DETERMINING TOTAL DYNAMIC HEAD

The total dynamic head of a water system must be considered when determining the size of pumping equipment to be installed. It determines the various head losses that the pump must overcome. Total dynamic head = elevation head + friction head loss + pressure head.

A. Elevation head - is the vertical distance which the water must be pumped. It is the elevation difference in feet between the pumping level in the well and the pressure tank.

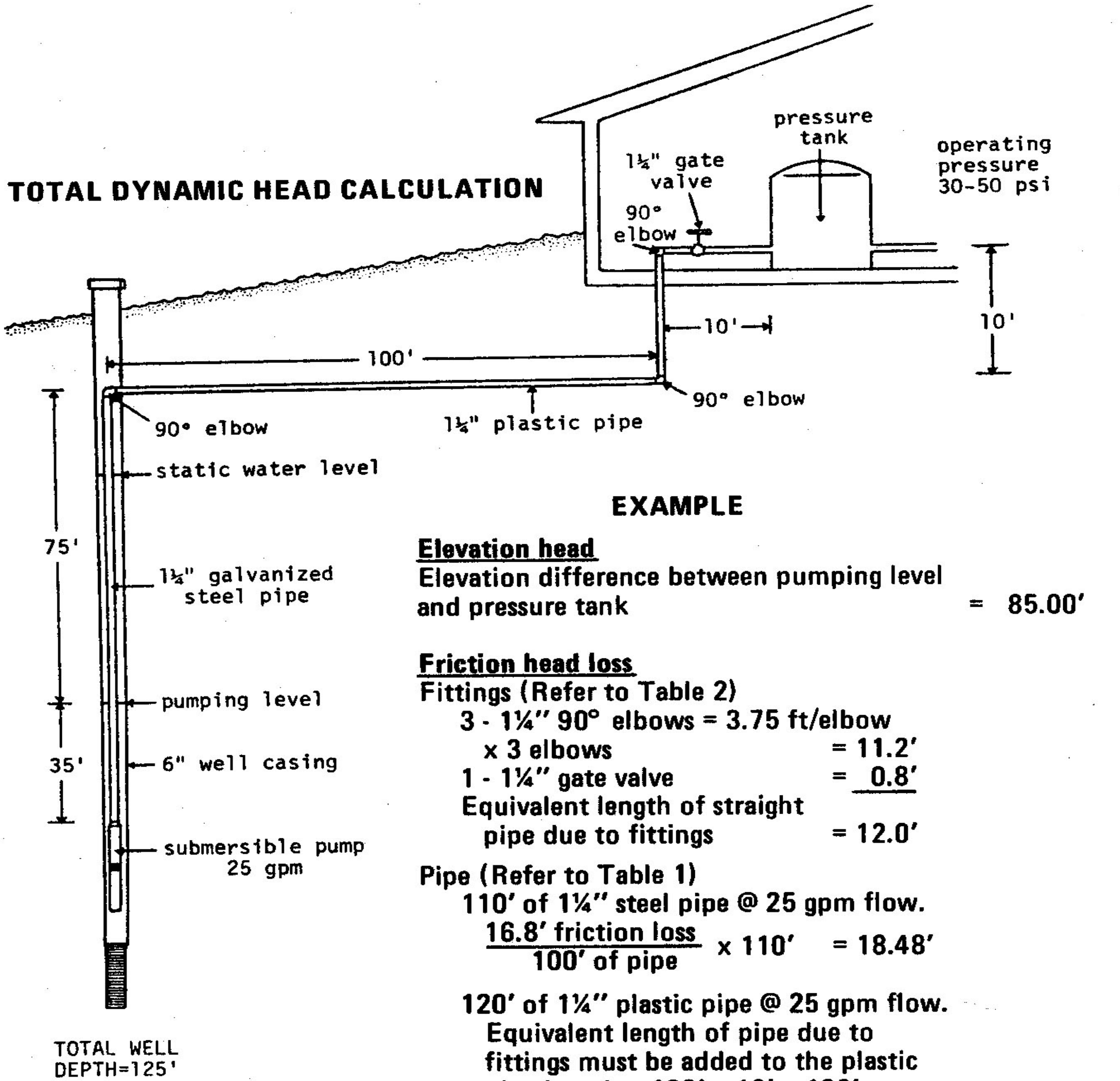
B. Friction head loss is the loss of pressure due to the flow of water through pipe and fittings. Determine diameter, length, and type of pipe material through which the water flows from the well to the pressure tank. Using the pump flow rate as determined from the Residential Unit Method or Fixture Method, refer to Table I (Friction Loss Charts) and Table 2 (Resistance of Valves and Fittings to Flow of Fluids) to determine friction head loss due to pipe and fittings. Friction loss can be overcome by using a larger pipe size or changing piping materials. (Note: In small water systems with few fittings, the head loss due to the fittings may he disregarded.)

C. Pressure head - is the maximum operating pressure of the water system converted from pressure (psi) to feet of head. If the pressure switch setting is 30-50 psi, then the maximum pressure is 50 psi. Convert psi to feet of head using the following conversion: 1psi = 2.31 feet of head. Therefore, pressure head equals maximum operating pressure x 2.31 feet.

D. Other head losses to be considered:

Water softener ……………………….	10 psi x 2.31 = head in feet
Iron filter……………………………..	20 psi x 2.31 = head in feet
Hot water heater ……………………..	2 psi x 2.31 = head in feet

TOTAL DYNAMIC HEAD CALCULATION



EXAMPLE

Elevation head

Elevation difference between pumping level and pressure tank = 85.00′

Friction head loss

Fittings (Refer to Table 2)

3 - 1¼″ 90° elbows = 3.75 ft/elbow
x 3 elbows = 11.2′
1 - 1¼″ gate valve = 0.8′
Equivalent length of straight pipe due to fittings = 12.0′

Pipe (Refer to Table 1)

110′ of 1¼″ steel pipe @ 25 gpm flow.

$$\frac{16.8' \text{ friction loss}}{100' \text{ of pipe}} \times 110' = 18.48'$$

120′ of 1¼″ plastic pipe @ 25 gpm flow.
Equivalent length of pipe due to fittings must be added to the plastic pipe length. 120′ + 12′ = 132′

$$\frac{9.06' \text{ friction loss}}{100' \text{ of pipe}} \times 132' = 11.95'$$

Friction head loss: 18.48′ + 11.95′ = 30.43′

Pressure head

30-50 psi pressure switch setting. Maximum discharge pressure = 50 psi.

50 psi x 2.31 ft/psi = 115.50′

Total dynamic head

85.00′ + 30.43′ + 115.50′ = 231′

FRICTION LOSS CHART

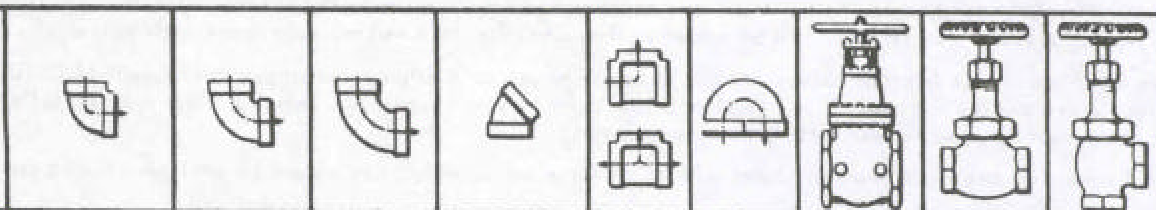
1 1/2 inch to 2 1/2 inch pipe and under 300 GPM

