Appendix B
Pump Selection Method

B-1. General

a. Purpose. This appendix provides a method to determine the size of a pump to meet certain pumping requirements. It also provides dimensions for the sump and station layout once the pump is selected. Certain information must be available before the pump selection can be started. This information includes the pumping requirements as determined from hydrology data, number of pumping units, and discharge/station arrangement as determined by EM 1110-2-3101.

b. Procedure. This appendix is divided into two major sections, selection of vertical wet pit pumps and selection of vertical submersible propeller pumps (Plates 23-25). Sample calculations are used to aid in understanding the selection procedures. Chart B-1 indicates the operating range of the various type pumps used in pumping stations. This chart indicates which pumps should be investigated during the alternative study phase.

c. Selection process.

(1) Vertical wet pit pumps. The selection process uses the model and affinity laws to obtain the performance of a prototype pump from the various supplied model pump performance data. Model performance data can be obtained from pump manufacturers, existing pumping stations, or from other Districts. The following general steps are used in the selection process:

(a) Determine pump operating conditions using the furnished hydrology and station/discharge arrangement.

(b) Determine prototype pump performance from model performance.

(2) Submersible pumps. The selection process makes use of typical catalog curves of head-capacity and Net Positive Suction Head Required (NPSHR). The

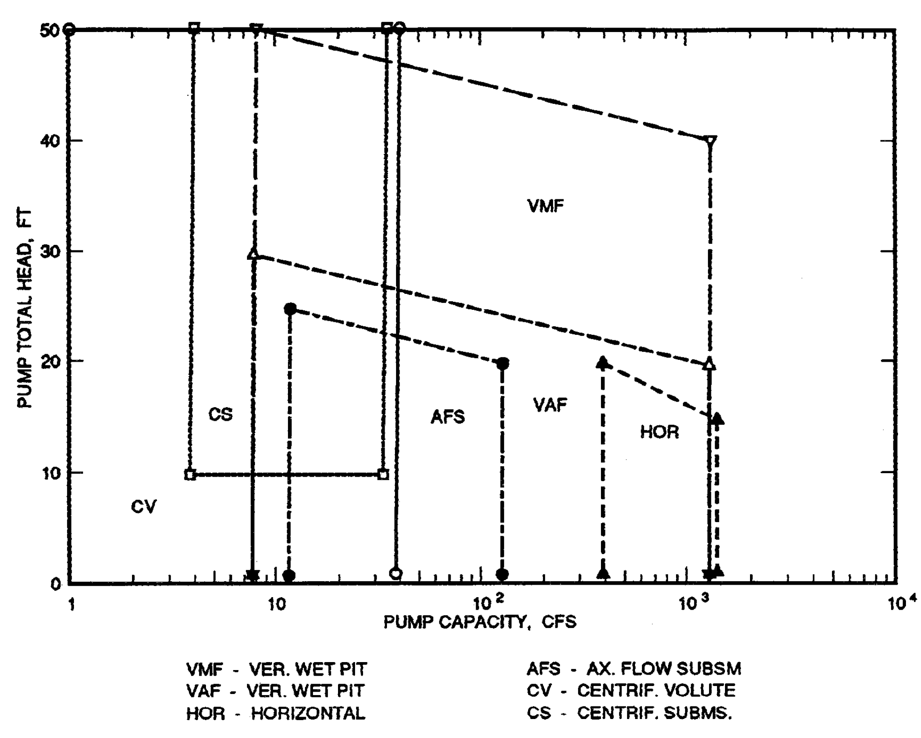


Chart B-1. Operating range of typical pumps

various curves allow direct selection of pumps after the system design conditions are known.

d. Information sources. The following is a list of information needed to perform the selection process and where it may be found:

Number of Pumps	EM 1110-2-3102
Pump Discharge Configuration	EM 1110-2-3102
Hydrology Data	Project Hydrology Report

e. Appendix results. The application of the methods illustrated in this appendix will allow the user to determine the following pump and station parameters.

(1) Maximum design head.

(2) Design heads at rated pumping station capacity.

(3) Capacity requirements other than those required by the hydrology requirements, such as capacity required for siphon priming.

(4) Type of pump.

(5) Estimated pump physical size.

(6) Power required at the design points.

(7) Pump speed.

(8) Station Net Positive Suction Head Available (NPSHA) and pump NPSHR.

(9) Sump dimensions.

B-2. Vertical Wet Pit Pump Selection Sample Problem

a. Design data and requirements.

(1) Pump conditions. The starting point for all pump selection is the hydrology requirements for the station site. The following is assumed given conditions for each pump:

Required from hydrology report:

Q_H = Flow rate at maximum differential head (design flood)

= 29,000 gpm @ river elevation (el) 339.0 and sump el 317.0

Q_L = Flow rate at minimum differential head (low head)

= 34,000 gpm @ river el 314.0 and sump el 314.0

(2) Station arrangement. Station general arrangement and discharge system are determined as presented in EM 1110-2-3102. For this example, a discharge over the protection with siphon assist was assumed (Figure B-1). A static head diagram (Figure B-2) should now be constructed. The top of the discharge pipe is obtained by sizing the pipe diameter based on an approximate maximum velocity in the pipe of 12 feet per second (fps) (using the greatest Q requirement) and adding the diameter to the invert elevation. The invert elevation is usually set equal to the top of the protection on either side of the station so that backflow will not occur with any river level to the top of the protection.

(3) Size discharge pipe.

$$\text{Velocity } (V_{pipe}) = Q_{max} / \text{Pipe Area}$$

$$Q_{max} = 34{,}000 \text{ gpm} = 75 \text{ cfs}$$

$$\text{Pipe Area} = \{[(\text{Pipe Dia.})^2] / 4\} \times 3.14$$

$$V_{pipe} = 12 \text{ fps}$$

$$\text{Pipe Area} = Q_{max} / V_{pipe}$$

$$\text{Pipe Diam.} = [(Q_{max} \times 4) / (V_{pipe} \times 3.14)]^{1/2}$$

$$= 2.83 \text{ feet or } 34 \text{ inches}$$

Use standard sized pipe, the next larger standard size pipe = 36 inches nominal (35.25 inches inside diameter (ID))

For this first calculation, use the following wall thickness:

1/4 inch, 12- to 20-inch diameter of pipe
3/8 inch, 24- to 42- inch diameter of pipe
1/2 inch, 48 inch and over *

* (larger pipe sizes may require thickness greater than 1/2 inch for support considerations)

