B.C. SPRINKLER IRRIGATION MANUAL

Chapter 9

Editor

Ted W. van der Gulik, P.Eng.
Senior Engineer

Authors

Stephanie Tam, P.Eng.
Water Management Engineer

Andrew Petersen, P.Ag.
Regional Resource Specialist

Prepared and Web Published by

BRITISH COLUMBIA

Ministry of Agriculture

2014 ISSUE

LIMITATION OF LIABILITY AND USER'S RESPONSIBILITY

The primary purpose of this manual is to provide irrigation professionals and consultants with a methodology to properly design an agricultural irrigation system. This manual is also used as the reference material for the Irrigation Industry Association's agriculture sprinkler irrigation certification program.

While every effort has been made to ensure the accuracy and completeness of these materials, additional materials may be required to complete more advanced design for some systems. Advice of appropriate professionals and experts may assist in completing designs that are not adequately convered in this manual.

All information in this publication and related materials are provided entirely "as is" and no representations, warranties or conditions, either expressed or implied, are made in connection with your use of, or reliance upon, this information. This information is provided to you as the user entirely at your risk.

The British Columbia Ministry of Agriculture and the Irrigation Industry Association of British Columbia, their Directors, agents, employees, or contractors will not be liable for any claims, damages or losses of any kind whatsoever arising out of the use of or reliance upon this information.

9 MOTORS, ENGINES AND POWER

A major component of annual irrigation operation and maintenance costs is the pump and power unit. Selecting a pump and motor combination that are adequately matched and perform to the irrigation system parameters can save producers thousands of dollars over the life of the system. This chapter provides information on selecting the correct pump type and corresponding power unit.

9.1 Pump Selection

An irrigation pump is selected to match two important irrigation system parameters, the total irrigation system flow rate and the total dynamic head required. The flow rate (Q) of an irrigation system, is determined by the maximum number of sprinklers that operate at the same time. Keep in mind that the sprinklers may have different nozzle sizes and therefore different flow rates. The Total Dynamic Head (TDH) is the maximum head pressure required by the irrigation system to operate properly. It is calculated by the following formula:

Equation 9.1 Total Dynamic Head (TDH)

$$TDH = H_e + H_s + H_f + H_p$$

where

H_e = elevation head, also called the static discharge head which is the elevation from the centre of the impeller to the highest sprinkler on the system

H_s = static suction head which is the elevation from the centre of the impeller down to water level while pumping [ft]

H_f = friction head which is the total friction loss of all fittings and pipe in both the suction and discharge [ft]

H_p = pressure head which is the pressure required to operate the sprinkler system, travelling gun or pivot [ft]

Horsepower

Water horsepower which the actual energy delivered to the water by the pump can be calculated using Equation 9.2

Equation 9.2 Water Horsepower (WHP)

$$WHP = \frac{Q \times TDH}{3960}$$

where	WHP =	water horsepower required by system
	Q =	irrigation system flow rate [US gpm]
	TDH =	total dynamic head [ft]

The brake horsepower required by an irrigation pump incorporates the efficiency losses in the pump. It can be calculated from Equation 9.3.

Equation 9.3 Brake Horsepower (HP)

$$HP = \frac{Q \times TDH}{3960 \times E}$$

where	HP =	brake horsepower required by system
	Q =	irrigation system flow rate [US gpm]
	TDH =	total dynamic head [ft]
	E =	pump efficiency [% in decimal form]

Helpful Tips – Pump Selection – Best Efficiency Point

Selecting a pump that operates at its best efficiency point for the flow and pressure requirement of irrigation system will ensure that the energy costs are minimized. For the pump shown in Figure 9.1 the best efficiency point of 85% occurs at a flow rate of 950 gpm at 350 ft of head. If this pump was to operate at 400 gpm the pump efficiency drops from 85% to about 63%. In addition the pressure generated increases from 350 ft of head to 400 ft of head. Since the additional head may not be required, the extra pressure generated is an additional inefficiency of 15%.

The operating cost of this pump at 400 gpm for 2000 hours per year @ $0.0441 / kw-hr is $4220.

If a different pump is selected, operating at its best efficiency point and is matched to the desired operating characteristics of 400 gpm and 350 ft of head, the cost of operating for 2000 hours per year would be $2836.00. This is a saving of $1384 or 33%.

Example 9.1 Pump Horsepower for Wheeline system in Armstrong

Question: The wheel line system in Armstrong, example 5.1 and 8.2, is operating 3 lines at 46 psi and a total flow rate of 693 USgpm. The maximum elevation of the field is 40 feet above the pump. The mainline and fitting friction loss calculated in Examples 8.3 and 8.4 is 7.8 psi. The pump impeller is situated 10 ft above the water surface. The pump to be selected has an efficiency of 74%. What horsepower will be required?

Information:

	Value	Ref	Unit
Elevation head (H_e)	40	1	ft
Suction head (H_s)	10	2	ft
Friction loss (H_f)	7.8	3	psi
Pressure at lateral (H_p)	46	4	psi
Total flow rate (Q)	693	5	US gpm
Pump efficiency (E)	0.74	6	

Calculation:

Step 1. Convert H_f and H_p from psi to feet

H_f = **psi x 2.31 ft/psi**

= 7.8 [3] psi x 2.31 ft/psi

= 18.0 [7] ft

H_p = **psi x 2.31 ft/psi**

= 46 [4] psi x 2.31 ft/psi

= 106 [8] ft

Equation 9.1

TDH = $H_e + H_s + H_f + H_p$

= (40 [1] + 10 [2] + 18.0 [7] + 106 [8]) ft

= 174 [9] ft

Answer:

Equation 9.1

$$\text{HP} = \frac{\text{Q x TDH}}{\text{3960 x E}}$$

$$= \frac{693\ [5]\ \text{US gpm x } 174\ [9]\ \text{ft}}{3960 \text{ x } 0.74\ [6]}$$

= 41 [10] hp

Centrifugal Pump Selection

Centrifugal pumps are commonly used for irrigation systems with total dynamic heads of less than 400 ft and suction lifts less than 20 ft. The pump selected should provide the operating requirements of the irrigation system at or close to its best efficiency point.

