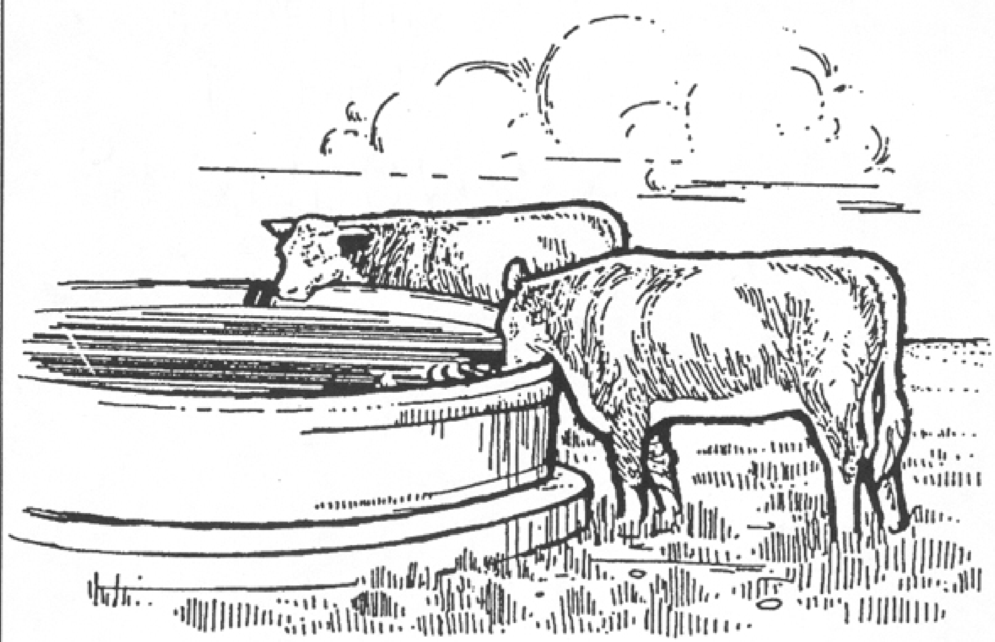
Montana Stockwater Pipeline Manual



USDA Natural Resources Conservation Service
Bozeman, Montana

January 1992

December 2004 (Minor Edits)

MONTANA

STOCKWATER PIPELINE MANUAL

January 1992

USDA Natural Resources Conservation Service
Bozeman, Montana

December 2004 (Minor Edits)

MONTANA STOCKWATER PIPELINE MANUAL

TABLE OF CONTENTS

MONTANA STOCKWATER PIPELINE MANUAL

TABLE OF CONTENTS (continued)

CHAPTER 7 AIR CONTROL

CHAPTER 8 SYSTEM ACCESSORIES

CHAPTER 9 HYDRAULIC DESIGN PROCEDURES

CHAPTER 10 STOCKWATER PIPELINE INSTALLATION

CHAPTER 11 OPERATION AND MAINTENANCE

APPENDICES

Chapter 1

Introduction

CHAPTER 1 INTRODUCTION

TABLE OF CONTENTS

Chapter 1

Introduction

1.1 PURPOSE AND OBJECTIVES

The purpose of the Montana Stockwater Pipeline Manual is to provide Natural Resources Conservation Service (NRCS) personnel and others, where appropriate, with detailed technical information and procedures which may be used for planning, design and management of stockwater pipelines in Montana.

Stockwater pipelines are installed to (1) provide improvement in the beneficial use of rangeland by providing better distribution of livestock, (2) prevent loss of water by evaporation and seepage, (3) maintain and improve the plant community, and (4) prevent erosion resulting from overgrazing near water sources.

This manual is only a guide, it does not set NRCS policy or standards. Policy and standards are set by NRCS documents such as the National Planning Manual, the National Engineering Manual, and the practice standards as contained in Section 4 of the Field Office Technical Guide (FOTG).

FOTG standards and specifications must be used in conjunction with conservation practices and procedures covered by this manual. Best available procedures and data should always be used, whether or not they are in this manual.

1.2 GENERAL

Stockwater pipelines come in many configurations and sizes in Montana. They may consist of anything from a short piece of pipe between a spring and stock tank, to many miles of long pipelines with pressures at the low point as high as 500 psi. Design may be as critical for a short pipeline as for a long one.

Consider what can happen if a pipeline fails. If there are little or no backup water available in a field, and the problem is not discovered promptly, livestock will die. During hot, dry, weather a cow can only last three or four days without water.

A stockwater pipeline can be a great improvement over previously used watering systems. Stockwater ponds tend to dry up at the worst times, windmills often don't work when they are needed and hauling water is an unpopular, losing proposition. On the other hand a stockwater pipeline can be made to be a very dependable water distribution system. Not only can it be dependable, but good quality water can be delivered to optimum locations to promote good grazing distribution and healthy animals.

Planning and design of a stockwater pipeline may be complex and pipelines can be a significant investment. It is very important that they be correctly planned and designed and be as economical as possible. This manual is dedicated to providing some of the information and tools needed to get this job done.

Chapter 2

Planning Considerations

CHAPTER 2 PLANNING CONSIDERATIONS

TABLE OF CONTENTS

FIGURES

TABLES

Chapter 2

Planning Considerations

2.1 GENERAL

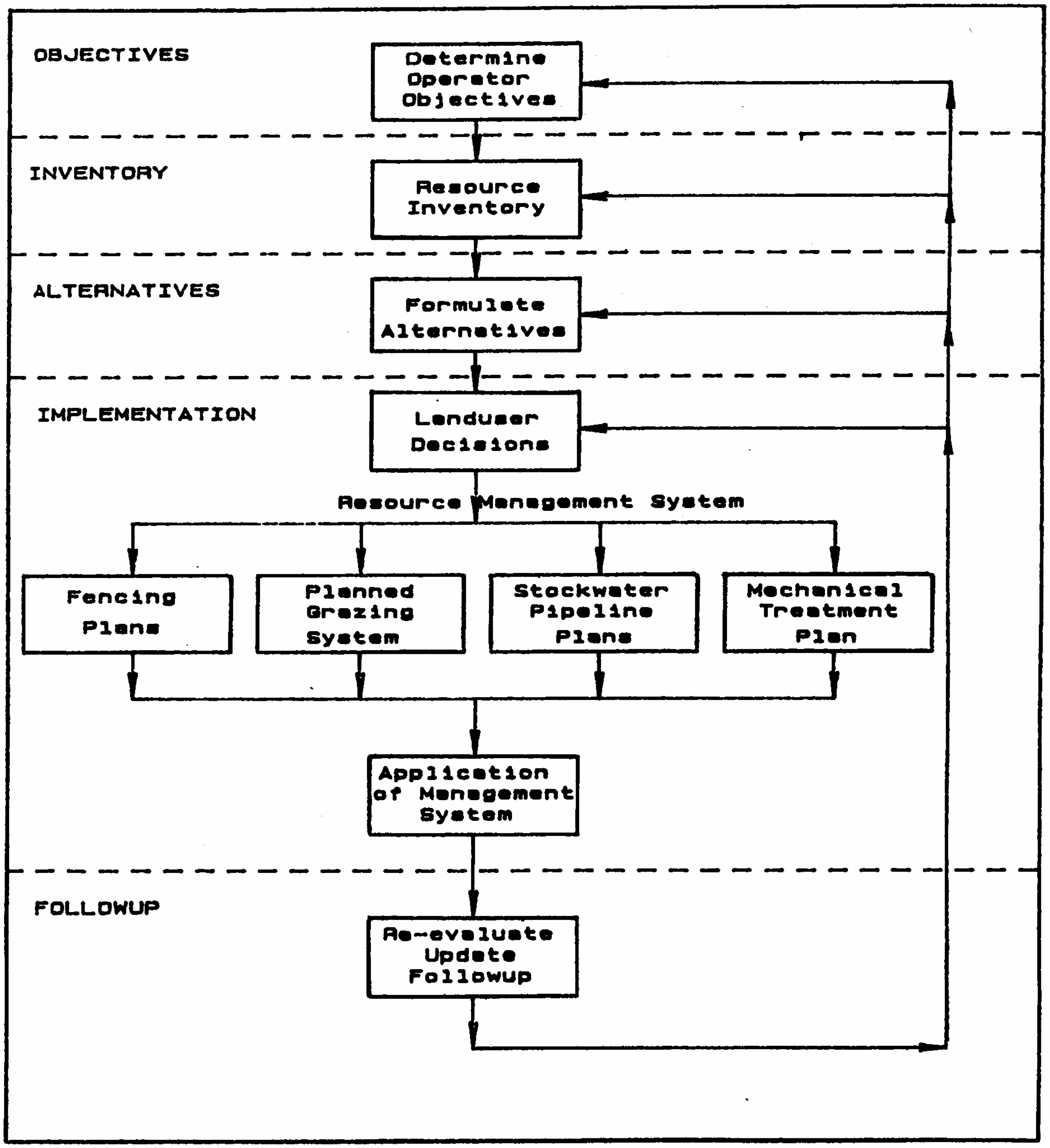
When planning a stockwater pipeline, it is always important to follow good resource planning procedures. Figure 2.1 illustrates the NRCS planning process as it relates to stockwater pipelines. The planning processes must be followed, even when we are involved with a system where the landowner knows exactly what he wants and we are in a rush to get the job done.

To do otherwise frequently leads to such problems as:

- System that does not meet resource conservation needs
- System that does not meet the needs of the cooperator
- System that cannot later be expanded
- An overly expensive system

Figure 2.1

STOCKWATER PIPELINE PLANNING PROCEDURE



2.2 PLANNING PROCEDURE

2.2.1 Objectives

Find out about the landowner's objectives. Does he or she want a more dependable supply of water, better grazing distribution, better water, or what? We also need to remember why we are involved and our objectives. They are to maintain the resource base, to maintain quality in the standard of living and to maintain or enhance the environment. We accomplish this by aiding the landuser in the development of a Resource Management System (RMS). These objectives should be clearly in mind before we start the next step.

2.2.2 Resource Inventory

Information which must be obtained when planning a stockwater pipeline system includes:

- The annual grazing period, including whether or not the pipeline will need to operate in freezing weather.
- The types and maximum number of livestock which will use water at any given time.
- The type of grazing system to be used.
- The area to be serviced by the pipeline.
- Location and details of existing water sources in the area to be serviced by the pipeline.
- Reliability and quality of existing water sources in the area to be serviced by the pipeline.
- Location, reliability and quality of water source or sources which may be used as a supply for the pipeline.
- Desirable watering locations, based on an analysis of range use patterns, range conditions, geology and topography.
- Geologic considerations including location of shallow bedrock, unstable soils, coarse gravel subsoils, old slide areas, wetland areas, sharp breaks in slope, etc.
- If wetland areas are to be traversed, a determination as to requirements or limitations involved in crossing the wetland.
- Property line and ownership considerations.
- Topographic information, including any necessary engineering surveys or study of topographic maps.

The worksheet illustrated in Figure 2.2 may be used as an aid in obtaining necessary resource information.

Figure 2.2
STOCKWATER PIPELINE RESOURCE INVENTORY WORKSHEET

U.S. Department of Agriculture
Soil Conservation Service

MT-ENG-20
1/1/92

STOCKWATER PIPELINE
RESOURCE INVENTORY WORKSHEET

Land user *Ed Stockman*
Job description *South pasture Pipeline*
Farm No. *532* Tract No. *3* Field No. *2* County *Gallatin*
Planner *J. Tech* Date *11/5/91* Checked by *JCD* Date *11/10/91*

Type of livestock *Cow-calf*

Type of grazing system: /X/ Conventional /_/ Intensive

Maximum number of livestock (No.) *100*

Typical dates stock will be in field: From *June* to *August*

Water requirements per head (V) *20* gal/day/head at peak use.

Total usage per day (T) = no x V = *100* x *20* = *2000* gal/day.

Add 10% for evaporation and spillage: (GT) = T + 10% T (optional)
GT = *2000* + .10 x *2000* = *2200* gal/day

Minimum required flow rate (Qm) = $\frac{GT}{1440}$ = $\frac{2200}{1440}$ = *1.53* gpm.

Desired number of hours for entire days needs to be delivered:

TT = *12* hrs

Design Flow Rate: (Q) = $\frac{24}{TT}$ x Qm

Q = $\frac{24}{12}$ x *1.53* = *3.06* gpm

Desired reserve storage time (RST) = *3* days

Total reserve storage required: (RS) = RST x GT
RS = *3* x *2,200* = *6,600* gallons total storage in pasture.

Other water sources available in the field: *25 year old dam. New well drilled at homestead.*

Dependability of water sources: *Dam is unreliable. Well has been tested at 6 gpm.*

Quality of water sources: *Well water is used for drinking water.*

Comments: ____________________

2.2.3 System Alternatives

Even though the landowner may have a very specific system in mind, take an overall planning look at all reasonable alternatives to make sure the alternative the landuser wants is the appropriate one.

Economic considerations are usually a major factor in determining stockwater system alternatives. It is important not to overlook upgrading existing water sources, such as ponds, spring developments and windmills as alternatives to an extensive stockwater pipeline system or as a backup to the pipeline system in the event of failure.

The use of average per foot cost data, computer spreadsheets and specialized computer programs can be an aid to making quick analysis of various pipeline alternatives. These aids should be used whenever they will save time and effort.

2.2.4 Landuser Decisions

We sometimes forget to obtain the landuser's complete decisions before proceeding with detailed pipeline design. Good, appropriately timed communication with the landuser is always critical to success of the project. To do otherwise will usually waste everyone's time and money.

2.2.5 Implementation

Implementation of the Resource Managenment System includes all necessary preparation of detailed plans for such practices as fencing, range reseeding and planned grazing system as well as design and preparation of pipeline and tank drawings, specifications, quantities, cost estimates and operation and maintenance plans for the pipeline. It also includes supervision during application and construction.

2.2.6 Followup

Pipelines can be complex and may sometimes experience problems. We must be constantly alert for problems such as waterhammer, freezing pipes, erosion, low flows and improperly functioning valves so that they can be corrected and can be avoided in future jobs. This means that we must maintain contact with the landowner and re-visit at least some of the pipelines after they have operated for a period of time.

2.3 WATER QUANTITY REQUIREMENTS

The quantity of supplemental stockwater required during any given period depends on the type and number of stock, climatic conditions and amount of natural water available. It has also been found that water usage is higher for stock in an intensive grazing system.

In general, the recommended daily water requirements of livestock in Montana are as follows:

Table 2.1
RECOMMENDED DAILY STOCKWATER REQUIREMENTS
MONTANA

Livestock	Conventional Grazing System Gal/Day	Intensive Grazing System Gal/Day	Maximum Water Spacing (Mi)	
			Rough Relief	Gentle Relief
Range Cow	15	20	1/2	1
Cow & Small Calf	20	25	1/2	1
Horse	15	20	1/2	1
Sheep	2	4	1/2	1
Dairy Cow	25		1/2	1
Hog	2			
Mule Deer	2		1	2
Antelope	2		2	3
Elk	8		1	3

There will usually be additional water lost to evaporation and spillage at drinking tanks or troughs. Evaporation from a water surface can amount to as much as 0.30 inches per day in eastern Montana, and 0.20 inches per day in western Montana during the hot part of the year. Adding 10 percent to calculated animal water usage will usually cover evaporation and spillage losses. It depends on the climate, how critical the water supply is and characteristics of the system as to whether or not an evaporation and spillage replacement amount should be added.

2.4 DESIGN FLOW RATE

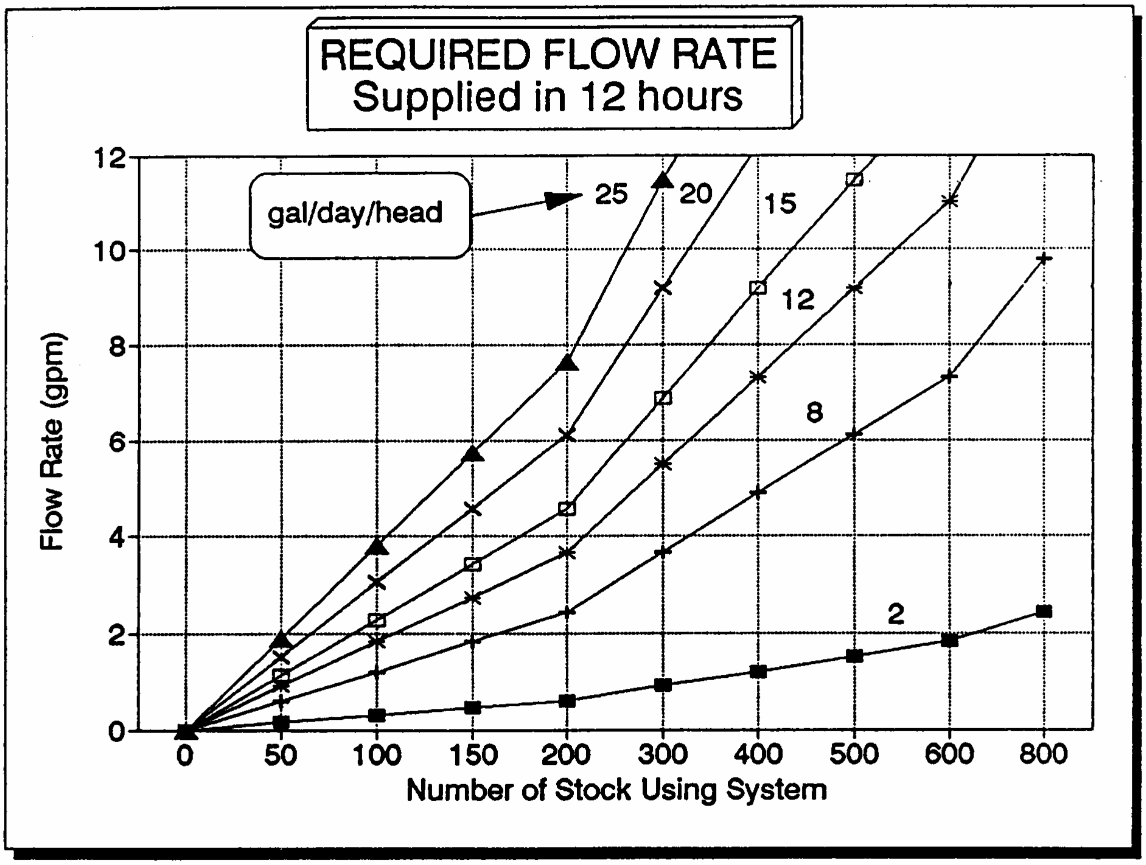
Minimum pipeline design flow rate must at least equal the flow rate, in gallons per minute, required to provide the peak daily water requirements in a 24-hour period for the maximum number of livestock to be run in the pasture. It is often desirable to provide additional capacity to allow tanks to refill more rapidly during the peak usage part of the day. Reasonable practice is to design pipeline capacity to provide full daily water needs in a 12-hour period.

Figure 2.3 shows flow rates required to meet daily needs in a 12-hour period. This chart assumes a 10 percent loss for evaporation and waste. Figure 2.4 shows flow rates required if flow rate is supplied over a 24-hour period.

Figure 2.3

FLOW RATE REQUIRED FOR DAILY NEEDS (SUPPLIED IN 12 HRS)

Based on Additional 10% for Evaporation and Waste



EXAMPLE:

Given: Conventional grazing system with 200 cow-calf pairs.

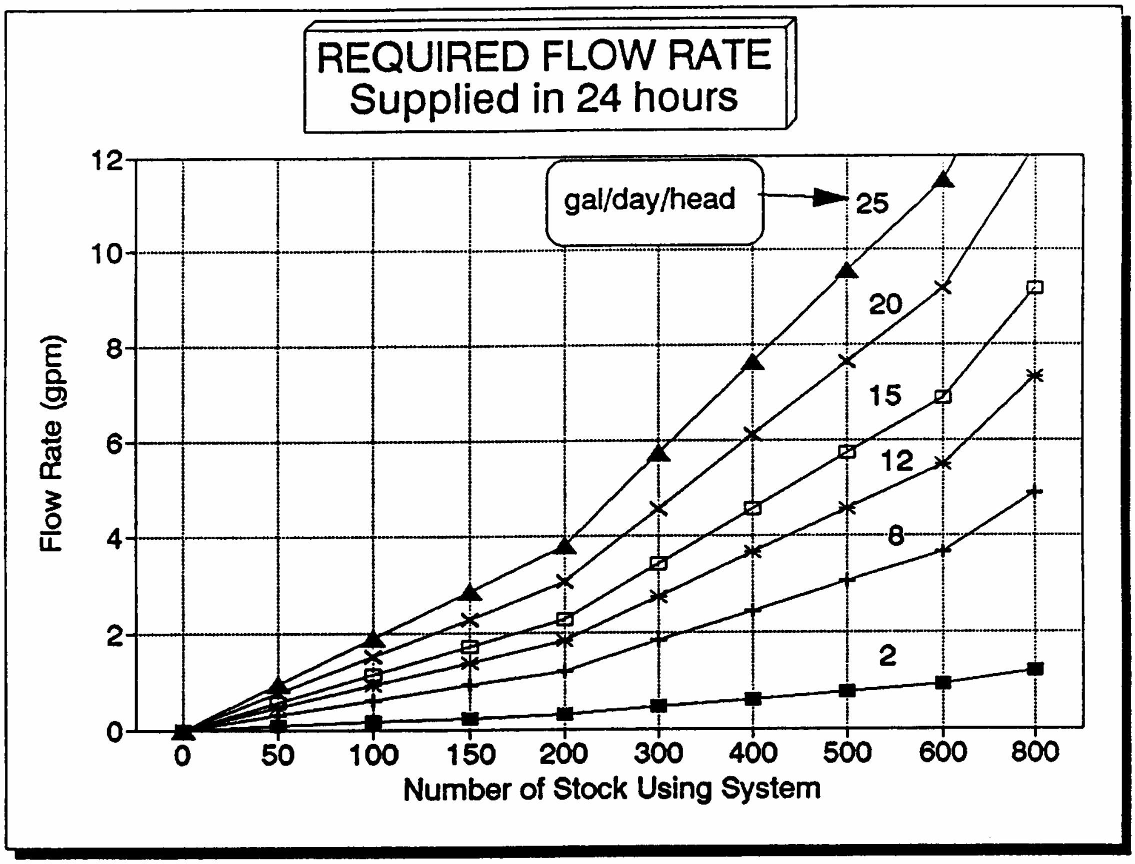
Find: Design flow rate meeting daily water requirements in a 12-hour period.

Solution:

From Table 2.1: 20 gal/day/head required during peak use period.
From Figure 2.3: Minimum flow requirement is 6.1 gpm.

Figure 2.4
FLOW RATE REQUIRED FOR DAILY NEEDS (SUPPLIED IN 24 HRS)

Based on Additional 10% for Evaporation and Waste



2.5 WATER STORAGE REQUIREMENTS

Table 2.2 shows approximate total stockwater requirements during a peak usage day. This table provides for an additional 10 percent allowance for evaporation and spillage.

The capacity of the pipeline supplied water storage facilities within a pasture must be determined on an individual basis in close consultation with the operator. In general, water storage capacity or other water sources in a pasture should be provided to meet water requirements for a minimum of three days where water supply, pipeline, power or pump failure could cause loss of pipeline supplied water. Minimum storage volume will depend on the reliability of the source, the hazards of exposure of the pipeline, reliability of the supply, management provided by the operator and how easy it is to move livestock if the water supply fails.

These factors should be thoroughly discussed with the operator. In the end it is the operator's decision as to how much storage is enough.

Table 2.2

TOTAL DAILY STOCKWATER REQUIREMENTS

Gallons/Day
Based on Additional 10% for Evaporation and Waste

Number of Stock Using System	WATER REQUIREMENTS - Gallons/Day/Head					
	2	8	12	15	20	25
25	55	220	330	413	550	688
50	110	440	660	825	1,100	1,375
75	165	660	990	1,238	1,650	2,063
100	220	880	1,320	1,650	2,200	2,750
125	275	1,100	1,650	2,063	2,750	3,438
150	330	1,320	1,980	2,475	3,300	4,125
175	385	1,540	2,310	2,888	3,850	4,813
200	440	1,760	2,640	3,300	4,400	5,500
250	550	2,200	3,300	4,125	5,500	6,875
300	660	2,640	3,960	4,950	6,600	8,250
350	770	3,080	4,620	5,775	7,700	9,625
400	880	3,520	5,280	6,600	8,800	11,000
450	990	3,960	5,940	7,425	9,900	12,375
500	1,100	4,400	6,600	8,250	11,000	13,750
600	1,320	5,280	7,920	9,900	13,200	16,500
700	1,540	6,160	9,240	11,550	15,400	19,250
800	1,760	7,040	10,560	13,200	17,600	22,000
900	1,980	7,920	11,880	14,850	19,800	24,750
1000	2,200	8,800	13,200	16,500	22,000	27,500

Table 2.3 tabulates storage capacity for round stock tanks.

Table 2.3
ROUND STOCK TANK STORAGE CAPACITY

Gallons

Tank Diameter (feet)	TANK DEPTH (feet) (Filled to within 3" of top)					
	1.0	1.5	2.0	2.5	3.0	3.5
4	70	117	164	211	258	305
6	159	264	370	476	582	687
8	282	470	658	846	1,034	1,222
10	441	734	1,028	1,322	1,615	1,909
12	634	1,057	1,480	1,903	2,326	2,749
15	991	1,652	2,313	2,974	3,635	4,296
20	1,762	2,937	4,112	5,287	6,462	7,637
25	2,754	4,589	6,425	8,261	10,096	11,932
30	3,965	6,609	9,252	11,896	14,539	17,182
36	5,710	9,516	13,323	17,130	20,936	24,743
40	7,049	11,749	16,448	21,148	25,847	30,546

Where a windmill is involved, and other water sources are not available, a minimum of 10 days' livestock water requirement plus about 10% evaporation and spillage loss should be provided in storage tanks.

There is no hard and fast rule as to how much emergency water storage is adequate. Much depends on how the operator operates. For example, if he or she is checking their stock every couple of days, less storage would be required than if the stock are checked only once a week.

Storage also depends on how easy it would be to move the stock to another field where water is located, should the water supply in the field where the stock are located be interrupted.

How much emergency storage is enough is a management decision that should be made by the operator after thorough discussion of all factors involved.

2.6 SOURCE OF WATER

Water for stocklines usually is obtained from wells or springs. Occasionally a surface source is used.

2.6.1 Springs

Springs often have varying degrees of dependability. If it is proposed that an extensive pipeline be run from a spring, the spring should be developed and used for a couple of years to prove its yield and dependability before installing an extensive pipeline.

Sediment, moss, scum, fish, frogs, mice and other solids must be excluded from spring pipelines to the extent possible. Where the spring collection system allows entry of this type of material, a spring box with screened pipe inlet must be employed. If a gravel/pipe type of collection system is used, a spring box is usually not necessary.

2.6.2 Surface Source

Special care must be used to exclude scum and sediment from pipelines using a surface water as a source. A screening or filtering device should always be used at the entrance to the pipeline. If sediment is a problem, consider constructing a settling pond at the entrance to the pipeline.

2.6.3 Well

Some wells produce considerable amounts of sand. A sand separator should be installed at the beginning of the pipeline in such a case. Sand separators are available through trickle irrigation supply sources.

2.6.4 Water Quality

Montana Technical Note Environment No. 13, Assessing Water Quality, provides details of stockwater quality requirements. The most common factors to consider are salinity and nitrates. Tables 2.4 and 2.5 describe tolerable levels of these elements.

Table 2.4
USE OF SALINE WATER FOR LIVESTOCK

Total Dissolved Solids mg/l	
1,000-3,000 mg/l	Very satisfactory for all classes of livestock. May cause temporary and mild diarrhea in livestock not accustomed to them.
3,000-5,000 mg/l	Satisfactory for livestock but may cause diarrhea or be refused at first by animals not accustomed to them.
5,000-7,000 mg/l	Can be used with reasonable safety for dairy and beef cattle, sheep, swine, and horses. Avoid use for pregnant or lactating animals.
7,000-10,000 mg/l	Considerable risk in using for lactating cows, horses, sheep, or for the young of these species. In general, use should be avoided although older ruminants, horses, and swine may subsist on them under certain conditions.
Over 10,000 mg/l	Risks with these highly saline waters are so great that they cannot be recommended for use under any conditions.

Table 2.5
EFFECTS OF NITRATES ON LIVESTOCK

Nitrate Concentration (mg/l NO3 as N)	Effect
10-30	Slight possibility of harm
30-50	Risky, especially over a long period of time
50-100	Interference syndrome likely (trembling, weakness, discolored urine)
100-145	More serious; possible acute losses
145-195	Increased acute loses, secondary diseases
195 up	Acute losses.

Chapter 3

Pipeline System Types

CHAPTER 3 PIPELINE SYSTEM TYPES

TABLE OF CONTENTS

FIGURES

Chapter 3

Pipeline System Types

3.1 GENERAL

There are several types of stockwater pipeline systems that we need to know how to design. More than one of these system types may be incorporated in a single system.

3.2 GRAVITY SYSTEMS

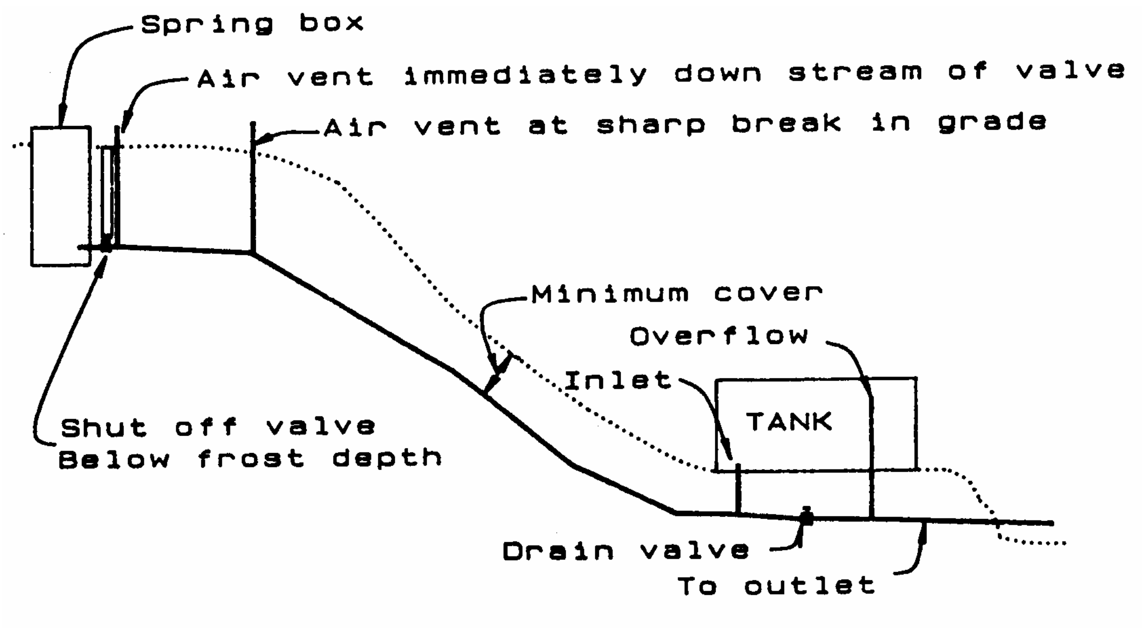
A gravity pipeline system is one in which the water supply surface is higher than all points in the pipeline and no pump is required. This type of system can generally be subdivided into two subtypes: (1) The low head gravity system and (2) the high head gravity system.

3.2.1 Low Head Gravity System

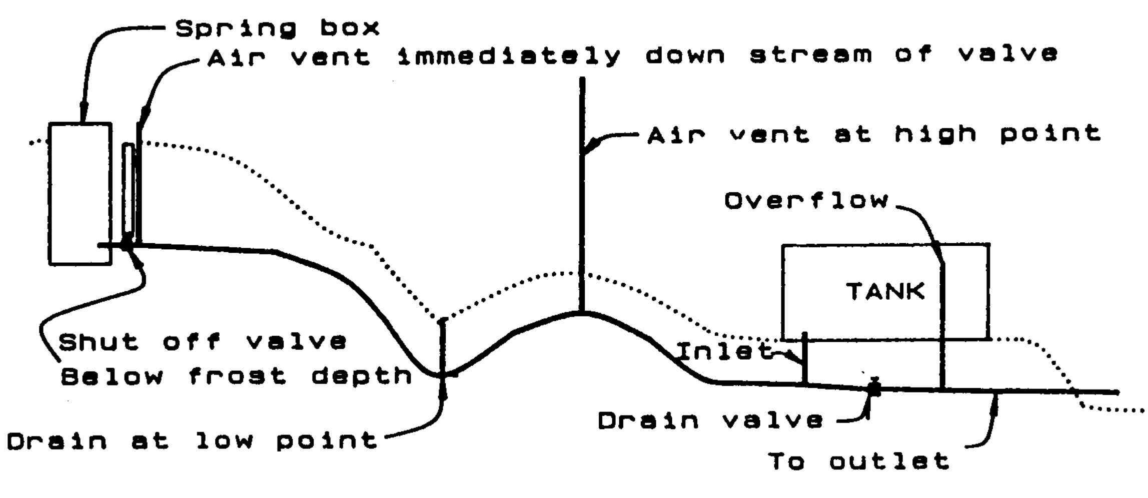
Low head is loosely defined as below 10 psi at all points in the line. An example of a typical low head gravity pipeline is shown in Figure 3.1. In this type of system the flow rate is usually whatever the spring or other water supply will provide.

It is important to make sure there can be no air locks in the system, and since the pipe is usually shallow, design the pipeline so that it freely drains when not in use. A low head gravity system is usually characterized by being installed on a positive grade in the direction of flow for its entire length. There is not enough pressure in the system to properly operate air valves, although stand pipes may be used.

Figure 3.1
TYPICAL LOW HEAD GRAVITY SYSTEMS



System With Downhill Grade in Direction of Flow



System With Undulating Grade

3.2.2 High Head Gravity System

Figure 3.2 illustrates a typical high head gravity system. This type of system is often located at the end of a pumped pipeline, starting at a storage tank at the top of a hill. Float valves are used on all tanks to control flow. Air locks at significant high points in the pipeline are prevented by installing air valves or vents.

3.3 AUTOMATIC PRESSURE SYSTEM

Pumped flow in an automatic pressure system is controlled by a pressure switch. A pressurized tank stores water between cut-in and cut-out cycles. Figure 3.3 illustrates a common configuration for this type of system. The advantages of an automatic pressure type system is that it does not take constant attention and a minimum amount of power and water are used.

3.4 TIMED OR MANUAL PRESSURE SYSTEM

A timed pressure pipeline system is one which uses a pump to pressurize the system and a timer to turn the pump on or off. A manual system is one in which a manually operated switch is used to turn the pump on or off.

Both of these systems operate in the same way and are illustrated in Figure 3.4. There is an overflow at the high point in the system which wastes excess water. At all other tanks, float valves or manually operated hydrants are used to keep the tanks full.

Timer or manually operated systems are usually used where high pressures make it impractical to use an automatic pressure system. Water waste is minimized by observation of stockwater usage and adjusting the pump operating times during the season. As a safety measure, it is usually advisable to provide additional water storage at various points in the system.

A large storage tank is usually located at the high point in the pipeline. Water flows from the storage tank back toward the pump during the periods when the pump is off.

3.5 FLOAT SWITCH OPERATED PRESSURE SYSTEM

A float switch operated pressure system is a pumped pipeline system in which the pump is turned on or off with a float switch located at the highest tank in the pipeline.

This type of system requires that an electric control wire run between the pump and storage tank. The wire can either be an overhead or buried line. A control wire is sometimes buried in the same trench as the pipeline.

The switch operated system is used instead of an automatic pressure system where pressures are too high for pressure tanks. The advantage of this system is that it does not waste water and power. The disadvantage is that an electric connecting wire and switching equipment can be costly.

Figure 3.5 shows a typical switch operated system. Switches are low voltage and telephone wire can be used as connecting wire. Used overhead telephone wire and poles could also be used.

Figure 3.2
TYPICAL HIGH HEAD GRAVITY SYSTEM

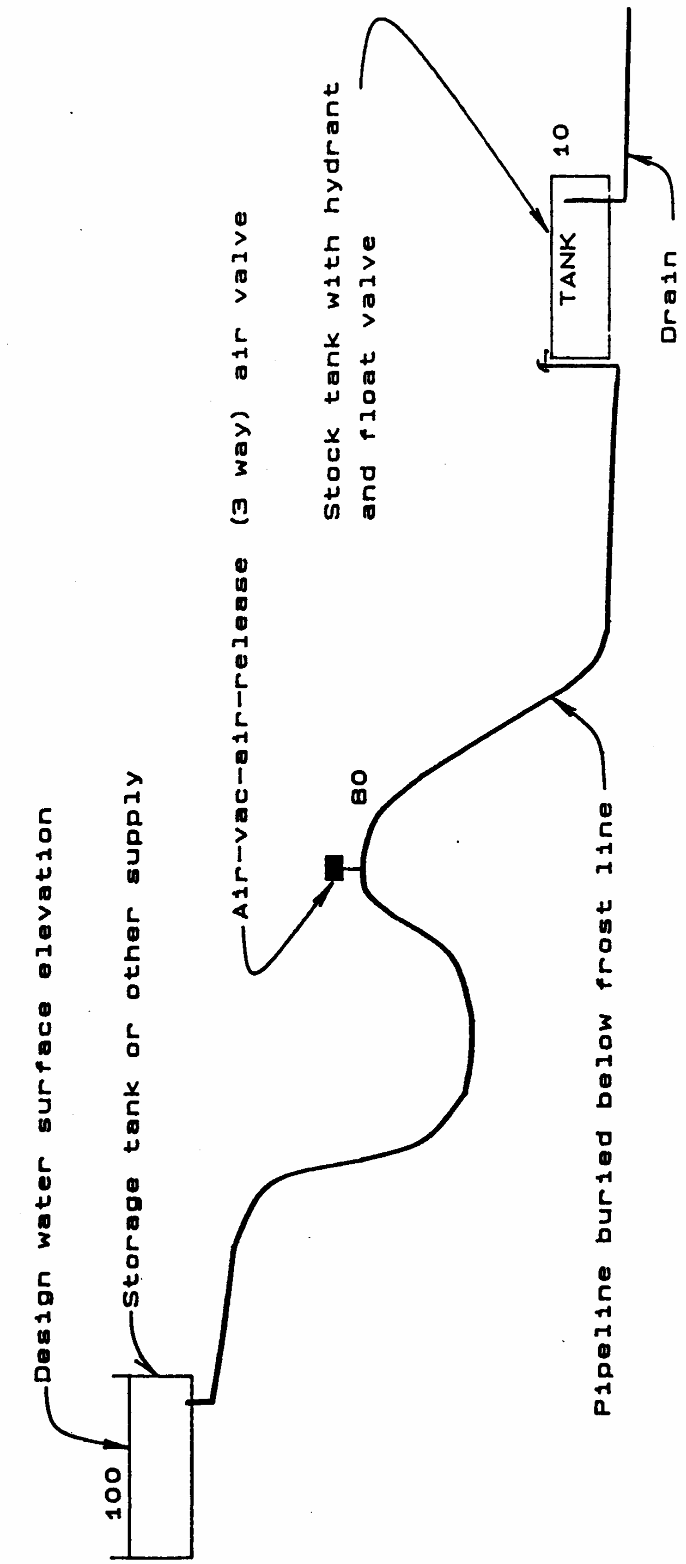


Figure 3.3
TYPICAL AUTOMATIC PRESSURE SYSTEM

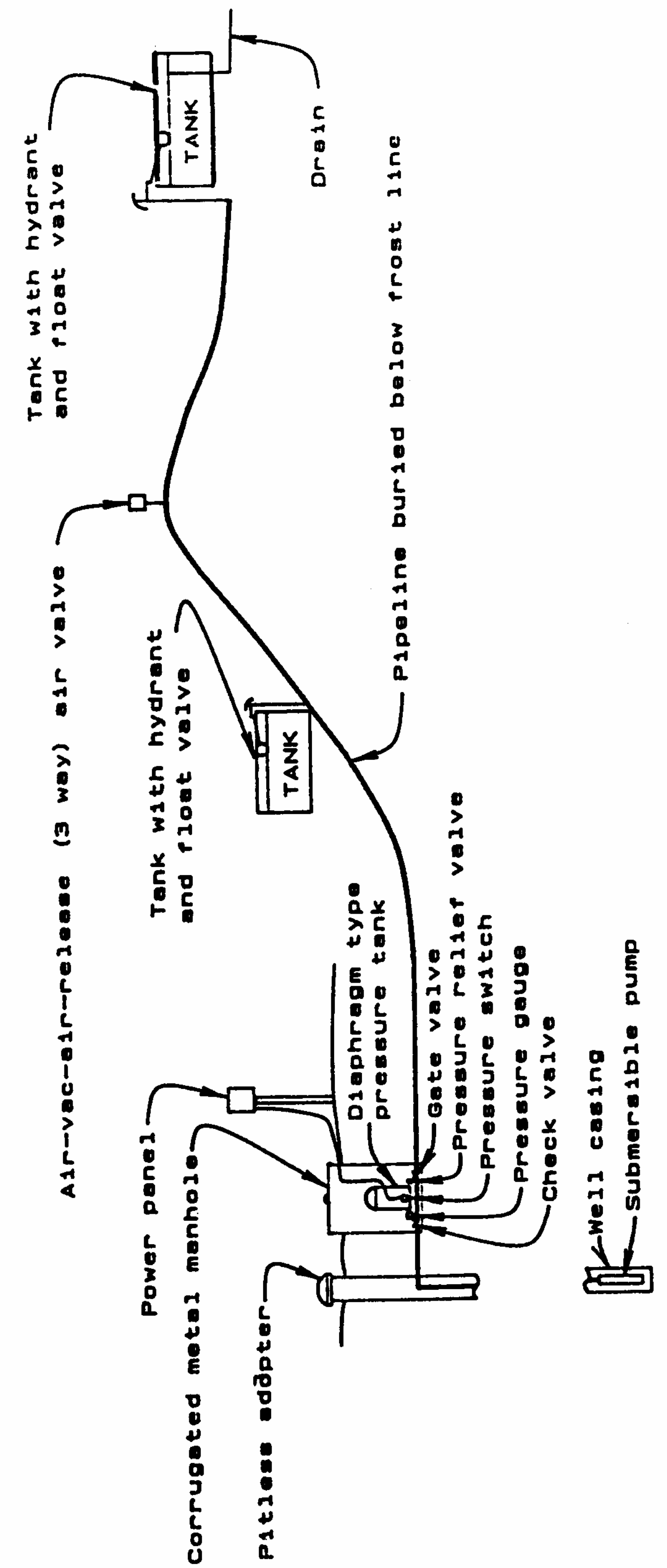


Figure 3.4
TYPICAL MANUAL OR TIMER OPERATED SYSTEM

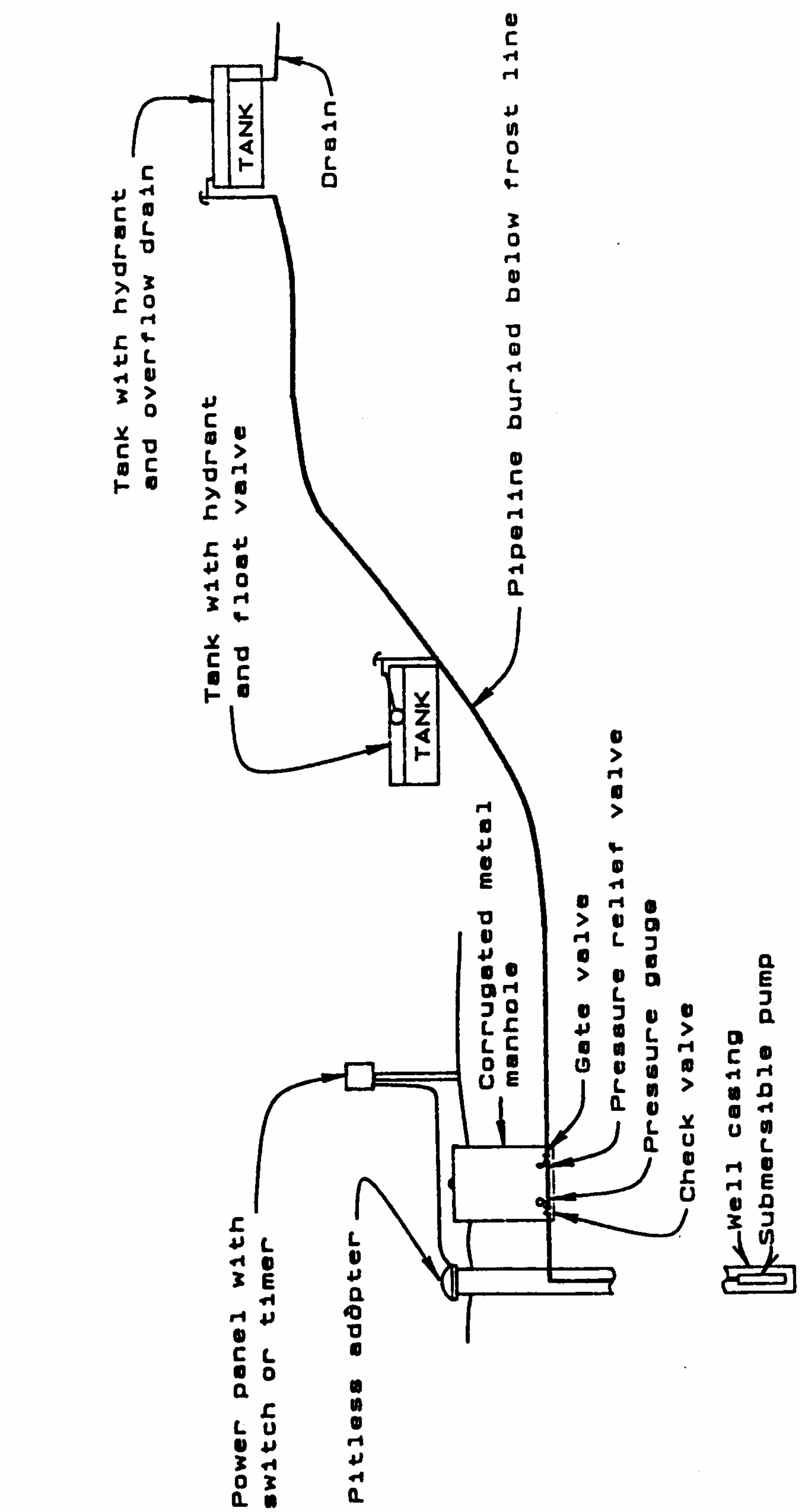
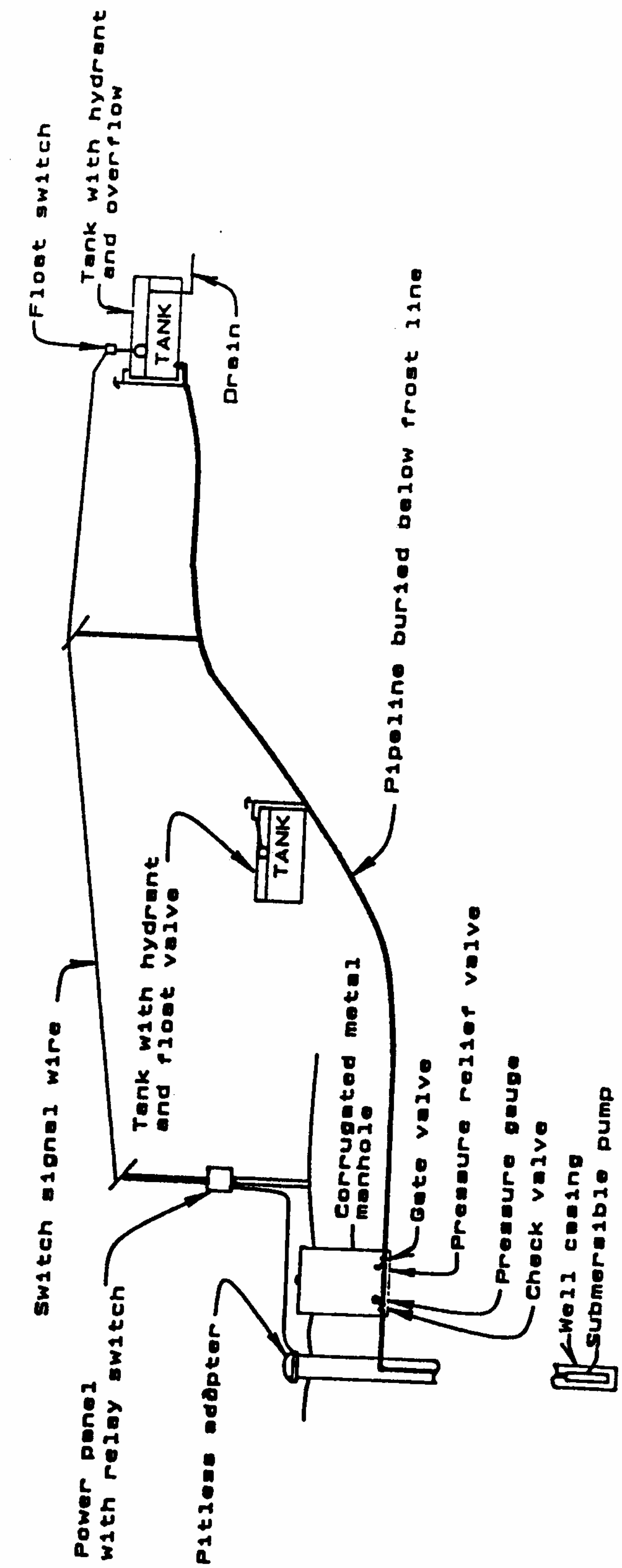


Figure 3.5
TYPICAL FLOAT SWITCH OPERATED SYSTEM



3.6 ALL YEAR VERSUS SUMMER PIPELINES

A pipeline that is only used in the summer can be buried at a shallow depth and drained during freezing weather. Such pipelines are usually buried 24 to 30 inches deep. By contrast, all year pipelines are buried below frost depth, which is five feet or more in Montana.

3.6.1 Summer Pipeline

The decision as to whether or not to use a shallow buried pipeline is most often dictated by how deep the soil is in a given area. Shallow soil over bedrock and cobbly soil, make it difficult or impossible to bury a pipeline below frost depth.

It is usually advantageous to bury a pipeline below frost depth in terrain that will allow this, even if the line is only going to be used in the summer. A deep line will not require draining every winter and is not as critical with respect to installation grades.

Shallow lines must be laid to a grade which will allow draining at low spots. Gravity, pumpout, or seepage pit-type drains must be installed at all low points.

Because of the necessity of draining shallow pipelines, more care must be taken during their installation. The pipe must be laid to grade at a tolerance such that low points in the pipe are not more than about 3/4 of a pipe diameter below grade.

Shallow lines are often buried by the "Pull-in" method. This is done with a large tractor and ripper with flexible pipe on a reel attached to the ripper and fed out behind. Flexible polyethylene pipe is usually used in this type of installation.

Where shallow pipelines cross watercourses, they are often suspended in air rather than buried. Suspended lines are usually made of steel pipe.

3.6.2 All Year Pipeline

For a pipeline to be operational during both summer and winter, the pipe must be buried below the frost line. The actual anticipated frost line and how deep a pipe should be buried depends upon several factors which include:

- Maximum low temperature and number of freezing days in a year
- Soil type and cover
- Sun exposure
- Moisture content of overlying soil
- Whether there is continuous flow in the pipeline
- Temperature of water source.

It is difficult to quantify and determine the actual effect of some of these factors. For situations where there is not continuous flow in the pipeline during the winter months, a pipeline should be buried at least five feet deep in Montana. North slope exposure, high altitudes, and moist soils are factors indicating the need for burying the pipe deeper. Even though the pipe is buried to these depths it could still freeze up in some portions of the line.

Because of equipment limitations it is difficult to bury a pipeline deeper than six feet. Therefore, the choices are to bury the pipeline a minimum of five feet in most normal conditions and six feet or deeper where exposure, elevation, long periods of stagnant water and/or moist conditions exist.

Appurtenances for all year pipelines must be designed in a way that will reduce the chance of frozen pipelines during cold weather. Valves of all kinds must be protected from freezing. This is usually done by installing them in a covered manhole or access hole. Frost free hydrants must be used. Float valves can be installed under a protective cover or in an insulated well.

Chapter 4

Pipeline Route Selection and Surveys

CHAPTER 4 PIPELINE ROUTE SELECTION AND SURVEYS

TABLE OF CONTENTS

FIGURES

Chapter 4

Pipeline Route Selection and Surveys

4.1 ROUTE CONSIDERATIONS

There are many considerations which should be made in selecting the route for a stockwater pipeline. Some of the most important ones are:

- Stockwater tanks should be located at sites with good drainage, be on solid ground and be where it will be easy to provide a tank overflow.
- The pipeline route should be selected to minimize the number of high and low spots in the line. High spots may require air valves and low spots in shallow lines require drains.
- Routing the pipeline over moderate slope terrain makes it easier to trench for the pipeline.
- There must be access to all portions of the route by trenching equipment.
- Soils should be deep enough for trenching to the design depth.
- Avoid landslide areas and avoid crossing watercourses that are eroding.
- Avoid areas classified as wetlands.
- Avoid crossing Federal or State land where possible. Permits are required for crossing these lands and the permitting process takes a considerable amount of time and effort to complete.
- Full consideration should be given to the possibility of future expansion to the system. If a pipeline extension is anticipated then pipe size and rating should be appropriate for the ultimate extension.
- If large stock tanks or storage tanks are to be installed, locate them where access to heavy equipment is possible.

4.2 ROUTE SURVEYS--GENERAL

The type of survey information required for a pipeline depends on the characteristics of the pipeline. For example, consider a spring development with a 300-foot pipeline, with total fall between water surface in spring and a tank of only four feet. This system may require a very detailed survey to insure that the pipe grade and tank elevation will allow the system to operate properly.

On the other hand, a four mile long pipeline that has an elevation gain of 400 feet may only need a careful study of contours on a U.S. Geological Survey (USGS) quadrangle map to get enough information for an adequate design.

And in a third example, a four-mile pipeline traveling over gently undulating topography and with total elevation differences not exceeding 25 feet may need a detailed profile run with an engineer's level.

The difference in these installations is that we must predict where air can collect in the pipe system and provide means for releasing it. Defining where these problem locations are will usually dictate the type of survey that should be completed.

4.3 ENGINEERING INSTRUMENT SURVEY

An engineering instrument survey should be used when available pressure head is small and where many small undulations in the terrain make it difficult to determine where all the high and low spots are located.

There are generally three types of instrument surveys that can be used:

- Differential level route surveys
- Stadia surveys, using vertical angles if necessary
- Total station instrument (Geodimeter) surveys

The type of survey which should be used will depend on which one will give the degree of accuracy necessary and which will be the most time and cost effective.

4.4 USE OF U.S. GEOLOGICAL SURVEY QUAD MAPS

For long pipelines with major elevation changes, it is usually adequate to use contour elevation data from 7-1/2 minute USGS quadrangle maps. Contour interval on most quad sheets of interest in Montana is 20 feet. Fairly accurate interpolations can be made to an elevation of 10 feet which is usually adequate for high pressure pipelines. One caution is that it is extremely important to accurately locate ground locations on the map. If there is any question as to location, other methods of determining elevations should be used.

Horizontal distances can be estimated from the maps to the nearest 100 feet. Corrections must be made for additional distance caused by elevation changes.

A common method of measuring pipeline lengths in the field on long pipelines is a measuring wheel. Figure 4.1 illustrates this device. The wheel should be run over the route in two directions. If the first and second run do not match within 2 percent, the route should be traversed again. The average of the readings should be used. Heavy grass, rocky ground or mud will prevent use of a measuring wheel.

Figure 4.1
MEASURING WHEEL

4.5 ALTIMETER

Where a 7-1/2 inch quad sheet is not available for an area, and you need to determine elevations for a pipeline with large elevation differences, an altimeter may be used.

The altimeter should be at least capable of being read to the nearest five feet.

Some altimeters are temperature compensated. There is a considerable advantage to using this type of instrument as corrections for temperature do not need to be made.

A measuring wheel is usually used to measure distances in conjunction with an altimeter survey.

4.5.1 Procedure for Using an Altimeter

There are three principal reasons for barometric variations at one elevation: (1) temperature changes, (2) overall weather changes, and (3) changes in local wind velocity and pattern.

The altimeter should be temperature normalized before use. Temperature of the altimeter should be as close as possible to that of the surrounding air when used.

The survey should be performed as rapidly as possible. After completing all readings throughout the length of the line, return to the beginning point and take a final reading. Corrections must be made for the difference in readings at the beginning point. This difference is proportionately applied as a correction to each reading point along the profile. Example notes, Figure 4.2, illustrates how to do this.

If the instrument is not temperature compensated, temperatures should be taken along with barometric readings. Corrections must then be made for temperature changes. Correction for temperature is approximately 0.0020 feet per degree F for each foot read from the instrument. For example, if temperature is 50 degrees F at the initial point, and it is then moved to an unknown point where, at a temperature of 70 degrees F, it reads 100 feet higher, the 100 feet should be increased by 0.0020 x (70 - 50) x 100, or 4 feet.

Example notes, Figure 4.3 shows a computer spreadsheet output for making temperature and elevation corrections.

Barometric pressure changes due to changes in weather and high or gusty winds can cause severe variations in altimeter readings. An altimeter should not be used during periods of significant weather changes and high or gusty winds.

