Example Problem for the ALPS Calculator

Including a Problem Statement, Data with Curves, Discussion, and Solution.

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Given:

A 1-stage water pump currently operating at 750-gpm, 36.2-ft, and 1760-rpm is analyzed for possible ways to decrease its operating capacity to 650-gpm. The existing static head is 15 ft, the “Ho” pump curve value is 75 ft, and the current pump efficiency is 82%.

Solution:

The ALPS calculator is used to test various scenarios to obtain the desired 650-gpm flow rate. Known and trial operating conditions are entered into the calculator’s green input cells before calculating an output.

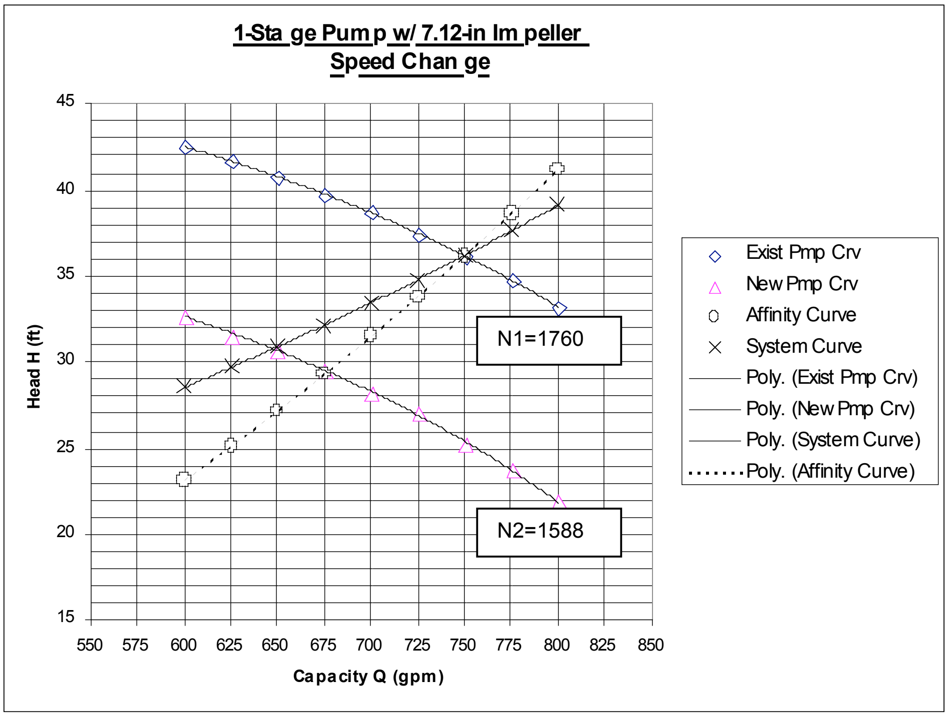
1. Speed Change Scenario

To test the effect of a speed change, the existing "D1" value is also assigned to "D2". Different reduced "N2" speed values are entered to determine the effect on "Qsystem" by pressing the "Solve ALPS" button after each entry. This process ends when the desired "Qsystem" value of 650 is obtained with an "N2" value of 1588.

ALPS Input and Output Data for the Speed Change Scenario:

Description	Symbol	Value	Units
Vertical axis intersection of pump curve tangent line at point Q_1, H_1	**Ho**	75.0	feet
System static head	**Hs**	15.0	feet
Original head	H_1	36.2	feet
Original head at the best efficiency point on the pump curve	H_{BEP}	39.5	feet
Original flow	Q_1	750	gpm
Original capacity at the best efficiency point on the pump curve	Q_{BEP}	675	gpm
Starting speed	N_1	1760	rpm
Ending speed	N_2	1588	rpm
Starting impeller diameter	D_1	7.12	inches
Ending impeller diameter	D_2	7.12	inches
Original Pump Efficiency (enter as 0.XX)	Eff_1	0.82	dimensionless
Ending Affinity Efficiency (enter as 0.XX) (= Eff_1 for speed chg only: D_2=D_1)	Eff_{2A}	0.82	dimensionless
Ending System Efficiency (enter as 0.XX)	Eff_{2Y}	0.82	dimensionless
System curve exponent for ($H=Hs+KQ^n$). Normally, **n**=2.	**n**	2.00	dimensionless
Specific Gravity of pumped liquid	**SG**	1.00	dimensionless
After filling in all green-cell values above, press "Solve ALPS II" for solution below. If required, make revisions and re-press "Solve ALPS II" or "re-Solve".		Solve ALPS II	
Specific Speed (only valid for a 1-stage pump)	**Ns**	2902	dimensionless
Speed ratio	N_2/N_1	0.902	dimensionless
Diameter ratio	D_2/D_1	1.000	dimensionless
Capacity ratio	Q_1/Q_{BEP}	1.111	dimensionless
Original brake horsepower	HP_1	8.4	horsepower
Head predicted by affinity laws	$H_{affinity}$	29.5	feet

