Pump training

KSB pump training at KSB Works
3rd April 2006

1. Hydraulic theory
2. “Ten ways to murder a pump”
3. Installation, commissioning, maintenance

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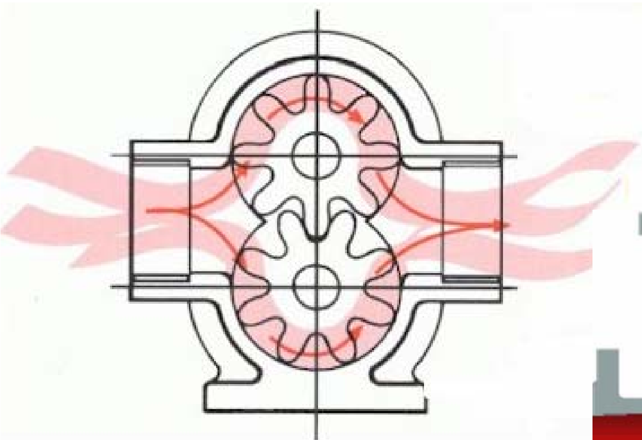
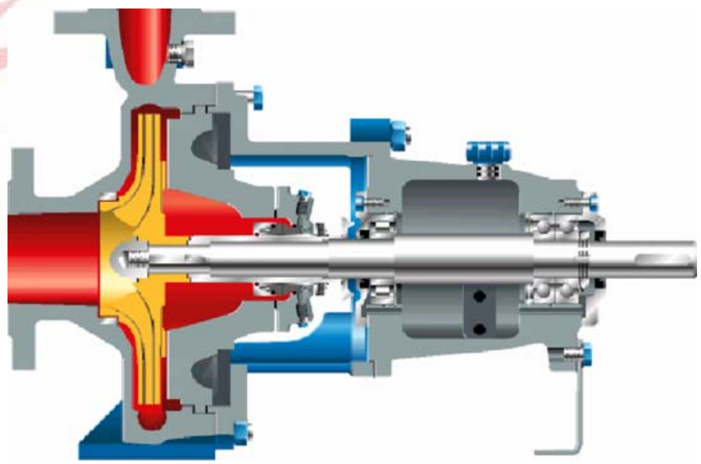
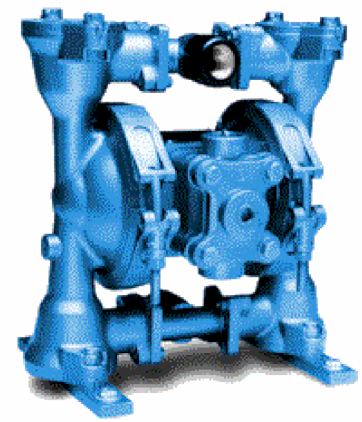
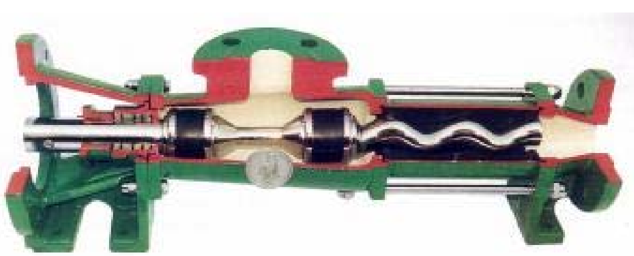
Pump types

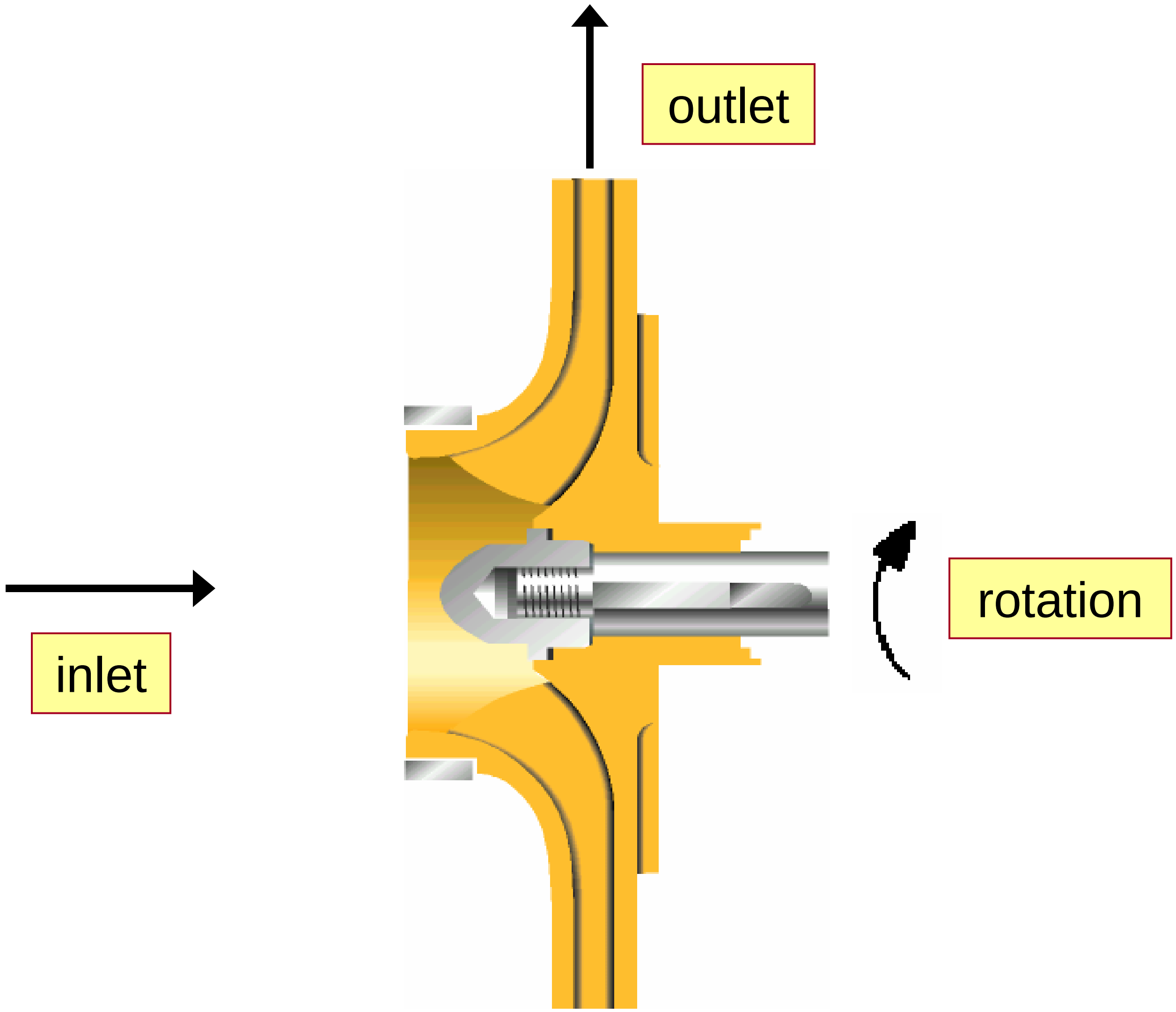






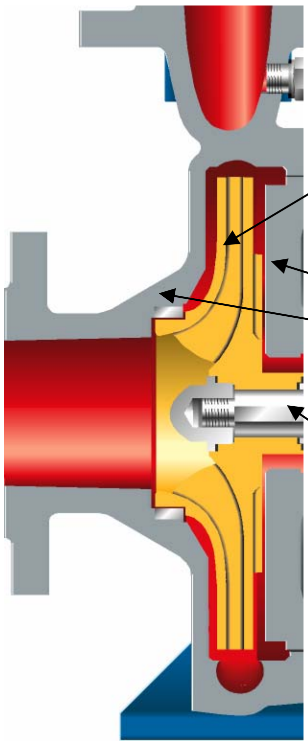


Pump hydraulics, impeller



Pump hydraulics, main parts

A centrifugal pump consists of 4 main elements:



1 Impeller which rotates
The impeller has vanes which transfer kinetic energy into the liquid pumped

2 Pump casing to convert kinetic energy into potential energy and also contain the liquid

3 Shaft to support the impeller

4 Generally a seal around the shaft to contain the liquid

A centrifugal pump:

1 Does not generate a vacuum, i.e. it cannot suck.
The impeller therefore has to be flooded in some way.

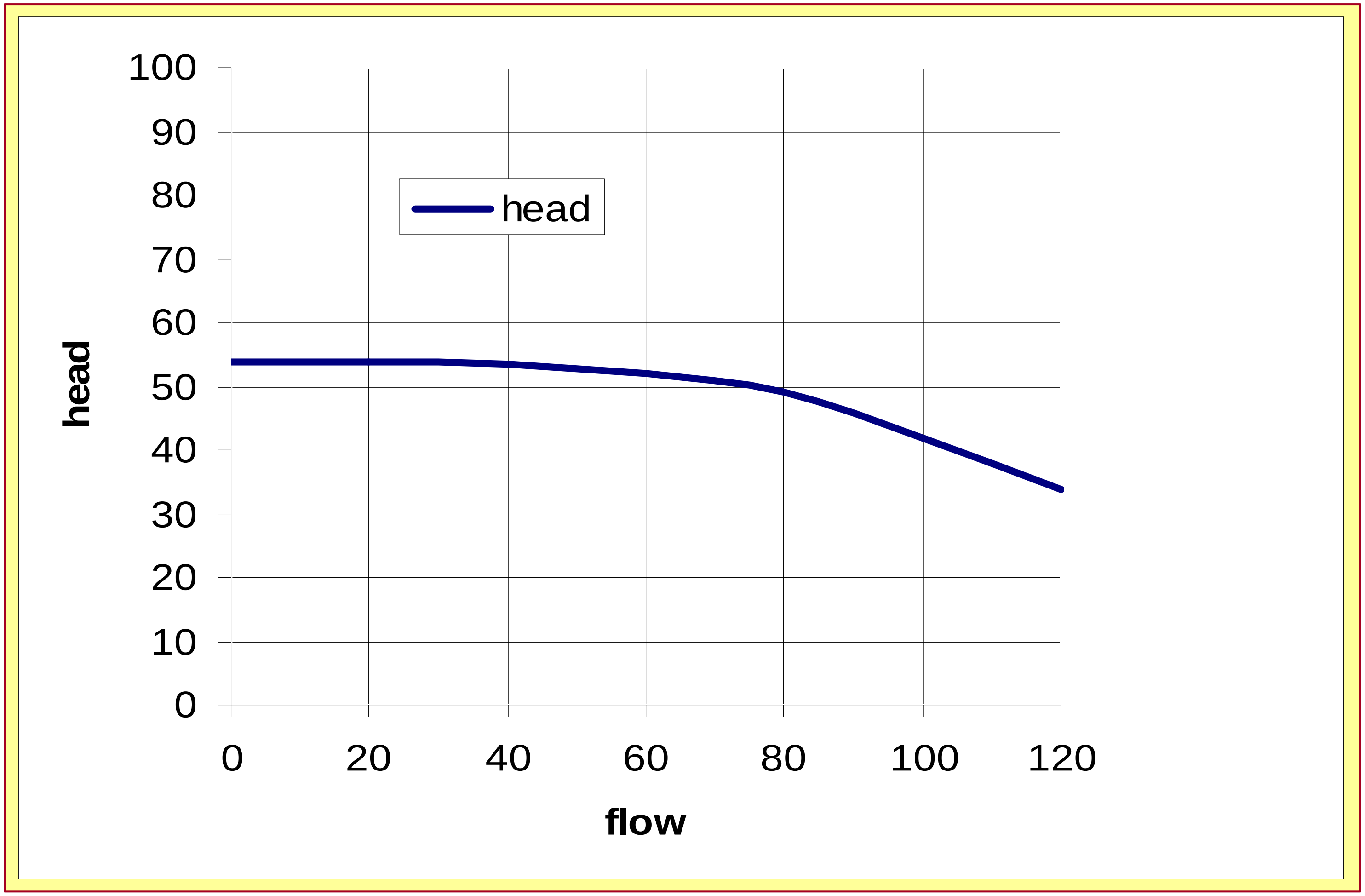
2 Centrifugal Pumps deliver volumetric flow and head. All curves are therefore expressed in m^3/h and m (or equivalent units)

E.g.:	pump design	100	m^3/h	102 m
	on water sg 1.0	100.000	kg/h	10 Bar
	on liquid sg 0.8	80.000	kg/h	8 Bar

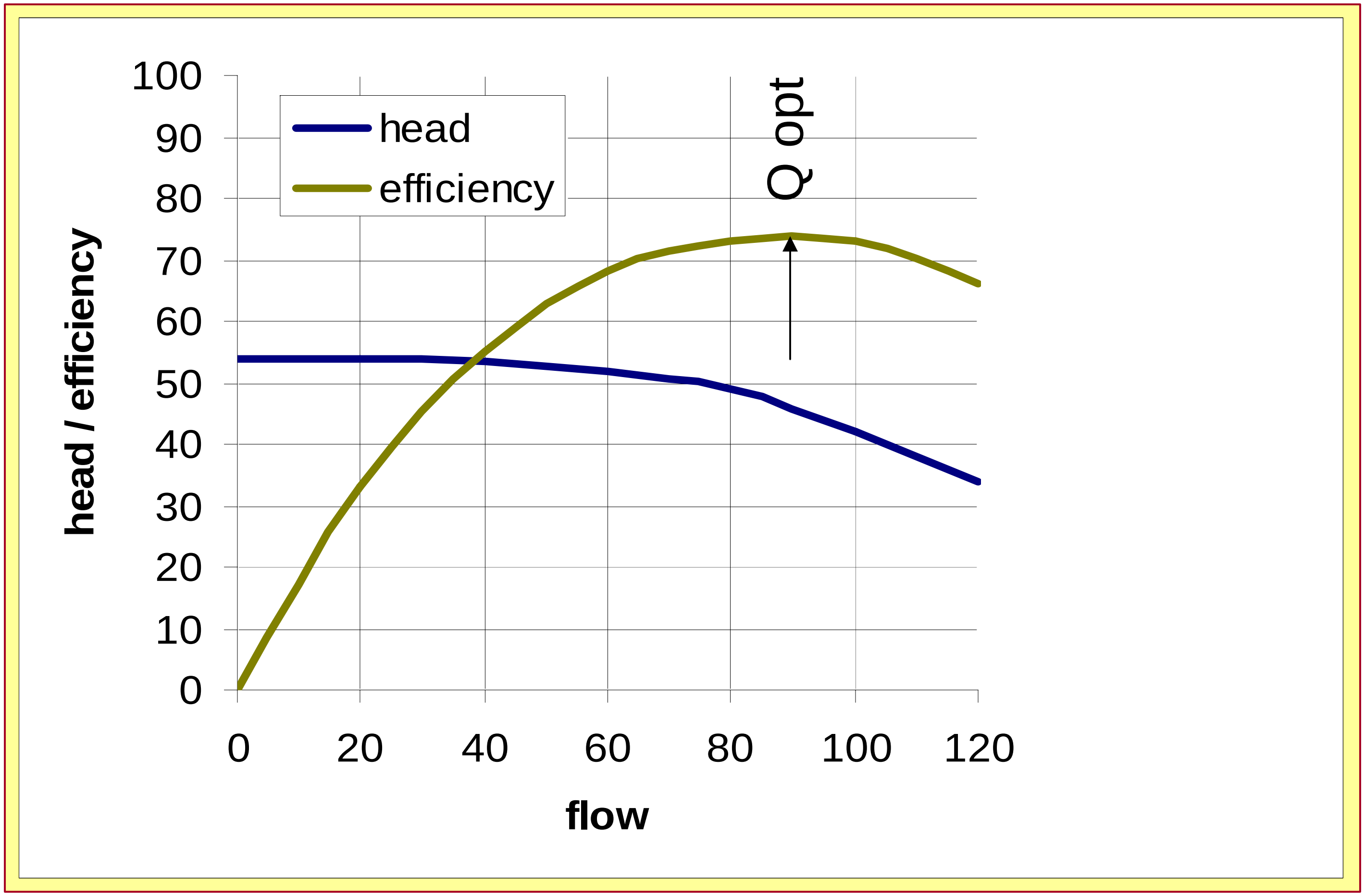
3 The flow and head developed are independent of the liquid pumped, apart from effects of viscosity