Figure 4.2
EXAMPLE ALTIMETER NOTES

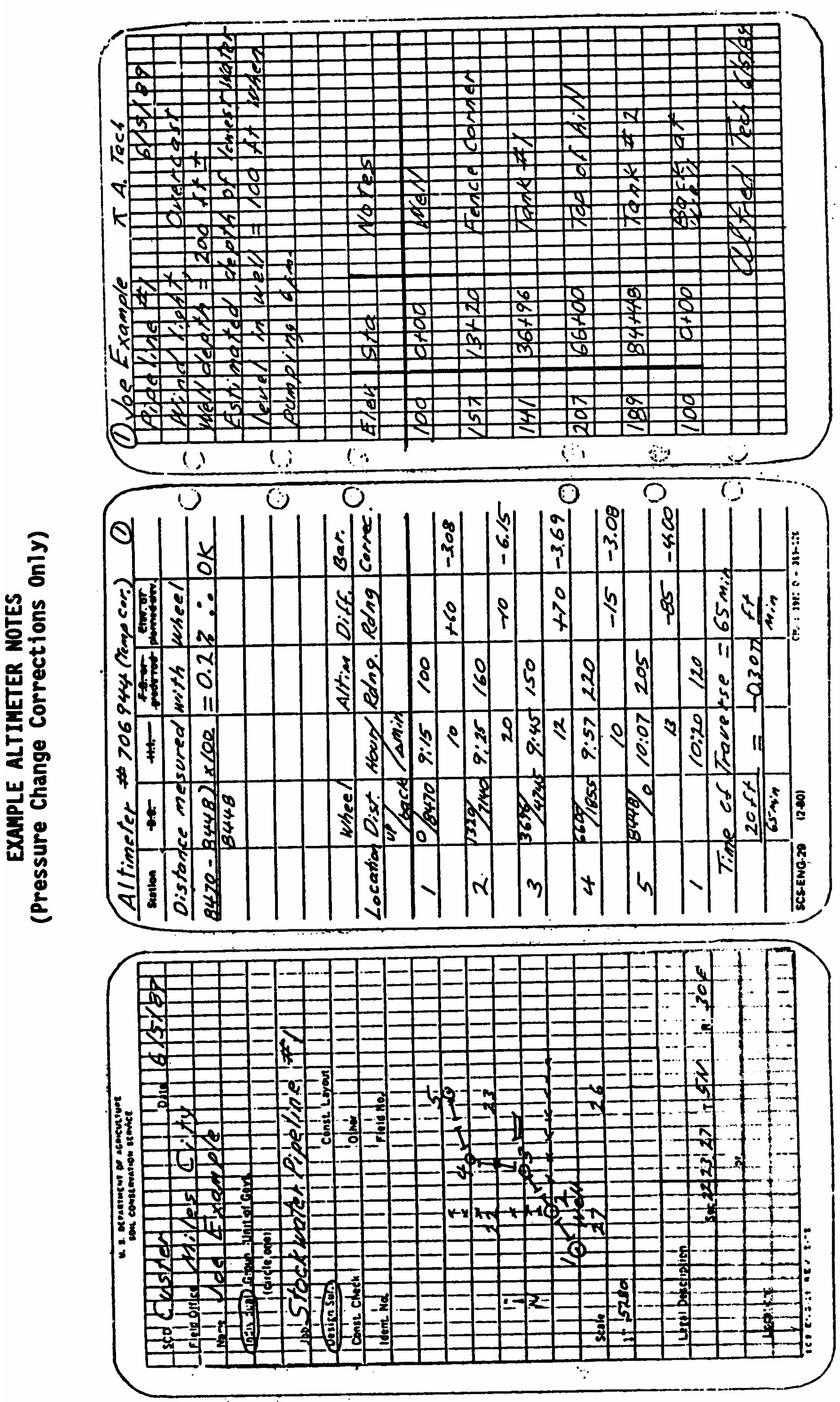


Figure 4.3
EXAMPLE ALTIMETER COMPUTATIONS

(Pressure and Temperature Corrections)
Using Computer Spreadsheet Program
(altimeter.wk1)

A L T I M E T E R
SURVEY SUMMARY
Job: Demo job
Date: 1/6/89
By: John Tech

Comment	Station	Observed Reading	Temperature (degrees F)	Time (hr)	Time (min)	Corrected Elevation
End at start	0	5018	100	3	13	5000
Start	0	5000	96	2	0	5000
	1800	5075	100	2	20	5071
	3000	5170	104	2	35	5162
	3900	5190	104	2	47	5178
	4500	5243	108	2	58	5229

Chapter 5

Pipe Materials Selection

CHAPTER 5 PIPE MATERIALS SELECTION

TABLE OF CONTENTS

FIGURES

TABLES

CHAPTER 5

PIPE MATERIALS SELECTION

5.1 GENERAL

There are several types of pipe that may be used in stockwater systems. The most commonly used types are discussed below. Usually, price per foot of pipe dictates the type of pipe that is used.

When designing a pipeline, it is important to know the type of pipe to be used. Internal pipe diameters vary depending on material type and pressure rating for a given nominal pipe size. Due to differing internal cross sectional area, and differing friction loss factors, friction loss in long pipelines can differ considerably from one type and rating of pipe to another.

5.2 PLASTIC PIPE CHARACTERISTICS

5.2.1 Pressure Rating of Pipe

Plastic pipe is rated at approximately half its tested rupture strength. This means that under normal temperature conditions, it can withstand occasional surge pressures up to twice its rated pressure.

Plastic pipe will weaken under repeated cycles of pressures in excess of those for which it is rated. The higher the surge pressure the faster the pipe will weaken. For this reason it is important to design the pipe system so that normal operating pressures are less than rated pressure of the pipe. The system should be designed and operated to limit the number and severity of pressure surges. Other sections of this manual describe ways to limit surge pressures.

5.2.2 How Temperature Affects Pressure Rating

The pressure rating of plastic pipe is determined at 73.4 degrees Fahrenheit (F). Strength of plastic pipe decreases as water temperature becomes warmer. In cases where warm well water is used, or where there is pipe exposure, water temperatures may exceed 73.4 degrees F. In that case, effective pressure rating of the pipe must be reduced.

Table 5.1 lists the temperature reduction factors for PVC pipe.

Table 5.1
PVC PLASTIC PIPE RATING REDUCTION DUE TO TEMPERATURE

Temperature Degrees F	Multiply Pressure Rating by:
73.4	1.00
80	.93
90	.77
100	.67
110	.51
120	.43
130	.33
140	.23

5.2.3 Freezing of Water in Pipe

Plastic pipe containing static water should be drained when temperatures below 32 degrees F are expected. If the water is moving, freezing is unlikely above 0 degrees Fahrenheit.

If freezing does occur in the line, the pipe material will influence whether the pipe is damaged. In changing phase from liquid to ice, water expands approximately 10% by volume. Some plastic pipe will not survive the required 3.2% linear elongation, but most will.

Pipes most likely to be damaged by freezing water are those made of rigid materials, which include PVC and CPVC.

Pipe most unlikely to be damaged by freezing water include the cellulose-aceto-butyrate, acrylonritrile-butadine-styrene, styrene rubber, and polyethylene materials. All of these pipes have elongation and recovery properties which should in most cases enable it to expand and recover without permanent damage.

Although some pipe material can usually withstand freezing without damage, no system should be knowingly designed to freeze while full of water. Resistant pipes can be used in areas of severe exposure as an extra safety factor against damage by freezing. An excellent example of this is a shallow pipeline leading from a spring.

5.3 POLYVINYL CHLORIDE (PVC) PLASTIC PIPE

Polyvinyl Chloride (PVC) is a commonly used type of pipe used for stockwater pipelines. This is a rigid plastic pipe that, in the configuration used for stockwater pipelines, usually comes in 20-foot lengths. Connections are usually made with glued fittings, although rubber gasketed joints are sometimes used.

When subject to long-term exposure to ultraviolet radiation (sunlight), PVC pipe will suffer slow deterioration. PVC pipe should be buried or installed in an enclosure. If PVC must be exposed it should be coated or wrapped. The coating may be exterior latex paint. Make sure the pipe is thoroughly cleaned before painting.

Exposed pipe should be protected from mechanical damage by livestock or other hazards. Plastic pipe is particularly vulnerable when cold, as it will easily shatter.

There are two types of PVC pipe. Standard Dimension Ratio-Pressure Rated pipe (SDR-PR) is manufactured under specification ASTM D2241. PVC Iron Pipe Size (PVC-IPS) pipe is manufactured under specification ASTM D1785.

SDR-PR rated pipe is rated using standard dimension ratio and pressure as factors. This is the most common pipe type used in stockwater pipelines in Montana. Tables 5.2 through 5.5 list available sizes, pressure ratings and friction loss factors.

PVC-IPS pipe has various pressure ratings depending on nominal diameter and schedule designations. Schedule 40, 80, and 120 pipe are available. Tables 5.6 through 5.8 list available sizes, pressure ratings, and friction loss factors.

For both of these types of pipe, the outside diameter is constant and the inside diameter varies.

5.4 POLYETHYLENE (PE) PLASTIC PIPE

Polyethylene (PE) pipe is the second most common pipe used in stockwater pipelines. It is flexible, comes in coils and is used for most "pull-in" type systems. Where pipe is installed in trenches, it is harder to lay flat in the trench than PVC pipe. Since it comes in coils, PE pipe takes fewer fittings to lay. Connecting this type of pipe is usually done with "stab" type fittings held together with stainless steel band clamps. Frost heave in shallow pipelines tends to pull these joints apart. Double clamping is usually necessary to combat this problem.

There are several types of PE pipe. The one most commonly used in stockwater pipelines is a controlled inside diameter version rated by standard thermoplastic dimension ratio and pressure rating (SIDR-PR) and is manufactured under specification ASTM D2239. SIDR 15, 100 psi pipe is usually the most available polyethylene pipe.

Table 5.9 shows available sizes, pressure ratings, and friction loss factors.

A high density polyethylene pipe (HDPE) is available which can be used for above ground installations. This is the same type of pipe as used in hose reel type irrigation sprinkler systems. The material is tough, will withstand long-term exposure to sunlight and may be used above ground where below ground installations are not possible. When used above ground it must be tied down so it will not pull apart and it must be protected or placed in a manner which will prevent mechanical damage. HDPE is only available in sizes 1-1/2 inch and larger.

This material is tough, flexible, and resistant to freeze damage. Although sometimes proposed for shallow non-drained pipelines, it should not be used in this way. This pipe will usually withstand freezing without damage, but the system should not be knowingly designed to freeze while water is in the line.

Table 5.10 tabulates available sizes, pressure ratings, and friction loss factors.

5.5 ACRYLONITRILE-BUTADIENE-STYRENE (ABS) PLASTIC PIPE

Although listed in the standards as an acceptable pipe material, ABS pipe is used little in the transmission pipeline portions of stockwater pipelines. ABS pipe is frequently used in stockwater systems as drain, vent, and waste system components. This black pipe has the advantages of being tough with good strength and stiffness. It is not tolerant to ultraviolet light, so it should be painted or wrapped if exposed to sunlight. It ranges in size from 1/8-inch to 12 inches in diameter.

5.6 POLYBUTYLENE (PB) PLASTIC PIPE

Polybutylene pipe, which is an alternative now sometimes used in household plumbing and underground water service, is occasionally used in stockwater pipeline applications.

This material is tough, flexible, and resistant to freeze damage. Although sometimes proposed for shallow non-drained pipelines which freeze in the winter, it should not be used in this way. This pipe will usually withstand freezing without damage, but the system should not be designed to freeze with water in the line.

Tables 5.11 through 5.13 tabulate available sizes, pressure ratings, and friction loss factors.

5.7 STEEL PIPE

Steel pipe is often used in system plumbing next to the pump. It is rarely used in main parts of the pipeline in buried installations.

Steel pipe is used in buried applications only as a last resort due to its high cost, high friction loss, and because it easily corrodes.

Galvanized pipe should be used for exposed installations such as at cable supported aerial stream crossings, and as plumbing in manholes. When buried, steel pipe should always be coated and wrapped. This is due to the corrosive nature of most soils in Montana.

Some water in Montana is highly corrosive. When long sections of steel pipe are used which cannot be easily replaced, then a sample of the water supply should be taken and a Lanelier Index run on the sample. If the test shows the water to be highly corrosive, unlined steel pipe should not be used. Analysis by the Lanelier Index is beyond the scope of this manual and should be referred to State or Area Engineering staff with knowledge of its use.

Occasionally, steel pipe must be used for very high pressure pipelines where plastic pipe is not available with adequate pressure ratings. Operating pressures in steel pipe should not exceed 50 percent of the rated yield strength pressure. Tables 5.14 through 5.15 tabulate pressure ratings corrected to 50 percent of rated yield strength pressure. These tables also show available sizes and friction loss factors.

5.8 FRICTION LOSS IN PIPING SYSTEM AT THE PUMP

Friction losses in the plumbing at the pump is significant enough that it should be considered when determining total dynamic pumping head. The typical pipe material used between a submersible pump and pressure tank is polyethylene pipe with some steel pipe at the pressure tank. High pressure systems sometimes use steel pipe between pump and pressure tank.

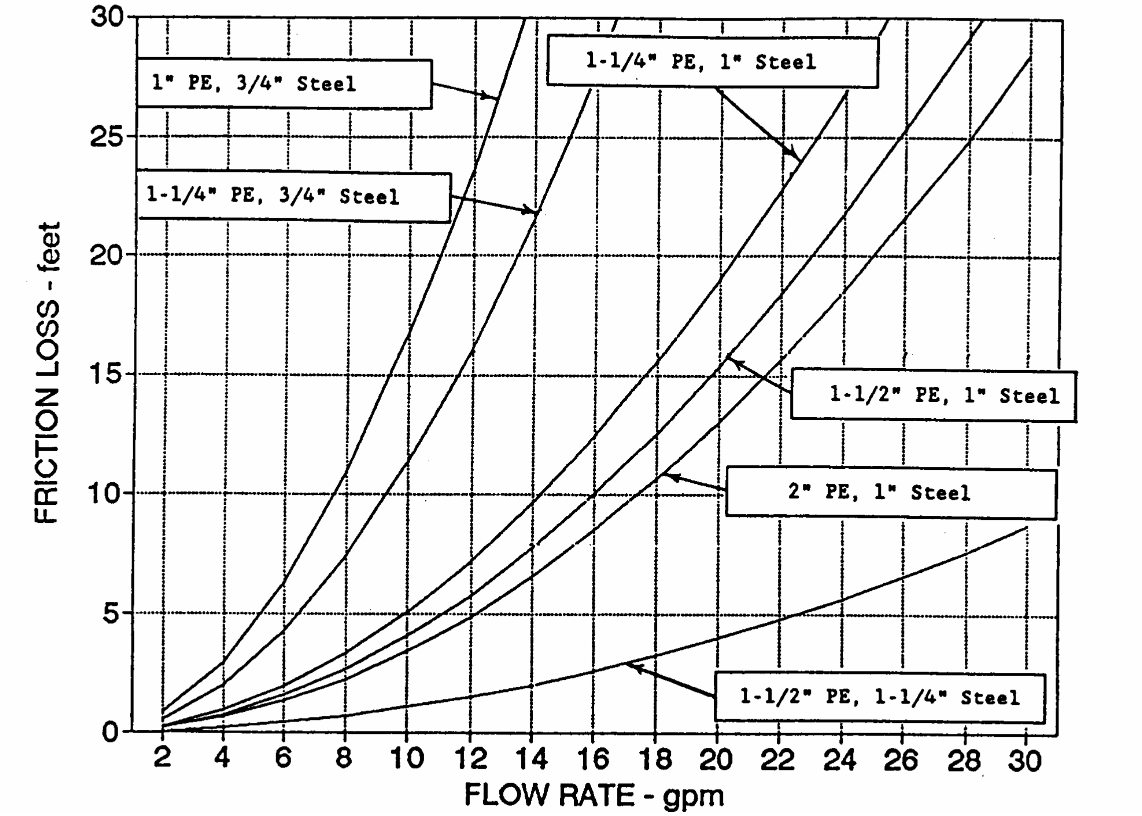
The plumbing elements for an automatic pressure system and a manual or timed system are about the same. Figure 5.1 is a graph which shows estimated friction loss values that can be used for most pumped flow installations.

Figure 5.1 assumes the following conditions:

- 100 feet pump depth in well
- PE pipe between pump and pressure tank
  (100 ft + 25 ft to manhole/tank = 125 ft length of PE pipe)
- 15 feet of galvanized steel pipe at manhole
- 4 90 degree elbows in steel pipe
- 1 "T" in steel pipe
- 1 open gate valve in steel pipe
- 1 check valve in steel pipe.

The friction loss in PE pipe is so low that well depths different than the assumed 100 feet will make little difference in total friction loss. If the total plumbing system is significantly different than assumed above, special calculations should be performed. If steel pipe is used to drop the pump in the well, special computations must be made.

Figure 5. 1
ESTIMATED FRICTION LOSS AT WELL



<u>Curve Type</u>

(1) 1" PE connector pipe, 3/4" steel plumbing at tank

(2) 1-1/4" PE connector pipe, 3/4" steel plumbing at tank

(3) 1-1/4" PE connector pipe, 1" steel plumbing at tank

(4) 1-1/2" PE connector pipe, 1" steel plumbing at tank

(5) 2" PE connector pipe, 1" steel plumbing at tank

(6) 2-1/2" PE connector pipe, 1-1/4" steel plumbing at tank

<u>Note</u>:

The above chart is based on:

100 feet to water surface in well
PE connector pipe
15 feet of steel pipe
4 steel pipe elbows
1 steel "T"
1 gate valve in steel pipe
1 check valve in steel pipe

5.9 PIPE FRICTION LOSS TABLES

The following tables are based on friction loss by the Hazen Williams formula. The form of the equation used is:

$$H_f = L\left(\frac{gpm}{C}\right)^{1.85185}\frac{10.4057}{d_i^{4.87037}}$$

C = Hazen Williams friction loss factor
gpm = Flow rate in gallons per minute
d_i = Pipe inside diameter
L = Length of pipe segment (100-feet used in calcs).

Table 5.2

PVC-SDR PIPE

FRICTION LOSS ft/100 ft

SDR 26, Pressure Rating = 160 psi @ 73.4^{o} F

Hazen Williams C = 150

Q gallons per min.	1 inch 0.0078 A 1.195 ID	1-1/4 inch 0.0128 A 1.532 ID	1-1/2 inch 0.0168 A 1.754 ID	2 inch 0.0262 A 2.193 ID	2-1/2 inch 0.0384 A 2.655 ID	3 inch 0.0569 A 3.230 ID	3-1/2 inch 0.0743 A 3.692 ID	4 inch 0.0941 A 4.154 ID
1	0.0408	0.0122	0.0063	0.0021	0.0008	0.0003	0.0002	0.0001
2	0.1473	0.0439	0.0227	0.0077	0.0030	0.0012	0.0006	0.0003
3	0.3120	0.0931	0.0481	0.0162	0.0064	0.0025	0.0013	0.0007
4	0.5316	0.1585	0.0820	0.0276	0.0109	0.0042	0.0022	0.0012
5	0.8036	0.2397	0.1240	0.0418	0.0165	0.0063	0.0033	0.0019
6	1.1264	0.3359	0.1738	0.0585	0.0231	0.0089	0.0046	0.0026
7	1.4985	0.4469	0.2312	0.0779	0.0307	0.0118	0.0062	0.0035
8	1.9189	0.5722	0.2960	0.0997	0.0393	0.0151	0.0079	0.0044
9	2.3866	0.7117	0.3682	0.1241	0.0489	0.0188	0.0098	0.0055
10	2.9008	0.8651	0.4475	0.1508	0.0594	0.0229	0.0119	0.0067
11	3.4607	1.0321	0.5339	0.1799	0.0709	0.0273	0.0142	0.0080
12	4.0658	1.2125	0.6273	0.2113	0.0833	0.0321	0.0167	0.0094
13	4.7154	1.4062	0.7275	0.2451	0.0966	0.0372	0.0194	0.0109
14	5.4091	1.6131	0.8345	0.2812	0.1108	0.0427	0.0222	0.0125
15	6.1463	1.8329	0.9482	0.3195	0.1259	0.0485	0.0253	0.0142
16	6.9265	2.0656	1.0686	0.3600	0.1419	0.0546	0.0285	0.0160
17	7.7495	2.3110	1.1956	0.4028	0.1588	0.0611	0.0319	0.0179
18	(1)	2.5691	1.3290	0.4478	0.1765	0.0679	0.0354	0.0199
19	(1)	2.8396	1.4690	0.4949	0.1951	0.0751	0.0392	0.0220
20	(1)	3.1226	1.6154	0.5443	0.2145	0.0826	0.0431	0.0242
21	(1)	3.4178	1.7681	0.5957	0.2348	0.0904	0.0471	0.0265
22	(1)	3.7253	1.9272	0.6493	0.2559	0.0985	0.0514	0.0289
23	(1)	4.0450	2.0926	0.7050	0.2779	0.1070	0.0558	0.0314
24	(1)	4.3767	2.2642	0.7628	0.3007	0.1157	0.0603	0.0340
25	(1)	4.7203	2.4420	0.8227	0.3243	0.1248	0.0651	0.0367

(1) Exceeds 5.0 feet per second velocity

(2) A = Flow area, square feet

(3) For ASTM D2241, materials 1120, 1120 or 2120. These are the most commonly used materials. Other materials have different ratings, see ASTM D2241.

Table 5.3

PVC-SDR PIPE
FRICTION LOSS ft/100 ft
SDR 21, Pressure Rating = 200 psi @ 73.4^o F
Hazen Williams C = 150

Q Gallons per min.	1 inch 0.0077 A 1.198 ID	1-1/4 inch 0.0123 A 1.502 ID	1-1/2 inch 0.0161 A 1.720 ID	2 inch 0.0252 A 2.149 ID	2-1/2 inch 0.0369 A 2.601 ID	3 inch 0.0547 A 3.166 ID	3-1/2 inch 0.0715 A 3.620 ID	4 inch 0.0904 A 4.072 ID
1	0.0403	0.0134	0.0069	0.0023	0.0009	0.0004	0.0002	0.0001
2	0.1455	0.0484	0.0250	0.0084	0.0033	0.0013	0.0007	0.0004
3	0.3083	0.1025	0.0530	0.0179	0.0071	0.0027	0.0014	0.0008
4	0.5252	0.1746	0.0902	0.0305	0.0120	0.0046	0.0024	0.0014
5	0.7939	0.2639	0.1364	0.0461	0.0182	0.0070	0.0036	0.0021
6	1.1127	0.3699	0.1912	0.0646	0.0255	0.0098	0.0051	0.0029
7	1.4803	0.4921	0.2543	0.0860	0.0339	0.0130	0.0068	0.0038
8	1.8956	0.6301	0.3257	0.1101	0.0434	0.0167	0.0087	0.0049
9	2.3576	0.7837	0.4050	0.1369	0.0540	0.0207	0.0108	0.0061
10	2.8656	0.9525	0.4923	0.1664	0.0657	0.0252	0.0131	0.0074
11	3.4187	1.1364	0.5873	0.1985	0.0784	0.0301	0.0157	0.0088
12	4.0165	1.3351	0.6900	0.2333	0.0921	0.0353	0.0184	0.0104
13	4.6582	1.5484	0.8002	0.2705	0.1068	0.0410	0.0213	0.0120
14	5.3434	1.7762	0.9180	0.3103	0.1225	0.0470	0.0245	0.0138
15	6.0717	2.0182	1.0431	0.3526	0.1392	0.0534	0.0278	0.0157
16	6.8425	2.2745	1.1755	0.3974	0.1568	0.0602	0.0313	0.0177
17	7.6554	2.5447	1.3151	0.4446	0.1755	0.0674	0.0351	0.0198
18	(1)	2.8288	1.4620	0.4942	0.1951	0.0749	0.0390	0.0220
19	(1)	3.1267	1.6159	0.5463	0.2156	0.0828	0.0431	0.0243
20	(1)	3.4383	1.7770	0.6007	0.2371	0.0910	0.0474	0.0267
21	(1)	3.7634	1.9450	0.6575	0.2595	0.0996	0.0519	0.0292
22	(1)	4.1020	2.1200	0.7167	0.2828	0.1086	0.0565	0.0319
23	(1)	4.4539	2.3019	0.7782	0.3071	0.1179	0.0614	0.0346
24	(1)	4.8192	2.4906	0.8420	0.3323	0.1276	0.0664	0.0374
25	(1)	5.1976	2.6862	0.9081	0.3584	0.1376	0.0716	0.0404

(1) Exceeds 5.0 feet per second velocity

(2) A = Flow area, square feet

(3) For ASTM D2241, materials 1120, 1120 or 2120. These are the most commonly used materials. Other materials have different ratings, see ASTM D2241.

Table 5.4
PVC-SDR PIPE
FRICTION LOSS ft/100 ft
SDR 17, Pressure Rating = 250 psi @ 73.4^o F
Hazen Williams C = 150

Q Gallons per min.	1 inch 0.0074 A 1.162 ID	1-1/4 inch 0.0117 A 1.464 ID	1-1/2 inch 0.0153 A 1.676 ID	2 inch 0.0239 A 2.095 10	2-1/2 inch 0.0351 A 2.537 ID	3 inch 0.0520 A 3.088 ID	3-1/2 inch 0.0680 A 3.530 ID	4 inch 0.0860 A 3.970 ID
1	0.0470	0.0152	0.0079	0.0026	0.0010	0.0004	0.0002	0.0001
2	0.1695	0.0548	0.0284	0.0096	0.0038	0.0014	0.0008	0.0004
3	0.3592	0.1161	0.0601	0.0203	0.0080	0.0031	0.0016	0.0009
4	0.611 8	0.1978	0.1024	0.0345	0.0136	0.0052	0.0027	0.0015
5	0.9249	0.2990	0.1547	0.0522	0.0205	0.0079	0.0041	0.0023
6	1.2964	0.4190	0.2169	0.0731	0.0288	0.0111	0.0058	0.0033
7	1.7247	0.5575	0.2885	0.0973	0.0383	0.0147	0.0077	0.0043
8	2.2085	0.7139	0.3695	0.1246	0.0491	0.0188	0.0098	0.0055
9	2.7468	0.8879	0.4595	0.1550	0.0610	0.0234	0.0122	0.0069
10	3.3386	1.0791	0.5585	0.1884	0.0742	0.0285	0.0148	0.0084
11	3.9831	1.2875	0.6663	0.2247	0.0885	0.0340	0.0177	0.0100
12	4.6795	1.5126	0.7828	0.2640	0.1039	0.0399	0.0208	0.0117
13	5.4272	1.7542	0.9079	0.3062	0.1205	0.0463	0.0241	0.0136
14	6.2255	2.0123	1.0414	0.3513	0.1383	0.0531	0.0277	0.0156
15	7.0740	2.2865	1.1834	0.3992	0.1571	0.0603	0.0314	0.0177
16	7.9720	2.5768	1.3336	0.4498	0.1771	0.0680	0.0354	0.0200
17	(1)	2.8830	1.4921	0.5033	0.1981	0.0761	0.0396	0.0224
18	(1)	3.2048	1.6587	0.5595	0.2202	0.0846	0.0441	0.0249
19	(1)	3.5423	1.8333	0.6184	0.2434	0.0935	0.0487	0.0275
20	(1)	3.8953	2.0160	0.6800	0.2677	0.1028	0.0536	0.0302
21	(1)	4.2637	2.2066	0.7443	0.2930	0.1125	0.0586	0.0331
22	(1)	4.6472	2.4052	0.8113	0.3193	0.1226	0.0639	0.0361
23	(1)	5.0460	2.6115	0.8809	0.3467	0.1331	0.0694	0.0392
24	(1)	5.4598	2.8257	0.9531	0.3752	0.1440	0.0751	0.0424
25	(1)	5.8885	3.0476	1.0279	0.4046	0.1554	0.0810	0.0457

(1) Exceeds 5.0 feet per second velocity

(2) A = Flow area, square feet

(3) For ASTM D2241, materials 1120, 1120 or 2120. These are the most commonly used materials. Other materials have different ratings, see ASTM D2241.

Table 5.5

PVC-SDR PIPE
FRICTION LOSS ft/100 ft
SDR 13.5, Pressure Rating = 315 psi @ 73.4^o F
Hazen Williams C = 150

Q Gallons per min.	1 inch 0.0069 A 1.121 ID	1-1/4 inch 0.0109 A 1.414 ID	1-1/2 inch 0.0143 A 1.618 ID	2 inch 0.0223 A 2.023 ID	2-1/2 inch 0.0327 A 2.449 ID	3 inch 0.0485 A 2.982 ID	3-1/2 inch 0.0633 A 3.408 ID	4 inch 0.0802 A 3.834 ID
1	0.0557	0.0180	0.0093	0.0031	0.0012	0.0005	0.0002	0.0001
2	0.2011	0.0649	0.0337	0.0113	0.0045	0.0017	0.0009	0.0005
3	0.4260	0.1375	0.0713	0.0240	0.0095	0.0036	0.0019	0.0011
4	0.7258	0.2342	0.1215	0.0409	0.0161	0.0062	0.0032	0.0018
5	1.0972	0.3541	0.1837	0.0619	0.0244	0.0094	0.0049	0.0027
6	1.5378	0.4963	0.2575	0.0867	0.0342	0.0131	0.0068	0.0039
7	2.0459	0.6603	0.3425	0.1154	0.0455	0.0174	0.0091	0.0051
8	2.6198	0.8455	0.4386	0.1478	0.0583	0.0223	0.0117	0.0066
9	3.2583	1.0516	0.5455	0.1838	0.0725	0.0278	0.0145	0.0082
10	3.9603	1.2782	0.6630	0.2234	0.0881	0.0338	0.0176	0.0099
11	4.7248	1.5249	0.7910	0.2665	0.1051	0.0403	0.0210	0.0118
12	5.5509	1.7915	0.9293	0.3131	0.1234	0.0473	0.0247	0.0139
13	6.4378	2.0777	1.0778	0.3631	0.1432	0.0549	0.0286	0.0161
14	7.3848	2.3834	1.2363	0.4165	0.1642	0.0629	0.0328	0.0185
15	8.3912	2.7082	1.4048	0.4733	0.1866	0.0715	0.0373	0.0210
16	(1)	3.0520	1.5832	0.5334	0.2103	0.0806	0.0421	0.0237
17	(1)	3.4146	1.7713	0.5967	0.2353	0.0902	0.0471	0.0265
18	(1)	3.7958	1.9690	0.6633	0.2615	0.1002	0.0523	0.0295
19	(1)	4.1956	2.1764	0.7332	0.2891	0.1108	0.0578	0.0326
20	(1)	4.6137	2.3932	0.8063	0.3179	0.1218	0.0636	0.0358
21	(1)	5.0499	2.6195	0.8825	0.3479	0.1334	0.0696	0.0392
22	(1)	5.5042	2.8552	0.9619	0.3792	0.1453	0.0759	0.0427
23	(1)	5.9765	3.1002	1.0444	0.4118	0.1578	0.0824	0.0464
24	(1)	6.4666	3.3544	1.1301	0.4456	0.1708	0.0891	0.0502
25	(1)	(1)	3.6178	1.2188	0.4805	0.1842	0.0961	0.0542

(1) Exceeds 5.0 feet per second velocity

(2) A = Flow area, square feet

(3) For ASTM D2241, materials 1120, 1120 or 2120. These are the most commonly used materials. Other materials have different ratings, see ASTM D2241.

Table 5.6
PVC-IPS SCHEDULE RATED PIPE
FRICTION LOSS ft/100 ft
Schedule 40 (3)
Hazen Williams C = 150

Q Gallons per min.	1 inch 450 psi 0.0060 A 1.049 ID	1-1/4 inch 370 psi 0.0104 A 1.380 ID	1-1/2 inch 330 psi 0.0141 A 1.610 ID	2 inch 280 psi 0.0233 A 2.067 ID	2-1/2 inch 300 psi 0.0332 A 2.469 ID	3 inch 260 psi 0.0513 A 3.068 ID	3-1/2 inch 240 psi 0.0687 A 3.548 ID	4 inch 220 psi 0.0884 A 4.026 ID
1	0.0770	0.0202	0.0096	0.0028	0.0012	0.0004	0.0002	0.0001
2	0.2778	0.0731	0.0345	0.0102	0.0043	0.0015	0.0007	0.0004
3	0.5886	0.1548	0.0731	0.0216	0.0091	0.0032	0.0016	0.0008
4	1.0028	0.2637	0.1245	0.0369	0.0155	0.0054	0.0027	0.0014
5	1.5159	0.3987	0.1882	0.0557	0.0234	0.0081	0.0040	0.0022
6	2.1248	0.5588	0.2637	0.0781	0.0329	0.0114	0.0056	0.0030
7	2.8267	0.7434	0.3509	0.1039	0.0437	0.0152	0.0075	0.0040
8	3.6198	0.9519	0.4493	0.1331	0.0560	0.0194	0.0096	0.0052
9	4.5020	1.1839	0.5588	0.1655	0.0696	0.0242	0.0119	0.0064
10	5.4720	1.4390	0.6792	0.2011	0.0846	0.0294	0.0145	0.0078
11	6.5282	1.7168	0.8103	0.2400	0.1010	0.0351	0.0173	0.0093
12	7.6696	2.0170	0.9520	0.2819	0.1186	0.0412	0.0203	0.0110
13	8.8950	2.3392	1.1041	0.3270	0.1376	0.0478	0.0235	0.0127
14	(1)	2.6833	1.2665	0.3751	0.1578	0.0548	0.0270	0.0146
15	(1)	3.0490	1.4391	0.4262	0.1793	0.0623	0.0307	0.0166
16	(1)	3.4361	1.6218	0.4803	0.2021	0.0702	0.0346	0.0187
17	(1)	3.8443	1.8145	0.5374	0.2261	0.0785	0.0387	0.0209
18	(1)	4.2736	2.0171	0.5973	0.2514	0.0873	0.0430	0.0232
19	(1)	4.7236	2.2296	0.6603	0.2779	0.0965	0.0475	0.0257
20	(1)	5.1943	2.4517	0.7260	0.3055	0.1061	0.0523	0.0282
21	(1)	5.6855	2.6836	0.7947	0.3344	0.1161	0.0572	0.0309
22	(1)	6.1970	2.9250	0.8662	0.3645	0.1266	0.0623	0.0337
23	(1)	6.7287	3.1760	0.9405	0.3958	0.1374	0.0677	0.0366
24	(1)	(1)	3.4364	1.0176	0.4283	0.1487	0.0732	0.0396
25	(1)	(1)	3.7062	1.0976	0.4619	0.1604	0.0790	0.0427

(1) Exceeds 5.0 feet per second velocity

(2) A = Flow area, square feet

(3) For ASTM D2241, materials 1120, 1120 or 2120. These are the most commonly used materials. Other materials have different ratings, see ASTM D2241. Pressure rating is at 73.4^{o} F.

Table 5.7

PVC-IPS SCHEDULE RATED PIPE
FRICTION LOSS ft/100 ft
Schedule 80 (3)
Hazen Williams C = 150

Q Gallons per min.	1 inch 630 psi 0.0050 A 0.957 ID	1-1/4 inch 520 psi 0.0089 A 1.278 ID	1-1/2 inch 470 psi 0.0123 A 1.500 ID	2 inch 400 psi 0.0205 A 1.939 ID	2-1/2 inch 420 psi 0.0294 A 2.323 ID	3 inch 370 psi 0.0459 A 2.900 ID	3-1/2 inch 350 psi 0.0617 A 3.364 ID	4 inch 320 psi 0.0798 A 3.826 ID
1	0.1203	0.0294	0.0135	0.0039	0.0016	0.0005	0.0003	0.0001
2	0.4344	0.1062	0.0487	0.0139	0.0058	0.0020	0.0010	0.0005
3	0.9204	0.2250	0.1031	0.0295	0.0123	0.0042	0.6020	0.0011
4	1.5681	0.3833	0.1757	0.0503	0.0209	0.0071	0.0034	0.0018
5	2.3704	0.5795	0.2656	0.0761	0.0316	0.0107	0.0052	0.0028
6	3.3225	0.8122	0.3723	0.1066	0.0442	0.0150	0.0073	0.0039
7	4.4202	1.0805	0.4953	0.1419	0.0588	0.0200	0.0097	0.0052
8	5.6602	1.3836	0.6342	0.1817	0.0753	0.0256	0.0124	0.0066
9	7.0397	1.7209	0.7888	0.2259	0.0937	0.0318	0.0154	0.0082
10	8.5564	2.0916	0.9587	0.2746	0.1139	0.0387	0.0188	0.0100
11	10.2081	2.4954	1.1438	0.3276	0.1359	0.0461	0.0224	0.0120
12	(1)	2.9317	1.3438	0.3849	0.1596	0.0542	0.0263	0.0141
13	(1)	3.4001	1.5585	0.4464	0.1852	0.0628	0.0305	0.0163
14	(1)	3.9002	1.7877	0.5121	0.2124	0.0721	0.0350	0.0187
15	(1)	4.4318	2.0314	0.5818	0.2413	0.0819	0.0398	0.0212
16	(1)	4.9944	2.2893	0.6557	0.2720	0.0923	0.0448	0.0239
17	(1)	5.5878	2.5613	0.7336	0.3043	0.1033	0.0501	0.0268
18	(1)	6.2117	2.8472	0.8155	0.3383	0.1148	0.0557	0.0298
19	(1)	6.8658	3.1471	0.9014	0.3739	0.1269	0.0616	0.0329
20	(1)	(1)	3.4607	0.9912	0.4111	0.1396	0.0677	0.0362
21	(1)	(1)	3.7879	1.0850	0.4500	0.1527	0.0741	0.0396
22	(1)	(1)	4.1287	1.1826	0.4905	0.1665	0.0808	0.0432
23	(1)	(1)	4.4829	1.2841	0.5326	0.1808	0.0877	0.0469
24	(1)	(1)	4.8506	1.3893	0.5763	0.1956	0.0949	0.0507
25	(1)	(1)	5.2315	1.4984	0.6215	0.2110	0.1024	0.0547

(1) Exceeds 5.0 feet per second velocity

(2) A = Flow area, square feet

(3) For ASTM D2241, materials 1120, 1120 or 2120. These are the most commonly used materials. Other materials have different ratings, see ASTM D2241. Pressure rating is at 73.4^{o} F.

Table 5.8
PVC-IPS SCHEDULE RATED PIPE
FRICTION LOSS ft/100 ft
Schedule 120 (3)
Hazen Williams C = 150

Q Gallons per min.	1 inch 720 psi 0.0060 A 0.915 ID	1-1/4 inch 600 psi 0.0104 A 1.230 ID	1-1/2 inch 540 psi 0.0141 A 1.450 ID	2 inch 470 psi 0.0233 A 1.875 ID	2-1/2 inch 470 psi 0.0332 A 2.275 ID	3 inch 440 psi 0.0513 A 2.800 ID	3-1/2 inch 380 psi 0.0687 A 3.300 ID	4 inch 430 psi 0.0884 A 3.626 ID
1	0.1498	0.0354	0.0159	0.0045	0.0018	0.0006	0.0003	0.0002
2	0.5405	0.1280	0.0574	0.0164	0.0064	0.0023	0.0010	0.0007
3	1.1453	0.2711	0.1216	0.0348	0.0136	0.0049	0.0022	0.0014
4	1.9512	0.4619	0.2072	0.0593	0.0231	0.0084	0.0038	0.0024
5	2.9496	0.6982	0.3133	0.0896	0.0349	0.0127	0.0057	0.0036
6	4.1342	0.9786	0.4391	0.1256	0.0490	0.0178	0.0080	0.0051
7	5.5000	1.3020	0.5842	0.1671	0.0651	0.0237	0.0106	0.0067
8	7.0430	1.6672	0.7481	0.2139	0.0834	0.0303	0.0136	0.0086
9	8.7596	2.0736	0.9304	0.2661	0.1037	0.0377	0.0170	0.0107
10	10.6468	2.5203	1.1308	0.3234	0.1261	0.0459	0.0206	0.0130
11	(1)	3.0068	1.3491	0.3858	0.1504	0.0547	0.0246	0.0155
12	(1)	3.5325	1.5850	0.4533	0.1767	0.0643	0.0289	0.0183
13	(1)	4.0970	1.8383	0.5257	0.2050	0.0746	0.0335	0.0212
14	(1)	4.6996	2.1087	0.6030	0.2351	0.0855	0.0384	0.0243
15	(1)	5.3401	2.3961	0.6852	0.2672	0.0972	0.0437	0.0276
16	(1)	6.0180	2.7003	0.7722	0.3011	0.1095	0.0492	0.0311
17	(1)	6.7331	3.0211	0.8639	0.3369	0.1225	0.0550	0.0348
18	(1)	7.4848	3.3584	0.9604	0.3745	0.1362	0.0612	0.0387
19	(1)	(1)	3.7121	1.0615	0.4139	0.1506	0.0676	0.0427
20	(1)	(1)	4.0819	1.1673	0.4552	0.1656	0.0744	0.0470
21	(1)	(1)	4.4679	1.2776	0.4982	0.1812	0.0814	0.0515
22	(1)	(1)	4.8699	1.3926	0.5430	0.1975	0.0887	0.0561
23	(1)	(1)	5.2877	1.5121	0.5896	0.2145	0.0963	0.0609
24	(1)	(1)	5.7214	1.6361	0.6380	0.2321	0.1042	0.0659
25	(1)	(1)	6.1706	1.7646	0.6881	0.2503	0.1124	0.0711

(1) Exceeds 5.0 feet per second velocity

(2) A = Flow area, square feet

(3) For ASTM D2241, materials 1120, 1120 or 2120. These are the most commonly used materials. Other materials have different ratings, see ASTM D2241. Pressure rating is at 73.4^o F.

Table 5.9
POLYETHYLENE (PE) SIDR-PR RATED PIPE
FRICTION LOSS ft/100 ft
ASTM D2239 (3)
Hazen Williams C = 145

Q Gallons per min.	1 inch 0.0060 A 1.049 ID	1-1/4 inch 0.0104 A 1.380 ID	1-1/2 inch 0.0141 A 1.610 ID	2 inch 0.0233 A 2.069 ID	2-1/2 inch 0.0333 A 2.469 ID	3 inch 0.0513 A 3.068 ID	4 inch 0.0884 A 4.026 ID
1	0.0820	0.0216	0.0102	0.0030	0.0013	0.0004	0.0001
2	0.2958	0.0778	0.0367	0.0109	0.0046	0.0016	0.0004
3	0.6268	0.1648	0.0778	0.0230	0.0097	0.0034	0.0009
4	1.0678	0.2808	0.1325	0.0393	0.0165	0.0057	0.0015
5	1.6142	0.4245	0.2004	0.0593	0.0250	0.0087	0.0023
6	2.2624	0.5950	0.2808	0.0832	0.0350	0.0122	0.0032
7	3.0099	0.7915	0.3736	0.1106	0.0466	0.0162	0.0043
8	3.8543	1.0136	0.4784	0.1417	0.0596	0.0207	0.0055
9	4.7937	1.2606	0.5950	0.1762	0.0742	0.0257	0.0069
10	5.8265	1.5322	0.7232	0.2142	0.0901	0.0313	0.0083
11	6.9512	1.8280	0.8628	0.2555	0.1075	0.0373	0.0099
12	8.1666	2.1476	1.0137	0.3002	0.1263	0.0439	0.0117
13	9.4714	2.4908	1.1757	0.3482	0.1465	0.0509	0.0135
14	(1)	2.8572	1.3486	0.3994	0.1681	0.0583	0.0155
15	(1)	3.2466	1.5324	0.4538	0.1910	0.0663	0.0176
16	(1)	3.6587	1.7269	0.5114	0.2152	0.0747	0.0199
17	(1)	4.0934	1.9321	0.5722	0.2408	0.0836	0.0223
18	(1)	4.5505	2.1478	0.6361	0.2677	0.0929	0.0247
19	(1)	5.0297	2.3740	0.7030	0.2959	0.1027	0.0273
20	(1)	5.5308	2.6106	0.7731	0.3253	0.1130	0.0301
21	(1)	6.0538	2.8574	0.8462	0.3561	0.1236	0.0329
22	(1)	6.5985	3.1145	0.9223	0.3881	0.1348	0.0359
23	(1)	7.1646	3.3817	1.0015	0.4214	0.1463	0.0389
24	(1)	(1)	3.6590	1.0836	0.4560	0.1583	0.0421
25	(1)	(1)	3.9464	1.1687	0.4918	0.1707	0.0455

AVAILABLE PE PIPE SIZES AND RATINGS (PE 3408)

Available Sizes	SDR	Pressure Rating @ 73.4^{o} F
1, 1-1/2, 2	15	100
1, 1-1/2, 2	11.5	125
1, 1-1/2, 2	9	160
1, 1-1/2, 2, 2-1/2, 3, 4	7	200
1, 1-1/2, 2, 2-1/2, 3, 4	5.3	250

(1) Exceeds 5.0 feet per second velocity

(2) A = Flow area, square feet

(3) For ASTM D2239, material PE3408. This is the most commonly used material. Other materials have different ratings, see ASTM D2239.

Revised December 2004

Table 5.10
HIGH DENSITY POLYETHYLENE (HDPE)
FRICTION LOSS ft/100 ft
ASTM D1248, Type III
Hazen Williams C = 150

Q Gallons per min.	1-1/2 inch 130 psi SDR 13.5 0.0143 A 1.62 ID	2 inch 130 psi SDR 13.5 0.0220 A 2.01 ID	1-1/2 inch 160 psi SDR 11 0.0131 A 1.55 ID	2 inch 160 psi SDR 11 0.0203 A 1.93 ID	1-1/2 inch 200 psi SDR 9 0.0119 A 1.48 ID	2 inch 200 psi SDR 9 0.0183 A 1.83 ID	1-1/2 inch 255 psi SDR 7.3 0.0104 A 1.38 ID	2 inch 255 psi SDR 7.3 0.0159 A 1.71 ID
1	0.0093	0.0032	0.0115	0.0040	0.0144	0.0051	0.0202	0.0071
2	0.0335	0.0117	0.0415	0.0143	0.0520	0.0185	0.0731	0.0257
3	0.0709	0.0248	0.0879	0.0302	0.1101	0.0392	0.1548	0.0545
4	0.1208	0.0422	0.1498	0.0515	0.1876	0.0667	0.2637	0.0928
5	0.1826	0.0639	0.2264	0.0778	0.2835	0.1008	0.3987	0.1403
6	0.2559	0.0895	0.3173	0.1091	0.3974	0.1413	0.5588	0.1967
7	0.3405	0.1191	0.4222	0.1451	0.5287	0.1880	0.7434	0.2616
8	0.4360	0.1525	0.5406	0.1858	0.6771	0.2408	0.9519	0.3350
9	0.5422	0.1896	0.6724	0.2311	0.8421	0.2995	1.1839	0.4167
10	0.6590	0.2305	0.8172	0.2809	1.0235	0.3640	1.4390	0.5065
11	0.7863	0.2750	0.9750	0.3351	1.2211	0.4343	1.7168	0.6042
12	0.9237	0.3231	1.1454	0.3937	1.4346	0.5102	2.0170	0.7099
13	1.0713	0.3747	1.3285	0.4566	1.6638	0.5917	2.3392	0.8233
14	1.2289	0.4298	1.5239	0.5238	1.9085	0.6787	2.6833	0.9444
15	1.3964	0.4884	1.7316	0.5952	2.1686	0.7712	3.0490	1.0731
16	1.5737	0.5504	1.9514	0.6707	2.4439	0.8691	3.4361	1.2093
17	1.7606	0.6158	2.1832	0.7504	2.7343	0.9724	3.8443	1.3530
18	1.9572	0.6845	2.4270	0.8342	3.0396	1.0810	4.2736	1.5041
19	2.1633	0.7566	2.6826	0.9221	3.3597	1.1948	4.7236	1.6625
20	2.3789	0.8320	2.9499	1.0140	3.6945	1.3139	5.1943	1.8282
21	2.6038	0.9107	3.2288	1.1098	4.0438	1.4381	5.6855	2.0010
22	2.8381	0.9926	3.5193	1.2097	4.4076	1.5675	6.1970	2.1810
23	3.0816	1.0777	3.8213	1.3135	4.7858	1.7020	6.7287	2.3682
24	3.3343	1.1661	4.1346	1.4212	5.1783	1.8416	(1)	2.5624
25	3.5961	1.2577	4.4593	1.5328	5.5849	1.9862	(1)	2.7636

(1) Exceeds 5.0 feet per second velocity

(2) Flow area, square feet

Table 5.11

IPS-ID POLYBUTYLENE WATER SERVICE PIPE
FRICTION LOSS ft/100 ft
ASTM D2662, SDR 11.5, 160 psi @ 73.4^o F
Hazen Williams C = 150

Q Gallons per min.	3/4 inch 0.00370 A 0.824 ID	1 inch 0.00600 A 1.049 ID	1-1/4 inch 0.01039 A 1.380 ID	1-1/2 inch 0.01414 A 1.610 ID	2 inch 0.02330 A 2.067 ID
1	0.2494	0.0770	0.0202	0.0096	0.0028
2	0.9003	0.2778	0.0731	0.0345	0.0102
3	1.9077	0.5886	0.1548	0.0731	0.0216
4	3.2499	1.0028	0.2637	0.1245	0.0369
5	4.9128	1.5159	0.3987	0.1882	0.0557
6	6.8859	2.1248	0.5588	0.2637	0.0781
7	9.1609	2.8267	0.7434	0.3509	0.1039
8	11.7308	3.6198	0.9519	0.4493	0.1331
9	(1)	4.5020	1.1839	0.5588	0.1655
10	(1)	5.4720	1.4390	0.6792	0.2011
11	(1)	6.5282	1.7168	0.8103	0.2400
12	(1)	7.6696	2.0170	0.9520	0.2819
13	(1)	8.8950	2.3392	1.1041	0.3270
14	(1)	(1)	2.6833	1.2665	0.3751
15	(1)	(1)	3.0490	1.4391	0.4262
16	(1)	(1)	3.4361	1.6218	0.4803
17	(1)	(1)	3.8443	1.8145	0.5374
18	(1)	(1)	4.2736	2.0171	0.5973
19	(1)	(1)	4.7236	2.2296	0.6603
20	(1)	(1)	5.1943	2.4517	0.7260
21	(1)	(1)	5.6855	2.6836	0.7947
22	(1)	(1)	6.1970	2.9250	0.8662
23	(1)	(1)	6.7287	3.1760	0.9405
24	(1)	(1)	(1)	3.4364	1.0176
25	(1)	(1)	(1)	3.7062	1.0976

(1) Exceeds 5.0 feet per second velocity

(2) A = Flow area, square feet

Table 5.12

CPS (Copper Pipe Size) POLYBUTYLENE WATER SERVICE PIPE FRICTION LOSS ft/100 ft ASTM D2666, SDR 13.5, 160 psi @ 73.40° F Hazen Williams C = 150

Q Gallons per min.	3/4 inch 0.00303 A 0.745 ID	1 inch 0.00499 A 0.957 ID	1-1/4 inch 0.00748 A 1.171 ID	1-1/2 inch 0.01050 A 1.385 ID	2 inch 0.01789 A 1.811 ID
1	0.4075	0.1203	0.0450	0.0199	0.0054
2	1.4709	0.4344	0.1626	0.0718	0.0194
3	3.1166	0.9204	0.3445	0.1521	0.0412
4	5.3094	1.5681	0.5868	0.2591	0.0702
5	8.0262	2.3704	0.8871	0.3917	0.1061
6	11.2497	3.3225	1.2434	0.5490	0.1487
7	(1)	4.4202	1.6541	0.7304	0.1978
8	(1)	5.6602	2.1182	0.9353	0.2533
9	(1)	7.0397	2.6345	1.1633	0.3151
10	(1)	8.5564	3.2021	1.4139	0.3830
11	(1)	10.2081	3.8202	1.6868	0.4569
12	(1)	(1)	4.4881	1.9817	0.5368
13	(1)	(1)	5.2052	2.2984	0.6226
14	(1)	(1)	5.9709	2.6365	0.7141
15	(1)	(1)	6.7846	2.9958	0.8115
16	(1)	(1)	7.6459	3.3761	0.9145
17	(1)	(1)	(1)	3.7772	1.0231
18	(1)	(1)	(1)	4.1989	1.1374
19	(1)	(1)	(1)	4.6411	1.2571
20	(1)	(1)	(1)	5.1036	1.3824
21	(1)	(1)	(1)	5.5862	1.5131
22	(1)	(1)	(1)	6.0888	1.6492
23	(1)	(1)	(1)	6.6112	1.7907
24	(1)	(1)	(1)	(1)	1.9376
25	(1)	(1)	(1)	(1)	2.0897

(1) Exceeds 5.0 feet per second velocity

(2) A = Flow area, square feet

Table 5.13

CPS (Copper Pipe Size) POLYBUTYLENE WATER SERVICE PIPE
FRICTION LOSS ft/100 ft
ASTM D2666, SDR 9, 250 psi @ 73.4^o F
Hazen Williams C = 150

Q Gallons per min.	3/4 inch 0.00248 A 0.675 ID	1 inch 0.00408 A 0.865 ID	1-1/4 inch 0.00617 A 1.064 ID	1-1/2 inch 0.00865 A 1.259 ID	2 inch 0.01480 A 1.649 ID
1	0.6589	0.1969	0.0718	0.0316	0.0085
2	2.3784	0.7107	0.2593	0.1142	0.0307
3	5.0395	1.5059	0.5493	0.2420	0.0650
4	8.5853	2.5654	0.9358	0.4123	0.1108
5	12.9783	3.8781	1.4146	0.6233	0.1675
6	(1)	5.4356	1.9828	0.8736	0.2347
7	(1)	7.2315	2.6379	1.1623	0.3123
8	(1)	9.2602	3.3779	1.4883	0.3999
9	(1)	11.5172	4.2012	1.8511	0.4973
10	(1)	(1)	5.1064	2.2499	0.6045
11	(1)	(1)	6.0921	2.6842	0.7212
12	(1)	(1)	7.1572	3.1535	0.8473
13	(1)	(1)	8.3007	3.6574	0.9826
14	(1)	(1)	(1)	4.1954	1.1272
15	(1)	(1)	(1)	4.7672	1.2808
16	(1)	(1)	(1)	5.3723	1.4434
17	(1)	(1)	(1)	6.0106	1.6149
18	(1)	(1)	(1)	6.6818	1.7952
19	(1)	(1)	(1)	7.3854	1.9842
20	(1)	(1)	(1)	(1)	2.1819
21	(1)	(1)	(1)	(1)	2.3883
22	(1)	(1)	(1)	(1)	2.6031
23	(1)	(1)	(1)	(1)	2.8265
24	(1)	(1)	(1)	(1)	3.0583
25	(1)	(1)	(1)	(1)	3.2984

(1) Exceeds 5.0 feet per second velocity

(2) A = Flow area, square feet

Table 5.14

BLACK OR GALVANIZED STEEL PIPE
FRICTION LOSS ft/100 ft
Schedule 40 (Standard)
Seamless & Electric Welded ASTM A120
Hazen Williams C = 100

Q Gallons per min.	1/2 inch *6310 psi 0.0021 A 0.622 ID	3/4 inch *4935 psi 0.0037 A 0.824 ID	1 inch *4565 psi 0.0060 A 1.049 ID	1-1/4 inch *3650 psi 0.0104 A 1.380 ID	1-1/2 inch *3240 psi 0.0141 A 1.610 ID	2 inch *2680 psi 0.0233 A 2.067 ID	2-1/2 inch *2960 psi 0.0332 A 2.469 ID	3 inch *2545 psi 0.0513 A 3.068 ID
1	2.0792	0.5285	0.1631	0.0429	0.0202	0.0060	0.0025	0.0009
2	7.5050	1.9077	0.5886	0.1548	0.0731	0.0216	0.0091	0.0032
3	15.9018	4.0420	1.2472	0.3280	0.1548	0.0458	0.0193	0.0067
4	27.0903	6.8859	2.1248	0.5588	0.2637	0.0781	0.0329	0.0114
5	40.9521	10.4094	3.2120	0.8447	0.3987	0.1181	0.0497	0.0173
6	57.3995	14.5900	4.5020	1.1839	0.5588	0.1655	0.0696	0.0242
7	76.3630	19.4103	5.9894	1.5751	0.7434	0.2202	0.0926	0.0322
8	97.7858	24.8556	7.6696	2.0170	0.9520	0.2819	0.1186	0.0412
9	121.6193	30.9137	9.5390	2.5085	1.1840	0.3506	0.1476	0.0512
10	(1)	37.5740	11.5941	3.0490	1.4391	0.4262	0.1793	0.0623
11	(1)	44.8270	13.8322	3.6376	1.7169	0.5085	0.2140	0.0743
12	(1)	52.6646	16.2506	4.2736	2.0171	0.5973	0.2514	0.0873
13	(1)	61.0791	18.8470	4.9564	2.3394	0.6928	0.2915	0.1012
14	(1)	70.0639	21.6194	5.6855	2.6836	0.7947	0.3344	0.1161
15	(1)	79.6125	24.5658	6.4603	3.0493	0.9030	0.3800	0.1319
16	(1)	89.7194	27.6845	7.2804	3.4364	1.0176	0.4283	0.1487
17	(1)	(1)	30.9738	8.1455	3.8447	1.1386	0.4791	0.1663
18	(1)	(1)	34.4321	9.0549	4.2739	1.2657	0.5326	0.1849
19	(1)	(1)	38.0581	10.0085	4.7240	1.3990	0.5887	0.2044
20	(1)	(1)	41.8504	11.0058	5.1948	1.5384	0.6474	0.2248
21	(1)	(1)	45.8077	12.0465	5.6860	1.6838	0.7086	0.2460
22	(1)	(1)	49.9289	13.1303	6.1975	1.8353	0.7723	0.2681
23	(1)	(1)	54.2129	14.2569	6.7293	1.9928	0.8386	0.2912
24	(1)	(1)	58.6585	15.4260	7.2811	2.1562	0.9074	0.3150
25	(1)	(1)	63.2648	16.6373	7.8529	2.3255	0.9786	0.3398

(1) Exceeds 10.0 feet per second velocity

(2) A = Flow area, square feet

*Fifty percent of yield strength pressure based on steel yield strength of 36,000 psi.

Revised December 2004

Table 5.15
BLACK OR GALVANIZED STEEL PIPE
FRICTION LOSS ft/100 ft
Schedule 80 (Standard)
Seamless & Electric Welded ASTM A120
Hazen Williams C = 100

Q Gallons per min.	1/2 inch *9690 psi 0.0016 A 0.546 ID	3/4 inch *7470 psi 0.0030 A 0.742 ID	1 inch *6735 psi 0.0050 A 0.957 ID	1-1/4 inch *5380 psi 0.0089 A 1.278 ID	1-112 inch *4800 psi 0.0123 A 1.500 ID	2 inch *4045 psi 0.0205 A 1.939 ID	2-1/2 inch *4275 psi 0.0294 A 2.323 ID	3 inch *3725 psi 0.0459 A 2.900 ID
1	3.9223	0.8805	0.2550	0.0623	0.0286	0.0082	0.0034	0.0012
2	14.1580	3.1784	0.9204	0.2250	0.1031	0.0295	0.0123	0.0042
3	29.9983	6.7346	1.9503	0.4767	0.2185	0.0626	0.0260	0.0088
4	51.1052	11.4730	3.3225	0.8122	0.3723	0.1066	0.0442	0.0150
5	77.2552	17.3436	5.0226	1.2278	0.5628	0.1612	0.0669	0.0227
6	108.2829	24.3093	7.0397	1.7209	0.7888	0.2259	0.0937	0.0318
7	144.0573	32.3405	9.3655	2.2894	1.0494	0.3006	0.1247	0.0423
8	(1)	41.4133	11.9929	2.9317	1.3438	0.3849	0.1596	0.0542
9	(1)	51.5070	14.9160	3.6462	1.6713	0.4787	0.1986	0.0674
10	(1)	62.6040	18.1296	4.4318	2.0314	0.5818	0.2413	0.0819
11	(1)	74.6888	21.6292	5.2872	2.4235	0.6942	0.2879	0.0977
12	(1)	87.7474	25.4108	6.2117	2.8472	0.8155	0.3383	0.1148
13	(1)	101.7673	29.4709	7.2041	3.3022	0.9458	0.3923	0.1332
14	(1)	(1)	33.8060	8.2639	3.7879	1.0850	0.4500	0.1527
15	(1)	(1)	38.4133	9.3901	4.3041	1.2328	0.5114	0.1736
16	(1)	(1)	43.2899	10.5822	4.8506	1.3893	0.5763	0.1956
17	(1)	(1)	48.4333	11.8395	5.4269	1.5544	0.6447	0.2188
18	(1)	(1)	53.8411	13.1614	6.0328	1.7280	0.7167	0.2433
19	(1)	(1)	59.5110	14.5474	6.6681	1.9099	0.7922	0.2689
20	(1)	(1)	65.4410	15.9970	7.3325	2.1003	0.8711	0.2957
21	(1)	(1)	71.6290	17.5097	8.0259	2.2989	0.9535	0.3236
22	(1)	(1)	78.0733	19.0850	8.7480	2.5057	1.0393	0.3528
23	(1)	(1)	(1)	20.7225	9.4986	2.7207	1.1285	0.3830
24	(1)	(1)	(1)	22.4218	10.2775	2.9438	1.2210	0.4144
25	(1)	(1)	(1)	24.1825	11.0845	3.1749	1.3169.	0.4470

(1) Exceeds 10.0 feet per second velocity

(2) A = Flow area, square feet

*Fifty percent of yield strength pressure based on steel yield strength of 36,000 psi.

