Shannon Harbour Lock 35 & 36

PUMP AUDIT SUMMARY REPORT

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Shannon Harbour Lock 35 & 36

PUMP AUDIT SUMMARY REPORT

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P1	28/11/19	N Taylor	J Bernard	N John	Issue for Comment
P2	21/02/19	N Taylor	J Bernard	N John	Updated from P1 Comments

Content

1 Introduction

This report summarises the key findings of the Phase 1 pump station audit for Lock 35 and 36 located near Shannon Harbour. The 2no pumping stations are used in a chain to supply water to the Grand Canal from the River Shannon/River Bresna confluence during dry periods to maintain navigable levels. This review is based upon the data provided by Waterways Ireland (WI) and a site visit undertaken on 18th September 2019.

Pump testing was undertaken at the site visit and the following parameters measured using calibrated instrumentation:

- Power (using Fluke power meter)
- Flow rate (using Panametrics PT878 ultrasonic flow meter)
- Levels and dimensions (laser/tape measure)

No pressure measurement point could be found to measure pressure.

The purpose of the site audit and pump performance testing is to estimate the existing pump performance, system curve (including rising main static head) and capture and evaluate key aspects of the existing arrangement in the context of assessing potential improvements.

2 System Description

2.1 Lock 36

Lock 36 is located near Shannon harbour, Clonony Beg, Co. Offaly. The pump house is the last of a chain of pumping stations along the Grand Canal designed to maintain an upstream level within the canal from the Shannon river/Bresna river confluence.

Figure 1 - Lock 36 PS on the Grand Canal (Left); Inside Lock 36 wet well (right)

Lock 36 PS comprises of 1no. ABS fixed-speed submersible pump (Model AFP 1521 M150 4-32). The pump station intake is direct from the Grand Canal downstream of Lock 36 via a concrete intake culvert. The intake is fully submerged and is protected with a 50 mm spaced bar screen within the wet well. A manually operated penstock (sluice gate) is located on the inlet to the chamber as a means of isolation.

The pump discharge pipework is 150mm nominal diameter (DN150) and manufactured from 16 bar rated flanged ductile iron pipe (DI, PN16). The DI pipework connects to a 250 mm diameter rising main of unknown material via a concentric taper. Due to the possibility of the rising main being asbestos concrete pipe, the decision was taken to stop investigating this section any further until a full assessment on the pipeline can be made.

The rising main discharges to a concrete outfall chamber. The exact nature of the discharge could not be ascertained as it was inaccessible at the time of the audit. Given the exit flow path of the water (the water appeared to be exiting in a jet from one edge of the outfall), it is assumed that there is no weir present.

There are no isolation or check valves contained within the pump station. 1no ultrasonic level probe is located within the wet well and for purposes of low level protection.

2.1.1 Additional Observations

- The are reports from the Lock keeper of the pumps at Lock 36 and Lock 35 not being able to cope with demand when the upstream level drops significantly, especially if the boat repair dry dock is in operation, which is fed from the canal. The pumps are reported to run continuously except for occasional periods such as during periods of flooding.
- Waterways Ireland are considering a new additional pump station at Lock 34. There are reports of substantial leaks in the system between Lock 31 and Lock 34, therefore additional capacity maybe required from Lock 36 and in turn Lock 35.
- During time of audit, the water level at both Lock 36 and Lock 35 was being maintained above the lock gate, as such there was significant over topping at both gates.
- At Lock 36 there are reports of pump trip from excessive current. It was reported that the Sprecher & Schuh CT 3-23 Overload relay was adjusted to stop this from happening, and it was observed that the ammeter on Lock 36 reads 22A instead of 27A as measured by the temporary power meter.

Figure 2 Lock 36 PS Outfall

Table 1 – Pump Details

Parameter	Description
Pump	ABS AFP 1521 M150/4-32
No. of Pumps	1
Duty Configuration	Duty (Submersible)
Rated Motor Output	15 kW
Impeller Diameter	Impellor Type 1 Closed Type
Drives	Star Delta
Pipework	Flanged 150 mm nominal diameter (DN150) ; 16 bar rated (PN16)
Non-Return Valves	N/A
Wet Well Level Sensor	Ultrasonic for Low level protection
Wet Well Level	31.85 m above ordnance datum (mAOD)
Pump Centre Line	30.53 mAOD

2.1.2 Rising Main

The Lock 36 rising main is approximately 34 m in length. The pipeline consists of approx. 3.5 m of flanged ductile iron pipework which connects to a 250 mm diameter rising main pipe via a concentric taper. The rising main section is approximately 30 m in length. The rising main material is unknown but is suspected to be asbestos concrete.

The rising main runs from the wet well and free discharges to a concrete outfall box on the Grand Canal. There are no isolation or check valves present on the rising main.

The pipeline condition is unknown but there are no reports of bursts arising since construction.

Table 2 – Rising Main Details

Parameter	Description	
Section	1	2
Approx. Length	3.5 m	30 m
Elevation Rise	1.71 m	0 m
Nominal Pipe Diameter	150 mm	250 mm
Discharge Level	33.58 mAOD	33.58 mAOD
Pipe Material	Ductile Iron	Undetermined (possible asbestos concrete)
Pipe Roughness	ks = 0.03 mm (assumed)	ks = 0.03 mm (assumed)

2.1.3 System Description

To evaluate the hydraulic performance of the pumps and its associated pipeline, system curves are used. A guide to system curves and how to read them is provided in Appendix C.

System curves have been derived for the following operating scenarios:

- 1no Pump operating only

The suction and delivery elevations have been based on the site recorded measurements as there is no drawing or instrument measured SCADA data.

As no pressure monitoring was possible, the pipe roughness has been based on recommended design roughness values for normal condition DI and AC pipes[1].

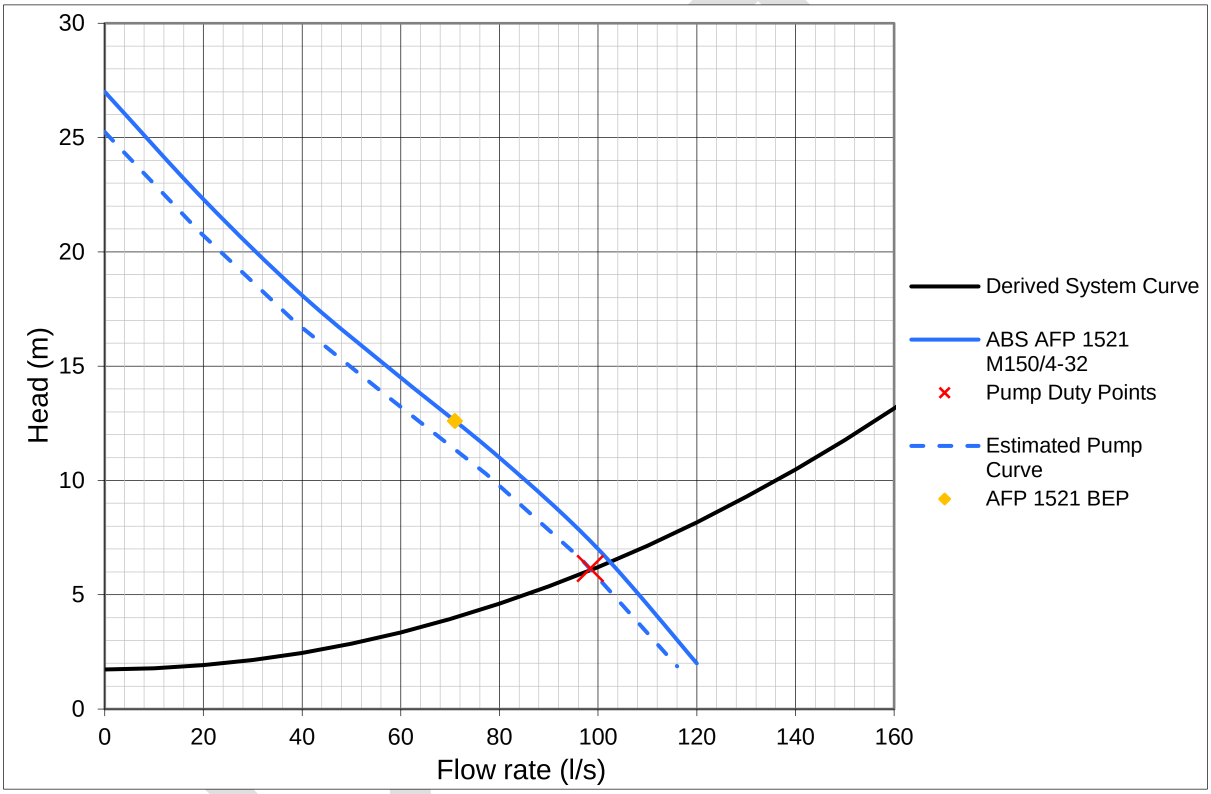


Figure 3 - Lock 36 Derived System Curve

[1] Wallingford, H R (1990)

1 INPUT DATA

Gravity, g	9.81	m/s2			
Atmos pressure	101.3	kPa	Sump levels		
Fluid	Water	[select]	TWL		mAOD
Temperature	4	°c	Design	31.85	mAOD
			BWL		mAOD
Kinem. viscosity	1.57E-06	m2/s			
Density	1000.0	kg/m³	Pump level:	30.53	mAOD
Vap pressure	0.0821	m	Pump station located before reach:	1	[select]

Suction | Discharge

Assumed Hydraulic Discharge levels

TWL		mAOD
Design	33.58	mAOD
BWL		mAOD

Static lift			
	Minimum	0.00	m
	Design	1.73	m
	Maximum	0.00	m

Reach:		1	2	3	4	5	6	7	8	9	10	11	12	13
Description		CI pump discharg	CI pump discharge	Aesbestos Concrete										
Length (m)		0.5	3.5	30										
Diameter (m)		0.15	0.15	0.2625										
Flow area (m²)		0.01767	0.01767	0.05412										
Roughness (mm)	Low													
	Design	0.03	0.03	0.03										
	High													
Proportion of station flow		1.00	1.00	1.00										

Global head loss factor: % (added to friction and fittings losses throughout)

Fittings Losses:	k-value	Number of fittings: 1	2	3	4	5	6	7	8	9	10	11	12	13
Inlet (slightly rounded)	0.25	1												
Short R 90° bend	0.75	1												
Taper up (4:5)	0.03													
Short R 90° bend	0.75		1											
Swing check valve	1													
Gate valve	0.12													
Gate valve	0.12													
Expansion 2:3	0.35		1											
Expansion 3:4	0.2													
Outlet	1			1										
Elbow 45° bend	0.4			1										
Elbow 22.5° bend	0.2													
Additional K (other devices)														
Total K		1.00	1.10	1.40	0.00									

Figure 4 - Hydraulic Calculation Input Data for Lock 36 Pump

2.2 Lock 35

Lock 35 is located near Shannon harbour, Clonony Beg, Co. Offaly. The pump house is the second from last in a chain of pumping stations along the Grand Canal designed to maintain an upstream level within the canal from the Shannon river/Bresna river confluence.