Loss of Head in Feet, Due to Friction Per 100 Feet of Pipe

1 1/2 INCH				2 INCH				2 1/2 INCH			
GPM	Steel	Copper	Plastic	GPM	Steel	Copper	Plastic	GPM	Steel	Copper	Plastic
	C=100	C=130	C=140		C=100	C=130	C=140		C=100	C=130	C=140
	ID=1.61"	ID=1.60"	ID=1.61"		ID=2.067"	ID=2.062"	ID=2.067		ID=2.469"	ID=2.50"	ID=2.469"
4	0.267	0.165	0.144	10	0.431	0.268	0.233	20	0.654	0.375	0.353
6	0.565	0.358	0.305	15	0.916	0.569	0.495	30	1.39	0.792	0.75
8	0.962	0.611	0.52	20	1.55	0.962	0.839	40	2.36	1.35	1.27
10	1.45	0.923	0.785	25	2.35	1.45	1.27	50	3.56	2.04	1.92
12	2.04	1.29	1.1	30	3.29	2.03	1.78	60	4.99	2.86	2.69
14	2.71	1.71	1.46	35	4.37	2.71	2.36	70	6.64	3.82	3.58
16	3.47	2.2	1.87	40	5.6	3.47	3.03	80	8.5	4.88	4.59
18	4.31	2.75	2.33	45	6.96	4.31	3.76	90	10.6	6.06	5.72
20	5.24	3.31	2.83	50	8.46	5.24	4.57	100	12.8	7.37	6.9
25	7.9	5	4.26	55	10.1	6.22	5.46	110	15.3	8.8	8.25
30	11.1	7	6	60	11.9	7.34	6.44	120	18	10.3	9.71
35	14.7	9.35	7.94	70	15.8	9.78	8.53	130	20.9	12	11.3
40	18.9	12	10.2	80	20.2	12.5	10.9	140	23.9	13.7	12.9
45	23.4	14.9	12.63	90	25.1	15.6	13.6	150	27.3	15.6	14.7
50	28.5	18.1	15.4	100	30.5	18.9	16.5	160	30.7	17.6	16.6
55	34	21.5	18.35	110	36.4	22.5	19.7	170	34.3	19.7	18.5
60	40	25.3	21.6	120	42.7	26.6	23.1	180	38.1	21.9	20.6
65	46.4	29	25.1	130	49.6	30.7	26.8	190	42.1	24.2	22.7
70	53.2	33.8	28.7	140	56.9	35.2	30.6	200	46.3	26.6	25
75	60.4	38	32.6	150	64.7	40.1	35	220	55.3	31.8	29.8
80	68.1	43.1	36.8	160	72.8	45.1	39.3	240	66.4	37.4	35.8
85	76.2	47.6	41.2	170	81.4	50.5	44	260	75.3	43.3	41.6
90	84.7	53.6	45.7	180	90.5	56.1	48.9	280	86.3	49.4	46.6
95	93.6	58.8	50.5	190	100	62	54	300	98.1	56.8	52.9
100	103	65.1	56.6	200	110	68	59.4				

Note: The area above the heavy line is recommended for normal operation based on a maximum flow velocity of 5 ft./sec.

FRICTION LOSSES THROUGH PIPE FITTINGS IN TERMS OF EQUIVALENT LENGTHS OF STANDARD PIPE



SIZE OF PIPE (SMALL DIA.)	STANDARD ELBOW	MEDIUM RADIUS ELBOW	LONG RADIUS ELBOW	45° ELBOW	TEE	RETURN BEND	GATE VALVE OPEN	GLOBE VALVE OPEN	ANGLE VALVE OPEN
LENGTH OF STRAIGHT PIPE GIVING EQUIVALENT RESISTANCE FLOW									
1/2"	1.5	1.4	1.1	.77	3.4	3.8	.35	16	8.4
3/4"	2.2	1.8	1.4	1.0	4.5	5.0	.47	22	12.
1"	2.7	2.3	1.7	1.3	5.8	6.1	.6	27	15.
1-1/4"	3.7	3.0	2.4	1.6	7.8	8.5	.8	37	18.
1-1/2"	4.3	3.6	2.8	2.0	9.0	10.	.95	44	22.
2"	5.5	4.6	3.5	2.5	11.	13.	1.2	57	28.
2-1/2"	6.5	5.4	4.2	3.0	14.	15.	1.4	66	33.
3"	8.1	6.8	5.1	3.8	17.	18.	1.7	85	42.
3-1/2"	9.5	8.0	6.0	4.4	19.	21.	2.	99	50.
4"	11.	9.1	7.0	5.0	22.	24.	2.3	110	58.
4-1/2"	12.	10.	7.9	5.6	24.	27.	2.6	130	61.
5"	14.	12.	8.9	6.1	27.	31.	2.9	140	70.
6"	16.	14.	11.	7.7	33.	37.	3.5	160	83.
8"	21.	18.	14.	10.	43.	49.	4.5	220	110.
10"	26.	22.	17.	13.	56.	61.	5.7	290	140.
12"	32.	26.	20.	15.	66.	73.	6.7	340	170.
14"	36.	31.	23.	17.	76.	85.	8.	390	190.
16"	42.	35.	27.	19.	87.	100.	9.	430	220.
18"	46.	40	30.	21.	100.	110.	10.2	500	250.
20"	52.	43.	34.	23.	110.	120.	12.	560	280.
22"	58.	50.	37.	25.	130.	140.	13.	610	310.
24"	63.	53.	40.	28.	140.	150.	14.	680	340.
30"	79.	68.	50.	35.	165.	190.	17.	860	420.
36"	94.	79.	60.	43.	200	220.	20.	1000	500.
42"	120.	95.	72.	50.	240	260.	23.	1200	600.
48"	135.	110.	82.	58.	275	300.	26.	1400	680.

From "Engineering Data On Flow Of Fluids In Pipes." - Crane Co.