Revised December 2004

5.10 PVC PIPE FITTINGS

Schedule 40 and 80 solvent weld and threaded fittings are covered by the following ASTM standards:

D2624 - Threaded Polyvinyl Chloride (PVC) Plastic Pipe Fittings, Schedule 80

D2466 - Polyvinyl Chloride (PVC) Plastic Pipe Fittings, Schedule 40

D2467 - Socket-Type Polyvinyl Chloride (PVC) Plastic Pipe Fittings, Schedule 80

These standards deal mainly with workmanship, materials, dimensions, tolerances, and testing. There are no pressure rating standards for PVC fittings in the ASTM specifications. The only pressure standards specified are for burst pressure.

One analysis, based very limited real data, proposes the upper limit working pressures for Schedule 40 and 80 PVC fittings as tabulated in Table 5.16. Use this as a general guide only. Actual allowable working pressures may vary widely with field conditions, particularly the frequency and degree of surge pressures anticipated. On high pressure pipelines, metal or other alternative type fittings may be needed.

Table 5.16

Estimated Upper Limit Working Pressures for Schedule 40 and Schedule 80 PVC Fittings

Nominal Diameter (in)	Outside Diameter (in)	Schedule 40 Pressure Rating		Schedule 80 Pressure Rating	
		Burst (psi)	Working (psi)	Burst (psi)	Working (psi)
½	0.840	1910	358	2720	509
3/4	1.050	1540	289	2200	413
1	1.315	1440	270	2020	378
1-1/4	1.660	1180	221	1660	312
1-1/2	1.900	1060	198	1510	282
2	2.375	890	166	1290	243
2-1/2	2.875	970	182	1360	255
3	3.500	840	158	1200	225

Chapter 6

Pressure and Surge Control

CHAPTER 6 PRESSURE AND SURGE CONTROL

TABLE OF CONTENTS

FIGURES

Chapter 6

Pressure and Surge Control

6.1 PIPELINE PRESSURE CONTROL

6.1.1 Need for Pressure Control

There are frequent circumstances in long pipelines where the operating pressure at a hydrant are too high. Due to the limitations of hydrant and float valve mechanisms, maximum pressure at a hydrant and/or float valve should be limited to not more than 80 psi. In such a case, pressure should be reduced before flow is turned into the valve.

The cost of high pressure pipe can sometimes be reduced by installing a pressure reducing station in the pipeline. This allows using a pipe with lower pressure rating. The cost savings must always be weighed against potential operation and maintenance problems which are frequently a result of installing a pressure reducing valve.

There are two ways to reduce pressure in a segment of pipeline. The first is to install a pressure reducing valve and the second is to install a tank with a float valve and a gravity pipeline extension.

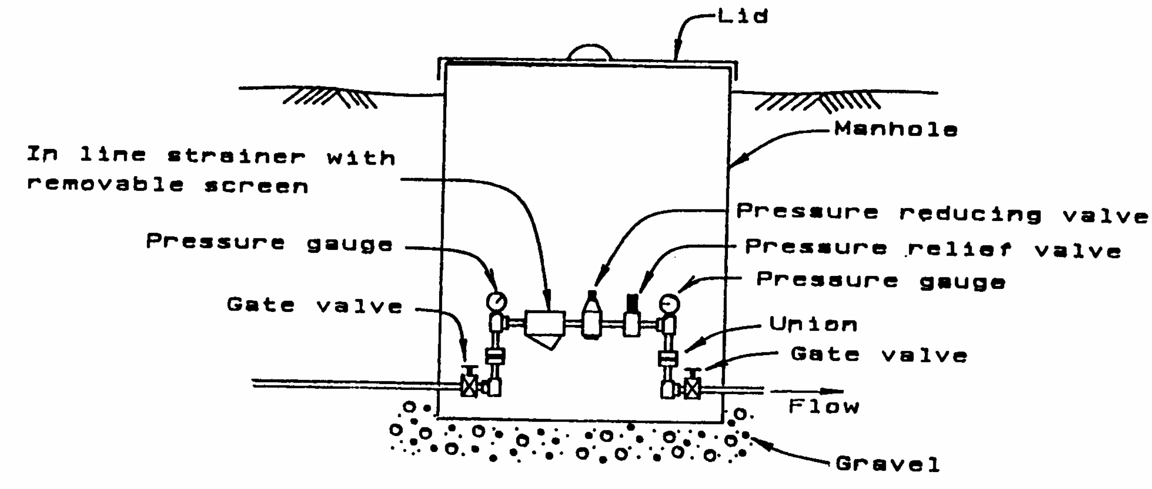
Pressure reducing valves or tank/float valves should be used as a last resort. They are mechanical devices that can and do sometimes go wrong. In many cases there is no other way to maintain pressures below 80 psi, so a pressure reducing device must be installed.

Examples in Chapter 9 show how to perform hydraulic calculations where pressure reduction is required.

6.1.2 Pressure Reducing Valves

Figure 6.1 illustrates a typical pressure reducing valve installation.

Figure 6.1
TYPICAL PRESSURE REDUCING VALVE INSTALLATION

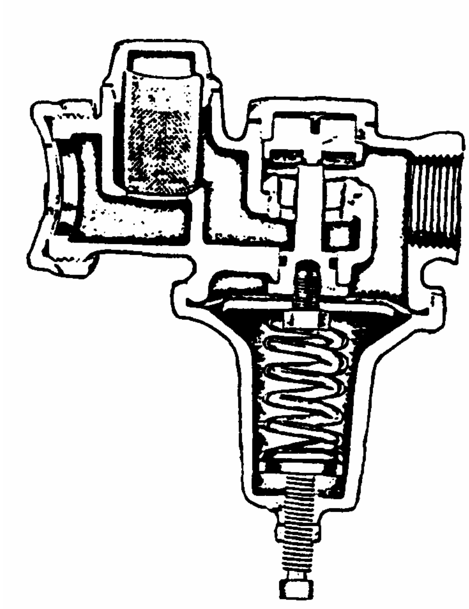


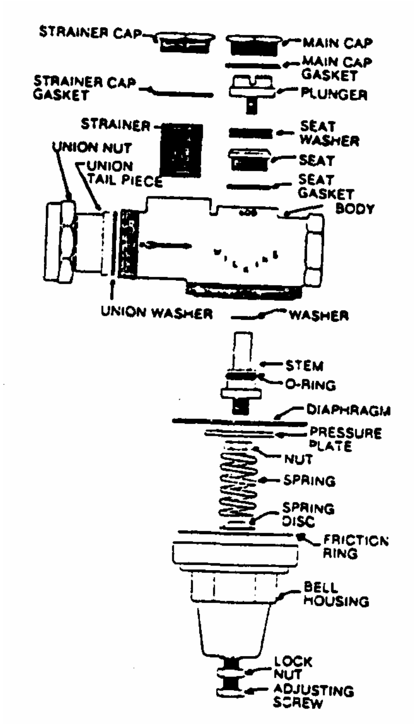
Pressure reducing valve size should be selected based on manufacturer's recommendations. Too small a valve will create very high velocities in the valve and cause rapid valve failure. Too large a valve will cause poor pressure regulation.

If the valve installation as shown in Figure 6.1 is at a high point in the pipeline, an air release valve or combination valve may also be required, as described in Chapter 7.

Figure 6.2 illustrates construction of a typical pressure reducing valve and a manufacturer design chart.

Figure 6.2
PRESSURE VALVE PARTS AND DESIGN CHARTS





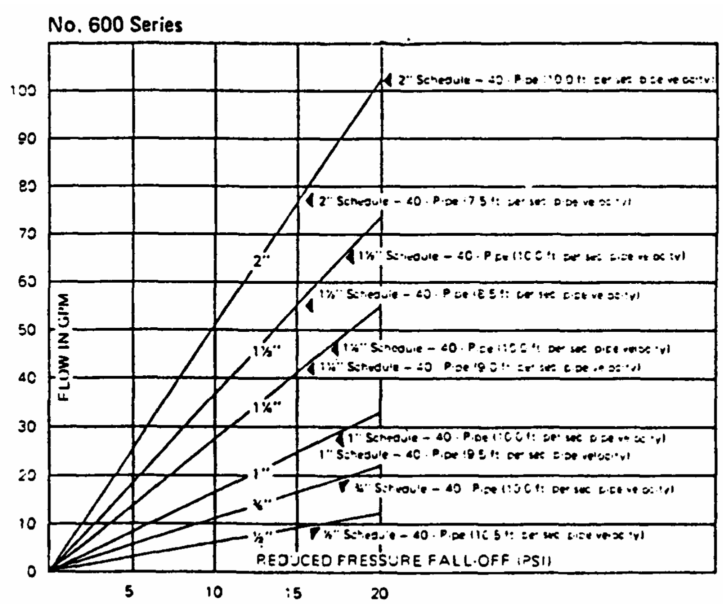
Engineering Data
(water capacities)

Wilkins No. 600 series pressure reducing valves.

Pressure diff. = inlet pressure minus set pressure.

Fall-Off = set pressure minus delivery pressure.

Pipe Size	Capacity in GPM based on		
	Average Velocity		10 Ft. Per Sec. Velocity
	Vel. (Ft.)	gpm	gpm
½"			9.47
¾"			16.60
1"	(9.5)	25.0	26.90
1¼"	(9.0)	42.0	46.70
1½"	(8.5)	54.8	64.50
2"	(7.5)	77.5	104.60



The valve illustrated in Figure 6.2 has a built-in strainer. Pressure reducing valves will not operate properly if debris get into the mechanism. Many pressure reducing valves have the small built in screens shown. Sediment and debris are enough of a problem in some pipelines that the screen soon becomes clogged. A more elaborate filter system may be required. If so, the types of filters used in home filter systems or trickle irrigation systems can be used.

Manufacturer’s charts show the maximum capacity for each size of valve based on design velocity. The flow rates in Stockwater pipelines are usually so low that maximum flow rate is usually not a problem.

There is a pressure reducing valve pressure loss called "Fall-off" that must be considered in the design. When no flow is passing through the valve there is zero fall-off. When maximum rated flow is passing through the valve there is up to 20 psi pressure fall-off. So if the pressure reducer is set at 75 psi at no flow, the static hydraulic grade line would be at (75 x 2.31) = 173 feet above valve elevation. If the valve were to operate at design flow, hydraulic grade line would start at the valve at [(75 - 20) x 2.31] = 127 feet above valve elevation.

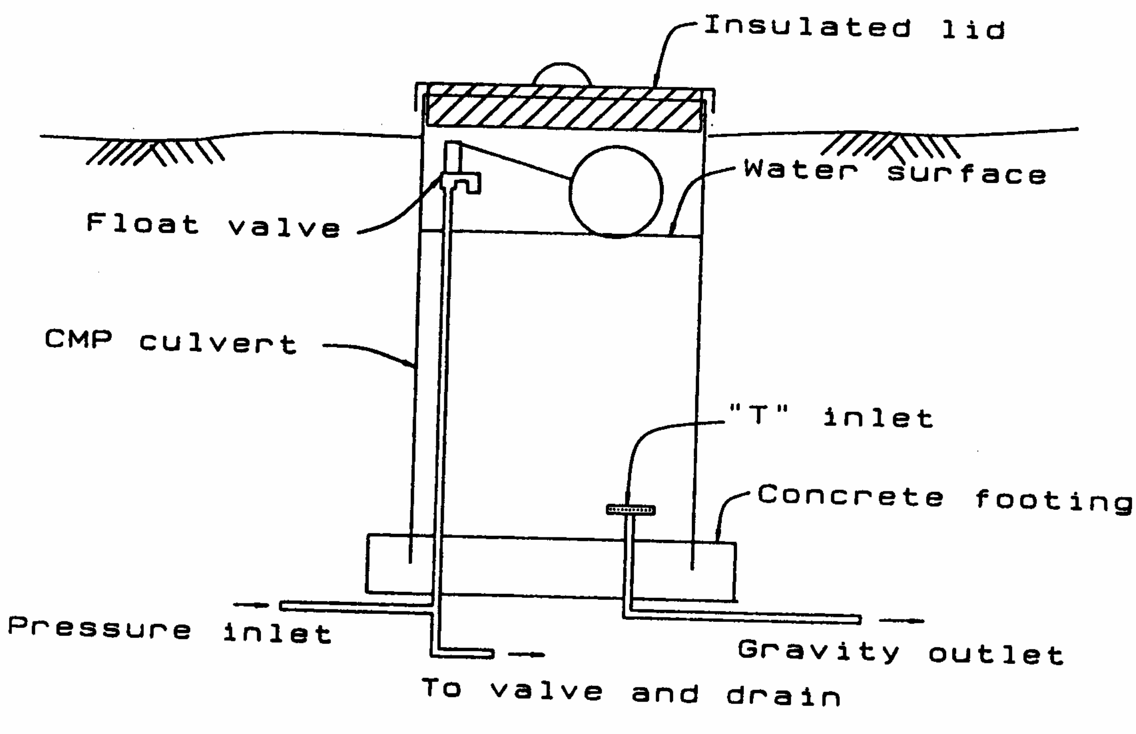
Figure 6.2 illustrates typical manufacturer information concerning valve fall-off values.

6.1.3 Grade Break at Tank

Starting a gravity pipeline at a tank is one positive way of controlling pressure in a segment of pipeline. If the float valve hangs up, the tank simply overflows. Both static and dynamic hydraulic grade line starts at the water surface in the tank. Only a usually insignificant pipeline entrance loss is experienced under design flow.

Figure 6.3 illustrates one type of tank/float valve installation. This is a small tank with a float valve strictly used for pressure regulation. A stock tank can be used in the same way. A strainer should always be added at the intake.

Figure 6.3
FLOAT VALVE BOX



6.2 SURGE CONTROL

Surge (water hammer) can be a serious problem in long stockwater pipelines. Consider what happens when a two mile long pipeline is suddenly shut off. The entire mass of water in the pipe is moving in the direction of flow. When the water is suddenly shut off, considerable force is required to stop the momentum of the large water mass.

Actual pressure build up depends on the total volume of water in the pipe, velocity at which the water is moving, and how fast the water is stopped. Pressures can be much greater than operating pressure, and can even be greater than static pressure in the pipeline.

In low head, low pressure pipelines, surge is usually not a significant consideration. The pipe and appurtenances have high enough safety factors to withstand minor surges. Surge is almost always a factor that must be addressed in long, high pressure pipelines where flow can be suddenly stopped for any reason.

A frequent surge problem is encountered on pumped systems. When the pump shuts off, the water starts to reverse in the line. A check valve closes, setting up a pressure wave and cyclic pressure surges. If the pump system contains an automatic pressure switch, the pump can rapidly cycle on and off causing damage to the pump, pipeline, and valves.

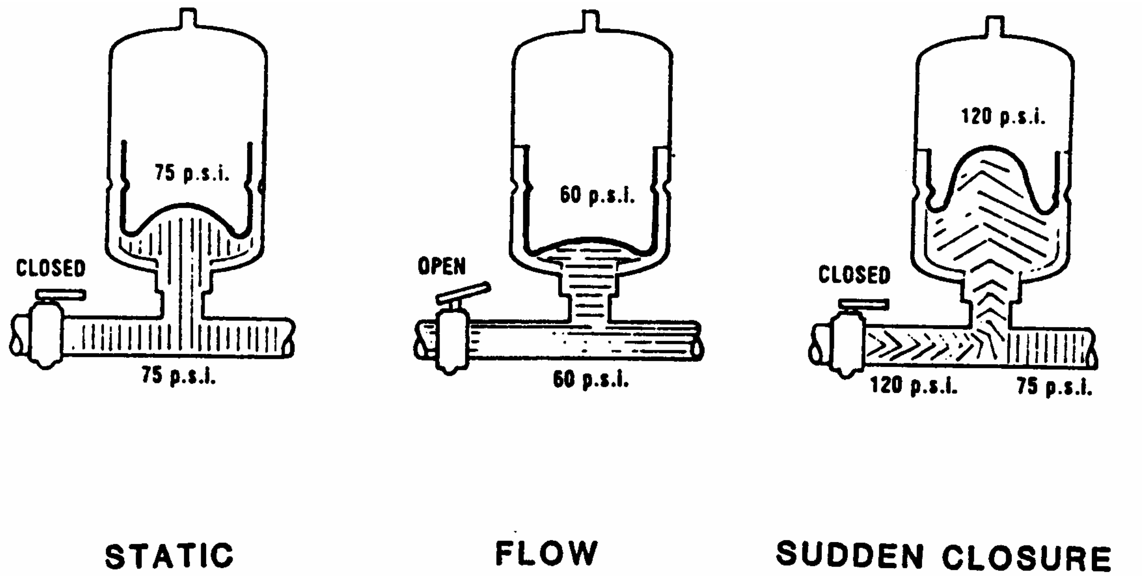
Another frequent cause of surges is rapidly turning off a hydrant. Frost free hydrants can be shut off very rapidly by slamming down the handle. This is sure to cause surges in the pipeline. Float valves will also be turned rapidly on or off if something causes the water in the tank to slosh around.

Ways in which surge can be controlled include:

6.2.1 Pressure Tank as Surge Chamber

For automatic pressure systems, a properly maintained pressure tank will act as a surge chamber. The air bubble in the pressure tank acts as a cushion for water reversing in the pipeline. Figure 6.4 illustrates how a surge chamber works.

Figure 6.4
OPERATION OF A SURGE CHAMBER



Sometimes when pressure at the pump is very high, a normal pressure tank cannot be used. In that case, it may be necessary to install a high pressure rated diaphragm-type pressure tank, or specially designed surge chamber. These are expensive but may be needed in high pressure automatic systems.

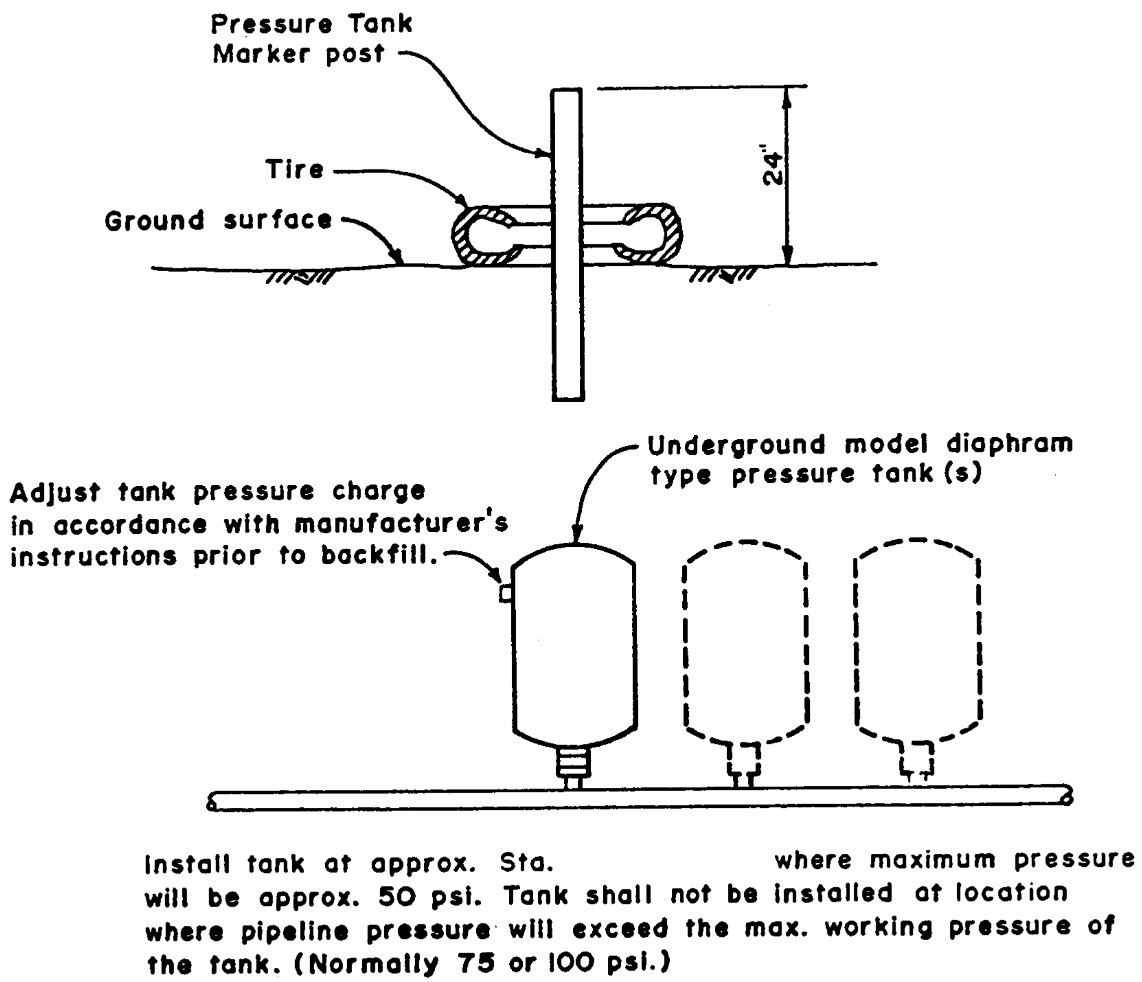
It is sometimes proposed that a homemade surge chamber be installed. This is a piece of pipe capped at one end and an air valve installed in the outer end. The chamber is filled with compressed air after the system is pressurized with water.

Homemade surge chambers are not recommended. Experience and studies have shown that this type of chamber soon waterlogs and becomes completely ineffective.

6.2.2 Minimize Frequency of Pump Cycles

Minimize the frequency of turning the pump on or off. This will reduce the number of surges that pipeline and system will have to endure. This can be accomplished by increasing pressure tank storage. Figure 6.5 illustrates a remote multiple tank setup for increased storage.

Figure 6.5
REMOTE MULTI-TANK INSTALLATION



Remote tanks can generate problems of their own. When the remote tank is far out on the pipeline, hydraulic conditions can be such that, during initial pump flow, friction loss in the pipe will cause pressure to buildup to cut out pressure and turn the pump off before the remote tanks have filled to design pressure. As pressure in the system equalizes, the pump will again start. A rapid cycling can be set up which can be very destructive to pump and pipeline.

Three possible solutions to this problem are:

1) Flow Control Valve

If this problem is encountered, one solution is to install an adjustable flow rate control valve in the pipeline near the pump. With this valve, flow rate is adjusted downward until rapid cycling is stopped. Figure 6.6 illustrates this type of installation and two types of flow rate control valves. The valves shown are expensive.

Sometimes rubber orifice flow control valves of the type used to control flow to sprinkler heads or trickle system laterals in irrigation systems can be used to control flow in moderate pressure systems. These non-adjustable flow control valves are inexpensive.

2) Flow Controlled Pressure Switch

There is a pressure regulator/pressure switch combination valve which works so that once the pump comes on, it will not shut off until all flow in the system has stopped. This guarantees that the pump will not cycle except between flow events. Figure 6.7 illustrates this type of valve. There are two models with different flow rate ratings. At least two pump manufacturer's supply this type of valve as an accessory.

If either of the above two valves are used, make sure that the pressure rating of the pipe between the pump and the valve is high enough to withstand the maximum pressure the pump is capable of generating. This will require a review of the pump curve. With these types of valves, the pressure between pump and valve will reach the maximum that the pump is able to generate.

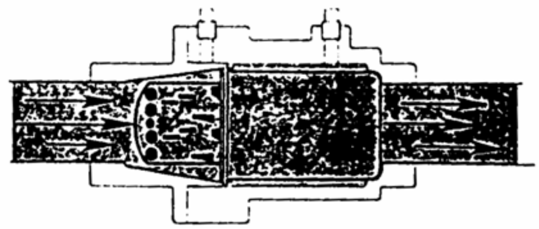
3) Pump Cycle Timer

Another possible solution is to install short period timers in conjunction with the pressure switch. The timer is set in a manner that will force minimum pump on or off cycle times. It will be especially important to have adequate pressure tank storage; tank, pipe and accessories rated for maximum pump pressure and pressure relief valves installed if this alternative is selected.

Figure 6.6
FLOW RATE CONTROLLER VALVES

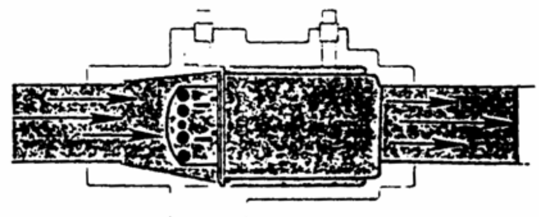
Below the control range

The cup is fully extended exposing the maximum orifice area. In this range, the valve acts as a variable flow device, allowing flow to be varied. Once the rated flow is achieved, the cup compresses, blocking the exposed orifice area to limit flow.



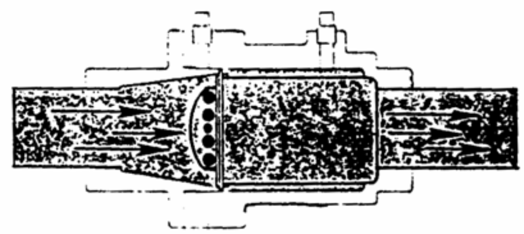
Within the control range

The cup modulates in response to pressure differential fluctuations. This motion will vary the exposed orifice area to maintain a constant flow rate within a ± 5% accuracy.



Above the control range

Once the pressure differential across the valve has exceeded the upper control limit, the cup compresses fully against a stop. Now with a minimal orifice areas exposed, the valve acts as a fixed orifice device to allow continuation of flow.



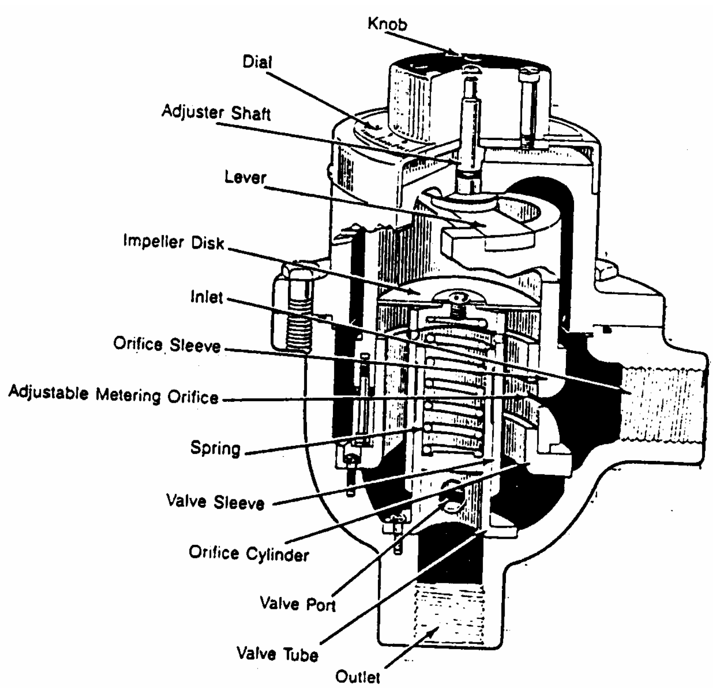
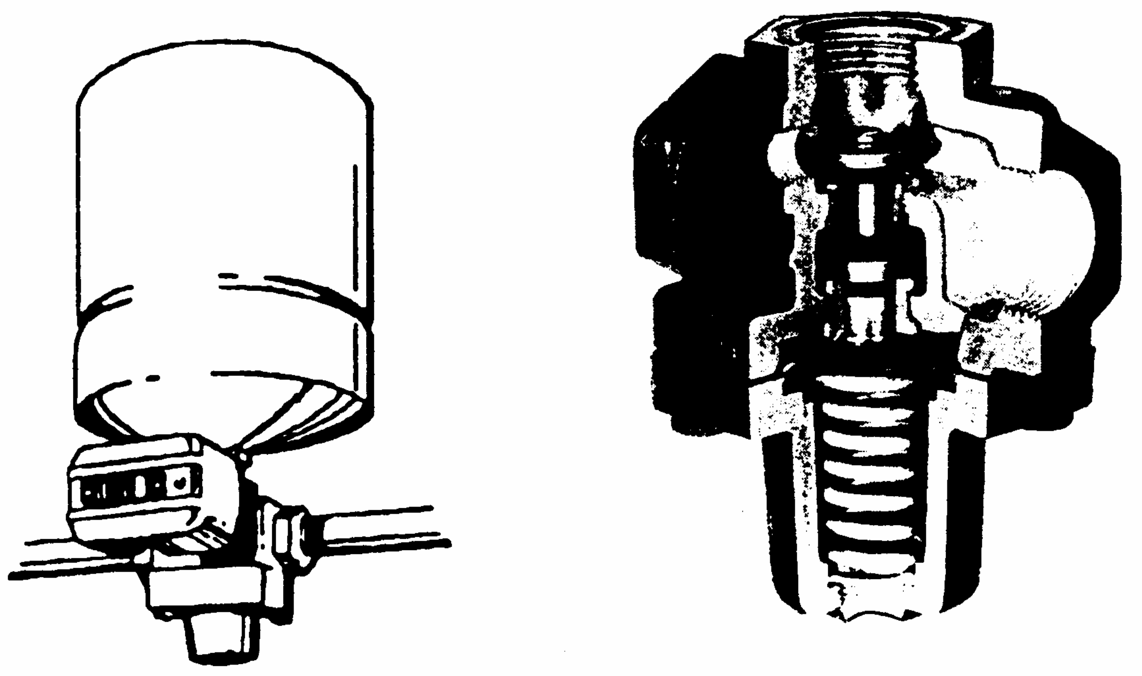


Figure 6.7
FLOW CONTROLLED PRESSURE SWITCH



6.2.3 Install Air Valves

Remnants of air in the pipeline can set up conditions that promote surges. Air valves or vents should be installed in the pipeline to remove air under pressure. See Chapter 7 for more details on air removal.

6.2.4 Use Slow Closing Valves

Install throttling type globe valves instead of frost free hydrants. Globe valves must be installed in access risers so that they are below frost line.

6.2.5 Control Flow Rate at Float Valve

Control the maximum flow rate through a float valve by installing an orifice or a flow control valve. Low cost rubber orifice type flow control valves of the type used in sprinkler systems can be installed just ahead of the float valve.

6.2.6 Operation Plan

Provide an operation plan to the operator cautioning he or she to close valves slowly and otherwise operate the system in a manner which will minimize surges in the system.

Chapter 7

Air Control

CHAPTER 7 AIR CONTROL

TABLE OF CONTENTS

FIGURES

Chapter 7

Air Control

7.1 GENERAL

Air trapped in stockwater pipelines can reduce or even completely stop the flow of water in the line. This is particularly a critical problem in pipelines that operate under very low heads or in long pipelines.

7.2 AIR/GAS PROBLEMS

Air or gas gets into a pipeline in several ways. These include:

- When a pipeline is drained, air enters the line through hydrants or any opening.
- There are various forms of gasses in well waters. These gases can come out of solution during pipeline operation. Some wells have more serious gas problems than others.
- If the water level in a well or other source falls below the pump intake, air is drawn into the pipeline by the pump.
- In gravity systems, air can be drawn into the pipeline when water surface falls below the pipeline entrance. In some live streams there can also be air bubbles entrapped in the water.

Figure 7.1
RELEASING AIR FROM PIPELINE

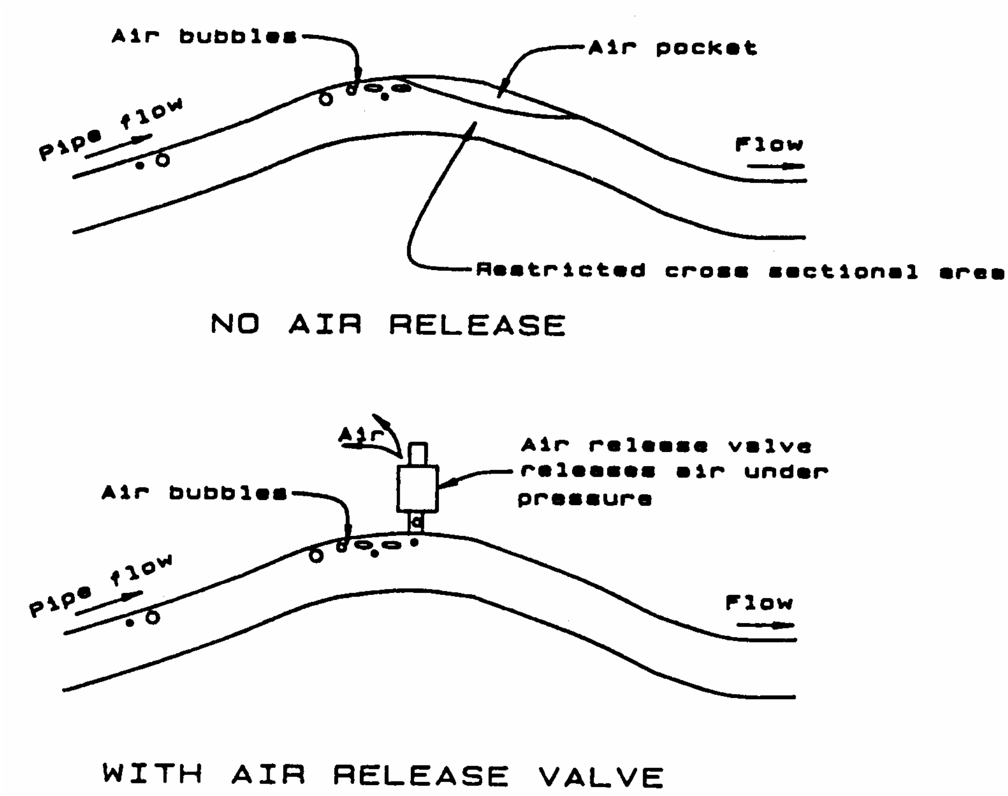


Figure 7.1 illustrates what happens when air is trapped at a high point in a pipeline. A bubble is formed at the high point. The effect is to reduce the cross-sectional area of the pipeline and thus restrict flow. This has the same effect as inserting a short length of small diameter pipe in the pipeline. Velocity accelerates through the smaller section of pipe and friction loss is increased. Since friction loss is a function of the square of velocity, friction loss can increase drastically when a large bubble is present. If the bubble is big enough, or there are many of them, flow can be cut off completely.

In addition to the flow restriction they cause, air pockets can react in a way that aggravate waterhammer problems.

As velocity increases, the air pocket tends to be pushed down the pipe in some sort of elongated bubble. There may be several separate bubbles formed. If velocities are high enough, and elevation difference to the next low point is not too great, the bubble may be pushed through to the next high point or outlet.

7.3 AIR IN LOW HEAD GRAVITY PIPELINES

Air locks are a frequent problem in very low flow, low pressure pipelines. An example of this type of system is a spring fed installation. In this case the velocity of water is very low. Air bubbles do not get pushed out, even if the summit in the line is only one pipe diameter above the rest of the line.

The solution for air lock problems can be either of the following:

- Install an open air vent at all summits in the line. Figure 3.1 in Chapter 3, illustrates an example of this type of pipeline system.

- Install the pipe so there are no summits in the line. Carefully lay out the pipe so it is on either a constantly increasing or decreasing grade.

For very low pressure pipelines, experience indicates that minimum pipe diameter should be:

1-1/4 inch nominal diameter for grades over 1.0 percent.
1-1/2 inch nominal diameter for grades from 0.5 to 1.0 percent.
2 inch nominal diameter for grades from 0.2 to 0.5 percent.

For grades less than 0.2 percent, gravity flow systems are not recommended. Where pipe of minimum size will not deliver the required flow, the size should be increased.

Cleaning may be made easier by placing "T's" or "Y's" with plugs at strategic points in the pipeline.

Outlet pipes from a spring box should be placed at least 6 inches above the box floor to allow for sediment storage. A tee and vent pipe or a screen should be installed on the pipe within the spring box to reduce plugging by leaves and trash.

Pipes starting at storage tanks or ponds should be screened and placed far enough above the tank bottom to prevent sediment from entering the system. Screens should be made of copper, plastic, or stainless steel. A swivel-elbow arrangement connected to a float will alleviate both bottom sediment and surface trash problems associated with ponds and large open storage tanks.

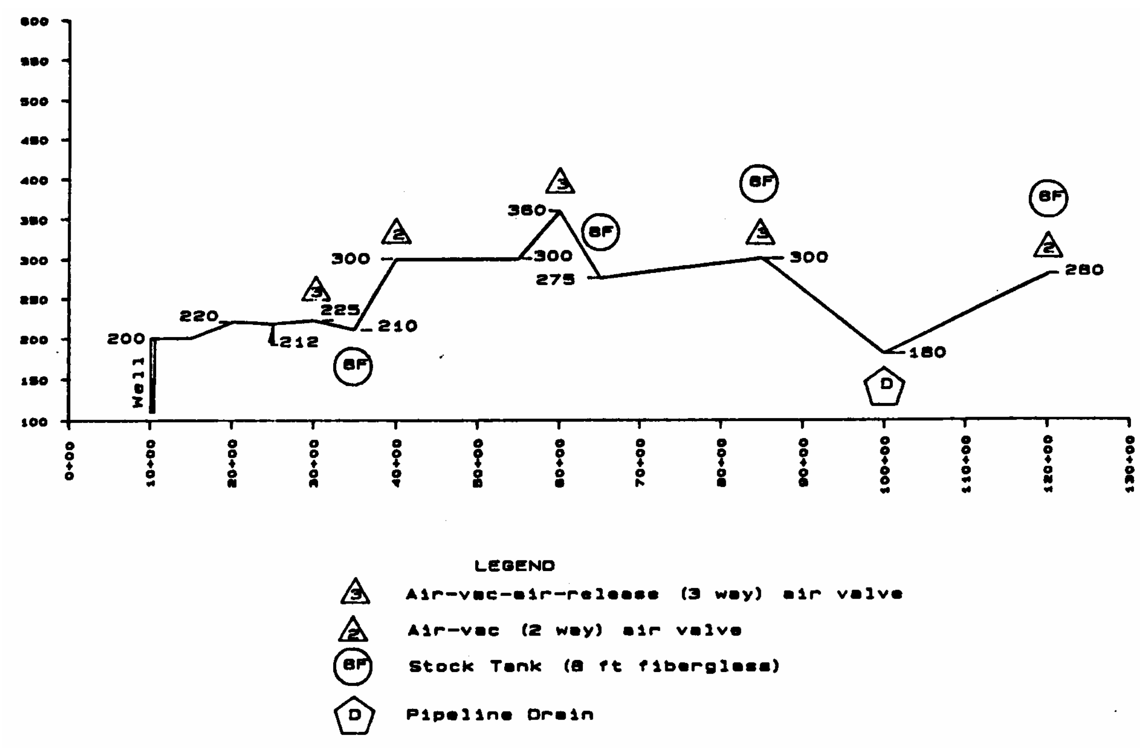
7.4 AIR CONTROL IN HIGH HEAD, LONG PIPELINES

There are two ways to resolve air problems in high pressure pipelines:

- Minimize the number of summits in the line by meandering the pipeline along the contour to avoid high points. There is a point where the extra cost of additional pipeline length makes this a non-cost effective approach.

- Install air valves at summits to control the entry and exhausting of air. Figure 7.2 shows this type of installation.

Figure 7.2
TYPICAL SYSTEM WITH AIR VALVES

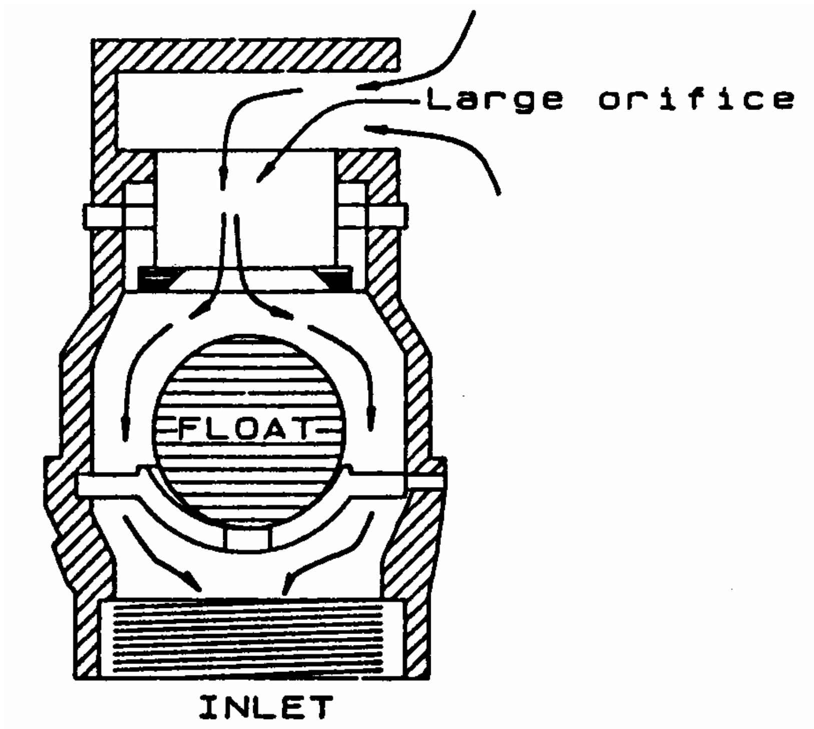


There are three types of functions that air valves perform:

1. When a pipeline is emptied, air must enter the line some place. If provisions are not made for entry of air, a vacuum can be created in the pipeline. This can lead to collapse of the pipe or at least breaking of the water column, which creates gas or water vapor pockets in the pipeline. Although it is unlikely that the small diameter pipe in stockwater lines will collapse due to vacuum, it is a bad design practice to allow significant vacuum to develop in the pipeline. It is therefore important to have a vacuum relief mechanism at significant high points in the line.

   Figure 7.3 illustrates how a typical air valve takes care of this function. Since there is no water in the valve chamber, the float drops on to a cage and allows air to enter the large orifice.

Figure 7.3
VACUUM RELIEF



2. When an empty pipe is filled with water, air in the line must be released in large volumes. This can be done by leaving the hydrants open. But what if the hydrants are closed? Air pressure will build up in the pipeline. When a hydrant or float valve is opened, high pressure air will escape and then, when water hits the end of the line, waterhammer will probably occur.

   For adequate system protection, there must be a mechanism to automatically release large volumes of air from the pipeline during filling. For best results, the mechanism should be located at all significant summits in the line.

   Figure 7.4 illustrates how a typical air valve takes care of this function. Since water has not yet entered the valve chamber, the float stays down on a cage. Large volumes of air escape through the large orifice.

   When the pipe fills, the float floats to the top of the valve and closes the large orifice. The valve then remains closed until the pipeline is again empty. The float will not drop unless pressure drops to zero, since pressure keeps it jammed against the orifice. This is the case even if an air pocket builds up in the valve chamber during operation.

   Figure 7.5 illustrates the closed valve.

Figure 7.4
RELEASE OF LARGE VOLUMES OF AIR DURING FILLING

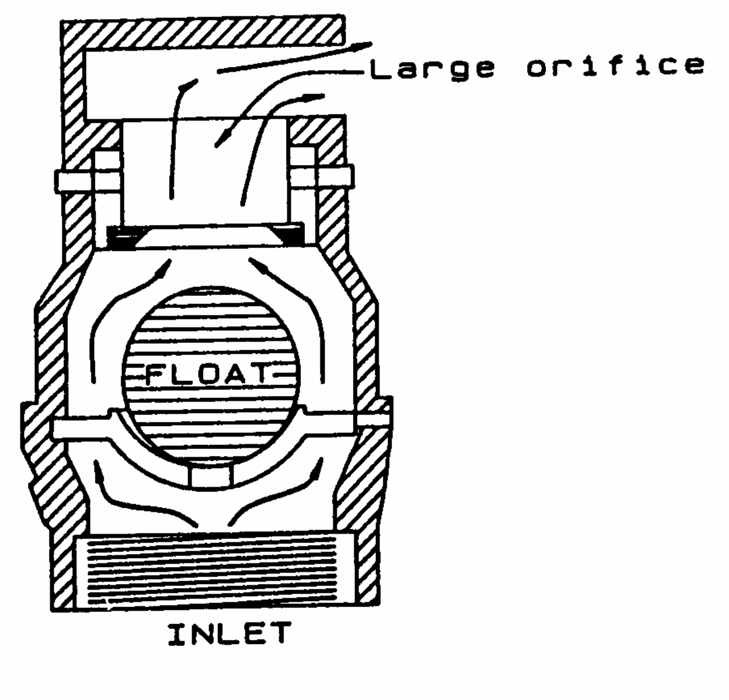
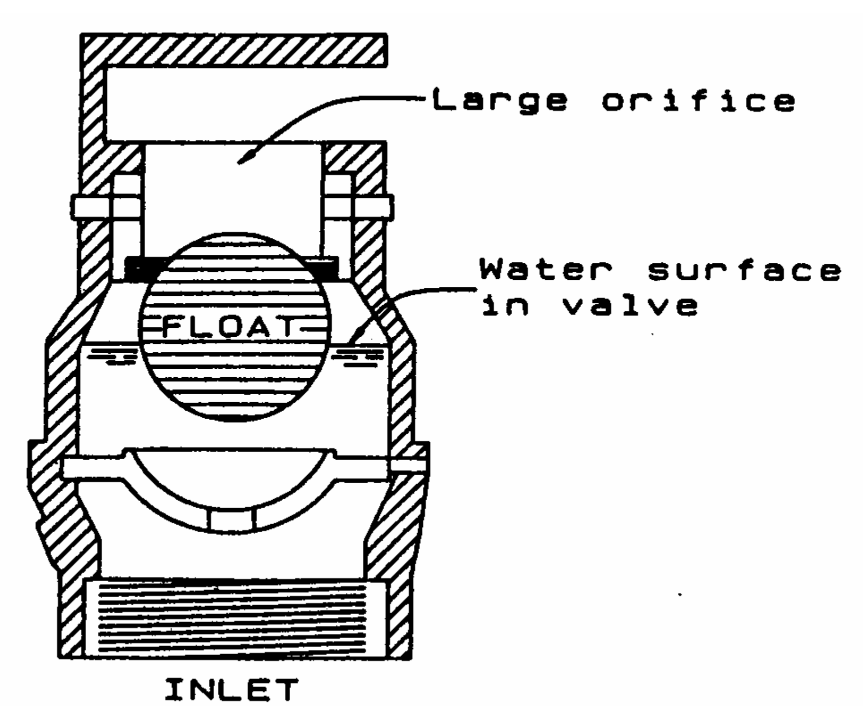


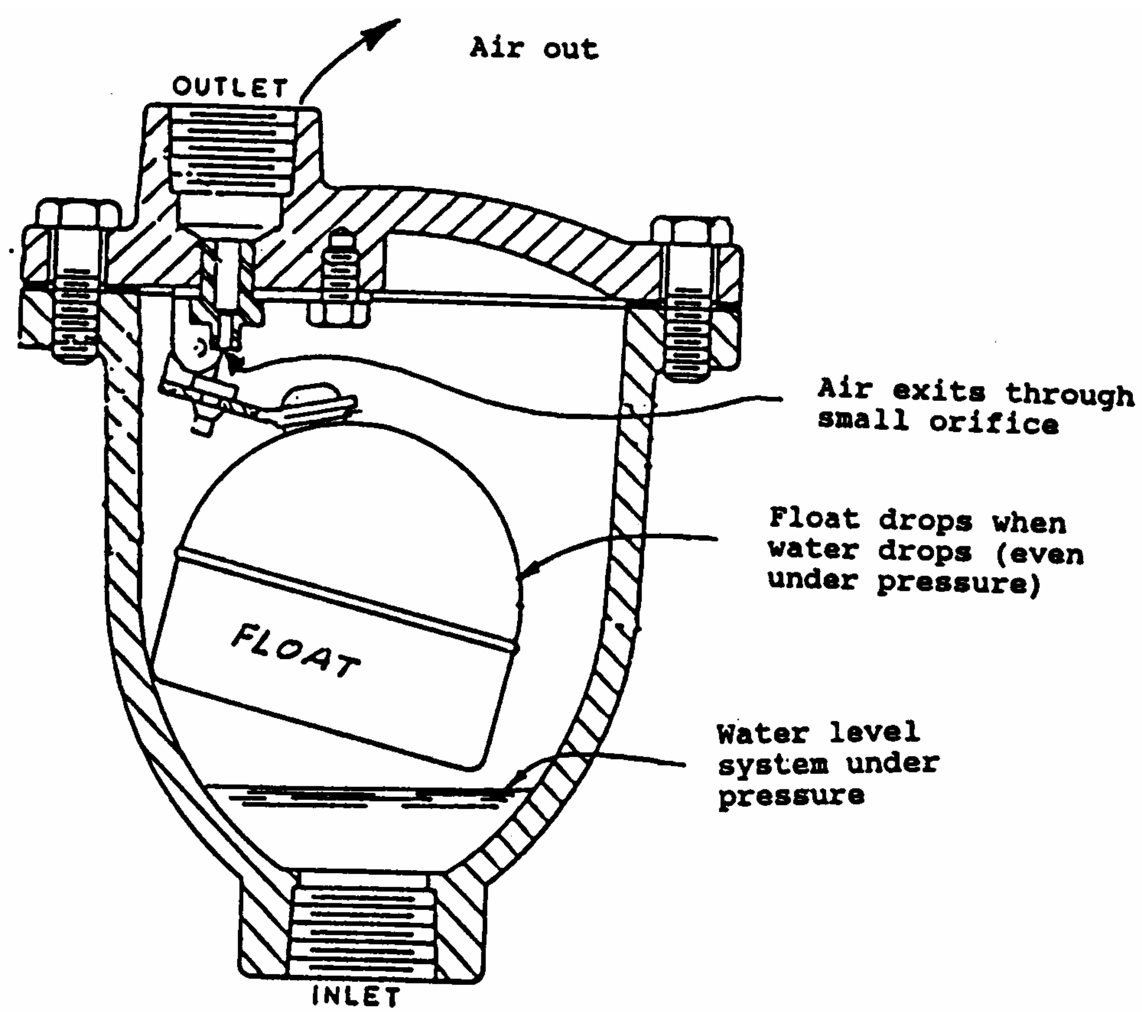
Figure 7.5
WATER AND PRESSURE KEEP FLOAT VALVE CLOSED



3. During operation of the pipeline, air bubbles and other gasses come out of solution and buildup as gas bubbles at summits in the line. There are usually also remnants of the large volumes of air present immediately after filling. If the summit is high enough, this air will never push on through the line. Gases may eventually buildup to the point where the flow rate is seriously reduced or flow may even stop. It is not possible to predict how serious a problem this may be when designing a pipeline.

   Figure 7.6 illustrates how a typical air release valve works. A heavy float and a small orifice allow the float to drop and open the orifice even when the system is under pressure. So when air bubbles gravitate to the air chamber, and the float drops, high pressure air is expelled from the valve.

Figure 7.6
AIR RELEASE VALVE
FOR RELEASING AIR WHILE PIPE IS UNDER PRESSURE



In the past, there have been long high pressure stockwater lines installed in Montana with little or no provision for air venting. Many of these systems work. A line that has worked for years will sometimes slow down or stop. The usual culprit is air in the line.

Long stockwater pipelines cost a lot of money. The cost of installing adequate air handling equipment during initial installation is a relatively small part of total installation cost. The cost of installing air valves is much less in the initial installation than going back later to add needed valves. Adequate air handling equipment should always be designed into a system at the time of initial installation.

In high pressure, moderate flow systems, there are frequently many small undulations in the ground surface and a few large humps. Trial and error on typical long stocklines in Montana has led to the conclusion that we can usually get away with not installing air vents or valves on summits that are less than ten feet high. So in most cases, it is recommended that air handling equipment be installed on all summits of ten feet or more, at the end of the pipeline and at the first high point of any kind past the pump.

Ignoring summits which are less than ten feet may occasionally lead to system operational problems. In that case, the owner will have to go back and install air valves or vents at all summits. So far, the risk involved in using this rule of thumb has proved acceptable. Remember that it is not acceptable to ignore summits in the line in low head, low velocity pipelines.

A particularly important location for a continuous acting air release valve is the first high point past the pump. This valve would catch and release most gas introduced at the pump.

The preferred locations for air venting is at high points in the line. Hydrants, open vents, or vacuum relief valves can be used. Where the hydraulic grade line is close to pipe elevation, open air vents are the best choice. Hydrants can be used if they are always opened at the time of draining and line filling. The risk of using hydrants is that there may be additional damage to the line if a sudden pipeline break should unexpectedly drain the line.

7.5 HOW AIR VALVES WORK

There are four general types of air valves. They are:

1. Vacuum relief valve (relieve vacuum only)

2. Air relief/vacuum relief valve (relieve vacuum and expel large volumes of air during filling)

3. Air release valve (release small volumes of air under pressure)

4. Combination air/vacuum relief, air release (combines all functions in one valve).

The latter three types of valves are usually used in stockwater pipelines. The smallest valves available are usually adequate. Valves are rated according to maximum pressure that they can operate under as well as by orifice size. Only appropriate pressure rated valves should be used.

Figures 7.5 through 7.9 illustrates cutaway views of typical air valves used in stockwater pipelines. Different manufacturers have different ways of doing the same job. Some valves are made of plastic. These generally are adequate for low pressure operation. The cast iron models are for high pressure operation.

It is sometimes claimed that the air release (small orifice) valve will also serve the purpose as vacuum relief valve. The small orifice is not adequate to prevent high vacuum from occurring if there is a sudden break or during emptying of the pipeline. The proper kind of valves should be used where they are needed.

In most cases, the combination (three way) valve should be installed at all significant summits. An air release valve will suffice at small summits. At the end of the line an air release/vacuum (two way) valve should be installed.

