Design Formulas

Precipitation Rate (in/hr)

S= Spacing

$$\text{Square} = \frac{96.3 \times GPM \times 360}{S \times S \times \text{Sprinkler Arc}}$$

$$\text{Triangular} = \frac{96.3 \times GPM \times 360}{S \times S \times 0.866 \times \text{Sprinkler Arc}}$$

$$\text{Single Row} = \frac{96.3 \times GPM}{S \times 0.8\ \text{Diameter}}$$

Run-Time

$$\text{Run-Time} = \frac{\text{Desired Application} \times 60}{\text{Precipitation Rate}}$$

Velocity

$$V = \frac{0.480 \times Q}{(ID)^2}$$

Where:
V = Velocity in feet per second
Q = Gallons per minute
ID = Inside diameter of pipe

Power Formulas

Horse Power

1 hp = 550 foot pounds per second
= 746 watts or 0.746 kW
= 1 second foot of water falling 8.8'

$$\text{Water HP} = \frac{GPM \times TDH}{3960}$$

Where:
GPM = Gallons per minute
TDH = Total dynamic head

$$\text{Brake HP} = \frac{GPM \times TDH}{3960 \times E}$$

Where:
GPM = Gallons per minute
TDH = Total dynamic head
E = Pump efficiency

1 kilowatt (kW) = 1,000 watts
= 1,341 HP
= 735.5 foot pounds per second

Electrical Power

$$3\phi\ kVA = \frac{1.732 \times FLA \times \text{Voltage}}{1000}$$

$$1\phi\ kVA = \frac{FLA \times \text{Voltage}}{1000}$$

Ohm's Law: V = IR

Where:
V = Voltage in Volts
I = Current in Amperes
R = Resistance in ohms

Amp Calculation
Amps = Watts / Volts

Pump Laws (Affinity Laws)

$RPM_2 / RPM_1 = Flow_2 / Flow_1$
$(RPM_2 / RPM_1)^2 = Pressure_2 / Pressure_1$
$(RPM_2 / RPM_1)^3 = Power_2 / Power_1$

Example: An irrigation pump operating at 1800 RPM and producing 600 gpm at 120 psi is switched to 3600 RPM:

RPM_2 / RPM_1 = $Flow_2 / Flow_1$
= 3600 RPM / 1800 RPM
= $Flow_2$ / 600 gpm = 1200 gpm

$(RPM_2 / RPM_1)^2$ = $Pressure_2 / Pressure_1$
= $(3600\ RPM / 1800\ RPM)^2$
= $Pressure_2$/120 psi = 480 psi

$(RPM_2 / RPM_1)^3$ = $Power_2 / Power_1$
= $(3600\ RPM / 1800\ RPM)^3$
= $Power_2$ / 60 HP = 480 HP

Electric Formulas for Calculating Amperes, Horsepower, Kilowatts and kVA

ALTERNATING CURRENT			
To Find:	**Single Phase**	**Two Phase-Four Phase Wire**	**Three Phase**
Amperes when "HP" is known	$\frac{HP \times 746}{E \times \%EFF \times PF}$	$\frac{HP \times 746}{E \times \%EFF \times PF \times 2}$	$\frac{HP \times 746}{E \times \%EFF \times PF \times 1.73}$
Amperes when "kW" is known	$\frac{kW \times 1000}{E \times PF}$	$\frac{kW \times 1000}{E \times PF \times 2}$	$\frac{kW \times 1000}{E \times PF \times 1.73}$
Amperes when "kVa" is known	$\frac{kVA \times 1000}{E}$	$\frac{kVA \times 1000}{E \times 2}$	$\frac{kVA \times 1000}{E \times 1.73}$
Kilowatts	$\frac{E \times I \times PF}{1000}$	$\frac{E \times I \times PF \times 2}{1000}$	$\frac{E \times I \times PF \times 1.73}{1000}$
Kilovolt-Amperes "kVA"	$\frac{E \times I}{1000}$	$\frac{E \times I \times 2}{1000}$	$\frac{E \times I \times 1.73}{1000}$
Horsepower	$\frac{E \times I \times \%EFF \times PF}{746}$	$\frac{E \times I \times \%EFF \times PF \times 2}{746}$	$\frac{E \times I \times \%EFF \times PF \times 1.73}{746}$