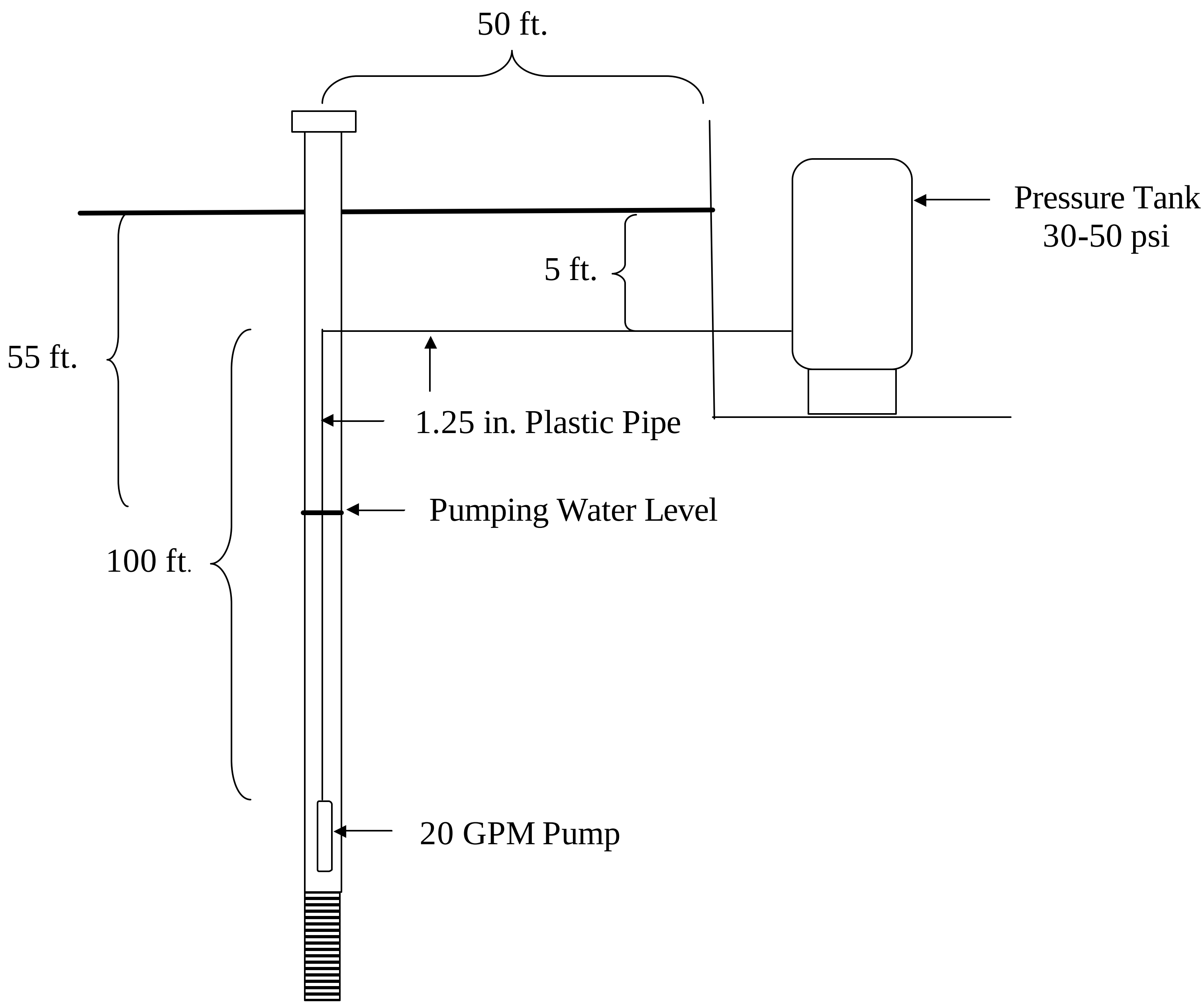
PUMP SELECTION USING A PUMP CURVE

In order to determine if the proposed well pump is properly sized, it is necessary to refer to the pump manufacturer's performance curve or chart, (Pump curves are available upon request from either the pump manufacturer or supplier.) The total dynamic head and desired pump capacity are applied to the pump curve to determine proper pump selection based on required electrical power input and optimum efficiency.

It is recommended that the sanitarian check the pump make and model number, horsepower, and pump capacity as listed on the Water Well and Pump Record to determine if adequately sized pumping equipment has been installed.

To determine proper pump size, locate the point on the pump curve where the pump capacity and total dynamic head intersect and select the pump which will provide the required capacity of water under the particular head conditions. If the point of intersection falls above the curve line, select the next highest pump size.

TOTAL DYNAMIC HEAD PROBLEM #1



TOTAL DYNAMIC HEAD WORKSHEET

Determine Total Elevation Head

1. How many vertical feet is it from the pumping water level to the pressure tank?
_____ ft.

Determine Friction Head

2. What is the pump capacity flow rate through pipe? _____ gpm

3. What is the diameter and material type of the water service line from the well to the pressure tank? Diameter _____in. Material _____________

4. Apply the answers to questions 2 and 3 to a friction loss chart to find the friction head per 100 feet of water service line. _____ ft./100 ft.

5. What is the length of the water service line? _____ ft.

6. What is the friction head for the water service line (multiply the answers for questions 4 and 5). _____ ft.

Example: Friction loss chart shows that 1 inch diameter plastic pipe at 10 gpm flow rate has a friction head loss of 6.3 ft. per 100 ft. $\frac{6.3 \text{ ft.}}{100 \text{ ft.}} \times$ pipe length = friction head

Water service line is 200 ft. in length.

$\frac{6.3 \text{ ft.}}{100 \text{ ft.}} \times 200 \text{ ft.} = 12.6$ ft. friction head

7. What is the diameter and material type of the drop pipe from the pump to the pitless adapter? Diameter _____in. Material _____________

8. Apply the answers to questions 2 and 7 to a friction loss chart to find the friction head per 100 feet of pump drop pipe. _____ ft./100 ft.

9. What is the length of the pump drop pipe? _____ ft.

10. What is the friction head for the water service line? (multiply the answers for questions 8 and 9 – see example in #6 above). _____ ft.

11. What is the total friction head? _____ ft.

Determine Pressure Head

12. What is the pressure switch pump cut-out setting? _____ psi

    Example: The pump cut-out setting is the pressure at which the pump will shut off at the end of the pump operating cycle. If the pressure switch setting is 30-50 psi, the pump cut-out setting is 50 psi.

13. Determine the pressure head by converting the answer from question 12 from pound per square inch to feet of head by multiplying it by 2.31 ft./psi. _____ ft.

    Example: 50 psi x 2.31 ft./psi = 115.5 ft.

Determine Total Dynamic Head

14. Determine TDH by adding answers for questions 1, 11, and 13.

Total dynamic head = _____ ft

- ANSWER #1-

TOTAL DYNAMIC HEAD WORKSHEET

Determine Total Elevation Head

1. How many vertical feet is it from the pumping water level to the pressure tank? _50__ ft.

Determine Friction Head

2. What is the pump capacity flow rate through pipe? _20__ gpm

3. What is the diameter and material type of the water service line from the well to the pressure tank? Diameter _1.25_in. Material __plastic__

4. Apply the answers to questions 2 and 3 to a friction loss chart to find the friction head per 100 feet of water service line. __6__ ft./100 ft.

5. What is the length of the water service line? __50_ ft.

6. What is the friction head for the water service line (multiply the answers for questions 4 and 5). __3__ ft.

   Example: Friction loss chart shows that 1 inch diameter plastic pipe at 10 gpm flow rate has a friction head loss of 6.3 ft. per 100 ft. $\frac{6.3 \text{ ft.}}{100 \text{ ft.}} \times$ pipe length = friction head

   Water service line is 200 ft. in length.

   $\frac{6.3 \text{ ft.}}{100 \text{ ft.}} \times 200 \text{ ft.} = 12.6$ ft. friction head

7. What is the diameter and material type of the drop pipe from the pump to the pitless adapter? Diameter _1.25_in. Material __plastic_

8. Apply the answers to questions 2 and 7 to a friction loss chart to find the friction head per 100 feet of pump drop pipe. __6__ ft./100 ft.

9. What is the length of the pump drop pipe? _100_ ft.

10. What is the friction head for the water service line? (multiply the answers for questions 8 and 9 – see example in #6 above). __6__ ft.

11. What is the total friction head? __9__ ft.

Determine Pressure Head

12. What is the pressure switch pump cut-out setting? __50_ psi

    Example: The pump cut-out setting is the pressure at which the pump will shut off at the end of the pump operating cycle. If the pressure switch setting is 30-50 psi, the pump cut-out setting is 50 psi.

13. Determine the pressure head by converting the answer from question 12 from pound per square inch to feet of head by multiplying it by 2.31 ft./psi. _115_ ft.

