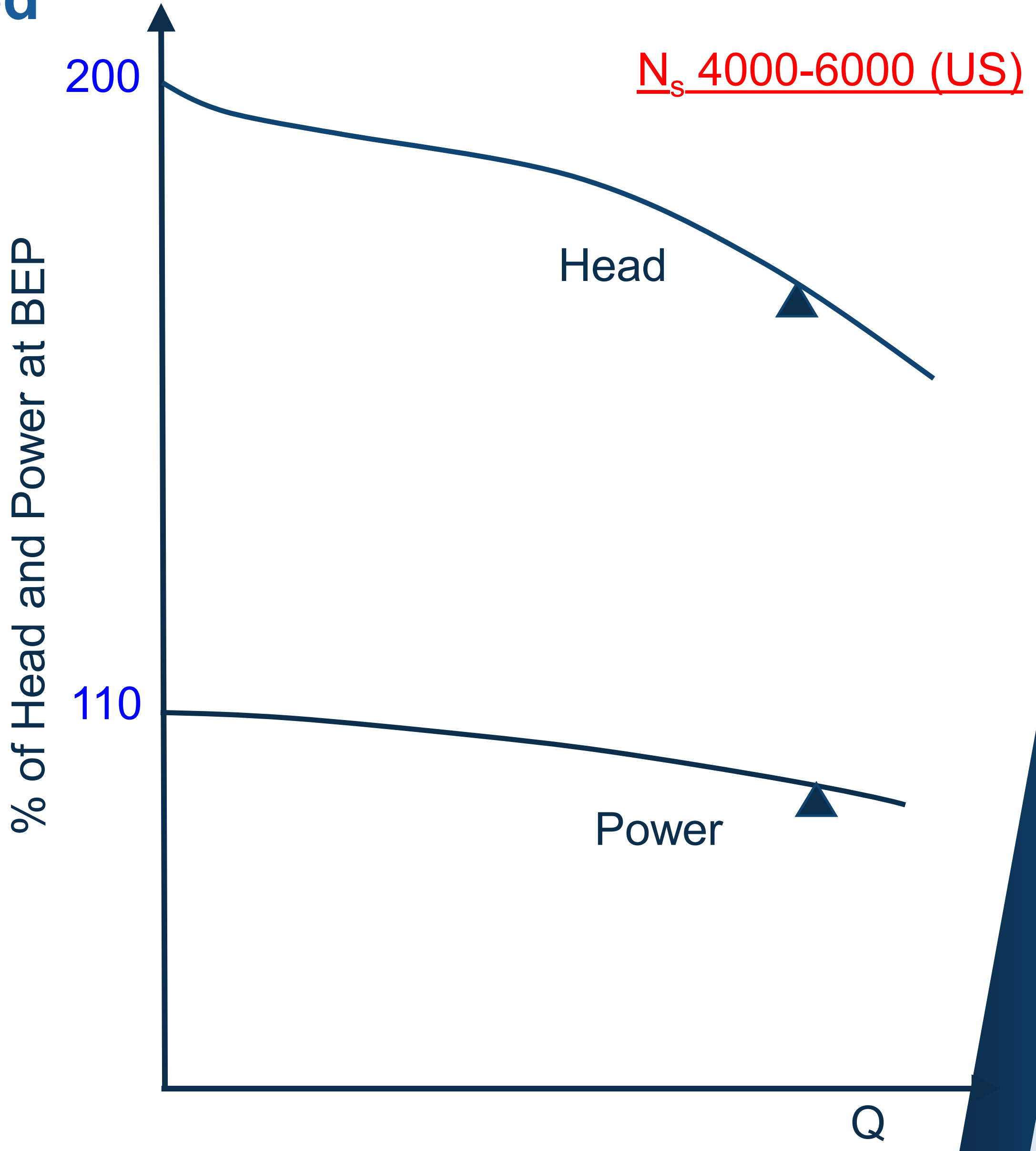
Pump Curve Shape vs Specific Speed



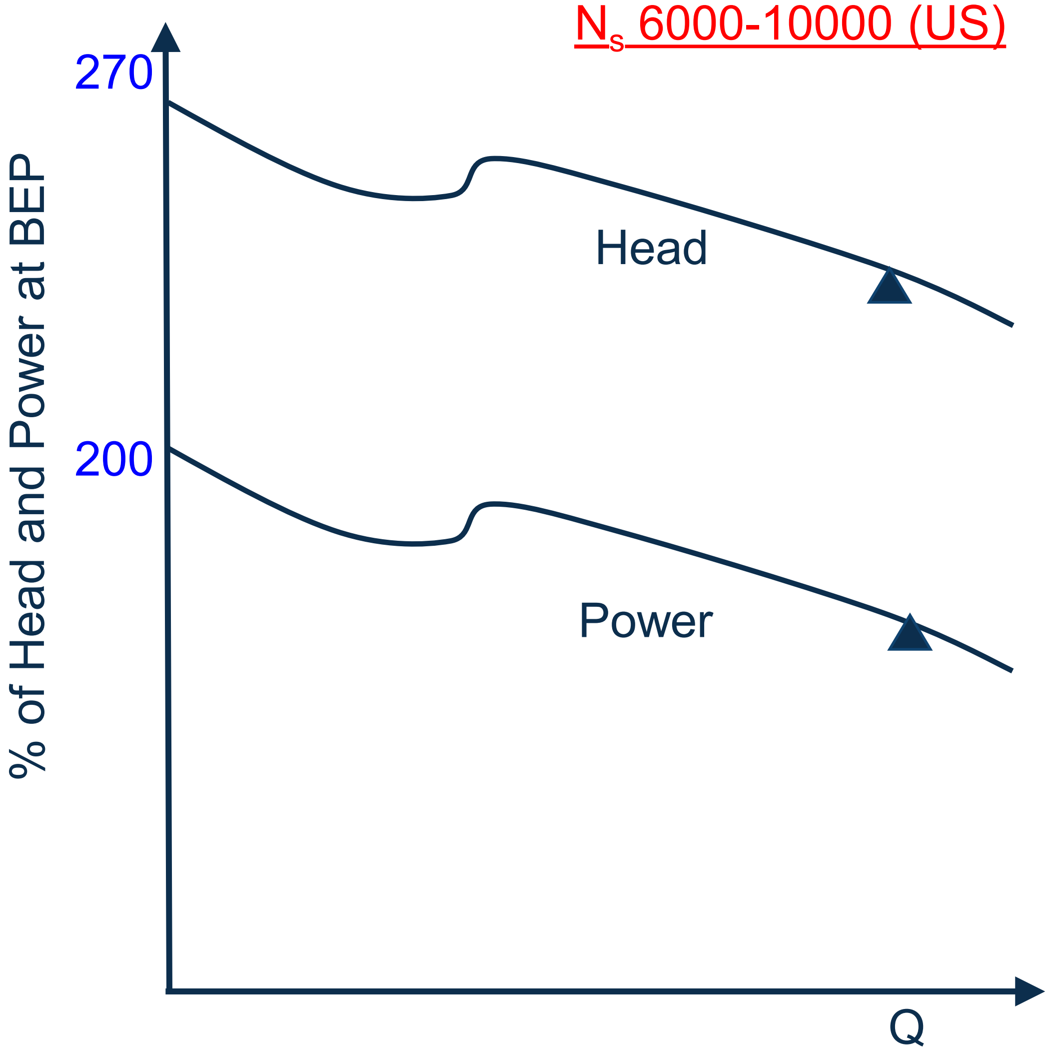


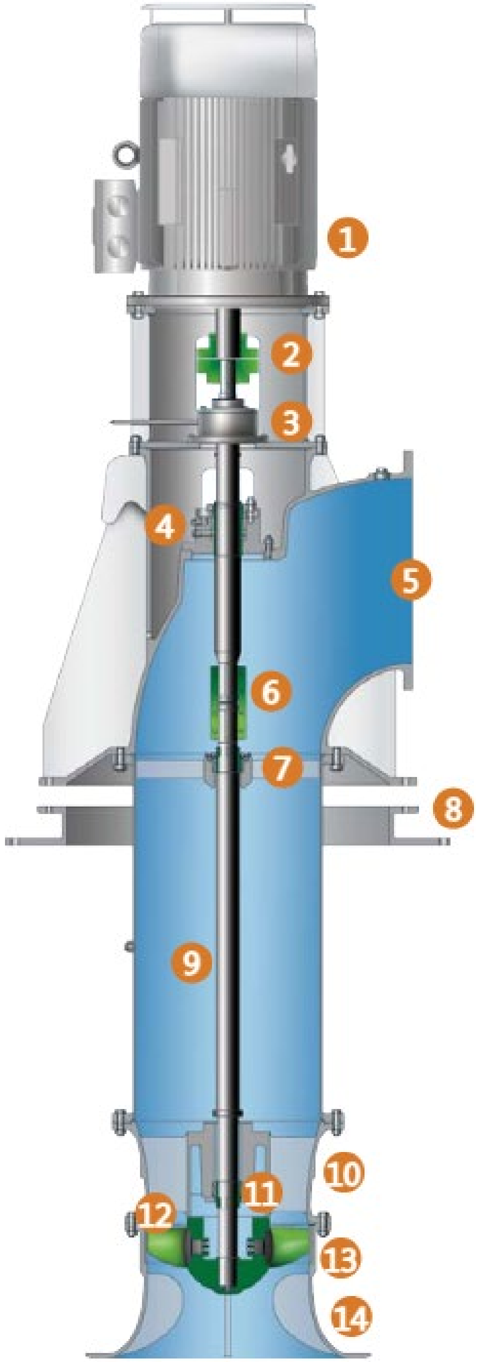
Pump Curve Shape vs Specific Speed





Pump Curve Shape vs Specific Speed



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3- System Control

Operating Bands & System Control

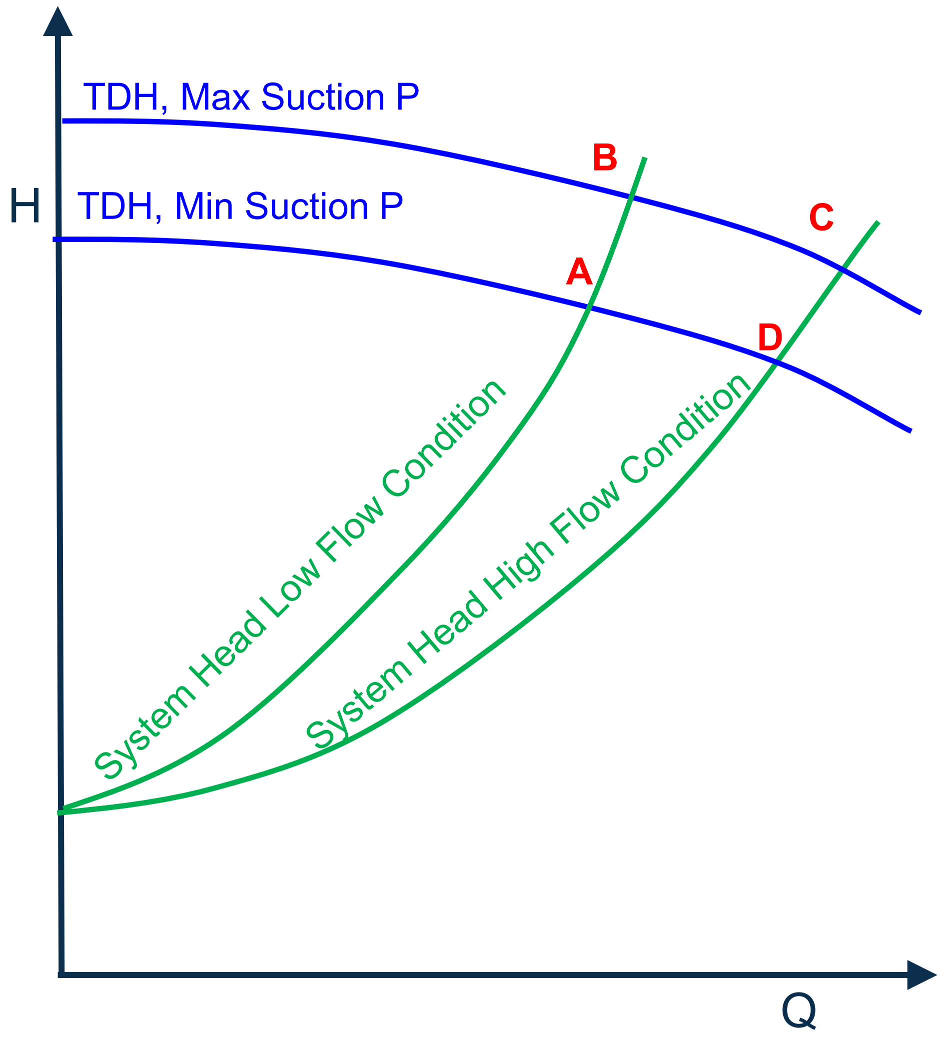