Best Efficiency Point (BEP)

The BEP of a centrifugal pump can vary from 45% to 85% but consideration should be given to selecting pumps that have BEPs of 65% or better. Small pumps, less than 5 hp, tend to be less efficient than this. A centrifugal pump should not be operated at less than 80% of its BEP. Therefore, a pump with a BEP of 80% should not be operated at an efficiency of less than 64%.

Total Dynamic Suction Lift (TDSL)

To ensure proper operation of a centrifugal pump, the suction capability should be checked. For efficient pump operation, the calculated Total Dynamic Suction Lift (TDSL) must be less than the allowable TDSL shown on the pump performance curves. Equation 9.4 illustrates how to determine TDSL.

Equation 9.4 Total Dynamic Suction Lift (TDSL) and Velocity Head (H_v)

(a)

$$TDSL = H_e + H_l + H_v$$

where TDSL = calculated total dynamic suction lift [ft]
H_e = vertical distance from the water level to the centre line of the impeller eye [ft
H_l = friction loss in the suction system [ft]
H_v = velocity head [ft]

(b)

$$H_V = \frac{V^2}{64.4}$$

where H_v = velocity head [ft]
V = flow velocity [ft/s] at the pump inlet as this is where the maximum velocity occurs

The calculated TDSL must be checked with the TDSL capability of the pump found on pump performance curves (see Figure 9.1). The TDSL values shown on the pump performance curves are for a pump operating at sea level at a water temperature of 70°F. Table 9.1 can be used to de-rate the TDSL ability of a pump operating at higher elevations or increased water temperatures. (The de-rated values shown are a combination of changing atmospheric pressures due to altitude and vapour pressure of water due to temperature).

Table 9.1 Total Dynamic Suction Lift Correction for Altitude and Water Temperatures [ft]

Altitude [ft]	Water Temperature [°F]							
	40 – 70	100	120	130	140	150	160	170
Sea Level	0.0	1.3	3.0	4.4	6.0	8.0	10.5	13.5
2,000	2.4	3.7	5.4	6.8	8.4	10.4	12.9	15.9
4,000	4.7	6.0	7.7	9.1	10.7	12.7	15.2	18.2
6,000	6.8	8.1	9.8	11.2	12.8	14.8	17.3	20.3
8,000	8.8	10.1	11.8	13.2	14.8	16.8	19.3	22.3
10,000	10.5	11.8	13.5	14.9	16.5	18.5	21.0	24.0

If the TDSL demand of the suction line system exceeds the TDSL ability of the pump, cavitations could be expected.

Cavitation

Cavitation is a condition in which a liquid (water), converts from the liquid phase into the vapour phase when subjected to an absolute pressure that is less than the vapour pressure, and then quickly returns to the liquid phase as the pressure is increased above the vapour pressure. For pumping systems, cavitation will occur if the TDSL of the suction system exceeds the TDSL ability of the pump. The conditions for which cavitation will occur can also be calculated by using Net Positive Suction Head (NPSH).

Vapour Pressure is the absolute pressure that must be maintained on a liquid, at a specified temperature, to prevent conversion from the liquid phase to the vapour phase.

Net Positive Suction Head Required (NPSHR) is the amount of energy required to move water into the eye of the impeller without the formation of water vapour bubbles. (It is the minimum absolute pressure required above vapour pressure). It is a function of the pump speed (rpm), impeller shape, liquid properties (temperature, etc.), and the discharge rate. NPSHR will vary with different pump models. It is determined by the pump manufacturers and shown on the pump performance curves.

The NPSHR of a pump does not change with water temperature or elevation. NPSHR can be calculated by using Equation 9.5.

Equation 9.5 NPSHR

$$NPSHR = 33\ ft - TDSL\ ability\ of\ \ pump\ at\ sea\ level$$

where NPSHR = net positive suction head required [ft]
TDSL = total dynamic suction lift [ft]

Net Positive Suction Head Available (NPSHA) is the amount of energy (absolute pressure) that is available at the inlet to the pump, and can be determined by using Equation 9.6.

Equation 9.6 NPSHA

$$NPSHA = 33\ ft - correction\ \ factor - TDSL\ calculated$$

where NPSHA = net positive suction head actual [ft]
Correction factor = Correction factor (Table 9.1)

Cavitation can be detected by:

- A clattering sound like gravel going through the pump.
- If the pump is not mounted properly, shaking of the unit.
- Pump performance may decrease significantly. A pump that is cavitating will not be able to generate the discharge pressure corresponding to the pump flow rate on the pump curves.

Cavitation can be caused by:

- A clogged strainer which is increasing the friction loss in the suction system.
- Suction pipe that is too long or too small.
- Suction lifts that may be too excessive.
- Excessive flow rates.

(Note that all of the above reduce the NPSHA to the pump impeller.)

Example 9.2 Centrifugal Pump Selection

Question:

The wheel line system in Armstrong requires a flow rate of 693 gpm at a total dynamic head of 174 ft. The pump will be operating at an elevation of 2,000 ft. The elevation from the water surface to the centre of the impeller is 10 ft. The suction line length is 50 ft with a suction inlet diameter of 8 inches. Is the pump model depicted in Figure 9.2 suitable for this installation?

Information:

Total flow rate (Q)	*693*	**1**	US gpm
Total dynamic head (TDH) (Example 9.1 Box 9)	*174*	**2**	ft
Elevation head (H_e)	*10*	**3**	ft
Suction line length	*50*	**4**	ft
Pump efficiency (E) (Figure 9.2)	*74*	**5**	%
NPSHR (Figure 9.2)	*17*	**6**	ft

Calculation:

When the pump is ordered from a supplier it has a full diameter impeller. It would be trimmed down to fit the design conditions or incremental horsepower size. Most irrigation electric motor pumps operate at a fixed speed. In this example the electric motor runs at 3,600 revolutions per minute (rpm). For best design practice the designer would look at the run out potential of the pump, i.e., if the motor will overload in case of a break in the line occurred and the flow rate increased dramatically. To prevent the motor from being overloaded, the impeller should be trimmed to full motor load. The pump manufacturer would supply this diameter upon request. The horsepower selected for this example would be 40 and impeller trimmed to 8.0 inches.

The suction line consists of 50 ft of 8" aluminium, one 45 degree elbow, an eccentric reducer and a strainer. The equivalent length of pipe must be calculated.