Figure 5 - Lock 35 PS on the Grand Canal (Left); Inside Lock 35 wet well (right)

Lock 35 PS comprises of 1no ABS fixed-speed submersible pump (Model AFP 1521 M150 4-32). The pump station intake is direct from the Grand Canal downstream of Lock 35 via a concrete intake culvert. The intake is fully submerged and is protected with a 50 mm spaced bar screen within the wet well. A manually operated penstock is located on the inlet to the chmaber as a means of isolation.

The pump discharge pipework is 150mm nominal diameter (DN150) and manufactured from 16 bar rated flanged ductile iron pipe (DI, PN16). The DI pipework connects to a 250 mm diameter rising main of unknown material via a concentric taper. Due to the possibility of the rising main being asbestos concrete pipe, the decision was taken to stop investigating this section any further until a full assessment on the pipeline can be made.

The rising main discharges to a concrete outfall chamber. The exact nature of the discharge could not be ascertained as it was inaccessible at the time of the audit. Given the exit flow path of the water (the water appeared to be exiting in a jet from one edge of the outfall), it is assumed that there is no weir present.

There are no isolation or check valves contained within the pump station. 1no ultrasonic level probe is located within the wet well and for purposes of low level protection.

Figure 6 Lock 35 PS Outfall

Table 3 – Pump Details

Parameter	Description
Pump	ABS (AFP 1521 M150/4-32)
No. of Pumps	1
Duty Configuration	Duty (Submersible)
Rated Motor Output	15 kW
Impeller Diameter	Impellor Type 1 Closed Type
Drives	Star Delta
Pipework	150 mm nominal diameter (DN150)
Non-Return Valves	N/A
Wet Well Level Sensor	Ultrasonic for Low level protection
Wet Well Level	32.97 mAOD
Pump Centre Line	31.35 mAOD

2.2.1 Rising Main

The Lock 35 rising main is approximately 34 m in length. The pipeline consists of approx. 3.5 m of DN150 PN16 flanged ductile iron which connects into a 250 mm rising main pipe via a concentric taper. The rising main section is approximately 30 m in length. The rising main material is unknown but is suspected to be asbestos concrete.

The rising main runs from the wet well and free discharges to a concrete outfall box on the Grand Canal. There are no isolation or check valves present on the rising main.

The pipeline condition is unknown but there are no reports of bursts arising since construction.

Table 4 – Rising Main Details

Parameter	Description	
Section	1	2
Approx. Length	3.5 m	30 m
Elevation Rise	1.81 m	0 m
Pipe Diameter	150 mm	250 mm
Discharge Level	34.78 mAOD	34.78 mAOD
Pipe Material	Ductile Iron	Asbestos Concrete
Pipe Roughness	ks = 0.03 mm assumed	ks = 0.03 mm assumed

2.2.2 System Description

System curves[2] have been derived for the following operating scenarios:

- 1no Pump operating only

The suction and delivery elevations have been based on the site recorded measurements as there is no drawing or instrument measured SCADA data.

As no pressure monitoring was possible, the pipe roughness has been based on recommended design roughness values for normal condition DI and AC pipes[3].

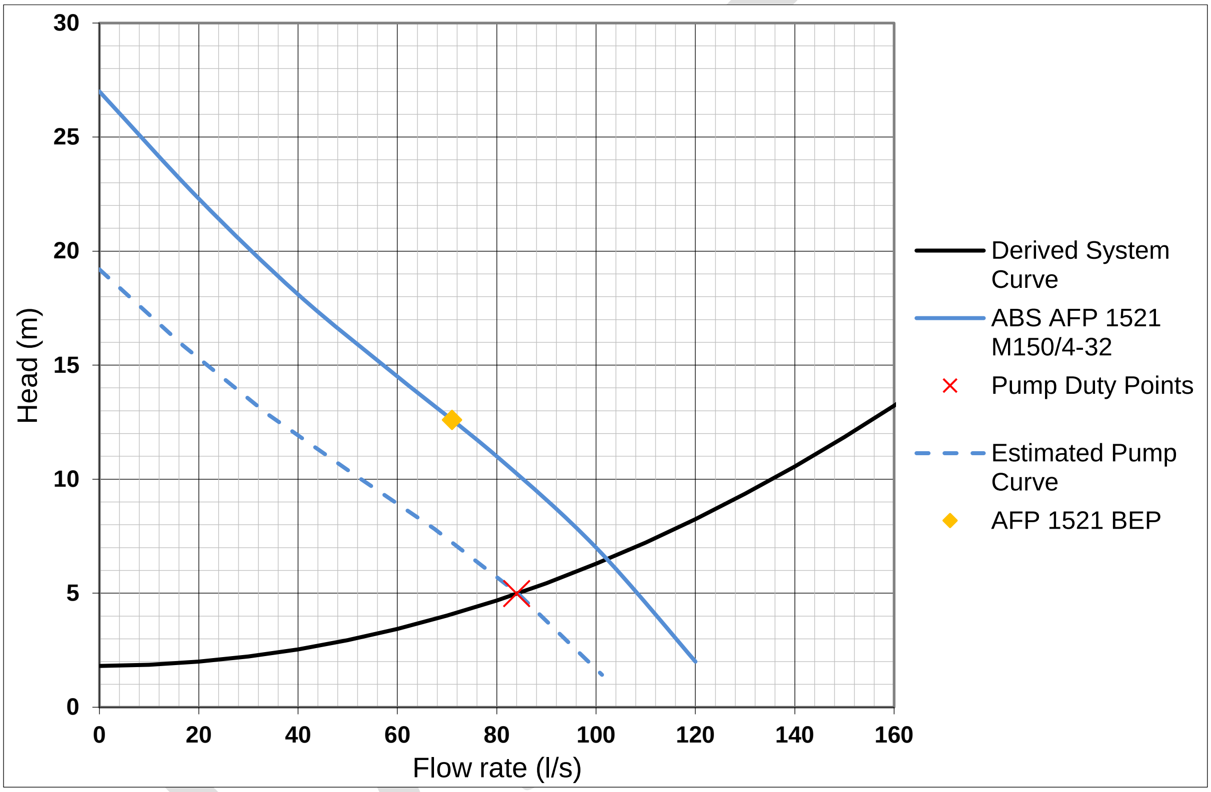
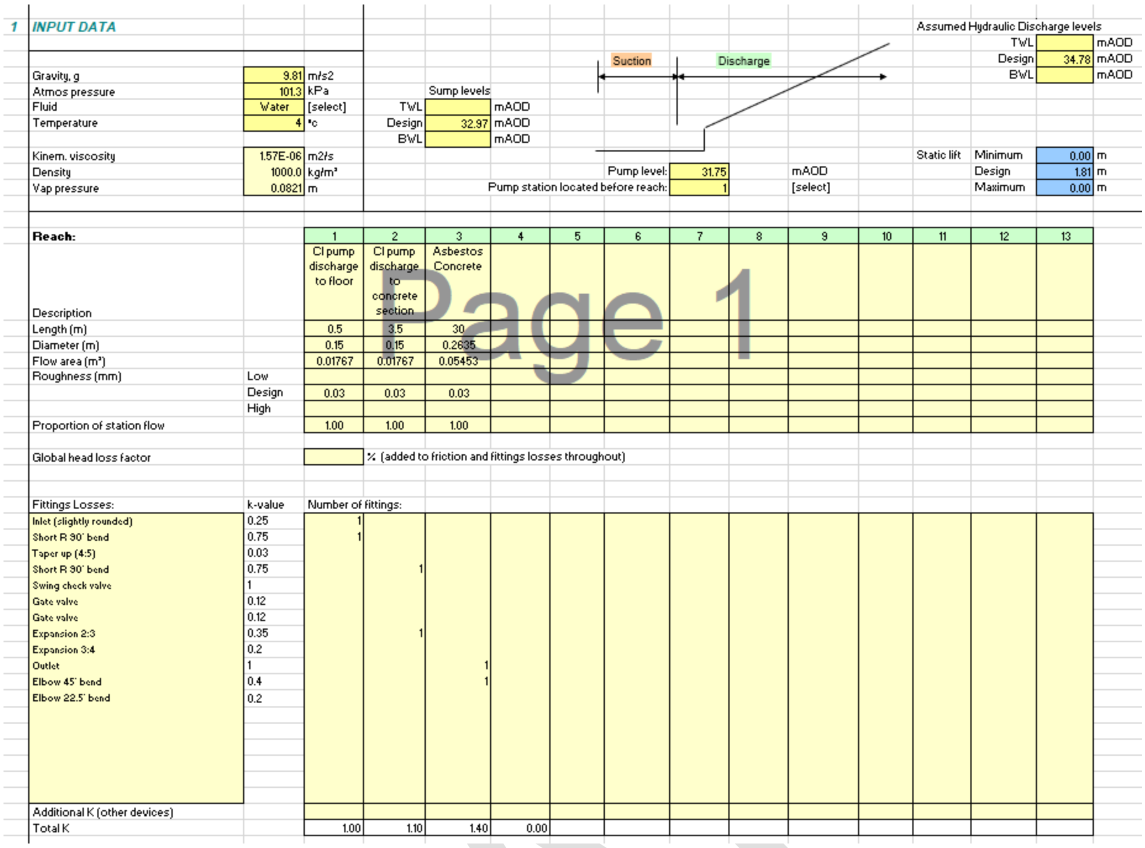


Figure 7 - Lock 35 Derived System Curve

[2] See Appendix C for Guidance on System Curves
[3] Wallingford, H R (1990)



1 INPUT DATA					
Gravity, g	9.81	m/s2			
Atmos pressure	101.3	kPa	Sump levels		
Fluid	Water	[select]	TWL		mAOD
Temperature	4	°c	Design	32.97	mAOD
			BWL		mAOD
Kinem. viscosity	1.57E-06	m2/s			
Density	1000.0	kg/m³	Pump level:	31.75	mAOD
Vap pressure	0.0821	m	Pump station located before reach:	1	[select]

Assumed Hydraulic Discharge levels			
	TWL		mAOD
	Design	34.78	mAOD
	BWL		mAOD
Static lift	Minimum	0.00	m
	Design	1.81	m
	Maximum	0.00	m

Reach:		1	2	3	4	5	6	7	8	9	10	11	12	13
Description		CI pump discharge to floor	CI pump discharge to concrete section	Asbestos Concrete										
Length (m)		0.5	3.5	30										
Diameter (m)		0.15	0.15	0.2635										
Flow area (m²)		0.01767	0.01767	0.05453										
Roughness (mm)	Low													
	Design	0.03	0.03	0.03										
	High													
Proportion of station flow		1.00	1.00	1.00										
Global head loss factor			% (added to friction and fittings losses throughout)											
Fittings Losses:	k-value	Number of fittings:												
Inlet (slightly rounded)	0.25	1												
Short R 90˚ bend	0.75	1												
Taper up (4:5)	0.03													
Short R 90˚ bend	0.75		1											
Swing check valve	1													
Gate valve	0.12													
Gate valve	0.12													
Expansion 2:3	0.35		1											
Expansion 3:4	0.2													
Outlet	1			1										
Elbow 45˚ bend	0.4			1										
Elbow 22.5˚ bend	0.2													
Additional K (other devices)														
Total K		1.00	1.10	1.40	0.00									

