ARMSTRONG

Calculation of Bowl head or Discharge head

Installation and operating instructions

File No: F51.183
Date: FEBRUARY 10, 2025
Supersedes: F51.183
Date: AUGUST 15, 2005

CONTENTS

1.0 CALCULATION OF BOWL HEAD OR DISCHARGE HEAD

For vertical turbine pumps, discharge head equals bowl head minus lift and internal pump loss. It can be shown as:

hD = hB - hL - hP

Where

hD = Discharge head. Pressure gauge reading in PSI multiplied by 2.31 for fresh cool water.

hB = Bowl head. Actual head in feet developed by the bowl assembly.

hL = Lift. Elevation difference in feet between the pumping water level and the pressure gauge.

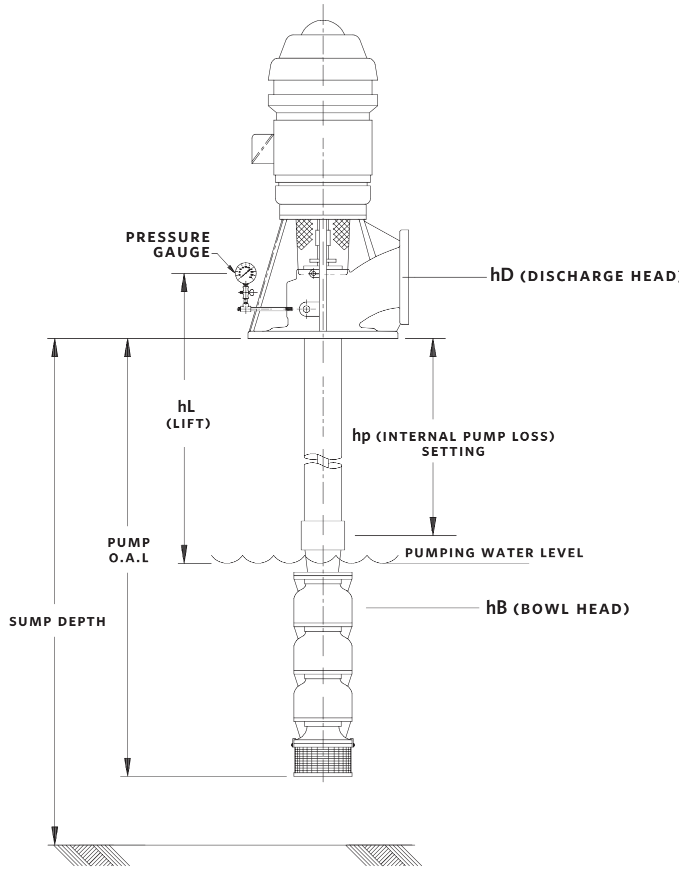
hP = Internal pump loss. Pump column loss plus discharge head loss in feet.

Conversely, bowl head equals discharge head plus lift and internal pump loss.

hB = hD + hL + hP

NOTES:

1 Test curves are plotted as bowl head (hB). Allowances must be made for lift and internal pump loss when comparing test curves to field performances.



2.0 USEFUL FORMULAS

$$\text{Water Horsepower} = \frac{\text{GPM x 8.33 x Head}}{33{,}000} = \frac{\text{GPM x Head}}{3{,}960}$$

Where
GPM = Gallons Per Minute
8.33 = Pounds of water per gallon
33,000 = Ft. Lbs. per minute in one Hp.
Head = Difference in energy head in feet (field head)

$$\text{Bowl BHP} = \frac{\text{Head x GPM x Sp. Gr.}}{\text{3,960 x Eff}}$$

Where
GPM= Gallons Per Minute
Head = Lab. Head (including column loss)
Eff. = Lab. Eff. of Pump Bowls (from performance curves)

Total BHP = Bowl BHP + Thrust Bearing Loss + Line Shaft Loss [3]