4 Viscous liquids reduce the flow and head of the pump. More later on this issue

Pump hydraulics, head curve

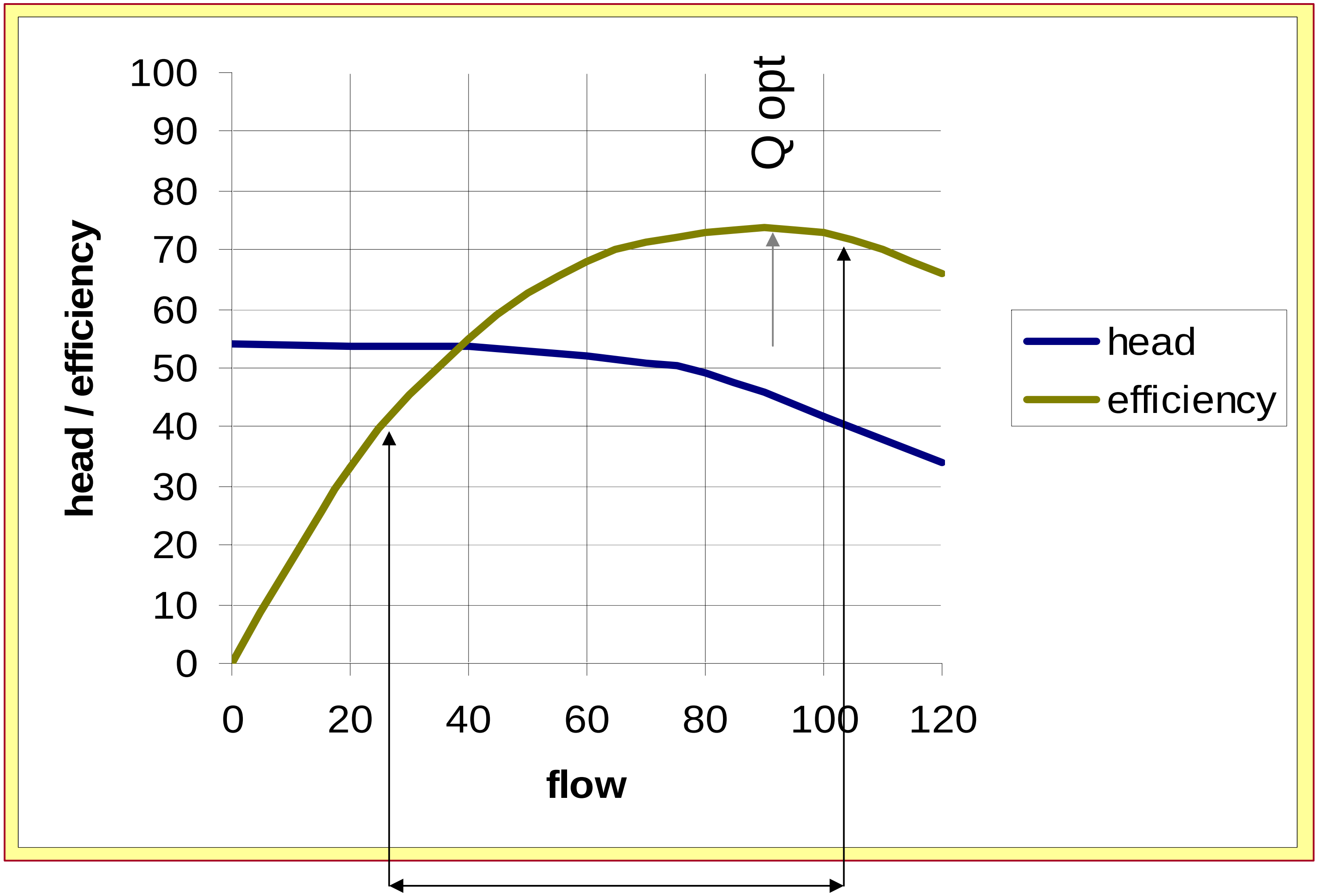


Pump hydraulics, head + efficiency



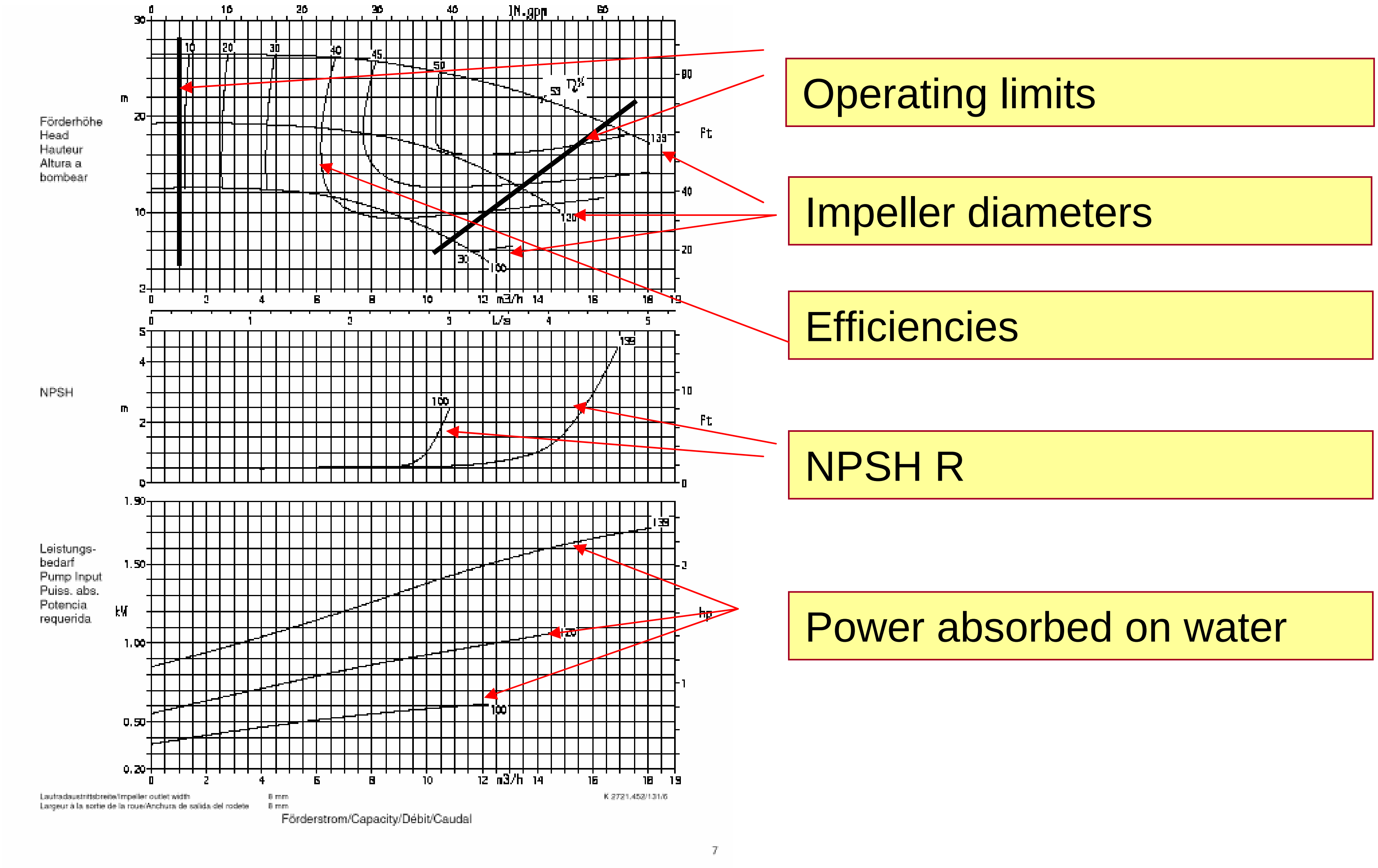
Q opt is the point at which a pump has the highest efficiency, also known as BEP (= best efficiency point)

Pump hydraulics, head + efficiency



Q min > 30% BEP **Desirable operating range** **Q max < 110% BEP**

Curve from book



Pump hydraulics, system

Delivery head (pump system) consists of various parts

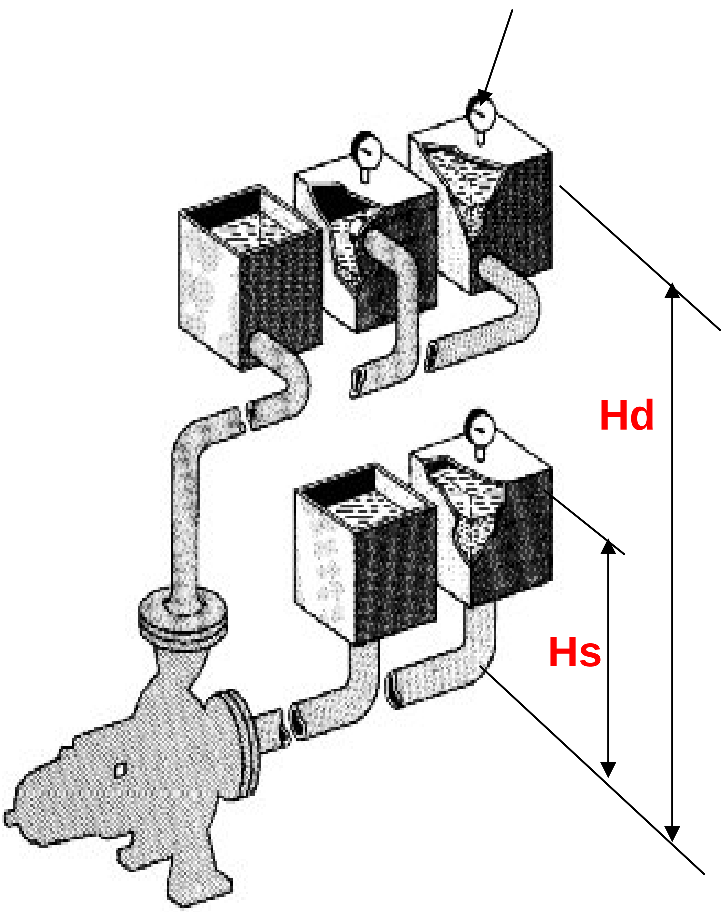
Static head on discharge side **Hd**

\+ Friction loss on the discharge side

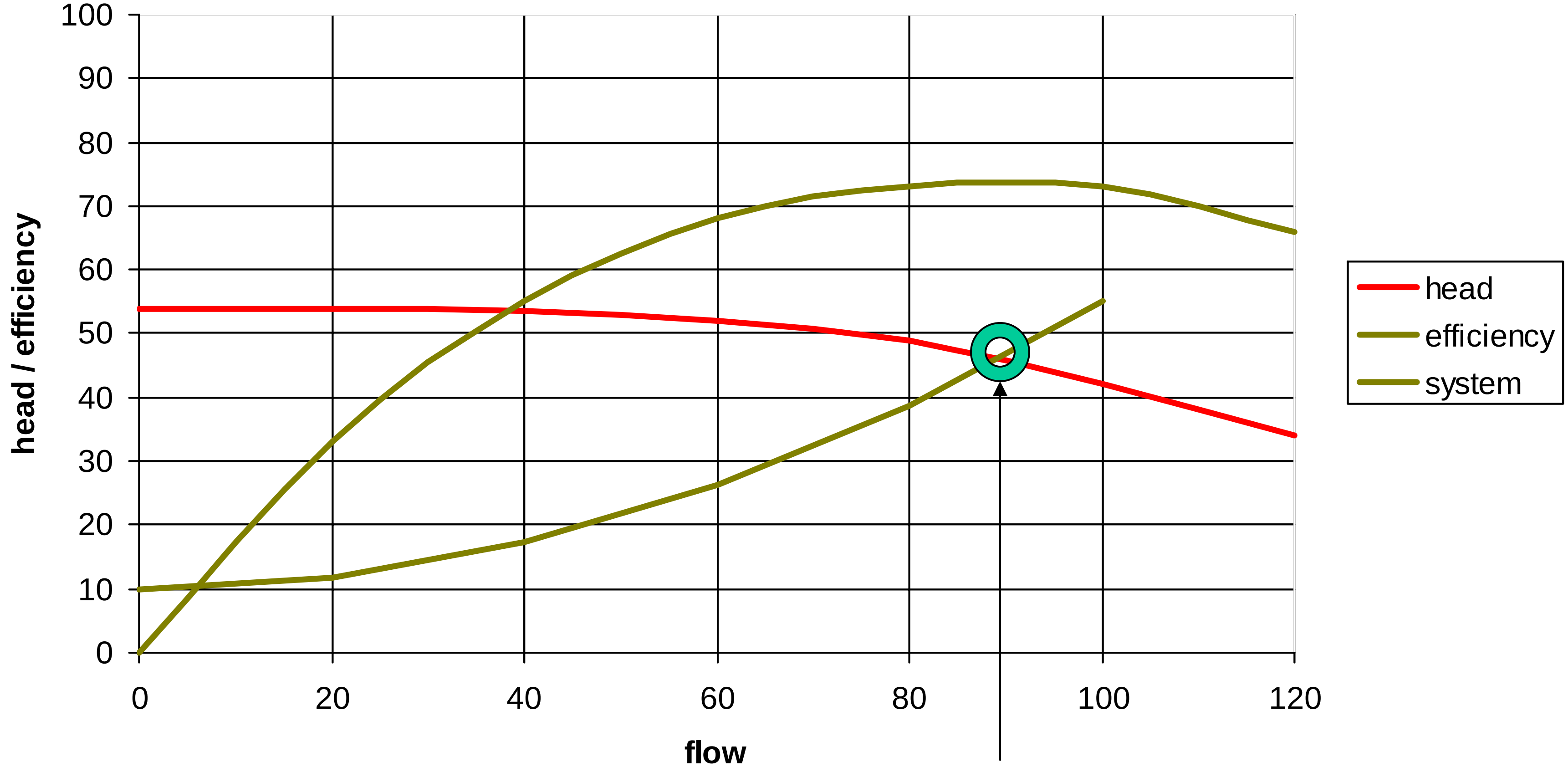
\+ Pressure in system,
i.e. at the discharge vessel **Pd**