Figure 8 - Hydraulic Calculation Input Data for Lock 35 Pump

2.3 Key Observations

2.3.1 From the derived System Curves

The key observations from the derived system curves are as follows:

a) Rising Main losses – a roughness of 0.03 mm for ductile iron and 0.03 mm for asbestos concrete was assumed based on HR Wallingford recommended roughness values. The actual condition and roughness equivalent of the mains is unknown, and no pressure data was taken during the time of the pump audit.

b) The ABS 1521 pumps at Lock 35 & 36 are operating well to the right of the BEP (Best Efficiency Point), and outside the recommended preferred operating region of 80-120% of BEP flow rate. Operating these pumps in this way could lead to a reduced operational life and mechanical issues over time.

c) The performance of the pumps at Lock 35 and Lock 36 appear to be operating below the "as new" system curves provided by ABS. The performance degradation in Lock 36 pump is slight/reasonable. The performance drop-off in the Lock 35 pump, is more significant.

d) If the pumps were operating on their "as new" curve, then the maximum efficiency that could be obtained would be circa 50%.

e) In order to align the site results with the information obtained on the pump curve from ABS, the performance of the pump curves has been lowered from their "as new" performance curves. The dashed line on the individual pump system curve represents the estimated actual pump curve derived using the affinity laws, to indicate wear or smaller impeller diameter.

f) It has been assumed in this instance that the motor efficiency has remained constant for each pump, which may not be case. Motor efficiency could not be ascertained, either from the site audit or from ABS/Sulzer, as such it has been estimated at 85% for the purposes of comparison.

2.3.2 Discussion

There could be several reasons for the lower pump performance, with possibilities including:

- Impeller wear and/or excessive impeller to plate gap clearance resulting in recirculation flow losses.
- Debris impinging on the impeller (floating vegetation/reeds in the canal was significant). Piles of reeds/vegetation were noticed within the wet well (Figure 1 & Figure 5) at each of the intake screens, which indicates that they are regularly cleared and that debris is a known issue.
- Increased rising main losses (e.g. unknown restriction), given that measured pressure data could not be ascertained at the time of testing.
- Measurement or Data inaccuracies taken from on-site data collection

During the site audit at Lock 35 & 36, there was significant over topping of both upstream lock gates (Figure 9)- this was noted (by the Lockkeeper) as a common occurrence. In addition, there was also significant leakage through the lock gate, it would be recommended that these gates be inspected as to limit the losses.

During the site audit at Lock 36, the pipework at ground level could be felt vibrating through the earth during operation. This could be due to the high velocities within the 150 mm sections (4.75 m/s) creating turbulence within the pipework. Alternatively, this could be early indication of something more significant, possibly the beginning of a bearing or seal failure. The high velocities within the 150 mm sections of both Lock 35 & 36 created approximately 2.5 m of losses.

Figure 9 – Over topping of lock gate at Lock 35

3 Net Positive Suction Head (NPSH) & Submergence

NPSH available (NPSHa) calculations have shown that there is 11.5m of positive suction head available within the system. No published NPSH required (NSPHr) data could be found on the AFP 1521 M150 4-32 pumps to provide a comparison, so this aspect cannot be investigated any further. It is recommended that if this data becomes available in the future that the NSPHr be verified as suitable.

Initial ANSI-98 submergence calculations based on the levels indicated from the site audit have shown that there is sufficient water coverage above the pumps at both Lock 36 and Lock 35. A minimum bell submergence of 942 mm is required which both Lock 35, and Lock 36 satisfied at the time of the audit.

Given the under performance of the pump at Lock 36 and Lock 35, it is recommended that the impeller be checked for cavitation marks during the next inspection.

4 Energy Analysis

During the pump audit visit by Samatrix Ltd, a temporary "Fluke" power meter was connected at each individual pump starter compartment to record power into the drives.

From the measured power, flow recorded, and estimated head based on system curve, an analysis of pumping efficiency and the amount of energy needed to pump flows has been undertaken. Table 5 & Table 6 summarise the measured input power, and derived efficiency and specific energy findings.

Table 5 – Lock 36 Input power, Efficiency and Specific Energy

Pump Configuration	Measured Flowrate (l/s)	Calculated Head (m)	Measured Power Factor	Measured power (kW)	Pump Efficiency	Specific energy (kWh/1000 m^3)
Actual ABS unit - Lock 36	98.4	6.1	0.85	15.9	44%	45
"As-New" ABS Unit	102	6.47	0.85	14.1*	54%	38.4

Table 6 - Lock 35 Input power, Efficiency and Specific Energy

Pump Configuration	Measured Flowrate (l/s)	Calculated Head (m)	Measured Power Factor	Measured power (kW)	Pump Efficiency	Specific energy (kWh/1000 m^3)
Actual ABS unit - Lock 35	84.0	5.0	0.85	15.3	32%	50.6
"As-New" ABS Unit	102	6.47	0.85	14.1*	54%	38.4

**Calculated power for the as-new pump estimated from ABS pump curves in Appendix A, assuming 85% motor efficiency*

- No data could be obtained on the motor efficiency of the ABS AFP 1521, as such it has been assumed that it operates at 85% (ABS Sulzer was contacted directly but were unable to provide this information).
- Table 5 and Table 8 show that the pumps at Lock 36 and 35 are operating less efficiently than an "as new" pump. The reduction in flow is equivalent to 3.3% for Lock 36 and 15.7% for Lock 35.
- The pumps at Lock 36 and Lock 35 both show a drop-in performance when compared to the ideal, it should be investigated to ascertain the reasons behind this. Possible explanations include:
  - Excessive gap between impeller and bottom plate
  - Debris within the pump casing/volute
  - Sump hydraulic issue
  - Damage or wear to impeller
  - Bearing/seal wear

- Unknown restriction in rising main

From Waterways Ireland own Technical Assessment for Green WIN, the energy consumed for locks 35 and 36 pumping stations in 2017 was 286,748 kWh costing €39,908. The estimated maximum daily water volume requirement is 550 m3 and estimated annual water volume requirement 100 Ml.

Based on the Energy Assessment in Table 5 and Table 6, and allowing an element (~1.5kW) of fixed energy usage per station for services, the energy consumed in 2017 equates to approximately 2750Ml which would require running the pumps continually for at least 11 months of the year. This is consistent with the Lock keepers reported account of the operation.

5 Potential Areas for Improvement

5.1 Desired Outcomes

Waterway Ireland have highlighted the following anticipated improvements for the Shannon Harbour pumping stations in their technical assessment.

- Optimising the system controls, including water level controls, such that the systems are not so reliant on manual input and avoid over spilling and unnecessary pumping.
- Pump replacement with dual duty stand by system (anticipate replacing 2 pumps during this project) with civils work (difficult installation originally).
- Construction of a new pumping station at Lock 34.

From discussion with Waterways Ireland, the ability to increase pumping station output flow rate to approximately 150l/s is very desirable.

5.2 Pump Control and Instrumentation

At present the pumps are effectively run manually in “hand” with the only control being an automatic stop from the low level ultrasonic contained within the wet well. This means that the pumps are likely pumping for periods where flow may not be required, and therefore wasting energy. The evidence suggest that the pumps run continually for approximately 11 months of the year, and therefore implementing level controls should provide a significant improvement on energy consumption based on running time.

Operation upon level would necessitate a level sensor, e.g. an ultrasonic or radar type installed within a stilling tube, on the Grand Canal to measure the level and provide a signal back to the pump control panel and possibly SCADA. Predetermined level thresholds would be as set start and stop levels for the pumps.

Regarding the type of sensors, ultrasonic or radar type sensors are recommended. Using either ultrasonic or radar type level sensors would allow the following benefits:

- Non-contact, low maintenance measurement
- Unaffected by medium properties and fouling
- Freely adjustable measuring range
- Measured level outputs can be used for both information and control

In addition, there is currently no instrumentation measuring pump performance such as a flow meter or pressure indicating device. Without any instrumentation there is little way of knowing how the pumps are operating day to day and it gives no opportunity for any proactive maintenance or trends to be ascertained for the system.

It is recommended that a flow meter be installed on each rising main as a minimum to measure and record flow rate.

It is recommended that a threaded process connection for a pressure transducer be installed on each line to facilitate temporary pressure measurement, in order to ascertain rising main losses for either energy management or fault finding. This could be included on any accessible section of pipework within the wet well for ease of access. The pump pressure could then be calculated from known levels and losses between the transducer and the pump.

It is recommended that a SCADA / telemetry system is implemented to facilitate effective remote monitoring and management of the pumping station. Displaying and trending alarms, status of key parameters, and intelligent diagnostics with a SCADA system would facilitate informative data analysis reporting, and ultimately would provide benefits for both reactive and planned maintenance, as well as ensuring good energy performance is actively managed.

It should be noted that this option would require a capital investment to upgrade the EICA components within the pumping stations to achieve this.

The use of variable speed drives (VSDs) would provide benefits in terms of adjusting flow output and optimising specific energy from pumping stations. However, variable speed drives are envisaged to bring only minor energy performance improvements at best and is not considered an essential need in order to generate energy savings. It is suggested that use of VSDs this is scrutinised in finer detail in Phase 2.

5.3 Pump Selection

On initial findings, the ABS pumps as installed, are not ideally matched for the system. Despite a significant head loss (2.7 m in Lock 35 and 3.8 m in Lock 36) within the 150 mm diameter pipework sections the pumps still operate at the far right of their performance curves, outside the preferred operating region. Investigations for alternative pumps with 150mm diameter connections from Xylem and Sulzer (ABS) have been conducted. These both find limited improvements with BEP points similarly at a much lower flow rate. The findings are summarised in Table 7 and displayed on System Curve in Figure 10.

Additionally, the head loss required to obtain a higher flow rate of 150l/s through the 150mm diameter pipework results in a significant flow velocity and dynamic head loss, outside best practice for an efficient pump system.

To achieve 150l/s, pump selections using a 250mm diameter (DN250) outlet connection and wet well riser pipework have been investigated. Both Xylem and Sulzer (ABS) manufacturer options have been considered for the purposes of the investigation. The assessment results are summarised in Table 8 and system curves displayed in Figure 11. The findings demonstrate that there is no benefit and perhaps some detriment in replacing the DN150mm pipework whilst maintaining the existing pump.

Given the history of impeller blockages it is recommended that the manufacturers are fully consulted on the history and nature of instances prior to any final selection and purchase.

The assessment conclusion is that replacing the existing DN150 wet well pipework with DN250 pipework and replacing with a new 250mm connection pump suited for the revised duty point provide significant energy savings, reducing the costs of pumping to a third of existing levels. In addition, the anticipated flow rate would meet or approach the desired flow rate of 150l/s.