Flow predicted by affinity laws	$Q_{affinity}$	677	gpm
Brake horsepower predicted by affinity laws	$HP_{affinity}$	6.1	horsepower
Head expected under new system conditions	H_{system}	**30.5**	feet
Flow expected under new system conditions	Q_{system}	**650**	gpm
Brake horsepower expected under new system conditions	HP_{system}	**6.1**	horsepower
Slope of line tan to affinity curve $H=KQ^2$ at Q_1, H_1 (see Overview 2.)	A	0.0965	feet/gpm
Slope of line tan to sys curve $H=Hs+KQ^n$ at Q_1, H_1 (see Overview 2.)	B	0.0565	feet/gpm
Slope of line tangent to pump curve at Q_1, H_1 (see Overview 2.)	C	-0.0517	feet/gpm
Speed and/or impeller diameter ratio (see Overview 2.)	r	0.9023	dimensionless



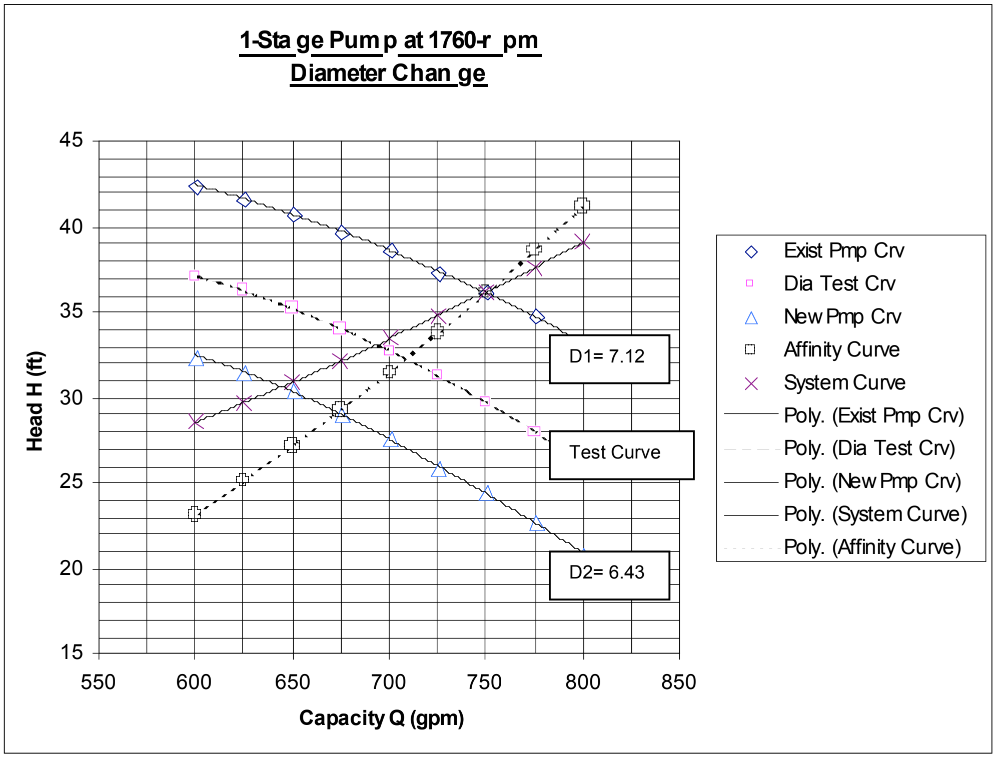
2. Diameter Change Scenario

The next scenario to be tested will be a reduction in the single-stage pump impeller diameter running at the original speed "N1". Different "D2" values are entered to determine the effect on "Qsystem" by pressing the "Solve ALPS II" button after each entry. This process ends when the desired "Qsystem" value of 650 is obtained with a "D2" value of 6.43.

