Hydraulics is the study and understanding of the behavior of liquids at rest and in motion. We are concerned with water, and the following characteristics of our application:

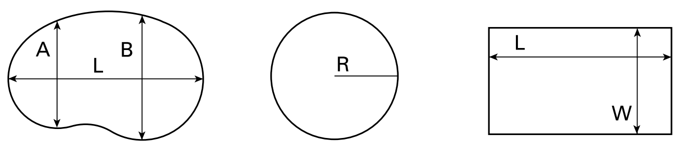
1. How much water do we have (Pool Capacity)?
2. How fast can we safely move the water (Turnover Rate and Water Velocity)?
3. How much resistance will this water meet while moving through the system (Friction Loss)?
4. How will we overcome this resistance (Pump/Filter Sizing)?

Following are step-by-step instructions to answer these four questions and ultimately determine the proper size pump or filter for virtually any installation. Below each step is a calculation based on the following example: 16 ft by 32 ft rectangular pool, 3 ft to 8 ft deep, 2" suction side and return side plumbing. Existing 1 HP pump; filter gauge reads 10 PSI (clean).

1. Pool Capacity

To determine total gallons, we must first calculate the surface area of the pool in square feet:

A. Surface Area



Area = (A+B)x L x .45   Area = R x R x 3.14   Area = L x W

____________ ft^2
(surface area)

Surface Area: 16 ft x 32 ft = 512 ft^2

Next, multiply the surface area by the average *depth* to determine the appropriate *volume* of the pool.

B. Average Depth

(____________ ft + ____________ ft) ÷ 2 = ____________ ft
(depth, shallow end) (depth, deep end) (average depth)

Average Depth = (3 ft. + 8 ft) ÷ 2 = 5.5 ft

C. Volume

____________ ft^2 x ____________ ft = ____________ ft^3
(surface area) (average depth) (volume)

Volume = 512 *ft^2* x 5.5 ft = 2,816 *ft^3*

Next, multiply the pool's volume in ft^3 by 7.5 to get the pool capacity in gallons:

D. Pool Capacity

____________ ft^3 x 7.5 gallons/ft^3 = ____________ gallons
(volume) (pool capacity)

Pool Capacity = 2,816 ft^3. x 7.5 gallons/ft^3 = 21,120 gallons

Some of the more common pool sizes are:

Above-Ground Size	Gallons*
15 ft Round	5,293
18 ft Round	7,622
21 ft Round	10,374
24 ft Round	13,550
12 ft x 24 ft Rectangle	8,626
27 ft Round	17,149
*Average Depth: 4 ft	

In-Ground Size	Gallons*
12 ft x 24 ft Rectangle	11,861
16 ft x 32 ft Rectangle	21,086
18 ft x 36 ft Rectangle	26,687
20 ft x 40 ft Rectangle	32,947
*Average Depth: 5.5 ft	

2. Flow Rate

While the actual flow rate of a pump is based on the total resistance of the system as described below, the desired flow rate must be calculated to verify it will satisfy Turnover Rate and Water Velocity requirements.

2A. Turnover Rate

The turnover rate for a swimming pool is the amount of time required to circulate the entire volume of water through the system once to meet reasonably clean, safe water standards. The minimum recommended turnover rate is twelve (12) hours, however an eight (8) to ten (10) hour rate is quite common. Check with local regulations for the minimum required turnover rate.

Based on the pool's capacity and the desired turnover rate, the *minimum* rate at which the water must be circulated in Gallons Per Minute (GPM) is calculated as follows:

A. Minimum Flow in Gallons per Hour (GPH)

____________ gallons ÷ ____________ hours = ____________ GPH
(pool capacity) (desired turnover rate) (minimum flow,gallons per hour)

Minimum Flow: 21,120 gallons ÷ 10 hours = 2,112 gallons per hour

B. Minimum Flow in Gallons per Hour (GPM)

____________ gallons per hour ÷ 60 minutes per hour = ____________ GPM
(minimum flow gallons per hour) (minimum flow, gallons per minute)

Minimum Flow: 2,112 gallons per hour ÷ 60 minutes per hour = 35 gallons per minute

2B. Water Velocity

The *maximum* recommended water velocity is six (6) or eight (8) feet per second for suction lines and ten (10) feet per second for return lines. Check with local regulations for the maximum water velocity for suction and return lines. The table below lists the *maximum* flow in GPM based on plumbing size and water velocity.