\+ Friction loss on the suction side

\- Static head on suction side **Hs**

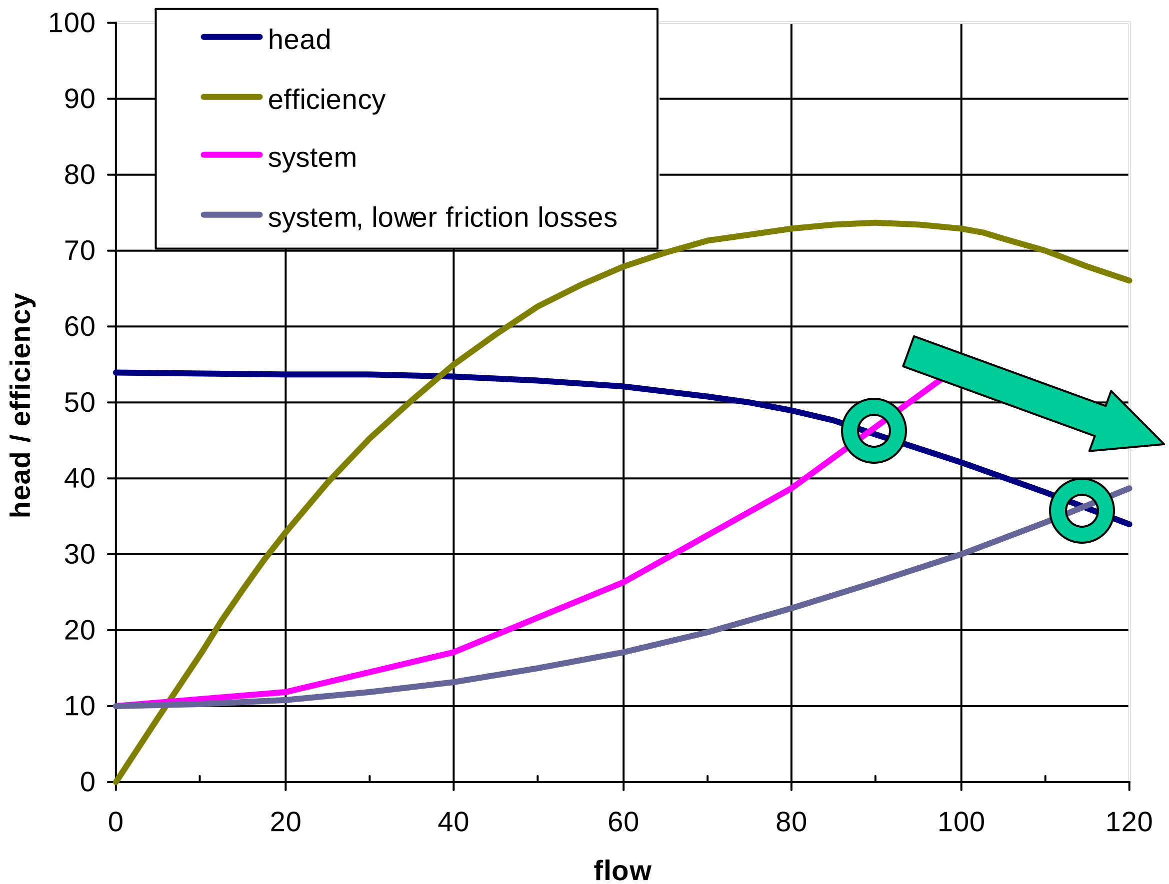


Pump interaction with system



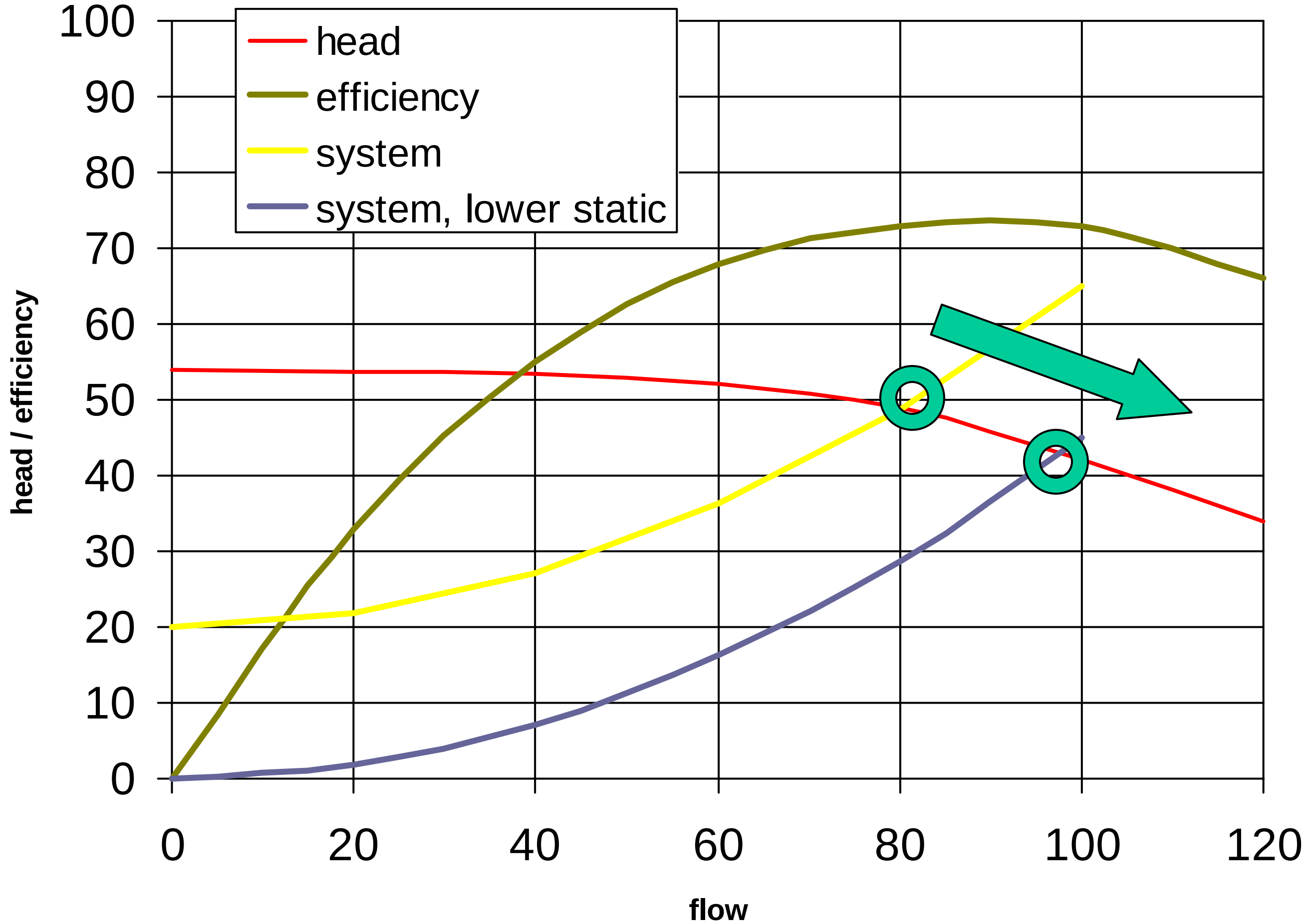
Pump operates where pump and system curve intersect

Pump hydraulics, system change



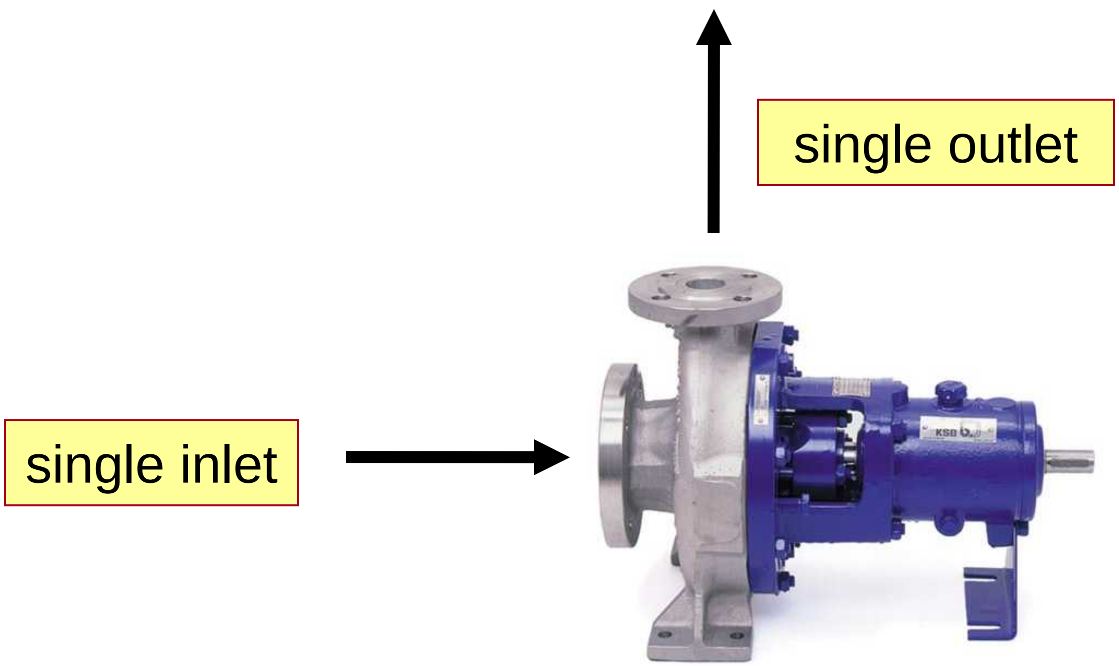
Note, with lower system curve, pump now delivers more flow

Pump hydraulics, system change

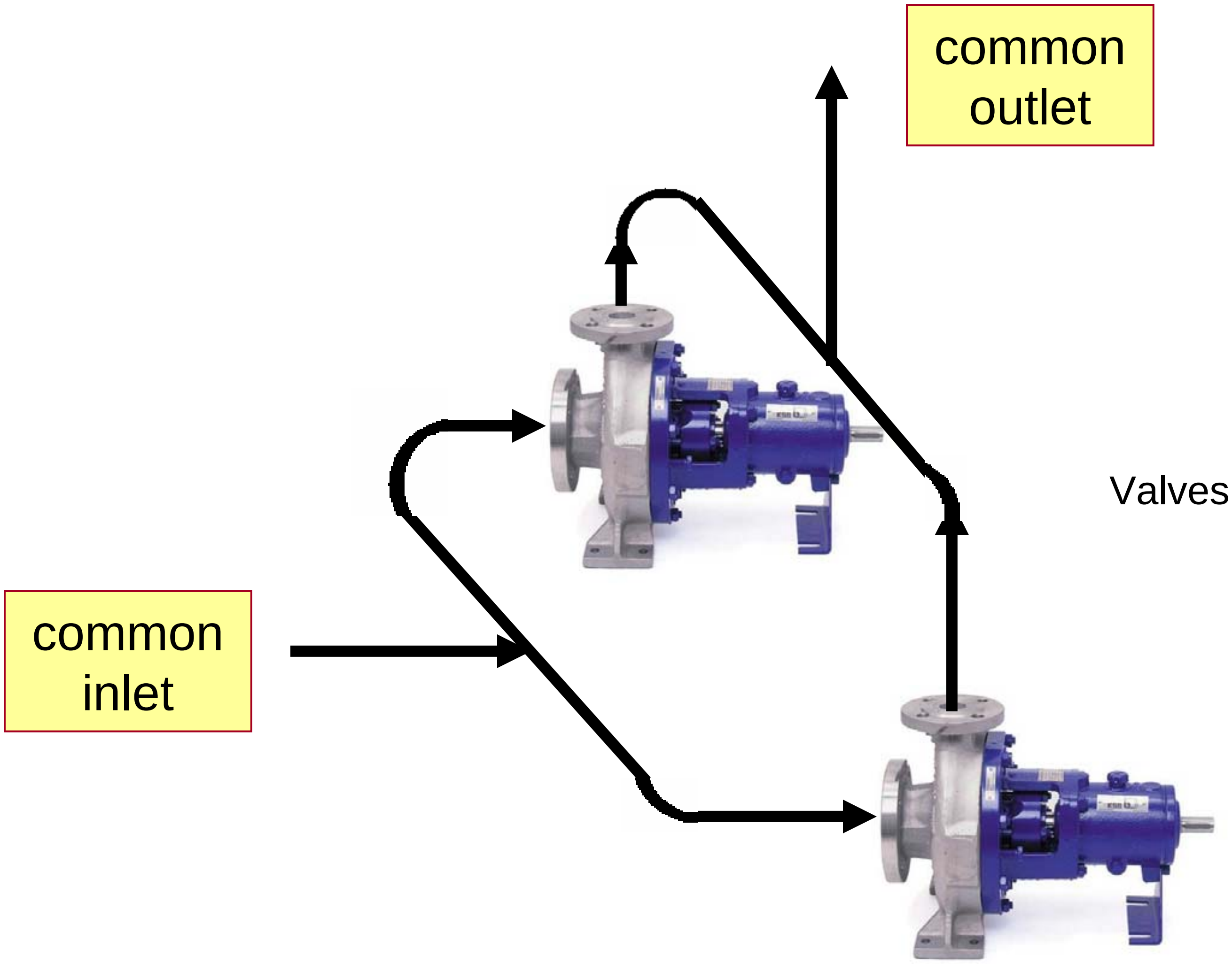


Note, with lower static curve, pump now delivers more flow

Pump hydraulics, single operation

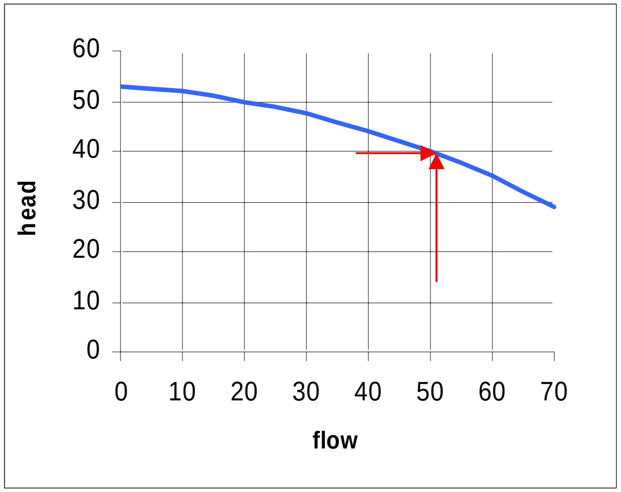


Pump hydraulics, parallel operation



Valves etc. excluded for clarity

Pump hydraulics, pumps in parallel



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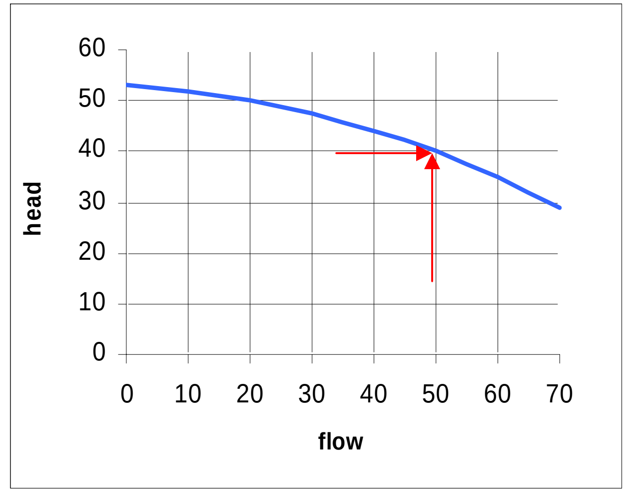