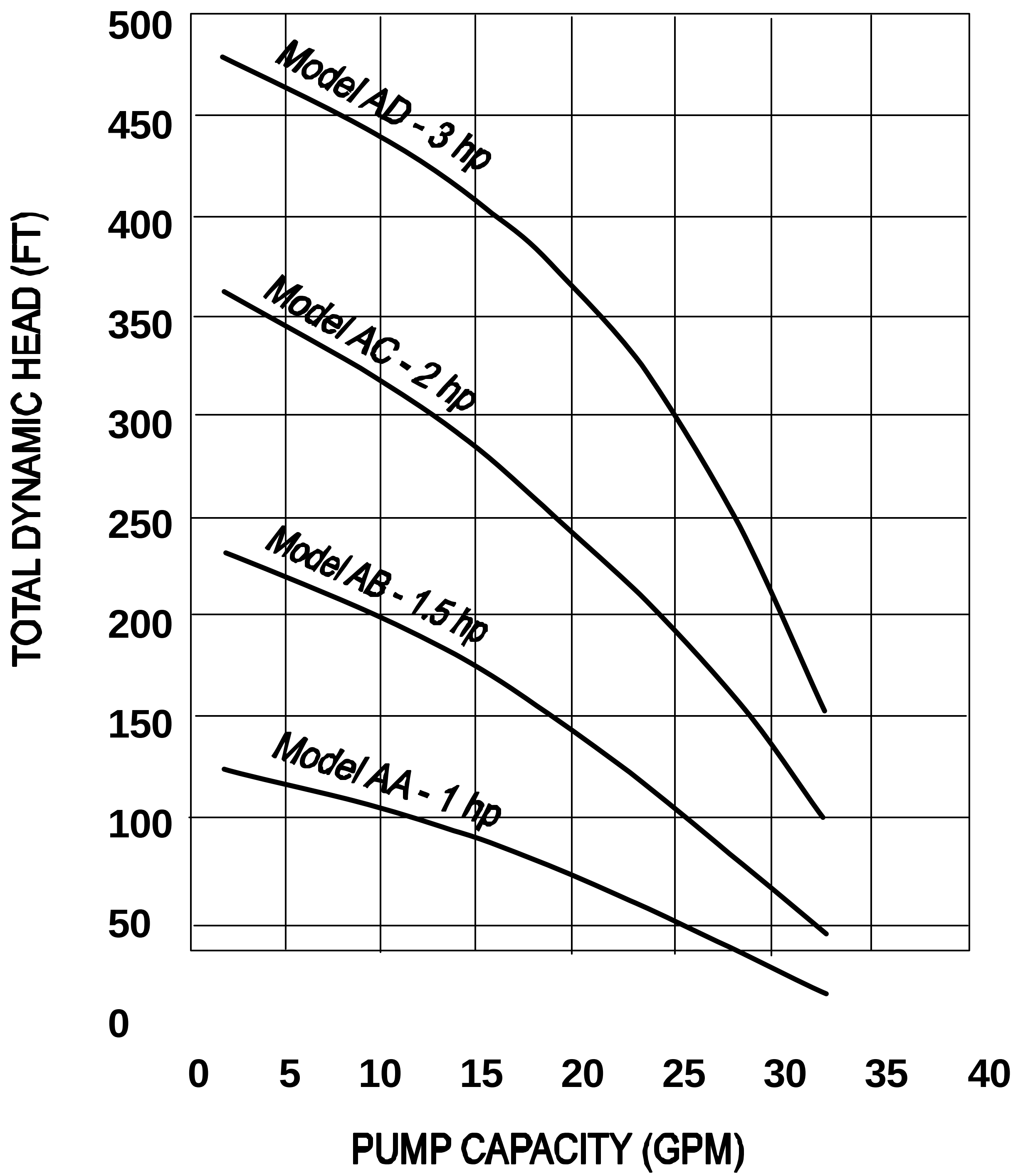
    Example: 50 psi x 2.31 ft./psi = 115.5 ft.

Determine Total Dynamic Head

14. Determine TDH by adding answers for questions 1, 11, and 13.

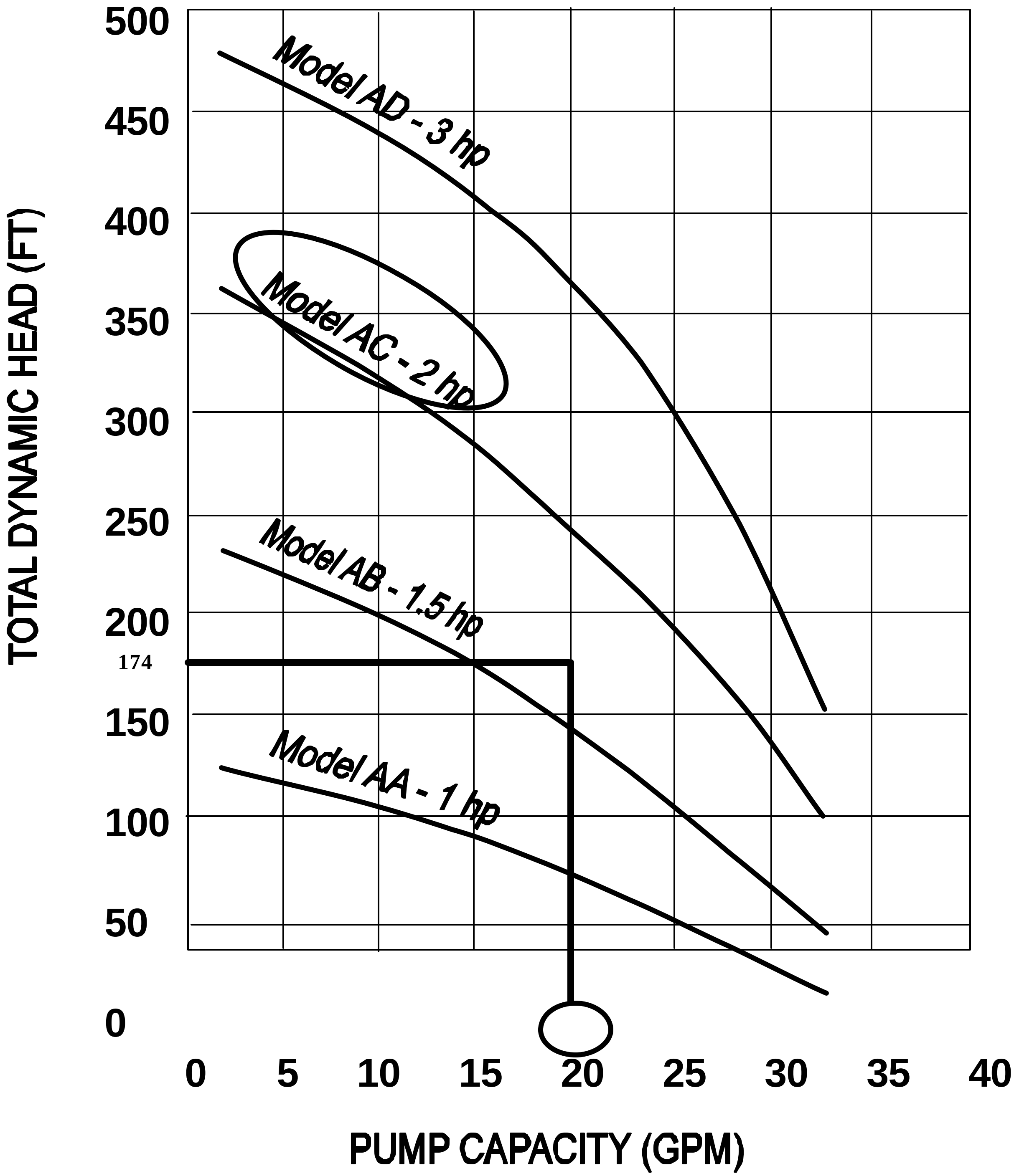
Total dynamic head = _174_ ft.