Pipe Size	Maximum Flow		
(in)	6.0 ft/sec	8.0 ft/sec	10.0 ft/sec
1 ½"	38 GPM	51 GPM	63 GPM
2"	63 GPM	84 GPM	105 GPM
2 ½"	90 GPM	119 GPM	149 GPM
3"	138 GPM	184 GPM	230 GPM

Maximum Flow: 2" suction side plumbing at 6.0 ft/sec = 63 gallons per minute

2C. Desired Flow

The desired flow rate must be between the minimum flow based on the Turnover Rate and the maximum flow based on the Water Velocity. Note that if higher flow rates are needed, such as for water features, the maximum possible flow would have to be increased by using larger size plumbing (e.g. increase from 2" to 2 ½" plumbing).

It is recommended to select a flow that is higher than the minimum to account for decrease in flow that naturally occurs as the filter is loaded with dirt and debris.

Minimum Flow (Turnover Rate): 35 GPM

Maximum Flow (Water Velocity): 63 GPM

Desired Flow: 50 GPM

3. Friction Loss

Everything that the water must pass through within the circulation system — plumbing and equipment — creates resistance, or Friction Loss. The friction loss for standard plumbing supplies such as pipe, elbows, fittings, etc. can be found using published reference tables. Friction loss for equipment such as filters, heaters, and chlorination systems can be found in charts and/or curves provided by the manufacturer. The sum of all the resistance is called Total Dynamic Head (TDH) and is typically measured in Feet of Water or Feet of Head.

A properly sized pump will have the ability to overcome the Total Dynamic Head of the system while, at the same time, providing flow that will satisfy Turnover Rate and Water Velocity requirements.

For new installations, it is possible to calculate TDH very accurately by using reference tables and manufacturer's data to determine the friction loss associated with every component in the circulation system.

For existing installations, we are often unable to determine the total amount of pipe and fittings … it's underground. Therefore, what follows is a simplified "rule-of-thumb" means of determining Total Dynamic Head.

We will need to add the resistance from the vacuum (suction) side of the existing pump to the resistance of the pressure side of the pump. Note this assumes the Static Suction Lift (i.e. vertical distance from the center of the pump's impeller to the surface of the water) is offset by the water returning to the pool.

A. Friction Loss (Vacuum)

__________inches of mercury x 1.13 ft of water = __________ft of water
(vacuum reading) (total resistance, vacuum)

Typically, however, a vacuum reading will not be available, therefore, the table below provides Common Head Loss Factors for today's high-efficiency pumps.

Pump Size	Head Loss Factor*
3/4 HP	4.5 to 5.5 ft of water
1 HP	7 to 9 ft of water
1 1/2 HP	10 to 12.5 ft of water
2 HP	13.5 to 16 ft of water

*Assumes 2" suction line, not to exceed 40 ft long, minimal fittings, one (1) 2" valve and full-rated pumps.

Total Resistance (Vacuum): 9 ft of water (existing 1 HP pump)

B. Friction Loss (Pressure)

______________ PSI x 2.31 ft of water / PSI = ______________ft of water
(filter pressure, clean) (total resistance, pressure)

Total Resistance (Pressure): 10 PSI x 2.31 ft of water / PSI = 23 ft of water

C. Total Dynamic Head

___________ ft of water + ___________ ft of water = ___________ft of water
(total resistance, vacuum) (total resistance, pressure) (total dynamic head)

Total Dynamic Head: 9 ft of water + 23 ft of water = 32 ft of water

4. Pump Sizing

We now have all the information necessary to select the proper size pump and/or filter and then proceed based on new vs. aftermarket installations.

A pump's performance data is provided in GPM (output) vs. Feet of Head (resistance). The specific performance data for Hayward pumps can be found in the Pump Section, pages 7-16.