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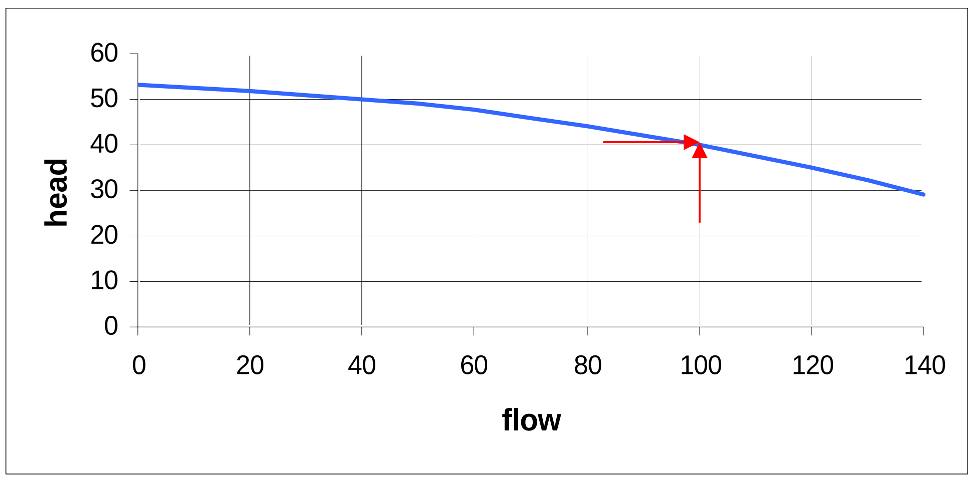
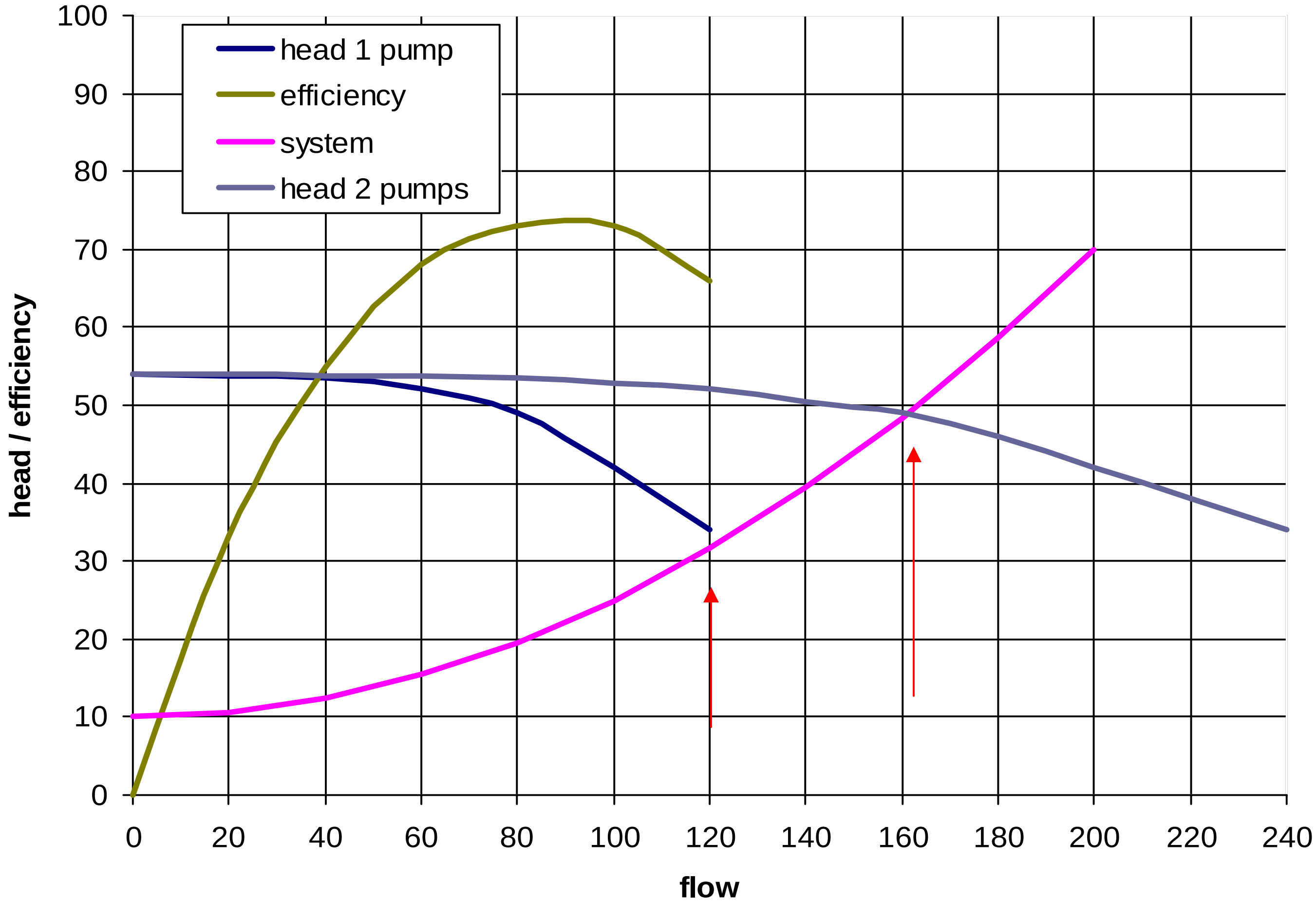


Pump hydraulics, single + dual pump



Example

1 pump running: total flow = 120 m3/h

2 pumps running: total flow = 160 m3/h flow per pump = 80 m3/h

Note with 1 pump running, flow is more than 1/2 of 2 pumps running

Pump hydraulics, Parallel operation

Issues to be considered:

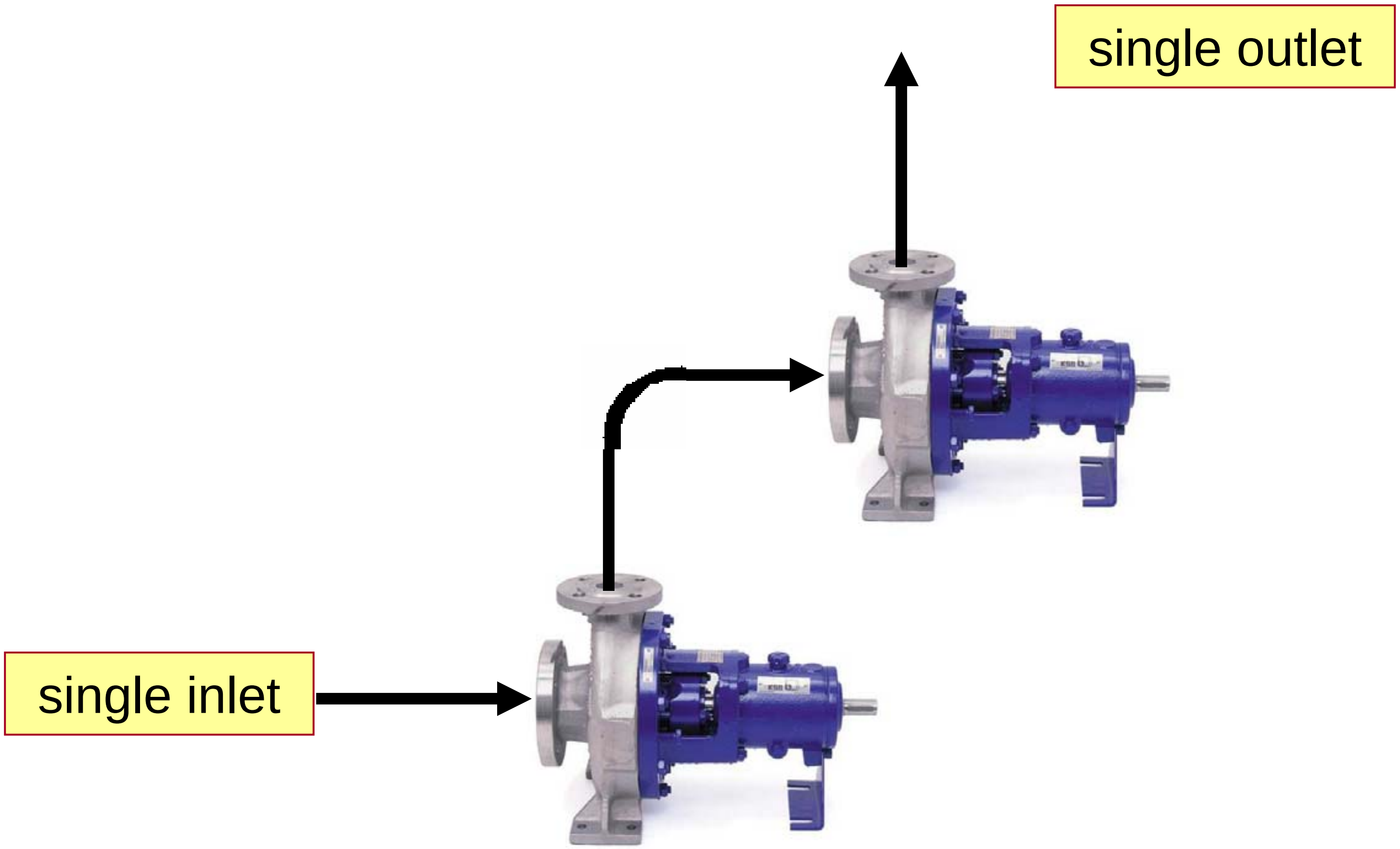
Flow per pump will always be lower than when operating on their own.

Therefore check that:

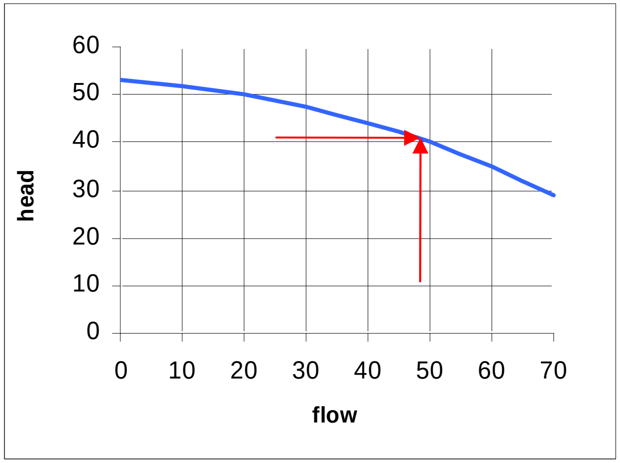
power of motor is adequate
NPSH a is adequate for the larger flow
the pump flow does not exceed the design limits
typically $Q < 125\%$ Q opt 4pole
$Q < 110\%$ Q opt 2 pole

Both pumps need to have similar shaped curves

Pump hydraulics, series operation



Pump hydraulics, pumps in series



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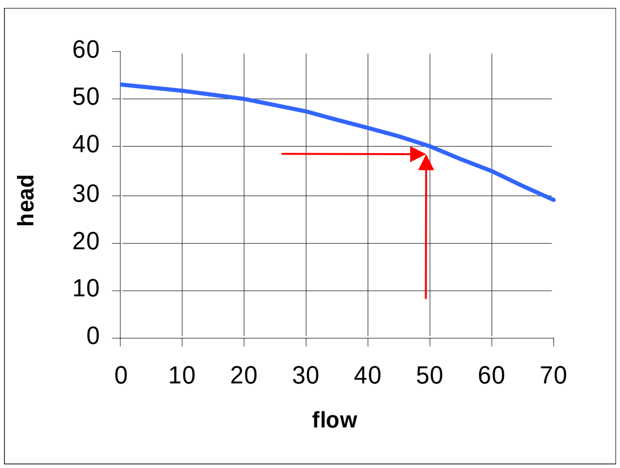

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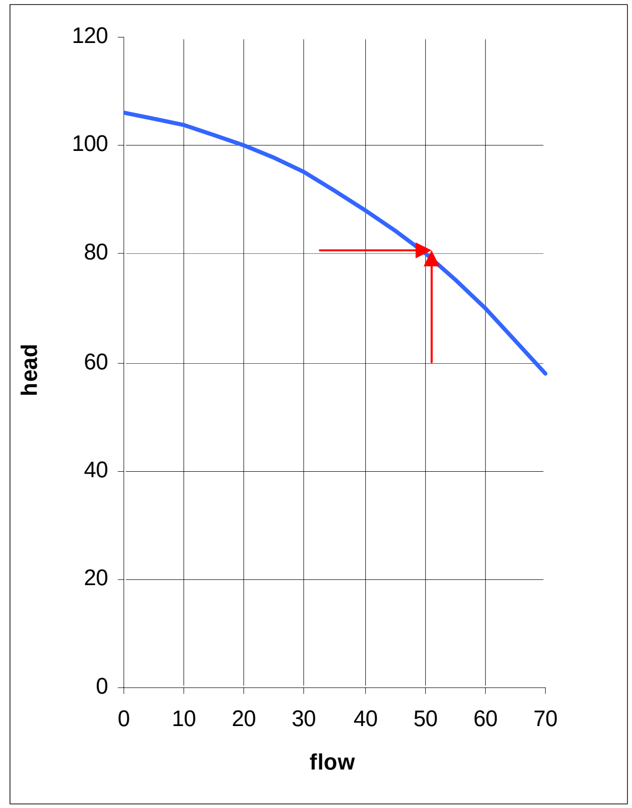
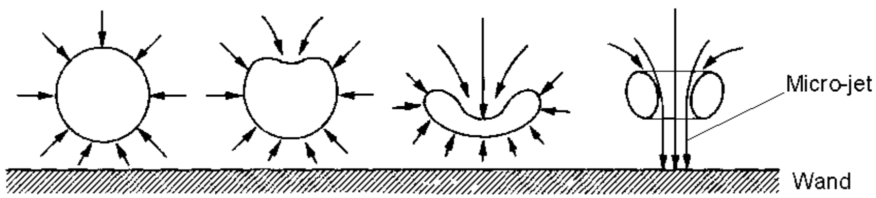
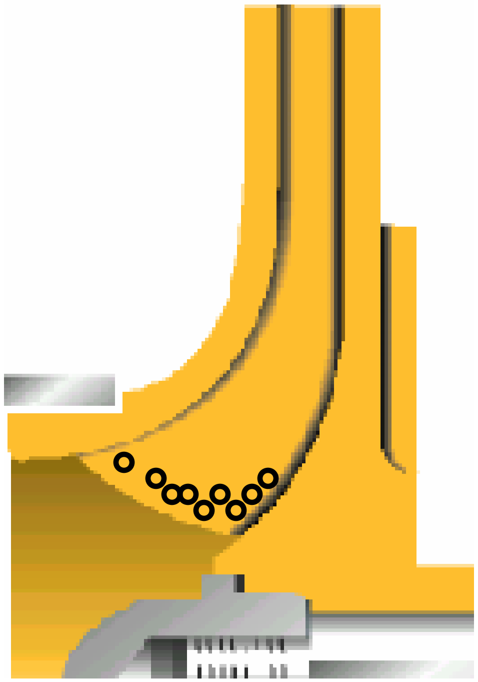


Pump hydraulics, Cavitation

Cavitation is caused by vapour bubbles forming in the pump.
A bubble is formed in the impeller at a point where the 'local' pressure is lower than the vapour pressure.
As the local pressure drops, more vapour bubbles will form in the pump.
As the liquid flows further through the pump into a higher pressure area the bubble collapses