PUMP CURVE

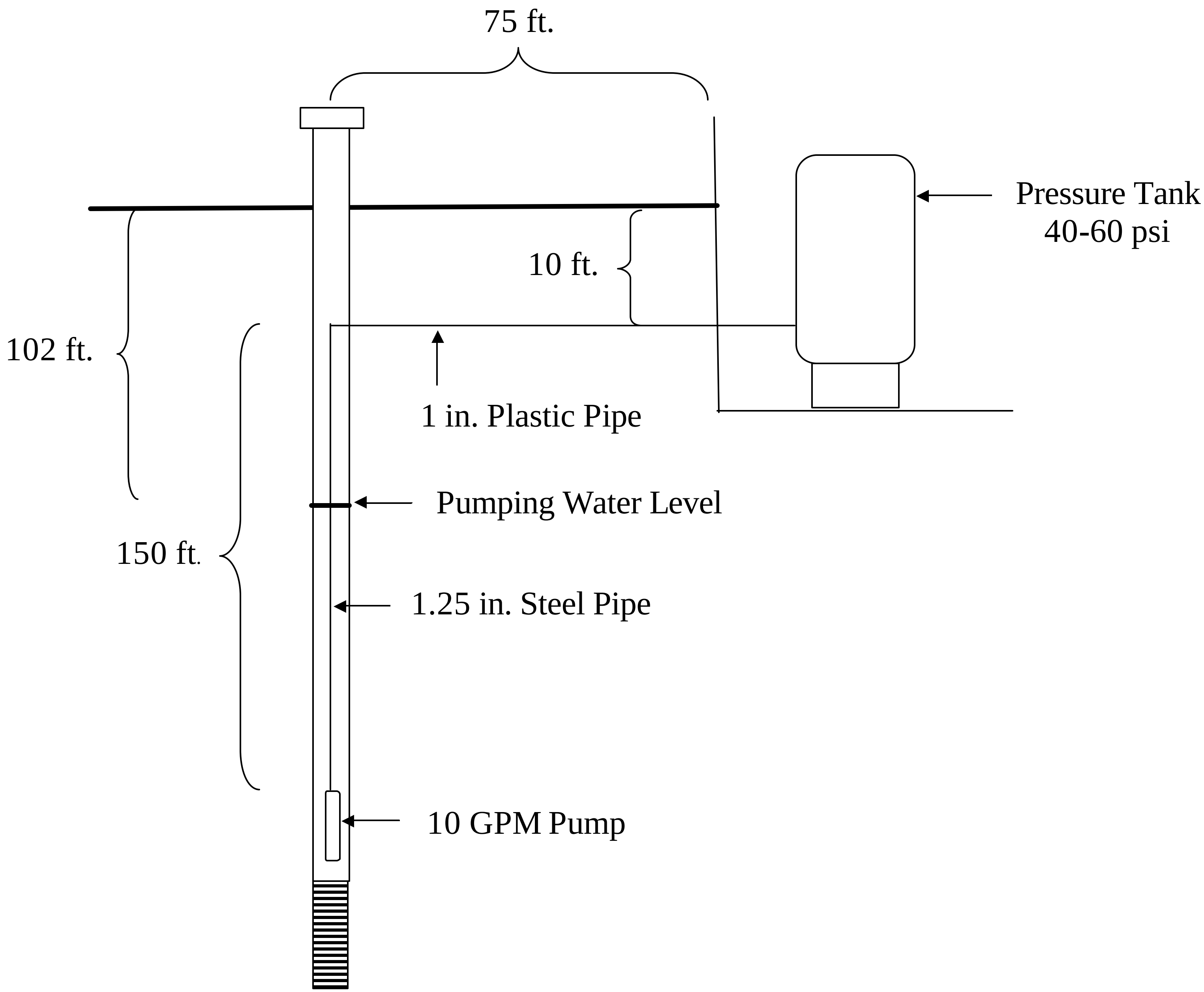


TOTAL DYNAMIC HEAD (FT)
500
450
400
350
300
250
200
150
100
50
0
Model AD - 3 hp
Model AC - 2 hp
Model AB - 1.5 hp
Model AA - 1 hp
0
5
10
15
20
25
30
35
40
PUMP CAPACITY (GPM)

PUMP CURVE #1


TOTAL DYNAMIC HEAD (FT)
500
450
400
350
300
250
200
174
150
100
50
0
Model AD - 3 hp
Model AC - 2 hp
Model AB - 1.5 hp
Model AA - 1 hp
0
5
10
15
20
25
30
35
40
PUMP CAPACITY (GPM)

TOTAL DYNAMIC HEAD PROBLEM #2



- ANSWER #2-

TOTAL DYNAMIC HEAD WORKSHEET

Determine Total Elevation Head

15. How many vertical feet is it from the pumping water level to the pressure tank?
__92__ ft.

Determine Friction Head

16. What is the pump capacity flow rate through pipe? __10__ gpm

17. What is the diameter and material type of the water service line from the well to the pressure tank? Diameter __1__ in. Material __plastic__

18. Apply the answers to questions 2 and 3 to a friction loss chart to find the friction head per 100 feet of water service line. __6.3__ ft./100 ft.

19. What is the length of the water service line? __75__ ft.

20. What is the friction head for the water service line (multiply the answers for questions 4 and 5).
__4.7__ ft.

Example: Friction loss chart shows that 1 inch diameter plastic pipe at 10 gpm flow rate has a friction head loss of 6.3 ft. per 100 ft. $\frac{6.3 \text{ ft.}}{100 \text{ ft.}}$ x pipe length = friction head

Water service line is 200 ft. in length.

$\frac{6.3 \text{ ft.}}{100 \text{ ft.}} \times 200 \text{ ft.} = 12.6$ ft. friction head

21. What is the diameter and material type of the drop pipe from the pump to the pitless adapter?
Diameter __1.25__ in. Material __steel__

22. Apply the answers to questions 2 and 7 to a friction loss chart to find the friction head per 100 feet of pump drop pipe. __3.1__ ft./100 ft.

23. What is the length of the pump drop pipe? __150__ ft.

24. What is the friction head for the water service line? (multiply the answers for questions 8 and 9 – see example in #6 above). __4.6__ ft.

25. What is the total friction head? __9.3__ ft.

Determine Pressure Head

26. What is the pressure switch pump cut-out setting? __60_ psi

    Example: The pump cut-out setting is the pressure at which the pump will shut off at the end of the pump operating cycle. If the pressure switch setting is 30-50 psi, the pump cut-out setting is 50 psi.

27. Determine the pressure head by converting the answer from question 12 from pound per square inch to feet of head by multiplying it by 2.31 ft./psi. _138_ ft.

