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:

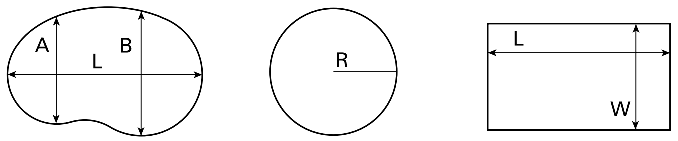
1. How much water do we have (Pool Capacity)?
2. How fast do we want to move the water (Turnover Rate)?
3. How much resistance will this water meet while moving through the system (Friction Loss)?
4. How will we overcome this resistance (Pump/Filter Sizing)?

Following are step-by-step instructions to answer these four questions, and, ultimately, determine the proper size pump or filter for virtually any aftermarket 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. Existing 1 H.P. pump; filter gauge reads 10 P.S.I. (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 square footage by *average depth* to determine the approximate *cube* 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. Cube

____________ ft.² x ____________ ft. = ____________ ft.³
(surface area) (average depth) (cube)

Cube: 512 ft.² x 5.5 ft. = 2,816 ft.³

Then, multiply the pool's approximate *cube* by 7.5, which represents the number of gallons of water in one cubic foot:

D. Pool Capacity

____________ ft.³ x 7.5 gallons/ft.³ = ____________ gallons
(cube) (pool capacity)

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

Some of the more common pool sizes are:

Above-Ground Size	Gallons*
15' Round	5,299
18' Round	7,630
21' Round	10,039
24' Round	13,565
12' X 24' Rectangle	8,640
27' Round	17,168

*Average Depth: 4 Feet

In-Ground Size	Gallons*
12' X 24' Rectangle	11,880
16' X 32' Rectangle	21,120
18' X 36' Rectangle	26,730
20' X 40' Rectangle	33,000

*Average Depth: 5 ½ Feet

Use these as a general guide to determine the pump and filter sizes necessary to properly turn the pool water over in an 8-12 hour period.

2. Turnover Rate

Once the pool's capacity has been calculated, the next step is to determine how fast the water must be circulated in Gallons Per Minute (GPM), to meet reasonably clean, safe water standards. The recommended *minimum* standards for swimming pools are not less than the flow rate to provide one (1) full turnover of the pool every twelve (12) hours. However, an eight (8) to ten (10) hour rate is quite common:

A. Turnover Rate in Gallons Per Hour (GPH)

____________ gallons ÷ ____________ hours = ____________ GPH
(pool capacity) (desired turnover time) (turnover rate – gallons per hour)

Turnover rate: 21,120 gallons ÷ 10 hours = 2,112 gallons per hour

B. Turnover Rate in Gallons Per Minute (GPM)

____________ gallons/hour ÷ 60 minutes = ____________ GPM
(turnover rate – gallons per hour) (turnover rate – gallons per minute)

Turnover rate: 2,112 gallons per hour ÷ 60 = 35 GPM

3. Friction Loss

Everything that the water must pass through within the recirculating system – plumbing and equipment – creates resistance, or Head Loss. The sum of all the resistance is called Total Dynamic Head, and is measured in Feet of Head.

Often, we are unable to determine the total amount of pipe and fittings in an existing installation … 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 pump, see A on next page, (measured in inches of mercury with a vacuum gauge; one (1) inch of mercury = 1.13 feet of water); to the resistance on the pressure side of the pump, see B on next page, (measured in pounds per square inch – as read from the pressure gauge on the filter when *clean*; one (1) P.S.I. = 2.31 feet of head), to determine Total Dynamic Head, see C next page.

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

Friction Loss (continued)

A. Friction Loss (Vacuum)

____________ in. mercury x 1.13 ft. of water = ____________ ft. of water
(vacuum reading) (total resistance –vacuum)

or COMMON HEAD LOSS FACTORS
Vacuum (At Pump) – Assumes 2" suction line, not to exceed 40' long, minimal fittings, one (1) 2" valve and full-rated pumps.