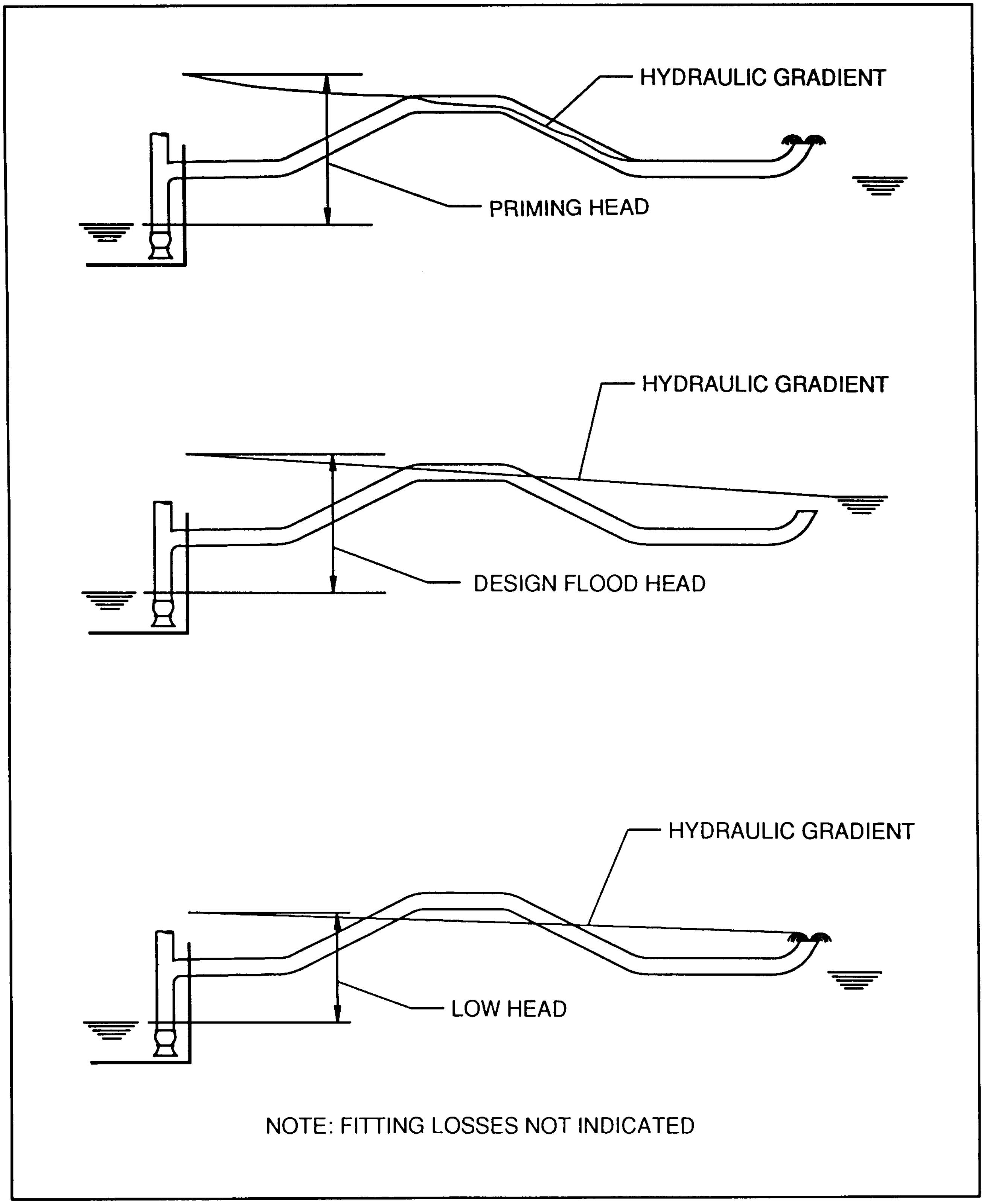


Figure B-1. Discharge pipe system

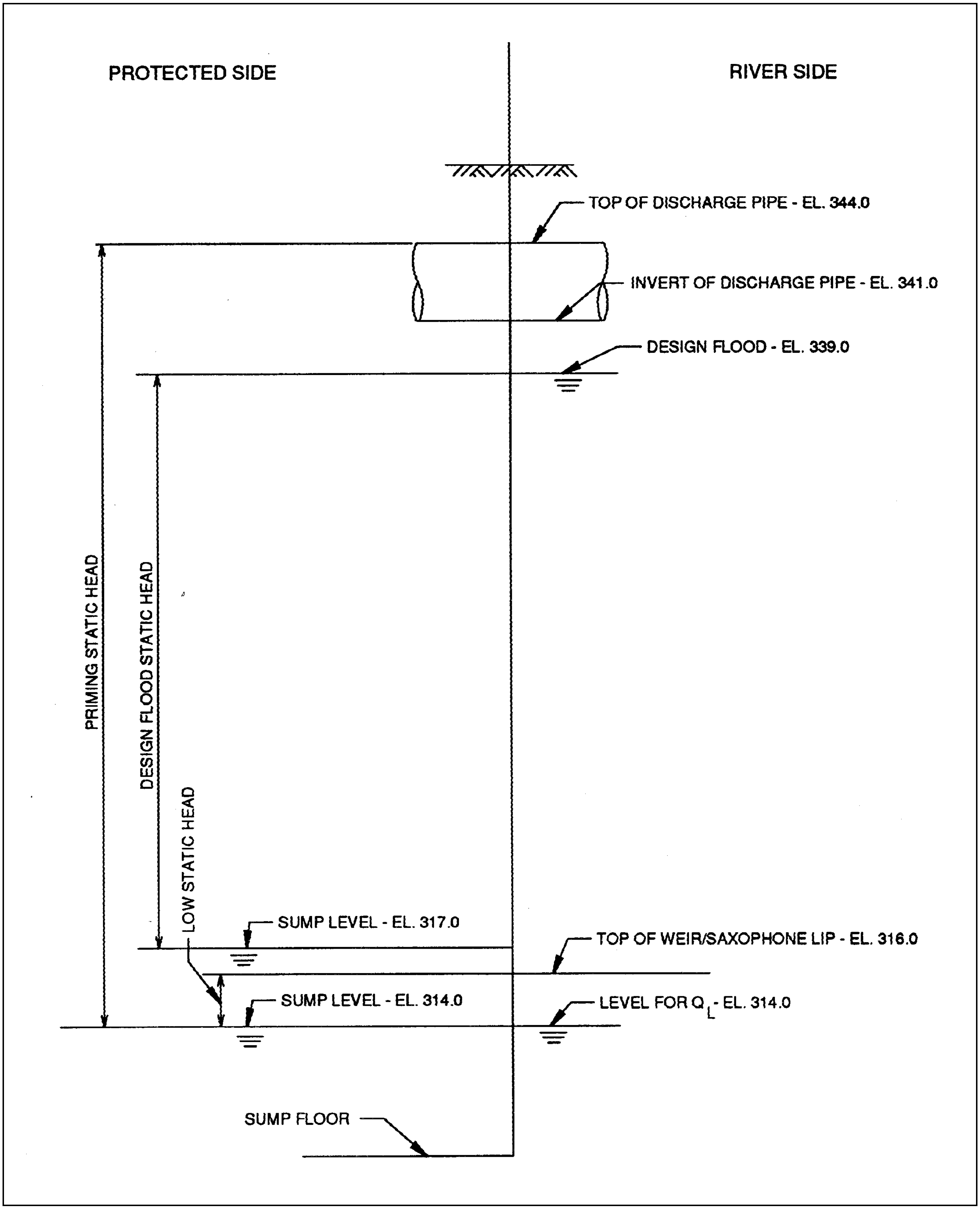


Figure B-2. Construct the static head diagram

A diagram of the typical over the levee discharge pipe system is shown in Figure B-1.

(4) Priming condition. Since the selected discharge system will use a siphon assist, another condition, priming, must be determined. The first step is to determine the required priming flow rate Q_{prime}. The computation is based on the flow required to obtain an average velocity in the discharge pipe at its highest point of 7 fps. The value of 7 fps will provide a prime for discharge pipe systems with diameters of 54 inches and less having no extra bends other than those necessary at the bottom and top of the levee. For discharge systems with larger diameters or unusual flow lines, consider using the critical depth of flow elevation occurring in the pipe instead of top of pipe. Methods used to calculate the critical depth in a circular pipe are shown in the *Handbook of Hydraulics* (King and Brater 1963).

$$Q = (\text{area})(\text{velocity})$$

$$Q_{prime} = (\text{pipe area - ft}^2)\ (7\ \text{fps})$$

$$= (6.77\ \text{ft}^2)\ (7\ \text{fps})$$

$$= 47.39\ \text{cfs or approximately } 21{,}300\ \text{gpm}$$

The priming static head (Figure B-2) is equal to the difference between the top of the discharge pipe at its highest point and the lowest pump sump level used for starting the pumps.

Highest point in discharge pipe at top of protection = elevation of protection + diameter of pipe = 341.0 + 3.0 = 344.0.

Priming static head = 344.0 - 314.0 = 30 ft

(5) Siphon condition. With a siphon assist system, it is required that the siphon recovery is not greater than 28 feet. The value of 28 feet is used to prevent possible water vaporization and siphon priming problems. An up-turned saxophone discharge pipe or a weir is used to limit the recovery to 28 feet and seal the end of the pipe. When one of these means is used, the low head must be checked based on the saxophone or weir elevations. If, at the pumping mode, the lowest water level on the discharge side provides for a recovery less than 28 feet, then a saxophone discharge or weir is not required. The discharge end of the pipe should be submerged when a separate vacuum priming system is provided to prime the pump. The computation is as follows:

Siphon recovery = top of pipe elevation - lowest river elevation for pumping

= 344.0 - 314.0

= 30 ft (2 ft over 28 ft)

Therefore some means must be used to limit recovery to 28 feet.

El top of weir/lip = el top of pipe - 28 ft

= 344.0 - 28

= 316.0

This elevation will be used in determination of the low static head.

(6) Suction requirements. The other part of the pump conditions is the pump suction requirements. This is specified as NPSHA for the various pumping conditions. It is computed as follows:

$$NPSHA = h_{sa} - h_{vpa}$$

where

$$h_{sa} = h_p + h_{se} - h_f$$

or

for pumps with suction head:

$$NPSHA = h_p + h_{se} - h_f - h_{vpa}$$

where

h_{sa} = total suction head in absolute feet

h_{vpa} = vapor pressure of water at given temperature

h_p = absolute pressure on water surface, for open sump = atmospheric pressure in feet

h_{se} = static water level above (+) or below (-) impeller eye datum

h_f = friction and entrance (0 for pumps with bellmouths in wet sumps)

Pumping Condition	Low Hd. Cond.	Design Fl. Cond.	Priming Cond.
Sump El*	314.0	317.0	314.0
Impeller El**	311.0	311.0	311.0
h_{se} - ft +3.0	+6.0	+3.0	
h_{vpa} (80 °F) - ft	1.2	1.2	1.2
h_p - ft	33.9	33.9	33.9
NPSHA - ft	35.7	38.7	35.7

* For this condition, use the lowest water that will occur for majority of the pumping; however, all operating water levels should be examined to determine if limiting suction operation will occur. Stop pump level should generally be the lowest sump level.
** The impeller eye (entrance) is set to provide the submergence listed below, depending on the station operating hours per year.

(7) Submergence requirements. The submergence shall be for the lowest pumping level at the station where the pumps will be operating for periods of time greater than 2 hours. Operation below these submergence levels is permitted as long as the operation time is less than 2 hours. In no case will any operation occur with water levels below the impeller eye or datum. Assume for this example that the operation time will be over 300 hours per year; therefore, the impeller elevation is 3 feet below lowest sump elevation for any pumping condition to assure a flooded impeller.

Total Est. Annual Operating Hours Per Year	Min. Submergence* ft
0 to 99	1.0
100 to 299	2.0
300 and over	3.0

* Minimum submergence over impeller eye or above NPSHR level, whichever is greater.

(8) Total system head. The next step is to compute the total system head curves for each condition. The total system curves will include all the losses plus the static head for that condition. For the purposes of pump selection, the total system curves will be constructed to include the losses in the pump beyond the pump bowl. This will permit the subsequent pump selection to be done on the basis of bowl heads. Bowl head is considered the head produced by a pump if it were measured immediately after the discharge vanes. Bowl heads therefore do not include any losses in the transition piece and elbow of the pump which is supplied with the pump. The bowl heads permit the user to use any type of discharge system beyond the pump bowl. For this example, there would be three system curves: design flood, low head, and priming. It should be noted that any system total head curves used for procurement of pumping equipment would only include system losses which would be external to the pump equipment being furnished by the pump manufacturer. Generally, the pump manufacturer would subtract the column pipe and discharge elbow losses from his bowl performance, thereby producing a performance curve referenced to the discharge point of the equipment being supplied. For this design the pipe lengths are as follows:

Priming - 175 ft, operating - 250 ft

The total system head required by the pump to deliver the minimum and the maximum flow rates required should be calculated and tabulated as shown in Table B-1. The total system head should include the discharge loss, pipe and elbow losses, and static head. The next step is to use this table and develop system head (pump bowl) loss curves as shown on Figure B-3.

b. Pump selection.