Thrust Bearing Loss = Horsepower Loss in Driver Thrust Bearings (see [1] below)

$$\text{Input Horsepower} = \frac{\text{Total BHP}}{\text{Motor Eff.}}$$

Motor efficiency from motor manufacturer (decimal)

$$\text{Field Efficiency} = \frac{\text{Water Horsepower}}{\text{Total BHP}}$$

Water Hp as determined above

$$\text{Overall Plant Efficiency} = \frac{\text{Water Horsepower}}{\text{Input Horsepower}}$$

Total Hp as determined above

Water Hp as determined above
Input Hp as determined above (See [2])

Electrical

$$\text{Input HP} = \frac{\text{BHP}}{\text{Mtr.Eff.}} = \frac{\text{4.826 x K x M x R}}{\text{T}} = \frac{\text{1.732 x E x I x PF}}{746}$$

Where
BHP = Brake Horsepower as determined above
Mtr. Eff. = Rated Motor Efficiency
K = Power Company Meter Constant
V = Power Company Meter Multiplier, or Ratio of Current and Potential Transformers Connected with Meter
R = Revolutions of Meter Disk
T = Time in Sec. for R
E = Voltage per Leg Applied to Motor
I = Amperes per Leg Applied to Motor
PF = Power Factor of Motor
1.732 = Factor for 3-phase Motors (This reduces to 1 for single phase motors.)

$$\text{Kilowatt Input to Motor} = \text{.746 x Input HP} = \frac{\text{1.733 x E x I x PE}}{1{,}000}$$

$$\frac{\text{KW-Hrs Per 1,000 Gallons}}{\text{of Cold Water Pumped Per Hr.}} = \frac{\text{Hd. (ft) x 0.00315}}{\text{Pump Eff. x Motor Eff}}$$

Misc.

$$\text{Discharge Head (in ft.of fluid pumped)} = \frac{\text{Discharge Pressure (PSI) x 2.31}}{\text{Sp. Gr. of Fluid Pumped}}$$

$$\text{Velocity Head} = \frac{V^2}{2G}$$

Where
V = Velocity of Water (ft./sec.)
G = Acceleration Due to Gravity = 32.2 ft./sec^2

$$\text{Forque (foot pounds)} = \frac{\text{Hp x 5,250}}{\text{N}}$$

Where
HP= Horsepower
N= RPM

NOTE:

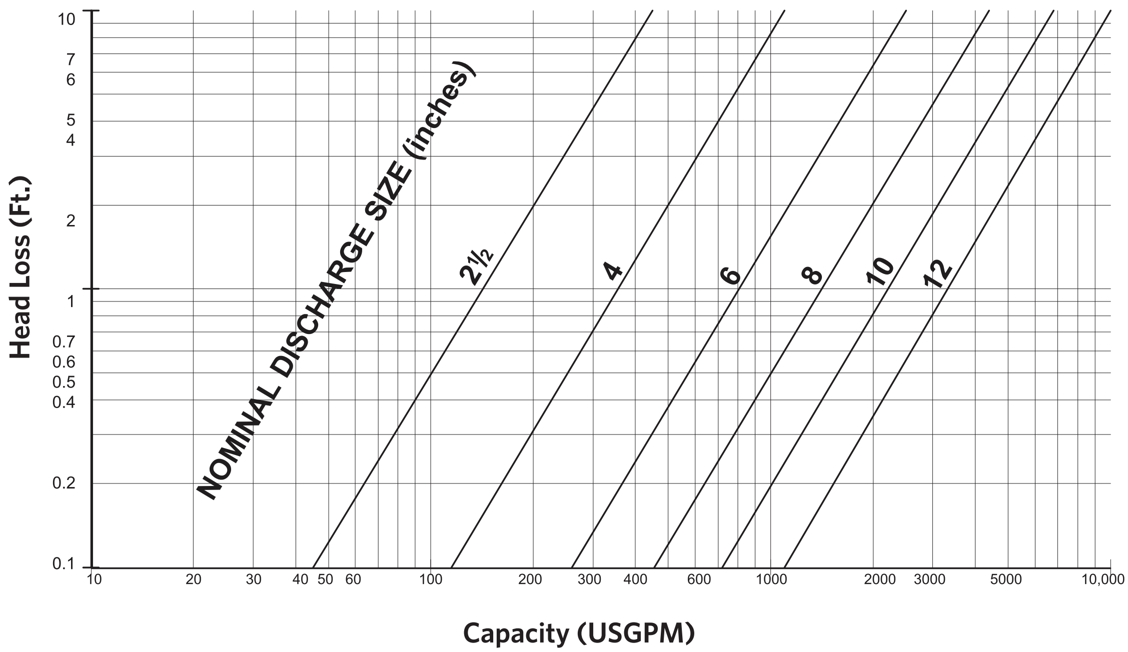
1 Thrust bearing losses in HP per 100 RPM per 1,000 lbs. thrust:
FR. 182TP–215TP – 0.0059
254TP – 0.0071
256TP–258TP – 0.0085
324TP–326TP – 0.0132
364TP–365TP – 0.0148
404TP–425TP – 0.0165
444TP–505TP – 0.0170
Stacked Brgs.