You will probably have a range of Suction Pressures and a range of Flow Rates to fulfill, and the pump might be asked to perform anywhere within the area A-B-C-D-A.

Condition D is probably the Rated Condition (worst case)

Some kind of system control will be required.

This might be

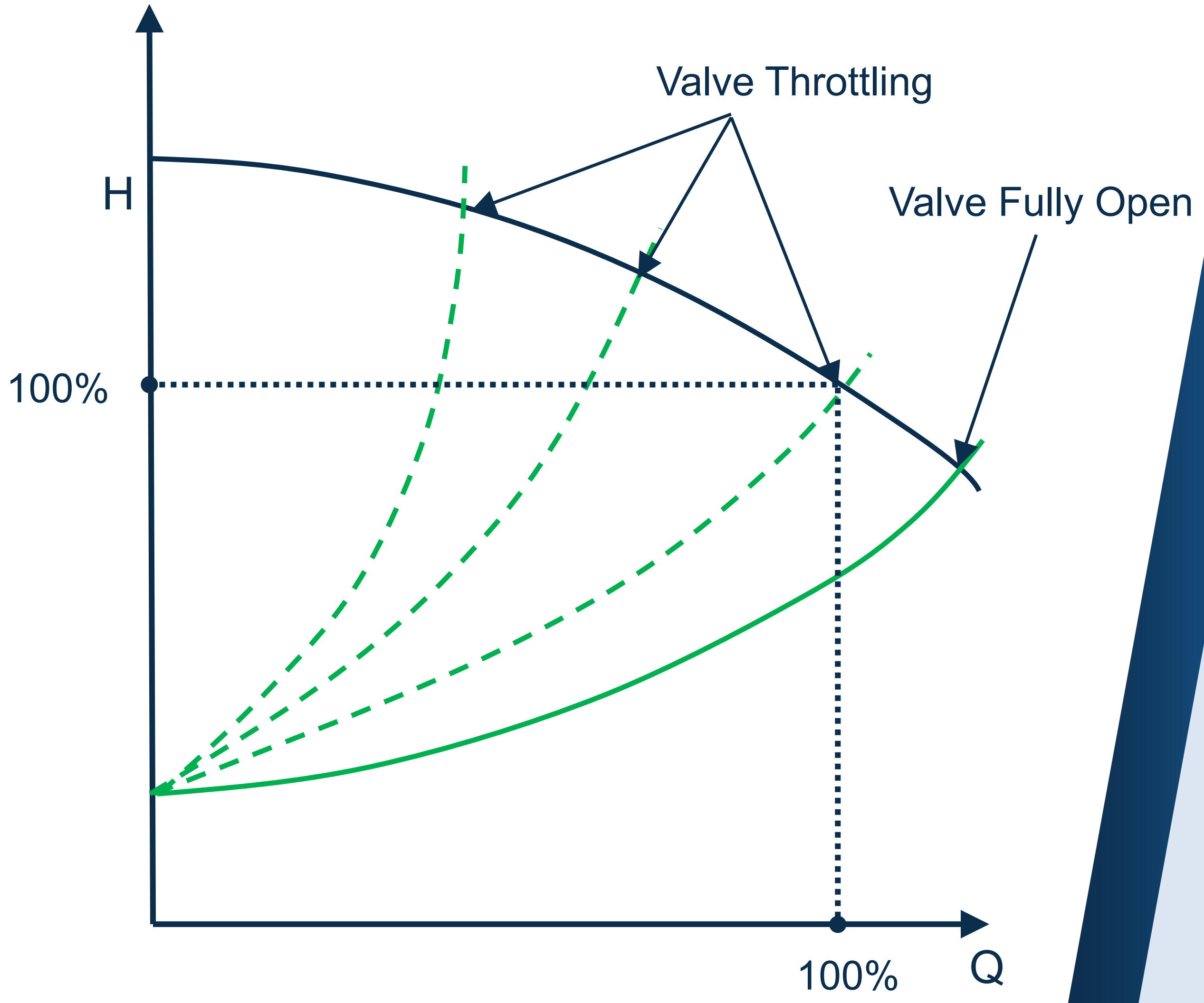
- Bypassing
- Valve Throttling
- Series or Parallel Pumping
- Variable Speed



System Control by Throttling

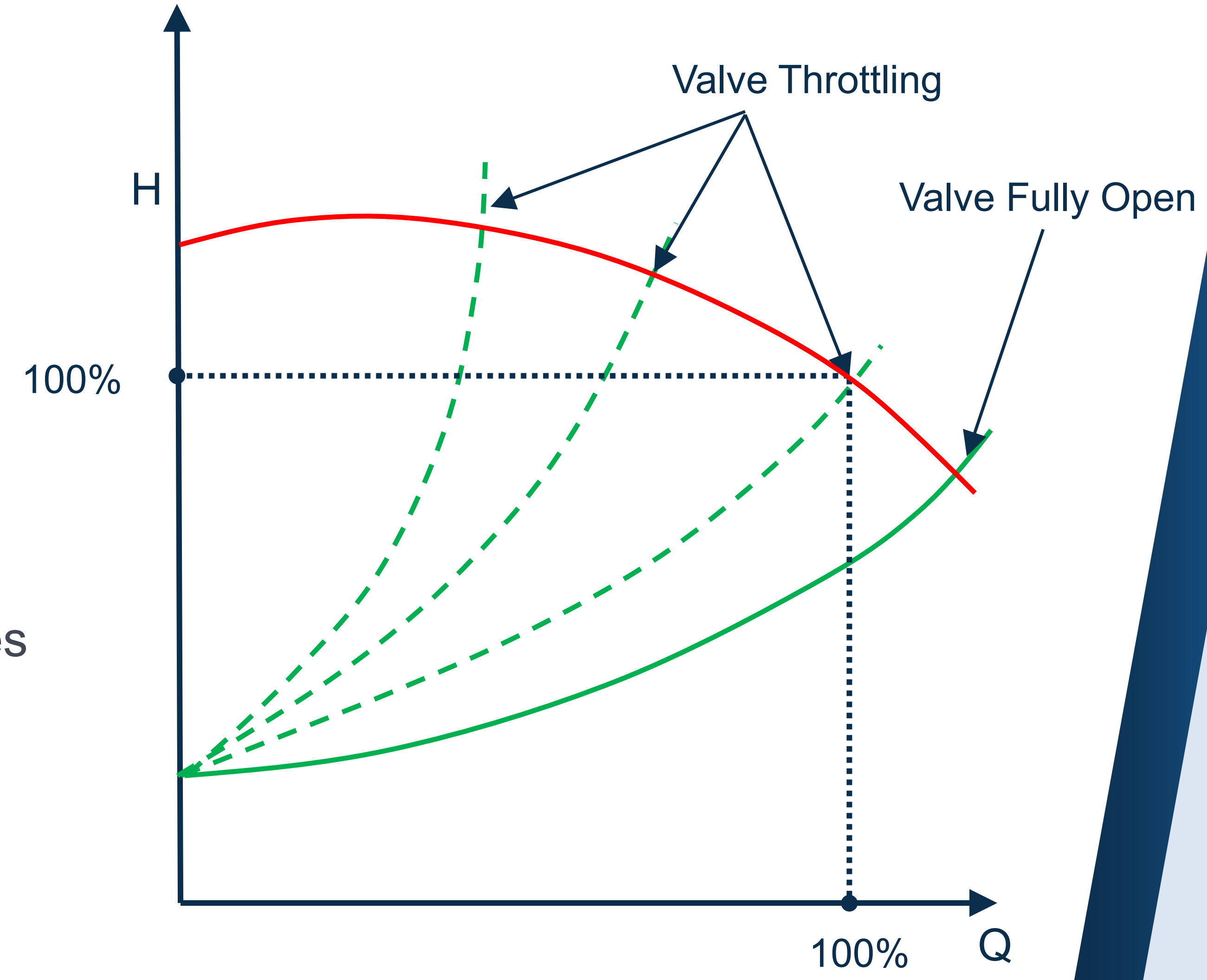
Probably the most common system control.