(1) Formulas used. The method of pump selection consists of computing the performance of a larger prototype pump from the performance a model pump or a small prototype pump. The following relationships are used for these computations. All relationships are based on pump bowl performance.

$$d_p = d_m(Q_p/Q_m)^{1/2}(H_m/H_p)^{1/4}$$

$$Q_p = Q_m(d_p/d_m)^3(N_p/N_m)$$

$$H_p = H_m(d_p/d_m)^2(N_p/N_m)^2$$

$$H_{sp} = H_{sm}(d_p/d_m)^2(N_p/N_m)^2$$

$$BHP_p = BHP_m(d_p/d_m)^5(N_p/N_m)^3$$

Table B-1
Total System Head

Q gpm	$\frac{V^2}{2g}$ ft	$H_{F/100}$ ft	$H_{F/250}$ ft	Other Pump K = 0.4 ft	Losses Bends K = 1.2 ft	Total[1] Loss ft	Low[3] Total Head ft	Design[4] Flood Total Head ft
Low Head and Design Flood Conditions								
20,000	0.67	0.25	0.62	0.27	0.81	2.37	4.37	24.37
25,000	1.05	0.38	0.95	0.42	1.26	3.68	5.68	25.68
30,000	1.51	0.54	1.35	0.61	1.82	5.29	7.29	27.29
35,000	2.06	0.72	1.81	0.82	2.47	7.17	9.17	29.17
40,000	2.69	0.94	2.35	1.08	3.23	9.35	11.35	31.35
45,000	3.41	1.18	2.95	1.36	4.09	11.81	13.81	33.81

Q gpm	$\frac{V^2}{2g}$ ft	$H_{F/100}$ ft	$H_{F/175}$ ft	Other Pump K = 0.4 ft	Losses Bends K = 0.8 ft	Total[2] Loss ft	Priming[3] Total Head ft
Priming Head Condition							
20,000	0.67	0.25	0.43	0.27	0.54	1.91	31.91
25,000	1.05	0.38	0.66	0.42	0.84	2.97	32.97
30,000	1.51	0.54	0.95	0.61	1.21	4.28	34.28
35,000	2.06	0.72	1.27	0.82	1.65	5.80	35.8
40,000	2.69	0.94	1.65	1.08	2.15	7.57	37.57
45,000	3.41	1.18	2.07	1.36	2.72	9.56	39.56

Examples (For Q = 20,000 gpm):
[1] Total Loss(Low Head/Design Flood) = 0.62+0.4(0.67)+1.2(0.67)+0.67 = 2.37 ft.
[2] Total Loss(Priming) = 0.43+(0.4)(0.67)+(0.8)(0.67)+0.67 = 1.91 ft.
Priming Static = 344 - 314 = 30 ft. Low Static = 316 - 314 = 2.0 ft.
Design Flood Static = 339.0 - 317.0 = 22.0 ft.
[3] Low T. H. = 2.37+2.0 = 4.37 ft. Priming T. H. = 1.91+30.0 = 31.91 ft.
[4] Design Flood T. H. = 2.37 + 22.0 = 24.37 ft.

where

d_p = Impeller exit diameter of prototype pump

d_m = Impeller exit diameter of model pump

Q_p = Capacity of prototype pump

Q_m = Capacity of model pump

H_m = Head of model pump

H_p = Head of prototype pump

N_p = Rotative speed of prototype pump

N_m = Rotative speed of model pump

H_{sp} = Required suction head of prototype pump

H_{sm} = Required suction head of model pump

BHP_p = Brake horsepower of prototype pump

BHP_m = Brake horsepower of model pump

(2) General. The performance of a prototype pump can be determined by the use of the above equations applied to the model pump performance. As can be seen from the above formula, the two variables are impeller diameter and rotative speed. The selection of these two factors should be to obtain a prototype unit which has the smallest impeller diameter and the highest rotative speed, while still meeting all of the performance requirements of head, capacity, and NPSHA. The impeller diameter is

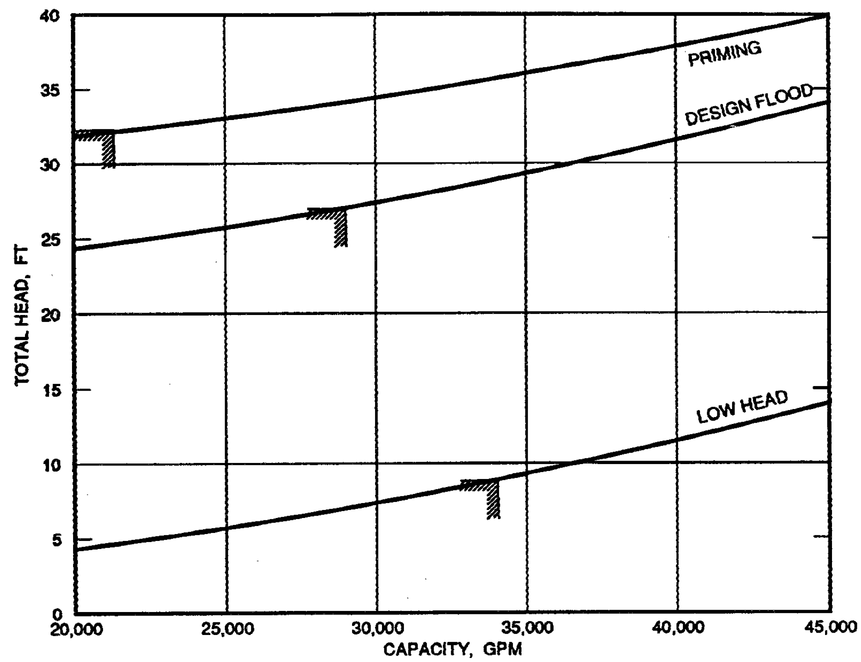


Figure B-3. System head (pump bowl) loss curves

shown on each model pump curve. For mixed-flow type pumps, the maximum impeller diameter is indicated on the curves. On mixed flow pumps, it is possible to reduce the impeller diameter by up to 5 percent, thereby changing the performance of the pump from that shown on the curves for full diameter performance. Blade pitches are taken into account and shown as different model pump curves.

(3) Calculation method. The actual calculations of the prototype pump performance is best done by trial and error. A personal computer using a spreadsheet type program simplifies and speeds these calculations and the pump selection. CECW-EE can furnish information of various Districts where different programs are available to perform these computations.

(4) Sample calculations. The following is an example of computations used to select a prototype pump. It is usually best to start with a model pump that has a head range near that of the required condition points. As a first try, use model curve MF-1 (Figure B-4) and calculate prototype performance. A mixed-flow impeller was tried because highest head requirement was over 20 feet. The selected prototype impeller is usually smaller than the discharge pipe diameter. The maximum prototype pump speed can be estimated by applying the following formula based on suction specific speed (S).

$$S = N_p \, (Q_p)^{1/2} / NPSHA_p^{3/4}$$

(a) For this sample problem, use a value of S = 8,000.

$$N_p = (8{,}000) \times (NPSHA)^{3/4} / (Q^{1/2})$$

where

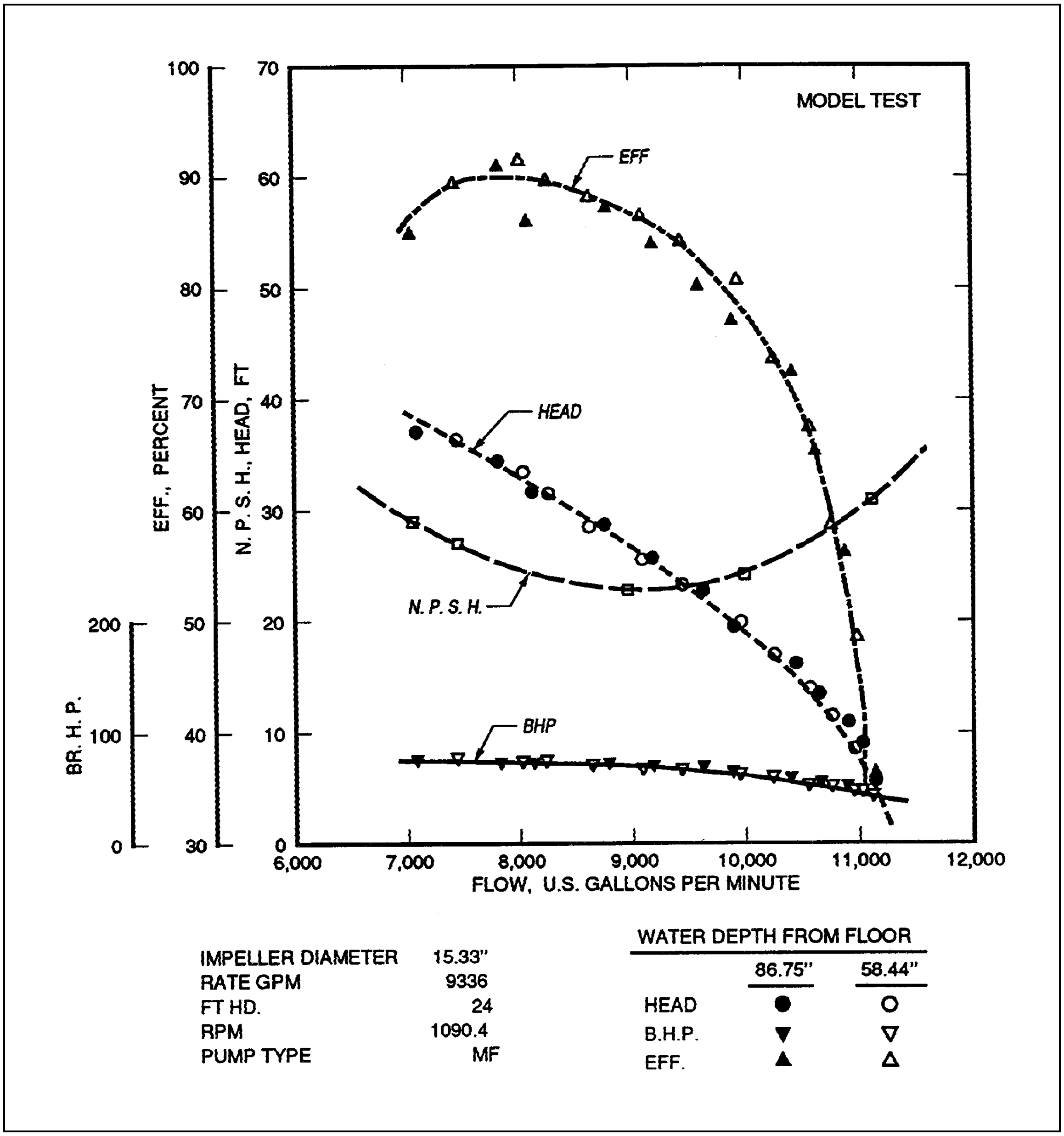


Figure B-4. Pump model curve MF-1

N_p = rotative speed of the pump, rpm

$NPSHA_p$ = calculated for the lowest head pumping condition, ft

Q_p = flow rate for lowest head pumping condition, gpm

therefore

$$N_p = (8,000) \times (35.7^{3/4}) / (34,000^{1/2})$$

N_p = 634 rpm

(b) The pump speed should not in general exceed this calculated rotative speed. The speed used must also meet the restrictions of the pump driver. If using an electric motor that is directly connected to the pump, then the synchronous speed of the motor must be considered.