ALPS Input and Output Data for the Diameter Change Scenario:

Ending speed	N_2	1760	rpm
Ending impeller diameter	D_2	6.43	inches
Ending Affinity Efficiency (enter as 0.XX) (= Eff_1 for speed chg only: $D_2=D_1$)	Eff_{2A}	0.83	dimensionless
Ending System Efficiency (enter as 0.XX)	Eff_{2Y}	0.83	dimensionless
Speed ratio	N_2/N_1	1.000	dimensionless

Diameter ratio	D_2/D_1	0.903	dimensionless
Original brake horsepower	HP_1	8.4	horsepower
Head predicted by affinity laws	$H_{affinity}$	29.5	feet
Flow predicted by affinity laws	$Q_{affinity}$	677	gpm
Brake horsepower predicted by affinity laws	$HP_{affinity}$	6.1	horsepower
Head expected under new system conditions	H_{system}	**30.6**	feet
Flow expected under new system conditions	Q_{system}	**650**	gpm
Brake horsepower expected under new system conditions	HP_{system}	**6.1**	horsepower



If the trimmed impeller option is chosen, then the following caution should be noted. Since the pump specific speed "Ns" is approximately 2900 and the required trim diameter ratio "D2/D1" is 0.903, an initial small trim is highly recommended to better determine the ballpark of a final diameter trim. The 2900 specific speed is close to the program 3000 limit and the diameter ratio is close to a 10% reduction limit. The affinity relationships involving diameter changes may tend to not be as accurate for higher specific speed pumps and larger impeller reduction percentages. (Refer to the “Assumptions” tab.)

For the above pump, a test impeller trim diameter of 6.88-in is tested to observe the actual resulting performance. Before testing, the trimmed exit vane tips were filed (streamlined and/or undercut and polished) to reflect the original conditions. After testing, a new performance curve was generated. By referring to this new test curve, the "ALPS" calculator was used to determine a "D2" impeller diameter that would produce "Hsystem" and "Qsystem" values that coincide with the test curve. The program predicted that a 6.74-in impeller diameter would produce head and flow values that agreed with a point on the test curve.

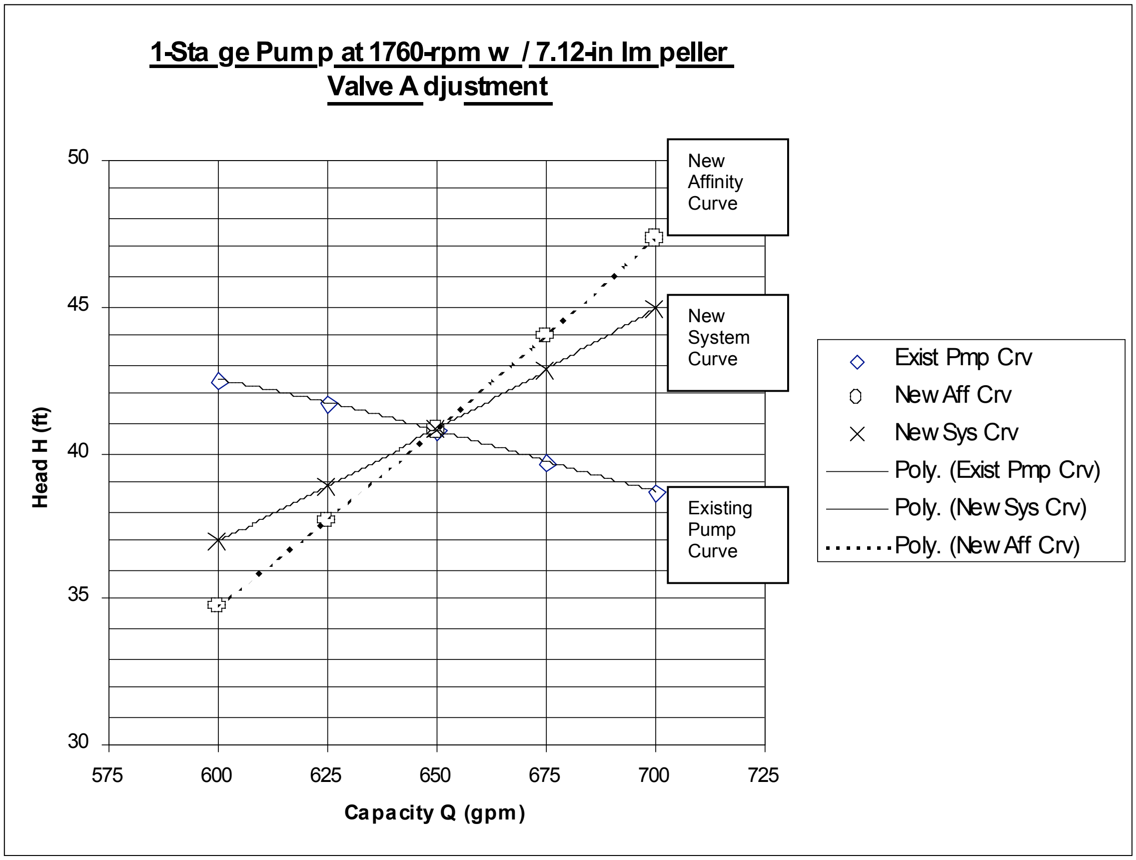
However, this 6.74-in impeller diameter does not agree with the tested 6.88-in value. Therefore, for this particular pump, an adjustment should be made to any program "D2" value before trimming. Note that the predicted head, flow, and power performance values are still valid. Only the "D2" values may be questionable. So, an adjustment should be made to the 6.43-in impeller diameter previously used in the program to obtain the desired 650-gpm performance. A linear approximation can be used to determine the final 1-stage impeller trim size. If Δtest = D1 – Dtest ; Δalpstest = D1 – Dalpstest ; and Δ2alps = D1 – D2alps , then an adjusted D2 = D1 – Δtest x Δ2alps / Δalpstest approximately. For this example, D1 = 7.12 , Dtest = 6.88 , Dalpstest = 6.74 , and D2alps = 6.43. So, the adjusted D2 = 6.68. If more caution is desired, only trim to, say, 6.75 and test again.