Figure 7.7
TYPICAL AIR RELEASE VALVES

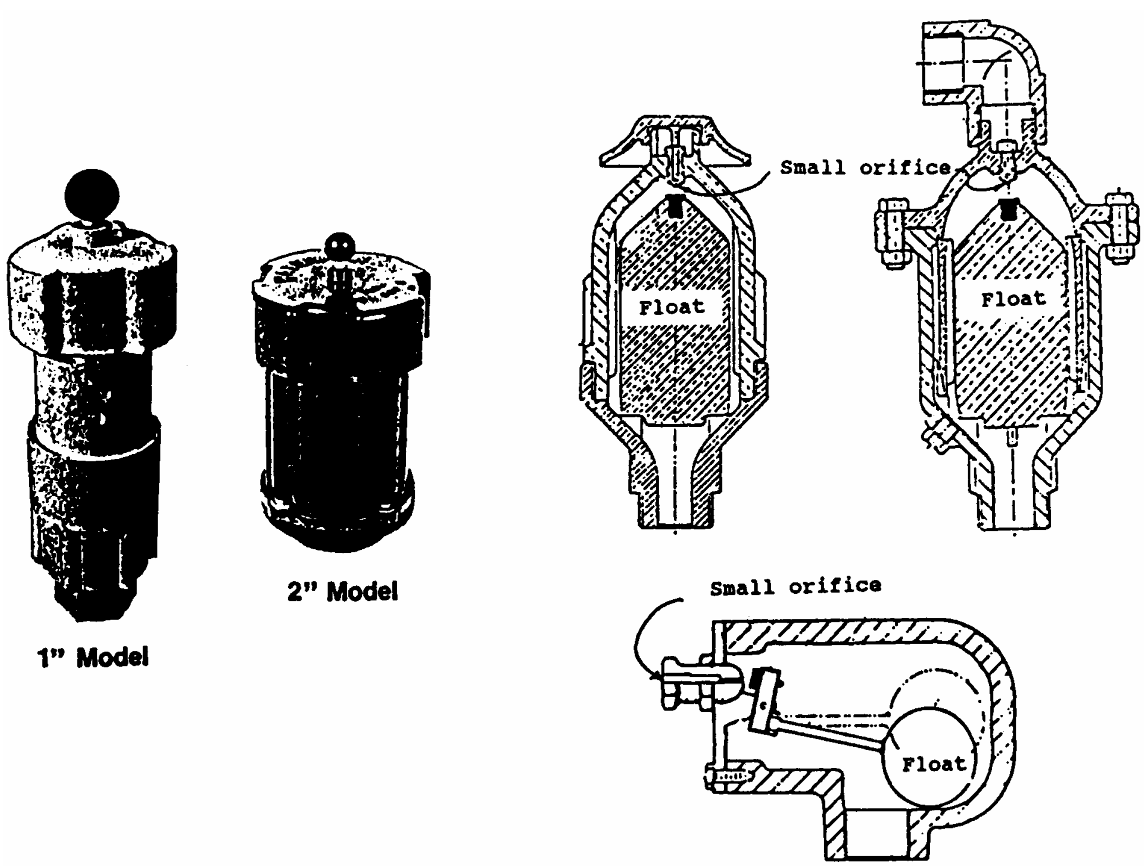


Figure 7.8
TYPICAL AIR RELIEF/VACUUM VALVES (TWO WAY)

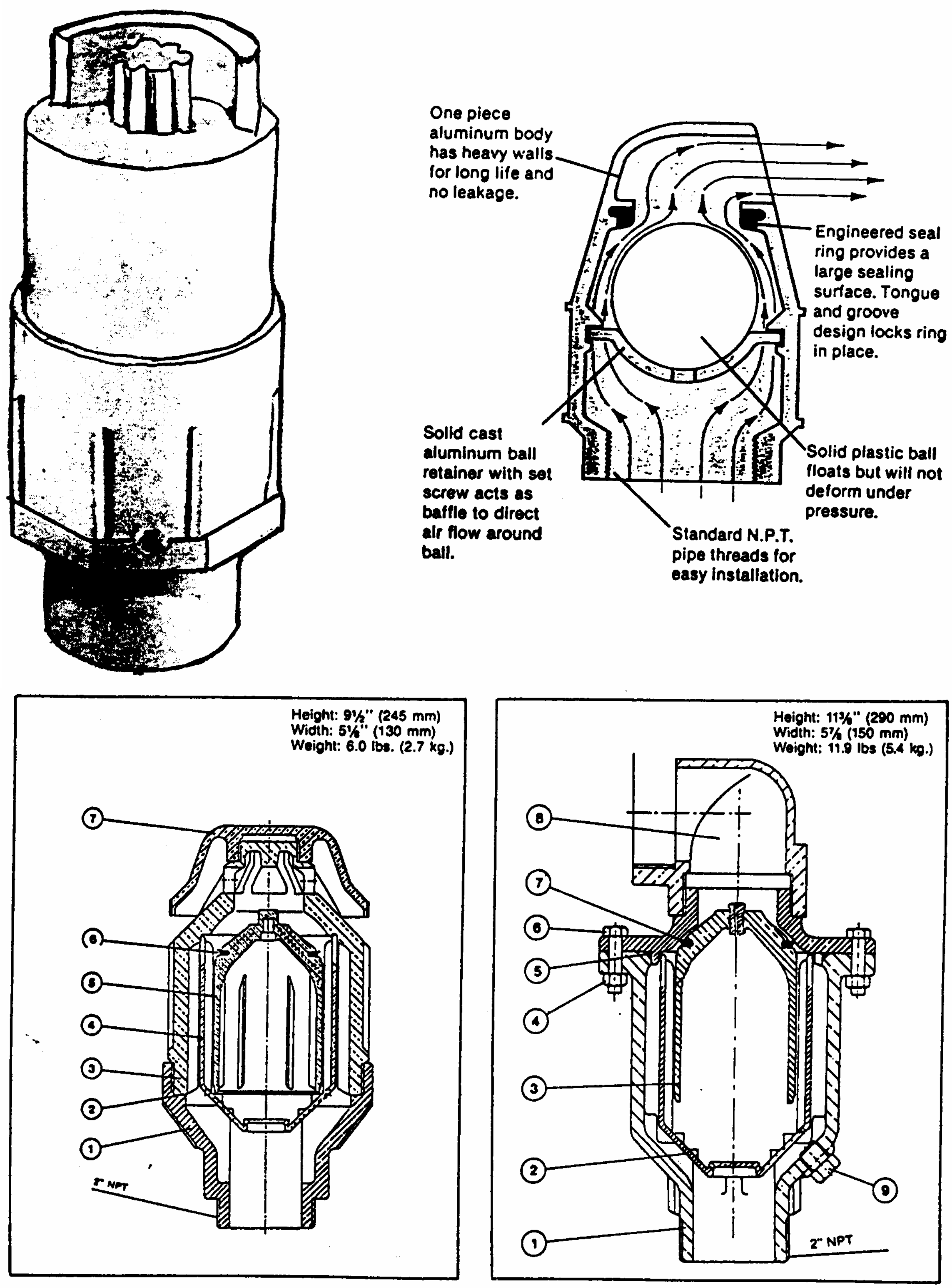
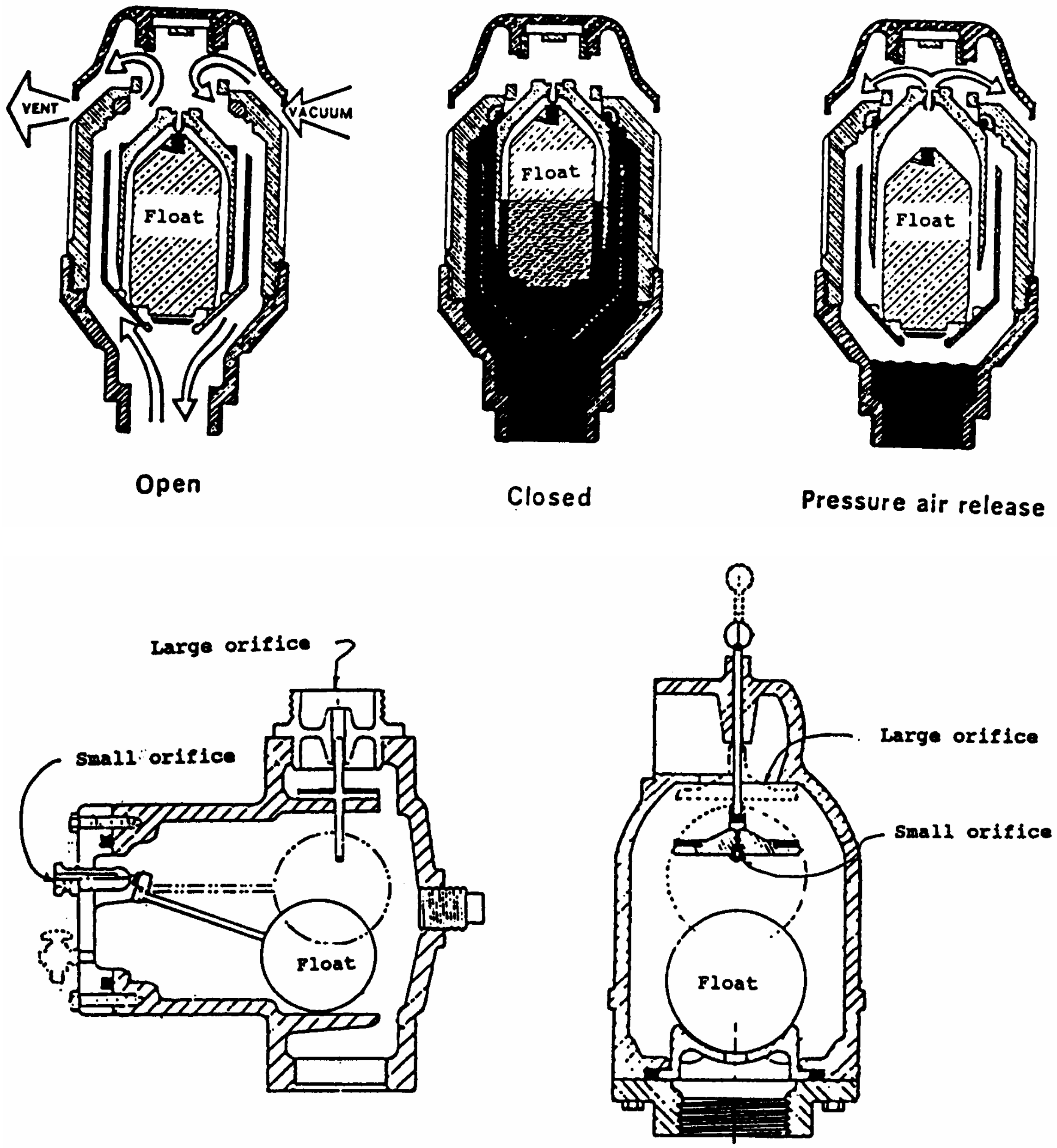


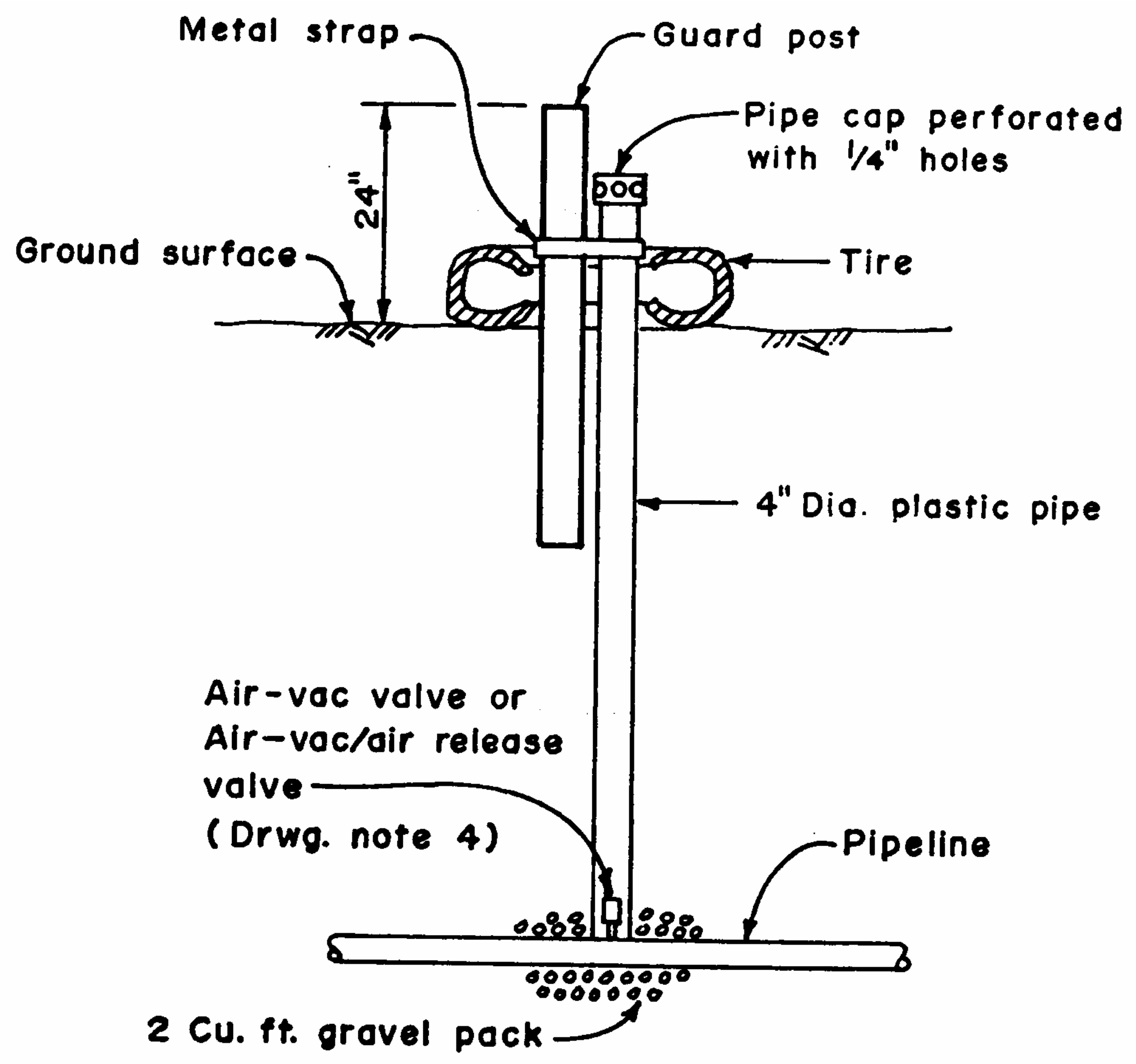
Figure 7.9
TYPICAL AIR/VAC/AIR RELEASE VALVES (THREE WAY)



7.6 AIR VALVE INSTALLATION

Figure 7.10 illustrates a good air valve installation. Since air valves can leak some water, provisions must be made to dissipate this water.

Figure 7.10
AIR VALVE INSTALLATION



Chapter 8

System Accessories

CHAPTER 8 SYSTEM ACCESSORIES

TABLE OF CONTENTS

FIGURES

TABLES

Chapter 8

Pipeline System Accessories

8.1 SPRING FED PIPELINE ENTRANCE

There are many ways that water can be collected at a spring and led into a pipeline. Figures 8.1 through 8.4 illustrate some typical installations.

If the spring yields any kind of sediment along with the water, a spring box should be installed. A spring box is also useful for monitoring and maintaining the spring water collection system.

Chapter 12 of the Natural Resources Conservation Service Engineering Field Manual provides information on developing springs and spring water collection systems.

Figure 8.1
TYPICAL SPRING BOX AND PIPE COLLECTION

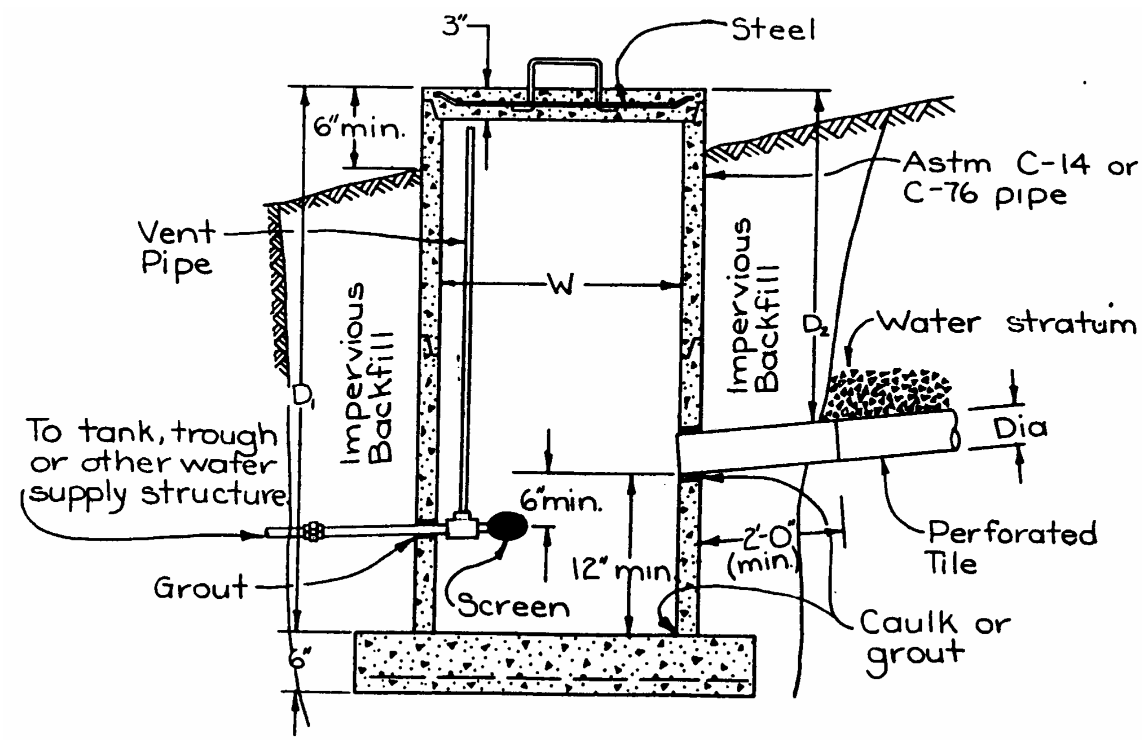


Figure 8.2
TYPICAL SPRING BOX DIRECT COLLECTION

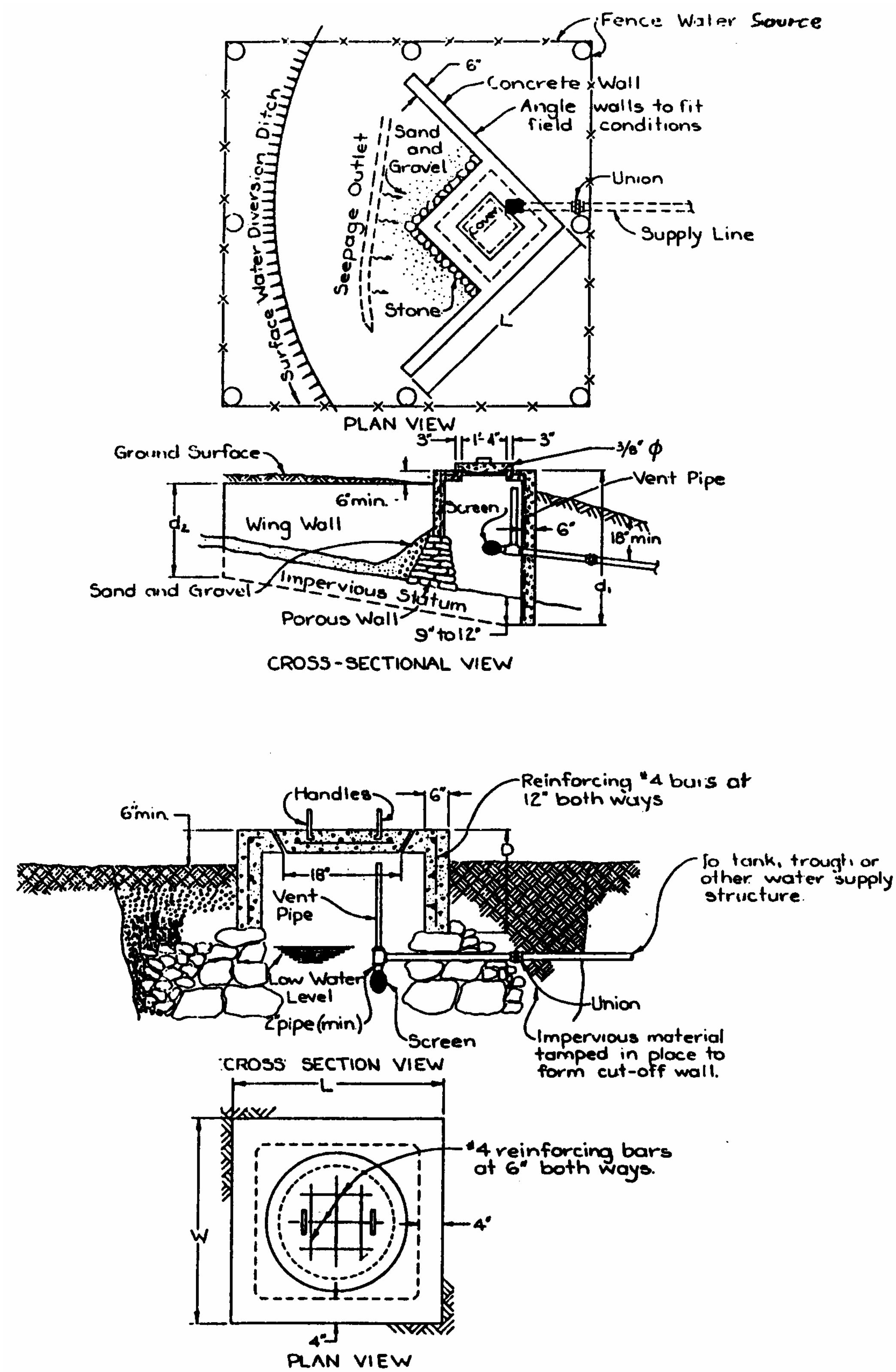
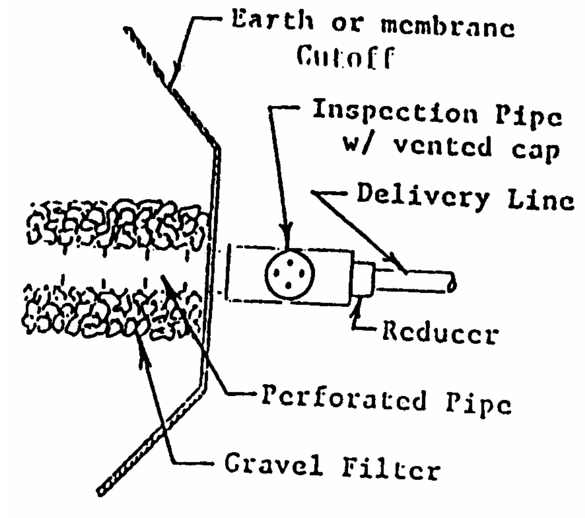
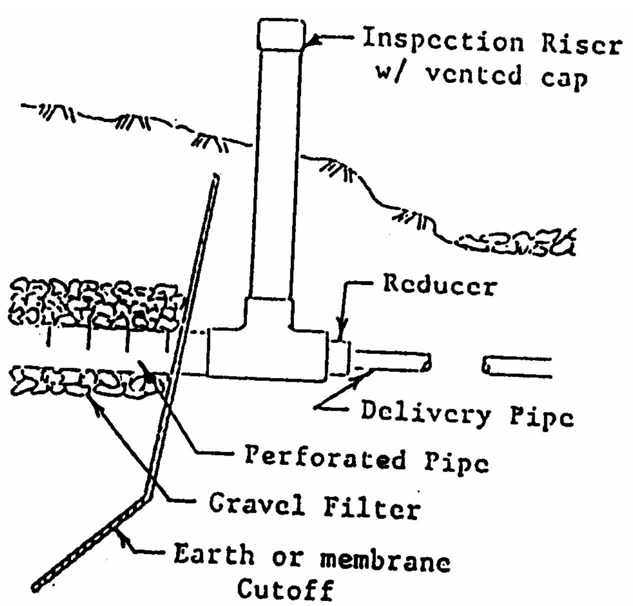


Figure 8.3
WATER COLLECTION WITHOUT SPRING BOX



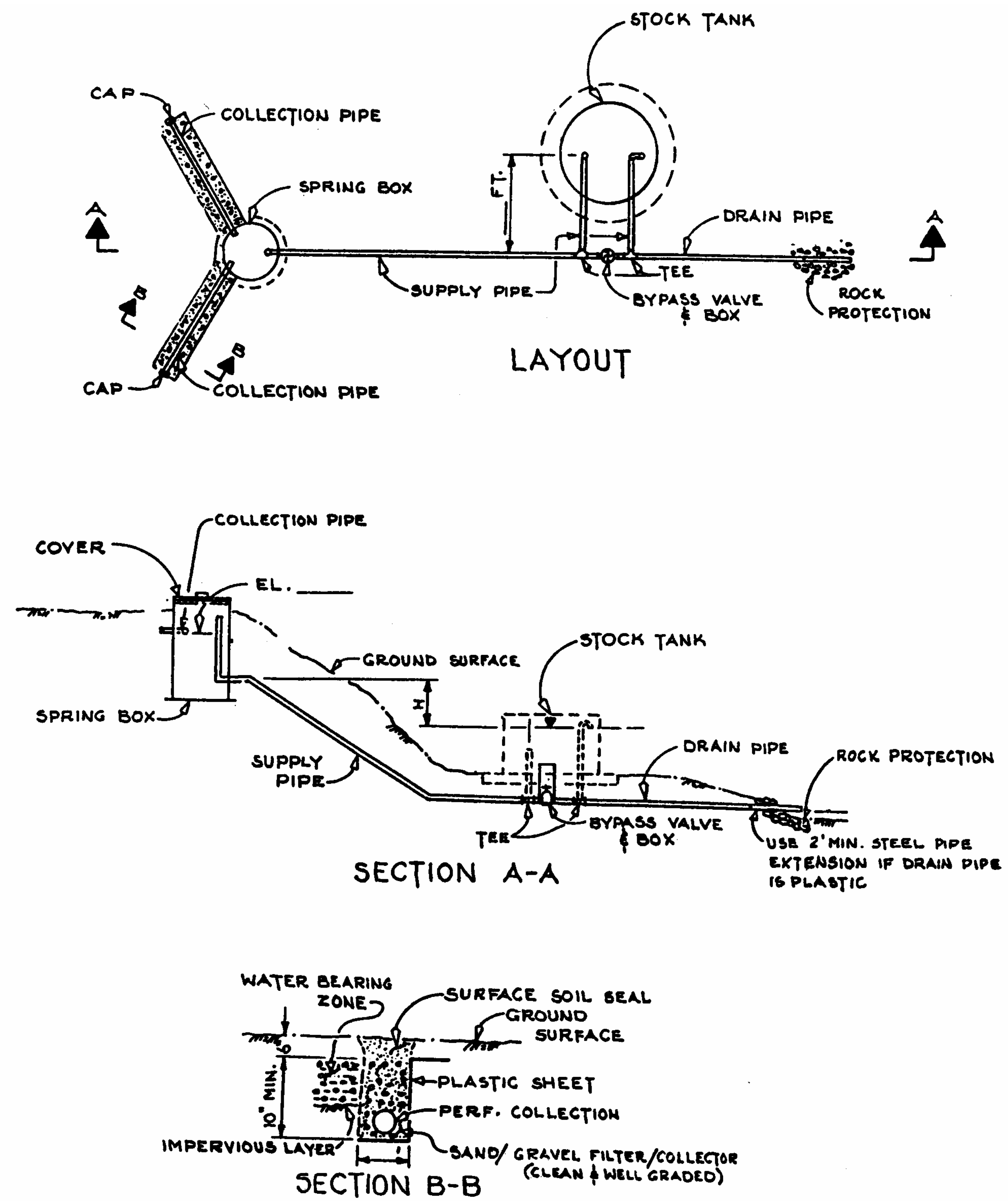
PLAN



Note: Instead of a "T", a "Y" may be installed with the riser at a 45 degree angle with the ground. This will allow using a snake to clean out the perforated drain pipe.

PROFILE

Figure 8.4
TYPICAL SPRING FED PIPELINE



8.2 WELLS AND SUMPS

Figure 8.6 illustrates a typical pitless adopter type of submersible pump installation. The pitless adopter puts the top of the well casing above the surrounding ground so contaminating water will not run into the well. The pipe exits the well casing below the frost line.

In the past, many wells were constructed so the top ended up below ground in the bottom of a pit. If the pit were flooded, the well, and possibly the groundwater aquifer, could become contaminated. This type of installation is no longer acceptable.

State health laws regulate how wells are constructed so the potential for water contamination is minimized. It is important to become familiar with these regulations when planning stockwater systems involving wells.

Chapter 12 of the Natural Resources Conservation Service Engineering Field Manual provides more information on wells.

8.3 PUMPS

There are many kinds of pumps used in stockwater pipelines. The kind which will work best depends on available sources of power, flow rate, head requirements, and water source.

Availability of electric power is frequently a major factor in determining whether or not an electric pump can be used. If power is not already available at the water source, it can be very expensive to bring in power. When planning a stockwater system requiring pumping, electric power availability and cost of bringing in electric power are two of the first things that must be considered.

8.3.1 Submersible Electric Pump

Figure 8.5 illustrates a typical submersible pump. This is the best type of pump for deep wells.

Some submersible pumps have a built-in check valve in the pump. It is a good idea though, particularly on high-pressure systems, to install another separate check valve on the pump side of the pressure tank.

Figure 8.6 illustrates a typical submersible pump system using a pitless adopter. Figure 8.7 illustrates a typical submersible pump curve.

Figure 8.5
SUBMERSIBLE PUMP

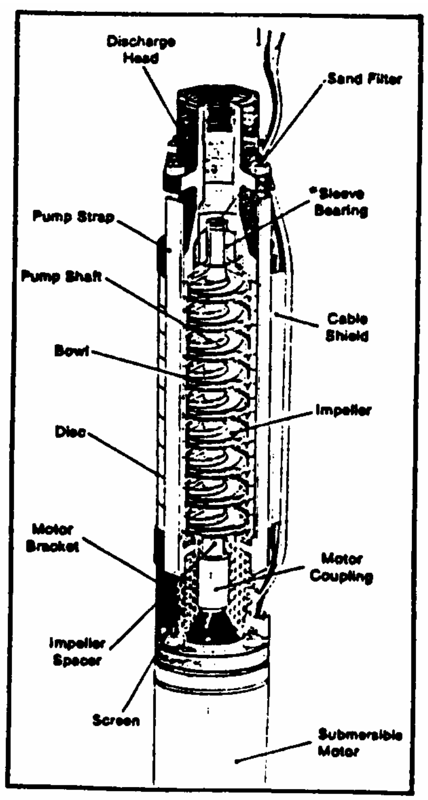


Figure 8.6
TYPICAL WELL WITH PITLESS ADOPTER AND SUBMERSIBLE PUMP

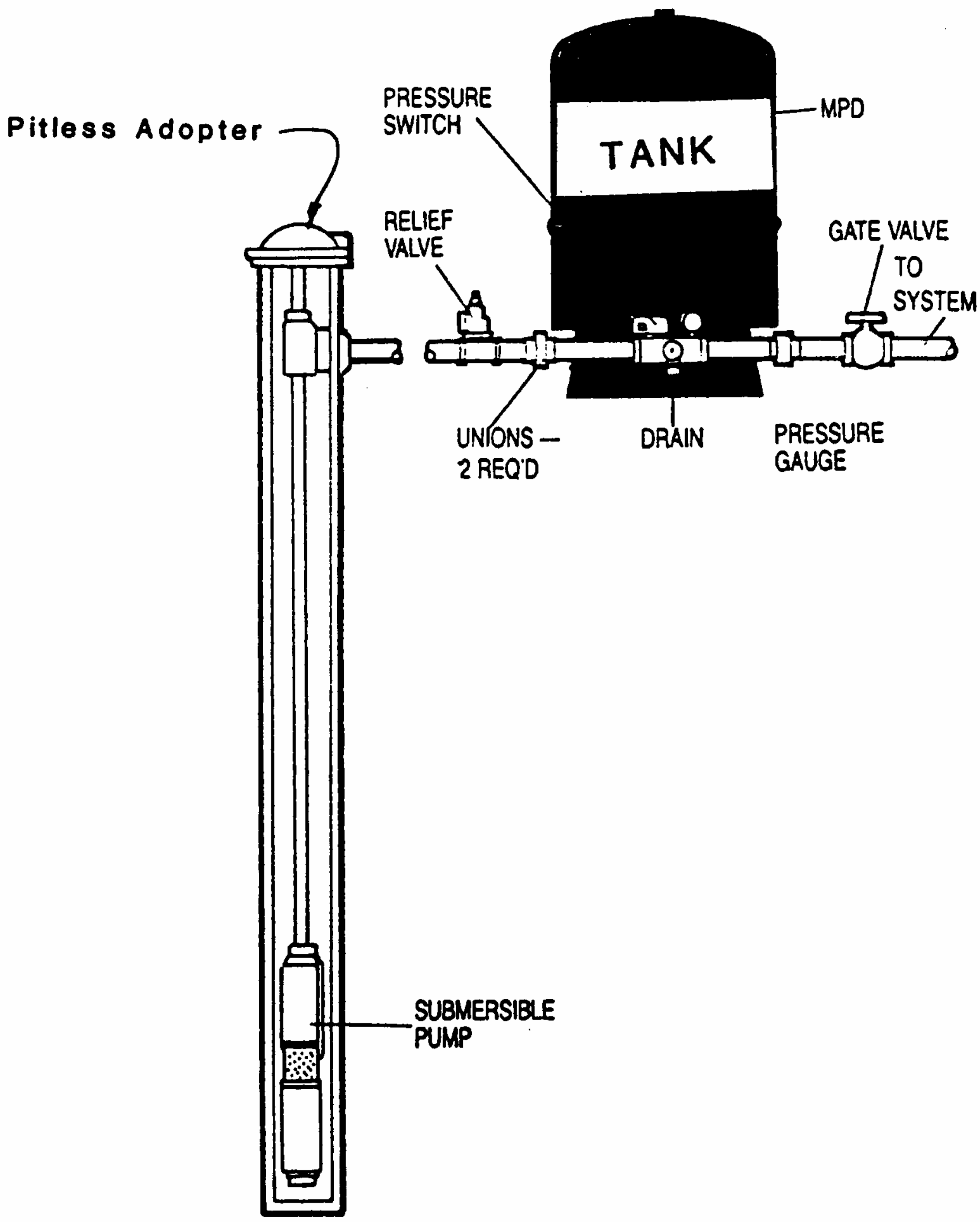
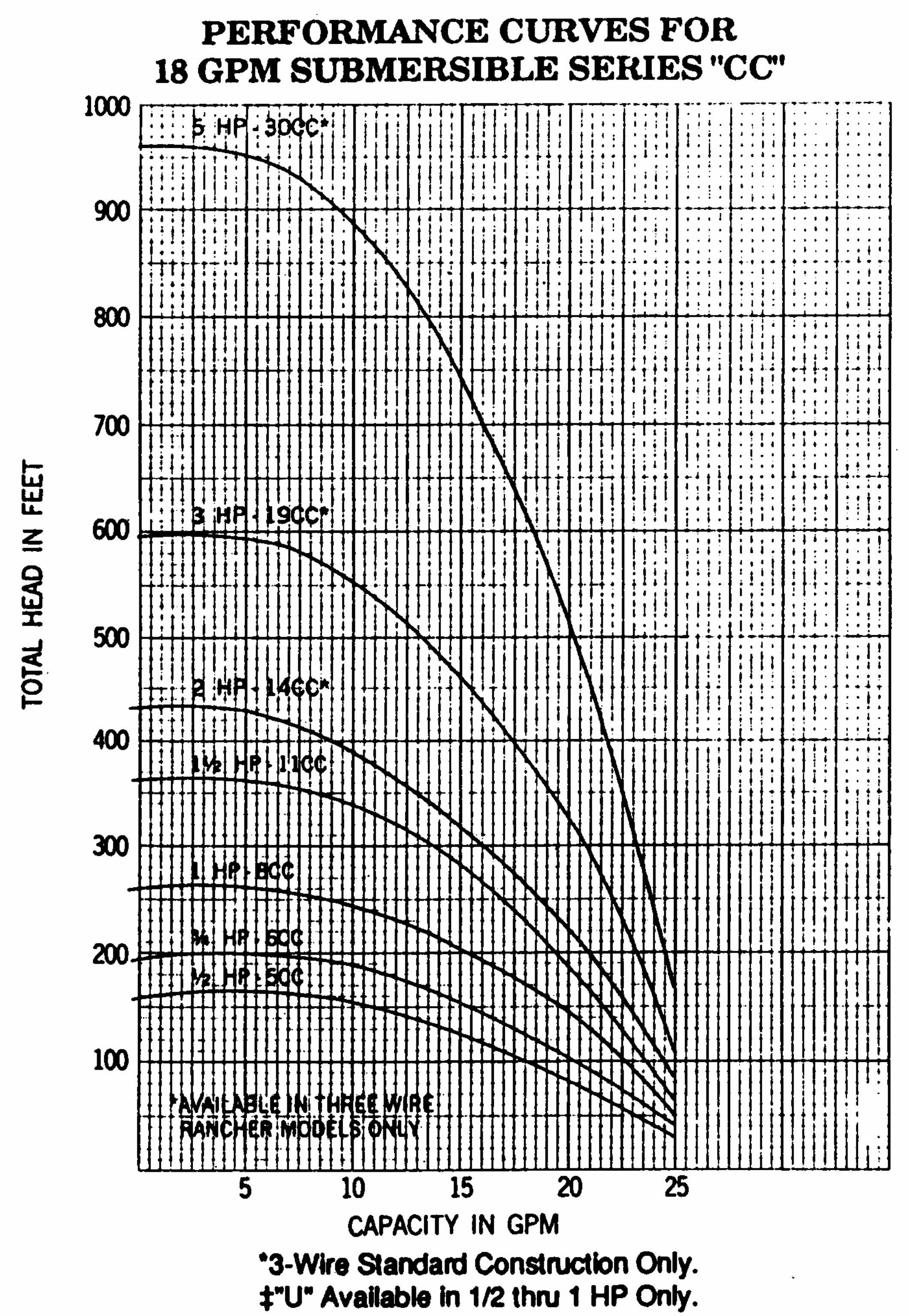


Figure 8.7
TYPICAL SUBMERSIBLE PUMP CURVE



8.3.2 Jet Pump

Figure 8.8 illustrates how a jet pump works. Jet pumps are used for shallow and medium depth wells. Jet pumps must usually be installed in an insulated aboveground enclosure. This allows the top of the well casing to extend above the ground.

Figure 8.8
HOW A JET PUMP WORKS

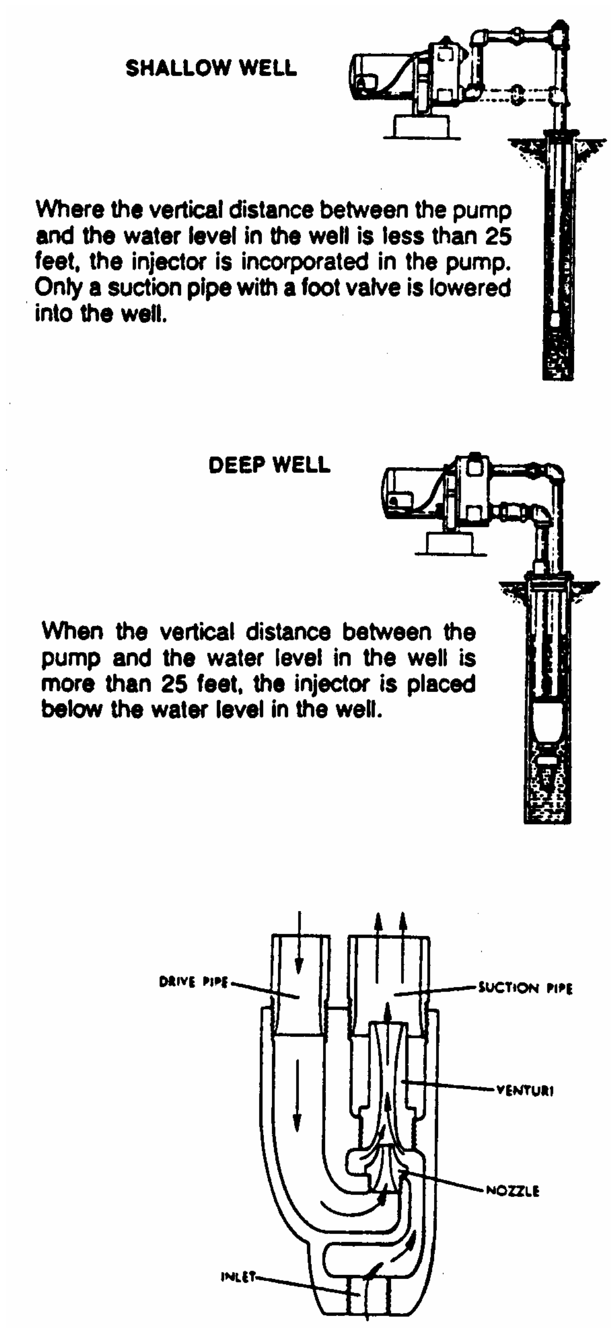
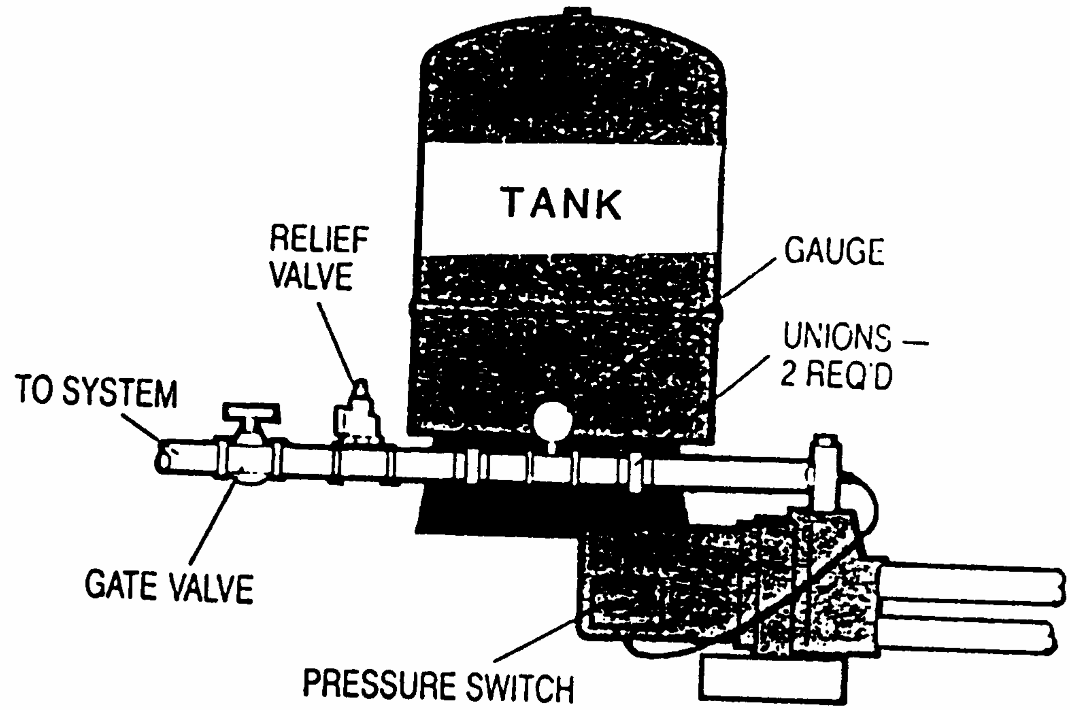


Figure 8.9
TYPICAL JET PUMP INSTALLATION AND CAPACITY TABLE

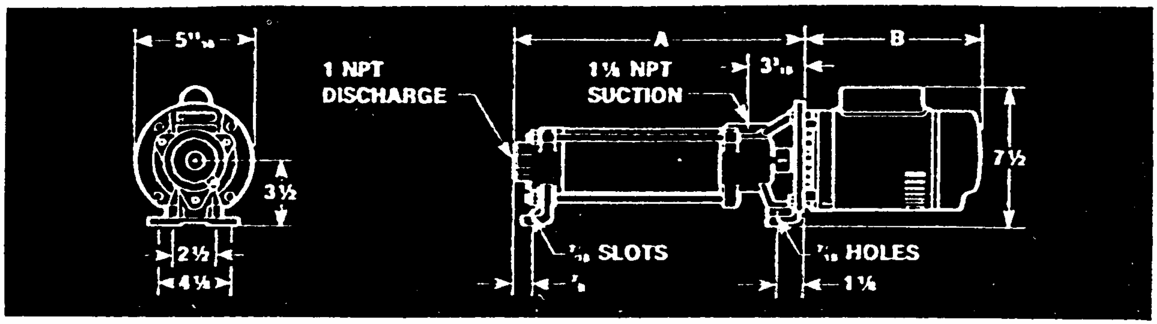


Basic Pump Catalog Number	Motor Horse Power	Jet Package Catalog Number: Twin Type, 4" Min. Well, Bronze	Twin Type, 4" Min. Well, Cast Iron	Packer Type, 3" Well	Packer Type, 2" Well	Average Operating Pressure	30	40	50	60	70	80	90	100	110	120	130	140	160	180
							Vertical Distance in Feet from Pump to Low Water Level — Capacity in Gallons Per Hour													
HCM50	½	A4M5	A4M5-I	JA3M5		35	700	615	530	450	380									
		B4M5	B4M5-I	JB3M5		35					380	330	290	250						
		C4M5	C4M5-I			35							270	230	200	170	135			
					JA2M5	35	640	540	480	390	300									
					JB2M5	35				360	320	270	230	185	150					
HCM75	¾	A4M7	A4M7-I			35	980	840	720											
		B4M7	B4M7-I	JB3M7-10-15		35			630	580	510	430	380	300						
		C4M7	C4M7-I			40							335	310	270	230	200	150		
					JA2M7	40	780	660	560	480										
					JB2M7	40				480	400	325	280	235						
					JC2M7	40							280	225	200	170	150			
HCM100	1	A4M10	A4M10-I			50	970	900	810	730	650									
		B4M10-15	B4M10-15-I	JB3M7-10-15		50					680	610	535	480	400	340				
		C4M10-15	C4M10-15-I	JC3M10-15		50									375	340	310	285	21[illegible]	155
					JA2M10	50	840	720	580	460										
					JB2M10-15	50				510	440	380	320	260						
					JC2M10	52								270	240	210	175	140		
HCM150	1½	A4M15	A4M15-I			50	1260	1150	1020	910	780	660								
		B4M10-15	B4M10-15-I	JB3M7-10-15		56						660	625	550	490	430				
		C4M10-15	C4M10-15-I	JC3M10-15		60										400	370	330	270	210
					JA2M15	55	1125	980	800	670	540									
					JB2M10-15	60				570	540	480	420	380						
					JC2M15	60								330	300	270	230	200		

8.3.3 Turbine Booster Pump

Turbine pumps in various configurations are occasionally used in stockwater installations. Figure 8.10 illustrates one type that can be used. The inner workings of this pump are the same as a submersible pump. This type of pump can be used to boost pressure from sources such as domestic water supplies and storage tanks.

Figure 8.10
TYPICAL TURBINE BOOSTER PUMP



Model	A	B	Model	A	B	Model	A	B	Model	A	B
3H45-7	14 3/16	8 3/16	3H410-4	12 1/4	8 3/16	5H418-5	13 15/16	8 1/2	7H425-5	14 13/16	9 3/16
5H45-10	16 9/16	8 1/2	5H410-6	14 1/16	8 1/2	7H418-7	16 7/16	9 3/16	1H425-6	16 1/16	10
7H45-14	19 3/4	9 5/16	7H410-9	16 11/16	9 5/16	1H418-9	18 3/16	10	15H425-9	19 3/4	11
1H45-18	22 13/16	10	1H410-12	19 3/8	10	15H418-12	21 7/16	11	2H425-11	22 5/16	11
Z1H45-18	23 3/8	9 3/4	15H410-16	22 13/16	11	2H418-15	24 1/2	11	3H425-16	28 1/4	12
			Z15H410-16	23 3/8	9 3/4	Z2H418-15	25 1/4	9 3/4	Z2H425-11	22 15/16	9 3/4

PERFORMANCE CHART

Pump Model No.	DISCHARGE PRESSURE AT PUMP (LBS/SQ INCH) WITH NO LIFT OR POSITIVE SUCTION PRESSURE — CAPACITY IN GALLONS PER MINUTE AT DISCHARGE PRESSURE SHOWN ABOVE																									Max. Pres. (LBS.)
	H.P.	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	260	
3H45-7	1/3			8.1	7.3	6.5	5.6	4.5	3.1																		98
5H45-10	1/2					7.9	7.3	6.8	6.2	5.6	4.8	4.0	2.9														140
7H45-14	3/4							7.8	7.4	7.0	6.6	6.1	5.7	5.2	4.6	4.1	3.4	2.5									192
1H45-18	1									7.8	7.5	7.2	6.8	6.5	6.2	5.8	5.4	5.1	4.7	4.2	3.7	3.1	2.3				244
3H410-4	1/3	14.4	12.6	10.5	7.5																						56
5H410-6	1/2	15.3	14.2	13.1	11.8	10.3	8.3	4.6																			84
7H410-9	3/4	15.8	15.1	14.4	13.6	12.7	11.8	10.8	9.7	8.4	6.9	4.3															125
1H410-12	1	16.2	15.7	15.2	14.6	14.1	13.5	12.9	12.2	11.5	10.8	9.9	8.9	7.8	6.3	4.2											166
15H410-16	1 1/2	16.7	16.2	15.8	15.3	14.9	14.4	14.0	13.5	13.1	12.6	12.1	11.6	11.0	10.4	9.8	9.1	8.4	7.6	6.6	5.3						220
5H418-5	1/2	24.3	21.7	18.1	13.7																						60
7H418-7	3/4	25.2	24.0	22.4	20.3	17.6	14.4	10.0																			88
1H418-9	1	25.7	24.7	23.8	22.2	20.5	18.4	16.2	13.8	10.2	4.0																111
15H418-12	1 1/2	26.0	25.4	24.8	24.0	23.3	22.3	21.1	19.8	18.2	16.4	14.4	12.0	8.2													148
2H418-15	2	26.5	26.0	25.4	24.7	24.0	23.4	22.5	21.6	20.5	19.4	18.1	16.7	15.3	13.6	11.6	8.4										179
7H425-5	3/4	33.0	30.0	26.4	20.8																						61
1H425-6	1	34.0	31.8	28.8	25.4	21.2	14.8																				76
15H425-9	1 1/2	35.4	34.0	32.8	31.0	29.0	26.8	24.0	20.8	17.0																	112
2H425-11	2	35.8	34.7	33.8	32.6	31.2	29.4	27.4	25.2	22.8	20.8	16.8	12.0														138
3H425-16	3	36.2	35.5	34.6	33.8	33.0	32.2	31.2	30.2	29.2	27.8	26.6	25.0	23.2	21.6	19.6	17.2	14.0	9.6								198
Z1H45-18	2 1/2	9.9	9.7	9.5	9.3	9.1	8.8	8.5	8.3	8.0	7.8	7.5	7.2	6.9	6.6	6.3	6.0	5.7	5.3	5.0	4.6	4.2	3.7	3.2	2.5		266
Z15H410-16	2 1/2	16.5	16.1	15.7	15.3	14.9	14.5	14.1	13.7	13.3	12.8	12.3	11.8	11.3	10.7	10.1	9.4	8.6	7.8	6.8	5.7	4.3	2.2				235
Z2H418-15	2 1/2	27.0	26.5	26.0	25.2	24.5	23.6	22.7	21.7	20.7	19.5	18.3	17.1	15.8	14.4	12.9	11.0	8.6	4.8								197
Z2H425-11	2 1/2	35.7	34.8	33.6	32.4	31.0	29.4	27.8	26.0	24.0	22.0	20.0	17.4	14.6	11.2	7.0											169

8.3.4 Piston Pumps

Electric or waterwheel driven piston pumps are sometimes used for very high pressure systems. Although piston pumps are able to supply high pressures, they have the disadvantage of having a pulsating delivery. These pressure surges must be counteracted by the use of surge chambers and adequate pressure rated pipe. Figure 8.11 illustrates the inner workings of one type of three piston pump.

8.3.5 Windmill

Windmills can still be used to great advantage when power is not available at a site. The most important factor is to provide adequate storage to carry over during periods of little or no wind. Windmills also require frequent checking and maintenance.

Figure 8.11
THREE PISTON PUMP

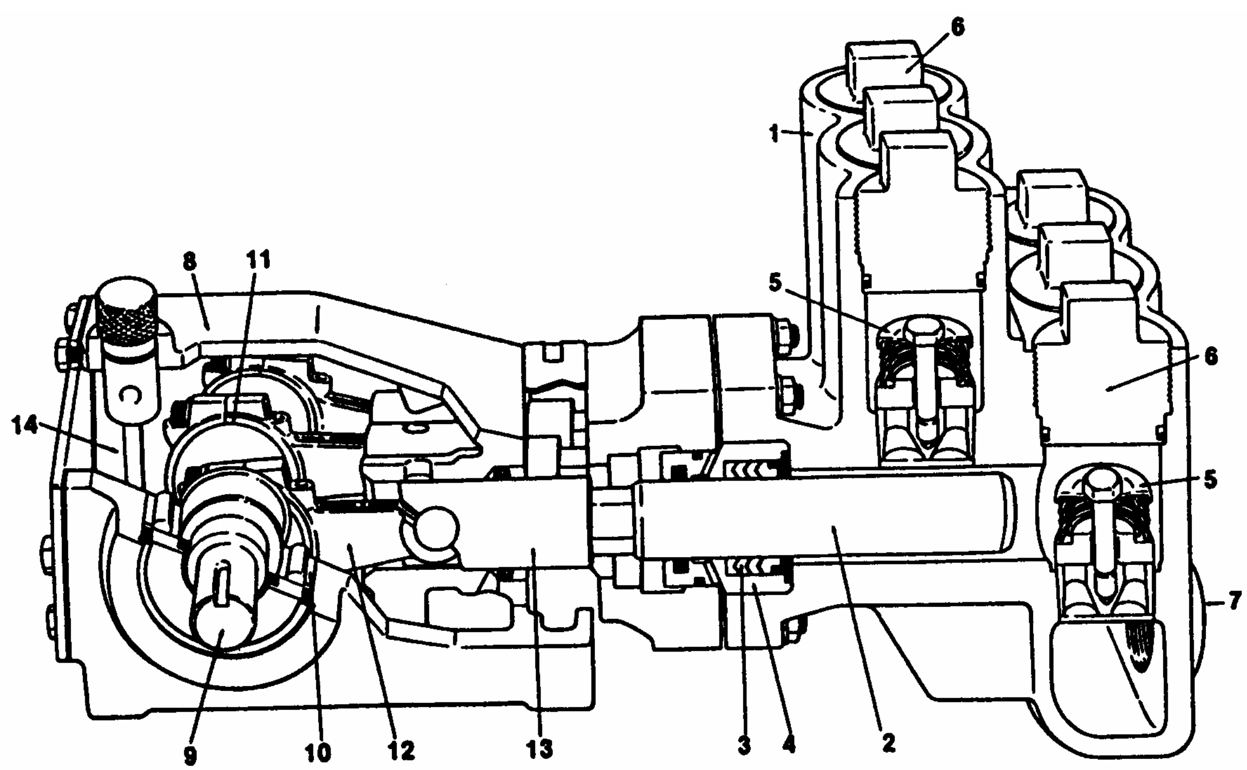


Figure 8.12
WINDMILL AS SUPPLY TO TANK

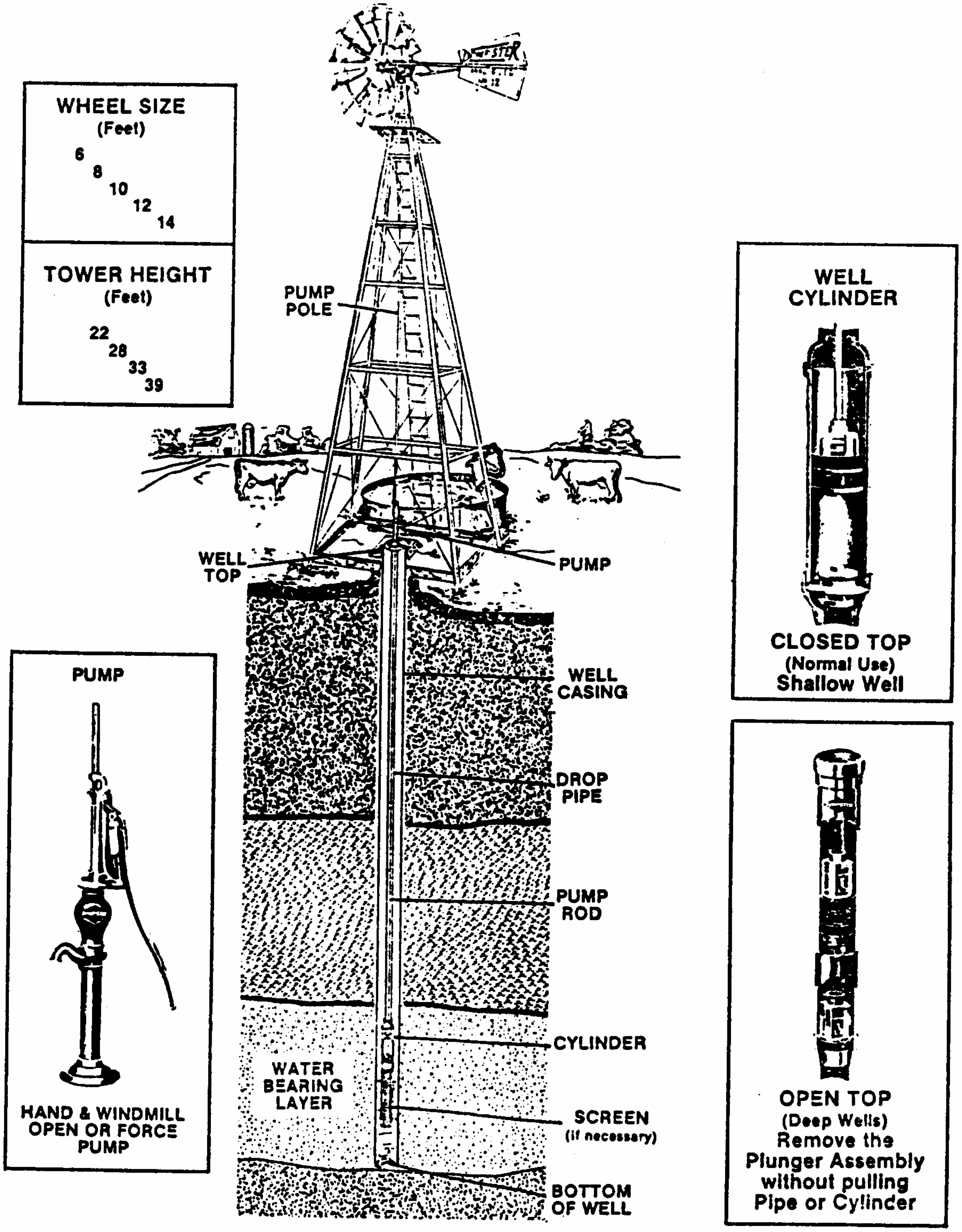


Figure 8.13 shows how to connect a windmill to a pipeline. When designing a windmill supplied pipeline the total dynamic head equals static head plus losses in the drop pipe plus pipeline losses.

Figure 8.13
WINDMILL CONNECTED TO PIPELINE

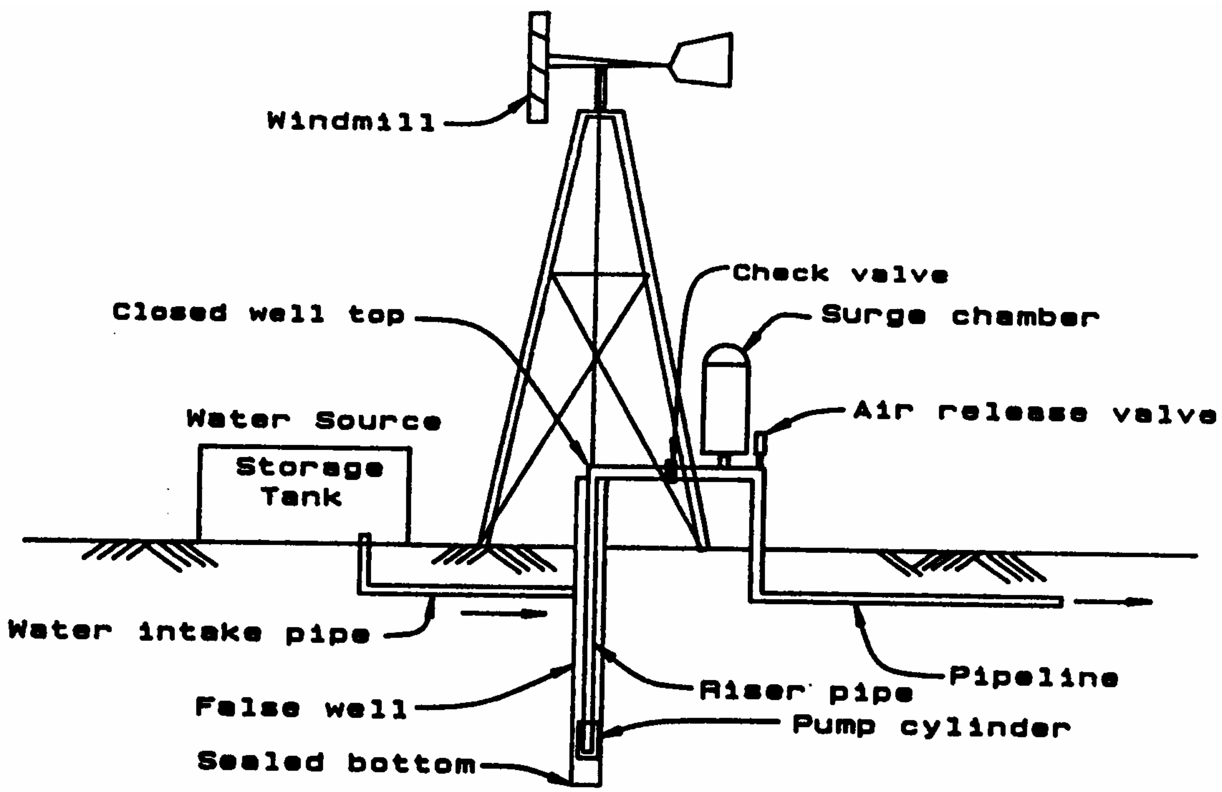


Table 8.1 tabulates approximate windmill capacities and Table 8.2 tabulates approximate pumping heads. These are based on winds exceeding 12 mph. Short stroke systems increase pumping head by 1/3 and reduce pumping capacity by 1/4.