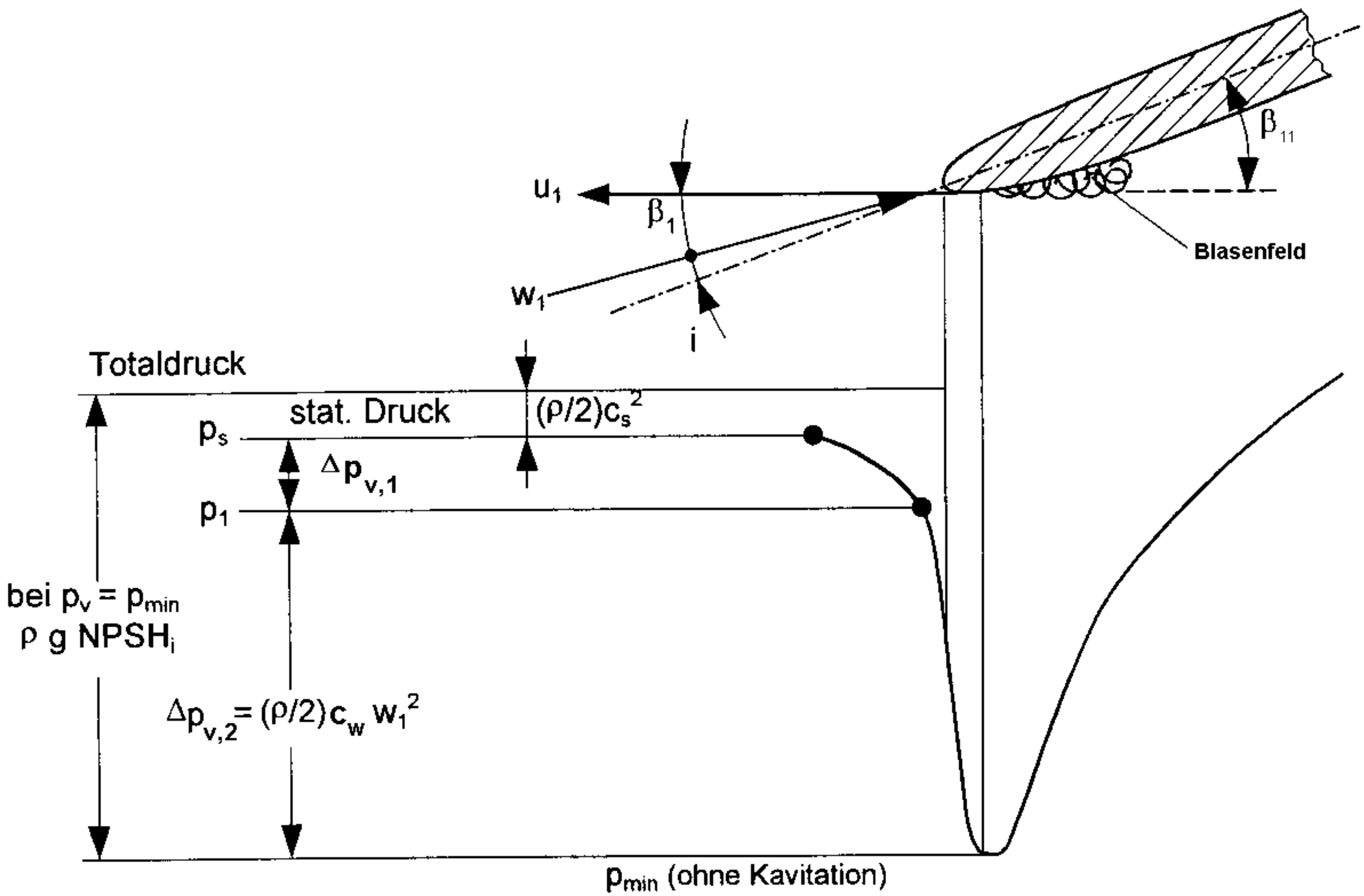




It's this bubble collapse that causes the pump damage. This often sounds like the pump is handling gravel. Continued cavitation will eventually destroy the pump.

To avoid cavitation, the npsh a > npsh r of the pump

Cavitation on the vanes



NPSH breakdown

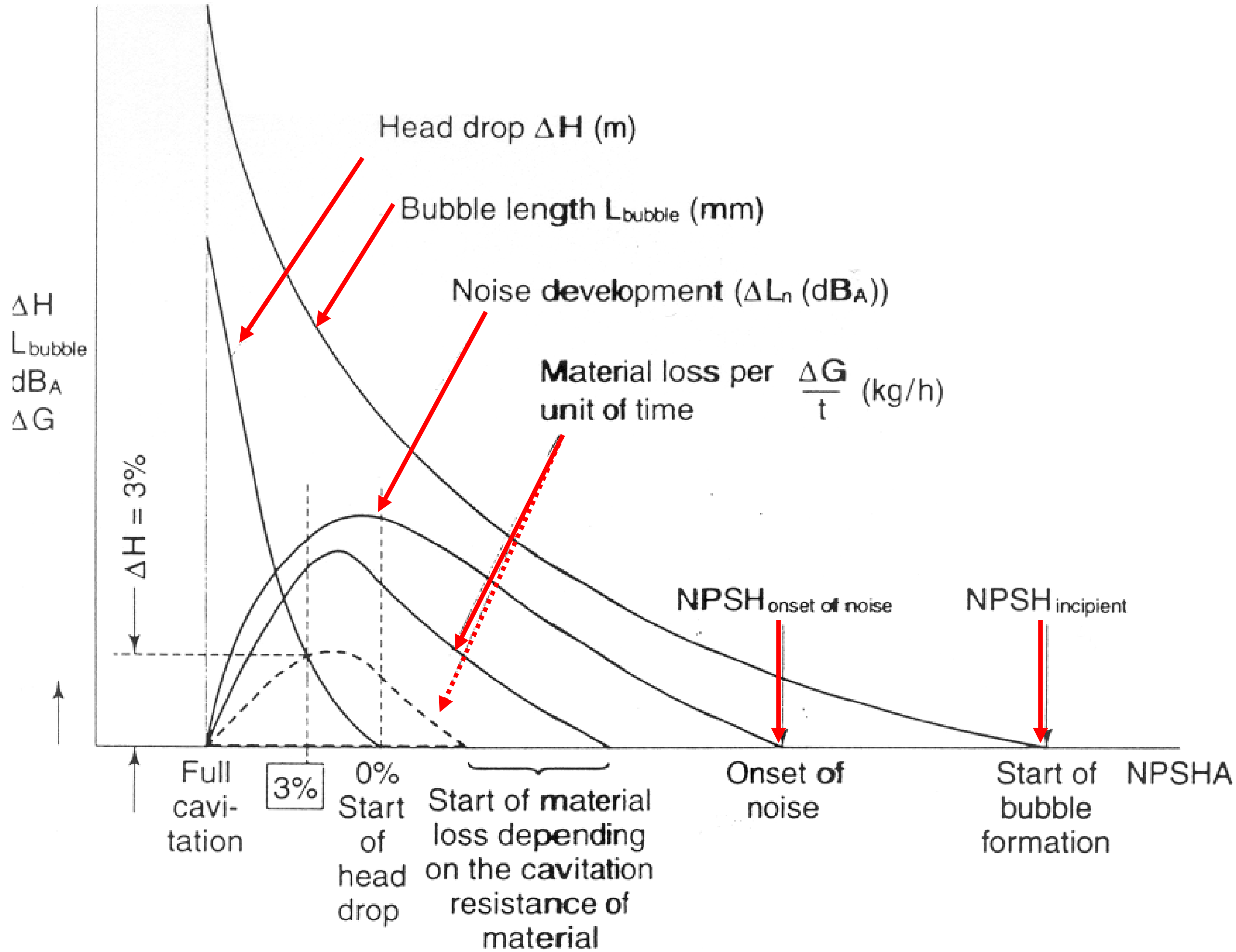


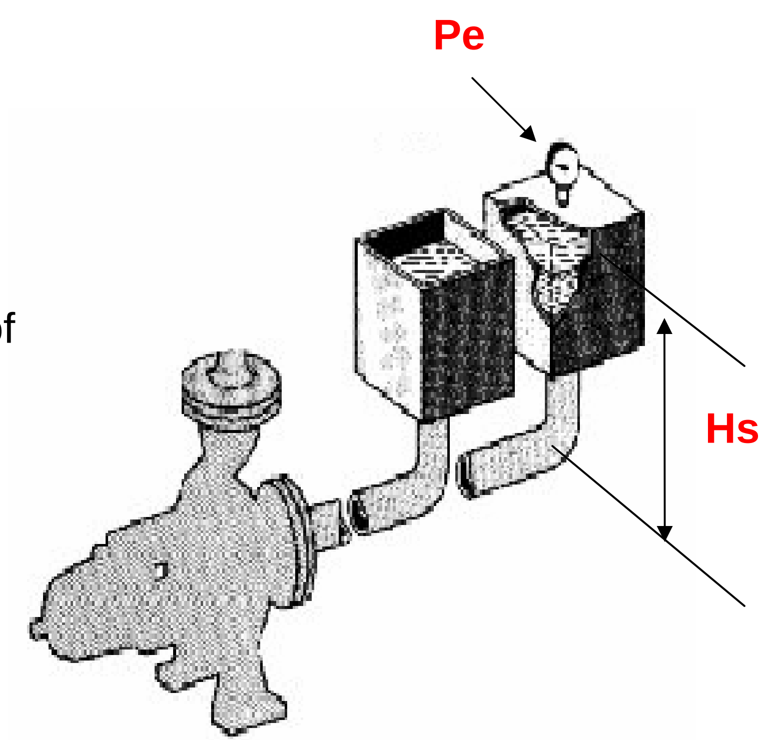
Figure 4(a) Bubble length, sound level, material loss and pump total head versus

Pump hydraulics, NPSH available

NPSH stands for	: net positive suction head
NPSH available	: npsh from the plant / system in which the pump operates
NPSH required	: npsh that the pump needs to stop cavitation

NPSH available consists of various parts:

	Hs	Static head on suction side
-		Friction losses in the suction line
+	**Pe**	Absolute pressure expressed in metres of liquid
+	$V^2/2g$	Velocity head in the pipework This is normally ignored
-	H_{vap}	Vapour pressure expressed in metres of liquid, at the pumped temperature



What does this mean?

So in practice this means:	in the following example, we've ignored the losses in the suction line		
Pump with static suction head of	+ 5 m	(Hs)	
Drawing from an open tank	+ 10 m	(Pe)	atmospheric pressure is roughly 10m with water
Handling water at 10 °C	- 0.125m	(Hvap)	this equates to the vapour pressure of water at 10 °C
So NPSH available is	**5 + 10 - 0.125**		**= 14.875 m**

However, contrast this with the same system at 90 Deg C:

Pump with static suction head of	+ 5 m	(Hs)	
Drawing from an open tank	+ 10 m	(Pe)	atmospheric pressure is roughly 10m with water
Handling water at 90 °C	- 7.41m	(Hvap)	this equates to the vapour pressure of water at 90 °C
So NPSH available is	**5 + 10 - 7.41**		**= 7.59 m**

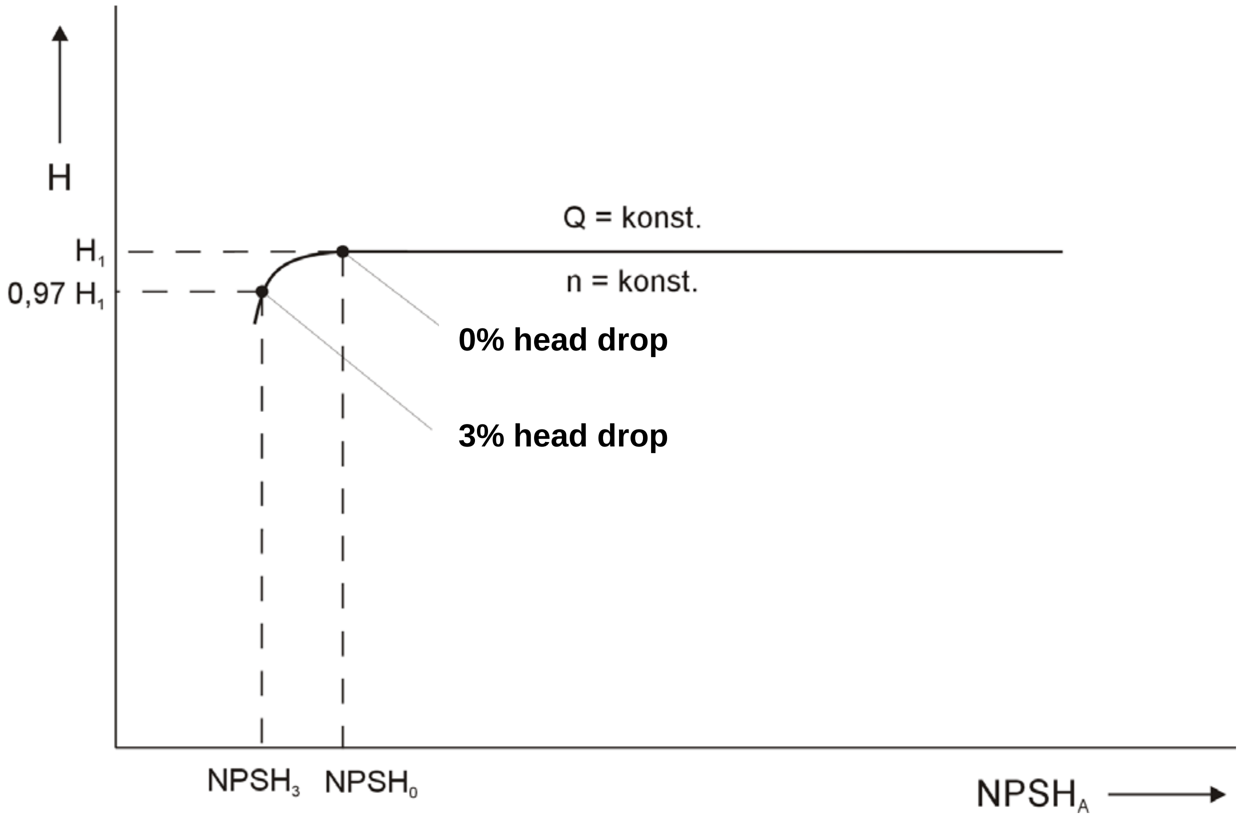
Suction head not the same as NPSH

Therefore you can see from the previous slide that suction head is not the same as NPSH.
The vapour pressure of the pumped liquid must be taken into account.

All pumps have an NPSH required curve. This is largely independent of the pumped liquid, so the NPSH available and NPSH required need to be compared to ensure that the pump will run properly.