The above findings assume that the wet well size and configuration can accommodate the alternative larger diameter pipework and associated pump.

The results from Table 8 suggest that savings totalling 175,300kWh are achievable. It should be noted that this is based on pumping flows of 2750Ml/annum. Reducing the annual pumped volume through the introduction of automatic level control would improve savings significantly further.

Table 7 – Comparison of alternative pump selections for reuse of existing wet well and pipes

CONFIGURATION	SELECTION	FLOW RATE (L/S)	PRESSURE (M)	INPUT POWER (KW)	PUMP AND MOTOR EFFICIENCY (%)	ESTIMATED SPECIFIC ENERGY PER PS (KWH/1000 M^3)	SAVING ON SPECIFIC ENERGY (KWH/1000 M^3)	ESTIMATED ANNUAL FLOW PER PS ** (ML)	COMBINED ENERGY USAGE ** (KWH)	COMBINED ENERGY USAGE SAVING ** (KWH)
Duty Option (1-pump) Fixed Speed / Existing wet well / DN150 Connection and Riser	Existing ABS AFP 1521 (Avg'd for Locks 35 & 36)					47.8*		2750	262,900*	
	Existing ABS AFP 1521 (Reconditioned to As New)	102	6.47	14.1	45.9	38.4	-9.4	2750	211,200	-51,700
	Sulzer (ABS) XFP 155J-CB2	107	6.78	11.8	60.3	30.6	-17.2	2750	168,300	-94,600
	Xylem NP3153.MT 432 249	105	6.59	12.6	53.6	33.3	-14.5	2750	183,150	-79,750

**taking an average of the current specific energy values for Lock 35 & Lock 36*

*** Based on like for like against estimated 2017 flow figures (minus services allowance)*

Table 8 – Comparison of alternative pump selections for new duty flow rate of 150l/s and upsized wet well pipe arrangement

CONFIGURATION	SELECTION	FLOW RATE (L/S)	PRESSURE (M)	INPUT POWER (KW)	PUMP AND MOTOR EFFICIENCY (%)	ESTIMATED SPECIFIC ENERGY PER PS (KWH/1000 M^3)	SAVING ON SPECIFIC ENERGY (KWH/1000 M^3)	ESTIMATED ANNUAL FLOW PER PS ** (ML)	COMBINED ENERGY USAGE ** (KWH)	COMBINED ENERGY USAGE SAVING ** (KWH)
Duty Option (1-pump) Fixed Speed / Existing wet well / DN250 Connection and Riser	Sulzer (ABS) AFP 1521	107	5.4	14.8	38.3	38.5	-9.4	2750	211,750	-51,150
	Sulzer (ABS) XFP 250J-CB2	142	3.77	8.1	64.5	15.9	-31.9	2750	87,600	-175,300
	Xylem NP3153 LT 321 252mm	151.6	4.05	9	67.2	16.4	-31.4	2750	90,300	-172,600

**taking an average of the current specific energy values for Lock 35 & Lock 36 at 47.8 kWh/1000 m3*

*** Based on like for like against estimated 2017 flow figures (minus services allowance)*

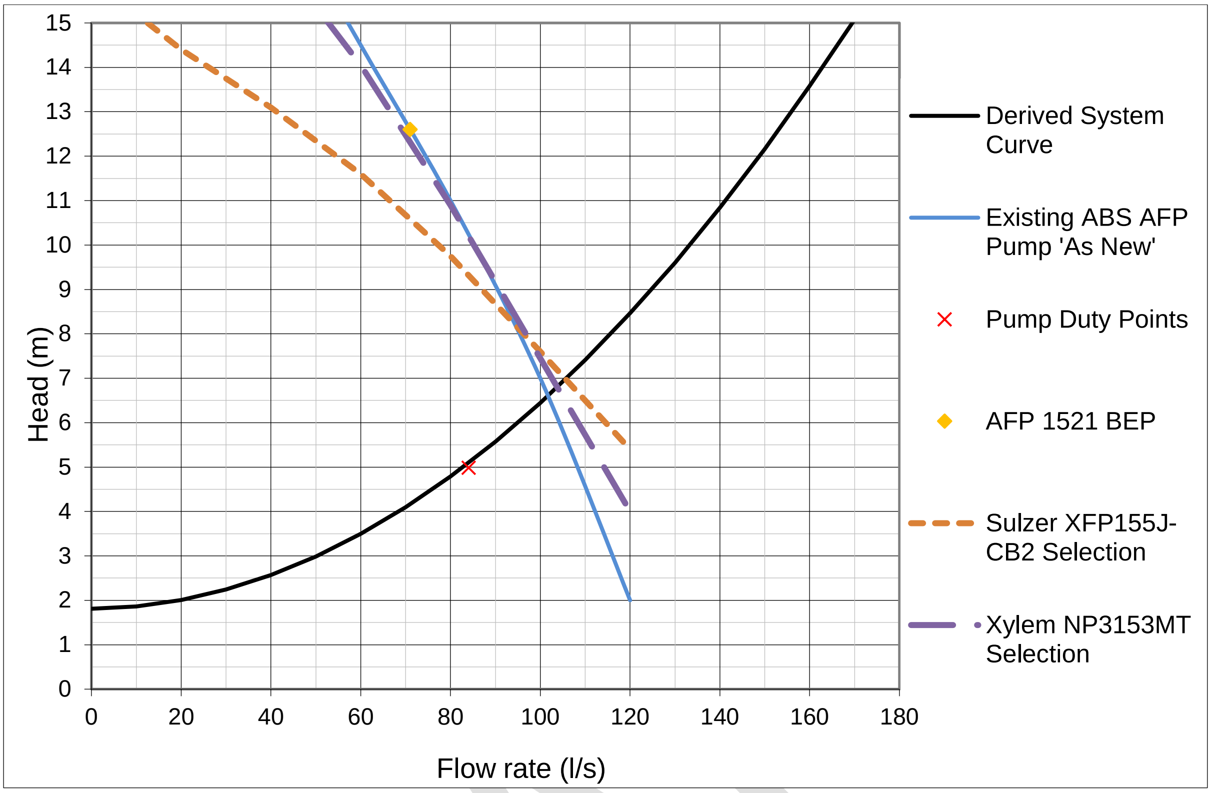


Figure 10 – Alternative pump selection maintaining use of existing DN150 outlet and riser pipework

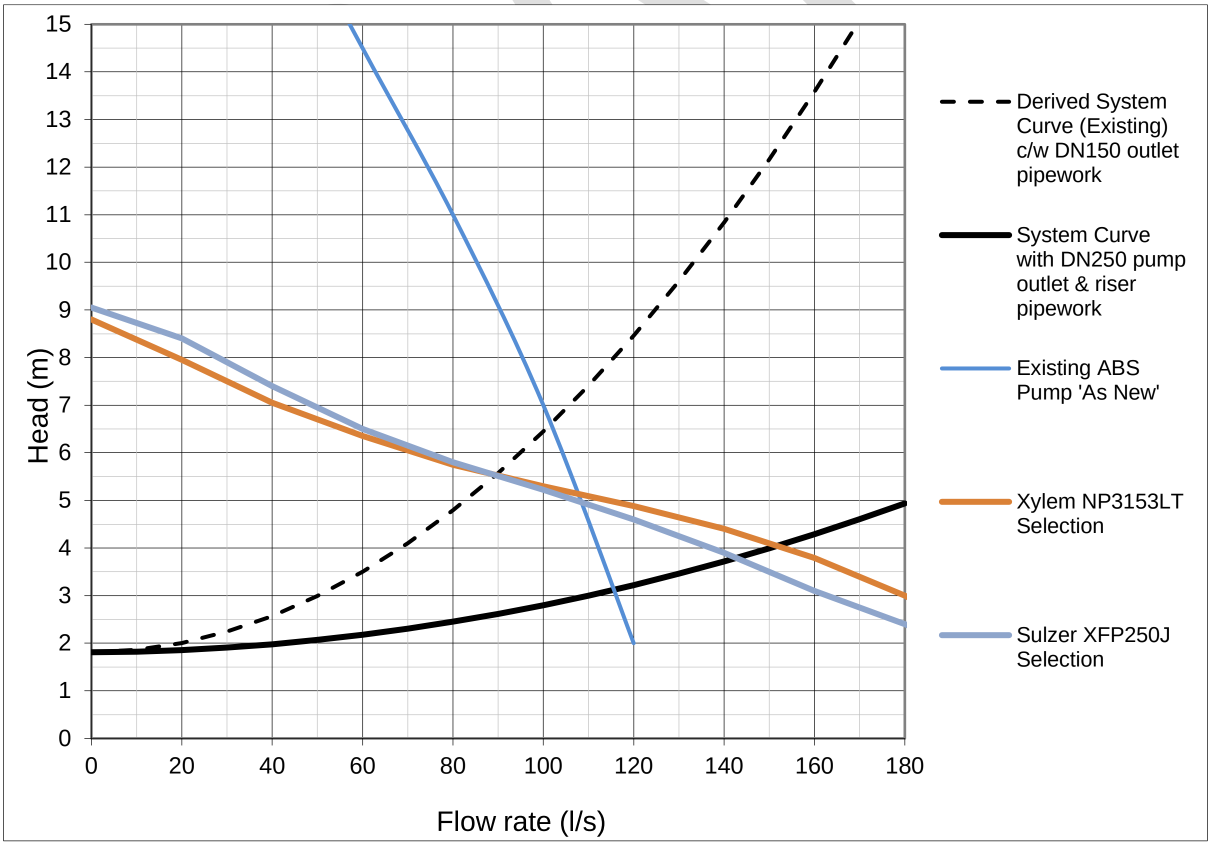


Figure 11 – Amended system curve and pump selection based on new DN250 outlet and riser pipework (replacing existing DN150)

6 Preliminary Recommendations

- As a short-term measure. Check the existing pumps, notably Lock 35, for signs of blockage, impeller damage, and impeller to bottom plate gap, adjusting as necessary.
- Temporary testing an alternative pump with a known performance curve would help ascertain the system requirements so that a permanent pump selection can be made with further confidence.
- Conduct a design survey, possibly point cloud survey, and outline design of the existing wet well to confirm the feasibility of accommodating larger DN250 pipework and pumps.
- Pending a successful outcome of the design survey, it is recommended that the pumps at Lock 35 & 36 be changed with a more efficient alternative with wet well pipework changed to DN250.
- Install a level control system on the pumps potentially via a radar/ultrasonic level sensor.
- Investigate the lock gates at Lock 35 & 36 for leakage and possible refurbishment.
- Install a flow meter and threaded process connection for a pressure transducer on each rising main to allow for trend data and proactive maintenance. It is recommended that flowmeter manufacturers are consulted regarding the proposed positioning to ascertain flowmeter measurement accuracy/certainty.
- Install permanent power monitoring.
- Install a SCADA / HMI system which can be used to remotely monitor the pumping stations and record data which can be used to optimise operation.
- Explore in detail the feasibility and benefits of using variable speed drives in Phase 2.
- A desktop review after a period of 1 year with instrumentation in operation to see if the potential for further gains can be ascertained.