For 12 mph winds, capacity is reduced about 20% and for 10 mph winds, about 38%. If prevailing winds are low, use of a cylinder smaller than shown will permit the mill to operate in lower wind velocity.

The drop pipe should never be smaller than the pump cylinder. For deep wells, use a ball valve and lightweight rod.

Table 8.1
APPROXIMATE WINDMILL CAPACITY

Cylinder Diameter (inches)	Wheel Diameter (feet)	
	6 feet	8-16 feet
1-3/4	105	150
1-7/8	125	180
2	130	190
2-1/4	180	260
2-1/2	225	325
2-3/4	265	385
3	320	470
3-1/4	370	550
3-1/2	440	640
3-3/4	500	730
4	570	830
4-1/4	-	940
4-1/2	725	1050
4-3/4	-	1170
5	900	1300
5-3/4	-	1700
6	-	1875
7	-	2550
8	-	3300

Table 8.2
WINDMILL PUMPING HEAD

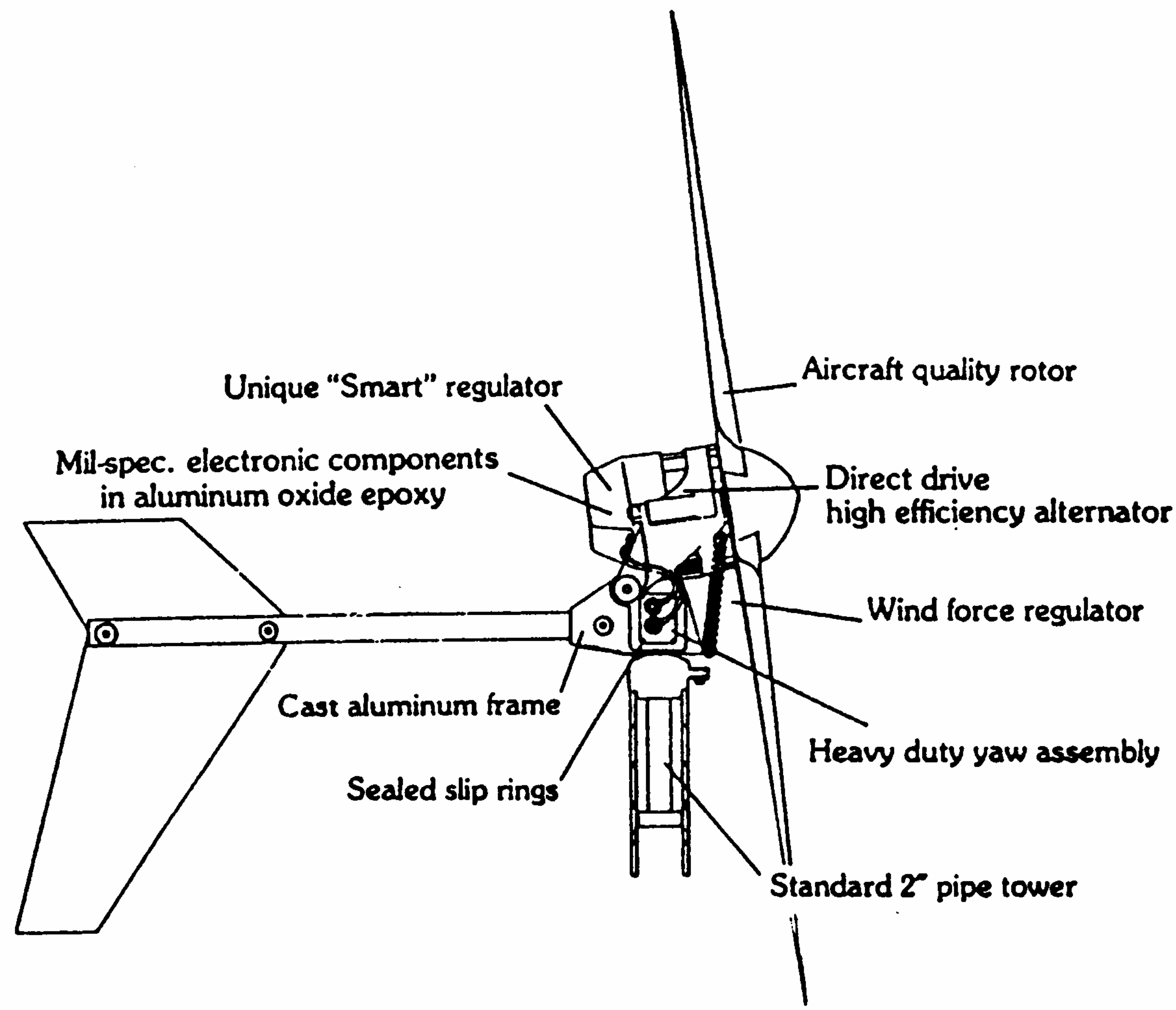
Cylinder Diameter (inches)	Wheel Diameter (feet)					
	6	8	10	12	14	16
3/4	130	185	280	420	600	1000
1-7/8	120	175	260	390	560	920
2	95	140	215	320	460	750
2-1/4	77	112	170	250	360	590
2-1/2	65	94	140	210	300	490
2-3/4	56	80	120	180	260	425
3	47	68	100	155	220	360
3-1/4	41	58	88	130	185	305
3-1/2	35	50	76	115	160	265
3-3/4	30	44	65	98	143	230
4	27	39	58	86	125	200
4-1/4	-	34	51	76	110	180
4-1/2	21	30	46	68	98	160
4-3/4	-	-	41	61	88	140
5	17	25	37	55	80	130
5-3/4	-	-	-	40	60	100
6	-	17	25	38	55	85
7	-	-	19	28	41	65
8	-	-	14	22	31	50

8.3.6 Wind Generator Powered Pump

Wind generators can be used to power low volume pumps. These systems are expensive and have the same disadvantage as windmills in that they depend on wind being available to pump water. They may be more reliable than windmills because there are less mechanical components to go wrong. It may also be possible to pump water from deeper depths.

Figure 8.14 illustrates a wind generator. This small generator delivers 12 or 24 volt power and might be used with the same type of pumps as solar powered pumps, or might be used in conjunction with solar power.

Figure 8.14
WIND GENERATOR POWERED PUMP



8.3.7 Solar Powered Pump System

Solar powered pumps have the advantage of operating as long as there is adequate sunlight. In many parts of Montana this is a particular advantage because we have a high percentage of non-overcast days.

The main disadvantage of this type of installation is that it is expensive. This can be more than compensated for though by not having to install power lines to the site.

As with wind powered systems, it is important to have adequate tank storage to carry through periods of low sunlight levels and heavy water use.

Figures 8.15 illustrates low voltage DC solar powered pump systems using a submersible pump in a well and a rotary vane type pump from a spring box. A tracking type solar panel allows greater power gain throughout the day. These are simple systems without batteries or converters.

Figure 8.16 illustrates a pump jack system. This works in deeper wells and is ideal for replacing windmill systems. The pump will pump water even under low light conditions, although pumping will be slower.

There are several different types of pump systems on the market. Each has particular advantages. Design must be done in close coordination with pump and solar panel suppliers.

Figure 8.15
TYPICAL SOLAR SUBMERSIBLE AND ROTARY VANE TYPE PUMPS

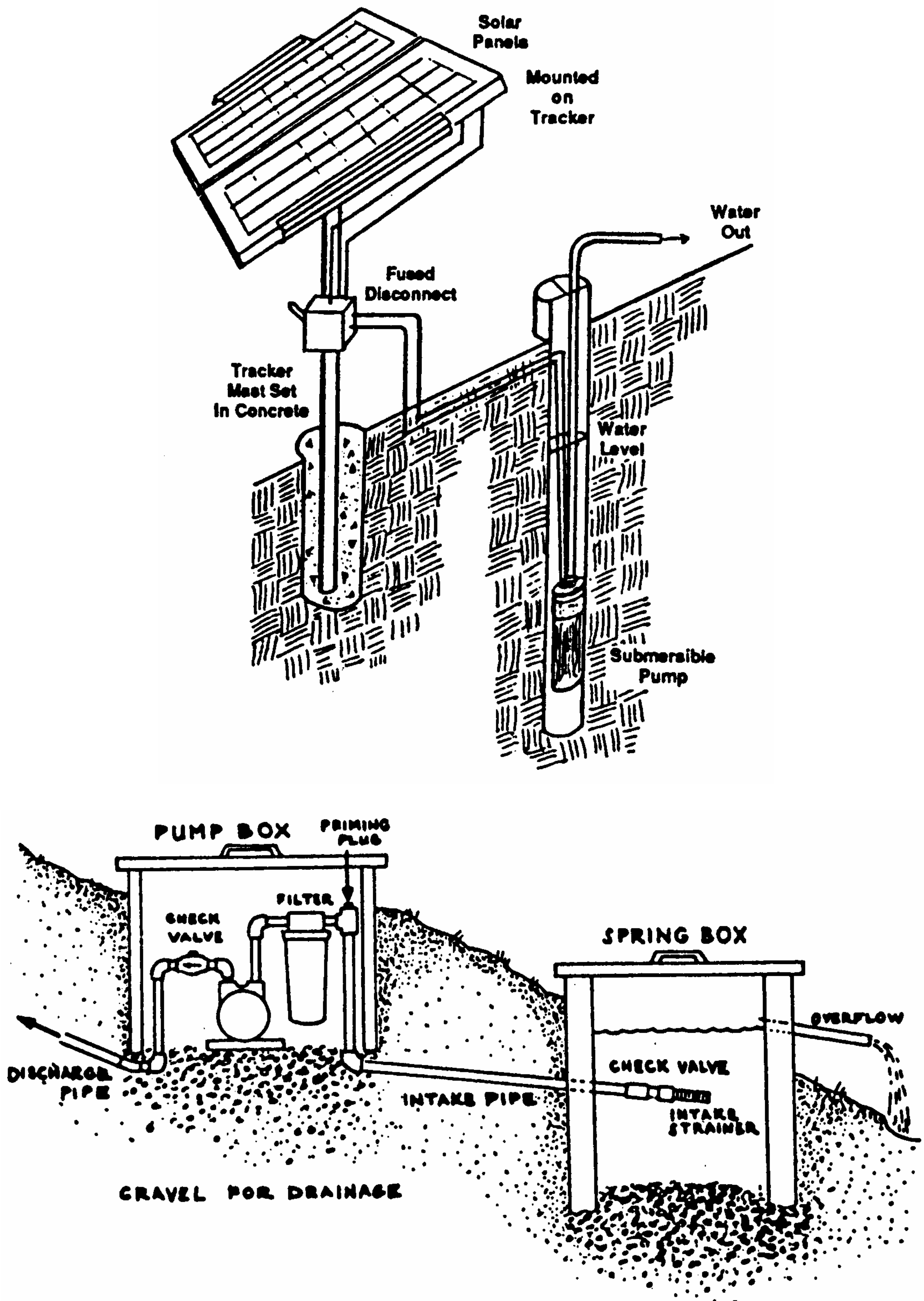
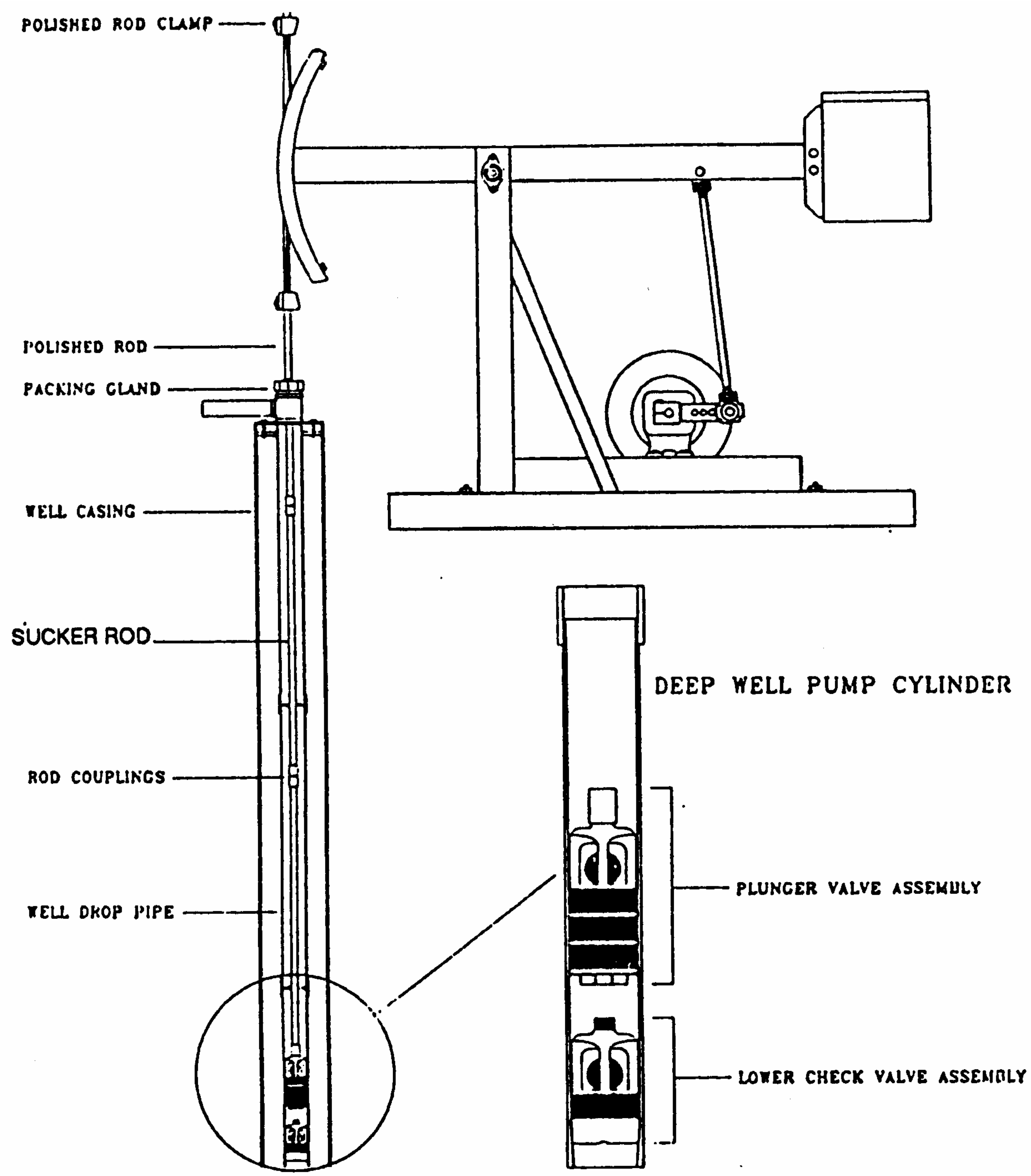


Figure 8.16
JACK TYPE SOLAR PUMP



8.3.8 Internal Combustion Engine Powered Pumps

Internal combustion engines can be used to operate stockwater pumps. The engines are sometimes started with float operated automatic starter and shutoff switches. These engines frequently use propane as a fuel.

Engine operated systems require frequent monitoring. A large water storage tank should be part of the system to supplement times when the system fails or for some other reason is not started on time.

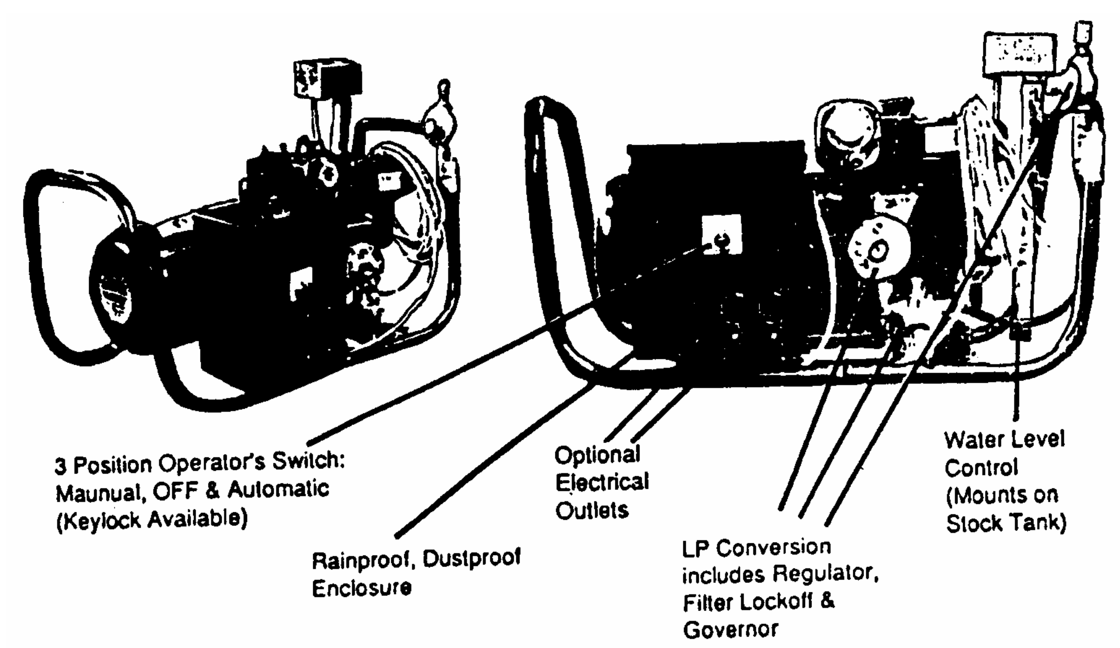
There are various ways that such a system can be set up. They include:

1. An engine operated pump jack is operated by gas or propane motor. Water is pumped into a large storage tank. The motor is started by hand. It can be shut off with simple grounding type float switch or when it simply runs out of gas. Sometimes an automatic starting system is used.

2. An engine operated generator which in turn operates any type of electrically driven pump system. This type of system either be automatically started and stopped with a float switch or manually started and then shut off by a float actuated switch in the storage tank. Figure 8.17 illustrates what a typical generating system may look like.

   This system has the advantage of being able to operate any size or pressure rated pump, depending on the size of the generating system. It is one of the most popular types of non-commercial power systems used in Montana.

Figure 8.17
PROPANE POWERED, AUTOMATIC GENERATOR FOR PUMP



8.3.9 Hydraulic Rams

A hydraulic ram works on the principal of using large volume flow at low head to pump smaller volumes of flow to a higher elevation.

Figure 8.18 illustrates how this type of system is set up. A popet valve in the ram opens allowing water to flow. As the water gains velocity in the supply pipe, it causes the popet to slam shut. This sudden closure causes a surge pressure which forces the water through the pump check valve. The surge pressure runs into the back pressure in the output line. Part of the water flow is forced into the air chamber, compressing the air and causing the flow to lose most of its energy.

As peak pressure subsides, the compressed air in the air chamber pushes downward on the column of water, closes the check valve and pushes some water up the delivery pipe. This process repeats itself about once a second.

A shock wave (waterhammer) moves back up the supply pipe. The pipe pressure rating should be adequate to withstand this repeated shock. A stand pipe is frequently installed at a location in the supply line that "tunes" the system shock wave. This stand pipe should be about 4 to 5 times the supply pipe fall away from the ram.

Ram manufacturer recommendations should be used to size the ram and design the system.

Figure 8.18
TYPICAL HYDRAULIC RAM INSTALLATION

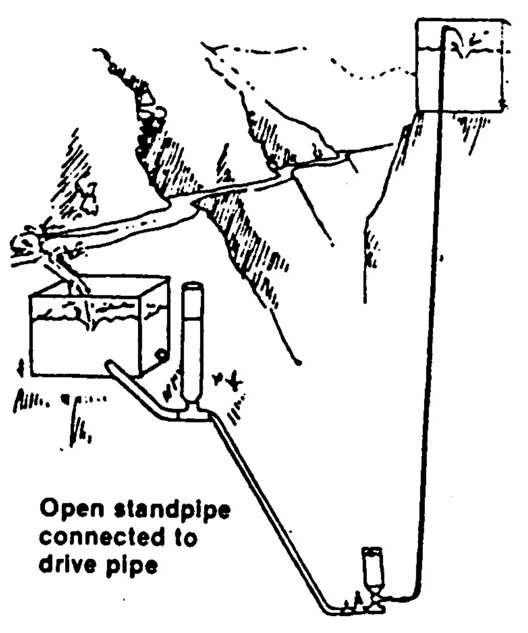


Figure 8.19
SMALL PLASTIC HYDRAULIC RAM

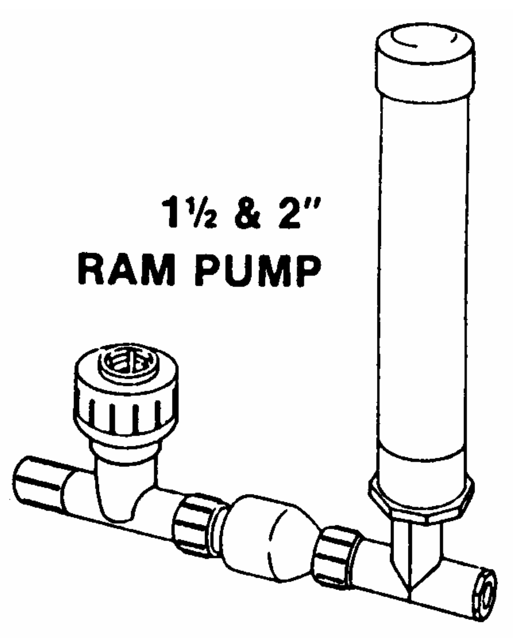
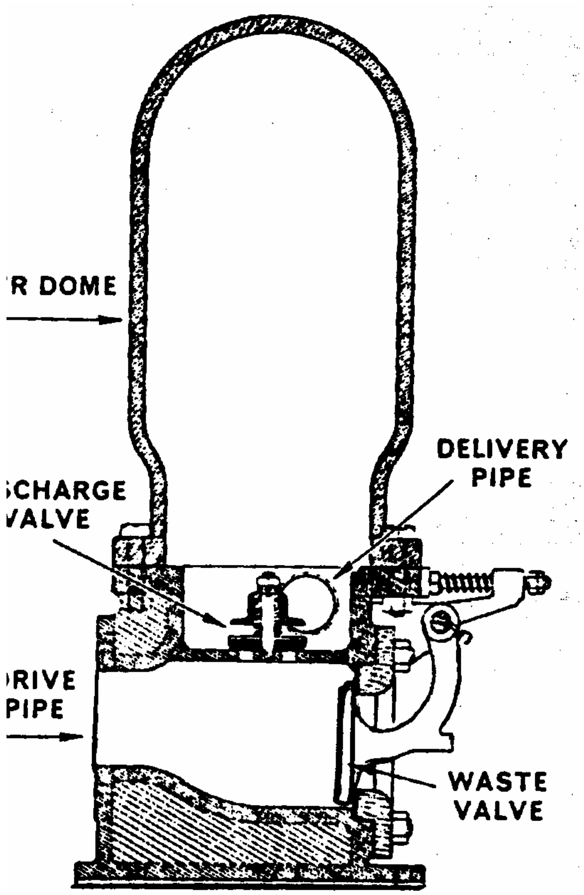
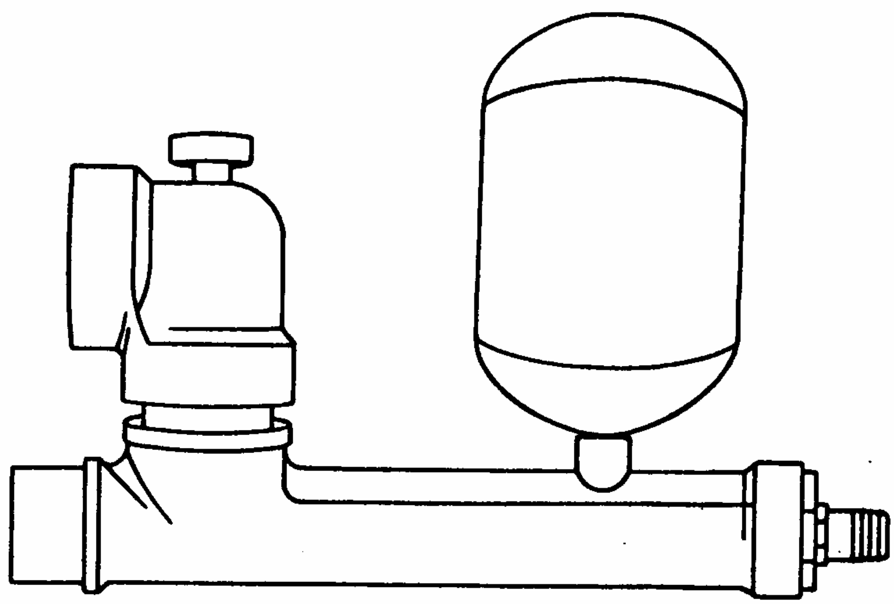


Figure 8.20
LARGE STEEL HYDRAULIC RAMS





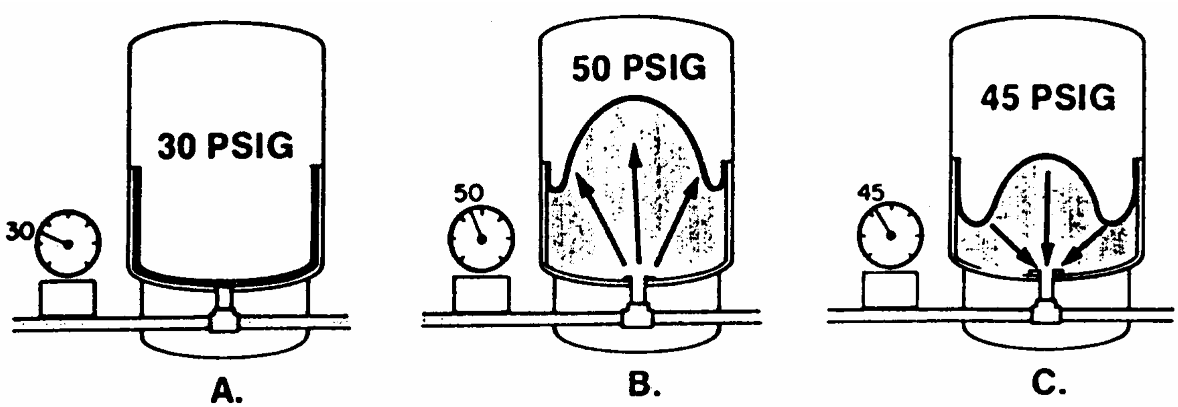
8.4 PRESSURE TANKS

Pneumatic pressure tank operation is based on the fact that air can be compressed but water cannot. The pressure required to force water from the tank through the pipeline to stock tanks is obtained by incorporating air in the tank and by the pump forcing water against the air pocket. The air is forced to occupy less and less space and so exerts more and more pressure on incoming water.

This air cushion acts like a large spring maintaining a constant pressure on the water in the tank which is conducted throughout the entire system. When a hydrant or float valve is opened, air expands to replace the water which is forced through the pipes by air pressure. When the pump starts and forces additional water into the tank, air is compressed at a higher pressure and occupies less space.

There are two types of pressure tanks, the plain tank and the diaphragm-type tank. Operation of both tanks is the same. The difference is that water and air are separated by a diaphragm in a diaphragm-type tank. The diaphragm prevents loss of air during operation. Figure 8.21 illustrates how a pressure tank works. Net effective storage of the tank is equal to the water volume that is stored between cut-in pressure and cut-out pressure.

Figure 8.21
HOW A PRESSURE TANK WORKS



A. Factory installed precharged air cushion. Pump off.

B. When pump starts, water enters the reservoir. At 50 psig, system is filled. Pump shuts off.

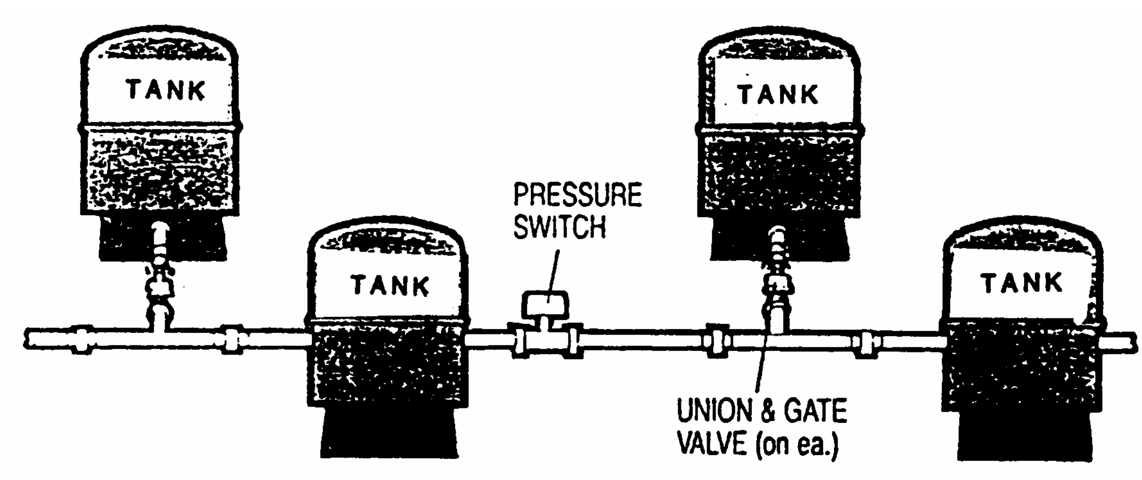
C. When water is demanded, pressure in the air chamber forces water into the system. Pump stays off.

Cut-in pressure is that pressure at which the pump is automatically turned on. Cut-out is the pressure at which the pump is turned off.

Tanks operating with a cut-out pressure of less than 80 psi usually have a 20 psi pressure spread between cut-in and cut-out. Tanks operating at pressures higher than that usually operate with a pressure spread of 30 psi. At pressures above 120 psi it sometimes may be advantageous to operate with a pressure spread greater than 30 psi. See Tables 8.3 through 8.12 for tank sizes based on flow rate and pressure spread between cut-in and cut-out.

More than one tank may be installed in a system to meet pressure tank capacity requirements. Figure 8.22 illustrates how this is done.

Figure 8.22
MULTIPLE PRESSURE TANK INSTALLATION



8.4.1 Plain Pressure Tank

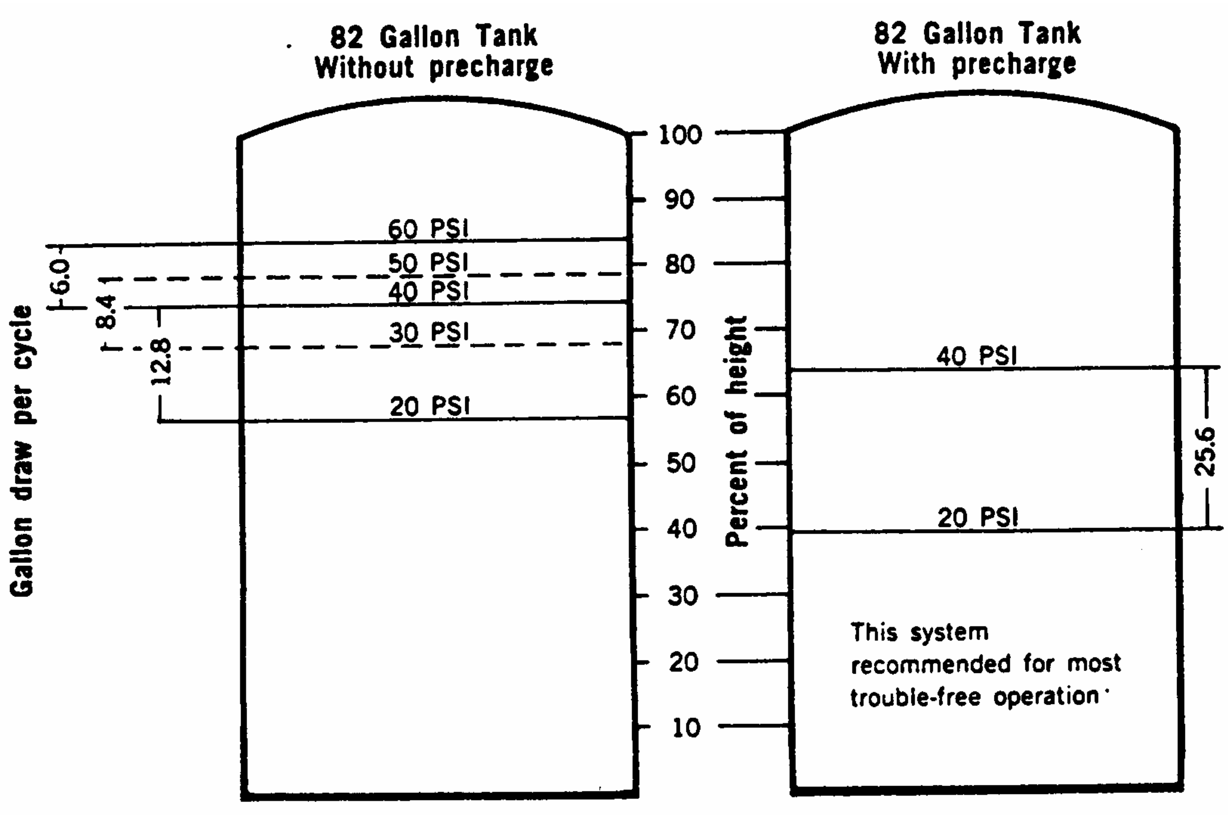
In a plain pressure tank, air can be lost over time. This loss is due to absorption into the water or, if pressure in the system falls below a certain point, air can escape into the pipeline.

Figure 8.23 illustrates the water level in a standard vertical tank at various pressures, percent of height, and gallons of drawdown per cycle. To determine the drawdown per cycle at a given pressure switch setting, refer to the left side of Figure 8.23. With a pressure setting of 20/40 psi and using an 82 gallon tank without pre-charge the amount of water available is 12.8 gallons. If the tank is pre-charged, as shown in the right side of Figure 8.23, the amount of available water will be 25.6 gallons.

There is a valve on the plain tank where compressed air can periodically be used to recharge the air space. This is usually done with a hand pump or portable compressor. In some systems, this must be done several times during a season. In larger installations, an automatic air compressor can be used to keep the tank properly charged.

There is a simple automatic charging valve available which can be used to automatically recharge the air tank. This valve only works in a jet-type pump installation. It will not work with a submersible pump. This valve can only be used on low-to-moderate pressure systems.

Figure 8.23
PLAIN PRESSURE TANK CAPACITY



8.4.2 Diaphragm-Type Tank

A diaphragm tank abolishes the need for tank air maintenance. In fact, properly protected diaphragm tanks can be buried after they are initially charged with air.

In the diaphragm-type tank, a flexible diaphragm separates air and water. An example of this type of tank is shown in Figure 8.21. Air cannot be absorbed by water and air cannot escape. After an initial charge of compressed air, periodic recharging is not required. This type of tank is almost universally used on new systems today and its use is highly recommended.

8.4.3 Tank Pressure Rating

Common pressure tanks are rated for maximum pressures between 72 psi and 110 psi. For this reason, there are increasing problems with using an automatic pressure system when operating pressures exceed 110 psi. Larger and higher pressure rated tanks are required at these higher pressures.

For practical reasons, the design upper limit for cut-out pressure is about 150 psi. For systems with pressures above this, timer operated, manually operated, or float switch operated systems should be used.

It is very dangerous to use a tank at higher than its rated pressure. A tank used beyond its rating could explode and cause death or serious injury to anyone working near the tank. For that reason **a pressure tank should never be used beyond its rated pressure**.

Sometimes owners want to use "used" tanks such as old propane tanks as water pressure tanks. These tanks are not designed for water use since they will soon corrode and weaken. **Pressure tanks not manufactured for water containment should not be used**.

Special pressure tanks are available with ratings beyond 110 psi. These are expensive and must be properly sized.

In any automatic high pressure system, additional efficient storage can be added by installing multiple diaphragm-type pressure tanks out on the pipeline where pressures are relatively low. These tanks are usually the buried-type. In such a system, it is desirable to have a primary high pressure tank located at the well. This tank takes the initial surge of flow and allows flow and pressures to equalize in the pipeline.

It also may be effective to install a flow regulating valve just up stream of the pressure switch to control initial flow rate. Without control of surge flow at the pump, frequent pump cycling can occur due to pressure surges actuating the pressure switch. This can quickly destroy the pump and/or pipeline.

Table 8.3
DIAPHRAGM PRESSURE TANK SIZE SELECTION
MINIMUM RECOMMENDED TOTAL STORAGE TANK SIZE (gallons)

Flow = 5 gpm, Minimum Pump Running Time = 1.5 minutes

Pump CUT-OUT Pressure (PSIG)	Pump CUT-IN Pressure (PSIG)												
	20	30	40	50	60	70	80	90	100	110	120	130	140
30	33												
40	20	41											
50	16	24	48										
60	14	19	28	56									
70	13	16	21	32	64								
80	12	14	18	24	36	71							
90	11	13	16	20	26	39	78						
100	11	12	14	17	22	29	43	86					
110	10	12	13	16	19	23	31	47	94				
120	10	11	13	14	17	20	25	34	50	107			
130	10	11	12	14	15	18	22	27	36	54	109		
140	10	11	12	13	15	17	19	23	29	39	58	117	
150	10	10	11	12	14	15	18	21	25	31	41	62	125

Table 8.4
DIAPHRAGM PRESSURE TANK SIZE SELECTION
MINIMUM RECOMMENDED TOTAL STORAGE TANK SIZE (gallons)

Flow = 10 gpm, Minimum Pump Running Time = 1.5 minutes

Pump CUT-OUT Pressure (PSIG)	Pump CUT-IN Pressure (PSIG)												
	20	30	40	50	60	70	80	90	100	110	120	130	140
30	67												
40	41	82											
50	32	49	97										
60	28	37	56	112									
70	25	32	42	64	127								
80	24	28	36	47	71	142							
90	22	26	31	39	52	79	156						
100	21	25	29	34	43	57	86	172					
110	21	23	27	31	37	47	62	94	188				
120	20	22	25	29	34	40	51	67	101	214			
130	20	22	24	27	31	36	43	54	72	109	217		
140	19	21	23	26	29	33	39	46	58	77	116	234	
150	19	21	22	25	27	31	35	41	49	62	82	124	250

Table 8.5

DIAPHRAGM PRESSURE TANK SIZE SELECTION
MINIMUM RECOMMENDED TOTAL STORAGE TANK SIZE (gallons)

Flow = 15 gpm, Minimum Pump Running Time = 1.5 minutes

Pump CUT-OUT Pressure (PSIG)	Pump CUT-IN Pressure (PSIG)												
	20	30	40	50	60	70	80	90	100	110	120	130	140
30	100												
40	61	123											
50	48	73	145										
60	42	56	84	168									
70	38	48	64	95	191								
80	35	43	53	71	107	212							
90	34	39	47	59	78	118	234						
100	32	37	43	52	65	86	129	259					
110	31	35	40	47	56	70	93	141	281				
120	30	34	38	43	50	61	76	101	151	321			
130	30	33	36	41	46	54	65	81	108	163	326		
140	29	32	35	39	44	50	58	69	87	116	174	352	
150	29	31	34	37	41	46	53	62	74	93	124	186	375

Table 8.6

DIAPHRAGM PRESSURE TANK SIZE SELECTION
MINIMUM RECOMMENDED TOTAL STORAGE TANK SIZE (gallons)

Flow = 20 gpm, Minimum Pump Running Time = 1.5 minutes

Pump CUT-OUT Pressure (PSIG)	Pump CUT-IN Pressure (PSIG)												
	20	30	40	50	60	70	80	90	100	110	120	130	140
30	134												
40	82	164											
50	65	97	194										
60	56	75	112	224									
70	51	64	85	127	254								
80	47	57	71	95	142	283							
90	45	52	63	79	105	157	313						
100	43	49	57	69	86	115	172	345					
110	41	47	53	62	75	93	124	188	375				
120	40	45	51	58	67	81	101	135	201	429			
130	39	43	48	54	62	72	87	108	144	217	435		
140	39	42	46	52	58	66	77	93	116	155	233	469	
150	38	41	45	49	55	62	70	82	98	123	165	248	500

Table 8.7
DIAPHRAGM PRESSURE TANK SIZE SELECTION
MINIMUM RECOMMENDED TOTAL STORAGE TANK SIZE (gallons)

Flow = 25 gpm, Minimum Pump Running Time = 1.5 minutes

Pump CUT-OUT Pressure (PSIG)	Pump CUT-IN Pressure (PSIG)												
	20	30	40	50	60	70	80	90	100	110	120	130	140
30	167												
40	102	205											
50	81	121	242										
60	70	93	140	280									
70	64	79	106	159	318								
80	59	71	89	118	178	354							
90	56	65	78	98	131	196	391						
100	54	61	72	86	108	144	216	431					
110	52	58	67	78	94	117	156	234	469				
120	51	56	63	72	84	101	126	168	252	536			
130	49	54	60	68	77	90	108	135	180	272	543		
140	48	53	58	64	73	83	97	116	145	193	291	586	
150	48	51	56	62	69	77	88	103	123	154	206	310	625

Table 8.8

PLAIN PRESSURE TANK SIZE SELECTION

MINIMUM RECOMMENDED TOTAL STORAGE TANK SIZE (gallons)

(Based on 3,000 ft. elevation above sea level)
WITHOUT AIR VALVE

Flow = 5 gpm, Minimum Pump Running Time = 1.5 minutes

Pump CUT-OUT Pressure (PSIG)	Pump CUT-IN Pressure (PSIG)								
	20	30	40	50	60	70	80	90	100
30	136								
40	83	216							
50	66	127	308						
60	57	97	177	417					
70	51	82	133	235	539				
80	48	74	113	177	308	719			
90	45	68	100	147	227	392	862		
100	43	64	90	128	185	281	462	995	
110	42	61	85	117	162	231	340	562	1294
120	40	58	78	105	141	190	259	370	588
130	39	56	75	99	129	170	223	301	431
140	39	54	73	95	123	160	205	270	370

NOTES:

(1) If an automatic air charge valve is used, tank size may be reduced by 50%.

(2) Increase tank size by 5% for each 1,000 feet elevation above 3,000 feet elevation.

Table 8.9
PLAIN PRESSURE TANK SIZE SELECTION
MINIMUM RECOMMENDED TOTAL STORAGE TANK SIZE (gallons)

(Based on 3,000 ft. elevation above sea level)
WITHOUT AIR VALVE

Flow = 10 gpm, Minimum Pump Running Time = 1.5 minutes

Pump CUT-OUT Pressure (PSIG)	Pump CUT-IN Pressure (PSIG)								
	20	30	40	50	60	70	80	90	100
30	272								
40	167	431							
50	131	254	616						
60	113	195	354	835					
70	103	165	267	470	1078				
80	96	148	225	354	616	1437			
90	91	136	199	294	454	784	1725		
100	87	127	181	256	370	562	924	1990	
110	84	121	169	233	323	462	681	1125	2587
120	81	115	157	210	281	381	517	739	1176
130	79	111	150	198	259	340	446	602	862
140	78	109	145	190	246	319	411	539	739

NOTES:

(1) If an automatic air charge valve is used, tank size may be reduced by 50%.

(2) Increase tank size by 5% for each 1,000 feet elevation above 3,000 feet elevation.

Table 8.10

PLAIN PRESSURE TANK SIZE SELECTION

MINIMUM RECOMMENDED TOTAL STORAGE TANK SIZE (gallons)

(Based on 3,000 ft. elevation above sea level)
WITHOUT AIR VALVE

Flow = 15 gpm, Minimum Pump Running Time = 1.5 minutes

Pump CUT-OUT Pressure (PSIG)	Pump CUT-IN Pressure (PSIG)								
	20	30	40	50	60	70	80	90	100
30	409								
40	250	647							
50	197	381	924						
60	170	292	532	1252					
70	154	247	400	706	1617				
80	144	222	338	532	924	2156			
90	136	204	299	441	681	1176	2587		
100	130	191	271	384	554	844	1386	2986	
110	126	182	254	350	485	693	1021	1687	3881
120	121	173	235	316	422	571	776	1109	1764
130	118	167	224	296	388	511	669	903	1294
140	117	163	218	285	370	479	616	809	1109

NOTES:

(1) If an automatic air charge valve is used, tank size may be reduced by 50%.

(2) Increase tank size by 5% for each 1,000 feet elevation above 3,000 feet elevation.

Table 8.11
PLAIN PRESSURE TANK SIZE SELECTION
MINIMUM RECOMMENDED TOTAL STORAGE TANK SIZE (gallons)

(Based on 3,000 ft. elevation above sea level)
WITHOUT AIR VALVE

Flow = 20 gpm, Minimum Pump Running Time = 1.5 minutes

Pump CUT-OUT Pressure (PSIG)	Pump CUT-IN Pressure (PSIG)								
	20	30	40	50	60	70	80	90	100
30	545								
40	334	863							
50	263	507	1232						
60	227	389	709	1669					
70	205	330	534	941	2156				
80	192	296	450	709	1232	2875			
90	182	272	398	588	908	1568	3450		
100	174	255	362	512	739	1125	1848	3981	
110	168	243	338	466	647	924	1362	2250	5175
120	162	230	314	421	563	761	1035	1479	2352
130	158	222	299	395	518	681	892	1203	1725
140	155	217	291	381	493	639	821	1078	1479

NOTES:

(1) If an automatic air charge valve is used, tank size may be reduced by 50%.

(2) Increase tank size by 5% for each 1,000 feet elevation above 3,000 feet elevation.

Table 8.12

PLAIN PRESSURE TANK SIZE SELECTION

MINIMUM RECOMMENDED TOTAL STORAGE TANK SIZE (gallons)

(Based on 3,000 ft. elevation above sea level)
WITHOUT AIR VALVE

Flow = 25 gpm, Minimum Pump Running Time = 1.5 minutes

Pump CUT-OUT Pressure (PSIG)	Pump CUT-IN Pressure (PSIG)								
	20	30	40	50	60	70	80	90	100
30	681								
40	417	1078							
50	328	634	1540						
60	284	486	886	2087					
70	257	412	667	1176	2695				
80	240	370	563	886	1540	3594			
90	227	340	498	735	1135	1960	4312		
100	217	319	452	640	924	1406	2310	4976	
110	210	304	423	583	809	1155	1702	2812	6469
120	202	288	392	526	703	951	1294	1848	2940
130	197	278	374	494	647	851	1115	1504	2156
140	194	272	363	476	616	799	1027	1348	1848

NOTES:

(1) If an automatic air charge valve is used, tank size may be reduced by 50%.

(2) Increase tank size by 5% for each 1,000 feet elevation above 3,000 feet elevation.

8.5 PRESSURE SWITCHES

8.5.1 Switch Characteristics

Pressure switches are designed for certain pressure ranges, and electric voltage and amperage services. For most low pressure systems the switch pressure settings are pre-set at the factory. For higher pressure switches, the threshold cut-in and cut-out pressures can usually be adjusted.

The pressure range which should be used to set cut-in and cut-out pressure depends on the operating pressure of the system. Since air is compressed into a very small volume at high pressures, a greater pressure difference is required to store a given volume of water at higher pressures.

Tables 8.3 through 8.12 provide recommended cut-in and cut-out pressures for various pump flow rates and tank capacities. The time that a pump should stay on depends on motor characteristics. Too short a cycling time will heat the motor up and shorten the life of the motor and pump. The increased number of pressure surges caused by rapid cycling also hastens deterioration of pipe, valves and fittings.

Tables 8.3 through 8.12 are based on time between pump cycles of 1-1/2 minutes. This is typically a conservative minimum time as recommended by pump motor manufacturers. The tank volumes can be corrected to other run times by using the following equation:

$$\text{Corrected tank volume} = \frac{\text{Run time (minutes)} \times \text{Table volume}}{1.5}$$

8.5.2 Pressure Gauges

An accurate pressure gauge is a very important accessory for a pressure pipeline. With a good pressure gauge, problems such as leaks, pump wear and pressure surges can be spotted.

Frequently, low cost pressure gauges are used. They last a very short time in the damp atmosphere of most pump enclosures. For about $40.00, a good liquid filled gauge with a stainless steel case can be obtained and is highly recommended.

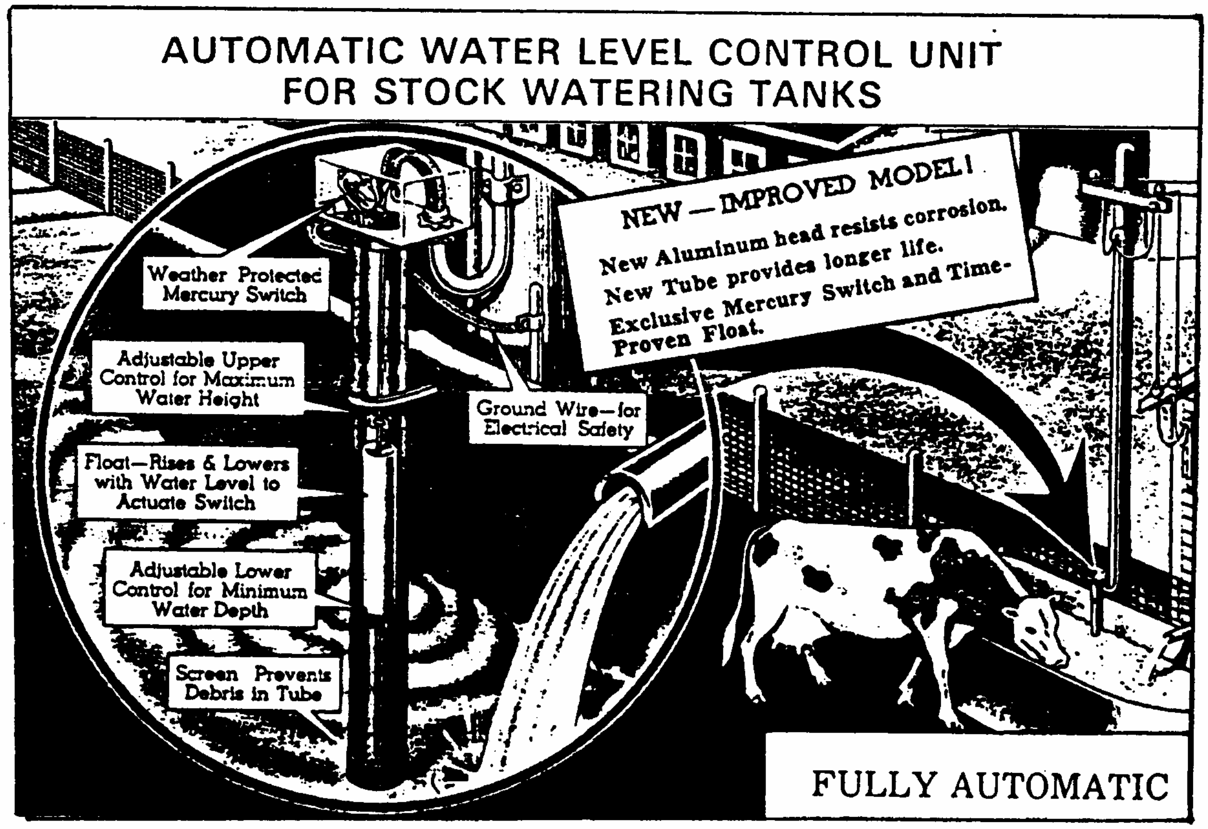
8.6 ELECTRICAL PUMP CONTROL EQUIPMENT

8.6.1 Automatic Water Level Control

A float switch which directly controls a pump is illustrated in Figure 8.24.

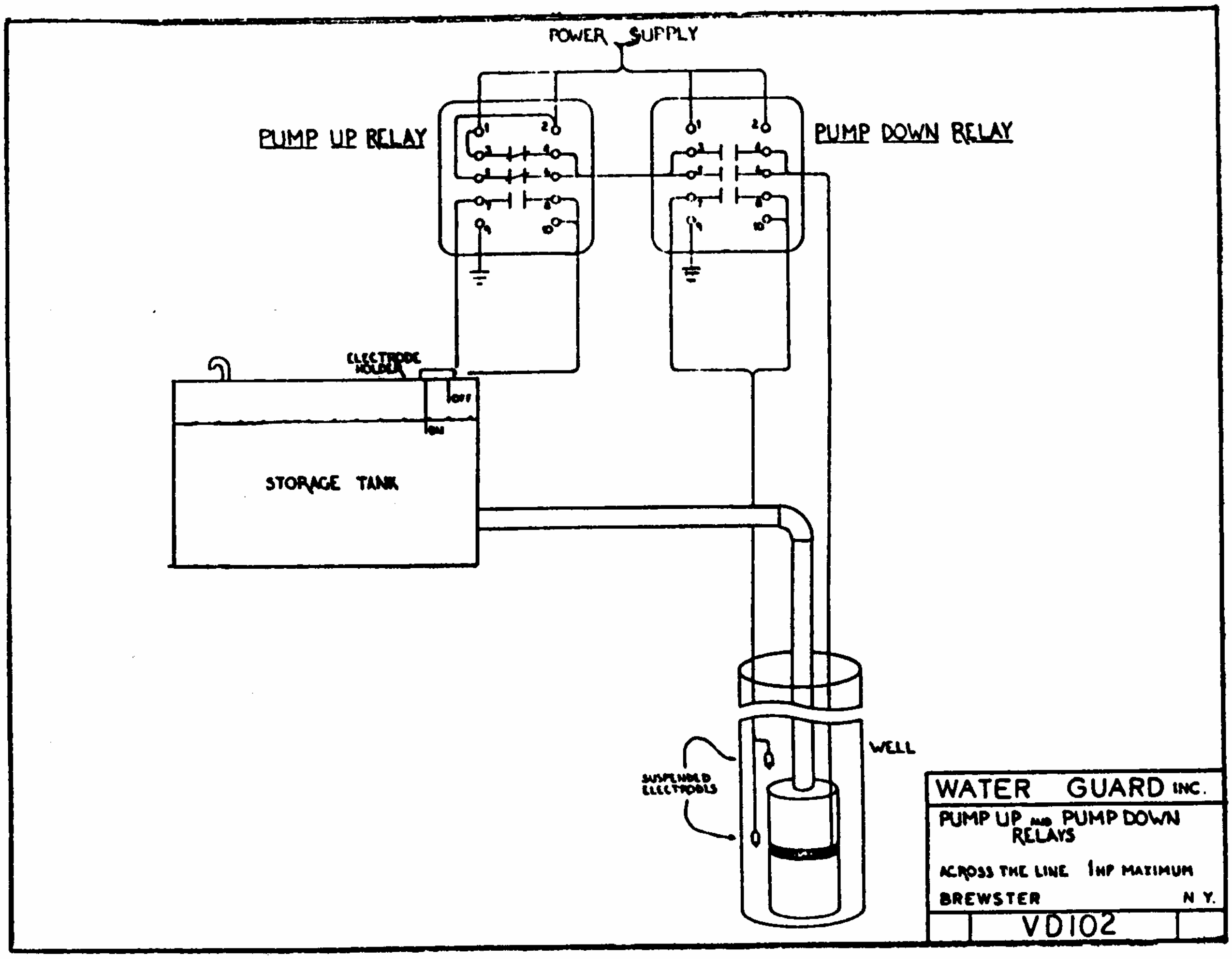
In addition to controlling the filling of a single tank, these types of switches can be used to fill a tank from which a gravity pipeline system is fed.

Figure 8.24
FLOAT SWITCH PUMP CONTROL



A mechanism to control a pump based on water levels in both well and tank is shown in Figure 8.25. This should be used where water level in the well must control the pump.

Figure 8.25
SWITCH CONTROL OF WATER LEVEL IN STORAGE TANK AND IN WELL



8.6.2 Remote Control Pump Float Switch

A float switch at a remote storage tank is connected to a pump relay switch via low voltage telephone line or signal wires. The wires may be underground or aboveground. Used telephone wires might be used aboveground. Figure 3.5 illustrates this type of system. This is the most preferred type of system for very high pressure pipelines. The storage tank is located at the highest point in the system.

Figure 8.26 illustrates typical switching equipment for a remote tank. Figure 8.27 shows various kinds of float switches that might be used in the storage tank.

A mercury float level control on a cable is a simple reliable mechanism. The pumping differential is controlled by the length of free cable.