When using an induction motor, the full-load speed can be estimated to be 97 percent of the synchronous speed. The synchronous speed can be calculated using the following formula for electricity with a frequency of 60 cycles.

N_p = 7,200/number of motor poles (such as 10,12,14...)

Motor speed = 7,200/12 or 7,200/10

= 600 rpm or 720 rpm

(c) Since 720 rpm is over the calculated maximum of 634 rpm, the lower synchronous speed of 600 rpm is used. Assuming an induction motor is to be used, the running speed when operating at full load is estimated to be 97 percent of 600 rpm or 582 rpm.

(d) Try Model MF-1. Based on the Pump Model Curve MF-1 (Figure B-4), calculate the diameter of the prototype impeller using the model law (constant specific speed and equal heads.

$$d_p = d_m (Q_p/Q_m)^{0.5}$$

where

d_p = 15.33 (29,000/8,900)$^{0.5}$ = 27.7 inches

d_m (from model curve MF-1) = 15.33 inches

$Q_p = Q_H$ (design flood) = 29,000 gpm at 27 feet TDH

Q_m (from model curve MF-1) = 8,900 gpm at 27 feet TDH

(e) Develop prototype performance curve based on model curve MF-1 and verify that design conditions have been met (Figure B-5).

$$Q_p = Q_m (d_p/d_m)^3 (N_p/N_m)$$

$$BHP_p = BHP_m (d_p/d_m)^5 (N_p/N_m)^3$$

where

$$Q_p = Q_m (1.81)^3 (0.534) = Q_m (3.17)$$

$$d_p/d_m = 27.7/15.33 = 1.81$$

$$N_p/N_m = 582/1,090.4 = 0.534$$

$$BHP_p = BHP_m (1.81)^5 (0.534)^3 = BHP_m (2.96)$$

From curve MF-1 model pump performance			Calculated prototype pump performance		
Q_m	H_m	BHP_m	Q_p	H_p	BHP_p
7,000	38.8	75	22,200	38.8	222
8,000	33.2	73	25,400	33.2	216
9,000	26.9	70	28,530	26.9	207
10,000	19.0	60	31,700	19.0	178
11,000	7.2	45	34,900	7.2	133

(f) The results of the first prototype pump computation are plotted on the system head loss curves. Results show that a pump with a 27.7-inch impeller rotating at 582 rpm will satisfy the design requirements. Next, other model pumps and different prototype speeds would have been tried to find other prototype pumps that will meet the requirements. An average prototype pump size could then be calculated. All station layout dimensions would be based on the corresponding standard size pump. The NPSH required by the prototype or model is then checked against the NPSH available. Cavitation curve MF-1 (Figure B-6) confirms that there is adequate submergence.

(5) Pump dimensions.

(a) General. Determine the dimensions for all the model pumps selected. Since the sump dimensions and elevations used depend on the pump dimensions, some means must be used to determine the dimensions to use for the station layout from the range of pumps selected. The selection of dimensions to allow the maximum number of pumps to meet the guidelines is given below.

(b) Bell diameter.

The bell diameter = D

Average D, (D_A) = sum of bell diameter for all selected pumps divided by number of selected pumps.

Largest bell diameter (D_{LARGE}), but not larger than 1.2 times D_A

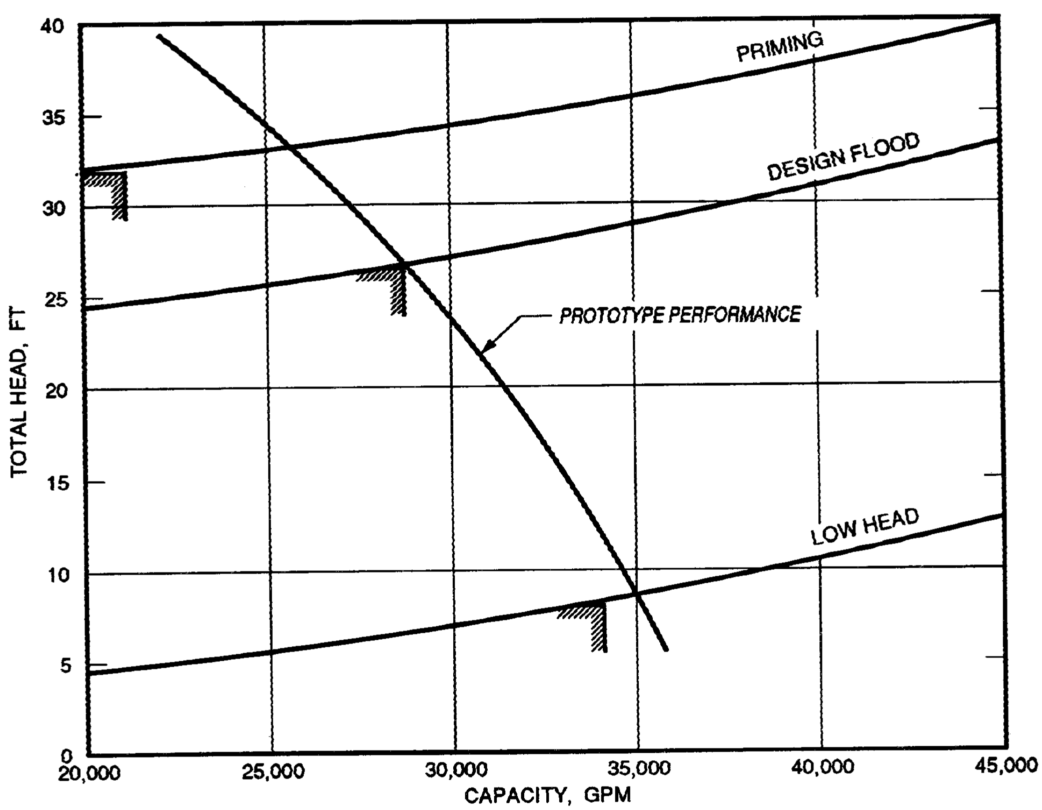


Figure B-5. Prototype performance curve superimposed on the system head curves (pump bowl) pump MF-1

Smallest bell diameter (D_{SMALL}), but not less than 0.9 times D_A

Sump $width_1$ = 2 times D_{LARGE}

Sump $width_2$ = 2.5 times D_{SMALL}

Sump width is the larger of sump $width_1$ or $width_2$

D = 1/2 of the sump width from the above step.

(c) Impeller elevation. The impeller eye (entrance) is set to provide the submergence indicated above in the paragraph on pump conditions. In this example, the impeller was set at el 311.0. The bottom of the bell and sump floor elevation are set as follows:

Bottom of pump bell = impeller eye elevation minus 1/2 D

Floor of sump = bottom of bell elevation minus 1/2 D

(d) Minimum pump height. The minimum distance from the floor of the sump to the centerline of the pump discharge must be determined to establish a minimum floor elevation. The dimension form the floor of the sump to the bell inlet is determined above. The distance between the centerline of the discharge to the suction bell inlet should be provided by pump manufacturers offering the type and size of pump indicated by the prototype. This pump dimension will vary from one manufacturer to another. The maximum distance found should be used to determine the minimum operating floor. Other