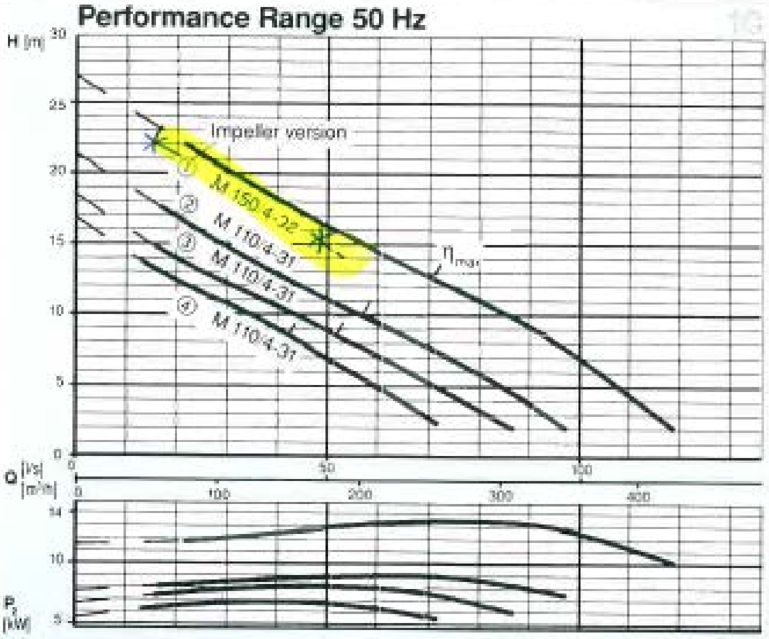
APPENDIX A

MANUFACTURERS DATASHEET FOR EXISTING INSTALLED PUMP MODEL

ABS

AFP 1521... DN 150

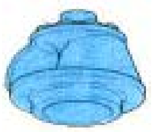
Performance Range 50 Hz



DN 150

4-pole (1480 min⁻¹)

Solid size: 100 mm



1-channel impeller closed

H = Total head
Q = Discharge volume
1 m = 0,1 bar = 3,28 ft
1 bar = 10 m
1 m³ = 220,0 Imp.gal = 264,2 US.gal
1 l = 0,2200 Imp.gal = 0,2642 US.gal
Curves to ISO 2548, class C
Curves for 60 Hz are available on request.

Pump Type Hydraulics	Impeller version	Motor	Motor power* P_1 kW	P_2 kW	Speed at 50 Hz min⁻¹	Rated voltage V 3~	Rated current at 400 V A	Cable type** Stand.	Starting	Ex	Weight *** with/without Cooling jacket kg
AFP 1521	①	M 150/4 - 32	17,8	15,0	1480	400	31,8	(4)	Y△	(6)	274,0/259,5
AFP 1521	②	M 110/4 - 31	13,2	11,0	1480	400	23,0	(5)	Y△	(6)	257,0/244,5
AFP 1521	③	M 110/4 - 31	13,2	11,0	1480	400	23,0	(5)	Y△	(6)	257,5/245,0
AFP 1521	④	M 110/4 - 31	13,2	11,0	1480	400	23,0	(5)	Y△	(6)	257,0/244,5

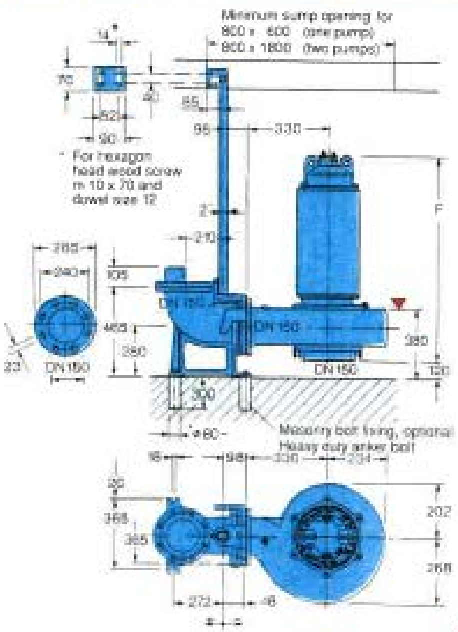
* P_1 = Power taken from mains
* P_2 = Power at motor shaft

Pumps are supplied as standard with 10 m cable and free cable ends.

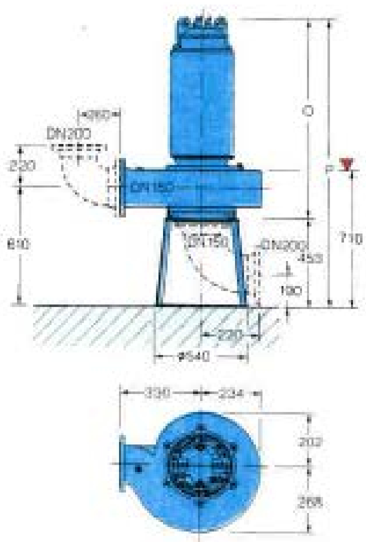
** Cable type: (4) = A07RN-F10G2,5(Ø22,5±0,5)
(5) = A07RN-F10G1,5(Ø18,5±0,5)
(6) = NSSHöu-J10×1,5(Ø18±0,5)

*** without cable

Wet Installation, stationary



Dry Installation, vertical



Dimensions in mm

Motor	F	O	P
M 110/4-31	947	944	1397
M 150/4-32	1047	1044	1497

Dimensions for portable version and horizontal dry-well installation on request.

Flanges according to DIN 2633, PN 16

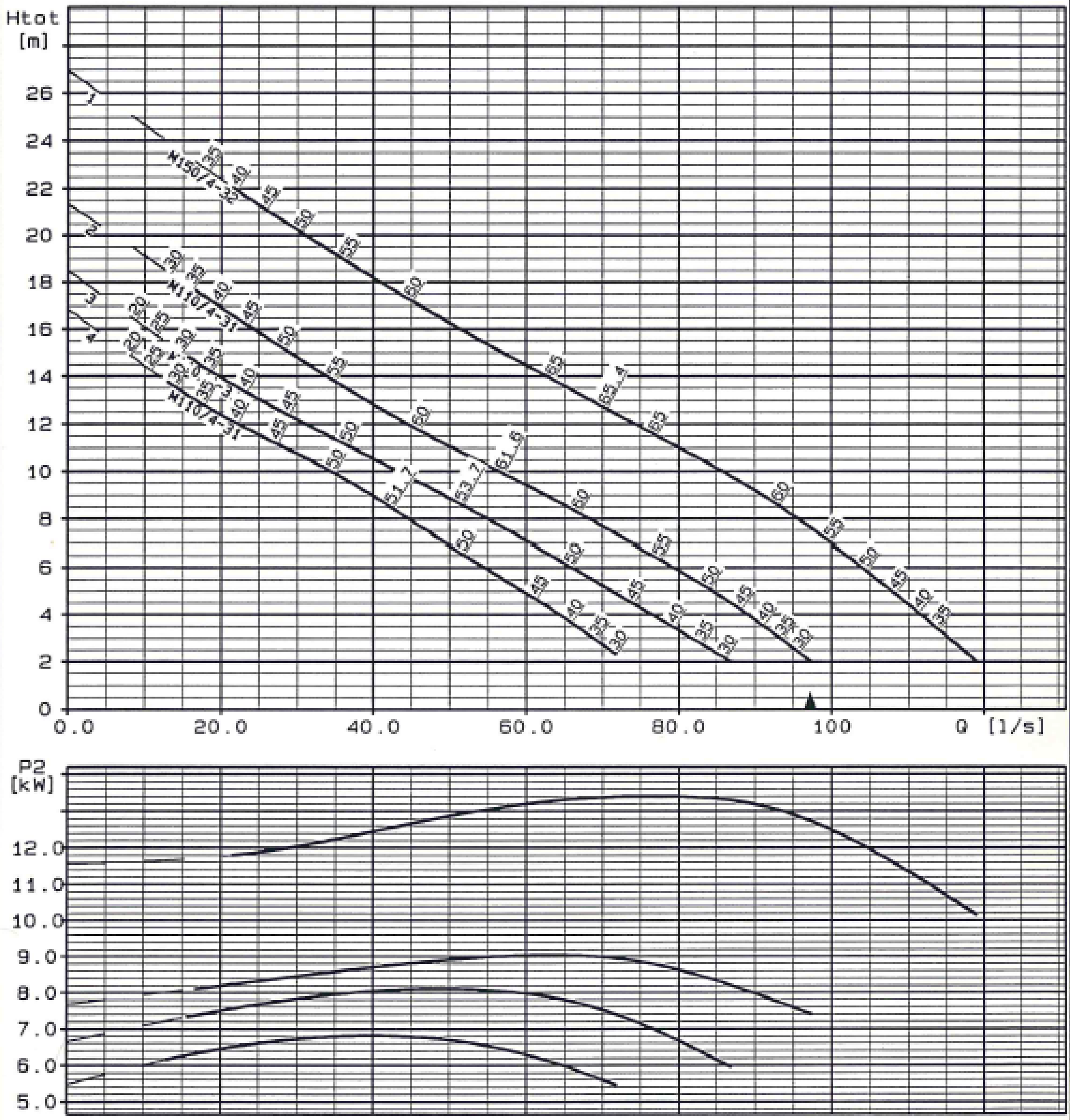
▼ Lowest switching off point for automatic control

ABS

performance field

50 Hz

AFP 1521 4 p.