2 Overall Plant Efficiency sometimes referred to as **Wire to Water** Efficiency.

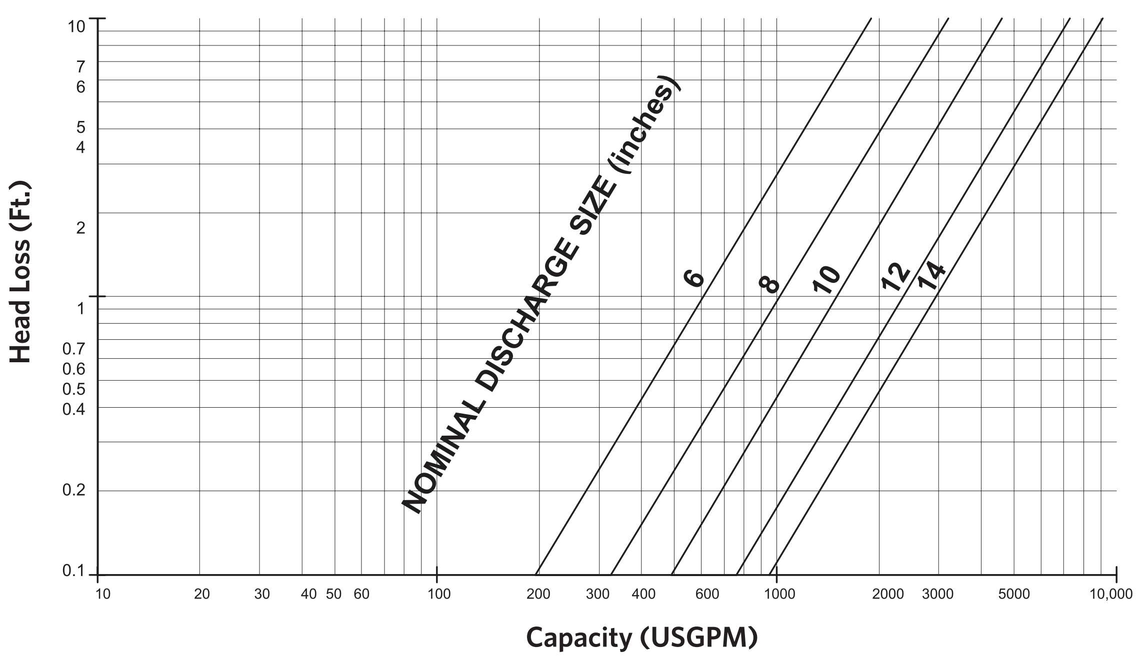
3 Add 4% to maximum bowl HP to cover right angle gear and flexible shaft mechanical losses.