Step 1. From Table B.9, use the steel chart to calculate the equivalent length in all the fittings and pipe for 8” aluminum:

Size [in] [in]	Fitting Type	Equivalent L [ft]	x	Quantity	=	Total Equivalent L [ft]
8	*Elbow 45°*	*10*	x	*1*	=	*10*
8	*Eccentric Red.*	*21*	x	*1*	=	*21*
8	*Strainer*	*30*	x	*1*	=	*30*
8	*Pipe*	*1*	x	*50*	=	*50*

Total = *111* **7** ft

Step 2. Based on the flow rate of 693 gpm, the friction loss of 8” aluminum is:

Friction loss (H_l) (from Table B.1) *0.42* **8** psi/100 ft

Determine suction line friction loss (H_l)

$$H_l = \frac{0.42 \ [8] \text{ psi}}{100 \text{ ft}} \times 111 \ [7] \text{ ft} \times 2.31 \text{ ft/psi}$$

$= 1.1$ [9] ft

Step 3. Determine velocity (v)

Suction inlet radius 4 [10] in

Equation

$A = \Pi r^2$

$$= \frac{3.14 \times (4 \ [10] \text{ in})^2 \times 1 \text{ ft}^2}{144 \text{ in}^2}$$

$= 0.35$ [11] ft^2

Equation

$$v = \frac{Q}{A}$$

$$= \frac{693 \ [1] \text{ US gpm}}{0.35 \ [11] \text{ ft}^2} \times \frac{1 \text{ ft}^3}{7.48 \text{ gal}} \times \frac{1 \text{ min}}{60 \text{ sec}}$$

$= 4.4$ [12] ft/sec

Step 4. Determine velocity head (H_v)

Equation 9.4(b)

$$H_V = \frac{v^2}{64.4}$$

$$= \frac{(4.4 \ [12] \text{ ft/sec})^2}{64.4}$$

$= 0.30$ [13] ft

Equation 9.1

TDSL = $H_e + H_l + H_v$

$= (10$ [3] $+ 1.1$ [9] $+ 0.30$ [13] $)$ ft

$= 11.4$ [14] ft

Answer:

Correction factor (Table 9.1) 2.4 [15]

Equation 9.6

NPSHA = 33 ft – correction factor – TDSL calculated

$= 33$ ft – 2.4 [15] – 11.4 [14] ft

$= 19.2$ [16] ft

Since the NPSHA (19.2 ft) exceeds the NPSHR (17 ft) on the pump curve, the pump from Figure 9.2 should operate satisfactorily at the operating conditions required by the irrigation system.