Where:

$$\text{Power Factor (PF)} = \frac{\text{Power Used (Watts)}}{\text{Apparent Power}} \text{ or } \frac{kW}{kVA}$$

$$\text{Power Efficiency (\%EFF)} = \frac{\text{Output (Watts)}}{\text{Input (Watts)}}$$

E = Volts

I = Amperes

W = Watts

APPENDIX

Conductor Properties For Insulated Annealed Copper Direct Current Resistance

OHMS PER 1,000 FEET

Copper Awg	Temperature 167° F (75° C)	149° F (65° C)	77° F (25° C)	68° F (20° C)	Cross Sectional Area Circular Mils
18 Solid	7.77	7.519	6.515	6.390	1,620
18 Stranded	7.95	7.693	6.666	6.538	1,620
16 Solid	4.89	4.732	4.100	4.021	2,580
16 Stranded	4.99	4.829	4.184	4.104	2,580
14 Solid	3.07	2.971	2.574	2.525	4,110
14 Stranded	3.14	3.039	2.633	2.582	4,110
12 Solid	1.93	1.868	1.618	1.587	6,530
12 Stranded	1.98	1.916	1.660	1.628	6,530
10 Solid	1.21	1.171	1.015	0.995	10,380
10 Stranded	1.24	1.200	1.040	1.020	10,380
8 Solid	0.764	0.739	0.641	0.628	16,510
8 Stranded	0.778	0.753	0.652	0.640	16,510
6 Stranded	0.491	0.475	0.412	0.404	26,240
4 Stranded	0.308	0.298	0.258	0.253	41,740
2 Stranded	0.194	0.188	0.163	0.160	66,360
1/0 Stranded	0.122	0.118	0.102	0.100	105,600
2/0 Stranded	0.097	0.094	0.081	0.080	133,100

Source: 2008 Edition of *National Electric Code* (NFPA 70), Chapter 9, Table 8.
System designer must use resistance values which correlate to temperatures and applications for each specific project.

Full Load Amperage (FLA)

Motor HP	Single Phase A-C 115 VOLTS	230 VOLTS*	Three Phase A-C Induction Type Squirrel Cage & Wound Rotor 230 VOLTS*	460 VOLTS	575 VOLTS
½	9.8	4.9	2.2	1.1	0.9
¾	13.8	6.9	3.2	1.6	1.3
1	16	8	4.2	2.1	1.7
1 ½	20	10	6.0	3.0	2.4
2	24	12	6.8	3.4	2.7
3	34	17	9.6	4.8	3.9
5	56	28	15.2	7.6	6.1
7 ½	80	40	22	11	9
10	100	50	28	14	11
15	—	—	42	21	17
20	—	—	54	27	22
25	—	—	68	34	27
30	—	—	80	40	32
40	—	—	104	52	41
50	—	—	130	65	52
60	—	—	154	77	62
75	—	—	192	96	77
100	—	—	240	120	96
125	—	—	296	148	118
150	—	—	350	175	140
200	—	—	456	228	182
250	—	—	558	279	223

*For 208V applications, increase the 230V FLA by 10%.

Horsepower to Kilowatts

Horsepower	Kilowatt
1	0.746
3	2.2
5	3.7
10	7.5
15	11.2
20	14.9
25	18.7
30	22.4
40	29.8
50	37.3
60	44.8
75	56.0

To calculate the FLA of a pump motor operating on a VFD, multiply the nominal FLA by 1.24. To estimate FLA station, multiply the largest load by 1.25 and then add this to remaining component FLAs. **EXAMPLE: A 460V 2 x 50HP pump station with a 5HP PM pump would have an FLA of 173.4 Amps.**