By opening or closing a control valve on the pump discharge, a “family” of system curves are created reflecting the ever-increasing frictional component of the system head.



System Control by Throttling – Hooked Curve (Gasp!)

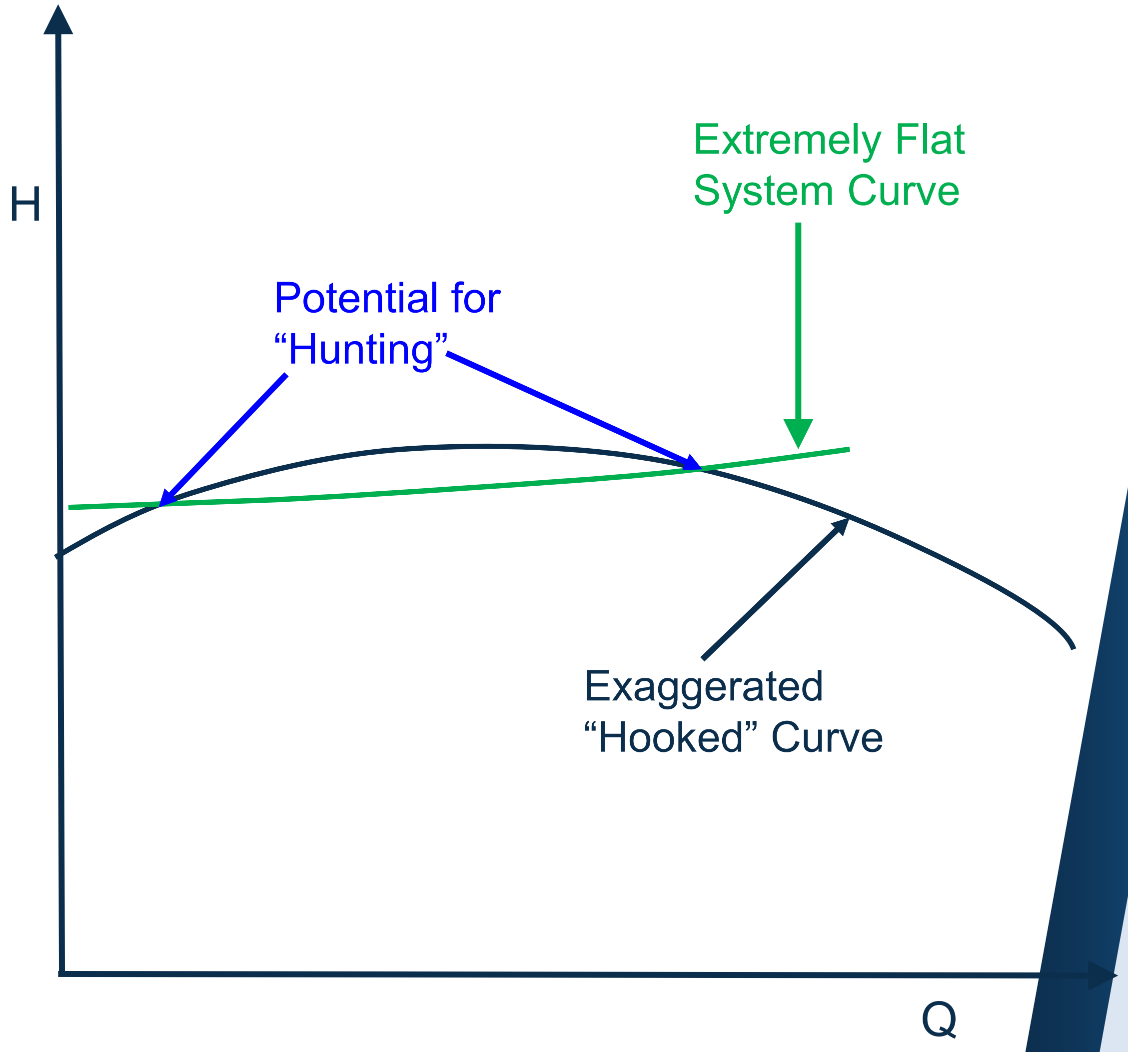
- Many specifiers run a mile from a hooked curve believing they are unstable.
- **A pump will only operate where the system permits – where the system curve crosses the pump curve.**
- **"The pump is slave to the system" ***
- Even as the control valve is gradually closed, each system curve only crosses the pump curve once.
- So no "hunting" is possible



* Simon Bradshaw

System Control by Throttling – Hooked Curve (Gasp!) Extreme Case

Only in the extremely rare case of an almost totally flat system curve (nearly all static head, very low frictional head) and a ***severely*** hooked curve might the system curve cross the pump curve more than once.

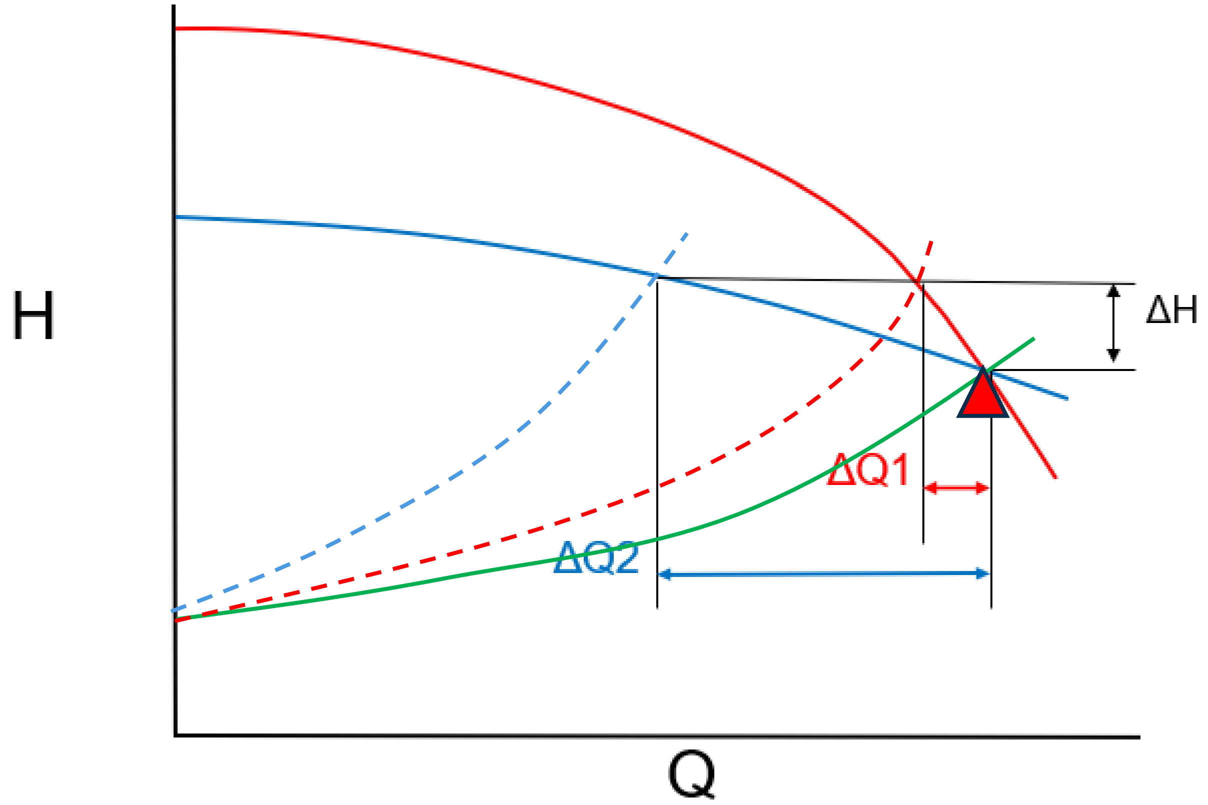


Steep or Flat Pump Curve?

- The question is “What do you want to achieve?”
- With a Flat pump curve **small** changes in System Head lead to **big** changes in Flow.
- With a steep pump curve **small** changes in System Head lead to **small** changes in Flow.