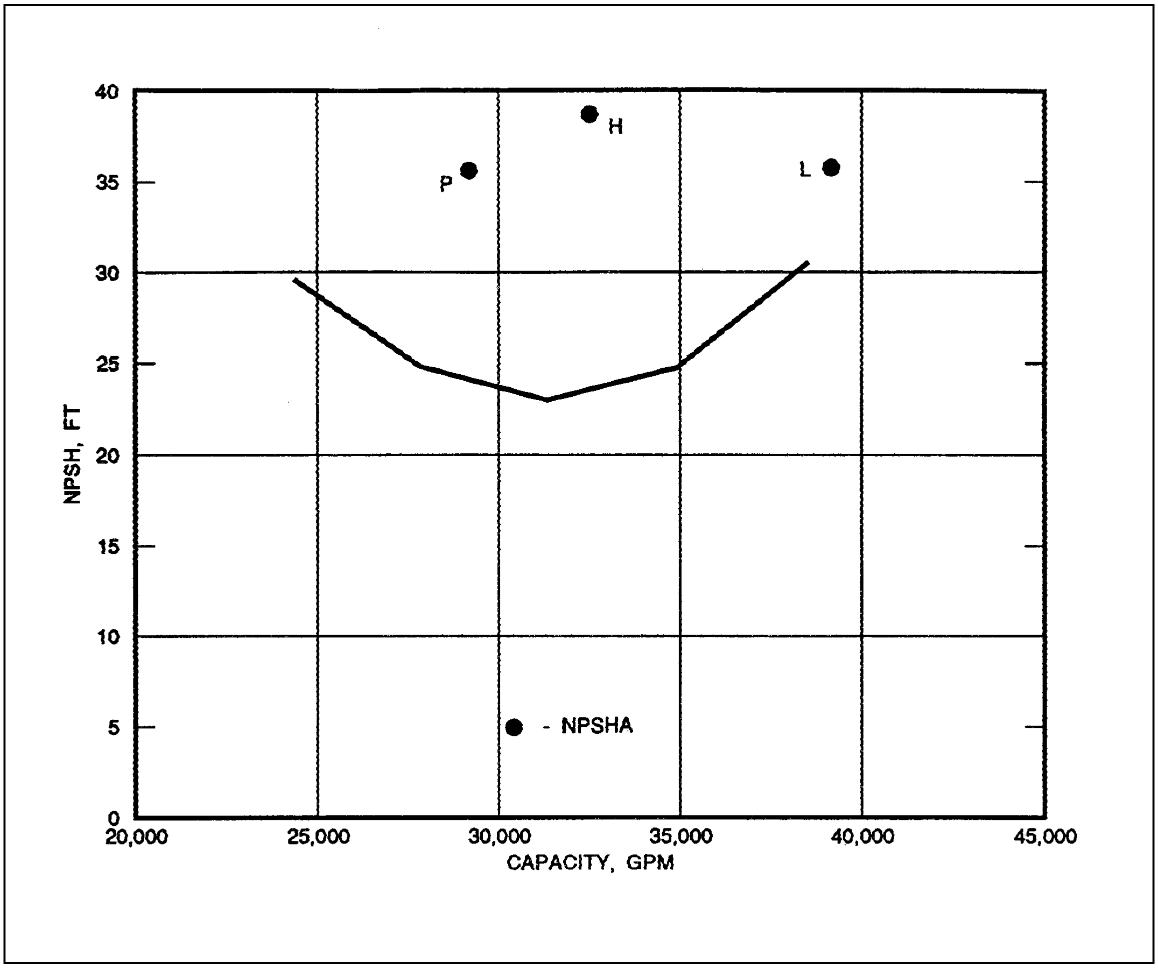


Figure B-6. Cavitation curve MF-1

considerations such as local flooding due to power outage and surrounding ground elevations may require a higher operating floor elevation.

c. Station layout.

(1) Pump dimensions. For stations with up to three equal sized pumps having capacities not greater than 5.66 m^3/s (200 cfs), and with straight inflow, in front of the station, the dimensions indicated on Chart B-2 may be used. The flow to the station should occur in a straight symmetrical channel with a length equal to or greater than five times the station width (W on Chart B-2). The invert of the channel in front of the station should not contain any slopes greater than 10°. The submergence indicated on Chart B-2 is the depth of water suggested to prevent harmful vortexes. In most cases the water depth will be greater due to the cavitation allowance listed above. If there are any unique inflow conditions or problems the designer should contact the Waterways Experiment Station Hydraulic Laboratory to determine alternative layouts to correct or compensate for the problems.

(2) Considerations for station layout.

(a) Space inside of the station is provided to set one pump driver and disassemble one pump using the overhead crane.

(b) Space in front, side and back of electrical equipment is provided as required by the electrical code requirements.

(c) Space is provided to remove any pumping unit without disassembly of another unit or electrical gear.

(d) Space is provided for an office and sanitary facilities for any station that will be manned.

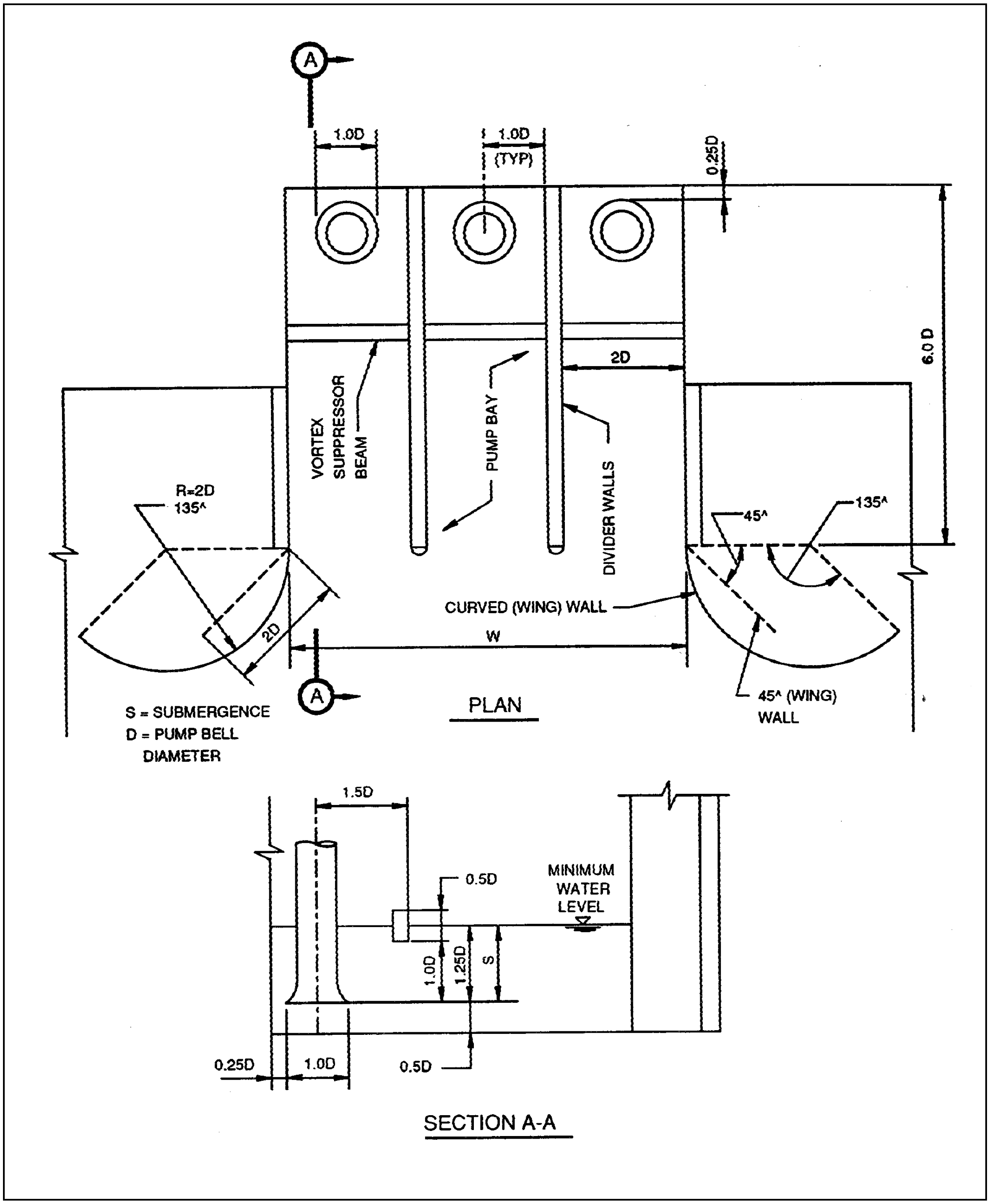


Chart B-2. Vertical pump sump dimensions

(e) Space is provided for spare parts and maintenance equipment to be stored at the station.

(f) Location of electrical gear is coordinated with service entrance.

(g) Exit and equipment door are provided and properly located.

(h) Straight approach to pump sump is provided.

(i) Any sump closure gate is neck down at least 4D from the pumps.

(j) Access is provided to trashrack platform for trash removal by truck.

(k) Sufficient room is provided to position a truck for equipment removal.

(l) Minimum slope is provided in ditch flow line beyond the front of the trashrack.

(m) Incoming overhead power lines do not present a hazard to operation and maintenance of the station.

d. Pump manufacture's selection. Using the preliminary layout, correct any system head curves such as change in low head due to different elbow elevation. Check the pump selections using the new system requirements and refine layout as necessary. It is also best at this time to request pump selections from the pump manufacturers using the requirements and sump layout above. This will confirm the pump selections. Chart B-3 is an example of the information to be furnished and requested from the pump manufacturer.

B-3. Vertical Submersible Pump Selection

a. Design data and requirements.

(1) Pump conditions. The sample calculations are based on a pumping station with a through-the-protection discharge, pumping into a discharge chamber. The following is the assumed conditions for each pump.

(a) Required from hydrology report:

Q_H = The flow rate at maximum differential head

= 27,000 gpm @ river el 339.0 and sump el 321.0

= 1,715 L/S

Q_L = The flow rate at minimum differential head

= 33,000 gpm @ river el 322.0 and sump el 319.0

= 2,095 L/S

Pump stop elevation - 315.0
Pump start elevation - 318.0
Normal pumping elevation - 316.0
(Level at which the majority of pump operation will occur)

(b) Submersible propeller pumps (Plate 24) typically are constructed in such a manner that the pitch angle of the propeller blades can be changed; therefore, the selection method used is different from that used with fixed blade pumps. The selection procedure used for submersible pumps will be to compute the system requirements, and then select a pump from available performance curves. After the initial selection is made, then the system requirements can be corrected if necessary due to a more accurate discharge tube sizing and the pump selection confirmed or changed. In addition to the selection based on pump head and capacity requirements, the pump selected must also be checked to ensure that its suction requirements are satisfied by those provided by the station layout.

(c) The pumping system is composed of a discharge/support tube in which the submersible pumping unit is located. In this example, the tube would be fitted with an elbow section and a horizontal pipe terminating with a flap gate. For submersible pump installations of this type, the discharge line invert should be well above the motor to hold the elbow losses to a minimum but low enough to keep reasonable the static head reasonable.