3.0 DISCHARGE HEAD LOSS

Head Loss in Cast Discharge Heads (Types W, A and AF)



Head Loss in Fabricated Discharge Heads (Types F, VF and VU)



4.0 COLUMN FRICTION LOSS

2½" Through 12" Column Size

Friction Loss (Ft.) Per. 100' of column (Open or Enclosed Line Shaft Design)

GPM	Column and Shaft size (Inches)														
	2½	4	6		8			10		12			14		
	¾	1	1	1¼	1¼	1½ 1 11/16	1 15/16	1½ 1 11/16	1 15/16	1 11/16	1 15/16	2¼	1 11/16	1 15/16	2¼
10	1.2														
15	2.0														
20	2.8														
25	3.5														
30	4.2														
40	5.4	0.6													
50	6.6	0.9													
60	9.0	1.2													
70		1.6													
80		1.9													
90		2.4													
100		2.8													
125		4.2													
150		5.													
175		7.5													
200			0.7	1.0											
225			0.9	1.2											
250			1.1	1.4											
275			1.3	1.7											
300			1.5	2.0											
325			1.7	2.3											
350			2.0	2.6											
375			2.2	2.9											
400			2.5	3.3	0.6	0.7	1.0								
450			3.1	4.1	0.8	0.9	1.3								
500			3.7	5.0	1.0	1.1	1.5								
550			4.4	5.8	1.2	1.3	1.8								
600			5.2	6.8	1.4	1.5	2.1								
650			6.0		1.6	1.8	2.5								
700					1.9	2.0	2.8								
750					2.1	2.3	3.2								
800					2.4	2.6	3.6	0.7	0.8						
850					2.7	2.9	4.0	0.8	0.9						
900					3.0	3.2	4.5	0.8	1.0						
950					3.3	3.6	4.9	0.9	1.1						
1000					3.6	3.9	5.4	1.0	1.2	0.4	0.4	0.5			
1200					5.1	5.6	7.6	1.4	1.7	0.6	0.6	0.7			
1400					6.8	7.4	10.0	1.9	2.2	0.8	0.8	1.0			
1600					8.8	9.5		2.4	2.8	1.0	1.1	1.2	0.5	0.5	0.6
1800					11.0	11.9		3.0	3.5	1.2	1.3	1.5	0.6	0.7	0.7
2000								3.7	4.3	1.5	1.6	1.8	0.7	0.8	0.9
2200								4.4	5.1	1.8	1.9	2.1	0.9	1.0	1.1
2400								5.2	6.0	2.1	2.3	2.5	1.0	1.1	1.2
2600								6.1	7.0	2.5	2.6	2.9	1.1	1.3	1.4
2800								7.0	8.0	2.8	3.0	3.3	1.3	1.5	1.6
3000								7.9	9.1	3.2	3.4	3.8	1.5	1.7	1.9
3200										4.1	4.3	4.8	1.9	2.1	2.4
3400										4.5	4.8	5.3	2.1	2.4	2.6
3600										5.0	5.3	5.9	2.3	2.6	2.9
3800										5.0	5.3	5.9	2.3	2.9	3.2
4200										6.0	6.4	7.1	2.8	3.1	3.5
4400										6.6	7.0	7.7	3.0	3.4	3.8
4600										7.2	7.6	8.6	3.3	3.7	41
4800										7.8	8.3	9.0	3.5	4.0	4.4
5000													3.8	4.3	4.8
5200													4.2	4.7	5.2
5500													4.6	5.1	5.7
5750													5.0	5.5	6.2
6000													5.4	6.0	6.7

5.0 MECHANICAL FRICTION IN LINE SHAFTS

The horsepower loss due to mechanical friction in column shaft rotation may be determined from the chart below. Total brake horsepower is obtained by adding the mechanical friction losses to the laboratory brake horsepower.