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).



Control by Variable Speed

Affinity Laws

$Q1/Q2 = RPM1/RPM2$

$H1/H2 = (RPM1/RPM2)^2$

Flow changes in DIRECT proportion to the speed change.

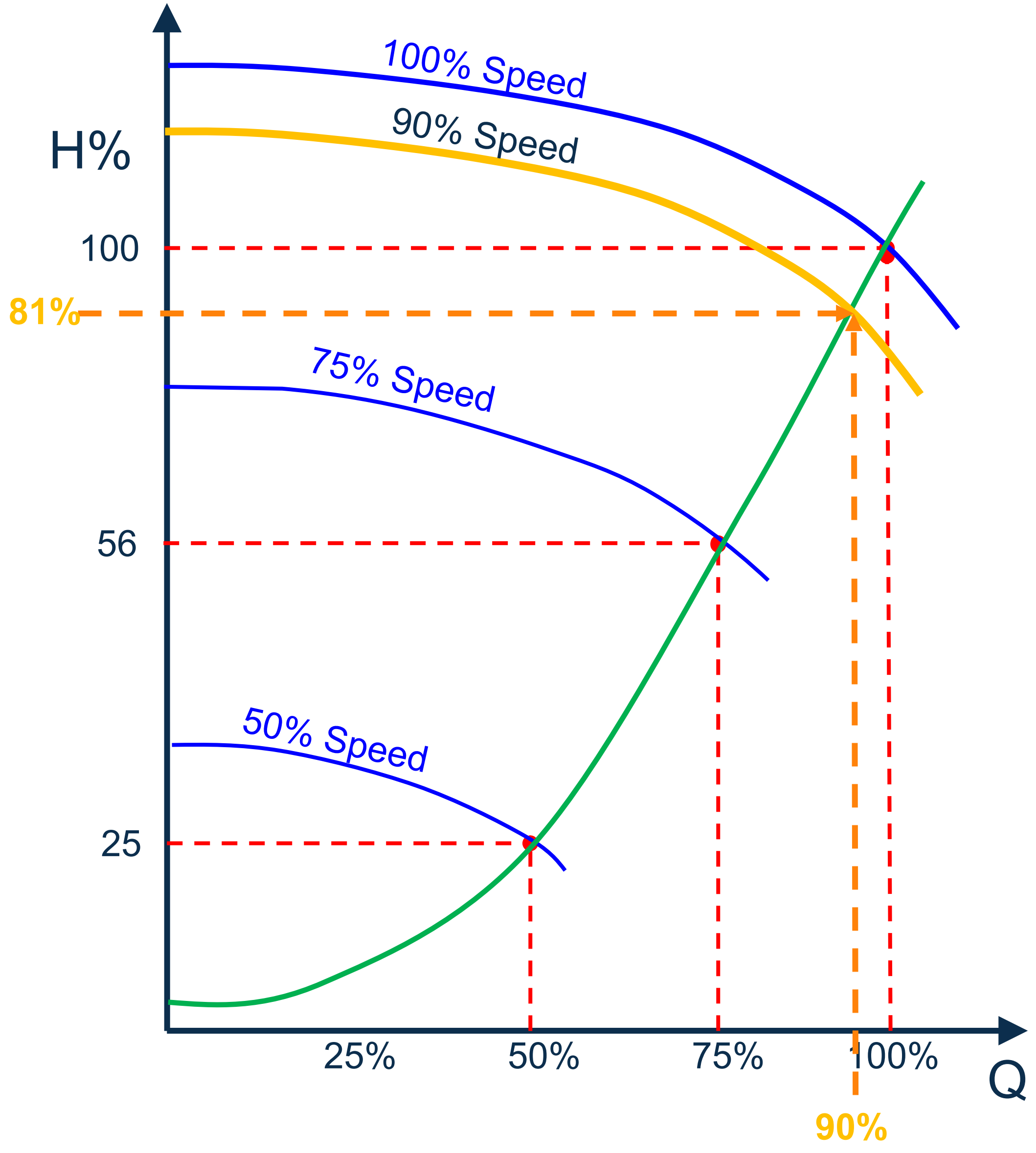
Developed Head changes by the SQUARE of the speed change.

So…reduce the speed to 90% of full

Flow reduces to 90% of full flow

TDH reduces to 81% of full head

Variable Speed is not the "Cure-All" that many people expect!