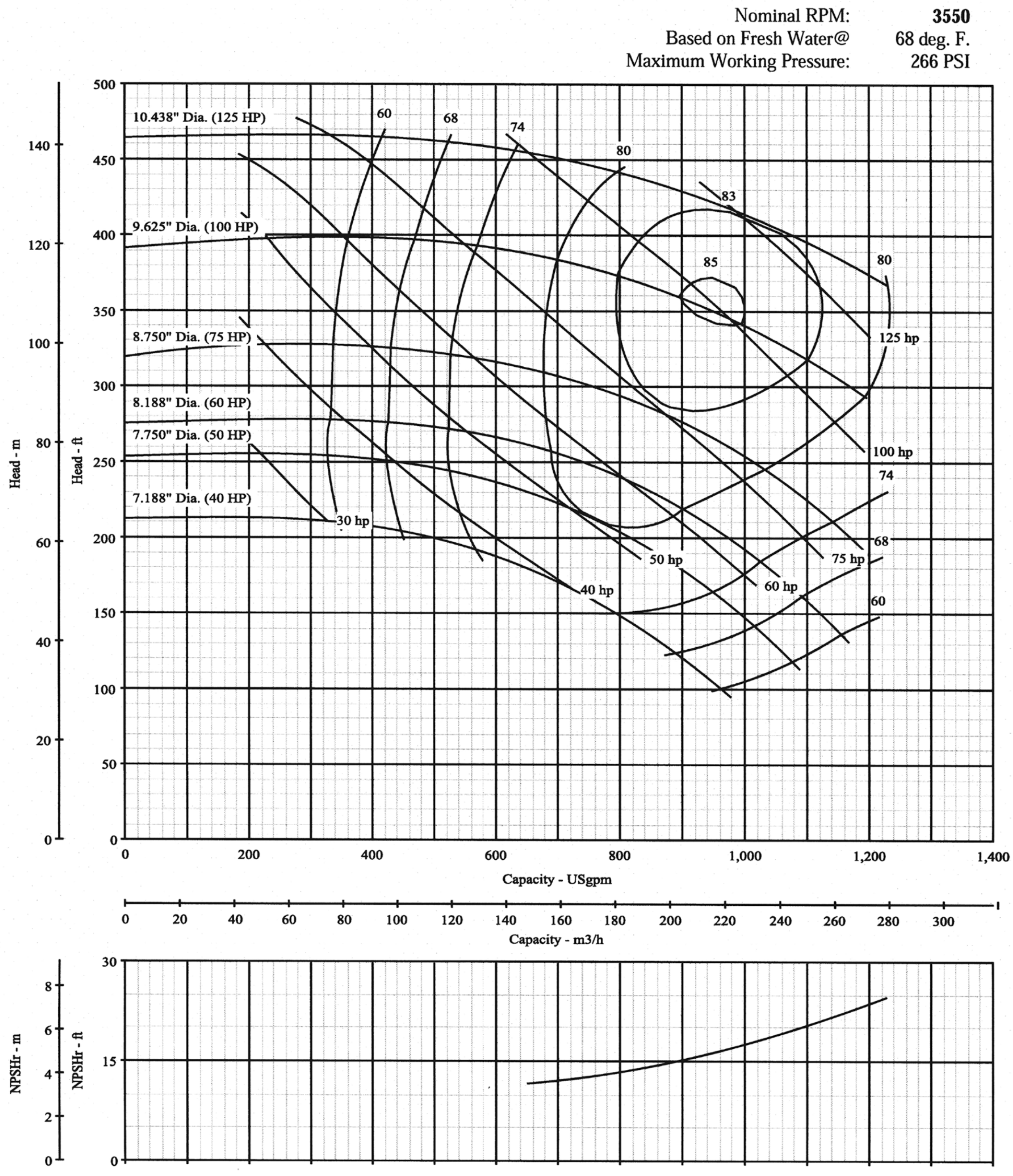

Figure 9.1 Centrifugal Pump Curve – Berkeley

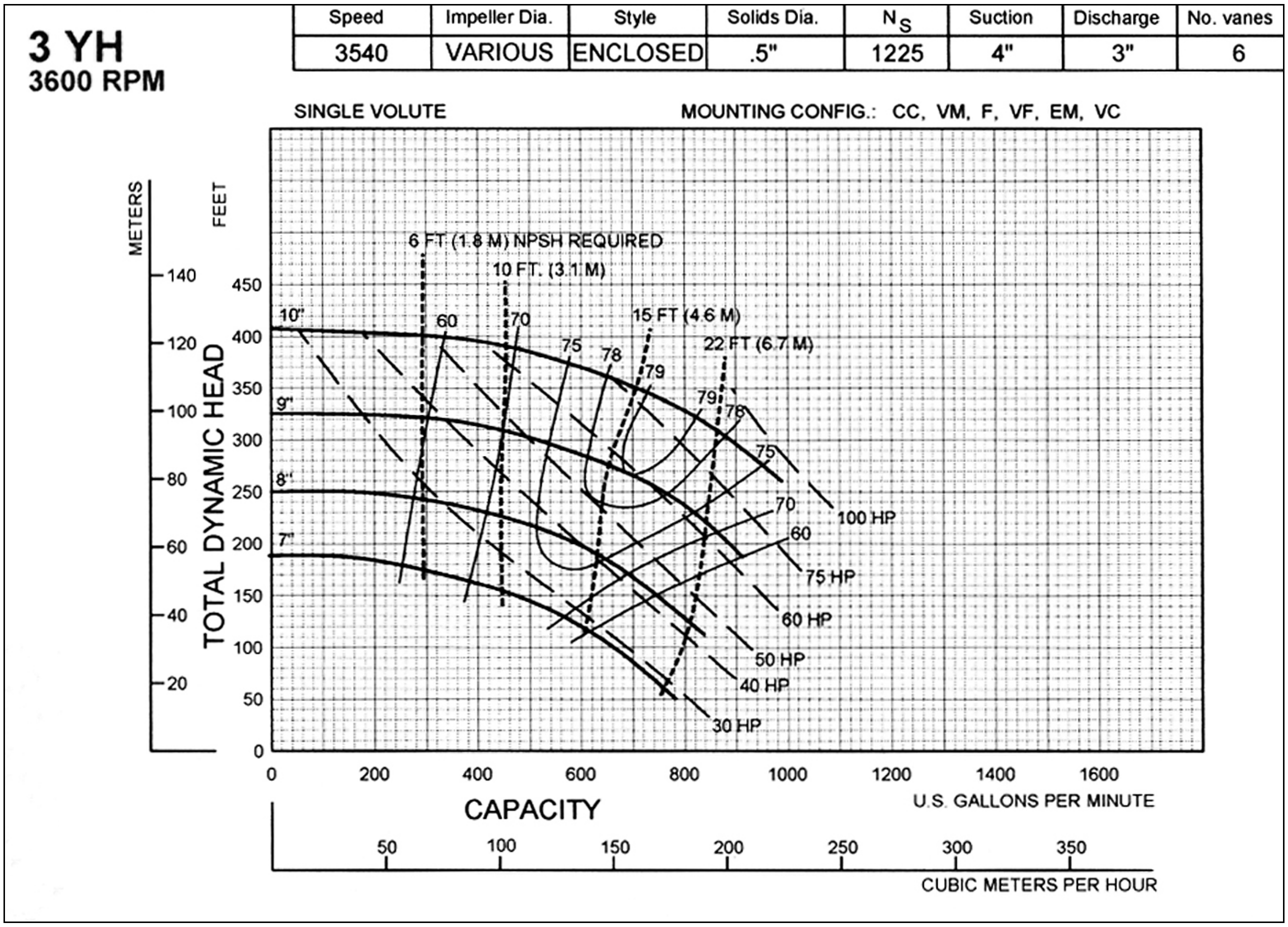

Figure 9.2 Centrifugal Pump Curve – Cornell

Centrifugal Pump Installation

A centrifugal pump unit should be located as close to the water surface as possible to minimize vertical suction lifts and to allow for short, direct suction piping with a minimum number of fittings. The following points should be considered when installing a centrifugal pump:

- The suction and discharge pipes should be naturally aligned with the pump and independently supported to prevent strain on the pump case.
- A totally enclosed fan cooled motor should be used in severe weather situations where other shelters are not practical.
- The pump unit must be properly anchored to prevent movement during operation.
- A majority of suction pumps are supplied with a packing gland. Water must drip from the packing for lubrication and

cooling. Typical recommendations are one drip per second. The motor feet should be elevated 3 to 4 inches. Adequate drainage should be provided to prevent packing water from accumulating under the motor air intake openings.

- The friction loss in the suction system must be controlled within acceptable limits. The minimum suction pipe size to be used can be determined by a comparison of the allowable TDSL by the pump (from the pump curves) and the calculated TDSL of the suction system.

- The flow velocity in the suction pipe should be less than 5 ft/sec.

- The suction pipe size should be at least one or two sizes larger than the suction nozzle on the pump.