Figure 8.26

REMOTE TANK FLOAT OPERATED SWITCHING EQUIPMENT

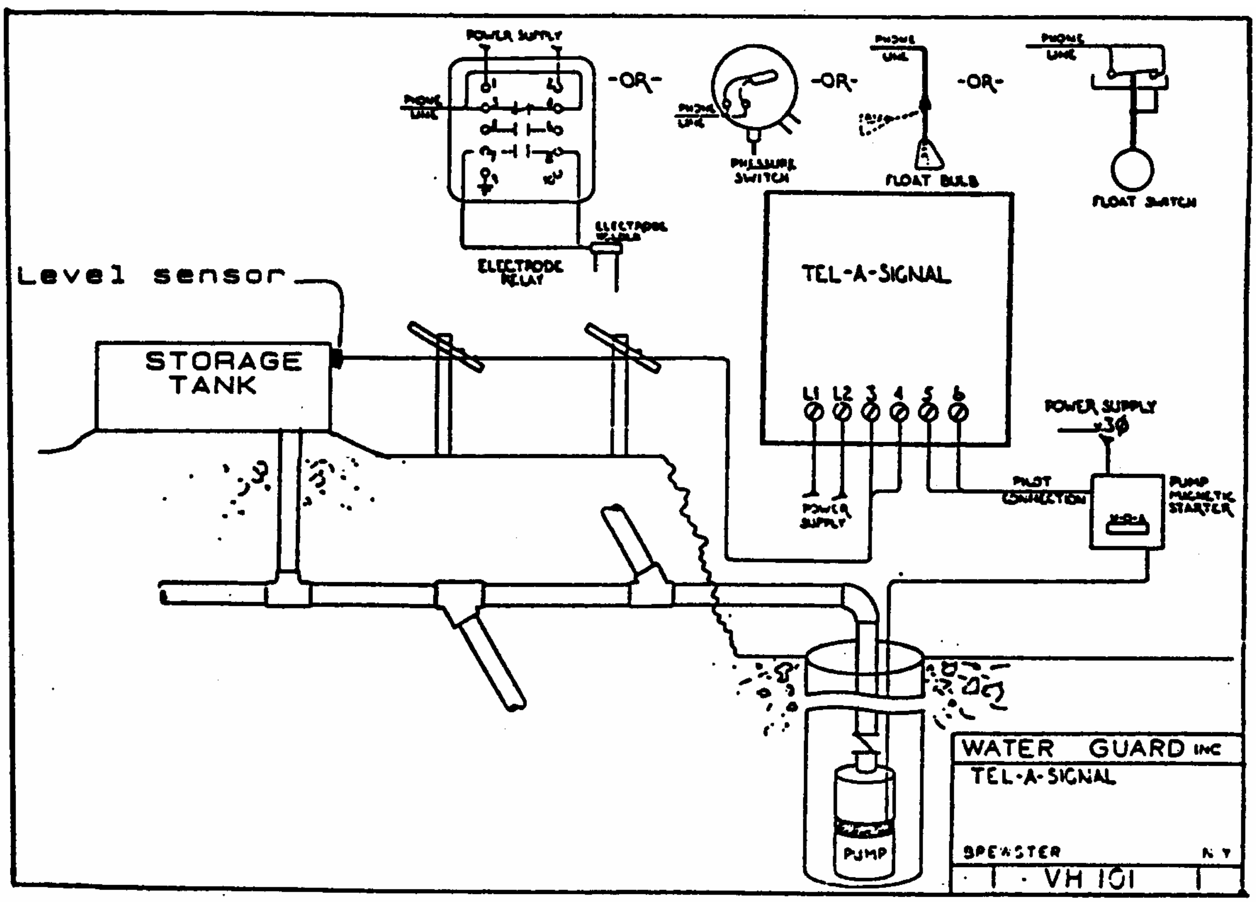
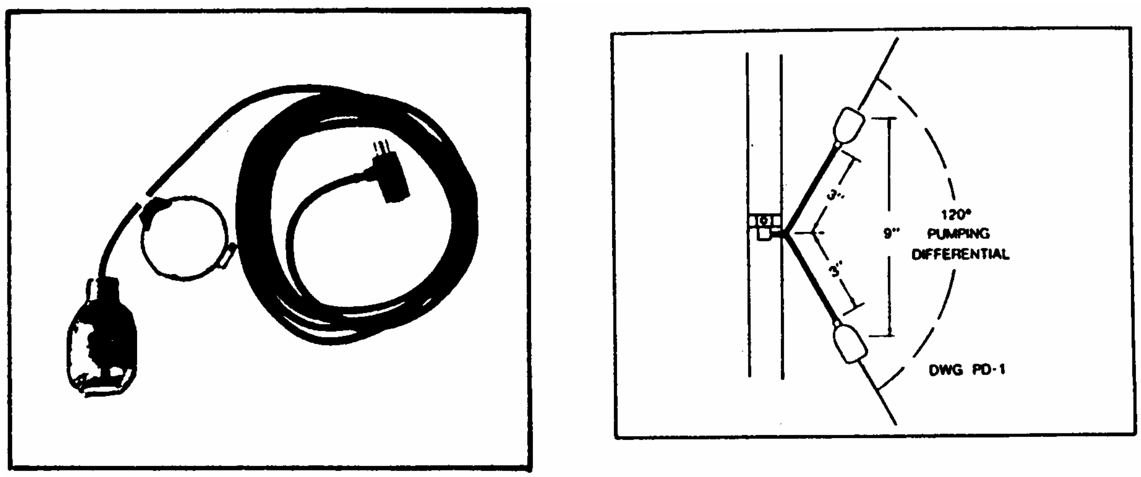
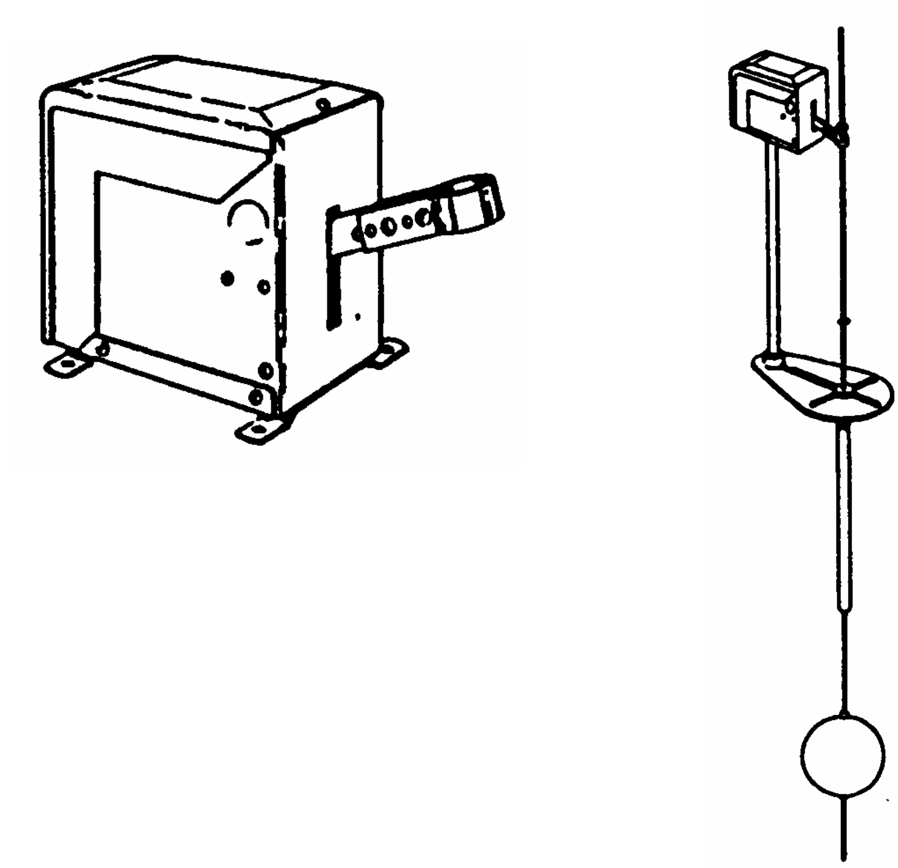


Figure 8.27
WATER LEVEL CONTROL SWITCHES



MERCURY FLOAT LEVEL CONTROL



MECHANICAL FLOAT SWITCH

8.7 STOCKWATER TANKS

Stockwater tanks come in an almost infinite number of shapes and sizes and are made from many different materials. Almost anything which will hold water and can be reached by an animal has been used.

It takes careful consideration to design a stock tank that will serve its function and be cost effective and last for at least a reasonable length of time. A stock tank must withstand a very hostile environment. Water used by livestock is often corrosive; ice and frost heave tend to damage the tank and foundations; animals step in tanks and rub up against them; people shoot at them; and animals tromp away the soil around a tank. All of these factors working together can make a tank short lived if proper precautions are not taken.

8.7.1 Tank Materials

Materials should be chosen not only for economic reasons, but to resist attack by the particular environmental hazards predominating at the site.

Concrete Tanks

Concrete is one of the most durable materials that can be used to build stock tanks. To be durable though, concrete must be made and placed properly. The two environmental factors that will rapidly deteriorate concrete are freeze-thaw action and sulfates in the water.

High sulfate concentrations are present in many waters used for stock-watering in the west. It is important to become aware of this if you are working in an area where sulfate is a problem.

Since stock tanks are often used during freezing weather, they are in an ideal environment for damage due to freezing and thawing. Pores in the concrete fill with water, freeze, and as a result the concrete will spall.

There are practical things that should be done to make quality concrete that will resist these elements:

1. Use a low water cement ratio. Use the minimum amount of water in the concrete that is possible consistent with being able to place the concrete. Use a minimum of 6 bags of cement per cubic yard of concrete.

2. Place the concrete within 1-1/2 hours after adding water to the cement. This is sometimes a challenge when using readymix concrete at remote sites. If travel time between batch plant and the site is a problem, add the cement and water at the site. Adding water to make concrete placeable after it has been in the truck too long is a leading cause of poor concrete.

3. Use air entrained concrete with air content within NRCS specification range. Air entrainment can be obtained by using cement with built-in air entrainment additives, or by adding admixtures at the concrete batch plant. Cement with air additives built-in is cement type IIA.

Foundation frost heave can also be a problem, particularly if the foundation is wet when the ground freezes. The solution is to build the tank so there will be good drainage away from the tank, provide proper overflow drains for the tanks, and provide a well drained base material under the tank.

Figure 8.28 illustrates a typical concrete tank. Figure 8.29 details a concrete trough. Figure 8.30 illustrates a tank made out of a section of large diameter concrete pipe. Figure 8.31 shows plans for a concrete frost free tank.

These tanks all require some skill to construct. If multiple copies of the same tank are to be constructed, costs can be reduced and quality increased by constructing reusable concrete forms.

Figure 8.28
CONCRETE TANK

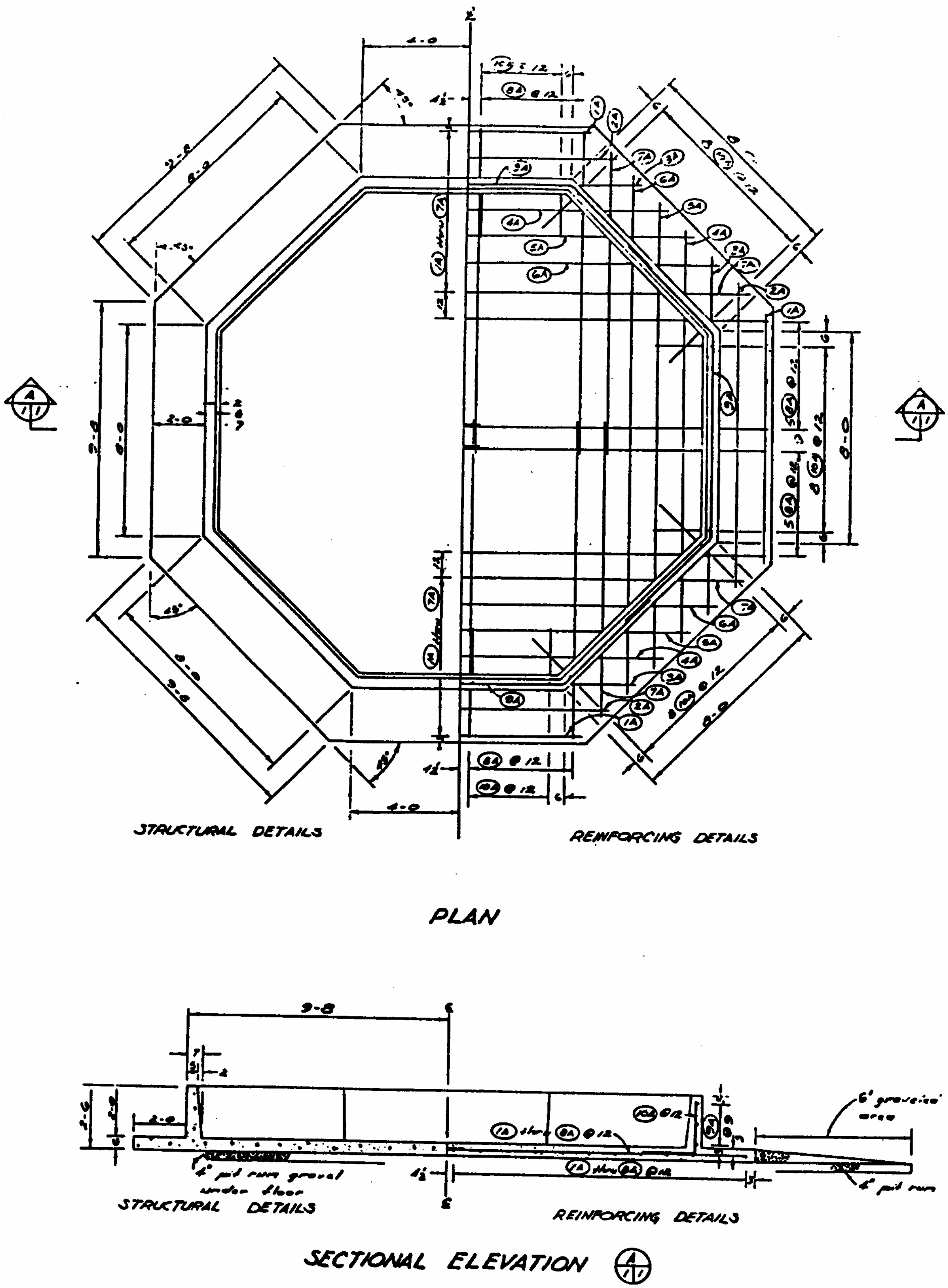


Figure 8.29
CONCRETE TROUGH

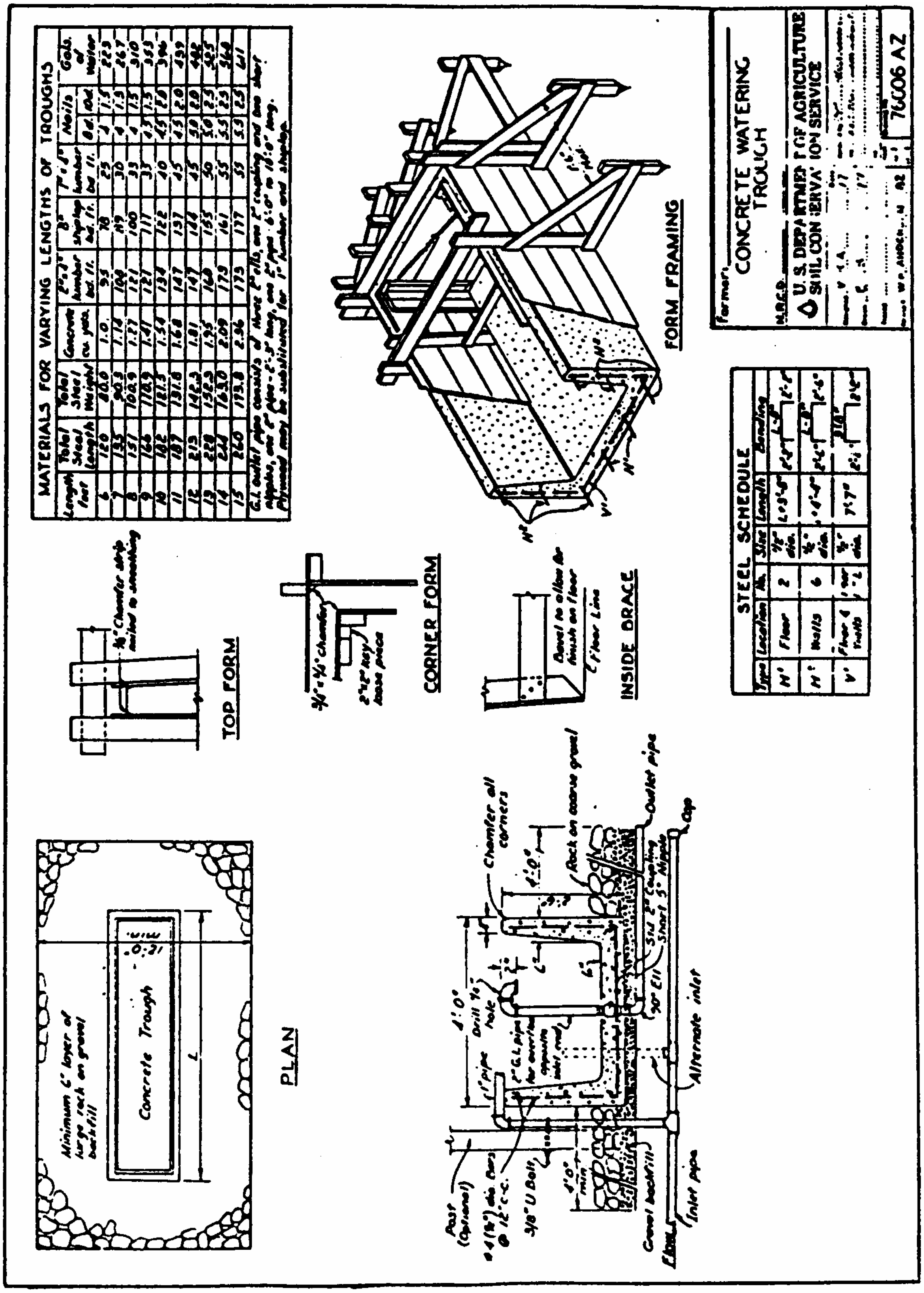


Figure 8.30
TANK MADE FROM CONCRETE PIPE

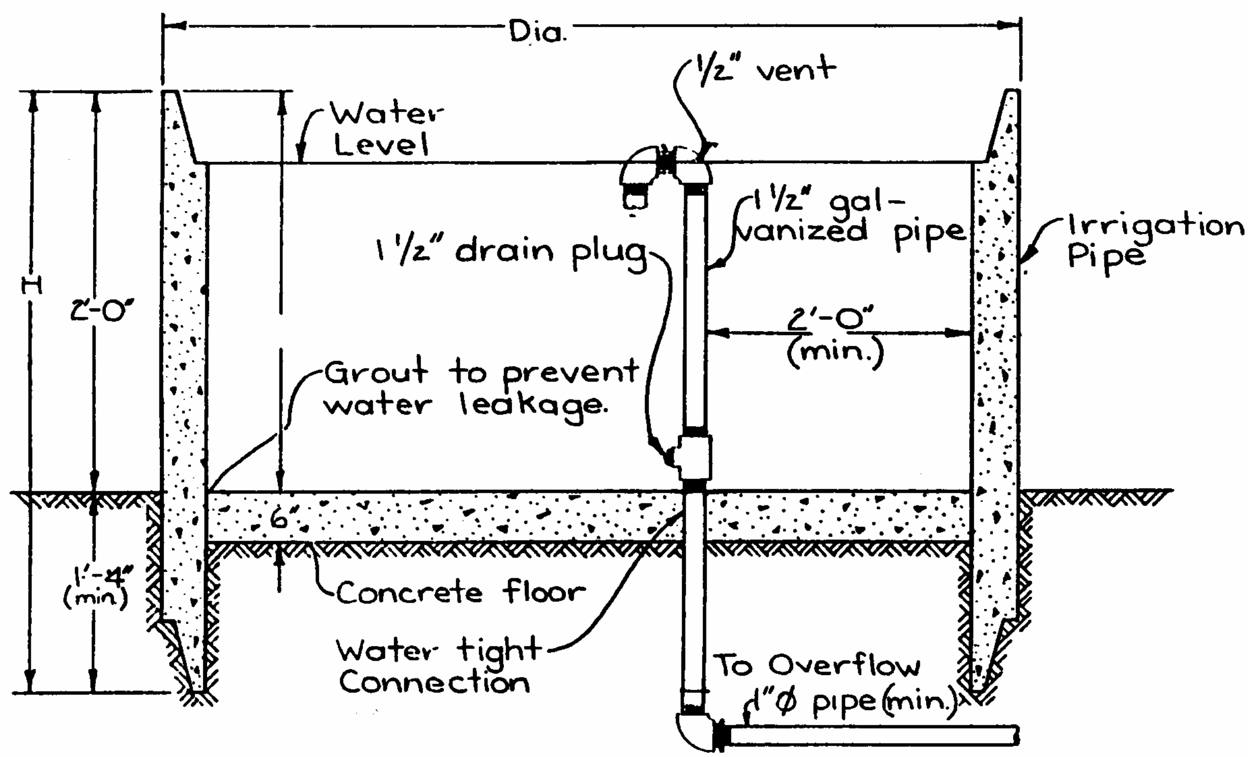
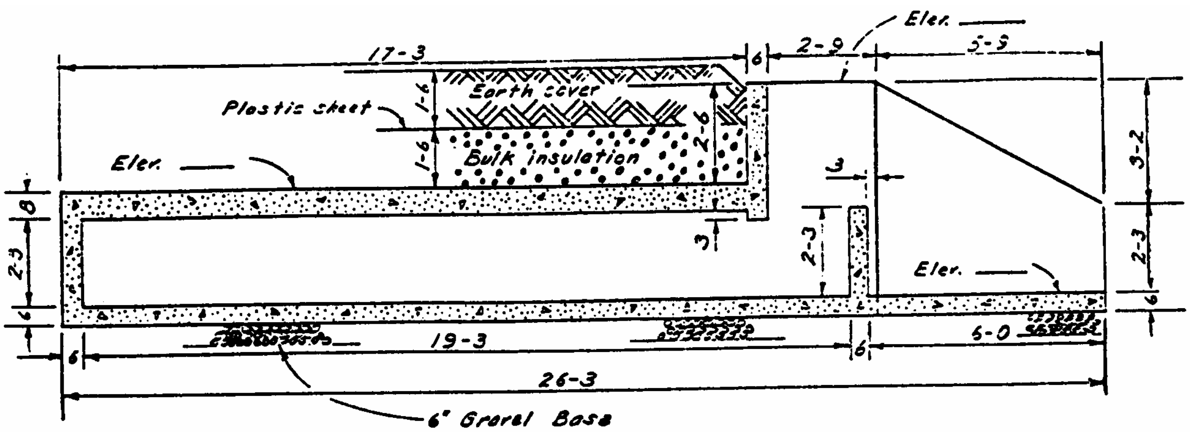
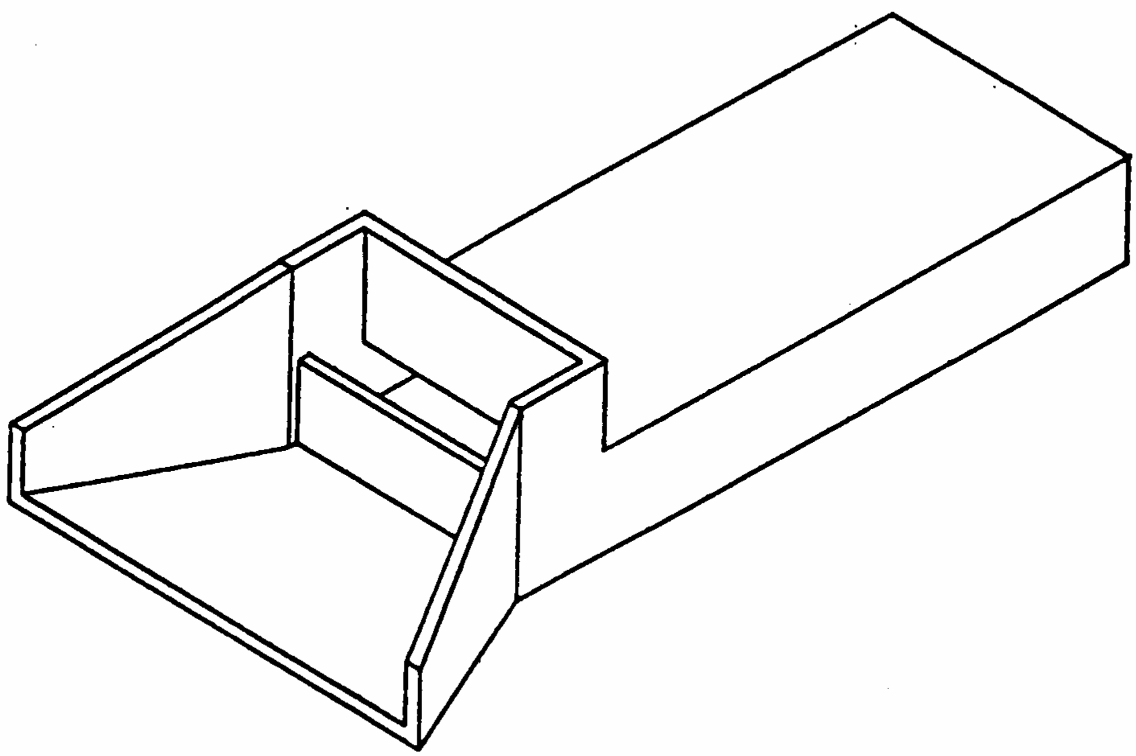


Figure 8.31
FROST PROOF CONCRETE TANK



SECTION A/11
Scale: 3/16" = 1'-0"



ISOMETRIC VIEW
Not to scale

Fiberglass Tanks

Many stock tanks are now made out of fiberglass. Fiberglass is very resistant to deterioration by chemical attack. It is also light and easy to install. It is however, subject to mechanical damage.

Since fiberglass is so light, wind and animals can easily move it out of place. If a large animal gets into a fiberglass tank, the tank bottom can be damaged and it might be difficult for the animal to get out.

For these reasons, it is important to provide hold downs and protective rails when installing a fiberglass tank.

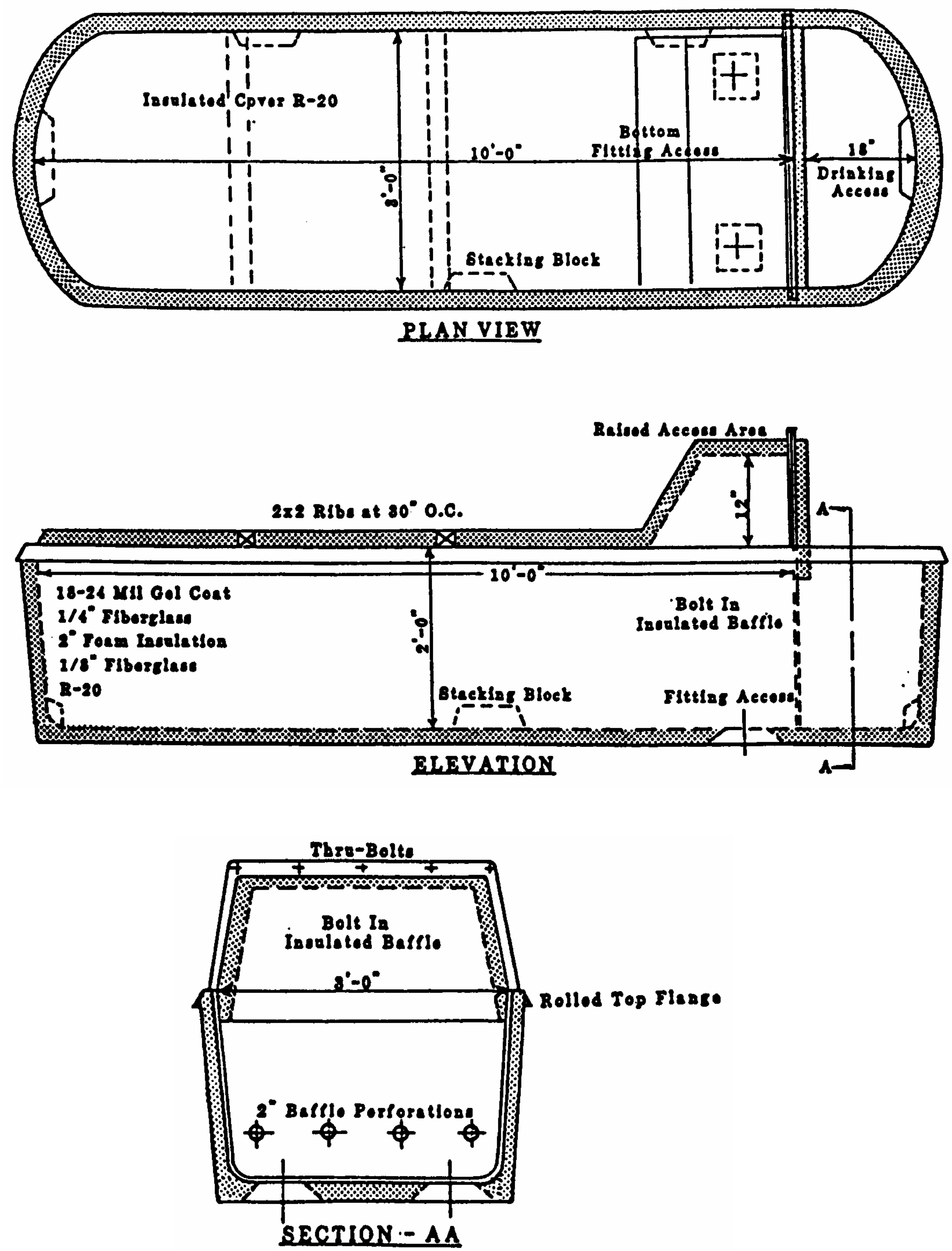
Thickness of fiberglass will determine how resistant the tank is to mechanical damage. Thickness should be at least the minimum specified in NRCS specifications. It is possible to repair damaged fiberglass, which is one advantage of using this material.

Tanks size is limited to what can be transported to the site. Sometimes this limitation is overcome by combining tanks built-up from two or more component parts. Several tanks can also be put together in series to get the total gallons required.

Plastic Tanks

Some tanks and troughs are now being made out of high strength plastics without fiberglass reinforcement. The science of plastics is very complex and it is difficult to know what the life will be of any given plastic formulation and tank configuration. Only brands and configurations which have received NRCS State Conservation Engineer approval should be recommended.

Figure 8.32
FROST FREE FIBERGLASS TANK



Galvanized Steel Tanks

There are generally two kinds of galvanized steel tanks: (1) Those assembled at the site from standard corrugated or formed steel segments and (2) Completely self contained manufactured tanks.

1) Stock tanks made from corrugated steel segments

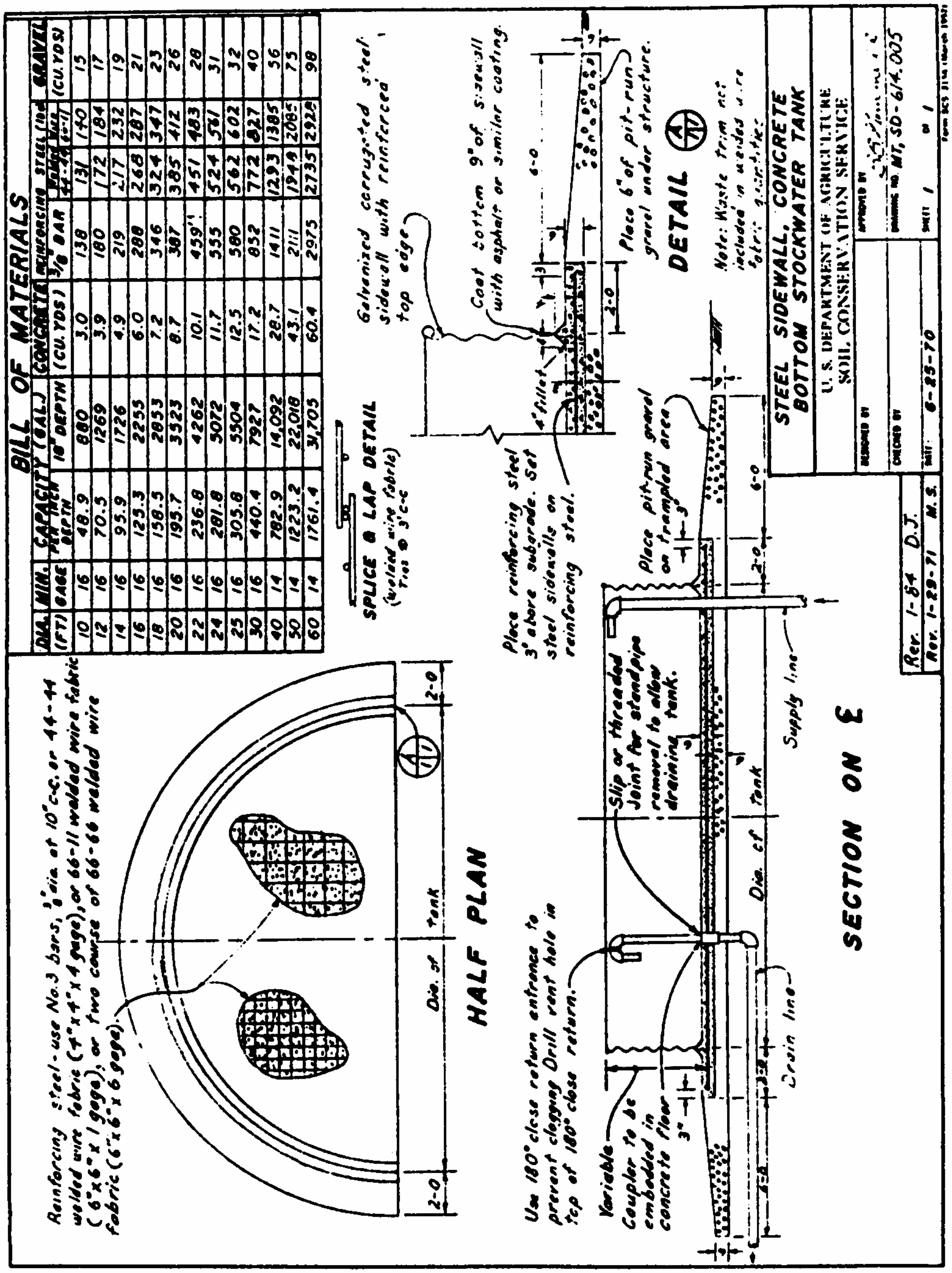
   Large diameter stock tanks are made up of curved corrugated galvanized steel sheets, which are bolted together. Mastic is used in the joints. The steel and galvanizing are usually heavy. The bottom of the tank can be made of reinforced concrete, bentonite, heavy plastic liner, or rubber sheeting material. This type of tank will usually last a long time if properly installed and cared for.

2) Manufactured steel stock tanks

   The thickness of steel and galvanizing vary widely in manufactured steel tanks. The tanks are frequently small and made of light gauge steel with minimum galvanizing. As with fiberglass tanks, these must be properly tied down and protected from livestock. Do not use these tanks in locations where water or soil is corrosive to steel.

Figure 8.33 details a tank made from corrugated steel plate segments. Figure 8.34 illustrates typical manufactured steel tanks. Figure 8.35 shows a commercially available frost free steel tank which is fabricated from corrugated steel pipe.

Figure 8.33
TANK MADE FROM CORRUGATED STEEL SEGMENTS



BILL OF MATERIALS

DIA. (FT)	MIN. GAGE	CAPACITY (GAL.) PER INCH DEPTH	CAPACITY (GAL.) 18" DEPTH	CONCRETE (CU. YDS)	REINFORCING STEEL (lbs) 3/8" BAR	REINFORCING STEEL (lbs) Welded Wire 44-44	REINFORCING STEEL (lbs) Welded Wire 66-11	GRAVEL (CU. YDS)
10	16	48.9	880	3.0	138	131	140	15
12	16	70.5	1269	3.9	180	172	184	17
14	16	95.9	1726	4.9	219	217	232	19
16	16	125.3	2255	6.0	288	268	287	21
18	16	158.5	2853	7.2	346	324	347	23
20	16	195.7	3523	8.7	387	385	412	26
22	16	236.8	4262	10.1	459	451	483	28
24	16	281.8	5072	11.7	555	524	561	31
25	16	305.8	5504	12.5	580	562	602	32
30	16	440.4	7927	17.2	852	772	827	40
40	14	782.9	14,092	28.7	1411	1293	1385	56
50	14	1223.2	22,018	43.1	2111	1949	2085	75
60	14	1761.4	31,705	60.4	2975	2735	2928	98

Figure 8.34
MANUFACTURED STEEL TANK

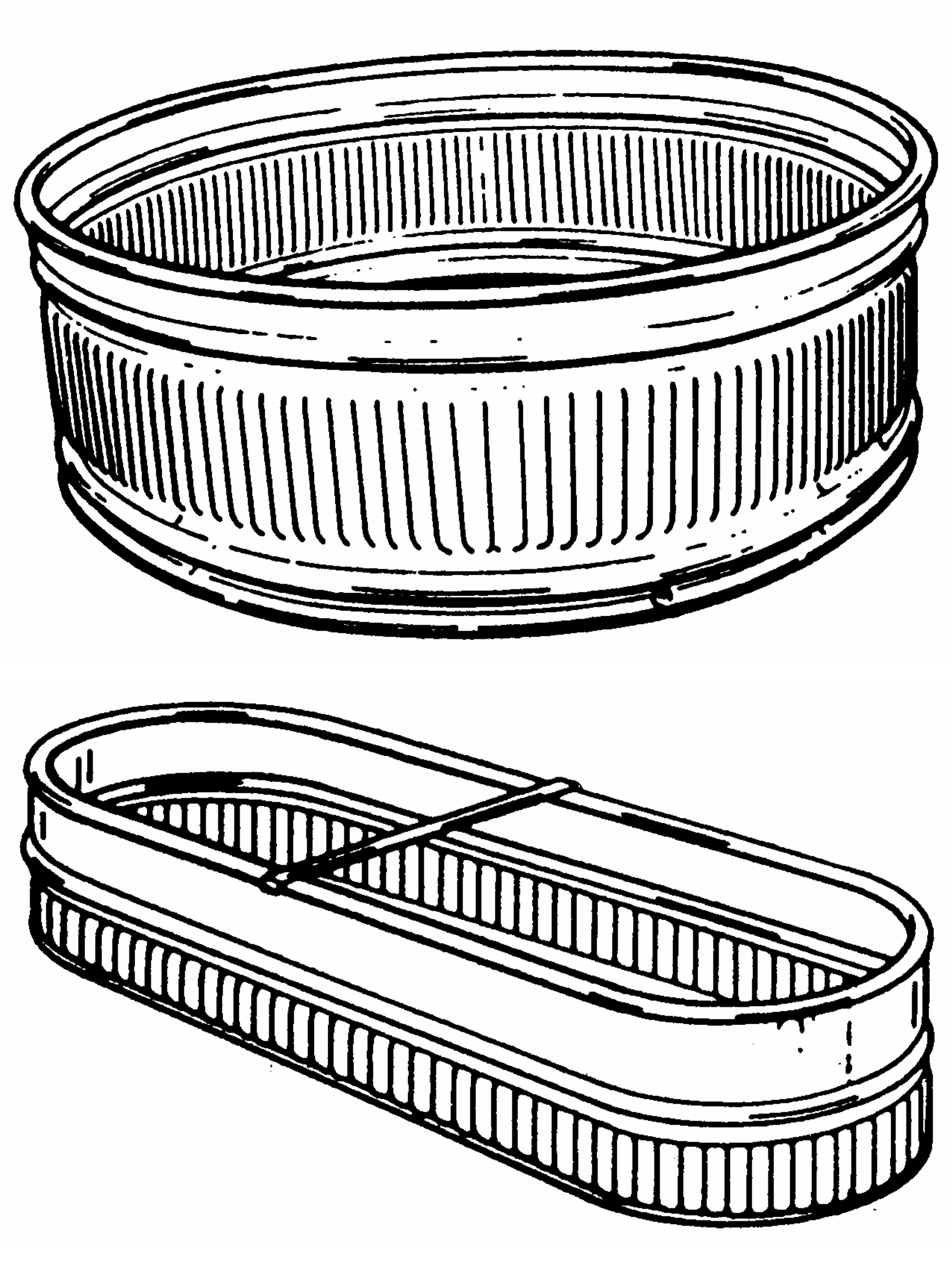
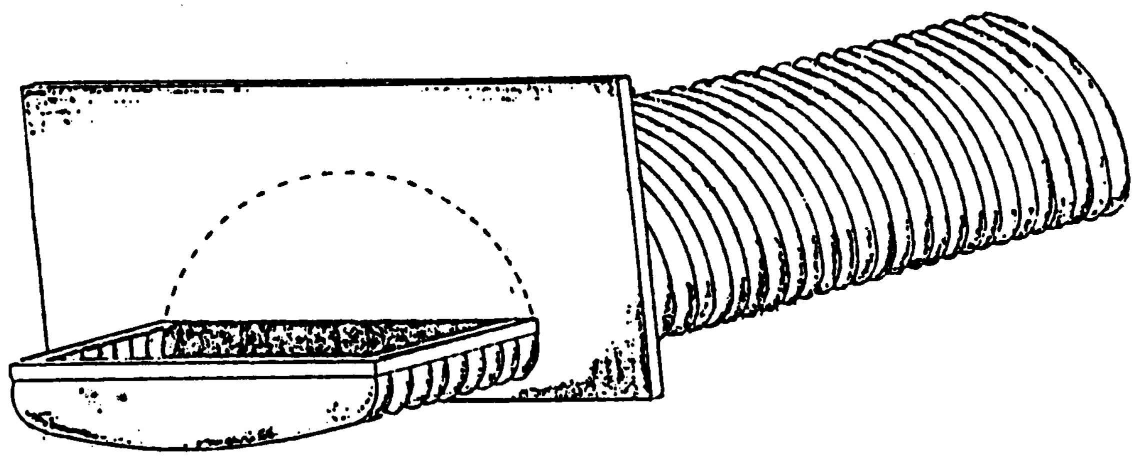


Figure 8.35
FROST FREE STEEL TANK



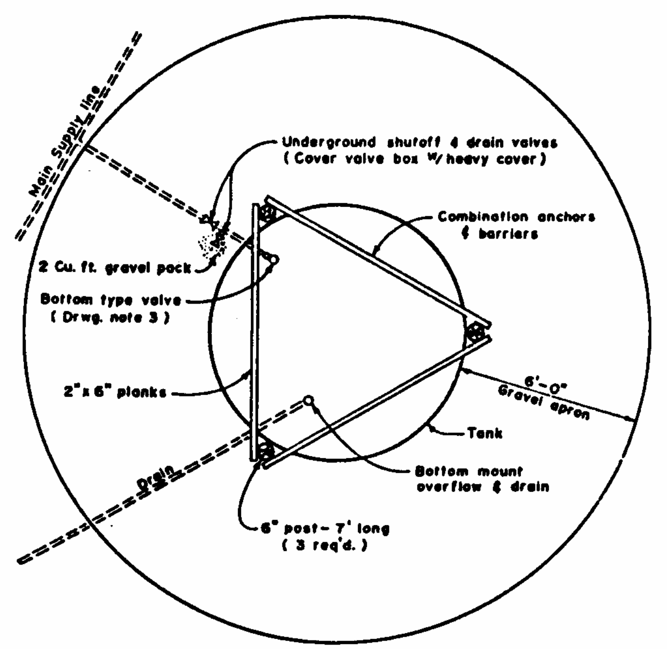
8.7.2 Water Inlet Protection

Water inlets must be protected from mechanical damage by animals and from freezing. One way to do this is to install the inlet under the water at the bottom of the tank. Float valves can be installed below water level with the float floating at the water surface on a chain. Water level valves are also available which are controlled by water depth induced pressure.

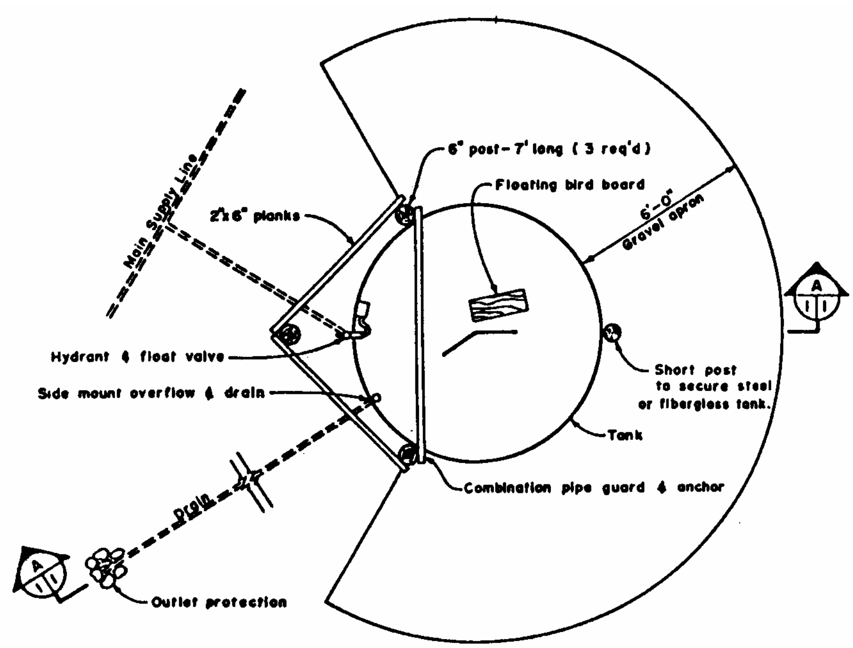
Combination float valves and thermostatically controlled valves are available which will open in the event that temperature of the water gets down to just above freezing. These are installed at the bottom of the tank. The valve opens to provide a constant flow during periods of freezing weather. It is very important to have an adequate overflow system when this type of valve is installed.

Figures 8.36 through 8.38 illustrate commonly used systems of tank and inlet protection.

Figure 8.36
TYPICAL TANK LAYOUT PLANS

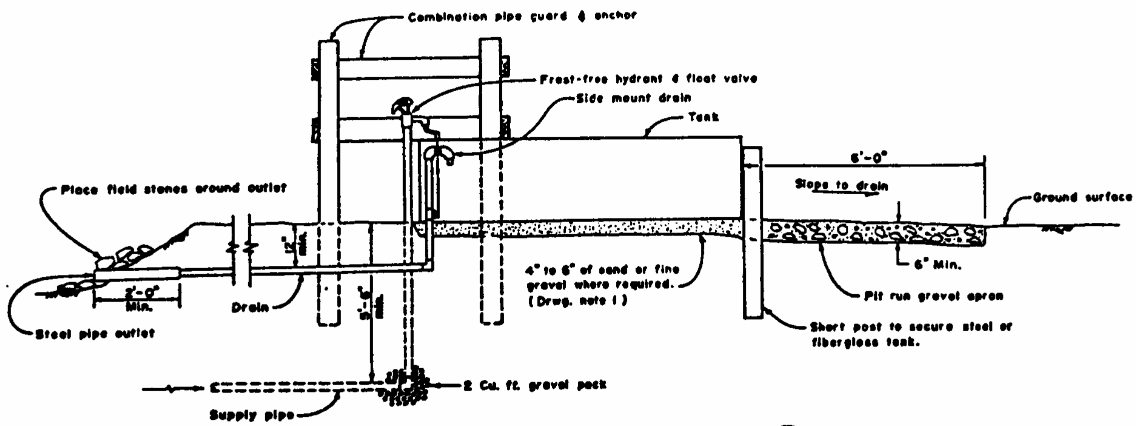


TYPICAL TANK LAYOUT
W/ BOTTOM VALVE & STOCK BARRIER

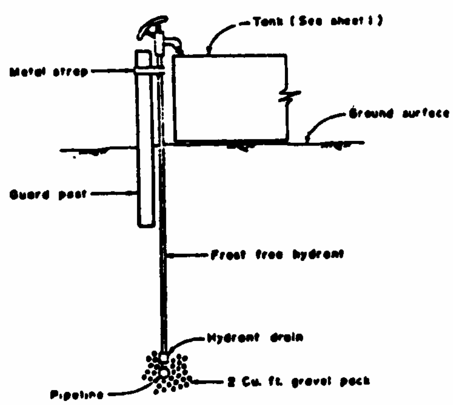


TYPICAL TANK LAYOUT
W/SIDE DRAIN & PIPE GUARD

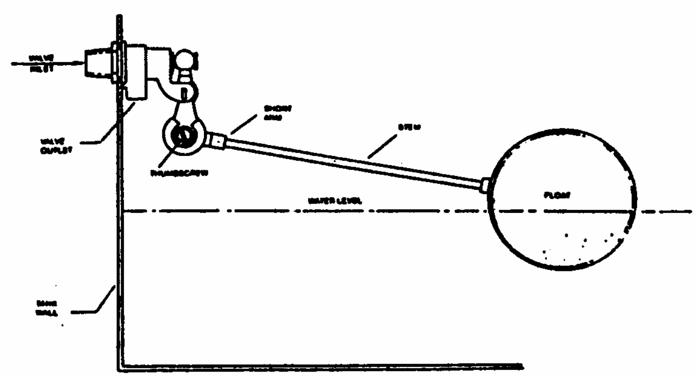
Figure 8.37
TANK DETAILS

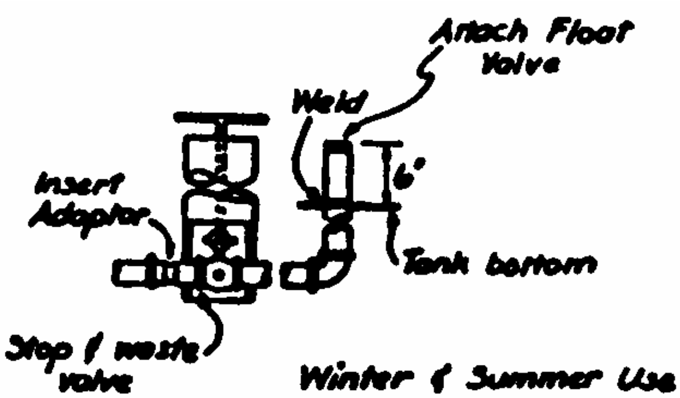


TYPICAL TANK SECTION



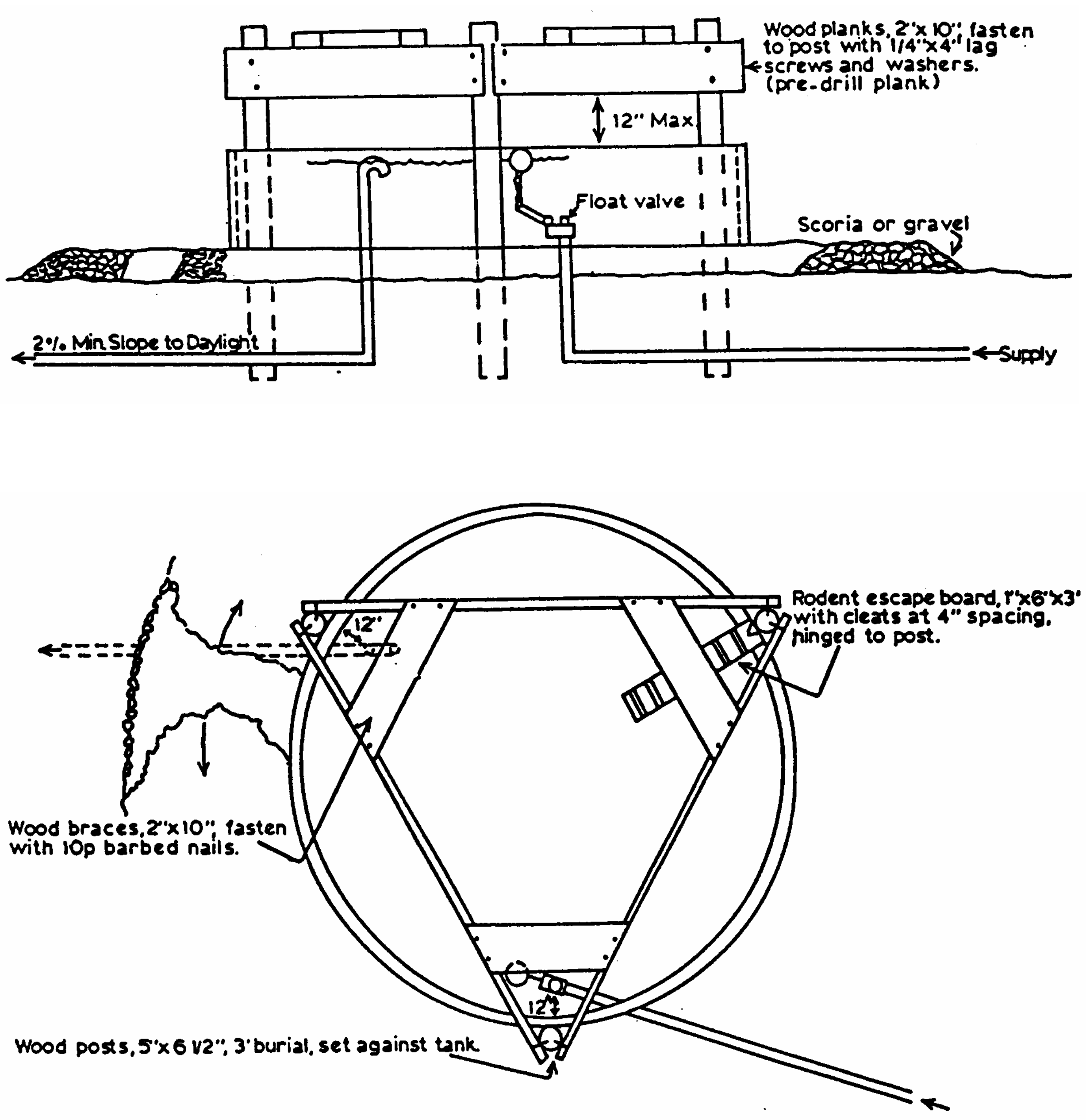
HYDRANT DETAILS





ALTERNATE INLET

Figure 8.38
LAYOUT USING SUBMERGED FLOAT VALVE



8.7.3 Protection Around Tanks

Livestock can wear the ground down around a tank very rapidly, particularly under wet conditions. If the ground is not naturally gravelly, a gravel or concrete base should be installed around the base of the tank. Figures 8.36 through 8.38 show examples of good tank bases.

8.7.4 Tank Overflows

Tank overflows are required when there is no control on the amount of water coming into the tank. They are also highly recommended even when a float valve is used to control flow into the tank. Float valves occasionally do not close properly and an overflow is insurance against damage caused by overflow.

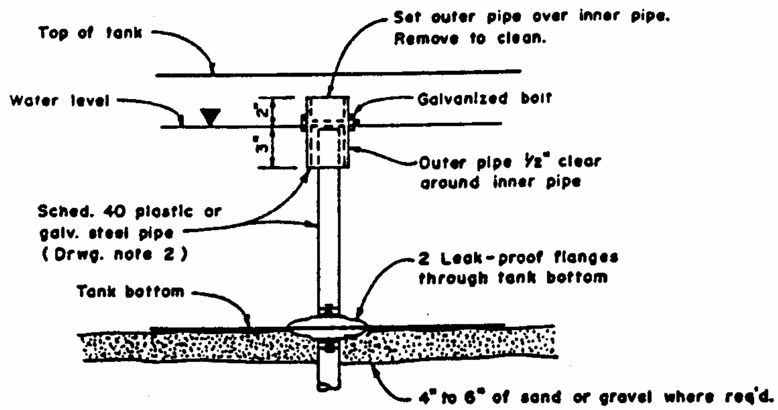
The purpose of an overflow is to carry excess water away so excess water does not make a bog around the tank. The overflow should be long enough to carry the water to a place where it will not cause a problem.

The inlet to the overflow should be constructed at the elevation of water level in the tank. The entrance should be designed so that floating debris, scum and ice will not clog it.

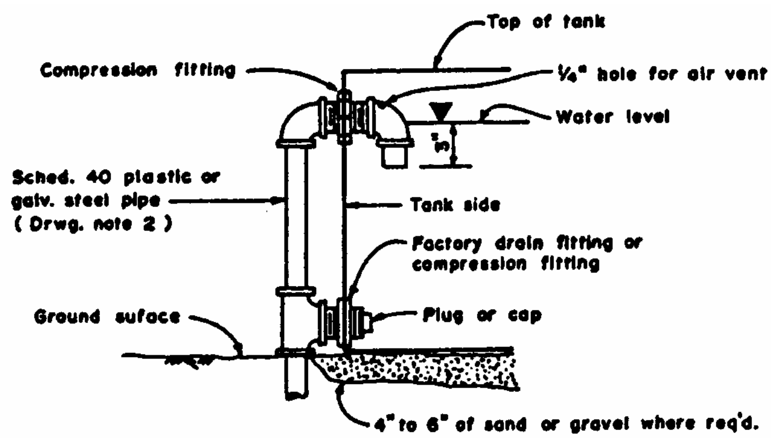
Figure 8.39 illustrates some commonly used overflow inlet systems.

The outlet end of the drain pipe should be protected from being damaged by livestock or from being run over by vehicles. Figure 8.37 shows one way that this can be accomplished.

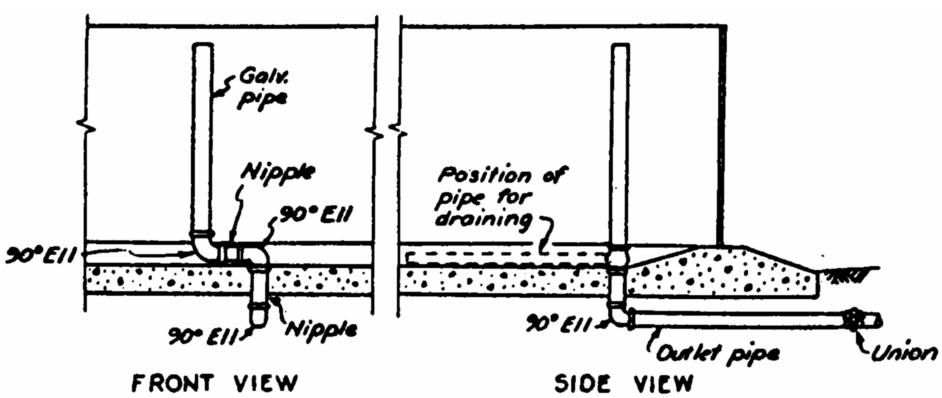
Figure 8.39
OVERFLOWS



TYPICAL BOTTOM MOUNT
OVERFLOW & DRAIN



TYPICAL SIDE MOUNT
OVERFLOW & DRAIN

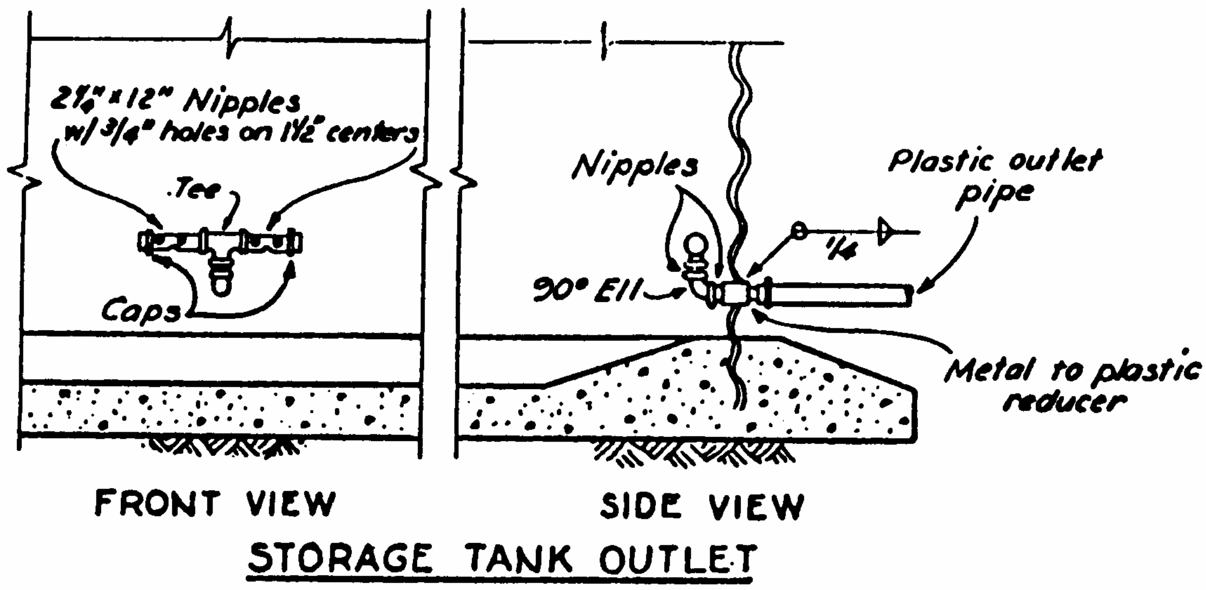


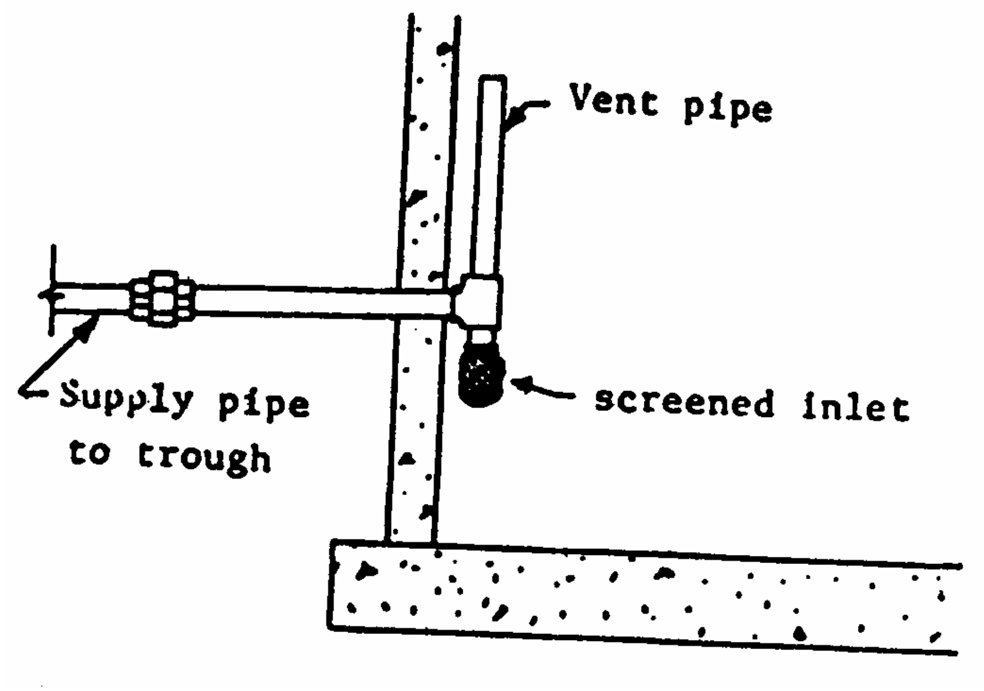
SWIVEL STORAGE TANK OUTLET

8.7.5 Inlet to Pipeline from Tank

When an inlet to a continuing pipeline is located in a tank, some form of inlet screen should be installed. Figure 8.40 illustrates two types of inlet designs.