4A. Pump Sizing, New Installations

For new installations, use the desired flow rate and Total Dynamic Head calculated from tables and manufacturer's data:

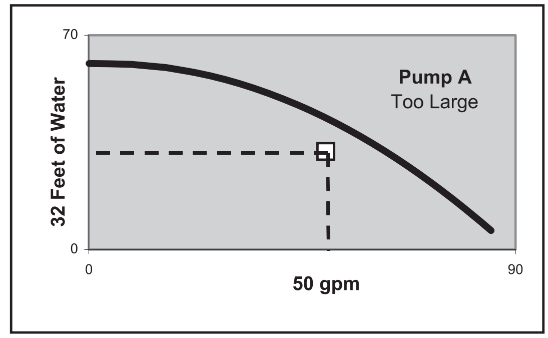
Desired Flow ______________ GPM

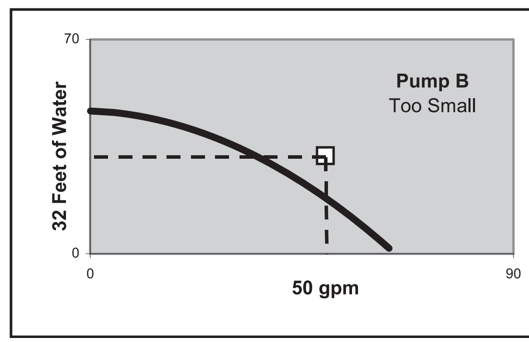
Total Dynamic Head ______________ ft of water

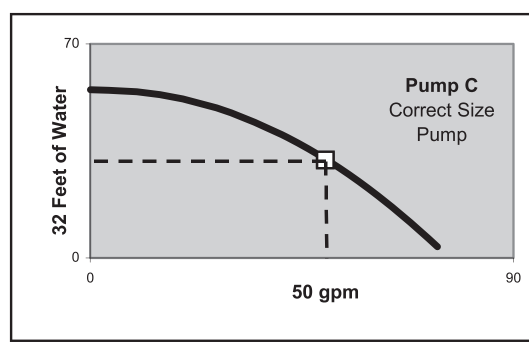
Using Hayward Pump Performance Curves or Tables, identify which pump's performance comes closest to matching the point where the Desired Flow intersects with the Total Dynamic Head.

Desired Flow: 50 GPM

Total Dynamic Head: 32 ft of water (assume to be the same as determined above)







4B. Pump Sizing, Existing Installations

For existing installations, use the Total Dynamic Head calculated from the Friction Loss on the Vacuum and Pressure side of the pump.

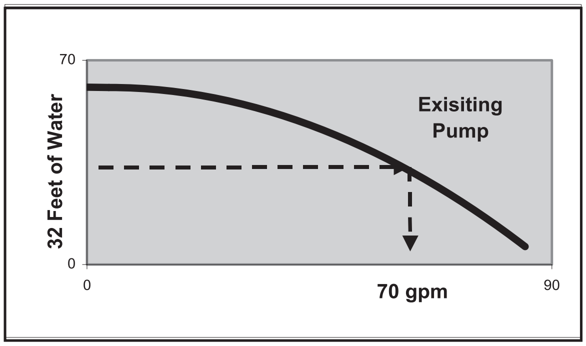
Total Dynamic Head ______________ ft of water

Using the manufacturer's performance curve for the existing pump, find the flow that corresponds to the Total Dynamic Head. This is the actual flow at which the pump is currently operating, which may or may not meet Turnover Rate and Water Velocity requirements. Verify the actual flow rate is between the minimum flow based on the Turnover Rate and the maximum flow based on the Water Velocity.

Total Dynamic Head: 32 ft of water (assume to be the same as determined above)

If the actual flow rate does not meet the Turnover Rate and Water Velocity requirements, you must either modify the system to add or remove restrictions (e.g. use less restrictive plumbing fittings and/or equipment) or vary the flow by changing size of the pump.

If you increase or decrease your flow for any reason, your resistance will increase or decrease respectively. You cannot read horizontally across the curve at the same Total Dynamic Head to choose another pump. You must create a system curve based on the following relationship:



__________ft of water x (_______ GPM ÷ _______GPM)^2 = _______ft of water
(current friction loss) (new flow rate) (current flow rate) (new friction loss)

Choose the minimum and maximum flow rates based on Turnover Rate and Water Velocity and calculate the corresponding friction loss using the formula above. Plot each combination of friction loss and flow to create the system curve.