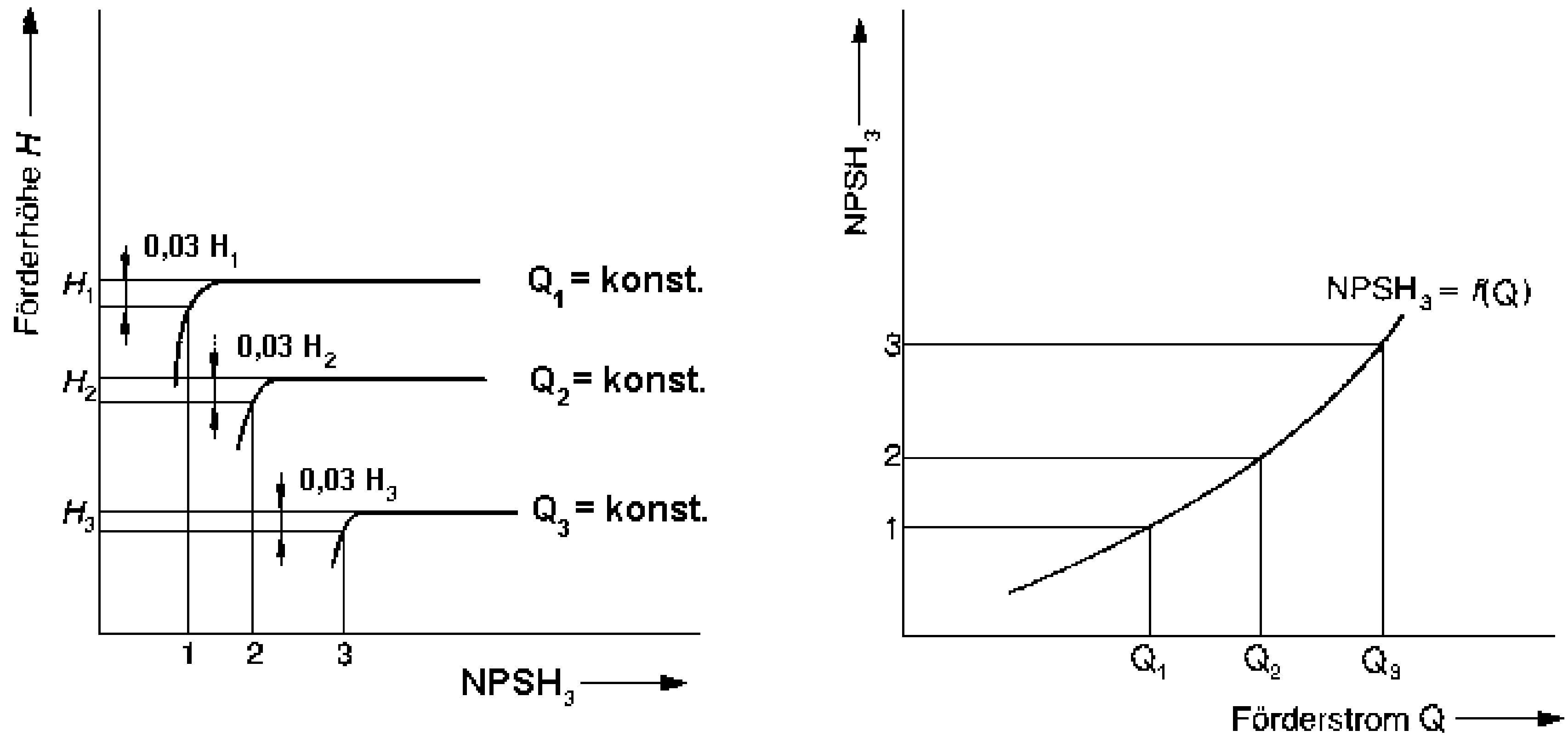
The NPSH r curve of the pump generally indicates the value at which the pump will cavitate. Therefore it’s important to have a margin between the NPSH available and the NPSH required to prevent cavitation.

NPSH required

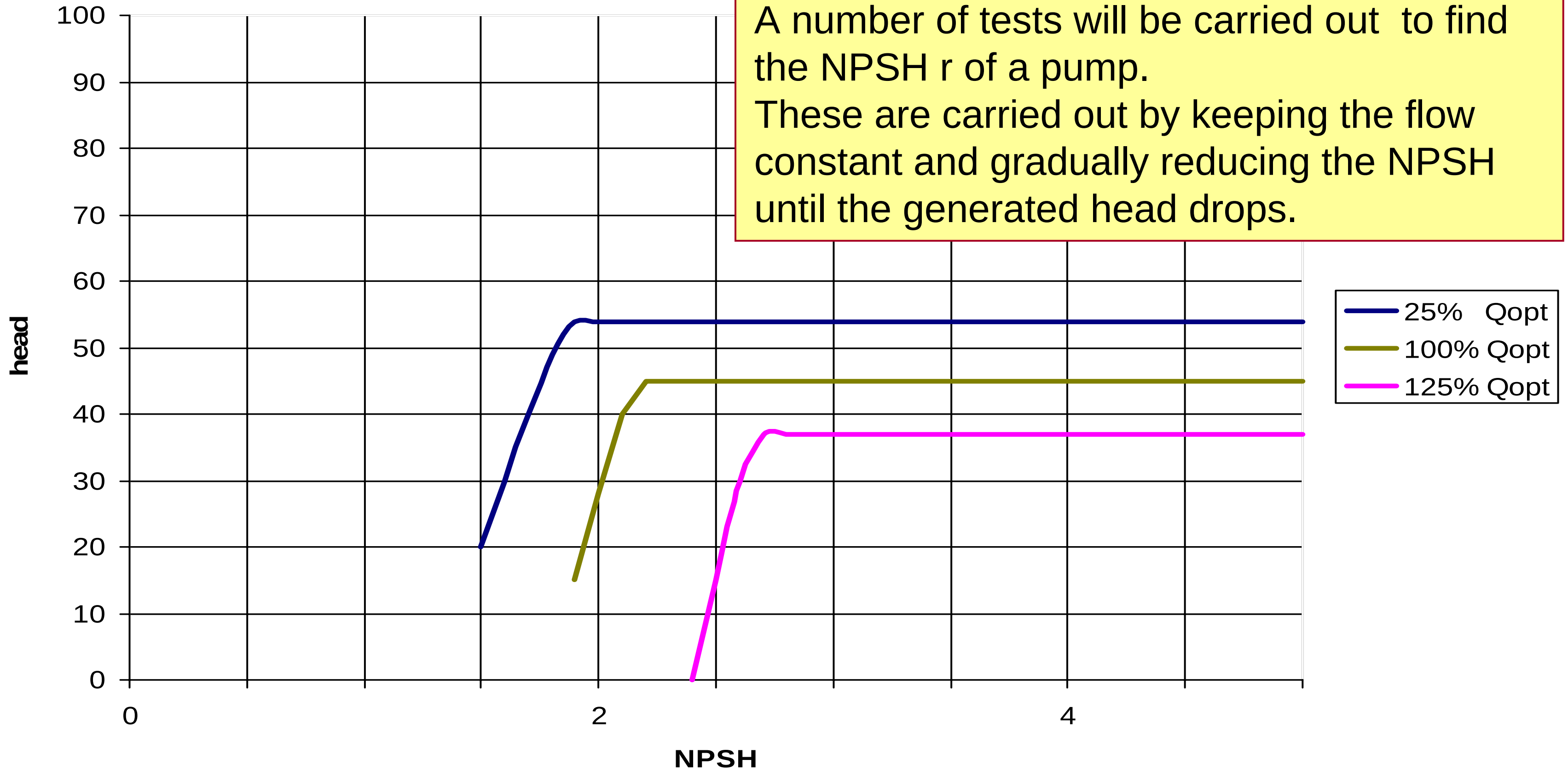


Note, when NPSH test is made, head drop is measured (3%)

NPSH required



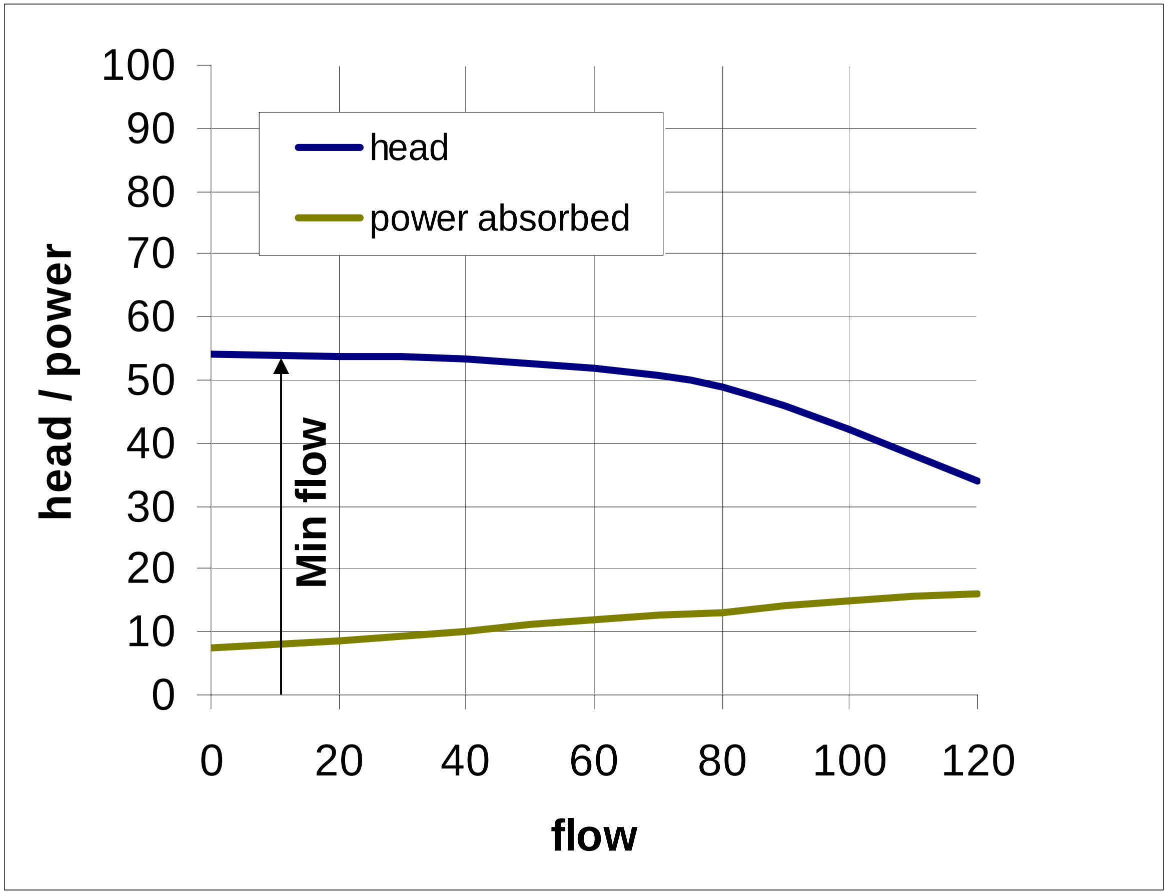
Pump hydraulics, NPSH required



A number of tests will be carried out to find the NPSH r of a pump.
These are carried out by keeping the flow constant and gradually reducing the NPSH until the generated head drops.

NPSH r normally classed as the point when the head drops by 3% from the 'non cavitating' head

Pump hydraulics, minimum flow



Why min flow?

Kettle:	2kW
Capacity:	1.5 l
Time to boil:	4.5 min

Pump

Power at Q=0:	8kW
Pump volume:	2.5 l

Minimum permissible flow prevents pump from overheating

Pump hydraulics, minimum flow

Other considerations for minimum flow:

Heat	Temperature rise in the pump as losses in the pump heat up the pumped liquid.
Pump curve	Flat or unstable curve. At low flow there is a risk of ‘hunting’
Radial loads	These increase at low flow, shortening bearing and seal life through increased shaft deflection
NPSH req	Generally increases at very low flow
Power	On side channel pumps, power increases as the flow reduces
Guideline	Qmin > 15% of Q opt

Pump hydraulics, speed changes

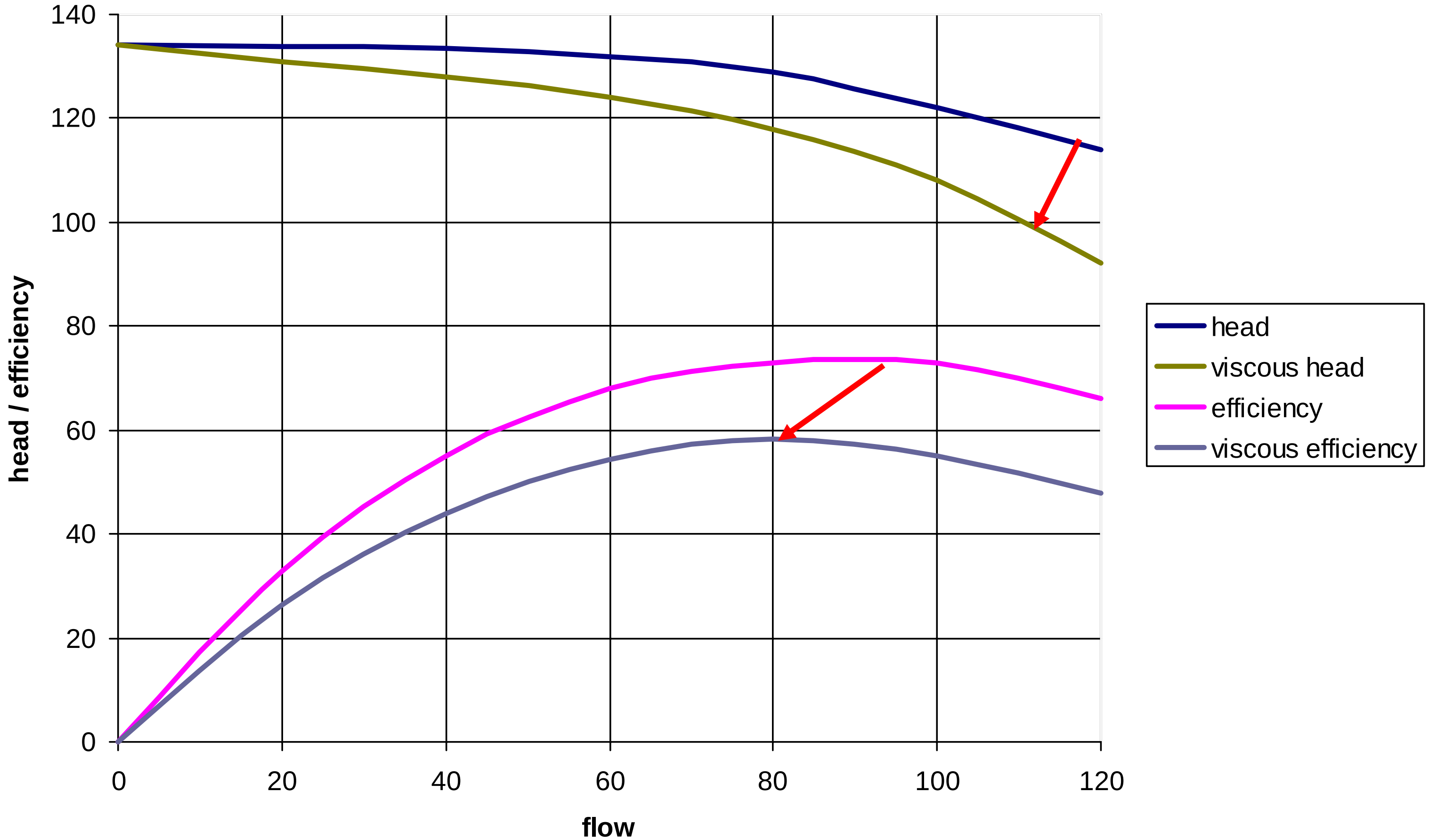
Affinity laws govern all centrifugal pumps:

Flow is proportional to Speed
Head is proportional to Speed ^{2}
Power is proportional to Speed ^{3}

This means for doubling the speed of a pump:

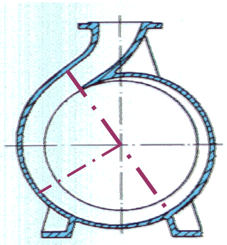
Pump speed	1450	rpm	2900	rpm
Flow	50	m3/h	100	m3/h
Head	50	m	200	m
Power	9	kW	72	kW