Figure 8.40
PIPELINE TANK INLET





8.8 STORAGE TANKS

A large storage tank is sometimes used at the highest point in the pipeline as a reservoir to store water for distribution in a gravity pipeline. Another frequent use is for large volume storage for output from springs, windmills, solar pumps and engine powered pumps.

Used railroad tanker cars, used underground fuel storage tanks and other used tanks are sometimes used as storage tanks. These can be a bargain but they must be thoroughly cleaned and properly treated before they can be used. Leaded gasoline and various chemicals may not be adequately cleaned out by steam cleaning. State health regulations must be followed when using such tanks

If a used tank is not coated on the inside, it will have a limited life, depending on the tanks condition and corrosiveness of the water.

The site must be accessible enough to be able to move a large tank to the site.

Large diameter steel stock tanks are sometimes used. They have the advantage as being usable as stock tanks as well as for storage. The disadvantage is that they are open at the top and can collect debris and there may be considerable water loss due to evaporation.

Evaporation from large open tanks can be controlled by covering the tank with a floating cover. Floating covers constructed from low-density, closed cell (EPDM) synthetic rubber have proved to work well. The strips of foam are 1/4-inch thick and are glued together with contact cement. Half-inch in diameter bail holes are drilled in the foam to allow rainfall to drain from the surface.

Pits lined with commercial plastic lining material can be used. These must be fenced out to insure animals stay out of the pit. Floating plastic covers held up by floats under the plastic can be used to seal them.

Figure 8.41 depicts a commercial corrugated steel tank. This tank is similar to a grain bin except that it is designed to hold water. It has the advantage of being transportable to remote sites in pieces.

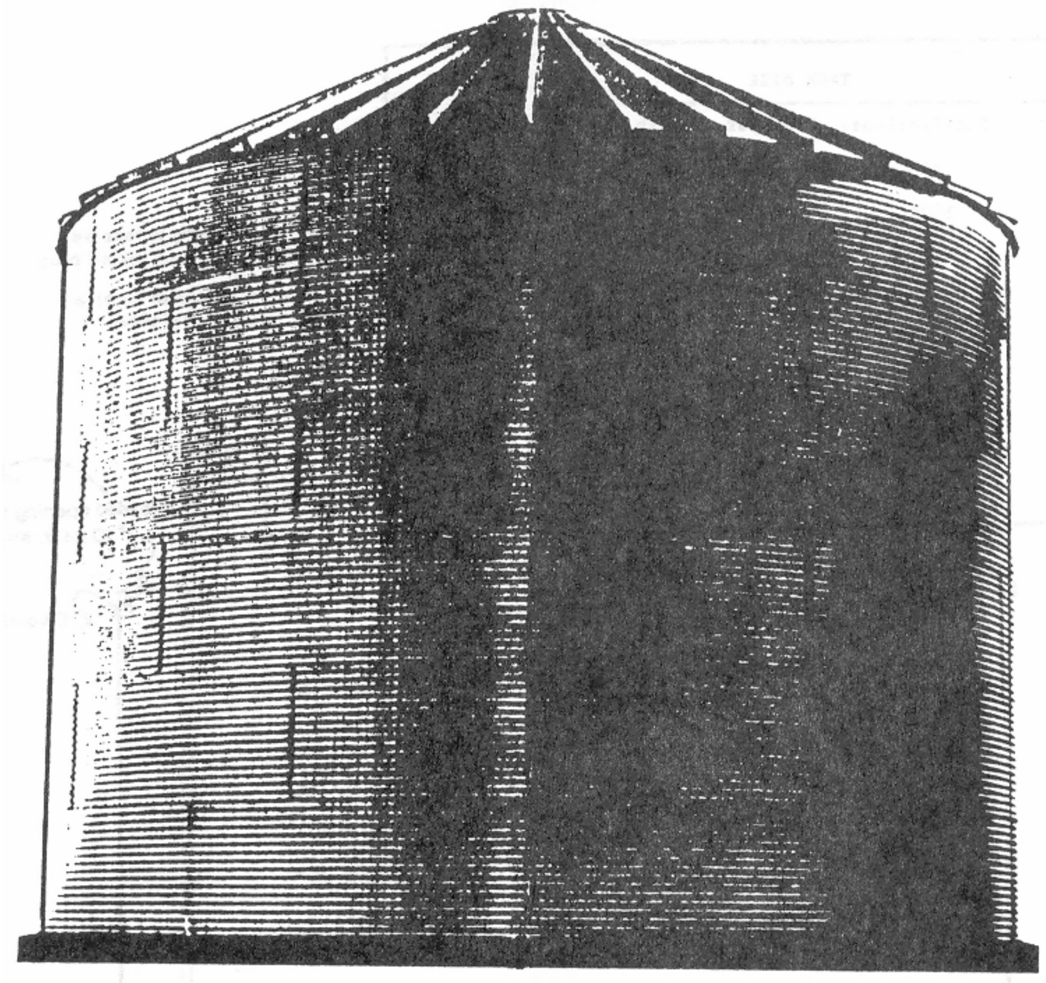
Figure 8.42 illustrates typical plans for a tank fabricated from sheet steel. The inside should be epoxy coated. The outside would be coated with coal tar material or epoxy. Cathodic protection may be needed depending on the corrosivity of the soil.

Figure 8.43 illustrates a large steel tank constructed out of corrugated structural plates.

Figure 8.44 depicts one type of fiberglass storage tank.

Figure 8.45 illustrates a storage bag-type installation. A large rubberized fabric or plastic water storage bag is used for long-term storage. Figure 8.45 depicts such a bag used in conjunction with a water harvesting catchment system. This type of system can be used in remote areas where no other source of water is available and where it would cost too much to construct a pipeline from another area.

Figure 8.41
COMMERCIAL STEEL WATER STORAGE TANK



Wide Selection of Sizes for You!

TANK CONSISTS OF CORRUGATED GALVANIZED STEEL BODY, 30° CONICAL GALVANIZED STEEL ROOF AND 0.025-INCH FDA-APPROVED WHITE VINYL LINER. ANCHOR BOLTS, ANCHOR CLIPS, BOLTS, NUTS AND HARDWARE FOR ASSEMBLING TANK ARE INCLUDED.

MODEL NUMBER	DIAMETER		OVERALL HEIGHT		CAPACITY	
	FEET	METERS	FEET	METERS	GALLON	LITERS
601	6'	1.83	5' 7"	1.70	600	2,270
602	6'	1.83	9' 2"	2.79	1,400	5,300
603	6'	1.83	12' 9"	3.89	2,100	7,950
604	6'	1.83	16' 3"	4.95	2,900	10,980
901	9'	2.74	7' 1"	2.16	1,500	5,680
902	9'	2.74	10' 8"	3.25	3,100	11,740
903	9'	2.74	14' 3"	4.34	4,800	18,170
904	9'	2.74	17' 9"	5.41	6,500	24,605
1201	12'	3.66	6' 10"	2.08	2,600	9,840
1202	12'	3.66	10' 5"	3.18	5,600	21,200
1203	12'	3.66	14' 0"	4.27	8,600	32,550
1204	12'	3.66	17' 6"	5.33	11,600	43,910
1501	15'	4.57	7' 7"	2.31	4,100	15,520
1502	15'	4.57	11' 2"	3.40	8,800	33,310
1503	15'	4.57	14' 9"	4.50	13,500	51,100
1504	15'	4.57	18' 3"	5.56	18,100	68,515
1801	18'	5.49	8' 4"	2.54	6,000	22,712
1802	18'	5.49	11' 11"	3.63	12,700	48,075
1803	18'	5.49	15' 6"	4.72	19,400	73,440
1804	18'	5.49	19' 0"	5.79	26,100	98,800
2101	21'	6.40	9' 1"	2.77	8,200	31,040
2102	21'	6.40	12' 8"	3.86	17,300	65,490
2103	21'	6.40	16' 3"	4.95	26,400	99,930
2104	21'	6.40	19' 9"	6.02	35,600	134,760
2401	24'	7.32	9' 10"	3.00	10,700	40,500
2402	24'	7.32	13' 5"	4.09	22,600	85,550
2403	24'	7.32	17' 0"	5.18	34,500	130,600
2404	24'	7.32	20' 6"	6.25	46,500	176,020
2701	27'	8.23	10' 11"	3.33	13,500	51,100
2702	27'	8.23	14' 6"	4.42	28,600	108,260
2703	27'	8.23	18' 1"	5.51	43,700	165,420
2704	27'	8.23	21' 7"	6.58	58,800	222,580
3001	30'	9.14	11' 9"	3.58	16,700	63,220
3002	30'	9.14	15' 4"	4.67	35,300	133,625
3003	30'	9.14	18' 11"	5.77	54,000	204,410
3004	30'	9.14	22' 5"	6.83	72,600	274,820
3301	33'	10.06	12' 7"	3.83	20,200	76,465
3302	33'	10.06	16' 2"	4.93	42,700	161,640
3303	33'	10.06	19' 9"	6.02	65,300	247,190
3304	33'	10.06	23' 3"	7.09	87,900	332,740
3601	36'	10.97	13' 6"	4.11	24,100	91,230
3602	36'	10.97	17' 1"	5.21	50,900	192,675
3603	36'	10.97	20' 8"	6.30	77,800	294,500
3604	36'	10.97	24' 2"	7.37	104,600	396,950
3901	39'	11.89	14' 5"	4.40	28,200	106,750
3902	39'	11.89	18' 0"	5.49	59,700	225,990
3903	39'	11.89	21' 7"	6.58	91,300	345,600
3904	39'	11.89	25' 1"	7.65	122,700	464,470
4201	42'	12.80	15' 2"	4.62	32,700	123,780
4202	42'	12.80	18' 9"	5.72	69,200	261,950
4203	42'	12.80	22' 4"	6.81	105,800	400,500
4204	42'	12.80	25' 10"	7.87	142,300	538,660
4801	48'	14.63	18' 3"	5.56	42,800	162,015
4802	48'	14.63	21' 10"	6.65	90,500	342,580
4803	48'	14.63	25' 5"	7.34	138,300	523,520
4804	48'	14.63	28' 11"	8.81	185,900	703,700
6001	60'	18.29	22' 1"	6.73	66,900	253,240
6002	60'	18.29	25' 8"	7.82	141,500	535,635
6003	60'	18.29	29' 3"	8.92	216,000	817,650
6004	60'	18.29	32' 9"	9.98	290,600	1,100,000

Figure 8.42
FABRICATED STEEL STORAGE TANK

STEEL GAUGE		TANK SIZE			
Gallons	Gauge Min.	Size(gallons)	Diameter	x	Length
to 560	12	550	4'	x	6'
561-1100	10	1000	4'	x	11'
1101-4000	3/16"	2000	6'	x	12'
4001-12000	1/4"	5000	8'	x	14'
12001-20000	5/16"	6000	8'	x	16'
		8000	8'	x	21'
		10000	9'	x	21'
		12000	9'	x	25'

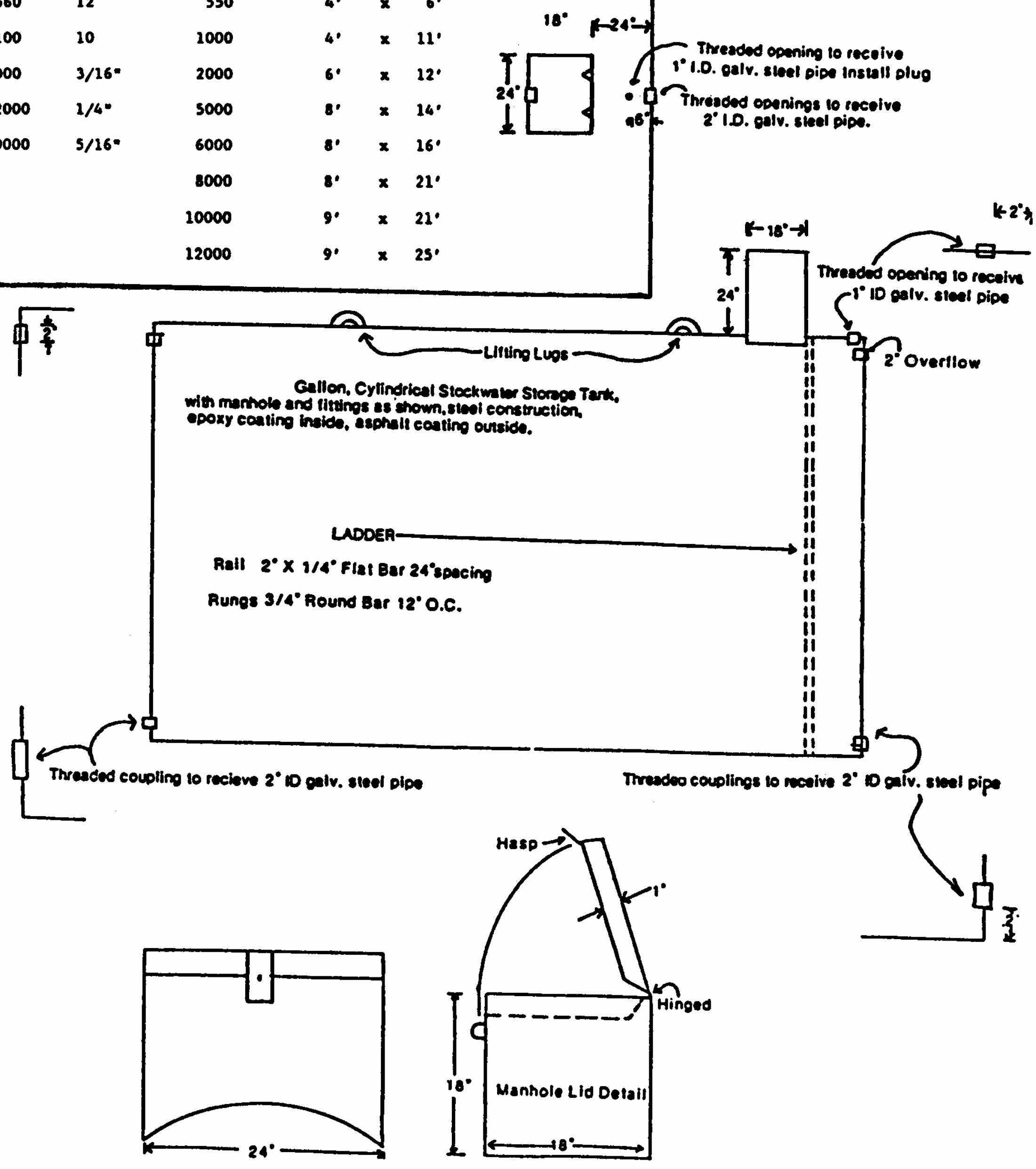


Figure 8.43

CONSTRUCTED CORRUGATED STEEL STORAGE TANK

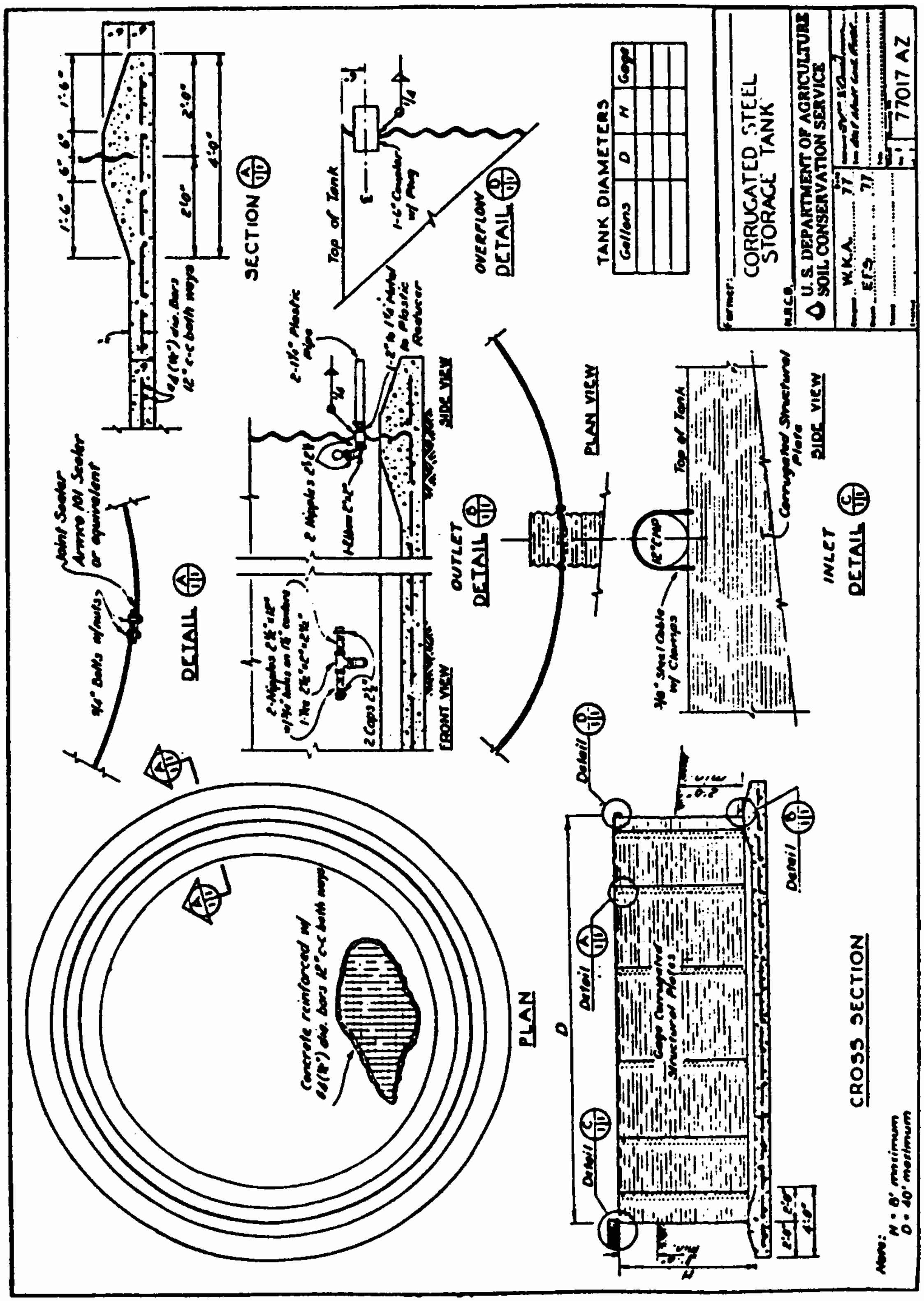
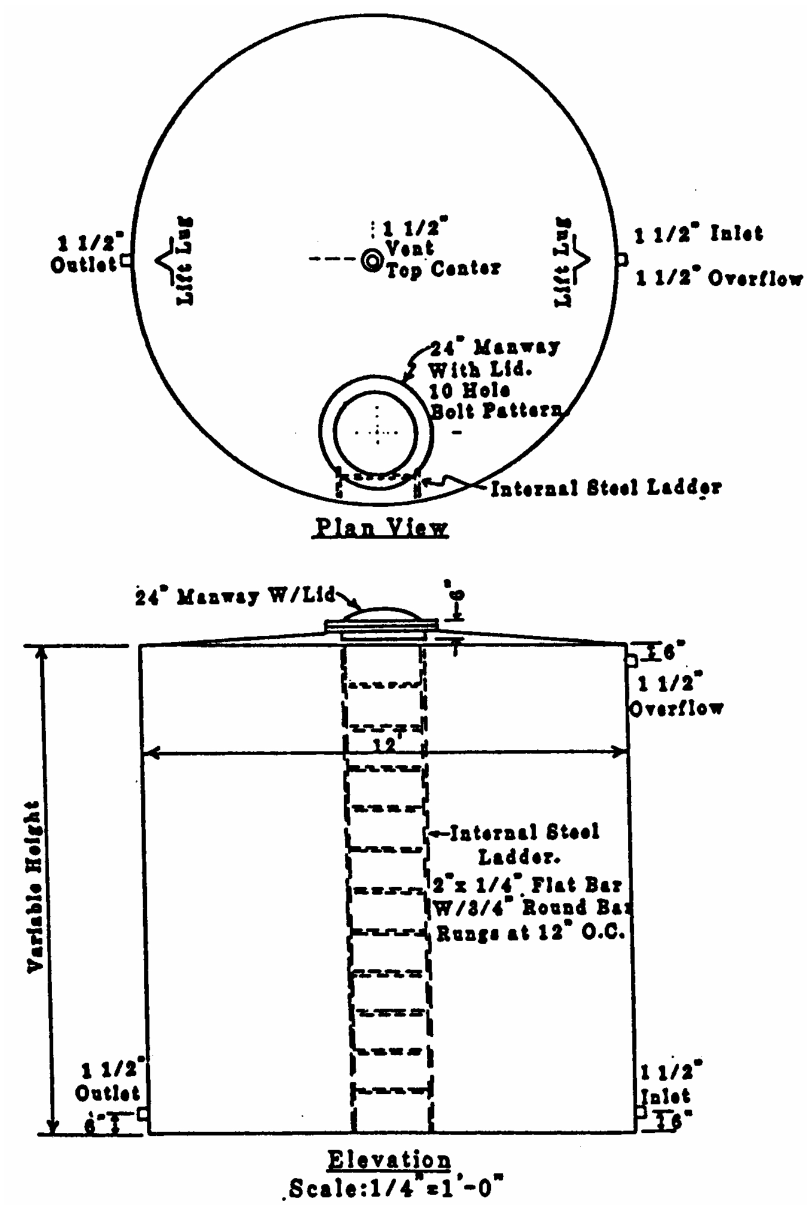


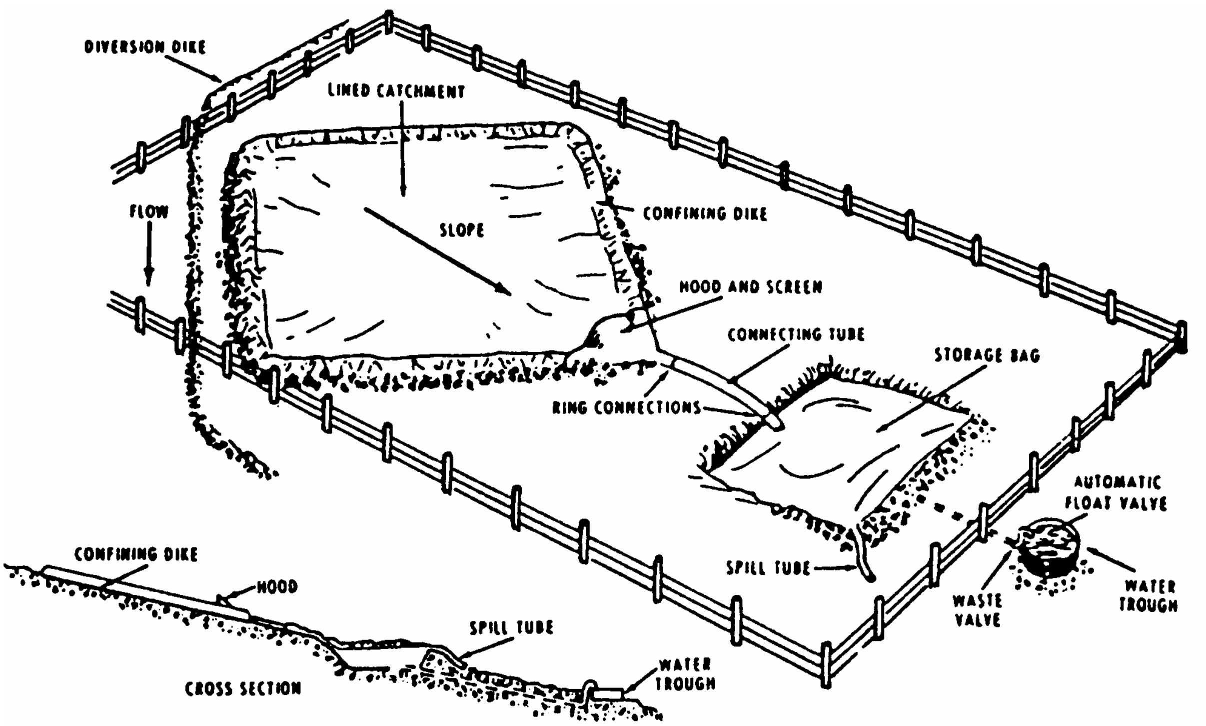
Figure 8.44
FIBERGLASS STORAGE TANK



WALL THICKNESS TABLE

Distance From Top In Feet	Tank Diameter In Feet														
	2	2½	3	3½	4	4½	5	5½	6	7	8	9	10	11	12
	Wall Thickness in Inches														
2	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16
4	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16
6	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16	1/4	1/4	1/4
8	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16	1/4	1/4	1/4	1/4	1/4	1/4
10	3/16	3/16	3/16	3/16	3/16	3/16	3/16	1/4	1/4	1/4	1/4	1/4	5/16	5/16	5/16
12	3/16	3/16	3/16	3/16	3/16	3/16	1/4	1/4	1/4	1/4	1/4	5/16	5/16	5/16	3/8

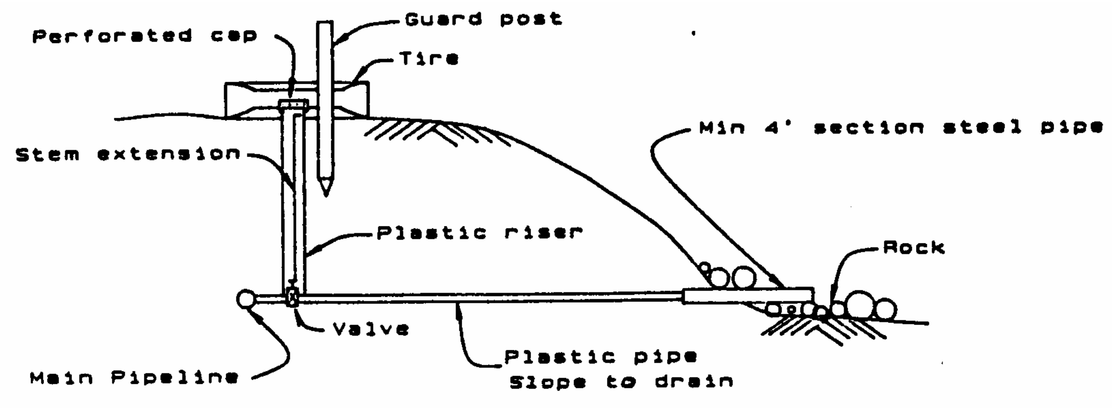
Figure 8.45
WATER HARVESTING SYSTEM USING RUBBERIZED FABRIC STORAGE BAG



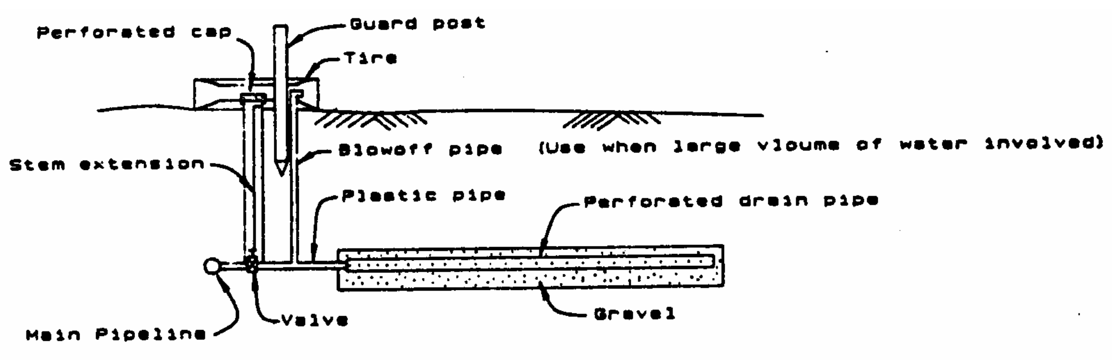
8.9 PIPELINE DRAINS

Pipeline drains are required at all low spots in pipelines that are subject to freezing. They are also sometimes installed in frost free pipelines where it is desired to have the ability to drain a pipeline for maintenance. When it is not possible to drain a pipeline by gravity, a blind drain or pumpout drain is required. Figure 8.46 illustrates typical drain details.

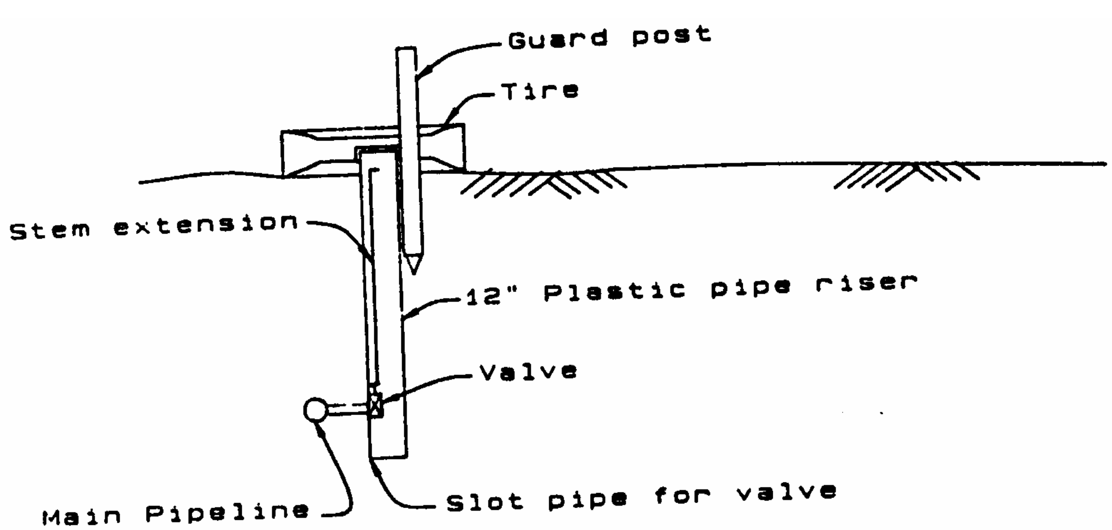
Figure 8.46
PIPELINE DRAINS



GRAVITY DRAIN



BLIND DRAIN



PUMPOUT

Chapter 9

Hydraulic Design Procedures

CHAPTER 9 HYDRAULIC DESIGN PROCEDURES

TABLE OF CONTENTS

FIGURES

Chapter 9

Hydraulic Design Procedures

9.1 GENERAL

There are three major categories of hydraulic designs associated with stockwater pipelines. They are:

1. Gravity flow pipeline
2. Pumped pipeline
3. Lateral pipeline pressurized from a mainline.

Sometimes the system types are combined on one job. For instance, water may be pumped to a large storage tank on a hill and then a gravity pipeline will exit from the storage tank. The design approach in such a case is to perform the hydraulic calculations separately for each calculation category.

Example No. 1 illustrates hydraulic design for a very simple, low head gravity pipeline leading from a spring. Example No. 2 illustrates an automatic pumped pressure system which incorporates one lateral. Example number 3 represents a manually operated pumped system that incorporates a gravity segment and a lateral. Between these examples, most computational procedures you will encounter are illustrated.

Appendix A contains master copies of the worksheets used in these examples. These worksheets are for your convenience. Use them only if they will aid in the computations.

Computer programs can be used to aid in computations. Appendix B illustrates the use of currently available programs.

9.2 EXAMPLE 1, LOW HEAD GRAVITY SYSTEM

Figure 9.1 illustrates the profile for a very low head system. The pipeline originates at a spring box and terminates at a stock tank. An overflow is built into the stock tank. There is not float valve at the tank and the entire spring flow goes to the tank. A gate-type valve could be installed at the spring box to throttle the flow or shut it off when water is not wanted. A valve at the tank allows drainage of the pipeline during non-use. The pipeline is buried below the frost line.

There is little hydraulic design involved in this installation. Size of pipe is the minimum dictated by the standards. Montana NRCS standards state the following:

Pipe size shall be no smaller than:

- 1-1/4 inch nominal diameter for grades over 1.0 percent
- 1-1/2 inch nominal diameter for grades from 0.5 to 1.0
- 2 inch nominal diameter for grades from 0.2 to 0.5 percent

Figure 9.2 is the calculations that were made. The slope of each segment is calculated and pipe size is based on the slope. Pressure rated PVC pipe was selected due to its availability and low cost. The pressure rating of the pipe is 160 psi, which is normally the lowest pressure rated PVC pipe commonly available in the desired sizes. Since the available head is so low, it is obvious that pressure rating of the pipe will not be exceeded. In this case it would not be necessary to calculate pressures. We did though, and the maximum static pressure when the gate valve is shut off is 21.6 psi.

It is important in this installation to install the vent and air valve at the locations shown. If they were not installed, this system would almost certainly air lock.

Figure 9.1
LOW HEAD GRAVITY SYSTEM

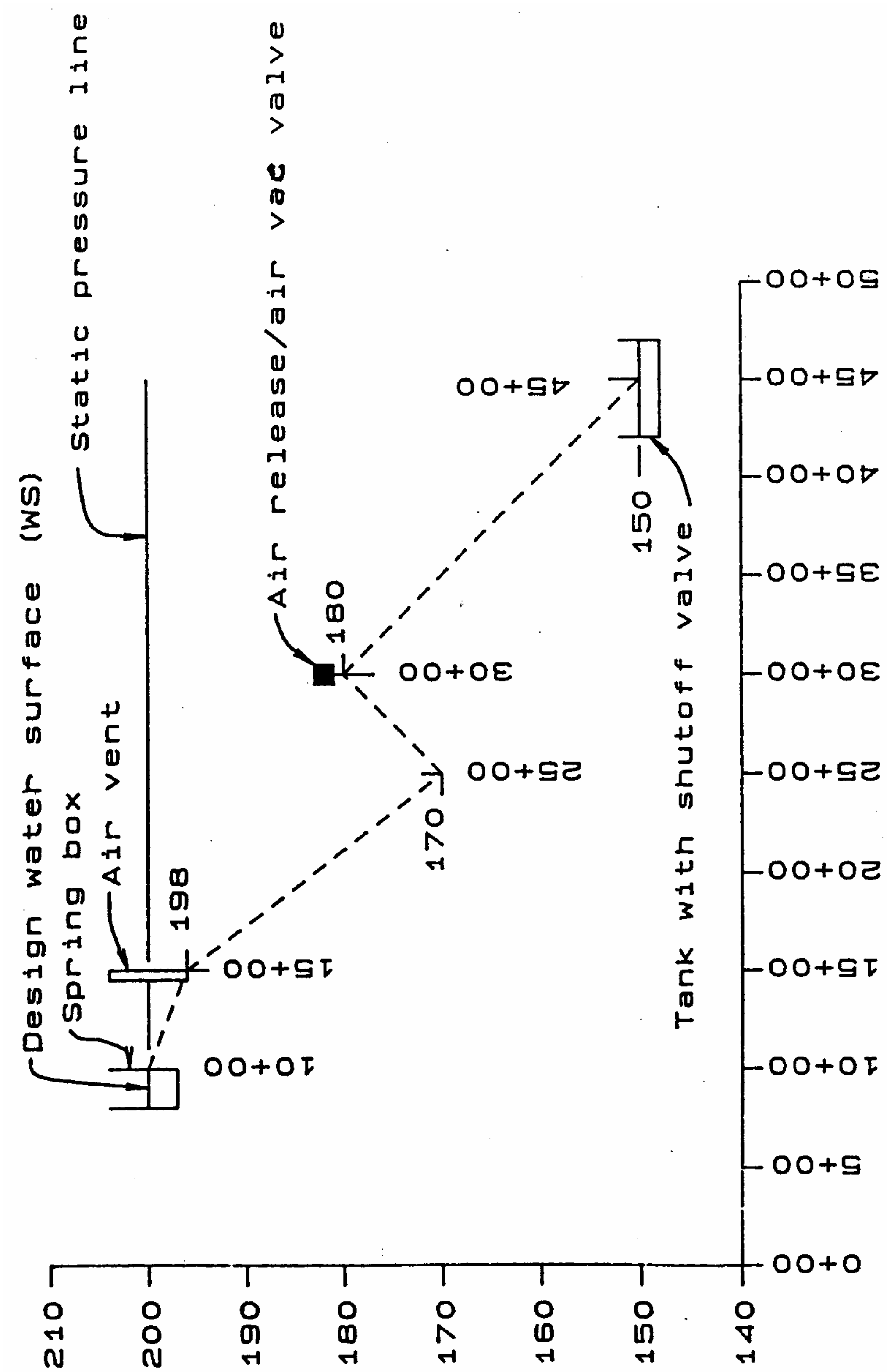


Figure 9.2
LOW HEAD GRAVITY SYSTEM COMPUTATIONS

U.S. Department of Agriculture
Soil Conservation Service

MT-ENG-21C
1/1/91

GRAVITY STOCKWATER PIPELINE
HYDRAULIC COMPUTATION WORKSHEET

Land user: Example NO. 1
Job description: South pasture Pipeline
Farm No. 532 Tract No. 3 Field No. 2 County Gallatin
Designer V. Tech Date 11/8/90 Checked by JCD Date 11/10/90

Water surface elevation (WS) 200
Critical point along pipeline (CP): Station — Elevation ______
Clearance Head (CH) at critical point: ______ ft x .433 = ______ psi
Minimum required HGL at CP = CP elevation + CH ft = ______ + ______ = ______
Estimated pipeline entrance losses (EL) = ______ ft
Starting HGL elevation = WS − EL = ______ − ______ = ______

Free flow -- Hydraulic calc's not required.

(1) Station	(2) Reach Length (ft)	(3) Pipe Elevation	(4) Design Flow Rate (gpm)	(5) Nominal Pipe Diameter (in)	(6) Pipe Type	(7) Pipe Pressure Rating (psi)	(8) Friction Factor H_f/100ft (ft/100)	(9) Reach Total H_f (ft) (2)x(8)	(10) HGL Elev (from start HGL)	(11) Max Pressure on Pipe (psi) WS - (3) x .433	Comments (slope%)
10+00		200									at source
15+00	500	198		2	PVC SDR 26						0.4%
25+00	1000	170		1¼							2.8%
30+00	500	180		1¼							-2.0%
45+00	1500	150		1¼						21.6	2.0%

(Column 4, written vertically: Pipe size based on minimum standards)

21.6 psi < 160 psi ∴ OK

9.3 EXAMPLE 2, PUMPED AUTOMATIC PRESSURE PIPELINE DESIGN

Example number 2 covers the hydraulic elements that must be determined in a typical automatic pumped system as illustrated in Figure 9.3. Figure 9.4 shows the automatic pump pipeline calculations. Figure 9.5 illustrates a lateral pipeline profile. Figure 9.6 is the hydraulic computations for lateral "A".

9.3.1 Pumped Automatic Pressure System Computations

After plotting the profile, determine where the most critical point (CP) in the pipeline is located. This is usually, but not always, the highest point in any part of the line. The criteria for selecting the critical point is to find where the hydraulic grade line (HGL) will pass closest to the profile. This is sometimes a trial and error determination. In other words, select a critical point and then compute the hydraulic grade line. Plot the HGL on the profile and see how close it passes to all high points.

We want the HGL to pass within a certain clearance head (CH) above the ground line. The CH value will depend on the type of engineering survey made to determine the ground profile and the type of air valves installed in the pipe. See Chapters 4 and 6 for more explanation. In this case we selected a CH value of 25 feet.

A 30 psi pressure range between pump cut-in and cut-out is selected. In a flowing pipeline, when the pressure is near cut-in, the flow will be less than when the pressure is near cut-out. We calculate the hydraulic grade line at the average of the cut-in/cut-out pressures so the average flow rate will be equal or greater than the design flow rate.

It is important that the cut-in pressure be high enough that flow will clear the high point even when the pressure at t he pump is at or near cut-in. We also need to make sure that the design flow rate will clear the high point. For this reason we must check both the clearance of cut-in pressure head and of the hydraulic grade line.

Minimum cut-in pressure head is equal to the critical point elevation plus clearance head. The hydraulic grade line is computed starting at the clearance head point and then working backward to the pump. Pipe friction loss data is obtained from Tables 5.2 through 5.15 in Chapter 5.

In some cases it may be desirable to provide minimum acceptable flow rate at pump cut-in pressure. In this situation pump cut-in pressure would have to be raised to a level equal to critical point elevation plus clearance head plus friction loss at minimum acceptable flow rate. Keep in mind this may increase pump and pipe pressure requirements and thus would increase installation and operating costs.

At the pump, an additional loss is added for the losses in the plumbing at the pump. These losses can be estimated using Figure 5.1 in Chapter 5, or by making special detailed computations. In most cases estimates based on Figure 5.1 will be adequate.

If the calculated hydraulic grade line at the pump is lower than the cut-in head plus 1/2 of the pressure range head, then the HGL is raised until the start is halfway between cut-in and cut-out pressure.

The greatest pressure at any point in the pipeline is when the flow stops in the pipeline and the pump runs the pressure up to cut-out pressure and stops. Static pressure everywhere in the pipeline is then computed from cut-out OFF pressure.

Compute maximum pressure at all stations. If pressure at any point in the line is greater than the rating of the pipe, use a higher pressure rated pipe in the appropriate location and redo the HGL computations.

The total dynamic head (TDH) at the pump is computed by taking the difference in HGL at the pump and the drawdown water surface in the well or other water source. The drawdown water surface is the lowest water surface during pumping.

Figure 9.4 illustrates the example computations.

9.3.2 Lateral Computations

The OFF pressure and HGL at the mainline takeoff point are used in computations at the start of the lateral. Figure 9.5 illustrates a profile and Figure 9.6 is computations for this type of installation.

It may not be necessary to actually compute the HGL on a lateral of this nature. It is sometimes obvious that the HGL will clear the critical head point and that pipe pressure rating will not be exceeded.

Figure 9.3
PUMPED AUTOMATIC PRESSURE SYSTEM

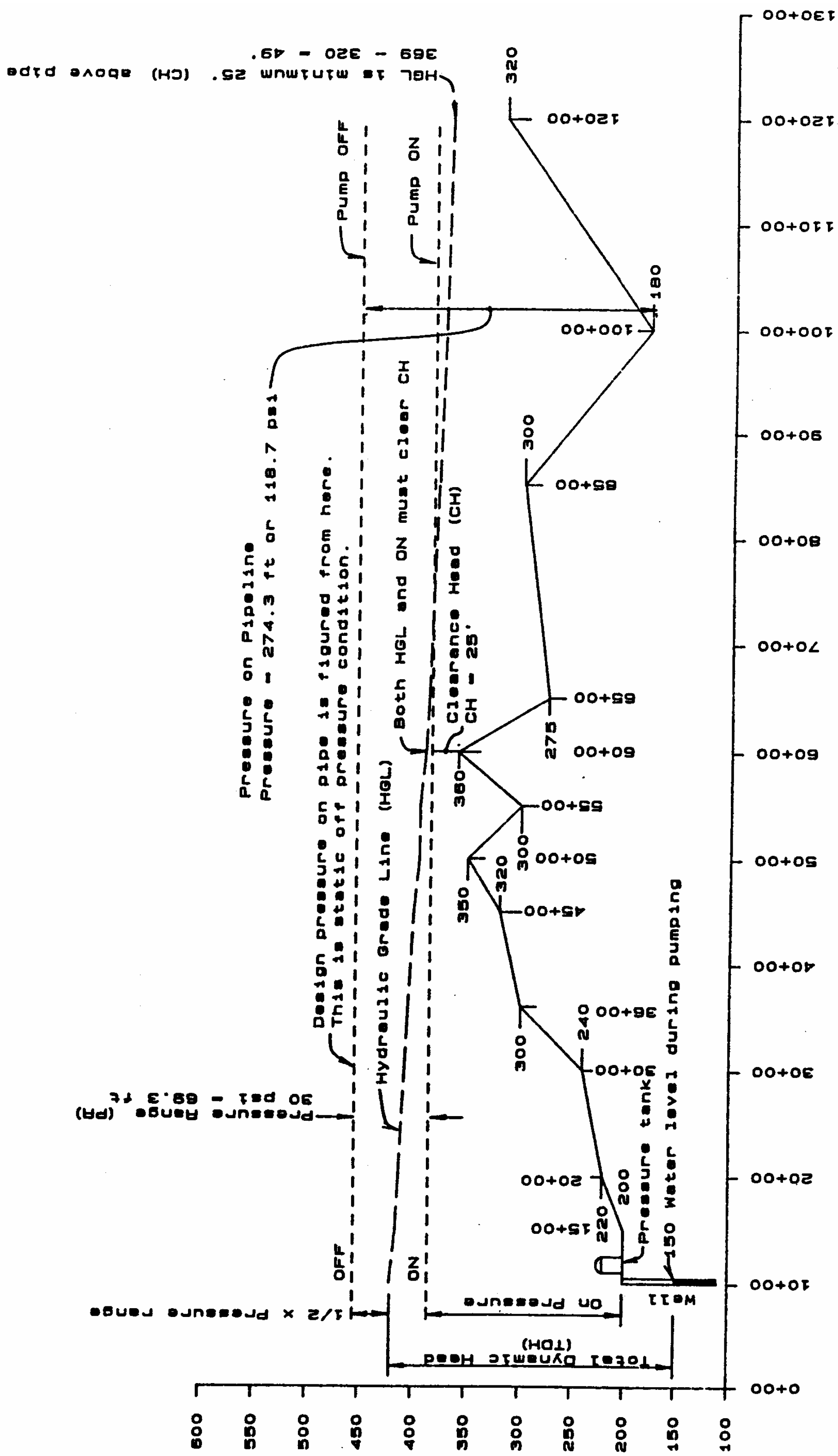


Figure 9.4
AUTOMATIC PRESSURE COMPUTATIONS

U.S. Department of Agriculture
Soil Conservation Service

MT-ENG-21A
1/1/91

AUTOMATIC PRESSURE STOCKWATER PIPELINE HYDRAULIC COMPUTATION WORKSHEET

Land user Example No. 2

Job description West pasture

Farm No. 532 Tract No. 3 Field No. 3 County Gallatin

Designer J. Tech Date 11/8/90 Checked by JCW Date 11/10/90

Water surface elevation during pumping (WS) 150

Critical point along profile (CP): Station 60+00 Elevation 360

Clearance Head (CH) at critical point: 25 ft x .433 = 10.8 psi

Cut in/Cut out pressure range (PR): 30 psi x 2.31 = 69.3 ft

Losses in plumbing at pump (PL): 4 ft

Minimum ON elevation = CP elevation + CH ft = 360 + 25 = 385

ON elev based on HGL = HGL_{pump} + PL − (PR ft/2) = 413.6 + 4 − (69.3 /2) = 382.9

ON elevation used (greatest elevation of above alternatives): 385

OFF elevation = ON elevation + PR ft = 385 + 693 = 454.3

Total Dynamic Head (TDH) = OFF elev − (PR ft/2) − WS = 454.3 − (69.3 /2) − 150 = 269.6 ft

Pump HP = ____ HP (Select from pump curves)

(1) Station	(2) Reach Length (ft)	(3) Pipe Elevation	(4) Design Flow Rate (gpm)	(5) Nominal Pipe Diameter (in)	(6) Pipe Type	(7) Pipe Pressure Rating (psi)	(8) Friction Factor H_f/100ft (ft/100)	(9) Reach Total H_f (ft) (2)x(8)	(10) HGL Elev (from CP elev)	(11) Max Pressure on Pipe (psi) (OFF-(3)) x .433	Comments
10+00		200							413.6	110.1	at pump
15+00	500	200	8	1.25	PVC SDR 26	160	.572	2.86	410.7	110.1	
20+00	500	220	8					2.86	407.9	101.5	
30+00	1000	240	9					5.72	402.2	92.8	
36+00	600	300	8					3.43	398.7	66.8	
45+00	900	320	8					5.15	393.6	58.2	
50+00	500	350	8					2.86	390.7	45.2	
55+00	500	300	8					2.86	387.9	66.8	
60+00	500	360	8					2.86	385.0	40.8	Critical point
65+00	500	275	8					2.86	382.1	77.6	
85+00	2000	300	6				.336	6.72	376.4	66.8	
100+00	1500	180	6					5.04	370.4	118.9	
120+00	2000	320	6					6.72	363.7	58.2	

Figure 9.5
LATERAL PROFILE

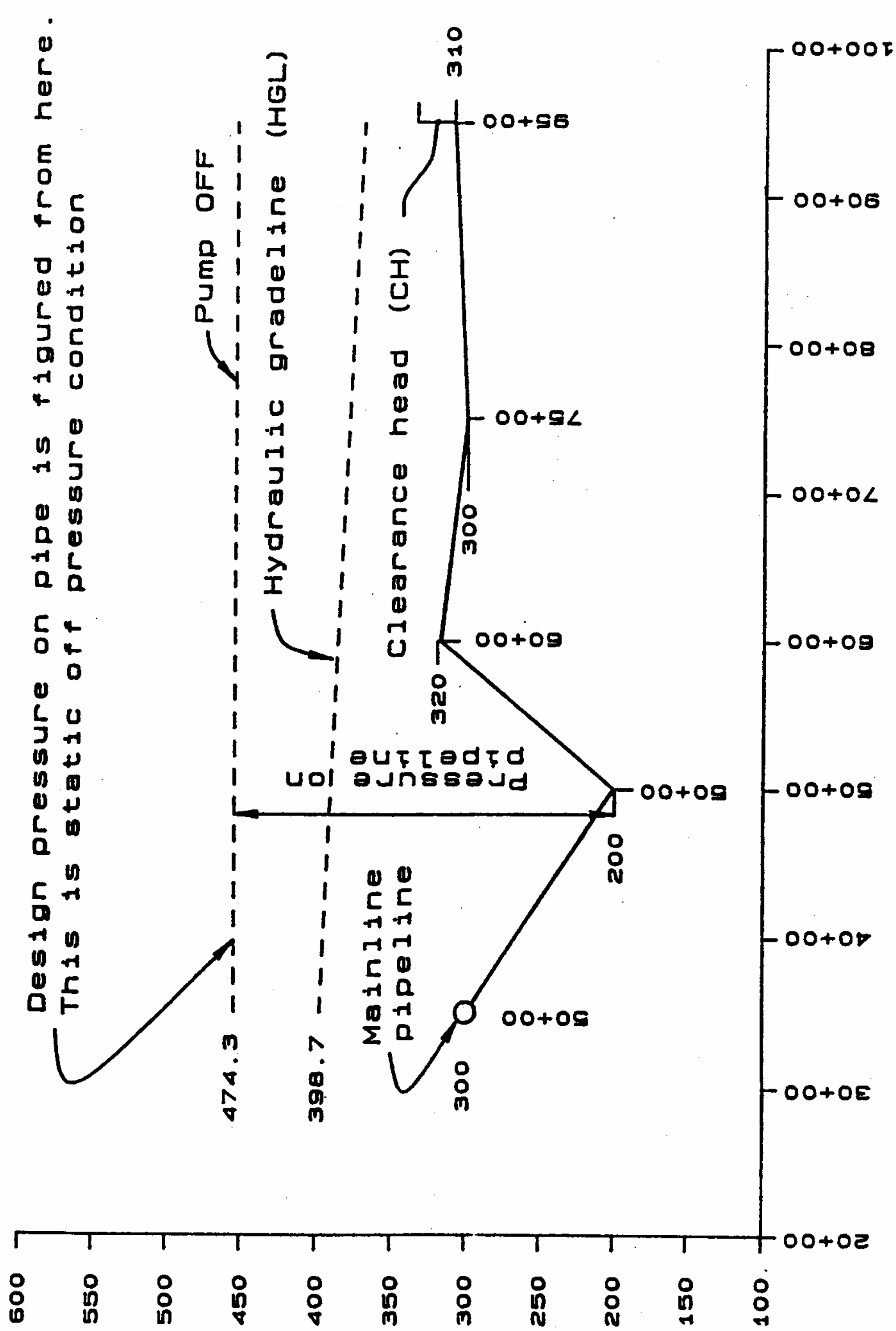


Figure 9.6
LATERAL COMPUTATIONS

U.S. Department of Agriculture
Soil Conservation Service

MT-ENG-21D
1/1/91

LATERAL STOCKWATER PIPELINE HYDRAULIC COMPUTATION WORKSHEET

Land user: Example No. 2 (Lateral A)
Job description: West pasture
Farm No. 532 Tract No. 3 Field No. 3 County Gallatin
Designer J. Tech Date 11/8/90 Checked by JCD Date 11/10/90

HGL at mainline 398.7
Pump OFF elevation (Automatic pressure system only) 474.3
Flow in lateral - OFF elevation (manual, timed or gravity) —
Critical point along lateral (CP): Station 95+00 Elevation 310.0
Clearance Head (CH) at critical point: 25 ft x .433 = 10.8 psi
Minimum required HGL at CP = CP elevation + CH ft = 310 + 25 = 335

(1) Station	(2) Reach Length (ft)	(3) Pipe Elevation	(4) Design Flow Rate (gpm)	(5) Nominal Pipe Diameter (in)	(6) Pipe Type	(7) Pipe Pressure Rating (psi)	(8) Friction Factor H_f/100ft (ft/100)	(9) Reach Total H_f (ft) (2)x(8)	(10) HGL Elev (from main)	(11) Max Pressure on Pipe (psi) OFF - (3) x .433	Comments
36+00		300							398.7	75.5	at main
	1400		8	1.25	PVC SDR 26	160	.572	8.01			
50+00		200							390.7	118.8	
	1000		8	↓	↓	↓	.572	5.72			
60+00		320							385.0	66.8	
	1500		6	↓	↓	↓	.336	5.04			
75+00		300							379.9	75.5	
	2000		6	↓	↓	↓	.336	6.72			
95+00		310								71.1	373.2 > 335 ∴ OK

9.4 EXAMPLE 3, TIMER OR MANUALLY OPERATED PRESSURE SYSTEM

Example number 3 covers hydraulic elements that must be determined in a typical pumped pressurized, manually or timer operated system. In the example system, a storage tank is installed at the system high point. The pipe beyond the storage tank exits from the tank as a gravity pipeline. The plumbing at the storage tank is set up so water will flow back into the supply line when the pump is off.

Figure 9.7 illustrates the pipeline profile. Figure 9.8 illustrates details of the storage tank plumbing. Figure 9.9 shows pump calculations. Figure 9.10 shows computations for the gravity flow portion of the pipeline. Figure 9.11 is hydraulic computations for lateral "A".

9.4.1 Timer or Manually Operated Pumped System Computations

After plotting the profile, determine where the highest point in the pipeline is located. This is where the outlet storage tank will be located. The outlet storage tank must have an overflow capable of handling the design flow over extended periods of time. Plot the HGL on the profile and see how close it passes to all high points.

We want the HGL to pass within a certain clearance head (CH) above the ground line. The CH value will depend on the type of engineering survey used to determine the ground profile and the type of air valves installed in the pipe. See Chapters 4 and 6 for more explanation. In this case we selected a CH value of 25 feet.

Hydraulic grade line is computed starting at the clearance head point and working backward to the pump. Pipe friction loss data is obtained from Tables 5.2 through 5.15 in Chapter 5.

At the pump, an additional loss is added for losses in the plumbing at the pump. These losses can be estimated using Figure 5.1 in Chapter 5 or by making special detailed computations. In most cases estimates based on Figure 5.1 will be adequate.

The greatest pressure on any point in the pipeline is the head measured between the HGL and the pipe. Compute maximum pressure at all stations. If pressure at any point in the line is greater than the pressure rating of the pipe, use a higher pressure rated pipe in the appropriate location and redo the HGL computations.

Total dynamic head (TDH) at the pump is computed by taking the difference between HGL at the pump and the drawdown water surface in the well.

Figure 9.8 illustrates storage tank plumbing and Figure 9.9 shows an example of pumped system computations.