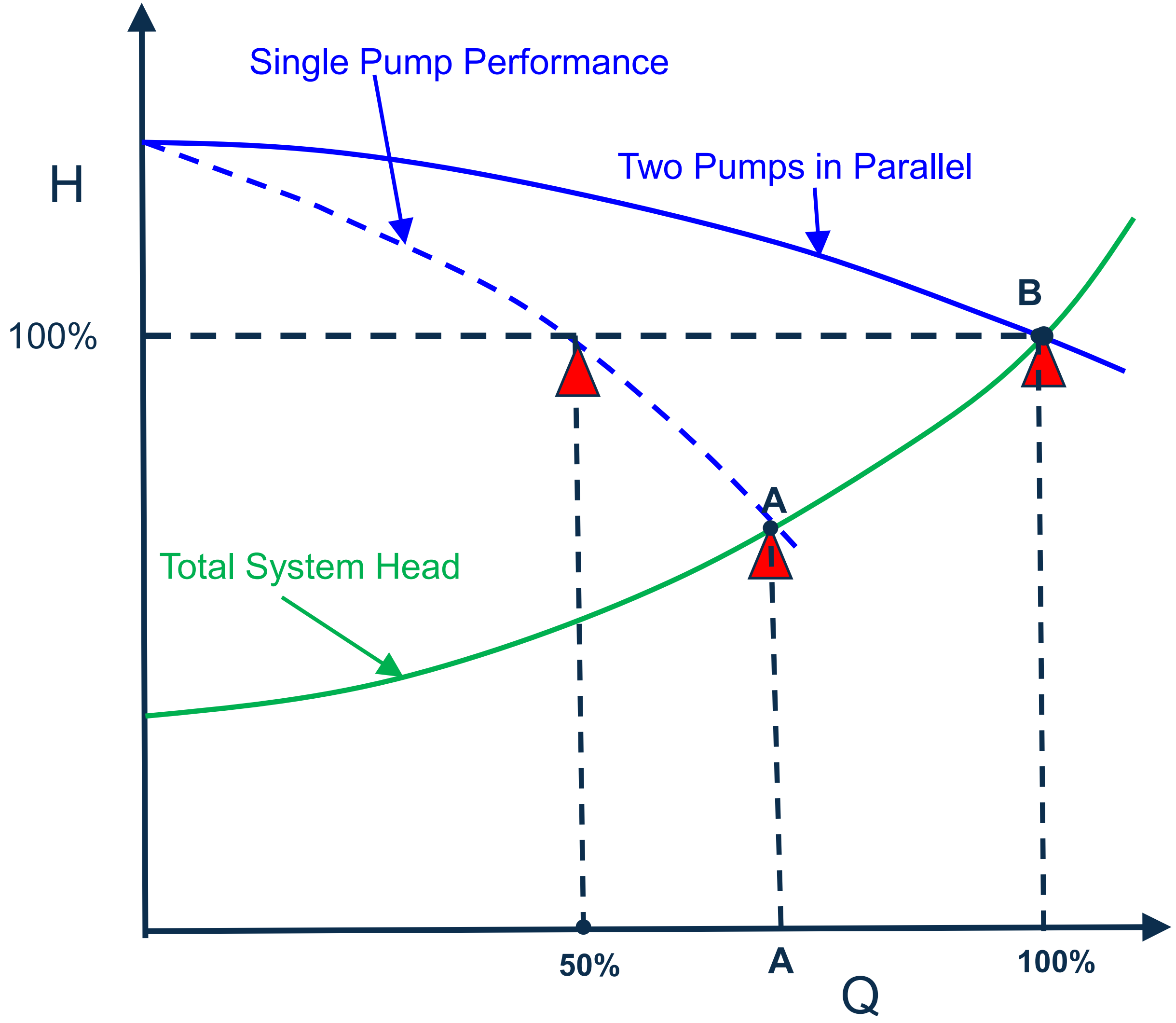


4- Parallel and Series Operation

Parallel Operation

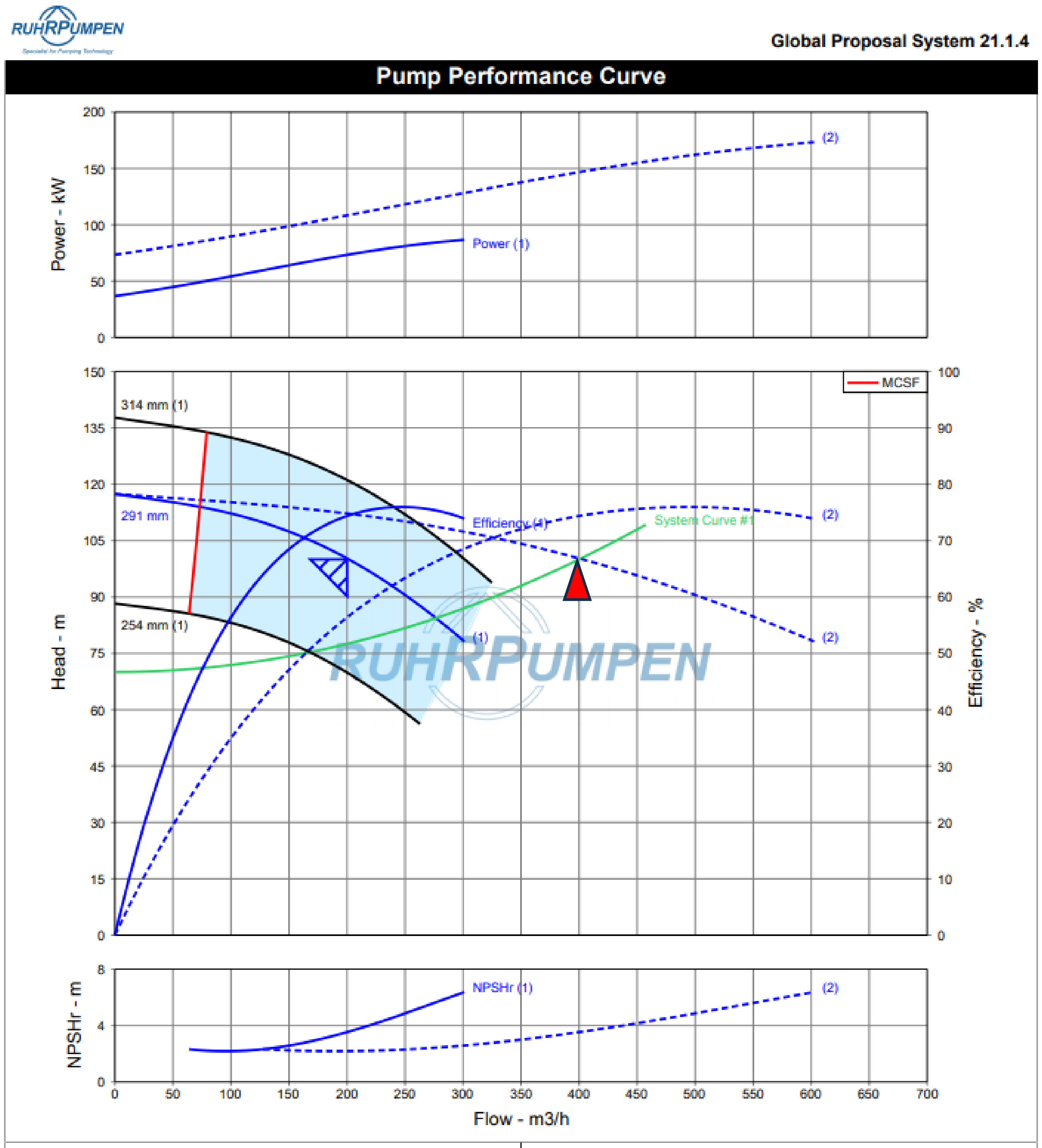
When operating in parallel, pumps will always develop an identical head value at whatever their equivalent flow rate is for that developed head, and the sum of their capacities will equal the system flow.

With one pump operating, system flow will occur at point A and with both pumps in operation, flow will occur at point B.



Parallel Operation

Typical manufacturer's curve with the system curve superimposed for parallel operation.



API610 12th & Parallel Operation

- *6.1.13 If parallel operation is specified and the pumps are not individually flow controlled, the following is required:*

  a) the pump head curves shall be continuously rising to shutoff;

  b) the head rise from rated point to shutoff shall be at least 10 %;

  c) the head values of the pumps at any given flow within the preferred operating range shall be within 3 % of each other for pumps larger than 3 in. (80 mm) discharge.

Here is why this is so important.

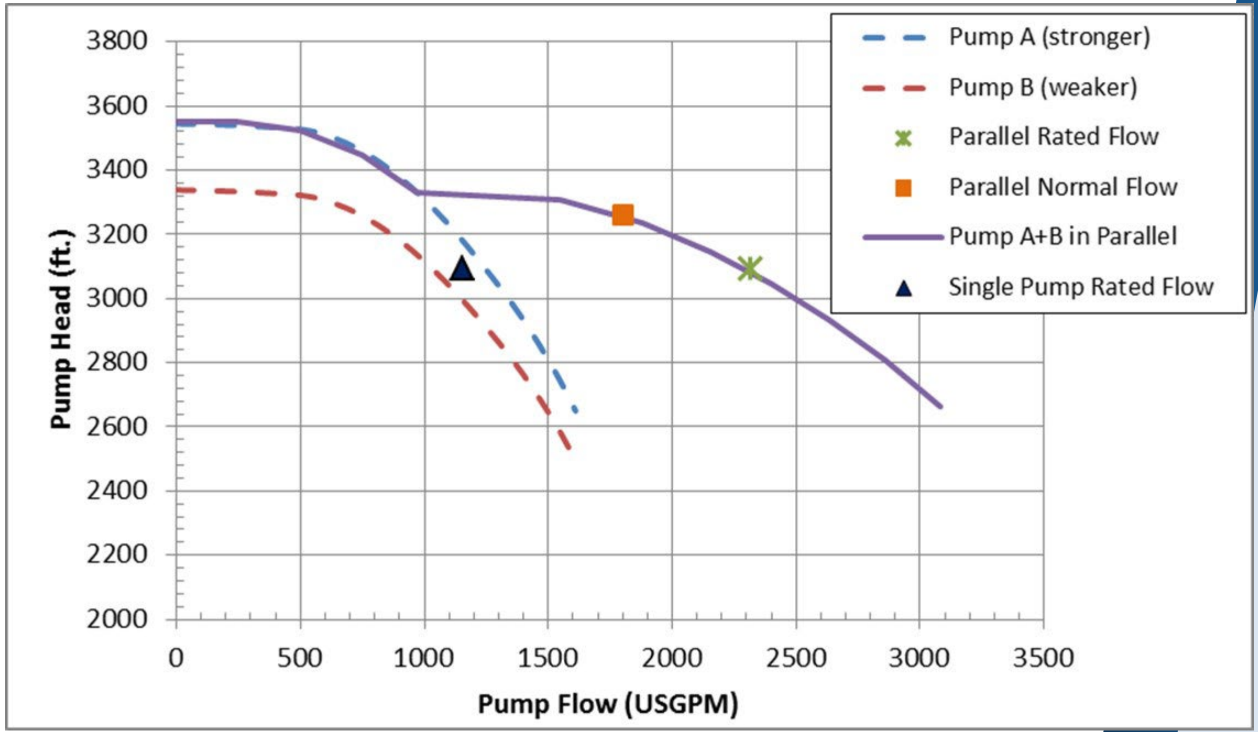
API Table 16 allows Performance Tolerances +/-3% of Total Head at rated flow and +/- 5%, 8% or 10% (depending on head) at shutoff.

So without this change two "identical" pumps could easily have a "stronger pump" operating in parallel with a "weaker pump" as illustrated below.

API610 12th & Parallel Flow

The resulting combined Pump A+B parallel curve is discontinuous due to the mismatching of the two pumps. This exhibits itself as a step at around 1000 USGPM. (Below that point Pump B would operate at zero flow resulting in rapid failure).

In this scenario Pump A being stronger will force Pump B to operate back on its curve. If the system is operated at its Parallel Normal Flow, **Pump B will be running at around only 50% of BEP**. This is well outside the preferred operating range and will result in Pump B seeing higher wear and ultimately needing repair *much* sooner.

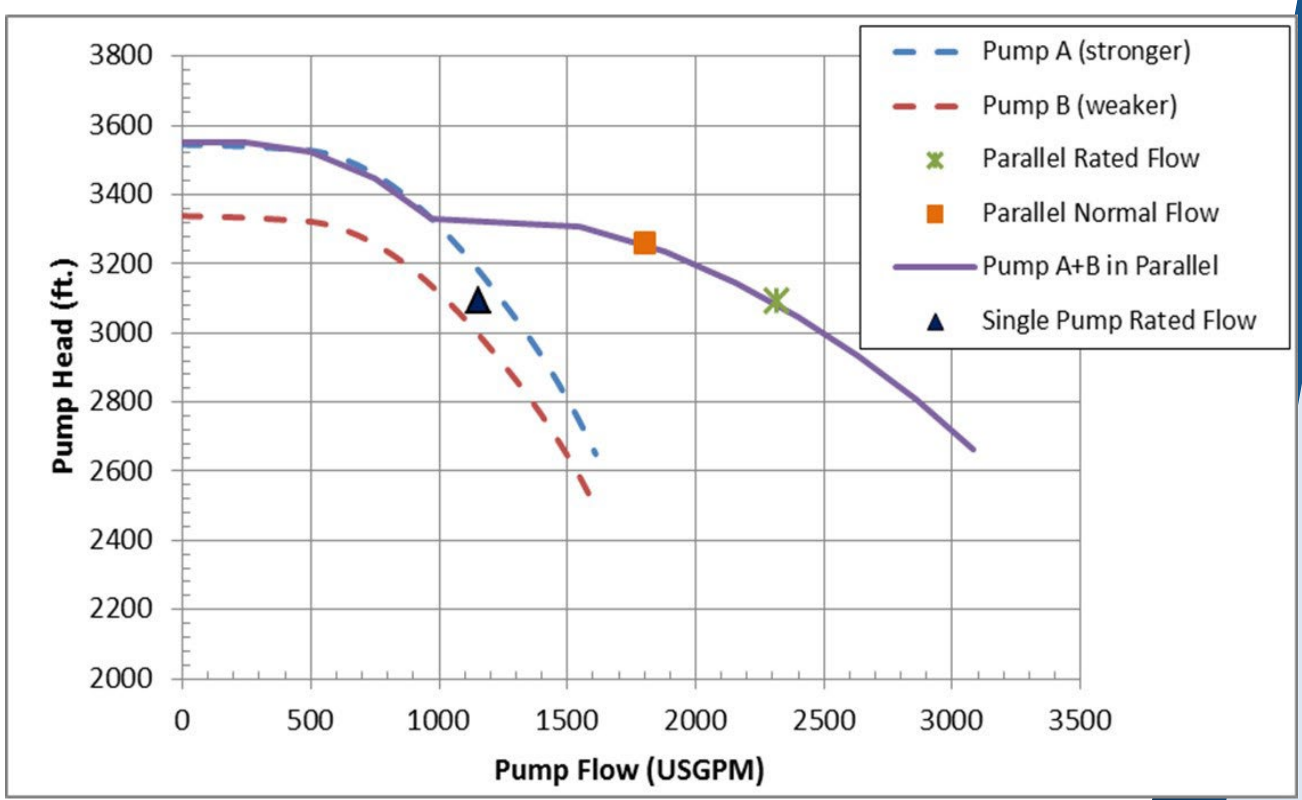


(Source – Simon Bradshaw, Director Engineering, Trillium Flow Technologies)

Parallel Operation

Non-Identical Pumps in Parallel

Two non-identical pumps can still work in parallel but you will need to control the outlet stream of each pump independently. Otherwise one pump may well push the other out of its allowable operating range.