Pump hydraulics,viscosity

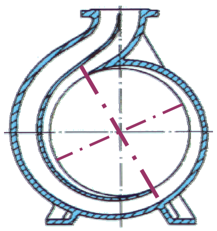


viscosity correction factors f_Q, f_H, f_{eta}

Pump hydraulics, casings

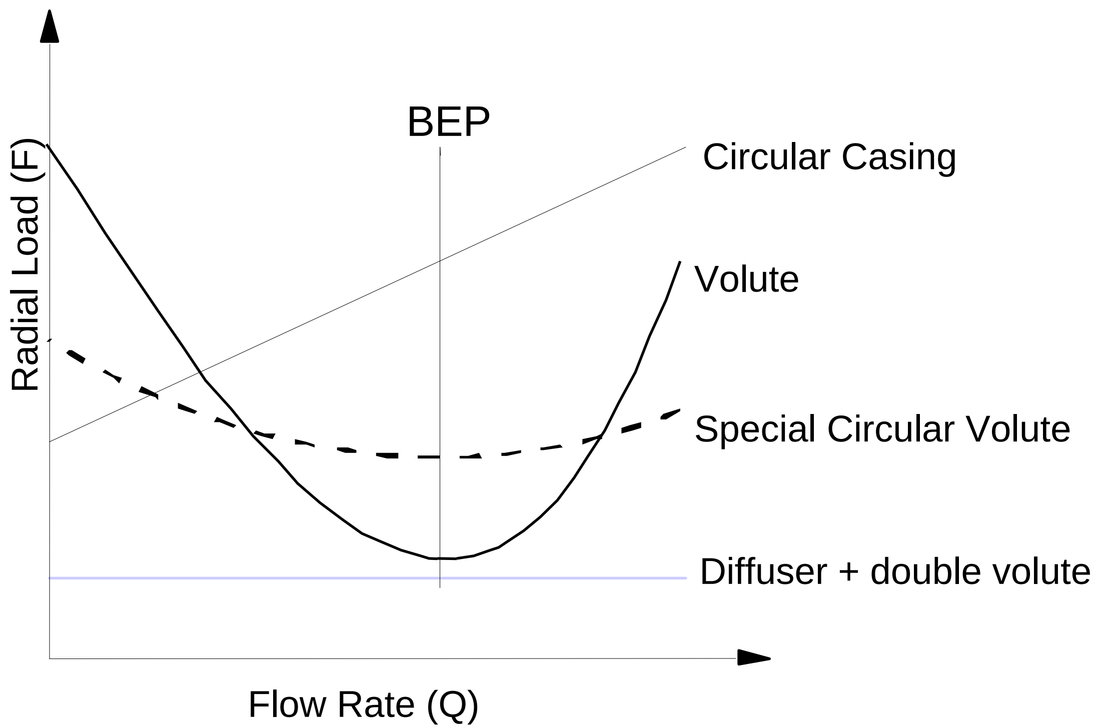


Single Volute



Double Volute

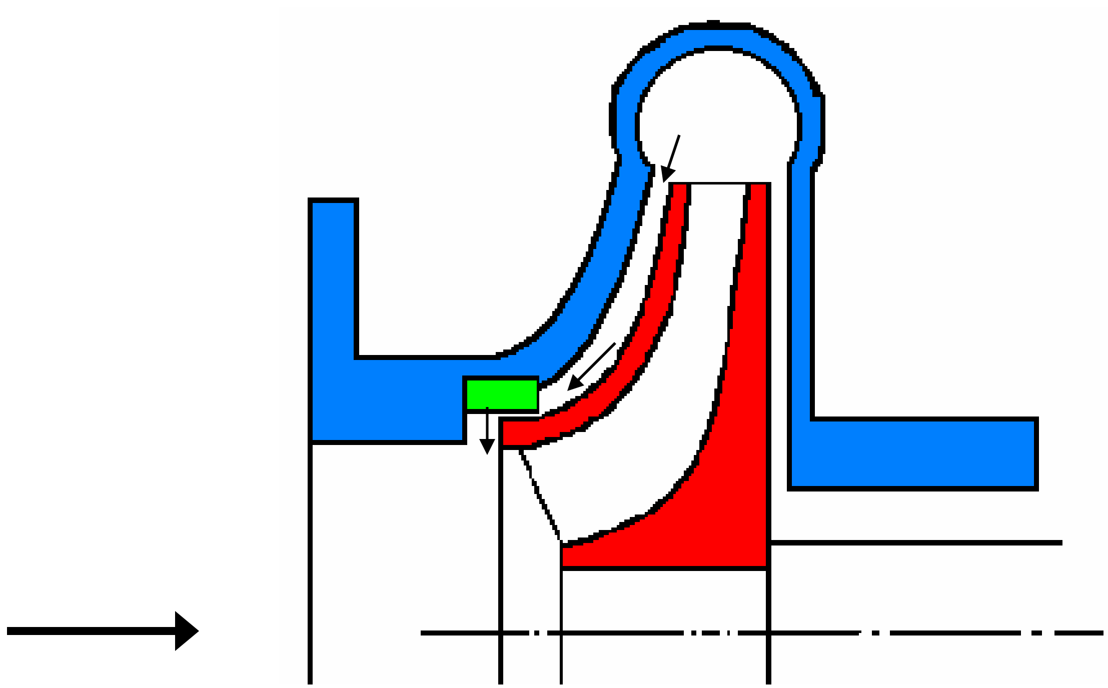
Diffuser

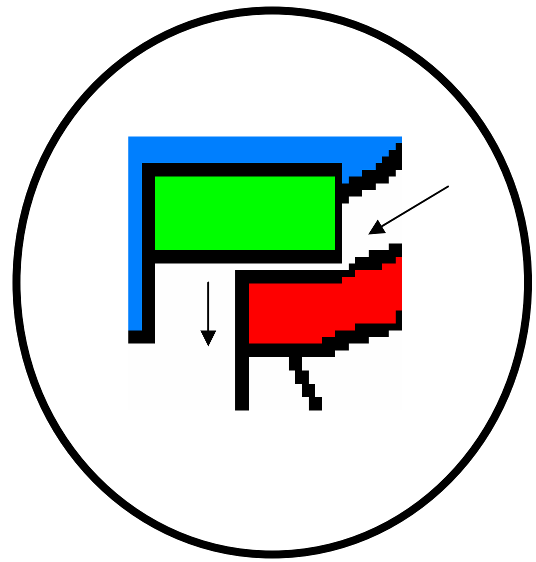


Pump hydraulics, enquiry data

Factors for (hydraulic) pump selection:

Capacity (Flow)	m3/h	l/s	gpm
Pump head or diff. pressure	m (bar)		ft (psi)
Liquid	including specific gravity		
Temperature	°C		°F
Suction head or pressure	bar		psi
Materials of construction			
Sealing requirements			
Environment / area of use			
Electrical supply	V/phase/cycles		



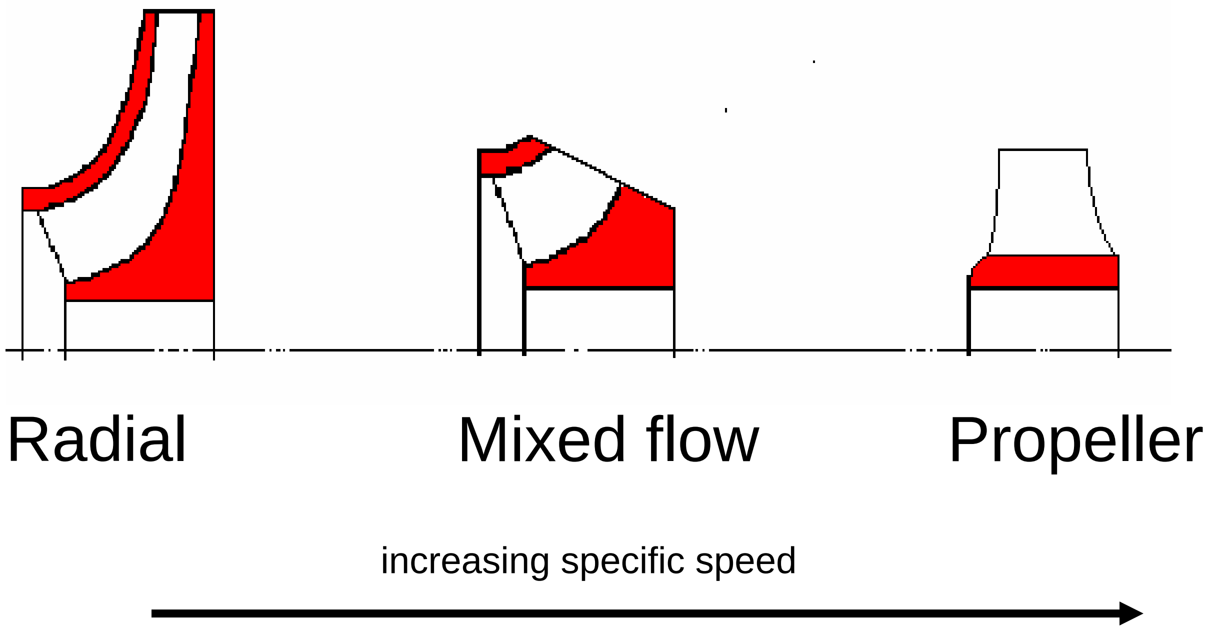


Flow between wear rings

Increased wear ring clearance reduces efficiency

Pump hydraulics, specific speed

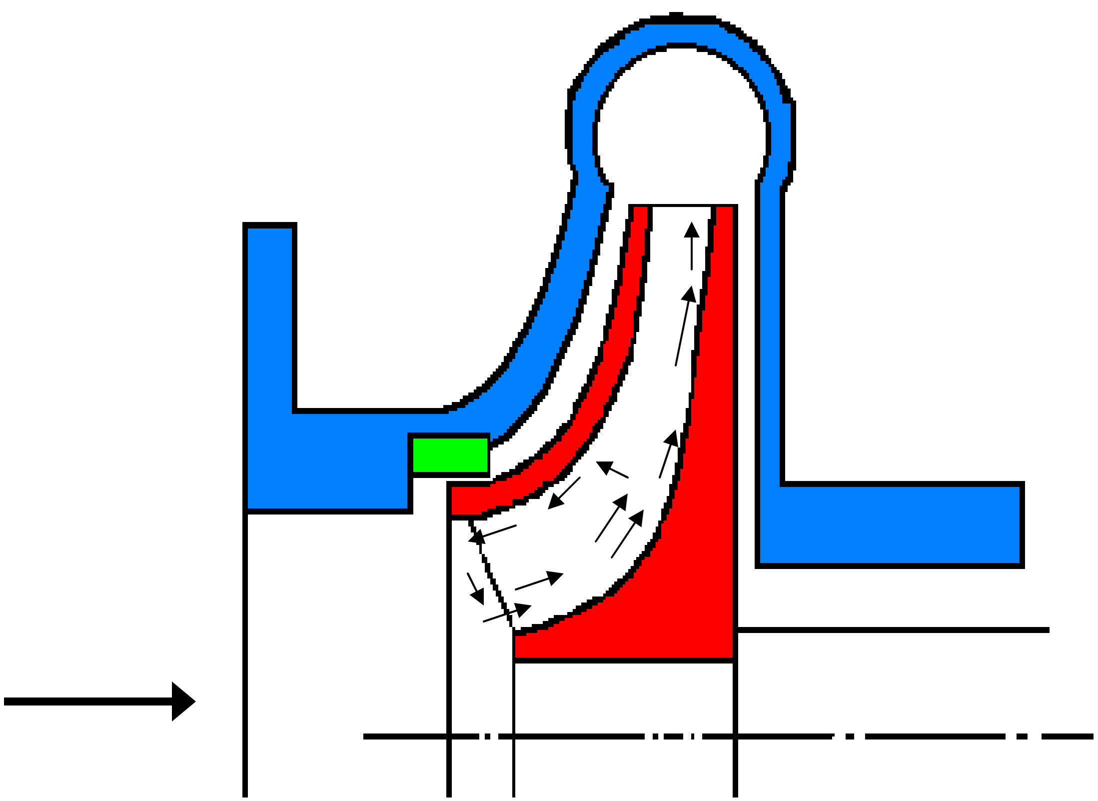
$$\text{specific speed} = \frac{\text{speed} \times (\text{flow})^{1/2}}{(\text{head})^{3/4}}$$



Note, units must be specified in quoting specific speed

Pump hydraulics, suction recirculation

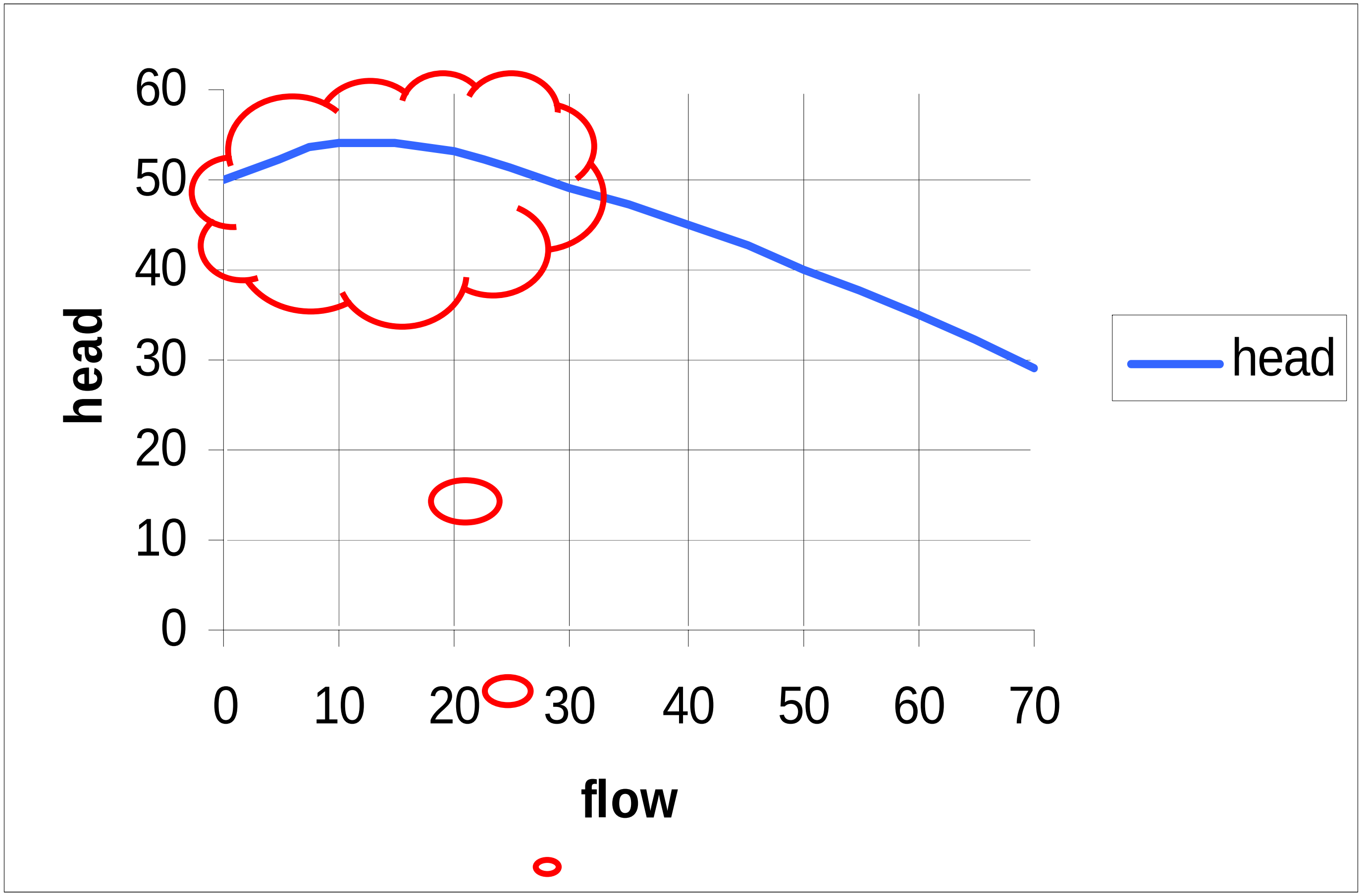
$$\text{suction specific speed} = \frac{\text{speed} \times (\text{flow})^{1/2}}{(\text{NPSH})^{3/4}}$$