(d) The first estimate of the tube diameter can be based on the size required using a 6.5-fps velocity and the greatest required capacity. After calculating a diameter based on these conditions, the nearest size tube diameter as shown on Table B-2 shall be used for the preliminary calculations. For the example problem, the calculated discharge is 45.4 inches. The nearest standard tube diameter of 48 inches is used. The bottom of the tube can be set using the minimum tube submergence required. These submergence requirements are provided by the submersible pump manufacturer and are based on annual operating hours and pump tube design. For this example, 3.0-ft minimum submergence is required.

Elevation bottom of the tube = 315.0 - 3.0 = 312.0

PUMP MANUFACTURER'S DATA SHEET

Information furnished:

Name of station
Type of driver and operating voltage if electric
Type of pump
System head curves, using losses external to the pump, showing required condition points
Pump setting elevation
Sump layout
Number of pumping units to be installed

Information requested from the pump manufacturer:

Pump model/type number
Pump size - discharge, bell and impeller diameter
Pump diameter below impeller where a formed suction intake would attach
Pump operating speed
Pump setting elevation including;
- Elevation of bell
- Elevation of impeller
- Height of the motor above baseplate elevation
- Length of pump elbow of discharge flange dimensions
- Minimum distance from impeller elevation to centerline of elbow
- Elevation of attachment of a formed suction intake

Estimated pump weight
Estimated motor weight
Estimated pump cost
Estimated motor cost
Pump performance curve showing head, horsepower, efficiency, and NPSHR plotted against capacity

For large pumps over 54-inch size, additional information such as the WR^2 of both the pump and motor along with starting torque curves would also be requested.

Chart B-3. Pump manufacturer's data sheet

Table B-2
Submersible Pump Dimensions

Pump No.	Discharge Tube Diameter inches	Pump Speed rpm	Height of Pump/Mot. inches	Max. Wt. Pump.Mot. pounds	Motor kW rating
AF-S-1	40	705	97	7,350	236
AF-S-2	48	590	135	12,200	355

(e) The bottom of the tube elevation may need to be lowered later to satisfy the sump velocity criteria as indicated in Figure B-7; however, this will not affect the pump selection.

(f) The minimum invert elevation must be above the top of the motor. With the bottom of the tube set at el 312.0, the minimum elevation of the elbow invert can be determined by adding the pump/motor height indicated on Table B-2 to the bottom tube elevation.

Minimum invert elevation of elbow = 312.0 + 135 inches = 323.25

(g) This elevation will be used since it is above the river elevation for the low head condition. The horizontal discharge pipe connected to the tube is sized based on the flow velocity of 12 fps at maximum capacity. The calculated horizontal discharge pipe size is approximately 33.5 inches; use nominal 36-inch pipe.

(h) A static head diagram is constructed (Figure B-8) using the given hydrology information and preliminary information determined above on the pump tube and the discharge piping. The floor elevation is set 1/2 tube diameter below the bottom of the tube. This first static head diagram will be used to make a preliminary pump selection. In most cases, at least one or more static head diagrams will need to be prepared after the preliminary pump selection is made to allow the pumping unit dimensions to agree with the static head diagram. The pump selection process would follow the steps below:

1		2		3		4		5
Prepare Static Head Diagram	---->	Prepare System Head Curves	---->	Make Prel. Pump Select.	---->	Check Pump NPSHR	---->	Repeat Steps 1, 2,3 & 4 If Nec.

(2) System head. The next step is to compute the system head curves (Table B-3). The system head curves include all of the losses plus the static head for that condition (Figure B-9). The system loss curves include all the losses beyond the pump motor, since losses below this point are included in the given pump curves. A loss of K = 0.7 is used for the losses in the pump column and elbow. The other losses in this example are considered to be equal to the velocity head. Next, calculate the net positive suction head available (NPSHA) for the various pumping conditions. Refer back to the previous example problem for the definition of terms.

Pumping Condition	Low Hd. Cond.	High Hd. Cond.
Sump Water El*	316.0	316.0
Bottom of Tube**	312.0	312.0
h_{se}*** - ft	+4.0	+4.0
h_{vpa} (80 °F) - ft	1.2	1.2
h_p - ft	33.9	33.9
NPSHA - ft	36.7	36.7
NPSHA - m	11.2	11.2

* For this condition, use the lowest water level that will occur for majority of the pumping; however, all operating water levels should be examined to determine if potential damaging operation will occur. For this example, it has been assumed this elevation to be 1 foot above the pump stop elevation.
** The NPSHR curves are referenced to the bottom of the tube location rather than the impeller entrance or eye.
*** 4 feet is the submergence above the bottom of the tube.

$$NPSHA = h_p + h_{se} - h_f - h_{vpa}$$

b. Pump selection.

(1) General. Using the pump curves AS-F-1 and AS-F-2 (Figures B-10 and B-11) and the required condition points from the system head loss curves, a preliminary pump selection can be made. The pump performance head-capacity curves are shown for the various blade angles that are available for that pump. A single blade angle that satisfies all design conditions should be used. Changing blade angles during flood events should not be considered because of the need to remove the pumping unit and thereby taking it out of operation. These pumps have the motors directly attached to the pumping unit. The motors' ratings are

For the example pump conditions the selected pump would have the following sump dimensions:

D = 48 in., a = 36 in., b = 96 in., c = 24 in., L = 16 ft.

S = submergence over bottom of tube

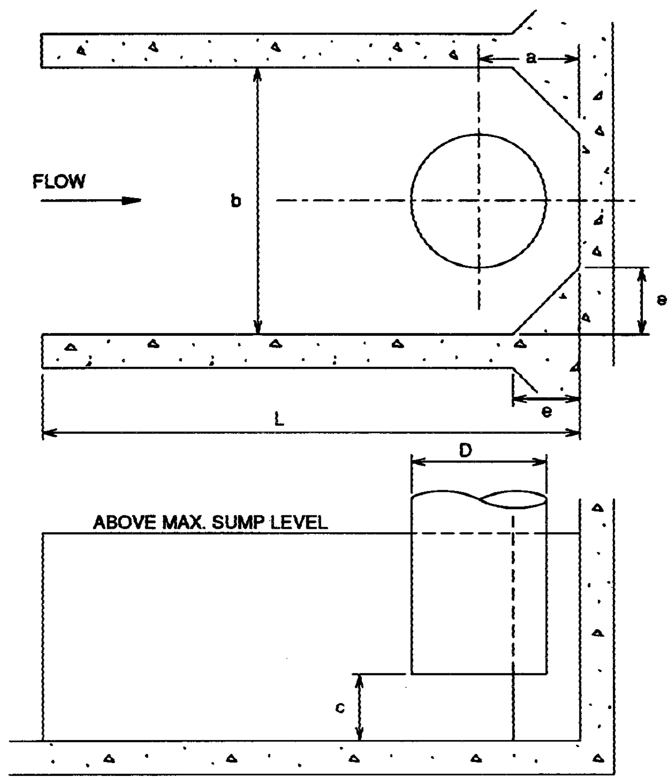
V = Q/A and if V = 1.2 fps, then A = Q/1.2 also A = 2D x (S+.5D)

then $S = (Q\ / 2.4D_{cond}) - .5D_{cfs}$ and $S = 5.66_{ft}$ ft. ft

Bottom of tube = Pump stop level minus submergence

= 315.0 - 5.66 ft. = El. 309.34 instead of El. 312.0

Submersible Pump Sump Layout



TUBE DIA.	DIM.
a	0.75D
b	2.0D
c	0.5D
e	0.5D
L	4D Min.

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Figure B-7. Typical submersible pump sump layout