3. Throttling Scenario

Another option would involve adjusting a discharge line valve until a 650-gpm flow rate is obtained while utilizing the original impeller size and operating speed. Per the "Assumptions" tab item 5.: "Any subsequent control valve or static head changes will vary the original system curve; the original flow and head will no longer be valid". This is true since a new original head "H1" and capacity "Q1" will be needed for modeling a valve (system) adjustment. By referring to the performance curve that came with this pump, a head value of 40.8-ft is read for a 650-gpm flow rate. A pump efficiency value of 83% can also be read. These new original operating values are entered into program green cells along with original speeds and diameters. The "Solve ALPS" button is then pressed for an outcome.

ALPS Input and Output Data for the Throttling Scenario:

Description	Symbol	Value	Units
Original head	H_1	40.8	feet
Original flow	Q_1	650	gpm
Ending speed	N_2	1760	rpm
Ending impeller diameter	D_2	7.12	inches
Original Pump Efficiency (enter as 0.XX)	Eff_1	0.83	dimensionless
Ending Affinity Efficiency (enter as 0.XX) (= Eff_1 for speed chg only: D_2=D_1)	Eff_{2A}	0.83	dimensionless
Ending System Efficiency (enter as 0.XX)	Eff_{2Y}	0.83	dimensionless
Original brake horsepower	HP_1	8.1	horsepower
Head predicted by affinity laws	$H_{affinity}$	40.8	feet
Flow predicted by affinity laws	$Q_{affinity}$	650	gpm
Brake horsepower predicted by affinity laws	$HP_{affinity}$	8.1	horsepower
Head expected under new system conditions	H_{system}	**40.8**	feet
Flow expected under new system conditions	Q_{system}	**650**	gpm
Brake horsepower expected under new system conditions	HP_{system}	**8.1**	horsepower



Pump power (BHP) requirements, per ALPS, for the above scenarios:

Current Operation (ref)	**HP_1**	8.4	(hp)
Reduced Speed	**HP_{system}**	**6.1**	(hp)
Reduced Impeller Diameter	**HP_{system}**	**6.1**	(hp)
Discharge Valve Adjustment	**HP_1**	8.1	(hp)

Conclusions:

Based on power requirements for the three analyzed options, the reduced operating speed and reduced impeller diameter choices both appear to be good for long-term cost effectiveness. However, the cost of a new inverter-duty motor and VFD along with the associated motor efficiency at the lower speed should be compared with the initial cost of downtime plus trimming and testing an impeller two or more times before a final determination is made.

If economically justified, the VFD option provides several benefits over the other options, such as allowing for future process changes and providing higher reliability at the reduced operating speed.