Figure 9.7
TIMER OR MANUALLY OPERATED SYSTEM

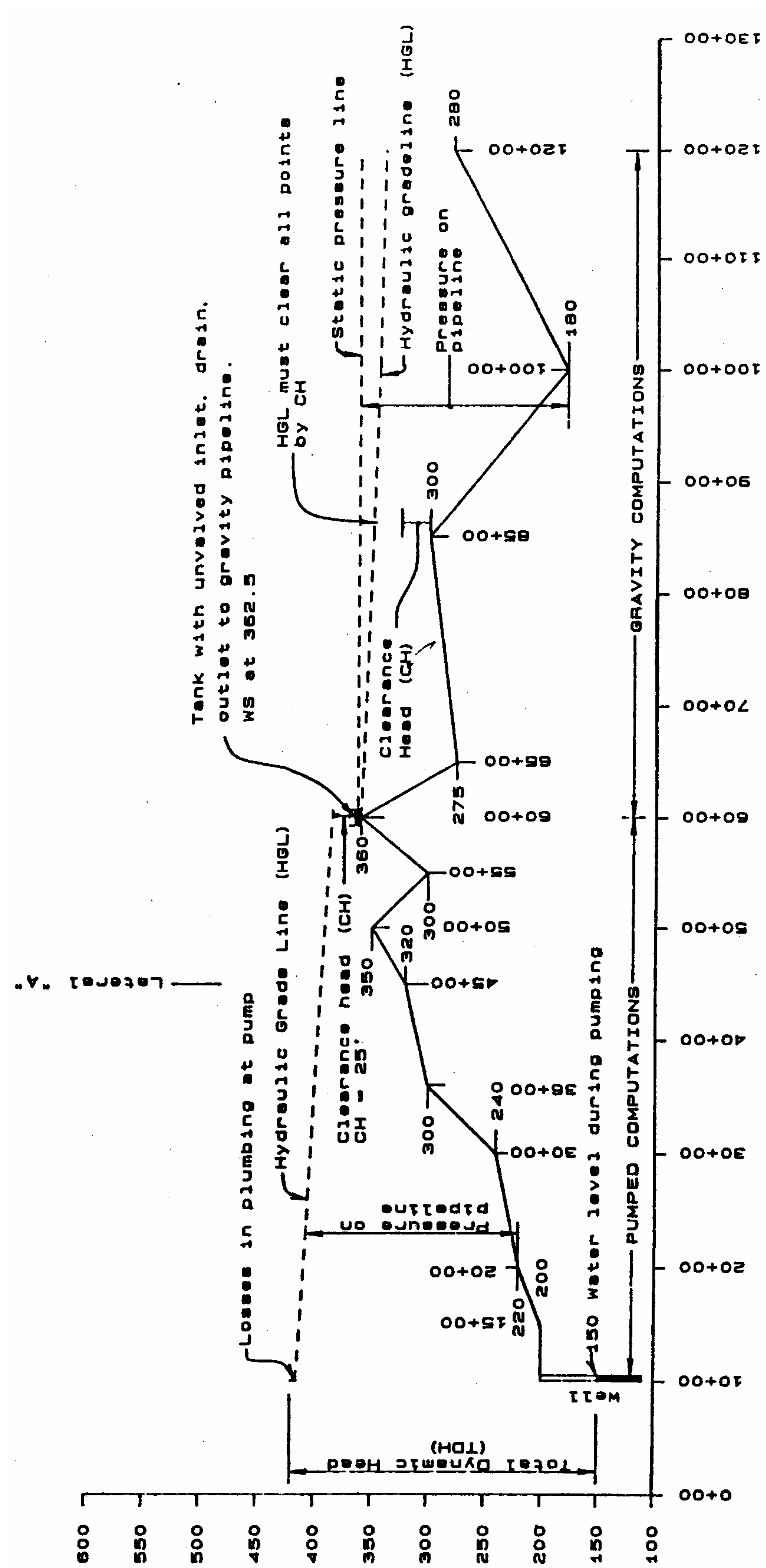


Figure 9.8
STORAGE TANK PLUMBING

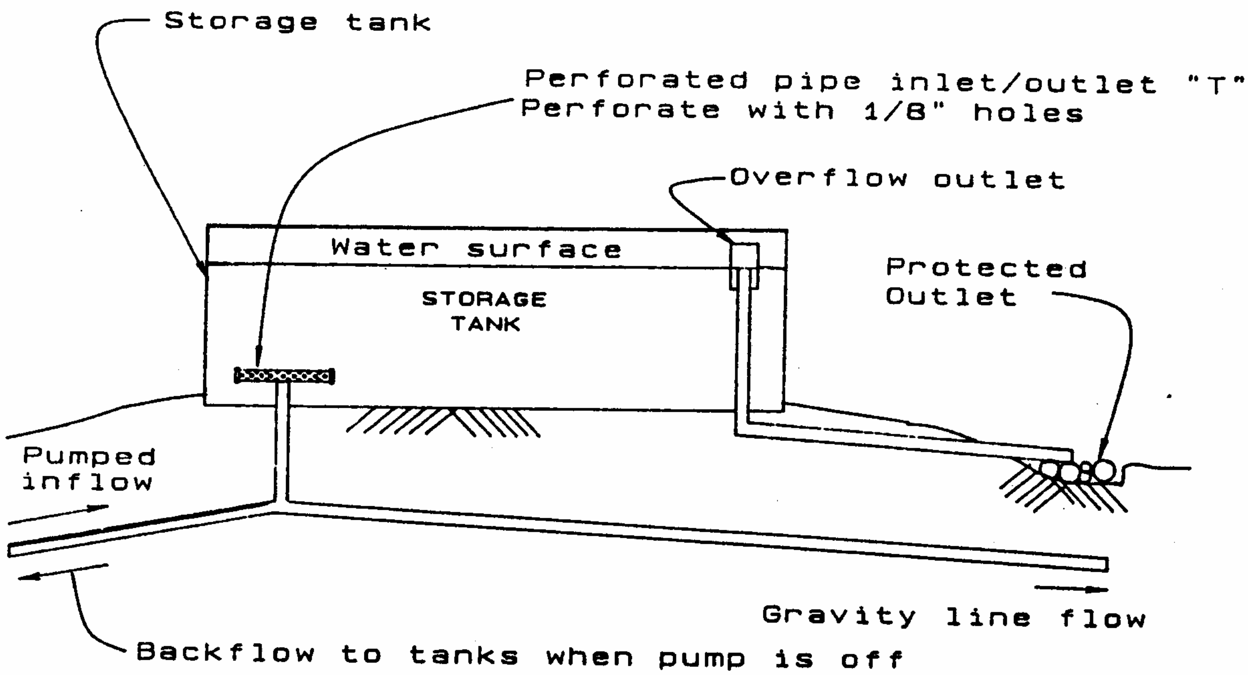


Figure 9.9
TIMER OR MANUALLY OPERATED PUMP SYSTEM COMPUTATIONS

U.S Department of Agriculture
Soil Conservation Service

MT-ENG-21B
1/1/92

MANUAL OR TIMER OPERATED STOCKWATER PIPELINE
PUMPED SEGMENT HYDRAULIC COMPUTATION WORKSHEET Sheet 1 of 3

Land user Example No. 3
Job description West pasture
Farm No. 532 Tract No. 3 Field No. 3 County Gallatin
Designer J. Tech Date 11/8/90 Checked by JCD Date 11/10/90

Water surface elevation during pumping (WS) 150
Pumped segment end station critical point (CP): Station 60+00 Elevation 360
Clearance Head (CH) at critical point: 25 ft x .433 = 10.8 psi
Losses in plumbing at pump (PL): 4 ft
HGL at CP = CP elevation + CH ft = 360 + 25 = 385
HGL_{pump} = HGL from profile + PL = 413.6 + 4 = 417.6
Total Dynamic Head (TDH) = HGL_{pump} - WS = 417.6 - 150 = 267.6 ft
Pump HP ________ HP (Select from pump curves)

(1) Station	(2) Reach Length (ft)	(3) Pipe Elevation	(4) Design Flow Rate (gpm)	(5) Nominal Pipe Diameter (in)	(6) Pipe Type	(7) Pipe Pressure Rating (psi)	(8) Friction Factor H_f/100ft (ft/100)	(9) Reach Total H_f (ft) (2)x(8)	(10) HGL Elev (from CP elev)	(11) Max Pressure on Pipe (psi) ((10)-(3)) x .433	Comments
10+00		200	8	1.25	PVC SDR 26	160	.572		413.6	92.5	at pump
15+00	500	200	8					2.86	410.7	91.2	
20+00	500	220	8					2.86	407.9	81.4	
30+00	1000	240	8					5.72	402.2	70.2	
36+00	600	300	8					3.43	398.7	42.7	
45+00	900	320	8					5.15	393.6	31.9	
50+00	500	350	8					2.86	390.7	17.6	
55+00	500	300	8					2.86	387.9	38.1	
60+00	500	360	8					2.86	385.0	10.8	Critical point
(1)											

(1) See Sheet 2 for gravity computations continuation.

9.4.2 Gravity Line Computations

As in previous examples, a critical point is selected. The computed hydraulic grade line must clear the CP plus CH.

Water surface (WS) in the storage tank is used as a starting point for the hydraulic computations. Friction loss is subtracted from WS to compute HGL. Figure 9.10 is computations that were performed for this example.

Figure 9.10
GRAVITY FLOW COMPUTATIONS

U.S. Department of Agriculture
Soil Conservation Service

MT-ENG-21C
1/1/91

GRAVITY STOCKWATER PIPELINE
HYDRAULIC COMPUTATION WORKSHEET Sheet 2 of 3

Land user: Example No. 3 (Gravity Extension)
Job description: West pasture
Farm No.: 532 Tract No.: 3 Field No.: 3 County: Gallatin
Designer: J. Tech Date: 11/8/90 Checked by: JCO Date: 11/10/90

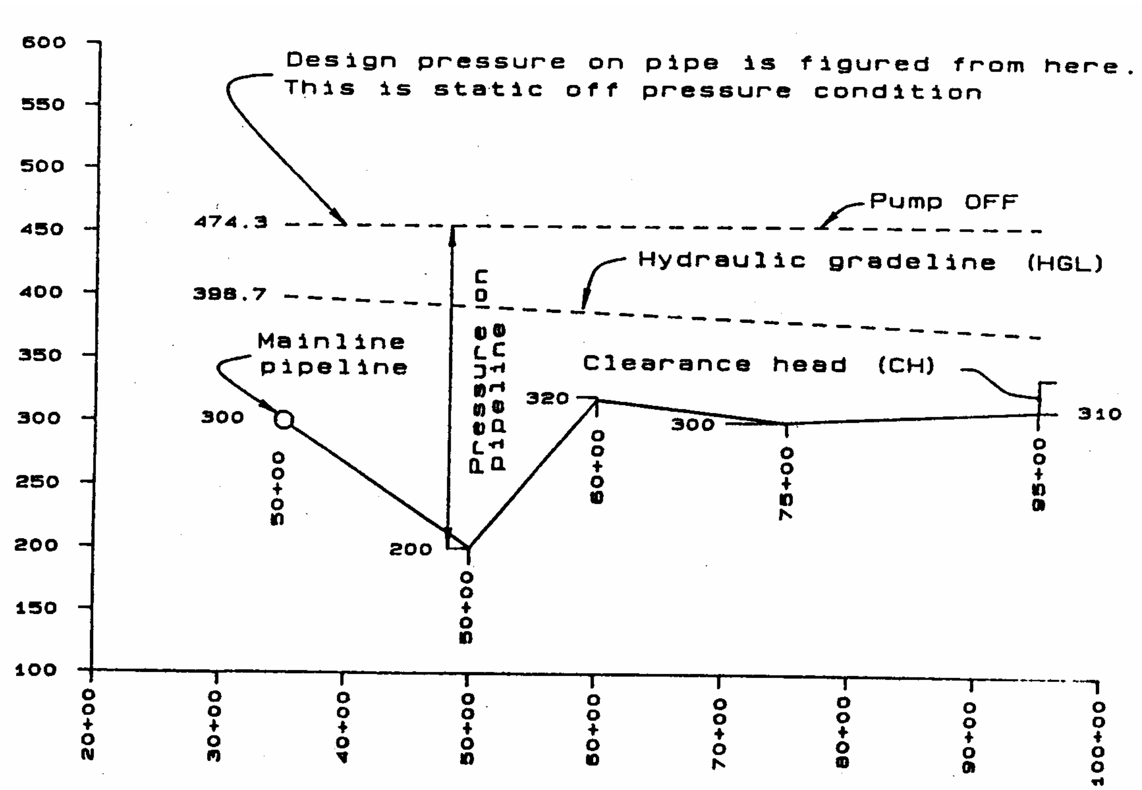
Water surface elevation (WS): 362.5 (Intake at sta 60+00)
Critical point along pipeline (CP): Station 85+00 Elevation 300
Clearance Head (CH) at critical point: 25 ft x .433 = 10.8 psi
Minimum required HGL at CP = CP elevation + CH ft = 300 + 25 = 325
Estimated pipeline entrance losses (EL) = ______ ft
Starting HGL elevation = WS − EL = 362.5 − 1.0 = 361.5

(1) Station	(2) Reach Length (ft)	(3) Pipe Elevation	(4) Design Flow Rate (gpm)	(5) Nominal Pipe Diameter (in)	(6) Pipe Type	(7) Pipe Pressure Rating (psi)	(8) Friction Factor H_f/100ft (ft/100)	(9) Reach Total H_f (ft) (2)x(8)	(10) HGL Elev (from start HGL)	(11) Max Pressure on Pipe (psi) WS -(3) x .433	Comments
60+00		360							361.5	1.1	
	500		8	1.25	PVC SDR 26	160	.572	2.86			at source
65+00		275							358.6	37.9	
	2000		6	↓	↓	↓	.336	6.72			
85+00		300							351.9	27.1	critical point
	1500		6				↓	5.04			
100+00		180							346.9	79.0	
	2000		6					6.72			
120+00		280							340.2	35.7	

9.4.3 Lateral Computations

Hydraulic grade line (HGL) at the mainline takeoff point is used in computations at the start of the lateral. The highest pressure condition at any point in the pipeline is when the flow in the lateral stops. In that case pressure is measured from HGL elevation at the connection with the mainline pipe. Figure 9.11 shows a gravity lateral profile and Figure 9.12 is computations for this type of installation.

Figure 9.11
GRAVITY FLOW LATERAL PROFILE



It sometimes may not be necessary to actually compute HGL on a lateral of this nature. It will often be obvious that HGL will clear the critical head point.

Figure 9.12
GRAVITY FLOW LATERAL COMPUTATIONS

U.S. Department of Agriculture
Soil Conservation Service

MT-ENG-21D
1/1/92

LATERAL STOCKWATER PIPELINE
HYDRAULIC COMPUTATION WORKSHEET

Land user Example No. 2 (Lateral A)
Job description West pasture
Farm No. 532 Tract No. 3 Field No. 3 County Gallatin
Designer J. Tech Date 11/8/90 Checked by JCD Date 11/10/90

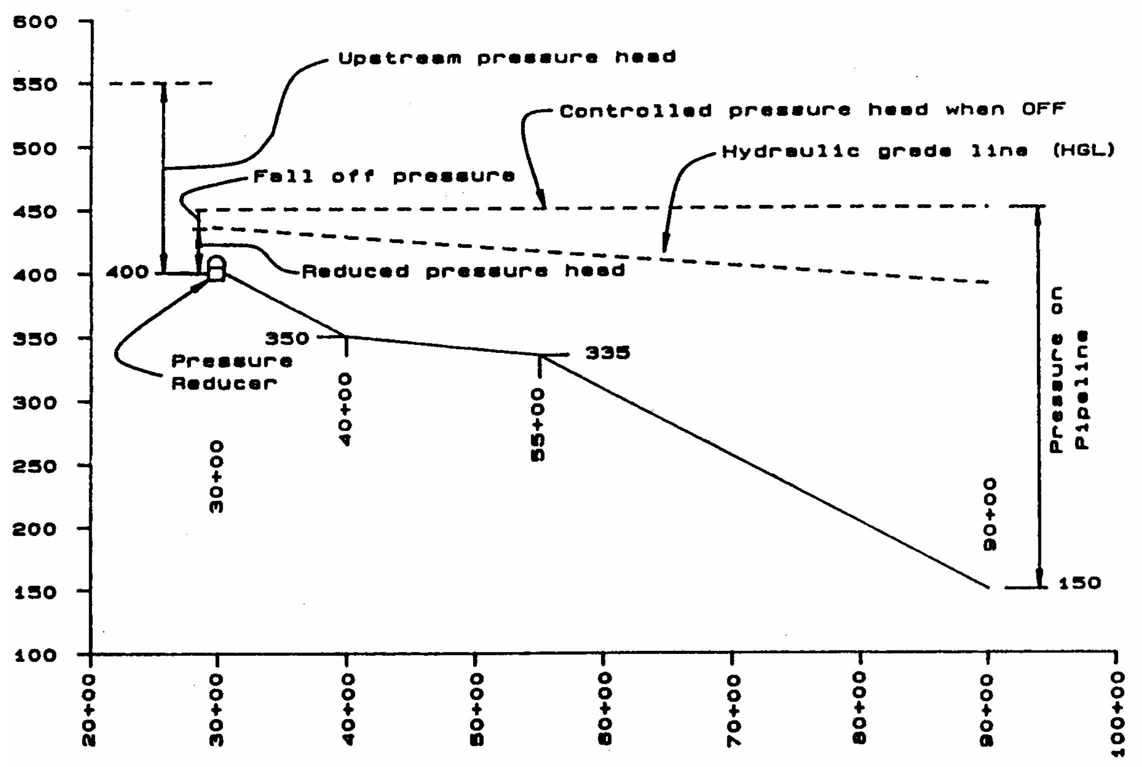
HGL at mainline 398.7
Pump OFF elevation (Automatic pressure system only) 474.3
Flow in lateral - OFF elevation (manual, timed or gravity) —
Critical point along lateral (CP): Station 95+00 Elevation 310.0
Clearance Head (CH) at critical point: 25 ft x .433 = 10.8 psi
Minimum required HGL at CP = CP elevation + CH ft = 310 + 25 = 335

(1) Station	(2) Reach Length (ft)	(3) Pipe Elevation	(4) Design Flow Rate (gpm)	(5) Nominal Pipe Diameter (in)	(6) Pipe Type	(7) Pipe Pressure Rating (psi)	(8) Friction Factor H_f/100ft (ft/100)	(9) Reach Total H_f (ft) (2)x(8)	(10) HGL Elev (from main)	(11) Max Pressure on Pipe (psi) OFF - (3) x .433	Comments
36+00		300							398.7	75.5	at main
	1400		8	1.25	PVC SDR 26	160	.572	8.01			
50+00		200							390.7	118.8	
	1000		8	↓	↓	↓	.572	5.72			
60+00		320							386.0	66.8	
	1500		6				.336	5.04			
75+00		300							379.9	75.5	
	2000		6				.336	6.72			
95+00		310								71.1	373.2 > 335 ∴ OK

9.5 EXAMPLE 4, PRESSURE REDUCER

Figure 9.13 depicts a typical pipeline system incorporating a pressure reducing valve. See Chapter 6 for examples of pressure reducing valve installations.

Figure 9.13
PRESSURE REDUCER VALVE INSTALLATION



Pressure reducing valve controlled pipeline computations are handled as if the pipeline beyond the pressure reducer were a lateral. The hydraulic grade line must clear any critical point by the CH value.

There is a "Fall-Off" loss that must be added to the losses at the pressure reducer when computing the hydraulic gradeline. Pressure at the pressure reducer is set at the no flow condition to the desired pressure. When flow takes place, there is a fall-off loss in the valve. This is subtracted from the desired OFF pressure head elevation when computing the hydraulic gradeline.

Pressure on the pipeline is calculated from the pressure head OFF elevation. The hydraulic gradeline is calculated starting at the pressure reducer at the same elevation.

Figure 9.14 is the hydraulic computations for this type of installation.

Figure 9.14

PRESSURE REDUCER VALVE SYSTEM COMPUTATIONS

U.S. Department of Agriculture
Soil Conservation Service

MT-ENG-21D
1/1/92

LATERAL STOCKWATER PIPELINE
HYDRAULIC COMPUTATION WORKSHEET

Land user: Example No. 4 (Pressure Reducer)

Job description: North pasture

Farm No. 532 Tract No. 3 Field No. 4 County Gallatin

Designer J. Tech Date 11/8/90 Checked by JCD Date 11/10/90

~~ON~~ OFF at mainline 450

Pump OFF elevation (Automatic pressure system only) —

Flow in lateral - OFF elevation (manual, timed or gravity) —

Critical point along lateral (CP): Station — Elevation —

Clearance Head (CH) at critical point: — ft x .433 = — psi

Minimum required HGL at CP = CP elevation + CH ft = — + — = —

From manufaturer – Fall off = 4.0 psi at reducing valve

4.0 psi x 2.31 = 9.2 ft. 450 - 9.2 = 440.8

(1) Station	(2) Reach Length (ft)	(3) Pipe Elevation	(4) Design Flow Rate (gpm)	(5) Nominal Pipe Diameter (in)	(6) Pipe Type	(7) Pipe Pressure Rating (psi)	(8) Friction Factor H_f/100ft (ft/100)	(9) Reach Total H_f (ft) (2)x(8)	(10) HGL Elev (from main)	(11) Max Pressure on Pipe (psi) OFF - (3) x .433	Comments
30+00		400							440.8	21.7	at main
40+00	1000	350	10	1 1/4	PVC SDR 26	160	0.865	8.65	432.2	43.3	
55+00	1500	335	10	↓	↓	↓	0.865	13.0	419.2	49.8	
90+00	4500	150	10				0.865	38.9	380.3	129.9	129.9 < 160 ∴ OK

Chapter 10

Stockwater Pipeline Installation

CHAPTER 10 STOCKWATER PIPELINE INSTALLATION

TABLE OF CONTENTS

FIGURES

Chapter 10

Stockwater Pipeline Installation

10.1 TRENCHING

10.1.1 Trencher Constructed Trenches

When conditions permit, trenching for pipelines which are buried from 5 to 6 feet are usually done with a narrow 4- to 6-inch wide chain trencher. Where there is little gravel, and the ground is not too wet, these trenchers bring up well pulverized soil that makes good backfill material. The material is usually bulldozed back in the trench with a trencher mounted blade. Where rocks are not present, any of this material may be backfilled directly around the pipe.

There is no practical way to compact the fill in these narrow trenches. Within two to five years the backfill material will usually consolidate to the maximum extent. There will be low spots in the trench backfill when the material consolidates. These can be a hazard to livestock, humans, and equipment and are frequently a starting point for gully erosion.

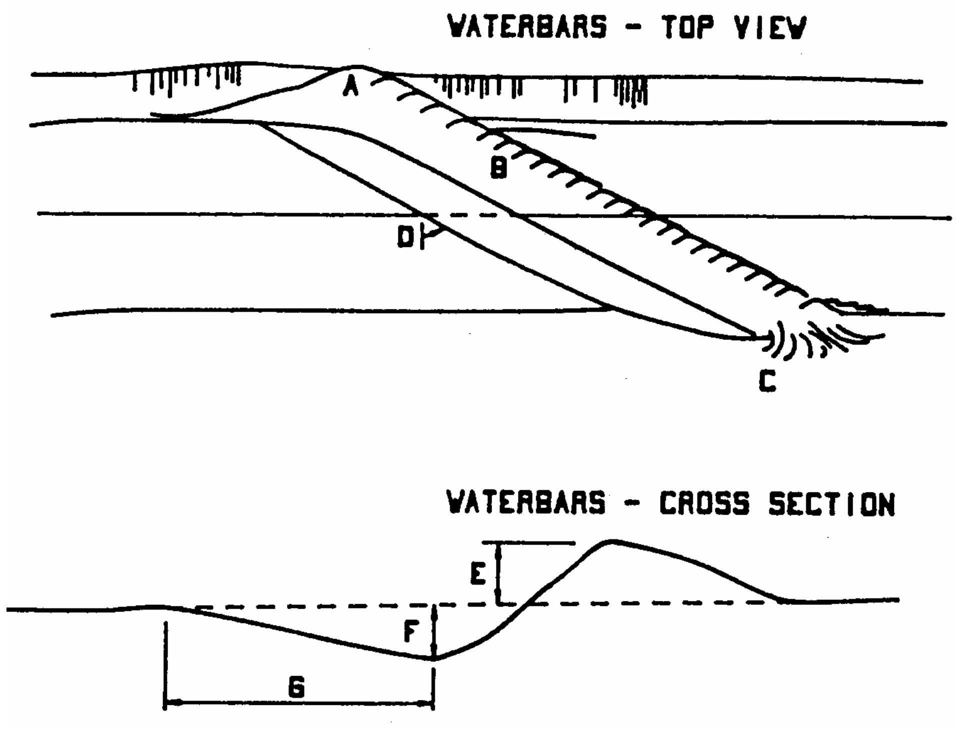
There are three things that always should be done to minimize these problems:

1. Make it clearly understood by the landowner that there must be maintenance of the backfill each year for several years. This maintenance will consist of adding fill to low spots and repairing any erosion that may occur.

2. When backfilling, mound the soil over the trench to the maximum extent possible.

3. Construct "water bars" at right angles to the trench at periodic intervals. These are simply very small diversion dikes across the trench at locations where the trench is traveling up or down the slope. The purpose of these diversions is to prevent concentration of water in the trench and erosion of the backfill. Figure 10.1 illustrates a water bar.

Figure 10.1
WATER BAR



1. Waterbar construction for forest or ranch roads, firebreaks, & stocktrails & walkways. Specifications are average, and may be adjusted to conditions.
2. A--Bank tie-in point, cut 6" to 1 foot into the roadbed.
3. B--Cross drain berm height 1 to 2 feet above the roadbed.
4. C--Drain outlet cut 8" to 16" into roadbed.
5. Angle drain 30 to 45 degrees downgrade with road centerline.--D
6. E--up to 2 feet in height.
7. F--Depth to 18 inches.
8. G--3 to 4 feet.
9. Remember energy dissipator, waterspreaders.

10.1.2 Backhoe Constructed Trench

Backhoe trenches are usually a minimum of 12 inches wide. The material frequently comes out of the trench as clods, large chunks and rocks.

It is important to backfill immediately over the pipe with 4 to 6 inches of soil that is free of large rocks and clods. This sometimes can be done by carefully selecting from the excavated material.

If adequate excavated material isn't available, then material such as sand or fine gravel should be imported and placed around the pipe to a depth of 4 to 6 inches over the top of the pipe.

10.1.3 Road Crossings

All backfill material must be compacted by some adequate means at road crossings. It may be easiest to import sand or fine gravel to fill the trench at road crossings. Rodding and hand tamping can be used to consolidate this granular material. Saturating the material will assist in compaction.

10.2 PIPE JOINTS

Experience has shown that the most common cause of pipeline failure is joint failure. Particular care must be taken to make joints in the manner specified in the specifications and as recommended by the manufacturer. Only materials approved for use with the specific type and rating of pipe must be used.

Polyvinyl chloride (PVC) and other rigid plastic pipes are usually joined using glued joints. Only solvents and glues designed for the specific plastic type must be used. A solvent cleaning and preparation process should always be done if recommended. Connections must be stabbed full depth into fittings.

Polyethylene and other flexible plastic pipe is often connected with "stab" joints. Stab joints must be properly clamped. Two stainless steel band clamps are recommended per joint. Snaking the pipe in the trench helps keep pipe from pulling apart.

Plastic pipe connected together and placed in a trench while warm will contract as it cools off. This can pull joints apart and is the reason that care should be taken to place pipe when it is cool or allow for the contraction by snaking or other means. Backfill should never be placed when the pipe is warm.

Plastic becomes brittle when cold. The amount of brittleness will depend on the material. Pipe should not be handled or backfill placed when the weather is significantly below freezing.

10.3 INSPECTION DURING CONSTRUCTION

Frequent inspection during construction of stockwater pipelines cannot usually be performed by the NRCS. We should make a point though to view each contractor's work while pipe is actively being laid at least once during the construction season. If there are an unusual number of problems occurring from job to job, then more frequent visits must be made. We must provide enough inspection to assure ourselves that pipe is being installed in accordance with the drawings and specifications.

A good way to get more inspection is to enlist the aid of the landuser. The landuser has a vested interest in seeing that a good job is being done. Spending some time with the landuser explaining exactly what to look for during construction can pay big dividends.

10.4 MEASUREMENT FOR PAYMENT

Contractors usually keep track of the number of pipe lengths that are installed and then base their measurement of the installed length of pipeline on the total pipe lengths counted. The laid length is not the same as the total of nominal pipe lengths. Pipe section lengths are not consistently the same and there are length differences caused by couplings and fittings. Damaged or broken sections also seem to end up in the count.

The final payment length should always be measured when the pipe is in place. Frequently this is done with a measuring wheel. Sometimes a tape or chain is used. If a wheel is used, measurements should always be run up the line and then back again. If the two measurements do not agree within two percent, the length should be re-measured. The pipeline total should be the average of at least two measurements. If a contractor's measurements are accepted, it should be on the basis of actual measurement, not a count of pipe sections.

Chapter 11

Operation and Maintenance

CHAPTER 11 OPERATION AND MAINTENANCE

TABLE OF CONTENTS

FIGURES

Chapter 11

Operation and Maintenance

11.1 GENERAL

A stockwater pipeline and the associated tanks and equipment can soon fall into disrepair if not properly operated and maintained. There is no reason a properly constructed stockwater pipeline should not last in excess of 20 years if adequate operation and maintenance are performed.

11.2 WINTERIZING

Shallow pipelines must be drained prior to freeze-up. The need to drain the line in a timely manner must be emphasized to the landuser. Even small pockets of water in low areas can cause damage to the pipeline.

Where a pipeline has many small undulations it may be possible to minimize the number of drain locations required by blowing the line out with compressed air. Drains will then only be needed at major low areas. Facilities for connecting an air compressor to the line must be installed. The air compressor must have enough volume to properly blow out the line. Pressure on the pipeline must be regulated to not exceed the pressure rating of the pipe. The air should be run through the line long enough to evacuate small remaining amounts of water that will flow back into low areas after the air is removed. All of this should be specified in the operation and maintenance plan.

11.3 OPERATION AND MAINTENANCE PLAN

An operation and maintenance plan should be prepared for all stockwater pipelines and discussed with the landuser. Figure 11.1 is an Operation and Maintenance Guide, which can be used for most pipelines. When there are unique or critical factors associated with a system, a supplemental or special operation and maintenance plan should be provided.

Figure 11.1
Operation and Maintenance Guide

United States Department of Agriculture
Soil Conservation Service
Montana

OPERATION AND MAINTENANCE GUIDE FOR YOUR STOCKWATER PIPELINE AND TANKS

Operator: ______________________________
Project: ______________________________
Location: __________ Sec. ________, T. ________, R. ________
SCS Office ______________________ Phone __________

A properly operated and maintained stockwater pipeline and tank system is an asset to your operation. This system was designed and installed as a permanent solution to stockwatering deficiencies. The estimated life span of the installation is at least 20 years and can be assured and usually increased by carrying out the following recommendations. This checklist is provided for your convenience in order to help you develop a good operation and maintenance plan.

OPERATION CHECKLIST

[ ] The system was designed for a maximum of ______ (number) of ______________ (livestock). If the number are increased, additional water supplies may be needed during peak use periods.

[ ] Close all hydrants and valves slowly to prevent water hammer.

[ ] Make sure all pressure tanks, pressure relief valves and pressure reducer valves are operating within design pressure limits and are properly adjusted.

Properly operating pressure gauges at appropriate locations are a valuable aid in monitoring the system.

[ ] If this is an automatic pumped system, make sure the system does not cycle on and off more than __________ times per hour. If rapid cycling is a problem, make operation adjustments or system modifications.

[ ] Drain the following sections of pipeline prior to the date shown:
Stations ______________________________
Date ____________

____
____
____
____
____

Figure 11.1 (cont.)
Operation and Maintenance Guide

Montana Stockwater Pipeline and Tanks

MAINTENANCE CHECKLIST

[ ] Inspect the system for sudden changes in quantity of water received from the source.

[ ] Check periodically to see if debris is restricting inflow or outflow to a tank or trough.

[ ] Check tank overflow outlets. If the outlet being damaged by livestock, or a bog is creating a problem, protect the outlet with rocks, fencing, or other protective material.

[ ] Periodically check tank or trough for leaks and cracks and repair immediately as necessary.

[ ] Periodically check all aboveground facilities for physical damage and repair as necessary.

[ ] At the beginning of the year, inspect the entire length of the pipeline for any signs of leaks or pipe damage.

[ ] Once a year, inspect the entire length of pipeline for signs of erosion and pipeline trench settlement. This is particularly important for the first two or three years after installation.

Repair eroded areas and construct water bars (diversions) or other protective measures to keep water from running down trenches or into the area around tanks.

Add backfill where pipeline trenches have settled.

[ ] Check automatic water level devices to insure that they are operating properly. Adjust or repair as necessary.

[ ] Check air valves and vents periodically to make sure they are operating properly and are not leaking.

[ ] Check the area adjacent to troughs or tanks for erosion and wear-and-tear by stock. Use gravel, scoria, concrete, compacted earth or other durable material to build the area back up.

[ ] If algae and iron sludge in tanks or troughs is a problem consider using chemicals such as chlorine, copper sulfate, or adding small fish to the tank to keep it clean.

Operation and Maintenance Guide page 2

APPENDIX A

WORKSHEETS

APPENDIX A

WORKSHEETS

MT-ENG-20	Stockwater Pipeline Resource Inventory Worksheet (Revised December 2002)
MT-ENG-21A	Automatic Pressure Stockwater Pipeline Hydraulic Computation Worksheet (Revised December 2002)
MT-ENG-21B	Manual or Timer Operated Stockwater Pipeline Pumped Segment Hydraulic Computation Worksheet (Revised December 2002)
MT-ENG-21C	Gravity Stockwater Pipeline Hydraulic Computation Worksheet (Revised December 2002)
MT-ENG-21D	Lateral Stockwater Pipeline Hydraulic Computation Worksheet (Revised December 2002)

U.S. Department of Agriculture
Natural Resources Conservation Service

MT-ENG-20
Rev. 12/02

STOCKWATER PIPELINE RESOURCE INVENTORY WORKSHEET

Land user ______________________________ Field Office ______________________________
Job description ______________________________
Location ______________________________
Planner ________________ Date _________ Checked by ________________ Date _________

Type of livestock ______________________________

Type of grazing system: ☐ Conventional ☐ Intensive

Maximum number of livestock (No.) _____________

Typical dates stock will be in field: From __________ to ___________

Water requirements per head (V) __________ gal/day/head at peak use.

Total usage per day (T) = No. x V = _______ x ________ = ________ gal/day.

Add 10% for evaporation and spillage: (GT) = T x 1.1 (optional)
GT = _________ x 1.1 = _________ gal/day

Minimum required flow rate (Qm) = $\frac{GT}{1440}$ = $\frac{\_\_\_\_}{1440}$ = ____ gpm.

Desired number of hours for entire days needs to be delivered:

TOT (Total Operating Time/Day) = __________ hrs

Design Flow Rate: (Q) = $\frac{24}{TOT}$ x Qm

Q = $\frac{24}{\_\_\_\_\_\_\_\_ \text{(TOT)}}$ x _________(Qm) = __________ gpm

Desired reserve storage time (RST) = __________ days

Total reserve storage required: (RS) = RST x GT
RS = _________ x _________ = _________ gallons total storage in pasture.

Other water sources available in the field: ______________________________
____

Dependability of water sources: ______________________________
____

Quality of water sources: ______________________________
____

Comments: ______________________________
____

U.S. Department of Agriculture
Natural Resources Conservation Service

MT-ENG-21A
Rev. 12/02

AUTOMATIC PRESSURE STOCKWATER PIPELINE
HYDRAULIC COMPUTATION WORKSHEET

Land user ____________________________ Field Office________________________________
Job description ____
Location ____
Planner ________________ Date _________ Checked by ___________ Date ____________

(1) Station	(2) Reach Length (ft)	(3) Pipe Elev.	(4) Design Flow Rate (gpm)	(5) Nominal Pipe Diameter (in)	(6) Pipe Type	(7) Pipe Pressure Rating (psi)	(8) Friction Factor H_f/100ft (ft/100)	(9) Reach Total H_f (ft) (2)/100 x (8)	(10) HGL Elev. (from CP elev)	(11) Max. Pressure on Pipe (psi) (OFF-(3)) x .433	Comments
											at pump

Page 1

U.S. Department of Agriculture
Natural Resources Conservation Service

MT-ENG-21A
Rev. 12/02

**AUTOMATIC PRESSURE STOCKWATER PIPELINE
HYDRAULIC COMPUTATION WORKSHEET**

Land user ____

Job description ____

Farm No. ____________ Tract No. ________ Field No. ____________ County ________________

Designer ___________________ Date ___________ Checked by __________ Date ____________

Water surface elevation during pumping (WS) _______________

Critical point along profile (CP): Station ________________ Elevation ____________

Clearance Head (CH) at critical point: _______________ ft x .433 = _______________ psi

Cut in/Cut out pressure range (PR): ______________ psi x 2.31 = _____________ ft

Losses in plumbing at pump (PL): _______________ ft

Minimum ON elevation = CP elevation + CH ft = _____________ + _____________ = __________

ON elev based on HGL = HGL_{pump} + PL – (PR ft/2) = ________ + ________ – (_________ /2) = _____

ON elevation used (greatest elevation of above alternatives): ___________

OFF elevation = ON elevation + PR ft = ______________ + ______________ = _____________

Total Dynamic Head (TDH) = OFF elev – (PR ft/2) – WS = ______ – (______ /2) – ______ = ____ ft

Pump HP = ______________ HP (Select from pump curves)

U.S. Department of Agriculture
Natural Resources Conservation Service

MT-ENG-21B
Rev. 12/02

MANUAL OR TIMER OPERATED STOCKWATER PIPELINE PUMPED SEGMENT HYDRAULIC COMPUTATION WORKSHEET

Land user ______________________ Field Office __________________________

Job description ____

Location ____

Planner ____________ Date _______ Checked by ________ Date _________

(1) Station	(2) Reach Length (ft)	(3) Pipe Elev.	(4) Design Flow Rate (gpm)	(5) Nominal Pipe Diameter (in)	(6) Pipe Type	(7) Pipe Pressure Rating (psi)	(8) Friction Factor H_f/100ft (ft/100)	(9) Reach Total H_f (ft) (2)/100 x (8)	(10) HGL Elev. (from CP elev)	(11) Max. Pressure on Pipe (psi) [(10) - (3)] x .433	Comments
											at pump

Page 1

U.S. Department of Agriculture MT-ENG-21B
Natural Resources Conservation Service Rev. 12/02

MANUAL OR TIMER OPERATED STOCKWATER PIPELINE
PUMPED SEGMENT HYDRAULIC COMPUTATION WORKSHEET

Land user ____

Job description ____

Farm No. ____________ Tract No. ________ Field No. ____________ County ________________

Designer __________________ Date ___________ Checked by __________ Date ____________

Water surface elevation during pumping (WS) _______________

Pumped segment end station critical point (CP): Station _____________ Elevation ___________

Clearance Head (CH) at critical point: _______________ ft x .433 = _______________ psi

Losses in plumbing at pump (PL): _______________ ft

HGL at CP = CP elevation + CH ft = _______________ + _______________ = ________________

HGL_{pump} = HGL from profile + PL = _________________ + ________________ = ________________

Total Dynamic Head (TDH) = HGL_{pump} – WS = _____________ – ___________ = _____________ ft

Pump HP ______________ HP (Select from pump curves)

U.S. Department of Agriculture
Natural Resources Conservation Service

MT-ENG-21C
Rev. 12/02

GRAVITY STOCKWATER PIPELINE
HYDRAULIC COMPUTATION WORKSHEET

Land user ____________________________ Field Office_________________________________
Job description ____
Location ____
Planner ________________ Date _________ Checked by ___________ Date ____________

(1) Station	(2) Reach Length (ft)	(3) Pipe Elev.	(4) Design Flow Rate (gpm)	(5) Nominal Pipe Diameter (in)	(6) Pipe Type	(7) Pipe Pressure Rating (psi)	(8) Friction Factor H_f/100ft (ft/100)	(9) Reach Total H_f (ft) (2)/100 x (8)	(10) HGL Elev. (from start HGL)	(11) Max. Pressure on Pipe (psi) WS* - (3) x .433	Comments
											at source

*See definition on next page.

Page 1

U.S. Department of Agriculture
Natural Resources Conservation Service

MT-ENG-21C
Rev. 12/02

GRAVITY STOCKWATER PIPELINE
HYDRAULIC COMPUTATION WORKSHEET

Land user ____

Job description ____

Farm No. ____________ Tract No. ________ Field No. ____________ County ________________

Designer __________________ Date ___________ Checked by __________ Date ____________

Water surface elevation (WS) _______________

Critical point along pipeline (CP): Station _______________ Elevation_______________

Clearance Head (CH) at critical point: _______________ ft x .433 = _______________ psi

Minimum required HGL at CP = CP elevation + CH ft = _________ + ________ = ______________

Estimated pipeline entrance losses (EL) = _________________ ft

Starting HGL elevation = WS – EL = _______________ – _________________ = _______________

Page 2

U.S. Department of Agriculture
Natural Resources Conservation Service

MT-ENG-21D
Rev. 12/02

LATERAL STOCKWATER PIPELINE
HYDRAULIC COMPUTATION WORKSHEET

Land user ______________________________ Field Office ___________________________________
Job description ____
Location ____
Planner _________________ Date __________ Checked by ____________ Date _____________

(1) Station	(2) Reach Length (ft)	(3) Pipe Elev.	(4) Design Flow Rate (gpm)	(5) Nominal Pipe Diameter (in)	(6) Pipe Type	(7) Pipe Pressure Rating (psi)	(8) Friction Factor H_f/100ft (ft/100)	(9) Reach Total H_f (ft) (2)/100 x (8)	(10) HGL Elev. (from CP elev)	(11) Max. Pressure on Pipe (psi) (10) - (3) x .433	Comments
											at main

Page 1

U.S. Department of Agriculture MT-ENG-21D
Natural Resources Conservation Service Rev. 12/02

LATERAL STOCKWATER PIPELINE
HYDRAULIC COMPUTATION WORKSHEET

Land user____

Job description____

Farm No.__________________ Date_____________ Checked by_____________ Date___________

Designer__________________ Date_____________ Checked by_____________ Date___________

HGL at mainline ____________

Pump OFF elevation (Automatic pressure system only) _______________

Flow in lateral - OFF elevation (manual, timed or gravity) ________________

Critical point along lateral (CP): Station _______________ Elevation ________________

Clearance Head (CH) at critical point: _____________ ft x .433 = _____________ psi

Minimum required HGL at CP = CP elevation + CH ft = ___________ + ___________ = _________

APPENDIX B

COMPUTER PROGRAMS

WILL BE REVISED AT A LATER DATE (December 2004)

APPENDIX C

MATERIALS SOURCES

APPENDIX C

MATERIALS SOURCES

The following types of plumbing devices are commonly used in stockwater pipeline systems. The specific brands and models listed are examples of commonly used items, and do not represent a comprehensive listing. Other acceptable devices, brands and models may be available. This list will be updated as alternative devices are brought to the attention of the NRCS Engineering Staff Agricultural Engineer as listed in the Preface to this Manual.

TABLE OF CONTENTS

C1 VALVES

C1.1 Air-Release Valves (1-way air release valve)

Continuous acting valves that have a small venting orifice generally ranging between 1/16 and 3/8 inch in size. This type of valve releases pockets of air from the pipeline once the line is filled and under working pressure. These devices require venting to the atmosphere. They periodically dispense small amounts of water during normal operation so provisions must be made to dispose of such water.

Brand Name	Model No	Inlet Size (in)	Orifice Size (in)	Maximum Pressure	Price Range
Apco	50	1/2, 3/4, 1	3/32	150	< $50
Apco	55	1/2	3/32	150	< $100
Apco	65	3/4	1/8	150	< $100
Apco	50	1/2, 3/4, 1	1/16	300	< $50
Apco	200A	1, 2	3/16	150	< $150
Apco	200A	1, 2	3/32	300	< $150
Val-Matic	15	1/2, 3/4, 1	1/16	175	< $100
Val-Matic	22	1/2, 3/4, 1	3/32	175	< $150
Val-Matic	25	3/4, 1	1/8	150	< $150
Val-Matic	25	3/4, 1	5/64	300	< $150
Val-Matic	38	1, 2	3/16	150	< $200
Val-Matic	38	1, 2	3/32	300	< $180
Bermad	4405	1	-	170	< $100
Waterman	CAV-6	1	-	150	< $100
Western	WAAV-4405	1		180	
Hoffman	78			150	

C1.2 Air-and-Vacuum Valve (2-way valve)

These valves have a large venting orifice, exhaust large quantities of air from the pipeline during filling operations, allow air to re-enter the line, and prevent a vacuum from forming during emptying. These valves are not continuous acting because they do not allow further escape of air at working pressure once the valves close. These devices require venting to the atmosphere. They periodically dispense small amounts of water during normal operation, so provisions must be made to dispose of such water.

Brand Name	Model No	Inlet Size (in)	Orifice Size (in)	Maximum Pressure	Price Range
Apco	141	1/2	1/2	300	< $100
Apco	142	1	1	300	< $150
Apco	144	2	2	150	< $200
Val-Matic	100	1/2	1/2	150/300	< $200
Val-Matic	101	1	1	150/300	< $200
Val-Matic	102	2	2	150/300	< $350
Bermad	4420	2	-	170	< $150
Waterman	AV-150	1-1/2, 2	-	150	< $50
Waterman	AVP-1	1	plastic	110	
Western	WKAV-4420	2		250	

C1.3 Air-Vacuum-Air Release Valve (3-way valve)

Three way valves combine the functions of the previous two valves. These devices require venting to the atmosphere. They periodically dispense small amounts of water during normal operation. Provision must be made to dispose of such water.

Brand Name	Model No	Inlet Size (in)	Orifice Size (in)	Maximum Pressure	Price Range
Apco	143C	1	1 & 5/64	300	< $200
Apco	145C	2	2 & 3/32	300	< $300
Val-Matic	201C	1	1 & 5/64	300	< $300
Val-Matic	202C	2	2 & 3/32	300	< $450
Bermad	4415	2	- -	170	< $200
Waterman	CRP8	1	plastic	85	< $50
Waterman	CRP8	2	- -	100	< $100
Waterman	AVR-2	3/4, 1 1-1/4, 1-1/2	2 & 1/8	150	< $300
Waterman	CR-100	2	2 & 1/16	100	< $150
Western	WDPAV-4415	2		250	

C1.4 Pressure Reducing Valve

Pressure reducing valves reduce pressure to pipelines, hydrants, float valves, etc. Access to the valve is required for adjustment and maintenance.

Brand Name	Model No.	Size (in)	Note	Maximum Operating Pressure (1)
Jordan	Mark 60, 61	1/2, 2	(2)	300+
Watts	U5B	1/2, 2	(2)	300
Wilkins	600	1/2, 2	(2)	300
Amtrol	100UBT	1/2, 2		250
Cash-Acme	Type E, Series 3	1/2, 2	(2)	300
Bermad	PRV 150	1/2	(2)	160

C1.5 Pressure Relief Valve

Keeps pressure in pipelines at a safe value when a pump pressure switch or pressure reducer valve malfunctions.

Brand Name	Model No.	Size (in)	Note	Maximum Operating Pressure (1)
Kunkle	Liquid		(2)	300
Watts	174-A		(2)	160
Cash-Acme	FWC	1/2, 3/4		175
Waterman	AA-6a	2		120
Waterman	AA-6b	2		120

C1.6 Flow Rate Controller

This type of valve controls flow rate in a pipeline. It is usually used near a pump to control surge pressures during pump start up in long pipelines with remote pressure tanks.

Brand Name	Model No.	Size (in)	Note	Maximum Operating Pressure (1)
Kates (adjustable)	4FA	1-1/2		150 & 300
Harvard (non-adjustable)	DV			200
Griswald (non-adjustable)	varies	3/4-3		128
Dole (non-adjustable)	GX	1		125

C1.7 Flow Controlled Pressure Valve/Switch

Brand Name	Model No.	Size	Note	Maximum Operating Pressure
Red Jacket	Hydroservant I	20 gpm		

C2 SURGE SUPPRESSOR

These devices are diaphragm-type water shock arresters. They are located near the pump when pressure tank is not used at the pump. When ordering certain models, it is necessary to specify the operating pressure range. This will allow pre-charging to the proper pressure. If needed, more than one arrester can be used at a site.

Brand Name	Model No.	Size	Note	Maximum Operating Pressure (1)
Greer Hydraulics	SurgeKushon	2 to 10 gal		275
Myers	12-CU		(4)(5)	200
Hydrotrol	5000	3/4"-2"	(4)(5)	150
Hammertrol	506	1"	(4)(5)	150
Watts	150		(4)(5)	125
Mini-Trol	500	1/2"	(4)(5)	125

C3 PRESSURE TANKS

Brand Name	Model No.	Size (gal)	Note	Maximum Operating Pressure (1)
Con-Aire	CA	15-220		
Wel-X-Trol	WX	2-119		100 to 150
Myers		2-96		100
Well Mate	WM	20-115	(fiberglass)	100 to 125
AO Smith, Aqua Air	V	2-85		100
Clayton Mark	CM	2-109		100

NOTES

(1) These are maximum operating pressures as listed by the manufacturer for the particular model listed. These pressures should not be exceeded.

(2) Specify pressure and flow range when ordering.

(3) When ordering certain models it is necessary to specify the operating pressure range. This will allow pre-charging to the proper pressure.

(4) It is difficult to determine the amount of water hammer protection needed. If one does not solve the problem, a second or third suppressor may be added. Some brands are also available in several sizes. Larger sizes should be used where the water hammer problem is severe.

(5) These are small capacity suppressors and may not be adequate for long pipelines.

APPENDIX D

PLANNING and DESIGN GUIDE

APPENDIX D

PLANNING AND DESIGN GUIDE

The following guide may be used as a checklist to organize pipeline planning and design. It is particularly useful as an aid for those new to planning and designing stockwater pipeline systems.

Montana

Stockwater Pipeline and Tanks

Planning and Design Guide

	References
DETERMINE OPERATOR OBJECTIVES	
Work with the operator to refine and define operator objectives before spending significant time on detailed planning.	NPM 506.10
RESOURCE INVENTORY	NPM 506.10
(May use Stockwater Pipeline Resource Inventory Worksheet, MT-ENG-20)	MSPM Ch. 2
1. Annual grazing period.	
2. Whether or not pipeline will need to operate in freezing weather.	
3. Types and maximum number of livestock using system.	
4. Type of grazing system to be used.	FOTG 556
5. Define and measure area to be serviced by the pipeline.	
6. Location and details of existing water sources in the area to be serviced by the pipeline.	
7. Details concerning wells and pumps, including yield, condition, depth-to-water surface, and elevation.	
8. Availability and cost of bringing in electric power.	
9. Reliability and quality of existing water sources.	
10. Water source that is proposed for use as supply for pipeline system.	
11. Initial topographic information for the service area. This often can be accomplished by study of USGS Quadrangle maps, altimeter surveys, or aerial photos.	
12. Geologic considerations which will effect pipeline route including location of shallow bedrock, unsuitable soils, coarse gravel subsoils, old slide areas, swampy areas, sharp breaks in the slope, etc.	
13. Property line and ownership considerations which will effect the pipeline route.	

14. Management factors:	
_ How frequently are livestock checked?	
_ Can livestock be quickly moved if the pipeline system fails?	
15. Determine the user's desires concerning the system.	
16. Site considerations:	
_ Determine location and details of any buried or overhead utilities in the construction area.	NEH 503.03
_ Is the site within a flood plain?	NPM MT506.17
_ Will wetlands be modified or disturbed by installing the project?	NPM MT506.17
_ Make archaeological and historical resource survey, if one is required.	NPM MT506.17
INTERPRETING, ANALYZING, AND EVALUATING	
1 The pipeline and appurtenances will be planned as an integral part of a resource management system. Work with and educate the landuser to accomplish this.	NPM 506.12
2. Are there other alternatives to the proposed pipeline system? Can existing water sources be improved at less cost?	
3. Are there soil or geologic conditions which will limit the type of pipeline system or how it is installed?	
4. Are there labor, economic, management, or physical constraints on the system?	
5. Is water source quality, timing and availability adequate?	
6. Prepare a preliminary analysis of environmental effects and prepare an environmental checklist (MT-EVC-1) and other required documents.	NPM 506.17 MT-EVC-1
DEVELOPING AND EVALUATING ALTERNATIVES	
1. Determine minimum flow requirements during the period of peak stockwater use.	FOTG 614 FOTG 516 MSPM Ch. 2
2. Determine desirable drinking tank locations. Standards set maximum distance between drinking locations.	FOTG 516

3. Determine minimum water storage requirements.	FOTG 516 FOTG 614
4. Determine drinking tank-type and capacity.	MSPM Ch. 8
5. Determine storage tank-type and capacity.	MSPM Ch. 8
6. Based on all known factors, design the pipeline system alternative alignments.	MSPM Ch. 9
7. Type of system (automatic pressure, timed, gravity).	MSPM Ch. 3
8. Based on all available known factors, select a pipe-type and bury depth.	
9. Preliminary design of pump and gravity inlet facilities.	MSPM Ch. 8
9. Preliminary design of drinking and storage tanks, including types, locations and preliminary sizes and elevations.	MSPM Ch. 8
10. Perform preliminary hydraulics to set size and grades. (Use SPIPE, IPIPE, or other approved computer programs may be used to aid with calculations.)	EFM Ch 3 MSPM Ch 9 MSPM App B
MAKING DECISIONS AND DOCUMENTING	NPM 506.10
1. Present developed alternatives to the operator.	
2. Make sure the operator has made a decision before proceeding.	
3. Document decisions in NRCS-CPA-6 planning notes and on the NRCS-CPA-68 Record of Cooperator's Decisions.	NPM MT506.31
4. If required, revise the MT-EVC-1 and associated documents.	NPM MT505.21
IMPLEMENTING DECISIONS	NPM 506.10
<u>Permits</u> Make sure all required permits are obtained before proceeding with detailed design and layout.	NPM 506.17 NPM MT506.17
1. Water right permits	
2. Permits to cross State or Federal land and easements to cross private land.	
<u>Approval Authority</u>	NEM MT501.04 Individual
1. Determine approval authority for pipelines, tanks and other appurtenances.	

Collect Final Data for Design	
1. Additional detailed engineering surveys which were not obtained during initial planning. A profile should be run just to the accuracy necessary for the particular installation. This may involve detailed bench level, transit, EDM, altimeter or simply a close study of 7-1/2 minute USGS maps, depending on the installation.	TR62 EFM Ch. 1 MSPM Ch 4
System Design	FOTG 516 MSPM
1. Detailed hydraulics which were not done previously.	
_ Pipeline hydraulics (Can use SPIPE and IPIPE programs to aid in calc's)	EFM Ch 3 MSPM Ch 9
2. Pressure tank size requirements	MSPM Ch 8
3. Pressure, surge and air control features	MSPM Ch 6, 8
4. Pump size and pressure requirements	MSPM Ch 8
5. System accessory design	MSPM Ch. 8
6. Quantity calculations (if needed for cost share, bidding or other reasons).	
_ Schedule of pipe sizes, type and rating	
_ Schedule of tank types, sizes and locations	
_ Schedule of valve types and sizes	
Drawings and Specifications	EFM Ch 5
1. Prepare drawings	MT Draft.Guide
_ Use standard drawings when possible.	MT Std. Dng. Handbk.
_ Minimum drawings shall include:	NEM
o Location map or enough description on plan view map to adequately locate job.	
o Plan view map showing location of all pipelines, tanks and water source.	
o Profiles along each pipeline. Show location of all appurtenances such as tanks, troughs, hydrants, valves, pressure reducers, etc.	

o Show elevations including water surface or starting pressure head, ground line, design hydraulic grade line, and static grade line.

o Table or drawing notes showing elevations, descriptions, dimensions and size of all structures, valves, special fittings and appurtenances.

o Standard details of tanks and pipeline — MT Std Drawing Handbk.

o Special detail drawings of appurtenances not otherwise described.

2. Specifications — FOTG Sec IV

_ Standard Montana practice specifications shall be used to the maximum extent possible.

_ Special provisions shall be prepared and made a part of the practice specifications when needed. — NEM MT542.01, NPM MT506.31

<u>Operation and Maintenance plan</u> — MSPM Ch 11

_ All important aspects of management and operation shall be documented in an operation and maintenance plan (O&M) and discussed with the operator.

_ Maintenance recommendations shall be included in the O&M plan and discussed with the operator.

<u>Layout</u> — NEM 540.03, EFM Ch. 1, TR62

1. Set permanent bench marks (2 minimum).

_ Firmly set bench marks out of harms way

_ Clearly describe in notes

_ Show on drawings

2. Layout surveys shall be recorded in loose-leaf survey books or special forms and in accordance with TR62 and/or Chapter 1 of Engineering Field Manual. — NEM 540.02, TR62, EFM Ch. 1

<u>Compliance Checking</u>

1. Adequate periodic inspection shall be scheduled and performed during construction. Frequent inspection during construction of stockwater pipelines cannot usually be performed by the NRCS. We can make a point to view each contractor's work while the pipe is actually being laid at least once during the season. More frequent visits will be necessary if there are an unusual number of problems cropping up from job to job. We should provide enough inspection to assure ourselves that the pipe and tanks are being installed in accordance with the drawings and specifications. — NEM 512.33

Properly coached, the landuser can provide useful inspections during construction. Explain to the landuser what the drawings and specifications mean and what to look for as the job progresses.

2. As-built drawings should be prepared.

Complete documentation

The following documentation shall be in the case file: NPM 506

1. Complete planner notes on Conservation Assistance Notes Form NRCS-CPA-6. Documentation of operator decisions should be complete.

2. Original survey notes

3. Copy of all calculations, initialled and dated by the person doing the work and the person doing the checking.

4. Copy of all drawings

   _ Signature of person with approval authority on first drawing

   _ As-Built details noted on drawings

5. Specifications, either a copy of specs or list of specs with copy of signature sheet and special provisions.

6. Copy of sheet showing review of drawings and specs by operator.

7. Copy of all statements relating to the completion check.

8. Where underground utilities are located in the construction area, a copy of completed Forms NRCS-ENG-5 and NRCS-ENG-6 must be in the file.

9. Copy of water rights or signed statement by producer that they are adequate.

10. Completed Environmental Checklist MT-EVC-1 or notes in NRCS-CPA-6.

11. Cultural Resources Survey MT-CPA-8, if one is required.

References:

FOTG NRCS Field Office Technical Guide: Montana Practice Standards in FOTG, Section IV.
NPM NRCS National Planning Manual
NEM NRCS National Engineering Manual
EFM NRCS Engineering Field Manual
MSPM NRCS Montana Stockwater Pipeline Manual
NEH NRCS National Engineering Handbook
TR62 NRCS Technical Release--Engineering Layout, Notes, Staking and Calculations
NRCS Montana Drafting Guide
NRCS Montana Handbook of Standard Drawings