Suction recirculation
at low flow

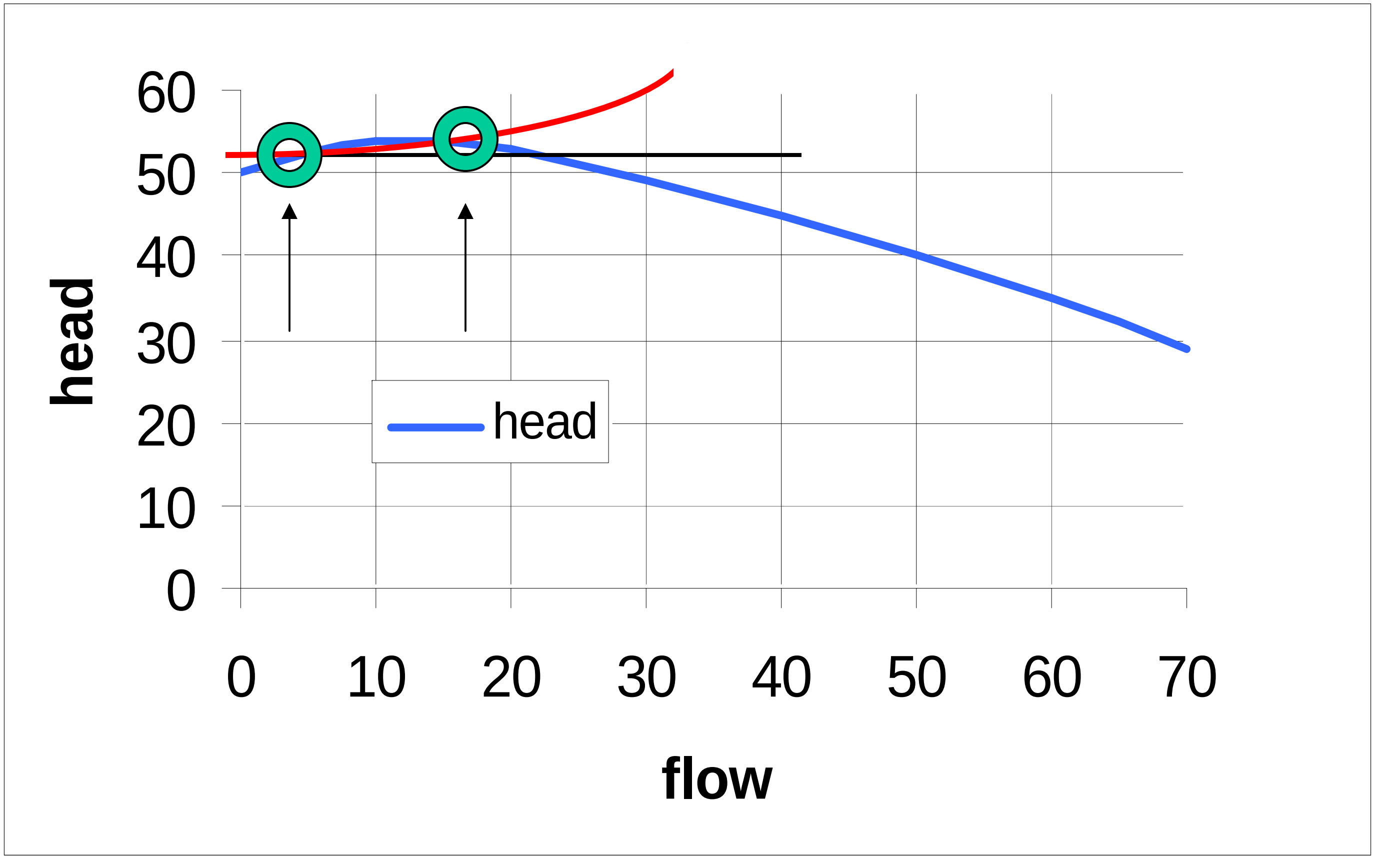
higher nss = lower NPSH r
but suction recirculation
more likely

Pump hydraulics, Unstable curves



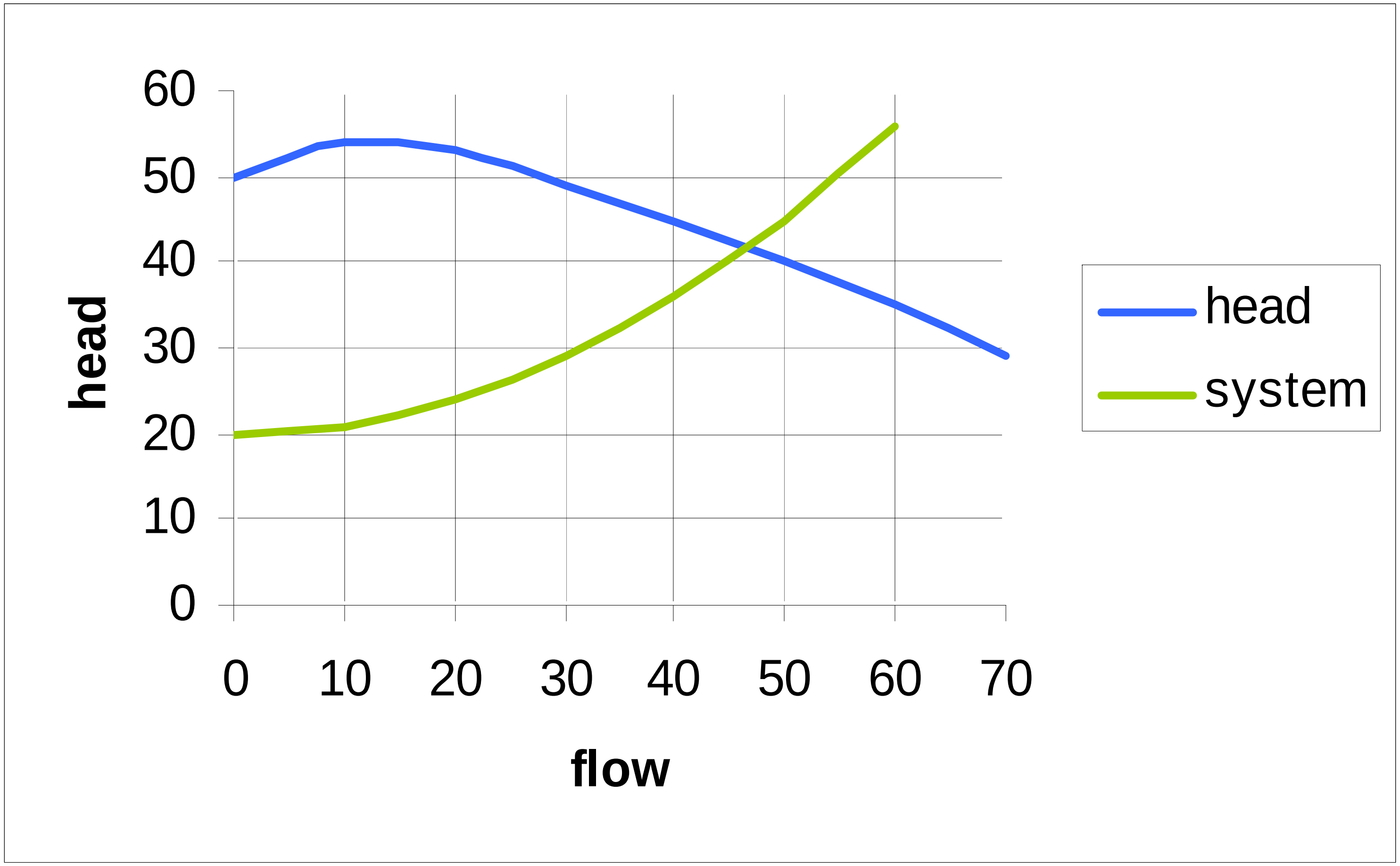
The generated head does not fall continuously as the flow increases

Unstable curves, “flat” system



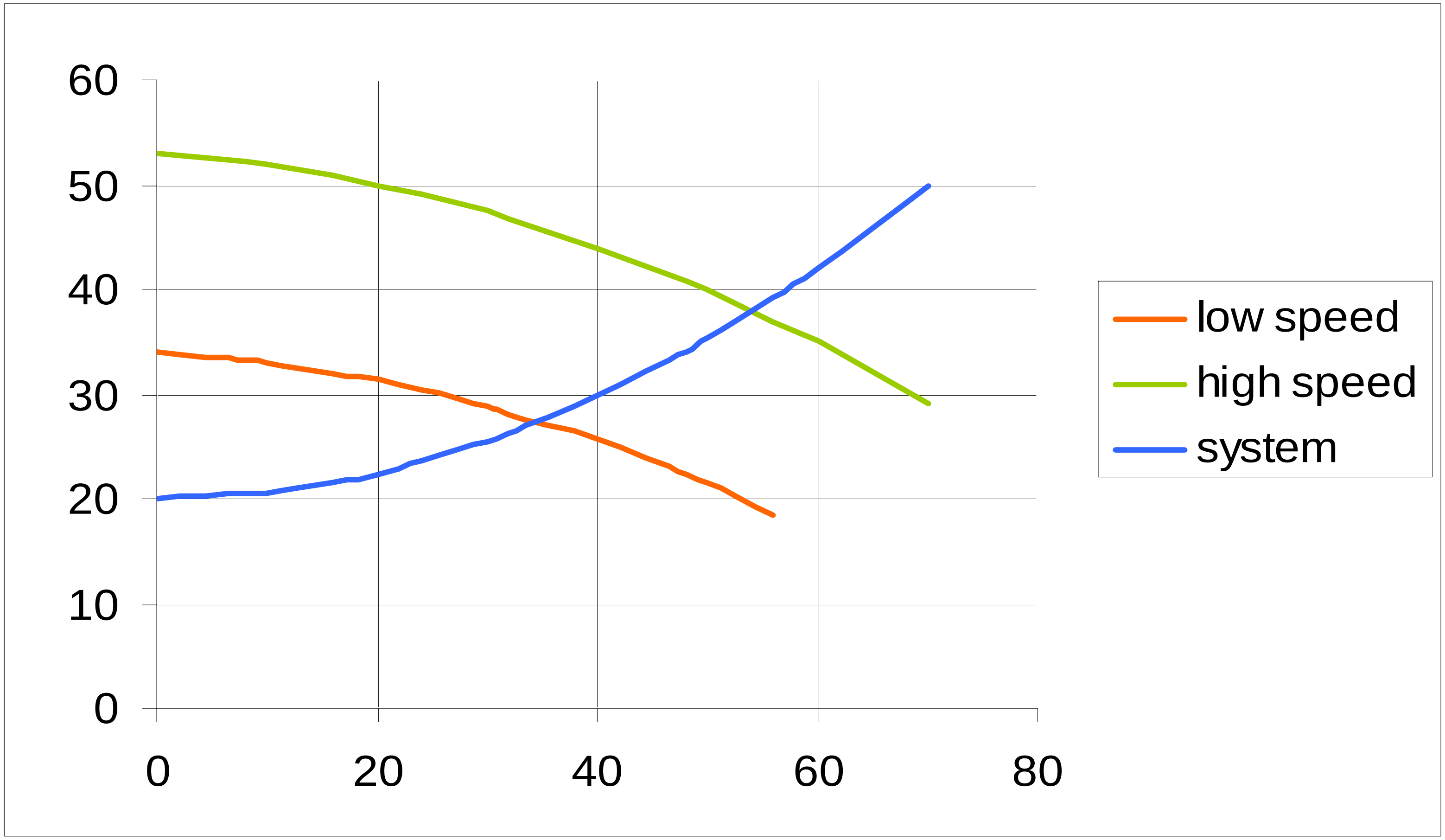
For a flat system curve, the pump could operate at one of two flows, or hunt between the two

Unstable pump curve, “steep” system



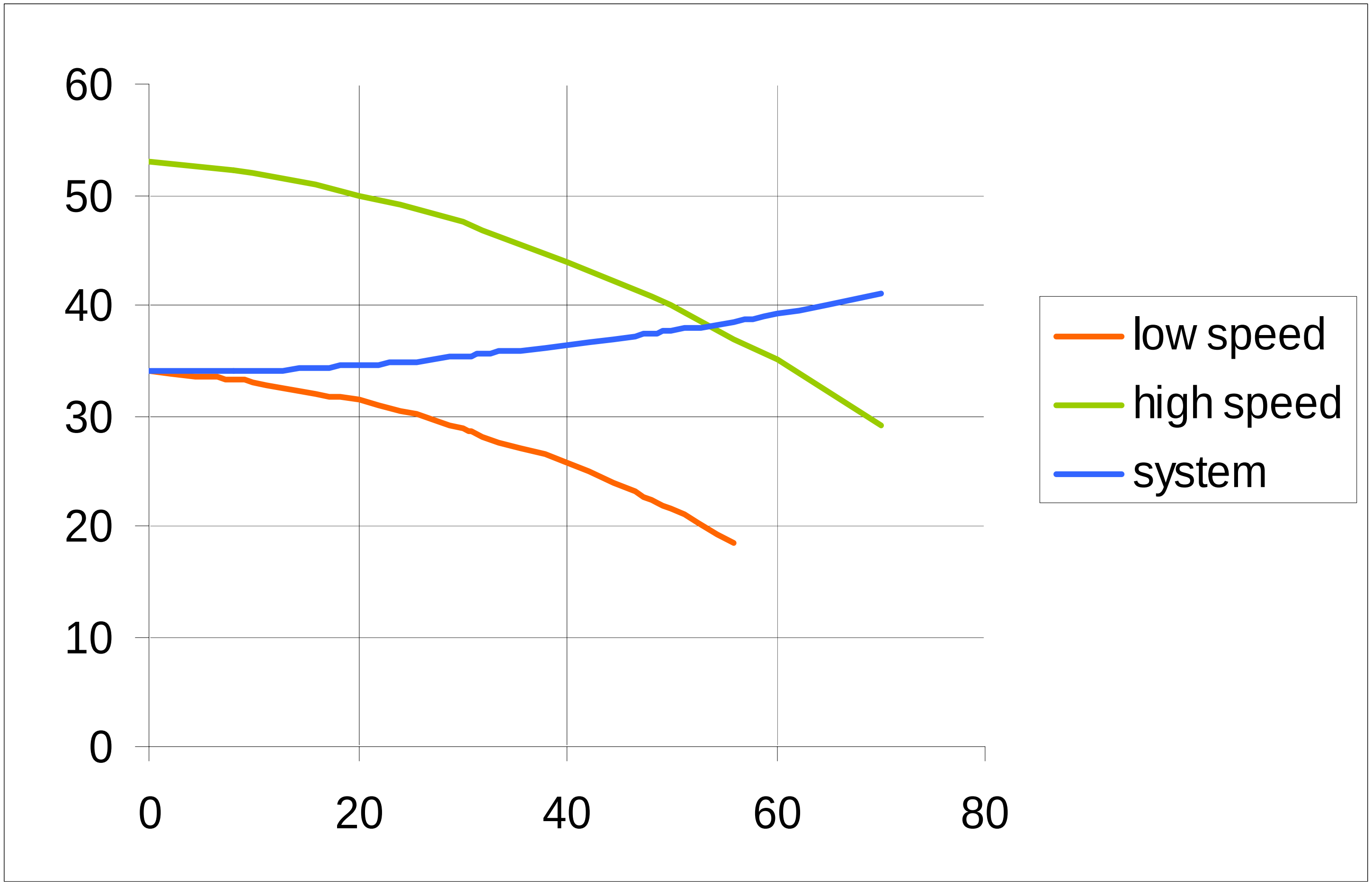
For a steep system curve, the pump can still only operate at one flow

Pump hydraulics, Speed change



For a steep system curve, the pump flow will change with speed

Pump hydraulics, Speed change, flat curve



For a flatter system curve, at low speed the pump flow may be zero.