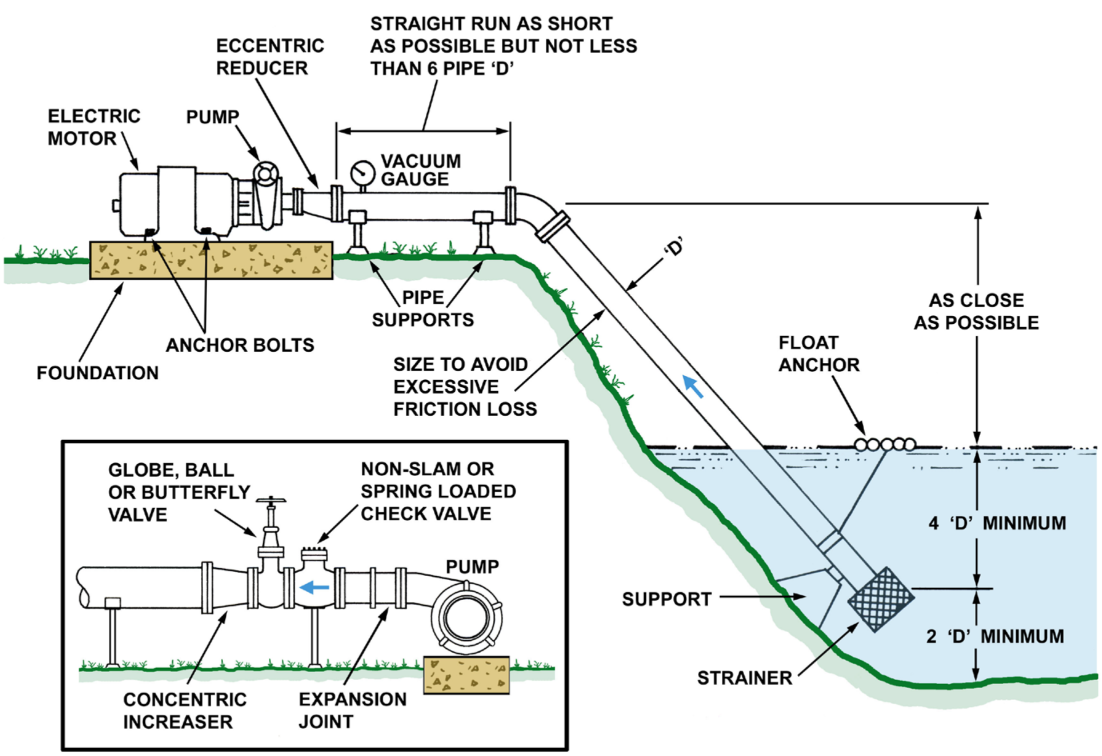

Figure 9.3 Suction Pipe and Discharge Pipe Installation

The following points should be considered to prevent air from entering or becoming entrapped in the suction system:

- An eccentric reducer must be used as a transition between the suction line and the pump inlet. The eccentric reducer should be attached directly to the pump inlet with the flat side on top.
- The entire suction piping system should incline slightly upward toward the pump. A suggested minimum slope is ¼ inch per foot.
- All flanged joints should be fitted with a gasket and be airtight.
- The suction pipe inlet should be submerged at least 4 pipe diameters and be at least two pipe diameter off the bottom. In situations where there is not enough submergence an anti-vortex plate should be used to prevent air from being drawn into the suction system.
- A control valve should never be installed on the suction piping if the pump is operating with a suction lift. (A valve on the discharge piping should be used for throttling the pump).
- A straight piece of pipe at least 6 pipe diameters long should be used between the pump suction nozzle and the elbow. An elbow attached directly at the pump suction causes unequal thrust due to the liquid filling one side of the suction chamber and impeller eye more than the other.
- A strainer should always be installed on the suction system of a centrifugal pump. The strainer must be capable of extracting objects that are too large to pass through the pump or irrigation system. The strainer must have an open area at least three times the area of the suction pipe.
- When drawing water from a fish bearing stream or lake the maximum flow velocity through the screen must be restricted to 0.1 ft/sec. Also the maximum screen openings should not exceed 1/10 (0.1) of an inch. Keep in mind that most intake screens have only about 50 to 60 percent open area. See Table 9.2.

Table 9.2 Intake Screen Area			
Flow Rate [US gpm]	**Open Area [ft^2]**		
	Standard Market Grade Wire Mesh	**60%**	**50%**
50	1.1	1.9	2.2
100	2.2	3.7	4.5
150	3.3	5.6	6.7
200	4.5	7.4	8.9
250	5.6	9.3	11.1
300	6.7	11.1	13.4
350	7.8	13.0	15.6
400	8.9	14.9	17.8

The following points should be considered for the discharge piping:

- The maximum flow velocity in the discharge line should not exceed 5 ft/sec. This will help limit any pressure surges that may occur due to sudden flow stoppages (i.e., pump shut down, valve closure, etc.).
- The discharge valve should be either a ball, a globe or a butterfly valve if it is to be used as a flow or pressure throttling device. A gate valve can only be used as a shut-off valve (i.e., either fully open or closed). Note: caution should be used in operating a ball or butterfly valve to prevent serious pressure surges from occurring.
- A non-slam or spring-loaded check valve should be used to prevent back flow through the pump during shut down. A spring loaded check valve is desired as it will close before a reverse velocity occurs.
- Tapered reducers or increasers should be used when changing from one pipe size to another. A concentric increaser is sufficient for the discharge piping system.

Submersible Pumps

Submersible pumps are used when pumping from drilled wells with a static water level below 15 ft. The pump section is on the top and the motor is on the bottom. This ensures that water is flowing past the motor for cooling purposes. Submersibles are available up to 10" in diameter and motor sizes up to 100 hp. Submersibles exceeding 60 hp are not often used for irrigation purposes. Submersible pumps come in two types, turbine bowl assembly and flat bowl assembly. The turbine bowl assembly will be of brass or cast iron construction while the flat bowl will be of plastic. The turbine bowl assembly will generally involve less stages and offer longer life. The submersible pump will most often be selected at 3,600 rpm to reduce cost and motor size allowing the pump to fit into a smaller diameter well. Consequently, care should be taken to ensure that this pump is pumping silt free water.

Line Shaft Turbine Pumps

Vertical (line shaft) turbines are often used instead of centrifugal pumps for total dynamic heads exceeding 400 feet. Also for canal or river installations where fluctuating suction lifts are a problem. Line shaft turbines have the motor installed at the top of the well, and the driving impellers located at the bottom. The motors are often 100's of horsepower. They are capable of pumping much higher volumes and total dynamic heads than submersibles.

Line shaft turbines fall into two general classifications: semi-open impeller and enclosed impeller. Open impeller bowls can be adjusted to regulate the total head and capacity or to compensate for wear. Enclosed impeller pumps have less down thrust and are better suited to variable head conditions as they are less sensitive to shaft elongation.

For optimum life line shaft turbines should operate at 1,800 rpm. They can also be selected at 1200 rpm for low lift situations and where silt is a problem. Wells should be at least one nominal size larger than the pump. Table 9.3 provides information on recommended well diameters for different pump types and flow rates.