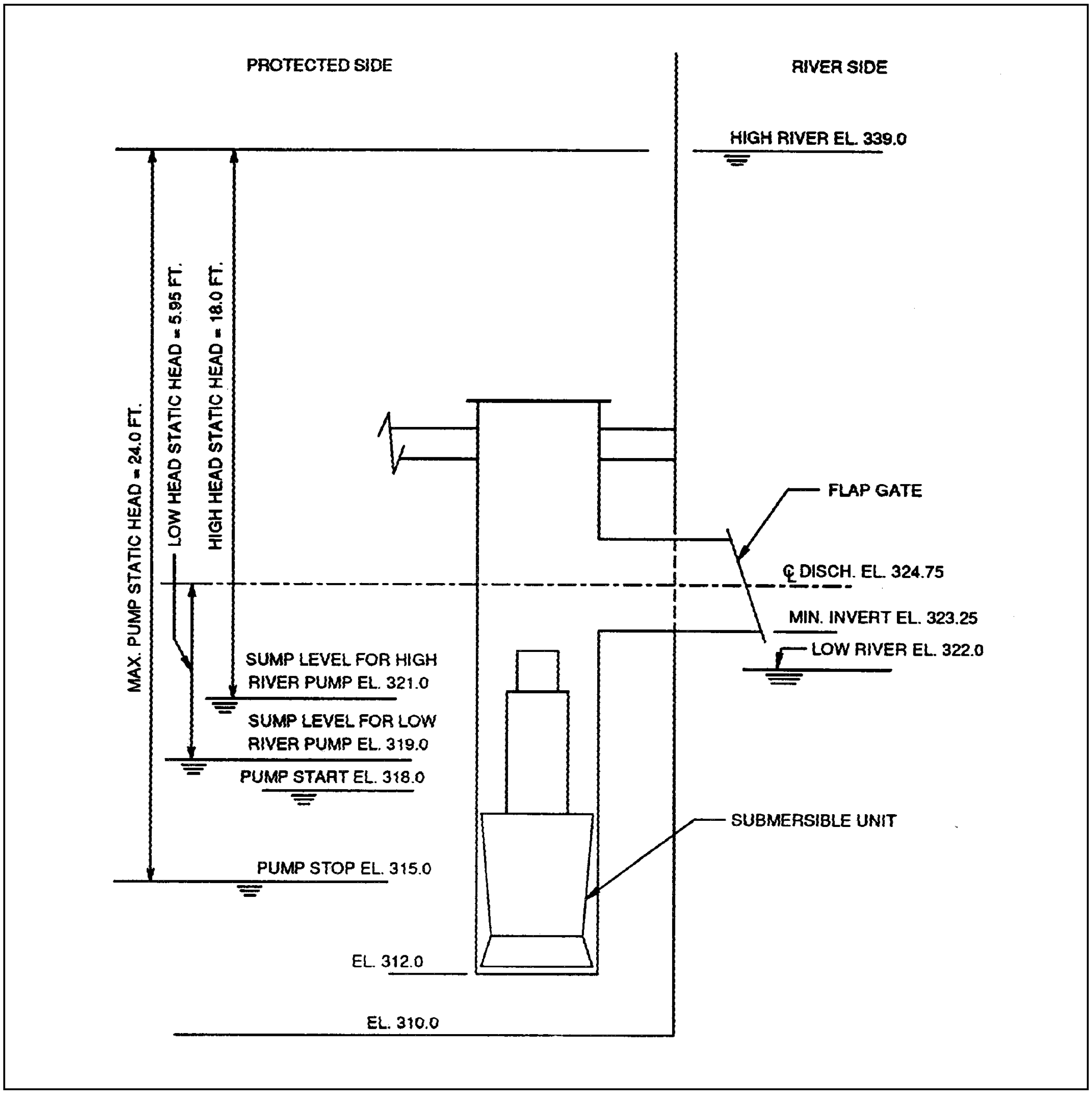

Figure B-8. Static head diagram

Table B-3
Low and High Head Conditions

Q gpm	$\frac{V^2}{2g}$ ft	Pump & Elbow K = 0.7 ft	Total Losses ft	Total Head Low Hd/ ft	m	Total Head High Hd. ft	m	Max. Head ft
20,000	0.22	0.15	0.37	6.3	1.93	18.4	5.61	24.4
25,000	0.28	0.19	0.47	6.4	1.96	18.5	5.63	24.5
30,000	0.33	0.23	0.56	6.5	1.98	18.6	5.66	24.6
35,000	0.39	0.27	0.66	6.6	2.02	18.7	5.69	24.7
40,000	0.44	0.31	0.75	6.7	2.04	18.8	5.72	24.8
45,000	0.50	0.35	0.85	6.8	2.07	18.9	5.75	24.9
50,000	0.55	0.38	0.95	6.9	2.10	19.0	5.78	25.0

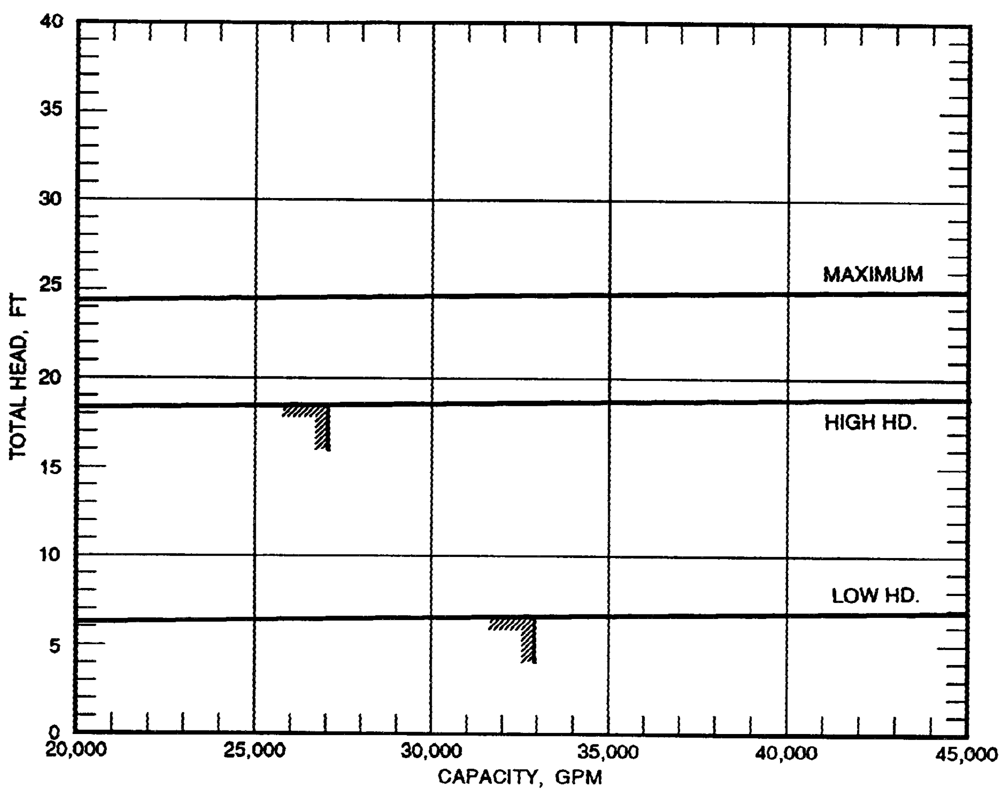

Figure B-9. System head loss curves

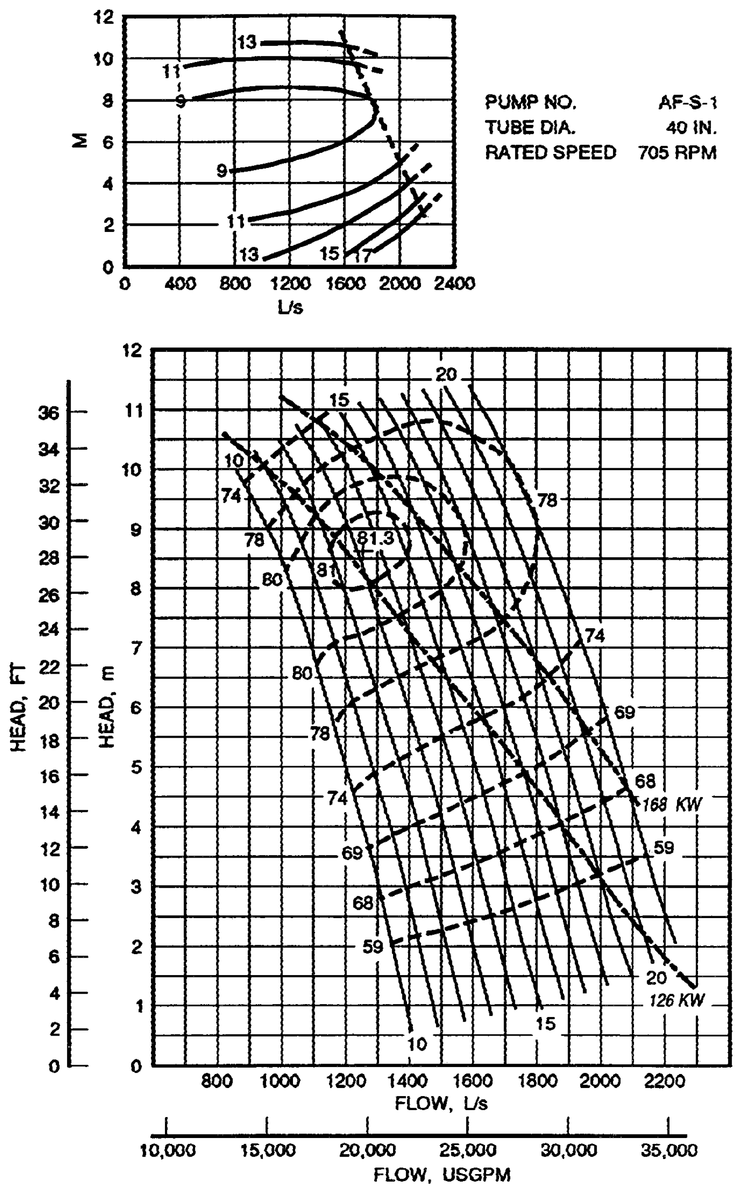

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Figure B-10. Submersible pump curve AF-S-1

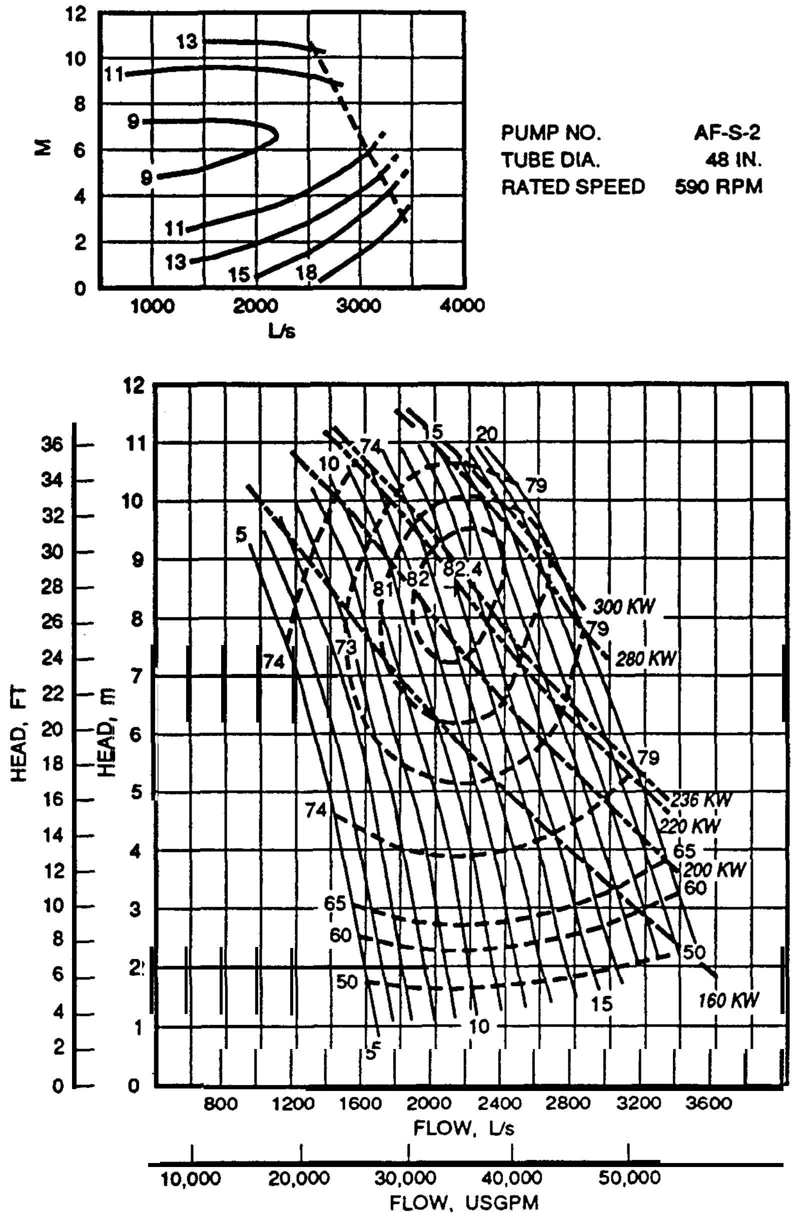

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Figure B-11. Submersible pump curve AF-S-2 shown in kilowatts, which is the input: power to the pump shaft, The dashed lines running diagonally from upper left to the lower right show the motor sizes available. Any design condition below these dashed lines may use the motor rating indicated for that line. The information furnished in this manual can be used for the preliminary layout of submersible type pumping stations; however, information should be requested from all manufacturers for the design memorandum.