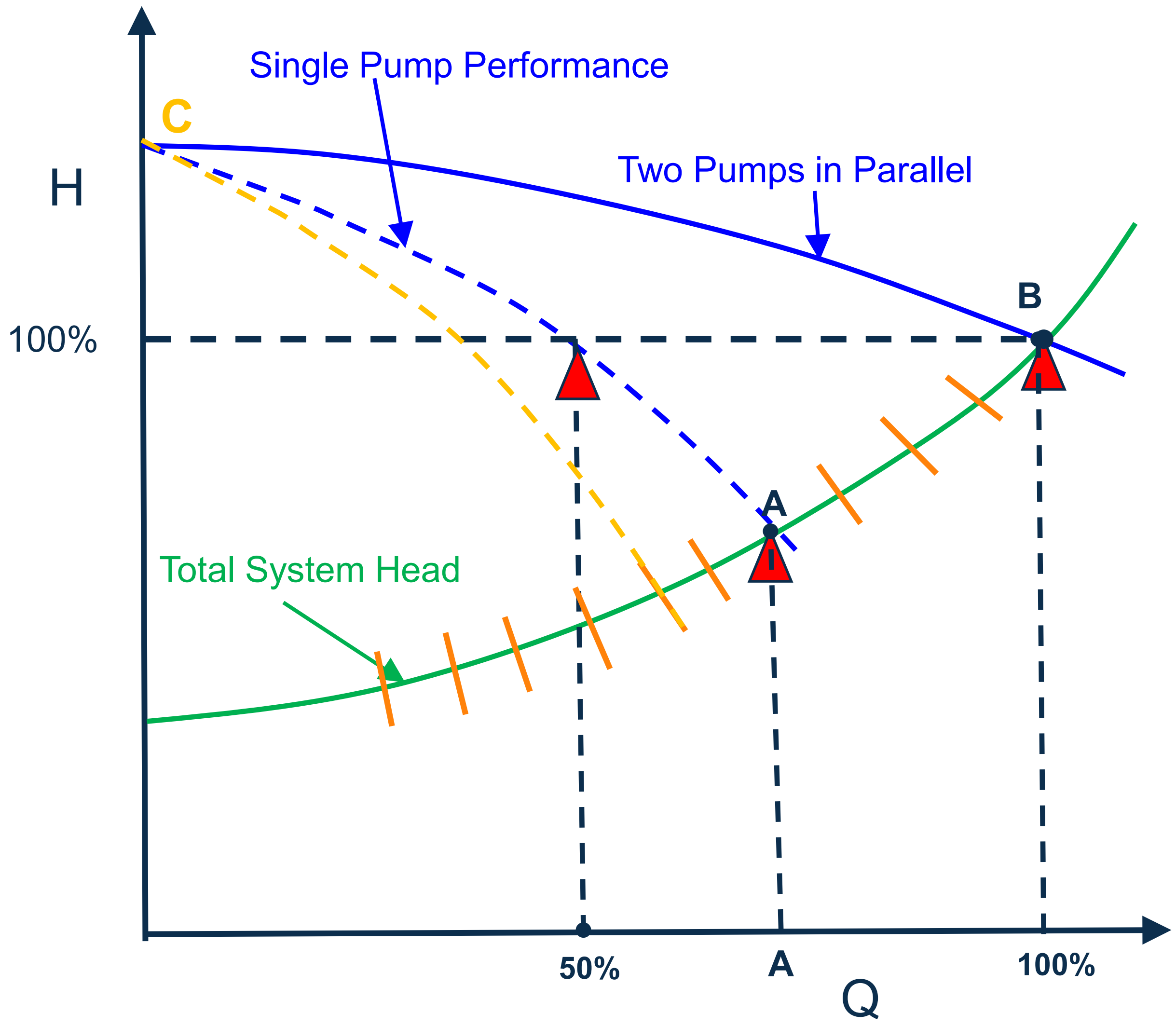
Parallel Operation with Variable Speed

With variable speed you have an infinite number of Pump Curves (partial curves illustrated in orange)

Typically you would start the lead pump under variable speed.

It would climb the system curve until it reached Point A at which point it is at full speed and would be locked at that speed.

The second (lag) pump would start under variable speed and continue to climb the system curve from Point A to Point B

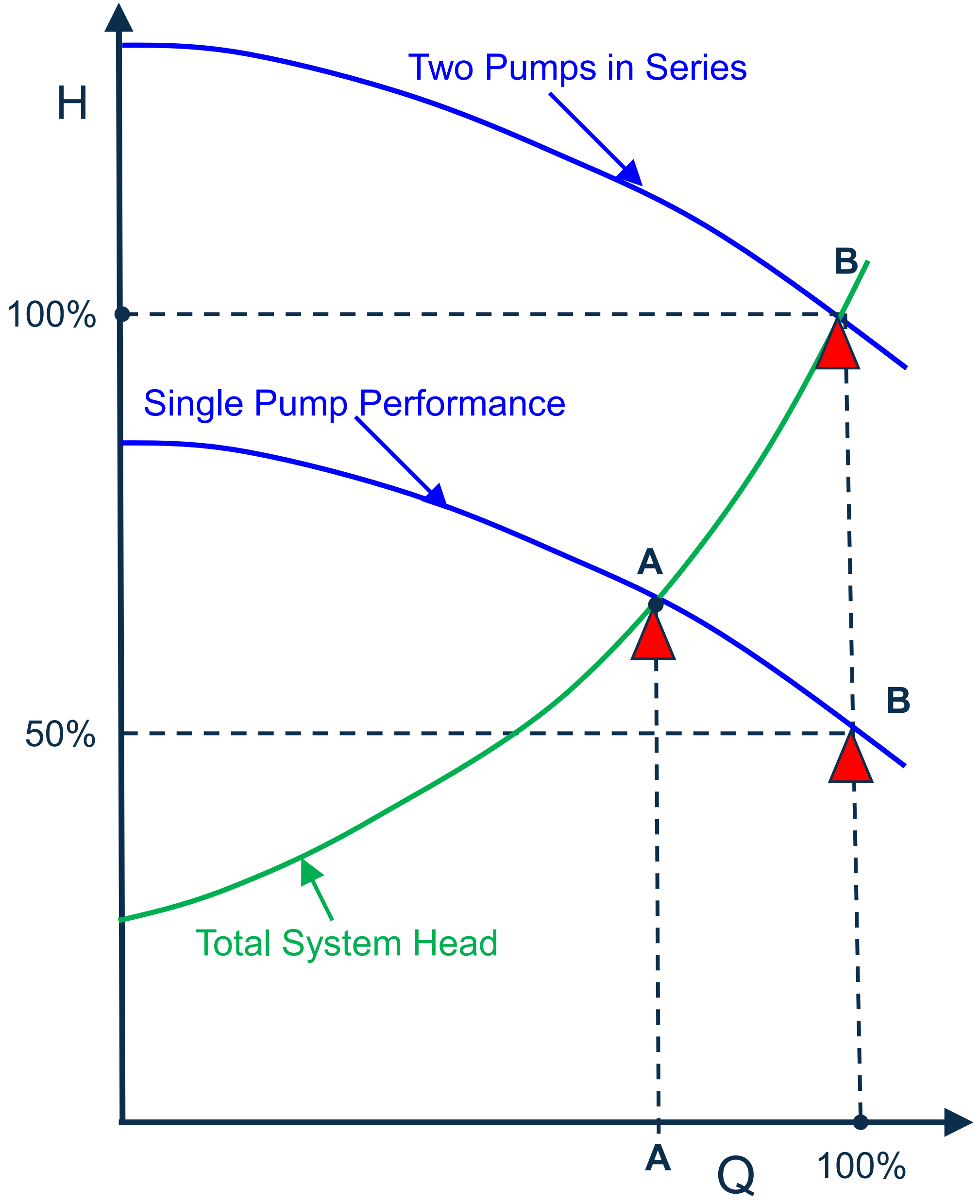


Series Operation

When operating in series, the total developed head will be the sum of the heads developed by each pump at any given flow.

Each pump must be selected to operate satisfactorily at the system design flow.