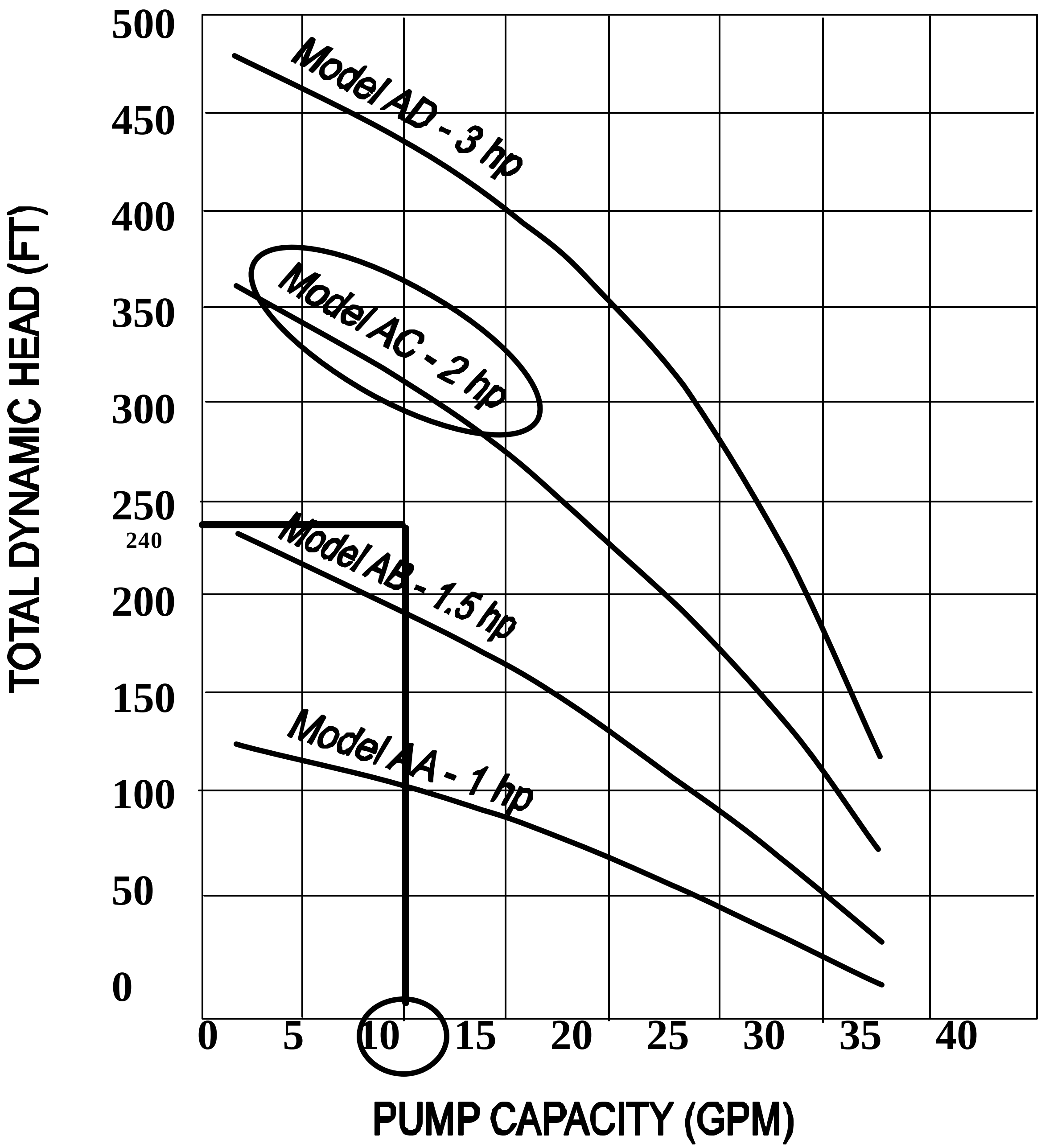
    Example: 50 psi x 2.31 ft./psi = 115.5 ft.

Determine Total Dynamic Head

28. Determine TDH by adding answers for questions 1, 11, and 13.

    Total dynamic head = _239.3_ ft.

PUMP CURVE #2


TOTAL DYNAMIC HEAD (FT)
500
450
400
350
300
250
240
200
150
100
50
0
Model AD - 3 hp
Model AC - 2 hp
Model AB - 1.5 hp
Model AA - 1 hp
0
5
10
15
20
25
30
35
40
PUMP CAPACITY (GPM)

DETERMINING STORAGE CAPACITY

INTRODUCTION

The basic functions of a storage tank are to minimize wear of electrical starting components, increase pump life by preventing rapid stopping and starting (short cycling), and provide water under pressure for delivery between pump cycles. Generally, there is more friction to overcome, and therefore, more electrical energy is required for starting larger pumps as opposed to smaller. As a result, larger pumps should be allowed to operate for longer periods of time than smaller domestic pumps. In a properly designed system, the storage tank should be sized to insure a minimum pump running time consistent with the cycling rate recommended by the manufacturer. Where no cycling rate is specified, Table I may be used as a guide:

TABLE 1.

Gallons per Minute	Pump Running Time (Min.)
10 - 20	1
21 - 50	2
51 - 75	3
76 - 100	4
>100	Consult MDEQ

BLADDER OR DIAPHRAGM TYPE TANK WITH PRECHARGE

The available water capacity in gallons (draw-off) should equal or exceed the pump capacity times minimum pump running time. The available water in a precharge tank at a 30-50 psi setting is about 25 percent of the total tank volume. Figures on amounts of available water under various pressure settings can be obtained from the tank manufacturers' specifications.

EXAMPLE

25 gpm x 2 min. running time = 50 gallons of available water

Total volume (T) x 25% = 50 gallons. Therefore ...

T x .25 = 50 gallons $\qquad T = \frac{50}{.25} \qquad$ T = 200 gallons

Total volume of bladder or diaphragm tank with precharge = 200 gallons

CONVENTIONAL STEEL TANK (no bladder or diaphragm) WITH PRECHARGE

Available draw-off should equal or exceed the pump capacity times minimum pump running time. The available water in the steel tank with pre-charge with a 30-50 psi setting is about 20 percent of the total tank volume when the high water level is maintained at 55 percent of total capacity. *(Note:* If the high water level becomes greater than 55 percent, less usable capacity is available; i.e., at 70 percent, usable capacity is 13 percent and then the tank is becoming water logged), EXAMPLE

25 gpm x 2 min. running time = 50 gallons of available water

Total volume (T) x 20% = 50 gallons. Therefore ...

T x .20 - 50 gallons $T = \frac{50}{.20}$ T = 250 gallons

Total volume of conventional steel tank with pre-charge = 250 gallons

CONVENTIONAL STEEL TANK WITH NO PRE-CHARGE

Available draw-off should equal or exceed the pump capacity times minimum pump running time. The available water in the steel tank without precharge with a 30-50 psi setting is about 10 percent of the total tank volume.

EXAMPLE

25 gpm x 2 min. running time = 50 gallons of available water

Total volume (T) x 10% = 50 gallons. Therefore ...

T x .10 = 50 gallons $T= \frac{50}{.10}$ T = 500 gallons

Total volume of conventional steel tank without pre-charge = 500 gallons

The examples given use 30-50 psi as the assumed pressure switch setting, since 30-50 psi is now becoming more common to the water well industry than the 20-40 psi setting. Variations in system operating pressure and pre-charging of pressure tanks will alter the amount of available water (draw-off) from the pressure tank, Table 2 shows that precharging of the tank increases the draw-off, and increasing the operating pressure of the system decreases the tank draw-off. Operating pressure and tank precharge pressure must be taken into consideration when evaluating proposed storage facilities.

TABLE 2
GALLONS DRAW-OFF PER PUMP CYCLE

		Total Tank Volume		
		42 gal.	82 gal.	120 gal.
20-40 psi system pressure	no precharge	6.5	12.8	18.6
	10 psi precharge	10.8	21.3	31.0
	15 psi precharge	13.0	25.6	37.4
30-50 psi system pressure	no precharge	4.3	8.4	12.3
	15 psi precharge	8.6	16.8	24.6
	20 psi precharge	10.0	19.6	28.7
	25 psi precharge	11.5	22.4	32.8

For details on water storage facilities for flowing wells or for situations where the well cannot produce the minimum desired capacity, consult MDEQ, Water Bureau.

PRESSURE TANK STORAGE CAPACITY CALCULATIONS

A well has just been completed for a proposed residence. Due to local geological conditions, the well will produce only 7 gpm. The residence will have 4 bedrooms and 2 full bathrooms and a total of 15 water using fixtures. The estimated peak water demand for the residence based on 1 gprn per fixture is 15 gpm for a 7 minute peak demand period. In order to meet the peak demand for the residence, the difference between the peak demand and the pump capacity must be provided by the storage tank. The following procedure may be used for determining the size of the storage tank to be installed.