Common Application Comparison:

Submersible Pumps

- deep wells, small volume
- small well casing
- lower priced with 3,600 rpm
- need clean water

Line Shaft Turbine Pumps

- deep and shallow wells
- need large casing
- higher priced with 1,800 rpm
- use slower speed in dirty water

NPSHR is often high in these pumps and must be considered when submergence is minimal.

Recommendations on minimum wall thicknesses and maximum depth of use for various types of well casings can be found in "Guidelines for Minimum Standards in Water Well Construction", Province of British Columbia, available from Groundwater Section, Ministry of Environment.

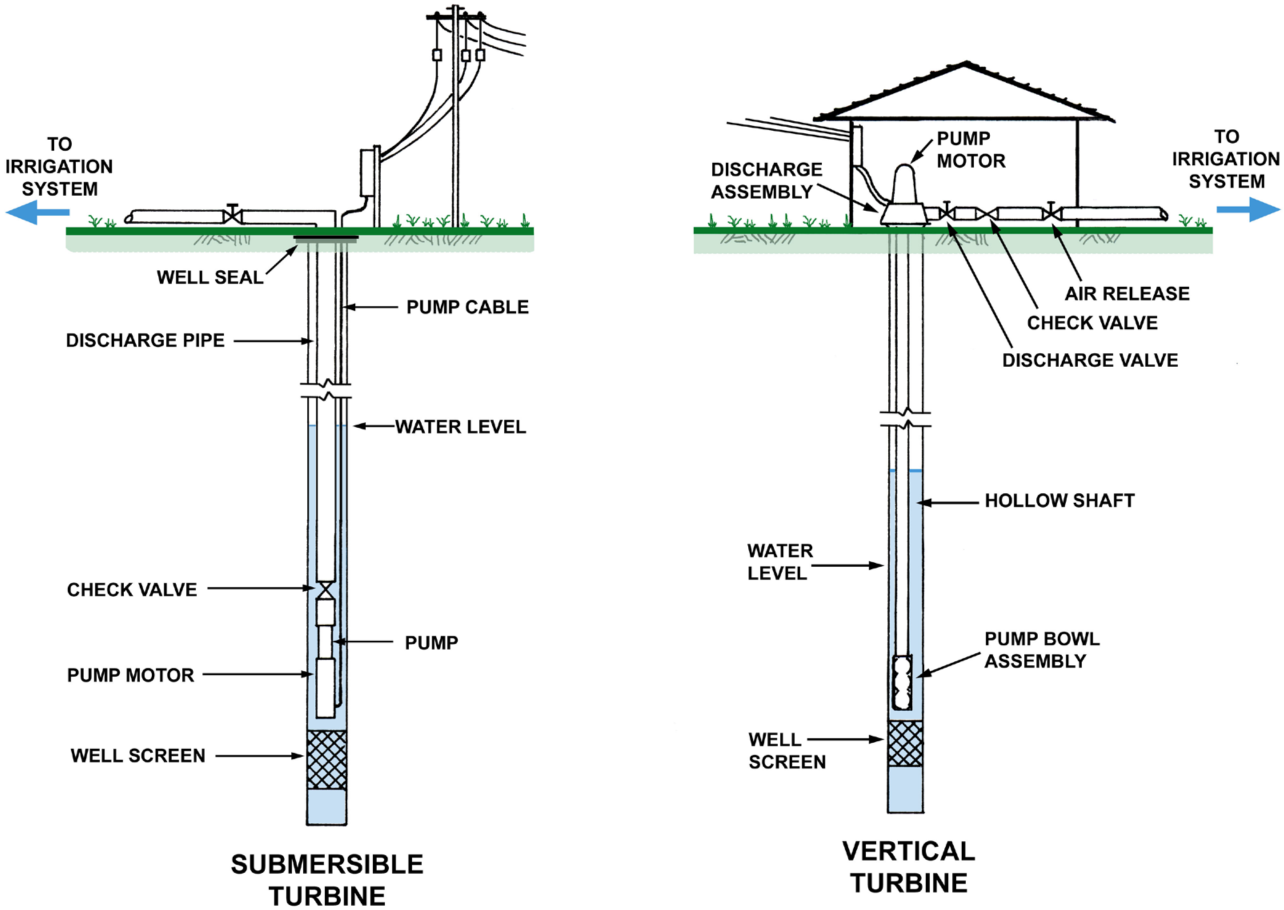

Figure 9.4 Turbine Installation

Table 9.3 Recommended Well Diameters

Anticipated Well Yield [US gpm]	Nominal Size of Pump Bowls [in]	Submersible Well Casing		Line Shaft Turbine 1,800 rpm Recommended Casing Size [in]
		Optimum	Smallest	
< 100	4	6 I.D.	6 I.D.	6 I.D.
75 – 175	5	8 I.D.	8 I.D.	8 I.D.
150 – 400	6	10 I.D.	8 I.D.	10 I.D.
350 – 600	8	12 I.D.	10 I.D.	12 I.D.
600 – 900	10	14 O.D.	12 O.D.	14 O.D.
900 – 1,300	12	16 O.D.	14 O.D.	16 O.D.
1,300 – 1,800	14	20 O.D.	16 O.D.	20 O.D.
1,800 – 3,000	16	24 O.D.	20 O.D.	24 O.D.

9.2 Motor Selection

Electric motors and internal combustion engines are the most common sources of power units for irrigation pumps. Internal combustion engines are generally fuelled by natural gas, propane, gasoline or diesel.

Electric Motors

If sufficient electric power is available close by, most irrigators select an electric pump. The advantages of electricity are:

Low Initial Cost (if power is available)

Electric motors are less expensive than internal combustion engines for identically rated units.

High Efficiency

Depending on motor size, electric motors have efficiencies in the 85% to 90% range. Energy efficient electric motors are also available with efficiencies in excess of 90%. Diesel or natural gas engines may only be 25% to 30% efficient.

Minimum Maintenance

Electric motors have only one moving part, a rotor, supported by two bearings, and when properly matched to the load will provide years of trouble free service.

Longer Life

Electric motors can be expected to operate for 20 to 30 years.

Range of Sizes

Electric motors are available in a much wider range of sizes than internal combustion engine drives.