With one pump operating, system flow will occur at point A and with both pumps in operation, flow will occur at point B which is the System Design Flow

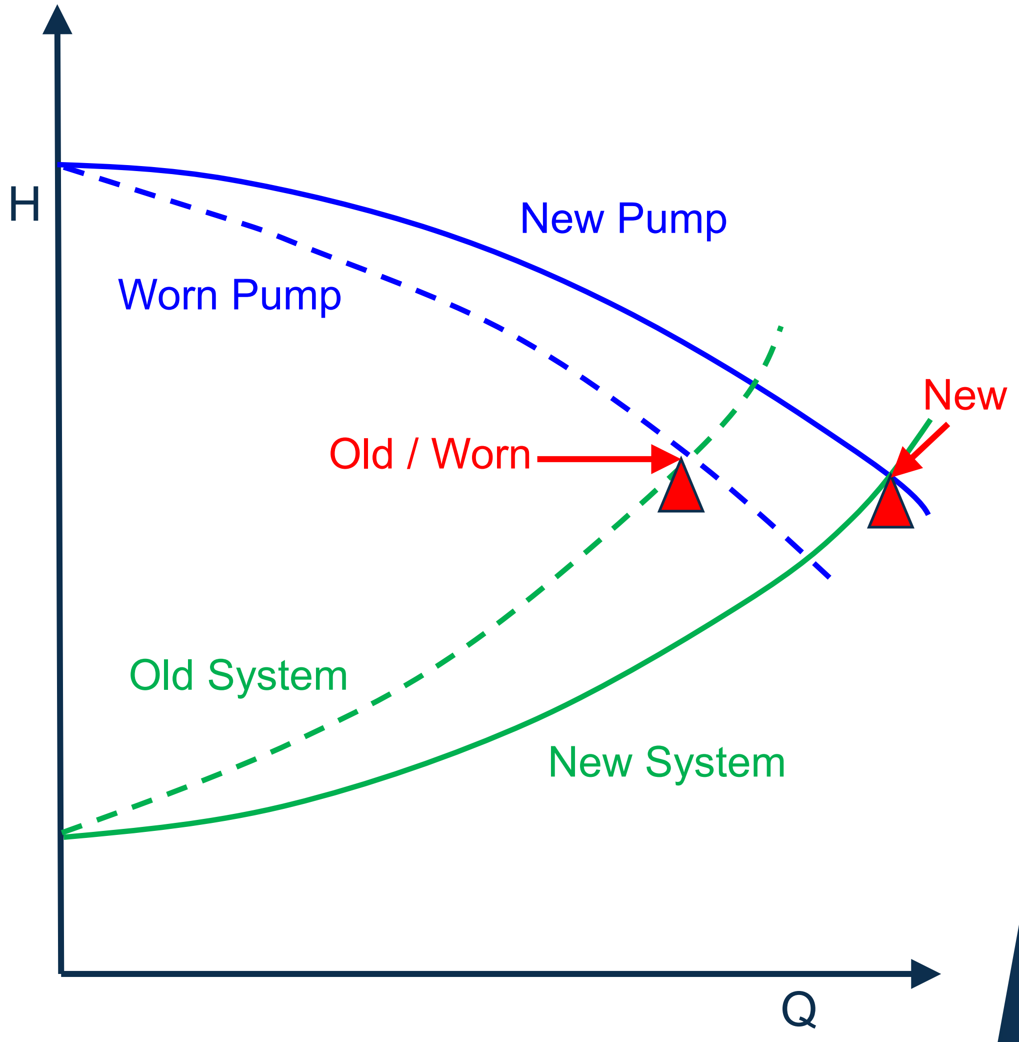


Old Age

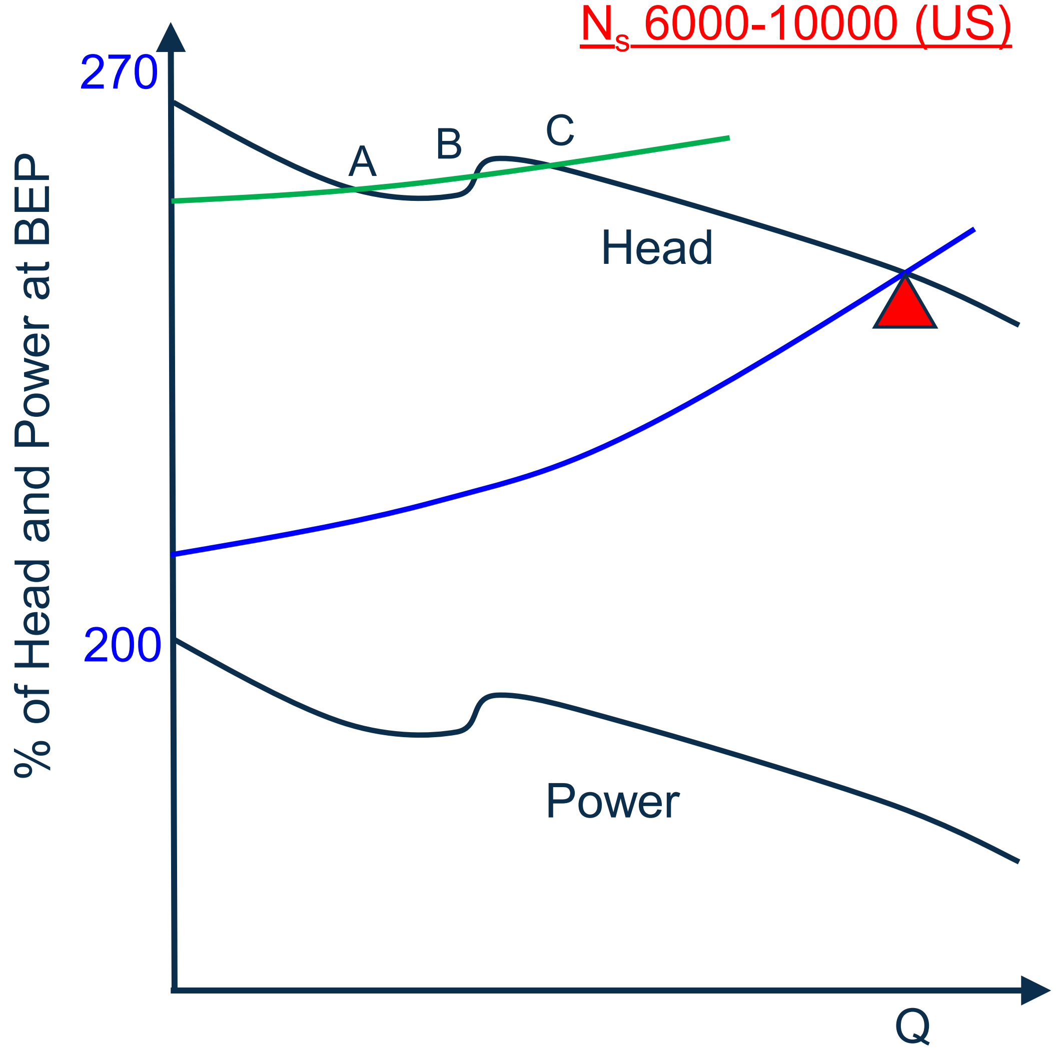
(It comes to us all!)

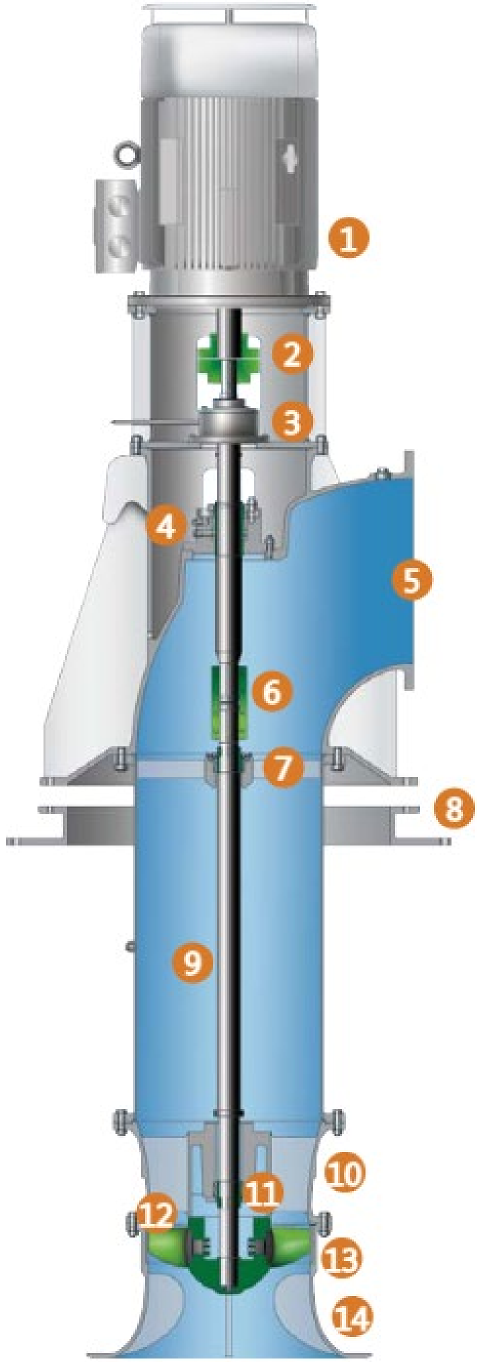
A worn pump will see its performance curve fall off as shown by the dashed line.

Similarly frictional resistance will increase in an aging system due to corrosion and scale build up.



Operating Near the "Saddle"





Coming Attractions ☺

"NPSH & Nss made Simple (well Simpler Anyway!)"