solid size : 100 mm	no.of vane : 1

speed motor: 1480 RPM
speed hydr.: 1480 RPM

DN 150

tolerance according to ISO 2548 Klasse C

issue : 15.Mar 1993 V2/1

S01/SEA

APPENDIX B

ALTERNATIVE PUMP SELECTIONS

1 - REUSE OF EXISTING WET WELL, DN150 PUMP CONNECTION AND PIPEWORK RISERS

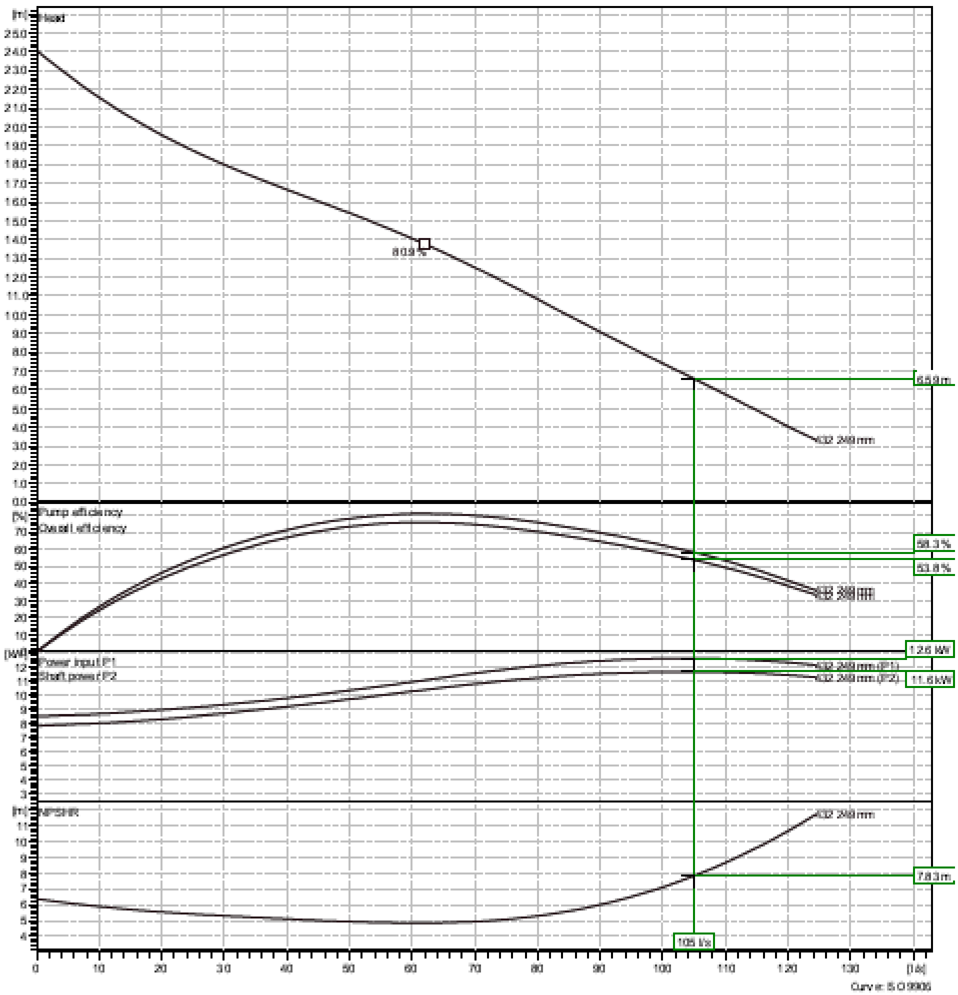
NP 3153 MT 3~ 432

Performance curve

Duty point

Flow	Head
105 l/s	6.59 m

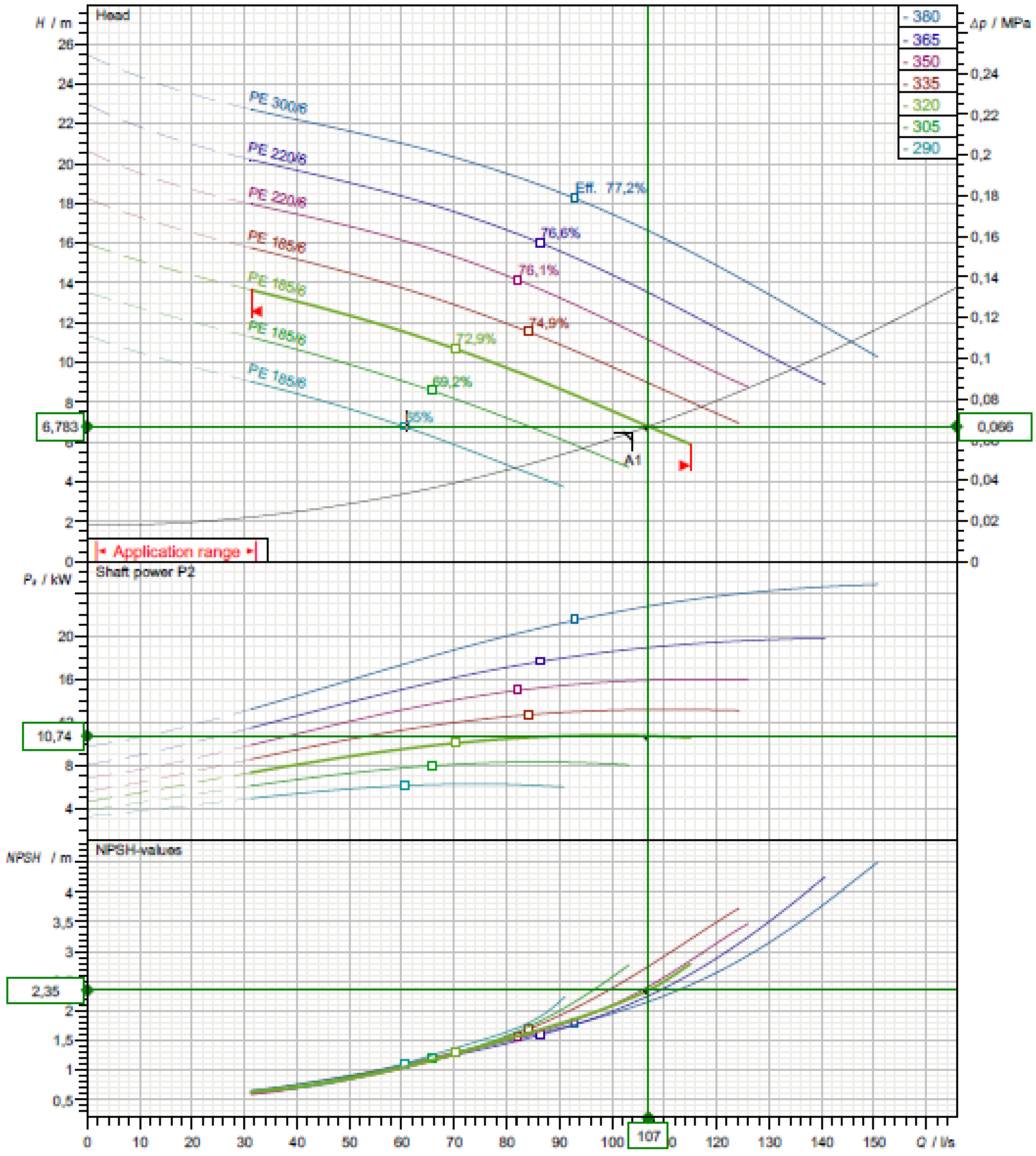
Curves according to: Water, pure [100%], 4 °C, 999.9 kg/m³, 1.5692 mm²/s



Project		Created by		Last update
Block		Created on	2/19/2020	

Curve number	Pump performance curves	SULZER
Reference curve XFP 155J-CB2 50 HZ	XFP 155J-CB2 50 HZ	

					Discharge	Frequency
					DN150	50 Hz
Density	Viscosity	Testnorm			Rated speed	Date
998,3 kg/m³	1,005 mm²/s	ISO9906:2012,HI 11.6/14.6 Gr2B			986,8 1/min	2020-02-18
Flow	Head	Shaft power	Power input	Rated power P2	Hydraulic efficiency	NPSH
107 l/s	6,78 m	10,7 kW	11,8 kW	18,5 kW	67,3 %	2,35 m



Impeller size	N° of vanes	Impeller	Solid size	Revision
320 mm	2	Contrablock Plus impeller	75 x 100 mm	

Sulzer reserves the right to change any data and dimensions without prior notice and can not be held responsible for the use of information contained in this software.

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ALTERNATIVE PUMP SELECTIONS – NEW WET WELL