Automation

Automatic controls can be purchased to operate electric motors based on speed, temperature, time and soil moisture levels. Since many of these controls use electricity, it is easy to start and stop electric motors by these devices. Electric motors are clean, quiet, designed for continuous operation, have little vibration and can withstand temporary overloads.

Disadvantages of electric motors include:

Lack of Portability

Since electric power services are fixed, the electric motors are usually permanently placed in position.

Constant Speed

The output speed of an electric motor is fixed by the design of the machine and the frequency of the power supply. Therefore, if the irrigation system water requirements are reduced, the water flow must be restricted by throttling the pump discharge. Variable frequency controllers can be purchased to regulate motor speed, but these are expensive.

Internal Combustion Engines

Internal combustion engines are used in areas where sufficient electric power is not available, if the pumping unit must be moved to several locations or if the irrigation season is very short. The type of engine used is determined by the fuel available. Natural gas is usually not available in rural B.C., therefore, diesel is the most common type of engine used for irrigation.

Based on power costs only, a diesel unit is more economical than an electric drive for operating times less than 450 hours per irrigation season. (This is due to the minimum billing charged on electric irrigation accounts).

Internal combustion engines and pump packages should be selected so that speeds are compatible and maximum engine life and performance are achieved. Consideration must be given to altitude and ambient air temperatures when selecting internal combustion engines. Engines are usually rated by net continuous crankshaft horsepower output, at sea level with an air temperature of 20°C and relative humidity at 65%. For different conditions the engine must be de-rated as follows:

- a decrease in output of 3% per 1000 ft elevation above sea level
- a decrease of 1% for an air temperature rise of every 2.8°C above 20°C
- a decrease of 3% per 10% relative humidity increase above 65%

Safety features that should be installed on internal combustion engines include:

- low system pressure shutoff
- low oil pressure shutoff
- high engine water temperature shutoff

Electrical Power Supply

The following transformer arrangements are the most common provided by the power utility:

Secondary service

Service is provided directly from a transformer on the hydro system (only short distances can be accommodated).

Primary service

A primary voltage power line is required to connect the hydro system to the pumping station. The transformers are installed close to the pumping station (for longer distances from the public utility).

Single phase

Service is provided from one primary voltage line through one transformer.

Three phase

Service is provided from three primary voltage lines through three transformers.

Voltages Available

The standard primary distribution voltages in B.C. are:

- Single phase: 7,200 volt or 14,400 volt (phase to neutral)
- Three phase: 12,000 volt or 25,000 volt (phase to phase)

The service voltages available are:

- Single phase: 208 volt or 240 volt
- Three phase: 208 volt, and 600 volt

In the past 480 volt services were available, but are no longer provided as a standard voltage by hydro utilities in B.C. Check with the power utility before purchasing 480 volt equipment or changing loads on existing 480 volt services.

Power Cost

Table 9.4 indicates the water horsepower hours produced per unit of fuel for efficiently installed pumping units. Water horsepower-hour is equivalent to developing one water horsepower for one hour. An example comparison of fuel costs to produce 24 water horsepower hours (one day) using the water horsepower values and typical per unit fuel costs is also shown in the table.

Table 9.4 Water Horsepower per Unit of Fuel and Fuel Cost Comparison						
Fuel	**Water Horsepower Hour per Unit of Fuel**		**Fuel to Produce 24 Water Horsepower Hours (1 day)**		**Fuel Cost**	
					Cost per Unit of Fuel [$]	**Cost per Day per Horsepower [$]**
Gasoline	2.14	Litre	11.21	Litre	1.2	13.45
Diesel	2.9	Litre	8.26	Litre	1.2	9.91
Natural Gas	70.4	Giga Joule (GJ)	0.3408	GJ	10	3.41
Electricity	0.885	Kilowatt-Hour (KWh)	27.1	KWh	0.0447	1.21

The information in Table 9.4 indicates that if electric power is available, at current energy rates (2008), electricity is the cheapest energy available. (Actual fuel consumption will vary depending on motor selection, efficiency, load, elevation, etc.).

Power Availability

The following is an excerpt from B.C. Hydro and Canadian Electric Association. Table 9.5 provides a summary of the information.

Single Phase Motors

The standard electrical distribution system in rural areas is single phase; therefore, many irrigation systems operate off a 240 volt single phase service. Standard single phase motors range in size up to 10 hp. Larger single phase motors are available; however, the size of single phase motor permitted by Hydro will depend on the effect the motor will have on service to other customers. The connection of motors over 10 hp in size on single phase service requires Hydro approval. The available voltage and service should be confirmed by Hydro before installation of wiring or motors.

Three Phase Motors

Where three phase service is provided by the power utility, the customer usually is not restricted by the amount of horsepower than can be connected. Three phase motors offer several advantages over single phase motors:

- they are less expensive and more readily available than single phase motors;
- they are lighter, smaller and have a greater range of available sizes;
- they are simpler in construction and consequently more reliable and require less maintenance.

Parallel or Series Connected Pumps

One method of increasing the pump horsepower system that can be operated off single phase is the connection of two or more pumps in parallel or series. Two 10 hp pumps, if connected in parallel, will provide the same water volume as a 20 hp system. Two 10 hp pumps connected in series will provide the water volume of one pump and the combined pressure of two pumps.

Soft Start Single Phase Motors

Larger single phase motors are available in "soft" or "soft soft start". These motors offer a lower starting current than a standard motor of the same size. The starting current will vary with the manufacturer and between a "soft" (one starting stage) and "soft soft" (two starting stages) unit. The lower starting current allows the connection of larger motors on a single phase line with less disruption to other users.

While soft start motors develop less starting torque than standard motors, this is not a problem with horizontal centrifugal pumps. Starting torque can be a problem however, if the motor is used connected to a line shaft turbine through a right angle drive. For this application, a "soft start" (one starting stage) should be used, or consult the manufacturer. Soft start motors are available up to 100 hp but are commonly used in sizes ranging from 15 - 50 hp.

Where three phase power is not readily available, the soft start is a good alternative, especially for single pump installations, as the unit cost includes the motor starter.

Phase Converters

Phase converters can be installed on single phase service to convert the single phase to three phase and allow the connection of three phase motors. The size of phase converter and three phase motor permitted to be connected to single phase service will depend on the capacity of and existing load on the single phase distribution serving the area.