Mechanical Friction in BHP per 100' of Shaft

SHAFT SIZE (inches)	RPM OF SHAFT		WEIGHT PER FOOT (lbs.)
	3460	1760	
¾	0.60		1.50
1		0.53	2.67
1¼		0.79	4.17
1½		1.14	6.01
$1\frac{11}{16}$		1.43	7.60
$1\frac{15}{16}$		1.83	10.02
2¼		2.40	13.52

6.0 THRUST LOADS

The total downthrust produced is the sum of the hydraulic thrust plus the static thrust (dead weight) of the shaft and impellers. The impeller and bowl shaft weights, however, are usually a small percentage of the static thrust and can usually be neglected.

Total Thrust Formula

Total Thrust = (K+H) + (W_s x S) = (W_i x No. Imp's)

Where

K = Thrust factor for pump
H = Bowl head (feet)
W_s = Wt. of shaft (lbs. per foot)
W_i = imp. Wt. (lbs.)
S = Column length (feet)

Example:
Calculate the total thrust for a 5 stage 14LKM-FP pump with 50 feet of 1½ x 8 column.
Capacity is 1,000 GPM at 450' bowl head.
Total Thrust
= (12.5 x 450) + (6.01 x 50) + 5 x 25.5)
= 5,626 + 301 + 127
= 6,053 lbs.

7.0 SPECIAL MATERIAL BOWL ASSEMBLIES PERFORMANCE MULTIPLIERS

Pump performance curves are based on a standard bowl metallurgy. Impeller material is ASTM B584 bronze for all sizes. Bowl material is ASTM A48 Class 30 cast iron with porcelain enameled water passages. When casting bowls and impellers in special materials, pump performance is reduced by a decrease in head and efficiency. The chart below gives multipliers for calculating the reductions in head and efficiency at the pump's standard catalog **best efficiency point** (B.E.P.). Special material reductions in head and efficiency gradually decrease as pump capacity shifts from B.E.P. to shut-off where the performance is the same as catalog performance. Conversely, performance continues to decline as pump capacity shifts from B.E.P. to maximum flow.

If impellers and bowls are both cast in special material, then **both** multipliers are used. See the example below.

NOTES: Efficiency reductions for bowl staging must be made in addition to correction factors for special material.

EXAMPLE: 6X10H VTF (zincless bronze) at 1770 rpm, single stage performance based on multistage unit at best efficiency point (B.E.P.):

Standard unit

GPM = 725

Head (ft.) = 38

Eff (%) = 81

S.O. Head (ft.) = 57

Cast iron enamel bowl with zincless bronze impeller

GPM = 725 x .99 = 718

Head (Ft.) = 38 x .99 = 37.6

Eff (%) = 81 x .99 = 80.2

S.O. Head (Ft) = 57 x 1 = 57

Zincless bronze bowl and impeller

GPM = 725 x .99 x .98 = 703

Head (ft.) = 38 x .99 x .98 = 36.9

Eff (%) = 81 x .99 x .98 = 78.6

S.O. Head (ft.) = 57 x 1 = 57

These performance multipliers are intended for use in approximating pump performance. Consult factory for guaranteed performance.

PUMP SIZE & TYPE	BOWLS		IMPELLERS	
	ANY BRONZE	STEEL S.STEEL NI-RESIST	ANY BRONZE	STEEL S.STEEL NI-RESIST
4HO	0.96	...	0.99	0.94
8JK	0.98	0.97	1.00	0.95
10DK	0.98	0.98	0.99	0.95
12LK	0.98	0.96	1.00	0.96
12FK/14LK 15DK/16MK	0.99	0.98	1.00	0.97
18MKL/19FK 20MK	1.00	0.99	1.00	0.98

(Sample Curve for Single Stage Performance for 500 gpm Model 6X10H VTF Fire Pump at 1770 rpm)

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