NP 3153 LT 3~ 621

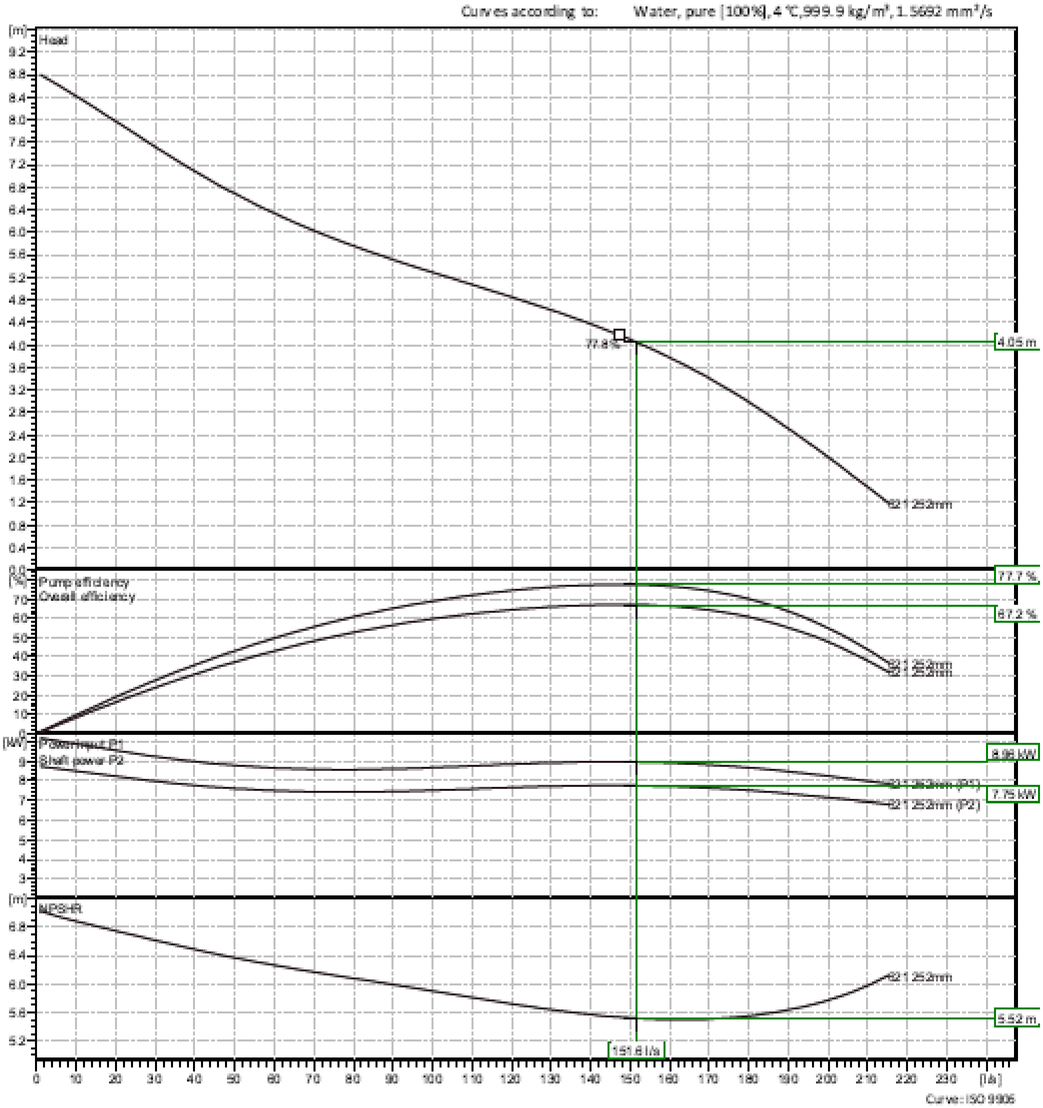
Performance curve

FLYGT a xylem brand

Duty point

Flow
152 l/s

Head
4.05 m



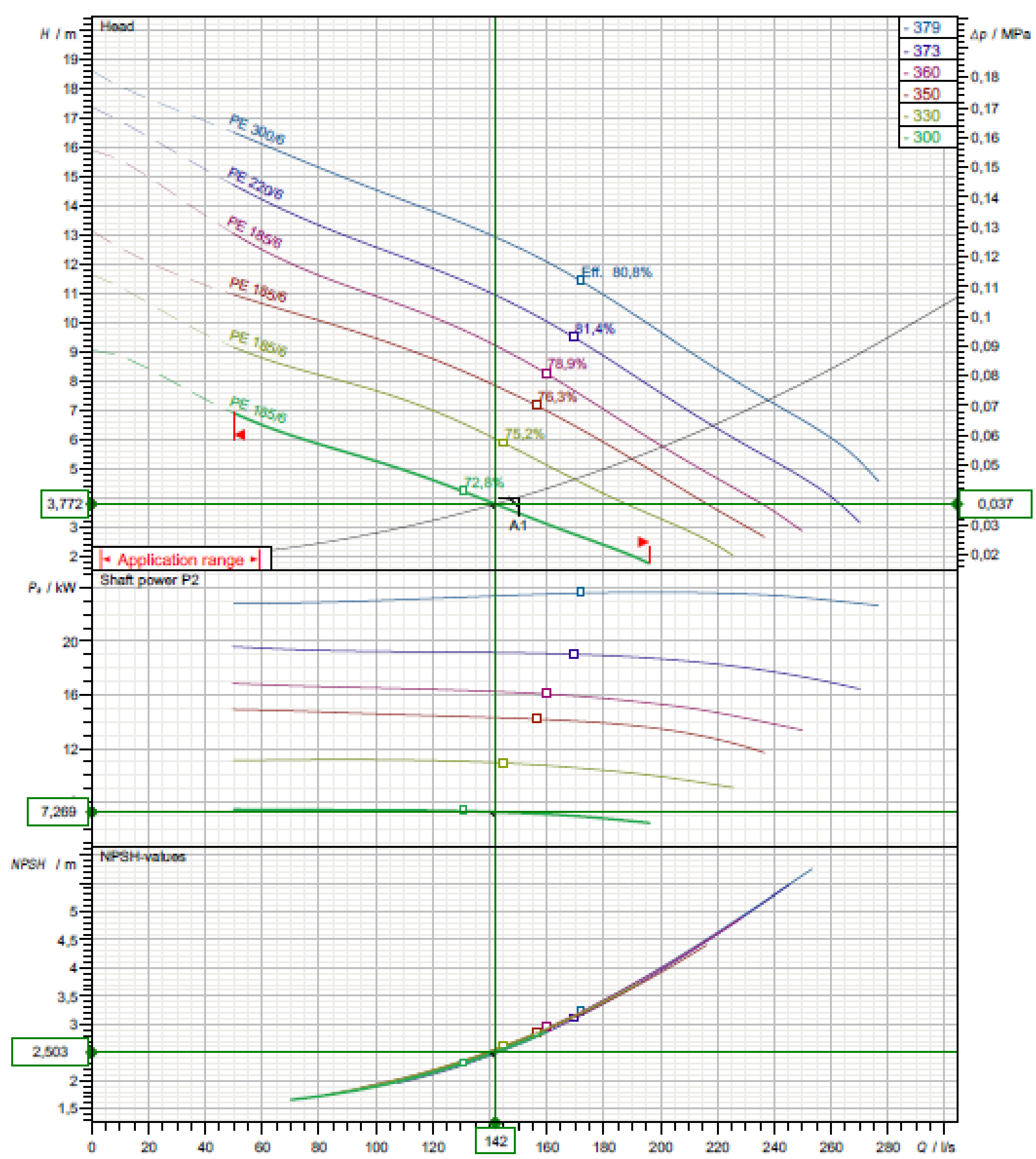
Project		**Created by**		**Last update**	
Block		**Created on**	2/19/2020		

Pump performance curves

XFP 250J-CB2 50 HZ

SULZER

Curve number						
Reference curve XFP 250J-CB2 50 HZ						
					Discharge DN250	Frequency 50 Hz
Density 998,3 kg/m³	Viscosity 1,005 mm²/s	Testnorm ISO9906:2012,HI 11.6/14.6 Gr2B			Rated speed 989,8 1/min	Date 2020-02-19
Flow 142 l/s	Head 3,77 m	Shaft power 7,27 kW	Power input 8,14 kW	Rated power P2 18,5 kW	Hydraulic efficiency 72,3 %	NPSH 2,5 m



Impeller size	N° of vanes	Impeller	Solid size	Revision
300 mm	2	Contrabloc impeller, 2 vane	120 mm	

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Data version Sept 2019

APPENDIX C

A GUIDE TO SYSTEM CURVES AND PUMP CURVES

The System Curve

Consider a pump system (Figure 11) where water is required to be conveyed from Point A to Point B at a Flow Rate of Q_D.

As the elevation of the water surface at the delivery Point B is higher than at A, it cannot flow under gravity so pumps are required to lift the water. The elevation difference that the pumps are required to overcome is known as the static head, H_S, where H_S = Surface Elevation @ B – Surface Elevation at A.

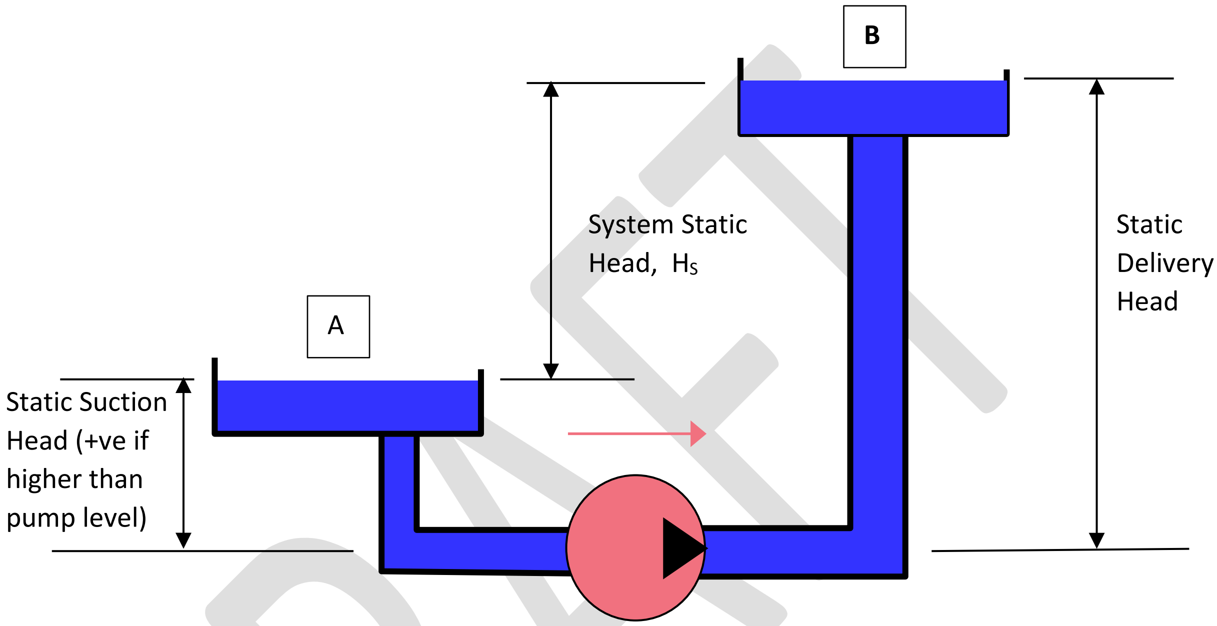
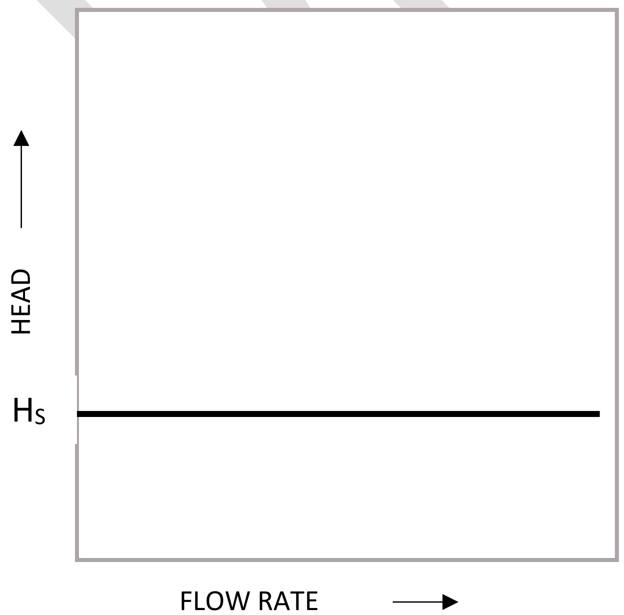


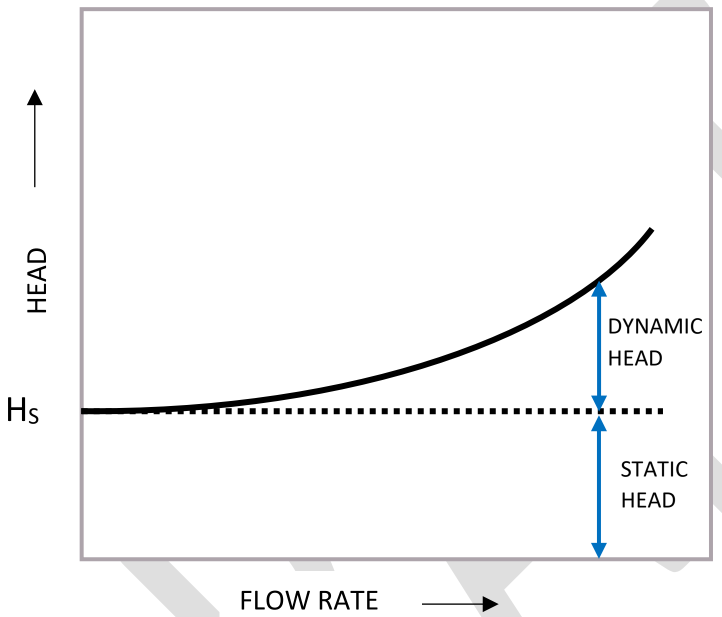
Figure 12 – Pump System Representation

The calculated static head can be represented on a chart with head on the y -axis and flow rate on the x-axis, as follows:

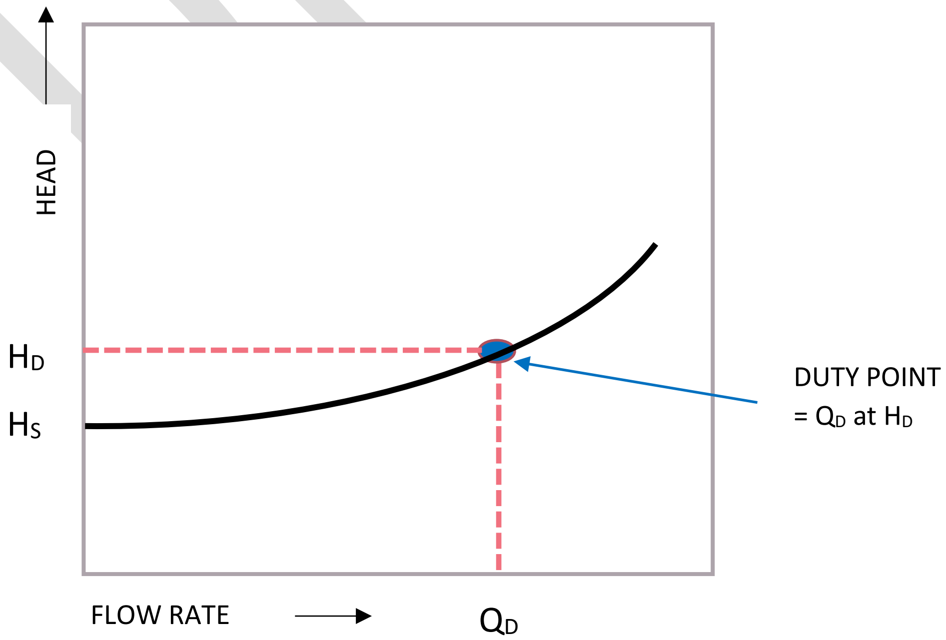


With an increasing flow rate, the flow resistance of the pipe and pipe fittings increases due to friction. So to achieve a higher flow rate, more pressure (or head) is then needed to be generated by the pump. The head losses due to friction increase proportionally to the square of flow velocity and is referred as "Dynamic Head". The Total Head for a given flow rate is the sum of Static Head and Dynamic Head.

Using established equations and loss coefficients the head unique to the pipe system can be calculated at various flow rates and its curve plotted as shown below. This is known as the "SYSTEM CURVE" or "SYSTEM CHARACTERISTIC".

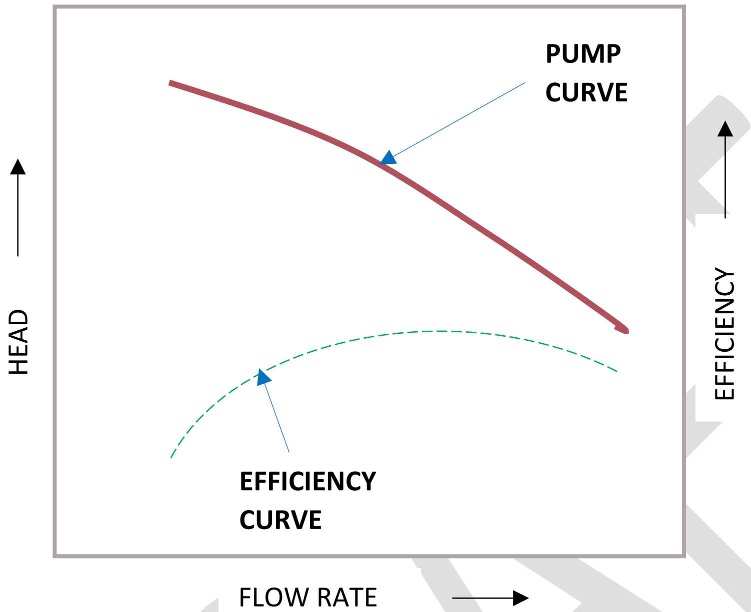


To select a pump for the desired flow rate, Q_D, the intersection point at H_D, is translated from the system curve. This is known as the desired "Duty Point".



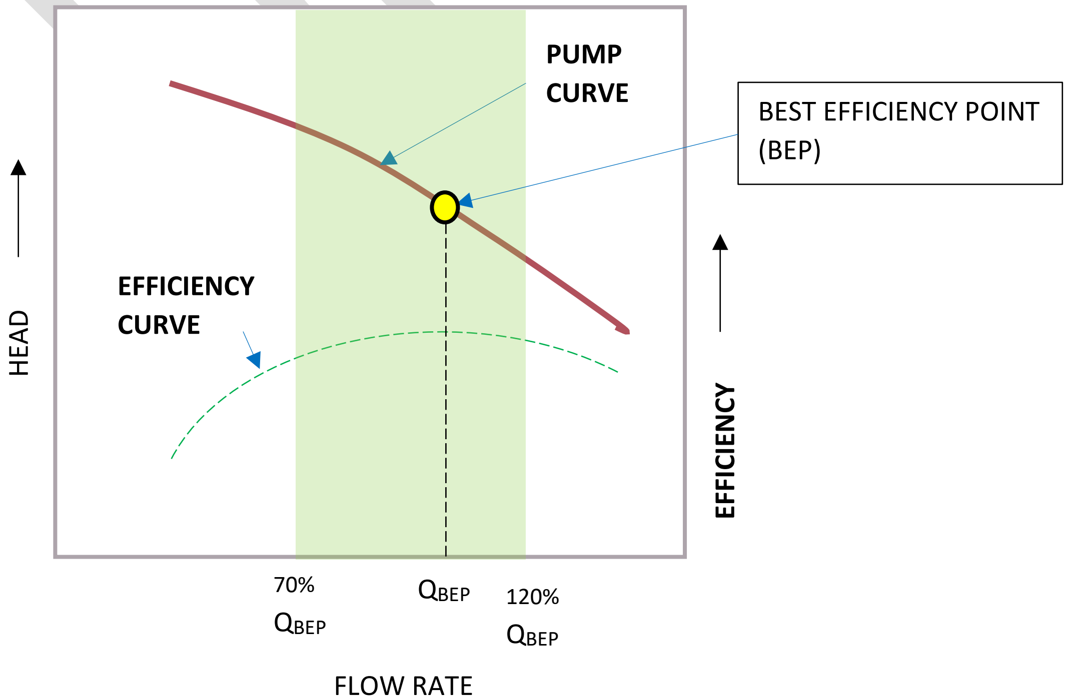
Pump Performance Curves

Centrifugal pumps have a flow-head characteristic known as the "PUMP PERFORMANCE CURVE" or "PUMP CURVE". This shows the flow rate that can be generated by the pump for a given head. The pump curve will typically fall as flow rate increases. The pump efficiency will typically vary with flow rate, initially rising to a peak and then falling away at higher flow rates. These can be represented by curves aginst flow rate as shown below.



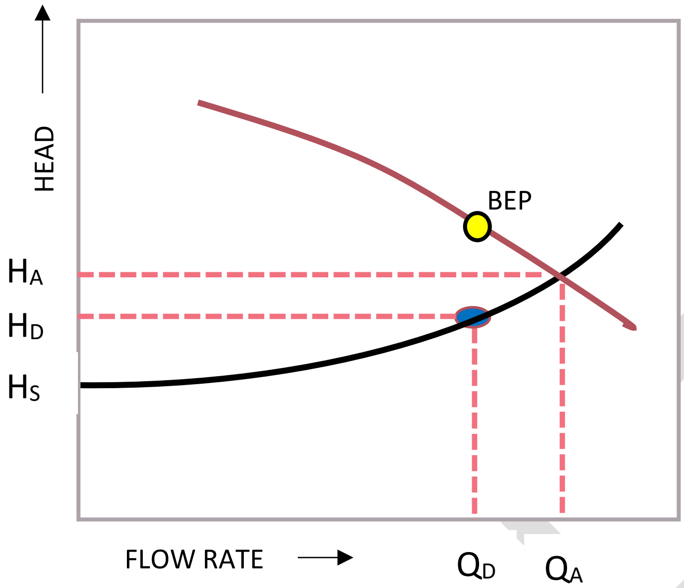
The point on the pump curve where efficiency is highest is known as the "BEST EFFICIENCY POINT", abbreviated to "BEP". The flow rate at this point is abbreviated to Q_{BEP}.

Well selected pumps generally perform at flow rates within 70%< Q_{BEP} < 120%, in what is known as the "PREFFERRED OPERATING REGION" as highlighted below.



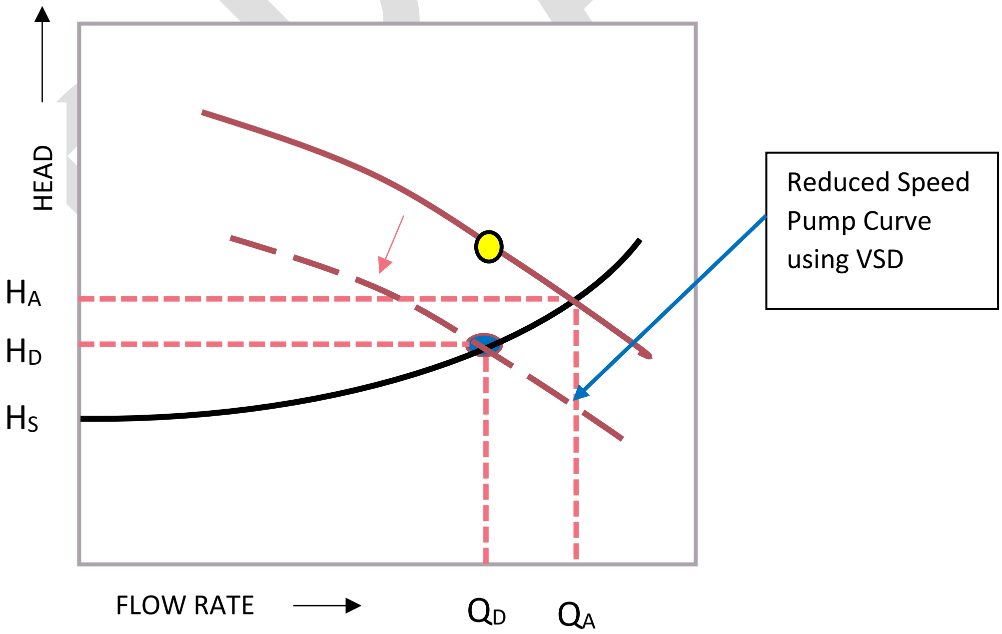
Combining System and Pump Performance Curves

The performance curve for a pump can be overlaid on the system curve. The expected flow rate for a particular pump is indicated where the pump curve intersects the system curve.



In the above example, the pump will pass forward a flow rate, Q_A at a head of H_A (Actual Duty Point) which is higher than the desired duty flow rate, Q_D and higher than (to the right) of its best efficiency flow rate, Q_{BEP}.

Pump Manufacturers can provide a pump curve reflective of a particular model of pump "as new". Sites tests can provide an actual pump performance curve through varying pump speed or adjusting valves and measuring flow rate and pressure.



Using variable speed drives it is possible to change the pump speed by changing the frequency of input power to the pump motor. This varies its performance curve meaning that it can meet a desired flow rate In this example the speed is reduced to meet the desired duty flow rate, Q_D.

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