Phase converters range in size up to 100 horsepower.

A phase converter does not allow the motor to operate as efficiently as in a solid three phase system. Various types and models of phase converters are available. Static phase converters have no moving parts other than switching relays. There are three main types of static phase converters; the phase shifter, the capacitor and regrouped double Wye and the autotransformer-capacitor converter. A rotary phase converter consists of a rotating unit, similar to a motor, and an enclosure which contains capacitors.

Capacitor Phase Shifter

The capacitor phase shifter is the oldest and simplest version of the phase converter. The 90° phase shifted voltage from the capacitor is applied to the third terminal of the electrical motor. At no load, the current in terminal 3 is high and at full load the currents are excessive in terminals 1 and 2. Consequently, the motors utilized with the phase shifter are limited to 75% of the converter nameplate rating.

The capacitor phase shifter only works with Wye (star) connected electric motors and is best suited for older, larger motors with poor power factor. They are limited in their application for electric driven irrigation systems.

Capacitor Phase Converter

The capacitor phase converter is typically available in sizes up to 60 hp but can be manufactured in sizes up to 100 hp in certain cases. It can only be used with a 12 lead star (or Wye) connected motor. Three phase motors are typically wound in a 9 lead star but the windings can easily be regrouped for connection to the converter. The three phase electric motor is operated as a single phase capacitor start, capacitor run motor with the new connection.

The currents drawn by a three phase motor supplied by a capacitor converter will appear to be unbalanced because of the regrouped windings. For example, a 230 volt, 50 hp motor would draw 176.0, 125.0, and 62.5 amps respectively on terminals T1, T2, and T3 at full load. The rated full load three phase current for the motor is 130 amps. However, the currents are actually "in balance" for the regrouped winding motor.

Efficiency and output are lower than the normal three phase motor because the windings, which were designed for 120° phase displacement, are operated at close to 90° phase displacement. For older, larger, "U" frame motors with plenty of iron and copper, the capacitor converter can produce close to full load output. Modern electric motors are a "T" frame design and must be de-rated to 85% of nameplate for use with the capacitor converter. Consequently, the converter and motor should be oversized (approximately 15%), to ensure satisfactory performance for a given load. The service factor of the electric motor should not be used for over sizing the motor (i.e., a motor with a 1.15 service factor is not 15% larger). The capacitor phase conversion system requires 1 kVA of transformer capacity for every horsepower of motor capacity.

Selection of the overload relays is important with the capacitor phase converter. When using a totally enclosed 55°C rise motor the heaters are sized according to the single phase amperage (1.41 x rated 3 phase amps). With a 40°C rise motor the heaters should be chosen one size smaller.

For the wheel roll or hand move sprinkler irrigation application, which represent a continuous and relatively steady load, the capacitor conversion system represents a strong alternative to the high cost of three phase power lines.

Autotransformer Phase Converter

The autotransformer phase converter can be used on any three phase electric motor regardless of connection. The autotransformer is used to balance the three phase currents at a given load (usually full load) and consequently the converter can extract the full motor nameplate capacity (including the service factor for certain motors). At loads other than the balanced load, the currents become unbalanced. Also, if not properly balanced, high currents can burn out the electric motor at full load. The converter is available in sizes up to 100 hp. The autotransformer phase converter is about five times the weight and more expensive than the previous models discussed.

The autotransformer capacitor phase converter is a good choice for steady loads such as wheel roll or hand move sprinkler irrigation systems, particularly if the farmer has already purchased a pump and drive unit for the system. Chances are the electric motor does not have the proper connection for use with the capacitor phase conversion system and has probably been sized for full load output. For those systems with submersible pumps which have high service factors, the autotransformer converter is a very good choice.

Rotary Phase Converter

The rotary phase converter can be purchased to handle a number of three phase motors at once or can be used to operate a single electric motor. The rotary converter allows the farmer to establish a three phase service next to the single phase service and distribute to each of the three phase loads. By supplying 3 lines with close to 120° phase displacement, this converter will allow the three phase electric motors to run up to full load, providing they are not overloaded.

The rotary converter can handle individual motor loads up to 50 hp and total motor loads of 150 hp. There are different models of the rotary converter available depending on the starting and running requirements of the load. The starting torque of the larger three phase motor operated on the rotary converter will be about 1/2 that from a normal three phase line. The starting torque of the smaller motors will be more than adequate. However, small motors operated alone on the larger rotary converters will experience nbalanced currents and nuisance tripping.

The rotary converter is the most versatile of the phase converters available and can be purchased to fit most electric drive applications including irrigation. For center pivot irrigation systems the rotary converter with multi-motor capability is probably the best choice as the pivot has numerous electric motors and a varying electric load. The single motor rotary converter is also a good choice for other irrigation systems and is competitively priced with the autotransformer model.

Table 9.5 Summary of Phase Converter Systems for Irrigation					
Type	**Example**	**Line Inrush**	**Loading Ability**	**Available Sizes (up to) [hp]**	**Application**
Phase Shifter	–	5 x	75%	–	Not recommended
Capacitor	H.A.S.	4 x	85%	60	Single motor systems Star (Wye) connected motors only
Auto Transformer	Add-A-Phase	3 x	100+%	100	Single motor
	Duo-Add-A-Phase	3 x	100%	100	Multi-motor
	Phasor	3.5 x	66%	40	Single-motor
Rotary				**Largest Motor/Total Motor Load**	
	Roto-Phase	5 x	100%	50/50	Single and multi-motor models available
	Roto-verter	5 x	100%	75/150	
	Phase master	–	100%	100/225	–
	Rota Dyna	–	100%	50/150	–
Information based on available manufacturer's literature. Other manufacturers and models might also be available (From B.C. Hydro).					

Adjustable Speed Drives

Adjustable speed drives are electronic units that change the revolution per minute of the motor. The most common type used are Variable Frequency Drives (VFD). The VFD controls the rotational speed of an alternating current motor. It controls and changes the frequency of the electric power supply coming into the motor. The units can be purchased for both single phase and three phase systems.

The selection of any "single phase", "soft start", or "phase converting" system should include consideration of the final connected cost. These costs vary considerably between the different systems and should include entrance switches, motor starters, and installed wiring.

(BLANK)