Thur 30th Nov – 08.00 (UK GMT) (Eastern Hemisphere) & 17.00 (UK GMT) (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 of the fundamentals and practical aspects of NPSH – probably the most difficult and misunderstood concept in pumping
Will cover such topics as Cavitation damage, Suction Specific Speed and the "11,000 limitation", understanding the NPSH Curve

Future subjects in preparation include:

- API610 12th Edition
- Curve Shape, Head-Rise to Shutoff and "Zero Tolerances"

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Q & A

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RUHRPUMPEN AT A GLANCE

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A GLOBAL COMPANY

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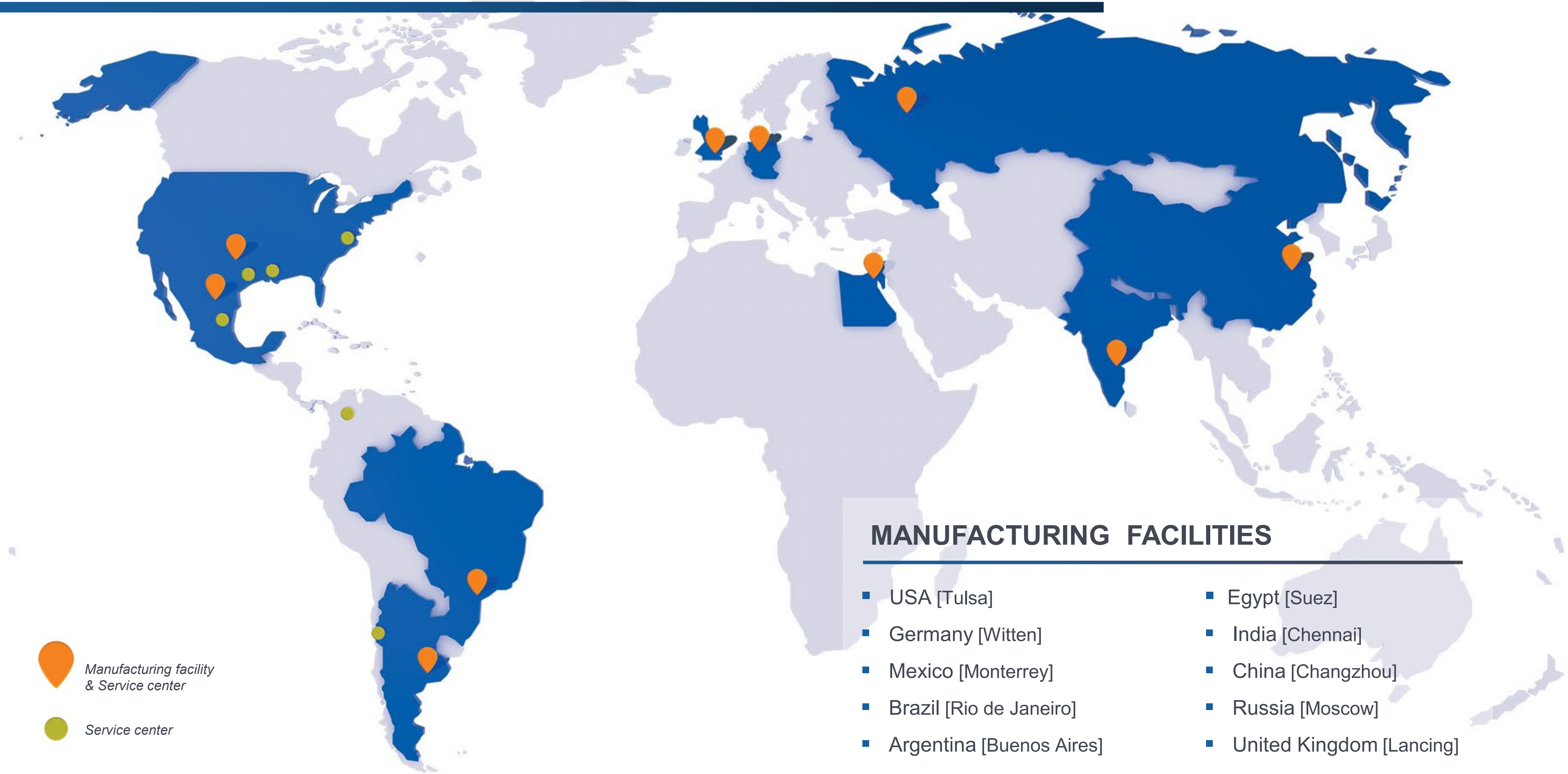
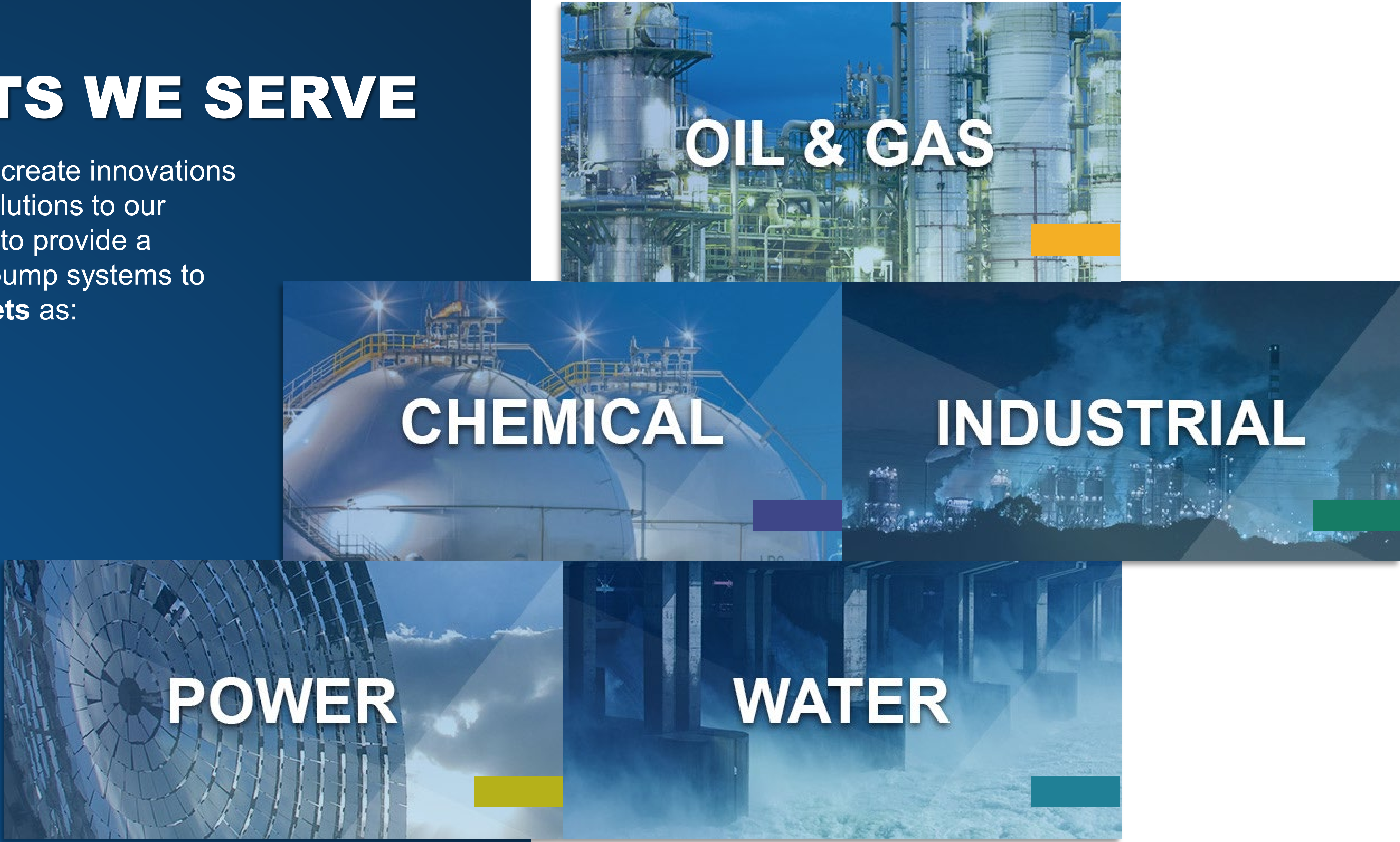


MANUFACTURING FACILITIES

- 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:

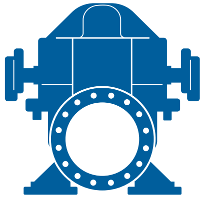
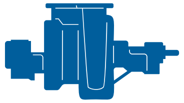
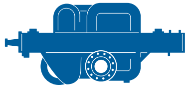
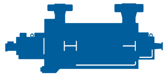
- Single Stage Overhung Pumps
- Between Bearings Pumps
- Horizontal Multi-Stage Pumps
- Vertical Multi-Stage Pumps
- Vertical Mixed Flow & Axial Flow Pumps
- Positive Displacement Pumps
- Full Range of Industrial Pumps
- Submersible Pumps
- Magnetic Drive Pumps
- Decoking Systems
- Packaged Systems
-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

OUR PUMPS

OVERHUNG PUMPS

CATEGORY	RP MODEL	DESIGN STANDARD
Sealless Magnetic Drive Pumps	CRP-M / CRP-M-CC	ISO 2858 & 15783 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) ANSI B73.1
	CPO / CPO-L	HI design (OH1) ANSI B73.1
	CRP	HI design (OH1) 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) Dimensionally compliant with ANSI B73.2
	SPN	API 610 (OH5)

BETWEEN BEARING PUMPS

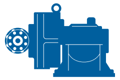
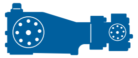
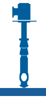
CATEGORY		RP MODEL	DESIGN STANDARD	
1 and 2 stage	Axially split	HSC / HSD / HSL HSR / ZW	HI design (BB1)	
		HSM	HI design (BB3)	
		ZM / ZMS ZLM / ZME	API design (BB1)	
	Radially split	HVN / J	API design (BB2)	
		RON / RON-D	API design (BB2)	
Multi-stage	Axially split	SM / SM-I	API design (BB3)	
		JTN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

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 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** UL and FM approved components