(2) Selection procedure. Review of the pump curves indicates that an AF-S-1 size pump operating at a speed of 705 rpm and set at a blade angle of 20 degrees will satisfy the head-capacity &sign conditions.

(a) The next step is to check the suction requirements of the pump. This is done by plotting the head-capacity curve for the blade angle chosen above on the NPSHR curve for that pump. The plotted head-capacity curve crosses the various NPSHR curves for that pump indicating the required suction head for different pumping requirements. The curve shown below indicates that the preliminary AF-S-l pump selection requires a greater submergence than is available; therefore, another pump must be tried or greater submergence provided. Unless the additional submergence required is less then 1 or 2 feet, it is usually less expensive to provide a larger, slower speed pump than provide a deeper station. A cost comparison can be made to more accurately compare a deeper sump station with that station requiring a larger area because of increased pump size.

(b) The next choice would then be the next larger size pump operating at its the highest available speed and meeting all the required design conditions. This would be the AF-S-2 size pumping unit operating at 590 rpm. The lo-degree blade angle satisfies the design conditions and the suction requirements.

(c) Since the selected size pump of AR-S-2 has the same size tube as that first selected, the static head diagram and system head curves are connect.

(d) The net positive suction head requirements for the pump are determined by plotting the selected blade angle head-capacity curve on the cavitation curve. Where this head-capacity curve crosses the NPSHR lines indicates the NPSHR values for the pump.

(3) Station layout. Using the listed discharge tube diameter (Table B-2), the sump can be sized according to Figure B-7. Check the pump selections using the new system requirements and refine the layout as necessary. The sump layout is now complete, and the remainder of the station layout can now be done. It is also best at this time to request pump selections from the pump manufacturers using the requirements and sump layout above. This will confirm the pump selections and permits adequate bidding competition. The following are considerations for station layout:

(a) Sump velocities. The average velocity in each pump sump in front of the pump for continuous operation should not be greater than 0.37 meter per second (1.2 feet per second). For intermittent operation (less than 200 hours per year), the average velocity may be increased to 0.49 meter per second (1.6 feet per second). To obtain these velocities, the sump depth is varied while the sump width is kept equal to two tube diameters. These. maximum velocities are maintained to diminish the formation of vortices in the sump. The water levels obtained by application of these velocities may not be high enough to satisfy the pump's NPSHR. The NPSHR takes precedent, and the resultant submergence will be greater than that necessary to prevent vortices.

(b) Superstructure. A structure should be provided to house the motor starters, switchgear, and engine generator, if provided, and office space for operating personnel. Unless dictated by climatic conditions or needed to satisfy some other specific purpose, the structure need not cover the pump locations.

(c) Hoist. A method for removing the pumping units should be provided. Any inspection or repair work to the pumping unit is done with the unit removed from the tube. Inspection which requires the removal of the pumping unit are required at least annually to check the integrity of the pump/motor seal system. A monorail hoist capable of lifting the entire pumping unit should be provided. If the maintenance organization has a truck crane of sufficient capacity to raise the pumping unit or such a crane would be readily available on an emergency basis, then a permanent hoist would not be required.

B-4. Formed Suction Intakes

a. General. The formed suction intake (FSI) is used on pumps to improve flow to the impeller of vertical pumps. The FSI can be used on almost any pumping application. It is, however, recommended when adverse flow conditions occur upstream. Figure B-12 shows a
* typical FSI. Appendix I provides additional information. *
The FSI can be used on small pumps: however, the

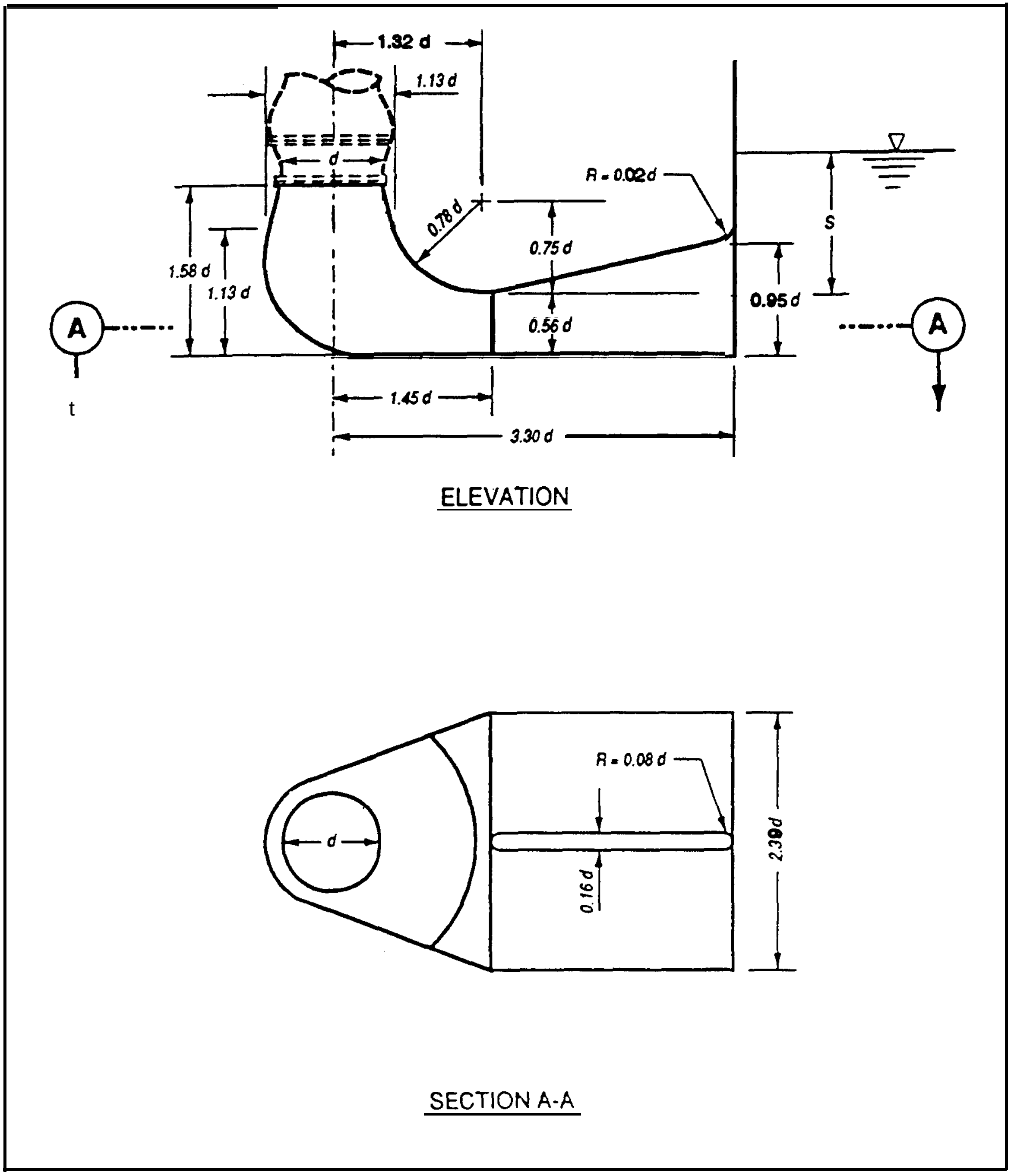

Figure B-12. Typical formed suction intake

*

small openings could clog or silt in during nonoperational periods.

b. FSI size determination. FSI is connected directly to the suction flange below the impeller. This diameter, d, will determine the size of the FSI. The selection of the pump will be the same as that used for the vertical wet pit pump except for the additional suction loss. Whereas the conventional vertical pump with a bell uses a suction loss of zero, the pump equipped with an FSI should use a loss of K = 0.15. After the pump has been selected, it is necessary to determine the suction flange connection inside diameter, d For axial flow pumps, d will be the same diameter as that determined for the impeller. For mixed flow impellers, d can be estimated to be 0.85 of the impeller diameter d. After d has been determined, the rest of the dimensions of the FSI can be found by applying the ratios indicated in Figure B-12. In a typical pump selection, the suction diameter will vary with different pump manufacturers. To permit maximum biddability, the FSI must be sized to allow sufficient manufacturers to bid.

c. FSI connection. For vertical wet pit pumps which are suspended from the operating floor, the connection between the FSI and the pump is determined by the pump manufacturer after the pump manufacturer performs a dynamic analysis of the pumping unit to determine the critical speeds of the pump. It is recommended that the FSI be formed or cast integral with the sump concrete.