Current Flow: 70 GPM

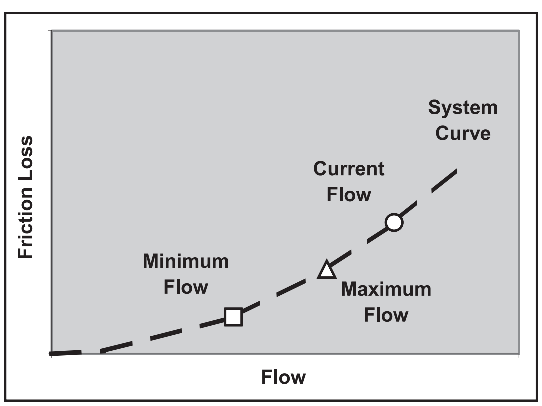
Current Friction Loss: 32 ft of water

New Flow Rate (per Turnover Rate) = 35 GPM

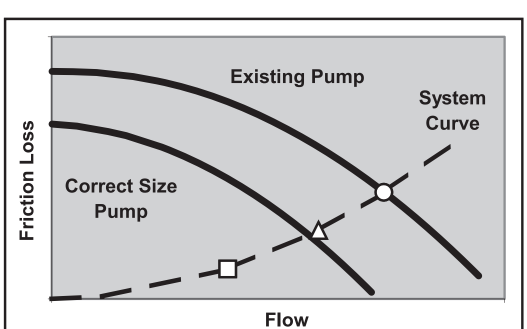
New Friction Loss = (32 ft of water) x (35 GPM ÷ 70 GPM)^2 = 8 ft of water

New Flow Rate (per Water Velocity) = 63 GPM

New Friction Loss = (32 ft of water) x (63 GPM ÷ 70 GPM)^2 = 26 ft of water



The point where the performance curve for a particular pump intersects the system curve determines the flow and Total Dynamic Head where that pump will operate.



Saving Money by Saving Energy

Depending upon utility rates, pool characteristics, and equipment selected, it is possible to recoup the premium cost of an upgrade from a standard pump to an energy efficient pump in the first year of operation.

For example, a system featuring an energy efficient high performance pump drawing 5.34 amps at 230 volts where the local utility rate is $0.12 per kWh will cost you approximately $1.78 over a 12 hour period per day. A standard pump drawing 7.0 amps will cost you approximately $2.32 per day or an extra $197 annually!

Use this worksheet to help determine your energy savings:

A. Motor Amp Rating	A
B. Voltage (e.g. 115 volts or 230 volts)	B
C. Local Energy Rate ($ per kWh) *	C
D. Approximate Power Usage (Watts) = A x B	D
E. Kilowatts = D / 1000	E
F. $ per hour = E x C	F
G. Hours of Operation	G
H. Cost per Day = F x G	H
J. Monthly Cost = H x 30	J
K. Yearly Cost = H x 365	K

*Refer to your utility bill to determine locate rate

4B. Filter Sizing

A filter, be it DE, sand, or cartridge, has a Design Flow Rate in GPM as well as a Turnover Capacity in Gallons. See the table below, for example. The specific performance data for Hayward filters is provided in the Filter Section, pages 20-35.

Select a filter that meets or exceeds the desired flow rate and turnover capacity in gallons.

Model Number	Effective Filtration Rate Area	Design Flow	Turnover Capacity (Gallons)	
			8 Hours	10 Hours
S180T	1.75 ft^2	35 GPM	16,800	21,000
S210T	2.20 ft^2	44 GPM	21,120	26,400
S220T	**2.64 ft^2**	**52 GPM**	**24,960**	**31,200**
S244T	3.14 ft^2	62 GPM	29,760	37,200
S270T	3.70 ft^2	74 GPM	35,520	44,400
S310T	4.91 ft^2	98 GPM	47,040	58,800
S360SX	6.50 ft^2	131 GPM	62,400	78,000

Desired Flow: 50 GPM

Turnover 21,120 gallons in 10 hours

Select S220T (minimum)

One additional factor to consider in filter sizing is bather load. Busier pools require larger filters. Also, larger filters provide longer cycles, reducing everyday maintenance required by the consumer during the pool season.

Summary

Using the information calculated above, you can properly size the pump, filter, and corresponding equipment, assuring you meet Turnover Rate and Water Velocity requirements while eliminating the electrical waste and potential damage to other system components associated with a needlessly oversized pump.