Determine the total volume of water that will he used during the peak period by multiplying the peak demand by the peak demand period.

15 gpm x 7 minutes = 105 gallons

Determine the total volume of water delivered by the pump during the peak demand period by multiplying the pump capacity by the peak demand period.

7 gpm x 7 minutes = 49 gallons

Determine the volume of water to be provided from storage by finding the difference between the amount of water produced by the pump during the peak demand period and the total volume of water used during the peak demand period.

105 gallons - 49 gallons = 56 gallons

In most cases a precharged diaphragm type pressure tank will he installed. It is necessary to consult the manufacturer's specifications to determine which model tank will provide the required volume of water at the desired operating pressure.

A typical tank manufacturer's specification sheet would include a table similar to that shown below. Select the model tank or a combination of tanks that will provide the 56 gallons of water at a 20-40 psi operating range.

		DRAWDOWN (AVAILABLE VOLUME IN GAL.)		
MODEL	**TOTAL CAPACITY**	**20-40 psi**	**30-50 psi**	**40-60 psi**
A	20 gal.	6.8	6.9	5.1
B	30 gal.	10.3	8.8	7.7
C	40 gal.	13.7	11.8	10.3
D	80 gal.	27.8	23.8	20.8
E	120 gal.	41.4	35.4	31.0

In order to provide 56 gallons of available storage, it would be necessary to install 2 Model A tanks (27.8 gal. x 2 = 55.6 gal.), a Model E and C tank (41.4 + 13.7 = 55.1 gal.), or another combination totaling close to 56 gallons of tank drawdown.

CONSTANT PRESSURE SYSTEMS

Constant pressure (CP) technology for water well systems is becoming increasingly popular. Pump manufacturers are marketing the new technology as the biggest advancement since the development of the submersible pump. Sanitarians should become familiar with CP systems and the differences between conventional pump/pressure tank system and CP system design and operation.

Two methods are used to control the water pressure in CP systems: variable frequency drives (VFDs), also known as variable speed pumps, and pressure control valves (PCVs). A system using a VFD provides constant pressure over a fairly broad range of flow rates by electronically changing the speed of the motor as the water demand changes. The second means of furnishing CP is by installing a pressure control valve (PCV). PCVs are installed upstream of the pressure tank, between the pump and the pressure switch. They respond to downstream pressure by automatically opening or closing a valve to maintain system pressure. PCVs are used with standard submersible pumps that do not have variable speed motors

VFDs and PCVs are designed to provide consistent pressure to the building occupants and eliminate pressure fluctuations that occur with a conventional system. CP system manufacturers advertise that they provide steady "city-like" water pressure, which does not fluctuate as in a conventional water well system. Space limitations are minimized with the VFD pumps because a large pressure tank is not necessary to make the system work correctly. A much smaller pressure tank can be used to control a VFD system. A VFD system may also save on electrical costs by minimizing the number of starts and stops. Another VFD benefit is the reduction of water hammer.

Conventional pressure tank sizing methodology is not applicable to VFD systems, because the need to achieve a minimum pump run time (as with conventional fixed speed pumps) is not a concern. Therefore, the traditional pressure tank sizing criteria found in MDEQ, Water Division and Noncommunity Manuals should not be applied to VFD systems. To determine appropriate pressure tank sizes for VFD systems follow the manufacturer’s installation specifications.

More and more well drillers and facility owners are expected to request approval to install VFD systems. Sanitarians can approve the installation of these systems with the appropriate reduction in pressure tank sizing for VFD systems. Pressure tank sizes are not reduced for PCV installations unless there is continuous water usage; such as community and large industry process water usage or irrigation systems that are using water continually. Therefore, the pump must be sized to meet the requisite peak demand/well capacity requirements and the pressure tank is sized to meet the pump manufacturers sizing requirements.

Some PCVs have internal check valves that violate state well code provisions. Product specifications should be checked to ensure that the particular PCV proposed to be used does not have a check valve and will comply with state regulations.

RESIDENTIAL WATER SYSTEM SIZING

INTRODUCTION

A properly designed residential water supply system should deliver water at the desired quantity, quality, and pressure to any outlet on the system during periods of heaviest use. To accomplish this, the peak demand for the home is determined and the well and pump are sized to meet or exceed the demand. If local geological conditions prohibit the development of a water supply with quantity to meet the demand, additional storage facilities are necessary.

DETERMINING THE PUMP CAPACITY

A simple method of determining pump capacity is based on the number of water using fixtures or outlets. The pump capacity (in gallons per minute or GPM) should equal the total number of fixtures in the home.

EXAMPLE

> The Smith residence has 2 bathrooms (each with a water closet, tub/shower, and lavatory), kitchen sink, garbage disposal, dishwasher, washing machine, laundry sink, and 3 outside hose bibs. A total of 14 fixtures are present. Therefore, the minimum pump capacity should be 14 gpm.

Peak demand periods occur when several fixtures are used at the same time. The average time of high water usage from fixtures such as showers, dishwashers, washing machines, etc., is seven (7) minutes. The seven minute peak demand and minimum pump size for modern residences may be obtained from Table 1.

TABLE 1

No. of Bathrooms	7 Minute Peak Demand (GAL)*	Minimum Pump Size to Meet PD (GPM)**
1	45	7
1.5	70	10
2 to 2.5	98	14
3 to 4	122	17

* Includes water usage for kitchen sink, washing machine, and dishwasher. Additional demand for farm, irrigation, and sprinkling must be added to peak demand figures if usage will occur during peak demand periods.

** Minimum pump size to meet peak demands without supplemental storage.

PUMP CAPACITY MEETS OR EXCEEDS DEMAND

If the actual pump capacity is equal to or exceeds the minimum pump size indicated in Table 1, supplemental storage is not required. The pressure tank should then be sized to provide a tank draw-off equal to the pump capacity for a one to two minute pump cycle.

EXAMPLE

The well for the Smith residence is capable of sustaining a 14 gpm pump. Table 1 indicates the 7 minute peak demand for the Smith's 2-bathroom home is 98 gpm. Since the 14 gpm pump will supply 98 gallons during the 7 minute peak period, supplemental storage is not necessary. A one minute pump cycle would produce 14 gallons of water. Therefore, the pressure tank selected should provide a minimum draw-off (available water volume) of 14 gallons. If a two minute pump cycle were desired, the pressure tank should be sized to provide 28 gallons of available water. Manufacturer's specifications should be consulted to determine which model pressure tank will supply the necessary volume at the desired operating pressure.

PUMP CAPACITY LESS THAN DEMAND

If the actual pump capacity is less than the minimum pump size indicated in Table 1, supplemental storage is necessary to meet peak demands. The difference between the 7 minute peak demand and the amount of water provided by the pump during a 7 minute period is the volume that must be provided from storage. The pressure tank should then be sized to provide a tank draw-off equal to the difference between the 7 minute peak demand and the 7 minute pump capacity.

EXAMPLE

The well for the Jones residence is capable of sustaining a 10 gpm pump. The 7 minute peak demand for the Jones residence is 98 gpm. During the 7 minute period, the pump will produce 70 gallons of water. 98 – 70 = 28 gallons. Twenty eight gallons must be supplied from storage during the 7 minute peak demand period. Therefore, the pressure tank selected should provide a minimum draw-off (available water volume) of 28 gallons.

The additional volume required can also be provided by precharging the pressure tank and adjusting the pressure switch settings. Precharging is the addition of air to the pressure tank. If the precharge pressure is about 5 psi below the pump cut-in pressure, supplemental supply is obtained from the tank. When the demand exceeds the pump capacity the pressure will drop, and the supplemental supply from the tank will be used to meet the demand.