3/4 H.P. Pump – 4.5 to 5.5 ft. of water
1 H.P. Pump – 7 to 9 ft. of water
1 ½ H.P. Pump – 10 to 12.5 ft. of water
2 H.P. Pump – 13.5 to 16 ft. of water

Total Resistance (Vacuum): 9 ft. of water (existing 1 H.P. pump)

B. Friction Loss (Pressure)

____________ P.S.I. x 2.31 ft. of head/P.S.I. = ____________ ft. of head
(filter-clean) (total resistance – pressure)

Total Resistance (Pressure): 10 P.S.I. x 2.31 = 23 ft. of head

C. Total Dynamic Head

__________ ft. of water + __________ ft. of head = __________ft. of head
(total resistance-vacuum) (total resistance-pressure) (total resistance to flow)

Total Resistance to flow: 9 ft. of water + 23 ft. of head = 32 ft. of head

NOTE: the table below provides a maximum flow (GPM) through 1 ½" and 2" PVC pipe without exceeding the maximum standards for velocity (ft./sec.), i.e., suction line (8 ft./sec.) and return line (10 ft./sec.).

Pipe Size (PVC)	Suction Line	Return Line
1 ½"	50 GPM	65 GPM
2"	85 GPM	105 GPM
2 ½"	125 GPM	150 GPM

Re-Cap

We now have all of the information necessary to select the proper size pump and/or filter. To re-cap, enter the final calculations from the previous three sections in the spaces below, which will serve as our road map to sizing:

Pool Capacity ____________ gallons

Turnover Rate ____________ gallons per minute (GPM)

Friction Loss ____________ ft. of head

Pool capacity: 21,120 gallons ***Turnover rate: 35 GPM***
Friction loss : 32 ft. of head

4A. Pump Sizing

Since the one and only function of the pump is to overcome the total resistance to flow in the system, proper selection is of utmost importance. A pump's performance data is provided in GPM (output) vs. Feet of Head (resistance). See the table below, for example. The specific performance data for Hayward pumps can be found in the Pump Section, pages 5 to 11.

Performance Data – Pump

Model No. Max Rated	Model No. Full Rated	Pump Output (GPM) vs. Total Resistance To Flow (Feet of Head)					
		20 ft.	30 ft.	40 ft.	50 ft.	60 ft.	70 ft.
SP2600X5	—	55	45	29	—	—	—
SP2605X7	—	67	58	**47**	31	—	—
SP2607X10	SP2607	85	76	65	50	27	—
SP2610X15	SP2610	97	90	80	67	50	10
SP2615X20	SP2615	116	111	99	85	70	51
SP2621X25	SP2621	109	109	104	95	84	69

Select SP2605X7

NOTE: Always move up to next level of resistance (i.e., 32 to 40 ft. of head), and specify the pump that exceeds the turnover rate required (i.e., 47 vs. 35 GPM).

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 $.12 per kWh will cost you $1.78 over a 12 hour period per day. A standard pump drawing 7.0 amps will cost you $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 (115v or 230v)	B
C. Local Energy Rate $ per kWh*	C
D. Watts = A x B	D
E. Kilowatts = D/1000	E
F. $ per kWh = 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

Energy Efficient

* Refer to your utility bill to determine local rate
See your pool professional for assistance.

4B. Filter Sizing

A filter, be it D.E., sand or cartridge, has a Design Flow Rate (in Gallons Per Minute – GPM), as well as a Turnover Rate (Pool Capacity in Gallons). See the table below, for example. The specific performance data for Hayward filters is provided in the filter section, pages 14 to 31.

Performance Data – Sand Filter

Model Number	Effective Filtration Area	Design Flow Rate	Turnover (In 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	3.7 ft.²	74 GPM	35,520	44,400
S310T	4.91 ft.²	98 GPM	47,040	58,800
S360SX	6.5 ft.²	130.6 GPM	62,400	78,000

Select S210T (minimum) to adequately filter pool (i.e., 44 vs. 35 GPM turnover rate; will handle pools up to 21,120 gallons in 8 hours).

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

Summary

Using the information in the re-cap section above, based upon your calculations, choose the desired pump and/or filter model, then select the proper size component to meet the needs of the installation.

It is important to remember that your Turnover Rate calculation is keyed directly to a specific Total Dynamic Head calculation (i.e., GPM vs. Feet of Head). If you increase or decrease your GPM for any reason, your resistance will increase or decrease respectively.