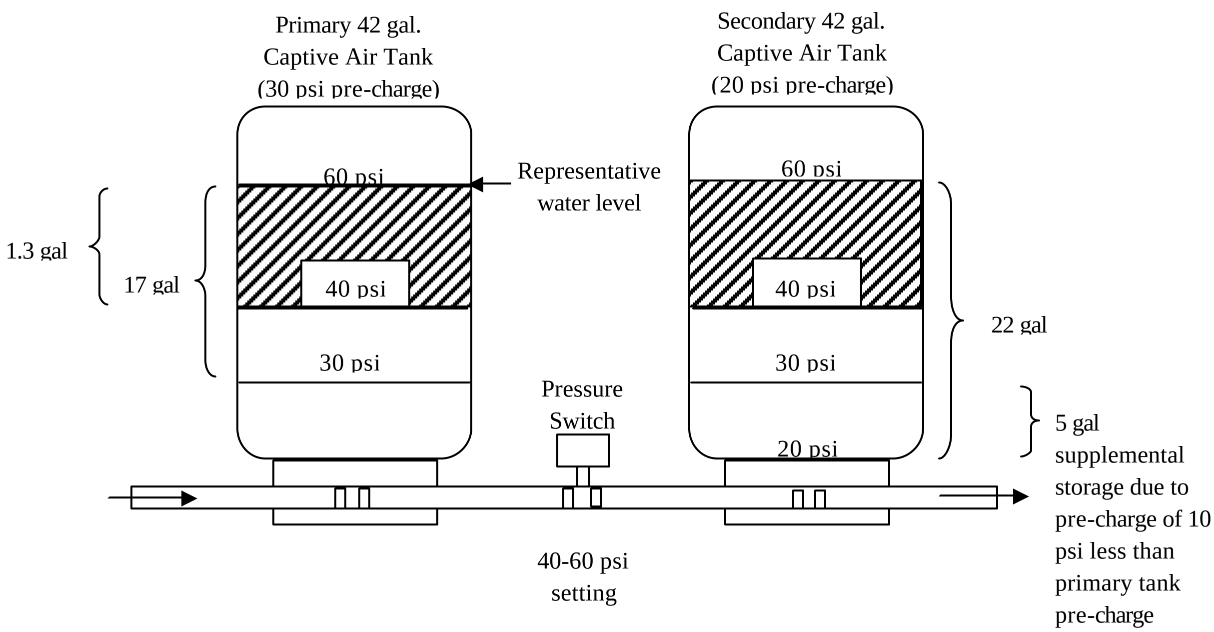
EXAMPLE

It was determined that the minimum tank draw-off for the Jones residence should be 28 gallons. If a 120 gallon plain steel tank (no diaphragm) were installed and operated at 30-50 psi without a precharge, about 10 percent of the total tank volume, or 12 gallons (from manufacturer's specifications) would be available from the tank. By lowering the operating pressure to 20-40 psi and precharging the tank to 15 psi the usable tank capacity will increase to 37.4 gallons or 31 percent. This volume would then meet the 7 minute peak demand.

If an additional pressure tank is installed for supplemental storage, the precharge of the second tank should be lower than that of the primary tank. The differential pressure switch range should also be set closer. This will increase the overall operating range of the system and provide additional water for peak demand.

EXAMPLE

The Black residence has a 7 minute peak demand of 70 gallons. The Blacks complain of running out of water and have requested that additional storage be added. The well produces 5 gpm and a 42 gallon diaphragm-type captive air tank is currently installed. The system is operating at 30-50 psi and the tank has a precharge of 30 psi. During the 7 minute peak demand, the pump will produce 35 gpm. 70 – 35 = 35 gallons. Thirty five gallons must be produced from storage during the 7 minute peak demand period. Therefore, the present tank plus the additional tank must provide at least 35 gallons of water. The usable capacity of the existing tank is about 31 percent or 13 gallons. Therefore, the supplemental storage must provide 22 gallons of water. If an additional 42 gallon tank, precharged to 20 psi, is installed and the pressure switch adjusted to 40-60 psi, the usable capacity o the primary tank will increase to 17 gallons and the second tank will provide about 22 gallons. The pressure tanks will provide water over a 40 psi differential, from 20-60 psi, and the total volume of available water from the pressure tank has now increased to 39 gallons. When the pressure drops, to the pump cut-in pressure of 40 psi, there will be about 5.7 gallons left in the primary tank and 10.7 gallons in the secondary tank. If the demand lowers the pressure to 30 psi, the first tank will essentially be out of water and 5 gallons will remain in the secondary tank. If the pressure continues to decrease to 20 psi, both tanks will be out of water and the only supply will be from the pump. The diagram below illustrates this installation.



Reference: Water Systems Handbook, 7th Edition, 1980.
Water Systems Council, 221 N. LaSalle St., Chicago, IL 60601

HYDROGEOLOGIC DEFINITIONS

Artesian Aquifer
An aquifer where ground water is under sufficient pressure to rise above the level at which it is encountered. A flowing artesian well is a well completed in such an aquifer where water will rise above the ground surface.

Cone of Depression
In flowing through a porous media, the hydraulic gradient varies directly with the velocity (according to Darcy's Law). With increasing velocity, the hydraulic gradient increases as flow converges toward a well. As a result, the lowered water surface develops a continually steeper slope toward the well. The form of this surface resembles a cone-shaped depression.

Darcy's Law
The flow of water through a column of saturated sand is proportional to the difference in hydraulic head at the ends of the column and inversely proportional to the length of the column.

Drawdown
The extent of lowering of the water level when pumping is in progress or when water is discharging from the flowing well. Drawdown is the difference, measured in feet, between the static water level and the pumping level.

Flow velocity
The rate in distance per unit of time that ground water moves through a soil or rock.

Head
Pressure of water on an area due to the height at which the water stands above the point where the pressure is determined.

Hydraulic gradient
The rate of change in pressure head per unit distance of flow at given points in a given direction.

Permeability
A rock type or soil's capacity for transmitting a fluid. The coefficient of permeability is the rate of flow in gallons per day/square foot.

Piezometric Surface
The surface to which the water from a given aquifer will rise under its full head. (Also known as potentiametric surface.)

Porosity
The ratio, measured in percent, of soil or rock void volume per total volume.

Pumping Level

The level at which water stands in the well when pumping is in progress. In a flowing well, it is the level at which water may be flowing from the well.

Radius of Influence

The distance from the center of the well to the limit of the cone of depression.

Recovery

After pumping is stopped, water levels rise and approach the static water level observed before pumping started.

Specific Capacity

Specific capacity of a well is its yield per unit of drawdown, usually expressed as gpm per foot of drawdown. Dividing the yield by the drawdown, each measured at the same time, gives the value of the specific capacity. As an example, if the pumping rate is 160 gpm at 20 feet of drawdown, the specific capacity is 8 gpm/foot drawdown at the time the measurements are taken.

Static Water Level

The level at which water stands in a well when no water is being taken from the aquifer by pumping or free flow. It is usually expressed as the distance from the ground surface to the water level in the well. For a flowing well, the static water level is above the ground surface.

Transmissivity

The capacity of an aquifer material to transmit water under the influence of a pressure gradient.

Well Interference

Drawdown in a pumping well due to drawdown from another pumping well.

Well Yield

The volume of water per unit of time discharged from a well, either by pumping or by free flow. The pumping rate is commonly measured in gallons per minute (gpm). Other units used are gallons per hour (gph) for small yields and cubic feet per second (cfs) for large yields.

Water Table Aquifer

The upper surface of a zone of saturation.

PUMPING WELL DIAGRAM